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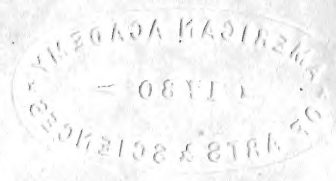
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D U R A D E N

A MONOGRAPH OF THE YELLOW SANDSTONE

AND ITS REMARKABLE FOSSIL REMAINS.



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Scotland. Geology.

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# DURADEN

A MONOGRAPH OF THE YELLOW SANDSTONE

AND ITS REMARKABLE FOSSIL REMAINS.

BY

JOHN ANDERSON, D.D. F.G.S. E.P.S. ETC.

AUTHOR OF "THE COURSE OF CREATION," "GEOLOGY OF SCOTLAND," ETC.

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TO

THE RIGHT HON. LORD KINNAIRD, K.T. F.G.S.

AND

SIR RODERICK I. MURCHISON, G.C.St.S. D.C.L. V.P.R.S. ETC.

ACTIVE COADJUTORS IN THE FOSSIL DISCOVERIES

OF SEPTEMBER 16, 1858,

THIS VOLUME IS RESPECTFULLY DEDICATED

BY

THE AUTHOR.



## LIST OF ILLUSTRATIONS.

VIGNETTE OF DURA DEN, Coloured, . . . . .	<i>Titlepage.</i>
MAP OF THE DISTRICT, Geologically Coloured, . . . . .	PAGE 5
SECTIONS SHOWING THE SERIES OF ROCK GROUPS, PRIMARY AND SECONDARY, . . . . .	21
PLATES—	
I.—First Group of Fossil Remains found in Dura Den, . . . . .	49
II.—Figure of Glyptopomus Minor, . . . . .	55
III.—Figure of Glyptolæmus Kinnairdi, . . . . .	63
IV.—Perfect Figure of ditto, . . . . .	65
V.—Figure of Phaneropleuron Andersoni, . . . . .	67
VI.—Full Jugular Aspect of ditto, . . . . .	69
VII.—Figure of the large Holoptychius, . . . . .	73
VIII.—Group of Fossil Remains, . . . . .	96
WOODCUTS—	
Sphenopteris Affinis, in the Dura Den Carboniferous Sandstone, . . . . .	48
Heterocercal and Homocercal Fins, . . . . .	39
Holoptychius Nobilissimus, . . . . .	56
New Delineation of the type Holoptychius, . . . . .	71



# MONOGRAPH OF DURA DEN.

## INTRODUCTORY.

THE yellow sandstone deposits of Dura Den have excited considerable interest among geologists for many years, and recently they have become still more worthy of notice. The *Poissons Fossiles* of Agassiz contain descriptions of their organic remains which have given celebrity to the locality in every quarter of the world. The autumn of last year introduced them for the first time to the personal acquaintance of the illustrious author of the *Siluria*. Sir Charles Lyell visited Dura Den, in company with myself, in the summer of 1842; and in the same year Dr. J. Malcolmson, on his return from India, was attracted by the fame of their rich fossiliferous beds to examine and note their relations to the Elgin and Morayshire sandstones. Hugh Miller was an explorer in this fertile and controversial field. Dr. Fleming had closely examined every rock and quarry in the ravine and the vicinity for miles round. As his "daily haunt and neighbourhood," my ever-active and distinguished friend, Dr. George Buist of Bombay, made Dura Den the scene of his constant explorations, while, by his excellent text-books and otherwise, Mr. Page has contributed much to elucidate and extend the knowledge of its interesting fossil remains.

My own descriptions and speculations are successively recorded in *Fife Illustrated*; in the gold medal "Prize Essay,"

published in the *Agricultural Transactions* for 1840 ; in the *Course of Creation*, where a chapter is devoted to the consideration of the yellow sandstone of Dura Den ; and in the *Edinburgh New Philosophical Journal*.

More recently, and since the publication of these works, several additions have been made to the collection of the interesting organic remains. The 16th day of September, 1858, will ever be memorable in the annals of Dura Den, when, in presence of Sir Roderick J. Murchison, Lord and Lady Kinnaird, and a distinguished party from Rossie Priory, the largest fossil *Holoptychius* ever discovered was exhumed from the rock, in full and perfect outline and entireness, and measuring upwards of three feet in length. A great many specimens of smaller dimensions were obtained on the same fortunate occasion. Another trial was made about two months afterwards by the proprietors, Mr. and Mrs. Dalgleish of Dura, when a considerable space of rock being first cleared of superficial detritus, nearly a THOUSAND fossil fishes were lifted from their stony bed of ages ! Many of these were of large dimensions, and their several organs of heads, teeth, scales, and fins beautifully preserved. The prevailing family is that of the holoptychius, but along with these some entirely new forms were discovered ; portions of former, but imperfect and undescribed genera and species were detected by us among the trophies of the day ; and hence the more immediate occasion furnished to the author for now undertaking this monographical record of a locality so remarkably rich in the numbers and variety of its fossiliferous treasures.

This classic field of geology has some special attractions in itself, besides those arising from its forms—"new and strange"—in its rocky foundations. No lover of the beautiful can fail to be arrested by the fine grouping of objects that successively fall upon the eye in traversing the ravine, enclosed by high precipitous rocks on both sides, and which are diversified by the various colours of their interlaminated beds of shales and sandstones, of traps and ironstones. The mansion-houses of



Dura, Blebo, and Kemback, nestle on the sloping banks of the dell, amidst stately clusters of plantation ; the church and manse occupy an elevated plateau in a bay of the rock ; the ever-busy mills, and their neat workmen's cottages, are seen at intervals beneath ; the Castle of Dairsie stands in ruins in the close vicinity of the parish church, the erection of Archbishop Spottiswoode, still in perfect preservation, and the former famed in Scottish story as the house of parliament in which were discussed the contending claims of Bruce and Baliol. Here, in the caverns of the rock, persecuted saints have found a refuge in covenanting days ; a short detour to the left presents a sight of Magus Muir, of cruel memory and most indefensible policy ; and nearer to the right are the lands of Pitscottie, the birth-place and retreat of Robert Lindsay, the learned author of the *History of Scotland*.

No apology therefore is required for a separate Memoir of a locality combining so many points of historic interest and geologic illustration. Dura Den ranks with the celebrated deposits of Cromarty, Caithness, Elgin, Isle of Eigg, Clashbennie, Babruddery, and Carmylie, in their vast stores of organic remains, while it presents as yet a monopoly of several genera and species of the ganoid order of fishes—the precise types of organic life, and beautiful enamelled forms of the yellow sandstone of the district, being nowhere else discovered in any of our geological formations. Lying nearly equidistant between the firths of Forth and Tay, the county town of Cupar, and the city of St. Andrews, the railway traverses the opening of the Den, and on every side it is of the easiest access.

Dura Den, thus distinguished in its local and archæological connexions, is about two miles in length in its direct lineal extension from the church of Spottiswoode to the lands of Pitscottie. The record of events of their own time, by these celebrated chroniclers, is perhaps less trustworthy than the legends inscribed on the rocks beneath, of creatures that battled in their hard scaly armature, and in the far antepast of geologic

times ; whose families have become utterly extinct amidst revolutions and convulsions by which sea and land have interchanged places, and whereby the physical aspects of all around have been modified or produced ; and now entombed in their marble sepulchres—

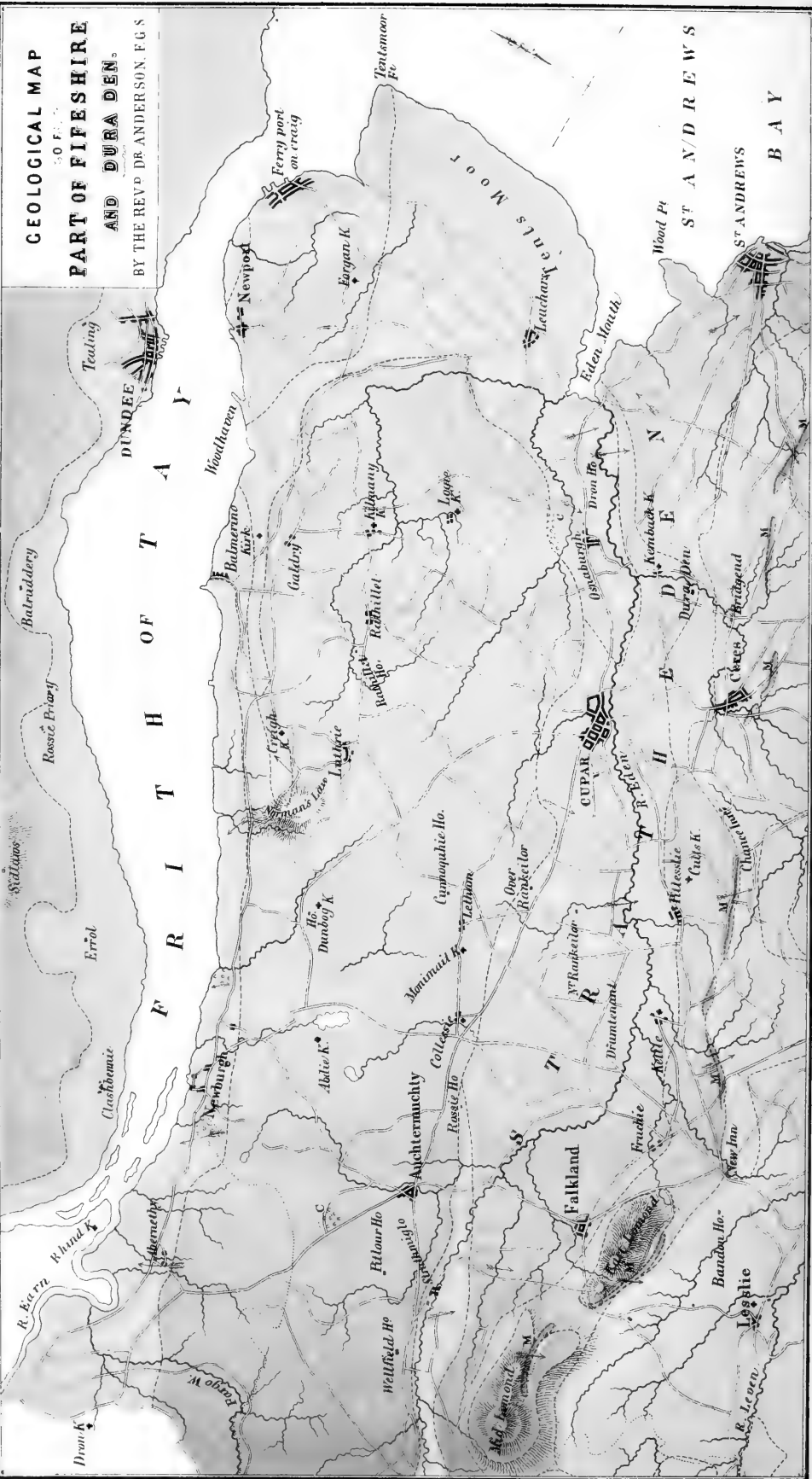
“ Sand hath fill'd up their palaces of old,  
Sea-weed o'ergrown their halls of revelry.”

The arrangement proposed to be followed in this Memoir will comprise,—

- I. A general topographical description of the district.
- II. The geological position of the yellow sandstone, and its relations to the Primary, Devonian, and Carboniferous systems.
- III. History of the fossil remains.
- IV. Descriptions of the fossil remains and their remarkable characteristics.
- V. General inferences as to the conditions of the primeval seas ; earliest appearances of vegetable and animal life ; the great fish epoch in the Devonian period ; causes of extinction ; the igneous and trap formations and disturbances ; and the subsequent vast development of the carboniferous flora in the production of coal, ironstone, and limestone.

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**GEOLOGICAL MAP**  
 50 F.  
**PART OF FIFESHIRE**  
**AND DURADEN.**  
 BY THE REV. DR. ANDERSON, F.G.S.



- REFERENCES**
- Upper Coal Series.
  - Yellow Sandstone.
  - Mountain Limestone.
  - Old Red Sandstone.
  - Trap.
  - Comstone.
  - Under Coal series.

## CHAPTER I.

## THE TOPOGRAPHY.

FIFESHIRE forms the eastern portion of the great central coal district of Scotland. Its form is peninsular, being enclosed on three sides by sea—the German Ocean on the east, the firths of Forth and Tay on the south and north, and on the west it is bounded by the shires of Perth, Kinross, and Clackmannan. The greatest length from east to west, along the rocky shores of the Forth, is forty-one miles; about the centre-line from St. Andrews to Lochleven, it is twenty-three miles; on the northern boundary from Ferry-Port-on-Craig to Mugdrum, near the confluence of the river Earn with the Tay, it is eighteen miles. The breadth across the centre, in the line of Dura Den, is fourteen miles.

Within this area there are included about 467 square miles of land, and about six square miles of lakes. The number of cultivated acres imperial is nearly 260,000; of uncultivated, in woods and hill-pastures, about 70,000; and of under-ground coal measures there is an area of nearly 16,000 square acres. The county lies between  $56^{\circ} 2'$  and  $56^{\circ} 27'$  N. lat., and between  $2^{\circ} 20'$  and  $3^{\circ} 12'$  W. long.

The general contour of Fifeshire partakes more of the gentle and undulating outline of the downs of England than of the bolder and more striking features which characterize the mountain land of Caledonia. The Ochils, traversing its northern boundary, and the Lomonds, running through the centre division, separate the county into three well-defined subordinate districts,

which, as will be afterwards noticed, correspond to three equally marked geological formations. The Ochils consist of a chain of trap hills, extending through a course of upwards of fifty miles, gently rising on their eastern extremity to about 400 feet, and attaining on the western, in Bencluch and Dalmyatt, an elevation of nearly 3000 feet above the level of the sea. The Lomond ridge consists of an elevated table-land, about four miles in length, completely insulated from the neighbouring hills, with a gentle slope towards the south; but on the north the acclivity is precipitous and rocky, and springs from the valley of Stratheden to the height of nine to ten hundred feet. The east top is 1466, and the west 1721 feet above the sea-level. Overlooking the whole county, and the two noble rivers by which it is encompassed, with the German Ocean to the east, the towers of Stirling and “the lofty Benlomond” to the west, the rugged serrated outline of the Grampians to the north, and the extensive plains of the Lothians, begirt by the Pentlands and Lammermuirs, the Bass and Berwick-Law to the south,—the prospect from either summit may vie with any in the kingdom, presenting at once to the eye whatever is necessary in water, forest, and mountain, to form the beautiful, the picturesque, or the grand. Some of the objects in the immediate vicinity give additional charm to the scene—the Palace of Falkland, which lies at the base of the East Lomond, and Lochleven, which washes the sloping defiles of the west peak, and where, in the middle of the deep blue lake, may still be observed the ruins of the keep in which the unfortunate Mary Stuart was imprisoned by her subjects. Standing by Cross-Macduff, in the parish of Newburgh, the poet says, almost to the letter of the description,—

“ You do gaze—

Strangers are wont to do so—on the prospect.  
 Yon is the Tay, roll'd down from Highland hills,  
 That rests his waves, after so rude a race,  
 In the fair plains of Gowrie. Farther westward  
 Proud Stirling rises. Yonder, to the east,  
 Dundee—the gift of God, and fair Montrose,  
 And still more northward, lie the ancient towers  
 Of Edzell.”

Besides the Forth and Tay, that traverse the confines of the county, there are three rivers of considerable dimensions, as well as of mercantile importance, which flow through the district, and lay open in several places valuable sections of the rocks. These are the Eden, the Leven, and the Orr. The Eden takes its rise near the western extremity of the shire, in the parish of Strathmiglo, and, after a course of eighteen miles, falls into the sea at the Guard Bridge, near the Bay of St. Andrews. The Leven issues from the loch of the same name, and runs along the southern escarpment of the Lomonds into the Forth, near the Bay of Largo ; and the Orr, which rises in the coal-basin of Blair-Adam, and joining the Leven a few miles to the north of Largo, discharge their united waters into the bay at Leven. The lochs connected with the county are Loch-Fitty, Loch-Gelly, Loch-Leven, Loch-Mill, the Black-Loch, Lindores, and Kilconquhar, all of which are well stocked with pike and perch, some of them with excellent trout. They are frequented with various species of wild-fowl, and their banks are adorned with tribes of flowering aquatic and cryptogamic plants.

## DURA DEN.

LINES BY THE REV. JOHN ANDERSON, MINISTER OF KINNOULL,  
AUTHOR OF THE "PLEASURES OF HOME."

How many pass, unthinking and unmoved,  
Through scenes that wake in others noble thought—  
O'er vivid footprints of the unseen God—  
'Mid speaking witnesses of scheming man!  
Pause, traveller! for thou treadest such a scene;  
Records of God and man surround thee here!

That Ruin, beetling o'er the rippling stream,  
Where pensile wild-flowers drink the crystal wave,  
And flitting flies betray the lurking trout  
To the keen angler; mark that mouldering wreck;  
'Tis the hoar remnant of a famous pile,  
Where the last Scottish Parliament convened,  
And feebly grasp'd a sceptre, soon to pass  
To other hands, stretch'd eagerly for power.

Note yonder hill, by far-seen pillar crown'd,  
And cinctured by a zone of stately trees;  
A prouder glory rests upon its brow;  
More deathless verdure clothes its classic side;  
For there a Bard, whose name shall never die,  
Sir David Lindsay, sang his Doric lay.



Dim in the distance, like the tales they tell,  
 St. Andrew's sacred turrets pierce the sky—  
 Grey spectres standing sadly by the sea,  
 As if they mourn'd some ravagè it had wrought.  
 A different sea swept o'er them—it is gone!  
 But these bleak fragments live to tell its fury.

Where winds the quiet, greenly-mantled dell  
 Into the bosom of the uplands, rich  
 With russet grain, or dappled o'er with flocks—  
 There stretch'd, in days gone by, a dreary moor—  
 Dreary and voiceless; save when one wild night  
 It rang with ringing steel and cries of terror,  
 And blood, by murder shed, its heath-bloom deepen'd,  
 Leaving a stain no floods can wash away!  
 There Sharp—weak zealot of a despot-creed—  
 Died; and so dying half redeemed his life.  
 Thus ruthless violence defeats its end,  
 And makes a martyr where it sought a victim!

Far up the crag, where waves the feathery fern,  
 And the gay foxglove hangs its purple bloom;  
 Where glides the weasel on its noiseless way,  
 And clings the bat till evening shadows fall;  
 The damp and dripping cavern wont to hide  
 Devoted men, who worshipp'd God by stealth,  
 When temples made with hands refused their praise.

These are the records, these the deeds of men;  
 But other deeds and dates find record here.  
 Far different wrecks lie buried 'neath your feet,  
 Proclaiming other changes, other times.  
 No billow breaks upon this sealess beach—  
 Nought save a tiny brook runs wimpling here;  
 Yet forms of life—once sporting 'mid the waves,

Their home green ocean-caves and plains and vales—  
Start from the rock at every clanging blow,  
Filling the dusty workman with amaze,  
And wafting back the sage's puzzled thoughts  
O'er the dusk gulf of dim, unnumber'd years !

What sea, receding from what former world,  
Consign'd these tribes to stony sepulchres ?  
Bewilder'd sage ! proclaim thy wisdom folly,  
And where thy REASON fails let FAITH begin :  
The rocks have sacred secrets of their own,  
That teach the wise humility and praise.

## CHAPTER II.

## GEOLOGY.

## THE ORDER AND ARRANGEMENT OF THE ROCKS.

Geology informs us that there is no portion of the surface of our planet that has not been immersed in the waters of the deep. It is also an acknowledged principle of the science, that there is no portion of the earth's surface that has not been under the influence of fire or the action of subterranean heat. The whole superficial crust of the globe, it therefore follows, is composed of two great systems of rocks, namely, those which are sedimentary or stratified, and those which are termed igneous or unstratified. All sandstones, limestones, and shales belong to the former class ; the granites, traps, and lavas are all ranged under the latter class. They are termed primary, secondary, and tertiary, according to their geological age or order of superposition.

The following table exhibits both divisions, and their subdivisions according to their mineral constituents, chronological order, and relative superposition :—

PRIMARY FORMATION.	LOWER SECONDARY FORMATION.	UPPER SECONDARY AND TERTIARY.
Gneiss.	Cambrian Schists.	Trias—Red Marls, Keuper,
Mica-Schist.	Silurian Schists.	New Red Sandstone.
Quartz Rock.	Old Red Sandstone.	Oolitic—Wealden, Lias.
Limestone or Marble.	Carboniferous Series.	Cretaceous—Greensand,
Clay-Slate.	Permian Magnesian Lime- stone.	Marls.
		Tertiary Series—the Eocene, Miocene, Pliocene, and Pleistocene.
	THE IGNEOUS ROCKS:	
Granite.	Felspar Porphyry.	Amygdaloid.
Basalt.	Compact Felspar.	Clinkstone.
Clay-Stone.	Greenstone.	Tufa.
		Lava.

The primary series, according to this tabular view, are by far the most widely developed of the rock formations of the earth. In Scotland they cover upwards of NINETEEN THOUSAND SQUARE MILES, or about two-thirds of its superficial extent. They prevail chiefly in the Northern Highlands; and, from their upheaval by subterranean fires, give rise to all their picturesque grandeur and diversified outline of mountain, strath, loch, glen, and valley. The lower group of the secondary formation is, in part of the series, limited to the southern division and border districts, and the central districts are occupied with the old red sandstone, the coal metals, ironstone, and limestone.

The upper secondary and tertiary formations are in Scotland of very limited extent, and chiefly in small patches confined to Dumfriesshire and the Hebrides. They constitute the prevailing rocks over nearly two-thirds of England, in all the eastern, southern, and midland counties. The igneous class of rocks again, with the exception of the granite, all lie within the area of the coal-field, or form its outworks, constituting the Sidlaw, Ochil, Campsie, Kilpatrick, and Pentland ranges of hills. The Grampians, and other lofty mountains in Arran, Skye, Ross and Sutherland shires, are composed of granite, gneiss, mica-schist, quartz, limestone and clay-slate.

Following the line of Section, we shall briefly notice the relations and mineral constituents of the successive formations, in their order of superposition, from the Grampians to Dura Den, including a space of about twenty miles in lineal extent.

GRANITE constitutes the nucleus of the Grampian range from shore to shore over Scotland. It is the lowest fundamental rock, having its seat deep in the crust of the earth; and it likewise forms the top of nearly all the Bens, the loftiest mountains in the Highlands. The prevailing constituents are quartz, felspar, and mica. Where hornblende is

added or substituted, as it often is, for mica, it is then denominated SIENITE—the form which it assumes chiefly on the borders of the Upper Nile, and of which many of the grandest ruins in Egypt consist. The mica sparkles like gold, and exists sometimes in crystals, of more than a foot square, when it is split up into thin plates, and used as a substitute for glass. Some granites are binary, consisting only of two minerals, felspar with quartz or hornblende, and when polished break into irregular lines resembling Arabic letters, on which account it has been called graphic granite. A vein of this rock traverses the district about a mile east of the town of Portsoy in Banffshire, in connexion with mica-slate and a bed of lustrous marble of great celebrity.

The rock which immediately overlies the granite is GNEISS, of which there are three varieties, each composed of felspar, quartz, and mica, and only distinguishable by the size, form, and arrangement of the crystals that constitute the mass. Gneiss is essentially, therefore, a granite in its component parts, but differs from granite in being always stratified, and in presenting none of the phenomena that accompany the agency of fire. It is indisputably admitted to be of aqueous origin, formed by precipitation in water, and afterwards indurated by chemical action or mechanical pressure. It consists of a series of thin lenticular plates, which give it a ribbon-like appearance, and which, according to the predominance of one of the ingredients, causes the rock to assume the slaty, granular, or aggregate structure. Talc, hornblende, chlorite, actinolite, as in granite, are not unfrequently diffused through the substance of gneiss, whence particular names have been adopted to distinguish the varieties in which they occur. Thus, when talc or chlorite is mixed in the substance, it is termed *protogine* by the French geologists; when the crystals of felspar and quartz are very minute, the rock is named whitestone or *leptinite*; when the hornblende and felspar predominate, mixed with actinolite, it graduates into a *primitive greenstone*; and

when the quartz and felspar are scarcely visible from their extreme attenuation, it merges into a variety of *Hornstone*.

Gneiss, the lowest of the stratified rocks, is likewise the most widely diffused of the Scottish primary series, filling an area of 9600 square miles, and with scarcely a break over this extensive district of country. It occupies nearly the entire northern counties of Sutherland, Ross, and Inverness; great part of Nairn, Elgin, Aberdeen, and Perth shires; most of the western islands, as Tiree, Coll, South and North Uist, Harris, and Lewis, consist of the formation, as also considerable tracts in Orkney and Shetland. While in a soft state, or from the vast pressure to which it has been subjected, this rock often assumes the most singular contorted appearances, whole miles presenting twistings and undulations as if the substance had been moved and tossed like a stormy sea, and sometimes crumpled and bent, or rolled into gentle unbroken flexures like a web of cloth. It will thus, in such cases, exhibit beautiful and picturesque aspects; and where exposed in ravines along with other rocks, with which it finely contrasts, no better pictures or groupings of rock scenery are to be met with. But in general, where the gneiss is unbroken, and as it seldom rises into peaks or serrated ridges, the districts in which it prevails are rather monotonous and unpleasing, not unfrequently disfigured by spongy heaths and boggy wastes. The most desolate, uninteresting portion of the Highlands is unquestionably the north-western districts of Ross and Sutherland, where the hills of this formation are all flat and shapeless, surrounded by unvarying solitudes of brown moor, interminable deserts of sand, and scarcely enlivened by a river, or broken in their silence by a waterfall. Gneiss is the oldest rock known in the records of Geology—the lowest floor of the most ancient seas—probably the first dry land that rose above their surface; and here, in these sterile wastes, presenting a scene of almost primitive chaos and desolation.

The next number of the series, in the ascending order, is

MICA-SLATE or Schist, which, as possessing more mica and being of a more slaty structure, is so denominated. This rock is readily distinguished from gneiss by its glistening aspect, and from granite by the absence of felspar, although it occasionally seems to graduate into both when in contact. The particles of which it is composed are uniformly more broken and rounded than those of gneiss, which probably arises from their being partly derived from the granite and partly from the gneiss, and have in consequence undergone a double process of attrition. Veins of quartz, parallel with the strata or crossing them in every direction, are so predominant often as to change the usual colour from a glistening grey into a mottled white. Vertical dykes of the purest quartz, sometimes several yards in breadth, and traceable for miles along the surface, are likewise of frequent occurrence. One variety is termed garnet-schist, from the circumstance of these beautiful crystals being so abundantly distributed through the substance of the rock as to form a principal ingredient, as well as greatly to enhance the sparkling lustre of the mica. The garnets vary from the size of a small seed to an inch in diameter, are of a dark crimson colour or blackish brown, and under a bright sun look like gems in a setting of gold. They occur plentifully in the formation near Huntly, in the upper districts of Strath Tay, and of considerable dimension and very perfect in the Isle of Mull.

The geographical distribution of this rock is much inferior in extent to the gneiss: it is chiefly confined to the more central division of the Grampians, which it accompanies in one continuous envelope, along the range from sea to sea. The mica-schist thus embraces within its course the finest and most celebrated scenery of the Highlands. No lover of the picturesque, in his most favoured haunts, can fail to recognise it, whether by its bright metallic aspect or the remarkable flexures into which the strata are twisted and folded up. Suffice it to mention the beautiful ravines on the Esk and Isla, the Pass of Killiecrankie, the Trosachs, the charming environs of Loch Ketterin and Loch Lomond, the precipitous defiles of Glencoe, and

the dark rugged mountains that surround Loch Goyle, Loch Fyne, and Loch Awe. The hills of this formation are among the loftiest and most notable in the Grampian range, rising to 4000 feet and upwards ; as Cairnwell, Ben-y-gloe, Schiehallion, Ben Lawers, Ben Vorlich, Ben Ledi, Ben Venue, Ben Lomond, and all the bold serrated ridges to the west. The long headland terminating in the Mull of Cantyre, great part of the islands of Bute, Arran, Jura, Isla, and the whole of Colonsay, consist of mica-slate.

QUARTZ-ROCK exists as an independent member of the series, as well as an ingredient in every one of the primary, and of nearly all other rocks. One set of theorists regard it as only an altered sandstone, which, through the intense action of heat, has been fused, and on cooling was crystallized. The more prevailing opinion is that which ascribes it, like gneiss and mica-schist, to precipitation in water ; but as it alternates with both, sometimes resting on the granite, sometimes intermediate betwixt the gneiss and schist, not unfrequently overlying the latter, and plentifully distributed through them all, in the form of veins and dykes, which penetrate, like the granite itself, the whole members of the system, it is difficult to ascribe to either view, and still more difficult to find a substitute for either theory of formation. There are problems in every subject which science has not yet solved. That there should be mysteries in geology on the formative processes of rocks, the sources of their constituent elements, and their mode of aggregation, is according to the rule and not the exception of speculative inquiry. The quartz-rock, thus difficult in theory to be accounted for, has a range and position in the Grampians nearly co-extensive with the mica-slate, with whose substance it is so mixed up and forms so large a proportion.

The rock which succeeds the quartz, and sometimes alternates with it, or is enclosed in its beds, is the PRIMARY LIMESTONE or marble, so extensively used for ornamental purposes. This formation consists of nearly equal parts of lime and carbonic acid, with a trace of silica. It resembles the quartz in outward



appearance, in being granular, white, and lustrous in colour, and regularly stratified, and in hardness is scarcely distinguishable ; but how different in its susceptibility of polish and other practical uses. Famed among the ancients in the celebrated quarries of Paros, Pentelicus, and Carrara, their finest and most enduring specimens of sculpture were chiselled from the same family of rocks which claim a parentage with the limestone of the Grampians. There are several varieties, differing chiefly in colour, fineness of texture, or as containing imbedded crystals of tremolite, sahlite, augite, asbestos, and steatite, whence it derives its unctuous feel and variegated colours, as mottled, striped, and veined by lines of pink, green, and yellow. Its range is nearly co-extensive with that of the quartz formation, being generally imbedded in its mass, or accompanying its outcrop. It is burnt in a great many places into quicklime, but as the concretions have an extreme tendency to exfoliate and separate during the process, by the volatilization of the carbonic acid, it is difficult to preserve its cohesive and other chemical properties, and is accordingly not rendered so applicable to economic uses as it otherwise might be, from the large proportion of calcareous matter contained in it. Preserving the same line of bearing with the quartz-rock, this limestone stretches along the more central parts of the Grampians, and is found in almost every position—in the bottoms of valleys, in the beds of rivers, on the sloping acclivities of mountains, or even capping their ridges and summits. It occurs plentifully on both sides of the Dee, from Ballater towards the Castletown of Braemar, at which latter place it nearly composes the beautiful hill called the Lion's Face, and thence passes westward by Glen Clunie and the base of the quartz-capped Morven. Appearing at several intervening localities, it descends Glentilt, where it is so frequently penetrated by the granitic veins of Ben-y-gloe ; and, crossing the river Garry, it may be observed high on the sides of the green hill of Tulloch ; and spreading over the extensive tract southwards to Loch Earn, there are various openings in

the strata for quarries—in Glen Tummel, Glenlyon, near Loch Earn head, at Aberfoyle, Auchmar, Loch Lomond—when it is again traceable through all the western isles, from Lismore to the more quartzzy regions of Jura and Isla.

The CLAY-SLATE forms a very narrow strip, of about five or six miles in breadth, and may be described as the outer envelope of the primary series and upper crust of the Grampian range. It extends from Stonehaven, in a continuous belt, to Roseneath, and through Bute to Arran, where, at Loch Ranza, it is penetrated by the granite, and is seen in connexion with the mica-slate. It consists of a fine-grained argillaceous basis, of considerable hardness, of various colours, from a greenish-black to a deep mottled purple, and, from its splintery fissile structure, is admirably adapted for roofing-slate. Some of the smaller islands in the vicinity of Oban, as Luing, Eisdill, and Seil, are composed of a different slate, chiefly the chlorite, and of older formation. Various other bands of slate occur, in groups of different kinds and qualities, among the primary mountains. They are confined to no particular mineralogical district, but are distributed at long intervals, and appear as outliers indiscriminately in the granite, gneiss, and mica-slate series. They are termed talc, chlorite, actinolite, and hornblende schists, according to the prevalence of any one of these mineral substances in the mass. They have less or more an unctuous feel, a foliated or fibrous structure, an extremely flexible texture, and a fine glossy lustre. The chlorite schist is very abundant in the Cairnwell and Glenshee group; the hornblende variety, also strongly impregnated with cubical iron pyrites, occurs at Ballahulish and Appin, and Ben Lair, in Ross-shire; talc-slate is not abundant, and is generally incorporated with the mica-slate, by the substitution of the talc for the mica plates. Actinolite schist is usually associated with, as it differs little in character from gneiss and some specimens of granite, and is found in considerable quantity in Glenelg, and the high and beautifully sloping passes of Glen Shiel.

After this brief description of the primary rocks, it only remains to be noticed, in connexion with the adopted theory of their formation, that in proportion to their relative distances from the fundamental granite, the greater is the comminution of their particles, and the less crystalline their structure. Assuming the igneous origin of granite, it necessarily follows that its surface, penetrating the waters of the primitive seas, would be subject to the disintegrating influence of atmospheric, aqueous, and chemical agencies. The waters themselves, especially when resting in the newly-formed hollows, must have been heated to a high degree, the air loaded with vapours, and the superficies of the earth raised to a corresponding temperature. The process of disintegration would consequently be much accelerated. The runnels and streams would carry down the loose particles, disposing the heavier portions first and nearest, and bearing the lighter and smaller to deeper basins. Hence there exists the greatest affinity betwixt these rocks, where, according to the law of their aggregation, the granite is sometimes fused into the gneiss, the gneiss into the mica-schist, and the quartz rock, marble, and other beds all welded into each other; and thus strongly warranting the inference, that the whole series have been exposed to the action of heat after the deposition and arrangement of their component parts.

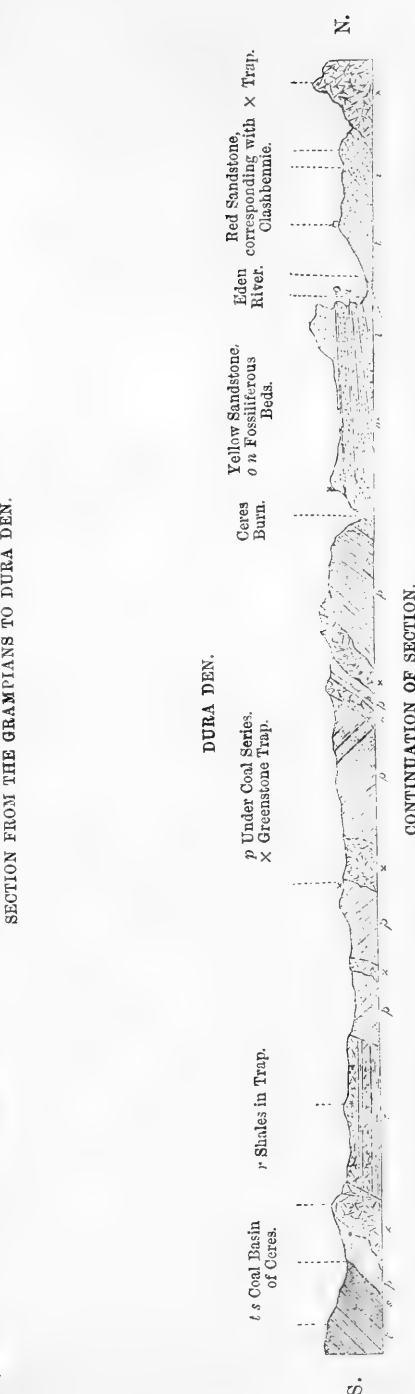
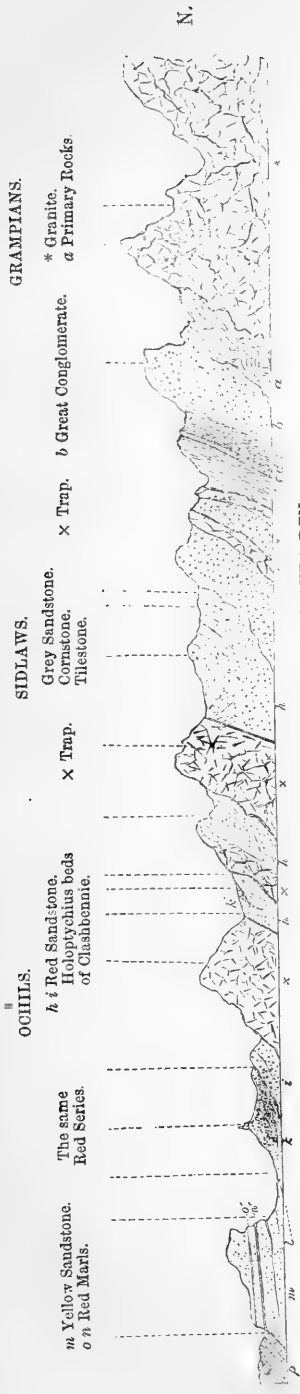
Heat alone, of all known causes, could produce such results. Added to the phenomena of veins—in the changes, dislocation, and induration invariably produced upon the strata through which they pass—there are few dogmas of science that can boast of resting upon a wider induction of facts, than that the mountains of the earth owe their elevation to the expansive force of internal fire, and that its massive foundations have been consolidated through the instrumentality of the same agent.

The rudiments of all the rocks and after-formations are thus re-compounded only from the waste and debris of the originally solid parts, or have been cast out from beneath by the

influence of the causes which produced their elevation. The quartz of the granite constitutes the substance of some of the more precious gems ; the mica is divisible into plates of the three hundred-thousandth part of an inch in thickness, and enters as an ingredient into almost every combination of rock ; the felspar is reduced to clay, and, mixed with the hornblende, forms the soil of our most fertile carses. Here also among the primary series—wherever existing on the globe—is the vein of the silver and the gold and all the rare metals, and the emerald, sapphire, beryl, topaz, and amethyst all nestle in their crystal cavities. The marble to decorate our temples, the slates to furnish a commodious roofing to our dwellings, the granite to give endurance to our monuments, are among the first of Nature's offerings ; and thus combining security and elegance, usefulness and beauty, richness and variety, the foundations of our steadfast earth, and arrangement of its mineral wealth, are well calculated to speak the praises of its munificent Creator, and to form a noble subject of contemplation to its intelligent inhabitants.

The primary series of rocks now described are followed, as represented on the Section, by a COARSE CONGLOMERATE of great depth and extent (*b*). Grey and red fine-grained sandstones rest unconformably upon this mass, intermixed every where with outbursts of trap or the igneous rocks (*f e d c x*).

The large boulder conglomerates of Caithness, Sutherland, and Orkney, first described in the conjoint papers of Murchison and Sedgwick, and recently so admirably worked out in all their bearings in the appendix of the new edition of *Siluria*, may be considered as the true equivalents, in age and position, of the great conglomerate masses that flank the southern outliers of the Grampians. These rocks contain large portions of all the primary series, rolled as well as angular, some of which are eight or ten feet in diameter. They are deeply cut, and beautifully exposed to view, by the wearing channels of the



rivers Esks, the Isla, the Ericht, the Brand, the Tay, the Earn, and other mountain-streams that leap from Glen-Artney and precipitous passes to the westward. Good sections of this formation have been exposed on the Dunkeld line of railway, under Birnam hill ; the main drive of the newly-formed aqueduct from Loch Vennachar to Glasgow intersects the conglomerate, where it is elevated in many places into lofty ridges of several hundred feet in height ; and, at intervals, it is traceable along the shores of the Clyde, and largely developed in the islands of Bute, the Cumbrays, and Arran.

A series of *grey sandstones* of great thickness succeed the conglomerate, resting unconformably upon its more inclined edges (*g h*). These correspond in age and position with the Caithness fossiliferous flagstones, while several of the beds are wanting, especially those so rich in the *cocosteus*, *palæoniscus*, and *cheirolepis* families. They range over the Mearns, Strathmore, and Forfarshire ; occupy the central and upper districts of Strathearn from Comrie to Doune ; and, easterly, traverse the Carse of Gowrie and estuary of the Tay to Dundee and Arbroath. The celebrated fossiliferous deposits of Balruddery, Carmylie, Tealing, Craig, and Parkhill are all embraced within the area now traced of these grey sandstones, some of which are extremely fissile and flaggy in their beds, and others more gritty and micaceous in their characters.

The strata all dip off from the Grampians, generally in a south-easterly direction, and at various degrees of inclination. The thickness of the group may be estimated at about 2000 feet. The deepest section is exposed in the quarries of Balbeuchlie ; and the beds, uptilted at various angles, proceed along the ridges and numerous valleys of the highest crest of the Sidlaws. There are in the line of strike from north to south, two well-defined *synclines* and three *anticlines*, occasioned by the upheaval of the trappean formations.

The suite of sandstones under consideration are extremely rich in organic remains, consisting of *cephalaspis*, *pterogotus*,

various forms of crustacea altogether unknown in zoology, *Parka decipiens*, stems of trees, and several kinds of marine and fluviatile vegetables. A space of rock, about ten feet square, was lately cleared in the presence of the author, every patch of which contained fossil markings of some kind or other; and on one portion of flagstone now before me, seven inches by five, I enumerate about eighty distinct impressions of the *Parka decipiens*, or egg-sac of the pterogotus. The locality is the Coral Den of Tealing, new to collectors, and the habitat of a complete form of *Pterogotus Anglicus*, now in the Watt Institution of Dundee, and rivalling even the splendid specimen from Balruddery, in the collection of Lord Kinnaird at Rossie Priory. Besides several specimens of *pterogotus*, with their huge prehensile claws and swimming paddles, and scale-like sculptured segments, which often indicate individuals five and six feet in length, "We have," says Mr. Page, "the *ceratiocaris*, a shrimp-like form (*ceratium*, a pod, *caris*, a shrimp), so called from the pod-like shape of its cephalic shield; the *kampecaris*, a diminutive form (*kampé*, a grub or caterpillar), named from its caterpillar-like appearance, and occurring in shoals in the Forfarshire flags; the cumoid forms found so abundantly in the mud-stones of Upper Lanark, and which may be provisionally ranked as new genera, under the titles *Himantopterus* (thong-winged) and *Slimonia* (after their discoverer, Mr. Slimon); and, more recently, the quaint-looking *Stylonurus Powriensis*, obtained by Mr. Powrie from the tile-stones of Forfar, and so named from the peculiar style-like form of its caudal appendage. All these, and other forms yet undescribed, are totally new to science, are here \* for the first time figured, and open up a fresh and inviting field to the crustaceologist."

In addition to the remarkable list of organisms thus enumerated, there are spines and other osseous fragments in the greatest profusion—teeth, jaws, and foot-like markings. The

\* *Advanced Text-Book*, p. 135.

spine forms are in many places so numerous that the surface of the rock is literally covered with them ; the white spear-like projections contrasting strongly with the fucoid masses in which they are entangled. The plant remains are no less abundant, consisting of stems and branches of trees, and tufts of water-grasses thickly matted together. The stems are generally flattened ; often three to four inches broad ; but the bark is so changed by carbonization as to render the application of the microscope of little use. The sedge-like grasses (*juncites*) are slender and jointed, and sometimes several feet in length. Over large areas, and for miles east and west, in every opening of the tilestone bands, the surface of the rock is entirely blackened by these and the other organisms, clearly demonstrating a quiet inland shore-line or marshy lagoon, over which much of the detritus may have been cast by the action of the tides, and in the silt of which several of the grasses may have flourished *in situ*. Thither would roam the pterogotus, cephalaspis, and other fishes and crustaceans in quest of food, so plentifully supplied by the shrimps, grubs, and other small creatures that lived in the shallows, or there sought a fitting place for the deposition of their spawn among the sea-weeds of the period.

Resting upon these grey sandstones—the true zone of the cephalaspis and pterogotus—*Red Bands* of rock succeed (*ik*) ; and in the lower basin of the Tay and Earn, they consist of three varieties—a fine-grained, a compact gritty, and a conglomerate. The Clashbennie beds may be taken as the type or representative of the first ; they are always unconformable to the grey sandstones, when seen in conjunction, as in Rossieden and Balruddery, Parkhill and Wormit Bay. This, and the upper series of Dura Den, may be considered as constituting the true zone of the genus *holoptychius*, which now for the first time appears in the ascending order of the rocks, along with the *phyllolepis* and *glyptolepis*, whose scales are very abundant in Clashbennie, Parkhill, and Drumdreel in Stratheden.



The same series of sandstones as those now described extend into Fifeshire, skirting the south bank of the Tay, and reposing on the northern slope of the Ochil Hills from Ferry-Port-on-Craig to Newburgh. The grey bands are the lowest, and correspond in geological age and horizon with the cephalaspis and pterogotus beds of Balruddery and Carmylie, although they rise on Norman's Law to an elevation of nearly eight hundred feet. No animal remains have as yet been detected in the grey beds of Fifeshire, but the *Parka decipiens* is everywhere abundant. This rock stretches over the parish of Balmerino into the valleys of Kilmany, rising on the ridges to the south, and dipping under the red deposits which extend into Dura Den on an anticlinal axis (*ik*).

The red-coloured series consists of three distinct varieties, the conglomerate, the fine-grained, and the yellow spotted, which, however, are regularly associated, sometimes separated from each other by bands of clay and marl, and sometimes passing insensibly into one another without any perceptible line of demarcation between them. This division of our lithology, as marked on the line of section, extends from the Grampians to the opening of Dura Den at the church of Dairsie. In Strathmore, to the north of the Sidlaws, the outcrop of the series may be observed in several places, as from Meigle to Blairgowrie, and along the channel of the Tay from the Bridge of Isla to Stanley.

The conglomerate is the lowest of the series, lying inconformably on the grey bands beneath, and consists, like the older and coarser variety, of portions of the primary rocks, granite, gneiss, schist, quartz, porphyry, and hornblende. They are in the form of rounded nodules, or sometimes of blunt angular fragments, varying from an inch to six inches in diameter. The interstices between the nodular masses are composed of smaller portions of similar materials, and possess a considerable degree of cohesion. The compact variety rests conformably above the conglomerate, and so intimately connected are they,

that, in raising a block from the quarry, they are generally attached; the nodules in the lower bed perforate the more compact substance of the upper, and lead to the conclusion that they are contemporaneous deposits, and were produced under the same circumstances, the heavier portions assuming their position in the bed according to their specific gravity. The fine-grained is uppermost, is generally of a deeper red, and contains more argillaceous matter than the other two; the mica is also more abundantly distributed in minute grains through the rock.

Spots of a round spherical form, and of a yellow colour, are common to all the beds, but are most numerous, as well as of larger dimensions, in the upper. In some localities the spots are so abundant as to cover more than a third of the surface, and vary from the minutest points to nearly a foot in diameter. A section of the spot across the plane of stratification is uniformly circular, but when cut at right angles the figure is invariably spherical, with a dark-coloured nucleus in the centre, which is occasioned, in all probability, by the discharging influence of animal matter. One thing is certain, that portions of scales and minute bones have been detected in the centre of the spots. Of this I have several specimens from Parkhill and Inchtute, which distinctly show the animal matter in the act of solution as it were, and thereby staining the matrix in the manner referred to; while in a period so prolific in all kinds of marine products, animal and vegetable, innumerable organic particles would be everywhere floating in the waters, and finally enveloped among the mineral deposits. The best specimens of this rock are to be found at Inchtute and Ballindean in the Carse of Gowrie, and at Birkhill, the Glen of Abernethy, and Drumdreel in Fifeshire, stretching eastward through Stratheden in the line of Dura Den towards the Guard Bridge.

The extent and direction of these red sandstones may be briefly traced. On the eastern coast the deposits commence

near Stonehaven in Kincardineshire, and, extending across the Bay of St. Andrews, skirt the slope of the Ochils towards the river Eden. They trend in a westerly direction by Dura Den, the base of the Lomonds, and stretching on the east and north of Kinross, through the parishes of Strathmiglo, Arngask, and Orwell, they occupy the valley from Dollar to Stirling; thence by the northern flank of the Campsie Hills towards Loch Lomond and the basin of the Clyde. The materials of which these beds have been formed have unquestionably been derived from the debris of the older primary formations, by which they are encompassed north and south of the Grampian range, and in many of the lateral glens and valleys, as in a setting of parti-coloured framework. The Grampians were, in all probability, elevated before a particle of these sandstones was yet disintegrated from its parent rock; while the Sidlaws and Ochils were raised into position in ages long after, when these sedimentary deposits formed the banks and tidal detritus of estuaries and rivers that now have no place in the geography of the earth.

The *Cornstone*, or *Limestone*, is the next member of the series in the ascending order of superposition. It occurs at various places throughout the county, as Craigfoodie, Newton of Auchtermuchty, Parkhill, Clatchart, Newburgh, and Clunie. At Craigfoodie it appears as an outlier or mere patch among the trap; it presents a similar aspect at Newburgh station, on the line of railway, and trending in among the rocks to the west it is scarcely distinguishable from the igneous mass; while at Newton the limestone has been tossed up to the summit of the Ochils. At Parkhill it reposes conformably upon the Old Red sandstone, and consists of four beds separated from one another by brown and greenish-red marl, traversed by veins of crystallized carbonate of lime. The lowest bed is five feet thick, the second is two feet, the third is about nine inches, and the upper bed is four feet thick. This bed is more arenaceous than any of the rest,

and seems to pass insensibly into a yellow-coloured sandstone, some blocks of which, indeed, are scarcely to be distinguished from that rock. The position of the cornstone, therefore, appears distinctly to be betwixt the red and yellow sandstones ; and, accordingly, at Craigfoodie, although tilted out of its natural position by the trap, it lies in the near vicinity of the yellow beds of Dura Den.

The cornstone, a little to the south of Parkhill, is curiously tossed up under the western slope of Clatchart, over-roofed by a mass of clinkstone trap of 200 feet thick, and underlaid by the grey sandstone, which, again, is intermixed with the trap whose point of contact exhibits their fusion into each other. The cornstone and sandstone are pitched up at an angle of twenty-three degrees, and the accompanying marl-beds, wasted away, show the lines of stratification in beautiful relief. There is a *greenstone dyke* a few hundred yards to the west, which crosses the ridge south and north, and clearly manifests itself as the lever-power which has elevated the whole huge mass of Clatchart, with its overhanging cliffs and sedimentary foundations of lime and sandstone.

This limestone is hard, compact, and sub-crystalline, and generally of a yellowish-green or grey colour. The structure is concretionary ; some portions of it are cherty, containing chalcedonic veins and small globular cells, which are coated over with mammillated reddish chalcedony ; but generally it may be described as a compact concretionary deposit, with several interposed beds of a green and red pyritous marl, and stained on the surface with innumerable dendritic figures. At Newton it assumes the appearance of a calcareous breccia, containing nodules of chert and jasper ; while two miles to the north-east, on the property of Clunie in Strathearn, it is of a soft friable nature, known in the neighbourhood as "the marl pit," and long used as such for agricultural purposes. No organic remains have been detected in any of its numerous localities, and the rock is nowhere observable but in very limited por-

tions, feathering out and in among the sandstones and traps throughout the estuaries of the Tay and Earn, in the Carse of Gowrie, and over the range of Strathmore to the line of the Grampians.

The *yellow sandstone* occurs as the next overlying rock in the ascending series, commencing on the western side of Dura Den (*m*) on the banks of the river Eden, and stretching southwards about a mile to the middle of the ravine, where it abuts against a trap dyke, which separates the Devonian from the Carboniferous strata. On the eastern side, at the entrance to the Den, the rock is wasted away by the action of the waters, which leaves a large open space, where the underlying red member of the series is exposed to view. The deposit occupies the valley of Stratheden, and ranges under the Carboniferous cliffs of Nydie, Blebo, Cults, the Lomonds, Binarty, the Cleish and Saline hills, and in great part of this range the two systems are separated by masses of greenstone trap. At the northern opening of the Den the rock reposes unconformably on the underlying red beds, which are here of identical colour and mineral texture with those of Clashbennie, and characterized by similar white-stained large scales of the *Holoptychius nobilissimus*. The lower beds of the Carboniferous series, of great thickness, rise again over the yellow beds towards the southern opening of the ravine, which are likewise unconformable, and maintain the same relative unconformable superposition through the entire range, as already described, except where disturbed by the intervention of the igneous rocks. Thus enclosed between these two well-marked and distinctly separated systems, the intermediate lying beds of the yellow deposit of Dura Den present facilities for study which are seldom to be met with, unmistakably define the limits and the relations of their respective systems in the geological calendar, and from their rich and varied fossiliferous remains, justly entitled to be classed with that remarkable series of

rocks which constitute the fish epoch, and of which the Old Red sandstone forms the true distinguishing type.

The yellow sandstone reappears in the western districts of Scotland, at Kilbarchan in Renfrew, at Girvan in Ayrshire, and, across the Channel, in Ireland, at Cultra in Down, and at Ballinascreen in Derry. The deposit maintains throughout the same relative position to the underlying red and superincumbent strata of the coal-field. It is marked by the same mineralogical peculiarities of structure, and distinguished by similar organic remains. Hence, like all the great leading Scottish formations, it extends persistently across the island, concealed in the more central localities by the traps and carboniferous sandstones, but everywhere maintaining its deep saffron tinge and variegated mottled bands of red shales and concretionary marls. *Pterichthys major* is abundant in the upper Old Red of the "Heads of Ayr;" and *Holoptychius nobilissimus* abounds, along with *Cyclopteris Hibernicus*, in Prestonhaugh quarry, near Dunse.

The deposit, along the tract now indicated, may be estimated at four to five hundred feet in thickness, and varies from half a mile to a mile in average breadth. The inclination of the beds is various. North of Cupar, as seen in the Ladyburn, the dip is about an angle of  $20^{\circ}$ ; at Cuparmuir quarry and at Hospital-mill it is at an angle of  $16^{\circ}$ ; while in Dura Den, Drumdryan, Glenvale, and other localities to the westward on the farm of Lappa, the inclination is generally from  $10^{\circ}$  to  $6^{\circ}$ . The rise, or outcrop of the strata, is towards the north, on the slope of the Ochils, and the dip to the south-east. From Cults-hill westwards to the base of the East Lomond, the strata have been thrown down several hundred feet by a series of faults which occur there; from this point they are again elevated, when the yellow sandstone may be observed along the northern escarpment of the Lomonds, reposing upon the red beds of Drumdreel and Urquhart, where they are cut and abraded into large tabular masses, and grooved in many places by glacial action.

The organic remains of this interesting deposit have as yet only been found on the western side of the Den, where the strata are abruptly cut off by the greenstone trap referred to ; but, in following out the dip to the eastward, little doubt can be entertained of their equally rich distribution in that quarter. The rock there attains its greatest depth and elevation, showing a breast of several hundred feet of variegated marls and sandstone (*see Vignette*). It is here, at the bend occupied by the mills, that the structure of the rocks and the perspective of the valley are seen to the greatest advantage—the deep-tinged yellow masses and mottled stripes rising overhead, enlivened and beautifully diversified by running streams, leaping waterfalls, and tangled thickets of the bracken and milk-white thorn. The hand of art, in cutting the precipitous face of rock, has greatly enriched the scene, and given facilities to the geologist in admitting him to the richest and finest tract of fossil remains that ever gladdened his eyes or adorned his cabinet.

It is a lovely place, and at the side  
Rises a mountain-rock in rugged pride,  
And in that rock are shapes of shells, and forms  
Of creatures in old worlds. . . .

But no ! the *shells* are not in the yellow sandstone. They are nevertheless in the nearest vicinity, and in the mountain limestone of the neighbouring coal-field they exist in countless myriads. Dura Den exhibits, in the closest juxtaposition, the wonders of the two geologic ages. A step carries you from the one series of rocks to the other ; and, leaping across the stream, in this narrow dell, you pass the shadowy bourne which separates two of the oldest and most singular epochs in the world's history. The epoch of fishes of the most remarkable characters—the shining enamelled ganoid class—is succeeded by the epoch of vegetables, all nearly of tropical climes, of the most exuberant growth and affluent abundance. The mighty operations are marked here on a small scale, though recorded in the most legible characters. A slight depression

in the dip of the strata on the one side ; a few black lines interspersed among stripes of white on the other side ; and this is the simple lithograph by which nature tells of energies whose products are mountains and valleys, new teeming lands of forest wealth, seas swarming with the moving things that have life, and mineral treasures enclosed for man's use which time only can exhaust.

The northern line of the *Carboniferous system*—the lip of the great coal-basin in Scotland—lies within the valley of Dura Den. It is distinguished by three or four thin seams of coal, with alternating bands of whitish sandstone, and all much broken, indurated, and upheaved by an outburst of greenstone trap. At the point of junction ( $p \times$ ) the sandstone is converted into chert, and in several places so welded to the igneous rock as scarcely to be disjoined by the stroke of the hammer. In the more southern part of the Den, the trap repeatedly alternates with the sandstone, which is there of great thickness, and thin bands of ironstone, shale, coal, and limestone begin to appear as the harbingers of the true coal series in the Ceres basin. There the beds of coal are of great thickness, the main seam being sixteen feet ; and the limestone is equally remarkable for its vast profusion of animal remains, some of the bands at Teases, Craighall, and Drumcarro being an aggregation of encrinites, producti, and other molluscs. The *Mytilus* alone forms a band of shale of several feet thick, extending from the West Lomond to the Witch Lake at St. Andrews, in nearly one continuous mass of dark-coloured shells.

The mountain limestone defines throughout the district the limits and outcrop of the true series of coal-metals. All the beds *beneath* are of little value as combustibles, and unremunerative in the working ; those *above* this calcareous mass are extremely rich in quality, and amount upon an average to fifteen workable seams of coal, while in the Dysart basin they are thirty-three in number, and some of them of



great thickness. The *yellow sandstone* is the clear and certain line of demarcation along the northern verge of the under-coal series. And as if to render that line still more definite, the truncated edges of every member of the series are severally brought to the surface along the elevated ridge to the east and west. Thus, at St. Andrews, the beds are all exposed to view by the action of the waves, under the line of the Castle rock and the Witch Lake, where they amount to twenty-two in number, and to about 150 feet in aggregate thickness. The Lomond acclivities display the relative position of the two classes of rocks in the same distinct manner, where the beds can be counted individually, from the mountain encrinal limestone to the yellow sandstone of Glenvale and Urquhart ; and along the Cleish, Saline, and Dollar hills there is everywhere a favourable opportunity of examining in detail the several members of the group.

As it is not my intention to go into details in this memoir of Dura Den and its relative rocks, suffice it to state that Fifeshire contains an epitome of the Carboniferous system, divided into numerous local basins, and everywhere characterized by the boundary lines of the lower and older formations. The eruptive rocks, within the area of the coal-field, are here also to be studied to great advantage, where they have played no insignificant part in giving shape and outline to the landscape, and in laying open the enclosed treasures. It were indeed impossible to convey an adequate idea, in mere description, of the marvellous display of plutonic action of which the district around has been the theatre ; subterranean movements crushing and grinding into fragments the solid strata, parting and heaving them like forest leaves asunder, or crumpling into complicated folds the tougher and more unyielding beds, like some fabric of manufacture tossed and twisted by the wind. The storm lifts the ocean into lofty curling billows, leaving long narrow troughs and frightful yawning chasms beneath. Here, in like manner, and all over the surface, the crust has

been broken up, and the minerals tossed about or agitated like wreck upon the waves, and subsiding, have been cast into the form of ridges, or of broad tabular masses. The ridges, with their broken edges in the interior of the county, have been gradually rounded off, and are now covered with soil ; while along the shores they still present the effects of the violent commotions to which they have been subjected—exposed and laid bare by the action of the sea upon the lower levels of the disrupted strata.

Hence the coal-metals were at once indurated, and shared in the general elevation of the trap-hills, where they are either folded round their bases, or are depending, drapery-wise, from the sides. The lowest of the beds in the under series are raised about a thousand feet along the Lomond ridge, encompassing the east and west cones ; and Largo and Kelly Laws have each their coal-basins, of workable minerals, stretched along their eminences, while on the low grounds which skirt them on the south, the metals are collected in various independent hollows by the shore, and dip rapidly into the estuary of the Forth. Fifeshire thus owes its diversified shape and contour, and easy access to all its vast mineral treasures, to the early disturbances by which it has been all over dislocated and furrowed. Every district has a section, separate and independent, of its own ; sweetly pastoral in its uplands ; richly alluvial in its straths and valleys ; deeply loamy in its hollows and hill-sides ; pre-eminently fertile in its agricultural conditions ; and in its mineral stores of lime, iron, and coal, not surpassed in amount and value by any proportional area on the surface of the globe.

The only other noticeable point connected with the structural arrangements of Dura Den, is a vein of galena or sulphuret of lead, which occurs on the farm of Myretown of Blebo, and which runs across the strata from nearly south to north. Its discovery was made in the year 1722—a year of disastrous gold-hunting and ill-devised mining researches throughout

Scotland—by large outliers and masses of ore found on the surface of the ground. Some of these are described as weighing from ten to twenty-four stones in weight. A vein was opened about two feet thick, and gradually decreased from seven to about three inches, when, by the disturbed and ruptured state of the strata, and frequent intrusion of the trap, the operations were abandoned as being unremunerative. The shaft, which is still open, was carried through the trappean rock; and thus the position of the vein gives probability to the theory that the igneous agency which forced upward the trap, produced also by sublimation the ore which is found enclosed within its mass or near vicinity.

TRAP DYKES, composed of concretionary greenstone and basalt, occur frequently in the neighbourhood, and, indeed, are everywhere distributed over the coal-basin. They range in all directions, rising perpendicularly through the stratified rocks, and often stand several feet above the strata, like a wall rudely piled up by Cyclopean builders. The adjacent strata in the line of their direction are generally altered in position, upheaved or thrown down by faults, and their structural characters are much changed. The coal for some distance is calcined and valueless; the limestone near them will not burn into quick-lime; and the shales and sandstones are hardened and chertified. The transference of mineral qualities is likewise remarkable in the intruding trap itself, which at the point of contact becomes more or less calcareous and siliceous—often coated with iron, and enclosing portions of coal or carbon. These changes resulted clearly from the igneous agency, which by its upward pressure severed the superincumbent mass of stratified rocks, and then poured like molten lead its subterranean materials into the fissures. Once observed in any district, these natural dykes are of too marked a character not to excite inquiries, in every intelligent observer, as to their uses and mode of formation; and occurring, as they do, in every region,

and among all classes of rocks, from the oldest primary to the newest tertiary, they are obviously designed to subserve some grand purpose in the plan of creation.

The coal measures are likewise intersected by *faults* or *fractures*, the fissures occasioned by which are usually filled with clay and debris of the surrounding rocks. They may be considered as so many excellent mechanical contrivances, by means of which the useful mineral has been rendered accessible to man. Had they not existed, the pits must have speedily filled with water, or the water have accumulated in such quantities as to have exceeded all power of machinery in effecting the drainage of a mine; whereas, by the natural arrangement of a system of *faults*, the continuous beds of shale and sandstone, alternating with the coal, are broken up into limited sections, and the water percolates in limited quantities. The component strata are thus divided into insulated masses, rising one above another in the form of a stair, and inclined at a considerable angle to the horizon; so that, while each section is separated from the adjacent beds by a mass of clay impervious to water, the limited extent which it occupies, and the inclined position into which it has been thrown, serve to render the operations of the miner comparatively easy, as well as greatly to diminish the expenses of excavating the mineral.

The first appearance of the coal deposit in Dura Den furnishes a beautiful example of these remarkable phenomena in the action of both dykes and faults. Three beds of coal, with their enclosing shales and sandstones, are severally lifted from their original horizontal position, elevated to an angle of forty-two degrees—some of them to the perpendicular—are again shifted downwards, and finally replaced in the most perfect horizontality towards the upper part of the Den. There are several repetitions of similar dislocations, upheavals, and depressions, as the coal metals rise southwards to Largo-ward, there attaining an elevation of 600 feet above the level of Dura Den, and even higher in the coal basin of Rires on the sloping

sides of Largo Law. The general contour of the district is that of a series of ridges, with alternating hollows, all the result of corresponding disturbance in the rocky masses beneath, and all so arranged internally by a wise Providence, as at once to impart beauty and variety to the landscape, and to render the enclosed treasures of coal, lime, and iron most subservient to the use and comfort of man.

The several systems or formations of rocks thus briefly glanced at, when studied on the great scale, are all of the easiest access for observation, and are all separated by well-marked physical distinctions. Approached from the north, as we have done, they all lie face to face with the observer, trending from east to west, and successively protruding in regular serial order from below upwards. The courses of a building are not better defined, nor the colours of a picture more clearly delineated, and every rock in its due place of superposition stretches across the mainland from sea to sea. In no district are any of the members of the series, primary or secondary, covered up or entirely concealed from view. Where the continuity is broken by straths, rivers, or arms of the sea, or, as often occurs, by the eruptive rocks, the formation can again be traced out with little difficulty on the opposite sides. This arrangement, more especially with all the divisions of the Old Red, is uniformly persistent, and as nearly as possible according to lineal perspective. From the blue slates of the Grampians to the variegated sandstones of Dura Den, there is a continuous succession of ascending layers of rock, lying with their out-crops tilted one above another, chapter after chapter of the world's history stereotyped on their stony tablets, and the families of its earliest annals, in countless numbers of vegetable and animal forms, preserved for the inspection of all who will read the instructive pages.

Sir R. I. Murchison, in the course of last year, went over the whole of the district now described, and in the concluding

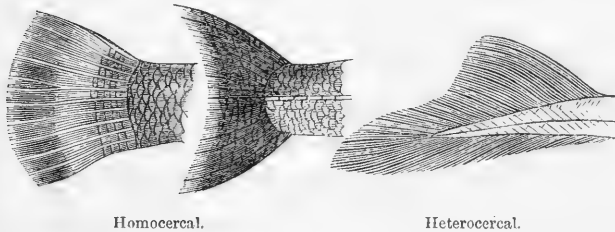
chapter of *Siluria*, after stating that the oldest known rocks of the British Isles are composed of a highly crystalline, hornblendic gneiss, with powerful granite veins, and that in the North Highlands of Scotland there is from that rock an ascending order in proceeding from north-west to south-east, proceeds to observe "that the conglomerates and sandstones which in the North-eastern Highlands form the base of this series, are compounded out of all the pre-existing rocks above described, whether gneiss, older grits, quartz rock, mica-schist, granite, &c., as ranging in ascending order from the west to the east coast. It is this great and thick lower zone of the Old Red of the Northern Highlands which I consider to be equivalent *in time* of those beds on the eastern and southern flanks of the Grampians,—Arbroath, Dundee, and Balruddery,—and which, unquestionably, constitute the base of the group, as demonstrated in England by their conformable union downward with the true Ludlow rocks or uppermost Silurian."

"The true base," continues Sir Roderick, "in Shropshire and Herefordshire of the old red sandstone, properly so called, is, I repeat, seen to be a red rock, containing cephalaspis and pteraspis, and gradually passing down into the grey Ludlow rock; and in both of these contiguous and united strata, remains of large pterygoti are found, but of different species in the two bands. Now, although the Arbroath paving-stone, and the grey rocks ranging to the north of Dundee, much resemble the uppermost Ludlow rock, they contain the *Cephalaspis Lyellii*, with another kindred species, and are therefore to be classed with the Devonian rocks, though they must, under every circumstance, be viewed as the very base of that natural group. It follows, therefore, that, if the great lower conglomerates on the flanks of the Grampians really underlie all those grey rocks with pterygoti, cephalaspides, and *Parka decipiens*, they can no longer be united as they have been with the Old Red or Devonian, but must represent some portion of the Silurian system.

"Lastly, I visited Dura Den, in Fifeshire, in the company of

Lord Kinnaird and the Rev. Dr. John Anderson, whose able work on that beautiful tract is well known to geologists, and now I entertain no doubt whatever, that the yellow sandstones with red layers pertain truly to the Old Red group, that they are entirely subjacent to the equally yellow carboniferous sandstones with coal plants, and are of about the same age as the yellow sandstones of Elgin. A splendid specimen of the genus *holoptychius*, three feet long, was found on the occasion of this visit, on the property of Mrs. Dalgleish; and as a form very similar abounds also in the lower red portions of the deposit at Clashbennie, the age of the yellow sandstone is clearly substantiated. . . . Dr. Anderson is now convinced that this splendid specimen, now in the collection at Rossie Priory, is truly the *Holoptychius Andersoni* of Agassiz.

“ He further informs me that the yellow sandstones of Dura Den contain ichthyolites of the genera *Platygnathus*, *Diplopterus*, *Glyptopomus*, *Holoptychius*, *Pterichthys* (*Pamphractus*), with a new genus, an assemblage which shows that certain genera range from the Caithness flags, or central portion of the Old Red group, up into its highest zone. Dr. Anderson’s finest specimens are in the British Museum.”\*



Homocercal.

Heterocercal.

\* *Siluria*, Third Edition, pp. 553, 556, 559, 574.

## CHAPTER III.

## HISTORY OF THE FOSSIL REMAINS.

THESE comprise several distinct genera as well as species of their different families. There is one belonging to the order of crustacea, and the rest are of the type of true fishes. Some of the genera are entirely new to science, and some are new species, whose generic forms have been found in other localities. The remains of these fishes are so very abundant in the yellow sandstone deposit of Dura Den, that a space of little more than three square yards, as already noticed, when the writer was present, yielded about a THOUSAND fishes, most of them perfect in their outline, the scales and fins quite entire, and the forms of the creatures often starting freely out of their hard stony matrix in their complete armature of scale, fin, and bone.

This peculiarity of entireness, and even of freshness in these olden denizens of the waters, is so remarkable that, when first exposed to view on the newly split-up rock, there is a life-like glistering over the clear, shining, scaly forms, that one can scarcely divest himself of the idea, instead of the innumerable series of geologic terms to be counted, he is looking actually upon the creations of yesterday, the relics of things that had just ceased to breathe. "Here is a living one!" exclaimed a workman, as he raised from the bed of the river a large flagstone on which were counted upwards of fifty fishes, one pre-



eminently beautiful, full, and rounded in its form. Indeed, the most splendid representations of an Audubon, a Gould, or a Landseer, on their glossy canvas, will shrink in comparison beside these pictures of nature-painting, brighter than the dyes of the artist as set in their stony tablets, and contrasting finely with the rich saffron-coloured rock in which, uninjured and unstained, they have hung for ages.

Here, doubtless, were inlets to deep waters, and projecting creeks, and oozy sandbanks, and currents with their affluents, and arrangements of seas, lakes, and lands now all utterly obliterated. The sands are piled up into thick-set rocks of hundreds of feet in height. The waters are drained off. Hills and ridges of different mud accumulations give form to a scene altered and varied in every feature. But the alteration is only external. Everything within and beneath the surface preserves entire the character and phenomena of the laws by which the seasons, the tides, and the atmosphere were ruled in these ancient days. The very ripple-mark is there, attesting the shore-lines, the flow and recess of the waters over their silty banks. The direction of the winds are to be traced in the general trend of the furrows impressed upon the surface. The tiny pits and hollows of the rain-drop tell of clouds that obscured the sky, and even the quarter of the heavens whence issued the breeze that bore them onwards. And in the vast numbers and the bulky forms of the fishes there is evidence of the rich provisions of nature in supplying them with food.

How long since these things were! how very short a period since they were regarded with either interest or understanding! A quarter of a century has scarcely elapsed since we had any knowledge of them at all. Dura Den was a sealed-up book, and all its letterpress of the deep interior, and the long antepast of historic times, unread by a single human eye. A little brief space before this quarter of a century, and men only wondered at the strange figures which nature presented in the rocks, and assigned superstitious tales and occult qualities to the misun-

derstood representations of plants and animals. The past generation actually disputed about the plastic virtues of the earth, the mystic influences of matter, and fancied that in the fossils they saw the sports of nature or the germs of future creations. Scholastic theologians viewed with suspicion emblems of living things of which they had no account to give in their narrow interpretations of the sacred text ; and have sounded, in many a huge folio, how the narrative of the creative week was endangered by the discovery of pages which they neither deciphered nor comprehended aright.

One now smiles at the recollection of the simple and casual manner in which attention was gradually awakened to these interesting relics. We think how many must have been destroyed through ignorance or carelessness ; how many a rich fossiliferous neuk must have been exhausted, by sheer indifference to gather up the curiosities exposed to view. An esteemed lady of the ancient house of Fingask, Miss Murray Thriepland, and imbued with a fine taste for things of antiquarian research, was the first to place in safety, in the Perth Museum, the earliest fossil relic from the quarries of Clashbennie, now figured and described by Dr. Fleming in No. II. of the *New Series of the Edinburgh Journal of Natural and Geographical Science* for 1830. A student of St. Andrews University brought to the same distinguished naturalist, in the summer of 1827, a few scales on a piece of sandstone from Drumdryan, a mile to the westward of Dura Den, which are figured in the same paper, and noticed as *probably belonging to a fish* of the vertebrated class. Mr. David Buist, a land-surveyor in Perth, invited the writer to see his collection of Scottish pebbles, cairngorms, and other crystals, in the autumn of 1828, when my eye was arrested by some pieces of red sandstone which were covered with large whitish scales, regarded at the time as oyster shells from Coupar-Angus and Clashbennie quarries, but now better known as the appendages of *Holoptychius Murchisoni* and *H. noblissimus*. While engaged

at a meeting of Presbytery, in a discussion on ecclesiastical matters, in the spring of 1836, a mason called me out and showed me an entire fossil fish, plump and round in shape, "which leaped into his hands," he said, at the opening of a slab in Dura Den; this specimen was the first that was figured of the family of holoptychius, and is fully described in the *Monograph* of Agassiz on the Old Red sandstone, as *Holoptychius Andersoni*, the most abundant of all the fossil relics and species in this celebrated locality. The Clashbennie quarry has been worked for upwards of a century, during which period what destruction of its varied treasures. As Isaak Walton might say, we ourselves had a glorious nibble of the great Fish, when, on the 19th March 1839, in company with Dr. Malcolmson, I visited the quarry, and found the workmen on a rich bed of fossils and rudely smashing a large fin—cautioned them against the rough operation—and promised a reward for the chance-find on the flag-stone. Next day the splendid specimen was in the hands of another. Now it fittingly reposes among the trophies of the British Museum—but no fin, save sadly mutilated.

Many labourers were now in the field, and many provisional names were bestowed on fossils that were afterwards to be changed as their characters became better understood. The rich deposits of the chalk in the south, and the pitchy-stained flagstones of Caithness and the Orkneys in the north, were eagerly explored, as each seemed the terminal points of organic life at the two extremes of the geological scale. The tertiaries had not as yet attracted the eloquent pen of Sir Charles Lyell to record their remarkable divisional histories. The domains of Siluria had no place in the system. The Old Red was just settling into position, and casting about for a distinctive appellation, under the hard, dry details of Hibbert, Sedgwick, and Trail. And Hugh Miller, without chart or compass, was navigating the creeks and bays of Cromarty, gathering and laying up creatures of new and strange mould, or gazing with blank

wonderment on forms of which no one could tell him the names, or furnish him a key to unravel the mystery of the rocks in which they were entombed.

But the master-hand of Louis Agassiz was at work also, who, in his *Synoptical Table of British Fossil Fishes*, reported to the British Association in 1843, the discovery of sixty-four generic and specific forms of ichthyologic life in the Devonian system of rocks alone, chiefly from the Caithness, Moray, Perth, and Fife members of the Old Red. The list has been since greatly extended. And now, in the last edition of *Siluria*, there are enumerated about forty genera, and nearly two hundred species of the fish and crustacean types, as found in this system of rocks in Britain, Russia, and America. Agassiz notices only six genera of ichthyolites, crustaceans, and plants belonging to the great Silurian formation; the list in Murchison's new work shows an increase of at least fifty new genera and of five or six hundred species, and all of most remarkable characters and forms, chiefly of the invertebrata and the crustacea.

"Geologists," says M. Agassiz,\* "hardly seem to appreciate fully the whole extent of the intricate relations exhibited by the animals and plants whose remains are found in the different successive geological formations. I do not mean to say that the investigations we possess respecting the zoological and botanical characters of these remains are not remarkable for the accuracy and for the ingenuity with which they have been traced. On the contrary, having myself thus far devoted the better part of my life to the investigation of fossil remains, I have learned early, from the difficulties inherent in the subject, better to appreciate the wonderful skill, the high intellectual powers, the vast erudition displayed in the investigations of Cuvier and his successors upon the faunæ and floræ of past ages. But I cannot refrain from expressing my wonder at the puerility of the discussions in which some geologists allow

\* *Contributions to the Natural History of the United States.* By L. Agassiz. Vol. i. pp. 93, 94. Little, Brown, and Co., London. 1857.

themselves still to indulge, in the face of such a vast amount of well-digested facts as our science now possesses. They have hardly yet learned to see that there exists a definite order in the succession of these innumerable extinct beings, and of the relations of this gradation to the great features exhibited by the animal kingdom : of the great fact, that the development of LIFE is the prominent trait in the history of our globe, they seem either to know nothing, or to look upon it only as a vague speculation, plausible perhaps, but hardly deserving the notice of sober science.

“ It is true, Palæontology as a science is very young ; it has had to fight its course through the unrelenting opposition of ignorance and prejudice. What amount of labour and patience it has cost only to establish the fact that fossils are really the remains of animals and plants that once actually lived upon the earth, only those know who are familiar with the history of the science. Then it had to be proved that they are not the wrecks of the Mosaic Deluge, which for a time was the prevailing opinion, even among scientific men ! After Cuvier had shown, beyond question, that they are the remains of animals no longer to be found upon earth among the living, Palæontology acquired for the first time a solid basis. Yet what an amount of labour it has cost to ascertain, by direct evidence, how these remains are distributed in the solid crust of our globe,—what are the differences they exhibit in successive formations,—what is their geographical distribution, only those can fully appreciate who have had a hand in the work. And even now, how many important questions still await an answer ! ”

One result stands now unquestioned : the existence during each great geological era of an assemblage of animals and plants differing essentially for each period. Hence those minor subdivisions in the successive sets of beds of rocks which constitute the stratified crust of our globe, the number of which is daily increasing, as our investigations become more extensive and

more precise. Along the line of our geological section, from the azoic members of the primary series to the upper fossiliferous strata of the Devonian system, there are at least three well-characterized suites of rocks, with their correlative enclosed organic remains. The lower grey sandstones represent a zone of life when huge crustacean types prevailed in the seas and estuaries of the district, in the remarkable forms of pterogotus, pterichthys, cephalaspis, coccosteus, himantopterus, and stylonurus. Next appeared the thick, shining-scaled sauroids and calacanth, represented by dipterus, osteolepis, cheiracanthus, dendrodus, acanthodi, and other genera of cartilaginous fishes. The highest zone of the period embraces the red and yellow sandstones of Clashbennie and Dura Den, when the holoptychius family appears for the first time in countless numbers and gigantic forms, and accompanied by congeners of strong affinities in size and scaly armature, as the platygnathus, glyptopomus, glyptolepis, phyllolepis, diplopterus, and now, as in this work for the first time figured and described, the *Glyptolæmus* and the *Phaneropleuron*. The grand EPOS of organic life immediately succeeds, ushered in by a vast profusion of plants, countless multitudes of molluscs, an extraordinary increase of fishes which "the waters brought forth abundantly;" and now also, as appears to be clearly established, the higher reptilian structure of organization is brought upon the scene. Thus the tribes and products of the carboniferous age have their representatives among the plants in immense varieties of ferns, lycopodiums, calamites, sigillaria, lepidodendrons, coniferæ, and cycadecæ; among the shell forms are the encrinites, producti, inocerami, pectens, mytilli, orthes, spirifers, bellerophons, goniatites, nautili, and orthoceratites; among the fishes are the well-marked amblypterus, palæoniscus, gyracanthus, cteracanthus, eurypterus, and megalichthys; and all of whose combined remains now constitute our rich deposits of coals, ironstone bands, and lofty mountains of limestone.

Dura Den stands on the verge of the two great epochs—

marking the outgoing and the incoming of the two most remarkable phenomenal aspects of the physical history of our planet—and the products of which, garnered up in ages long past, are now so essential to our progress in art, science, and commercial enterprise.

The fishes up to this period are all of a type, and are modelled according to a special plan, both in the scaly envelope and osseous structure. The interior skeleton is composed of cartilage, and the outward covering of true bone, the scales, fins, tail, and external plates of the head being all constructed of bony material. The back-bone, or dermal ridge, extends to the extremity of the tail-fin, thus at once adding strength to the cartilaginous body, and giving a greater degree of propelling power to its caudal organ. It is hence called HETEROCERCAL, in contrast with all existing fishes whose back-bone terminates within the tail-fin, and is therefore termed the HOMOCERCAL, or equally-lobed structure. The existing ray, shark, and sturgeon are exceptional cases. Hence in these and in some other respects, especially in their dentition, Agassiz remarks that the fishes of this period all partake, more or less, of the characters which, at a later time, are exclusively found in reptiles, and no longer belong to the fishes of the present day. They are therefore classed among the Order of *Sauroids*, to denote their reptilian affinities; and thus Agassiz considers that “the earliest fishes are rather the oldest representatives of the type of vertebrata than of the class of fishes, and that this class assumes only its proper characters after the introduction of the class of reptiles upon earth.”\*

It should be the great aim of the geologist, in following out these generalizations, to ascertain with more and more precision the true affinities of the groups of the same zone and period to one another, and to those especially of the preceding and following epochs; and thus to note the character of the successive changes the organic kingdom has undergone, the

\* *Essay on Classification*, p. 110, by M. Agassiz.

combination of the successive tribes into distinct faunæ and floræ during each period of change, and to gain some insight, if possible, into the causes, or even the circumstances, under which the changes themselves may have taken place. Our small contribution to this interesting department of Palæontology comprises a group of creatures, which, in structure and form, have many affinities to each other, and comparatively few to the occupants of the waters in succeeding times, or to any now living; and, in point of geographical distribution, our field of review is of very limited extent, covering only as yet a few square yards of fossiliferous sandstone, lying on the confines of the Devonian and Carboniferous epochs of organic life.



*Sphenopteris Affinis.*

(Carboniferous Sandstone of Dura Den.)



*Pamphractus Andersoni*.—Ag.  
*Pterichthys Hydrophilus*.—Eg.

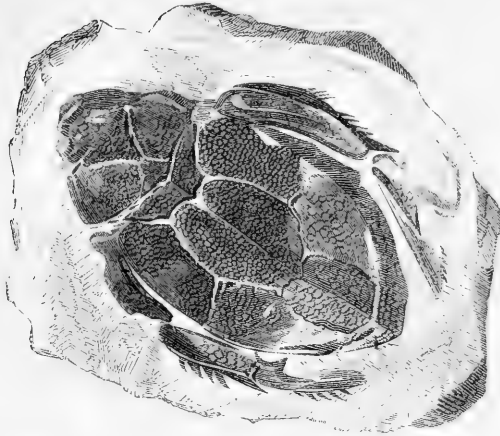
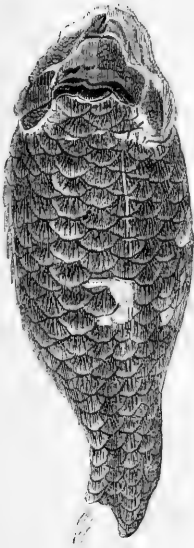


Fig. 1

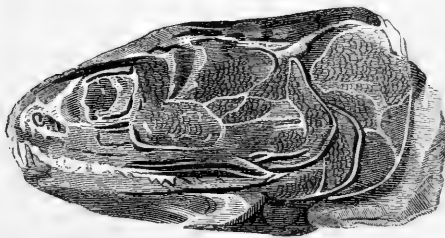
*Holoptychius Andersoni*.—Ag.  
Fig. 3.



*Platygnathus Jamesoni*.—Ag.  
Fig. 2.



Fig. 4.



*Diplopterus Dalgleisiensis*.—Ag.

THE FIRST GROUP OF FOSSIL REMAINS DISCOVERED IN DURA DEN, 1836.

## CHAPTER IV.

## DESCRIPTION OF THE FOSSIL REMAINS.

THE generic and specific descriptions of several of this remarkable group of fossils are already well known to geologists by the works of M. Agassiz, the *Poissons Fossiles* and the *Monographie du Vieux Grès Rouge*, and which we mainly adopt in the following abridgment of his more elaborate details. The contributions of my distinguished friend Professor Huxley now for the first time enrich the science of Palæontology, and cannot fail to be deeply interesting, especially in the new views advanced on the affinities of the genus *Holoptychius*. His descriptions of the new genus *Phaneropleuron* show the importance to all fossil collectors of carefully preserving every organic fragment, however small, they may casually obtain,—the several portions of this beautiful representation having been procured by me at the intervals of many years—some twenty years ago, some ten, the last within the present year, furnishing the large development of the caudal and dorsal fins—and now out of all, in the hands of the scientific artificer, the perfected model of this unknown creature of the rocks. Agassiz first named this fish *Glypticus* simply, but, from the fuller and more perfect specimens lately submitted to him, he agrees to the more descriptive appellation now assigned by Professor Huxley.

The Plates VII. and VIII., from the beautiful drawings of Lady Kinnaird, show the figures of the fishes as they lie in the

matrix, in their full rounded forms, and each a third part of their natural sizes. The large caudal system of fins in Plate VIII. fig. 1, is nine inches and a quarter in length, and five inches and nearly a half in breadth, and, adjoined to the holoptychius in Plate VII., renders the restored length of that magnificent specimen to be about forty-two inches. The greatest breadth in the anterior part of the body is fully thirteen inches and a half. In both, the pictorial effect, which was chiefly aimed at, is finely brought out according to Nature's own arrangement in her enduring and faithful lithograph.

The fishes of the Old Red Sandstone formation all belong to the placoid and ganoid *orders*; and their *families* are represented by the lepidoids, the sauroids, and cœlacanth. The fossil remains of Dura Den fall to be arranged under these natural divisions, and furnish of their several kinds perhaps the best specimens, in perfect outline and preservation, that have anywhere been detected in the rocks of the earth. "Geology demonstrates," says Professor Owen, "that the creative force has not deserted this earth during any of her epochs of time; and that in respect to no one class of animals has the manifestation of that force been limited to one epoch. Not a species of fish that now lives, but has come into being during a comparatively recent period: the existing species were preceded by other species, and these again by others still more different from the present. No existing genus of fishes can be traced back beyond a moiety of known creative time. Two entire orders (cycloids and ctenoids) have come into being, and have almost superseded two other orders (ganoids and placoids) since the newest or latest of the secondary formations of the earth's crust."\*

\* Address by Richard Owen, V.P.R.S., to the British Association at Leeds, 1858.

*Pamphractus Andersoni*.—AGASSIZ.

*Pterichthys hydrophilus*.—EGERTON.

The bed of rock in which specimens of this genus (Pl. I. fig. 1) were found, is about fifty feet above the holoptychius bed, which lies in the bottom of the ravine, and on a level with the rivulet which traverses it. A small projecting ledge of sandstone was cleared away twenty-four years ago, and then, and never since, this singular mine of fossil wealth was laid open. The fossil spot, according to the inquiries I made at the time, was literally blackened by the shoal of "frog-like creatures," as the workmen termed them, exposed to view; but so friable was the stone in which they were embedded, that few of the forms were preserved entire. Many were carried away, and others speedily reduced to dust. One flag only, with thirty-three impressions, and about two feet square, was saved at the time from the wreck. A portion of this slab was forwarded by me to Agassiz, then resident at Neufchatel; another is now in the Agricultural Geological Museum at Edinburgh; a fragment has been deposited in the British Museum at London; and the remaining portion, in the possession of the proprietor of Dura Den, has gradually yielded to the influence of decay, the figures being much injured and obliterated.

The history of this remarkable fossil is now, therefore, chiefly to be read in the earlier discussions that took place immediately upon the discovery. These are to be found in the *Poissons Fossiles* and the *Monograph* on the Old Red, of Agassiz; in the *Old Red Sandstone* of Hugh Miller; the *Palichthyologic Notes* of Sir Philip Egerton; and in the *Course of Creation* and *Prize Essay* of the author.

These curious crustacean fossils, when transmitted to Neufchatel, were at first regarded by M. Agassiz to belong to the genus *Pterichthys*; but upon a more minute examination of the new group cephalaspis, coccosteus, and pterichthys, Agassiz was convinced of distinctions not formerly observed. "I had," he says, "at first connected pterichthys, the only species known of that genus, by calling it *Pterichthys hydrophilus*; but a more profound study and attentive comparison of that species with the genus coccosteus, have proved that it ought to form a distinct genus, intermediate betwixt pterichthys and coccosteus, which I have named *Pamphractus*, in consequence of the divided form of the carapace. The pectoral fins of pamphractus resemble very much those of pterichthys in their form—being slender, elongated, and crooked. But the plates of the carapace are all differently arranged. The central plate is very large (*énorme*); it covers two-thirds of the whole carapace. The lateral plates, which acquire so great a development in the pterichthys, are here reduced to narrow stripes, stretching to the edge of the carapace; while, on the other hand, the posterior plates are of very great size, and form, with a small intercalated plate, the extremity of the carapace. The disposition of the plates of the head is likewise very different from that of the pterichthys, in which we discern no thoracic cincture as in that genus, but a transverse line, which separates, in a striking manner, the plates of the

head from those of the carapace. . . . The excessive development, in short," he concludes, "of the central plate of the carapace, which reaches the articulation of the head, the absence of a thoracic cincture making the round of the body, and the distinct separation of the occipital articulation, will always distinguish this genus from that of pterichthys."

This is decisive language, nor is anything more of descriptive detail required to make the structure and the generic characters of pamphractus thoroughly understood. But as matter of geological history, as well as of controversy, it may be proper to state, that when the accuracy of these distinctions was challenged by Dr. Fleming and Hugh Miller, upon the ground of alleged exaggerations in my plate-figures, Agassiz at once repelled the assertion. The impressions on the fossil slab forwarded to Neufchatel are ELEVEN in number, three of the "broad" and eight of the "narrow" species; and comparing the one with the other, the print with the fossils, he records, "They have been figured *very fairly* by Dr. Anderson, in his interesting Memoir on the Geology of Fifeshire." The print, in fact, is a perfect transcript of the fossil, as if taken in a mould, curves, projections, plates, arms, and tubercles all duly and "fairly" preserved as in the original; and with all the materials, and so many actual forms of the creature before him, Agassiz hesitated not to change his views, and to feel assured that it was really a pamphractus, and not a pterichthys that he was examining, and decided for the new genus accordingly.\*

Sir Philip Egerton, however, and I believe many other eminent authorities, dissent from the views of M. Agassiz on the revised and altered cognomen of the Dura Den fossil. In a conjunct paper read before the Geological Society of London on the 19th April 1848, and published thereafter in the Transactions of the year, there occurs the following statement:—"In searching for further evidence in support of my views, by comparing pterichthys with the description and figures given by Agassiz of the allied genera, I have been surprised by the great similarity between the restoration of the genus *Pamphractus* and the dorsal integuments of *Pterichthys*. Having never seen a specimen of *Pamphractus*, I should not be justified in expressing any positive opinion regarding this genus, but I cannot help thinking that it is founded on a specimen showing the true dorsal arrangement of the lorication of *Pterichthys*. . . . The most important point for my argument is fortunately that which is best known, namely, the occurrence of a central lozenge-shaped

\* Dr. Anderson, dans une notice très-intéressante qu'il a publiée sur la *Géologie et la Botanique* du comté de Fife, donne la figure d'un poisson (Fig. 6 de sa planche) qui ressemble beaucoup à mon *Pamphractus hydrophilus*, mais qui en diffère cependant par la forme plus allongée de la tête et par le développement de la ceinture thoracique qui est visible entre la tête et la carapace. A moins que ces différences ne soient l'expression des caractères particuliers des faces supérieure et inférieure de la carapace, que je n'ai pas pu comparer entre elles, il faudra considérer ce fossile comme une espèce particulière que je signale à l'attention des géologues écossais, en proposant de l'appeler *Pamphractus Andersoni*. Je suis d'autant plus disposé à considérer le poisson de Dr. Anderson comme une espèce à part, que la forme de ses contours diffère de celle du *Pamphractus hydrophilus*; mais une comparaison d'un nombre plus considérable d'exemplaires mieux conservés pourra seule décider cette question.—*Monographie*, Chap. iii.

plate, similar in form, in position and structure, to that found in *Pterichthys*. This plate characterizes the ventral region of the fish, and thus affords remarkable testimony to the accuracy of the view I have taken in assigning the like position to the homologous plate in *Pterichthys*.\*

Since the publication of this paper I believe M. Agassiz has not again turned his attention to the subject, nor amidst his numerous elaborate investigations has had either leisure or opportunity of doing so. But in a communication I recently had the honour to be favoured with, he says, "You must know that I have had no opportunity of making a renewed examination of the Dura Den fossils since I was favoured with a sight of those you forwarded to me at Neufchatel twenty years ago, and that I have no chance whatsoever of making now the comparisons necessary to verify the suggestions of Sir Philip Egerton. At the same time, I have, like all those who know him, such implicit confidence in his accuracy and ability to decide in such matters, that I should feel reluctant to insist upon the correctness of my own opinions, expressed so long ago, in contradiction to his views, resulting from a more recent examination of the facts. I have not the remotest doubt that Sir P. Egerton has shown a closer affinity to exist between the *Pamphractus Andersoni* and the species of *Pterichthys proper*, than I supposed there was between them. Still I am not yet, on that account, satisfied that the genus pamphractus must be given up. Judging from my figures and descriptions, I am now inclined to believe that coccosteus and cephalaspis can no longer remain in one and the same family with pterichthys. Again, the views I have presented respecting the limitation of genera in my Essay on Classification, will require a revision of all the pterichthys, with reference to their genuine characters, and I look forward, from the indications I can gather in my own work, to the necessity rather of subdividing the species which have been united as pterichthys into several genera, than to the propriety of combining pamphractus and pterichthys. I throw out this suggestion for your consideration, and must leave it to the palæontologists who have the necessary materials on hand finally to settle these points."†

While these generic resemblances, as well as distinctions, must be left for future revision and determination, let it be observed that pterichthys, cephalaspis, coccosteus, and pamphractus are all of the family type of *Lepidoides*, and have such affinity in outward form as readily, in mutilated specimens at least, to be mistaken for each other. The appendages of the head, having the appearance of wings, suggested the terms of *Pterichthys*, or the winged fish (*pteros*, a wing; *ichthys*, a fish). The plates covering the body, according to their number and position and form, gave rise to the generic distinctions, and the species of each have been determined by minor differences. The external organs in all are enamelled, and discover, like all the crustacea of the period, the tuberculated surface. The pterichthys of the northern counties, in Cromarty, Moray, and Elgin, vary in size from nearly a foot to an inch in length, and the wings generally are extended perpendicularly to the body. The pamphractus of Dura Den are all of a size, from two inches to

\* Vol. iv. p. 308.

† Dated Boston, Cambridge, U.S., 4th December 1858.

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CLYPTOPOMUS MINOR, Agassiz.



three inches in length, and about an inch and a half in breadth; the wings, in every specimen yet discovered, are depressed and inclined to the sides; and in no instance has any portion of the caudal organ been detected, in the least remaining tracery or impression. The carapace, in all the plates and lateral appendages, is fully defined; and, as remarked by Hugh Miller upon a reconsideration of my specimens presented to the Edinburgh Geological and Agricultural Museum, "one of the most striking specific distinctions of the *Pamphractus Andersoni* consists in the length and bulk of the arms, and the comparatively great prominence of those angular projections by which they are studded on the edges,"—projections which seem to be but expansions of those confluent lines of tubercles by which the arms of all the numerous species of the genus pterichthys are fringed.

*Glyptopomus minor*.—AGASSIZ.

PL. II.

"I am only acquainted," says M. Agassiz, "with a single specimen of this genus, from the collection of Professor Jameson, which I at first took for a *Platygnathus*. Afterwards, when I had leisure to make a more minute examination, I was soon convinced that, notwithstanding the resemblance of its exterior with the platygnathus, it was distinguished by particulars of structure too important to admit of its remaining associated with this type, and consequently I was obliged to form a separate genus."

We may now perhaps express our surprise that, by so discriminating a judge of fossil fishes, a moment's hesitation could have existed as to the wide and obvious distinctions manifest in every outline of the specimens in question. That the *Glyptopomus* and the *Asterolepis* might for a time be confounded, one can readily admit, more especially so long as only the scales and plates of the latter were the sole means of comparison. But in nothing do the platygnathus and the glyptopomus, in general appearance and external structure, seem to bear the slightest resemblance.

The differences, as pointed out in the *Monographie du Vieux Grès Rouge*, upon subsequent examination are very clearly stated. "The scales of the platygnathus are round and imbricated, so that the posterior edge of one scale covers the anterior edge of the following one, and possessing in this respect all the characteristics of the scales of the cælacanth; on the other hand, those of the glyptopomus resemble the scales of the sauroids, which are rhomboidal or quadrangular, placed in juxtaposition to each other, and are never imbricated. Moreover, the platygnathi are elongated fishes, furnished with a long tail and a very powerful rudder fin; whereas the glyptopomi are much thicker, and their tails shorter and less branching in the bundles of rays. The ornaments on the scales of the glyptopomus are deeply marked, resembling those of the cælacanth, while all the plates of the head are strongly tuberculated with a beautiful shagreen enamel."

This description was given by M. Agassiz upon inspection of the specimen now in the British Museum, which has a large thick flat body, approaching in form to the *Holoptychius Andersoni*. The head is proportionally small,

with the frontlets nearly in the middle; the nostrils are behind. The occipital, and a great enamelled plate on the side of the head, indicate that it was covered, like the polypterus, by a single osseous plate, under which was fixed the great masticating muscle. A specimen now in my own possession shows, in addition, the edge of the lower jaw, with one or two small teeth, which is extremely strong and massive, and upwards of four inches in length. The head is proportionally larger too, though considerably crushed on the right side; it is invested with irregularly marked enamelled bones, which appear, as on the other specimen, to be covered by a thick and variegated granulation. There are no traces of the fins in either observable, except a few straggling rays which present no characters of form, size, number, or position.

A very large head of the same genus I afterwards found in one of my excursions to Dura Den. It measures from the snout lengthways seven inches, and in breadth it is eight inches. It is considerably flattened by pressure, and varies from an inch to an inch and half in thickness. The snout is rounded; both upper and lower sides of the entire head are exposed in the specimen; and the glosso-hyal, the occipital, and other plates, are in their places and largely developed. This splendid specimen now forms part of the Old Red collection in the British Museum, which, along with specimens of pampfractus, holoptychius, phaneropleuron, glyptolæmus, and platygnathus, I presented to that national depository of science.

*Platygnathus Jamesoni*.—AGASSIZ.

The genus *Platygnathus* (Pl. I. fig. 2) has been established by M. Agassiz upon two imperfect fossil specimens, the one consisting of a jawbone, found in the Orcades by Dr. Trail, and the other being the posterior part of the body which were discovered in Dura Den among the first researches made in that locality. The jawbone from the Orcades, besides in itself incomplete, consists only of the under half of the organ, but presenting the upper side with two large broken teeth. The interior of these incisors is filled, without a medullar cavity, and exhibit a radiated appearance, as in the teeth of the dendrodus. Their section is perfectly circular. The external edge of the jawbone is likewise supplied with several ranges of small conical teeth, united the one to the other, and considerably developed. The internal edge is covered by a fine granulation, having the appearance of shagreen.

The Orcadean specimen is four inches and a half in length, and more than an inch in width at the posterior part. The socket of the jaw contains four large compartments nearly square, and formed by osseous supports extending between the external and internal branches of the jaw.

The Dura Den fossil is much finer, fuller in development, and more complete in details. It is twelve inches in length, six in breadth to the upper edge of the dorsal fin, and seems to present about a third part of the body of the fish. How marvellous the revelations of science, which can combine from such fragmentary relics generic alliances, and demonstrate the one, from

such different organs, to be kindred to the other! Wide asunder in geographical area as these interesting relics were detected, they are in their geological horizon and position still further apart—the one occupying the lowest and the other the upper series of the Old Red formation. My unpractised eye, when I first saw them and compared them side by side, could neither guess nor decipher anything of their family relationship.

But it was chiefly upon the characters exhibited by the Dura Den fossil that the genus was established. The resemblance to the *holoptychius* was first observed, and the scales were supposed to be identical. But several points of distinction were very marked, both in these and in other appendages of the fish. Thus the scales in *platygnathus* are rounded, broader than long, especially towards the tail. They are likewise ornamented by horizontal well-marked lines, often interrupted, and although placed in rows they do not form continuous crests. The lines, besides, are not so well defined nor so strongly relieved as in the *holoptychius*. The tail, again, of *platygnathus* is very long and contracts very gradually, which characteristics are very different in the other genus. The fins are also much larger, the dorsals, of which there are two, being at least twice the height of the tail, and composed of elongated close flexible rays. The posterior extremity of this organ is slightly raised, and on the inferior edge there may be observed a number of short rays, which probably composed the under lobe of the fin. Under the belly of the fish a narrow and very long fin can be distinguished, which seems to be the anal; it ranges along the tail, and appears to have been as wide as the dorsal when spread out.

The great peculiarity, then, of this genus of fishes, is the enormous development of the fins. They are all, caudal and dorsal, of the largest dimensions, and heterocercal, and the vertebral column extending to the extremity of the finny appendages, it is justly inferred that they must have been powerful swimmers. The same organs indicate their voracity and great development of jawbone and teeth. Hence the connexion presumed to exist between the Orcadean and the Dura Den fossils; and, found so wide apart as in the inferior and the upper members of the Old Red, the interest in their discovery is all the more important and heightened by the circumstance of their being solitary examples of their respective species, in the long-separated periods of the geologic relations.

1. *Holoptychius Andersoni*.—AGASSIZ.

PL. I. VII. VIII.

2. *Holoptychius Flemingii*.—AGASSIZ.

The yellow sandstone of Dura Den may pre-eminently be distinguished as the habitat of this race of fishes, since so many hundreds have been disinterred from a single bed of the deposit, and nearly all of the same species, the *Holoptychius Andersoni*. Our description, therefore, of this fertile family will admit of being as particular and minute as we have access to the writings of its most celebrated historians.

*The Scales*.—The characters of the scales are remarkably striking in all

the species, as well as individuals of this type of fishes. They are extremely ornamental, regularly and beautifully arranged, and cannot fail to fill with admiration the most indifferent observer. Their glossiness of colour, roundness of form, firmness of texture, deep-set groovings of tracery, and comparative largeness of size, at once mark the family as one of peculiar interest, a singular combination of strength and harmony in animal structure. They have been represented as "the scavengers" of the seas in ancient geologic times; we would rather say they were the "rover-kings" who issued from their rocky fastnesses, armed cap-a-pie in cuirass and mail, and able to do battle with every ocean tribe that opposed them.

The scales, according to M. Agassiz, consisted of a dense, thick osseous substance, formed in parallel and superposed beds, and turned against the inner edge of the skin, while concentrated markings of growth, repeating the figures of the scales, are distinctly traceable over all the surface. They are crossed by fine rays, radiating from the centre outwards, which are formed by very delicate channels scarcely in relief, and in which were probably fixed the fibres of the skin. Numerous small canals, conductors of the blood-vessels, ascend by these rays into the substance of the scales, and near the surface they branch out horizontally, forming a very straight net-work of mail. Above this net-work—indicating the space between the osseous and enamelled substances—lies the enamelled bed which occasions the external ornament and fine-tint material of the organ, and the bed itself is only a thicker osseous membrane through which the corpuscles are ramified and diffused.

The form of the scales is uniformly, in all the Old Red species at least, oval or rounded, and many of them on particular parts of the body, are nearly circular. This is remarkably the case with all on the ventral side, which by compression, I observe, in a great many instances, are detached or in slightly connected rows, and the circular tendency is clearly manifested. The scales are imbricated, or slightly raised—the one edge of the superior, along the median line, and from the head lengthways, over the posterior in their successive courses. The covered part is smooth and devoid of ornaments, whilst the exposed part of the surface is richly ornamented by longitudinal ridges and eminences, radiating, or more and less diffused, extending to the extremities, or leaving an outer border and even selvedge across the edge of the scale. The arrangement of these ridges and groovings serve not only to distinguish the different species, but to determine the character and to give name to the genus—*Holoptychius*—the *holos* and *ptyché*—the entire wrinkled scale fish.

The mode of formation of this organ in fishes resembles the growth of hair, feathers, and wool in other animals, and consists of nearly the same elements as hoofs, beaks, claws, and nails. An extremely delicate and finely organized pulp, composed partly of a congeries of minute vessels, and partly of a gelatinous substance in which these vessels are imbedded, constitutes the apparatus by which the nutrient particles are selected, combined and elaborated into the materials of the intended structure. The original form, situation, disposition, and mass of this vascular pulp, determine the future figure and extent of the growth of the organ on the several kinds of fishes to which they

are attached. Hence scales vary remarkably in their form, structure, mode of adhesion, and position in different families. In general, they may be described as flat plates, variously marked and laminated. The plates in some classes are more numerous than in others, the lowest are the largest, and the upper surface becomes in consequence somewhat imbricated. The breadth of each new layer is greater than the last, its edges project farther, and gradually the whole surface assumes that concentric striated appearance which renders it so characteristic a feature in all the scales of the *Dura Den* fossils. The scales in the genus *holoptychius* are imbricated, with the distal edge free, and the epidermis enveloping their base. But in other fishes, as *glyptopomus* and *diplopterus*, where the scales are remarkably thick, they are arranged laterally, without resting upon each other, and have a covering of the epidermis spread over them, or uniting them at their base.

The materials of which scales are composed are deposited sometimes in masses, as in the scales of the crocodile; in filaments, as in hairs; and in layers, as in hoofs, nails, and scales of fishes. The annual additions are made to them at their base, or root, where the vessels deposit fresh materials, and they gradually increase in size, protrude and extend along the skin, and continue to grow by the same process as long as these vessels continue in activity. Hence, as by the horns of mammalia, the plates of insects, and the concentric rings in the woody tissue of trees, the age of fishes may likewise be determined by the successive increments of growth to their scaly envelope. The scales of the *holoptychius* sometimes attain to an enormous size, those from *Clashbennie* and *Parkhill*, in the author's possession, exceeding three inches in length, by two inches in breadth, and the wrinkled striæ raised in proportional depth. The constituents of a scale from *Clashbennie* of this genus, analysed by Professor A. Connell, and published in the *Edinburgh New Philosophical Journal*, are as follows, viz. :—

Phosphate of lime, with a little fluoride of calcium, . . . . .	91.42
Carbonate of lime, . . . . .	7.05
Chloride of potassium, . . . . .	0.27
Chloride of water, . . . . .	0.97
Sandstone matrix, . . . . .	2.38
Phosphate of magnesia and animal matter, trace, . . . . .	

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102.09

*The Head.*—This organ in the genus *holoptychius* is proportional and in keeping with the general size of the fish. All the bones are incrustated with a thick coating of enamel, slightly marked, and almost the same as the cephalic bones or the scales of the sturgeons. The external surface is rough, forming a coarse granulation, approaching the deep wrinkles with which the scales are ornamented. The under jaws are large, curved, forming a half circle round the head, and incrustated all over with a granulated enamel. The branchiote rays are supplied, as in most of the ancient sauroids, and as in the living *polypterus* of the African rivers, by two large enamelled plates uniting at the median line, and filling all the opening of the throat between the two branches of the lower jaw. They are termed the *glosso-hyal* plates, which are the supporters of the lower jaw, and resemble very much the corresponding

plates in the existing *Sudis gigas* of South America. The huge *Megalichthys* of our coal-fields, so common in the iron-band shales of Fifeshire, possessed three of these glosso-hyal pillars, as if nature in her arrangements had made size a condition of organic structure. These two plates in the holoptychius and other Dura Den ganoids are moveable, and seem to have been constructed so as to change their true signification, and especially, when dislocated with a view to cover their edges, would serve as frontlets under the eyes. The bones of the skull, in this as in all sauroid fishes, are united by closer sutures than those of existing fishes. The vertebræ articulate with the spinous processes by sutures, like the vertebræ of saurians; and the ribs also articulate with the extremities of the spinous processes. The caudal vertebræ have distinct chevron bones, and the general condition of the whole skeleton is stronger and more solid than in other fishes.

*The Teeth.*—The family of fishes, including holoptychius under consideration, have many characters in common with the class of reptiles, and among these the teeth are more especially allied to the reptilian type. They are striated longitudinally towards the base, and have a hollow cone within; and the bones of the palate are also furnished, as in that order, with a large apparatus of teeth, their back edges terminating in a sharp point, which rendered them singularly adapted to drag and to lacerate. Another provision, strongly allied to the dentition of the lizard-type, consists in the manner in which these teeth were inserted in the jaw, with their roots entangled and ramified through the osseous substance, and thus indicating the violence with which they could be sunk into the body of a living fish. There was a double row or set of teeth in the lower jaw, consisting of three or more, larger, and others much smaller and less acute, placed in the interstices of the bony matrix; a condition of arrangement existing likewise in the voracious family of the megalichthys, and serving, not so much perhaps for mastication, as a provisional apparatus for securing the slippery bodies of their prey when dragged into the mouth.

*The Fins.*—M. Agassiz, generally from incomplete specimens, but with his usual skill and sagacity, had clearly defined the nature and positions of the fin-organs in the genus *Holoptychius*; and, where the information could not be supplied by the specimens submitted, he had conjecturally, but most accurately, assumed what Nature herself must have done in the circumstances. We have a remarkable instance of this in his succinct but lucid description of the arrangement of the fins on the *Holoptychius nobilissimus*. "At present," he says, "I only know of the ventral and base of the caudal fins, which are visible on the magnificent specimen of the *Holoptychius nobilissimus* in the collection of the British Museum, and which I have represented in Plate 22.\* The ventral fins are very much thrown back, the one far distant from the other, and carried back on the sides of the belly to the anal opening. They are small, composed of several rays, but they are not in good enough preservation for me to give more particular details of their form and structure. The caudal has a strong radius, which leads me to suppose considerable development of that locomotive appendage. The pectorals appear to have been

\* *Monographie des Poissons Fossiles du Vieux Grès Rouge*, Chap. iv. Plate F.

small, and placed high up on the sides of the body, the thoracic girdle rather feeble, and there seems to have been but slight development of these fins."

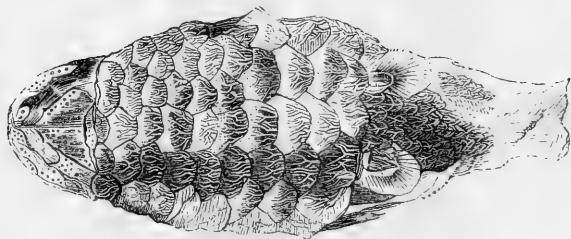
Had the whole recent discoveries of Dura Den been lying on the cabinet-tables of the eminent naturalist, he could not have furnished, from a comparison of the mass of specimens before him, anything more descriptive and accurate than what is here related. From an examination of hundreds of the most clearly-defined fossil remains, of all sizes of bodies, from six inches to forty, we have been able to verify every one of the details in the picture. The vast depth and breadth over the shoulders of the large specimen recently dug up in Dura Den, show how well Nature has attended to the laws of gravity and equipoise in placing, as she there has done, the pectorals "high up on the sides of the body;" while Agassiz' own profound knowledge of structural conditions is verified to the letter in the "considerable development of that locomotive appendage," the caudal fin, or, rather I should say, the system of fins. The specimen of this organ now in Lord Kinnaird's collection measures exactly nine inches in length from the termination of the scales to the extremity of the fin-rays in the tail; it is five inches and a half in breadth, and consists of three distinct groups or cords of rays, uniting at the roots, but separable outwardly on their extended radius. The form of this powerful propeller, on the terminal fulcrum of motion and strength, is that of a graceful fan in repose, and shows its expansive capacity of development, when unfolded, in the massive assemblage of filaments of which it is constructed.

Nor, let it be remarked, does this thick and condensed cordage of fin-substance conceal the normal structure of the caudal portion of the skeleton. The normal arrangements are fully manifested, where in this largely developed specimen the upper fin-lobe is comparatively smaller, and the extended vertebral column very distinctly defined. It is the same in one and all of the innumerable specimens furnished in this prolific locality. And I simply notice the fact, because in the last posthumous edition of the *Old Red Sandstone* of Hugh Miller, a figure of the *Holoptychius*, from Dura Den, is there given with the *homocercal* representation of the fin-organ, and shortening of the vertebral column. The engraving, in every particular, is defective in execution; and compared with the fossil specimen itself, it is equally defective in the scales, and inaccurate in omitting the vertebral column, which in the specimen is distinctly traceable to the extremity of the tail-fin.

There are fourteen species of this genus known and described, of which six belong to the Old Red and eight to the coal measures. Their chief distinctions consist in the form and granulation of the scales, and in the size and position of the fins. Thus the scales of *Holoptychius Flemingii* are very much longer than broad on the sides, but round under the belly, and the ornaments form undulating lines running horizontally towards the posterior edge, without any visible ramification. The *Holoptychius Andersoni* is partly characterized by the absence of the tubercular zone, by the extension of the folds to the posterior edge, and by the length equalling nearly the breadth. The scales of *Holoptychius Murchisoni* differ from both in the greater elevation of the ridges, in their distinct and confluent ramification towards the posterior

edge, and in exhibiting three well-marked zones, which are smooth in front, and covered with rounded tubercles behind. The most clearly defined distinction in *Holoptychius nobilissimus* consists in the size and general roughness of the scales, which are very large on the middle of the belly, and become arched in diminishing gradually towards the tail. In *Holoptychius giganteus* the scales are very thick, of a rounded form, resting on smooth zones, and beautifully ornamented on the inferior side, as in the medullar lines and osseous supports of the *Glyptolepis leptopterus*. *Holoptychius Omaliusii* is distinguished from all the above specific forms in the enormous magnitude and thickness of the scales, which are deeply furrowed, with longitudinal and parallel ridges, which, from their fine irregular granulation, give the appearance of shagreen; and, above all, by the size of a body that must have attained the length of at least twelve feet! This fossil, but very imperfect, has only been found in one locality, namely, in the Old Red of the neighbourhood of Namur, by M. Omalius de Halloy. The other five species belong to Dura Den and Clashbennie.

The specimen on which was determined the species—*Holoptychius Andersoni*—was the first discovered of the genus in anything like completeness, and was figured, in 1837, in my *Geological and Botanical Description of Fifeshire*. The large specimen discovered in 1858, along with the massive caudal fins, on another tablet of rock, completes the entire equipments of this cœlacanthic fossil, showing it in full outline and perspective, and producing as perfect a restoration of a form of extinct life as any in the annals of geological discovery yet recorded. The massive dimensions to which it has attained, and corresponding magnitude of the scales, show a very considerable affinity and resemblance to the Clashbennie *Holoptychius nobilissimus*, but besides many minute discrepancies in the granulation of the cephalic bones and the ridgy eminences on the scales, the Dura Den fossil justifies its claims to a specific honour, upon the ground of its occupying a position in the *upper series* of the system, and thus standing so much higher in the order of stratigraphical arrangement, and so much later in the geological horizon of animal life.



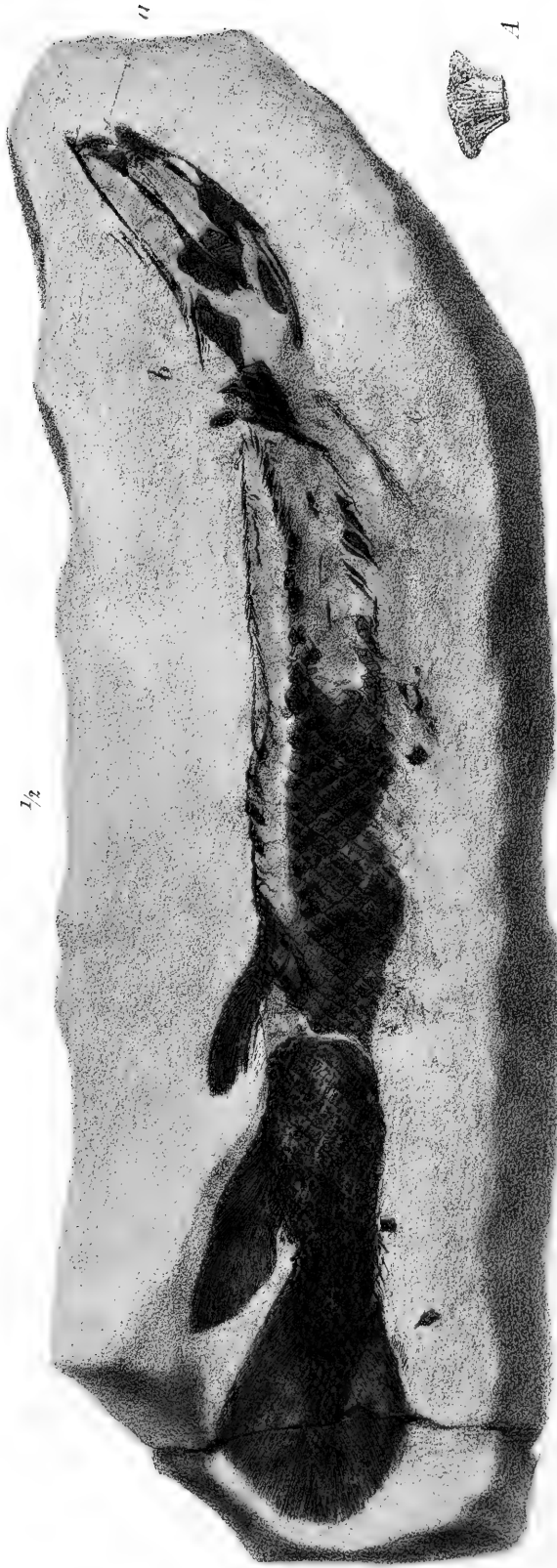
*Holoptychius Nobilissimus*.—AGASSIZ.



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Fig 1

1/2



G *Glyptolœmus* (Nov Genus). Agass.  
*Glyptolœmus Künneardi* (Nov Species). Agass.

The following descriptions of *Glyptolæmus*, *Phaneropleuron*, and the *Structure* of *Holoptychius*, are furnished by Professor Huxley, whose position among our first-class men justly entitles him to pronounce as one having authority, and whose clear distinctions are founded upon a most extensive acquaintance with ichthyological organization. The fine drawings and restored figures, in particular, of the phaneropleuron and holoptychius, show the results of the most patient study, elaborate comparisons, wide generalizations, and profound knowledge of the science of Palæontology. The *specific* distinction of *Glyptolæmus Kinnairdi* was proposed by me at the meeting, on the 18th May last, of the London Geological Society, and unanimously agreed to, in honour of Lord Kinnaird, whose zeal in promoting the interests of geology is only equalled by his enlightened endeavours to advance the interests of everything connected with our social and industrial wellbeing as a statesman. That an Agassiz and a Huxley have added the weight of their high authority to both specific distinctions, in the new genera of glyptolæmus and phaneropleuron, enhances the value of the honour to the author and his noble friend.

*Glyptolæmus* (*Nov. Genus*).—HUXLEY.

PL. III. IV.

*Glyptolæmus Kinnairdi* (*Nov. Species*).—HUXLEY.

The specimens upon which I have founded this new genus and species, some time ago became the property of the Museum of Practical Geology, with the understanding that they should be figured for the present work, and that I would furnish Dr. Anderson with an account of their characteristic peculiarities. In the meanwhile the fish remained unnamed, but, on my exhibiting them as new forms to Professor Agassiz,\* during his recent visit to our museum, I was glad not only to obtain his sanction to the establishment of a new genus for them, but to adopt the name of *Glyptolæmus*,† which he suggested on account of the marked sculpture of the jugular plates in one of the specimens.

Of the two specimens figured, that in Plate III. affords an almost complete

\* By an inadvertency the distinguished name of Agassiz has been printed in the plates instead of Huxley. The true orthography is *Glyptolæmus*.

† Γλυπτός, λαίμós.

view of the left half of the dermal skeleton from the inner side, and lies in the same block with a number of *Holoptychii*.

The slender-looking fish measures fifteen inches and a half in length, while its depth nowhere exceeds an inch and three quarters, attaining this amount about the middle of the body, and diminishing thence with almost equal rapidity towards the head and the tail. The exact length of the head is nowhere precisely determinable, but, from the extremity of the snout to the posterior edge of what seems to be the operculum (*b*) is a distance of three inches. The depth of the head, including the lower jaw, nowhere exceeds an inch.

The end of the snout is obtusely pointed, and from it, a bony bar, which may be the remains either of the premaxillary and maxillary bones, or of the ethmoid and sphenoid, is traceable backwards along the line of the base of the skull. A much more slender broken line of bony matter, which attains at most a distance of three-eighths of an inch from the preceding, is all that remains of the roof of the cranium. The matrix fills the interspace between these two thin portions of bone, and exhibits a faint circular impression which may possibly have been produced by the eye.

Three-eighths of an inch from the end of the snout, the lower bony boundary of the skull gives attachment to the enlarged base of a great tooth (*a*). This base is fully a quarter of an inch in diameter, but the tooth rapidly narrows, so that, although not more than an eighth of an inch of it remains, its broken end is less than an eighth of an inch in diameter. The outer surface of the tooth is marked with longitudinal striæ. (See the magnified view *A*.) Immediately behind this tooth is seen the impression of the pointed apex of another large tooth which must have been implanted in the mandible.

The exposed ramus of the mandible is either broken at its extremity, or did not extend so far forward as the premaxilla. It is very slender anteriorly, not exceeding one-eighth of an inch in thickness, but, an inch from its anterior extremity, it rises into a rounded coronary elevation, and attains a depth of one-fourth of an inch. Behind this point it is broken away.

A confused bony expansion, resulting, to all appearance, partly from the petrosals, and partly from the pre-operculum, lies above the coronary portion of the mandible, while, posteriorly, part of what I take to be the operculum, is seen at *b*. The surface of this bone exhibits a grooved and ridged sculpturing.

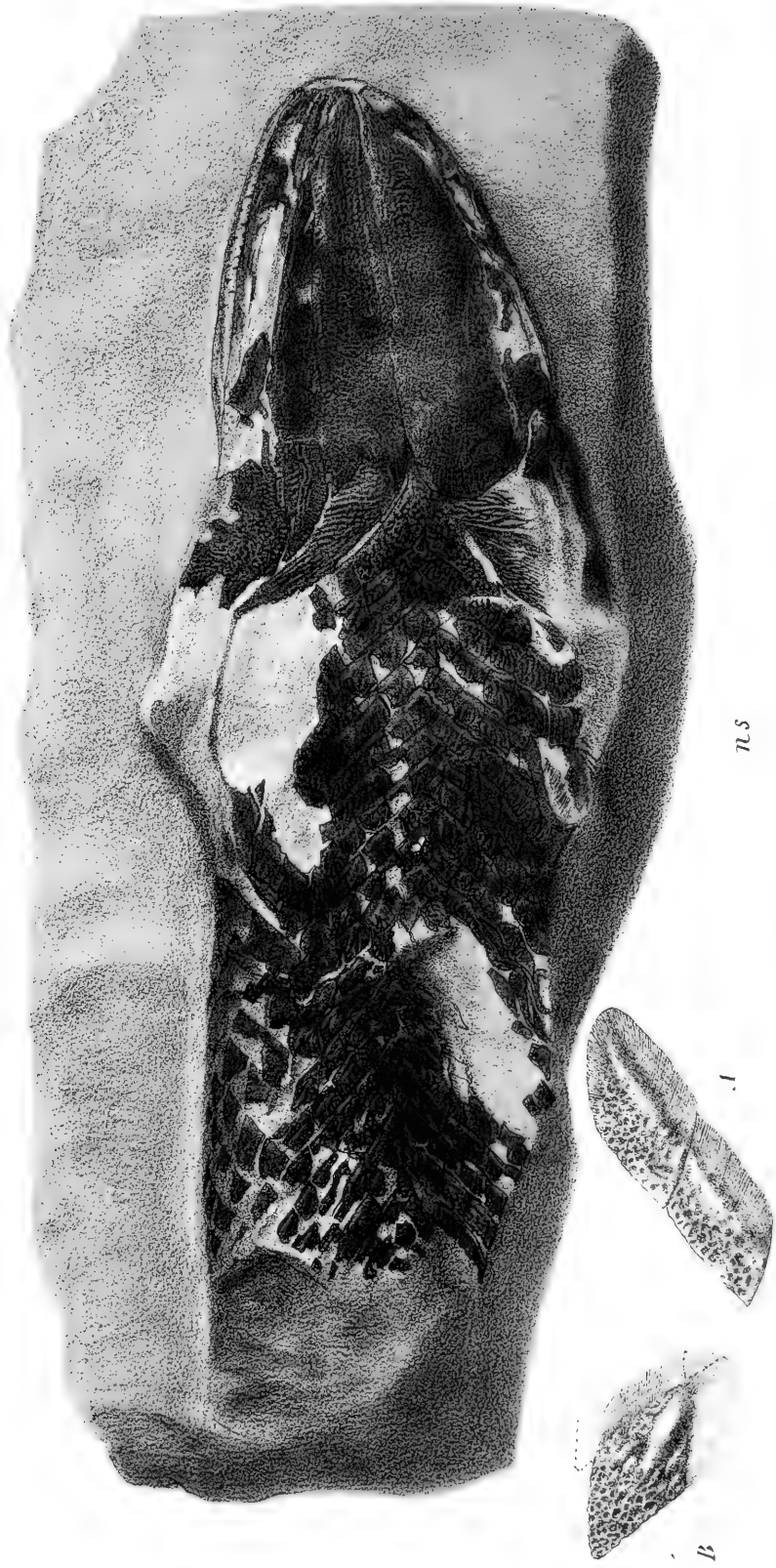
An indication of a pectoral fin is shown at *c*, and behind this, the inner faces of the successive rows of rhomboidal scales are exhibited, the anterior series being obscured by the matrix. These scales are thin, smooth internally, and, in the middle of the body, about a sixth of an inch wide in their transverse or short diameter.

The outer face of no one of these scales is exhibited, but the casts (*B*) left upon the surface of the stone whence they have been detached, show that the external surface of each scale was pitted and ridged almost as in *Glyptopomus*. The scales are, however, very much thinner and less bony than in that fish.

The sculpture exhibits a certain tendency to a radiating arrangement, longitudinal striæ diverging from the anterior to the posterior margin as is seen in the enlarged scale *B*.

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Fig. 2.



G *Glyptloencus* (Nov. Genus). Agass.  
*Glyptloencus Kinnairdi* (Nov. Species). Agass.

Of the system of median fins there are two dorsals situated very far back, the anterior edge of the root of the first being  $9\frac{1}{2}$  inches distant from the end of the snout. The first dorsal is remarkably slender and of a somewhat semi-oval outline. Its base measures  $\frac{9}{16}$  of an inch, while its total length is about  $1\frac{1}{3}$  inch. Its anterior margin is nearly straight, the posterior being much more convex. The anterior edge of the root of the second dorsal is eleven and a half inches distant from the end of the snout. It has a very similar form to the first dorsal, but is larger, measuring seven-eighths of an inch along its base, and two inches along its longest axis, while its greatest breadth is three-fourths of an inch.

The dorsal lobe of the caudal fin begins about half an inch behind the second dorsal, and opposite the commencement of the ventral lobe, the two lobes being very nearly equal, and the tapering caudal end of the body being but very slightly inclined upwards. The fin rays of the ventral lobe are stronger than those of the dorsal lobe, and the end of the fin, which attains a width of  $2\frac{1}{2}$  inches, is abruptly truncated, so as to be something between triangular and round in its contour. No lateral line is distinguishable, and there is a mere indication of what appear to be the rays of the anal or ventral fin, opposite the first dorsal, which last indeed looks so exceedingly like a ventral fin that I was inclined to regard it as such, until Mr. Dinkel's valuable suggestions led me to look into the question more carefully.

The second specimen figured (Plate IV.) under the name of *Glyptolæmus*, displays only the ventral surface of the anterior moiety, seven inches in length, of a fish, whose transverse diameter nowhere exceeds two inches. At the end of the block, to the left in the figure, the transverse section of the body has the form of a transversely-elongated semi-oval, flat ventrally and convex dorsally, its depth from above downwards being about an inch.

The symphyseal end of the lower jaw is rounded, the rami measuring about two and a quarter inches in length. Their thickness is fully one-fourth of an inch, and posteriorly they are an inch and a half apart. The bony substance of the jaw is very thin, and where its outer surface is preserved, it exhibits a ridged sculpture.

The middle of the interval between the rami is filled by two large jugular plates, which are separated from the rami by, apparently, five small plates on each side.

The large jugular plates have an elongated triangular form, and are two and a quarter inches long, half an inch broad at the broadest; the left being rather wider than the right, and overlapping the latter by its uneven inner edge. The bones are thin, and their posterior margins are rounded; that of the right side being broken.

The surface of the plates exhibits a pitted and lineated sculpture, which is so disposed as to radiate from a point near the outer margin of each plate; and, at about the junction of its anterior two-fifths with its posterior three-fifths, the sculpture of the posterior part of the anterior division of each plate is particularly coarsely reticulated.

The small lateral jugular bones increase in length and in width from before backwards, and exhibit a pitted or reticulated sculpture, which is coarsest in

the most posterior and largest of the plates on each side. The hinder edge of this is overlapped by the lowest of the opercular bones, which exhibits a well-marked ridged sculpture.

There are faint traces of small teeth in the edges of the mandibles, and in what remains of the maxilla, but no large tooth is anywhere visible. The posterior edges of the large jugular plates overlap the anterior portion of the bones of the pectoral arch, which exhibit a reticulated sculpture, whose meshes are elongated in the direction of the long axis of the bone.

The scales, of which about twenty-four series are visible, diverge from the median line in the ordinary way. They are rhomboidal, and have an average short diameter of one-sixth of an inch; but they are somewhat larger on the anterior part of the ventral surface, than on the posterior part of the same surface, and at the side of the body than on the belly.

The angles of each scale (*A, B*) are slightly rounded off. Along the anterior and the inner sides, from a third to two-fifths of the outer surface of the scale is smooth, or marked only by radiating and concentric striæ, being overlapped by the edges of the adjacent scales. The rest of the outer surface is beautifully and variously sculptured. In the anterior part of the ventral region the sculpture, for the most part, takes the form of strong, more or less longitudinal, thick ridges; but, posteriorly, these become superseded by a pitted or reticulated structure. The weaker parts of the scale breaking away more readily than the others, their free margins often appear toothed or irregular.

No fins are distinctly definable in this specimen, but there is a broken patch on the right side, where the right pectoral should have been, and a few fin rays are traceable in the place of the left pectoral.

From the totally different views of the body presented by these two specimens, the only points of comparison between them are furnished by the scales, which exhibit a general correspondence in form and size, while the middle ventral scales of the second specimen would leave impressions, not unlike those visible on the matrix in the middle lateral region of the first specimen. It is certainly a little difficult to reconcile the thick and depressed form of the second specimen, with the apparently much thinner and more compressed figure of the first; but it must be remembered that of this specimen we have only half, and that the direction in which pressure has been exerted may have greatly modified the forms of both specimens.

Again, the impressions and the general aspect of the scales in the first specimen do not tally exactly with what might be expected from the perfectly preserved corresponding organs in the second; but then it must be recollected that the precisely corresponding scales in the two fishes cannot be compared.

On the whole, although not by any means satisfied as to the specific identity of the two fish, I think it better to assume it until further evidence proves the contrary.\*

\* Since the above was written, I have seen specimens of *Glyptolæmus* in the collection of Lord Kinnaird, at Rossie Priory, which leave no doubt on my mind as to the correctness of this assumption. In one of these specimens the edge of the maxilla exhibits a single series of small and slender teeth.



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Fig. 1

$\frac{2}{3}$



G *Phaneropleuron* (Nov Genus). Huxley. (*Glypticus*. Agass.)  
*Phaneropleuron Andersoni* (Nov Species) Huxley.

*Phaneropleuron*—HUXLEY (*Glypticus*—AGASSIZ.) (Nov. Genus.) Pl. V. VI.  
*Phaneropleuron Andersoni*—HUXLEY. (Nov. Species.)

Of this new genus and species of Devonian fish, several fragments, now in the Museum of Practical Geology, have been sent to me by Dr. Anderson; but the most complete specimen, figured in Plate VI., is in the collection of the British Museum, where it lies in the midst of a group of fish which have been regarded as *Holoptychii*, but which almost all, in reality, belong to this new species. This specimen likewise, I understand, originally formed a part of the collection of Dr. Anderson.

The specimen measures about twelve and a half inches in length, while its depth nowhere exceeds two and a half inches. It is difficult to define the posterior boundary of the head, but it appears to be about two inches long, and its anterior contour slopes rapidly downwards to the sharp snout.

The boundaries of the cranial bones are not traceable. Their surfaces are almost smooth, and wholly devoid of such sculpture as is exhibited by the bones of the head in specimens of *Holoptychius*, in the same slab of sandstone.

The scales are exceedingly thin, and all that can be certainly made out of their structure is, that they have a circular outline, and are marked only by fine, close-set, radiating ridges. The lateral line takes a curved direction from the occipital region downwards to the middle of the body, and then courses along the middle line to the tail. Its scales exhibit a slight longitudinal elevation.

The pectoral fins are not visible in this specimen, but in another, traces of them remain, and they appear to have been similar to the ventrals. The latter are very remarkable. In the specimen under description that of the right side only is visible. It is attached, seven inches behind the end of the snout, by a base which is nearly half an inch broad, and it attains a length of  $2\frac{3}{4}$  inches. The central part of the fin is formed by a solid tapering axis covered with small scales like those on the body, and the fine fin-rays are disposed symmetrically along the anterior and posterior margins of this central axis.

Ventral fins having the structure which has been described, were more or less plainly discernible in several of the specimens of *Phaneropleuron* in the collection of the British Museum.

The rays of the dorsal fin commence a little in front of the middle of the back, and of the root of the ventral fin. They are at first very short, but they gradually increase in length backwards, as the dorsal line of the body falls away in the caudal region, so that the top of the fin remains throughout nearly on the same level, and forms a line parallel with the longitudinal axis of the fish. The most posterior part of the fin, which attains a height of  $1\frac{1}{4}$  inch, is consequently the deepest.

No separation can be traced between the dorsal fin and the dorsal lobe of the caudal, as which, in all probability, the posterior part of the dorsal should be regarded.

The inferior lobe of the caudal measures close upon three inches in length, and attains nearly the same depth posteriorly as the dorsal lobe, or posterior end of the dorsal fin.

The extreme termination of the tail of this specimen is not well shown, but it is clearly displayed in that figured in Plate V. Here the dorso-caudal fin ends posteriorly in a steep truncated margin, beyond which the persistent notochord is continued for nearly two inches. The inferior lobe of the caudal fin, on the other hand, is continued very much farther backwards.

The narrow anal fin (Plate VI.) is attached  $9\frac{1}{4}$  inches behind the snout; it measures  $2\frac{1}{2}$  in. in length, and is brush-like in form, being broader towards the end than at the root, but tapering almost to a point at its free extremity.

The anterior end of the mandible of one specimen displays a strong conical tooth, and there is evidence that *Phaneropleuron Andersoni* attained eighteen inches in length.

The specimens figured in Plate V. and Plate VI. fig. 3, again, show far better than that first described, those peculiarities in the internal organization of the fish on which I have based its name. In the specimen figured in Plate V., the persistent gelatinous notochord has left an impression three-eighths of an inch thick anteriorly, which continues straight, and of about the same thickness, for seven inches and a half; it then bends up at an obtuse angle, and, with a slightly concave superior contour, tapers to the extremity of the tail.

Above the notochord, from its anterior end to where it bends up, lie numerous slender but well ossified neural arches and spines, which are so bent as to be slightly convex posteriorly, slightly concave anteriorly. The anterior ones are about an inch long, and are slightly expanded at both ends.

A series of shorter, interspinous bones, at most three-eighths of an inch long, occupy the interspace between these and the base of the dorsal fin. These bones also are slightly expanded at each end, and disappear posteriorly at the bend of the notochord.

Below the notochord lie in confusion a number of curved, slender, well-ossified ribs, one-twentieth of an inch in diameter, which cease to be traceable posteriorly about five inches and a half from the anterior end of the specimen.

A second fragment exhibits the opposite face of the middle region of another fish of about the same size as that just described. The dorsal fin diminishes anteriorly, the interspinous bones becoming shorter, but the neural spines, retaining their curvature, become longer and stronger, and the ribs increase in length.

A third fragment (Plate VI., fig. 3) consists of the anterior part of the body, with the hinder region of the head, whose upper walls have disappeared, leaving part of the opercular apparatus and of the pectoral arch. The ribs diminish in length anteriorly, but they retain their characteristic forms and their well-ossified structure.

Professor Agassiz originally called this fish *Glypticus*, but he did not describe it or define the genus, and as the name was already in use it must be changed. The generic appellation which I have proposed expresses the most striking character of the fish—the curious obtusiveness, if I may so say, of its ribs, arising from their complete ossification and the thinness of the scales.\*

The affinity of *Phaneropleuron* with the typical cœlacanth is indicated not only by its singular tail, but by its persistent notochord, by its lobate pec-

\* Φανερός, πλευρόν.

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but in some specimens the lateral bones meet in the middle line in front of the median one. The lateral bones have radiating striæ on the posterior halves of their outer surfaces. The anterior margin of each unites with the parietal of its side, and then passes backwards and outwards, so as to form a large re-entering angle with the postero-lateral edge of the parietal. Into this re-entering angle, two bones, which would seem to represent the squamosal of ordinary fishes, are fitted. A large, suborbital bone extends from the post-frontal to the maxilla, and forms the posterior boundary of the orbit. The pre-operculum is a very considerable bone, which is attached to the parietal between the squamosal and post-frontal; to the latter bone and to the suborbital bone by its concave anterior margin; to the representatives of the squamosal, and to the operculum and sub-operculum, by its convex posterior margin, while inferiorly it extends to the angle of the mouth. The operculum is a broad bone, larger behind, where it is convex, than in front, where it is concave, and much longer than it is deep. The inferior limits of the sub-operculum were not distinct in any specimen I examined, but the bone appears to have been deeper than long.

The rami of the lower jaw are stout and strong, and form a very broad, almost semicircular arch. Two broad, triangular, jugular plates occupy the middle of their interval, and are separated from the rami by a number of smaller bony plates on each side. There is no median plate between the anterior ends of the principal jugular plates.

The outer surfaces of the bones of the pectoral arch exhibit radiating ridges, where they are not overlapped by the opercular bones.

The characters of the scales are well known. Those of the lateral line exhibit a slight median elevation, and form a series which descends from close to the occipital region downwards and backwards upon the sides of the body, whose axis it very nearly follows in the caudal region.

A small triangular dorsal fin begins opposite the hinder edge of the root of the ventral fin, and is situated a little behind the middle of the body. It is separated by about the breadth of its own base from the commencement of the dorsal lobe of the caudal fin,\* which occupies nearly the posterior third of the whole length of the body, and attains its greatest height about the middle of its length. The caudal end of the body gradually tapers to a point which is not at all bent upwards, and the ventral lobe of the caudal fin, though rather shorter than the dorsal lobe, has the same depth. The caudal fin consequently forms a very nearly symmetrical rhomboid, and is not, in the ordinary sense, heterocercal. The anal fin is [rather larger than the dorsal, and is separated by but a very small interval from the ventral lobe of the caudal.

A wide space separates the ventral fins from the anal, the former being situated just beneath the middle of the body. Each has a short, conical, scaly stem, from either side of which long fin rays proceed.

\* Sir Philip Egerton, in a valuable memoir recently read before the Geological Society, expresses his belief that *Holoptychius* has two dorsal fins. I am very loath to controvert the opinion of so experienced and skilful an observer, the more particularly as specimens of *Holoptychius* with perfect tails are very rare, but the one or two complete examples I have seen, leave no room in my mind for any other conclusion than that stated above.

The pectoral fin is very much larger than the ventral, attaining to a quarter of the length of the body. A solid axis, covered with small scales, and tapering to a fine point at its extremity, traverses the whole length of the fin, and has the comparatively short fin rays attached to its anterior and posterior margin, as in *Phaneropleuron*.

The teeth of *Holoptychius* are, for the most part, short, straight, slender, and conical; but the anterior part of the mandible of a specimen in the Museum of Practical Geology, exhibits a long, slender, and somewhat recurved tusk, more than twice as long as any of the other teeth. The surface of this tooth presents a number of fine sharp longitudinal ridges. An outline of the left ramus of this mandible, of the natural size, and a magnified view of the tusk, are given in the woodcut. It will be observed that these teeth are totally different from those of *Rhizodus*.

*Diplopterus Dalgleisicensis*.—AGASSIZ.

PL. I. FIG. 4.

The specimens of this genus have now been found in the several suites of rocks, from the lower Old Red to the upper Yellow Sandstone of Dura Den, and likewise in the coal-measures. Like the *Holoptychius*, it is therefore of vast geologic range, commencing and terminating with that strong bright scaled family in the same early series of deposits. The specimens obtained in Dura Den consist only of two portions, a head, which is quite perfect, and the posterior part of the body. These were forwarded by me to M. Agassiz in 1837, and returned labelled as "*Diplopterus*, new species."

The individuals of this genus are represented as being of great bulk, attaining a length of several feet, slender, and tapering in the body, and, from the size and position of the fins, powerful swimmers. The head is comparatively large and well proportioned in its divisional parts. The eyes are placed in the middle of the head, close on the median line, which are large, and surrounded by strong osseous projections; and the frontlets, which form the top of the cranium, are flat, narrowing between the eyes, and dilating before and behind. The snout is rounded; and the teeth are placed in a simple dental cavity, are destitute of folded dentition, and greatly resemble the teeth of the *Polypterus*. The branchiostic rays, which are multiplied in other fishes, are, in the *Diplopterus*, as well as in the *Polypterus*, supplied by two strong and large triangular plates, occupying all the under part of the throat, and comprised between the two branches of the under jaws. These two moveable plates are separated by the median line, and permitted the throat to dilate, by imparting to it a great degree of solidity. The Dura Den fossil has this arrangement of these thoracic plates entire and most beautifully preserved, showing one by one their position and relations to each other.

The scales of the *Diplopterus*, like all the ganoid fishes of the period, are extremely marked in their characters, and must have subserved important purposes in the functions of marine life. These organs are comparatively large, massive, and compact; in form they are rhomboidal, hooked or engrained by their oblique edges, and show a fine granulation caused by a number of small holes opening on the surface. These probably are holes of

passage for the numerous minute sanguinary vessels which traverse the body, and allow the scale to adhere to the epidermis or outer skin. When examined through a microscope, the scales present a thick bed of enamel, under which we find an osseous tissue, showing a very beautiful net-work, differing only from the *Polypterus* in its greater development, and in many respects resembling the scaly cuirass of the new genus *Gyroptychius*. Two large, sharp-pointed teeth project from the outer edge of the lower jaw, and there are also distinct traces of several smaller teeth in the posterior margin.

This new species of diplopterus has been named the *Dalgleisiensis*, in honour of the much respected proprietors of the rich fossiliferous deposit of Dura Den, whose kindness to all who visit the locality is so justly appreciated, and whose liberality in distributing specimens among our public museums and the private collections of the scientific is so beneficially and widely experienced.

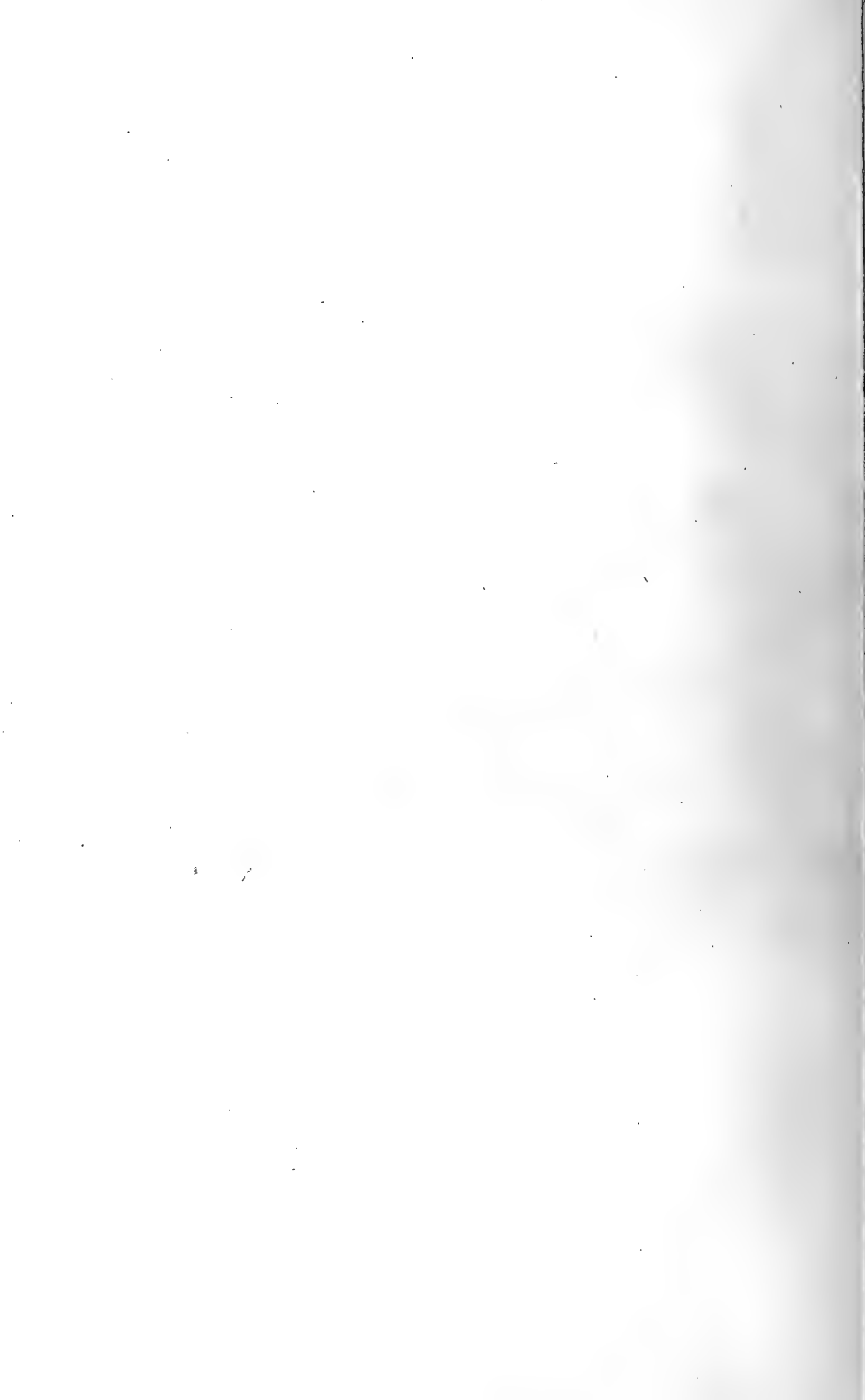
A single tooth of *Dendrodus*, it remains only to be noticed, is all of this genus yet detected in the Dura sandstone. It measures about an inch in length, and is nearly a fourth part of an inch broad at the root. It is sharp-pointed and curved downwards, and hollow in the posterior end. It is figured in *Fife Illustrated*, along with other characteristic fossils of Dura Den. Several scales of *Phyllolepis concentricus* have also been discovered in the deposit, and one of them has been described to me as being three inches in length by two in breadth. Nor are coprolites of large size wanting to attest the existence of perhaps creatures of still huger dimensions, and of more pre-daceous habits. Still our list is large; and whatever may be in store for future explorers in this rich field of fossil research, our numerous visits, extending now over a large period of time, have been no less amply rewarded than they have been the occasions of much delightful recreation—of many pleasing hours in acquiring useful knowledge—of many opportunities of cultivating and renewing agreeable friendships—and, above all, of privileged times in deepening our feelings of admiration for the works of the GREAT DIVINE CONTRIVER and HEAD OF ALL.



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## CHAPTER V.

## GENERAL INFERENCES.

1. THE *position* of the Yellow Sandstone. This we consider to be clearly established both by its mineral relations and fossil remains. Step by step the Devonian series is well defined, in the order of superposition, from the Grampians into the opening of Dura Den, where the Clashbennie *red* deposit immediately underlies the yellow beds of the locality. There is no other line of demarcation than what occurs among the divisions of the series; and it may be safely averred that, in no quarter of the world yet examined is there a group of rocks similar to those of Dura Den, unequivocally attested or asserted to belong to the coal measures. But the FOSSIL REMAINS, in all their types and characters, are clearly sufficient in themselves to determine the question. The pterichthyan forms are only found in the middle series of the Old Red, while the numerical abundance of the holoptychian tribe, in conjunction with so many allied fishes, all of the ganoid granulated scale order, establish relations up and down through the whole Devonian system that must satisfy the most scrupulous inquirer on the point at issue. Dura Den yellow sandstone, in its geognostic position, mineral qualities, and fossil organisms, vindicates the claim to be ranked among the rocks of the great Fish Epoch rather than to be allied with those which enclose the flora of the succeeding age of gigantic vegetables and mountain chains of shelly limestone,—not a shell or vestige of plant being any-

where found in the whole composite mass, nor in any one of the numerous quarries in the district.

2. What constitutes a geological *formation*, and how are the limits to be determined? Here, in the yellow sandstone alone, the fossil remains consist of *nine genera* and of *eleven species*, namely: Pamphractus Andersoni (pterichthys), Holoptychius Andersoni and Flemingii, Platygnathus Jamesoni and Minor, Glyptopomus Minor, Glyptolæmus Kinnairdi, Phaneropleuron Andersoni, Diplopterus Dalgleisiensis, Phyllolepis Concentricus, and Dendrodus (?). Two of the genera are common to the Old Red and the Carboniferous systems, *Holoptychius* and *Diplopterus*. Three of the genera are found in the Lower and the Upper series of the Old Red, *Pterichthys*, *Platygnathus*, and *Diplopterus*. Three genera are common to the Middle series of Morayshire and Clashbennie, and the Upper series of Dura Den, *Dendrodus*, *Phyllolepis*, and *Diplopterus*.

The determination of a geological formation or system, according to this list, cannot be made exclusively to depend upon the specific, nor even upon the generic forms of organic remains included in a series of rocks. The holoptychius and diplopterus belong to two different formations, and pterichthys, platygnathus, and diplopterus range from the lowest to the highest beds of the Old Red strata. Will independent suites of rocks, included in the same or in different formations, serve for the determination of specific distinctions? Suppose a disposition to exist among palæontologists to merge four species of holoptychius into one and the same, namely, *Holoptychius Murchisoni*, *nobilissimus*, *Andersoni*, and *Flemingii*, what amount of consideration would be due to their several positions in the systems in which they are respectively included? M. Agassiz asserts that he does not know a single species of fossil fish which is found successively in two formations, while he is acquainted with a good number which have a very considerable horizontal extent.\*

\* *Edinburgh Philosophical Journal*, p. 175.

The question has been raised with regard to vegetable fossils, and some interesting results have been brought out. Sir H. de la Beché relates\* that it has for some time been held by continental geologists, that plants similar to those in the coal-measures are discovered in the Silurian strata. M. Burat asserted, in 1834, that fossil vegetables, consisting of reeds and ferns, found in the upper grauwaké (Silurian) are analogous to those found in the coal-measures. M. Omalius de Halley also mentions the remains of carboniferous plants as occurring among the transition slates of Ardennes. Professor Lindley noticed a *Stigmaria ficoides*, one of the commonest of our coal-field organisms, in the upper grauwaké of Brittany, at St. George's, Chatellaisson, and Montrelais, as well as at Bitchweiler in the department of the Upper Rhine. In a very recent memoir on the nature of the plants which have existed on the surface of the earth at different epochs, M. Adolphe Brongniart† observes that there does not appear to him more difference in the fossil plants of the rocks earlier than the coal-measures, as compared with those of the latter epoch, than there occurs between the plants in the upper and lower beds of the coal formation itself.

Nor do animal fossil remains appear to be more restricted in their range up and down among the rocks. Thus, it is asserted‡ that fossils belonging to the mountain limestone are got in red sandstone in the river at Kildress in Tyrone, in the middle, as well as near the bottom, of the Old Red Sandstone system of that county. After a tabular statement of "the North Devon, Silurian, and the Irish carboniferous localities," Mr. Kelly in the same paper records,§ "as may be seen by this little table, many of the fossils are common to the grauwaké and to the carboniferous systems. *Out of the sixty-three species recorded in the Silurian rocks of North Devon, thirty occur also in the Carboniferous limestone of Ireland, and its underlying*

\* *Geo. Re. on Cornwall*, p. 132.

† M. A. Brong. *Mém. de l'Acad. Roy. des Sc.*, 11th Sept. 1839.

‡ John Kelly on the Carboniferous Rocks of Ireland, p. 27, 1859.

§ Page 53.

calcareous slate, those thirty being all taken from Mr. M'Coy's determination of the specimens submitted to him. *Seven* of those which I have noted out of the sixty-three, are of the *most common kinds* found in the Irish carboniferous limestone system." Instances of the same kind occur up and down among all the systematic divisions, showing how Nature carries forward her great progressional types with exceptional cases in every epoch.

But still, with all these interpolations in palæontological reading, it is convenient to have respect to lithological subdivisions, as already established on the greater scale of the Silurian, Devonian, and carboniferous formations. Throughout the great straths and valleys of Scotland the lines of demarcation are generally well defined, and with no system of rocks are they seen in finer relief than in those of the Old Red. From the primary rocks of the Grampians to the Lomonds, with successive anticlinal and synclinal dips, the outcrops of every series are clearly traced; the prevailing kinds of fossils are persistent in the general suites of strata; and, closing up with the yellow sandstone of Dura Den, their mineralogical characters all bear a family resemblance to one another, and to the normal type of which the Devonian consists. The infinite variety of mineral strata, especially, that build up the carboniferous system; the vast masses of lime, iron, and coal repeatedly alternating with each other; and the astonishing profusion of details manifest in all the arrangements, are indicative of such cosmical changes and conditions to which no former period of the geological history of our globe bears any resemblance; and if Nature did from time to time cast off a few of her typical specimens, and distribute them widely over sea and land, as traced in the vertical superposition of the rocks, her great divisional epochs, organic and inorganic, are not the less strikingly marked and numbered. A remarkable class of fishes, with a wide distribution and prolific development, characterizes the epoch of the Old Red Sandstone; and from



the lowest Caithness beds to the upper sandstone of Dura Den, in which several of the species reach the culminating point of size and numbers, the whole intermediate suites of strata contain more or less of the prevailing ichthyological fauna, and are conveniently therefore grouped into one great geological system.

3. The clearly defined arrangements in the locality of Dura Den and neighbouring district, may be studied with advantage in working out the details of the system in other quarters. The discussions, more especially in Ireland, respecting the carboniferous and yellow sandstone deposits, may be greatly aided by an examination of the rocks in question. The term, "yellow sandstone," I observe, is employed by Sir R. Griffith, Jukes, and Kelly, indifferently to denote all the variety of yellow-whitish rock embraced within the coal-measures. By Scottish geologists it is restricted to the upper series of the Old Red exclusively, and from shore to shore over Scotland, with intermixtures of reddish marls, the prevailing colour is yellow. The position in Ireland of a sandstone of the same mineralogical features is identical with the rock of Dura Den, and bed by bed, as described by Mr. Kelly, they occupy precisely the same identical relations to each other. "In the carboniferous formation there are two black or grey shales,—one below the main mass of the limestone, called carboniferous slate, one above it called millstone grit, or, as it is sometimes called, coal shale, because, in this country, it forms the base of the coal-measures. There are two sandstones also, the Old Red below, *the top of which is yellow or white*, and the sandstone of the coal measures above, which consists of several bands, and which are also yellow or white, and separated by black shales."\*

This is precisely the colour, nature, and relations of the beds in Dura Den, and in all the adjoining range east and west along the lines of junction. Nor is the identity con-

\* Page 4.

fined to these points alone. The dip, inclination, and general bearing of the strata are perfectly similar. "In the district between Drumquin and Pettigo, we have the whole of the constituent rocks of the carboniferous formation; *on the north the Old Red Sandstone*, succeeded on the south by the calciferous slate and mountain limestone, and these again by the black shale, all with regular dip and in regular succession;"\* the beds dipping mostly south-east and at a small angle, and in the same stratigraphical arrangement. The thickness of the yellow rock at the top of the Old Red is represented from 50 to 100 feet in Sligo and Mayo; in the King's and Queen's counties, it is from 200 to 500 feet, and in Galway and Clare, "the yellow colour prevails altogether, and the thickness of the red beds near the base is only about fifty feet."

The faults, dislocations, and intrusions of the igneous rocks are, however, so numerous and deranging everywhere in the Old Red and coal-field districts of Ireland, that any attempt to work out the geology of any one of the systems by the succession and other peculiarities in the strata alone, is extremely difficult, and perhaps scarcely practicable. The discovery of organic remains, of the Dura Den type, would greatly facilitate the solution of the points at issue, and I have little doubt, from the large-scaled *Holoptychius Portlocki* found in the beds at Cultra, that they may yet be detected in abundance in the subjacent strata in the vicinity. *Palæoniscus* scales, and rays and teeth of *Gyracanthus*, are everywhere abundant in the ironstone shales in Fifeshire; and a few miles to the eastward of Dura Den, at Mount Melville near St. Andrews, large jaw-bones with teeth of great size and in the most perfect state of preservation, along with bright enamelled scales and other relics, are very numerous.

4. Have we evidence to determine whether these are marine or lacustrine deposits, and of what aqueous habits were the fishes under review? Professor Huxley, "On Cephalaspis and

\* Pp. 18, 21, *et passim*.

Pteraspis,"\* says that ganoid fishes are distinguished from all others by certain peculiarities which are connected with the form of the commissure of the optic nerves, the aorta, branchiæ, the intestines, and the ventral fins. "These essential characters," as described in the paper, "are shared by only six genera of existing fishes, *Lepidosteus*, *Polypterus*, *Amia*, *Acipenser*, *Scapirhynchus*, and *Spatularia*, which are no less singular in their distribution than in their anatomy. All are essentially *fresh-water* fishes; all are found in the northern hemisphere; three—*Lepidosteus*, *Amia*, and *Spatularia*, are exclusively North American; *Polypterus* is only known in the rivers of Africa, while *Acipenser* is common to Europe, Asia, and North America." The palæontological ganoids are no less extensively distributed, prevailing wherever the Old Red Sandstone is found, all over the north of Europe and America, the central regions of Asia, and other quarters of the globe.

But, on the other hand, says Mr. Page,† looking at the whole system of the Old Red Sandstone, both in point of time and composition, we are prominently reminded of *marine* conditions—"of sea-shores whose sands formed sandstones, and of beaches whose gravel was consolidated into conglomerates and puddingstone—of receding tides that produced ripple-marks, and of showers that left their impressions on the half-dried silt of muddy estuaries." Shall we add, that the vast and world-wide geographical extent of these deposits confirm the marine theory of their origin, since we can scarcely suppose fresh-water lakes of co-ordinate dimensions at any time existing on the face of the planet? But, again, when we examine the fossil *vegetable* remains enclosed in the strata, and these most abundant not among the littoral grits and breccia, but in the tilestones and finest micaceous beds inferring deep-water formation, we are constrained to recognise the existence of marshes and river-banks which gave birth to a growth of ferns, trees, and shrub-like plants; and of estuaries and feenny lagoons,

\* *Quart. Journ. Geol.* vol. iv. p. 279.

† *Advanced Text-Book of Geology*, p. 133.

where frog-like reptiles enjoyed the necessary conditions of an amphibious life.

The following is from an extensive and excellent Paper of R. Godwin-Austen, Esq., on the coal-measures beneath the south-eastern part of England, in the *Quarterly Journal of the Geological Society of London* for February 1856 :—

“ Much confusion in the chronology of geological changes has been caused by the reference of this formation to the marine series. If due weight be allowed to the facts of an accompanying terrestrial and fluviatile vegetation, to the occurrence of the genus *Cyclas*, together with air-breathing oviparous quadrupeds and terrestrial Chelonians, the early suggestion of Dr. Fleming, though based on other considerations, will surely be adopted; and the Old Red Sandstone of Scotland will be referred to the lacustrine series of formations. The ‘Old Red Sandstone’ fishes offer a subject well worthy of special treatment, with reference to the conditions of the area of water in which they lived; but the conclusions would probably be in accordance with those of Dr. Mantell; that these conditions were such as those of the *Lepidosteus* and *Polypterus*.

“ Of the three divisions into which Sir R. Murchison divided the ‘Old Red Sandstone’ series of the Welsh area, the lowest or ‘Tilestone group,’ which alone contains the remains of marine forms, has been since very generally referred to the ‘Upper Ludlow’ deposits. The two higher divisions alone represent the typical ‘Old Red Sandstone;’ of these the argillo-calcareous or ‘Cornstone’ group contains just such an assemblage of fishes as is met with in the palæozoic fluvio-lacustrine deposits of Scotland; whilst the upper or ‘conglomerate and sandstone group,’ which as yet has only afforded the remains of a *Holoptychius*, includes somewhat abundantly the spoil of a terrestrial surface. On such considerations the ‘Old Red Sandstone’ of Hereford, Monmouth, and Somerset becomes the representative of another fresh-water area, the relation and extent of which are indicated in the accompanying Map (Pl. I.) Had not the true character of these two peculiar assemblages of depositions been misapprehended, the creation of a ‘Devonian System’ would not have been needed.

“ There are traces of ‘Old Red Sandstone’ at intermediate places between the two great areas of Wales and Scotland; and these are of interest, as they indicate with equal clearness an immediate subordination to a terrestrial surface. The little patches which are dotted along the eastern skirts of the mass of the old slate mountains of Westmoreland and Cumberland are in every case so closely related to the rocks of the particular locality, as to suggest that they are the alluvial beds of the ancient valley-courses of that region. A like local relationship, as was long ago observed by M. Boué,\* is to be traced along the whole of the junction-line of the ‘Old Red Sandstone of Scotland;’ and here the accumulation often parts with its character of water-rounded conglomerate, and assumes that of the angular talus so common in subaërial detritus.”

\* *Géol. de l'Écosse.*

The solution of the difficulty will not be advanced by a consideration of the remarkable contrasts exhibited throughout the series of the deposit, inclusive of the lower and the upper beds of Caithness and Dura Den, where the more characteristic features of Animated Nature in the ancient period present the most striking resemblances to the existing condition of things, terrestrial and marine. Thus there are the large lobster-like forms of Balruddery in contrast with the small shrimps of Reswallie, the huge *Stagonolepis* of Elgin to confront with the crab-like pterichthyan fossils of Carmylie and Dura Den, the mail-clad massive holoptychius of Clashbennie with the kampecaris or caterpillar-like appearance, occurring in shoals in the Forfarshire flagstones, and the great cyclopteris or tree-fern, so abundant in the system in Ireland, with the small berry-shaped impressions of Parkhill and Tealing.

5. Have we any means of ascertaining the amount of *Time* that may have lapsed during the accumulation of the materials of the Old Red Sandstone series, or of any of the geological formations? The question has many aspects and bearings, and there are many agencies concerned in the solution of the problem.

Looking at the current operations of the laws of Nature, and supposing their uniformity in past ages, a scale of increment is laid down for the several deposits of which the whole crust of the earth is composed. An approximation is thus attempted as to the number of years required for each, and the result is, that the geological estimate embraces an inconceivably lengthened and bewildering series. The calculation proceeds not by hundreds, or even thousands, but by millions of the terms of our numerical notation; and as the fossiliferous strata alone are reckoned at an average of ten miles in thickness, the time that has elapsed since the appearance of LIFE upon the planet has also been made a subject of investigation, including myriads of the brief fleeting years of man's existence.

But the *position* in the rock of the Dura Den fossils leads clearly to the conclusion that they were suddenly and simultaneously imbedded in the sands and the silts of the period. Their numbers, entireness, and general state of preservation, evidently show that they have been overtaken by one and the same cause of destruction, and instantly dropped to the bottom of the waters. There is never a broken fin, nor a scale displaced upon any of the specimens. They have not been carried from a distance, nor rolled about for any length of time. Everything indicates an immediate enclosure in their soft sandy sepulchres, and, consequently, a rapid process of silting up in the depths to which they sank. But for hundreds of feet in the vertical thickness, up and down through the rock, not a fragment or scale of a fish is detected. The mass is completely non-fossiliferous, although consisting of several varieties of materials, such as clays, marls, fine arenaceous bands, and gritty beds.

No long period, therefore, we may justly infer, could have elapsed during the progress of accumulation, as within a given amount of time many creatures must necessarily have perished, and their remains been enclosed in the rocky mass. The absence of fossils in a hundred feet of sandstone would warrant the conclusion, from their natural term of existence, that nothing like hundreds of years were spent in the accumulation of the materials of the rock. And as with one series of the formation, the same conditions, as we actually find them in the lower series through immense depths of non-fossiliferous strata, justifies the inference as to the proportion of the element of time involved in the problem of their lithological antiquity.

There is another test of considerable value, furnished by the *fossil trees* in the sandstones of the Carboniferous formation around this district, by which to ascertain the rate of accumulation in the materials of these rocks. The action of currents in every case must be admitted as necessary for conveying the

muds, sands, and gravels of which the different beds consist : and the same agency that washed in the rocky matter would likewise convey the trees and plants so abundantly diffused through the mass. Fossilized trees, stems, and branches are very numerous in every coal-field. They are often traced through several layers of strata, in an upright position, or but little inclined to the plane of stratification. The quarries on Blebo hill, at a height of six hundred feet, and directly superincumbent on the yellow sandstone of Dura Den, are full of these interesting relics,—large masses of *stigmæria*, *sigillaria*, *coniferæ*, and other species of trees, and lying in every position in the sandstone, from the horizontal to the vertical. Many of the imbedded trees in the coal-measures of the district, from the Castle-rock of St. Andrews to the highest slopes of the Lomonds, are of great length, and carried into the depths or shallows, might often stand hundreds of feet above the waters. A fossilized tree was exposed in the carboniferous sandstones of Blair-Adam in the summer of 1857, in an upright position, the roots entire, and spreading in all directions around, about fifteen feet of stem in length by four to five feet in diameter, and the carbonized bark adhering over the exposed section. This tree originally might measure from two to three hundred feet in height ; and whether, in or out of the waters, in part or in whole, the woody mass could not long resist the destroying action of the elements—the currents, waves, winds, and other atmospheric agencies of the period.

Fossil trees of gigantic dimensions were, a few years ago, dug out of the quarries of Craighleith and Granton, the roots and some of the branches attached to the stem, and lying at an angle of about twenty degrees to the horizon, as well as the strata in which they were imbedded. The Purbeck “dirt-beds,” or old terrestrial surfaces and soils, contain at different levels *erect trunks*, and stumps of *coniferæ* and *cycads*, with their roots all attached and *in situ*. At Beadnell, Northumberland, large areas in the coal-measures are covered with roots

and trunks, passing through several bands of shale and sandstone ; and to come to more recent times in the earth's history, there is a remarkably curious record of a clump of petrified trees in a rocky passage of the Cordillera in the Uspallata range of South America. Eleven of the trees are silicified, and from thirty to forty are converted into coarsely crystallized white calcareous spar ; the trunks are from three to five feet in circumference, abruptly broken off and projecting several feet above the ground. The sandstone in which they are imbedded, and from which they must have sprung, has been accumulated in *successive thin layers* around their stems, retaining the impression of the bark, and now raised amid enormous masses of volcanic rock seven thousand feet above the level of the valley.

“It required little geological practice,” says Darwin, “to interpret the marvellous story which this scene at once unfolded ;\* though I confess I was at first so much astonished that I could scarcely believe the plainest evidence of it. I saw the spot where a cluster of fine trees had once waved their branches on the shores of the Atlantic, when that ocean—now driven back 700 miles—approached the base of the Andes. I saw that they had sprung from a volcanic soil which had been raised above the level of the sea, and that this dry land, with its upright trees, had subsequently been let down to the depths of the ocean. There it was covered by sedimentary matter, and this again by enormous streams of submarine lava,—one such mass alone attaining the thickness of a thousand feet ; and these deluges of melted stone and aqueous deposits had been five times spread out alternately. The ocean which received such masses must have been deep ; but again the subterranean forces exerted their powers, and I now beheld the bed of that sea forming a chain of mountains more than 7000 feet in altitude. Nor had those antagonist forces been dormant which are always at work to wear down the surface of the land to one level ;—the great piles of strata had been intersected by many wide valleys, and the trees, now changed into siliceous, were exposed projecting from the volcanic soil now changed into rock, whence formerly, in a green and budding state, they had raised their stately heads. Now all is utterly irreclaimable and desert ; even the lichen cannot adhere to the stony casts of former trees. Vast and scarcely comprehensible as such changes must ever appear, yet they have all occurred within a period recent when compared with the history of the Cordillera ; and that Cordillera itself is modern as compared with some other of the fossiliferous strata of South America.”

\* *Journal of Researches*, by Charles Darwin, Esq., F.R.S., p. 406.



These *instantie crucis* may be multiplied and extended to every sedimentary deposit in which fossil trees are found, and an estimate derived of the formative process of the rocky mass, layer after layer, from the duration of time that a tree, standing in water, was able to preserve its structure and resist the destroying action of the elements. Look at any of the nearest river embankments, margined by trees, during the season of floodings or overflows. Observe the oak, the hardest specimen of our forests, engulfed in the waters, and then consider the plain question, How many years, or months, or days, will that noble stem and those giant branches be able to bear themselves aloft, and laterally, or uprightly? or how long be able to contend with the currents and other wasting agencies, atmospheric and otherwise, by which they are assailed? Certainly not tens nor twenties—most assuredly not hundreds of years—far less the thousands registered in the calendars of the geologist! If the silting process is to be gauged by the enduring powers of wood immersed in water, it is not perhaps too much to say, that all the yellow sandstone rock of Dura Den might have been collected, and piled bed upon bed, in a shorter period than has been occupied in eroding and scooping out the ravine itself by the action of the stream on the now consolidated mass.

We have a remarkable instance of rapid formation, by sedimentary and volcanic processes, in the island of Mull, where huge mountains of basalt have been formed and upheaved within comparatively recent times. The headland of Ardtun shows in a vertical cliff of several hundred feet in height, alternating beds of basalt, tuff, pumice or scorix, and ligneous mud, all indicating that the island and district were the theatres of great volcanic action during the tertiary age. This interesting discovery was made by the Duke of Argyll, who, in a paper published in the *Geological Quarterly Journal* for May 1851, adduces clear and satisfactory evidence of vast subterranean operations in Mull and the other western isles, and

at Antrim and the Giant's Causeway, where alternating leaf-beds and lignites are repeatedly mixed up with amorphous and columnar igneous rocks. The account serves to establish the important geological inferences, that Scotland and Ireland were at the period of the eruptions parts of one and the same country; that the Hebrides and mainlands were united on both sides; and that all the marine interspaces were overflowed by volcanic mud and ashes, which embraced, season after season, the annual sheddings of a forest vegetation. After describing the characters of the lignites and organic remains, and the igneous mass of basalt rock in which they are imbedded, the noble author proceeds to observe:—

“No one who has followed this description of the Ardtun Head, the ‘Point of Waves,’ and is acquainted with Staffa, will fail to recognise a remarkably corresponding feature. The lowest two members of the Ardtun series, the massive amorphous basalt, passing into and resting upon the columnar, offer a precise representation, on a smaller scale, of that wonderful front which lies opposite, at some five or six miles’ distance. The whole group of the Trishnish Islands, ‘which guard famed Staffa round,’ would seem, from their low tabular appearance, to belong to the same prolonged sheets of trap, and may represent the skeleton of that country now destroyed, from whose forests the Ardtun leaves were shed. It is not improbable that by future researches amid the conglomerates, and other stratified matters associated with the traps, in Mull and the neighbouring islands, portions of the more substantial parts of those forests will yet be found. It appears, from Dr. M’Culloch’s account of the traps of the middle district of the island of Mull, that he did actually find the carbonized stem of a tree, whose structure proved to be coniferous. His notice of the ‘vein’ in which it occurred is an accurate description of the tuff which covers the leaves of Ardtun; but he expressly says, that it occupied a *perpendicular* instead of a horizontal position in the cliff; and the headland of Bourg seems to be indicated, although not very clearly, as the locality.”

Geologists have long been acquainted with the surturbrand beds of Iceland; that is, bituminized wood embedded in the igneous rocks of that volcanic island. The characters of the two classes of phenomena are almost identical; a sympathy betwixt the localities is still maintained by the shocks of earthquake that, from time to time, reach our shores. Hecla is still in fiery activity, casting up volcanic mud and ashes, and thus

are we reminded of the comparatively short period of time, as of the close proximity in distance, since volcanoes existed in our own island, and their subterranean fires, which have only retreated a few hundred miles, melted materials sufficient to form cones, to shatter and upheave mountains.

And if so, in the comparatively modern, how much greater were the agencies at work and the changes effected in the older days of the earth's history? The bulk of dry land, compared with water, was in the primary times of these cosmical arrangements, perhaps only a twentieth instead of a third part, as now, of the supermarine area of the globe. How infinitely greater, therefore, the action of the waters over all the materials subject to their disintegrating power; whether upon the islands and continents already elevated above their waves, or upon the immense submarine tracts of rock just lifting up their peaks and being raised into the air? Nor, in alluding to volcanic products, can we fail to perceive how greatly inferior are all the modern to those of the palæozoic ages; the mountains of the historic and the tertiary periods to those of the secondary and primary, when all the loftiest ranges were bursting into position—the great American Continent, not as now with a few isolated cones, but rending all over as the mighty Andes, Cordilleras, and Rocky Mountains were rising above the deep, and acquiring outline; and in every quarter of the globe, through Asia, Africa, and Europe, when our great Alpine groups were formed, and all the plutonic, erosive, and denuding agencies were upon a scale of corresponding magnitude and force.

“It is true, indeed,” says an eloquent writer,\* “that Nature is constant and regular in her operations; but if, in the short course of our experience or of that of past observers, no variation may have been noticed in the uniformity of her workings, it is that the little segment of her duration's cycle over which we and they have travelled, is but as a straight line, an infinitesimal element, whose curvature can only appear when referred to a much larger portion of her circumference. That besides the particular laws with which we are acquainted, there have been others once most active, whose agency is now either suspended or concealed, the study of the world must easily convince

\* Dr. Wiseman's *Lectures*, p. 154.

us. There were times, within the range of mythological history, when volcanoes raged in almost every chain of mountains; when lakes were dried up or suddenly appeared in many valleys; when seas burst over their boundaries and created new islands, or retired from their beds and increased old continents; when, in fine, there was a power of production and arrangements on a great magnificent scale, when nature seemed employed not merely in yearly renovation of plants and insects, but in the production from age to age of the vaster and more massive elements of her sphere,—when her task was not confined to embroidering the meadows in spring, or to paring away of shores by the slow eating action of tides and currents, but when she toiled in the great laboratories of the earth, upheaving mountains, and displacing seas, and thus giving to the world its great indelible features.”

The distinguished author of the *Siluria* has expressed his views upon the same point in similar eloquent terms.

“As well,” says Sir Roderick Murchison, “might the naturalist, upon witnessing the gigantic growth of the African or American forests, compared with the pigmy stature of our trees, calculate that, if the oak has required its hundreds of years to reach its strength, they must have been rooted for thousands in the soil, as the geologist conclude, that so many myriads of ages must have been requisite to give to the systems of rocks their consistency and consolidation.” And again: “The uniformitarian who would explain every natural event in the earliest periods by reference to existing conditions of being, is stopped at the very threshold of the palace of former life (none being *before* Silurian) which he cannot deprive of its true foundations. Nature herself, in short, tells him, through her most ancient monuments, that though she has worked during all ages on the same grand principles of destruction and renovation of the surface, there was formerly a distribution of land in reference to the sea, very different in outline from that which now prevails. That primeval state was followed by outbursts of great volumes of igneous matter from the interior, the extraordinary violence of which is made manifest by clear evidences. Fractures in the crust of the earth, accompanied by oscillations that suddenly displaced masses to thousands of feet above or beneath their previous levels, were necessarily productive of such translations of water as to abrade and destroy solid materials, and spread them over continents to an extent infinitely surpassing any change of which the historical era affords example. I could here refer to the works of Leopold von Buch, Elie de Beaumont, Sedgwick, Studin, and numerous other geologists, for countless proofs of this grander intensity of former causation, by which gigantic masses were inverted, and strata forming mountains have been so wrenched, broken, and twisted, as to pass under the very rocks out of whose materials they were constructed. In the Alps there are signs of such former catastrophes, each of which resulted from convulsions utterly immeasurable and inexplicable by any reference to those puny oscillations of the earth which can be appealed to during the times of history.”\*

\* *Siluria*. By Sir R. I. Murchison, D.C.L. Third edition, p. 523.

If the rocks of Dura Den were formed during the epoch of such violent agencies, we, therefore, conclude that the fishes now embedded in their consolidated materials were suddenly destroyed by one of the disturbances of the period, and that their position as confined to a single bed furnishes an additional proof of the rapid collection and silting up of the materials of which the rocks themselves are constituted. Leibnitz, in his *Protogeia*, has largely dwelt upon these points, which, although geology in his time was in no ways systematized, are remarkably in harmony with the deductions of modern discovery; in his masterly sketch, especially of the leading geognostic canons of the science, he successfully advocates the intensive energy with which physical causes must have acted in primordial times; and considers that the disruptions and igneous accumulations of the earth's crust, from the disturbances communicated to the incumbent waters, must have been accompanied with diluvial action, the *maximæ secutæ inundationes*, on the largest scale and the most extensive results.

6. But upon any view of these interesting speculations, a terrestrial flora, on a scale of magnitude incomparably greater than any in modern times, was now preparing for economic purposes, the uses and the wants of creatures yet to emerge in long after-periods. The dense forests that were to supply the materials of our coal-fields, and the heaths and other herbaceous shrubs that were to secrete the metal in our ironstone, required an extent of plains, uplands, and mountain slopes which must have surpassed in extent all existing carse, strath, or highland glen in "Caledonia wild," or anywhere in the British Isles. The seas likewise were to undergo mighty changes, both in their deep oceanic troughs and their more shallow littoral arrangements. Submarine volcanoes, whose poisonous elements destroyed these shoals of ganoid fishes, were now to eject volumes of calcareous and muddy materials, out of which coral-agency was to elaborate the mountain limestones, and in whose soft banks the countless shell-fish of the period were to burrow,

and their remains to be afterwards enclosed in the shales and breccias of the system. New shores likewise were to be formed, new basins to be constructed, new boundary lines to be cast up from below, and dry lands submerged from above, and a mechanism of forces arranged underneath the crust whereby to admit the successive deposition of marine, estuary, and fresh-water detritus of which the coal-measures all over the earth are so marvellously composed. Here is presented the evidence of vast changes of physical condition and oscillations of level, showing that as frequently as the successive strata were deposited, so frequently did the seas swarm with their teeming inhabitants, and the lands wave under a dense vegetation ; while as many times were there the repeated alternations of lakes, estuaries, lagoons, and seas of deeper and sometimes of shallower bottoms.

The peculiarity of this flora is the great number of the vascular cryptogamic plants, which amount to two-thirds of the species of vegetables discovered in the carboniferous deposits. With these are associated a few palms, coniferæ, cycadeæ, and some species of plants allied to the cactæ and euphorbiacæ. The ferns are the most prevailing types, large arborescent kinds, of which several hundred, belonging to many genera, have been determined. Many of the strata of shale are entirely made up of carbonized fern leaves and stems closely pressed together. The roof of a coal mine, when newly exposed, often presents the most wonderful appearance, from the amazing abundance of these most graceful of all plants, and the infinite variety of leaves, branches, and stems that are displayed, sometimes in relief, sometimes impressed on the dark shining surface. When the shale or stone is of a light colour, the contrast of the black carbonized foliage renders the effect perfectly enchanting, rivalling everything in the shape of sculpture, mosaic intaglio tracery, or all that was collected of art in the most admired compartment of the Crystal Palace. But most remarkable of all, the plants of the coal-measures, from Greenland to Aus-

tralia, from Vancouver's Island in the far west, to the remotest corners of Russia, in Eastern Asia, are possessed of one uniform botanical character, the same species being found in every latitude, all now allied to those only of tropical countries, and when the denseness and luxuriance of an Indian jungle prevailed in every clime.

A calculation has actually been made of the amount of woody substance contained in a given quantity of coal.\* The results, which are highly interesting, are as follow : wood affords in general about twenty per cent., and coal about seventy per cent. of charcoal. Throwing out of the calculation the oxygen and hydrogen, it must therefore have required three and a half tons of wood to produce the charcoal contained in one ton of coal. Suppose now a forest, composed of trees, every one of which is eighty feet high—that the trunk of each tree contains eighty cubic feet, and the branches forty—and it results, that the weight of each will be about two and a quarter tons. Allowing one hundred and thirty such trees to an acre, we have three hundred tons of woody matter on that area of ground. Now a cubic yard of coal weighs very nearly one ton ; a bed of coal one acre in extent, and three feet thick, will contain about four thousand eight hundred tons ; and hence one acre of coal, with only one bed of three feet thick, is equal to the produce of nearly two thousand acres of forest. But instead of one bed there is an average of eight to ten in the coal-measures of Scotland, with an average aggregate thickness of twelve feet of the pure mineral substance ; in England, there is a much higher ratio ; and in the vast coal basins of America it is higher still. We leave the reader to pursue for himself the arithmetical enumeration and comparison which these data furnish ; and we may simply ask him to consider what amount of forest, all the world over, is now buried in these subterranean regions, shedding, year after year, their leaves and fruits to fill up the dense bituminous mass, and where the lands on which their mighty trunks

\* *Geology of Fife and the Lothians*, p. 116, by C. Maclaren, Esq., F.R.S.E.

were sustained? These families are nearly all extinct, or, as in the ferns, and club-moss, and horse-tail tribes, a stunted, pigmy race; and faintly allied, in a few others, in the arborescent kinds of the tropics, to the giant types of the coal age. How few of us all, who are in the daily enjoyment of the blessings, in a thousand forms, derived from our easy and abundant supplies of this fuel, think of the long and singular processes by which it was prepared, ages ago, in the laboratory of nature, where the forests of primeval times, deprived of their watery and volatile parts, but retaining all their combustible matter, were stored up for our use in inexhaustible quantities, under our feet, closely packed and walled in by a solid masonry of rock! Twenty years have scarcely elapsed since Witham, a Yorkshire gentleman, visited Edinburgh, obtained prepared slices of our different coals from the late Mr. Nicol, lapidary, placed them under the microscope, and revealed, for the first time, in all their marvellous woody tissue, the structure and composition of our combustible treasures.

But the wonders of our coal-fields are not half exhausted by these disclosures. The chemists tell us that the ironstone and black-band, which are co-extensive almost with the coal in geographical area, have chiefly derived their metallic properties from the residue of the same plants which furnished the bituminous compound. Much of the iron, doubtless, resulted from the decomposed rocks of an anterior period, and was washed down by the rivers into the basins in which the coal materials were collected. Part of it likewise would be cast out in the plutonic products from the innumerable volcanic foci which everywhere existed in the coal-measures. But as in the bog plants of the present time, which form our peat mosses, so charged with solutions of iron, in like manner in the exuberant vegetation of the carboniferous age, it is affirmed, that enough of the metal existed to form the ores of iron with which the coal beds are everywhere accompanied. There are at present, in Scotland alone, upwards of a hundred



hot-blast furnaces in operation, each smelting at the rate of sixteen to twenty tons of pig-iron daily, or about 6240 annually, and thus yielding a total of 624,100 tons. The market price for the article, in this crude condition, is now about £3 per ton. Hence the annual value of metallic ore, extracted from the coal-fields of Scotland, is £1,872,300, nearly two millions sterling; for a product which the flora of the age yielded, over and above the still richer mines of the combustible elements of the coal itself.

And yet there are circumstances connected with the ingredients and physical arrangements of the coal-measures, more marvellous even than anything now stated. We allude to the limestones, and more especially to the encrinital portions of the formation. This mass of calcareous matter, often sixty feet thick, as at Silver Mine Quarry, near Linlithgow, consists almost entirely of shells and skeletons of other marine animals. This limestone is co-extensive with the coal-measures throughout the world, feathering out and in among the metals, often in the form of a vertical wall, separating the basins of one district from those of another, and more generally underlying the coal-beds in such a manner, as at the same time to constitute the outer lip or edges of the great trough of the carboniferous formation. Encrinites are corals. They belong to the same zoophytic class of creatures which are now piling up the coral reefs in the Pacific. They are composed of similar varieties; they wrought after the same fashion; they made corresponding diversities, according to the conditions of their ocean bed, of the ring, atoll, and lagoon structure of coral reef; and they left their skeletons to construct the vast mountain limestone strata under consideration. These strata are common to all parts of the world. They exist in Melville Island, in Greenland, and in every coal territory washed by the Northern Ocean; and in like manner over the central and southern hemispheres of the earth's surface. Like the coal plants, the polyps of the ancient seas were ubiquitous, abund-

ing in all climes, and simultaneously in every latitude, breasting the ocean wave, and rearing up their massive courses of natural masonry.

The coral classes are distinguished in the Linnæan arrangements into several genera, and the analogy as to size and the products of their working, is here wonderfully maintained betwixt the extinct and the existing species of polyps. As, for example, in the diminutive ferns, horse-tails, and club-mosses of our northern latitudes, there are the allied families of the tropical aborescent kinds in the largest forms of trees, so among the *tubipores*, *cellepores*, and *antipathes*, now so active and skilful in rearing their huge piles of coral reef in the tropical seas, there are their representative species of *Fascicula*, *Hydra*, and others, found on the shores of Greenland, and still plying their pigmy functions amid the rigours of the Northern Ocean. Thus nature clings to her types of animal as of vegetable life through all time. Thus she enlightens our scepticism, and removes our doubts, as to the surprising means by which she accomplishes her purposes on the greater as on the smaller scale; and shows, by what she is doing now, through these humble instruments, she has done ages ago, in constructing the fabric of our earthy dwelling, and in storing the inner chambers with the most valuable materials for our use and comfort. The busy artisans that now rise upon the ocean surge, are one and the same in nature, habit, and toiling aim, with those earlier denizens of the sea whose wondrous structures rose above the breakers, elaborating their food and their coral bed from the elements of the same water, and manifesting their instincts as the voice of the same God who commanded the waters to bring forth abundantly the moving creature that hath life.

“ Even as one essence of pervading light  
Shines in the brightness of ten thousand stars,  
And the meek worm that feeds her lonely lamp  
Couched in the dewy grass.”

The mind that sees not in these singular operations evidences of design, foresight, and purpose, can have no proper conception

of the relative influence of cause and effect, of wisdom and contrivance. We have here a combination of materials in every coal-field, rough and rude as all about it may appear, which directly speaks to us of intelligent superintendence. These things by accident or chance could not have happened. The heavens declare the glory of their Author. A voice from the deep places of the earth speaketh of His ways. Astronomy unfolds the wonders and stability of the starry system. Geology lays open the interior structure and the beautiful arrangements of our own planet. One series of rocks only have we touched upon. To the eye of the common observer all appears confusion and disorder—materials cast out and piled upon each other at random, rocks upheaved and rent asunder according to no method or law, and all within exhibiting the still more repulsive features of sterility and death. The eye of science looks a little deeper, where it sees order, symmetry, and a boundless profusion of the richest materials, stored up ages ago for man's use and social advancement, affording sustenance and enjoyment to earth's varied tribes in far bygone times, and now these stony chambers beneath, the Necropolis of its countless, long-buried dead! The illustrious Bacon has beautifully said: "*Philosophia naturalis, post verbum Dei, certissima superstitionis medicina est; eademque probatissimum fidei alimentum.*" How truly is this the case with geological researches as to the "*potestas Dei*" of which he afterwards speaks, where the arrangements, diversity, and constituent elements of the framework of the globe present such manifest illustrations of the power, wisdom, and goodness of Him who reared the stupendous fabric, and made our humble dwelling-place one of the bright rolling planets of the universe!

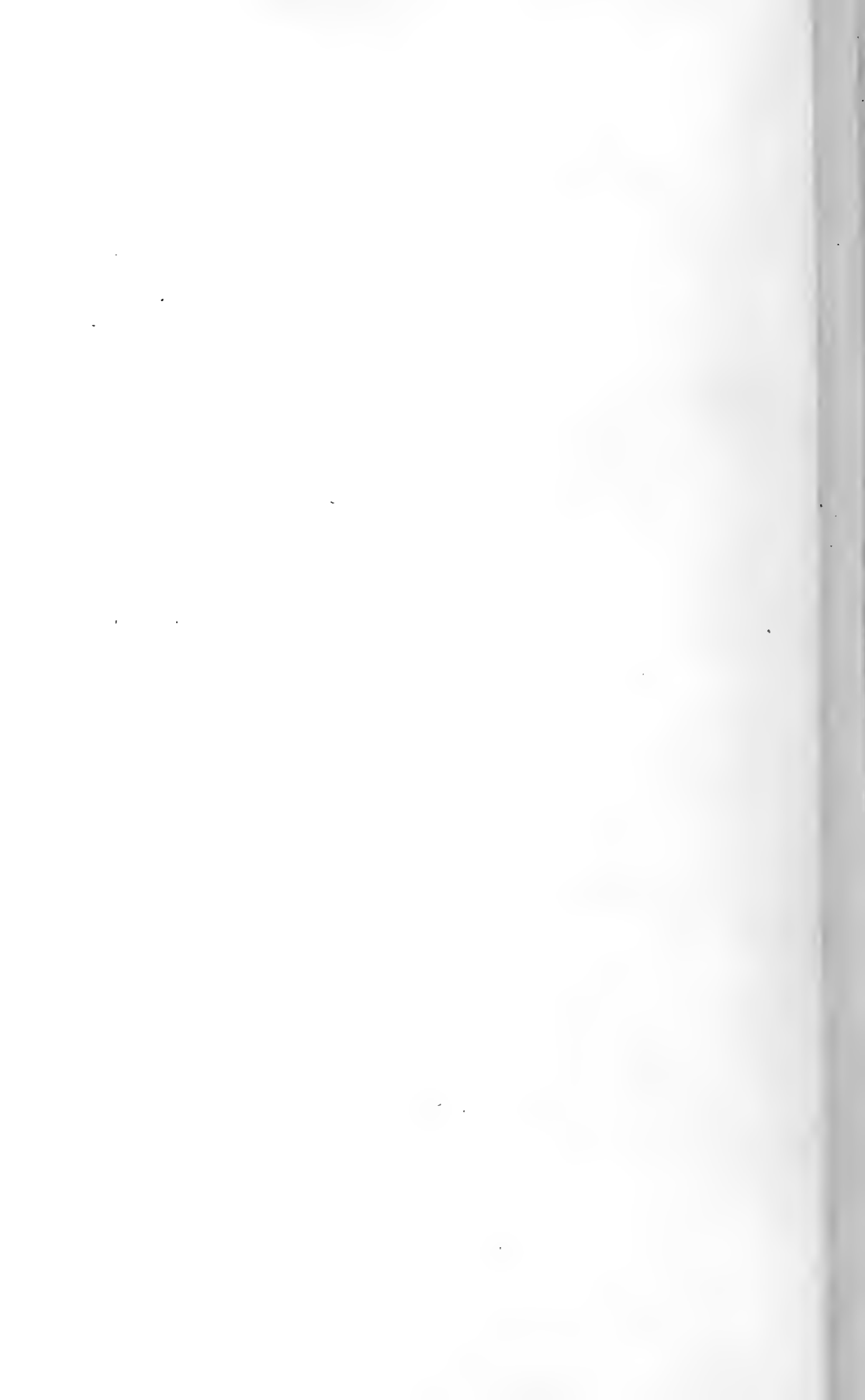
Who would refuse to study and examine into these things? What interesting disclosures are missed when we do! What culpable, unpardonable neglect, or indolence, or prejudice, in passing over knowledge so readily, and in every spot of earth's

surface, acquired! The world long panted after what was termed *the philosopher's stone*. The wonderfully transmuting material has been discovered at last. There are two words, containing only eleven letters, but expressive of the most valuable minerals in the world—COAL and DIAMOND. No two minerals are more unlike, and yet essentially the same. The one is bright and dazzling: the other black and forbidding. The one sparkles on the brows of queens and nobles: the other is every man's comfort and a country's wealth. Coal builds towns and factories everywhere around it. It has bridged the ocean; it has made a highway over the earth; and it will become the civilizer of the world. The Christian missionary will hail its beacon-light in the wilderness; the solitary place will be made glad by it; the Gospel message will speed along the lines of its accelerating power. How curious the reflection, that the present commercial greatness of Britain, and in which all its noble philanthropic schemes are built up, should be intimately connected with a black combustible mineral, the product of arboraceous ferns and gigantic reeds—vegetables of strange forms and uncouth names, which flourished and decayed on the surface of the earth, age after age, ere the mountains in many a land were yet upheaved—and plains and mountains, which then towered aloft with their dense forests, are again engulfed—and when as yet there was no man to till the ground! But such truths geology teaches us, the lessons engraven as with a pen of iron on the flinty rocks, and the readings as legible and accurate as the print of yesterday.

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