CHAPTER V.

QUEENSFERRY AND FORTH BRIDGE.

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The Oil Shale Group of the Lothians belongs to a remarkable sedimentary phase of the British Carboniferous rocks, and one which is confined to a relatively small area in the East of Scotland. The strata concerned are almost wholly of fresh-water or estuarine origin, and they lie below the series of marine limestones, etc., which is known in Scotland as the Carboniferous Limestone Series; nevertheless, they are homotaxial with much of the Mountain Limestone of England.*

In the vertical section (page 5) the various subdivisions of the Carboniferous system of the Lothians are represented, but it ought to be clearly borne in mind that even within these limits the rocks vary greatly in thickness from place to place. The sedimentation in the Oil Shale Group is especially irregular, but the strata contain many persistent beds which serve as stratigraphical constants. The group is from 3,000 to 4,000 ft. thick, and contains, in its higher part, beds of impure coal, and farther down six main seams of oil-shale, interstratified with beds of sandstone, shale, fireclay, marl, and estuarine limestones.

The whole group is clearly of shallow-water origin, and was deposited over an area marked by intermittent subsidence of irregular amount, where incursions of the open sea were extremely rare. Much of the sediment must have accumulated under mud-flat conditions, for sun-cracks and "desiccation breccias" are commonly met with, especially in the marly strata that bulk so largely in the series.

PHYSICAL CHARACTERS OF OIL SHALE.

A Scottish oil-shale is a fine black or brownish clay shale, with certain special features which enable it to be easily distinguished in the field. Miners term it "shale," and the stratified rock described by geologists as "carbonaceous shale" or "mudstone" is called "blaes." These two types graduate insensibly into one another, but good oil-shale can be distinguished by its

* More precisely, the Oil Shale Group may be taken as equivalent to the Scar or Mountain Limestone of Ingleborough, coupled with the lower part of the Yoredale rocks; or, in the terms of Dr. Vaughan's scheme, the group ranges through the S and D zones. These correlations are based on the detailed mapping of the North of England by the Geological Survey. A greatly condensed account of the main stratigraphical results of this work, as regards correlations between England and Scotland, was given by W. Gunn (*Geol. Mag.*, dec. iv, vol. iv, pp. 342-349, 1898). Excellent comparative sections of the Carboniferous rocks in Scotland and along the English border have been given by Messrs. Peach and Horne in their paper on the Canonbie Coalfield (*Trans. Roy. Soc. Edin.*, vol. xl, Part 4, No. 32, Plate 4, 1903).

brown streak, toughness, and resistance to weathering influences; it resembles hard, dark wood or leather, is flexible in thin plates, and curls up under the edge of a sharp knife. Ordinary shale or mudstone is far heavier, brittle, and often gritty, and crumbles easily after exposure.

It should be noticed that Scottish oil-shales do not contain oil in the free state; this can only be obtained by destructive distillation, but compensation is afforded by their property of yielding sulphate of ammonia. This is a by-product not obtained from American petroleum, and of late years it has become of the first importance to the industry, so much so that the Pumpherston Shales, which are rich in ammonia but relatively poor in oil, are now the most valuable seams of all, although in early days they were hardly considered a workable subject.

The Oil Shales around Queensferry.

The sections around Queensferry give a very good idea of some of the most interesting portions of the Oil Shale Group. They afford a complete record of a large part of the lower measures, from the Dunnet Shale down to below the Pumpherston position, and in addition there is an excellent railway-cutting section in higher strata about the horizon of the Houston Coal.

The Coast Section (Plate 4, Fig. 2).

The strata between Whitehouse Point and Port Edgar are arranged in a broad synclinal fold, with two minor anticlines in the centre, on which the town of Queensferry is built. Traversing the coast from east to west the section may be said to begin at Whitehouse Point, where the great teschenite sill of Mons Hill reaches the shore, and by its contact alteration causes a curious spotting in the overlying sandy marls and mudstones. Proceeding westwards there are several exposures of sandstones, shales, and one or two seams of oil-shale, but the section is obscure and faulted, so that a definite sequence, with known horizons, is not reached until we come to the long ridge running out to sea some 200 yards west of the Long Craig pier. This ridge is formed by the Queensferry Cements, which underlie the Pumpherston Oil Shales in the northern shale-fields. The cements are close-grained, and have a bright ochreous weathering; they are calcareous, but they can hardly be termed true limestones, like those of the Burdiehouse type, and they are in two bands, the upper full of oolitic grains, while the lower one, 5 ft. thick, has an abundance of small "worm-tubes." "Cements" of this nature are common enough all through the shale measures, and for stratigraphical purposes have only a local value.

In the low cliff on the shore, 4 ft. above the top of the Queensferry Cements, there is a bed of soft shale, little more than a foot in thickness, with a grey floury coating of gypsum crystals. This inconspicuous object is the Pumpherston Shell-bed, and marks a leading datum line in the Oil Shale Group. It contains *Orthoceras*, small lamellibranchs (chiefly *Pseudamusium*), fragments of goniatites, and entomostraca, in indifferent preservation, and often pyritised. Poor as it looks, this band extends all over the shale region, and, lying at the base of the Pumpherston Shales, has lately proved an invaluable guide to the position of these seams when boring; for the Scottish oil-shales are subject to destructive alteration by dolerite intrusions and from other more obscure agencies, so that a seam often becomes unrecognisable without some good "mark," such as this shell-bed affords. These marine horizons are few and far between; in higher strata the first definite band yet known is the Mungle Shell-bed, which lies 2,000 ft. or more above the Pumpherston position. (See Plate 4, Fig. 2.)

Immediately above the shell-bed there are capital exposures of the Pumpherston Shales, the series being 60 ft. thick. The best seam outcrops at the mouth of the little streamlet, on its eastern side, and here six feet of good oil-shale can be seen: it is a tough dark "shale" of normal type, curling freely under the knife. The overlying seams are not in good condition here, they are papery and fissile, and a miner would term them "shaly blaes," rather than "shale."

At the top of the Pumpherston Shales is a finely laminated yellow cement, showing curious contortions and brecciation, probably of contemporaneous origin; immediately above is a sill of decomposed dolerite ("white trap"), followed by massive sandstones in which another sill of "white trap" can be seen; these intrusions belong to the Hopetoun sill, which is strongly developed a mile or two to the west, on much the same horizon.

The next point of interest is the Burdiehouse Limestone, which is exposed on the shore at low tide, a few yards east of the sandstone crags near the Forth Bridge. The limestone is quite typically developed—it is a light grey entomostracan limestone with a glassy fracture and pale bluish weathering.

The Burdiehouse Limestone was one of the first horizons recognised by geologists in the Scottish shale-fields, and it extends over the whole region, with little alteration in character. Here it is only 5 ft. thick, but in certain districts is more strongly developed, being nearly 50 ft. near Pumpherston, where it also contains numerous chert bands. The stone is very pure and has considerable value as a flux in iron furnaces, being still mined for this purpose at one or two places.

Resting on the limestone near the Forth Bridge, part of the Camps Shale is seen, but most of it is cut out by faulting; the

oil-shale invariably accompanies the limestone, but is not often of good quality.

Farther west flaggy sandstones are seen along the shore, and resting on them is the Dunnet Shale, accompanied by a thin sill of "white trap." These strata are thrown into a couple of sharp folds west of the Forth Bridge, but the sequence is only partially exposed, and is seen to better advantage in the railway cuttings now to be described.

The Port Edgar Railway Cuttings.

The branch line running from Dalmeny down to the shore at Port Edgar, west of Queensferry, gives an excellent section from the Burdiehouse position up to the Dunnet Shale. The strata all dip eastwards, so that the lowest beds appear at the mouth of the cutting at Port Edgar. The Burdiehouse Limestone, with the accompanying Camps Shale, is not exposed here, but lies immediately beneath the railway on the west side of the bridge, where there are several "sits" caused by the old underground workings of the limestone. At this point dark, limy sandstones rest on shales with cement ribs, these passing eastwards under the bridge. The sandstones are succeeded by a few feet of dark shale, on which is a very remarkable brecciated bed known as the "Port Edgar Ash." This breccia is here nearly 40 ft. thick, and can be traced four or five miles farther west into the Philpstoun shale-field, where it dies out. It is composed entirely of sedimentary materials set at all angles in a dark sandy matrix. The fragments are mostly angular, although at first sight many appear to be rounded, owing to the adherent matrix; they mostly consist of clay ironstone, cements, or dark "blaes," such as are found in the strata immediately above or below.

The origin of this curious breccia is somewhat puzzling. In many respects it is like a "desiccation breccia" (*i.e.*, a bed of angular fragments of purely local origin, formed by the drying up and consequent flaking of a mud-flat, the particles being subsequently spread out and mixed by flooding). Breccias of this nature can frequently be noticed in the Scottish shale-measures, which are in large part mud-flat deposits; they are, however, rarely more than a foot or so thick, and, moreover, in this case we have also to account for the occasional presence of foreign material (coal, yellow pyritous sandstone, etc.) and lenticles of dark shale, 3 ft. or more in length. These suggest that we may be dealing with the products of a dust explosion from one of the numerous volcanic vents found on either side of the Firth of Forth. At the same time it is a remarkable fact that there seem to be no fragments of the Burdiehouse Limestone, which is only 10 fathoms or so below. Mr. Cadell suggests that the breccia may have been thrown out of a parasitic cone proceeding from

a dolerite sill intruded about the Camps Shale position early in Carboniferous times, when only a few feet of cover had been deposited on the shale. The theory does not seem impossible, and certain intrusions of teschenite are known at this level in the neighbourhood.

Proceeding eastwards along the cutting, nearly 140 ft. of dark fissile shales, with abundant ribs of greyish-yellow cement-stone, are seen above the breccia. (It may be noted in passing that these strata are mostly replaced by sandstone on the east side of the main syncline around the Forth Bridge.) The cement ribs are frequently broken by small reversed faults, which die out in the surrounding shales, and may, perhaps, have been caused by expansions during the original consolidation of the stone. Towards the top of the shaly series the cements assume a curiously nodular form, reminiscent of the "kunkar" strings found in modern tropical soils. These strata are followed by sandstones, of which there are only detached exposures until the Queensferry Goods Station is reached, where the uppermost beds are clearly seen, with the Dunnet Shale on top. This is one of the chief oil-shales in the Lothians, and is here quite characteristically developed; it is a "plain shale" (*i.e.*, it is evenly bedded), and is about 5 ft. thick. Between the bottom of the shale and the sandstone below there are a few inches of soft yellow tuff, greatly decomposed and pyritous, and mingled with some amount of sedimentary material. This is the Barracks Ash, and invariably accompanies the Dunnet seam, so that it is the chief "mark" for the position when boring. In the roof of the shale there is a sill of "white trap," 17 in. thick, but this has little effect on the seam, only a few inches of shale being burnt on either side.*

Nothing more can be seen along the railway for half a mile or so, after which there is a notable section that extends for several hundred yards until the branch joins the main line near Dalmeny Station. The strata dip northwards, and they lie high up in the Oil Shale Group, being thrown in by the Ochiltree Fault, one of the major displacements of the shale-fields. Unfortunately the fault is concealed by boulder-clay hereabouts; it crosses the cutting just before the rock section begins, and has a downthrow to the south of over 1,400 ft.

The first (and highest) beds seen in the cutting are the Houston Marls, of which some 40 ft. are visible. These marls, which are a well-known stratigraphical horizon in the shale-fields, have a characteristic green colour, and there is a good deal of red marl also, both types being accompanied by seams of yellow cement-stone.

* The numerous intrusions in the Scottish Oil Shale Group vary greatly in their effect on the sediments, and the amount of alteration has no constant relation to the size of the intrusion. There is a brief discussion of the subject on page 15 of the recent *Geological Survey Memoir* on "The Oil-Shales of the Lothians."

The origin of the marls is a most difficult question, which is as yet unsolved. Looking at their thickness and impalpable nature, one would naturally suppose that their deposition was a lengthy process ; yet they occasionally contain angular fragments of quartz or felsite, and in this section there is at least one interbedded band of coarse grit. The subject has been discussed at length by Mr. Cadell, in a paper which is one of the classics of Scottish geology.*

Below the marls there are alternations of entomostracan limestone and shales, passing down into 4 ft. of "shaly blaes" (the Grey Shale), which rest on a seam of soft, foul coal, with fireclay partings. This is the upper part of the Houston Coal, a well-known index horizon, usually forming a single seam, but in this district split into two portions by sandstones accompanied by a thick volcanic ash. The ash is very well seen higher up the cutting, and is coarse and agglomeratic in nature ; calcified plant remains have been found in it, showing excellent original structure.

The lower leaf of the Houston Coal can be seen under the ash, but in the upper part of the cutting the strata are greatly disturbed and faulted, possibly owing to the vicinity of a volcanic neck, proved hereabouts by the underground workings in the Broxburn Shale, which has been wrought extensively in the neighbourhood.

* "The Geology of the Oil-Shale Fields of the Lothians." *Trans. Edin. Geol. Soc.* vol. viii (1905), p. 132.