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Its Origin and Exploitation

BY

S. J. DULY, B.A. Cantab.

HODDER AND STOUGHTON
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PREFACE

I HAVE set down summarily on page 5 the aim I had before me in writing the following pages. Throughout the book there is a coherent argument, claiming for geology the basic place among the studies which help to explain the development of civilisation and the localisation of the industrial arts. I have included in the plan of the book the chief of those ideas which should guide the student, in whatever part of the world he should later find himself, in acquiring a good general conception of the scheme of material things in his neighbourhood. This is my apology for the "industrial" sections which link the geological and the geographical chapters in the book.

My best thanks are eagerly given to Messrs. Ropeways, Ltd., Messrs. The Aluminium Corporation, Ltd., and Messrs. The Ingersoll Rand Mining Co., Ltd., for permission to use photographs of their plant, and also to Mr. Philip Lake for the map upon which that on pages 310 and 311 is based.

S. J. DULY.

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PART I—GEOLOGICAL

CHAPTER I

THE EARTH IS THE SOURCE FROM WHICH ALL OUR NEEDS ARE SUPPLIED

1. ALL things we handle or make use of, and all things we depend on in our daily lives, come from the earth. Let us think of the materials employed in making this book, and let us trace them back to their origins. Consider first the paper it is printed on. There is no difficulty in connecting the paper with its probable source, for it was most likely made from wood-pulp, which would then have come from the forest trees rooted in the brown earth of Quebec. To make it white it was bleached with bleaching powder manufactured from salt from the mines of Cheshire, let us say. So again we arrive at a source in the earth. The ink used to print its pages is a mixture of resin oil and lampblack. These are easily traced back. The resin oil was collected from slits made in the barks of pine trees in the American forests. The lampblack, mixed with it to make the printer's ink, was got from our

coal mines, for it was made by distilling coal tar.

ii. The pages are sewn together with needle and thread. The needles were made perhaps at Redditch from the iron mines of the Midlands, and the thread spun from the fibre of the flax plants grown in Ulster. Each time we ask where this or that article was obtained we arrive at last at a source in the earth. The cardboard cover was very likely made from esparto grass grown on the Pampas of America. It was bound with woven linen and dyed with colours made with great skill from the tarry waste of the gas-works; and this tarry waste came from coal, as the lampblack did for the printer's ink.

iii. Let us proceed further and examine a few other objects to see whether we may by any chance hit upon some constituent which we cannot trace back to some forest, farm, mine or sea. The articles of furniture within the room are easily seen to be turned out of hard woods from the oak and beech forests. The building itself may be directly traced back to the clay and sand pits from which its bricks were made, and the cement which holds them together consists of lime and sand, both of which come straight from the quarry. In a similar way, our food comes to us from the farm-lands. Our clothing is just as directly derived from the land. The wool from which our suits are woven comes from the sheep farms, and cotton from the plantations of Virginia and

Egypt. So we may continue to split up any article we like into its constituent parts and trace each part back to its crude condition in the earth as a metal or material, or growing on the earth as a tree or shrub, or feeding on the earth's vegetation as an animal.

iv. This is as true as ever when we stop to consider artificial products. At first it seems as if artificial products should not have a natural origin. Thus real diamonds are mined at Kimberley in South Africa. Where do artificial diamonds come from? They are made in the factory from sand and salt, both straight from the earth. Real butter is supplied from the farm where cows' milk is churned, so that butter comes straight from the pasture. Where does artificial butter, margarine, come from? It comes from the fertile tropical countries where oily seeds and nuts ripen. These oils are pressed out and churned with separated milk to form margarine. So that margarine also comes from the earth, although it is artificial. Real silk is spun by the silkworm and woven in factories into lengths of silk material. But there are vast quantities of artificial silk in the shops. Does that also come from the earth? It is made from cotton waste and is therefore a direct product of the plantation.

v. We might continue in this way to examine every artificial product we could think of, and we should find that they are all derived from the land in exactly the same way as we have

found natural products to be derived therefrom. It is not only true that all natural and artificial products are directly traceable to the earth, but all the machinery needed to handle and shape them is also obtained from the same single source. When this book was made the materials enumerated above were not the only things needed in its making. Machinery was required also to print its pages and coal to drive the machinery. But the machinery is made of steel, produced from the iron mines, and the coal itself is obtained from coal mines.

vi. *The earth, then, is the great inexhaustible storehouse.* Everything we use, whether it be a natural or an artificial product—our food, clothing, and all our goods—everything, without any exception, comes from the earth. Besides this, the earth is the theatre of our activities. We work together on it, gather together in cities on the banks of its rivers, mine its coal and metals, farm its soil and cross its seas. Since, then, the earth means so much to us both as our only storehouse of raw materials and as the scene of our daily work, should we not endeavour to know as clearly as we can, at least of our own Island, the way it is built up, how it supplies us with raw materials, and how the population is grouped in towns upon its surface or spread out over its agricultural provinces according to the nature of the activities of its groups ?

vii. Our object then will be threefold :—

(*a*) To learn how our Island is built up.

(*b*) To learn how men get their raw materials from the earth and how they use them in making and distributing goods.

(*c*) To learn how men group themselves over the earth's surface in towns and villages according to the kind of work they do.

Questions.

1. Trace a few common articles back to the sources of the raw materials used in making them.

2. How do artificial products differ from natural ones? Are their sources alike? Try to distinguish between a counterfeit and an artificial product.

3. Why should you endeavour to learn about the earth's surface and the rocks beneath?

CHAPTER II

CLAYS, SANDSTONES AND LIMESTONES IN PROCESS OF FORMATION

1. If you boil salt water the steam coming from it will contain no salt. All the salt is left in the saucepan. When the sun falls on the wide expanses of the ocean it vaporises the water and saturates the air above it with water vapour. But the other constituents of the sea-water, its salts and sands and muds, are left behind and only the pure water is carried off as a vapour. Now the winds drive these clouds of vapour until they reach a colder region, especially a mountain range, where they discharge their pure water as rain on the earth. In the course of its fall down the mountain side into the rivers which will eventually take it back again to the sea, this rain water becomes contaminated with dusty particles and with minerals in the earth which it can dissolve. These it takes with it out to sea. But when it is again evaporated and again returns as rain it comes back pure. In this way it constantly goes out to sea turbid with dissolved and

suspended particles, but always leaves them behind and comes back pure. The salts and solids in the sea are consequently on the increase, and for this reason sea water is salt.

ii. The amount of solid material carried out to sea by a river is enormous. Every moment, day in, day out, week in, week out, and year by year, a gigantic load of suspended and dissolved material is borne out to sea by each of the thousands of rivers in the world. Every frost and every hot day loosens the material of the earth's surface by splitting it up and drying it to dust, and every rainstorm carries this loosened material, dust and pebbles, by countless runnels, into the streams which flow down to the rivers and out to sea. This slow process never stops. Above all, it never works backwards. Once a pebble on a slope has been dislodged and is washed downward it can never return. And this is true of every particle of every hill above sea-level. The hills all the world over are gradually being carried out to sea, particle by particle, and never by any chance is any being replaced. In countries like Switzerland, where the mountains are piled thousands of feet high, the levelling process is going on at a great rate. Sometimes great masses of rock are loosened and detached and crash down into the chasms below. But in England the process of levelling has reached its very last stages. All our high mountains have long ago disappeared into the ocean bottom and we shall learn later to recog-

nise the traces left of them. England now is a comparatively flat country.

iii. Yet the River Thames is estimated to carry out to sea at least a ton of dissolved minerals each minute, besides another ton of sediment borne away by the speed of the stream. Altogether, therefore, about a million tons of solid materials are removed from the land each year and carried out to sea by this one single river.

iv. What happens to the material so carried away and distributed over the ocean floor? As soon as the river current reaches the sea and its speed is slowed down, it drops its heavier material. Pebbles and coarse sands are deposited just round the coast and lie more or less evenly over the floor of the sea out to the hundred-fathom line. The smaller material is carried much farther out to sea and is deposited in the depths of the ocean as mud. The smaller the particles are, the farther from the shore are they deposited. Thus the deposits found far out to sea are very fine muds or oozes. As we approach land they become coarser and coarser, sand being predominant in the accumulations nearest the shores. Besides these sandy deposits close to land and muddy deposits out at sea, there is another kind of deposit being formed on the ocean floor. The shells and hard parts of millions of small shell-fish are constantly accumulating as these creatures die. They do not inhabit the waters of the globe without regard to the district, but they live in colonies

where the temperature and condition of the water are suitable. Thus their shells accumulate in the same part of the sea floor for ages. These animals are endowed with the power of extracting the lime dissolved in the sea-water and making their shells from it, so that the accumulation of their dead bodies is made up of lime.

v. We have seen how at the present day large formations of sands, muds and shells are accumulating in every sea. Many of them are hundreds of feet thick, and they are all made up of layer upon layer of sand or mud or limestone, the oldest layer resting on the bottom. In the course of ages during which they have been accumulating they have generally become compact and hard, and form stratified deposits of sandstone, limestone or clay on the floor of the ocean.

vi. We have seen also that the continents are gradually being worn level, and the mountains carried out to sea. If this process has always been going steadily on, how is it now that, let us say, England has not been entirely washed away? The answer to this question is that the crust of the earth upon which the rain falls is not stationary, but is constantly moving. Some parts of the world are gradually being forced upwards out of the sea, and others are gradually sinking. Often the movements are so sudden as to be noticeable to the inhabitants. These are called earthquakes. But very few areas of the earth are free from

slight upward or downward movements, and by means of the *seismograph*, an instrument designed to record them, earth tremors can be detected daily even in Britain. Many times during the history of its formation Britain has been entirely covered by the sea, and while it formed the ocean-bed, great deposits of sands, clays or limestones were spread out over the area it occupied. These deposits accumulated until they were thousands of feet in thickness. Gradually the area rose again from the sea until dry land appeared. The sands and clays which had collected at the sea bottom now formed the mountains and hills of the new land. Upon these the rain fell until they were at last levelled down and much of their material again spread out in the surrounding seas. Then the area sank and the process set in again. Again vast deposits of sands, clays and limestones gathered in the ocean-bed where the land once existed. Then after an epoch of time it re-emerged from the sea, formed land, and was again washed away.

vii. Now let us take a journey across England to see whether we may recognise the remains of these old deposits which were formed ages ago while the sea occupied the place where England now is. Whichever way we go we shall soon meet with hills of limestone or sandstone and valleys of clay. The Chalk Downs are a pure limestone. London is situated on a great basin of clay. The River Trent flows more than a hundred miles in a valley of clay. The Pennines

are made of sandstone and limestone. Thus England is largely made up of the remains of old deposits of limestone, sandstone and clay which were originally laid down in the beds of successive oceans.

Questions.

1. Was the sea always as salt as it is now? Why should the Mediterranean Sea be salter than the Baltic?
2. What are the three chief kinds of deposits being formed in the ocean bed? Say how they are formed.
3. What is the effect of constant rainfall upon the rocks of a country? Might a country be washed entirely away?

CHAPTER III

HOW GRANITES, SLATES AND MARBLES ARISE

1. If our search for limestones, clays and sandstones should take us into Cornwall or Devon, or into Cumberland, we should discover large tracts of country made of granite. This granite has a very different origin from that of the formations we traced to the bottom of the sea. Granites and rocks like them are formed by the cooling of the molten interior of the earth. Just as we are able to observe the movement of the earth's crust when it is violent enough to form an earthquake, so we may observe the formation of these granite-like rocks from their molten state, when volcanoes are active. Volcanoes are the vents or pipe-lines which lead down to the molten reservoirs beneath the earth's crust. Sometimes the molten granite boils up the vent and spreads out as lava on the earth's surface, where it rapidly cools. There are many old lava flows of this kind in Wales. The reservoirs to which the volcanoes lead have sometimes become cold. Here and there on the earth's surface they are exposed to view, as in Cornwall and

Devon, just as they crystallised out on cooling down. This is indeed the chief way of recognising a piece of rock which has been formed from the molten state, like a granite or a lava. The crystals which formed as it cooled down may often be distinguished with the naked eye. Sometimes they fit into each other like a piece of mosaic work. But in other rocks the crystals are too small to distinguish without a microscope, except when some larger crystal may be seen like a plum in a pudding. Everywhere in the world such rocks lie beneath the sedimentary deposits on the surface.

ii. The crystalline rocks formed by the cooling of the earth's crust are naturally the oldest formations. They were the first solid crust to be formed on the earth when it cooled from its incandescent condition. They contained all the metals and valuable materials we now make use of. Imagine a country made of granite mountains. The rain which falls upon them weathers them away and carries them out to sea grain by grain. The rain water also dissolves out great quantities of minerals from them, which are carried away in solution. The larger grains derived from the granite will go to form sandstones, the finer will form ocean muds, and the dissolved minerals will feed the shell fish and enable them to make limestone banks. In this way sedimentary rocks have all been derived from granites and crystalline rocks which were once molten.

iii. Just as there are three very different

kinds of deposits always being formed on the ocean beds, so there are three kinds of constituent crystals in granites from which they are derived. When granite is weathered, the three constituent crystals come apart. The first is the sandy constituent known as silica, which you may recognise in a piece of granite as a glassy-looking crystal. Silica is almost insoluble in water, but the grains of sand which are derived from granite become rounded by constant friction as they are carried down to sea. The second constituent is felspar. This you may recognise very easily in a fresh piece of granite. It is sometimes milky-white, sometimes pink, but, unlike silica, it always shows its crystal structure. Now felspars contain a great deal of lime and alumina (from which clay is derived) and they are easily split into these compounds by weathering. Thus we see that they give rise to limestones and clays. The third constituent of granite comprises all the various metallic compounds. They may be recognised as dark crystals in the granite. When they are weathered they are often entirely split up and deposited with the limestones, clays and sandstones to which the silica and the felspars give rise.

iv. We may now summarise what we have learnt. The oldest rocks on the earth are the granites, which were formed by the cooling of the earth's crust from the molten condition. Sands, muds and limestones were derived from these granites by the agency of rain and running

water. These sands, muds and limestones were laid on the ocean bed as sedimentary rocks. By the gradual movement of the crust of the earth these sedimentary rocks on the sea floor have become land and have themselves been weathered away and again carried out to sea. Then the area has sunk beneath the sea and fresh deposits have been laid down on the remains of the first. This process has been repeated in our Island many times. The rocks which now form the land of England are the remains of the original granite crust, and the successive formations of limestone, sandstone and clay which have been deposited upon that crust one upon the other at successive epochs.

v. At various periods during the formation of England the whole world has been much more unstable than it is at present. These are known as periods of mountain-building. While mountains are being reared up by folds in the earth's crust, the rocks which compose the folds are compressed to an extent which we can hardly imagine. The Alps were the last great mountain range to be heaved up from the bottom of the sea by the crumpling of the earth's crust as you might crumple a table-cloth by holding your hand flat upon it as it is spread over the table and pushing it along (Fig. 1). The effect of such an enormous compression on the rocks themselves is very peculiar. All clays are pressed first into shales and then into slates. Slates are produced from clay by earth pressure. Many precious

stones are produced by the same means. Diamonds result from great pressure upon carbon. Sapphire, ruby, aquamarine and topaz are crystalline forms of clay.

vi. Another effect of mountain-building

FIG. 1.—Folds.

movements is to break the earth right through the crust. Such a break is known as a *Fault* (Fig. 2). There are many thousand faults in England, some of which may easily be seen on the surface of the fields, and we shall learn later how to detect them.

vii. At the present day active volcanoes are to be seen in many parts of the world. In

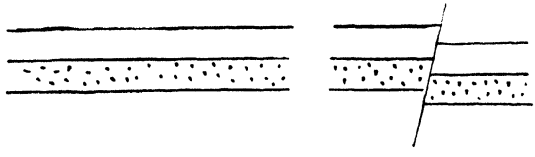


FIG. 2.—A fault.

Iceland the molten lava wells up through faults in the earth many miles in length and spreads itself out over the surface. To-day in Great Britain you may frequently come across a fissure or fault up which molten rock has come. The *igneous* rock (that is, the rock which was once molten) may be seen as a ridge

running across the country. It is called a *dyke*. At many periods during the formation of our Island there have been volcanoes in Great Britain. As you would expect, the molten lava bakes the rocks, through which it splits in getting to the surface. When limestone is baked in this fashion marble is formed. In the Peak district of Derbyshire, which is formed of limestone, there are many sills of volcanic rock which have come up from the molten depths of the earth and squeezed their way in between the layers of limestone which form the hills. They are, of course, connected with a granite reservoir deep in the earth, and they found their way into the weak planes between the layers of limestone while they were molten. These "Toadstones," which is the name given to them in Derbyshire, have baked the limestone sufficiently well to form marble good enough to quarry.

viii. Coal is a specially valuable deposit quite separate from the various kinds of rocks we have considered. Its mode of formation is also unique. Coal is the hardened and consolidated product of ancient forests. The trees which flourished in the swampy coal forests are unlike any in existence to-day. But their remains can be clearly discovered as fossils in the coal itself. Forest upon forest of trees lived and died in the places where our coal mines now exist, and when hundreds of feet of dead leaves, trunks and roots had accumulated, the whole area was submerged and

covered by an impervious red marl. Its valuable carbon was thus protected until it had formed solid coal. In the course of time, the abundant forest remains have been compressed to a few feet—the thickness of an ordinary coal seam.

ix. We have now considered all the kinds of rocks we are likely to meet with in our country. The soil on the surface is the product of the disintegrating effect of the weather on the underlying rock. But in addition to the material derived from that source, there are generally two or three other sources from which the soil has come.

(*a*) In the first place a stream may have transported alluvium or silt and added it to the soil derived from the rocks on the spot, although the stream may long ago have disappeared.

(*b*) A great part of England has been covered with glaciers which have left sand and clays in the districts which they traversed.

(*c*) Generation after generation of plant life has lived and died on the surface, and their remains have been added gradually to the soil.

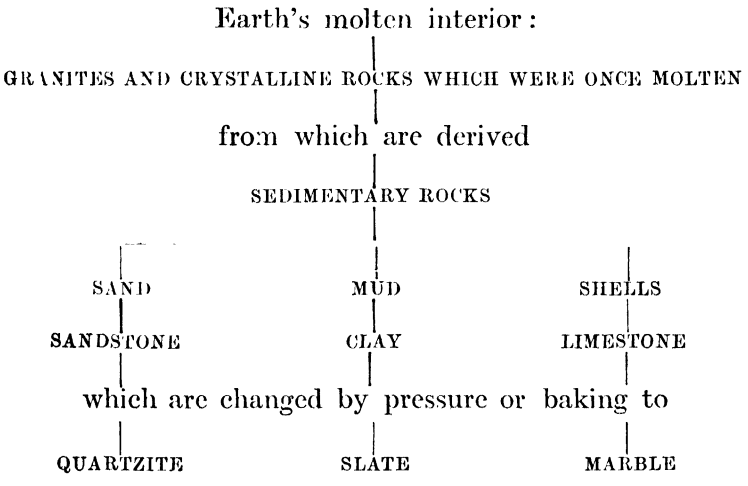
(*d*) Animals of all kinds, earthworms, moles and rabbits, have burrowed and thoroughly mixed the components of the soil.

Now let us take a handful of soil and separate

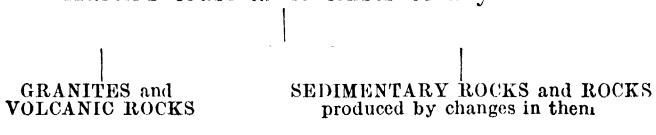
its constituents. First there may be large stones. If we look at these we shall see that they are pieces of igneous rock or pebbles of silica. If we picked out these stones and washed the rest of the soil with water we should wash away all the minute clay-like particles and leave fine sand. This sand, then, is the second constituent. The minute clay particles, too small to be seen individually, are mixed with the remains of dead plants and animals, and these are therefore the third and fourth constituents.

x. The kind of soil in a district will depend on the proportions in which these four constituents are present. If there is much sand and little clay the soil is called sandy. On the other hand, a clay soil will contain but little sand. Now sand has no food value for plant life to draw upon, so that a sandy soil is barren. On the other hand, there are many minerals in clay particles which plants need, yet a clay soil is so sticky that plants rooted in clay can get no air. Consequently, a clay soil is not altogether suitable for plant life either. The best soils for crops contain both clay and sand. The clay supplies the food and the sand secures air passages to the roots. The remains of dead plants and animals which are mixed with the clay supply food, and, what is even more important, the warmth necessary for growth.

xi. The following plan summarises the story of the development of the rocks of the earth's crust.



Or we may put it thus :—



QUESTIONS.

1. How do rocks which were once molten differ from sedimentary rocks ?
2. Describe a piece of granite. (Try to get a piece to examine.)
3. What is the origin of slate ? What districts would you expect to yield slates ?
4. Describe some changes which rocks undergo, and say how they are produced.

CHAPTER IV

A SANDSTONE QUARRY IN FAULTED COUNTRY

1. When the Liverpool Corporation decided to bring their drinking water in pipes laid underground from Lake Vyrnwy in Wales

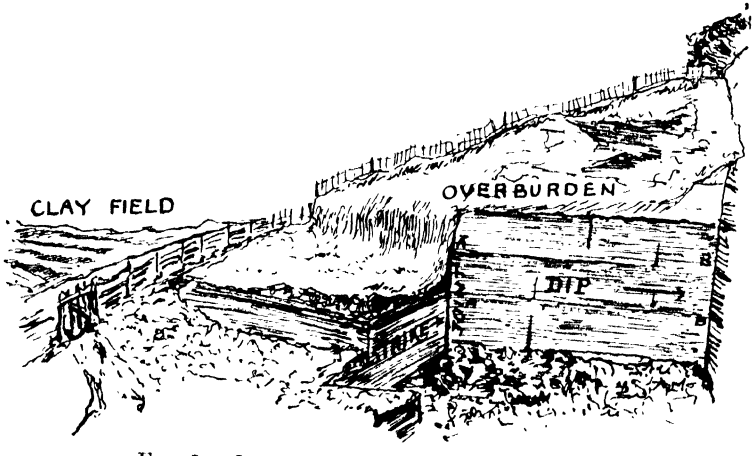


Fig. 3.—Quarry at Norton. View facing dip.

through Cheshire and Lancashire they opened a quarry at Norton on the Great Western Railway between Chester and Warrington. Above is a picture of the quarry which was to supply sandstone to build a water tower close by We

must examine this picture carefully. First of all we see the massive sandstone resting in regular layers all sloping in the same direction. The sandstone is said to be bedded in that direction, and the lines *A*, *B* mark the bedding-planes. These bedding-planes are the successive surfaces upon which the sandstone accumulated when it was formed on the sea bottom. The blocks of sandstone which are quarried are most easily detached along the bedding-planes.

ii. Let us now examine the way in which the sandstone slopes. If we go round to the front of the pit we get the view given below (Fig. 4).

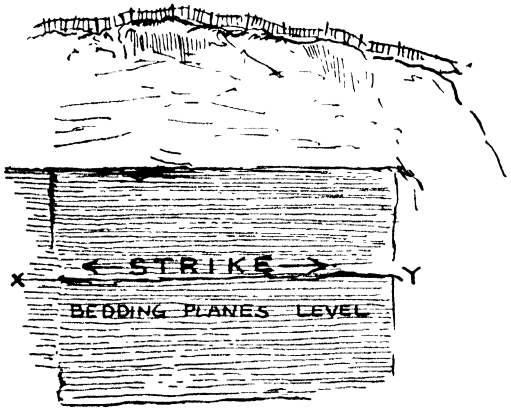


FIG. 4.—Same quarry. View facing strike.

Again we see the lines formed by the bedding-planes. But this time they are level and not tilted as in the previous view. The direction in which these lines are level is known as the *Strike*. The sandstone is said to strike in the direction *X Y*. Each layer of sandstone

between two bedding-planes is called a *Stratum*. Now the first view shows the side of the pit at right angles to the second, and in the first view the rocks are tilted. The amount of tilt is known as the *Dip*. The sandstone is said to dip at an angle of so many degrees from the horizontal. It follows that the direction of the dip is at right angles to the direction of the strike.

iii. There is another interesting point in the picture that we must not miss. Between the bedding-planes in either picture there are vertical cracks in the sandstone at more or less regular intervals. These cracks are known as *Joints*. The quarryman takes care to use these joints in detaching the blocks of building stone, for the joints enable him to get a purchase on the block he wishes to detach and to remove it along the bedding-planes with comparative ease. It is certainly important in any mining or quarrying operation to study carefully how the joints in the rocks are arranged. In the picture there is one set of joints parallel to the dip and one parallel to the strike.

iv. Next, Fig. 3 shows the effect of some past earthquake. The field on the left and the path leading past the quarry are formed of a stiff clay totally unlike the sandstone which it runs up against. Moreover, if we walk past the quarry along the path in the direction of the strike, we constantly see the continuation of the sandstone rocks on the right hand of the path. The surprising thing is that the sandstones

which go down deep in the quarry do not continue across the clay field, as the dotted lines in the diagram below indicate that they should. The reason why they do not is that there is a great break, more or less upright, in the earth's crust just here running right along the path.

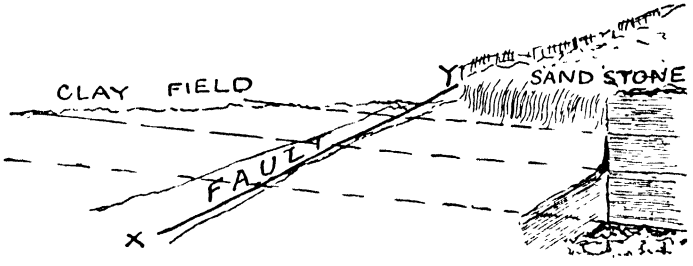


FIG. 5.—View of Norton quarry to show the fault.

This is a fault, and the line *X Y* (Fig. 5) indicates its position on the surface.

v. If we are doubtful about this conclusion we may prove it in the following manner. If the crust of the earth has cracked along this line, the sandstone rocks should be sunk deep down under the clay field. And if they were sunk, they should come up to the surface some distance away. Now the following figure shows how they actually do this. *Q* (Fig. 6) is the sandstone quarry. One mile away the same sandstone forms the steep hill on which the village of Halton is built. Close by the quarry the sandstone lies many feet beneath the clay field. From there it gradually rises until it appears at the surface at Halton. The appear-

ance of a rock at the surface of the earth is known as its *Outcrop.*

vi. The fault *X Y*, which cuts off the sandstone in the quarry from the clay in the fields, runs right along the strike of the rocks. It is therefore called a *Strike Fault.* A strike fault is a break in the earth's crust which runs in the

FIG. 6.—Section through Halton to Norton.

direction of the strike of the rocks it breaks through. Now let us imagine ourselves on the sandstone hill of Halton. When we look towards Norton we shall be looking in the direction of the dip (Fig. 6). Suppose now we turn and walk, *not towards Norton,* but at right angles to that direction, namely, along the hill top in the direction of the strike, that is, in the direction in which the bedding-planes are level. In the annexed diagram (Fig. 7) Norton lies right behind the church on Halton Hill, and we propose walking towards the point *P.* Now as long as we walk in the direction of the strike we ought to remain on sandstone, for in the direction of the strike the sandstone lies level and cannot disappear underground.

But before we have gone half a mile the sandstone ends abruptly and we come upon clay fields again! This is due to another fault at *P*, running in the direction of the dip to Norton. A fault which runs in the direction of the dip is known as a *Dip Fault.* The strike fault and dip fault we have discussed above are at right angles to each other and meet each other, thus

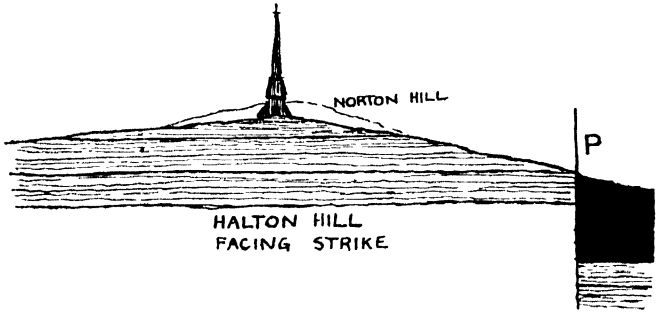


FIG. 7.

cutting out a gigantic block of the earth's crust one mile long and of great width.

vii. We may learn another important thing from the picture showing the relationship between the rocks at Halton and the quarry at Norton. Notice the slope of the hill-side above the quarry. We must be extremely careful not to confuse this slope or gradient of the hill-side with the dip of the rocks which form the hill. The hill-side slopes from *P* to *Q*, but the rocks dip from *Q* to *R*. Thus the dip and gradient (or slope of the hill) are two entirely different quantities.

viii. The same picture shows also what is known as an *Escarpment.* From the quarry to Halton the land rises gently. But at Halton there is a steep hill down to the road at *T.* The steep face of the hill made up of the abutting ends of the sandstone is known as an escarpment. A gentle slope like that from Halton to Norton is called a *Dip Slope,* because it follows the dip of the rocks beneath it. We shall frequently meet with dip slopes and escarpments later, and it is therefore important to understand their relationship to each other.

Questions.

1. What is an outcrop? Could you tell the direction in which it strikes?
2. Name the hills in your neighbourhood. See if you can distinguish between the escarpment and the dip slope of any of them.
3. If a sedimentary formation has no dip at all, what do you know about the way it lies? How does it strike?
4. What happens to a formation when a fault breaks through it? Does it depend on the direction in which the fault runs?

CHAPTER V

FOLDED ROCKS

i. THE clay overlying the sandstone in Fig. 6 strikes in the same direction and dips to the same extent as the sandstone itself. That is to say, the clay lies in layers or strata on the top of the sandstone with no break between them and no change in the direction or amount of dip. In the field you may prove this by going to any of the ponds, or " pits " as they are called by the farmers, which are dug several feet deep in the clay. In the side of the pond the clay may be seen sloping in layers in the same direction and to the same extent as the sandstone in the quarry. Of course, you cannot see this on the surface of the fields, for they are ploughed, and even if they were not the soil would obscure the structure beneath. Now when two formations lie one on the other with no break between them, as we have seen in the example of the sandstone and clay of Halton, the upper one is said to be *conformable* to the lower one. Thus here the clay is conformable to the sandstone.

ii. Formations do not invariably lie conformably. On the contrary, we may often

find a quarry (Fig. 8) where an overlying formation is bedded in an entirely different direction from the formation below it. Here the level strata above do not lie parallel with the strata of the mountain limestone below, as you may see from the bedding-planes. Those above are said to rest *unconformably* on those

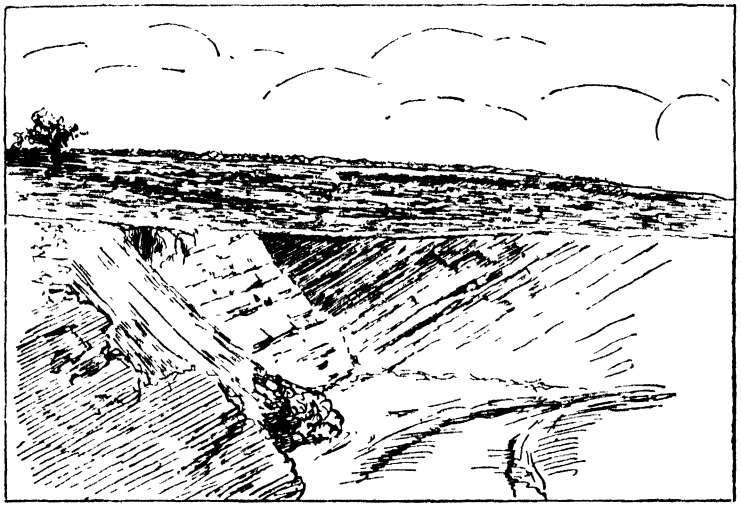


FIG. 8—A quarry in unconformable limestones.

below. Let us endeavour to understand what the real difference between conformity and unconformity is.

iii. Two formations are said to be conformable when :—

(1) The second lies on the first;

(2) They both strike in the same direction ;

(3) They both dip to the same extent.

We have already learnt how to recognise conformable beds in nature. Now those beds are conformable because the uppermost was laid down upon the undermost as soon as the latter had accumulated upon the sea floor. The older bed lay spread out over the ocean floor, and while it still remained there the newer bed was spread out upon it. There was therefore no break between the older and the newer beds. The earth movements which have raised them and tilted them into their present position occurred after they were both formed, and have affected both equally.

iv. Two formations are said to be unconformable when :—

(1) The second lies on the first;

(2) Either the direction of the strike or the amount of the dip is not the same in each, or,

(3) Neither the direction of the strike nor the amount of the dip is the same in each.

We have learnt in section ii how to recognise an unconformity in nature. The lines formed by the bedding-planes of the upper (or newer) formation are not parallel to those formed by the bedding-plane of the under (or older) formation. What has caused this change in direction which is characteristic of unconformable beds ? After the older formation had accumulated on the sea bottom it was raised by an earth movement until it became dry

land, as we have studied in the second chapter. Then the frost and sun and rain wore it down until it had partly disappeared. The whole district then gradually sank beneath the waves, and as it sank the newer formation gradually accumulated upon its worn edges. After the newer formation had accumulated upon the remains of the older, they were both raised into the position they now occupy. We see, therefore, that a great earth movement had taken

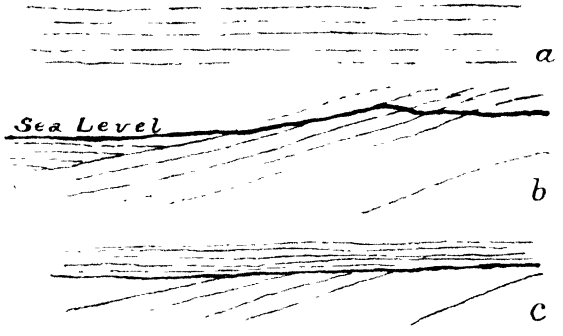


FIG. 9.—Illustrating the formation of an unconformity.

place between the time of formation of the older beds and the time of formation of the newer beds. It is this that constitutes the great difference between conformity and unconformity. To-day those formations which are accumulating round the shores of our Island are unconformable to the rocks beneath the coast.

v. Suppose the older formation to lie at the bottom of the sea as represented in Fig. 9 (*a*). Next comes an earth movement raising it

and the rocks beneath it as in (*b*). The weather then sculptures the surface into hills and valleys and wears it almost flat, perhaps even wearing the topmost formation right away and exposing an older one underneath. The dark line represents the worn surface. Then the sea washes right over it and deposits another (unconformable) formation upon it as represented in (*c*). Lastly, another earth movement raises the whole area again until it forms part of the land surface. A quarry exposing a record of the unconformity would then present the appearance of that in Fig. 8.

vi. A glance at the picture below will show that rocks are flexible enough to be bent or

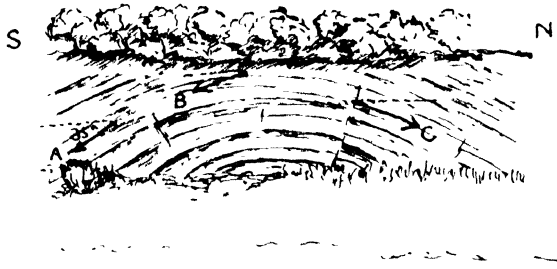


Fig. 10.—Anticline in sandstone at Frodsham, Cheshire.

folded. An arch-shaped bend like that in the illustration is known as an *Anticline* or *Saddle*. When rocks are folded to form a *Basin* or *Trough*, the structure is known as a *Syncline*. If the picture were turned upside down the folded beds would reproduce the appearance of

a syncline. What is the dip at the point *A*? It is about 35° south, measured from the level. What is it at *B*? It is about 15° south, and again at *C* it is about 30° north. Thus, anticlines (and synclines) show changes in the amount of dip. Notice that in unfolded rocks we found the amount of the dip constant in conformable formations. Here it changes, although the rocks are conformable.

vii. Anticlines of a very great span are common. Thus journeying from London to Brighton we cross the North Downs about ten miles south of London, and the South Downs about forty miles south of London. These Downs are made of chalk, and the country lying between them is mostly sandstone. Now the dip of the North Downs is four or five degrees north, and that of the South Downs is four or five degrees south, as the arrows in the diagram show. The North and South Downs

FIG. 11.—Section from London to Brighton.

were once continuous and formed a gigantic anticlinal mountain following the dotted lines. The rain has washed all but the Downs away, and the sandy country between is the core of the original mountain.

viii. Snowdon, in North Wales, has the

structure of a syncline. The distance across the mountain is about seven miles. On the north side the rocks dip inwards towards its

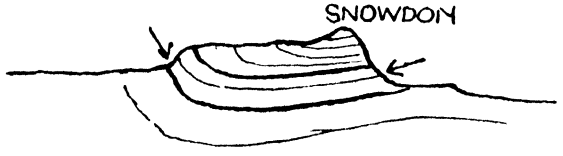


FIG. 12.—The Snowdon Syncline.

centre and similarly on the south side. We draw from this example the important inference that a mountain is by no means necessarily an anticline, that is, an arch-shaped structure.

ix. Let us now turn our attention to the granite-like rocks, which have once been molten. If we look into a quarry where such rocks are blasted we shall miss in the first place the bedding-planes which we saw in the quarry on page 21. After all, bedding-planes result from the accumulation of layer upon layer of material on the sea bottom. Now the rocks we are considering here were not formed at the bottom of the sea, so there could not possibly be bedding-planes in them. But the joints we met with in sandstone occur in these rocks too, and they are useful in mining, for the rock-masses are weakest along the joints. Another important distinction between the two classes of rock, namely, the sedimentary rocks formed as sediments on the sea floor, and the igneous rocks formed from the molten condition by

cooling, is this : the sedimentary rocks contain vestiges of all kinds of shell-fish and sea animals, for their skeletons fall to the bottom of the sea and are covered up by the accumulating sediments. They are thus preserved. But the igneous rocks could not possibly contain the remains of organisms. Thus, although we may find fossil remains in sandstones, limestones and clays, we should not find them in any igneous rocks. Some sedimentary rocks have been changed by earth pressure to such an extent that they resemble igneous rocks very closely. To distinguish them it is often necessary to cut thin, transparent slices from chips of them and to examine the slices under the microscope. The microscope then reveals whether they have been molten or not.

x. Igneous rocks may be faulted just as sedimentary rocks are. But they naturally offer greater resistance both to faulting and folding. One reason for this is that they have their roots far down in the interior of the earth, and, besides, the inter-engagement of the crystals of which they are composed makes them extremely strong. If we take a section through a granite mass like Dartmoor in Devon, we shall find that the granite goes down and down into the earth, not coming to an end as far as we can bore. Yet you may easily bore through the sandstones and limestones round it and reach the granite base upon which they rest. Fig. 13 will show this. It will be easily

understood that an igneous mass like Dartmoor would offer great resistance to faulting and

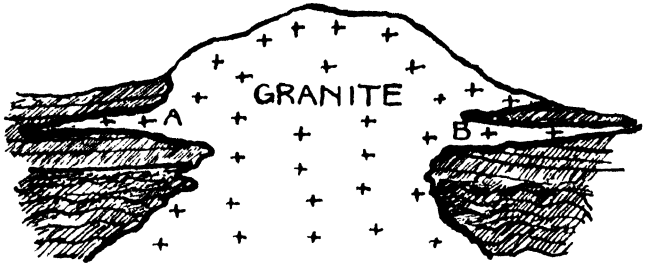


FIG. 13.—Section through a granite mountain.

folding. Usually the molten granite has found its way along the weak bedding-planes of the surrounding sedimentary rocks as illustrated at *A* and *B*.

QUESTIONS.

1. Show how rocks dip when they are folded into anticlines and synclines.

2. The diagram showing the section across the Downs south of London displays an eroded anticline. Describe this structure and point out how the rocks dip, and how they strike. Mark the escarpments and the dip slopes. (See Fig. 11.)

3. How would you recognise an unconformity? What has caused such a structure?

4. If you bore through the sedimentary crust of the earth, what do you arrive at? How do rocks which lie below the sedimentary rocks form an outcrop? What is the country like in such a district?

CHAPTER VI

HOW THE SHAPE OF THE EARTH'S SURFACE HAS BEEN DETERMINED

i. MOUNTAINS and high hills are always formed of hard rocks. They have been left standing while the softer rocks were washed away. Sandstones, especially hardened and compact sandstones, generally resist the onslaught of the weather, and form hilly or mountainous country. Many of the high mountains in the Pennine Range—Whernside, for instance—and the Peak are capped with a resistant sandstone known as Millstone Grit.

ii. Limestone also forms hilly ground. One reason for this is that limestone is usually well jointed, so that when rain falls upon it, it is quickly drained off down the joints and disappears underground. In this way a complicated network of underground streams is created in the interior of the mountain. This process is facilitated by the ease with which water dissolves limestone. The streams run through cave after cave until they issue lower down the mountain. The result of such underground drainage is to prevent the limestone

from getting weathered away. Chalk hills, in a similar manner, absorb the rain that falls upon them. You very rarely see a stream in chalk country, because the water soaks away so quickly. Thus the chalk avoids relatively the destructive effect of the weather. The rain which soaks through frequently issues from the side of the hill as a spring.

iii. Clays are most easily washed away by the rain. They are impervious—that is to say, the water does not sink into them. Consequently all the rain that falls upon them has either to drain off into streams and rivers or else to get dried up by the sun. Now the particles which compose the clay are extremely small; they are less than one 10,000th part of an inch across. A single drop of rain can easily carry off a number of particles of this minute size, while it could not carry a grain of sand one-eighth of an inch across. So the clays are easily weathered away and form the plains.

iv. Altered rocks, particularly slates and slaty rocks such as shales, which were formed from muds and clays, make hilly and mountainous country. The rain cannot easily detach the slate particles as it could the particles of clay. Moreover, slates are frequently bedded at a high angle (that is, they are almost upright in the ground), so that the rain runs off them without making any impression upon them. Practically the whole of Cardiganshire, a great part of North Wales, and Cumberland, which

form some of the most mountainous districts in Britain, are composed of slaty rocks.

v. Igneous rocks are usually hard to weather. Some kinds are more resistant than others. The effect of the weather upon granites is to work into them along the joints. In granite scenery you will observe great and small blocks of granite, quite detached from the rock beneath them, littering the valleys, especially in the stream beds. Water has the power of dissolving out certain of the crystals which compose the granite. In this way the joints are enlarged until the block formed by the joints is detached. Other kinds of igneous rocks—certain lavas, for instance—are extremely resistant to weathering, to a greater extent even than sandstone. This is because they are made so largely of silica, which the rain can hardly dissolve at all. Such rocks form the gigantic precipices of Cader Idris.

vi. Now let us think of some hills and valleys and ask ourselves why they are hills and why they are valleys. First of all, let us consider the sandstone hill at Halton pictured in Fig. 6. It is true that the sandstone is harder than the clay which rests upon it. But it is not the resistance of the sandstone alone that has formed the hill. The hill is there because the sandstone comes up out of the earth from the fault by the quarry, as the figure illustrates. So it was the *structure* of the ground that determined the position of the hill, that is, the way the rocks lay underneath. The weathering

away of the overlying clay more than the underlying sandstone gave the hill its final shape.

vii. The North Downs which run through Kent and Surrey will provide us with a similar example. Their position is fixed by the structure of the anticline we discussed in Chapter V. But their shape has been determined by the action of the weather upon that anticline. We might continue to examine district after district in this way, including the sea-coast, where the waves are constantly hammering at the rocks which form the coast. Everywhere we should find that structure determines the position of the main features of the district, and that weathering adds the graceful outline by wearing down the harsh irregularities.

viii. By this time we should understand with complete clearness the part played by each of the three factors which decide the form of the earth's surface, namely :—

(1) Structure ;
(2) Kind of rock ;
(3) Weather.

This is such a weighty matter that it would be well to summarise here the argument of the preceding paragraphs.

(1) The structure of an area is the arrangement of the rocks composing the area. Their arrangement is due entirely to earth movements. Such movements have reared the rocks into their position from the sea bottom, have tilted them and given them a dip, and have

folded them perhaps into anticlines and synclines, or broken them by strike faults or dip faults. They constitute, as it were, the architectural design of the earth's crust in the district, and this design decides the position of the hills and valleys.

(2) The kinds of rocks which form the district and which have been slowly forced into the structures we have described are (*a*) sandstones, limestones and clays, together with varieties of these and their altered products, and (*b*) granites and other igneous rocks. To some extent the kind of rock will also affect the structure, for some rocks are more resistant to earth movement than others.

(3) Weathering agents are sun and frost, wind and rain, waves and tides. Ice, too, has had a tremendous effect as a weathering agent in past times in England. In other countries it still continues as the greatest weathering agent of all. These agents work relentlessly upon the rocks arranged by earth movements in their several structures. They always destroy the land, and build it up again in the ocean bottom. Their work of destruction is much more vigorous on some kinds of rocks than on others. Their effect is, therefore, differential, and in consequence their work is to shape the surface of the earth. They work on the structure and modify the shape which the structure gives to the land. They give the land its present-day graceful contours.

ix. There is one aspect of weathering which

we must consider more closely because it has had a great influence on the rise of civilisation. It is the development of rivers by means of which the greatest part of the weathering of the land is effected. Fig. 14 shows a section along the dip of Norton Hill with which we are now familiar.

In which direction would you expect to find a stream flowing? Surely down the dip slope *P Q*. A stream which develops along a dip slope is known as a *Dip Stream*. Now past

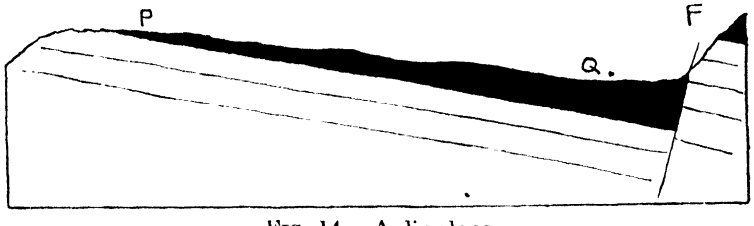


FIG. 14.—A dip slope.

P Q there is a fault *F*, which brings up hard sandstone. Along this fault a larger brook has developed in the direction of the strike of the clay. The dip stream flowing down *P Q* is a tributary of the *Strike Stream* in the fault. Now the strike stream flows on until it meets a still larger dip stream, into which it in turn empties. It is clear that a dip stream may start its course from any elevated land, whatever its nature. But a strike stream can only develop along soft rocks, such as clays or easily disintegrated sandstones. We shall learn later that the courses of all rivers have been determined by the structure and rock-types of the

formations over which they flow, just as here we see the dip stream rise from the hard sandstone and the strike stream develop along the soft clay. But to study this more fully we shall need the help of a map. Consequently, we shall return to this subject after we have learnt something about maps.

x. Would you expect to find all valleys more

FIG. 15.—A section across the Thames valley.

or less alike in their general shape? To answer this we shall compare three typical valleys:—

(1) The valley of the Thames through London;

(2) The valley of the Tawe through Swansea;

(3) The valley of the Aber in North Wales.

The Thames through London runs in the direction of the strike of the clay which fills the basin

FIG. 16.—A section across the Tawe valley.

formed by the syncline of chalk on which London is situated. The valley is very broad.

From London Bridge one has to go five or six miles northward or southward before one has climbed one hundred feet, and to climb five hundred it is necessary to travel about twelve miles southward or eighteen to the north. The river drops very slowly to the sea. Fig. 17 shows the gradient of the valley. It drops less than one foot per mile.

The Tawe is a dip stream which crosses the South Wales coalfield and enters the sea at Swansea. The valley is very narrow. A mile from the stream on either side the land rises

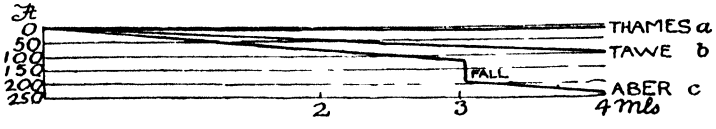


Fig. 17.—River gradients. (*a*) Strike stream; (*b*) Dip stream; (*c*) Dip stream with water-fall in its course.

above seven hundred feet. Factories are built on the flats by the river banks and people live on the steep hill-sides. The river runs fast to the sea. Fig. 17 shows the gradient of the valley. It drops twenty-five feet per mile. The Aber is also a dip stream. Its interest lies in the water-fall which interrupts its course. Fig. 17 shows the effect of the water-fall on the gradient.

xi. Waterfalls are likely to be formed wherever a fast stream is traversing formations of unequal hardness. When the stream leaves a hard formation and passes on to a softer one it cuts its bed down faster in the softer formation

than in the harder one, so that a sudden change in the gradient is produced. The water then leaps from its bed in the harder formation to that in the softer. The Niagara Falls are a good example of the development of such a waterfall. The river falls over a hard limestone on to a softer shale. We shall describe the formation of another kind of waterfall in a later section, page 122.

xii. We learn therefore that valleys are by no means all alike. Broad strike valleys through which a river flows gently are admirable sites for great centres of modern civilisation. Of these the finest in Great Britain is the Thames Valley. Narrow dip valleys through which a river hurries to the sea are usually important highways of communication across hilly or mountainous country, or sites of industrial centres where the power of the rushing stream can be converted into electricity or used in other ways in manufacturing operations.

Questions.

1. Name some kinds of rocks which resist weathering. Describe the way running water acts upon them.

2. Clay formations form low-lying country. Explain this.

3. Show what part is played by (*a*) the structure of a district, and (*b*) the kind of rocks in the district, in forming the surface relief.

4. What is a strike stream? How does the valley of a strike stream differ from that of a dip stream?

5. The Thames is 225 miles in length. Certain intermittent springs start at 800 feet in the Cotswold Hills.

From its main source near Cirencester to Lechlade, a distance of 15 miles, it drops at a rate of seven feet per mile. From Lechlade to Teddington, a distance of 140 miles, it drops about $1\frac{3}{4}$ feet per mile, and from Teddington to London Bridge, 20 miles, about one foot per mile. Draw a graph of its course to scale. At what height does its main stream rise ?

CHAPTER VII

HOW THE RELATIVE AGES OF ROCKS ARE FIXED

1. The road from London to Portsmouth in the neighbourhood of Petersfield crosses a clay formation known as the Gault (1), and passes on to the Chalk (2) of the South Downs. On

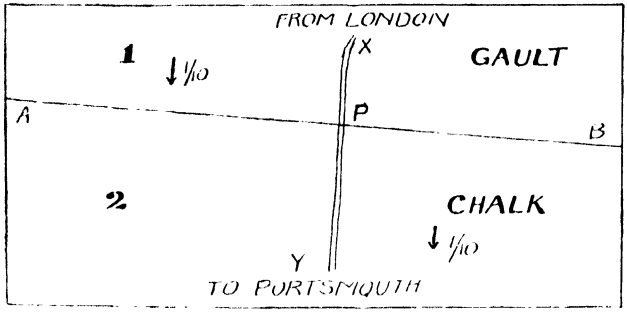


Fig. 18.

the above map the line *A B* marks off the Gault outcrop from that of the Chalk as you would see it from an aeroplane. If you were now told that the Gault was older than the Chalk, would you be able to draw a section of the crust along the line formed by the road ? Suppose the line *X Y* (Fig. 19) to represent the road and *P*

the point at which you cross from one formation to the other. Since the Gault is older than the Chalk it must lie beneath. In order to illustrate this on the section we must draw a line *P Q* (Fig. 19) showing the Chalk above it resting upon the Gault below. *P Q* is the base of the Chalk, and the Chalk dips in that direction. We may therefore draw lines in the Chalk part of the section parallel to *P Q* to indicate the bedding-planes dipping southwards. If the Chalk is conformable to the Gault we may draw more

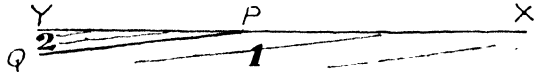


Fig. 19.—Section through map on page 47.

lines in the Gault part of the section parallel to *P Q* to illustrate the dip of the Gault.

ii. From paragraph i we learn that it is necessary to know the relative ages of geological formations before we can draw a section from a map. The question arises therefore, "How do geologists discover which is the older of any two formations?" There are several ways in which this may be done.

(*a*) In the first place it is clear that if we can actually see in the field some quarry or cutting or natural exposure where the formations in question lie upon one another, then we may be sure that the one above is younger than the one it rests upon. This is known as the *Test of Superposition.* But we should take notice that in rare cases the area may

have been so folded or faulted that the true order has been reversed, and the older formation has actually been brought to rest on the younger.

iii. When the geologist is seeking for evidence of superposition he goes to a quarry or cutting and observes the way in which the exposed rocks are dipping. He then puts in an arrow on his map indicating the direction of the dip. Thus, in the map given, the arrows indicate that the formations dip in the direction in which they are placed to the amount of one foot in ten feet. Now this is as good as knowing that the Chalk rests upon the Gault, for if the opposite were true the arrows would point in the reverse direction.

iv. When we know the amount of the dip we may draw a more accurate section. Here it is given as 1 in 10. We can now tell the slope of the line *P Q*. In order to draw it correctly we measure one inch from *P* along the horizontal towards *Y* and then drop $\frac{1}{10}$th of an inch to *Q*. The line *P Q* then dips to the correct amount. Now sections are sometimes required, not in the direction of the dip, but in some other direction. Suppose, for instance, we required a section in the direction *L M* (Fig. 20). As before, we should draw a horizontal line *L M* (Fig. 21) and mark on it a point *P* where the formations change. At what inclination must we draw the line *P Q* in this section? It clearly cannot be 1 in 10, for *P Q* only dips 1 in 10 in the direction of the arrow. To find

the amount of the dip in the direction PM we draw a line $A'B'$ parallel to AB at a distance of ten units from AB. (If we make each unit equal to one-tenth of an inch, then this distance will be one inch.) We then set off from P in the section the length PP' and drop one unit

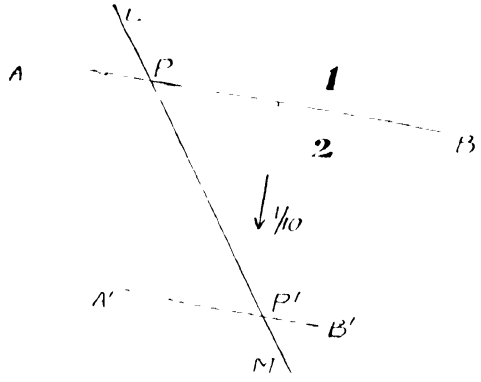


FIG. 20

FIG. 21.—Section along $L\,M$, Fig. 20.

($\frac{1}{10}$th of an inch) below to Q. PQ will then be the true inclination of the base of the upper formation in the direction of LM. To understand the reason for this, all we need observe is that :—

(1) AB is the base of the upper (Chalk) formation ;

(2) By the definition of dip, the base lies one unit below the surface all along $A'B'$ if $A'B'$ is ten units distant from AB;

(3) In passing from P to P', the base consequently falls one unit in the distance PP'.

v. We shall now return to consider the other indications of the relative ages of rocks.

(*b*) If fragments of one formation, A, are discovered incorporated in another formation, B (as pebbles say, or minerals), then B is partly derived from A and A must therefore be older.

(*c*) We may know the age of a certain formation in a certain district by one of the tests given under (*a*), (*b*), (*d*). If we discover rocks in another district altogether which exactly match those of the known formation we may infer that the two are of the same age.

(*d*) The finest evidence of the age of a formation is given by the fossils which occur embedded within it. The animals and plants which inhabit the globe at the present day are by no means the same in appearance and form as those which used to inhabit it. There was a time when man had not appeared upon the earth. Earlier no mammals, such as horses and cattle, tigers and giraffes, existed. Earlier still birds were absent; earlier again, reptiles; and earlier yet, fish. It was Charles Darwin's great work to conceive a theory to account for the successive rise of new species of life ending in the forms of life which we see around us to-day. It is known as the Evolutionary Theory. According to this theory there was a time in the remote past when the only life which existed upon the earth was in the form

of minute jelly-like cells. Some of these were green and gave rise to lowly forms of sea-weeds and green algæ. Later they found their way to the land and developed into lowly moss-like plants from which there arose, after long ages of variation, ferns and trees. Then other cells were colourless and led to lowly forms of animal life—curious shell-fish, some long since extinct, but the shells of which remain, sponges and corals, then fish with backbones. From these arose reptiles, and from the reptiles, birds and mammals. What use can the geologist make of this evolutionary record ? He can use it as an index to the age of a formation. Each formation contains the vestiges of animal or plant life in a fossil form, and each particular variety of animal or plant occurs only in definite formations, perhaps only in one. This is often such an accurate guide that every few inches of a formation may contain some characteristic fossil. If this fossil is found in some other district, the geologist knows at once the precise age of the formation in which it occurs.

vi. Guided by the three rules (*a*), (*b*), (*c*) above and by the evolutionary record (*d*), geologists have divided the stratified rocks into three main groups, namely :—

(3) Cainozoic or Tertiary Rocks;
(2) Mesozoic or Secondary Rocks;
(1) Palæozoic or Primary Rocks.

Each of these groups is again subdivided into systems which we shall learn later, and a

shorter list of which is given on page 309. The oldest group, namely, the Palæozoic, contains vestiges of the most ancient forms of animal and plant life. The Mesozoic is the age of enormous reptiles, birds and mammals, and the Cainozoic, of forms of life more closely allied to those in existence to-day. These are the meanings of the words from which the group names are derived.

vii. The age of an igneous rock is decided by the age of the sedimentary rocks round it. It must be younger than the youngest beds it affects. The sills of volcanic rock mentioned on page 17, for instance, could not have found their way into the limestone, if the limestone had not been there first. The sill of volcanic rock is consequently younger than the limestone.

QUESTIONS.

1. What does the geologist call the "test of superposition"? What is the use of this test, and how would you use it in the field?

2. Many geologists make collections of fossils. What is the chief use of the fossil remains in a formation?

3. Make a summary of the tests which are used in determining the age of sedimentary rocks.

4. Two formations dip 1 in 10. Draw five sections across their outcrops on a level surface—(i) along the dip, (ii) in a direction inclined at 30° to the direction of the dip, (iii) in a direction inclined at 45°, (iv) at 60°, (v) at 80°. What do you gather from these sections?

CHAPTER VIII

UNCONFORMABLE BEDS

i. THE plan of a district showing the manner in which the geological formations appear on the surface, as, for instance, on page 47, is called a *Geological Map.* The formations are named (Gault, Chalk, etc.) according to their ages, decided as in the previous chapter. The order of the formations according to their age is usually given at the side of the map, the oldest being marked 1, the next 2, and so on.

ii. Let us now see how the various structures we have discussed in former chapters show up on a geological map. There is a hill behind Portsmouth known as Portsdown, which overlooks Spithead. Fig. 22 is a geological map of the district. The hill is made of chalk (marked 1). North and south of it are strips of newer sandy country (marked 2), and further north and south a stiff clay (marked 3). The numbers represent the relative ages of the formations. What is the structure of the hill? Draw a line *A B* (Fig. 23) and mark on it the points in which the line *X Y* (Fig. 22) cuts the outcrops in the map, namely, *a, b, c, d.* Now

apply the rule of superposition. 2 is older than 3. Consequently we must draw a line *a a* showing 3 resting upon 2. 1 is older than 2. Draw *b b* showing 2 resting upon 1. In the same way draw *c c* and *d d*. Joining *a a*, *d d*

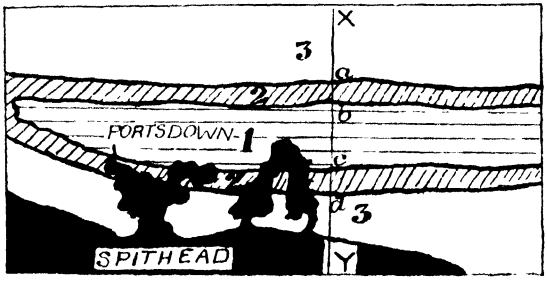


FIG. 22.

and *b b*, *c c* above *A B*, we discover that the hill has the form of an anticline, the top of which has been denuded. There is no difference between the appearance of an anticline and of a syncline on such a map. We need the order of the for-

FIG. 23.—Section through Portsdown.

mations to discover whether we have one or the other. If, for instance, the order were reversed, as in Fig. 24, the section obtained by the rule of superposition would be that of a syncline.

iii. In the small geological map of Fig. 18 the strike of the rocks is parallel to *A B*. The dip is also constant, because the beds are con-

formable. In the geological map of Fig. 22 the strike of the rocks is constant and parallel to the direction of the hill, although the dips

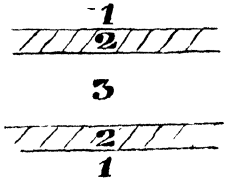


FIG. 24.

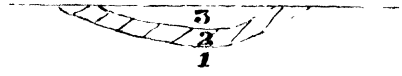


FIG. 25.—Section through the above.

vary as the section shows. These maps then illustrate the structures described on pages 32 and 33. We shall next consider how a map shows an unconformity, characterised by a change in strike. Suppose three beds *A*, *B* and

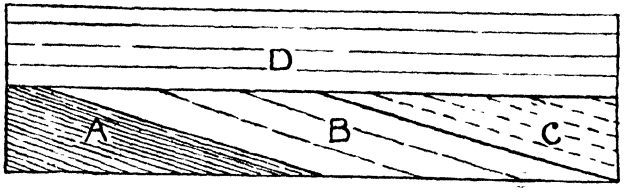


FIG. 26.—Unconformable beds.

C (Fig. 26) are conformable and dip as in the diagram, and suppose a fourth bed, *D*, to be deposited upon *A*, *B* and *C* unconformably. This is the view you might get in a quarry side. Now *A*, *B* and *C* are conformable, so

that they all strike in the same direction. We have learnt that rocks strike in the direction in which their bedding-planes are level, or, in other words, in the direction in which their bedding-planes cut the level ground. Suppose *P Q* (Fig. 27) be the direction in which the base of the formation *B* cuts the level ground. Then the line *R S* parallel to it will be the direction in which the base of the conformable bed *C* cuts the level ground. But the base of the formation *D* will strike in some other direction. Now lines are either parallel or else they meet when they are produced. So that the line in which the base of the formation *D* cuts the level ground will fall across the lines *P Q*, *R S*, as the broken line *X Y* indicates. Now dips are always at right angles to strikes. Hence, we may indicate on the map the change in dip, by putting in small arrows showing the directions of the dips. Whenever we see a formation on a geological map cutting across other formations in this way we know that an unconformity has occurred. Remembering what causes an unconformity, we know at once that between *C* and *D* an earth move-

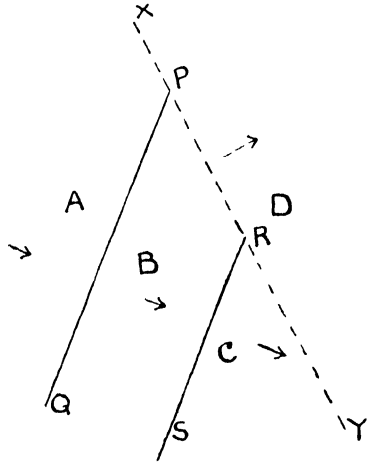


Fig. 27.

ment has taken place which has raised the undermost beds above sea-level and worn them down by weather before the uppermost unconformable bed was laid down upon them.

iv. Next we must learn how to draw a section across an unconformable area. In Fig. 28,

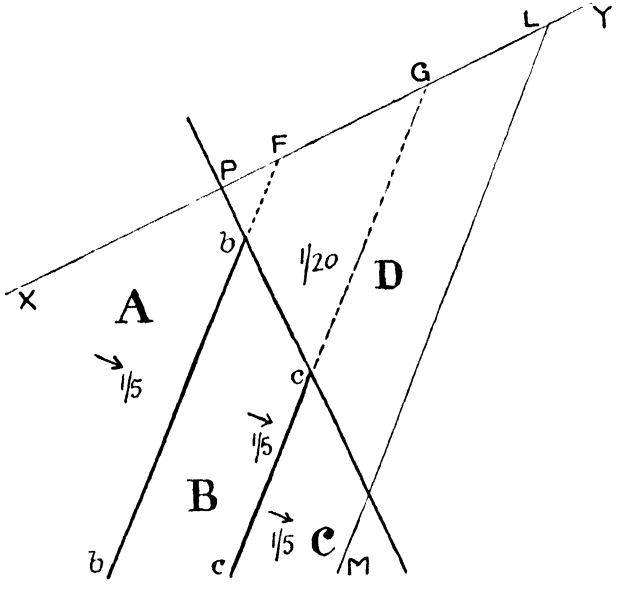


Fig. 28.

suppose *A* dips at 1 in 5, *B* and *C* lie conformably above it, *C* dipping at 1 in 20. We are required to draw a section along *X Y*. First of all, draw a horizontal line *H K* (Fig. 29) and mark on it a point *P* where the formation changes from *A* to *D*. Now in the direction of *X Y*, *D* dips at 1 in 20. To insert the dip correctly, therefore, we mark off five

inches from *P* along *H K* and drop $\frac{1}{4}$th of an inch ($\frac{1}{4}$ inch in 5 inches is 1 in 20). Join the point so obtained to the point *P*. This is the true base of the bed *D*. Where do the beds *B* and *C* occur? They do not reach the surface, for the line *X Y* does not pass through their outcrops. The unconformable bed *D* overlies them. In order to discover their position below *D* we continue the lines *b b*, *c c* to meet *X Y* in *F* and *G*. Now, if the formations *A*, *B* and *C* had not been worn away and covered over by *D*, they would have passed through *F*

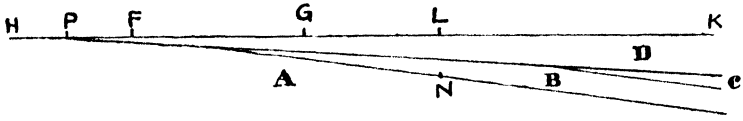


Fig. 29.—Section along *X Y*, Fig. 28.

and *G* respectively, for these points are on their lines of strike. Mark off on *H K*, therefore, points *F* and *G* at the corresponding distances from *P*. At what angle do *A*, *B* and *C* dip? Their true dip is 1 in 5. But this is in the direction at right angles to their strike. We want it in the direction *X Y*. Using the method of paragraph iv of the previous chapter to find this, we draw a line *L M* parallel to *b b* at a distance of 5 units from *b b*. Making each unit $\frac{1}{5}$th of an inch, this distance becomes one inch. Then all along the line *L M* the base of *B* lies one unit ($\frac{1}{5}$th of an inch) below the surface. Hence we set off from *F* in the section a distance *F L* and drop $\frac{1}{5}$th of an inch below *L*

to the point *N*. Then the base of *B* is found by joining *F N*. In drawing this line we take care to stop short at the base of *D*. To complete the section we draw from *G* a line parallel to *F N*, giving the base of *C*.

Questions.

1. Write a short essay on unconformable beds. Say how they appear in a quarry, what past conditions an unconformity records, how it appears on a map, and how you take a section across such a map.

2. Show how the width of an outcrop on a level surface depends on the amount of the dip.

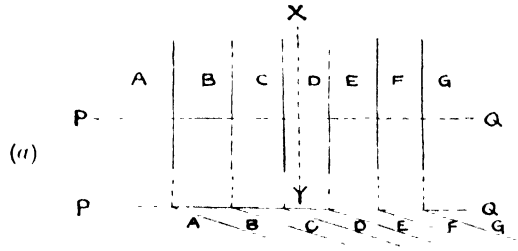
CHAPTER IX

FAULTS

i. We are now about to consider the representation of faults on a geological map. It would therefore be well in order to appreciate what follows to refer to Chapter IV, where two classes of faults are described. We began by a strike fault and discovered that its chief effect on the neighbourhood was to bring about a repetition of the beds in which the fault occurred. Thus, travelling along the dip from Halton to Norton (Fig. 6), we leave the sandstone upon which the church is built, cross on to the clay and arrive at the fault. Beyond the fault we stand on the same sandstones as at Halton, and continuing over Norton Hill we come again to the clay.

ii. We must now account for this repetition of outcrop caused by the strike fault and learn how to recognise such a fault in the field or on the map. Suppose *A*, *B*, *C*, *D*, *E*, *F*, *G* is a series of conformable strata with a constant dip. We have learned that the geological map of such a series of beds on a level surface would appear as a set of parallel lines, all running in

the direction of the strike. This is shown in Fig. 30. The lower half of the diagram is a section through the upper half exactly similar in kind to that through the Chalk and Gault in Chapter VII. Now suppose a strike fault to pass through the bed *D*. Further, suppose the



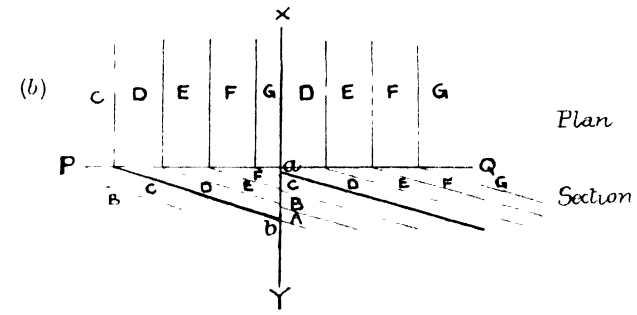


Fig. 30.—A strike fault (*a*). Fig. 31.—A strike fault (*b*).

fault to be vertical, and suppose all the land to the left of the fault to be let down a distance of a few hundred feet. Thus the beds *A*, *B*, *C* and part of *D* have been let down in this manner. Let us consider the section along *PQ* after this dislocation. *XY* (Fig. 31) is the fault. To the right of the fault the beds are undisturbed. But to the left they have

been let down, so that the base of any one, say *D*, has dropped a distance *a b*. This distance measured vertically is known as the *Throw* of the fault, and the side on which the beds have dropped is called the *downthrow* side of the fault.

iii. Now let us see how this affects the outcrop on the map. By projecting upwards

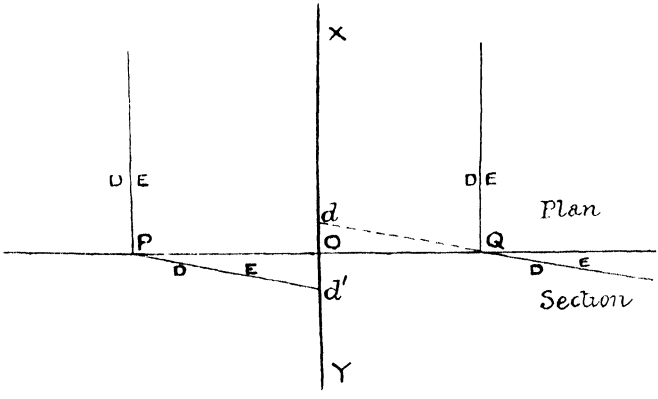


FIG. 32.

the points where the beds crop out, as in the upper half of Fig. 31, we discover that the outcrops have been made to occur twice owing to the fault, and that the younger bed, *G*, has been brought right up against the older bed, *D*, just as in the Norton quarry the clay is brought up against the older sandstone. What determines the distance between the two outcrops of any one bed ? We see that it is fixed by (1) the amount of the dip, and (2) by the throw of the fault. If the dip is

1 in 6, and the throw is 180 feet, the distance between the base of the formation *E*, say, in the two outcrops of that bed will be 180 × 6 = 1080 feet. In order to make sure of the geometrical relationship between the throw, the dip and the distance which separates the faulted beds, we may re-draw Fig. 31 in a simplified manner (see Fig. 32). We shall consider only the base of *E* as it crops out twice. Produce the base of *E* to *d*. Then the distance *d d'* is the throw of the fault, by definition. Also, if the dip is 1 in 6, *O P* is six times *O d'* and *O Q* is six times *O d*. Therefore *P Q* is six times *d d'*. That is, the distance between the outcrops is equal to the throw of the fault multiplied by the denominator of the dip when expressed as a unitary fraction (1 in so many).

iv. What would the district represented in Fig. 31 have looked like if the downthrow side had been to the right instead of to the left, that is, if it had occurred on the dip side of the fault ? As before, we should have the line *P Q* (Fig. 33) along which the section is taken, together with the vertical fault through the bed *D*. This time the beds to the left are unaffected, but to the right the beds have been let down. The effect on the outcrop is then clear. We see that one of the beds, *E*, never gets to the surface at all ! It has been *faulted out*. It might happen that just this particular bed carried some mineral or would yield a useful building-stone, and yet it might remain undetected. This is all the more probable

since strike faults with the downthrow on the dip side are often very difficult to locate in nature. They run in the direction of the strike, and very little indication is given of their presence. Strike faults like that at Norton are

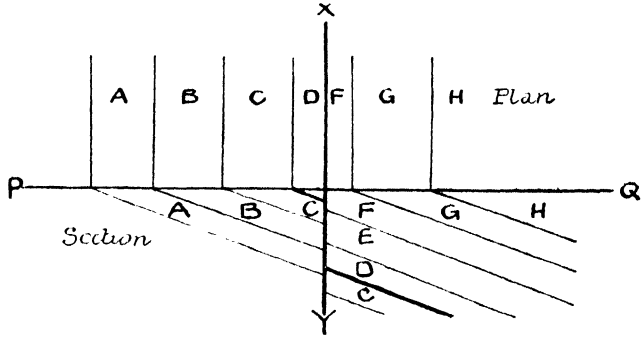
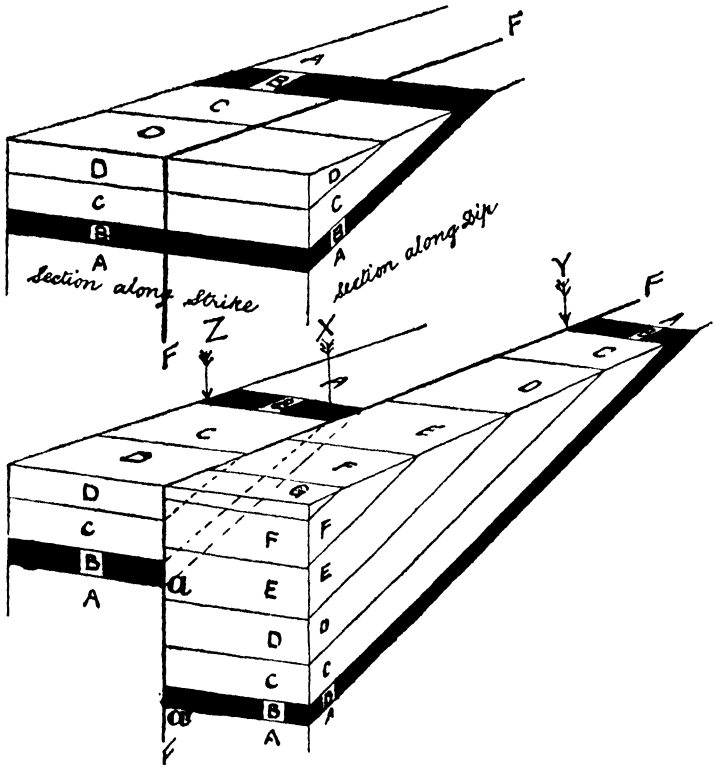


FIG. 33.—A strike fault.

not so difficult to discover, because they cause the repetition of beds, as we have seen.

v. We shall consider dip faults in another way, in perspective. Fig. 34 shows a block of the earth's crust cut to display (1) a section along the dip, (2) a section along the strike (bedding-planes horizontal), (3) the map or plan. Now let us suppose a dip fault, *F F*, dislocates this block. Let the downthrow side be that nearest you. A glance shows what effect the fault has on the outcrop. It produces a lateral displacement of the outcrop. Suppose, for instance, the bed *B* were of sandstone and you were walking along the strike from *Z* to *X* just as we described on page 25. You would suddenly cross on to the bed *E*, which we will

suppose is clay. The sandstone would probably have a dry, sandy soil, but the clay a sticky, wet one. In this way you would become aware of the presence of the fault. In order to pick



FIGS. 34 and 35.—A dip fault.

up the sandstone again, it would be necessary to turn and walk along the fault to *Y*. What determines the distance from *X* to *Y*? By studying Fig. 35 it will be seen, as before, that the distance depends on the two factors,

(1) the amount of the dip, and (2) the amount of the throw. Thus if the beds dip 1 in 6 and the throw of the fault is 250 feet (that is, from a to a'), then the distance from X to Y along the fault would be $6 \times 250 = 1500$ feet.

vi. Nature does not usually display the simplicity we have assumed to exist in the above paragraphs. Strike faults do not as a rule run quite parallel to the strike, nor do dip faults run quite at right angles to the strike. On the contrary, a strike fault usually cuts across the line of strike and is only approxi-

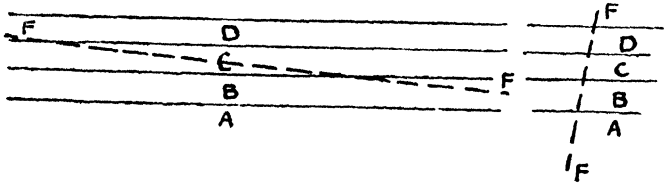


FIG. 36.—A strike fault. FIG. 37.—A dip fault.

mately in the direction of the strike. The line $F F$ (Fig. 36), which runs more or less in the direction of the outcrops of A, B, C, D, would be called a strike fault, and in Fig. 37 $F F$ would be called a dip fault. It follows therefore that the strike fault in nature is also to a small extent a dip fault, and the dip fault to a small extent a strike fault. Now the characteristics of a strike fault are either (1) it causes a repetition of the beds on the surface, or (2) it causes the disappearance of certain beds, according as the downthrow is on one side or the other of the fault, whereas the

characteristic of a strike fault is that it causes a lateral displacement of the beds along the fault. We should therefore expect usually to find in nature a combination of the characteristics of a strike fault and a dip fault in any given fault.

vii. This is illustrated in the series of diagrams of Fig. 38. The first diagram of that set repeats that of paragraph ii (with the downthrow on the side opposite to the dip), showing how a strike fault with the downthrow on the side opposite to the dip causes a repetition of beds. If the dip of the beds is 1 in 7, then the throw of the fault is $\frac{1}{7} \times bb$. The amount of the throw is constant in all the diagrams. This may be tested by measuring the distance between the two base-lines of any one formation. When the fault is only approximately parallel to the strike, as in the second diagram, the repetition still occurs, so that when travelling from *P* to *Q* you must cross the formations *A* and *B* twice, but at the same time there has been a lateral displacement of the outcrops. Thus the base of *B* has been shifted from *c* to *c'*. As the fault becomes more of a dip fault, the repetition of the beds becomes less marked. Thus the area within which a repetition of the beds occurs in diagram 4 is very limited, and finally in 5 the repetition ceases to exist, the whole effect of the fault being to displace the beds laterally.

viii. The series illustrating the effect of faults in which the downthrow occurs on the dip-side is similar. In 1 the bed *C* is faulted out

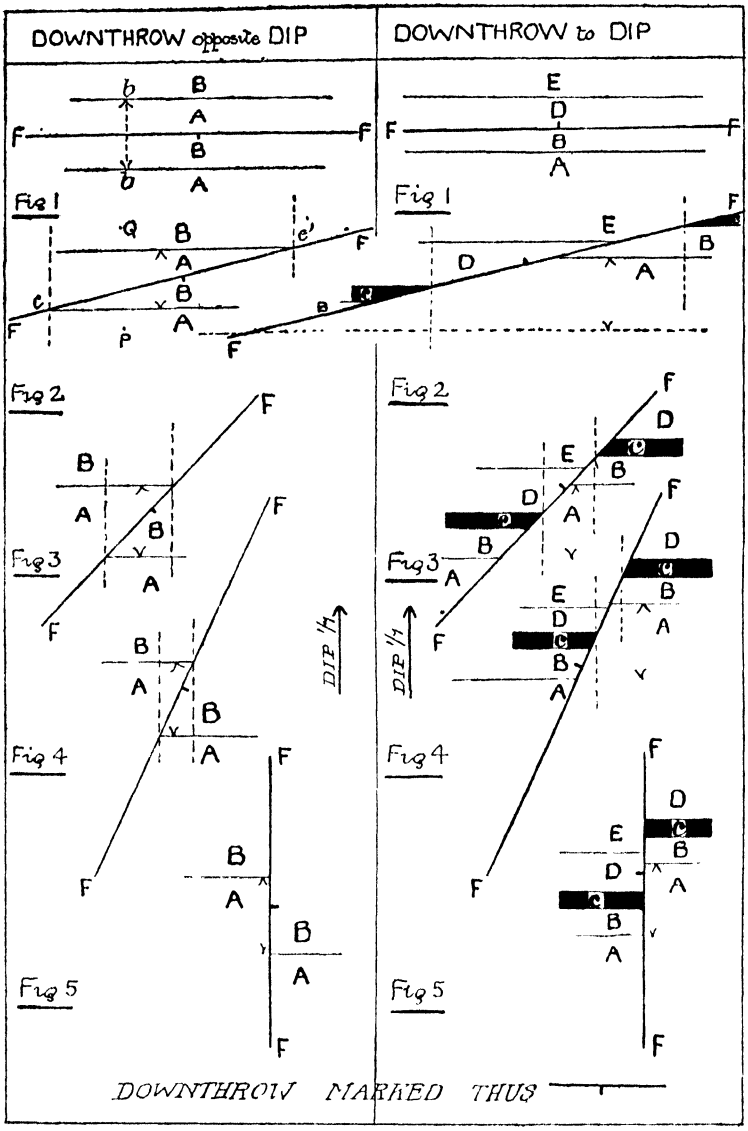


FIG. 38.—Showing the general effect of faults on outcrops. Notice the diminishing areas between the pairs of dotted lines in each successive figure.

entirely. In 2 the dip component in the fault brings up the bed *C* by lateral displacement. But there still remains a large area, indicated by the dotted lines, within which this bed is altogether missing. The dip effect increases, and with it the area within the dotted lines decreases, until in 5 all the beds are present in their entirety, so that the strike effect which faults out beds has quite disappeared.

ix. Faults are rarely quite vertical, although they are generally steeply inclined. They are said to *hade*, just as beds are said to dip. Thus you will hear a miner speak of a fault which hades 1 in 2 to the south. By this he means that the fault strikes east-west (or that it would cut the level surface of the earth in a line running from east to west), and that it dips at right angles to this, dropping two feet in each foot forward. But for the present we need not consider the effects of faults which hade. On level ground their outcrops and their effect on the outcrops of beds are precisely similar to those of vertical faults.

Questions.

1. Show how strike faults differ from dip faults in their effect on the outcrops of sedimentary rocks.

2. If the distance from Halton to Norton is one mile, and the dip of the beds is 1 in 13, what is the throw of the fault? (Fig. 6.)

3. On page 26 a dip fault is described as cutting off Norton Hill (Fig. 7). The sandstone of Halton Hill is quarried two miles farther on, on the other side of the fault. If the beds dip constantly at 1 in 13, what is the throw of the fault?

CHAPTER X

VALLEYS

i. MAPS are drawn on all sorts of scales. A small atlas might contain a map of England on a scale of 50 miles to an inch. On this the distance across England from Liverpool to Grimsby (150 miles) would be three inches. Now the Peak is 2000 feet high. On this scale what upright line would represent the

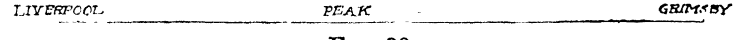


FIG. 39.

Peak ? The answer is $\frac{1}{1320}$ inch. If we draw a section across England on this scale (Fig. 39) the highest mountain is represented by such a small quantity that we cannot distinguish it from the straight line joining the two towns. It is true that we could agree to exaggerate the vertical scale, making it, let us say, one hundred times the horizontal scale. Then the Peak would be represented by a line $\frac{1}{1320} \times 100 =$ 0·76 inch high. And this is what is usually

done in drawing sections from small-scale maps to show mountains and valleys.

ii. From the above paragraph it follows that we may regard the surface of England on a small map as absolutely level. Now this is important to us as geologists, for we have learnt that formations strike in the direction in which their bedding-planes cut the level ground. So we see at once that outcrops on a geological map of small scale run in the direction of the strike. We may consequently take sections across such a geological map by the simple rules we discussed in Chapter VII, for in that chapter we assumed all through that the surface was level, and that in consequence the outcrop of a formation followed accurately the direction of its strike.

iii. But the maps which geologists, prospectors and mining engineers mostly employ are on a very large scale. The three scales commonly used are :—

(1) 1 mile represented by 1 inch;
(2) 1 mile represented by 6 inches;
(3) 1 mile represented by 25 inches.

On a scale of 6 inches to a mile the mountain spoken of above would be represented by 2·3 inches. On such a scale the detail of the countryside is very full, every hedge and house being marked, and the area considered at any one time is only as much as you might easily walk in an hour. So we cannot assume in this case that the outcrops will run in the direction

of the strike, since the surface cannot be regarded as level.

iv. Suppose, for instance, you were standing on the sloping bank of the stream at the point marked *T* in the map on page 310, you might be tempted to conclude that the formation *E* struck across the country in the direction of its outcrop, namely, from *p* to *q*. But this conclusion would be entirely erroneous. As we shall see later, this formation strikes in an altogether different direction. This is one of the difficulties experienced in actually following beds across country. The shape of the earth's surface distorts the outcrop, so that the strike is sometimes not at all easy to discover, and even when it is discovered the outcrop of the bed does not follow it in direction.

v. Consequently we must consider the effect that the shape of the earth's surface has in modifying that regularity of outcrop present when the surface is level. We must investigate the following problem. If Fig. 40 represents the outcrops of two conformable beds, *A* and *B*, on a level surface, so that the line *R T*, which is the base of *B*, is straight, what will be the effect on this line if a stream should develop a valley in the direction *X Y* ? Would *R T* remain straight, or would it bend ? If it bends, which way will it bend ?

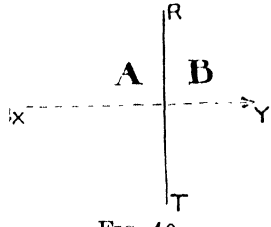


FIG. 40.

vi. Fig. 41 represents the plan and section of two conformable beds in the manner with which we are now familiar. Above the horizontal line $X\,Y$ is the plan (looking down on the earth's surface), and below is the corresponding vertical section along $X\,Y$ (as if you were looking at a quarry face). Thus the page of the paper is to be regarded as bent at right angles along $X\,Y$. It will perhaps be clearer to the student if he draws the diagram on a sheet

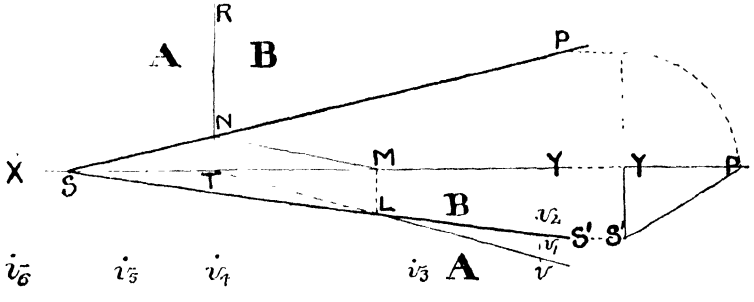


FIG. 41.

of paper and actually folds it. We now assume that a stream works along in the direction X to Y, and cuts its bed down to $S\,S'$. Half the breadth of its valley is then indicated in the plan by the line $S\,P$, starting at S and broadening out as the stream develops in the direction of Y. The right hand of the diagram shows a section across the valley at $P\,Y\,S'$. The stream runs in the bottom at S'.

vii. The older bed, A, is now exposed in the bottom of the valley along the stream past the

point *L*, which in the plan will correspond with the point *M* above it. Thus we see that the original outcrop *R N T* has been diverted by the stream to *R N M*. The outcrop will then be changed from what it was in Fig. 40 to that in Fig. 42. The shape of the V will depend on the following three factors :—

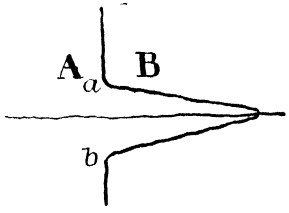


Fig. 42.

(1) The breadth of the valley (from *a* to *b*) ;
(2) The gradient of the valley ;
(3) The dip of the beds.

If we keep the shape of the valley [fixed by (1) and (2)] constant and vary the dip of the bed, we shall obtain several interesting and important results. In Fig. 41 suppose the beds were dipping much more steeply, so that the base of *B* passed through the point v_3. It is easy to see that the point *M* would then be much nearer to *T* than it is in the diagram. That is, the effect on the outcrop would be much less. If the beds were upright in the ground, so that the base of *B* passed through v_4, then the point *M* would coincide with the point *T*, and the valley would not affect the outcrop (Fig. 43, v_4). This is an important result to bear in mind, namely, that the outcrops of upright beds (and vertical faults) are unaffected by hills and valleys. If the beds dip in the opposite direction to that of the bottom of the valley, through v_5, for example,

the point *M* then passes to the left of *T* and the V outcrop points up the valley (Fig. 43, v_5). As the dip in this direction gets less, so that the base of the formation passes through v_6,

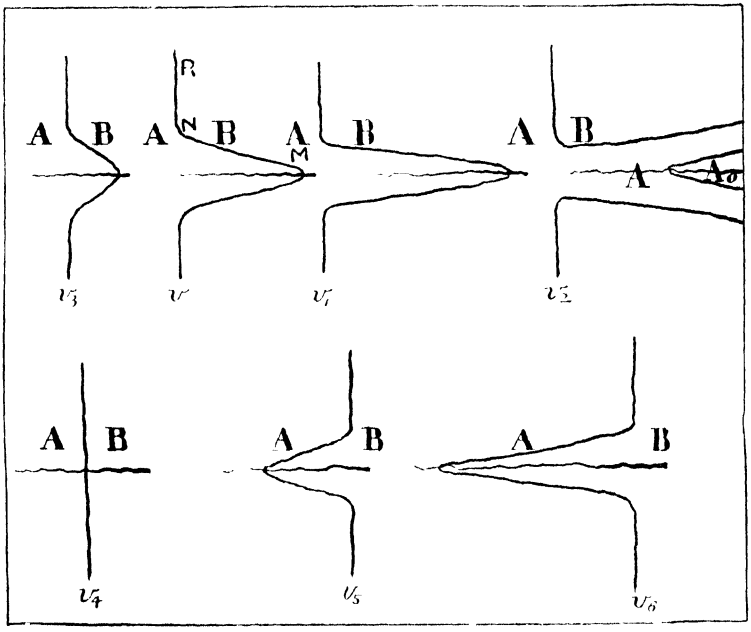


FIG. 43.

the V outcrop becomes longer and longer (Fig. 43, v_6).

viii. We must next investigate what happens when the beds dip in the direction of the gradient of the stream, but more gently than in the diagram. Suppose, for instance, the base of *B* passes through v_1. The V outcrop downstream now becomes very much accentuated. At last we arrive at a point where v_2

lies above S', and the beds dip at a less angle than the bottom of the valley. Then the shape of the V turns so that it points upstream. As we continue down the course of the stream we find that it cuts into beds A_0 (Fig. 43) older than A, which then have their V outcrop pointing upstream (Fig. 43, v_2).

ix. Summarising these results, we learn that :—

(1) When a V outcrop points downstream the formation in which the V occurs dips in the downstream direction at a greater angle than that of the bed of the valley ;

(2) When a V outcrop points upstream, either

(a) the formation dips in an upstream direction, or

(b) the formation dips in the downstream direction at a less angle than that of the bed of the valley.

We may further note that the gentler the dip of the beds, the more does the shape of the outcrop depend on the shape of the earth's surface. When the beds are vertical, the outcrop is independent of the shape of the surface.

x. By the aid of these general rules we may go a long way towards understanding the structure which a geological map records. Almost all the irregularities of the earth's surface are formed by valleys, since rivers were

the great agents which caused these irregularities. We have now studied the effect of valleys on outcrops and ought therefore to be able to solve most of the map problems depending on the influence of the shape of the earth's surface on outcrops. Let us examine, for instance, the map on pages 310 and 311. The broad V formed by the line *a b c* points down the valley. It follows, therefore, that the bed *B* dips downstream at a greater angle than the gradient of the bed of the stream. Conse-

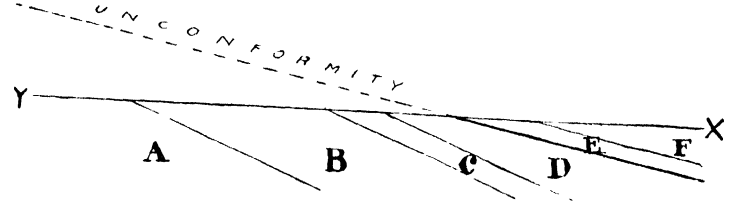


Fig. 44.—Diagrammatic section across model map on pages 310 and 311.

quently *A* is older than *B* by the test of superposition, and the line *a b c* is the base of *B*, the base of *A* not being shown. This may then be indicated on a rough section from *X* to *Y* (Fig. 44). Next, the shape of the V formed by *d e f* is very similar to that just described. If the shape of the river valley has not altered much in the distance between the two, we may take it that the bed marked *C* dips to the same extent as *B*. Now *D*, the base of which is *g h k*, has a V outcrop precisely similar to that of *C*. Hence *D* lies conformably upon *C*. The formation *E* has a much longer V outcrop in the stream bed than those we have just

considered. It follows from our rules, therefore, that the dip of *E* is gentler than the dip of the beds below it. So this change must be shown in the section. Next the line *l m n*, which is the base of *F*, follows closely the base of *E*, hence *F* conforms to *E*. As for *G*, we have no definite indication of its dip, since its outcrop is largely covered over with a layer of river mud, or alluvium. But *H* and *K*, judging from their base lines in the top left-hand corner, are conformable, since both have similar V outcrops pointing upstream. Applying the rule, we have two alternative explanations of this. But the second, (*b*) page 77, will be seen to be useless here, since it would lead to an almost impossible structure. The obvious interpretation is that the beds dip upstream.

xi. At this stage we shall not examine the map more closely. But we may think of what we have discovered with regard to it. We have discovered one change in dip, namely, that in passing from *D* to *E*. This means that we have an unconformity between the two. Its nature is revealed when we examine the section (Fig. 44). The bed *E* overlaps *D*, *C* and *B*, and the base of *E* is consequently a plane of unconformity. In describing an unconformity on page 57 we noted that it was characterised on the map by one bed cutting across the outcrop of another. This is seen in our example, for the outcrop of *E* cuts right across that of *D* and *C* and passes on to *B* (see map, page 311).

xii. There is no accurate way of deducing

the direction of the strike from the V-shaped outcrops of the various formations. But since strikes and dips are at right angles in direction, it follows that all the beds strike more or less from east to west, for the V's point more or less from north to south. We now see how wrong we should have been if we had concluded from the direction of the outcrop of the bed *E* at *T* that its strike ran from north to south. Thus we gather enough information to conclude that the stream marked No. 1 is a strike stream, and that marked No. 2 a dip stream.

xiii. When we need more precise knowledge of a district than we have yet been able to discover, when, for instance, we want to know the thickness in feet of the formation *B*, or how deep we should need to sink a shaft at *G* in order to come upon the formation *E*, or, again, what the true direction of strike of the formation *H* was, we find that we must have some accurate means of registering on the map the shape of the earth's surface. For instance, the depth that we should need to mine at *G* in order to reach the formation *E* depends partly on the *elevation* of *G*. We must therefore consider the method adopted to map changes in elevation on the earth's surface, that is, to map the hills and valleys.

Questions.

1. Make a cardboard rule for use with a 6-inch map, so that you may be able to read off the distance between any two points by means of it. This may be done in the

following simple manner: Take a strip of cardboard measuring 7 inches by 1 inch. Mark along one edge two points *P*, *R*, 6 inches apart. From *P* draw a faint pencil line *P Q*, and mark along it five divisions of 1 inch and one division of 0·28 inch (estimated with a ruler marked in tenths). Join the point *S* so obtained to the point *R*, and draw lines parallel to *R S* through the division marks along *P S* to cut *P R*. The points so obtained will then mark out the distances which represent 1000 feet each, except the last, which will represent 280 feet. The first division should then be similarly divided into ten equal parts each to represent 100 feet.

2. Show why it is fair to assume on a small-scale geological map that the strike and the outcrop coincide in direction.

3. Is the shape of the outcrop of a formation affected by its dip? Can you say how the outcrops of horizontal beds would be affected by hills and valleys?

4. If you see a dyke of igneous rock, like that described in Chapter III, paragraph vi, mapped as running across the country, regardless of hills and valleys, what may you deduce as to its structure? Explain why.

CHAPTER XI

CONTOURS

i. The map (Fig. 45) shows how the shape of the earth's surface is recorded. On it we see the surface relief, that is, the hills and valleys of the district. Such a map supplies all the precise information which we saw the need of at the end of the last chapter, and we must learn how to make use of this information. The lines against which the numbers are placed are formed by joining all the points in the district which have the same elevation in feet above sea-level, namely, that represented by the numbers. Thus the closed curve marked 1100 tells us that the land is above 1100 feet within the ring, and below that height outside it. In the same way the line marked 600 indicates that anywhere on that line the land lies 600 feet above sea-level, but on the 700 side of it, it rises above 600 feet, while on the 500 side of it, it falls below 600 feet. Such lines are called *Contours* or *Contour Lines*.

ii. In town or country you frequently notice a broad arrow chiselled on a wall or gate-post. This is the record made by an officer of His

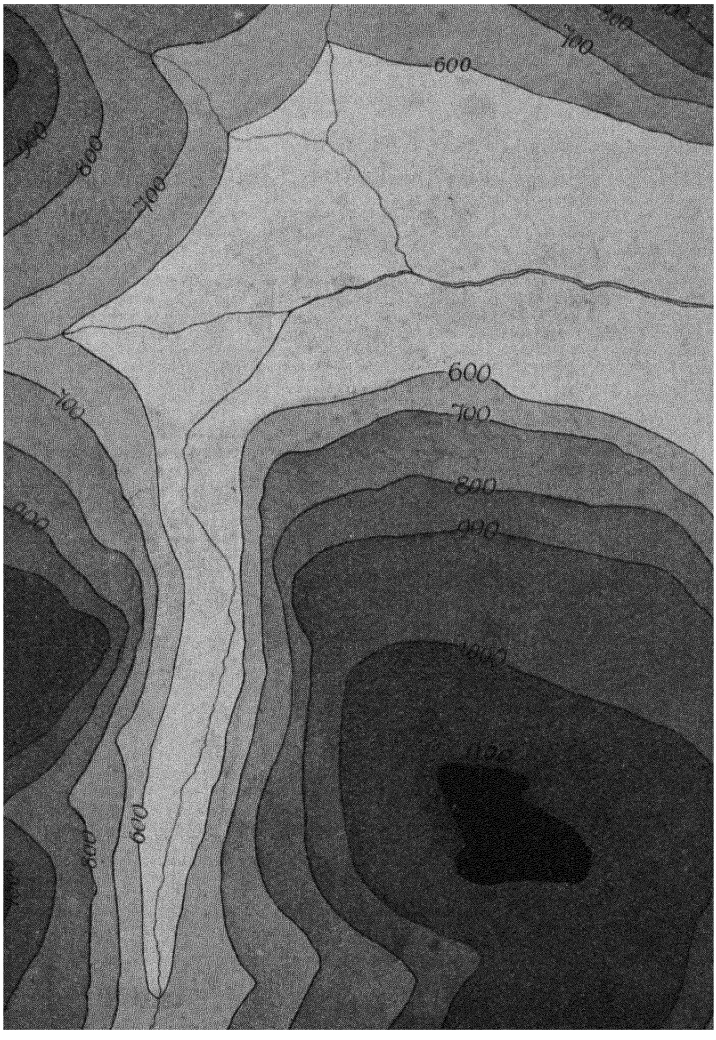


FIG. 45.

Majesty's Survey of the height of the land at that point. If you were to buy a 6-inch Ordnance map of the district, you would find the exact height at the point marked by the broad arrow given in figures on the map. Such an indication of the height is known as a *Bench-mark*. On all 6-inch Ordnance maps published by the Government bench-marks as well as contours are inserted. In mapping contour lines across country, the surveyor takes his level from some bench-mark, which we shall suppose is 194·3 feet above sea-level. From this point he proceeds by means of an instrument known as a *Level* to mark on the surrounding land a point exactly 200 feet above sea-level. Then by means of his instrument he can follow out along the hill-side all points at 200 feet. As he goes along he inserts on his map the positions of the points he observes, and then by joining these he forms the 200 feet contour. On modern maps such lines are marked in blue. It is very helpful in geological work to have them clearly marked. When such lines have been drawn in at vertical intervals, the resulting map, like that on page 83, affords an accurate replica of the natural relief. The shape of the hills and valleys is faithfully reproduced in miniature.

FIG. 46.—A bench-mark.

iii. We will now look at the model map on pages 310 and 311, and observe some of the

characteristics of contours. We notice first that as the contour lines follow the valleys up towards the sources of the streams the same contour on each side of the valley comes to a point on the stream. Next we may discover how to find the slope of the hill-side between two contour lines. Three inches on the map represent one mile, that is, 5280 feet. Therefore one inch represents 1760 feet. The distance on the map from the point *P* on the 1100-feet contour line to the point *Q* is 0·6 inch. This corresponds to 0·6 × 1760 feet in nature, namely, 1056 feet. The hill-side consequently drops 100 feet in 1056, or 1 in 10·56. From *Q* to *R* the distance is only 0·25 inch. The gradient is therefore 100 in 0·25 × 1760, or 1 in 4·4. So the hill-side is more than twice as steep between *Q* and *R* as between *P* and *Q*. From *R* to *S* is again 0·25 inch, so that the slope continues unaltered from *Q* to *S*. From these examples we may draw the important conclusion that the steeper the hill-side the closer the contours come together, and a little thought will show that when the hill is so steep as to form a cliff the contours touch one another. With this rule in mind we see that the upper course of the principal stream runs in a deep valley flanked by steep hills, for the contour lines are bunched together along its course. But where it turns, the hills which form the sides of its valley are much more gentle. Indeed, the valley between *F* and *G* is broad, and the slope on its right bank (from *B* across

E and *F* to the river) is gentle. Now this is exactly what we should expect, for we gathered from paragraph xii of the previous chapter that stream No. 1 was a strike stream and No. 2 a dip stream, and these valleys have been seen to be characteristic of such streams.

iv. When we wish to estimate the height at a point not on a contour line, but between two, say the point *P* (Fig. 47), we draw a line, *A B*, through the point *P* across the two contours, choosing the shortest path between them. We then assume that the slope from

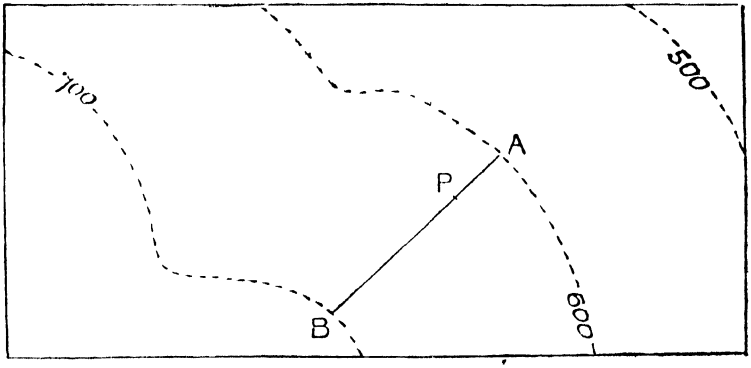


FIG. 47.

the higher contour to the lower is constant. The height of the point will be that of the lower contour, here 600, plus that fraction of 100 which *A P* is of *A B*. *A P* = 0·3 inch, *A B* = 1·1. therefore

$$\frac{AP}{AB} \times 100 = \frac{30}{1{\cdot}1} = 27 \text{ feet.}$$

The altitude at P is consequently 600 + 27 = 627 feet. Thus we divide AP by AB, multiply by 100 and add the result to the lower contour. (This estimate may also be obtained graphically.)

v. We must next learn how to draw a section from a contoured map. We shall draw two sections :

(1) From X_3 to Y_3 across the valley of the dip stream.

(2) From X_1 to Y_1 across the valley of the strike stream.

We start with a base line and mark it off in

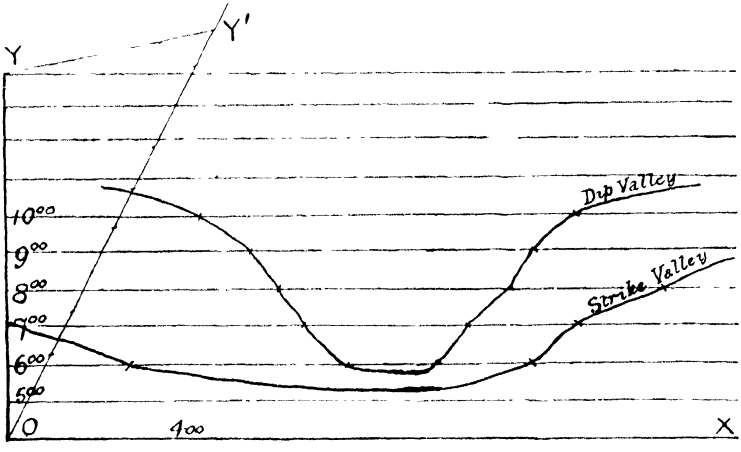


FIG. 48.

inches. Since the map is on a scale of three inches to a mile, each mile represents 1760 feet. Consequently 1000 feet will be represented by $\frac{1000}{1760}$, or 0·567 inch, and 100 feet will be represented by a tenth of this, namely, 0·0567 inch.

Now this is too small a quantity to serve as a unit for the vertical scale. We shall therefore make the vertical scale three times the horizontal, a device we referred to on page 72. 1000 feet will then be represented by 3 × 0·567 inch or 1·70 inches. So we mark a point *Y* directly above *O* at a distance of 1·7 inches. Next we must divide *O Y* into ten equal parts, so that each part represents 100 feet. The simplest way to do this is to draw any other line *O Y′* and mark off upon it ten equal divisions of any unit size. We then join *Y Y′* and draw lines parallel through the points on *O Y′* to cut *O Y*. We shall thus have divided *O Y* into ten equal parts. Next we draw a series of lines parallel to the base *O X* through the points so found and number them in feet. A great deal of labour may be saved when many sections are to be drawn by employing rules made to scale as described on page 81.

vi. To draw the section, place a piece of paper on the map (pages 310 and 311) so that its edge lies along the line of section from the point X_1 to the point Y_1. Then mark on the paper the points at which it cuts the contour lines and number them as you mark. Next transfer the paper to the framework prepared for the section. Place it with its edge along *O X* (Fig. 48) and mark off above each of the points the corresponding position in the scale. When they are joined by a continuous curve the true outline results. If this is carried out along X_1Y_1 and X_3Y_3 the two sections which we set

out to obtain will be found. They afford a good illustration of the points discussed in Chapter VI, which might here be revised.

Questions.

1. Describe the use of contour lines.

2. Try to get a contoured map, preferably of large scale. Take a few sections across the map. Estimate the gradients of the hills along the line of section by the method of paragraph iii. Convert them into degrees by the table on page 104. Compare the values so obtained with the values read off the section by means of a protractor.

3. In the map on pages 310 and 311 what do you estimate to be the gradient of the two principal river beds? Draw a graph of them, and indicate the hills in the background.

CHAPTER XII

OUTCROPS

i. LET us compare the relief map on page 83 with the corresponding geological map at the end of the book. The relief map supplies us with precise information about the shape of the earth's surface in the district. We have learnt how to estimate from it the elevation at any point, the slope of the hill-side and the drop in the river-bed. In order to heighten the pictorial effect of the surface relief the areas between the contours have been shaded darker and darker as the land rose higher and higher. We are then enabled to see at a glance how the hills and valleys lie. This map, then, illustrates the effect of weathering agents on the land. Now the geological map contains all the information which is given by the relief map, only it is not shaded like the latter, since that would confuse the equally important geological information which this map has to give.

ii. We have seen that the earth's shape has a profound influence on the shape of an outcrop. A bed which would crop out in a straight band

along a level surface assumes a V-shaped outcrop when the surface is intersected by a stream. Since then we have learnt how the exact shapes of valleys are recorded by contours, so that we may now proceed to discover more exactly how given outcrops are modified by given contours. We shall begin with the formation *F*, which will serve as a particular example of the general method of discovering accurately the structure of a district from any map which shows (1) contours and (2) outcrops.

iii. The line *l m n* is the base of the formation *F*. We shall consider one of the contour lines which cuts this base line. The 600-feet contour, for instance, cuts it at *M* and *N*. It follows, therefore, that the base of the formation *F* lies at a height of 600 feet above sea-level at *M* and *N*. In other words, it lies level along a line joining *M* and *N*. But the direction in which a bed lies level is known as the strike. We therefore have the simple rule that in order to find the strike of a bed we join the points where the same contour line intersects twice the base of the formation. In the example chosen, the base of the formation *F* is level and 600 feet high in the direction of *M N*. Consequently it must remain level at that height any distance either way on prolonging *M N*. It follows therefore that if the base of *F* is ever exposed again at a height of 600 feet, the point where it is exposed at that height must lie on a continuation of *M N*. In the map (Fig. 49) this is at once made clear by

producing *M N*, when it will be seen that it passes through *O*, the point on the other side of the valley where the base lies at 600 feet.

iv. Any other contour line which cuts the base of the formation *F* would have served equally well for the purpose of establishing the above results. Suppose, for instance, we draw the line *R T* on the 700 contour. It will be found to be parallel to *M N*, that is, in the

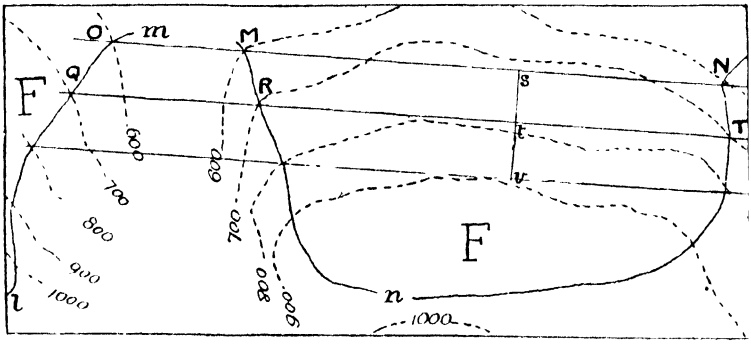


FIG. 49.

direction of the strike of the formation *F*, and on continuing it, *s t* is seen to pass through *Q*. Now draw a line *s t* at right angles to the strike, that is, in the direction of the dip. It will be seen that this direction agrees with the forecast we made in a previous chapter from the shape of the V's. It is parallel to the upper course of the stream.

Next we may obtain the *amount* of the dip. The line *s t* is 0·3 inch long. That corresponds to 0·3 × 1760 = 528 feet in nature. Now at *s* the base of the formation *F* lies at 600 feet,

whereas at t it lies at 700 feet. Thus it rises 100 feet from s to t, that is, in 528 feet. The dip is therefore 1 in 5·28 in the direction ts.

v. Of course we have no guarantee that any bed on a geological map will have a constant dip. It may be curved into an anticlinal or synclinal fold (Fig. 50). Whether it is folded or not, the strike will with rare exceptions remain constant over considerable areas. This follows from the fact that once beds have been folded along an axis as Fig. 1 illustrates, they

FIG. 50.—(*a*) Constant dip; (*b*) Changing dip, synclinal; (*c*) Changing dip, anticlinal.

naturally keep the same strike, although the dip constantly varies.

By joining the points of intersection of contours and outcrops in the manner described above, we obtain a series of strike lines which will in general be parallel. Now if these strike lines are equally spaced the dip must be constant and the bed must therefore dip as a flat stratum. But if they are not equally spaced, it follows that the bed has not a constant dip. The distances between the strike lines show the way the formation bends. The closer together the strike lines are, the steeper does the formation dip, and the converse is also true.

vi. In the map we have been considering

each bed dips at a constant angle, for $s\,t$ is equal to $t\,v$. Below is a map of two formations, *A* and *B*, of which *B* is seen to have a changing dip. It will be useful to see how a section of such a map may be drawn. We propose drawing a section along the line *P Q*. To do this we first construct a framework similar to that

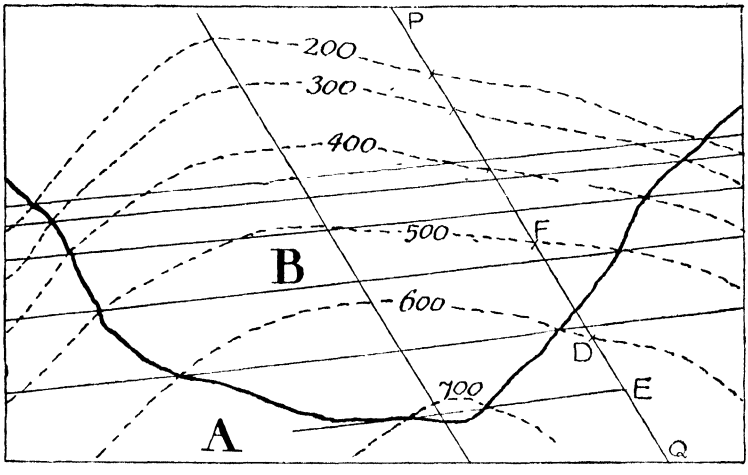


FIG. 51.—Strike lines unequally spaced. Dip not constant.

described previously, only it is not necessary to take care over the absolute value of the vertical scale. It will be sufficient to draw ten equally spaced horizontal lines, each space, say $\frac{1}{10}$ inch, to represent 100 feet. Place a piece of paper on the map with its straight edge along *P Q*. Mark upon it

(1) The point in *P Q* where the formation *A* changes to *B*;

(2) The points in which PQ cuts the contour lines ;

(3) The points in which PQ cuts the strike lines formed by joining the points of intersection of the contours with the base of B.

It will be found advantageous to mark each of these sets of points in a different colour, or in some other distinguishing manner. Now transfer the paper so that its edge lies along the base XY of the section (Fig. 52). Project the

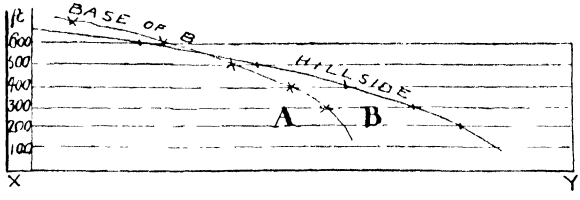


FIG. 52.—Section across preceding map, along PQ.

points grouped under (2) to their correct places in the framework. Then draw in the profile of the hill. Next mark the point on the hillside where the change in the formation occurs. To find how the base of B lies, we use the fact that where the line PQ cuts any strike line, there the base of the bed must lie at a height given by the contour which decides the position of that strike line. Thus, at the point F in PQ, the base of B lies at 500 feet. Consequently all we need do is to project the points grouped under (3) vertically upwards to the corresponding height in the framework. The points

so obtained and marked by crosses will determine the position of the base of the bed. We note that the points obtained by projecting *D* and *E* lie in the air above the hill. This means that the formation *B* once occupied that position, but has since been eroded to its present height. If a section were taken through the middle of the hill, this apparently

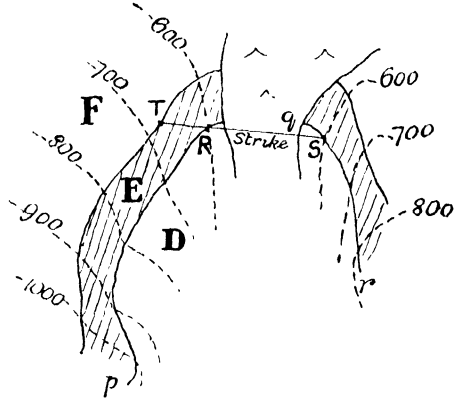


FIG. 53.—Showing how to read the thickness of a formation from the contours.

impossible result would at once be accounted for.

We have thus seen how the strike and dip may be accurately determined from (1) the outcrops and (2) the contours.

vii. We may often find the thickness of beds very simply from a geological map. But this is not always quite easy. We will take a simple case, namely, the thickness of the formation *E* (Fig. 53) which reproduces part

of the map on page 310. The line $p\,q\,r$ forms the base of the outcrop of E. Joining the points $R\,S$ where the 600-feet contour cuts this base line, we obtain the strike line at the height of 600 feet. Produce it to cut the base line of the next higher formation F in the point T. What do we know about this point T? By the method of page 86 we know that its height is 680 feet. Now immediately beneath it, the base of E lies at an altitude of 600 feet, for it lies level along the strike through R and S.

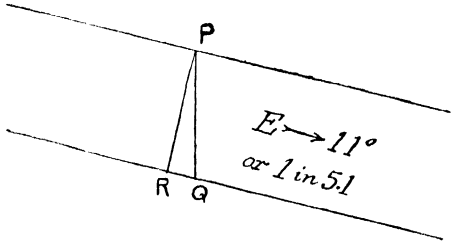


Fig. 54.

The vertical thickness of the formation E at this point must therefore be 80 feet. This is not the true thickness, but only the thickness that a vertical boring would pass through in getting from the top to the bottom of the bed. In order to deduce from this the true thickness of the formation, we must allow for the effect of the dip. In Fig. 54 above, which illustrates the formation E dipping at 1 in 5·1, the distance given by the above method is marked $P\,Q$. The true thickness of the bed is $P\,R$, and $Q\,P\,R$ is the angle of dip. The

thickness is seen to be $PQ \cos \angle QPR$. If the dip is less than 1 in 8, there is no need to correct the thickness.

Questions.

1. How do you find the direction of the strike of a formation from a geological map giving contours? How will you decide which line of the outcrop is the base line? Justify your procedure in both parts.
2. Explain how to find the dip from a contoured geological map.
3. How do you discover from a map whether strata dip uniformly?
4. Show how the thickness of a formation may be estimated from a geological map.

CHAPTER XIII

IN THE FIELD: GEOLOGICAL CAMPAIGNING

i. We shall now return from our study of maps to the countryside again. If we have a grasp on the principles set out in the preceding chapters we should be able to apply them to the land itself. We shall suppose ourselves in a district with which we are unfamiliar, but we shall provide ourselves with 6-inch Ordnance maps as a guide to the topography of the new district. The topography will include roads and hedges, woods and streams, buildings and railways, as well as contours and bench-marks, all of which are included on the map. Thus equipped, we propose to observe the lie of the land in an orderly manner so as to discover its geological structure. This may well take a good many months in practice, but it is a problem which usually requires little more than patience and a love of outdoor life to solve.

ii. First we decide what area we shall study. A district three miles by three miles, extending it later if that seems advantageous, may very well occupy all one's leisure time for a year. The first thing to do in such a district is to get

thoroughly familiar with the topographical design. Get to know the hills and valleys and their shapes. Remember that if a road goes downhill it must be going down the side of some valley. If it goes uphill it must be going up the side of some valley. By frequent walks, get to know how these valleys run, and do not forget to connect in your mind the direction of the valleys with the slopes of the roadways. It is especially easy in a town to lose sight of the shape of the valleys, and to omit to connect a hilly road with the valleys it cuts across; and this is particularly true in a district where the streams which flow in the bottoms of the valleys have been drained. A ready familiarity with the shape of the earth's surface in the district will certainly be acquired quickly if the map is frequently consulted and the contours are taken into account.

iii. Such preliminary outings should soon disclose a number of interesting features :—

(*a*) Perhaps some regularity in the direction of the streams will lead you to suspect the direction of the strike and dip;

(*b*) You may make a list of the important exposures of rocks in the district. They may be in railway cuttings or in the roadside, in canal banks or in stream beds;

(*c*) You will have noticed in a rough way what the rocks of the district are composed of—whether sandstone, limestone or clay;

(*d*) You may then resolve to study

more carefully one such bed, naturally that one which is most easily recognised, either on account of its colour or texture or perhaps its hardness or dampness, or because it contains some easily recognisable fossil.

iv. Having made quite sure that you would recognise this rock anywhere, you proceed to study all its exposures in the district. Aim at getting its strike, that is, the direction in which its bedding-planes are horizontal. How are you to do this ?

(*a*) Perhaps you may be fortunate enough to discover an exposure where the bedding-planes are actually horizontal, as in the Norton quarry. Then you have no difficulty in recording the direction of the strike. It is usual, as we have learnt, to make this record by means of an arrow pointing in the direction at right angles to the strike.

(*b*) But an exposure like that referred to is rarely met with. More usually we find the rocks dipping at some gentle angle. Is it possible to find the strike from such an exposure ? No, that is clearly not possible. In Chapter VII we found that the amount of the dip varies from a maximum in the direction at right angles to the strike to zero in the direction of the strike. Any given exposure will probably show the beds dipping

between the two. How can we use such an exposure? We need two.

The crossways in Fig. 55 are cut through well-bedded sandstones so that exposures of

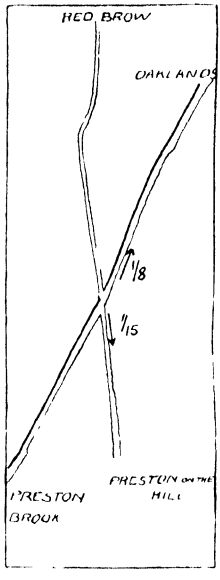


FIG. 55.

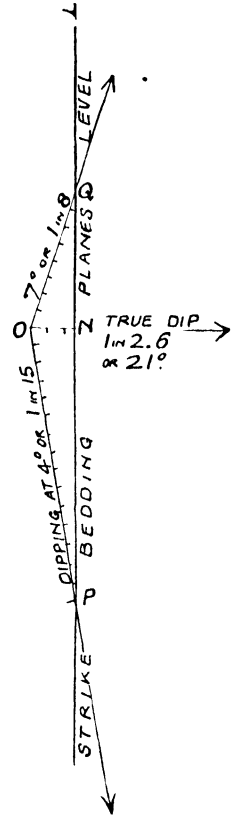


FIG. 56.

the sandstones occur in the roadsides. In the roadside to Preston on the Hill from the cross-

roads, the beds dip at 1 in 15, and in that to Oaklands they dip at 1 in 8. What is the true dip? In the direction of Oaklands mark off 15 units (Fig. 56). A bed which lies at the surface at the cross-roads will lie one unit below that level at *P*. In the direction of Preston on the Hill mark off eight units. The same bed must lie one unit below the level of the cross-roads at *Q*. It therefore lies level along *P Q*. This, then, must be the direction of the strike. Now, the dip is perpendicular to the strike, so that if we draw through the cross-roads the line *O N* perpendicular to *P Q*, we know that *O N* is in the direction of the dip. But a bed which comes to the surface at *O* lies one unit below that level at *N*. Hence it drops one in as many units as there are in *O N*, namely, 2·6. This, then, is the magnitude of the dip.

v. The next consideration is the manner in which the dip is to be measured in the roadside or elsewhere. A suitable instrument may be made by bolting a small metal pointer, *P*, to a protractor, so that it swings freely. When it is held at arm's length so that its straight edge covers a horizontal line, say a window-sill facing the observer, the pointer will read 90°. When it is used to measure the dip of an exposure in a roadside it should be held at arm's length so that the straight edge is parallel to the dipping bed, the observer standing some distance away from the exposure. The pointer will then swing vertical. The number of

degrees through which it swings from the 90° division to the vertical is equal to the dip.

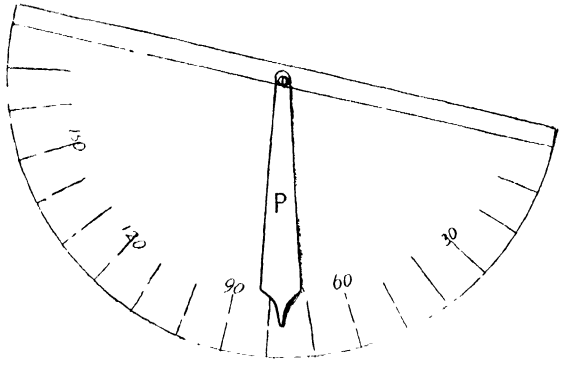


FIG. 57.

The following table gives the dip so measured in the form used in previous chapters, namely, one in so many.

Degrees	One in	Degrees	One in	Degrees	One in
1	57	11	5·1	25	2·1
2	29	12	4·7	30	1·7
3	19	13	4·3	35	1·4
4	14	14	4·0	40	1·2
5	11·4	15	3·7	45	1·0
6	9·5	16	3·5	50	0·8
7	8·1	17	3·25	60	0·58
8	7·1	18	3·0	70	0·36
9	6·3	19	2·9	80	0·17
10	5·7	20	2·75	85	0·09

vi. It follows from the above paragraph that a quick way to find the strike and dip of the chosen formation is to make two observations by means of the protractor in two

different exposures and to combine the readings graphically on a slip of paper as in Fig. 56. In that example the directions in which the two exposures lie are given on the map, for they occur in the roadsides. But often the only available exposures are in the open country. In that case it is necessary to make an observation of the direction also. This is done by means of a pocket compass. Place a stick on the ground in the direction of the exposure and upon it place a compass, turning it until the needle covers the north. You record the number of degrees from the north that the direction of the stick makes.

vii. We assume now that numerous observations of the kind described have led to the determination of the direction in which the chosen bed strikes. This direction should be carefully borne in mind. It is a good plan to remember the direction with reference to two easily recognised landmarks; for instance, you may remember that the strike is in the direction joining two farm houses, or a church spire and a hill-top. In the open country, where such landmarks are absent, it is best to rely on the compass when once the direction of the strike has been determined.

What use now can we make of this strike? We know first of all that if we walk in a direction at right angles to the strike, that is, in the direction of the dip, we shall cross formation after formation in their order. Hence our first task is to explore the country carefully,

starting from the chosen bed and walking from it in the direction of the dip. There will quite probably be a dip stream to explore. It is surprising what a mine of good things the bed of a small dip stream contains for the geologist. Journeying up the stream in the direction of the dip, especially very near its source, through a dense wood perhaps, you rarely fail to find some interesting exposure of rocks through which the stream has made a clean cut. The valley in this part of the stream is often comparatively narrow and deep, with a little brook trickling in the bottom. The steep sides of the stream expose the bedded rocks.

viii. Now there are two possibilities in journeying along the dip from the chosen bed. You

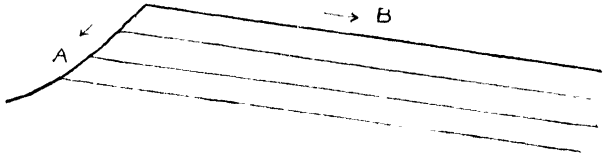


FIG. 58.

may travel along in the scarp direction (*A*, Fig. 58) or in the dip direction (*B*). Once the strike has been discovered the contours should be examined on the map, and the scarp slopes marked. They should then be explored in turn. As Fig. 58 shows, they will very likely reveal the order of the beds. And this is the next problem. The order of the beds must be studied until it is known. Each formation should be the object of careful examination.

You should try to see each formation in as many aspects as possible, and always make a record in a note-book of the features which strike you. You should note the colour, texture and nature of each bed; how it weathers; whether a fresh piece of it differs from one which has long been exposed to the atmosphere; what it is like when wet, and how it changes when dry; what sort of soil it gives rise to; what trees and shrubs grow wild upon it. Hand specimens should be collected of each formation and compared with each other. Each journey of discovery should be planned beforehand, starting from the chosen bed and walking in the direction of the dip.

ix. This is very often a difficult task, for a beginner does not easily recognise significant differences in rock types, but nothing more can be done until each formation may be recognised with a fair measure of certainty. (A useful guide to the solution of this task is afforded by a 1-inch geological map of the district.) But when the various formations and their orders have been learnt, the next step follows. If you walk in the direction of the dip you cross from formation to formation in regular succession. If, then, you come upon the same formation twice, you conclude that you have either crossed a fault, or else that the beds are folded. These two hypotheses should be tested in the field. We know that if the beds have been affected by a strike fault, the direction of the dip will remain much the same,

but the outcrops of the beds will occur on each side of the fault. This has been fully dealt with in Chapter IX. If, on the other hand, a fold has caused the second appearance of the bed, then the direction of the dips should reveal this; for the dip will change in a folded region, and the beds will reappear in the reverse order.

x. You now change your campaign, and instead of working along the dip so as to cross the formations as rapidly as possible, you work along the strike in order to explore each formation separately. We have already seen that by walking in the direction of the strike you remain in the same formation. At this stage the contour of the district will need careful study. But at the same time it becomes especially attractive for the following reason:

Suppose the contours on the 6-inch map appear as in the diagram opposite, and suppose you have worked on the district until you have arrived at the stage we are now describing, that is, you are assumed to have discovered (1) the strike, (2) the amount of the dip, (3) the order of succession of the rocks. Suppose, then, you come upon a small outcrop at *P* (Fig. 59), which you estimate to be at an altitude of 125 feet. Knowing the dip, can you not forecast where the same bed will occur elsewhere in the district? Through *P* draw a line on the map in the direction of the strike. Then, where this line cuts the 125-feet contour, the bed should be present (at *P'*). You then make a trip to

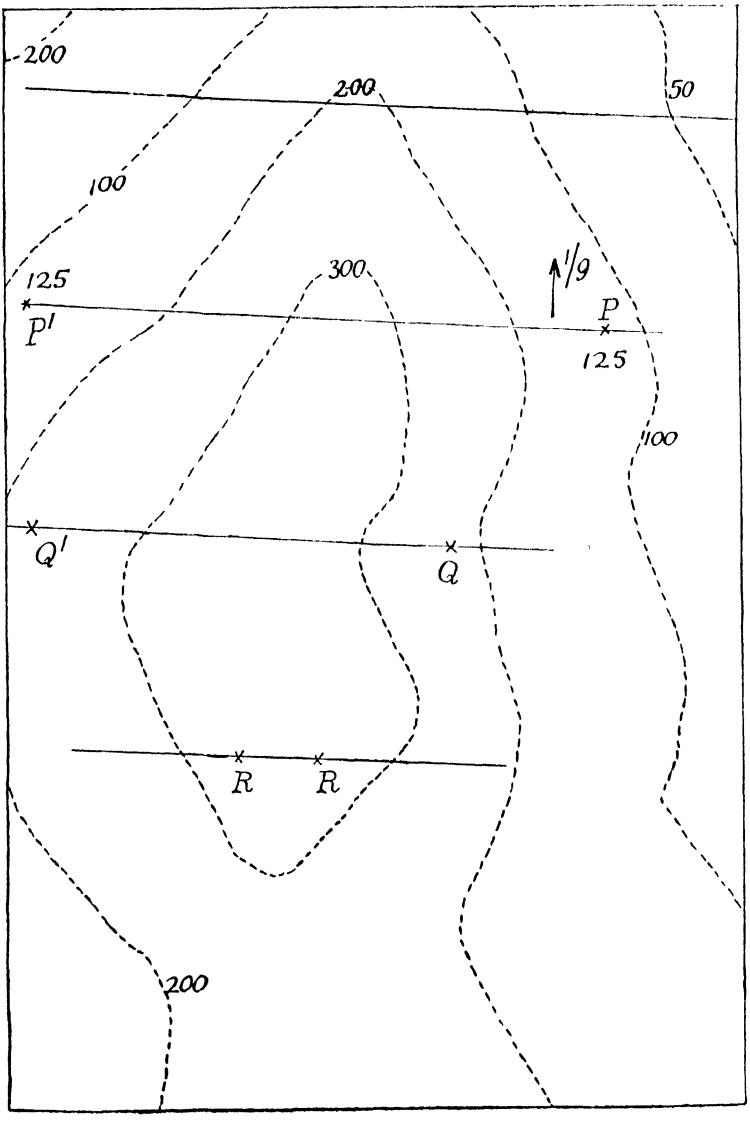


FIG. 59.—Forecasting outcrops.

P' and search the district for a trace of the formation. If it does not occur, you have either misjudged or failed to locate it, or else a dip fault has cut it off between P and P'.

You must next trace it round the hill. The beds dip at 1 in 9, let us say. Consequently they drop 100 feet in every 900 feet. But 900 feet is represented by $\frac{6 \times 900}{5280} = 1$ inch approximately. Therefore you may forecast the position of the outcrop round the hill by drawing lines parallel to PP' at a distance of one inch apart. These will indicate the positions of the outcrop at altitudes of 25 feet, 225 feet, 325 feet and so on. The next thing to do therefore is to test this in the field, and see whether the formation does actually agree with the forecast. If the forecast has been carried out correctly and yet the beds do not appear in the position they should occupy, you may be sure that the dip has changed and so thrown your calculations out, or else, as before, a dip fault has displaced the bed.

xi. The only way to find out whether the dip has changed is to check it on the spot by means of the instrument described in paragraph v. If a dip fault has cut off the bed, we know that in order to pick it up again we must leave the strike and travel in the direction of the dip until we find it.

When observation after observation has been recorded and entered on the map, a good general idea of the geological structure of the

district will at last be obtained. No very specialised knowledge is necessary before undertaking the study of a district, and few outdoor pursuits are healthier and more full of interest.

Questions.

1. The best exercise on this chapter is to secure a 1-inch geological map of the district in which you live and endeavour to study the district on the lines set out in the chapter.
2. Summarise the order you would adopt in studying the geology of a new district.
3. Trace all the streams in your district.

CHAPTER XIV

INTERPRETING GEOLOGICAL MAPS

1. The geological map is an exact miniature of the original as we have studied it in the open field. What is on the map is also to be found in nature. One repeats the other on a minute scale. But this difference in scale makes all the difference in the way each must be studied. Consider again the map on pages 310 and 311. Suppose you were standing at the point marked *T*. You would be so very small in comparison with the hills and valleys that you would only be able to observe just those few yards round you, an area so limited that it could only be represented on the map by a point. But when the country has been mapped and reduced to scale you are very much bigger than the map and can study it as a whole in a manner altogether impossible in the field. The map has been prepared by months of careful observation and tabulation of records, as we described in the last chapter. But when it is finished it may be interpreted in half an hour by anyone familiar with maps, even although he does not know the district in the least. The result

of months of work is thus made available for us and may be rapidly interpreted.

ii. So our next problem is this. The geological map of a district is given to us. We are required to interpret it, to find out the structure of the district it represents, and everything else we can about it. Whereas the work described in the last chapter may occupy us a year in frequent excursions, the present problem must be solved at a sitting. For convenience we may take the map already referred to and deal with it in an orderly way.

iii. As in paragraph ii of the last chapter our first aim in the field was to master the topography, so here that must be our first business. It will be found a good plan to draw a small sketch about a third the size of the original map, putting in roughly the contours. When they are shaded the surface relief will be clearly seen. It is nearly always advisable to begin the examination of a map by a small sketch of this kind. It is then likely that you will be able to infer something of the structure from the general trend of the valleys. The main broad valley runs from *P* to *Q* (Fig. 60). The others run off from this in a direction more or less at right angles to it, and of these the largest is narrow. You might therefore make a guess that the strike is generally east-west and that the narrow valley is along the dip.

iv. You next apply the **V** test set out on page 77 to each of the valleys. This has already been done in Chapter X. The result,

it will be remembered, was to discover the general trend of the rocks and their relative order, and to bring to light one unconformity. The tests by which this result was obtained are always worth applying to any new map.

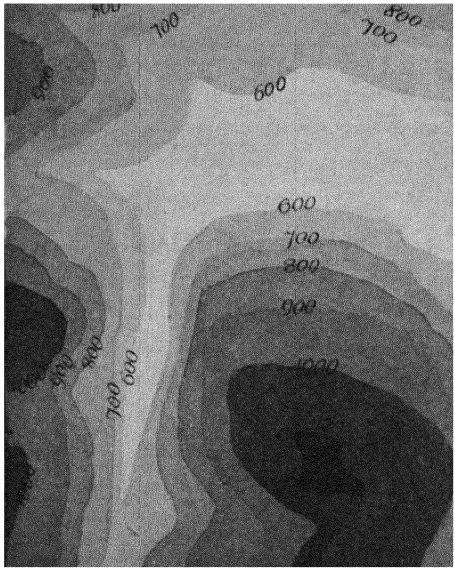


FIG. 60.

A good forecast may frequently be made by means of them in a short time. Rough sections should be drawn to show the result of their application, similar in kind to Fig. 44.

So far, then, the beds *A*, *B*, *C*, *D* appear to be conformable and to strike roughly east-west, and *E*, *F*, *G*, *H*, *K* appear to rest upon

them unconformably, the strike trending generally east-west.

Note.—At this point it is well to observe whether any beds are (1) vertical or (2) horizontal. Vertical beds cut across the hills and valleys regardless of the contours. Horizontal beds follow the contours round, for the plane formed by any contour line is itself horizontal.

v. More accurate account must now be taken of the effect of the contours on the outcrops. Taking each formation in turn, you join up the points in which any given contour line intersects more than once the base of the formation. This line gives the strike. When this is done for more than one contour line, it is enough, in order to find the dip, to draw a line parallel to the strike through the point of intersection of any other contour line and the base of the formation, even if that other contour line only cuts the base of the formation once.

When the above construction is carried out on the map we have under consideration, we discover that the strike is not as constant as the V tests would lead us to think. Three changes in direction are discovered. *A* and *B* strike W2°S., *C* and *D* W4°N., *E*, *F* and *G* W4°N., and *H* and *K* W9°S. These directions are drawn in the accompanying figure. From the distance between the strike lines of the respective formations, the following dips are found. *A* and *B* dip at 40° (or 1 in 1·2), *C* and

D dip similarly at 40°. *E*, *F* and *G* dip at 11° (or 1 in 5·1) and *H* and *K* at 7° (or 1 in 8·1). From this we see that there are three unconformities, one of which is minor and two major. That between *D* and *E*, which is accompanied

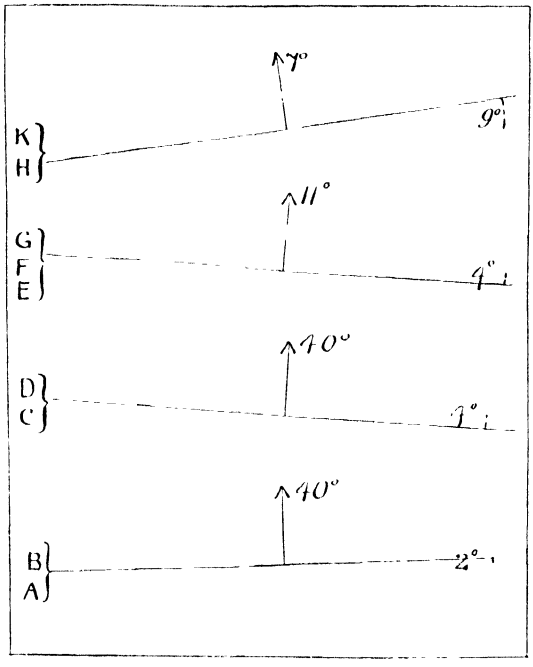


FIG. 61.—Structural diagram of the formations represented in the geological map on pages 310 and 311.

by a change in dip of 29° (40° less 11°), is the most conspicuous, and has already been detected by means of the V test. The other great unconformity is that between *G* and *H*, which is accompanied by a considerable change in strike, besides a change of 4° in the dip. We

might have spotted it before by the way the bed *H* crosses *G* and *F* in the top left-hand corner of the map. The one minor unconformity is between *B* and *C*, and could not have been detected in any other way than by an analysis of the strike lines.

vi. All these changes must now be recorded by means of a section. It is usual for this purpose to take a section along the dip, although the method employed to make a section in any direction is the same. The line of section we shall choose will be *X Y*. We proceed, as before, to draw a framework to take the section, but without exaggerating the vertical scale. That is, we make 0·57 inch represent 1000 feet, since this corresponds most nearly with a scale of 3 inches to the mile, and divide it into ten equal parts, each to represent 100 feet. Then we mark off on a piece of paper placed with its edge along *X Y* the points in which the line of section cuts the contour lines. These we transfer to the framework and so draw in the profile. Next the outcrops of the beds are transferred in a similar way from the map to the section. Thus we obtain (1) the line of the hills and valleys, (2) the points along that line where the respective formations come to the surface. We have then (1) the line *R S* (Fig. 63) fixed by the points h_1, h_2, h_3, etc., where the contours cut the line of section, and (2) the points *B*, *C*, *D*, *E*, where the bases of the respective formations appear on the surface. How are we to know

the dip of each formation? We could, of course, calculate it as on page 92. But a simpler graphical method depending on the same principles may be used without any calculation. We mark on the piece of paper used to transfer the contours and the outcrops from the map to the section, the points in which all the strike lines (obtained by joining up the points of intersection of contours with outcrops) cut the line of section. By that means we obtain a series of points showing the height at which the base of each formation lies.

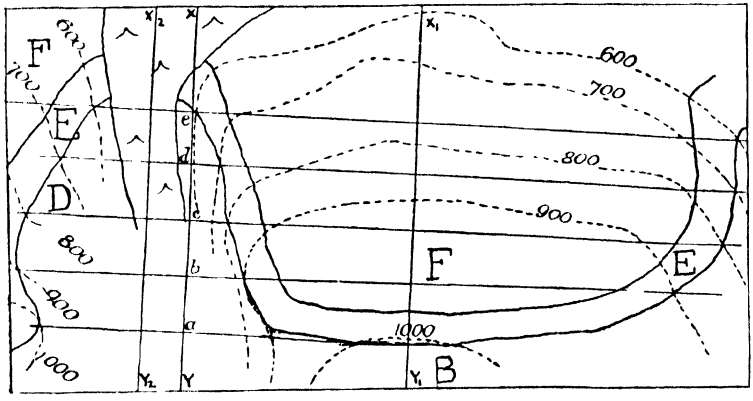


FIG. 62.

vii. In the accompanying figure, for instance (which is taken from the map on page 311), the strike lines through the base of the formation *E* are drawn, and the section is taken along the dip. We mark on the transfer paper the points *a*, *b*, *c*, *d*, *e*, in which the strike lines through the base of *E* cut the line of section.

We know then that the base of *E* lies at a thousand feet at *a*, 900 at *b*, 800 at *c*, 700 at *d*, and 600 at *e*. When we transfer these points to their places in the framework, we obtain *a*, *b*, *c*, *d*, *e* (Fig. 63), the first three of which lie in the air above the surface of the valley. We have already discussed this phenomenon. The positions of these points show where the bed lay before it was eroded. Clearly the points so found will lie on a straight line, if the beds are flat; but if they are not, the true shape will be revealed, as we saw in Chapter XII. When this procedure is carried out for each formation in turn the structure is at last obtained. *A* and *B*, and *C* and *D* conform to each other. *E* rests upon *D* with a conspicuous change in dip. Then follow *F* and *G* dipping to the same extent as *E*, and lastly *H* and *K* with a second considerable change.

viii. This completes the section. But we may extend it. It represents what remains of a more complete structure. If we produce the lines in the section which form the bases of the respective formations, we see that originally *E* not only overlapped *D*, but transgressed *C*, *B* and *A*; and *H*, in its turn, spread over the top of all of them. It was a mere chance that we took a section along the valley. If we had taken it along X_1 Y_1 across the hill we should have obtained a different relief curve. But the structure beneath would be the same along any line of section parallel to *X Y*. We understand from this how it comes about that the

formation *D* just appears in the river-bed and does not reach the surface in the section through the hill. The river cuts its valley down far enough just to expose it along the *X Y* section. It is interesting here to compare the profile we have just drawn (Fig. 63) with Fig. 41. Would it not have been possible to forecast the structure of this district at a glance from its similarity to that diagram ?

ix. Suppose we had taken our first section along the line X_1 Y_1, so that the beds *C* and *D*

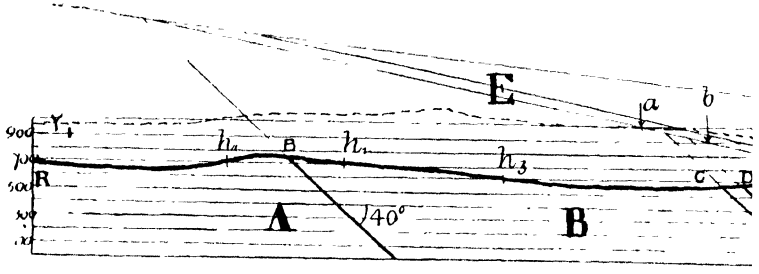


FIG. 63.—Section across the strikes of the formatio

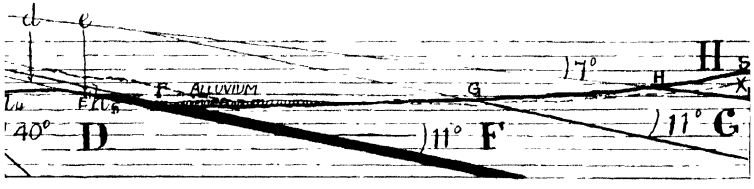
were not included. Would it have been possible to find the position of these beds in the centre of the hill, for the purpose, say, of sinking a shaft into them ? Certainly, we need only produce the strike lines through the bases of *C* and *D* to cut the line of section X_1 Y_1. We should then know precisely where the base lay.

x. The dips and thicknesses may now be read from the section and checked against the figures obtained by calculation. If the vertical scale of the section is the same as the horizontal,

this is a simple procedure. The dips are read from the section by a protractor, and the thicknesses by a paper scale the divisions of which are obtained from the section itself. Thus, for our own section we should simply mark the vertical scale from the side of the section on a piece of paper and transfer it from formation to formation. We should then read off:—

B 2000 feet	*D* 600 feet at least	*F* 400 feet.
C 100 feet	*E* 80 feet	*G* 400 feet.

xi. Finally, we may say a word about the kind of district the map represents. The dip



1 the geological map on pages 310 and 311.

stream makes its way through a deep ravine similar to that mapped on page 124, through which the River Rheidol runs. The slopes of the ravine are often precipitous. At the bottom, the water boils over the upturned edges of the beds *B*, *C*, *D* and *E* and shoots down their smooth dip faces. This is sketched in Fig. 64. The beds dip steeply down the stream, as the section indicates. The progress of the water will be impeded at each successive layer of the formation as it projects up into the stream bed. If any small streamlet joins the dip stream

along the ravine, it will tumble over the edge as a waterfall and join the dip stream in leaps. As soon as the stream gains the soft formation *F*, it turns and works along it, headed away east by the harder unconformable beds *H* and

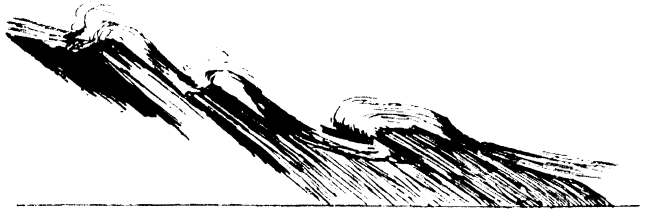


FIG. 64.—Beds dipping downstream forming rapids.

K which form rising ground to the north and west.

There is still much to be learnt from this map, but we have now covered enough ground to enable us to see how useful a geological map may be.

QUESTIONS.

The only adequate exercise on this chapter is the actual examination of geological maps of scales 1 inch = 1 mile and larger.

CHAPTER XV

MINING AND QUARRYING

i. We shall suppose the area mapped and mining operations about to begin. A careful survey has indicated the position of our mineral, building stone, road-metal, or whatever else we intend to exploit. Shall we sink a shaft, drive a level, or tear up the surface in order to get at our product? Then when we are in sight of it, how shall we mine it? May we blast it, or do we want it in a shapely condition? Next, how shall we transport it to the surface, and dress it for the market?

ii. First of all we must consider its position. On the accompanying map of an area in Cardiganshire, the fault *F F* carries lead. A section along the fault, obtained in the manner with which we are familiar, is given below. How shall we exploit the lead? We drive a tunnel or "level" into the side of the hill at some point where the shape of the hill-side is convenient for placing machinery. When the tunnel opens into the faulted ground we turn and work along the fault, mining the lead-ore in a way to be described presently. But we

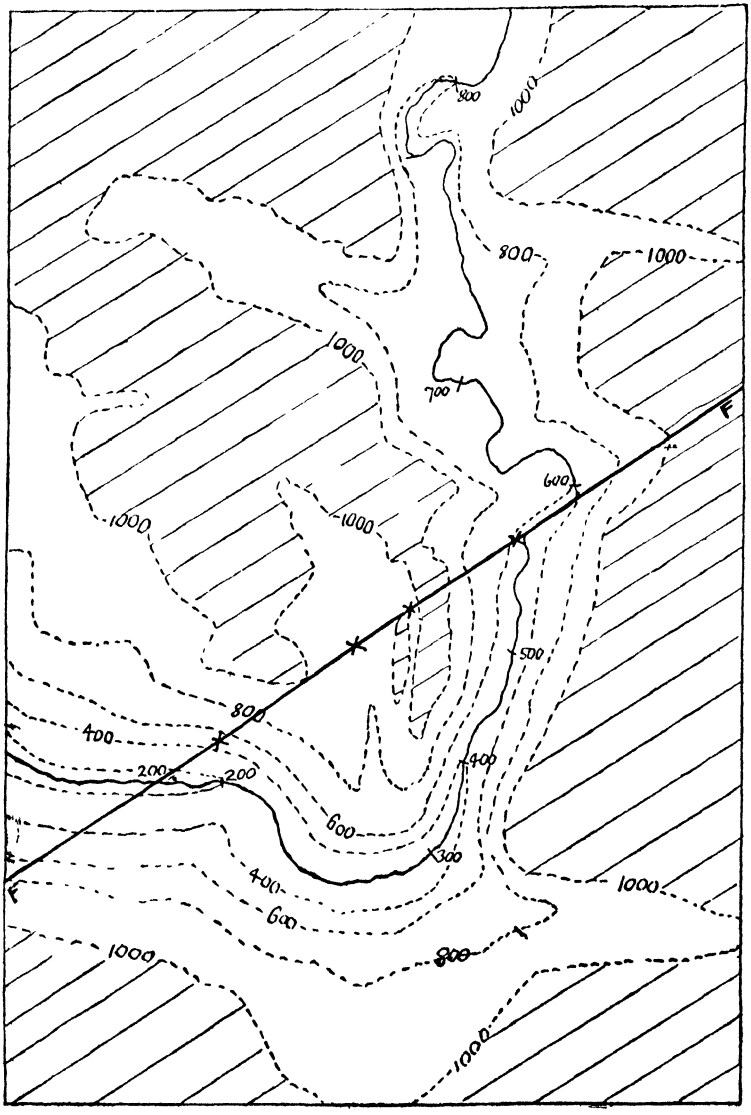


FIG. 65.—Scale 3½" represents 3 miles.

might find it more convenient to sink a vertical shaft *S S* (Fig. 67) from the hill-top and then work in levels *L L* developed from the shaft. In the first case the ore would be loaded into

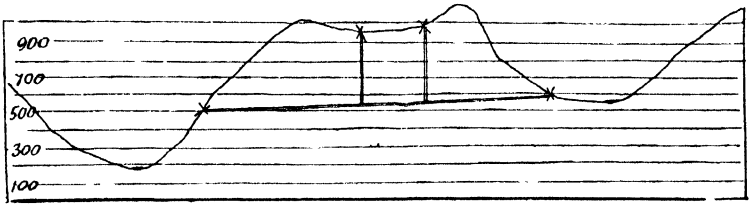


FIG. 66.—Positions of the mines (xx) and methods of working by shafts and by levels. Horizontal scale $3\frac{1}{2}'' = 3$ miles.

trucks and trammed out to the mouth of the level in the hill-side by means of a steel rope fastened at one end to the trucks and at the

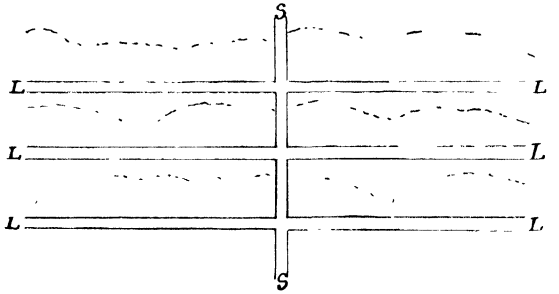


FIG. 67.—*S* shaft; *L L L* levels.

other to a winch. In the second case, the mineral would have to be loaded into buckets and hoisted vertically to the surface by winding machinery.

The workings must, of course, be drained, and this is frequently a costly operation.

Wherever it is possible a main "level," called an *adit*, is driven, which then forms the drainage tunnel of the mine. Pumps are set to work to drain all the water from workings below the adit so as to discharge the water into

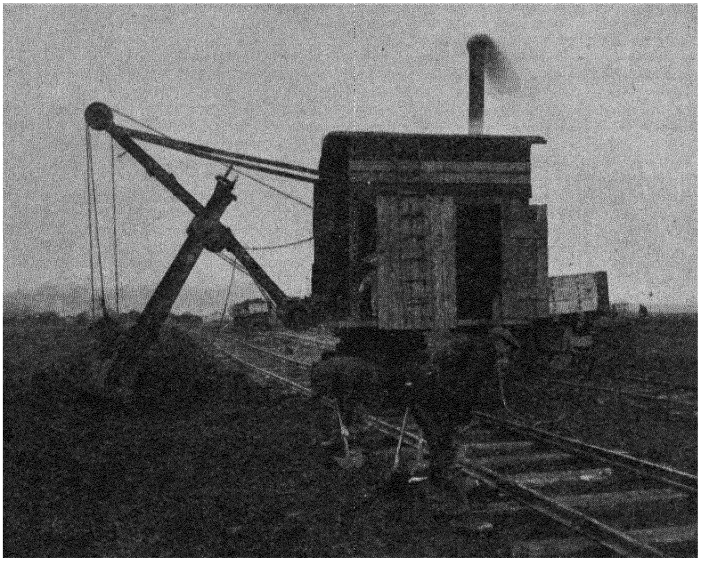


FIG. 68.—A steam shovel at work.

the adit, through which it flows to the opening in the hill-side and thence to the principal stream in the district.

iii. But when the material we want lies fairly near the surface and in fair quantities, it is usual to strip off the "overburden," or useless ground covering the mineral, and so expose it. Phosphates in the Eastern Counties

have been mined in this way. The phosphate bed lies with a gentle dip about 20 feet below the surface where operations were carried on. The top soil, which was used as arable land, was stripped off by means of steam shovels. Fig. 68 shows a shovel of this description at work. There are many designs, each suitable

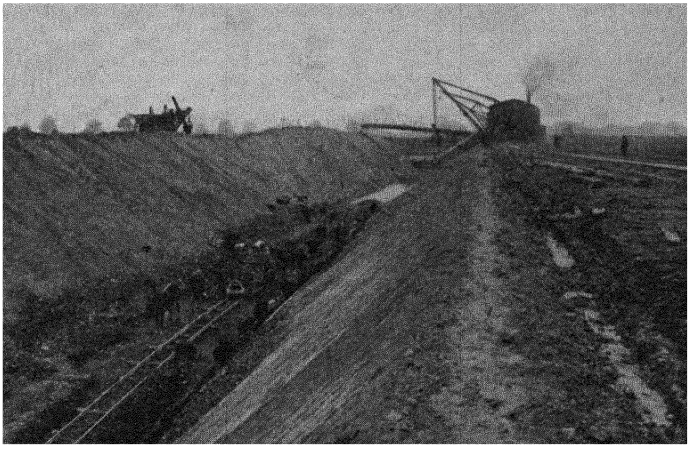
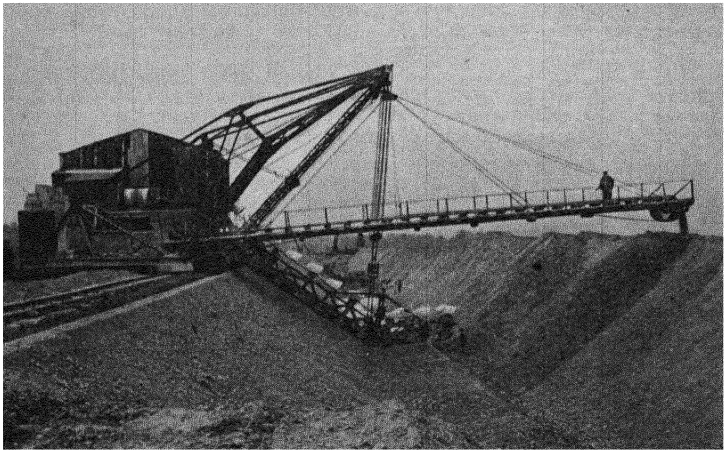


FIG. 69.—A steam excavator at work, cutting away the nearer bank and at the same time replacing upon the farther one the material dug away.

for a definite type of work. That in the figure operates by means of jaws, which close together. The load is then carried round on a crane to trucks on a light railway behind.

After the top soil has been removed, an excavation shaped like a canal, several hundred yards long, is made in the direction of the strike of the phosphate bed. To do this, rails are

laid along the strike and steam excavators set to work. Fig. 69 shows one in use. It travels at a rate of about two miles an hour along the rails and at the same time it digs away the nearer bank of the trough. The material thus dug up is thrown automatically on to a travelling belt which carries it across the



trough, a distance of 90 feet, and throws it down on the opposite bank (Fig. 70). In this way the excavation is made to travel across country in the direction of the dip, one side being constantly encroached upon and the other made up with the same material. It is necessary to pull up the track of the steam excavator and relay it further back as time goes on. Gradually the whole bed of mineral is exposed and again covered up. To win the mineral, a light

railway is laid in the bottom of the trough and the phosphates are dug out with a pick-axe. As the bed is exhausted the land is replaced by the excavator as described above, and the top soil spread over it so that it is ready for agriculture again.

iv. Steam shovels are used in much the same way to get iron ores in Northamptonshire. But overburdens are not always removed in this way. Often the top soil and the useless material above are blasted out by charges of gunpowder and the loosened material dug away by hand labour. This is often done in removing the overburden from slate quarries, as, for instance, in Cornwall.

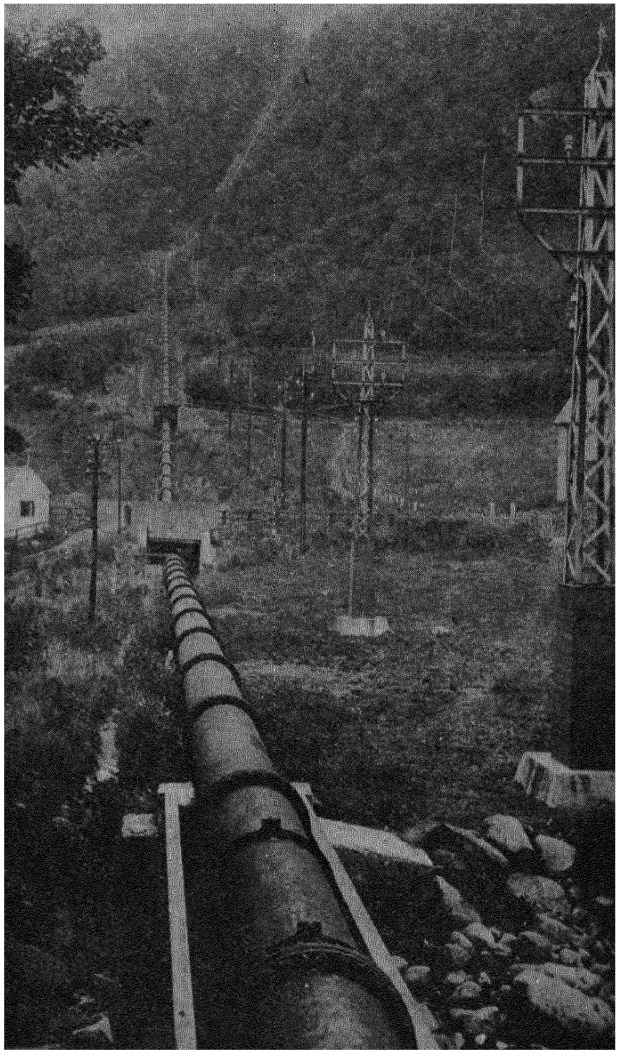
v. Every mine stands in need of power. In modern mines as much as possible is done by power. Coal is often difficult to obtain and is, generally speaking, only used where a local supply is available. But where water is to be had the greatest use is made of it.

(*a*) Where coal is employed, steam is first generated in boilers and used in steam turbines to drive dynamos or air compressors. The air is then taken right into the mine in iron pipes and used to operate drills and to drive winches. Air has the advantage that it ventilates the mine at the same time as it drives the machinery. Sometimes a gigantic fan is placed over a shaft to create a draught through the workings. This fan is driven from an electric motor.

(*b*) Water power is utilised in two ways. The

old method of working was with a water-wheel. The water was brought down in "leats," or open troughs made of wood, from some lake in the hills or the upper reaches of some river across which a dam had been thrown. It was then directed to fall on the top of the wheel. The amount of power to be obtained by this means is limited by the size of the wheel. The larger the wheel the bigger the waterfall. Consequently, it used to be the aim of mining engineers to construct very large wheels, like that of Laxey in the Isle of Man. But to-day it is usual to bring the water down in enclosed pipe-lines.

vi. Pascal, a famous French philosopher of the seventeenth century, once carried out the following experiment: He filled a barrel to the top with water, and fitted it with a lid through which he passed a long vertical pipe of small cross section. As he foresaw, he only needed to pour water down the pipe in order to create sufficient pressure in the barrel to burst it! What is it that determines the pressure to be obtained at the bottom of the pipe? The answer is, the head of water. When an open leat is used to convey water to drive a water-wheel, the head of water is wasted. The power to be obtained just depends on the quantity of water delivered to the wheel and the diameter of the wheel. But by bringing the water down in a closed pipe-line, as Fig. 71 illustrates, the power to be obtained depends principally on the head of water, that



[*By the courtesy of the Aluminium Corporation, Ltd., Dolgarrog.*

FIG. 71.—A power line from a lake in the hills.

is, the vertical distance from the water turbines (which replace the water-wheel) to the lake which feeds the pipe. The power to be obtained is now no longer limited by the size of the turbine, but by the pressure of the water issuing from the bottom of the pipe-line.

vii. In older mines the crushing, dressing and winding machinery is all geared up with the water-wheel. But to-day power is transmitted right into the mine, either as electricity or as air under pressure. The dressing and winding machinery, and all other plant at the dressing station, is then worked similarly from these two supplies.

viii. Next we must refer to the methods employed to win the material from the mine or the quarry. The first consideration is whether we want it shaped for use, as, for instance, when the product is to be building stone, marble or slate, or whether its shape is immaterial. In the first case explosives may hardly be used at all, whereas in the second we rely principally on a regular use of blasting gelatine, gelignite, or some other explosive, to get the product. We shall first consider the exploitation of building stone, say Red Sandstone. It is no use to blast the stone, for that would shatter it. The top soil and overburden may be removed in this way (see Fig. 3) and a level space cleared for operations. The surface must now be examined in order to find how the joints run. Usually there will be one promi-

nent set of joints and a second less pronounced set. Frequently the second set is practically absent. A start may then be made by explosives along a joint parallel to the strike, so as to open out a shallow trench down below the first bedding-plane. Next, a cutting machine is set to work to make a vertical incision along another joint parallel to that already opened up. The machine travels along on rails and may be made to cut down a depth of a few feet for any distance, say 50 feet. The motion of the cutting edge of the machine is interesting. It is toothed like a saw, but the motion is not backwards and forwards as in wood-sawing, but upwards and downwards as in suet-chopping. The machine is usually driven by compressed air, pistons working the saw rapidly up and down, a rack carrying it forward at the same time. The machine may then be set to cut along the joints at right

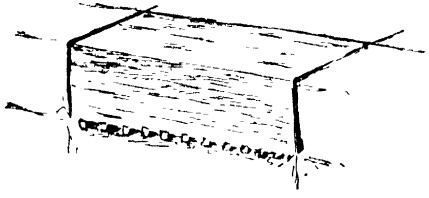


FIG. 72.—Prising up a block of building stone in a quarry.

angles to the first incision. In this way the whole block is loosened. On three sides it has been cut away, the top is exposed to the atmosphere and the fourth side left free in the trench. A series of wedges is now driven under

the block along the bedding-plane. The block, thus prised up, is lifted out by a crane and hoisted round on to a truck, which carries it away to be cut to size. Similar principles are observed in winning slates from the quarry (Fig. 88). The direction of the cleavage and the main joints decide where wedges must be driven in order to loosen the slates.

Fig. 73.—Operating an Ingersoll Rand rock drill.

ix. When mining operations are being carried on for minerals or road-metal, the method almost universally employed is exploitation by drilling and blasting. Fig. 73 shows a modern drill at work. The machine is sometimes carried by an upright pillar which is wedged

between the floor and roof of the mine. It may be set to point in any direction. The drills, which may be from 6 to 20 feet in length, are made of steel and traversed by a channel through the central axis, through which water is driven. The drill is placed in the machine and screwed tightly. It is then turned so that the drill touches the face of the mine, into which a hole is to be bored. When it is firmly screwed, the compressed air which feeds it is gradually turned on by the miner, when the drill begins rapidly to rotate and at the same time to hammer at the rock. The dust from the disintegrated rock is laid by the spray of water issuing from the end of the drill. As the drill functions it gradually moves forward into the rock in the hole it makes for itself. Smaller machines of this type are used in open quarries and in coal mines and are supported by the miners instead of being screwed to an upright.

x. The question arises: Where should the holes be driven? Will the explosive which is placed in them be equally effective in breaking out the rock in whatever way the holes are made? Again the joints play a prominent part. It is usual to work along the face of the formation by steps or benches formed by joint planes. In Fig. 74 benches formed by joint planes are shown and arrows put in to indicate where the rock would be holed. Then when these holes are filled with explosives and the charges detonated, the whole of the jointed

blocks fall away shattered, leaving clean faces formed by the next joints.

xi. The miner must always take care to break out as little as possible of the rock which underlies and overlies that particular formation which carries his ore. This is the reason why the workings of mines are frequently so narrow or low. The rock below the mineral bed is known as the foot-wall, and that above is called the roof or hanging-wall. We shall first describe briefly the manner of working in a mine where the mineral is bedded at a fairly low angle, as in a coal mine. Here you stand on the foot-wall, and the hanging-wall forms the roof above your head.

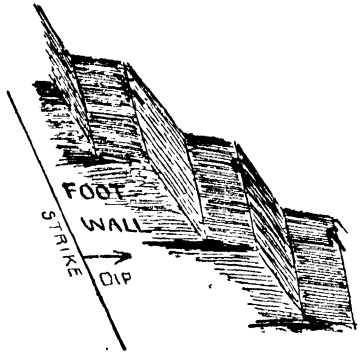


FIG. 74.—Benches.

xii. Coal seams vary in thickness from a few inches to seven or eight feet. The coal is reached by means of a vertical shaft, up and down which two cages are wound which serve to take the miners to and from the scene of their work, and also to hoist the trucks of coal to the surface from the workings underground. The method of working on a seam up to four feet in thickness is the following: From the bottom of the shaft, which is sunk as far as the coal seam, a tunnel is made in the direction of

the dip of the coal. This tunnel will consequently be driven in the coal itself. All the coal will be removed, and in addition a foot or so of the foot-wall and about three feet of the solid roof. In plan the tunnel is represented by *A B* (Fig. 75), which runs in the direction of the dip, as the arrow indicates. In section the dip is seen to facilitate the removal of coal

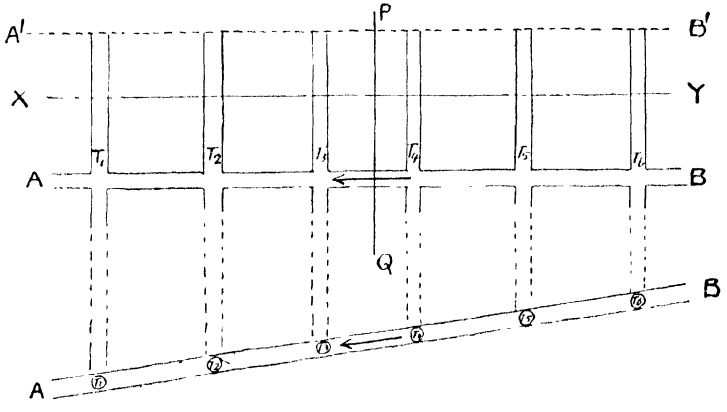


FIG. 75.—Long Wall method of coal mining.

by gravity. The four-foot coal seam will of course be exposed on each upright wall of the tunnel (see Fig. 76). First of all the shale forming the foot-wall beneath the coal seam is cut away, either by machine or by pick-axe, to a joint parallel to the face. Holes are then drilled in the coal near the top of the seam. When explosives are placed in these holes and detonated, the coal is brought down as far as it has been undercut. The shattered coal breaks clear along the joint plane, and this

joint plane then forms the fresh working-face. The coal is loaded into trucks and taken by ponies to the shaft to be hoisted in cages to the surface.

xiii. The freshly exposed face is now undercut in its turn to the next joint plane, and blasted. Working in this way from the two sides of the tunnel, the coal is gradually removed, leaving the hanging-wall. It should be understood that none of the hanging-wall is removed at the working-face, whereas in the tunnel three feet have been excavated. What now will be the consequence of continued operations of the kind we have described?

(1) The roof will sink on account of the removal of the coal.

(2) There will be no way back from the working-faces [which by this time have been taken as far, say, as A' B' (Fig. 75)], to the main tunnel, for all the coal will have been removed in the area between A B and $A'B'$, and this area will have collapsed.

xiv. To meet these difficulties the following

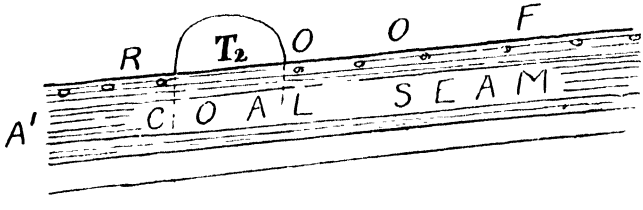


FIG. 76.

course is adopted. Instead of working uniformly along the coal-face the miner enlarges

the working at intervals into tunnels by removing three feet of the solid roof just as in the main dip tunnel. In Fig. 75 these tunnels are marked T_1, T_2, T_3 . . ., and are seen to run along the strike of the coal-bed. They are constructed as the exploitation of the coal proceeds. Now, suppose the workings were to collapse utterly. Even then there would be a passage-way of three feet between the arch in the roof and the foot-wall. But the workings cannot so collapse on account of the method of propping which is employed. To illustrate this we propose to draw a section

Fig. 77.

(Fig. 77) from the working-face along $A'B'$ to the main tunnel at $A\,B$. (It should be understood that there is no *tunnel* along $A'B'$.) Let $P\,Q$ be the line of section. It will be horizontal, for it is in the direction of the strike. The miners at the coal-face will be getting the coal as we described in paragraph ix. They first remove the foot-wall back to a joint, and then blow down the face, exposing a new one behind. Their next concern is to prop up the hanging-wall behind their backs. This is done by wedging props of spruce between the roof and the ground, as the figure illustrates. Running parallel with the direction which the figure depicts will be the numerous

strike tunnels T_1, T_2, T_3, etc. From these, as we have seen, three feet of solid roof are removed in addition to the coal. The material from the roof is thrown under the workings where no tunnels exist. Now, as time goes on, the roof begins to subside, in spite of the props and roof material. But these prevent a complete collapse. Near the face the props will be in good order, but farther back they will be broken and mixed with the waste. The effect of the drag of the subsidence on the coal is to shear it forward in such a way as to make it easier to win. As it is blasted down, it is trammed from the face to the strike tunnels and thence to the main dip tunnel. To complete the description, a section will be taken along the dip from *X* to *Y* (Fig. 75) across the strike tunnels. The strike tunnels are

FIG. 78.

clearly seen. They lead directly from the working-face to the dip tunnel. Their arches are cut in the solid roof, and between them the coal has been removed. It is to be noted that, mining in this way, (1) no coal is left behind, and (2) no waste is hoisted with the coal, but, instead, (3) the waste is used to support the workings. This method of coal mining is known as *Long Wall*.

xv. Another method, known as the Bord and Pillar system, has also been extensively used, not only in coal mining but also in winning other minerals such as pyrites and salt. It applies to the exploitation of coal seams thicker than four feet. The seam to be mined is first dissected by narrow strike- and dip-tunnels. Miners then commence cutting and drilling at each of the corners so formed, and work along the benches or joints until only a pillar of coal remains of the original sectors formed by the small tunnels. These pillars are sometimes left to support the roof.

Questions.

1. Describe the chief ways of opening up ground to get building stone or ore. Might docks and canals be excavated mechanically?
2. Say what you can about "power" on a mine.
3. Describe the Long Wall method of winning coal.

CHAPTER XVI

WINNING ORES

i. MINERAL veins frequently occur in more or less vertical faults. The methods described above for the exploitation of minerals bedded with a low dip are then inapplicable. Suppose, for instance, the parallel lines *A B*, *C D* (Fig. 79) represent the fault referred to in paragraph ii of last chapter as it would be shown in a vertical section along the dip, the fault being a strike fault. The fault is, let us say, 20 feet wide and carries lead. To win the lead, a shaft, *S*, is sunk vertically into the vein from the surface, or a level, *L*, is driven in from the side of the hill. Having struck the ore, we work along the fault, making a level at right angles to *L* or *S*. Let *F* represent this level. Its sides will be formed of the country rock, that is, the rock proper to the formations through which the fault breaks, while the fault will be filled with masses of broken rock derived from the formations round and known as breccia. The hanging-wall and foot-wall will be easily recognised. The problem is, how to exploit the mineral above the level *F*.

To begin with, the roof, *F*, is thoroughly timbered. Then at various points along *F* the miner works above the tunnel, in the areas indicated by dotted lines, allowing the waste blasted out to accumulate above the tunnel roof, and sending the ore by chutes through the roof of the tunnel into trucks. In this way the

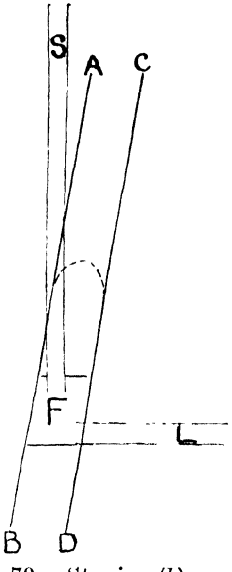


Fig. 79.—Stoping (*b*).

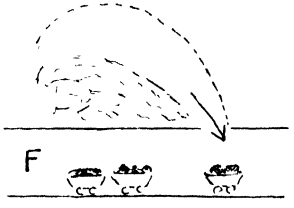


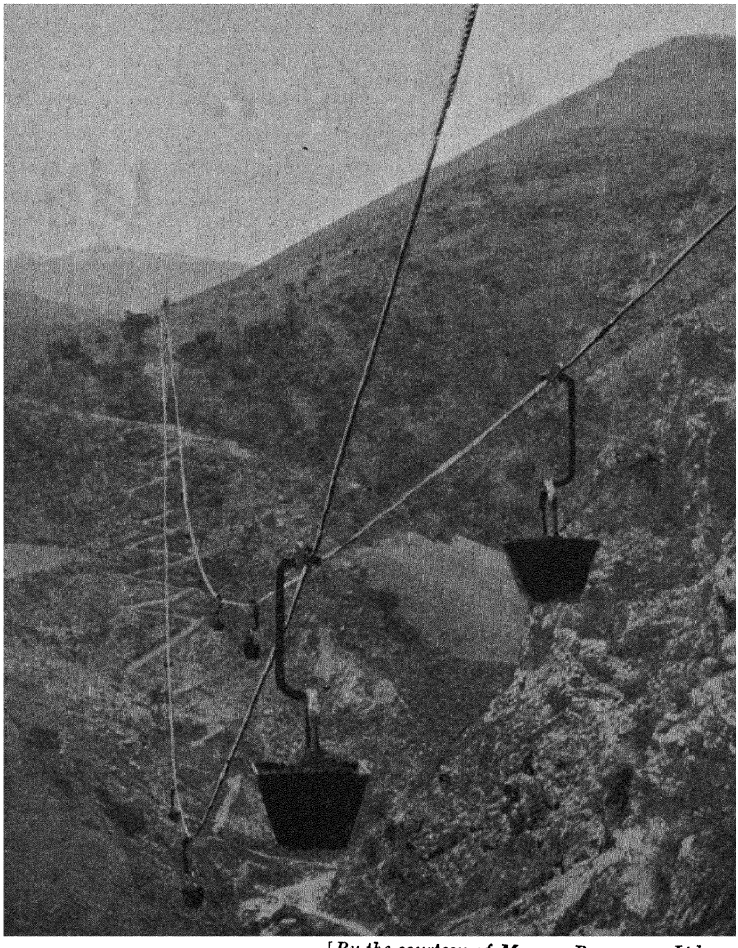
Fig. 80.—Stoping (*a*).

whole of the ore for many fathoms above the tunnel is gradually won (see Fig. 67). The operation is known as *Stoping*, and is carried out by drilling with stope hammers, and by using explosives. When stoping can no longer be carried on profitably from that level, the shaft must be lowered and another level opened up, so that stoping may begin from the

lower level and work may proceed upwards to that already abandoned.

ii. Mining machinery is designed to treat and transport vast quantities of heavy materials. The mining engineer endeavours to lay out his plant so that the product is passed from one part of the plant to the next, always downhill. If he can, he will start uphill, so that he may run out the mineral by gravity from the hill-side, crush it, screen it, and sort it in order down the hill-side, and then transport the product to the railway by an aerial ropeway without touching it by hand from the moment it is loaded on to the truck in the mine until the time it is tipped into the railway truck from the ropeway.

iii. When the ore reaches the surface it must, generally speaking, be treated, either to remove waste or to sort it according to size. Coal, for instance, comes to the surface in trucks which are run off from the cages at the pithead on to rails, which carry them by their own weight into a frame designed to tip them upside down so that their contents fall on to grizzley bars. Each emptied truck is put back automatically on to the track again so as to be lowered in another cage. Grizzley bars (Fig. 82) are nothing more than straight steel bars rectangular in cross section placed parallel to each other in an inclined position to form a sieve. Sometimes they are given a jerking motion by eccentric gearing, so that when the mineral falls upon them the rougher is jolted



[*By the courtesy of Messrs. Ropeways, Ltd.*

FIG. 81.—Transport of ore by aerial ropeways.

off the bars and the finer passes through. The "fines" fall into a bin which may stand over a railway siding or deliver into buckets on a ropeway. The "roughs" are then sorted by hand before they are shipped away.

iv. There are a great number of devices by which material too large to pass through $1\frac{1}{2}$-inch

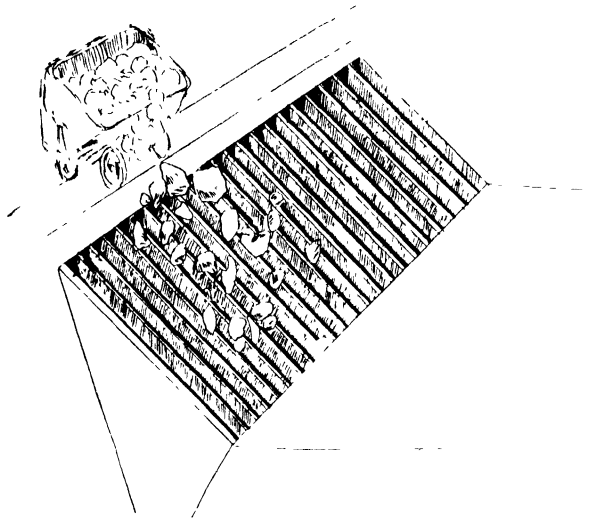


Fig. 82.—Grizzley bars

grizzley bars may be sorted by hand. The object of the process of sorting is to remove the waste from the valuable product. The waste may consist of part of the hanging- or foot-wall, which has been unavoidably blasted out with the mineral. Coal, for instance, may be mixed with shale, sandstone or "brasses" (iron pyrites), which must be separated from it before it is sent from the mine. In order to

do this the rough material which is thrown off the grizzley bars is shot into a bin which delivers on to a broad, endless travelling belt. Operatives are stationed at intervals along each side of the belt, and as the material passes them they pick out the waste and throw it into bins (Fig. 83). Mining operations should be so carried on as to reduce the percentage of waste to the lowest possible.

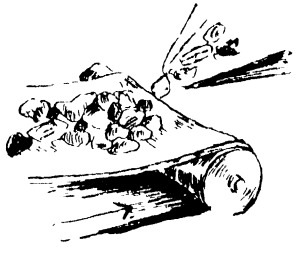


Fig. 83

Another mechanical device is a rotating circular table from which the centre is cut away. The sorting is similar to that already described. Frequently the material mined is so covered with dust that it is impossible to distinguish with the eye the valuable from the useless constituents of the material mined. Then the dust must be washed off by powerful sprays of water, which are made to play on the material as it falls on to the band or table. After this it is easy to distinguish, say, road-metal from pyrites or grit.

v. If the product is in a sufficiently pure state and sufficiently small for sale after the treatment described above, it only remains to transport it to the railway. Coal, road-metal, pyrites and iron ore would be ready at this stage, but most ores require a more elaborate treatment. In order to obtain such metals as zinc, lead, silver, gold and tin, for instance,

the product of the mine must first be crushed. There is a variety of crushing machines from which any particular type would be chosen according to the output of the mine, the nature of the ore which it is desired to treat and the method of treatment adopted. The commonest form of crusher is one in which the product is dropped between toughened steel jaws (Fig. 84). One jaw is fixed while the other crushes the ore against it. To reduce it to a finer size still, it may be passed through steel rollers. One of the finest types of crushing machines, largely used in South Africa, is known as the Stamp Battery. In this form of crusher five steel hammers carried by vertical shafts are dropped successively upon the ore as it lies in an iron mortar. They are lifted and released by cams attached to a piece of horizontal shafting.

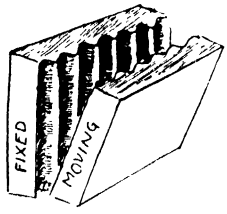


FIG. 84.—Crusher jaws of manganese steel.

By one means or other the product of the mine is at last reduced to a fine state of subdivision. The size to which the individual particle of the crushed material is reduced depends on the method which is to be employed in extracting the mineral. There are three in common use :—

(1) Extraction by gravity, *e.g.*, by jigs and Wilfley tables, etc.;

(2) Extraction by chemical methods;

(3) Extraction by flotation.

vi. Suppose an ore contains (1) galena (lead sulphide), (2) blende (zinc sulphide) and (3) waste. The specific gravity of galena is 8·5, of blende 4·0, and of waste about 2·5. Can we not take advantage of these differences in specific gravity to separate the constituents? The ore is first crushed in jaws and the product separated into four different grades according to size, ranging from $1\frac{1}{2}$ inches to $\frac{1}{8}$ inch, say.

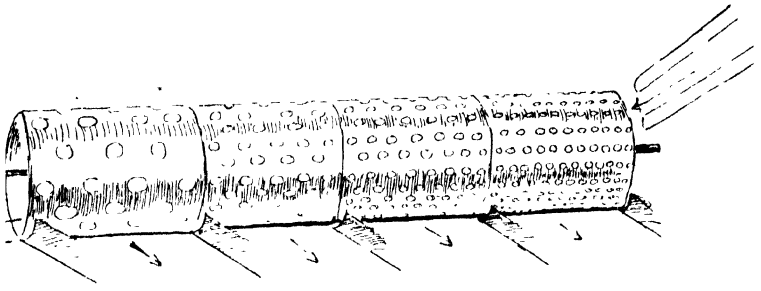


FIG. 85.—Screens or Trommels.

This separation is effected by means of screens (Fig. 85). These are cylinders placed with their axes slightly inclined. Each is pierced with holes of a definite diameter. They are geared to a shafting which causes them to revolve. When a series of such screens is employed the product may be graded according to size to any desired extent. Sprays of water are frequently made to play inside the revolving screens, and these remove clay or dust from the mineral. Crushed ore is delivered into the first revolving screen, the holes of which are, let us say, $\frac{1}{8}$ inch in diameter. All the material,

whether mineral or waste, of less than that diameter will pass through the screen and be caught by a tray placed under the screen. The water-sprays which play on the revolving ore inside the screens wash the small material through the holes on to the tray and down a chute. The material from which the $\frac{1}{8}$ inch constituent has been eliminated passes on to the next screen, from which the $\frac{1}{4}$ inch is

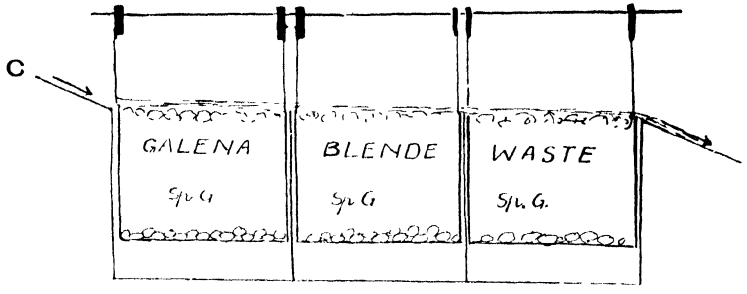


FIG. 86.

eliminated. Continuing in this way, the whole of the product is classified into four or five groups, according to the size of its constituent particles. Each group is then separately treated, but each in the same manner.

vii. Consider briefly what happens to the $\frac{1}{2}$-inch group. This will contain blende, galena and waste between the sizes of $\frac{1}{2}$ inch and $\frac{1}{4}$ inch. It will be washed down a chute, *C* (Fig. 86), from the corresponding stream into a long trough. In the trough are three or four wooden boxes which just fit easily into a corresponding number of compartments, into

which the trough is divided. The bottom of each of these boxes contains an iron sieve plate of $\frac{1}{2}$-inch mesh. In the first, these holes are covered by selected specimens of $\frac{1}{2}$-inch galena, just too large to pass through. In the next, blende is used in a similar way, and in the last, quartz or slate or some other constituent of the gangue. Each box is geared eccentrically to a shafting, so that when it is set going each is given a rapid sifting motion. Now consider what happens when the crushed ore falls into the first box. The box quickly fills with blende, galena and gangue (or waste), all suspended in water. When the box is agitated up and down by the eccentric gear, the galena gradually sinks to the bottom. Then, since the selected galena over the holes in the sieve is of a maximum size for this grade of ore, that which sinks is sifted through into the bottom of the trough. As the box fills, the galena accumulates until there is nothing but that mineral in it, all the remaining constituents of the crushed ore passing into the next box. The feed is maintained at such a rate that the box sifts away just as much galena as is freshly added to it. If you watched the process when it was established you would appear to see the following: The crushed ore fed into the first box contains three easily recognised constituents. The galena box would be full and the agitation of its contents suspended in water would cause the galena to drop and the blende to pass into the second

box together with the waste. Here the blende would fall in turn, and the waste pass on. A continued selection is thus effected. This principle of separation by gravity and running water is embodied in a great variety of mechanical appliances, but these will not now be described.

viii. When separation is to be effected by chemical means, very thorough crushing is generally needed, although this is not invariable. For instance, great deposits of iron pyrites contain about 2 per cent. of copper, from which the copper may be largely removed by the simple process of irrigating the dumps of ore with running water. Water leaches out the copper, which may then be precipitated in metallic form by causing the water containing it to run over scrap iron.

But often nothing can be done until the ore is finely divided. Thus the gold from gold-bearing ores may be extracted by mercury. After the ore has been crushed in a stamp battery, and the particles reduced to $\frac{1}{40}$ of an inch, the product is made to flow over mercury, which forms an amalgam with the gold particles, allowing the waste to flow on. The gold is recovered by distilling the mercury away. It is left in the retort and the mercury condensed. Extraction of gold by the use of a 0·2 per cent. solution of sodium cyanide is the chief example of chemical extraction in the mines. The finely crushed ore is placed in vats and a weak cyanide solution allowed to leach out the gold

during a period of twenty-four hours. The gold is now held in solution by the liquid and

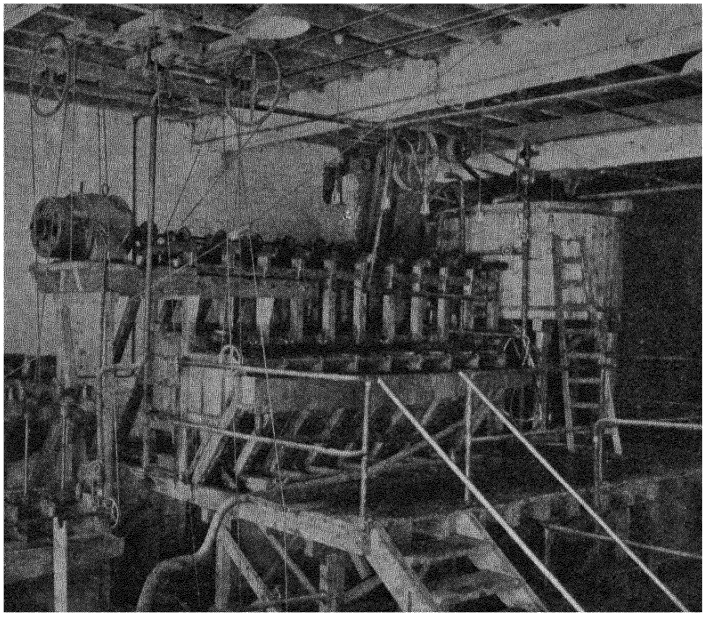


FIG. 87.—Type of standard plant for the separation of minerals by oil flotation. Twelve similar units are shown, motor-driven stirring gear, and oil vat. The process is continuous. The finely crushed ore suspended in water is fed into the first unit (behind) and is strongly agitated with a small quantity of oil. It then flows into the corresponding compartment (forward), where much of the heavy mineral is floated to the surface and overflows into the launder. The remainder, with the waste, is pumped into the second unit (behind) and again subjected to the same treatment, and so on.

removed from it by the addition of clean zinc, upon which the gold deposits itself.

ix. The most recent and successful method

of extracting minerals from their ores is the *Flotation Process*. The gist of the method is that when a small quantity of oil is churned up with finely divided particles of gangue and mineral suspended in water, the oil selects the heavy mineral, coats it and floats it to the surface, leaving the waste, although it is lighter, untouched. In this way the mineral may be skimmed off. The success of the flotation process has been phenomenal. In the United States, where it has been most fully developed, 20 million tons of ore were separated in this way during 1913, although the process is hardly ten years old. Up to the present time the only ores which may be said to have been treated with complete success by oil flotation are the sulphides, blende and galena, for instance. The ore is first crushed very fine and then washed with water into a box. A feed of oil (about half a gallon per ton of aqueous mixture) enters the box and the whole is vigorously agitated. This may be effected by a continuous uprush of compressed air through a perforated bottom to the box, or by means of motor-driven paddles. The mineral then rises to the surface and flows away. This method of separation is 30 per cent. more efficient than others described, and much more direct. It is expected to have a great future.

x. As mining proceeds, some record must be kept of the quality of the daily or weekly yield. This is done (1) by sampling the faces,

and (2) by putting aside a certain percentage of the tonnage after crushing and sorting, as a sample. When many samples are taken from the working-faces and their positions recorded, their values on analysis afford a guide to further exploitation. But samples taken after crushing and sorting indicate, on analysis, the value of the output for sale. The problem of transporting ores and dressed minerals to the railway has largely been solved by the use of the aerial. An aerial is usually a fixed steel ropeway supported in the air by uprights. Buckets containing the material to be transported are pulled along the ropeway by smaller cables. Otherwise the main aerial moves. The bucket then grips the steel rope by a small toothed contrivance which carries it. As the rope moves, the bucket travels with it, and when it arrives at the railway or dock it tips automatically over and drops its contents.

xi. This ends our brief survey of the most obvious practical side to geology. But before we leave it we should try to answer a very reasonable query, but one the complete solution of which is unknown. How did the metals get there? It appears first of all as if the metals were scattered fairly uniformly through the original igneous crust of the earth's surface. For (1) if we examine any ancient igneous rock we discover in it, besides its main constituents, namely (*e.g.*) silicon, aluminium, potassium, sodium and calcium, traces of an exceedingly large number of other elements—titanium,

zirconium, iron, magnesium, phosphorus, etc., and (2) we must assume that all the metals now in existence in the earth were present originally when the crust cooled, but not necessarily in the same localities as those in which they exist to-day. We conclude, therefore, that the metals have been derived from the igneous rocks and have been concentrated in one way or another in various spots in the earth's crust. How has this concentration taken place ?

(*a*) Consider what would happen when a molten mass from the earth's interior broke through the solid crust and gradually cooled. To begin with, the cooling would by no means be uniform. The edges of the mass which came into contact with the cold solid crust would cool fastest. Secondly, the liquid constituents of the molten mass would not all crystallise at the same temperature. Instead, they would become solid in a definite order, which is fairly well known. In this way we see the possibility that certain constituents of the original molten mass should solidify separately and thus become concentrated. This is the first method of concentration, namely, by cooling from the molten state. This mode of origin is attributed to a great number of mineral deposits in igneous districts.

(*b*) We have seen that the chief agent of erosion and transport is running water. Now water may concentrate metallic compounds in two ways. It may act mechanically (as a jig)

down a stream bed, as it has undoubtedly in the Cornish stream-tin deposits, and in the various deposits of gold known as "placers." It simply separates the heavy metal and washes off the waste. Secondly, the water may perform its concentrating work by reason of its power of dissolving, to however minute an extent, practically all the known metallic compounds, even gold. How then have these compounds been concentrated? So far we have seen that they have been collected by running water from the hills, but only in minute quantities. It remains to be seen how they have been deposited.

xii. In the first place running water may sink into fissures, cracks, joints or faults, and by evaporation gradually concentrate its load until it is precipitated as the salt of a metal. This appears to be the mode of origin of the fault deposits in Wales. In a similar way a lake may dry up, leaving a deposit of salt, potassium or magnesium chloride. The salt which was once disseminated through many thousand miles of territory has been washed out in minute quantities into some inland lake, which has at last dried up, leaving the salts concentrated. This is now happening in Utah and the Dead Sea and has taken place extensively in past epochs in England, as our own salt deposits testify.

xiii. The second way in which the salts contained in running water are concentrated is by the aid of living organisms. Plants

depend for their existence on the salts which rain-water dissolves. Solid particles cannot enter a plant as they can an animal. The plant's food must be air and liquid. It takes in the air through its green leaves, and the salts, dissolved in water, through its roots. These two supplies meet in the green leaves. The air furnishes oxygen and carbon dioxide, and the liquid supplies nitrates, phosphates, iron, calcium, sodium, magnesium and other salts. Then the plant manufactures its food and its tissue by combining its air supply of oxygen and carbon with its water supply of salts. But if either supply were cut off it would die. There are two or three ways in which this concentration of material in plants and trees has been utilised.

(1) The plants have lived and died, forming a rich carbonaceous deposit as coal.

(2) The trees have been felled and treated chemically for their valuable contents.

(3) Animals (which cannot manufacture their own food as plants can) feed on them, and their bones and excrementa derived from the plants have become fossilised. (This is the origin of most phosphate deposits in various parts of the world.)

xiv. Then animals play a large part in extracting from sea-water the metallic salts brought down by the rivers. Thus shell-fish

extract limestone from the water, as we saw in an earlier chapter. Magnesium is also fixed. Silica forms the hard parts of many organisms, and as these die their skeletons collect in the sea bottom. Kieselguhr has been so formed.

Thus we gain at least a general idea of the way in which minerals have been concentrated in the earth's crust.

Questions.

1. What is a stope hammer? How is it used in exploiting ores?
2. How is an ore separated from the waste mined with it (1) by hand; (2) mechanically?
3. What is meant by "mineral separation by flotation"?

END OF PART ONE.

PART II—INDUSTRIAL

CHAPTER XVII

THE FOUR FUNDAMENTAL INDUSTRIES: FARMS, FORESTS, MINES AND SEAS

i. THE display of articles in the shopping centre of any busy town is endless in its variety. It would be a formidable task to attempt to classify the thousand-and-one things exposed for sale according to the industries which aided their manufacture. How should we proceed to do this with such an article as a pair of boots? What industries have been active in supplying the various parts which make up the boots? The Chemical industries prepared the blacking to shine them. The Hardware industries stamped the nails and eyelets. The Textiles spun the thread with which the soles are sewn. The Tanneries dressed the hides and made them into leather. Now, each of these industries in its turn depends on a great number of other industries for its supplies of machinery and raw materials. If we meet with such a complexity of industries when we endeavour to discover the way a pair of boots

is made, what a confusion would result if we were to try to discover this for all the articles to be bought in the shops!

ii. Fortunately, the scheme of industries may be followed in a much simpler manner. We have already made the observation that, however diverse in character an array of articles may be, their parts may all be traced back ultimately to some source in the earth. We carried out a careful examination of this conception in the first chapter by taking particular examples. We saw what sources were drawn upon to supply the material for this book, for the furniture of the room, and for the buildings round. In each case we arrived at last at an origin in the earth. Instead, therefore, of trying to classify industries by studying the great variety of commodities put out in shops for sale, suppose we start at the other end and see what groups of industries are nearest to the earth itself. These are very few in number and are of vast importance, for they supply all other industries with their raw materials. Let us see what they are. First, there are the Farms, next the Forests, then the Mines, and, lastly, the Fisheries.

iii. *Farms.*—On page 18 we examined the manner of formation of the soils which almost everywhere overlie the solid rock beneath. We found that the soil was derived from the solid rock by the gradual and continued action of sun, rain and frost. Then grass and all kinds of vegetation grew wild upon this soil.

Winter after winter, as these plants died, their remains were added to the soil, producing the dark, blackish appearance so familiar in soil where plants grow wild. This black plant residue is known as *Humus*. On cultivated fields where the crops are removed each year, this dark component of the soil is much less visible, as you may see from any railway carriage-window when fields are ploughed.

iv. We have seen how the soil is produced from the solid rock. Now soils are not by any means all alike, but they range in kind from clay soils, sticky in winter and hard in summer, to dry, sandy soils. Between these two extremes, neither of which is very fertile, there is a great group of excellent soils known as *Loams*. These are part sandy and part clayey. Now the best land is always ploughed up and sown with seed. Since loams are the most fertile soils, they are almost always ploughed up. Land that is fit to be ploughed is known as *arable* land, and it is arable land that supplies us with our wheat, barley and oats, as well as hops, potatoes, beans and peas. Besides this, many loams are good for fruit-growing. They usually occupy the broad valleys of rivers. We have noted what enormous quantities of sands and muds a river carries down to the sea. The splendid loams which occupy the river valleys have mostly been deposited by the rivers in times gone by, before we have historical record of man's existence upon the earth. In those remote days the rivers con-

stantly changed their courses and constantly overflowed their banks, each time spreading a rich covering of mud and sand (or loam) upon the valley. Nowadays rivers rarely alter their courses and rarely flood the land, because they are well embanked and carefully watched.

v. When the soil has much more sand than clay in it, it ceases to be as fertile as a loam and is often left uncultivated as a sandy heath covered with gorse and heather. But even a sandy soil can be ploughed and rendered fertile by adding plenty of farmyard manure to it and occasionally ploughing green crops into it. On light, sandy soils crops ripen quickly, and consequently they are admirably suited for growing market-garden produce for the early market; so districts with sandy soils near large towns are often used as market-garden areas.

vi. The worst of clay soils is that they are so impervious to water that they drown the seeds sown in them. On many a clay farm where corn was sown during the war, on what was usually not considered good enough soil for ploughing because of its clayey nature, the seeds were quite drowned by the water which collected in the fields. These fields had to be sown again with oats later in the year, when the rains had ceased. On this account heavy soils are very often left unploughed. Instead, grasses and clovers are grown upon them, and horses and cattle put out to feed upon them. Fields kept for grazing in this way are called *pasture*.

Farms that develop permanent pasture are known as dairy farms, because the cows give milk from which cheese and butter are made, and the farmyard supplies eggs and poultry. The animals also provide meat and bones.

But clay lands may be drained by laying earthenware pipes about 2 feet 9 inches below the surface and ten yards apart and filling in the soil on top. This is naturally an expensive undertaking, and is not by any means sufficiently frequently performed. Besides this, you may often see heaps of lime, during January and February, spread out over heavy soils. The lime has the effect of changing the clay into something very like a rich loam and lightening it enough to make it easy to plough.

vii. It is not the nature of the soil alone that decides whether it is suitable for ploughing, for dairy farming, or for any other agricultural purpose. There are two other important considerations. The first is its elevation, and the second its climate. As soon as the country begins to get hilly, the soil on the hills gets thinner, and consequently ploughed lands get less in area. Mountainous districts are rarely ploughed except just where they meet the valley. Instead, flocks of sheep are set free to rove over the hills. These supply us with food and wool.

viii. *Forests.*—The hills, too, should form the forest areas below the height of 1500 feet. But in Great Britain our forests are sadly deficient. We have seen that the plough-

lands and pastures supply us with food and wool. The forests should supply us with an enormous variety of raw materials for industry. Yet only 5 out of every 100 acres of land in England are wooded. Timber is used for a great number of purposes. Among these we may note its use in building and supporting underground workings—for instance, in the mines, where the roof is braced by pit-props. All kinds of furniture and fittings are made of wood. Besides this, nearly a million tons are used in England alone for paper-making every year. Then a long catalogue of chemicals is manufactured by distilling wood. As we have so little of our own, we import about fifty-four million pounds' worth from Russia, Sweden, France and America each year.

ix. The climate in England is not suitable for the cultivation of many trees and shrubs, the products of which we nevertheless need. We are dependent on the tropical countries for a vast number of our daily wants. Summarising the chief of these, we note, (*a*) in the first place, our own farms cannot supply all the fats we need. Vast quantities of nuts are brought from Africa and America for margarine-making. (*b*) Many products of tropical plantations cannot be grown at all in England—such, for instance, as tea, coffee, cocoa, cane-sugar, rubber and many kinds of fruits. (*c*) Then other products cannot be reared successfully. The grape will not ripen in the open in England, so we have no wines of our own. Silk is spun

by the silkworm on the mulberry tree, which fails in England.

x. We see now what a great variety of produce we owe directly to the land, when it is farmed or planted with forests. From arable farmlands come grains, roots and vegetables. From pastures come dairy produce, meat and hides. From forests and woodlands timber for many purposes is drawn, including paper-making and chemical manufactures. In addition to these from home, there are the corresponding products from tropical countries just summarised.

Fisheries interest us here because they form an industry as fundamental as mining and farming. But a description of the industry is outside the province of this book.

Questions.

1. What four industries stand at the base of industrial production? Explain how this is so.
2. What constitutes the difference between light and heavy soils?
3. What districts in Britain are most suitable for sheep farming? (Use the atlas.)
4. From a contoured map of Great Britain say where you think forests might be planted. Give reasons.
5. Make sure of the nature of the soil in your own district and write an essay on the use to which it is put.

CHAPTER XVIII

MINES AND QUARRIES

i. If we climb to a spot from which we may look out across London, what chiefly attracts our eye is the magnificent whiteness of certain outstanding buildings—church spires, the Cathedral, Somerset House, Whitehall, the Abbey and a hundred other buildings. They are not usually white on all sides, but only on the weather side, the blackness of their unweathered surfaces affording a singularly beautiful contrast. They show up white in this way because they are built of white limestone. Buildings of granite or sandstone, even when new, look drab in comparison with these. Let us distinguish between a few of the chief British building stones and learn their sources.

ii. The Banqueting Hall in Whitehall, built in 1619 by a famous London architect, Inigo Jones, is a fine example of the use of Portland stone, a limestone from the quarries of the island of Portland. This stone, which weathers so white and which shows up so well, is the queen of British building stones. Sir Christopher Wren employed it in building St. Paul's Cathe-

dral. Another example of its use is seen in Somerset House.

Next in importance among the English limestones is the Bath Oolite. This is mined rather than quarried in extensive underground workings. Buckingham Palace was built of it.

The Houses of Parliament are also built of limestone, but you would judge from the light buff colour of the stone that it differs from those mentioned. It was quarried at Bolsover in Derbyshire, from a valuable formation of building stone known as Magnesium Limestone.

There is one other limestone we should not omit to mention, and that is the Carboniferous or Mountain Limestone. The Guildhall in London was built of it in 1789 from the quarries of Hopton Wood in Derbyshire.

iii. We should distinguish three important sandstones used for constructional purposes. First, there is York Stone, quarried round Halifax and Bradford. This is usually a very light buff colour. The War Office was partly built of it, as well as many other notable public buildings.

Then there is a Scotch sand-stone from Craigleith, near Edinburgh, which is largely employed on fine buildings. It was used to build the Bank of England.

The third sandstone is hardly suited for public buildings, but more for embankments, bridges and docks, since it is very difficult to work. It is known as Millstone Grit. The London and North-Western Railway Company

have employed it in the imposing entrance arch to Euston Station. It is easily recognised anywhere by its rough surface (usually black when weathered) with occasional bands of coarse sand-grains immovably embedded.

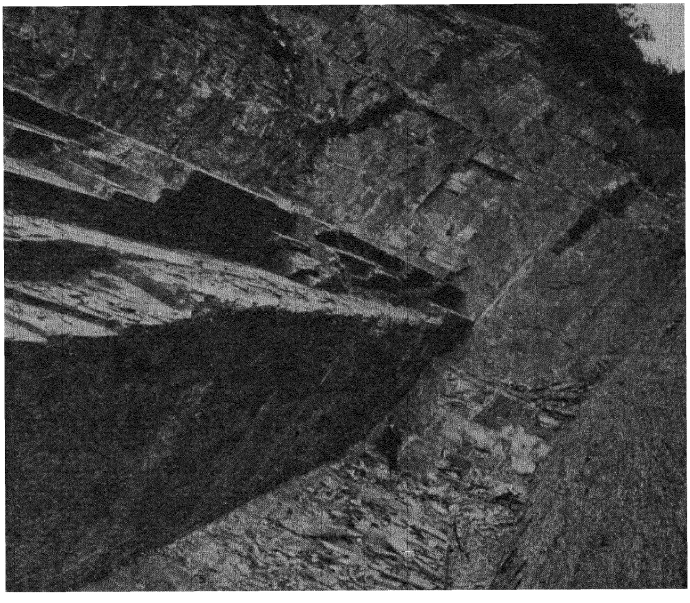
iv. Various British granites are employed in public buildings. Of these the chief sources are Cornwall and Devonshire, Cumberland and Aberdeen. Dartmoor supplied the granite for many of London's public works—London Bridge, Waterloo Bridge and the Embankment, for instance. You should be able to recognise at a glance whether any particular building stone is a granite, sandstone, limestone or marble. The surface of a granite resembles a piece of mosaic work. Little crystals fit into each other, leaving no spaces between. The crystals are not all the same, as we remember from our description in Chapter III. Some are milk-white or pink, some black or grey or flash like flakes of tinsel, while others are more or less glass-like. The Cumberland granites are often pink, and those from the West of England and Aberdeen mostly grey, formed of small black and white crystals, sometimes with large white crystals of felspar.

v. One of the first things to strike an Englishman when he travels in Europe is the absence of naked brickwork. On the Continent, speaking generally, the front of every house is faced with building stone. The bricks are regarded as ugly and are consequently covered over. A building is thought of as unfinished

until the brickwork is hidden. We have as fine a supply of building stone to draw upon as any nation, and yet we are content with bricks. We have, it is true, excellent supplies of clay, sand and limestone for making bricks and mortar. London is built on an enormous clay and gravel basin flanked on the north and south by Chalk hills. We can see now how readily London may be supplied with bricks. Perhaps the origin of covering brickwork up is to be sought in the use of Plaster of Paris by the Parisians. Within a few miles of Paris there are enormous deposits of Gypsum. The use of this mineral to make plaster was early discovered, and it was customary to put "stucco" façades on the houses in that city. This custom spread from Paris over the Continent. Plaster is not nowadays employed. Instead, façades of limestone or sandstone are used. But the use of plaster probably trained foreign publics to regard brickwork as unfinished. Plaster of Paris is now used to adorn the entrances of picture palaces.

vi. Besides the building materials described above, slates and marbles must also be mentioned. Some of the finest slates in the world come from the district north of Snowdon. They are mostly of a bluish-violet colour and are extremely fissile. They do not, however, split along their bedding-planes. On the contrary, they split along so-called cleavages, which cut across the bedding-planes. These cleavage planes (Fig. 88) have been developed

in the slates by great earth-pressure. Other slates come from similar areas in Cumberland, where they are rather greenish; and those from Delabole in Cornwall were at one time by far the commonest in England. Marble is



[*By permission of H.M. Geological Survey.*

FIG. 88.—The slate quarry, Coryton.

quarried in several English counties, the chief sources being Derbyshire and Devonshire.

vii. We now arrive at the last great group of raw materials derived from the earth's crust, namely, the minerals. We have already described the general methods employed to

win them, so we shall proceed now to group them according to their uses in industry. Much the most important in the modern world are Coal and Iron. For its size, Great Britain is singularly well endowed with these two minerals, and we were, moreover, the first to recognise their value and to exploit them. Their distribution will be considered later in detail, according to the industrial districts to which they have given rise. Here we shall simply notice that in 1915 we mined about 14 million tons of iron ore and brought in from abroad a further 7 millions to be smelted. As for coal, our output in 1913 was about 280 million tons, of which about 40 millions were more than we needed at home and were exported.

viii. The steel industry is no longer confined to the production of steel from iron ores. Nowadays there is an increasing number of steels which contain, in addition to iron and carbon (common to all steels), small proportions of other rarer metals. Steels which have been so alloyed acquire new and valuable properties, which ordinary steel does not possess. Ores of these rarer metals occur in many places in Great Britain. (Most minerals may be found in our islands. There is even a gold mine near Dolgelly which has produced £369,000 worth of gold during the past fifty years.) But ores of the metals needed in modern steels rarely occur in sufficient quantities to attract mining engineers. Yet they are becoming of greater

and greater importance. The chief are (1) Manganese, most of which comes from India and Russia. A deposit at Rhiw in Carnarvonshire is rich enough to mine. (2) Nickel, (3) Cobalt, (4) Chromium, (5) Tungsten, (6) Molybdenum. In Part III. we shall indicate their uses in steel-making.

ix. Mining for tin, lead, zinc and copper ores is still being profitably pursued in various parts of Great Britain, in spite of the discovery abroad of vast deposits of these ores. Early in last century we were the principal copper producers of the world, and Cornwall's tin mines were known before Roman days, and are still in operation. The only other metal of importance in metallurgy which we have omitted is Aluminium. The ores from which this metal is obtained are chiefly imported. Fig. 71 illustrates part of the power installation of the plant designed to produce aluminium from its ores.

x. We are well supplied with salt, which is mined and pumped as brine in many districts. But salt alone is of very little use. It must be either near a supply of coal for generating electricity to split it up or near a supply of sulphur. Now we have practically no sulphur ores in Great Britain. The great bulk of them comes to us from Spain. So that industries which depend on the use of great quantities of sulphur are usually near ports. Other minerals which we are obliged to import in quantity, because we have no deposits of our own rich

enough to work, are Nitrates (from Chile), Phosphates (from Algeria), and Potash (from France and Germany).

xi. Clays for pottery and for brick-making are common. Of these the most noted for brick-making are those of the London brick-fields, those of Fletton (Peterborough) on Oxford Clay, and those of Staffordshire. The clays of Staffordshire are no longer employed in making pottery. Their use is confined to the making of "seggars," or ovens in which the pottery is baked. Instead, Kaolin, a white clay obtained from decomposed granite, is brought from Cornwall. Cornish Stone is a similar igneous product which has not been weathered to the extent of having become clay, and this is also used extensively in Staffordshire. The clays of Dorsetshire are taken to Staffordshire to be mixed with the Cornish products. Flints, also used in the manufacture of pottery, are obtained in abundance from the Chalk and from the Oolitic Limestones which cross England.

xii. This completes our short survey of the raw materials which the earth has to offer us. These supply all our wants, and the daily efforts of most of us are directed towards handling these and working them up into useful or beautiful products. People who work on the land either as farmers or planters, or who are engaged in mining or quarrying, or who sail as fishermen, stand at the very base of the industrial system. They, as it were, govern

the whole scheme of production, for they are in contact with the earth itself and supply the raw materials upon which all life in an industrial civilisation depends.

Questions.

1. Make a list of the buildings in your district which are built entirely, or partly, of (i) limestone, (ii) sandstone, (iii) granite, (iv) marble.
2. Make a list of the building materials used in your district. Find out where they come from.
3. What are the chief materials mined in Great Britain? What is their use?

CHAPTER XIX

TYPES OF INDUSTRIES

i. LET us next see how these raw materials are first utilised. It is clear that the ore mined from the earth must undergo a fair number of changes before it appears as a piece of subtle mechanism in a complicated machine. The changes which a piece of coal must undergo before its products are changed into a delicate dye or a powerful explosive are more striking still. Generally speaking, the raw materials obtained from the earth are first of all sent to a factory to be partly worked up. Metals, for instance, must be extracted from the minerals which contain them. We shall glance at the process by which steel bars are made from the ore. This will give us some idea of the type of factory which performs the first of the constructive chain of industrial processes which transform the raw material in the earth into the finished product in the shop-window.

ii. You will be struck at once by the enormous size of the plant which deals at first hand with raw materials. Railway sidings cross in all directions. Ores come in by the

thousand tons and are handled by gigantic machines. In the production of steel three train-loads of raw materials are needed : (1) of iron ore, (2) of limestone, (3) of coke. These are tipped on to elevators in measured quantities and fed into a series of blast furnaces. The combustion of the coke, intensified by a powerful and continuous blast of hot air which is driven in near the base of each furnace, causes a change to take place between the iron ore and the limestone, by which the iron is set free as a molten metal, while the limestone forms a molten slag with the silica in the ore. As the fused metal and slag run to the bottom and are tapped off, a fresh charge is put into the furnace above. In this way the process is made continuous. The fused metal is tapped off from beneath the slag which floats upon it, and is then known as pig iron. It is run into an enormous cauldron which is hoisted by an electric crane. This carries it to a converter, in which the iron is changed into steel. The crane is adjusted to tip the cauldron so as to pour its molten contents into the converter. After the conversion, the liquid steel is poured into moulds, in which it soon solidifies. The moulds are then picked up one by one by an electric crane and the red-hot ingot weighing two or three tons is tipped out on to rollers which are let in the ground. The rollers are driven from an electric motor. They form the wheels upon which the ingot is carried forward into a press, which rolls it backwards and

forwards until it has reached the desired dimensions.

iii. In any big undertaking such as the one we have just described the question of power is extremely important. How are you going to lift thousands of tons of materials daily from spot to spot in the works? Some source of power is necessary here as it was on the mine. On blast furnaces this source of power is supplied in a surprising way. Instead of allowing the gases from the coke in the furnace to escape into the atmosphere, they are led through iron pipes of large diameter and used in gas-engines! These operate dynamos which feed electric cranes with power. We saw in a previous chapter how mining machinery was designed to handle vast quantities of solids. Machinery on a blast furnace is designed to handle enormous weights of molten and white-hot metal. An ingot of red-hot steel may be picked up from any part of the floor and placed anywhere else simply by the operation of electrical controls from a remote corner of the building.

iv. The extraction of most metals from their ores requires a similar type of industrial process. The raw material comes straight from the earth to the extractive factory and the product passes on to another type of factory, where it is worked up further. A firm which is carrying out smelting work will not have a shop-window in town for the sale of its products. Most of these products are never seen by the

buying public. They pass by rail from the great factories of the type we have described to be further dealt with in other factories. You would be amazed to see the long list of intermediate products which must necessarily be manufactured in passing from coal as it is mined to a dye or a drug ready for use.

v. Not only do ores and other mineral products require to be treated first of all in vast factories, but so also do all raw materials from the land. We may take a couple of

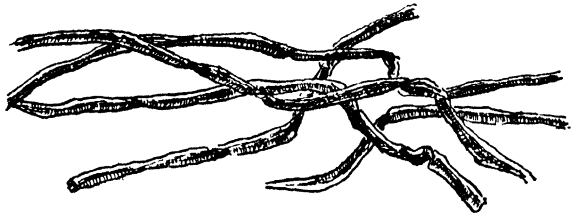


FIG. 89.—Cotton fibres.

examples. Before the tree which stands in the forest appears as a newspaper on the breakfast table it must first be pulped and bleached. Again, the contents of the bales of cotton which come into Liverpool from the United States must first be spun into threads before they are woven. You may take a piece of the material straight from the cotton-boll and tease it apart with your fingers until you obtain the finest possible hair-like fibres which, when magnified, have the appearance shown in the figure. In manufacturing cotton goods the fibres have first to be placed in the direction of

their length and twisted to form a thread. Wool, silk, mohair, asbestos, flax, jute and many other substances which occur naturally as hair-like fibres may similarly be spun into long threads. This process lies at the base of the textile industries. The weaving of these threads follows upon the spinning.

vi.

Year	Value of imports in millions of pounds sterling	Value of exports in millions of pounds sterling
1910 ...	678 ...	534
1911 ...	680 ...	557
1912 ...	744 ...	599
1913 .	768 ..	635
Totals	2870	2325

We must now inquire a little closer into the extent of our requirements of raw materials. Many foodstuffs and raw materials which are essential to us do not exist at all in our islands. Many others are not present in sufficient quantities. In consequence, we bring them across the seas from our colonies or from foreign sources. In the table above we see that the value of our imports increases year by year. Now these imported goods must be paid for. In the same table it will be seen that our exports are also of vast value. We pay for the imports by the exports. It does not much matter what countries the imports come from or what countries the exports go to, provided they are of about the same value. But compare for a moment the figures representing imports and exports each year. The value of the imports

is greater on each occasion than that of the exports. Adding up the values for the four years given, we see that we had £545,000,000 more goods from abroad than we sent out. Are we therefore in debt by those transactions? No, this sum, the difference between the value of our imports and exports, represents the amount that other countries paid us for our services in carrying their goods for them by our merchant navy, for the use of our capital in their railways and other enterprises of theirs, and for various services we performed. But now look at the figures for 1918:—

	Imports	Exports
1918 ...	949 ...	604

Here we have imported too much, and not made enough. This is the effect of the war. We are no longer at liberty to have this great difference between imports and exports. We must work to send out more exports or else be content to have less goods from abroad.

Questions.

1. Name the fundamental industries which use raw materials from the farms, forests and mines.
2. Describe such an industry and say how it differs from a small factory of the London type.
3. How is it that the value of our exports is always less than that of our imports? Should this be so?

CHAPTER XX

THE DISTRIBUTION OF INDUSTRIES

i. We now come to discuss an extremely interesting aspect of the industrial system, namely, the distribution of industries. We must try to find out how it is, for instance, that there is no shipbuilding on the Thames; that pottery is made in Staffordshire, while Kaolin, or china clay, on which the industry depends, is found in Cornwall; why an aluminium company puts down its extractive plant in the hills of Scotland or Wales, and not near the great industrial towns that use aluminium; and why jams and confectionery, for instance, are made in and round London.

ii. We must not expect to be able to state laws about the distribution of industries. We shall presently see that industries grow up and flourish wherever conditions are favourable. Let us begin by examining the necessary conditions for the growth of an industry. First of all, there is the need of raw material. If the raw material is enormously heavy, it is unlikely that it will be taken very far from the mine to be worked up, for carriage is costly and wasteful. But if it is light, the distance from its source to the factory is not so important. The

first factor, then, upon which the growth of an industry will depend is the nearness and availability of the supply of raw material.

Next comes power. In old days, before the rise of the steam-engine, there was only running water or hand-power to use. But to-day we rely on coal chiefly, then oil, and now to an increasing extent again on falling water. Do not mistake electricity for a source of power. Electricity has first to be generated, either from coal, oil or falling water. The use of electricity is an efficient and unsurpassed method of conveying power from one place to another. In some fundamental industries great quantities of coal are needed for power, and in consequence such industries are more likely to grow up on a coalfield than elsewhere.

Besides raw materials and power, we must have labour. When an industry has been carried on for many generations in any district, the inhabitants acquire a familiarity with all its technical details. In the town of Widnes, in Lancashire, where great quantities of chemicals are manufactured, the inhabitants are well acquainted with the methods of preparation and of handling corrosive liquids and poisonous gases. Daily at their work they observe all kinds of trivial details which one unfamiliar with the process would take no heed of. For instance, they will notice that when their acid plant is working badly the acid is slightly pink. They use this then as an indication that things are not going right, on some other

occasion when a pink colour begins to show in the acid. Each workman will gradually accumulate a great stock of such special "tips" about his work and use them as symptoms of the way the work is progressing. It would take a generation to train the inhabitants of any other town to that degree of expert knowledge in such chemicals. And, naturally, this applies to the skilled population of any other specialised industrial area.

Finally, the market must be considered. If you are making jam on a large scale you would prefer to make it in or near a big town so that it would have a ready sale without your being obliged to transport it any great distance.

These four factors, namely, (1) access to raw materials, (2) availability of power, (3) presence of competent and skilled workmen, (4) nearness to a ready market, decide the district in which the industry shall be carried on. According to the nature of the industry, one will be more important than another. Where all four can most conveniently be assembled, there the industry will most probably grow.

iii. When we say "be assembled" we immediately think of traffic. All four factors will hardly ever be together in one spot. One or two will almost certainly be absent where the others are. So we must bring them together. Generally speaking, the easiest to transport are the people. When gold was discovered at Klondike it did not take long for people to get there. But the workpeople are not always the

easiest to move from one place to another. Often the other factors have to be brought to where they are. We propose to discuss this more closely in a later section. We shall now consider a few examples of industries fixed by one or other of the above factors.

iv. As an instance of the presence of raw materials forming the deciding factor in the rise of a great industry, we may consider the production of steel in the Clyde basin. The coalfields between the Clyde and the Forth at one time contained some of the richest iron ores in the world. They have been worked now for more than one hundred years and are no longer so rich. Limestone is on the spot as well, so that coal, iron ore and limestone occur right by the city. Then the Clyde, a navigable river, offered an excellent site for the building of ships. While ships were built of wood, Glasgow held no advantage over London in the matter of shipbuilding. But with the rise of steel ships the industry naturally grew where the heavy raw materials occurred together near a navigable river. Both the "Lusitania" and the "Aquitania" were built in the Clyde shipyards. Glasgow is now the headquarters of marine engineering.

v. The deciding factor in many industries is the presence of cheap and abundant power—cheaper even than coal at the pit's mouth. This may be had wherever a waterfall exists, or a lake high up in the hills. The metal aluminium, so useful now in engineering on

account of its lightness and the strength of its alloys, its freedom from rusting and its resistance to acid vapours, exists in abundance in the earth's crust. There are enormous quantities of it in clay, for instance. But it is so closely combined in its mineral form that it requires much more energy to extract the metal than it does to get iron from its ores. Consequently, the extraction of the metal from aluminium ores is carried on electrically in places such as Foyers Falls in Inverness, Dolgarrog in North Wales, Schaffhausen in Switzerland, or at the Niagara Falls, where cheap and abundant water-power is available.

vi. As an example of an industry the position of which is fixed by skilled craftsmen, we may take the china and earthenware (ceramic) industries of North Staffordshire. This industry grew up on the Staffordshire coalfield and originally made use of local brownish clay in all its manufactured products. Gradually a skilled population grew up in the towns of Burslem, Hanley, Stoke and Newcastle, who had the technical details of the manufacture of pottery at their fingers' ends. When later a white clay (Kaolin) was discovered in Cornwall the industry did not migrate to Cornwall, but instead, the clay was transported to Staffordshire. Just the reverse happened in London in the case of shipbuilding. Gradually the shipbuilding industry of London collapsed, while its place was taken by the towns near the source of the raw materials.

vii. Seeing that London is a hundred miles away from a coal supply and about as far from any deposit of iron ore, and, moreover, has no water-power to make use of, it may seem at first surprising that any industry is carried on there. Yet there are a vast number of factories in and round London. London is indeed a great industrial centre. We cannot yet appreciate the unique position in the industrial system which London enjoys, because we have not yet considered the *commercial* aspect of industry. But we see at once that there must be a great centre of buying and selling where seven or eight million people live. London industries are chiefly concerned with making commodities for sale in retail shops. The power required to manufacture these must not be too large, since coal must be brought a long distance. The raw material will preferably be light, although it must be remembered that London is a giant port into which come raw materials from every quarter of the globe.

Let us look at a typical London factory, a cardboard-box-making factory, for instance. The building is usually compact and fairly small. Although it is not on a railway there will be one near by. Usually the goods are not heavy: cardboard (say) of every description, glue, a great variety of coloured papers, linen, resin, wax and cotton-wool. If we examine the packages we discover that some come from Holland, others from the United States, others

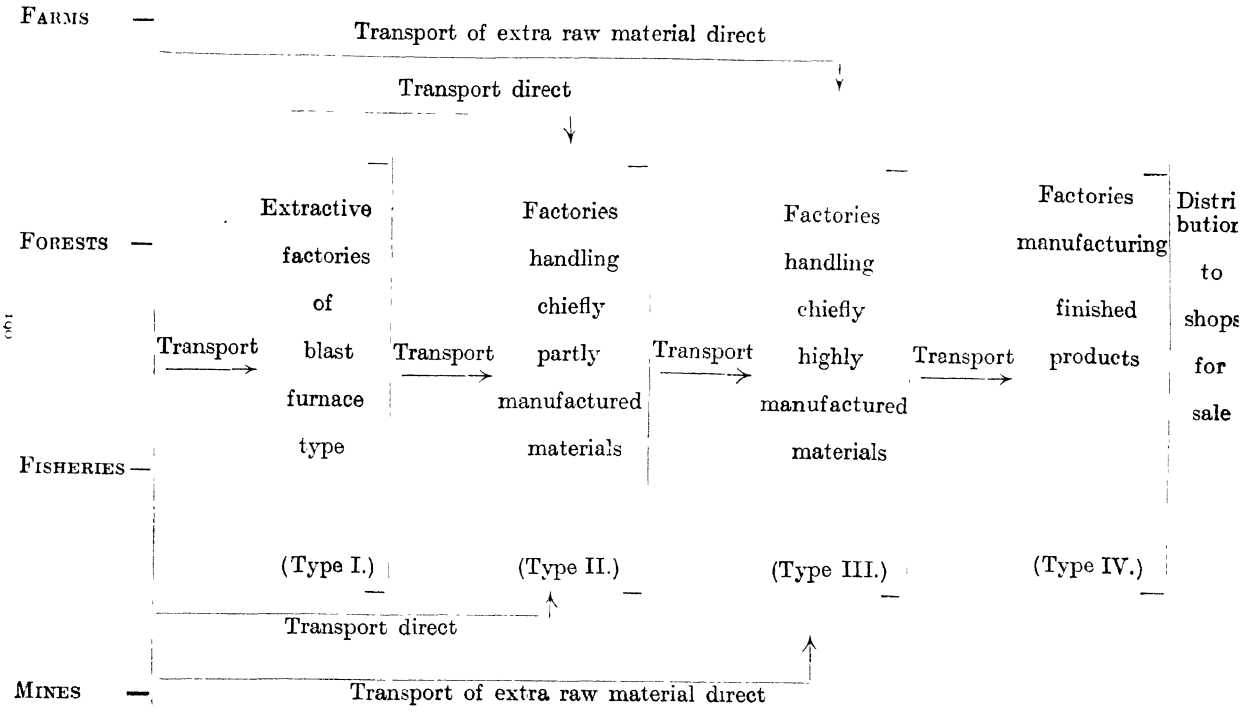
from Scotland, some from Wales, some from Japan, and others again from Sweden. The goods are brought in from the railway by horse and van or by motor lorry. In the factory there will be a small power installation either depending on a steam boiler or else on the municipal supply of electricity. This will work all the machinery in the factory. There will be two or three hundred small machines, all driven from this power-house, each machine being tended by an operative. One set of machines will score the cardboard, another cut it, the next fold and paste it, another curve the lid and perhaps pad the lid with cotton-wool. Then the boxes will be covered with coloured papers of all kinds, and perhaps stamped in gold letters. They will then be packed ready for use. Some will be suitable for packing cigarettes, some for chocolates, jewellery, boots, food, and a dozen other things.

viii. If we now go into the office and see what orders the post brings, we shall find that there are letters not only from all parts of London asking for supplies of various kinds of boxes, but also from towns in all parts of the country. Then there will be others from abroad relating to supplies of raw materials or new designs of machinery from the United States, as well as orders for finished boxes and similar cardboard articles for foreign cities. We now see why London is a suitable spot for the manufacture of such articles. First of all London can easily draw on the raw materials or half-

manufactured articles of all foreign countries; next it has a vast home market to supply straight away; and thirdly, it is admirably situated as a distributing centre for its finished goods. These finished goods can be sent not only directly to thousands of shops in London by van, but also to all parts of England by train and to all parts of the world by ships. Whereas a large steel works will draw its raw material from very few sources, mostly all local, as in Glasgow, a London factory will draw on a thousand different sources. Whereas the steel works will have a few big customers for their steel bars, the London factory will have thousands of small customers.

ix. When we survey the whole field of industry we find at one end those industries engaged in the fundamental processes of winning the raw materials from the earth. These are farming and mining. At the other end we have those engaged in making the great variety of commodities ready for use, and to be bought over the counter. Between the two there is a constant passage of goods. The mine supplies ore and the farm timber. These are used up in the extractive industries, those, for instance, which make iron and steel. Then these extractive industries supply the machine-shops and the foundries. These in their turn supply the factories which work up other raw or half-finished goods, until finally we reach factories of the London type which are engaged on the manufacture of finished articles.

DIAGRAM


Farms
Transport of extra raw material direct
Transport direct
Forests
Extractive factories of blast furnace type
Factories handling chiefly partly manufactured materials
Factories handling chiefly highly manufactured materials
Factories manufacturing finished products
Distribution to shops for sale
Transport
Transport
Transport
Transport
Fisheries
(Type I.)
(Type II.)
(Type III.)
(Type IV.)
Transport direct
Mines
Transport of extra raw material direct

We may look upon the scheme as in the diagram. The farms and mines supply the factories of the first type, then these supply factories of the second type (together with raw materials straight from the farm or mine again), and they in turn supply the next, until we arrive at the retail shop where the goods are finally exposed for sale. Between each stage the goods must be transported, and at the final stage the finished articles must be distributed. This brings us to the important question of traffic again.

QUESTIONS.

1. What industries are carried on in your district? How would you class them? Find out where their chief raw materials come from.
2. What are the chief factors which decide where an industry will grow up?
3. If there are any building plots in your district, estimate their value as industrial sites.

CHAPTER XXI

TRANSPORT

i. The high-roads of traffic across a country follow the valleys. Industries arise in those districts where raw materials and other necessary factors are most easily assembled. But the position of the valleys decides the precise

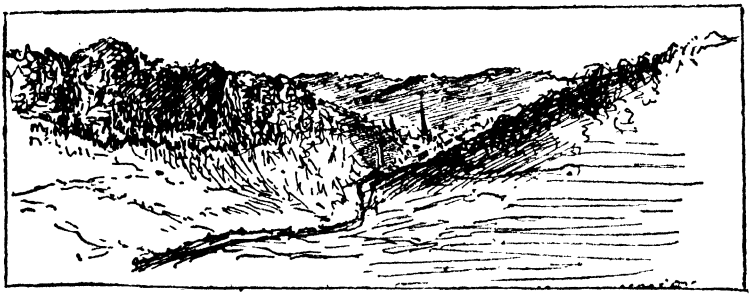


Fig. 90.—Sketch showing town in a valley through greensand hills.

spot in the district where a town will spring up. When a town is viewed from a neighbouring hill it invariably appears to radiate from a natural centre, growing outwards towards the less convenient outlying districts. Fig. 90 illustrates the growth of a small town in a valley through the hills of Kent. Where in the valley

will a town most likely grow up ? The picture shows a pass through a range of greensand hills which separates Mid-Kent from London. The road from the fruit- and farm-lands of the central Weald makes its way through the hills at this point. All the traffic for miles round naturally meets here, for it is the only convenient spot for crossing the hills. We make our first inference, therefore, that a town grows up where a valley breaks through a range of hills.

ii. Another fine position in the valley is where the tidal waters of the river which drains it reach farthest inland. London stands at the head of the Thames navigation. Great steamers from all quarters can reach London with their cargoes. Then the point at which a river is first bridged attracts the traffic from the country on each side, so that it converges on to the bridge. A map of England will show many instances of towns which occupy such positions as these. London, of course, adds to its advantage of tidal waters that which the position of the first bridge confers. This may be seen in the general view of London on page 306. The sites of some ancient towns were chosen on account of their suitability for defence. Where a navigable river flowed round a rocky eminence, a fortress or a castle would be built. This would become the governing centre of the district. Examples of this are numerous in our country, and we may mention Chester built upon just such a site.

iii. The earliest efforts to increase the ease with which goods could be transferred inland from one centre of manufacture to another were made by Brindley and the Duke of Bridgwater in the latter half of the eighteenth century, some sixty years before the appearance of the locomotive. During the period that followed Brindley's pioneer work canals were cut in all parts of the country until most of the chief industrial centres were linked up. Many of them still carry great quantities of merchandise. The amazing network of canals in the Birmingham district carry about 7 million tons of goods yearly, and that in the Aire and Calder valleys, in the West Riding of Yorkshire, about 3 million tons. The canals are mostly narrow and the barges pulled along by horses. It has been proposed to widen the four longest canals in England so as to connect the industrial area between Birmingham and Wolverhampton with the sea by four routes. This scheme, known as the "cross," was to enlarge the existing waterways marked on the accompanying map (Fig. 91). The network in the Birmingham area was to be left untouched, while the main highways of trade were to be made from that centre to (1) London, (2) Gloucester, (3) Runcorn for Liverpool, (4) Goole for Hull. Modern canals, large enough for ocean-going steamships, are steadily increasing in number. The chief, namely, the Manchester Ship Canal, will be considered in Part III.

iv. Brindley was a man full of enterprise.

Although he could not read nor write, he did not hesitate to drive a tunnel through a hill-side in order that his canal might reach a proposed

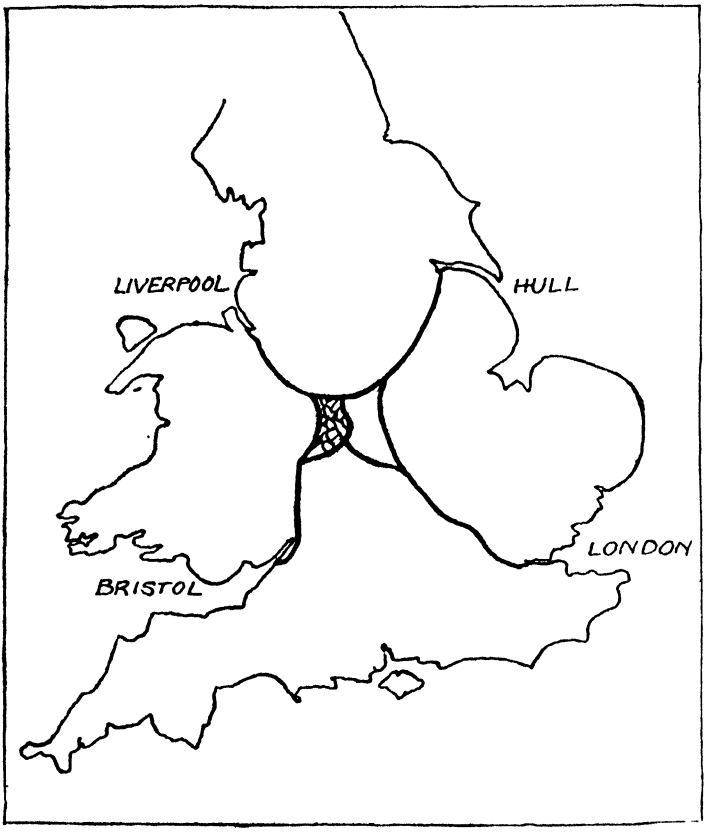


FIG. 91.—Proposed development of England's canal system.

point. He even took his first canal over the River Irwell on arches about 40 feet high when other engineers declared it to be impos-

sible. But we may see to-day that wherever it was at all possible these old canals were made to follow the contours very closely. Fig. 92 shows the 50 feet and 100 feet contour of a piece of country near Warrington. The contour lines indicate the position of a valley. In order to take a canal from the point *A* on

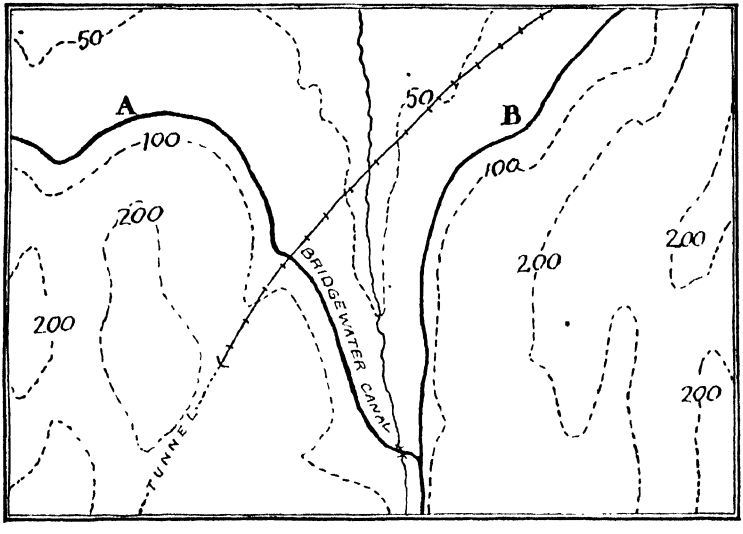


FIG. 92.—Map showing how closely the early canals followed the contours. Contrast the modern railway. Scale 1″=1 mile.

one side of the valley to the point *B* on the other side, the canal must travel down the side of the valley at the same level and then turn back along the other side. But the railway cuts straight across, taking its track along an embankment. The canals, then, follow the contours, rarely use embankments, and equally rarely use cuttings. The railways, on the

other hand, go as directly as possible to the point desired, only their general direction being decided by the topography.

v. Naturally, in their general direction railways follow the valleys. The admirable system

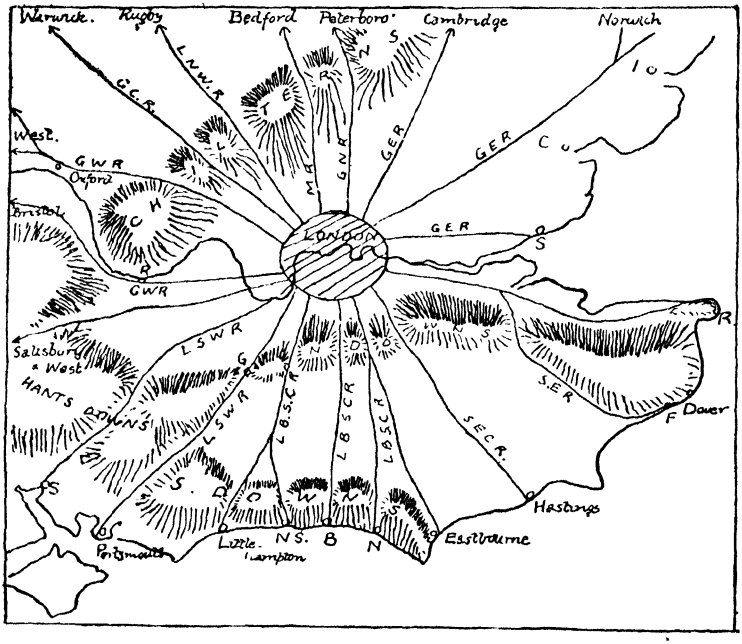


FIG. 93.—Map showing the relationship between the main-line railways which radiate from London, and the valleys through the chalk hills. (Diagrammatic.)

of railways which converge on London offers an excellent example of this, for they follow for the most part the valleys formed by the tributaries of the Thames. Fig. 11 on page 33 shows a section across two ranges of hills, the North and South Downs, through which traffic

from the South Coast to London must pass. If a contoured map of this district is examined, it will be seen that the railways running south from London generally follow the valleys which dip streams from the Downs have cut. The same is true of the system which radiates north and west from London. These must break through the same chalk hills, here known as the Chilterns. As an example, we will trace the London, Brighton and South Coast line from London to Littlehampton. At Leatherhead it takes the Mole Valley across the North Downs. The Mole is a dip stream which flows northwards into the Thames. Then to cross the South Downs it follows the beautiful valley of the Arun from Pulborough to the sea. The Arun is a fast dip stream which flows south and enters the sea at Littlehampton. The other lines from London might similarly be traced across the Chalk Downs north and south of London.

vi. Two mechanical inventions have brought traffic back to the road again. The first is the petrol engine and the second the high-pressure steam lorry. At the same time, a great improvement has taken place in the condition of the main roads. In populous industrial areas, as, for example, South Lancashire, an increasing amount of carriage of heavy goods is done by road. The goods may be loaded at the spot in the works where they have been manufactured and delivered directly just where they are required. This involves much less

handling than transport by rail, and is, moreover, much quicker, at any rate for short journeys.

vii. Shipping is the most valuable of our transport industries, as shipbuilding is of our manufactures. In Part III. we shall have frequent occasion to observe how excellently placed our chief estuaries are with regard to our coal deposits and their manufacturing districts. In addition to this, practically every river-mouth round the coast has its harbour or dock. Moreover, most of our rivers are comparatively slow-flowing, so that they are usually navigable for some distance and well repay artificial deepening and enlarging.

viii. What the future of air transport will bring we cannot yet foretell. Already Madrid has been reached in twelve hours and America in sixteen.* The effect of such communication (in virtually shrinking distances to one-seventh their old magnitude) will probably be felt more in commerce than in industry, for samples of goods will be carried sooner than bulky merchandise, and this will doubtless facilitate exchange of goods between countries. We must be ready for whatever changes air transport may introduce. Conceivably such changes will be even greater than those which the steam locomotive has produced.

ix. However we look at manufacture or at transport, we cannot help recurring to the subject of "power." At almost every stage

* Captain Sir John Alcock, June, 1919.

in manufacture power is needed. Water, coal and oil have been successively drawn upon to supply this urgent need. But these, except water, are disappearing from the earth. They are a diminishing asset. Electricity cannot replace them, as we have seen. What, then, is to be our future source of power? It may be that we shall learn how to tap some supply of energy hitherto unregarded. Certainly one possible source which need never fail would be alcohol made from potatoes and used in an internal-combustion engine instead of petrol.

x. In the last two chapters we have discussed the rise and localisation of industries in various districts according to the natural advantages which those districts offered. Next we saw how the position of towns in which those industries were engaged was naturally determined by the shape of the earth's surface in the district. Then we discussed the means of communication between those towns, and saw how closely they again depended upon the shape of the earth's surface. In order to complete our picture of the industrial system, we must now consider briefly its commercial and financial aspect.

Questions.

1. Trace the main roads, railways and canals in your district. To what extent are their positions fixed by the topography?

2. Why is it desirable to construct a canal between the Clyde and the Forth ?

3. What are the chief drawbacks to English canals ? Do you think they could be remedied ? Might they not take the same course as railways, regardless of contours ?

4. What function does transport serve in the industrial system ? Might it be classed with the mines and the farms as fundamental ?

CHAPTER XXII

AN INDUSTRIAL UNDERTAKING

i. When we see the lorries of a large firm hurrying through the main road with a load of goods, or a steamer making its way from the dock with a cargo for abroad, do we reflect at all on the work that was necessary to arrange for the loading and distribution of the goods? Suppose, for instance, the lorry belongs to an engineering firm. It may contain steel cylinders, spare parts, miscellaneous cases of machinery for customers. The steamer will probably be loaded with goods from an area of hundreds of square miles around. Who arranges for the collection of the goods to the dock-side, and who is responsible for their delivery at various destinations? Many firms with a great deal of incoming and outgoing traffic will employ a traffic manager who is responsible for the whole collection and distribution of goods. The steamship and railway companies make transport of people and goods their whole business. They carry from place to place the materials that industries use, and the finished products that industries manufacture. We see,

then, that many thousand workers in the industrial system are engaged in carrying-work, and that a large number are engaged in the offices of transport companies, arranging by telephone, telegram and letter the collection and distribution of goods, and issuing instructions to the transport workers.

ii. Now goods and services must be paid for. Who arranges this payment ? In a large manufacturing firm there are invariably a *Buying Department* and a *Selling Department.* The buying department is responsible for the purchase of raw materials and other goods employed in the course of manufacture. It follows, therefore, that the firm's buyers must be acquainted with the various markets where suitable raw materials are to be bought. On the other hand, the selling department must know the customers who require the goods which the firm manufactures, and keep a look-out for opportunities of enlarging their sales. Now some firms do nothing but buy and sell, and do not manufacture any goods at all. London is the greatest centre in the world for such *commercial* houses. Each merchant firm of this kind will be thoroughly acquainted with every source from which the kind of goods they trade in may be bought, and also everyone who wants to buy them. They do not confine their attention to British goods only, but to goods from all parts of the world ; and they do not sell them to British firms alone, but also to firms all over the world.

iii. Next, we must consider who it is that keeps the firm's accounts. Whenever there is a movement of goods anywhere in the industrial system, whether it be a movement of raw material from the farm or mine to the factory, or of partly manufactured material from one factory to another, or finally of finished products from the factory to the shop and so to the customer, a corresponding movement of money takes place. Each movement is registered as an item of buying and selling. The *Accountants' Department* in a large firm keeps a record of such financial transactions of the firm. Each firm then deposits its money with a bank, and thus the banks manage the money of the industrial and commercial firms.

iv. The above three sections point out the three commercial or *business* aspects of an industrial enterprise, namely :—

(1) Traffic (collection and distribution of goods);
(2) Buying and Selling;
(3) Accountancy and Banking.

Some towns are better fitted for carrying on commercial as opposed to industrial enterprise than others. The position of Manchester in this respect is described in Chapter XXV. Very often the manufacture of a firm's goods takes place in an altogether different town from that in which its commercial transactions are carried on. Generally speaking, the modern tendency in every town is for the factories to

be built in the outlying districts, while the centre of the town is reserved for the commercial headquarters of the various manufacturing firms.

v. But what interests us chiefly in industry is the way goods are made. Any industrial enterprise must both make and sell. We already see that selling is the concern of the commercial men in the firm. Now the actual manufacture is entirely different from this and is carried on by other men. The word *technical*, which is used to refer to the manufacture of goods just as "commercial" refers to their sale and purchase, is derived from a Greek word, "techne," meaning an art. Sometimes manufactures are referred to as the *Industrial Arts*. This emphasises the fact that their foundation is the practice of some art, as, for instance, painting or moulding. But in addition to this, they rest also on the natural sciences, and chiefly on physics, chemistry, geology and botany. Thus we see that any industrial undertaking has two sides, its technical side and its commercial side. On its technical side are ranged its chemists and engineers and the workers engaged in manufacture, as well as those engaged in researching on better or new kinds of goods; and on its commercial side, those engaged in the collection and disposal of goods that the technical men manufacture.

vi. Let us now say a good word for each of these groups. For the commercial men we may repeat President Wilson's utterance before

the merchants of Manchester: "Goodwill is the forerunner of trade, and trade is the great amicable instrument of the world on that account." For those engaged in production we may remember that manufacture is worthy because it stimulates artistic and scientific efforts, since it depends for its progress on fresh application of the sciences and the arts to practical ends.

Questions.

1. Would you sooner be engaged in commerce or in manufacture? Why?
2. Justify the expression "the industrial arts." Would you say it applied equally to buying and selling as to manufacturing goods?

END OF PART II.

PART III—GEOGRAPHICAL

CHAPTER XXIII

THE GROWTH OF A TOWN

i. It is invariably a good plan, whenever it is possible, to view a town from a height. Travellers early learn to appreciate the advantages to be gained from such a view, and it is to be expected that one of the chief attractions of aeroplane travel will be the prospect of the countryside seen from mid-air. Such a panoramic view enables one to master the whole design of the country beneath. We see how the rivers run and the towns develop. We get a compact picture of the busy activities of men as they work on the earth. Let us once again follow out this idea. Let us take our stand on some eminence and view some growing town; let us try to see why it grew where it is; then let us inquire into the way its inhabitants get their living and endeavour to see how and why its particular industries flourish as they do. These are the geographical problems which the following chapters are intended to discuss.

ii. To make our meaning clear, let us consider some particular town. Let us stand upon the limestone headland of the Mumbles and view the town of Swansea. We see a sheltered bay with a shore of yellow sand. The town lies three or four miles distant at the mouth of the Tawe, which flows into the bay, and stretches along the river and the bay. Fig. 94 shows a

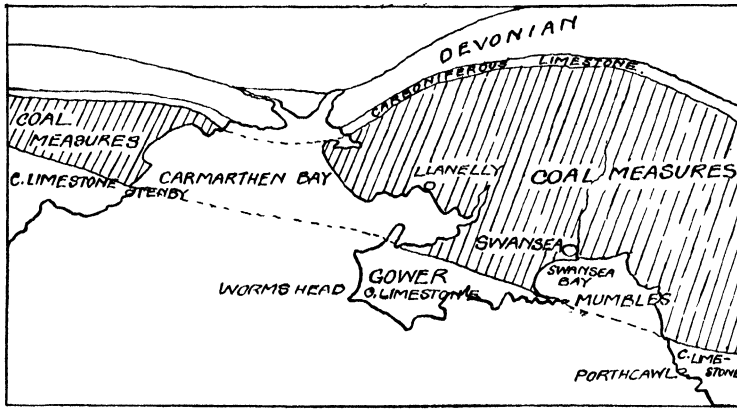


Fig. 94.

geological sketch-map of the district. First there is a long outcrop of limestone which runs from Pembrokeshire through the Gower Peninsula and up the Severn valley. North of this everywhere is an extremely valuable formation containing seams of coal and iron. These minerals are present in sandstones and shales, which rise to form mountainous country. The sea has made a breach in the limestone between Tenby and Wormshead and gone even so far as to encroach upon and engulf all the coal which

must once have existed in Carmarthen Bay. But on the Swansea side of the Gower Peninsula the sea has breached the limestone between the Mumbles and Porthcawl and has opened up a highway for steamers into the heart of the anthracite Coal Measures. When we stand on the Mumbles we see how the waves have destroyed the limestone and we notice that the rocks which continue from the head-

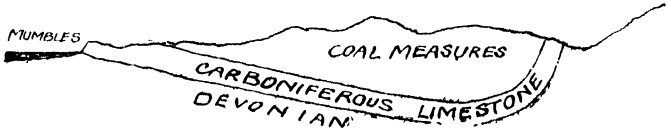


FIG. 95.

land into the bay are themselves part of the mainland separated by the weathering of the sea.

iii. The structure of the district is in its main features simple. The limestone underlies the Coal Measures, so that a section from north to south would indicate the limestone dipping inland so as to illustrate this. The strike of the rocks is E.S.E. The stream that interests us, namely, the Tawe, is consequently a dip stream. It crosses the coalfield from the mountains of Brecknockshire as a typical fast-running dip stream in a narrow valley. The sandstones and shales of which the Coal Measures are composed rise everywhere to form steep hills through which the river has worn its passage. The opportunity which this river offers for the establishment of a port suitable

for the transhipment of the valuable anthracites of West Glamorganshire could not be missed. Docks were long ago built for sailing-ships, and in recent times modernised to form the present Swansea Docks, with seventeen miles of sidings belonging to the Great Western Railway for the export of anthracite.

iv. We see then how the town first sprang up. The sea had breached the limestone, formed a sheltered bay, and opened a passage by way of the Tawe to the minerals in the Tawe valley. Now let us see how it has developed. What we have learnt to look for in the development of an industrial town is the presence of (*a*) raw materials, (*b*) power, (*c*) a skilled population, and (*d*) an easily reached market. We must therefore look round for raw materials. We have already noted coal and iron. We should therefore anticipate smelting. Now the coal of the Swansea district is especially good. Moreover, Swansea is the nearest port on the South Welsh coalfield to the rich mines of Cornwall. Up till 1850 Cornwall was the world's chief producer of ores: tin, copper, lead and zinc in chief. What was more natural than that these ores should be taken to the nearest district where coal was available for smelting? It thus arose that Swansea became the chief seat of the copper- and zinc-smelting industry. Besides Cornwall, Swansea is backed by another district which at one time was one of the world's chief sources of zinc and lead, namely, the shires of Cardigan and Carmarthen.

v. As for the growth of the tinplate and galvanising industries, we need only remember that the chief drawback to the use of ironware for ordinary purposes is that this metal rusts so easily. What we call "tin," when we speak of a cocoa-tin, for instance, is really sheet iron covered with an extremely thin coating of tin. In the same way, sheet iron is protected from the atmosphere by covering it with zinc in the form of galvanised iron. We may easily understand how it is that these industries should grow up in the Swansea district, where the population is skilled in the handling of molten metals.

vi. The presence of a skilled population then attracted other metals to Swansea. Recently the manufacture of nickel has been extensively developed in the valley, although the ores have to be brought across the Atlantic from Ontario. Swansea has maintained its position in the metal industry in spite of the falling off of home supplies of suitable ores. For it has the other factors which secure its position, namely, (1) power, (2) a skilled population and (3) an excellent position for importing raw materials and for exporting metals to home and foreign markets.

vii. We shall now make a summary of the way in which we traced the rise of this town.

I. We saw what types of *rocks* went to build up the district ;
II. What its *structure* was ;

III. How the district had been weathered both by wave action and by rain, producing the dip stream and a sheltered bay ;

IV. What advantages it enjoyed,
(*a*) from the presence of coal for power and export,
(*b*) from the easily available supplies of raw materials,
(*c*) from the growth of a skilled population,
(*d*) from the excellent harbour facilities for export to home and foreign markets.

viii. We shall always adhere to this routine method of inquiry into any new district. Some of the most important districts of Great Britain are analysed in this way in the following chapters to show how natural and reasonable their growth has been. Whenever you go to a fresh district for any length of time, such an inquiry, made first hand from your own observations, cannot fail to be a source of deep interest and pleasure to you. The growth and interconnection of industries in the district should be studied together with its geological structure until the whole begins to assume a harmonious form.

CHAPTER XXIV

CHESHIRE AND THE DISTRICTS ROUND: FEEDING COUNTIES

i. First of all, we propose considering a great food-growing area. The following device for the rapid study of district after district in conjunction with the map is extremely helpful. You draw an outline map of England on a sheet of cardboard, on a scale of 10 miles to the inch, and mark upon it the positions of twenty or thirty well-placed towns. Then cut the map out, not paying too much attention to detail, and pierce small holes in the cardboard where the towns come. In this way you obtain, as it were, a "cardboard negative" map of England. It may then be divided conveniently into rectangular sections, each the size of a page. We shall proceed now as if the reader had constructed his "cardboard negative." By its means the following sketch map (Fig. 96) should be drawn, namely—The coastline from Liverpool to Rhyl, with the towns: Liverpool, Birkenhead, Warrington, Manchester, Chester, Crewe, Shrewsbury and Stafford. It would then be a good exercise to fill in from the

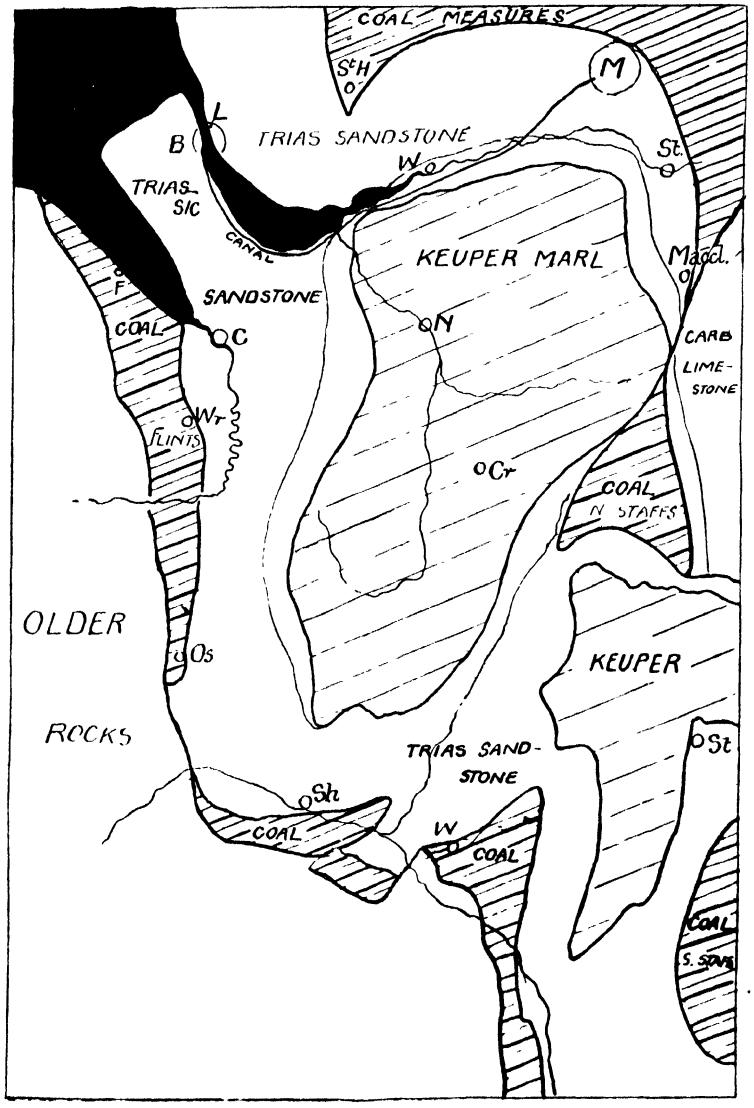

COAL MEASURES
St H
M
L
B
TRIAS SANDSTONE
W
St.
TRIAS S/C
CANAL
KEUPER MARL
Magcl.
F
SANDSTONE
N
COAL
C
CARB LIME-STONE
Wr
FLINTS
Cr
COAL IN STAFFS
OLDER
Os
KEUPER
ROCKS
TRIAS SAND-STONE
St
Sh
COAL
W
COAL
COAL
S. STAFFS

FIG. 96.

atlas the remaining towns that must be referred to during this chapter. These are Wrexham, Northwich, Sandbach, Congleton, Macclesfield, Stockport, Stalybridge, Bolton (in Lancashire), Runcorn, Northwich, Middlewich, Wellington and Oswestry ; and the rivers Mersey, Weaver, Dee, Severn and Tern.

ii. Let us draw in on our map the outcrops in our district.

First put in the southern boundary of the Lancashire coalfield and run it round to the North Staffordshire coalfield, leaving a gap by Macclesfield. Then continue in the Severn valley from Wellington past Shrewsbury. Starting again at Oswestry, run the outcrop of coal right through Flintshire. Shade these coal areas. We thus see that our district is ringed round by important coalfields north, south, east and west. What occupies the area within ? Newer rocks of the Triassic period. Almost concentric with the ring formed by the coal, draw the outcrop of the Keuper Marl, leaving a ring of Trias Sandstone all the way round except again by Macclesfield. This finishes our geological map. Next we must know the order of the formations. This order is :

3. Keuper Marl.
2. Triassic Sandstone.
1. Coal Measures.

iii. Since we know the order of the rocks and have a map of their outcrops, we may now

draw sections across the area to discover its structure.

First let us draw a section from the Flintshire coalfield to the Lancashire coalfield through Chester, Northwich and Stockport (Fig. 97).

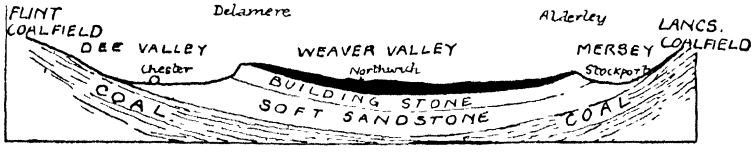


FIG. 97.

Applying the rules we have learnt in Part I, we see that on the Chester side all the formations dip towards the east. On the Stockport side, in the same way, the formations dip towards the west. Thus we build up the structure of the area and discover it to be a basin or syncline with the coal beneath, the sandstone above it, and the marl on the top as the figure shows.

In a similar way we may take a section from the Severn coalfield by Wellington to the

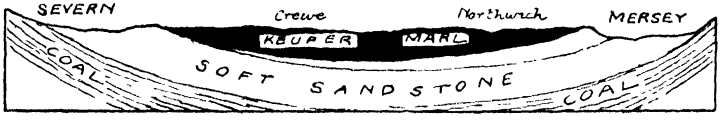


FIG. 98.

Lancashire coalfield by Bolton, through Crewe, Middlewich, Northwich, and thus we cross the basin from south to north (Fig. 98).

iv. Let us now inquire into the kinds of rocks which occupy the basin, namely, the

Triassic Sandstones (beneath) and the Keuper Marl (above). All the way round, the coal districts form high land.

Triassic Sandstone.—We see from the geological map and from the first section that this sandstone is soft, for the Dee, the Mersey, the Tern and the Severn have followed it in working out their valleys. It is a yellowish sandstone and is easily weathered, so that the Dee and the Mersey have carried out to their large estuaries vast quantities of yellow sand. In fact, the wide Dee estuary is silted up with miles of soft sands which make the river of very little use in spite of the broadness of its mouth. The same is true of the Mersey estuary, but for a reason we shall shortly see, the Mersey forms a magnificent entrance into Lancashire.

On the first section (Fig. 97) we see that the Dee valley is separated from the Weaver valley by a low range of hills on which Delamere Forest is situated. In the same way, the Mersey valley is separated from the Weaver by low hills (Alderley Edge, for example). What makes this high ground ? The answer is given when we know that the uppermost beds of the Triassic Sandstone are formed of a hard light red building stone which does not weather easily. Some of this hard rock is faulted up at the mouth of the Mersey by Liverpool and Birkenhead, and it is this which has enabled the river at Liverpool to be developed as a magnificent port, while the wider estuary of the Dee is choked with soft sand.

Keuper Marl.—Above the building stone comes the Cheshire Marl. The marl itself is a heavy red clay. It is called marl because of the presence in it of thin bands of limestone greyish in colour. The farmers open pits in the fields to get this limestone to spread on the fields. Now the marl contains two important minerals—(1) Salt, (2) gypsum. They are the deposits which were left when an ancient Triassic lake which occupied this area dried up completely as the Caspian Sea and Lake Utah are drying up at the present day. We shall shortly see how important the salt is to Cheshire.

v. Next we may observe how the structure and rock types which we have studied have been weathered into hills and valleys. The high land which separates the river valleys is seen to be due to hard sandstone. This forms a range of hills encircling the central plain. Sometimes their scarp slopes are very prominent and steep, as at Helsby and Frodsham. The lower sandstones are soft and form the river valleys. The marl makes very undulating country, but nowhere do the hills rise much above 200 feet or fall below 100 feet. This area is referred to as the Cheshire plain.

Now let us consider the coast-line. It is formed by two large estuaries which have developed in the soft sandstone as the Dee and Mersey approach the sea. The Dee estuary is, however, very unlike that of the Mersey. From the map it is seen to be V-shaped and about eight miles across at its

mouth. The hard rock at Liverpool, on the other hand, has caused the Mersey to narrow very considerably towards its mouth, where it is only about a mile wide. The river has not been able to wear out a great broad estuary through this bar of hard rock. But further inland it has developed a basin for itself five miles wide in the soft sandstone. The effect has been therefore to develop a " bottle-neck " at the mouth. Through this bottle-neck the water must always flow faster than it does on either side. So the tides and the river scour out the passage here and keep it free for navigation. What happens to the sand that the Mersey brings down ? We have learnt that when a river current slows down, it can no longer carry its load of sand, but drops it. So when the Mersey reaches the broad, shallow basin on the inland side of Liverpool, it deposits a great deal of its charge and flows on clear through the narrow passage. What it does not drop it carries straight out to sea, because it flows fast past the entrance. Compare now the advantages that Liverpool, and Manchester too, enjoy on account of this small outcrop of hard rock at Liverpool, with the disadvantages under which the towns on the Deeside coalfield suffer because of their sandbanks ! How is it that Manchester can share in the advantages that Liverpool enjoys as a great seaport ? Does not the sand in the upper part of the Mersey estuary prevent ships from proceeding beyond the narrow entrance ? It does, but by

a very fine piece of engineering they are enabled to steam right into Manchester through a ship canal which enters the Mersey at Eastham, where the river begins to narrow towards its mouth, and thus avoids the sandbanks. The canal then runs by the side of the river through the solid sandstone to Manchester. (Mark its course on the map: Eastham, Runcorn and direct to Manchester on the south side of the river all the way.)

vi. The chief industry of the area is farming, for it is well watered and has fine pasture on the marl. Consequently Cheshire and Shropshire are the great feeding counties for the industrial districts situated on the coalfields which ring the country round. We have learnt that clay lands are more suited for pasture than for the plough on account of the great cost of drainage. Consequently, Cheshire supplies the industrial districts with butter, eggs, milk and cheese. In the river valleys, where the soil is richer and lighter, crops are grown. In the shelter of the Welsh hills more grain is grown than in Mid-Cheshire, for the rainfall is much less. The market towns will be found between Chester and Shrewsbury.

vii. The towns in the middle of the farming district are not, however, market towns, but industrial. (Northwich, Middlewich, Nantwich.) This is owing to the salt deposits which occur deep down in the Keuper Marl. The way the salt is obtained is very interesting. A boring

is sunk, down which water is made to flow. This creates a lake of brine underground. Pumps are then set to work to pump up the brine. This process is carried on at various points in the Mid-Cheshire basin and has given rise to important industries. Looking a little closer into the needs of these chemical industries, we discover that there are four fundamental minerals which are required in great quantities for their maintenance. These are (1) salt, (2) limestone, (3) coal, (4) sulphur. An extraordinary array of substances may be manufactured from these four minerals. There is hardly an article in common everyday use which could exist if one or the other of these chemical substances were not employed in its manufacture.

viii. We see from the geological sketch map that coal is not difficult to obtain. In the Tyne district salt is carried to the coal. Here coal is brought to the salt. Limestone is available from the Derbyshire hills, and sulphur ores are brought to Liverpool from Spain and thence by steamer along the Manchester Ship Canal to Weston, and then up the Weaver. Great industrial centres are springing up along the Ship Canal. Indeed, brine which is pumped in Mid-Cheshire is carried in pipe-lines to the banks of the Ship Canal at Weston, and split up there into the various useful chemicals to which it gives rise. Great quantities of these chemicals are exported to foreign countries, and the convenience of the Ship Canal for that pur-

pose is bound to develop the growing towns upon its banks. The administrative headquarters of these industries are in Liverpool and Manchester.

ix. The Cheshire plain affords an excellent strategic centre for traffic. The main line of the London and North-Western Railway has its greatest junction at Crewe, in the centre of the plain. Thence it radiates in several directions, the main line running directly north to Warrington. The Great Western line follows the Severn and Dee valleys. The town of Chester has an excellent position of the old ecclesiastical and county administrative type. It is situated in a bend of the Dee, where that river was till very recently first bridged. It possesses, moreover, a rocky eminence of sandstone which rises from the river and upon which the Castle is built.

CHAPTER XXV

LANCASHIRE AND CHESHIRE COALFIELD : COTTON DISTRICTS

i. THE coast-line from Lancaster to Hoylake (Wirral) is stencilled on paper by means of the cardboard negative, and the following towns marked down : Preston, Blackburn, Accrington, Burnley, Colne ; Wigan, Bolton, Bury, Rochdale, Oldham ; Widnes, St. Helens, Warrington, Manchester. Part of the necessary preparation for this chapter will be to fill in the remaining towns which will be referred to, namely : Fleetwood, Blackpool, Southport, Liverpool, Birkenhead, Stockport and Macclesfield ; and the courses of the rivers Ribble, Mersey and Irwell. The Manchester Ship Canal should be added.

ii. Starting in the south-west corner by St. Helens, draw in the outcrop of the coalfield, first almost up to Preston, then parallel with the Ribble valley just north of the four weaving towns (Blackburn, Accrington, Burnley and Colne), then south down the Pennines to Macclesfield. Complete the outcrop by drawing

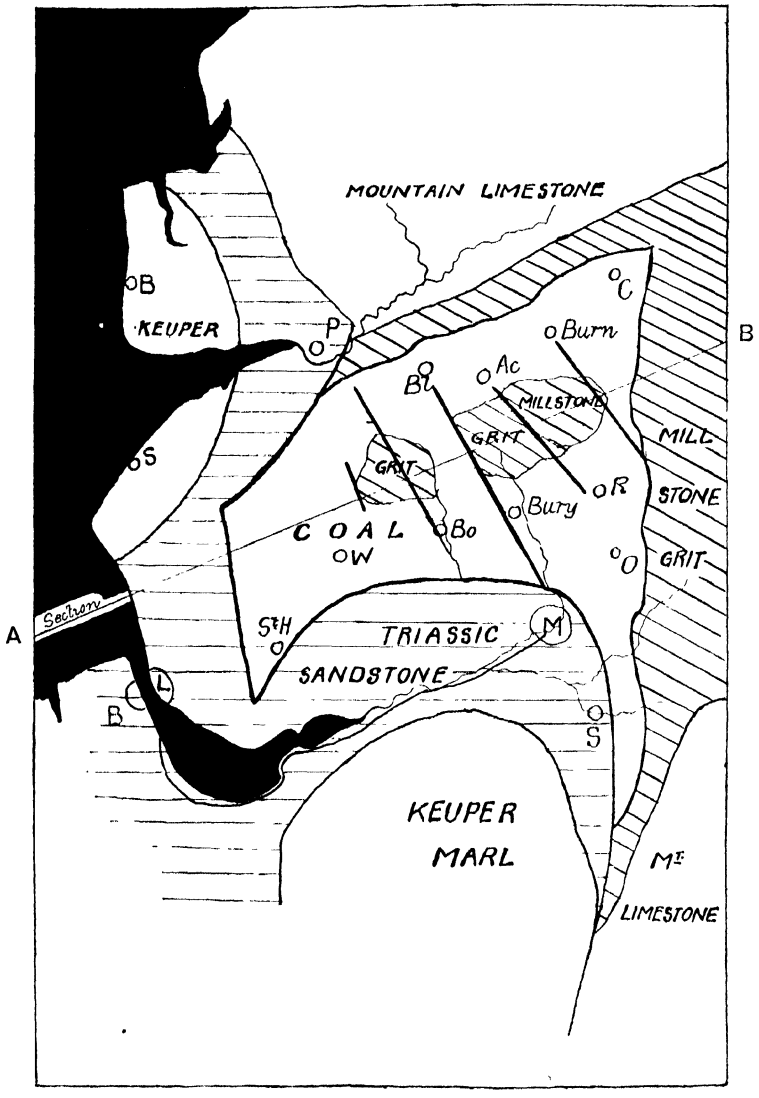

MOUNTAIN LIMESTONE
B
KEUPER
P
C
Burn
B
Ac
BL
MILLSTONE
GRIT
MILL
STONE
GRIT
S
GRIT
R
Bury
COAL
OW
Bo
O
GRIT
A
Sechern
STH
TRIASSIC
M
SANDSTONE
L
B
S
KEUPER
MARL
M
LIMESTONE

FIG. 99.

in the curved boundary past Stockport and Manchester to the starting-point by St. Helens. Mark the coal area, leaving patches of Millstone Grit which form *inliers** within it, between the two lines of towns. Next mark the limits of the Keuper Marl just south of the Mersey and the outcrop round the Ribble mouth. Shade the Marl. The country between the coalfield and the Keuper Marl is formed, as we know, of Triassic Sandstone, soft below and hard above. But the Triassic rocks which thus flank the coalfield on the west and south do not reappear on the north and east. The country to the east (the Pennines) is formed of a hard sandstone known as Millstone Grit, and a band of this grit runs along the north edge of the coalfield. It also makes its appearance in patches within the coalfield. Further north, it is followed by a parallel outcrop of Mountain Limestone, in which the Ribble valley lies. These two bands of rocks are suddenly faulted down in front of Preston, Triassic sandstones taking their places.

iii. All we need now in order to disentangle the general structure of the area is the order of the formations. From our previous lessons on the Cheshire district, we learnt the order from the Coal Measures to the Keuper Marl. This order was :

5. Keuper Marl.
4. Triassic Sandstone.
3. Coal Measures.

* See page 246.

We now make the acquaintance of rocks older than the Coal Measures, namely :

2. Millstone Grit.
1. Mountain Limestone.

Equipped with this key to the structure, we shall proceed to draw two sections, (1) from the Pennines to the sea; (2) from the Ribble to the Mersey. These will show us how the coalfield lies.

iv. Draw a line (Fig. 100) equal in length to the distance on the map from the sea coast to the Pennines along the chosen line of section.

Fig. 100.

Starting at the sea coast, mark the points where the Trias changes to the Coal Measures and where these give place to Millstone Grit. Then the structure follows by the rule of superposition, for the Trias overlies the Coal, and the Coal overlies the Grit. Thus we see that the Coal has been eroded from the area that the Pennines occupy, but disappears under the Trias plain in the west of Lancashire, and under the Irish Sea.

If we proceed in the same way to draw a skeleton section from the Ribble to the Mersey through the centre of the coalfield, we obtain the following result by the same rule. From this section we learn (Fig. 101) that there exists

a great disturbing anticline which runs across the centre of the field, bringing up a range of mountainous country formed of Millstone Grit. This anticline forms a water-parting across the Lancashire coalfield, separating the Ribble from the Mersey.

v. Although this is the general lie of the formations, we have in reality simplified the structure extremely. The Coal Measures do not disappear gently beneath the sandstone, as we have represented in Fig. 100, but they are let down by a great fault, so that they lie

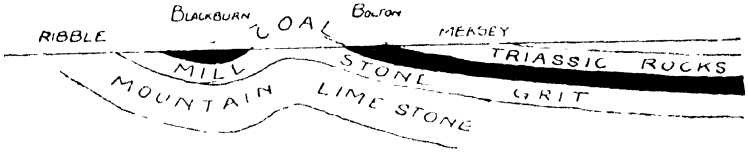


FIG. 101.

several hundred feet below to the west of the fault, while to the east they lie at the surface. And this fault is by no means the only one in the coalfield. There are at least five great faults crossing it, all approximately parallel to each other. In a general way they run from north-east to south-west through Bolton, Bury, Rochdale . . ., always maintaining their direction. (Put them in the map. Are these strike or dip faults? The beds dip down on each side of the central anticline. The faults are in the plane of the dip.) Let us now consider what effect these dip faults have on the simple structure represented in section iv.

Let *A B* (Fig. 99) represent a line crossing the coalfield in the direction of the strike (from the sea to the Pennines). Mark off the positions of the faults from the map and

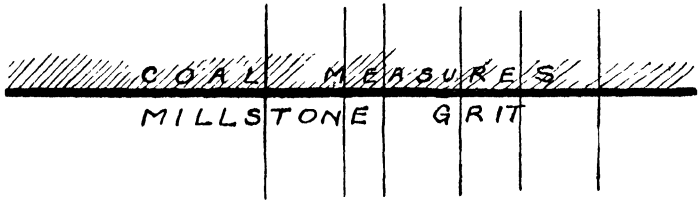


Fig. 102.

transfer them to the thick line (Fig. 102), which represents the simple position of the bottom of the Coal Measures before the faults broke them up. Then the effect of the faults has been to displace them thus:

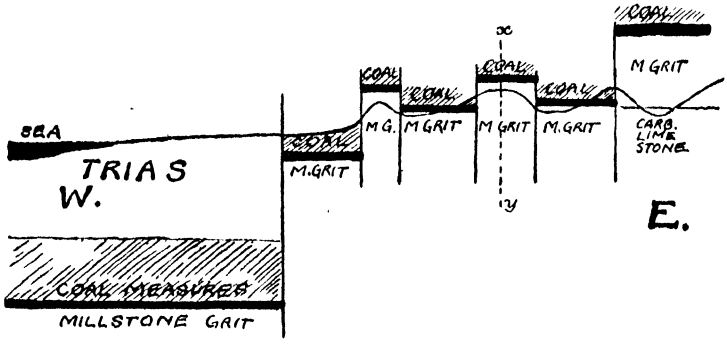


Fig. 103.

The Coal Measures and the beds above and below them have been let down in steps by faults until on the west the coal lies deep below the Trias, and on the east the Millstone Grit rises above it. The curved line in Fig. 103

represents the present outline of the hills, and shows how the coal has been left in some places and eroded away in others.

If we had taken a section parallel through the lower-lying country south of the watershed formed by the anticline (*i.e.*, through Bury, Bolton, Rochdale), we should have found much less coal eroded, as the following two diagrams indicate :

(1)

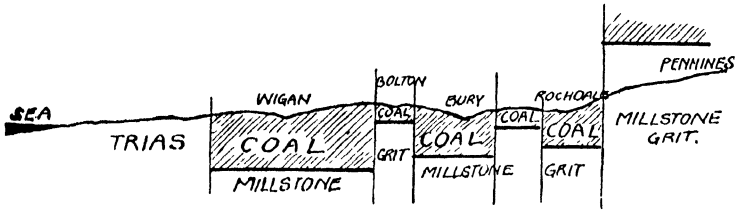


Fig. 104.

(2) A section at right angles to the above through *x y* (Fig. 103)

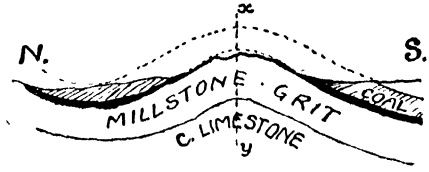


Fig. 105.

vi. Next we shall say a word about the kinds of rocks these Limestones, Grits and Coal Measures are. They are grouped together as the Carboniferous or coal-bearing rocks, and wherever they occur in the world they are rich in coal or oil.

The Carboniferous or *Mountain Limestone* is the oldest formation of the group. It is a massive limestone, grey in colour, yielding good building stone and marble. As the name indicates, Mountain Limestone forms hilly ground. It is commonly cavernous with underground streams. Those low grey walls built in place of hedges across the hills to keep the sheep in, are constructed of it. *Millstone Grit* comes next in order, overlying the limestone. It is a hard sandstone, with harder grains of silica embedded in it. This renders it excellent for grinding. It is not only used for making millstones for grinding corn, but for grindstones for cutlery and for mashing pulp in paper-making. Because of its extreme hardness and powers of resistance to weather, it is largely used in the construction of dock walls, reservoirs, bridges and embankments. For instance, it was employed in building the Thames Embankment. It is easy to gather from the uses to which this rock is put that it must form high peaks. Indeed, it caps all the high hills in the Pennine Chain and extends for many miles through the centre of the North of England as high land. Although the *Coal Measures* are thousands of feet in thickness, it must not be supposed that they consist of solid coal! The coal forms beds, sometimes only a few inches thick, sometimes a few yards, followed by beds of sandstone or shale, and then perhaps more coal, or a thin band of iron ore. The shales and sandstones frequently

make hilly ground. Often indeed the sandstones bedded in with the coal are fine enough to quarry for building. The War Office in London was built of stone from the Coal Measures of Yorkshire.

vii. Now let us look at the geological map and the sections we have drawn, and, bearing in mind the kinds of rocks we are dealing with, endeavour to see how the weather has carved out the hills and valleys from these rocks. On the east of them we have the massive grits of the Pennines. The moorland (up to 1500 feet) which they form and which runs from north to south continues across the middle of the Lancashire coalfield, as the arch of an anticline. This anticline strikes W.S.W. and forms the water-parting down which tributary dip streams run to join the strike streams, Mersey and Ribble. On each side of the anticline lie the coalfields. The dip faults which traverse these coalfields have determined the positions of the hills and valleys. The features are admirably reflected in the positions of the towns and the railways. We have already seen that the towns lie in two parallel lines. The two principal rivers and the central range of moors also run parallel. On account of the cross faults, the valleys have developed (though not along the faults) directly between the pairs of towns. The railways conform to this splendid arrangement. One line from Liverpool (Fig. 106) connects the top row of towns, while another, also from Liverpool, connects the bottom row.

Then each pair of towns is connected by rail through their respective valleys. The L.N.W.R. main line from Crewe to the north passes through Warrington and Wigan to Preston.

viii. Has Lancashire made use of this marvellous natural design? We shall see that extremely good use has been made of it. The

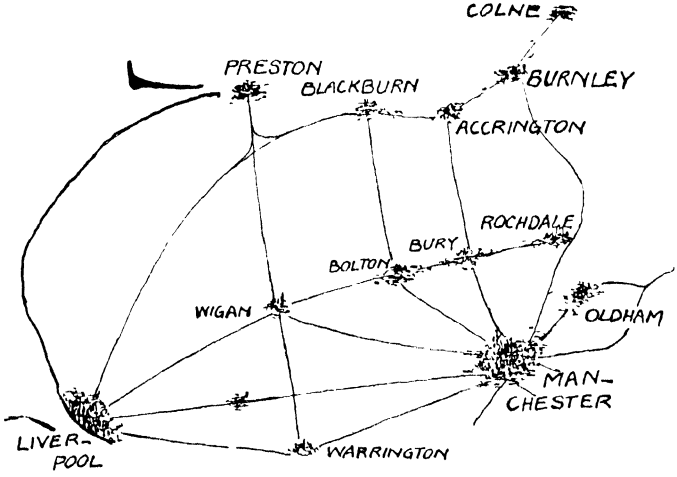


Fig. 106.

first effect of the design that we shall consider is that on the climate. The central range of moors, and the Pennines as well, have ensured a copious supply of rain in the county, for the prevailing winds come from the Atlantic and are full of clouds of vapour. The result is doubly favourable. First, the air is always moist, and consequently the climate is very suitable for spinning, for the fine threads of cotton easily snap in a dry climate. Secondly, the rain provides a valuable source of soft water

and power. So the towns which are engaged in spinning and weaving are situated in the cross valleys, where they can take advantage of the falling streams.

ix. Later, mechanical discoveries in methods of spinning and weaving which were largely made in these very towns led to an enormous use of the coal around, which had up till that time remained untouched. What a fortune for Lancashire that the coalfields happened to be just on the same spot as the mountains that condensed the moisture and supplied the water and the power! This is due, as we have seen, to the structure of the coalfield. The spinning industry continued to grow at a great rate until in 1843 there were many million spindles working in Manchester. Now we come to the marvellous use made of the structural design of which we spoke. At the present day there are no spindles at work in Manchester, and yet the quantity of cotton goods made from raw cotton in Lancashire is greater to-day than ever it has been.

x. Why are no cotton goods made in Manchester? We must find a reply to this question, and see how it depends on the geological structure.

First of all, raw cotton, a semi-tropical plant picked in the warm States of Alabama and Virginia or in Egypt comes across in bales and is unloaded at Liverpool. Already we have seen how it has been possible to make the magnificent seven miles of docks at Liverpool with their

forty miles of quay, thanks to the sandstone at the Mersey mouth, while the Ribble and the Dee, north and south of it, both have much wider but comparatively useless estuaries. Not only cotton, but food from America and Ireland comes into Liverpool. Now Liverpool has no spinning and weaving mills. It is a great port for handling raw material and passing it on. So in Liverpool there are great cold storages for food, and granaries for making flour from foreign wheat, just as there are in all great British ports, besides great offices where shipping and forwarding transactions, countless in number, are made and recorded.

The cotton is then sent from Liverpool to be spun into thread and woven into pieces, and this takes place in the towns on the coalfield. After the raw cotton has been converted into velveteen, sheeting, corduroy, or any of the fine textiles into which cotton may be made, these products are not put up for sale in the towns where they were manufactured. Instead, Lancashire men found that it was a far better plan to collect the special kinds of textile goods in one convenient spot for marketing. What more convenient spot could be discovered than Manchester? Goods made in each of the towns on the coalfield are sent down the valleys and collected by rail across to Manchester as the natural centre in the Mersey-Irwell valley. As this arrangement appeared to work well, it became more perfect. Manchester ceased gradually to make cotton goods, buying, collecting,

warehousing, forwarding and selling them instead. At the same time other textile goods naturally came to Manchester for marketing. The Yorkshire district sent along woollen goods, the Macclesfield district silks; alpaca, mohair and woven asbestos came in too, and jute from Bootle. Thus Manchester became the great *commercial* centre and warehouse for finished textiles.

xi. Let us see what is gained by this "centralisation" of the market and "decentralisation" of manufacture. First the spinning and weaving towns begin to specialise each in some particular kind of textile in the manufacture of which its inhabitants become highly skilled. Then the mills have one big customer, the merchant in Manchester, who will buy all their output, instead of their having to dispatch goods in small quantities to all parts of the world. Next, the smaller shops all over the country know that they need only deal with Manchester in order to secure samples of *all* the products of the separate towns. It follows, that to be a success, Manchester must be an excellent collecting and distributing centre. We have already seen how splendid its position is for collecting finished woven materials, especially from its cotton towns. Its position for distributing goods is equally splendid. It stands just where the Pennines may be crossed along five valleys. (They should be noted on the map.) (1) Up to Halifax, (2) to Huddersfield, (3) across to Barns-

ley, (4) to Sheffield, (5) to Derby through the Derwent valley, and thence to London. From these towns Manchester has direct communication with Scotland and the whole of the east and south-east of England. Then it has excellent trains across the Cheshire plains and so into the midlands and the west.

xii. But this does not exhaust Manchester's excellent advantages as a centre for distribution. A large proportion of the textile goods collected into Manchester are exported to all countries in the world. So in order to be a first-rank distributing centre, the city should be accessible to ocean-going ships. Thanks again to the sandstone of the Mersey and to the splendid mouth of that river, the Ship Canal has enabled Manchester to add this advantage to the list she already enjoyed. Raw cotton may now be unshipped in Liverpool, sent along to the mills on the coalfield by rail or by narrow canal, collected in Manchester from all sources, and shipped directly abroad again.

xiii. Naturally a large quantity of intricate machinery is needed in this highly organised area. This is chiefly made in and round Manchester. There is no useful iron ore in the coalfield here, but recently magnificent blast furnaces have been erected on the Ship Canal, the iron ore coming up the canal from abroad. Lancashire has its own valuable deposits of iron ore, but these lie away from the coalfield. They are the rich hæmatites of Cumberland and Barrow.

xiv. The mines in this part of Lancashire are chiefly coal mines. The description of a coal mine in Part I is from the Wigan area, which supplies most of the best Lancashire coal.

But there are also salt mines in the district. Judging from your knowledge of the position of the salt mines in Cheshire, where would you look for salt in Lancashire? In the Keuper Marl. Brine is pumped at Fleetwood, and a salt industry similar to that of Mid-Cheshire is carried on. This is not the only district within our area where chemicals are made, Widnes is a well-known centre for acid, alkali and soap production on a large scale. St. Helens and Warrington share the trade. At St. Helens, too, there is a large glass industry. Why should this corner of Lancashire specialise in chemicals? Salt from Cheshire and Fleetwood is fairly easily obtained, and pyrites (for the indispensable sulphur) from Spain comes into Liverpool, which is near at hand. Limestone is available from Buxton in Derbyshire and North Wales, and coal is on the spot. With these raw materials and liberty to make much smoke and smell, a great industry has grown up in this low-lying corner of Lancashire. Much is made for export, which is easy from the Mersey valley. As we noted in the case of the Cheshire chemicals, the commercial headquarters of the Lancashire industry is Liverpool.

As for quarries, there are some in all the

formations. The red sandstone round Liverpool supplies good building stone, of which, for instance, Liverpool Cathedral is built. The grey Millstone Grit near Preston is quarried as well as the buff sandstones of the Coal Measures to meet local needs.

xv. The Triassic area of Lancashire, in the neighbourhood of Liverpool and Ormskirk, repeats the agricultural districts of Cheshire. The sea coast has some excellent seaside towns. No account of Lancashire would be complete without mention of Blackpool. It has a fine stretch of esplanade and a long beach of blown sand-hills. It forms the pleasure ground of the busy workers from the mills in the cotton district, a release from the heavy atmosphere of the chemical towns, as well as a relaxation from the strain of business for the people of Liverpool and Manchester.

CHAPTER XXVI

THE SMALLER COALFIELDS ROUND THE PLAINS OF CHESHIRE, SHROPSHIRE AND STAFFORDSHIRE

i. THE outline map of Chapter XXIV should be redrawn, attention being given this time to the coalfields which, as we saw in that chapter, flank the central Trias areas. In addition to the towns mentioned there, Wolverhampton and Birmingham should be inserted. This may be carried out conveniently with the "cardboard negative." Then the following towns should be put in from the map :

(1) The Potteries, namely : Stoke, Hanley and Newcastle.
(2) Towns in the Black Country, namely : Walsall, Tipton, Bilston, Wednesbury, Smethwick, Halesowen and Stourbridge.
(3) Towns on the Severn Coalfield, namely : Wellington, Coalbrookdale, Ironbridge, Coalport and Bridgnorth.
(4) On the Severn : Kidderminster and Stourport.

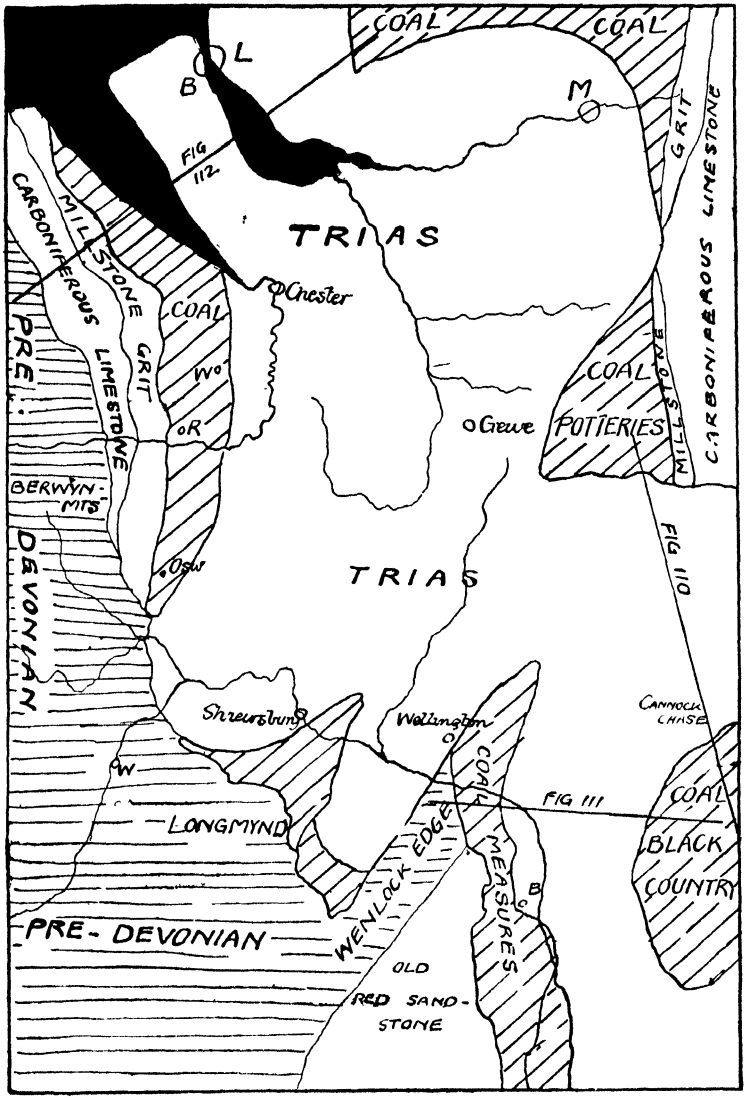

COAL
COAL
L
B
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FIG 112
GRIT
CARBONIFEROUS LIMESTONE
TRIAS
MILLSTONE GRIT
CARBONIFEROUS LIMESTONE
Chester
COAL
Wo
oR
PRE
COAL
POTTERIES
Crewe
MILLSTONE GRIT
CARBONIFEROUS LIMESTONE
BERWYN MTS
FIG 110
oSw
TRIAS
DEVONIAN
Shrewsbury
Wellington
COAL
Cannock Chase
W
FIG 111
COAL
LONGMYND
EDGE
MEASURES
B
BLACK COUNTRY
PRE-DEVONIAN
WENLOCK
OLD RED SANDSTONE

Fig. 107.

(5) Towns on the Welsh Coalfield, namely : Bagillt, Flint, Shotton, Queensferry, Buckley, Wrexham and Ruabon.

ii. The outcrops described under Cheshire should be completed by carefully inserting those of the coalfields which ring round that area. First draw in the North Staffordshire coalfield, roughly triangular in shape, on which the pottery towns are situated. Next, draw an oval outcrop of much the same area between Wolverhampton and Birmingham, in which all the towns of the Black Country are found. The coal outcrop of the Severn valley is irregular and dislocated by great dip faults. But it may be put in roughly as a thin strip, south from Wellington through Bridgnorth to Stourport. Then draw in the outcrops of the Flintshire field from the mouth of the Dee, in a fairly broad strip to Oswestry. Between the last two outcrops, unproductive Coal Measures run fairly continuously south of Shrewsbury. These should be inserted, since they are necessary in deciding the structure of the area.

We have learnt to expect to find Millstone Grit and Mountain Limestone underlying Coal Measures. Thus the outcrop of Millstone Grit and Mountain Limestone which lies east of the Lancashire coalfield continues south into Staffordshire, and should be put in, as in the sketch map, east of the Potteries. Similarly, on the opposite of the plain a long strip of Grit and Mountain Limestone lies to the west of the

Flintshire field from the sea coast of North Wales to Oswestry.

But none of the coalfields of the Midlands, those of South Staffordshire and the Severn valley, for instance, are accompanied by Carboniferous Grit and Limestone. Here these two formations are entirely absent. Instead, the Coal Measures rest directly upon much older rocks. That is to say, the Coal Measures are unconformable to the older rocks beneath them. We should remember what this indicates. Limestones are formed in ocean beds. It follows, therefore, that while the Carboniferous ocean spread over the North of England, the Midlands were land. But when the coal forests grew on the site of these old seas, the land of the Midlands had become swamp with the rest of England. Consequently the Coal Measures here, rest on rocks older than the Limestone.

iii. We are still faced with the problem of filling in the position of these pre-Carboniferous rocks. The whole of the area west of the Carboniferous outcrops of Flintshire and Shropshire may be marked pre-Carboniferous. But east of those same outcrops the older rocks only appear in extremely small *inliers* or isolated patches of rock peeping up unconformably from beneath newer formations. Instead, the Triassic rocks, with which we are now well acquainted, occupy all the country between the separate coalfields. Thus we may mark the area between the North and South Staffordshire coalfields, Trias; similarly, between the

South Staffordshire and the Severn valley coalfield; similarly, between the Severn valley and the Flintshire field. One interesting unconformity immediately becomes apparent. On page 57 we learnt to recognise an unconformity on a map by the way the outcrop of the unconformable bed cut across the outcrops of the beds upon which it lay unconformably. Here we see how the Triassic rocks south of the Potteries pass from the Coal Measures of the Potteries on to the neighbouring Limestone!

iv. These older rocks which form so large a part of Wales are all altered and generally very folded. We might conveniently divide them into two by a line stretching from the Coal Measures at Bridgnorth to Carmarthen. South of this line we may mark the area (4) Old Red Sandstone, and north of it (3) Silurian, (2) Ordovician and (1) Cambrian, the numbers representing their respective order, (1) being oldest. We shall not now attempt to distinguish between these various ancient formations, but we shall note that they invariably form mountainous country. The changes which they have undergone have hardened and folded them in such a manner that, although they are the oldest rocks known to the geologist, they have nevertheless resisted weathering and remain mountainous and rugged. But we should guard ourselves from the deduction that because any given area is mountainous it is therefore formed of ancient rocks. The Swiss Alps are

formed to a very large extent of relatively young formations, even including those of Tertiary age.

v. Having now completed the map, let us proceed to draw a series of sections. They will be extremely interesting this time on account of the way they reveal hidden coal-fields. We are already familiar with the general structure across Cheshire, but we may now extend it to include rocks older than the Coal Measures. It does not matter whether our section is taken from north to south, that is,

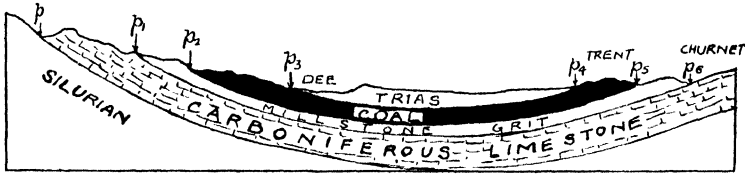


FIG. 108.

from the Lancashire to the Severn coalfields, or from east to west. Let us draw a section from east to west through Wrexham and Hanley (Fig. 108). Along the profile we mark the points p where the Silurian rocks disappear; p_1 where the Carboniferous Limestone passes under the Millstone Grit; p_2 where the Grit passes beneath the Coal Measures, and p_3 where the Trias appears. Then on the Staffordshire side mark p_4 where the coal comes up from beneath the Trias, p_5 where the edging of Millstone Grit appears, and p_6 where the Limestone follows.

From this the synclinal structure is at once clear. We also see that the coal which lies

under the Cheshire plain comes to the surface just at the edges of the basin.

Diagrammatically we may represent this by a circle (Fig. 109). The dark lines of the circumference show that here the Coal Measures are exposed at the surface. We see that, very generally speaking, there is a symmetry about the area, so that an east-west section is similar to a north-south section.

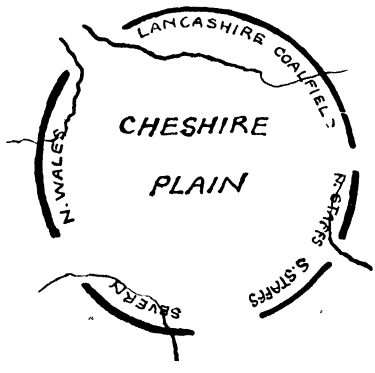


Fig. 109.

From Fig. 108 it is also clear that, although coal is concealed under Cheshire, none can possibly exist just east of the Potteries or west of the Flint field, for there the coal has been eroded and older beds appear.

vi. Next, let us inquire into the structure of the gaps between the coalfields. To do this we shall take sections between them. First, let us take that between the North and South Staffs coalfields from Hanley, let us say, to Birmingham (Fig. 110). We have four points to indicate the structure, namely, p_1 and p_2, which mark out the North Staffs outcrop along the line of section, and p_3 and p_4, which mark out the South Staffs outcrop along the same line. From the order of the beds we at once

see that the Coal Measures appear from beneath the overlying Triassic rocks at p_1, dip beneath them at p_2, and reappear from them between p_3 and p_4, to disappear beneath them again.

It is thus clear that a concealed coalfield exists between north and south Staffordshire. It is estimated that about 1700 million tons

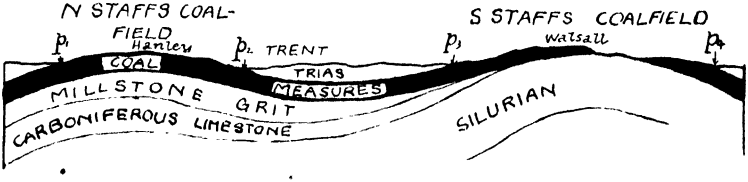


FIG. 110.

of coal lie concealed beneath the Trias at depths less than 5000 feet just south of the Pottery district.

vii. Beneath the Coal Measures of North Staffordshire lie, as we have seen, Millstone Grit and Carboniferous Limestone in order. Now, these formations do not continue into South Staffordshire. They thin out against an older formation of Silurian rocks, as the diagram shows. These Silurian rocks actually come up to the surface in the Black Country and peep through the Coal Measures! When an older formation makes an isolated appearance within the outcrop of a younger one as this does, its outcrop is known as an *inlier*. Thus the Silurian rocks in the Black Country form inliers in the Coal Measures. In the same way, we may say that the small isolated coalfields

themselves form inliers in the Triassic rocks round them.

viii. Our next section will be taken across the Severn valley between the South Staffs coalfield and the Severn coalfield, through Wolverhampton and Coalbrookdale (Fig. 111). It reveals precisely the same structure. The Silurian rocks of Wenlock Edge dip under the Coal Measures of Coalbrookdale. These dip under a Triassic basin through which the Severn flows, and reappear in the South Staffs coalfield, to disappear beneath the Triassic

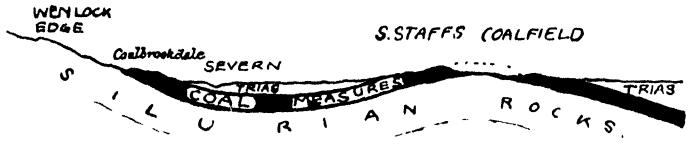


FIG. 111.

rocks again. The Silurian Core of the Black Country is thus seen to be an inlier of the main outcrop in Wales. It is estimated that there are 5000 million tons of coal available (less than 5000 feet deep) under the Triassic covering between the two coalfields in the diagram above.

ix. A section through the district between Oswestry and Shrewsbury would not reveal any concealed coalfield, since the old rocks on to which the Trias transgresses were land in the coal epoch.

But by taking a section between Flint and St. Helens across the Wirral we discover what

is estimated to be a rich hidden coal area of about 2880 million tons (Fig. 112).

The Silurian rocks of North Wales are seen to underlie all the other formations. Above them comes the Carboniferous Limestone and Millstone Grit. Both these formations reappear in the Pennine district of Lancashire, as we have seen, just as the Coal Measures of Flint reappear at St. Helens. Between these two towns the area is occupied by Triassic rocks through which the Dee and the Mersey gain the sea. It is worth noting that just as the

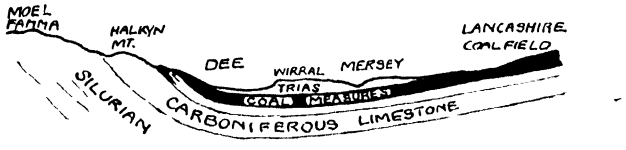


FIG. 112.

Silurian rocks of Wales form small inliers in South Staffordshire, so they do in the northern part of Lancashire. We have considered the structure of these hidden coalfields without reference to faults. Triassic rocks, wherever they occur, are always faulted, and it is to these faults that the disappearance of the Coal Measures under the Trias is largely due.

x. The effect of weathering on the structure, explained by the above paragraphs, must now be studied.

The Coal Measures everywhere form high ground, both on account of their structure and also on account of the resistant nature of

the shales and sandstones of which they are principally composed. Let us go round the coalfields in turn, starting from North Wales. From the Dee estuary inland the country rises rapidly. Each successive outcrop forms a range higher than the one in front of it. The easily weathered Triassic rocks have been eroded right up to the foot of these mountains and round to Prestatyn. In consequence, the L.N.W.R. main line to Holyhead clings to the shore right round the coast from Chester. The Carboniferous and Silurian hills run south to Oswestry, with one break, which forms the lower part of the exquisite valley of the Dee. Here the Dee leaves the hill country through which it has flowed as a dip stream and gains the soft sandstone of the Trias, along which it works to the sea as a strike stream.

xi. The Carboniferous hills south of the Dee are backed by the Berwyn mountains. These confine the Dee on its southern side almost to its source in the volcanic rocks of Merioneth. They are composed of roughly formed Silurian slates and grit, and are well reinforced by massive thicknesses of volcanic rocks. It is from these mountains that the city of Liverpool is fed with water.

The Severn breaks through on to the Trias plain between the Oswestry and Shrewsbury Coal Measures. As we have seen, the Berwyn mountains divide the catchment area of the Dee from that of the Severn in Wales. On the Shropshire side the Coal Measures are

backed by the hilly country of Longmynd, Wenlock Edge and the Wrekin, formed of Silurian and older rocks. South of these the Old Red Sandstone hills of Herefordshire back the Severn coalfield.

xii. We now come to the isolated coalfield of the Black Country. It lies high and forms the watershed between the Trent and the Severn. North-east of it lies the Trent valley, along which the L.N.W.R. main line from London to the North runs, and south-west of it lies the Severn valley. The main line avoids the climb up into Birmingham. When the canals from Cheshire to the Black Country reach Wolverhampton they are obliged to climb through fourteen or fifteen successive locks. The Black Country is intersected by a network of canals, into which water must be constantly pumped at great expense, on account of its elevation above the Trent and Severn valleys. The hilly country is formed partly of Coal Measures and partly of faulted Triassic Sandstones of the harder type. These form the uplands of Cannock Chase, much like the Delamere district.

xiii. The North Staffordshire coalfield forms a part of the Pennine system. Just as the Lancashire coalfield flanks the massive moorland Grits of the Pennines, so here the North Staffordshire coalfield flanks the Limestones of the southern Pennines. The upper waters of the River Trent, which rises here, flow away from the coalfield in a south-easterly direction

on to the Triassic marls and are soon joined by the Churnet, which runs by the eastern side of the coalfield.

This completes our study of the formations, their structure and the resulting hills and valleys. We must now trace the rise of industries and the grouping of towns upon them.

CHAPTER XXVII

FLINTSHIRE: THE POTTERIES AND THE BLACK COUNTRY

Industrial Development of the Smaller Coalfields

i. EACH of the coalfields possesses in itself a source of power. Since this is a prime factor in the development of industries, we should expect to find the coalfields covered with industrial towns. What these industries are will depend on other factors, which will vary from one coalfield to another. We shall take each district in turn.

ii. The Limestone mountains of Flintshire are full of lead and zinc. Flintshire is now the most important lead-producing county in Great Britain. The presence of these metals on a coalfield at once suggests a metal industry of the Swansea type. In fact, the whole of the twenty-five miles from Chester to Mostyn along the Dee valley is industrialised. Lead is mined in the Halkyn district. At Shotton there are large iron and galvanising works. The Cheshire salt has given rise to acid and alkali works at Flint, and the skilled population has attracted

extensive artificial silk works. Coal mines spread from north to south, and an industrial population has gathered round Buckley, Wrexham and Ruabon, where factories of various kinds have sprung up. Local supplies of clay have led to some well-known tiles and bricks from this district. The natural centre for traffic is Chester, but Chester is in no way an industrial town. It receives the coal for household supplies, but sends forward the goods manufactured on the coalfield. If the Dee had been more suited to navigation there is no doubt that this district would be of much greater importance. Only small boats can reach Shotton and Flint for export and import trade, and these cannot reach Chester, where the river was (until recently) first bridged.

iii. The coalfield of South Staffordshire is the site of a thickly populated industrial district. It was one of the very first coalfields to be exploited anywhere in the world, and signs of this are apparent everywhere. The whole of the Black Country between Wolverhampton and Birmingham, intersected by roads, canals, railways and tramways for an area of about 200 square miles, is a hive of industry. The district was opened up before the time of the locomotive, and canals were built as the best means of transport. There are said to be 159 miles of complicated narrow canals between Wolverhampton and Birmingham one way (10 miles) and Cannock Chase and Brierley Hill (20 miles) the other. Collieries, ironworks,

rolling mills, forges, tube, nail, metal and chemical works are built on the ground these canals intersect, so that the water laps against their walls. Hundreds of them have private basins, and in some colliery districts canals are the only means of transport. The congestion is so great that at one spot two railway lines and a canal cross each other at three different levels. The goods, which are collected by barge, are either delivered again where they are required in the Black Country, or they go on to some large collecting basin on the edge of the coalfield, where they are loaded into trucks, or make their way slowly down through a series of locks to the level of the plain. Besides the congestion and the extraordinary use of waterways in a district where water is naturally scarce, even the canal banks show that the Black Country was organised at an early period. Constant mining for coal and iron (which is abundant throughout the coalfield) has led to a gradual subsidence of the surface. In order to keep them at the original level, the banks have been made up time after time, so that they now often run at a higher level than the surrounding country, sometimes even on a level with the roofs of the houses.

iv. Coal and iron mining is the foundation of the manufactures of the Black Country. The iron ores of the country are not now so important as they used to be, since richer ores are more easily available from other districts. But blast furnaces and collieries are at work in

every direction. The kind of hardware in which the Black Country specialises is that which requires a good deal of skilled labour on a small weight of raw material—pen-nibs, for instance, nails, locks, screws, bedsteads, petrol motors and cycles. Otherwise the cost of shipping heavy finished articles would be out of proportion to their value. For this reason also, rolling stock is manufactured in the same area, since that does not require transport.

Birmingham is the headquarters of the non-ferrous metal industry, particularly brass, bronze and gunmetal. The products of the towns on the coalfield are mostly finished and ready for use, so that within the Black Country the whole series of productive factories may be witnessed. Here will be a colliery supplying a gigantic ironworks with coal and iron ore. The steel which it manufactures is supplied in bars to some engineering firms. These work it up for the machine shops. In some parts of the Black Country machine shops occur in every corner where a piece of shafting could be put up and a gas-engine installed. Finally, the parts will be assembled from the machine shops and fitted together at a central works to form a motor or a cycle or some other article ready for use.

v. The presence of coal and a ready supply of salt from the Keuper marls between the two Staffordshire coalfields have given rise to a large chemical and glass industry in South Staffordshire, just as in South Lancashire.

But the necessary sulphur ores from Spain have to be brought up by train from Swansea. Besides this, towards the Severn valley, pottery and fireclay are manufactured, Stourbridge giving its name to a variety of fireclay.

vi. These industries are for the most part very accurately confined within the coal area. Travelling across the Midlands through Birmingham and Wolverhampton, the scenery changes at once from the pastoral agriculture of the Trias to the blackness and grime of the Coal Measures. But the industries reappear on the small coalfield of the Severn and even across the valley from one coalfield to the other. In the Wellington, Lilleshall, Coalbrookdale district, coal and iron are mined and iron is smelted. The towns on the coalfield are engaged in the manufacture of hardware. Coalport, on the Severn, is noted for delicate china. Kidderminster, between the two coalfields, is a famous carpet centre, the industry having drawn on the wool of the Welsh hills. Brussels and Wilton carpets are chiefly manufactured.

vii. The North Staffordshire coalfield is famous as the district which supplies us with our china and earthenware. We should know something about the manufacture of pottery, as this industry is called, since its raw materials are so directly obtained from the earth. We should first appreciate that all manufactures in which clays are baked belong together. When the clay is impure and suitably fired, it forms bricks. When it is pure and carefully

chosen, it forms porcelain, or "china." We should recognise all the chief forms which such baked clays present. They vary principally according to the constituents of the plastic mass which is baked, and to the temperature to which it is raised. Bricks are formed when the percentage of sand in the clay is high. Now a brick-like material is useless as a household utensil, because it is porous and absorbs liquids. Consequently, such utensils must be coated with glass. A coating of this kind is known as glaze. The glazing process is carried out by covering the porous utensil with a sandy mixture which easily melts. When the utensil covered with such a mixture is put back into the oven, the coating melts while the body of the utensil remains unchanged. On cooling, it is found to be coated thinly with glass. So far, then, we see how a glazed earthenware object such as a brown ginger-beer bottle is made. Suppose the utensil is to be white. We may either change the colour of the clay, which can be seen through the glass, or else use an opaque glaze. The task of producing clear white pottery was pursued for a long period of time in Europe without much success, while the Chinese possessed the secret of porcelain manufacture many a century ago. The charm of porcelain is that it allows light partly to filter through, because its clay is very pure and has been almost molten. To make it, white clay, sometimes called China Clay or Kaolin, must be substituted for the common brown clay.

The whole of our supply of china clay comes from Cornwall and Devon, where the quarrying and preparation of that mineral is a large industry. Although the finest porcelain is made almost entirely from china clay, the ordinary forms of "china" ware are prepared from a mixture in which china clay only forms a part. The clays of Staffordshire are not now used, even as a constituent of the "china" ware made there. Instead, more suitable clays are quarried in Dorsetshire. The blue clay from Dorsetshire is mixed with the white clay from Cornwall, and fine pure sand is added to make the mixture melt more easily. The sand is prepared by burning flints from the chalk, quenching them in water and grinding them fine.

viii. The chief reason why the pottery industry is now so firmly rooted in North Staffordshire, although hardly any of the raw materials used in the manufacture are produced locally, is an historical one. When the industry was established it possessed the advantages of what was then considered suitable pottery clay and abundant coal and iron. But what secured a reputation for North Staffordshire pottery was the work of Josiah Wedgwood, who, with the artist John Flaxman, for the first time endeavoured to make the products of North Staffordshire excellent in design, quality and workmanship. In this way they fostered the growth of a skilful population. To-day, when the raw materials

must all be shipped to the Potteries, the presence of workpeople of traditional skill and the abundance of coal ensure the position of the industry. That the coalfield, like that of South Staffordshire, was very early exploited may be seen from the canals. The towns are all interconnected, Stoke-on-Trent being the most important.

ix. The chief towns off the coalfields are administrative, agricultural and residential centres. Chester and Shrewsbury are very similarly situated to each other. They owe their importance to their strategic positions. Valleys, and with them highways and railways, converge naturally on Chester in the north and on Shrewsbury in the south. Stafford occupies a central position in the Trias valley of the Trent system between the two coalfields of that county, and is similarly administrative and residential, although engineering works are rapidly making headway and leather industries have long been established there. It is also a brine-pumping station. The country round grows barley for brewing, and feeds the industrial districts in the manner described in Chapter XXIV.

The Agricultural Midlands

x. Just as the Coal Measures of North Staffordshire disappear beneath the Trias plain and emerge again at Wolverhampton, as Fig. 110 shows, so the Coal Measures of Nottingham

disappear beneath the same formation and emerge further south from it. If we draw a sketch map showing the towns of Nottingham, Loughborough, Leicester, Coventry, Warwick, we define approximately the most easterly extension of the Keuper outcrop in England. These towns all lie in this formation a few miles west of the line along which it disappears beneath the Lias, which we must presently study. For the present we shall confine our attention to the Keuper outcrop and its coal inliers.

xi. The main line of the London and North-Western Railway between Rugby and Crewe cuts directly across these agricultural midlands. Concerned chiefly with fast traffic for the North of England, this line avoids the hilly ground which the anticlinal outcrops of Coal Measures, with their cores of still older rocks, form in the otherwise level plain. When we have fixed these outcrops, the relief of the area is at once apparent. Besides the South Staffordshire coalfield there are two others, one in Leicestershire and one Warwick. The towns of Nuneaton, Lichfield, Stafford, on the L.N.W.R., and Burton and Derby will serve as a guide to the topography.

xii. The Trent, flowing down from the hills of North Staffordshire, first keeps to the low ground between the Coal Measures where it rises, and those of the South Staffordshire coalfield. It then meets the Tame, which flows through Tamworth between the latter

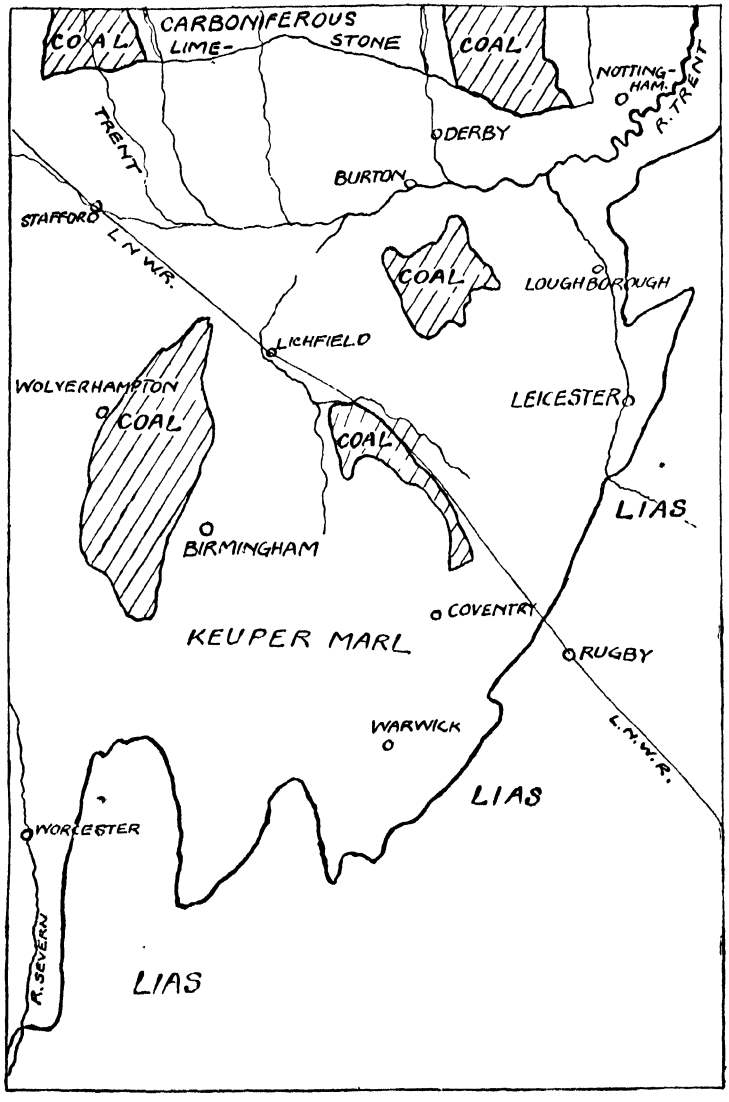

COAL
CARBONIFEROUS LIME-STONE
COAL
NOTTING-HAM
R. TRENT
TRENT
DERBY
BURTON
STAFFORD
L.N.W.R.
COAL
LOUGHBOROUGH
LICHFIELD
WOLVERHAMPTON
COAL
COAL
LEICESTER
LIAS
BIRMINGHAM
COVENTRY
KEUPER MARL
RUGBY
WARWICK
L.N.W.R.
LIAS
WORCESTER
R. SEVERN
LIAS

FIG. 113.

coalfield and that of Warwickshire. Other tributaries from the area between the Warwickshire and the Leicestershire coalfields also drain into the Trent, which then flows between the Leicestershire and the Nottinghamshire coalfields through Burton and Nottingham to the Humber. On its left bank it is met by three streams which come down from the Derbyshire Hills, namely, the Churnet, the Dove and the Derwent. Thus we see that the Trent drainage system of the Midlands is very complete. Towards Worcester and Gloucester, the Triassic outcrop is thinner and is drained by the lower Severn, on which the town of Worcester is situated.

xiii. Like the Cheshire plain of which the Midlands are a continuation, the main industry is dairy farming on permanent pasture, although barley flourishes in the Trent valley. The Keuper marls contain beds of gypsum (calcium sulphate), which the streams leach out. Water with the peculiar mineral contents which the marls thus supply is very suitable for brewing. It has now become customary to add these minerals artificially in other districts where the water is soft (that is, free from dissolved minerals) to harden them for brewing.

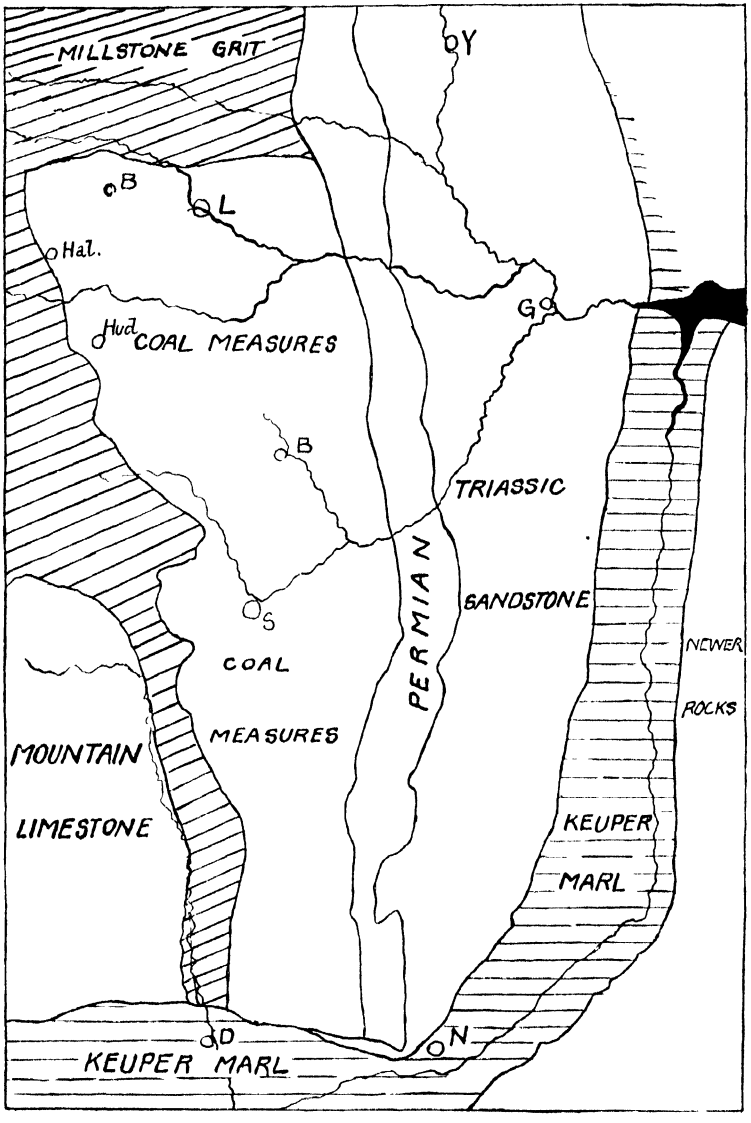
CHAPTER XXVIII

THE YORKSHIRE COALFIELD AND THE SURROUNDING AREAS : WOOLLEN AND STEEL MANUFACTURE

i. THE position of the bifurcation of the Humber into the Trent and the Ouse is stencilled on paper and the estuary taken as far as Hull. This is the nearest approach to the sea coast that will be considered in this chapter. The following towns are to be inserted :— York, Nottingham, Doncaster, Mansfield, Bradford, Leeds, Huddersfield, Wakefield, Barnsley, Sheffield and Derby. Part of the necessary preparation for the following account will be to fill in from the atlas the remaining important towns—Ilkeston, Belper, Matlock, Chesterfield, Rotherham, Dewsbury, Pontefract, Selby, Thorne, Bawtry, Retford. The course of the following rivers must be added with the guidance that the positions of the towns afford.

1. The Trent and its Derbyshire tributary the Derwent.

2. The Ouse system, comprising the main dip stream, the Aire, with its tributary the Calder, and the captured streams running into the Ouse, namely, the Wharfe (Nidd, Ure and Swale) ; then the Don to the south.


MILLSTONE GRIT
Y
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ROCKS
COAL
MEASURES
MOUNTAIN
LIMESTONE
KEUPER
MARL
D
N
KEUPER MARL

FIG. 114.

ii. Roughly the Coal Measures crop out in a rectilinear area. The limits of the coalfield should be drawn in approximately by a line above Bradford and Leeds on the north, and a shorter one parallel to it almost joining Derby and Nottingham on the south, and by lines running roughly from north to south joining the ends of these. Mark this area "Coal Measures." This will leave a strip of Millstone Grit country between the coalfield thus marked and the River Derwent. This strip widens to form the Pennines north of High Peak, where the Derwent rises. We should be familiar with this outcrop from our study of the Lancashire area. The country west of the Derwent is Carboniferous Limestone. Its limits should be drawn in along the Derwent as described. To the south it disappears on the east-west line on a level with the coalfield, as does the strip of Grit. Starting on this level *east* of the coalfield, a continuous tract of hilly country, eight miles broad on an average, flanks the whole length of the Coal Measures and continues into the north of Yorkshire and Durham to the sea. Draw in this outcrop through Mansfield and Doncaster, and so on, crossing all the tributaries of the Ouse in turn. The blank area now left through which run the Trent and the Ouse is the Trias plain, which we remember from our chapter on Cheshire. At Nottingham the outcrop turns at right angles to join the plains of Staffordshire and Cheshire. The Trent runs exclusively

through Keuper Marls which continue on the north side of the Humber. Between the Marls and the Coal Measures come the Triassic Sandstones, soft below and hard above, just as in Cheshire.

iii. We have already studied the order of the formations which go to build this area, except the one that flanks the coalfield on the east. It is known as the Permian formation, and its place in the geological record is between the Coal Measures and the Trias. The order thus becomes :

6. Keuper Marl.
5. Triassic Sandstone.
4. Permian.
3. Coal Measures.
2. Millstone Grit.
1. Mountain Limestone.

If this order be compared with that on page 225 it will be seen that they are alike except that here the Permian formation has been introduced. Now the Permian formation also occurs in Lancashire in the same relative position, but it has not the importance there that it has in the district with which we are now dealing. In consequence it was omitted in our description of that area.

iv. We should now have no difficulty in discovering the simple structure of this coalfield and its surroundings. Draw a line *A B* (Fig. 115) equal in length to the distance on the map from the Peak through Sheffield to the

Trent. Mark off upon it the points *c*, *d*, *e*, *f*, *g*, representing the outcrops of the formations passed through. Write in their names. In which direction do they dip? It must be towards the sea, for they lie conformably one on the other, and the Limestone is oldest. Thus the Grit overlies the Limestone, the Coal the Grit, the Permian the Coal, and so on. Let us now carry out a more accurate section than we have yet attempted. It is clear that from our geological maps alone we could not discover the height of the land at any point. All we may do is to infer from our knowledge of the kind of

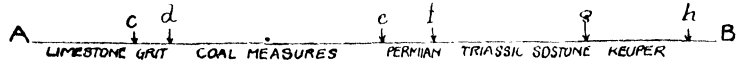


FIG. 115.

rock that crops out whether the country which it forms will be hilly or flat. We may, perhaps, say a little more than this if we also know the structure. But we cannot tell from the map what the actual height is at Sheffield or Doncaster, say. To be able to do that we should need a contoured map. Since this is not available we shall take the following heights as representative: Limestone 2000, Grit 1400, Coal Measures 500, Permian 800, Trias Sandstone 200, Keuper Marl 150. These numbers represent the heights in feet to which the respective formations rise, on passing from the Peak to the Trent along our chosen line of section. The river valleys passed through fall

to Derwent 500, Don 200, Trent 100. To make the section, draw a series of lines $\frac{1}{8}$ in. apart (Fig. 116)

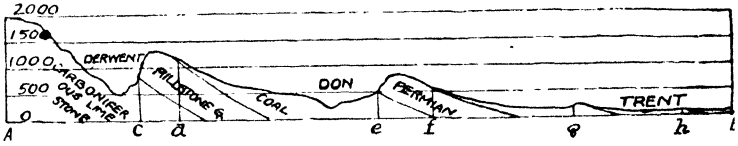


Fig. 116.

parallel to *A B*, mark them 0, 250, 500, 750 and so on up to 2000 feet. Now draw lines from *c*, *d*, *e*, *f*, *g* at right angles to *A B*. On this framework we may next draw the hills and valleys. Put the given representative heights to which the country rises in their right places in the scale according to the formation. Then put in the positions of the valleys. Join up all the points. This will give the profile as in the figure. Where the vertical lines through *c*, *d*, *e*, *f*, *g* cut this profile are the points where the formations appear on the surface. At this stage the student should turn back to page 226 and see how the section across the Lancashire coalfield there given (Fig. 100) fits in with this across Yorkshire.

Fig. 117.

v. A section from north to south through Harrogate, Leeds and Sheffield and so on to the Trent, may be carried out in a similar way.

We should find that between Leeds and the Wharfe Millstone Grit emerges from under the coal to form the Moors of the North Riding. In the south, on the contrary, the coal disappears under the Trias plain. A comparison between this coalfield and that of Lancashire will show that there are two great differences structurally: (1) the beds are undisturbed here, so that the surface of the coalfield is comparatively even; (2) it is free from faults. The structure is therefore straightforward, the beds striking N.S. and dipping towards the east in regular succession. The River Aire is a typical dip stream and the Derwent a strike stream. The Aire crosses formation after formation, while the Derwent flows always in one. The lower course of the Trent parallel to the Derwent also runs in the direction of the strike.

vi. We must describe the rocks of the Permian formation which we meet here for the first time. They are formed of a limestone which contains the metal magnesium, and the name given to this limestone is Dolomite. Towards the southern part of their outcrop by Mansfield the lower beds are sandstones and only the upper Dolomites. They are massive buff-coloured limestones, forming a fine escarpment which overlooks the coalfield, as the section shows. If we trace them further north along the outcrop they eventually reach the sea and form limestone cliffs. They constitute a valuable set of rocks for two reasons.

(1) They provide some of the most magnificent

building stones in England, the Palace at Sandringham being built of Mansfield sandstone as well as the Law Courts in London. Besides this, the Magnesian Limestone of Bolsover, near Mansfield, supplied the material for the Houses of Parliament. From Huddlestone, further to the north, came the building stone for King's College Chapel in Cambridge, one of the finest buildings in the world. It dates from 1446, so that it has withstood the storms of more than four centuries.

(2) Dolomite also possesses the property of removing impurity from iron when iron is being converted into steel. The Bessemer Convertor is lined with bricks of Dolomite. When the molten iron is run in, the compound of magnesium in the Dolomite removes the impurity in the iron. In addition to possessing this property, it is extremely hard to fuse, so that it forms suitable linings for furnaces.

vii. Next let us see how the hills and valleys depend on (1) the rock types, (2) the structure. First there is the mountainous country formed by the Carboniferous Limestone and the Millstone Grit. This is the Peak district and that of the Pennines between Lancashire and Yorkshire. From our sections across these two countries we see that this moorland is partly due to its anticlinal structure and partly to the hardness and resistance to weathering of the rocks which form the anticline. These mountains and moorlands are treeless and intersected by deep valleys. They afford pasture for thous-

ands of sheep. The Derwent has carved a very beautiful valley for itself in which are situated a number of excellent health resorts. Up the valley through Belper and Matlock cliffs of Millstone Grit and Carboniferous Limestone rise on each side. The little tributary streams which enter the Derwent from the limestone have hard water, and those from the grit soft water, for limestone makes water hard. The Coal Measures are not mountainous, as those of Lancashire are, through their disturbed structure. Here they dip gently and uniformly so that the hills in the Coal Measure district are due more to the wearing away of the softer rocks by water than to earth movements. As our diagram illustrates, and as the directions of the rivers show, they rise towards the west as they approach the Peak and Pennine district, and this, of course, is structural. The rivers that cross the Coal Measures on their way to the Ouse start in the Pennine chain and carve out deep and narrow valleys for themselves in which little industrial towns spring up which use the water. These valleys form the highways between Yorkshire, Lancashire and Cumberland, and are followed by the railways. Usually the railway follows the valley up the east side, crosses the highest part of the pass by means of a tunnel two or three miles long and then runs gently down the valley on the other side of the dividing range. The deep valleys continue into the Coal Measure district, where they broaden and where

larger towns grow on their banks. Here they are met by a great number of tributaries, and, thus reinforced, break through the Permian escarpment and reach the Trias Plain. The River Ouse has worked along the soft plain as a strike stream and collected the dip streams from the coalfield and the moors and taken them along to the Humber. (Compare the Mersey with the Ouse and the Weaver with the Trent.)

viii. Since the hilly districts each side of the central Pennine moorland repeat each other in structure and formation, as Figs. 100 and 116 show, we should expect Yorkshire to be engaged in the textile industry, for the same reasons that Lancashire is. The industry has grown up in the Aire and Calder valleys. These river valleys form excellent paths of communication across the Pennines for rail, road and canal. The Aire and Calder Canal, which is 85 miles long, carns more than any similar canal in Britain, although it does not carry so much as the Birmingham system. These two river systems were originally the sources of power for the spinning and weaving mills. But the coal in the formation through which they flow has now replaced the water as a source of power. The particular branch of textiles in which Yorkshire is engaged is the woollen industry. In early days, the small water-driven mills were supplied with wool wholly from the pastures which the Pennines and the Lincolnshire Downs afford. But as our export

trade grew, this source of raw material became insufficient and in consequence foreign and colonial wool was shipped to London and to Hull for Yorkshire. Hull is much further from the weaving district of Yorkshire than Liverpool is from the Lancashire district. Indeed, the Yorkshire textile district is in very close touch with that of Lancashire, both because their interests are similar (flannels, for instance, are largely made at Rochdale and woollens at Bury) and because they are all centred naturally in Manchester on account of the physical structure of the two districts. Yet Hull is the port from which great quantities of raw materials enter Yorkshire and from which finished woven materials are shipped to the Continent. It is the Liverpool of Yorkshire. Raw cotton which enters Liverpool is manufactured in Lancashire, marketed in Manchester, crosses the Pennines by one of the passes to Hull and is shipped to the Continent. Thus Hull is an important export port for Lancashire as well.

On the Calder system, the chief centres are Dewsbury, Halifax and Batley, which make army clothing and carpets (another branch of the textile industry), and Huddersfield, which is the centre for worsted cloth. On the Aire, Leeds and Bradford make cloth for suits. Huddersfield is also the most important town for the manufacture of dyes, and works in close conjunction with Manchester. Cloth is dyed in most of the above-named centres. The

textile industry is not limited to this northern part of the coalfield, but it is developed again in Nottingham and Derby.

ix. The coalfield which supplies the area with power supplies it also with iron for machinery. Ironstones are found bedded with the coal seams and are smelted with the coal and limestone from the Pennines. Another valuable mineral found in the Coal Measures is Ganister, which is used to line the furnaces in making pig-iron. Iron occurs in rich deposits at Low Moor and in the surrounding district. Here the seams are about one foot thick. Ironstone beds are again valuable between Sheffield and Barnsley, but although they occur right on to Nottingham they are no longer worked, richer ores from other districts being used in the industry. In the neighbourhood of Chesterfield oil has recently been struck. The headquarters of the steel industry is Sheffield, which, besides, uses the steel in the manufacture of its famous cutlery. Sheffield can depend on the following raw materials from local supplies, each from mines and quarries : (1) Coal, (2) Ironstone, (3) Ganister, (4) Limestone, (5) Dolomite, (6) Millstone Grit (this last for grinding purposes). A little thought will show their uses and help to account for the steel industry in the Don valley.

The steel is manufactured into locomotives, rails, machinery and tools of all descriptions. Sheffield is also the home of the special steels which are alloys of the metal iron with some

more valuable metal such as manganese, nickel, vanadium, chromium and tungsten. These special steels have various excellent properties which make them extremely useful. Manganese steel, for instance, is very tough, and is thus suitable for crushing machinery, or for steel rails. One nickel steel hardly expands at all with heat. Other steels do not soften and lose their edge when tools made from them get hot in the lathe. Chromium steels do not rust nor stain, and are therefore useful for cutlery. Others do not affect a magnet, and nickel steel possesses great tensile strength and is therefore extremely valuable in bridge building, for its strength enables the engineer to use very much less of it than he would need of ordinary steel. Some of these special metals are prepared in Widnes for further use in Sheffield. The special steels are largely made in electric furnaces.

x. Our district is famous for its supply of building stones. We have already dealt with the valuable Magnesian Limestones and Sandstones of the Permian system. The Coal Measures have supplied a vast quantity of freestone and flagstone for building and paving. The freestone has a buff colour and was used to build the War Office in London and the Woolwich Arsenal. It comes principally from quarries in the neighbourhood of Huddersfield, Halifax and Bradford, and is extensively used in building in this thickly populated district. It is known as York stone. Mill-

stone Grit both from the Derwent valley and from the district north of Leeds, where the Aire and Wharfe cut through the Pennines, is quarried for building stone. In a previous chapter we mentioned well-known constructions for which this stone was used. It is quarried in the Derwent valley for other purposes than building. It is made into millstones, grindstones and stone parts of pulping machinery for use in the paper industry.

xi. The Trias plain through which flow the Ouse and the Trent is entirely agricultural and feeds the more populous coalfield. It is a counterpart of the Dee valley and the Cheshire plain. But no brine is found in the marls here. Just as the Weaver is canalised in the red marls, so is the Trent. A further similarity is in the position of the capital, York. It is an ancient cathedral town situated in a fertile plain at a strategic point in the river. York has all the features that make Chester and Shrewsbury admirable county administrative centres.

CHAPTER XXIX

SCOTCH COALFIELDS : SHIPBUILDING

i. TRACE, for this chapter, the estuaries of the Clyde and the Forth, and the parallel courses of these rivers. Put in also the Ayrshire coast as far as Ayr. Then mark on the sketch map the following towns: Glasgow, Hamilton, Lanark, Edinburgh and Stirling. On the Ayrshire coalfield, note the towns of Irvine, Kilmarnock and Ayr. On the Lanarkshire coalfield, note Airdrie, Coatbridge and Motherwell; and in the neighbourhood of Glasgow, Renfrew, Paisley and Greenock, south of the Clyde mouth, and Dumbarton north.

ii. No formations newer than those which we have already considered in previous lessons occur in the Clyde basin.

The following are represented :—

5. Coal Measures.
4. Millstone Grit.
3. Carboniferous Limestone.
2. Old Red Sandstone (Devonian).
1. Silurian.

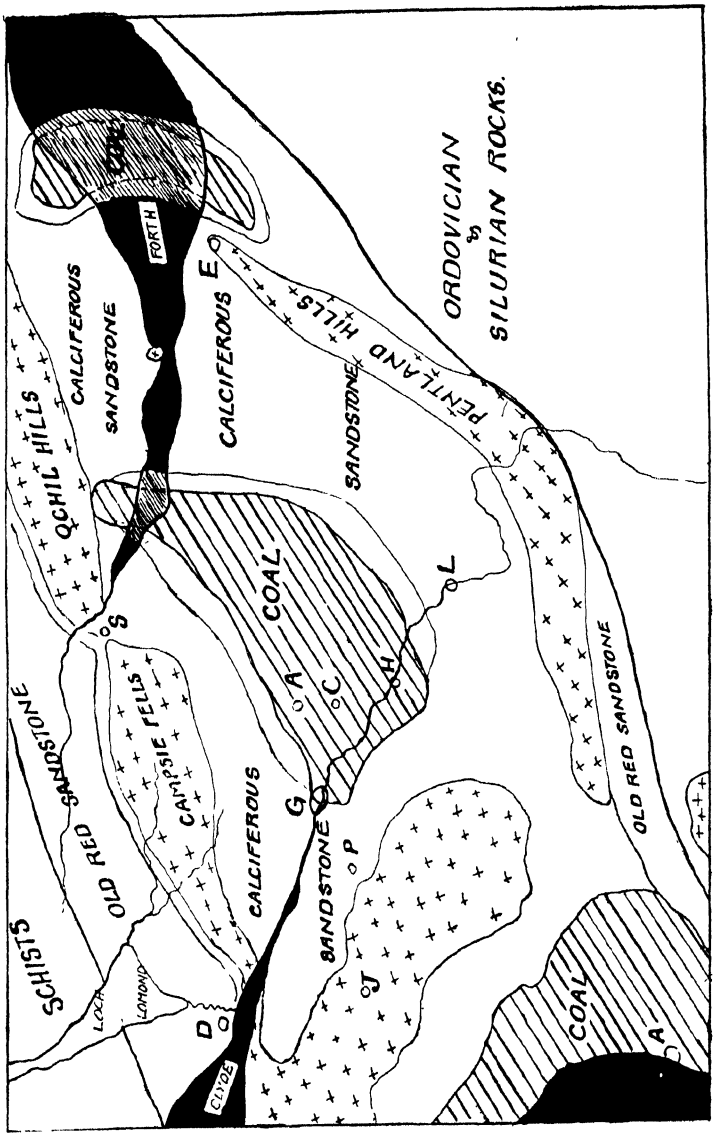

SCHISTS
LOCH LOMOND
OLD RED SANDSTONE
CAMPSIE FELLS
CALCIFEROUS
SANDSTONE
D
CLYDE
OCHIL HILLS
CALCIFEROUS
SANDSTONE
S
FORTH
COAL
A
C
H
G
P
J
CALCIFEROUS
SANDSTONE
E
SANDSTONE
PENTLAND HILLS
L
ORDOVICIAN
&
SILURIAN ROCKS.
OLD RED SANDSTONE
COAL
A

FIG. 118.

Triassic rocks, which we have learnt to expect above the Coal Measures, are absent from the area, except in one small patch on the Ayrshire coalfield, where they occur as an outlier. An *outlier* is the name given to a patch of rock resting upon older rocks and separated from its main outcrop. But a feature of the district which is absent from the English coal basins is the dominating presence of volcanic rocks. These, as we shall see, practically decide the topography.

iii. We shall first indicate the outcrop of Silurian rocks. If we join the towns of Girvan on the Ayrshire coast and Dunbar on the North Sea coast by a straight line, we may say that south of this line the rocks are Silurian. A line drawn parallel to this through Greenock will define the area which we are about to discuss. North of this line the rocks have been so changed that their nature has not yet been fully explained. They are all crystalline. The Coal Measures occupy three separate basins within the two lines defined above :

(1) From the sea coast at Ayr inland.

(2) From Glasgow across the River Forth in a N.E. direction, and 25 miles down the Clyde in a S.E. direction.

(3) East of Edinburgh and across the Firth of Forth to Fifeshire.

Round each of these basins stretches a fairly continuous band of Millstone Grit. The three coalfields thus marked out, together with the whole of the Firth of Forth, are situated in a

surrounding outcrop of Carboniferous Limestone. The Carboniferous Limestone series of Scotland differs altogether from that of England and Wales, although its age is, of course, the same. Instead of limestone forming the greater part of the deposit, it only occurs in the uppermost beds. The underlying beds are mainly formed of sandstone. But the sandstone is peculiar in having its individual sand-grains cemented together by Limestone (calcite). In consequence, the formation is often referred to as Calciferous Sandstone. To the east, in the Lothians and Fifeshire, a shale comes in which yields petroleum when it is distilled. Underlying this, both north and south, the Old Red Sandstone formation fills up the area defined by the two lines fixed above.

iv. It remains now to insert the igneous masses. With a few small exceptions they are volcanic and occur within the Carboniferous Limestone outcrops. North of the coal basins stretch the Campsie Fells and the Ochil Hills. Between the Ayrshire and the Lanarkshire coalfield stretch the volcanic fells of Renfrewshire overlooking the sea. The semicircle of these hills is continued south of the Ayrshire coalfield in the granite mountain of Merrick. The Pentland Hills, which run S.W. from Edinburgh, are similarly volcanic.

v. A section across the three coalfields at once shows their synclinal structure.

The Ayrshire coalfield dips under the sea. Behind it rise the volcanic fells of Renfrew-

shire. These slope away to the Clyde valley where it crosses the Lanarkshire coalfield. If the Forth and the North Sea had not breached

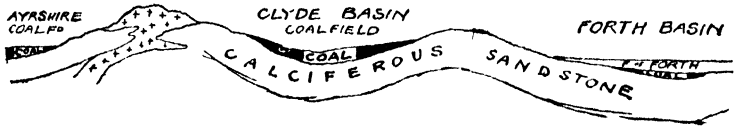


Fig. 119.

the Coal Measures of the third basin we should at once have recognised its structural similarity to the second.

A section across the coalfield from N.W. to S.E. would again reveal a synclinal structure. Both north and south the syncline is cut off by faults, the positions of which are given by the straight lines indicated in paragraph iii.

vi. When we come to look at the topography we are first struck by the fact that the two main rivers flow parallel within 30 miles of each other in opposite directions! The volcanic rocks of the Campsie Fells form one part of the watershed which separates them. The sandstones of the Coal Measures which rise gradually to the volcanic rocks of the Pentland Hills complete this watershed. These form continuous high ground running from N.W. to S.E. between the two rivers. Indeed, the headwaters of the Kelvin, which flows into the Clyde, and of Bonny water, which flows into the Forth, are only a few miles apart at the pass east of Kilsyth. Moreover, a small canal follows the valley from Bowling on the Clyde to Grange-

mouth on the Forth. But the difficulties of constructing a ship canal along the valley have not yet been overcome. The Ship Canal to Manchester and that to Gloucester certainly climb from the sea to the inland town, but in each case up the valley. A ship canal from Glasgow to the Forth would need to climb from the Clyde to the head of the Kelvin valley and then drop to the Forth estuary on the other side. (An alternative route is round the north of the Campsie Fells.)

vii. We must now account for the unusual topography which makes the Forth and the Clyde flow in opposite directions, although they are parallel and not far apart. The Clyde rises in the pre-Carboniferous district to the south. As we remember from the Welsh borderlands, these rocks are invariably mountainous. It is from these uplands (2500 feet) that the Clyde takes its rise. Then in its journey north-west it is confined by the volcanic mountains of Renfrewshire on one side and by the uplands described in paragraph vi on the other. Its journey is thus fixed across the Lanarkshire coalfield. Its estuary round by Greenock is similarly due to the Renfrewshire volcanic rocks which occupy the N.W. corner of that county and rise to a height of 1500 feet. In consequence, the estuary does not immediately open into the sea, but follows a semicircular channel. The Forth, on the other hand, comes down from the old crystalline rocks north of our area, which also form

mountainous country, more mountainous indeed than the Silurian and Ordovician rocks of South Scotland. It flows more directly to the sea than the Clyde, since the rocks through which its estuary has been carved out are not reinforced by volcanic masses. Consequently, the sea and the river have breached the Lower Carboniferous Sandstones, destroying most of the third coal basin and cutting across the second. Small volcanic outcrops occur in each side of the estuary, and good use is usually made of their excellent sites. The Clyde is bridged from Queensferry on to such a volcanic outcrop, and on the Fife coast the superb position of Edinburgh is also due to a volcanic mass.

viii. We have already referred to the coal and iron of the central coalfield which led to Glasgow's industrial pre-eminence in Scotland. The history of steamship building is closely connected with the Clyde. In 1812 the first steamship commenced to ply between Glasgow and Greenock. Since that time, when the Clyde at Glasgow even at high tide was only 5 or 6 feet deep, Glasgow engineers have not ceased to improve the waterway, until to-day the largest vessels can reach the city, and the finest liners are launched from her shores. Besides iron- and coal-mining, smelting and marine engineering, for which to-day the Clyde is chiefly famous, the textile industry is of very great importance, particularly in the towns west and south-west of Glasgow. The textile

industry of this district has indeed an older origin even than shipbuilding, for Glasgow of the early nineteenth century owed her wealth to cotton and tobacco.

Coal from the Ayrshire basin is shipped to Belfast, where industries similar to those of Glasgow are carried on. Belfast rivals Glasgow in output of steel ships, and in liners holds the first place.

ix. The Calciferous Sandstone round the Scotch coalfields yields some excellent building stones. Edinburgh has been supplied with Craigleith stone for a great number of fine buildings. This stone has even been shipped to London and was used in building the Bank of England. A beautiful cream building stone from the same series comes from Tranent, east of Edinburgh. In Renfrewshire, the same series has been quarried to supply Glasgow and other towns in the district, chiefly from Giffnock. The same sandstones yield the oil shales which are mined in the Lothians. As much as three million tons of oil shale are mined yearly. Each ton of shale yields twenty gallons of oil and forty-five pounds of ammonium sulphate, which is used as a fertiliser.

As for food, the industrial districts are well supplied from the pastures which the fells afford, and from the agricultural produce of the river valleys.

CHAPTER XXX

IRON-BEARING LIAS: THE CLEVELAND DISTRICT

i. The Liassic clays which follow on the marls of the Midland counties as we travel south or east away from them constitute one of our most valuable formations. Besides giving rise to a soil of extreme fertility as pasture, the Lias formation and the sands which overlie it provide eighty per cent. of our iron ores. Let us first consider the district which for many years has been the richest iron field in England, namely, the Cleveland district of the North Riding of Yorkshire.

ii. Draw the coast-line from the Tyne to Flamborough Head, and fix the following towns: Newcastle, Sunderland, Middlesbrough, Stockton, Darlington, Richmond and York. Mark the courses of the Tyne, Tees and Swale. Put in the outcrops of the various geological formations as follows: As far as the Tyne, Coal Measures reach the coast. Between the mouth of the Tyne and the mouth of the Tees, Magnesian Limestone of Permian age follows. The Tees wears a wide estuary for itself in the Triassic Sandstone and Keuper Marl. To the

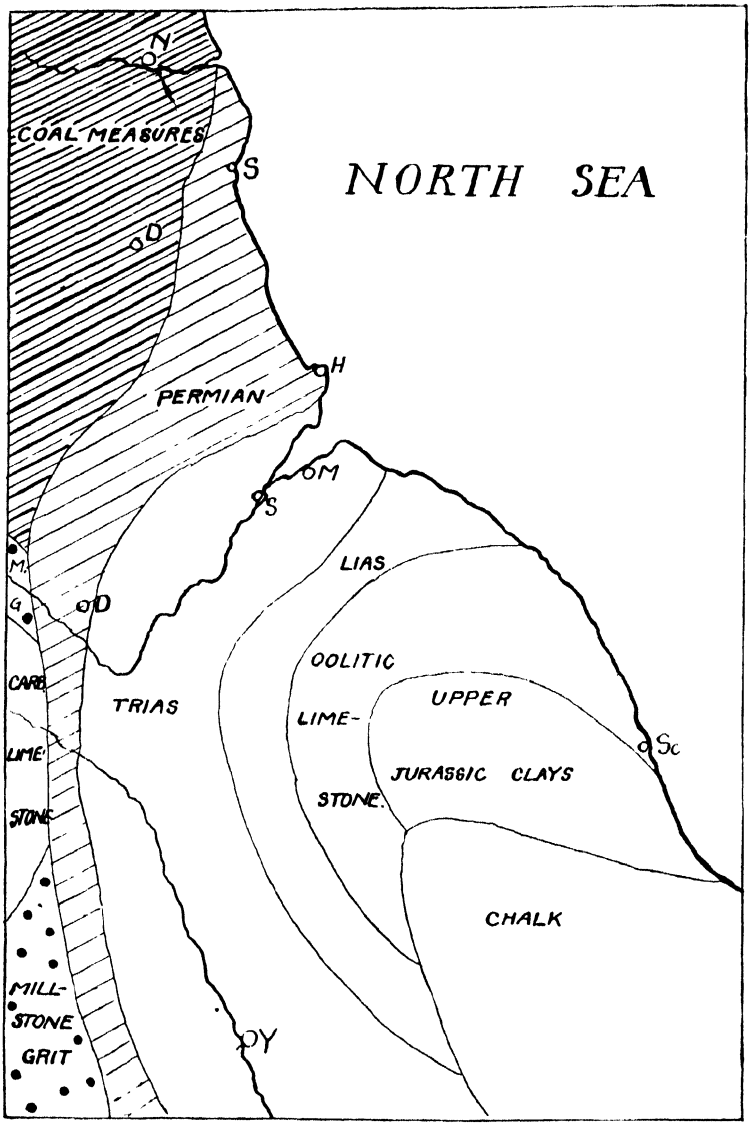

N
COAL MEASURES
S
NORTH SEA
D
H
PERMIAN
M
S
M.
G
D
LIAS
OOLITIC
CARB.
TRIAS
LIME-
UPPER
Sc
LIME-
JURASSIC CLAYS
STONE.
STONE
CHALK
MILL-
STONE
GRIT
Y

FIG. 120.

south of this estuary the Lias appears, followed by a long stretch of coast of limestone cliffs formed of Oolites. This takes us as far as Scarborough. Then come Jurassic Clays by Filey, and lastly the Chalk of Flamborough Head.

iii. We have already seen how the Permian Limestones flank the Coal Measures of Yorkshire. This structure is repeated again in Durham, and the strike stream of the Tees, flowing north in the Triassic sandstones, is a counterpart of the Swale and Ouse, which flow south along the same formation. The formations which are new to us comprise :

4. Chalk,
3. Jurassic Clays,
2. Oolitic Limestones,
1. Lias,

and in this chapter we are most closely concerned with the oldest, namely, the Lias. The first three systems, namely, the Lias, the Oolitic Limestones and the Jurassic Clays, together form the three chief divisions of the Jurassic system. The Chalk, which follows, is the chief member of the next system, namely, the Cretaceous.

The Lias shows an almost uninterrupted outcrop from the sea in North Yorkshire across England to Dorsetshire. This outcrop runs parallel with the Triassic rocks through which flow the Tees, the Yorkshire Ouse, the Trent and the Severn. The other two Jurassic for-

mations follow in order. But the Chalk overlies these formations unconformably, so that its outcrop cuts across the outcrops of the underlying beds, instead of running parallel to them, and even steps on to the Trias.

iv. We are now in a position to draw a section across the area, and to decide roughly

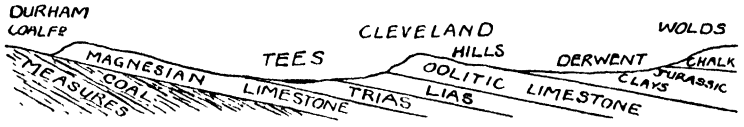


Fig. 121.

its structure. Let us first take a section across the Tees valley from the Chalk to the Coal Measures of Durham (Fig. 121).

Along this line of section each formation follows in order, dipping gently eastward. But a section from the Wolds (as the Chalk hills are called

Fig. 122.

in Yorkshire and Lincolnshire) across the Ouse valley south of York would reveal two unconformities (Fig. 122).

In the first place, the Chalk transgresses on to the Trias, covering the Jurassic formation altogether, and in the second place, the Permian Limestone oversteps the Coal Measures, which are thus hidden from view, and rests on the

Millstone Grit. Consequently, in travelling from Harrogate to the sea through York, no Coal Measures with their industries are encountered, nor do Jurassic hills intervene. Instead, you come immediately on to the Downs.

v. For our purpose in this chapter we need only describe the Lias formation. The Oolitic Limestones which form hills overlying the Lias country, the Jurassic Clays which overlie them, and the Chalk Downs will be described in the chapter on the River Thames (Chap. XXXII). All we need notice here is that the topography is decided by (1) the strike of the soft Triassic beds along which the Tees works, and (2) the high ground which the Permian and Carboniferous rocks form on the north-west of its valley, and which the Oolites of the Cleveland Hills form on the south-west. A glance at section 121 will make this topography quite clear.

The Lias of North Yorkshire is unlike the rich clay and limestone formation which affords such excellent pasture in the same formation in Gloucestershire, Warwickshire and Leicestershire. Here, where it is richest in iron, it is no longer formed of clay and limestone, but of sands and shales which contain four thick seams of ironstone, in the place of limestone. The main seam is eleven feet in thickness. The ore is mined by drilling and blasting, the bord and pillar system being followed. The mines are situated among the villages in the north-west of the county, where the Liassic formation

occurs. The amount of ore mined in Cleveland in 1915 was four and three-quarter million tons, which represents roughly a third of the country's home supply.

vi. Limestone from the Cleveland Hills, coal from Newcastle and refractory materials from the Permian rocks have then facilitated the rise of a great steel industry in this corner of Yorkshire.

The Keuper Marls of the Tees valley, again, carry salt, which has developed those acid and alkali industries which depend upon it. Middlesbrough has risen rapidly to be the centre of this industrial district since the discovery of the Cleveland ironstone in 1850. From the point of view of the presence of raw materials this town has an excellent position. Moreover, it possesses, in addition, excellent docks for the export of its steel plates, tubes, girders, wire and chemicals, and has easy communication through the Triassic plain to York and thence to London. It is interesting to remember that the first railway in England, constructed in 1825, ran between Stockton and Darlington in the Tees valley.

vii. Where the Lias reappears from beneath the overlapping Chalk, south of the Humber, it is again rich in iron ores. The structure of the district is straightforward once again. The Humber estuary breaks across the strike of the Cretaceous, Jurassic and Triassic rocks which we have described. South of the estuary, the outcrops of these rocks continue in more or less

parallel bands, widening towards the Wash drainage area, where the sea has breached the Chalk between Hunstanton and Skegness and encroached upon the Jurassic Clays of the Fens.

The Trent flows through the Keuper Marls past Gainsborough and Newark. Even where it turns to flow through the Midlands, it maintains its character as a stream flowing exclusively through Keuper Marls. But the Witham, which, with its tributary, flows more or less parallel to the Trent in the neighbouring Lias

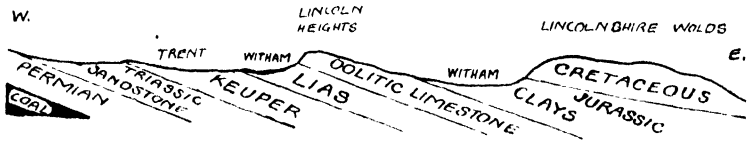


FIG. 123.

Clays, breaks through the Oolitic hills at Lincoln and gains the Wash through the Upper Jurassic Clays. Thus, whereas the Trent remains a strike stream, the Witham changes and becomes a dip stream. The position of Lincoln is one which in Roman days was so eminently suited for the establishment of a city, a hill upon which a castle, and later a cathedral, might stand, with a protecting river. The Oolites upon which Lincoln is built then continue as a broad tract of hilly country south-west across England. They are followed across by the overlying Chalk Downs. The general structure is given in Fig. 123.

viii. The second richest ironfield in Great Britain is found on the south shores of the Humber in the Lias outcrop. The product is known as Frodingham ore. In this district, the calcareous ores are won from open quarries. The iron-ore bed is sometimes as thick as twenty feet, the formation has a gentle dip and is free from faults. In 1915 this district supplied three million tons of ore, or rather more than a fifth of the country's whole output.

CHAPTER XXXI

THE NORTHAMPTON SANDS

i. WHEN the Jurassic outcrop is traced south from Lincoln, it rapidly increases in breadth until between Leicester and Cambridge it is about seventy miles broad along the dip. The Lias formation remains ferruginous. In Leicestershire, ironstone is worked from the calcareous bands in the Lias Clay at a dozen villages, the total yearly yield being somewhat less than three-quarters of a million tons. Apart from its economic use the Lias here forms excellent permanent pasture. The agricultural towns of Melton Mowbray and Market Harborough are markets for this produce. A glance at the map will show that this part of the Lias formation is drained by the Trent. This is because the Oolites still form the dominant watershed across the Midlands.

ii. Northamptonshire with an output of $2\frac{1}{2}$ million tons a year has the third largest output of iron ore of any district in the British Isles. It is not, however, the Lias which here carries the ore, but the overlying Oolitic formation. In Northamptonshire the limestones

of the Oolitic formation are largely replaced by a sand which contains ironstones. A journey

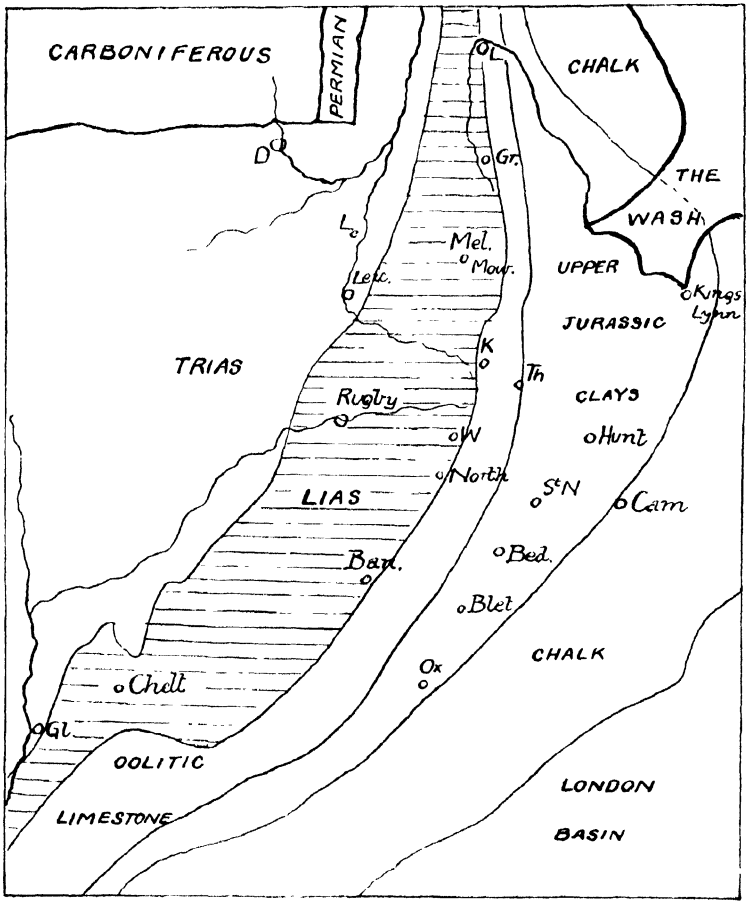


FIG. 124.

across the strike of the rocks from Huntingdon to Leicester will at once reveal the way they are exploited. Between Huntingdon and Thraps-

ton the road lies level and the Jurassic Clays are used as pasture. But between Thrapston and Kettering, where limestones and sands come in, great quarries are opened for ironstone and for limestone, which are taken to the Kettering furnaces. The road then leads into the valley of the Soar, which flows through Leicester. The Jurassic outcrop thus divides the Fen drainage from the Midland drainage.

iii. A great number of small towns and valleys are engaged in winning iron ores in Northamptonshire.

There are about 20 feet of sandy, brown, iron-bearing sands which are worked in the manner described in Part I by stripping the overburden and quarrying the ore. The ore is sometimes got by means of steam shovels, but underground workings also exist. The only remaining district of importance as an ironfield is in the Lias round Banbury, which, however, does not yet rank with the Cleveland, Lincolnshire and Northamptonshire deposits. The ores mined from Banbury are carried to the Black Country for smelting. The Lias formation remains ferruginous through Wiltshire and Gloucestershire, but it is now hardly worked in these counties. On the other hand, in the Severn and Avon valleys it gives rise to some of our best soils for orchard and dairy-farming.

CHAPTER XXXII

THE RIVER THAMES AND LONDON

i. From its source in the Cotswold Hills to the Port of London, the River Thames crosses all the remaining geological formations of

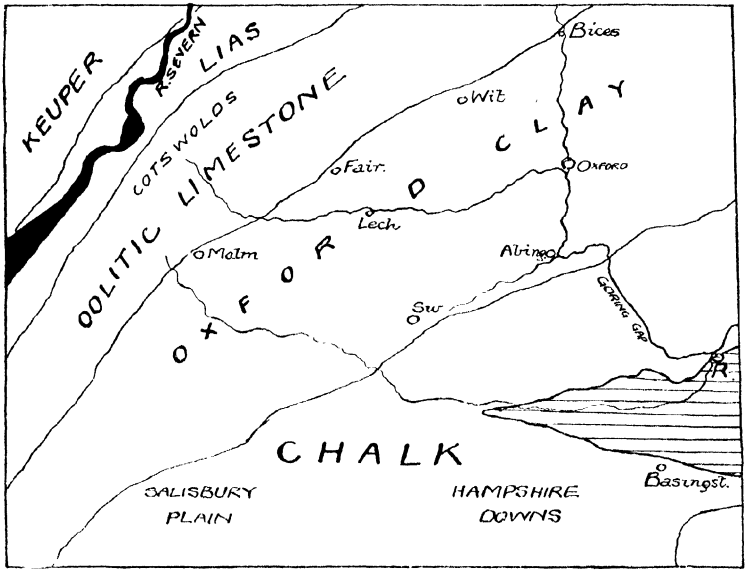


Fig. 125.

Great Britain that we need know. We shall require for this area a two-page sketch map

extending from the estuary of the Severn between Gloucester and Bristol to the estuary of the Thames at Sheerness. First mark in the estuaries. Then trace the following towns :

Starting north of London : Bishops Stortford, Hertford, Watford, Maidenhead, Reading, Newbury.

Starting south-west of London : Basingstoke, Guildford, Epsom, Croydon, Gravesend, Rochester, Chatham.

Roughly parallel with the lines which these

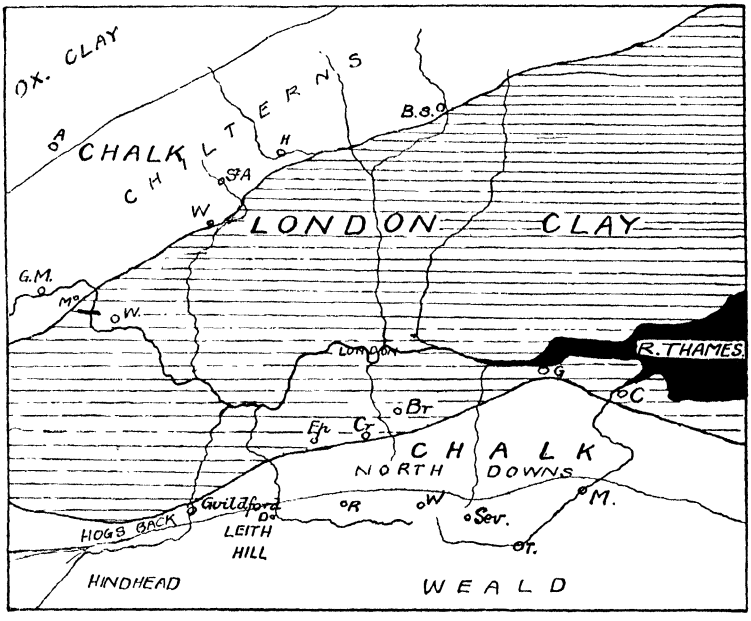


FIG. 125.

towns form continue : on the north, Aylesbury, Abingdon, Swindon ; on the south, Dorking,

Reigate, Westerham, Sevenoaks and Maidstone.

On the north again mark down a further line of towns, namely: Malmesbury, Fairford, Witney and Bicester.

ii. The formations through which the Thames flows are:

Eocene ..	5. London Clay.
Cretaceous	4. Chalk.
	3. Greensand and Gault.
Jurassic ..	2. Jurassic Clays of which the Oxford Clay is chief.
	1. Oolitic Limestones.

The outcrop of the London Clay (and the gravel beds associated with it above it and below) will be given by joining up the first two lists of towns in the previous paragraph from Bishops Stortford to Newbury and thence south of London to Gravesend and Chatham. Within this area, which forms the basin of the lower Thames, a stiff bluish clay, weathering a brown colour towards the surface, very largely predominates. But outside the area we pass on to the Chalk Downs. North of London they are known as the Chiltern Hills and south as the North Downs. The width of the Chalk outcrop varies considerably from about a mile at Guildford to twenty in Hertfordshire. By joining the towns comprised within the third

list in the previous paragraph the outcrop of the Chalk of the Chiltern district will be defined. These towns actually lie in the Upper Jurassic Clays which underlie the Cretaceous beds, and between them and the Chalk Downs there is an outcrop of Greensand and Gault. The Jurassic Clays, of which the Oxford Clay is the chief, form a strip of valley country twelve miles in breadth defined by the last list of towns from Malmesbury to Bicester. The Oolitic Limestones strike parallel to the Oxford Clay. Beneath them lie the Liassic Clays, and beneath these again the Triassic Sandstones and Marls of the Midlands. On the south of London the towns of Maidstone, Sevenoaks, Reigate and Dorking, which lie in the Greensand, give the approximate position of the Chalk outcrop. Between Guildford and Farnham this outcrop narrows to a ridge scarcely a mile wide and known as the Hog's Back. Beyond Farnham the Chalk broadens to the south across Hampshire and extends westward to Winchester and Salisbury.

iii. The first section to take is one across the Thames valley through Hertford to Croydon.

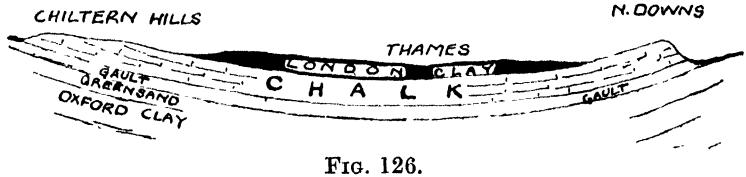


FIG. 126.

The river lies in a syncline of clay which is about 35 miles across at London. The Chalk

emerges from beneath this basin both north and south. Further beneath it follow older and older rocks in order, Jurassic, Carboniferous and pre-Carboniferous. (The Trias is absent from below the London basin.) The next section, from Reading to Gloucester, across the Cretaceous and Jurassic outcrops shows how these formations come up from beneath the newer rocks of the London basin.

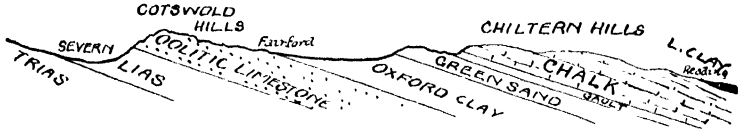


FIG. 127.

On the south side of the Thames they do not reappear at the surface, since, as we learnt in Part I, the Thames basin is followed by the Weald anticline, so that although the Jurassic rocks dip upwards towards the surface they only form a small inlier as a core of the anticline near Heathfield in Sussex. It is this anticline which brings the Coal Measures near enough

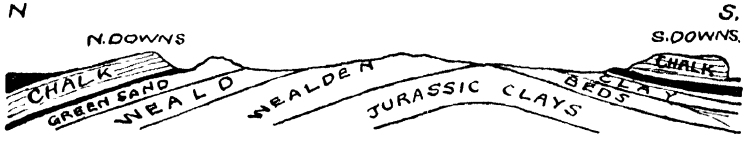


FIG. 128.

to the surface to make it possible to reach the coal by shafts.

iv. We should now have a clear conception of the structure of the country which the Thames

drains. Next we shall resume in a few words the characters of the various formations.

The Lower Oolites are a fine Limestone formation which have weathered into a clearly defined range of hilly country traversing England from S.W. to N.E. The scarp slopes of these hills face north-west and the dip slopes fall gently south-east. It is interesting to notice that this range, composed of rocks younger than the Coal Measures, naturally divides England into two. The great industrial districts which we have studied lie to the north of it on older rocks, while south of it the country is chiefly agricultural. The Limestone yields two of our finest building stones, the Bath Stone and the Portland Stone, each from the district after which the stone is named. Oolitic limestone may be easily distinguished by a close scrutiny of the grains. These will be seen to be perfectly spherical, granular, with the appearance of a hard roe. Houses and hedges in Oolitic counties are built almost entirely of one or the other kind of limestone, so that the whole countryside is dotted and intersected with grey buildings and walls in place of green hedges.

v. The Upper Jurassic Clays, which follow on the Limestone, form another clearly marked band of rich valley country between the Oolitic hills and the Chalk Downs. These clays run across England parallel in outcrop with the limestones just described. At the Wash they have been gradually eroded and swallowed up.

The Welland, the Nene and the Ouse strike along them into the Wash.

The Lower Cretaceous rocks consist of a series of clays and sands, two of which are important, namely, the Gault and the Greensand. These almost invariably accompany the Chalk. The Gault forms a narrow but well-marked valley at the foot of the Chalk escarpment, and the Greensand forms irregular, picturesque and well-wooded hills. Chalk scenery is extremely characteristic. Its hills are invariably smooth in outline with no abrupt changes. The tops of the hills are often flat, covered with flints and sometimes with a clay derived from the Chalk which has been eroded. Their grassy slopes form a rich pasture for sheep, and the bright green sheep walks along the Downs are unlike those on any other formation. The Downs are usually treeless, although beeches thrive well upon them. Where a quarry has been opened its dazzling white faces may be seen for miles against the green slopes.

vi. Let us now trace the course which the Thames pursues from its source to the sea. Several small streams from the limestone dip slopes of the Cotswolds in the neighbourhood of Sapperton, unite as they approach the plain which the Oxford Clay forms. Once the main streamlet gains the clay, it works along it merrily as a strike stream. Itself now the dominant stream, it collects tributaries from the Cotswold dip slopes on the one side and from the Cretaceous scarp slopes on the other. Continuously

reinforced in this way, it is large enough by the time it has travelled 15 miles to allow barges to navigate it, for the Thames may be reached by barges as far as Lechlade, 120 miles from the sea.* It continues to flow as a strike stream, growing slowly from the hills on each side for a distance of thirty or forty miles to Oxford, where it is joined by its first considerable tributary, the Cherwell. This stream flows due south as a dip stream from the limestone hills of Banbury. The two streams, now united, continue as a dip stream. Making its way across the Upper Jurassic Clays at Abingdon (where a smaller strike stream from Faringdon meets it), and working round the base of a Greensand hill, it comes by a circuitous path on to the Chalk and carves the magnificent Goring Gap through the Chalk hills and so reaches Reading.

vii. At Reading it is joined by the Kennet. But instead of continuing its course on to the London Clay, it turns and flows another twenty miles through Henley and Marlow as a strike stream in the soft Upper Chalk. By Maidenhead it leaves the Chalk and follows a meandering easterly course as a strike stream through the London Clay basin. Once it has reached the London Clay it receives a series of dip streams from the Chalk slopes of the Downs to the north and south. These are the streams which have carved the topography of the London area, and of London itself. It is

* Compare page 45.

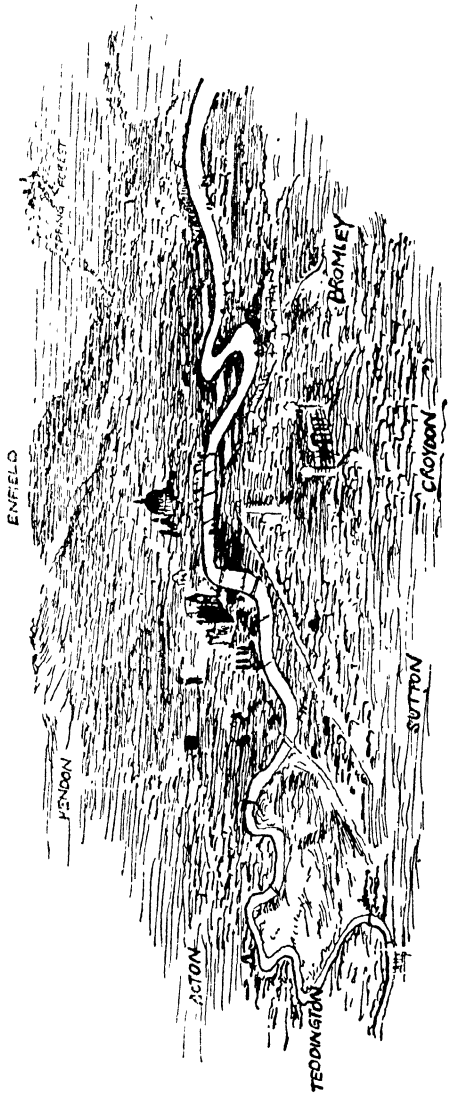
to them that London owes that excellent radial system of communications which we described in Chapter XXI. Each one forms the highway across hilly country for some railway or main highway. Those to the north rise in the Chalk, but to the south, where the Downs are near London, they have generally carved valleys through the Chalk and the Greensand and rise in the hilly Wealden beds beyond.

viii. The Thames, then, can neither be called a strike nor a dip stream. It rises on the Lower Oolites as a dip stream and traverses the harder formations between Oxford and Reading similarly as a dip stream. The pass-like valley it has worn through the Chalk between these last two towns is typical of a stream cutting across the strike of hard beds. But where it flows through clay counties, between the Cotswolds and Oxford, and between Windsor and London, the type of valley is very different. As a strike stream in the Oxford Clay it flows in the right direction of the formation to receive dip streams from the dip and scarp slopes of the underlying and overlying harder rocks, and again in the London Clay it receives the dip streams from the Chalk. Where its course is typically across the strike it does not receive any tributary waters, since its valley is narrow and the sides of the valley are steep.

ix. When a river is working along the strike of some soft formation and has cut its valley down until it lies only a few feet above sea-level,

there is not sufficient forward force in its waters to carry it straight to sea. Instead, it turns from its direct route to the sea to avoid every small irregularity in the formation. If the clay is a little harder or capped with gravel at one point, it turns to flow round it. Once it has turned from its direct course, the curves in its passage automatically become more pronounced, for the river deposits some of its load on the inside of the bend where the water slackens its speed, and erodes the bank on the outside of the bend where its speed is greater. In this way the river meanders, covering the plain with its alluvium. Now the Thames at its source is only about 360 feet above sea-level. Consequently it is nowhere a swiftly flowing stream, and where it works along the Oxford and the London Clays it is a characteristically meandering stream.

x. Its tide rises as far as Teddington (Tide-end-town), a distance of seventy miles from the sea. For many centuries the river was bridged first at London Bridge, where it is about 300 yards wide. The City of London naturally grew up at the strategic point where the river was first narrow enough to be bridged. It then developed westward from this point where to-day it is spanned by many bridges. To the east of London Bridge the river makes a horse-shoe bend to the foot of the low hill on which Greenwich Observatory is built. From the Observatory hill you may see how these


ENFIELD
EPPING FOREST
BROMLEY
CROYDON
SUTTON
HENDON
ACTON
TEDDINGTON

LONDON.

meanders have been used in forming the docks. The Isle of Dogs within the horse-shoe contains the East and West India and the Millwall docks. On the south-west of the bend at Deptford stretch the Surrey Commercial docks. On the city side come those of London and St. Katherine's, and in the bend to the east of these the Victoria and Albert docks. The river below London Bridge forms the busy Port of London, stretching out to the sea. London thus enjoys the advantages of a great seaport like Liverpool and in addition those of an inland town like Manchester. The development of Liverpool on the lines of London is seen to be impossible, for instead of narrowing inland the Mersey widens and cannot be bridged. On the other hand, Manchester has done as much as possible to develop what little natural resources it had as a port.

London as an inland town has developed for miles east of London Bridge and the traffic across the river grew with it until new traffic ways became indispensable. First, a granite bridge provided with a movable roadway to allow vessels to pass to and from the Pool of London was thrown across the river by the Tower. Then a number of tunnels were driven beneath the bed of the river to connect the growing districts on either side.

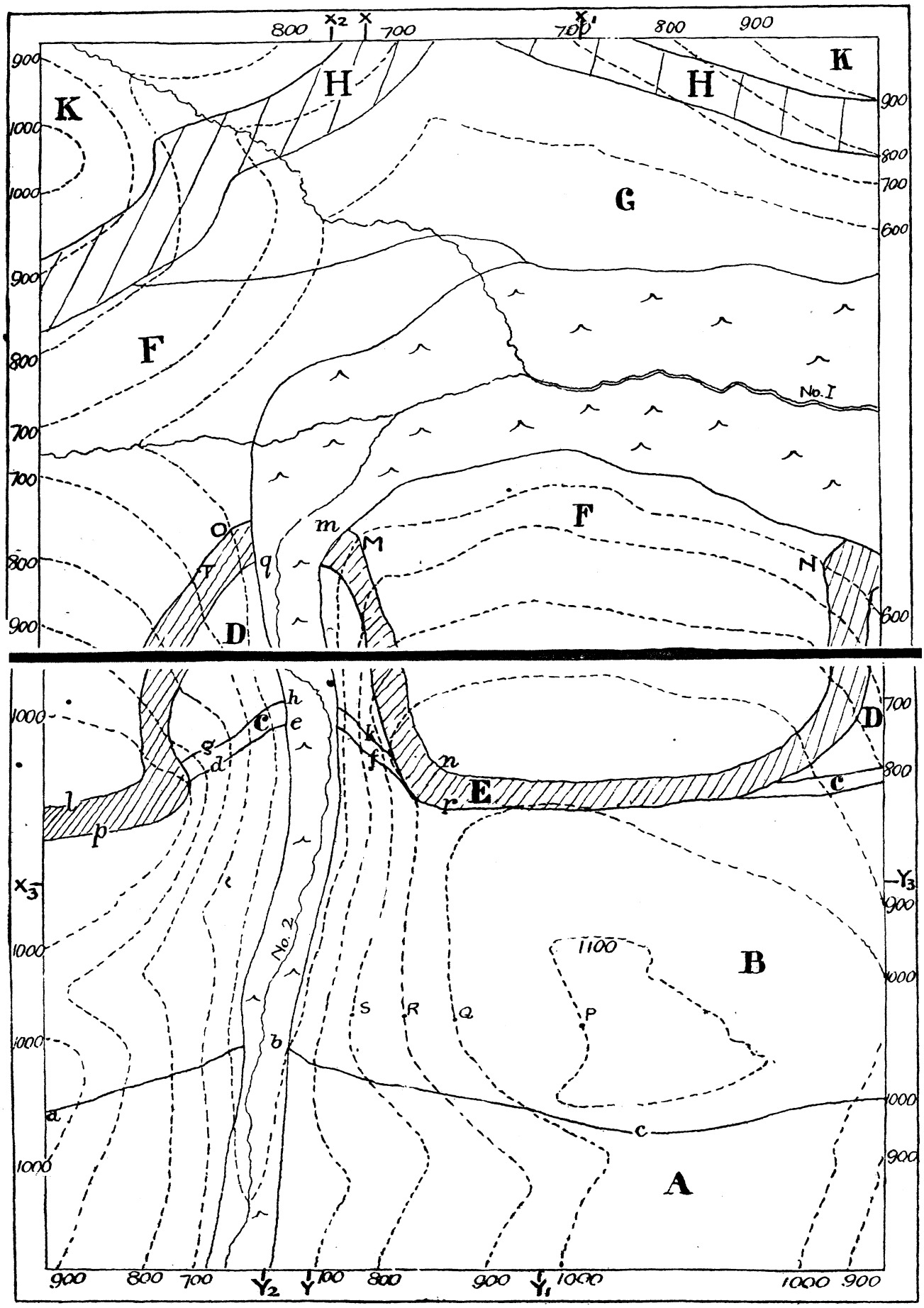
xi. When we reflect on the position that London enjoys as a port and as an inland town, and remember that its expansion is unhindered, indeed is altogether helped, by the broad and

gently rising clay basin up to the Chalk hills, we see that such an excellent site is not to be found again anywhere in Europe. London's supremacy is strategical. Except clay, sand and chalk, all useful materials for bricks and mortar, and supplies of fresh vegetables, fruit and hops from the fertile home counties, London has no raw materials, nor is it backed by any coalfield upon which it might draw. All the coal London needs must be brought from Yorkshire and the Midlands in hundreds of thousands of trucks. To a visitor, therefore, London appears as anything but an industrial town. Yet, as we saw in Part II, London is a gigantic manufacturing centre for an infinite variety of finished products. Its excellent position as a port and distributing centre ensures the gradual expansion of its manufactories in all directions, on its radial system of railways. A short journey of fifteen miles on any of the main lines out of London will illustrate how new factories line the highways. Then London's fine position has secured for it the headquarters of the country's Government, and the administrative headquarters of almost every industry.

END OF PART THREE

The Geological Record of Stratified Rocks.

Groups	Systems	Formations described in preceding pages
Tertiary	Rocks younger than Eocene	—
	Eocene	London Clay
Secondary	Cretaceous	Chalk Gault Greensand (Wealden)
	Jurassic	Upper Jurassic Clays, of which Oxford Clay is chief Oolitic Limestones Lias
	Triassic	Keuper Marls Bunter, Triassic, or New Red Sandstones
Primary	Permian	Magnesian Limestone
	Carboniferous	Coal Measures Millstone Grit Carboniferous or Mountain Limestone
	Devonian	Old Red Sandstone
	Rocks older than Devonian, viz.— Silurian, Ordovician, Cambrian and Pre-Cambrian	Referred to in Chapters XXVI and XXIX



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