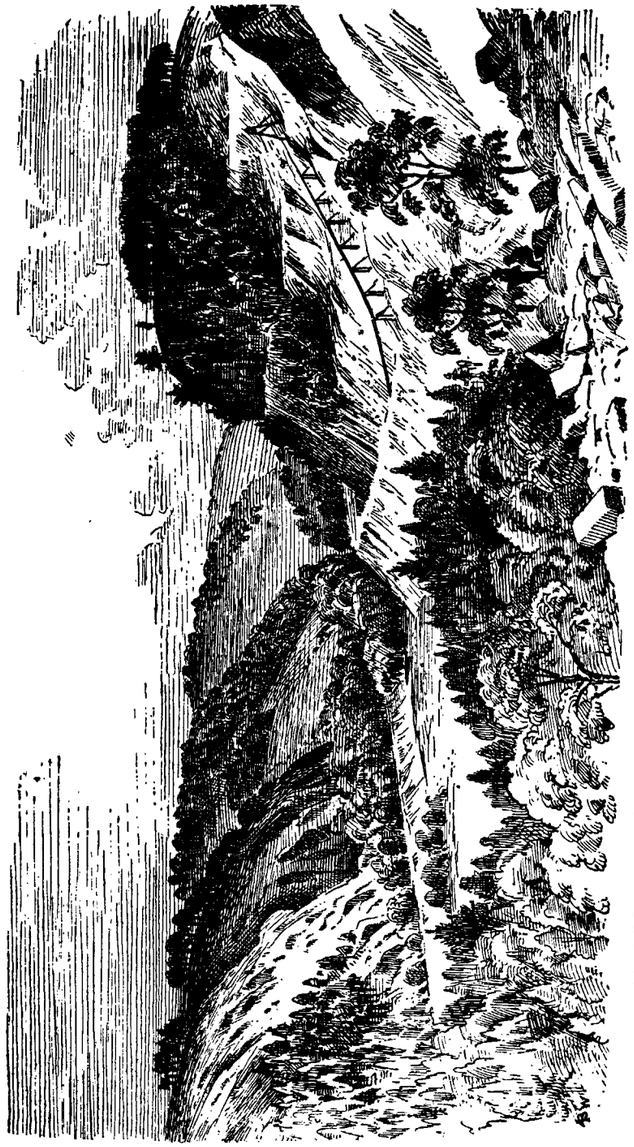
FRONTISPIECE.



The Bell Rock and the Ovoca Valley, with the Mining Ground on the right. (From a sketch by Mr. A. B. Wynne).

138 and 139.

Memoirs of the Geological Survey.

EXPLANATORY MEMOIR

TO ACCOMPANY

SHEETS 138 AND 139 OF THE MAP

OF THE

GEOLOGICAL SURVEY OF IRELAND,

By EDWARD HULL, LL.D., F.R.S.

WITH

AN ACCOUNT OF THE MINES,

By R. J. CRUISE, M.R.I.A.

AND

NOTES ON THE IGNEOUS ROCKS BY F. H. HATCH, PH.D., F.G.S.

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1888.

CONTENTS.

THE

GEOLOGICAL SURVEY OF THE UNITED KINGDOM

IS CONDUCTED UNDER THE POWERS OF THE

8TH & 9TH VICT., CHAP. 63.—31ST JULY, 1845.

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The observations made in the course of the Geological Survey, are entered, in the first instance, on the Maps of the Ordnance Townland Survey, which are on the scale of six inches to the mile. By means of marks, writing, and colours, the nature, extent, direction, and geological formation of all portions of rock visible at the surface are laid down on these maps, which are preserved as data maps and geological records in the office in Dublin.

The results of the Survey are published by means of coloured copies of the one-inch map of the Ordnance Survey, accompanied by printed explanations.

Longitudinal sections, on the scale of six inches to the mile, and vertical sections of coal-pits, &c., on the scale of forty feet to the inch, are also published, and in preparation.

Condensed memoirs on particular districts will also eventually appear.

The heights mentioned in these explanations are all taken from the Ordnance Maps.

AGENTS APPOINTED FOR THE SALE OF MEMOIRS, MAPS, SECTIONS, AND OTHER PUBLICATIONS OF THE GEOLOGICAL SURVEY OF THE UNITED KINGDOM.

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138, 139.

PREFACE.

THIS Memoir is the last of those of the south-east of Ireland, which, owing to causes which cannot be here stated in full, have been in arrears in reference to the publication of the Maps. The lamented death of Mr. Hardman, just as he had completed an examination of the district for the purpose of collecting materials for a descriptive Memoir, but before he had commenced to write, is one of the most recent and regretable causes of delay.

Mr. Hardman's notes having unfortunately been lost during his illness, I have had no opportunity of consulting them, and have myself undertaken the task of preparing the Memoir.

After a careful examination, extending over several years, Mr. Kinahan wrote an exhaustive account, giving the history, as far as could be obtained, of the mines of this region from ancient times down to 1882. This, however, was too extensive for the present Memoir. I therefore directed Mr. Cruise to draw up extracts from Mr. Kinahan's notes, and, as far as the Ovoca mining district is concerned, to visit this locality and obtain information regarding the present condition of the mines, which has been included in this Memoir. The observations of Mr. G. H. Kinahan have been made use of, as well as those of his son, the late Mr. Gerrard Kinahan, whose early death has caused a feeling of deep regret amongst those who had watched his promising career.

This area was originally surveyed by Messrs. Wyley, Willson, Oldham, and Smyth, under the direction of Captain James, R.E., and Dr. Oldham. The "trappean" and associated rocks are very complicated, and it is difficult to determine their relations to one another and the adjoining rocks. They were, at the first, examined and mapped by Mr. Wyley, and subsequently successively by Messrs. Du Noyer and Kinahan. The mapping of the two former appeared in the first and second editions of the one-inch map, and after due consideration it has been determined to allow the second edition to remain. The Petrographical Notes on the igneous rocks of the district, contributed by Dr. F. H. Hatch, and based largely on microscopical examination, will prove of interest to those engaged on studies of this kind.

EDWARD HULL, *Director.*

Geological Survey Office, Dublin,
August, 1887.

EXPLANATORY MEMOIR

TO ACCOMPANY

SHEETS 138 AND 139 OF THE MAP

OF THE

GEOLOGICAL SURVEY OF IRELAND.

I.—GENERAL DESCRIPTION.

The district about to be described lies chiefly in the southern part of county Wicklow, but includes small portions of the counties of Carlow and Wexford. The county boundary of Wicklow, starting from the sea-coast at Kilmichael Point, takes a westward direction, and passing over Croghan Kinshelagh, ultimately meets that of Carlow at Wicklow bridge, near Clonegal. The principal towns and villages are Tullow, Hacketstown, Shillelagh, Tinahely, Coolboy, Aughrim, Ovoca, and Arklow. The line of the Dublin, Wicklow, and Wexford Railway traverses the district from north to south, along the valley of the Ovoca River to Arklow, and thence southwards, while a branch runs westward to Tinahely and Shillelagh from the junction at Wooden Bridge above Arklow.

II.—PHYSICAL GEOGRAPHY.

Elevations.—The district forms a central section of the mountain range of Dublin, Wicklow and Wexford, with the adjoining maritime tract to the east; but, with the exception of the somewhat isolated mass of Croghan Kinshelagh, which reaches an elevation of 1,987 feet, does not contain much high ground as compared with the tract to the north, or even to the south. The northern tract is characterised by the presence of the highest elevations of the range, including Lugnaquillia, which reaches a height of 3,039 feet above the sea, forming a great dome of schist rising from a granitic plateau;* that to the south, some considerable elevations, such as Mount Leinster (2,610 feet in height) and Blackstairs (2,409 feet); so that the tract we are now considering may be said to form a somewhat depressed saddle in the granite range, as compared with the tracts by which it is bounded both towards the north and towards the south. The district also contrasts with those adjoining in another respect, namely, that the higher elevations do not lie within the general limits of the granitic tract, but rather outside and beyond it, amongst the Silurian and trappean rocks which stretch from the granitic region to the

* See Horizontal Section of the Geological Survey, Sheet I.

margin of the sea. The masses of Lugnaquillia and Mount Leinster, though capped by beds of schist, are situated well within the granitic region.

The only elevations worth mentioning are, in Sheet 138:—

Moyne,	1,754 feet.
Kilcommon,	1,416 ,,
Mullinacuff,	1,171 ,,

And in Sheet 139:—

Coolgarrow,	1,196 feet.
Cushbawn,	1,318 ,,
Annagh,	1,498 ,,
Croghan Kinshelagh,	1,987 ,,
Slievefoore,	1,356 ,,

Rivers.—The district is drained by several streams justly celebrated for the beauty of the scenery laid open along their banks. These are the Avonmore and Avonbeg Rivers, which, uniting at "The Meeting of the Waters," below Castle Howard, thence form the Ovoca River, and, flowing southwards along the deep and richly-wooded vale of that name, ultimately reach the sea at Arklow, having received the tributary waters of the Aughrim, Goldmine, and Glenart Rivers. The Avonmore, Avonbeg, and Aughrim streams take their rise high among the deep recesses of the Wicklow mountains. The sources of the former have already been described in the Memoir to Sheets 121 and 130.* That of the Aughrim issues from the southern flanks of Lugnaquillia, from which it descends under the name of the "Ow River" to Roddenagh Bridge, where it unites with the Derrywater, which has its sources in the elevated ground north and west of Tinahely.† The valleys of the Ow and Avonbeg Rivers are separated by a high ridge, which, commencing near Percy's Table at the eastern side of Lugnaquillia, ranges in a south-easterly direction by Kelly's Lough, Carrawaystick, Slievemoan, Croaghmoira, and Cushbawn to Wooden Bridge. On either side of this ridge the streams descend precipitously into the deep river channels which ultimately unite in the Vale of Ovoca, near Ballyarthur House.

The western and southern portions of the district are drained by the Slaney and its tributaries, the Derreen and Shillalagh, or Derry, Rivers; and the watershed which throws off these streams from those of the Ovoca and its tributaries ranges from the central mass of Lugnaquillia southwards, by Slievenamaan, Lybagh, Black Rock, and Rockingham House near Tinahely, to Annagh Hill, and thence towards Carnew.

The source of the Slaney is at North Prison, at an elevation of 2,552 feet above the level of the sea, and less than a half a mile from that of the Ow River. It enters Sheet 138 north of Rathvilly, and, pursuing a general course southward, leaves it again at the southern margin near Ballintemple House, ultimately entering the sea at Wexford Harbour. A short distance above Aghade Bridge it is joined by the Derreen River, which traverses the

* "Explanations to accompany Sheets 121 and 130," page 8.

† The source of the Ow River is at a point about a mile west of Percy's Table, at an elevation of 2,700 feet. See "Explanatory Memoir to Sheet 129," page 6.

central part of Sheet 138, and takes its rise about two miles from the source of the Ow, at Rathgorragh Upper, 1,775 feet above the sea level. Many minor streams contribute their waters to the Rivers Slaney and Ow, but do not require special notice. The watershed which throws off the tributaries of the Slaney from those of the Barrow, and which is of no great elevation in this district, follows very nearly the western margin of Sheet 138, and passing by Ballon, stretches southwards to the flanks of Mount Leinster. The River Burren which drains the south-western portion of the district, flows into the Barrow at Carlow.

III.—Formations and Varieties of Rock entering into the Structure of the District.

Age.	Name on the Map.	Colour and Sign on Map.	
	Aqueous Rocks.		
Recent,	Alluvium, Peat bog,	Pale sepia.	
Post-Pliocene, or Drift Deposits.	Sand, Gravel, and Marl, Boulder-clay and Moraine matter.	Engraved dots.	
Lower Silurian,	Bala (or Caradoc) Beds and Llandeilo Beds.	b^2. Pale purple.	
Do. altered,	Mica-schist, &c., passing into gneiss.	β^2. Pale pink.	
	Igneous and Volcanic Rocks.		
	Granite,	Pale carmine.	G.
	Felstone (Felsites),	Chrome.	F.
	Felspathic ash or tuff,	Light chrome dotted.	Fe.
	Quartziferous porphyry (Elvanite).	Dark carmine.	E.
	Greenstone (Diorites, Dolerites),	Burnt carmine.	D.
	Greenstone ash or tuff,	Light carmine, dotted.	Ds.

We shall consider these rocks and formations in ascending order—that is, in the order of their formation—commencing with the Lower Silurian beds, which are certainly the oldest in the district under consideration, not excluding even the granite.

Lower Silurian.

Both to the north and to the south of this district beds of grit, quartzite, and slate, referable to the Cambrian period, occur, and are laid open at Bray Head and Greystones to the north of Wicklow Head, and at Cahore Point, south of Courtown Harbour. These strata, the oldest in the east of Ireland, pass below those of the Lower Silurian series which occupy the whole of the intervening district, from the coast inland to the margin of the granite, and are probably unconformable to underlying Cambrian

rocks. This view was arrived at by the late Professor Jukes, in 1853, from an examination of the district south of the Devil's Glen,* but is also to be inferred from the fact that in Ireland there are no representatives of the Upper Cambrian (or Lingula) nor of the Tremadoc beds, both of which occur in North Wales between the Llandeilo and the Lower Cambrian series. There is therefore, a great *hiatus* between the two great systems, unrepresented by connecting strata; so that it is exceedingly probable that there was a considerable amount of disturbance and denudation of the Cambrian formation before the Llandeilo strata began to be deposited over and around them.

The Lower Silurian strata consist chiefly of black or dark-grey and blue slates, often interstratified with thin bands of grey grit. These are sometimes banded, and traversed by rude cleavage planes, striking parallel to the bedding, but sometimes dipping at a higher angle than the rock itself. The above represent the Llandeilo beds, and they are succeeded by brownish or grey sandy shales and speckled grits which are probably representative of the Caradoc group. No attempt has, however, been made to separate these divisions, which really form one continuous series differing only by the predominance of sandy strata above, and of slaty, below.

Fossils.—The only fossils found in this district are indistinct *Graptolites* from slaty beds a short distance N.W. of Arklow. They appear to be single graptolites allied to, or identical with, *Graptolithus Sedgwickii*. At Kilmichael Point, tracks and burrows of annelids were also observed. †

Strike.—Throughout the district, as well as in those to the north and south of it, the Silurian beds preserve a general "strike" from S.W. to N.E. This is indicated both by observations of the dip in various places, and by the direction assumed by the interbedded masses of "trap" and tuff. The dip, however, though generally towards the S.E. at a high angle is frequently reversed, and sharp folds ranging N.E. and S.W. are indicated by the suddenness of the change. One of these occurs at Forchester House, another at the Mizen Head, and others in the coast-section south of Arklow Head. Many similar folds must pass unobserved over the district; but enough have been noticed during the progress of the survey to indicate that the Silurian strata are distributed along a series of folds of greater or less magnitude, the axes of which follow a general N.E. and S.W. direction. The sections of the Silurian beds, with their accompanying volcanic masses laid open along the valley of the Avonmore and the railway cuttings, are (as stated by Mr. Du Noyer) the most clear and comprehensive of any to be found in the south-east of Ireland. The fossils from this neighbourhood, described by Mr. Baily, leave no doubt as to their geological age.‡

Metamorphism of the Lower Silurian Strata.—On approaching

* "Explanation to accompany Sheets 121 and 130," pp. 14, 15.
† Information furnished by Mr. W. H. Baily.
‡ "Explanation to Sheets 121 and 130," page 16.

the granitic region, the Silurian rocks are observed to undergo a marked change in their constitution. This change is sometimes rapid, at others, gradual. In the latter case the first intimation is the glossy appearance of the planes of bedding and the presence of sericitic slate; this variety gives place to more pronounced mica-schist with vein quartz. The junction of the granite is, however, generally sharp and decisive, though the granite itself is sometimes foliated near the margin, as may be observed in the valley near St. Columbkille's Well. Hornblende and andalusite are occasionally developed, as in the townland of Lynamanoge above Tinahely; and in other places bands of schist are caught up in the mass of the granite itself, as in the case near St. Columbkille's Well; another case occurs to the south of the River Ow, on the mountain side, above Coolballintaggart Lodge.*

On the other hand, bands of granite and elvanite are to be found peering up amongst the Silurian beds far beyond the granitic margin; and it cannot be doubted that they are physically connected with the deeply-seated granitic mass below. Of these the most remarkable in our district are the narrow bands, which, with a short interruption, have been traced by Sir W. Smyth for a distance of about six miles west and north of Tinahely.

A large boss of quartz-porphyry (or elvan) has been thrust up amongst the Silurian rocks at Crosspatrick, which from its form suggests the idea that it is the neck of one of the volcanoes from which some of the interstratified felspathic trap rocks may have been poured out. Several narrow reefs of elvanite, corresponding in direction with the general strike of the beds, have been observed in the district north of Tinahely. At Ballinaclash (in Sheet 130) two bands of granite, sometimes porphyritic, cross the Avonbeg River and range into the district of Sheet 139. Another mass comes up amongst mica-schist and clay slate east of Aughrim, and is considered to extend along the valley northwards to "Edward's Quarry," where it is worked. A dyke of elvanite, five yards wide, traverses the granite in the railway cutting. Granite again protrudes in several places amongst the schists of Cushbawn.

Sections.—The Lower Silurian strata are chiefly laid open to view along the banks of the deep river valleys and in the railway cuttings. Amongst these may be specially mentioned the section in the Ow River, and road cuttings near Coolballintaggart House, where numerous beds of mica-schist and quartz-schist passing into quartz-rock occupy the district bordering on the granite. The valley of the Aughrim River for about three miles above Wooden Bridge Inn also affords a good section. The beds dip S.E. at angles varying from 60° to 80°, and consist of grey, green, and dark slates and flags, with bands of felspathic ash or tuff.

* It ought to be mentioned that frequently the alteration in the constitution of the Lower Silurian rocks extends much further from the granite than is represented by the tinted band on the map. It would often be very difficult to determine where the incipient change takes place, and thus the tinted band is only intended to show the general effect of proximity to the granite.

Towards Aughrim they became distinctly altered, and they are traversed by dykes of elvan and diorite.

Sections are also laid open in the valley of the Avonmore from Ovoca upwards in connection with the outbursts of volcanic rocks which will be described further on.

In the townland of Ballintemple, two miles S. of Wooden Bridge, a quarry was formerly worked in slates, which are described by Prof. Jukes as "soft, purple, blue, and brown slates, exceedingly fissile; and showing a thickness of section of about fifty feet. The cleavage planes strike E. 35° N., dipping S.E. at 65°."* The quarry has been closed for some time.

At Mizen Head sections are exposed in grey and dark slates, penetrated by several narrow dykes of diabase. The upper surface of the slate is planed off evenly as if by ice,† and capped by a slight deposit of Drift clay. Other sections occur at intervals along the coast both to the north and south of Arklow Harbour, and are sufficiently indicated by the dips inserted on the one-inch map.

IV.—Igneous Rocks.

Granite.—The main mass of the granite occupies nearly the whole of the western, central, and northern portions of Sheet 138, including the districts surrounding Hacketstown, Rathvilly, and Tullow. The tract is only moderately elevated, the western portion having an average elevation of about 300 feet; the eastern, of about 400 feet. It is to a large extent covered with Drift deposits of clay, sand, and gravel, and is drained by the Slaney and its tributaries.

The boundary with the metamorphosed Silurian schists, takes a S.S.W.-N.N.E. course from the townland of St. Mullin's Upper, to that of Moyne, where it enters Sheet 129, and is, on the whole, pretty regular, except in the district of Moyne and Ballymaghroe, where it is complicated by indentations of the schist within the granite tract. In general the schists dip away from the granite along the margin of both formations. Numerous dykes, bosses, and irregular protrusions of granite and elvanite make their appearance amongst the Lower Silurian beds to the eastward.

Mineral Characters.—The granite of this district generally resembles that both to the north and south, described in former Memoirs.‡ It is light grey in colour, seldom tinted with red, and consists of orthoclase felspar, quartz, and white, and rarely black, mica. Both microscopic examination and chemical analysis indicate the presence in small proportions of plagioclase felspar.§ In texture the rock varies considerably from fine to coarse, and not unfrequently it is porphyritic by the development of large crystals of orthoclase. This is specially observable in the boss in

* Note on 6-inch field map.

† As recorded by Mr. Kinahan on the 6-inch field map.

‡ Explanatory Memoirs, Sheets 148 and 149, and 121 and 130.

§ This is the case with reference to specimens taken from Killiney, Ballyknockan, &c., and may be presumed to hold good with regard to the district now described. The reader is referred to the researches of the Rev. Dr. Haughton, F.R.S., on the granite of Leinster. Quart. Journ. Geol. Soc., vol. xii., p. 171, *et seq.*

the townland of Carrigroe, which bursts through the schists about a mile from the general mass of the granite, which commences at St. Columbkille's Well; this rock might, however, be considered as elvanite, and is so indicated on the Map (Sheet 138). Foliation is of common occurrence near the junction of the granite with the schists, as, for example, in the townland of Moyne. In the neighbourhood of Aghowle plumose mica is sometimes remarkably developed.

Although the country about Tullow, Hacketstown, and Rathvilly is generally covered with Drift gravel, yet granite bosses protrude here and there, as, for example, opposite Woodside House, S. of Hacketstown, where the rock is very quartzose, and contains a large mass of vein quartz. The principal openings are, however, to be observed along the banks of the Rivers Derreen and Slaney. In that remarkably straight part of the course of the last-named river between Aghade Bridge and its confluence with the Derry tributary, the stream flows between high and steep banks formed of granite traversed by nearly vertical joints; over the granite beds of gravel set in, forming the nearly flat tracts on either side.

Granitic intrusions or bosses in the Silurian districts.—These have been already referred to in connection with the phenomena of metamorphism, and together with dykes and bosses of quartz-porphyry or elvanite, are very abundant along a band of country extending about five or six miles eastward from the main granitic mass. One of these is represented on the map as ranging in a narrow band by Coolboy and Stonybatter. The rock, however, is only exposed along this tract south of Mount Pleasant, and marked on the Map in the form of blocks and boulders, some of which, at least, are certainly erratics. The schist at Stonybatter is micaceous and contains andalusite.

At Crosspatrick, the mass of igneous rock referred to above (p. 9), marked on the map as "elvan," is opened out in a quarry behind the chapel. It consists of a massive light brown granitoid finely crystalline rock formed of quartz, felspar, and black mica. (See Appendix F., p. 53.)

Another of these remarkable granitic protrusions amongst the Lower Silurian strata is that which stretches in a north-easterly direction by Aughrim, and which is well laid open in the railway cutting a short distance east of the station. It consists of fine-grained grey granite of quartz, felspar, grey and black mica. Its contact with the schists on the eastern side is clearly shown. These are micasized for a short distance and pass up into ferruginous beds, which remind us of those in the Ovoca valley below Castle Howard, and of which it is not improbable they are the representatives (see Appendix, p. 55). The granite is again laid open in a large quarry on the flank of the ridge above Aughrim. From its fine texture and extreme hardness it may be inferred that this stone would answer well for paving setts in neighbourhoods where the traffic is not excessive. The breadth of this granite protrusion, east of Aughrim, is about 200 yards, but it seems to wedge out in both directions, or rather disappears below the schistose beds.

Origin of the Granite.—This is not the place to enter upon any extended discussion regarding the origin and mode of formation of the granite of Wicklow. I concur generally in the view expressed by my predecessor, the late Professor Jukes,* that the granite in a molten condition did not act to any great extent as an elevating agent amongst the old Silurian beds, but worked its way upwards from the interior, melting down the slates and grits, or converting them into micaceous and hornblendic schist. The granite may, in fact, be regarded as in some places intrusive, in others, metamorphic. Along its margin, portions of the original grits and slates of the Lower Silurian period have possibly been converted, by intense hydro-thermal action under pressure, into rocks which can hardly be distinguished from foliated granite or gneiss. Where the process has not proceeded so far the beds remain in the condition of andalusite slates or micaceous schists. The foliation of the marginal parts of the granite, where not flow-structure, may be due, as in Scotland, to subsequent "shearing," movements whereby the component minerals of the rock were crushed and re-arranged along the planes of movement.

The appearance of detached bosses, ridges, and dykes of granite and elvans at a distance from the main mass amongst the Lower Silurian strata, and the presence of elvanite courses running generally in the direction of the strike, make it probable that the granite forms a floor with a very uneven surface at varying depths beneath the present surface of the ground. The sections drawn across Lugnaquillia, and published during the directorate of the late Dr. Oldham, very well illustrate this view, which is that of his successor, Professor Jukes.† At a distance of several miles from the granite mass, however, these isolated bosses and ridges of granite cease; and we may presume that this is in consequence of the increased thickness of the covering of Silurian strata. As regards the geological age of the intrusion of the granite, I have already expressed the opinion that it was antecedent to the period of the Old Red Sandstone, and possibly to that of the Upper Silurian.‡

Other Igneous and Volcanic Rocks.—Throughout the counties of Waterford, Wexford, and Wicklow, the Lower Silurian beds are associated with interstratified masses of igneous rock of varied composition; some of which have been erupted during the formation of the aqueous rocks themselves, others being of later date. These rocks are not dissimilar to those which in North Wales are associated with the Arenig and Bala beds, and are their representatives in geological age.

The rocks now about to be described may be arranged under two well-defined groups, (*a*) the felspathic, and (*b*) the hornblendic

*Explanatory Sheets, 121 and 130, p. 15.

† *Ibid.*, p. 15. The Rev. Dr. Haughton, however, considers that the granite of Cushbawn has been derived from a source differing from that of the main mass, and bases this conclusion on the difference in the chemical constitution of the two masses, the quantity of lime and soda being increased in the former, so as to render it a soda-granite.—*Loc. Cit.*, p. 182.

‡ "Physical Geology of Ireland," p. 128–9.

or pyroxenic; and from the fact that the latter are often observed to be intruded amongst, and to traverse the former, it is concluded that they (the hornblendic varieties) are more recent than the felspathic, which, as above stated, are of Lower Silurian age. This is the view arrived at by Mr. Hardman in his Memoir on the district to the south of the present,* and may also be inferred from the relations of the "greenstone" masses in the Rathdrum and Castletimon districts.† In North Wales the diorites are intruded into the sheets of felspathic trap and ash.

(*a*). The felspathic rocks consist of grey, blue, and yellow felsites, compact or micro-crystalline, sometimes vesicular, with or without distinct grains of quartz; when porphyritic, they contain crystals of felspar, and sometimes of hornblende. The petrographical characters of these ancient lavas are given in the Appendix F, p. 49. Along with these rocks, which have solidified from a molten condition, are masses of volcanic ash, or tuff, which have originally been blown out of the vents of eruption and distributed over the sea-bed of the period. These masses are generally laminated, frequently have a flaky structure, and decompose into a soft mass easily ground down to powder. They also contain small chips and fragments of felsite, or even of slate or other rock, and pass occasionally into breccia. The fragmental condition is generally to be observed with the lens when not by the naked eye.

A variety of this rock is "greenstone ash," which, as described by Prof. Jukes, is a dark apple-green slate, of a smooth compact texture, with a soapy feel. It would not, perhaps, be recognised as anything but an ordinary clay slate, were it not for its peculiar colour and texture, and its occurrence only among the trappean rocks.‡ These greenstone ashes are represented by Du Noyer as especially abundant in the range of Croghan Kinshelagh and the Aughrim valley above Wooden Bridge. (See Appendix F., p. 49.)

The masses of "greenstone" which are found penetrating the truly contemporaneous volcanic rocks are very numerous in the Croghan and Kilpatrick ranges. They embrace quartz-mica-diorite, quartz-diorite, diorite, augite-diorite, dolerite, epidiorite, and in one case serpentine. (See Appendix F., p. 49.) These rocks generally form dykes traversing the sheets of felstone or ash, as very clearly shown in the Kilpatrick range of hills, as well as in that of Tara Hill in Sheet 149. At what geological period these basic masses were intruded amongst the Lower Silurian volcanic beds is uncertain; but, doubtless, at one geologically very ancient, and possibly not widely separated from that of the Lower Silurian itself. We may suppose, with Durocher and

* Explanatory Memoir to Sheets 148 and 149, p. 9.

† See Geological Survey Map, Sheet 130. From the account given by Mr. Du Noyer, of the Avondale diorite, it may be inferred that he shared this view, though I cannot find it distinctly stated in the Memoir to Sheet 130. (See Explanatory Memoir, Sheets 121 and 130, p. 37).

‡ Jukes, "Explanation, Sheets 121 and 130," p. 13. It is doubtful, however, whether these ash-beds differ materially from the ordinary felspathic tuffs, except in the presence of chlorite, which imparts to them its greenish colour. These "greenstone-ashes" are probably only altered varieties of "greenstone." (See Appendix F., p. 49.)

many other petrographers, that owing to their greater specific gravity they come from a magma beneath that which has furnished the lighter felspathic lavas.

In the district under consideration the volcanic rocks are found in several more or less isolated tracts, rising above the surrounding plains formed of the slaty Silurian beds. These tracts are as follows:—1. Brittas, which is the southern extremity of the Castletimon district, already described by Mr. Du Noyer, and which need not be further alluded to;* 2. Barranisky and Kilpatrick; 3. Arklow Head; 4. Newbridge and Ovoca; and 5. Morale and Croghan Kinshelagh. A short account will now be given of each of these tracts.

(1.) The Barranisky and Kilpatrick Hills form two shoulders of one mass of elevated ground, and are connected together by a narrow neck crossing at the head of the Snugborough valley, which enters the range from the south. The Kilpatrick shoulder is the larger and more elevated of the two, and attains an elevation of 924 feet above Ordnance datum at the trigonometrical Station. This group of hills, though not very high, yet forms a prominent feature in the landscape, as it is surrounded on all sides except the west by low and nearly flat ground; and towards the east, where it faces the sea, the flanks descend abruptly to the plain formed of Lower Silurian slates, which is but slightly elevated above the sea level. The whole group consists of eruptive rocks of considerable variety, including felsites, ash or tuff, volcanic breccia, and various "greenstones." The following is an account of the section to be observed in crossing the range from west to east, beginning at Barranisky cross-roads.†

1. *Barranisky Cross-roads.*—Brown and purple slates, contorted; followed by grey and brown slates and flags with bands of ash.
2. Dark green coarse ash, with fragments of trap, in two thick beds, with slate between. Dip. S.E. at 65° to 70°.
3. *Foot of Hill, shown in quarry.*—Hard bluish-green felstone, chloritic, and weathering white, about forty feet thick.
4. *Flanks of Hill.*—Coarse green felspathic ash and breccia, with fragments of felstone and slate; numerous small crystals of felspar in some places. This mass is of considerable thickness.
5. Intrusive mass of augite-diorite, extending from near the trigonometrical Station (893 feet) to Snugborough House; penetrating the beds of ash, and sending branches out from the central mass. (See Appendix, p. 46)
6. *Snugborough Valley.*—At farm-houses brown and grey ribbon slates, succeeded on east side of the valley by massive coarse green ash and volcanic breccia, with large fragments of felstone. This rock is laid open in a large quarry near the head of the valley, and is succeeded in an easterly direction by finer beds of tuff.
7. Dyke of massive "greenstone," about 250 feet wide, penetrating the ash beds.
8. Light green compact felsite, weathering white, and containing small felspar crystals, and cavities filled with calcite and chlorite. This mass extends eastwards from the trigonometrical Station, marking the highest elevation of 917 feet, and stretches southwards towards the base of the hill.
9. Compact felspathic ash, succeeded by greenstone, then by beds of ash again in successive bands ranging nearly north and south.

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* Explanatory Sheets 121 and 130, p. 41.

† The names of the rocks in this section are very much the same as those given by Mr. Du Noyer. The district was twice visited by the author of this Memoir—first in 1884, and again, for the purposes of this Memoir, in 1887.

10. *Slopes above Ballinaskea House.*—Highly silicated grey felstone, weathering white, and containing a bed of ash.
11. *Ballinaskea House.*—Dark grey, glossy, steatitic slates, sometimes ribbon-marked. These slates extend under the plain to the sea-coast, where they crop out in the cliffs east of Johnstown House; the plain itself being covered by "marl" (Drift clay).

(2.) The volcanic rocks of Arklow Head are well laid open to view along the coast cliffs, and in the rugged hill surmounted by Arklow Rock, which rises to a height of 411 feet at some distance inland. They are similar to those of the Kilpatrick hills, consisting of felsites, tuff, and breccia, with intrusive masses of "greenstone" of later date; the whole of these rise from the midst of Lower Silurian slaty beds, which are shown at intervals in the ancient coast cliffs both to the north and south of the headland. The general strike of these rocks is E.N.E. and W.S.W., but the beds are undulating.

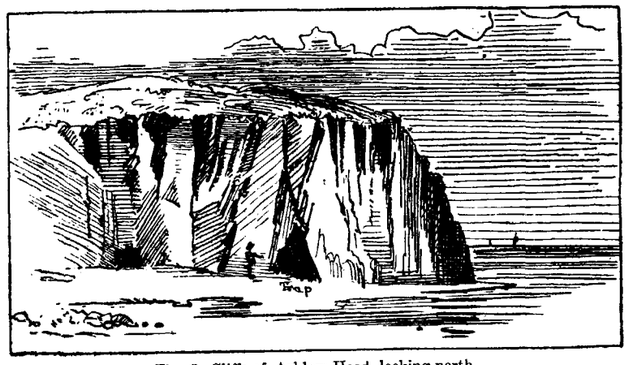

Fig. 2, Cliffs of Arklow Head, looking north.

In describing the rocks we shall commence at the north end of the Head in beds which appear to be at the base of the series.

a. Massive Dolerite.—Dyke which breaks out on the shore at the edge of the quarry. (See Appendix F, p. 48.)
b. Beds of green brecciated tuff, with fragments of trap and slate, dipping S.E. at 80°. In the upper part it decomposes, and an old adit has been driven upon it, probably under the supposition that it is metalliferous.
c. Massive crystalline "greenstone," with much pyrites. This is a dyke, and the walls are clearly defined on both sides.
d. Beds of baked slate and ash, penetrated near the centre by grey felsite; these beds are about 150 feet across.
e. Thick mass of grey and white felsite, penetrated by a dyke of "greenstone," running N.N.E. The felsite contains pieces of baked slate caught up in its mass.
f. Dark green and bluish "greenstone" finely crystalline, with crystals of magnetite and iron pyrites. It is traversed by transverse joint planes which give it a sub-columnar structure.
g. Greenish tuff of many varieties about 100 feet thick, dipping S.E. at 70°.
h. Slate, and hard, fine-grained white grit, about fifty feet thick. Dip S.E. at 80°.
i. Volcanic agglomerate, with rounded pebbles of vesicular trap, sometimes almost pumiceous, also angular fragments of felstone and other rocks; the whole about eighty feet thick.
j. Dark grey felsite; this is the highest of the volcanic rocks shown, and is succeeded by the cliffs of "marl" forming the ancient coast margin.

In a hill a short distance to the west of Arklow Rock, formed in part of greenstone and indurated slate, a mass of elvanite occurs. Of this Mr. Kinahan states, that it comes up irregularly through the slate, and that it changes into granite containing greenish or white mica.*

(3.) The section of the volcanic series of the Ovoca valley, north of Newbridge, is finely laid open to view on both sides of the river; but the description for one side will probably suffice for both, and we shall take the right bank of the river as being the most accessible. The beds cross the valley transversely, and are repeated on either side, though somewhat displaced by a fault which slightly shifts them to the northwards on the E. side of the valley. The general dip is S.S.E. at angles varying from 45° to 65°. Commencing with the grey slates N. of Newbridge we take the section in descending order, as follows :—

a. Tinnahinch House.—Highly silicated bluish felsite, weathering white, with platy structure, and containing veins of epidote or chlorite, and traversed by joint planes striking N.W.

b. Cleaved felsite, marked by Mr. Du Noyer as "ash." I could not, however, detect any fragmental structure. To the north of this is a valley hollowed out of dark grey slate.

c. Rocky hillock above farm buildings.—On south side this consists of white platy felsite with blebs of quartz; on the north side, of white felsite with chlorite, and sometimes showing spherular structure. To the north of this hillock is a valley hollowed out of slates.

d. Rocky Hillock.—Felsite with quartz-veins, passing downwards into hard fine-grained bluish felspathic tuff, this is succeeded by slate occupying the hollow.

e. Bell Rock.—Intrusive mass of white felsite, rising abruptly through slaty beds on either side, and traversed by joint planes ranging N. 30 W. This mass crosses the valley, and appears in a similar form, though not quite so lofty and abrupt as the Bell Rock on the right bank of the river. (See Frontispiece and Appendix F., p. 52).

f. Mining ground.—Hard grey, and reddish felspathic slate and ash, laminated and bedded, planes of lamination stained with iron pyrites and copper ore. These beds are several hundred feet thick, and resemble those of the volcanic series of Cumberland, formerly called by Professor Sedgwick "green slate and porphyry," but since recognised as fine volcanic ash which, having been blown out from submarine vents of eruption, afterwards were deposited as fine sediment and subsequently became indurated.

[These beds constitute the chief metalliferous ground of the district on both sides of the valley.]

g. Silicious green slates and grits lying at the base of the volcanic series.

The volcanic series which crosses the Aughrim valley above Wooden Bridge (according to Mr. Du Noyer) consists of interstratified "greenstone ash beds" and schists, which are well laid open in the banks of the Aughrim river, between Wooden Bridge and Coats Bridge, but some, if not all, of them are undoubtedly true "greenstones" which have undergone alteration, and appears now as epidiorite, and varieties showing a more or less schistose structure. Near Ballycoog Ford, where the road takes a sudden bend, a large dyke of "greenstone," formerly worked for paving setts,† for which the stone is well suited, traverses the schists. Its junction with the schists on the west side is very well shown, as these latter have been quarried along with the eruptive rock itself. The eastern wall is not, however, visible, as the rock is bounded by banks of Drift clay. The schists are highly chloritic, and somewhat flaggy. (See Appendix F., p. 49).

* Note on six-inch map.

† This quarry was closed on my visit to the locality, 1st August, 1887.

(4.) The almost mountainous range of Morale and Croghan Kinshelagh* rises conspicuously above the surrounding district, and is formed of a series of volcanic products, consisting chiefly of elvanites, felsites, and tuffs, with dykes and sheets of "greenstone," which are very abundant at the southern extremity of the range. These masses occur amongst Lower Silurian slates, which are often altered and mineralised. The steepest flank of the mountain is towards the west, and the general dip of the beds is eastwards, except near Clonroe cross roads, where the dip is W. or N.W., owing to local disturbances.

In order to illustrate the structure of this range I have selected two lines of section traversing the rocks across the direction of the dip, the former crossing the summit of Croghan Kinshelagh, the latter the ridge of Annagh, near the southern extremity of the volcanic range.

In the first section the beds are arranged in descending order.

Section 1.

1. Grey slates and thin grits.
2. Several narrow bands of hard green chloritic tuff, interstratified slates and grits.
3. Mass of elvanite penetrated by numerous quartz veins. (For petrographical character, see Appendix F, p. 53.)
4. Dark green schistose rock (epidiorite) forming the summit of the mountain under the Trigonometrical Station. (See Appendix F., p. 49.)
5. Talcose slate, with occasional beds of tuff; near the base occurs a band of dark green chloritic slaty tuff.
6. Elvanite.
7. Coarse grey slates.
8. Elvanite. This band, according to the map, is made to unite with No. 6 farther to the south, forming one thick mass, the intervening slates (No. 7) having thinned out.
9. Thin band of green chloritic compact slaty tuff.
10. Hard grey slates passing into tuff at some distance towards the south-west.
11. Felsite, almost pure, but with a little chlorite. Further south this passes into granitoid eurite, or quartz-porphyry.
12. Thin lenticular band of green ashy slate.
13. Alternating masses of green chloritic felsite, eurite and tuff beds. Further south towards Ballythomas Bridge dykes of "greenstone" are intruded into this mass.
14. Slates and grits lying below the above volcanic series.

Section 2.

A second section near the southern end of the volcanic range at Annagh offers the following succession, which contrasts some-

* This conspicuous mountain is called after Enna Kinsellagh, King of Leinster. Croaghan or Croghan is the diminutive of Croagh or Crogh, signifying a rick or stack, but in an extended sense is applied to hills, especially to those representing a round-stacked, or piled up appearance. Joyce, "Names of Irish Places," 2nd Edit., p. 334.

what with that across Croghan in the greater proportion of hornblendic beds. Commencing from the west near the margin of the peat-bog amongst Silurian slates we find as follows:—*

1. Large blocks of greenstone—probably over a mass *in situ*.
2. Large mass of greenstone with numerous well-developed granite veins.
3. Bed of greenish tuff.
4. Greenstone, with numerous felspathic veins, well developed.
5. Narrow bed of hard green tuff.
6. Bed of greenstone with granitic veins.
7. Rather thick bed of hard greenish slaty tuff.
8. Tongue or end of greenstone dyke which unites with the mass (No. 9) below.
9. Grey crystalline greenstone with elvanitic-looking veins, sometimes so thin and numerous as to make the greenstone weather out like a breccia.
10. A large mass of granitoid elvanite and felstone, with veins of seggregation. This mass is little more than a mile in length, and one-fourth of a mile in breadth; Clonroe cross-roads is situated on this mass.
11. Narrow bed of coarse green tuff.
12. Granitoid elvanite without mica—a narrow tongue descending from the north where it forms the western slopes of Morale.

The above pass below greenish and gray slates which extend indefinitely in an easterly direction.

V.—Post-Pliocene or Drift Deposits.

The deposits referrable to the Post-Pliocene consist of beds of boulder clay or "marl," sand and gravel, the latter usually found capping the former when both are present. It is very probable, however, that there are two clayey deposits separated by beds of sand and gravel; the upper being more properly the "shell marl" so much prized for agricultural purposes, the lower being a glacial deposit with stones and boulders, generally known as the Lower Boulder Clay. With one or other of these deposits the low-lying tracts bordering the coast are generally overspread as far as the flanks of the uplands; while to the west of the high lands which occupy the centre and west of Sheet 139, and the east of Sheet 138, the plain, which stretches towards the valley of the River Barrow, and which is drained by the Derreen and Slaney Rivers, is generally overspread with gravelly deposits, sometimes more or less clayey, and containing pebbles of limestone, chert, and grit, as well as of the more local rocks of granite and trap. These gravel beds are stratified, and have been deposited under the waters of the sea, when they overspread the great central plain of Ireland and the adjoining submerged districts high up along the slopes of the hills.

* These sections are taken very nearly in the words recorded on the six-inch field map worked by Mr. Du Noyer, and transferred to the 2nd edition of the one-inch Map, Sheet 139.

The upper limit of these Drift deposits may be taken at 1,200 feet above the sea, as determined in the districts to the north of the area now described; but in this latter district these deposits have been noted by Mr. Kinahan on the flanks of Cushbawn, to a level of about 900 feet.* In the flat tracts about Redcross, marl deposits occur, and have been noted by Mr. Wyley, in the banks of the stream. They are also seen capping the smooth surface of the slate rocks of Mizen Head, and at intervals from the coast inland both to the north and south of Arklow. At Johnstown R.C. Chapel these marl beds containing marine shells are overlain by beds of gravel, consisting of rolled fragments of Croghan elvanite, together with others of ordinary granite, sandstone, chert, and Carboniferous limestone.†

To the south of Glenart Castle, and near Ballygiffin House, gravel 30 feet thick, and obliquely stratified, has been noted, below which occurs marl or boulder clay. Similar beds occur between Shelton Abbey and the coast.

Boulders.—In connection with the drift-deposits must be mentioned the occurrence of boulders, or erratic blocks, of granite or other rock which are found at intervals scattered over the district, sometimes occurring in streams or mounds; at other times, singly and isolated. A few of these cases as recorded on the field maps may here be noted.

At Kilmacoo Upper, W. of Redcross, numerous granite boulders occur—some of large size. These are distant about twelve miles from their sources amongst the mountains above the head waters of the Avonbeg River. Boulders of granite occur also on the hill side of Kilcashel, west of the Ovoca valley, resting on slate or trap rock; and again at Knockan Ree Lower, near Newbridge.

Amongst the more remarkable boulder stones of this part of county Wicklow is that known by the name of "The Mota Stone,"‡ whatever that may mean, which is perched on the summit of the ridge of Connary Hill, at an elevation of 816 feet above the sea, behind the woods and terraces of Castle Howard. This large block consists of grey granite, such as must have come originally from the granitic region forming the slopes of Lugnaquillia, or some of the neighbouring heights towards the head of Glenmalure, and measures approximately fifteen feet in length, nine and a half feet in breadth, and nine feet in height above ground. It rests upon beds of ashy slate; and owing to its position on the highest part of the ridge, its size, and light colour which contrasts with the brown heather-clad hill forming its resting place, it is conspicuous from afar in all directions. Standing by its side one gains a magnificent prospect over the surrounding country; and looking westward across the deep glen of the Avonmore immediately below the spectator's position, the eye is directed towards the mountain slopes along the course of Glenmalure from where, it may be supposed, this huge granite block was carried on the

* On the 6-inch field map. † Mr. Wyley, as stated in 6-inch field map.
‡ Incorrectly spelt "Motto stone" on the Ordnance map.

surface of the ice-sheet eastwards towards the sea, till it found a resting place on the summit of the ridge where it stands, a

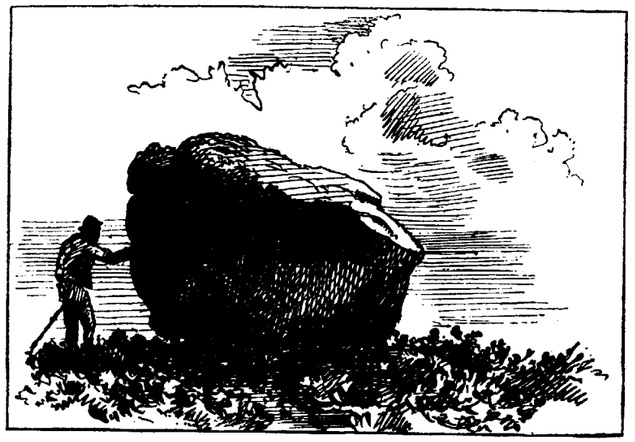

Fig. 2. The "Mota Stone," Connary Hill.

monument of the transporting power of glacier ice. The distance from its parent mass is probably not less than twelve or fifteen miles, and the weight of the block is probably but a little under two hundred tons.

Large numbers of granite boulders, some of them several tons in weight, are strewn along the valley near Pollahony Wood, S. of Glenart Castle, and near Ballygiffin House. The source of these must be even more distant than those of the preceding blocks recorded. In the neighbourhood of Shillelagh, although the valleys are more or less lined with Drift-clay, boulder stones are neither so large nor so numerous as those of the district lying to the north; but in the valley at Coolboy, granite boulders are abundant, and have been extensively broken up for building purposes.

In reference to the mode of transportation of these and similar large blocks lying at a distance from their parent masses, there can be only one cause assigned, namely, the transporting power of ice, either as a sheet of great thickness descending from the perennial snowfields which at a former period covered the Wicklow mountains, or as bergs floating in the open sea, at a time when the land was submerged and the waters covered the tracts at a lower relative level than 1,000 feet. The former is, in this instance, for many reasons the more probable explanation, and receives corroboration from the fact that most of the Wicklow valleys penetrating the mountains contain old moraines left by glaciers which once occupied the valleys, and that boulders increase in number and size as we ascend towards the upper parts of these recesses. Instances of these moraines may be observed in the

valleys of the Avonbeg, Avonmore and Glendassan, in this immediate neighbourhood.

Glacial Striæ.—In connection with this subject the occurrence of glacial striæ, or groovings on rock surfaces at several localities affords additional evidence of the former presence of sheets of ice. These striæ are not confined to the valleys. The following cases have been noted by Mr. Kinahan.*

EXTRACTED from Mr. KINAHAN'S MS. (Sheet 138.)†

CARLOW, 3/4.—*Ballybrit, east of Rathmore Bridge.*—Granite rocks dressed and rounded by ice; directions of flow very uncertain.

WICKLOW, 34/1.—*Ballinacappoge.*—Ice striæ N. and S. cut by ice going S. down valley of the Ow. These are on a crag at the edge of the river.

„ 34/3.—*Ballymanus.*—Ice striæ N. 85 E. on N.W. shoulder of the summit of Ballymanus Mountain; cut by ice going eastward apparently.

„ 47/1.—*Tomacork.*—Ice striæ N.W. going S.E. On Carrig, to the W. of the townland, on the eastern brow of the Shlilelagh valley, they are nearly parallel to others on the ridge east of Kilcavan, county Wexford.

WEXFORD, 2/3.—*Cummer, Upper.*—Striæ N. 30 W. going S. E. These are to the N.W. of the last, on south side of the hill ridge.

„ 2/3.—*Cummerduff.*—Striæ N. 40 W., grooves N. 60 W. going S. E. On one surface—which are oldest could not be determined—they are north of the last on the N. slope of the ridge at the bounds of the counties Wicklow and Wexford.

„ 2/3.—*Cummerduff.*—Striæ N. 30 W. going S.E. at the road a short distance E. of the last. Very conspicuous and well-marked on different rock surfaces

Glacial striæ were observed in the following places:—

WICKLOW, 34/4.—*Tinnakilly.*—The crags on the ridge rounded by ice, going S. W.

„ 35/3.—*Knocknamohill.*—Striæ N. 65 W. going southward. These are close to the summit of the hill, on the watershed between the Cronesallagh and the Derry water valleys. The ice seems to have been going to the Ovoca valley.

„ 35/3.—*Kilcasheel.*—Striæ N. 40° W. going S. E. These are on the W. brow of the Ovoca valley.

„ 36/1.—*Templelyon.*—Striæ N. 45° W. going S. E. These are in the low ground to the north of the Barranisky hill group; they are just at the north margin of the area.

„ 36/3.—*Kilpatrick.*—Striæ N. 60 W. and N. 35° W., going S. E. These places are on the north-east slope of the Barranisky hills, the last being a little higher up the steep slope than the first.

* From MS. Notes to Sheets 138 and 139.

† The figures attached to the Counties are the numbers of the Sheets and Quarter-sheets of the 6-inch Map.

WICKLOW, 36/4.—The surface of the rocks of the sea-cliff planed off smoothly as if by ice. This is very general along the coast of Wexford to the southward, although ice striæ were only observed in very few places.

" 40/1.—*Knocknamohill.*—Striæ N. 65 W. going S. E. in two localities, one immediately south of the striæ previously mentioned (Wicklow 35/3), and the other much lower down the slope, at the Cromleac to the S. of the house.

" 40/3.—*Monaglogh.*—Striæ N. 40 W. going S. E.

" 40/3.—*Killahurler, Upper.*—Two sets of striæ on one surface, oldest N. 50 W., newest N. 30 W., both going S.E. These are a mile S. W. of the last, on ground 250 feet higher. They are on the north slope of the ridge that divide the Gold-mine valley from the low country of the county Wexford.

" 41/3.—*Johnstown, South.*—Groves N. 60 E., going S. W. These are on the planed surface of the sea-cliff.

" 45/1.—*Killahurler, Upper.*—Striæ N. 80 E., going W. These are a little west of the striæ in the same townland (Wicklow 40/3) but on ground about fifty feet higher at a "*maum*" or gap in the ridge.

" 45/2.—*Arklow Rock (Big).*—The rocks rounded on the N. W. of the hill, as if by ice going S.

" " *Arklow Rock (Little).*—Striæ N. 70 E., appear to be going W. at S. E. corner of the hill.

WEXFORD, 2/2.—*Rathpierce.*—Striæ W. and E., going E. in the W and E. headwaters of the valley of the Bann.

" 2/3.—*Connahill.*—Striæ N. 70 E, and N. 40 W., going S.E. The first recorded by Wyley, near the summit of the ridge at the N. E. corner of the townland. The second set in the "*maum*" or pass through the ridge, N. W. corner of the townland. Their bearing is very similar to that of the striæ further mentioned on the ridge.

VI.—RAISED SEA COAST.

All along the coast of the counties of Wicklow and Wexford the evidences of a recent rise in the sea bed and adjoining coast are remarkably clear. These consist in the occurrence of terraces and flats formed of silt, sand and shelly gravel, rising a few feet above the high-water line, and bounded inland by cliffs or abrupt banks (according to the nature of the material and form of the ground) which originally constituted the sea margin at the time when the terraces and flats were submerged. The actual extent of rise of the coast and sea bed is uncertain; but the old sea bed generally lies from six to twelve feet above the highest tides. This level is often increased by hillocks or dunes of blown sand which have been thrown up by the winds; as is the case in Brittas Bay, Arklow Bay, and other protected inlets.

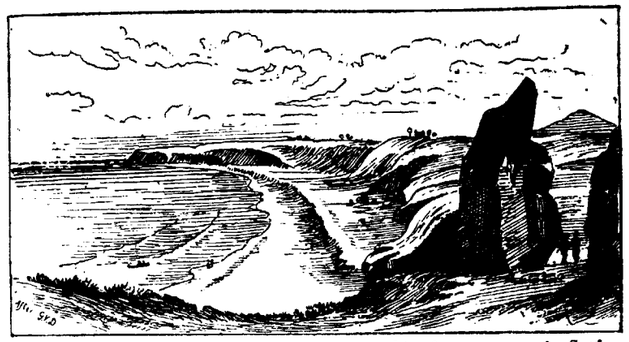

Fig. 3. Old raised Sea-bed, with cliffs of clay marking former sea-margin, S. of Arklow (from sketch by Mr. G. V. Du Noyer).

In the district contained in Sheet 139, examples of the raised coast are to be observed in the bays lying between the headlands; and in a direction from north to south they occur (1) in Brittas Bay between the Castle Rock of Ballynacarrig (Sheet 130) and Mizen Head; (2) between Mizen Head and the coast cliffs of Kilbride; (3) in Arklow Bay, both to the north and south of the Ovoca River; (4) in the bay south of Arklow Head (see Fig. 3), and (5, 6) in the Bays N. and S. of Kilmichael Point. The old sea margin is in these cases generally very clearly defined by banks from ten to thirty feet high, formed either of marl or slaty strata, from the base of which the low terrace stretches seaward as far as the abrupt descent which forms the margin of the existing sea shore. The old sea bed is now covered either by sand dunes, or where these are absent, is green with coarse grass and other land plants.

VII.—RIVER TERRACES AND AURIFEROUS GRAVEL.

River terraces.—It will be evident on consideration that the elevation of the sea bed must have produced some effect on those of the rivers which empty their waters directly into the sea. This effect is clearly indicated in the valley of the Ovoca River which flows in a channel cut down through ancient terraces of river gravel, once liable to be flooded, but which are now out of reach even of the highest floods. These old terraces may be noticed at intervals, as far up, at least, as Newbridge, and they will be observed to extend to the base of the lofty wooded banks of the valley at a height of from fifteen to twenty feet above the ordinary stream of the present day. So secure are these higher terraces from floods, that houses are built, and gardens and fields are planted, on them; but their formation is clearly due to the former action of the river itself.

In order to account for these high river terraces, we have only to recollect that when the land was submerged, from ten to fifteen feet or more below its present level, as explained above

(page 22), the beds of the rivers immediately entering must have gradually merged into those of the estuaries, the waters of which may during high tides have run far up into the present river valleys. At this time the rivers overflowed the upper terraces; but, on the elevation of the land, the streams were obliged to accommodate themselves to the new conditions, and to deepen their channels according as the land and coast rose. In this manner and from this cause, the older gravel beds were left dry, and new river terraces were formed at some depth below the position of the more ancient ones. It is not improbable that before the rise in the land began the waters of the sea formed an estuary extending inland at least as far as the junction of the Aughrim and Ovoca Rivers.

Auriferous Valley Gravel.—The district now described is considered to have been the chief source of gold in Ireland, both in ancient Celtic and more recent times.* The precious metal in the form of grains and nuggets occurs in the alluvial gravel of several streams, especially that of the Gold-mines valley which has its source in a deep recess under the summit of Croghan Kinshelagh, and flows down through a district formed of slate along the bed of a channel bounded by steep banks till it joins the Aughrim River at Wooden Bridge. About a mile above this junction, another stream joins the Gold-mines valley from the south, the alluvial gravels of which are also auriferous.

The source of the gold is exclusively the valley-gravel of these streams; and numerous attempts, both by sinking shafts and driving adits, to discover the veins of the gold *in situ*, have all been unsuccessful. At this moment all attempts to obtain gold have been abandoned; but an examination of the valleys will serve to show how extensive have been the trials in time past.

From information obtained on the spot, as well as from analogy with other auriferous districts, it seems probable that the richest deposits are those which lie at the bottom of the gravel where it rests upon the solid slate rock. Had this distribution been kept in view, the search for gold might have been more successful than has recently been the case. Where the gravel is deep, to get at the bottom of it necessitates much labour and expense; and it then becomes a question whether the gold occurs in sufficient quantity to prove remunerative.†

* Kane quotes from Delarne's "History of Caen," that when after the Norman Conquest treasure was extracted for the Exchequer of Normandy, the tribute from Ireland consisted of 400 marcs of silver and 400 ounces of gold, an enormous quantity for those times.

† The literature connected with gold-washing in county Wicklow is rather extensive, but the following are the more important writings bearing on the subject; they are given in order of date:—

1. Thomas Weaver, "On the Geological Relations of the East of Ireland." Trans. Geol. Soc. London, 1st Ser. Vol. V., pp. 117 and 207 (1821).
2. Sir Robert Kane, "Industrial Resources of Ireland," p. 208 (1844).
3. William Mallet, "On the Minerals in the Auriferous Districts of Wicklow." Journ. Geol. Soc. Dublin, Vol. IV., p. 269 (1851).
4. Warington W. Smyth, "On the Mines of Wicklow and Wexford." Records of the School of Mines, p. 400 (1853).
5. Gerrard A. Kinahan, "On the mode of occurrence and winning of Gold in Ireland." Jour. Roy. Geol. Soc. Ireland, Vol. VI., Part II. (New Series) p. 135.
6. George H. Kinahan, "On the possibility of gold being found in quantity in co. Wicklow." *Ibid.* Vol. VI., Part III., p. 207 (1883)

History of recent Gold-winning in Wicklow. The history of recent gold-winning in the Gold-mines valley and other streams has been given by Mr. Weaver, down to the beginning of the present century, and is somewhat as follows:—

Towards the close of the last century (1795) gold was accidentally found to occur along these streams by the country people. It occurred in massive lumps and small pieces down to the minutest grain. One piece weighed twenty-two ounces; another eighteen ounces; a third nine, and a fourth seven ounces.* The discovery attracted crowds of gold diggers, who were employed along the stream, and during about six weeks appropriated to themselves a considerable amount of pickings. After that time the Government, fortified by a special Act of Parliament,† established a more systematic *streaming*, under the direction of Messrs. Mills, King, and Weaver, and up to the outbreak of the Rebellion in May, 1798, continued to make the operations remunerative. During that unfortunate period the works were totally destroyed, and not until the year 1801 were they again brought into activity. It was now that the directors, reasoning on the evidence obtained in various countries, that alluvial gold has been derived from veins of that metal situated at no great distance up the streams, commenced the driving of a level (or gallery) into the sides of Croghan, and the cutting of a long series of trenches in various directions from the surface down to the solid rock for the purpose of discovering the lodes from which it was argued that the gold had travelled. Notwithstanding, however, extensive trenching and tunneling into the heart of the mountain to a distance of about 178 fathoms, not a particle of gold *in situ* ever rewarded this patient labour.‡

Meanwhile the stream works, or operations in the valley-gravels, were continued for some years, but the "crop," or best part had already been picked by the country people; and after a while the Government was advised to abandon the undertaking, having raised above 944 ounces of gold, the ingots of which were from $21\frac{3}{8}$ to $21\frac{7}{8}$ carats of fine gold, the alloy being silver, and the total value at the time being £3,675. The gold was purchased by the Bank of Ireland. Sir R. Kane states that it has been calculated that at least £10,000 was paid to the country people for gold collected before the Government took possession of the works.

The gold is associated in the alluvial deposits with magnetic iron ore, sometimes in large masses, together with other minerals, some of which are named by Mr. Weaver, and a list of which has been very carefully prepared by Mr. Mallet, the specimens having been obtained from gravel at various places along the bed of the

* The spot where the nugget of twenty-two ounces was taken from is said to be about 200 yards down from the bridge of Ballinvalley on the left bank.

† An Act "To enable the Lords Commissioners of His Majesty's Treasury to conduct the workings of a gold mine in the county of Wicklow," which received the Royal assent 24th April, 1797.

‡ W. W. Smyth, *loc. cit.*, p. 402.

stream; some of these have not been observed elsewhere in Ireland.* They are as follows:—

Gold	Galena.
Platina.	Sulphuret of Molybdenum.
Tinstone.	Sapphire.
Magnetic oxide of Iron.	Topaz.
Micaceous Iron.	Zircon.
Red Iron Ochre.	Garnet (2 varieties).
Hydrous peroxide of Iron.	Quartz.
Common clay iron-stone.	Prase.
Iron-pyrites.	Augite.
Titaniferous Iron.	Chlorite.
Wolfram.	Felspar.
Oxide of Manganese.	Mica.
Copper pyrites.	Spinelle.

The association of most, or all, of these minerals with gold is general over the world, and lends additional interest to this locality. The occurrence of tin-stone, first observed by Mr. Weaver, was found by Mr. Mallet in such quantity as, according to Mr. (now Sir W.) Smyth, to throw into the shade all the richest stream works ever found in Cornwall or on the Continent; but it cannot be supposed that this proportion was general throughout the valley. Since then gold-washings have been carried on from time to time, and within the last few years by several parties, terminating with Mr. F. Acheson, who ceased active operations in 1881.†

Gold-washings have been carried on along the courses of other streams besides that of the Gold-mine valley. The following are those stated by Mr. G. H. Kinahan.‡

Gold has been proved by streaming in the following places:—*Ballynacappoge*; in the flat at the inver of the Muchanagh brook a tributary of the Ow, which rises on the S.W. of Croaghmoira. This was worked by Weaver about the year 1800 and "*grain*"§ *gold* found. *Ballynascreen*, a tributary of the Derry (Darragh) Water which rises on Croaghan-moira, and flows southward by Macreddin to join the Derry Water at Aughrim Mills It was worked by Weaver, and only a little *grain gold* found. In the bed of the Ow, a little above or northward of Ballymanus bridge, gold was proved by Mr. F. Acheson in 1870, but unfortunately the works were flooded out before the gold sand was removed. *Tomaskela River*, a tributary of the Derry Water, (eastern Derry). Here gold is reported to have been found some years ago by a school-master of the Kilpipe school, and in the autumn of 1882 *eyesills* were found in the river gravel by "panning." *Coolbaun stream and tributaries*, worked by Weaver, Crockford and Co., Suter, and the country people. In the upper or south workings, *grain gold* principally occurs. There are, however, near the northern end of the stream, close to the Derry Water, old stream-workings, in which gold is recorded by Griffiths

* W. Mallet, *loc. cit.*, p. 270.

† A table of workings for gold below Croghan Kinshelagh is given by Mr. Gerrard A. Kinahan, between the years 1795 and 1879; showing a total produce of from 7,440 to 9,390 ounces; the value being from £28,855 to £36,185, *loc. cit.*, p. 147.

‡ MS. Notes.

§ Gold locally is divided up into *eyesills*, or very fine gold, often nearly invisible to the naked eye; *grain gold*, or small but well-marked particles or grains; and *nuggets*, or larger pieces, which names are hereafter used.

to have been found. These works were probably carried on by Suter or some one about that time; they are in the townland of *Killacloran*. To the west of this townland, in the glen of the *Cloon stream*, also a tributary of the Derry or Darragh Water, there are the remains of old "streaming," worked probably by the country people, as this locality does not specially appear in the records. *Derry Water*, at the Ballycoog ford, and *Ballintemple stream*, a tributary of the former, were worked by Crockford and Co., Suter, Carysford Mining Co., and the country people; only fine gold was found, but in considerable quantities.

In the eastern portions of the townlands of Killaqueeny and Castlemacadam, in the *Ovoca River* flat, gold was proved (1881) by panning the river gravel of the old river course to the southward of Newbridge.

Origin of the Gold.—We may now briefly discuss the possible source from whence the gold came, also if any more will probably be found. On this subject Mr. Kinahan remarks*:—

"From the explorations in different portions of the world, it has been learned that in connexion with a Placer mine, gold may be found—first, in the mother-rock (*reefs or veins*); second, in the higher shallow alluvium of the valley (*shallow placers*); third, in the lower deep alluvium of the valley (*deep placers*); fourth in the alluvium of the beds of the high, now dry, supplementary streams of the ancient or primary valley (*dry gulch placers*); and fifth, in the shelves, or high level flats, on the sides of valleys (*shelf-reef or bar placers*),† the latter being the relics or records left of the floor of the ancient primary valley—they proving that prior to the present time the gold was in the first instance deposited in a comparatively wide shallow valley; while the alluvium of the present stream is the re-washed drift of the ancient valley mixed with newer detritus. Now in modern times, in none of the valleys of the co. Wicklow has gold been found, or even looked for, except in the first, second, and fourth cases.

"The gold of this portion of Wicklow has been found sparingly, *without tin-ore*, in "black sand," and more abundantly in connexion with tin ore and wolfram. To the westward, in the Coolbawn valley, gold and tin were found in quantity north of a point 350 yards S.E. of Coolbawn House; in the S.W. branch of the Gold-mine river, gold and a quantity of tin were found north-east of Ballinasilloge Ford; while in the S. branch they were found north and north-east of the place where corn mill is marked on the map; it may, therefore, be naturally suggested that if a "mother rock" exists, it ought to be found somewhere near one of these points; while, as far as can be learned from the records, no researches have been made in connexion with such an idea. Mills indeed suggested that the high ground of Ballinasilloge, to the north of the ford should be tried, but his suggestion was overruled by Weaver and Kirwan; there is also the high land of Knockmiller, between this place and the site of the corn mill that has not been tried; while immediately eastward there is more untried high land, although in the valley of the townland of Mongan are indications that strongly

* Jour. Roy. Geol. Soc. Ireland, Vol. VI., Part 3 (New series), p. 207.

† The term reef is, in part, confusing, as "reef mining," as used in some countries, refers to the crushing up of the quartz veins or reefs—while in other places the same term "reef" is applied to the high level flats.

suggest the presence somewhere thereabouts of a mineral vein. It therefore appears to me that until after the high land in these localities has been investigated it would be rash to assert no gold reef exists.

"To the westward in the upper portion of the Tomashelagh river valley, gold has been proved to exist, but never worked. In the Coolbawn stream and its eastern tributaries all the diggings were shallow, the search being abandoned when the head of drift became twelve or fifteen feet deep. However, three miles to the N.W., near the Darragh water, where the alluvium was again shallow, the gold was worked. There is, therefore, in the Coolbawn valley three miles in length of untried deep alluvium.*

"In the valleys of the S.W. and S. branches of the Gold-mines river there are no workings more than thirty feet deep, while nearly all of them are less than twelve or fifteen feet; there is, therefore, in this valley at the least, over a mile of untried deep ground.

"In connection with the Derry water or Aughrim river, the gold-bearing tributaries are:—the Tomashelagh river, the Coolbawn stream, the Ow river, the Kilmacreddin stream, the Clone stream, the Ballintemple stream, and the Gold-mines river; yet the alluvium of the valley has not yet been tried, except at Ballycoog-steps, where gold was proved. The distance from the inver or mouth of the Tomashelagh river to the Lower meeting at Wooden Bridge is over eight miles.

"Gold has been found in the sand of the Ow and in the alluvium of its tributary, the Mucklagh brook; the untried valley from the Mucklagh brook to the Darragh water valley being over six miles in length.

"Only the shallow alluvium of the upper tributaries of the Macreddin stream have been worked, there being a length of over three miles of deep alluvium between them and the Derry water.

"In connection with the Ovoca, there is gold in the gossan of the Ballymurtagh, Upper Cronebane, and Connary mines, in the river gravel at Castlemacadam, and in the alluvium of the Darragh water and its tributaries. There is, therefore, from the Ovoca mines to the sea at Arklow a length of over six miles of untried deep alluvium. So much for the untried deep and shallow placers in the neighbourhood of the Gold-mines Valley.

"In connection with the S. branch of the Gold-mines Valley, one or two 'dry gulches' were worked by Weaver, who got in them 'large gold.' Nowhere else does there appear to have been exploration made in search for 'dry gulches.'

"The relics of the more ancient valleys, that is, 'shelf,' or 'bar placers,' have never been looked after; yet in many places there is a possibility, if not a probability, that such golden relics might be found. Experience in America and Australia has proved that such deposits usually, although not always, occur in the shelves at the convex side of valleys, below the level of the source of the gold; and such shelves, possibly gold-producing, are very conspicuous in places along the valleys of the Ovoca, the Derry water, and the Gold-mines river, at heights below the known points at which the gold was found in quantity associated with tin ore and wolfram. None of them have, as far as is known, been explored.

"There are other places in this neighbourhood, such as Ballinglen and the Tinnahela streams, in which gold has not yet been recorded or tried for, although the indications would suggest its existence.

*Weaver began trials in this deep ground; but when he found the drift was deep enough to prevent the country people from working there, he abandoned them; deep works being contrary to his instructions

"It should, however, be specially pointed out that the gold in the neighbourhood of Croghan Kinshelagh as also that in the neighbourhood of Croaghmoira, is found below, or on the fall of, the watersheds of the outcrops of the mineral veins."

The views of so high an authority as Sir Warington W. Smyth regarding the origin of the gold in the streams will fittingly conclude this chapter. Referring to the occurrence of gold in the valleys on the north side of Croghan, in Coolbawn and other places, he says:—

"The same minerals which I have above enumerated were generally associated, and it is not without interest to observe that many of them are identical with those exhibited in the lodes at Ballycoog and Moneyteige, and that from the form of the hills it would be very possible to derive the spread of the auriferous drift from that strongly-marked ridge. Indeed, I am inclined to infer that from the 'back' or upper part of these lodes was derived the waste which furnished the greater part of the alluvial metallic substances found in the valleys below, and amongst them of the gold."

VIII.—Ovoca Mines.

By R. J. Cruise.

The mineral veins and channels forming these mines extend in a general N.N.E. direction from the north-eastern slopes ot Croghan Kinshelagh in one-inch Sheet 139, to the "Deputy's Pass," in Sheet 130, a distance of fourteen miles, nine miles being included in Sheet 139.

It must not, however, be supposed that the lodes are continuous all the way, as they are frequently displaced by faults, and in many places along their course tracts, variable in extent, of "dead ground" occur, in which the lodes seem never to have been formed or are only represented by useless irregular small strings and veins.

The mines at the present time, August, 1887, are almost entirely abandoned. In the district south of the Aughrim River they are completely so, and the same may practically be said of the mines west of the Ovoca River.

East of the river the Tigrony and Cronebane mines are worked to a limited extent, but the pumping engines are all removed, the water being raised from the mine by a small water wheel, to the deep adit level. These two mines are now worked together, Mr. Revington holding the royalties of both. They are under the management of Captain Higgins,* who employs about 100 men in raising sulphur ore, ochre, and in precipitating copper. There is also a quantity of ore, locally called "bluestone,"† and some ochre at surface at the Connary Sett, but the engines were all sold.

* Acknowledgments for aid and information are due to Messrs. Henry Robinson, John Hodge, George Oates, P. Argall, J. Williams, and Captain Higgins, but especially to the latter, who assisted in making surveys of the old workings, of which the records were lost; and also, by permission of the Messrs. Williams, reopened the old levels and shafts, thereby giving opportunities for examining new ground and proving the existence of a north lode in West Cronebane, four lodes in the country south of East Cronebane, and a "sulphur lode" in what was known as the "dead ground."

† This ore consists mainly of a double sulphide of zinc and lead; for analysis by Dr. Tichborne see Appendix E.

Some few years ago an endless wire rope was put up, to be worked by a turbine erected near Sroughmore old glebe house, the wire rope running on pulleys to Connary engine shaft, a distance of over a mile. This mode of pumping the water from the mine has been quite a failure, and the works, as already stated, are now abandoned.

The description of the Ovoca mines may conveniently be divided into three parts. The Croghan Kinshelagh or Carysfort mines, the West Ovoca mines, and the East Ovoca mines.

The Croghan Kinshelagh or Carysfort mines lie S. of the River Aughrim, principally along the N.E. spur of the mountain, including the Moneyteige, Ballinasilloge, Ballykillager, Ballycoog and Ballintemple lodes.

In the West Ovoca mines are included those in the townlands of Knocknamohill, Ballymoneen, Ballymurtagh, Kilcashel and Knockanode, and Ballygahan all lying between the Aughrim and Ovoca Rivers.

The East Ovoca Mines include the well known mines of Tigroney, Cronebane, and Connary, with all mineral veins and lodes in the townlands of Kilmacoo, Castle Howard, and Shroughmore, east of the Ovoca River.

Croghan Kinshelagh or Carysfort Mines.—On the eastern shoulder of Croghan Kinshelagh a shaft was sunk on a sulphur lode, which, according to Professor O'Reilly, strikes S.W. and N.E. No further information available. Crossing the boundary between Ballinasilloge and Ballykillager Upper, three veins were noted about 150 feet apart, bearing N.N.E., the N. and S. veins being gossans, the central one iron pyrites. Farther N., due E. of the Trigonometrical Station 1,399, the outcrops of three other veins occur—namely, one of magnetic iron ore, and two of pyrites, about an equal distance being between. In 1851 a shaft was sunk on the latter veins, twenty-five fathoms deep, and a level was driven from the bottom in a N.N.E. direction along the strike, with no favourable results. At Ballycoog, eastward of the Trigonometrical point 1,169, two trial pits were sunk, one twenty-five fathoms and the other fifteen fathoms deep, quite close to the site of the ancient workings. Sir W. W. Smyth, writing in 1853,* describes the beds as "magnetic and oligiste or specular iron ores, associated with copper pyrites, quartz, and chlorite. These deposits are in each case two in number, at a small distance apart, and varying from a few inches to six or eight feet in width." Mr. Du Noyer in 1861 stated that "in the fifteen fathom sinking, Ballycoog Upper, magnetic iron ore, associated with copper pyrites, was found, and many tons of it exported in the year 1851; the work not since resumed."†

Farther east in the brow of the hill, overlooking the Aughrim River, numerous small veins and strings of copper and iron pyrites have been observed and tried, but were too small to be profitably

* Records of the School of Mines, Vol. I., Part iii., p. 371.
† MSS. six-inch Maps.

worked. Proceeding south-eastwards along the Aughrim valley Ballintemple lead mine is reached. The late Mr. Wyley describes it as "lead lode N. 38° W., cutting across the slates; about five inches was galenite, no veinstone; when cavities occurred they were filled with clay."* When I examined this mine in 1869, on behalf of the Carysfort Mining Company, the lode at the fifteen fathom level was eighteen inches wide. The workings were shortly after my visit discontinued, and have not since been resumed.

West Ovoca Mines.—Commencing in the townland of Knocknamohill, a short distance N. of the house, copper ore was raised by Crockford and Co. about the year 1840. A little further north there is a series of "old men's workings," nearly half a mile in length extending to Ballymoneen. It is very probable that the old workings were on the iron ore, and that the copper and sulphur ores (copper and iron pyrites), if any, are still undeveloped along this tract.

Ballygahan and Ballymurtagh.—Both these mines ceased working about 15 years ago. All the shafts are closed up, and nothing is seen at surface but the refuse and detritus of the old workings. The engines, &c., have been removed from both mines; the engine-houses and other buildings are falling into ruin, and the water-wheels are partly dismantled and falling to pieces; in fact, such a scene of desolation it would be hard to conceive. As I could obtain no fresh information on the ground, I must refer the reader for a description of these mines to papers on the subject by the various writers, but more particularly to the Reports and Papers by Mills, Weaver, King, Kirwan, W. W. Smyth and Edward Barnes.†

Mr. Kinahan, writing on these mines in 1882, says—"In the south lode of Ballymurtagh, also further eastwards in Ballygahan, nearly all the ore has been extracted above the 110 fathom level, below which, however, there is still some ore; while according to the late Mr. Henry Robinson, there is a shoot of good coppery ore ("kiln ore") coming in from Ballygahan to Ballymurtagh. In the north lode of Ballymurtagh, for a length of 210 fathoms, the major portion of the ore has been got to the sixty fathom level, but the lode has been proved for a further depth of ninety fathoms, as the fifty-six fathom cross-cut from the south lode, cuts the north lode at about a perpendicular depth from surface of 150 fathoms; the lode, however, considerably contracts in depth. The eastern portion of this lode is still unexplored, while very little has been done on the north lode of Ballygahan."‡

A small wheel at the Ovoca River still pumps the water from Ballygahan engine-shaft into launders, for copper precipitation. The remains of a tramway to Arklow is still in existence as far as Newbridge.

* MSS. six in Maps.
See List of Reports, Papers, &c., page 37.
‡ Extracted from MSS. by Mr. Kinahan.

East Ovoca Mines.—The lodes and mineral veins of these mines extend out of Sheet 139 into the townlands of Ballycapple and Ballard. Tigroney, Cronebane and Connary are included in Sheet 139. The different mines are all on a continuation of the great main channel or sulphur lode, similar to that in Ballygahan and Ballymurtagh.

Between Ballygahan and Tigroney, in the valley of the Ovoca River, there is a tract of "dead" or unproductive ground about 500 feet wide. Tigroney and West Cronebane were called by Mr. Weaver the Lower or New mine. The main lode in Tigroney terminates westwards against a line of fault running in a N. and S. direction, which is locally termed the "great flucan course." This fault causes a horizontal displacement of the main lode northwards, of about 800 feet.

The "great flucan course" or fault, which averages about twelve feet wide, underlies eastwards at 70°, and is composed principally of steatitic and grey decomposed slate. From the "flucan course" the lode runs in a general N. 40 E direction underlying eastwards at 45° at the Baronet's shaft, increasing gradually eastwards to 75° at the boundary shaft.

The main lode here varies in width from 30 feet at the surface to 60 feet at the ten fathom level, its greatest width, gradually decreasing to 30 feet at the 40 fathom level, and to 2 feet at the 90 fathom level, the greatest depth reached.* This peculiar wedge-shaped character of the lode is continuous through Cronebane along the lode so far as it has been traced.†

Most of the copper ore (copper pyrites) has been removed; but from what I observed on the south of the main lode this ore seems to run in irregular strings or parallel courses, and sometimes forming pockets.

Cronebane West is very similar in character to Tigroney; its greatest depth is, however, only 40 fathoms, both mines being now worked to that depth; the remaining levels down to the 90 fathom level in Tigroney are flooded.

In the Ballymurtagh and Ballygahan workings, the pillars left not being sufficient to sustain the weight, the entire mass collapsed about twenty-six years ago, fortunately without any fatal accidents, the run in some cases taking place from the surface.

The workings at present carried on are partly on the main lode and partly for recovering the pillars left in Weaver's old mine. For this purpose levels are driven for some distance along the great "flucan course," on account of its softness, cross cuts are then made to the main lode where the pillars are supposed to be. During my examination I had an opportunity of seeing two of those pillars which had been discovered by Captain Higgins. The ore was very rich and contained some copper pyrites.

* These depths are under the deep adit of Tigrony.

† As shown on W. W. Smyth's "Plan and Sections of the Ovoca Mines" (Edit. 1882), and Argall's "Notes on Mining Operations, &c." Scient. Proc. Roy. Dublin Soc. 1879.

Cementation, or precipitation of copper from solution, was recently carried on underground in Cronebane, with fair results, the copper being purer than that obtained at the surface where the waters were mixed with surface impurities, but the expense was comparatively high;* however, the then owners of the royalty of Cronebane could not succeed in saving the copper in any other manner, as the drainage of the mine passes into and mixes with that of Tigroney. Mr. Revington now works both mines and the process of cementation is entirely carried on in launders at the surface.†

Workings on a small scale are carried on for ochre, which occurs as iron ore, or gossan, on the back of the main lode, both in Tigroney and Cronebane. This gossan is in many cases thirty feet thick, in some places having a deposit of grey steatitic clay between it, and the main lode. Captain Argall, writing in 1881, gives the following particulars of the development of Tigrony, Cronebane, and Connary Mines, since the date of Professor W. W. Smyth's Report in 1853:—

"*Tigrony Mine.*—William's shaft, sunk from surface, cutting the great "flucan" at the forty fathom level; great flucan opened out and driven on. Baronet's shaft, sunk from surface, intersecting the reverse fault at the ten fathom level; this fault could be seen in the underground workings when Professor Smyth wrote, but I believe it was not recognized. Fault between Tigroney and Cronebane not recognized. The mine deepened thirty fathoms.

Cronebane Mine.—Fault forming the west boundary of the "dead ground;" grass level lodes and "yellow bottom" lodes not recorded. Magpie shaft sunk until the bottom of the lode was reached at a depth of eighty-three fathoms from surface, and a granite rock found forming the footwall. South lode, and Madam Butler's Veins, not recorded by Smyth; also the N. 32 E. (Magt.) head which heaves the lode northward into the Connary mine.

Connary Mine.—Bottom of the lode found in a shaft thirty fathoms east of the engine shaft, at a depth of ninety fathoms from surface. The lode proved to extend into Kilmacoo. The South Kilmacoo lode sunk and driven on; Kilmacoo "easthead" proved.‡

Cronebane East, Kilmacoo and Connary mines are now closed It would appear from Mr. Kinahan's field maps that the main lode in its course from Cronebane West, was repeatedly shifted by faults, and its continuity interrupted by "dead ground."

It would seem, however, from the following description by Mr. Argall, of Upper Cronebane and Connary, that the mineral character of the lode is somewhat different to that in Cronebane Lower and Tigroney:—

* The greater portion of the water used underground was carried down by the old shaft from the "attals" on the surface. The idea of carrying the water underground originated in seeing the quantity of the carbonate of copper that used to accumulate during dry weather.—G. H. K.

† For an elaborate description of the process of cementation, see paper on—"The recovery of copper from its solution in mine drainage with special reference to the Wicklow Mines, by Philip Argall and Gerard A. Kinahan."—Scientific Proceeds. Royal Dublin Society, Vol. iii.

‡ Extracted from MSS. by Mr. Kinahan.

Upper Mines.*	Lower Mines.
The gossan occurs in bunches in masses of ferruginous clay, and never occupies the full width of the lode. It contains auriferous silver.	The gossan in mass occupies the full width and length of the lode. No trace of auriferous silver can be found in it.
The iron pyrites never fills the lode, but occurs in cakes or lenticular masses in the filling stuff. The iron pyrites does not become coppery in depth. The clays or "soft ground" that forms the filling stuff of the lode continues soft down to its full depth.	The iron pyrites nearly invariably occupies the full width and length of the lode; in depth it becomes coppery. Near the surface there is a little soft ground, but none is found in depth.
The country on the north and south of the lode, except the felstone in the Lodge level, is very little mineralized.	The country on the north and south of the lode is more or less mineralized, especially the latter, in which occur copper lodes for a width of 25 fms. from the hanging wall.

From the refuse lying about Magpie Shaft and Connary, I obtained specimens of an ore, locally called "blue stone" [see *ante*, p. 29.] It appears to me to be a double sulphide of lead and zinc, and apparently highly argentiferous. Captain Higgins writes "that when the lode became unproductive for sulphur, the 'blue stone' came in, but only in bunches or pockets."

There are the remains of workings on the Lion's Bridge lode and on a lode to the N. E., in the townland of Meetings, probably a continuation of the same.

In Sroughmore two adits were commenced, it being intended to unwater the Connary Mine, but they were abandoned before reaching the lodes. Trials were made on several lodes, bearing N. 55° E. and underlying 65° S.W., in this townland, but without much success.

Other Mineral indications and Mines not hitherto referred to.

In Wicklow, six-inch Sheet 33, Mr. Wyley records the occurrence of carbonate lime and copper, with pyrites, in the townland of Sheilstown. In six-inch Sheet 38, Wicklow, in the townland of Carrigroe, on the top of the hill, the note on MSS. Map states —"Two shafts sunk and adit driven to lead mine worked about 100 years ago." In six-inch Sheet 42, Wicklow, Aghowla Upper, "brown iron ore, one foot wide in ravine, not worked." In six-inch Sheet 3, Wexford, in townland of Glenoge, "traces of lead found in 1870."

The origin of the lodes, particularly in the W. and E. Ovoca Mines, is a very interesting one, and as I had an opportunity of

* Philip H. Argall, Ancient and Recent Mining in East Ovoca. Proceed. Royal Dublin Society, Vol. ii., Part iii., page 222.

examining the main lode (sulphur) in Tigroney and Cronebane I have come to the conclusion that it was formed in a fissure along a line of fault. Previous to Sir W. W. Smyth's Report the general opinion was that all the lodes of the district coincided, both in dip and direction, with those of the rocks of this country; but this is not the case as the lode cuts across the general strike of the beds. What possibly led to this error is the deposition of argillaceous matter *in the fault* sometimes at both sides of the lode, and at others, at only one side; in those cases the dip and strike of the laminæ being the same as the lode. It is probable that this fault fissure, extending at least from Ballygahan to Connary, was at one time continuous, but was subsequently itself faulted—the faults being probably anterior to the formation of the lode. On examining the lode it is found to consist of a series of thin laminæ of iron pyrites parallel to the dip or grade of the lode (S.E. 60° to 80°) more or less impure, with a small percentage of copper pyrites in places, thus showing that the fissures must have opened gradually and slowly. This main fissure varies considerably in width, and is always wedge-shaped in depth.

Resting on the back of the lode, in some cases directly, and in others separated by argillaceous steatitic clay, is found a deposit of iron ore or "gossan," varying in thickness from a few feet up to thirty feet.

I am disposed to assign a slightly different origin to the formation of the lodes, both N. and S. of the main lode, namely, that they were formed in fissures (not faults) in the Silurian schists; but as most of the workings are closed up, I had no opportunity of examining them.

Antiquity of Mining.*

There can be very little doubt but that mining and smelting iron ore were carried on at various places in this district at a very early period, although no authentic records thereof remain. According to Mr. Kinahan, tradition says that "Moneyteigue and Ballycoog iron mines were worked by the early Irish, and subsequently by Shillary and Raymond, two of Strongbow's knights. Subsequently, prior to the insurrection of 1641, the Paynes, who settled at Tombreen, near Carnew, were brought over as iron smelters. About the year 1650, an Englishman, named Bacon, established a forge at Shillelagh and at numerous other places in the counties of Wexford and Wicklow.

Smelting works and forges were also established about 1782 at Aughrim, S. of the bridge at Woodenbridge, a little west of the Putland Arms Hotel; at Knocknamohill, in the Kiln field; at Ballynaclash, in the valley of the Avonbeg; at Furnace, in the Vale of Clara, and probably elsewhere.

The principal mines worked appear to have been Moneyteige, Ballycoog, Knocknamohill, and Ballycapple. Probably bog iron

* Extracted from MS. by Mr. G. H. Kinahan.

ore was also raised, as we know from Dr. Gerard Boate's history of the trade that it was extensively used in other parts of Ireland at this period.

The last forges that were put out appear to have been those at Shillelagh and Ballynaclash, a little prior to 1760. There are men still living whose fathers carried ore on horseback to these works. The iron forged was of excellent quality and considered superior to Swedish for horse nails, it being in such repute that all the holdfasts in the stone gate posts have been taken out of them by the local smiths, while "chamney chains," even at the present time, are highly valued for smith work.

Authentic records show that Ballymurtagh and Cronebane Mines were worked prior to 1752,* and on the authority of Dr. Rutly,† in the seven years preceeding 1765, the waters of the Cronebane Mine had yielded £17,260 worth of precipitate copper alone. Sir W. W. Smyth expresses his opinion, founded upon what he believes to be old deep open workings, that "mining had been carried on at a very early period in Cronebane."‡

* Rev. William Henry, D.D., Phil. Transactions, 1752.
† Natural History of Dublin, 1772.
‡ Record School of Mines, p. 388.

APPENDIX A.

LITERATURE of MINING DISTRICT with list of REPORTS, PAPERS, &c., in their order of publication.

Date.	Title of Publication.	Author.	Where Published.
1751	Copper Springs of Wicklow,	Rev. Henry Kinroy, D.D.,	Phil. Trans., vol. xlvii.
1752	Precipitation of copper from solution in Ballymurtagh Mines.	Rev. William Henry, D.D.,	Phil. Trans., vol. xlvii. for 1751 and 1752.
1772	Cronebane Mineral Waters,	Dr. Rutly,	Natural History of Dublin, 1772.
1800	Mineralogical account of the Gold Mines in the Co. Wicklow with a map.	A. Mills,	Trans. Roy. Dub. Soc., vol. ii., part i., p. 454.
1801	Report on Wicklow Mines,	Mills, King, Weaver, and Kirwan.	Trans. Roy. Dub. Soc., vol. ii., part ii.
1802	Second Report on the Wicklow Gold Mines,	A. Mills,	Trans. Roy. Dub. Soc., vol. iii., p. 81.
1804	Ovoca Mines,	Colonel Vallancey,	Collectanea de Rebus Hibernicis.
1818	Geological Relations of the East of Ireland,	Weaver,	Trans. Geo. Soc., London, vol. v.
1840	Tinstone on Croagh Kinshelagh.	D. A. Smith,	Proceedings Geo. Soc., Dublin, vol. ii.
1844	Industrial Resources of Ireland.	Sir R. Kane,	—
1850	—	William Mallet,	Journal Geo. Soc., Dublin, vol. iv.
1851	—	James Apjohn,	Journal Geo. Soc., Dublin, vol. v.
1853	Record of the School of Mines.	Professor W. W. Smyth, M.A.	Vol. i., part iii.
1853	—	Rev. S. Haughton, M.D.,	Journal Geo. Soc., Dublin, vol. v.
1864	Brief Description of Ballymurtagh Mine.	Edward Barnes,	—
1871	Metalliferous Deposits,	W. J. Henwood, with notes from Messrs. Hodge, Johnson, George Oates, Henry Robinson, Kempster Brown, W. J. Roberts, and John Read.	Trans. Roy. Geo. Soc., Cornwall.
1878	Geology of Ireland,	G. H. Kinahan	Chap. xxi., p. 339.
1879	Ancient and Recent Mining, East Ovoca.	P. H. Argall,	Proc. Roy. Dub. Soc., vol. ii., part iii.
1882	Report on the clearing of Peaty Waters. The principal Mineral impurities of the Ovoca.	Gerrard A. Kinahan,	Proc. Roy. Irish Acad., 2nd Series, vol. iii. (Science).
1882	On the recovery of Copper from its Solution in Mine Drainage, with special reference to the Wicklow Mines.	P. H. Argall and Gerrard A. Kinahan.	Scientific Proceed. Roy. Dub. Soc., vol. iii.

APPENDIX B.

ANALYSES showing chief Inorganic Impurities of the water of the OVOCA RIVER BASIN. Results stated in parts per 100,000.

By GERRARD A. KINAHAN.

AVONMORE.

No.	Where obtained.	Chief impurities determined.	Present, but not quantitatively estimated.	Traces detected.	Remarks.
I.	Glendasan, .	Lead, . . . 0·06 Total solids, 7·5	—	Fe, As H_2SO_4	(Turbid, and with much suspended matter, neutral.
II.	Clara Bridge,	Lead, . . . 0·04 Total solids, 4·1 Inorganic solids, 3·1 Chlorine, . . 1·4	— — —	As H_2SO_4 —	(Clear, but slightly peaty.
III.	Rathdrum Mill.	Lead, . . . 0·005 Solids, . . 3·9 Chlorine, . . 1·6	— — —	— — —	(Slightly peaty.
IV.	Meeting of the Waters.	Lead, . . . 0·02	—	—	Clear, and slightly peaty.

SMALL TRIBUTARIES OF THE OVOCA.

V.	Tigroney (launder).	Iron, . . . 163·0 Alumina, . 197·5	Cu, Mn Mg, H_2SO_4	As, Pb Zn	(Brown, with ochre in suspension, acid.
VI.	Ballygahan (launders).	Iron, . . . 199·0 Alumina, . 214·0 Copper, . . 7·5 Manganese, . 3·9 Zinc, . . . 2·4	Mg H_2SO_4 — —	Pb As Co Ca	(Brown, with ochre in suspension, acid.
VII.	"Red Road" Stream.	Ferric Oxide } 3·8 Alumina, } 3·8 Copper, . . 0·05	Mg H_2SO_2	— —	(Colourless, with ochre in suspension, slightly acid.
VIII.	Tinnahinch Stream.	Iron, . . . } Alumina, . } 4·8 Copper, . . 0·02 Solids, . . 22·5	Mg H_2SO_4	Zn Ca	(Colourless, brown sediment, slightly acid.
IX.	Sulphur Brook.	Solids, . . 12·8	Mg	Fe_2O_3, Zn Al_2O_3 H_2SO_4	(Colourless, with brown precipitate, faintly acid.

APPENDIX C.

TABLE 1.—Showing the amount of Precipitate and the amount of Copper produced by the consumption of one ton of Iron at different Mines and Metallurgical Establishments—quantities stated in hundred-weights.—GERRARD KINAHAN.

Number.	Locality, &c.	Date.	Amount of Precipitate in cwts. for ton of Iron.	Copper in cwts. for ton of iron consumed.	Nature of Precipitant used.	Remarks.
I.	Mona Mine, Anglesea, . .	(1832) (1866)	20·23	1·96	Scrap iron and tin plate.	(Lixivium from calcined ore and drainage from mine and waste heaps, treated in a series of large pits. Page 310.
II.	Pary's Mine, Anglesea, .	1844	—	1·83 2·00	Old iron, . .	Mine drainage passed through a series of large pits.
III.	Pary's Mine, . . .	(1862) (1866)	11·26	2·65	(Scrap iron), . .	(Mine drainage and lixivium from calcined ore, treated for ten weeks in large pits.
IV.	Cronebane Mines, Wicklow,	1862	8·00	2·80	Wrought iron, .	Mine and surface drainage during active operations, treated in inclined launders.
V.	Lucencia Mine, Huelva, Spain, ...	1859	4·00 5·00	2·00 3·00	Pig iron, . .	(Mine water passed through heaps of calcined ore, and treated in large pits. Pages 310 and 311.
VI.	Great (Gwennap) Adit, Cornwall, ...	(Since 1854	8·00 10·00	3·12 4·00	Scrap iron and tin plate.	(Mine drainage of large area, treated in pits (strips) along the stream. Page 310.
VII.	Connary, Wicklow, . .	(1860 (1861)	9·67	4·26	Scrap iron and tin plate.	(Mine drainage passed through horizontal tanks and inclined launders. Page 304.
VIII.	Devonshire Great Consolidated Copper Mines, .	1866	10·00 11·04	5·00 5·13	—	Drainage of mines. Page 310.
IX.	Wheal Agar, Cornwall, .	—	15·00	4·50 5·25	—	Adit drainage of an abandoned mine. Page 310.
X.	Agordo, Venetian Alps, .	1874	—	5·71 6·25	Cast iron, . .	(Lixivium from shells produced by "kernal roasting," and heated to 34°—40° R. in tanks. Pages 320 and 321.
XI.	Schmöllnitz, Hungary, .	1860	—	6·66	Cast iron, . .	Drainage of active mine, treated in inclined launders. Page 311.
XII.	Ballymurtagh, Wicklow, .	(1852) (1861)	16·00	7·12	Scrap iron, . .	(Mine drainage during active working, treated in steeply inclined launders. Page 304.
XIII.	Schmöllnitz, Hungary, .	1859	13·71	7·69	Wrought and cast iron.	Mine drainage treated in launders, inclined and vertical. Page 311.
XIV.	Agordo, Venetian Alps, .	1875	9·98	7·84	Cast iron, . .	Lixivium as in No. X., but after reduction with sulphurous acid. See pages 320 and 321.

TABLE 2.—Showing the amount of Precipitate and the amount of Copper produced by the consumption of one ton of Iron at different Mines and Metallurgical Establishments—quantities stated in hundred-weights—*continued.*

Number.	Locality, &c.	Date.	Amount of Precipitate in cwts. for ton of Iron.	Copper in cwts. for ton. of Iron consumed.	Nature of Precipitant used.	Remarks.
XV.	Agordo, Venetian Alps, .	1855	15·73	7·91	Cast iron, . .	Lixivium from "kernal roasting," heated to 62°—63° C. in "chambre de plomb." Pages 19 and 20.
XVI.	Rio Tinto, Huelva, Spain, .	1859	92·16	9·22	Cast iron, . .	Lixivium from calcined ore, poor portion of precipitate held in suspension, treated in pits. Pages 9 and 10.
XVII.	Rio Tinto, Huelva, Spain, .	1859	16·75	9·22	Cast iron, . .	Lixivium from calcined ore, treated in pits, precipitate adherent to iron. Pages 9 and 10.
XVIII.	Agordo, Venetian Alps, .	1855	19·76	9·44	Cast iron, . .	Lixivium from shells produced in "kernal roasting," heated to 62°—63° C. in "chambre de reverbere."
XIX.	Santiago Mines, Cuba, . .	1844	15·54	10·88	Scrap iron, . .	Weak mine drainage percolating through irons placed on racks in large tanks.
XX.	Cronebane, Wicklow, . .	1878	21·00	14·7	Tin-plate cuttings, .	Rich mine waters, treated in launders. Page 5.
XXI.	Santiago, Cuba	1844	20·00	15·00	Fresh bar iron, .	Weak mine waters, treated as No. XIX., but with clean iron.
XXII.	Twiste, Waldeck, . . .	—	—	16·00	Scrap iron, . .	Lixivium from treating carbonates with hydrochloric acid.
XXIII.	Connary, Wicklow, . .	1838 to 1839	—	19·94	Wrought iron and tin plate.	Mine waters in winter treated alternately in horizontal tanks and inclined launders. Page 5.
XXIV.	Cronebane, Wicklow, . .	1787 to 1811	—	20·6	Plate and scrap iron.	Mine drainage and lixivium from "kernal roasting" during Weavers' management. Geo. Soc. Transactions, Vol. v., p. 218.
XXV.	Santiago, Cuba, . . .	1844	24·00	21·48	Fresh bar iron, .	Rich mine water, treated as No. XIX., but with clean bar iron.
XXVI.	Theoretical result and Keith's Electrical.	—	22·67	22·67	Clean iron, . .	Result for cupric salts—$Cu\,So_4+Fe=Fe\,So_4+Cu$.
XXVII.	Napier's Electrical, . .	—	—	23·77	Clean iron, . .	See "Philosophical Magazine," Vol. XXIV., p. 365.
XXVIII.	Cronebane, Wicklow, . .	1751	39·5	31·6	Bar iron, . .	Apparently inaccurate. See page 2.
XXIX.	Hunt and Douglas process—Practical result. See page 21, ...	1870	—	33·33	Scrap iron, . .	Copper mostly in cuprous state. $Cu_2Cl_2+Fe=FeCl_2+cu_2$.

TABLE 3.—Analyses of the principal constituents of Ballygahan Water before and after Cementation, in parts per 100,000, by G. A. Kinahan.

—	Before Cementation.	After Cementation.
Ferrous Oxide,	81·81	94·75
Ferric Oxide,	4·30	6·70
Cupric Oxide,	9·32	1·91
Sulphuric Acid,	634·26	642·34
Manganous Oxide,	2·30	2·50
Zincic Oxide,	1·20	1·80
Total, . .	733·19	750·00

TABLE 4.—Analyses of the Mine Waters of Schmöllnitz before and after Cementation, in Vienna, lbs. per cub. ft.: by Lill von Lilienthal.

—	Before Cementation.	After Cementation.
Ferrous Sulphate, .	0·331	1·025
Ferric Sulphate, .	0·458	0·011
Sulphate of Copper, .	0·081	0·005
Sulphate of Zinc, .	0·049	0·045
Sulphate of Aluminium, .	0·497	0·448
Sulphate of Lime, .	0·063	0·060
Sulphate of Magnesia,	0·303	0·288
Total, . .	1·785	1·889

TABLE 5.—Analyses of Lixivium and Cement Copper at Agordo: by M. de Hubert.

Reduced Lixivium.	Before Cementation.	After Cementation.	Products of Cementation.	Cement Copper in Scales.	Cement Copper in Powder.
Cuprous Oxide, . .	1·38	0·66	Copper, . .	·8741	57·95
Ferrous Oxide, . .	6·91	8·72	Ferric Oxide, . .	3·40	10·95
Oxide of Zinc, . .	1·78	2·32	Oxide of Zinc, . .	0·60	1·78
Alumina, . . .	0·66	0·74	Alumina, . . .	0·25	0·33
Arsenious Acid, .	0·24*	—	Lime, . . .	2·00	1·90
Sulphuric Acid (combined), .	14·15	14·15	Sulphuric Acid, .	1·12	2·87
Free Sulphuric Acid, .	2·08	0·63	Arsenic, . .	0·69	4·93
Water, . . .	73·68	72·48	Water, . . .	1·00	3·83
			Insoluble residue, .	3·60	12·10
Total, . .	99·34	99·12	Total, . .	99·87	96·24

* Equivalent to 0·183 of Arsenic.

APPENDIX D.

* LIST of PLANS and SECTIONS deposited in the MINING RECORD OFFICE, LONDON, in connection with Mines and Mineral Lodes in this Memoir.

No. 1. Darragh Water or Aughrim Valley, with the mineral lodes on which trials have been made.

No. 2. Plan and Section Ballintemple Mine.

No. 3. Key Map of the Mining district from Croagh Kinshelagh to Ballard.

No. 4. Map of Weavers' Trenches or open casts in the neighbourhood of Croagh Kinshelagh.

No. 5. Map of the faults and lodes in connection with the East Ovoca Mines.

No. 6. Plan and Section of Weavers' Boat Level at Cronbane, by P. H. Aygall.

* Copied from Mr. G. H. Kinahan's MSS.

No. 7. Copy of Weavers' Section of the Copse and Boundary Workings, Cronebane.
No. 8. Key Map of the Ballymurtagh Mines.
No. 9. Plan of the North Lode of Ballymurtagh.
No. 10. Section of North Lode, Ballymurtagh.
No. 11. Section of Safety Levels, Ballygahan (East).
No. 12. Plan of Safety Levels, Ballygahan (East).
No. 13. Transverse Section, Ballygahan (East).
No. 14. Plan and Section, Lodge Level, Madam Butler's Lode, by P. H. Argall.
No. 15. Plan showing the relative positions of the Lodes in West and East Cronebane.
No. 16. } Cross Sections, Cronebane Mines.
No. 17. }
No. 18. }
No. 19. Plan and Sections of the Mines from Ballygahan north-eastwards to Connary.
No. 20. Tigroney Copper Lodes, by Captain Higgins.
No. 24. Tracing of the working on Tigroney Sulphur Lode up to date 1881.

APPENDIX E.

Analysis of "Argentiferous Galenitic Blende," so called "Blue Stone," found at Connary Mine, E. Wicklow, by C. R. C. Tichborne, LL.D., F.C.S., &c. :—

Silver,	0·024
Zinc,	25·27
Lead,	25·18
Iron,	5·51
Manganese,	trace
Antimony,	0·21
Arsenic,	0·08
Copper,	2·50
Aluminum,	0·60
Magnesium with traces of Calcium,	0·02
Sulphur,	23·71
Silica, &c.,	16·886
	100·000

This mineral may therefore be said to consist of

Sulphide of Zinc,	37·68 per cent.
Sulphide of Lead,	29·07 ,,
Sulphide of Silver,	00·275 ,,

and contains variable quantities of pyrites, which in this particular specimen amounts to 10 per cent.

The sulphide would represent nearly 22 per cent. of sulphur.

It was examined for the rarer metals but they were not to be found.

Gold was present in very small quantities. It was not estimated.

A similar ore occurs at Silvermines, Co. Tipperary—a specimen examined by me for silver in the year 1865 gave 0·025 per cent. of silver.

APPENDIX F.

Petrographical Notes on the Igneous Rocks referred to in this Memoir.* By F. H. Hatch, PH.D., F.G.S.

I. The Greenstones.

The greenstones occurring in the Wicklow district were found capable of arrangement under the following heads :—

a. Quartz-mica-diorite.
b. Quartz-diorite and Diorite.
c. Augite-diorite.
d. Dolerite.
e. Epidiorite.
f. Serpentine.

County Wicklow was visited in 1876 by the distinguished German petrographer, Dr. A. von Lasaulx, who afterwards described certain of these greenstones as diabases, diorites, and mica-diorites † Sections of some of them are also to be found in the Allport collection in the British Museum. The latter have been described by Mr. Teall.‡ Further reference will be made to both investigations in the sequel.

(*a.*) *Quartz-mica-diorite*—Rocks composed essentially of quartz, felspar (plagioclase and some orthoclase), biotite, and hornblende. This is the tonalite of vom Rath.§ The prefix "quartz" might perhaps be dropped with advantage, as it is doubtful whether any mica-diorites without quartz exist.

Between Kilmacurra West and Ballinaclare (four miles E. of Rathdrum ; Sheet 130), the road from Rathdrum to Kilboy Bridge traverses the central portion of a large irregular boss of greenstone. This rock is remarkable for its granitoid appearance, the grain being moderately coarse and the colour unusually light for rocks of this class. This granitoid character is tolerably persistent ; although in other respects the rock varies considerably, in some places being spangled over with lustrous six-sided plates of dark mica, while in others this mineral is conspicuous by its absence, its place being taken by the less brilliant chlorite. The component minerals are quartz, felspar, biotite, hornblende, chlorite, and apatite, the first four being essential constituents.

The abundant presence of brown mica and green hornblende in plates and crystals gives this rock rather a striking appearance under the microscope. The mica is a small-angled, almost uniaxial biotite. Its pleochroism is strong :—α = straw-yellow ; β and γ = dark chestnut-brown. Although quite fresh in some sections, it is in others surrounded by a border of chlorite, and finally passes completely over into this mineral, leaving, however, in some few cases a small nucleus of brown unaltered material to mark its former existence. These patches of chlorite contain, in considerable quantity, a granular mineral of high refractive power and strong double refraction, that has been shown by Petersen‖ to consist of epidote (see p. 45).

* A few rocks obtained from the ground (Sheet 130) north of that which forms the subject of the Memoir are also described in the following pages.

† "Petrographische Skizzen aus Irland." Tschermak's Min. u. Pet. Mitth. Vol. 1, 1878, p. 441.

‡ British Petrography, London, 1888, pp. 249 & 266.

§ Zeit. Deutsch. Geol. Ges., 1864. XVI., p. 249. Vom Rath lays especial stress on the abundance of brown mica as characteristic for the rock of Tonelli.

‖ Mikroskopische und chemische Untersuchungen am Enstatitporphyrit aus den Cheviot Hills. Kiel, 1884.

The hornblende occurs partly in pale-green idiomorphic crystals, partly in irregularly bounded patches. The former present a well-developed cleavage, and, more rarely, twin-lamellæ, intercalated parallel to the orthopinacoid (100). The more ragged patches are fibrous and give confused polarization-phenomena between crossed nicols, suggesting a secondary origin, viz., by alteration from augite. A few unaltered grains of pale augite (salite, malacolite) are, in fact, still to be found. This fibrous character of the hornblende is sometimes present in the central portion of a patch, the borders of which are formed by clear rectilinearly contoured hornblende substance giving uniform polarization. Such phenomena suggest the possibility of uralitic hornblende, derived from the alteration of augite, undergoing recrystallization, perhaps by the aid of percolating waters, and finally appearing in the form of idiomorphic crystals that bear all the conventional marks of original formation.

The felspar is mostly striated (plagioclase). It occurs in rectangular sections, containing dusky aggregations of minute specks and granules, resulting from kaolinization. Some of the crystals, however, are unstriated; so that it is probable that the plagioclase is accompanied by orthoclase.

Quartz is abundant. It was evidently the first mineral to separate, since it occurs in irregular grains, filling in all interspaces between the idiomorphic crystals of the earlier-formed minerals. Apatite is present in considerable quantity, its six-sided acicular microlites being found penetrating all the remaining minerals.

A mica-diorite, somewhat resembling this rock, has been described by v. Lasaulx* from Dunganstown, east of Rathdrum.

Mr. Teall† describes a section in the Allport collection in the British Museum, as containing plagioclase, augite, biotite, *olivine* and a *pleochroic pyroxene*. The locality given is Carrigmore, County Wicklow. There is a Carrigmore marked on the map (Sheet 130), four miles to the east of Rathdrum; and this place is adjacent to the large irregular mass of greenstone from which the specimens described above were derived. The mineralogical composition of the two rocks, however, appears to differ considerably.

(*b.*) *Quartz-diorite* and *diorite.*—Rocks composed of felspar (plagioclase) and *original* hornblende with and without quartz.

An excellent example of quartz-diorite occurs at Bologh Lower, three miles E. of Rathdrum. Near this place the road from Rathdrum to Redcross traverses a triangular mass of greenstone which is probably related to another larger one to the north-east, from which it has perhaps been severed by the fault which forms its eastern boundary. (See Sheet 120.)

This rock is a rather light-coloured granitic aggregate mainly of felspar and quartz but with some green hornblende and chlorite. It is of medium grain. With the aid of the microscope both monoclinic and triclinic felspar are found occurring in large rectangular and lath-shaped sections. The orthoclase grains appear fresh and unaltered. The plagioclase, on the other hand, has undergone a change consisting in the formation of countless, minute, brightly polarizing flecks, which give a turbid appearance under low powers. The alteration, however, has but slightly modified the polysynthetic twin-striation that characterizes triclinic felspar. The orthoclase shows only dual twinning on the Carlsbad type. Microperthite-structure is also shown by some sections.

* "Petrographische Skizzen aus Irland." Tschermak's Min. u. Pet. Mitth. Vol. i. 1878, p. 444.

† British Petrography, 1888, p. 249.

Quartz is abundant. It appears everywhere in grains of characteristic pellucidity, filling up the interspaces between the felspar crystals. Here and there both minerals break up into finely granular patches, producing the so-called "mosaic structure" when viewed between crossed nicols. Green hornblende occurs in isolated idiomorphic crystals; also in smaller grains embedded in patches of chlorite.

Both structure and mineralogical composition bring this rock into close relation with a widely-distributed member of the granite family. Like the diorite described above, hornblende-granitite consists essentially of quartz, orthoclase, plagioclase (oligoclase), and hornblende (with or without biotite). The triclinic felspar of the diorite may perhaps be somewhat more basic (andesine or labradorite) than that in the granite. But it cannot be denied that the quartz-diorites graduate imperceptibly into rocks that are petrographically indistinguishable from the more basic granites. But mode of occurrence and association are here of the highest importance; and in the present case they are such as to justify unmistakably the retention of this rock in the greenstone family.

Near Cummer Place, six miles east of Shillelagh, three dyke-like protrusions of greenstone have been recorded on the map (S. E. corner of Sheet 138). The specimen to be described was obtained from the northernmost patch. It is a fine-grained granitic aggregate of cream-coloured felspar and green hornblende (dark coloured in the hand specimen, pale green in section). Quartz is sparingly developed, and is invariably interstitial, being either secondary (*quartz d' infiltration*) or the last product of consolidation.

The felspar has undergone alteration, resulting in the formation of cloudy patches (kaolin) and small but numerous granules of epidote. Where less changed the felspar usually presents twin-striation and probably consists, for the greater part at least, of plagioclase. The hornblende occurs in abundant roundish grains, which rarely present crystalline contours. Its pleochroism and prismatic cleavage are well marked; and it does not envelope the felspar-lathes like the compact hornblende, derived from ophitic augite. With the hornblende chlorite is associated. This mineral contains streaky aggregates of a minutely granular mineral, which, from its general appearance and association with ilmenite, I am inclined to regard as sphene (leucoxene). Similar granules, enclosed in chlorite, have, after careful microchemical determination, been described by J. Petersen* as epidote. There is no reason for doubting this determination, and these streaky aggregates probably consist very often of epidote; but in the present instance the resemblance to leucoxene is too striking to remain unnoticed.

Another specimen from the same locality presents evidence of dynamic metamorphism. It is a compact rock of a pale greenish-grey colour, weathering with a white crust. Under the microscope it is seen to consist of ragged patches of pale-green hornblende separated by a colourless material giving aggregate-polarization between crossed nicols. This finely granular "mosaic" is composed of quartz and felspar of secondary origin probably resulting from a molecular rearrangement of the original felspar. The other minerals present are all secondary:—epidote, forming small granular aggregations; sphene, in part surrounding specks of ilmenite; and scales of specular iron.

* Loc. cit.

(*c.*) *Augite-diorite.*—I have given this name, first used by Zirkel for oligoclase-augite rocks, to a group very common in the district under consideration. The rocks constituting this group are composed essentially of felspar (plagioclase), and a pale variety of augite (salite, malacolite), occurring in isolated, often well-contoured crystals. They differ from the dolerites by the complete absence of ophitic structure, and by the presence of interstitial quartz.

Augite-diorite is one of the most common types of greenstone occurring in the district under consideration. The following is a list of localities where specimens were collected :—

(1.) One mile east of Ovoca Lodge, six miles south of Rathdrum. (Sheet 139).
(2.) Near (south of) Kilpatrick House ; seven miles south of Rathdrum. (Sheet 139).
(3.) Close to Carrycol Farmhouse ; two and a half miles north of Arklow. (Sheet 139).
(4.) Snugborough House ; three miles north of Arklow. (Sheet 139).
(5.) Near Lewisville ; two and a half miles north of Arklow. (Sheet 139).
(6.) Half mile west of Brittas Bridge ; five miles south of Wicklow Head. (Sheet 130).

The first on the list is a typical representative of the group, and has therefore been selected for a more detailed description than has been accorded to the rest. It is a small, insignificant mass of greenstone, erroneously marked on the map as felspathic ash. The rock is fine-grained ; but its essential constituents can readily be distinguished with the aid of a pocket-lens. They are quartz, plagioclase, and augite, to which may be added as accessories, ilmenite, accompanied by leucoxene (sphene), apatite and chlorite.

The felspar is of the usual character, giving lath-shaped sections, which are somewhat kaolinized, but exhibit, in places, the twin-striation characteristic of plagioclase. Enveloping the felspar-lathes are patches of clear quartz, the separate portions of which are in optical continuity. This "ophitic" relation of the two minerals reminds one of that shown by the felspar and augite of the dolerites. It is distinct from micropegmatite ; for in this structure both minerals present optical continuity, which is not the case in the present instance, the felspar lathes, penetrating the quartz, being independently orientated. Rosenbusch* refers to this property as being characteristic of the quartz of the diorites. Enclosed in some of the quartz-grains are microlites of hornblende. Similar enclosures in quartz have been observed by Bundjiro Koto†.

The mineral present in greatest abundance is a colourless augite (salite or malacolite) occurring in crystals and aggregated granules. This mineral is easily recognized by its bright colours between crossed nicols, and its high refractive power, the grains standing well out in the field of the binocular microscope (distinction from hornblende). Longitudinal sections (in the prismatic zone) give oblique extinctions which reach a maximum of 43° in sections parallel to the clinopinacoid (010).‡ Similar sections of epidote, to which this mineral bears a deceptive resemblance, are elongated in the direction of the brachydiagonal, and give, consequently, straight extinction. Sections across the vertical axis

* Physiographie der massigen Gesteine, 1887, p. 110.
† Q. J. G. S., XL., 1884, 455.
‡ Kalkowsky measured a maximum angle of 44°. "Uber den Salit als Gesteinsgemengtheil." Tschermak's Min. und Pet. Mitth. Jahrb. k. k. Geol. Reichsanstalt, Vol. XXV. (1875), p. 45.

are octagonal, being bounded by the faces of the prismatic zone (100), (010), (110) the latter subordinate. When normal, or nearly normal, to the vertical axis, these present the oblique emergence of an optic axis (β) in convergent polarized light. The most marked cleavage is pinacoidal : cracks parallel to the prism are less frequent. The longitudinal sections exhibit, in addition, a cross-jointing which has been referred to a basal cleavage.*

The remaining minerals, with the exception of the apatite, are secondary :—Chlorite, in fibrous patches ; leucoxene in white, turbid masses surrounding specks of unaltered ilmenite. The occurrence of augite exhibiting no trace of alteration in a rock that has undergone considerable mineralogical change is instructive; for it demonstrates the fact, that the non-aluminous variety of augite (salite, malacolite) is better able to withstand alteration-processes than the more commonly occurring iron-alumina pyroxene.

The specimens from the next four localities on the list were taken from greenstones that occur in the complex of igneous rock surrounding Kilpatrick, two or three miles to the west of Mizen Head. This mass of igneous material occupies an area of between two and three square miles, and is made up of roughly parallel, lenticular sheets and beds of felsite and felspathic ash, and irregular dyke-like protrusions of greenstone, all of which have a somewhat variable, but in the main, north-easterly and south-westerly strike.

These rocks differ but little in their petrographical characters from the augite-diorite described above. Like the latter they are characterized by a remarkable abundance of pale augite (salite, malacolite). This mineral usually occurs in small round granules, devoid of crystalline contours, except in the rare instances where octagonal sections, presenting the faces of the prismatic zone, are observable. Polysynthetic twinning parallel to the orthopinacoid is not infrequent. Felspar and quartz are generally quite subordinated to the augite. Apatite occurs in slender prisms giving hexagonal sections. Sphene is present in granules which have every appearance of being original, but are probably derived from the alteration of ilmenite ; for instances are not wanting where fragments of this mineral are surrounded by clear granular sphene instead of turbid leucoxene, and every gradation from the latter to the former can be traced. We have here probably another case of recrystallization *in situ* of the secondary mineral, similar to that suggested (on p. 44) to explain the occurrence of secondary hornblende with idiomorphic contours. Other alteration-products present in these rocks are :—Chlorite, epidote and uralitic hornblende. Some specimens are rich in finely disseminated pyrites.

The rock from Brittas Bridge differs from the preceding only in possessing a slightly porphyritic structure, the felspar occurring occasionally in larger individuals embedded in a groundmass of small felspar-lathes and granular augite. These felspar-crystals contain zonal inclusions of a chloritic substance, which perhaps represents altered glass. Patches of this "chloritic base" also occur in the groundmass.

(*d.*) *Dolerite* (*Diabase* of the Germans). Rocks composed essentially of plagioclase and augite. They are characterized by a well-marked ophitic structure (*diabasich-körnige Structur*) ; and are entirely free from olivine, a mineral eminently characteristic for the dolerites of some districts (*e.g.* Antrim and the western isles of Scotland). By the addition

* Kalkowsky, l.c.

of quartz, accompanied by a change in the nature and structure of the augite, they pass into the augite-diorites, the distinction between the two being, here as in other rock-groups, purely artificial, and not one marked by any striking difference in the mode of origin.

Excellent representatives of this group of rocks occur in the neighbourhood of Arklow Head, about two miles south of Arklow (Sheet 139). Alternate bands of greenstone, felsite and felspathic ash are there seen striking N.E. and S.W., in conformity with the strata in which they are intercalated, and cropping out in succession along the coast above the headland. These rocks occupy an area of about a square mile, and constitute a group of small hills that form a prominent feature in the landscape, looking southwards from Arklow town. A large quarry for paving-setts and road-metal has been opened up in the main mass of the Arklow greenstone by Mr. Parnell; and the stone has been extensively used in Dublin.

The rock is a dark-green, rather fine-grained aggregate of felspar and dark-coloured lustrous augite. Under the microscope the structure is seen to be that of a typical dolerite. Ophitic plates of augite are found enveloping lath-shaped sections of felspar. The latter mineral is fresh and well striated. Chlorite is present in patches embedding granules of epidote and needles of green, pleochroic hornblende (actinolite); and ilmenite occurs in plates. Some portions of the rock contain quartz. This mineral forms, in these sporadic patches, a matrix enveloping the felspars. It is either of secondary origin or due to some process of segregation which took place during the consolidation of the rock.

Three quarters of a mile to the west of the headland is a small patch of greenstone (near the little Arklow rock) which deserves mention as illustrating the change from augite-rock (dolerite) to hornblende-rock (epidiorite). This rock is of medium or fine grain. It contains numerous scattered particles of iron-pyrites and ilmenite, the former distinguished by their bright yellow colour, the latter by their silvery-white metallic lustre. Under the microscope it is seen to consist of turbid felspar, in lathes penetrating the augite; ilmenite, accompanied by leucoxene; chlorite in patches, containing tufts of actinolite-needles.

But the main interest attaches to the augite. This mineral presents every stage of alteration into a pale-green, pleochroic hornblende, beginning at the periphery and progressing towards the centre of the crystals. The earlier stages of the alteration, that might escape notice in ordinary light, are well brought out between crossed nicols; the narrow rim of secondary hornblende exhibiting a marked difference in its angle of extinction (amounting to 15°). This secondary hornblende soon becomes compact; and when a grain of augite has been completely converted into hornblende it is scarcely to be distinguished from primary hornblende. Its cleavage-cracks are perhaps less perfectly developed; and it presents, usually, no definite crystalline contours.* The mineralogical change appears to be purely paramorphic.

A handsome rather coarse-grained dolerite crops out behind the Station Hotel at Rathdrum (Sheet 130).† Under the microscope this rock consists of a plexus of good-sized lathes of felspar, enveloped by plates of ophitic augite. Ilmenite also occurs in plates which enclose both felspar and augite. Other minerals present are leucoxene, chlorite, pyrites, and apatite, the latter in abundant stout six-sided prisms.

* With reference to this point, see remarks on p. 44.
† This rock is described by v. Lasaulx, l.c. p. 442.

(*e.*) *Epidiorite**.—The rocks embraced under this head are dolerites altered by contact or dynamic metamorphism—perhaps by a combination of both. The special feature characterizing them is the complete conversion (paramorphism) of the augite of the dolerites to hornblende. This mineral occurs in ragged patches, which have often preserved the ophitic structure, originally presented by the augite in its relation to the felspar, turbid prisms of the latter being found penetrating the uralitic patches.

Other secondary minerals are calcite, chlorite, epidote in abundant lozenge-shaped and lath-shaped sections, and leucoxene, derived from the ilmenite. The leucoxene often presents elongated streaky forms, suggestive of linear extension.

That the rocks have undergone mechanical metamorphism is further shown by the cataclastic structure frequently presented by the felspar; this mineral being no longer homogeneous, but appearing in granular masses that give aggregate-polarization. In places the rocks are distinctly foliated, passing then into hornblendic and chloritic schists.

The sections on which the above description is based were made from specimens collected at the following localities:—

(1.) Summit of Croghan Kinshelagh.

(2.) West flank of Croghan Kinshelagh, near where the stream crosses the road about a mile N. of Wicklow Gap. (Sheet 139).

(3.) Between Wooden Bridge and Coats Bridge, on the road to Aughrim (sheet 139): numerous exposures, marked on map as greenstone-ash.†

(4.) Two miles east of Kilcavan House, near Shillelagh. (Sheet 138).

(*f.*) *Serpentine.*—Serpentinous greenstones are rare in the district examined. They represent a further state of alteration:—thus, the dolerites pass into epidiorites, the epidiorites into serpentine.

The more westerly portion of the greenstone-mass at the last locality mentioned in the preceding section (E. of Kilcavan House, near Shillelagh, sheet 135), consists for the greater part of green serpentinous material. A section made from this rock, shows layers of a colourless substance presenting all the usual diagnostic characters of serpentine, associated with a mineral resembling calcite or dolomite. A drop of acid applied to the hand-specimen produced no effervescence, thus indicating the latter.

II. The Felsites.

These rocks occur in great abundance in the district under consideration. They are intimately associated with the greenstones, but unlike these appear to have flowed at the surface, as they often associated with felspathic ashes. They are in fact acid lavas.

Their association and mode of occurrence in Lower Silurian rocks reminds one of the felsites of Wales. But although they bear a superficial resemblance to these rocks, my specimens show none of the nodular and spherulitic structures, the banding, fluxion-structure, and perlitic separation that have been described by Bonney, Cole, Rutley, and Ward, as characteristic for the Welsh felsites. On the other hand, v. Lasaulx‡ has described spherulitic structure in a felsite from Knock-

* Die paläolithischen Eruptivgesteine des Fichtelgebirges, München, 1874, p. 9.
† It was the schistose character of some of these rocks that caused them to be mapped as tuffs. At that time the part played by mechanical metamorphism in producing foliation had not been recognized.
‡ Loc. cit. p. 446.

anduff, county Waterford; and it is quite possible that the examination of a greater number of specimens would disclose the more frequent presence of this and similar structures.

Microscopic examination and chemical analysis show that these rocks consist, in part, at least, of soda-felsites or keratophyres, a group of rocks which up till now has not been described as occurring in the British Isles. The keratophyres (so named from their resemblance to hornstone *) were first described by Gümbel†; but it is to K. A. Lossen‡ that we are mainly indebted for working out the characters of these peculiar rocks, and vindicating their claim to consideration as a definite rock group. They are characterized by containing a remarkably high percentage of felspar, and especially of soda-felspar, which in some cases appears to be a soda-orthoclase or soda-microcline, in others, albite. In consequence of this, splinters fuse before the blowpipe more readily than those of the ordinary quartz-orthoclase felsites. Many of the specimens I have examined have a curious mottled appearance which is only apparent on a weathered surface.

Normally constituted felsites, that is to say, rocks composed of a crypto-crystalline aggregate of quartz and felspar (in greater part orthoclase) with or without porphyritic quartz, also occur in the Wicklow District; but there is little doubt that the two types graduate into one another, and it does not appear advisable to separate them sharply, either in the field or in the laboratory.

Specimens of keratophyre were collected from a rocky eminence quarter of a mile W. of Brittas Bridge, seven and a half miles W. of Rathdrum (Sheet 130).

This rock is a compact felsite, having the mottled appearance mentioned above. This is due to the presence of numerous greyish brown spots, of about a quarter inch diameter, crowded closely together, being only separated by a small quantity of a dark grey interstitial substance. The microscope affords no explanation for this appearance, the brown spots being quite indistinguishable from the grey parts in thin section. In the field where exposed to the action of the weather the rock is coated with an opaque white crust.

This interesting rock is seen under the microscope to be composed almost entirely of felspar and quartz, the former being in excess. The few porphyritic crystals are invariably felspar, the quartz being confined entirely to the groundmass. The texture of the latter is variable. In general it is microcrystalline, sometimes rising to the coarseness of a microgranite or granulite, and consisting of square and lath-shaped sections of felspar, between which are entangled irregular grains of quartz; in places, however, the texture sinks almost to cryptocrystalline, the individual granules being then so small as to be scarcely distinguishable, although by the use of a higher power the microcrystalline structure can generally be made out. There is no evidence of the presence of any "*microfelsitic*" (*isotropic*) *matter*.

Scattered sparingly through the sections are scales of chlorite, and isolated granules of sphene; occasionally also a few tiny specks of iron ore are to be found.

The porphyritic structure is ill-defined, there being but little difference in point of size between the "porphyritic" felspars and the crystals of

* Gr. *keras*, a horn.
† Die paläolithischen. Emptivgesteine des Fichtelgebirges. Munich, 1874, p. 45.
‡ Zeit. Deutsch. Geol. Ges., XXXIV. (1882), pp. 199 and 455.
" " " " XXXV. (1883), p. 215.
Jahrb. k. preuss. Geol. Landesanst. für 1884 (1885), p. 21.

that mineral belonging to the more evenly crystalline portions of the groundmass. It is only the occurrence of an isolated large crystal in a cryptocrystalline part that gives the porphyritic appearance.

These large felspars form broad rectangular crystals, which are sometimes slightly rounded. In some cases they present a fine twin-lineation either on one (the albite) or two (albite and pericline) types. In other cases the crystals show no trace of twinning.

These latter crystals, however, are characterized by another and somewhat remarkable structure. They appear, namely, between crossed nicols as if they were divided up into a number of rectangular patches by narrow partitions, which have an extinction-angle differing slightly from that of the main portion. In other cases the central portion extinguishes uniformly, while the marginal layer goes out at a slightly different angle. The latter case can sometimes be made out without the use of the nicols; for the rim of the felspar-section is clear, while the central portion is speckled over with minute opaque particles, giving it a somewhat cloudy appearance. Have these phenomena, more especially the first-mentioned, anything in common with the "felderweise mikroperthitische" structure mentioned by Lossen and Rosenbusch as characteristic for the felspar of the keratophyres? The smaller felspars of the groundmass are mostly striated.

A chemical analysis of this rock gave me the following result:—

SiO_2	=	77·29
Al_2O_3 . } Fe_2O_3 (a trace) }		14·62
CaO (a trace)		—
MgO		·38
K_2O	=	·16
Na_2O	=	7·60
Loss on ignition	=	·57
		100·62
Sp. G.	=	2 64

From this analysis the mineral composition of the rock was calculated to be the following:—

Free quartz	=	32·49
Orthoclase = ·95 }		
Albite = 64·33 }		
Felspar		65·28
Other substances	=	2·23
		100·00

The chemical analysis thus shows the rock to consist almost entirely of quartz and a soda-felspar (albite).

A specimen of a felsite obtained from an exposure immediately S. of the Bell rock, five miles S. of Rathdrum (Sheet 139), has a composition and structure exactly similar to the rock described above, and is consequently also referred to the keratophyres.

Another rock which may be described here crops out on the shore S. of Arklow head (Sheet 139).

It is a compact grey felsite, containing minute disseminated patches of pyrites. It has not, however, the mottled appearance of the keratophyres described above, and differs further from them by containing more quartz. It represents perhaps a passage between the keratophyres and the true quartz felsites. The quartz occurs in good-sized grains, which are somewhat rounded. They bear evidence of

having undergone crushing, grains, which in ordinary light appear to consist of one individual, being resolved by crossing the nicols into an aggregate of differently orientated granules.

The porphyritic felspars invariably show polysynthetic twin-striation. They also evince signs of having been subjected to mechanical force since their formation. One crystal, for instance, has been shattered into several fragments, which are re-cemented by the cryptocrystalline paste in which they lie. That they are parts of one and the same crystal is shown by the continuity of the twin-lineation from one fragment into another. The fact that the fragments are separated by the groundmass points to the fracture having taken place before the final consolidation of the rock. It is therefore probably connected with fluidal movements.

Near Ballyclogh, six miles S.E. of Rathdrum (Sheet 130), occurs a dark green, very compact (almost flinty) rock. Under the microscope it is seen to consist of irregular granules of quartz embedded in a confused crypto-crystalline matrix. In places there are indications of a "fluxion-structure," streaky bands of a somewhat coarser material being present. These consist of quartz-grains elongated in the direction of movement and separated from one another by films of a chloritic substance. From its easy fusibility before the blow-pipe it seems probable that this rock belongs to the keratophyres; but a chemical analysis would be necessary to settle this point.

Quartz-felsites of the ordinary type are however also represented in the district under consideration. Such, for example, is the Bell Rock, at the Ballymurtagh Mine, five miles S. of Rathdrum (Sheet 139); and probably, also, a rock occurring quarter of a mile W. of Kilboy Bridge, four miles E. of Rathdrum (Sheet 130). These are compact dark grey rocks, containing minute particles of pyrites. They differ mineralogically from the typical keratophyres by containing an abundance of small irregular grains of quartz embedded in a crypto-crystalline paste; no crystals of felspar are visible, and this constituent must be present in the felsitic groundmass.* Whether this groundmass contains isotropic matter ("microfelsitic base") I have not been able to determine satisfactorily. Some parts of the section certainly appear to remain dark during a complete rotation between crossed nicols; but it is quite possible that this may be due to the mineral matter being in a state of such minute sub-division as to be incapable of reacting on polarized light. In ordinary light the felsitic matter appears as a colourless substance in which are scattered minute scales of chlorite.

In the specimen from Kilboy Bridge there are wavy streaks (fluxion structure) produced by the unequal distribution of a fine dust of opaque particles (iron-ore).

The Bell-rock felsite has been analysed by Professor Haughton† with the following result:—

SiO_2	81·36
Al_2O_3	7·86
Fe_2O_3	3·32
CaO	·99
MgO	·45
K_2O	3·09
Na_2O	2·63
	99·70

* That these rocks do contain felspar is shown by the chemical analyses carried out by Professor Haughton.

† Trans. Roy. Irish Acad., Vol. XXIII. (1859), p. 615.

Calculating on the assumption that the felsite is composed essentially of quartz and orthoclase, Professor Haughton obtains the following result:—

Quartz,	= 45·54
Felspar,	= 54·16
	99·70

A very compact brownish grey felsite was obtained half a mile S. of the Barranisky Cross-roads, four miles N. of Arklow (Sheet 139). This rock consists entirely of the cryptocrystalline aggregate of quartz and felspar, there being present neither the larger quartz-grains nor the more coarsely crystalline portions occurring in the rocks described above. The mineral particles in this rock are so minute that between crossed nicols only a very faint dappled light is transmitted.

III.—The Elvans (microgranites).

On reference to the map (Sheets 138 and 139) we see that these rocks appear at the surface either in narrow dykes which strike N.E. and S.W. or in larger masses, elongated in the same general direction, as in the case of the hills constituting Croghan Kinshelagh and Morale; another mode of occurrence is in round or ovoid bosses as at Crosspatrick. They are essentially granitoid rocks of a rather fine grain. In colour the specimens from the larger masses vary from a creamy white to a yellowish brown; but those obtained from the dykes are of a more bluish white or grey. They are usually spotted over with small aggregations of a dark mineral (biotite, sometimes altered to chlorite).

The larger masses are taken first. Sections were made from rocks collected at the following localities:—

(1.) S. of Coolbawn House, Croghan Kinshelagh.
(2.) S.W. flank of Croghan Kinshelagh, two miles N. of Wicklow Gap.
(3.) Clonroe Bridge, one mile E. of Wicklow Gap.
(4.) Crosspatrick, five miles E. of Shillelagh (Sheet 139).

Examination under the microscope shows that these rocks consist essentially of quartz, orthoclase, and plagioclase, together with a small quantity of mica, in holo-crystalline and granitic aggregation. Sphene occurs as an accessory constituent in small grains. The unstriated felspar very generally presents microperthitic structure, lamellæ and irregular patches of triclinic felspar (sometimes with recognizable twin-striation) being intergrown with the orthoclase along definite crystalline planes. This structure gives the orthoclase a very curious and characteristic appearance under the microscope. (Clonroe Bridge.)

The mica is present only in very small quantities. When fresh it is a greenish brown variety (biotite), but it is often altered more or less completely into chlorite.

The rôle played by the quartz is interesting. This constituent is here often of slightly earlier origin than is the case in the true granites. Instead, therefore, of invariably occurring in angular patches wedged in between the felspars, and representing the residuum of crystallization, it is sometimes present in equi-dimensional grains that often attain considerable size (Crosspatrick). Still the quartz is always allotriomorphic (*i.e.* it presents no definite crystalline faces), as indeed are all the constituents of these rocks; nor can they be said to be porphyritic, as there is no separation into crystals and groundmass. The rocks, therefore, are *micro-granites*, but without porphyritic constituents. On the

other hand we find, here and there (Croghan Kinshelagh and Crosspatrick), a micropegmatitic or granophyric arrangement of the quartz and felspar as in the granophyres, with which, indeed, the microgranites are petrographically closely allied.

The effects of dynamic metamorphism are seen in the occasional undulose extinction of the quartz-grains between crossed nicols; and to the same cause must be ascribed the presence of a small amount of granular matter, fringing the larger grains. (Crosspatrick).

Specimens of elvan occurring in narrow dykes were obtained from a place W. of the road from Clash to Aughrim, three miles N.E. of Aughrim (Sheet 139), where three parallel dykes are marked on the map. This variety is also a microgranite; but it differs from the preceding in containing porphyritic crystals of orthoclase felspar, twinned on the Carlsbad type. It differs further in the nature of its mica, this being a colourless muscovite in blades and scales.

IV.—The Granites.

The petrographical relations of the Leinster granite have been so thoroughly investigated by Professor Haughton* that it is unnecessary to add much to his description.

The specimens obtained by me from Glendassen, Glenmalure (Sheet 130), and Killiney Hill, are medium-grained rocks of a light-grey colour, and speckled over with scales of a lustrous black mica. Here and there the rock assumes a foliated appearance, due to a parallel arrangement of the mica.

The essential constituents of this granite are quartz, orthoclase, plagioclase, and dark and light micas. In addition to these minerals abundant microcline was observed in a specimen from Killiney Hill. This mineral was evidently separated at a later period of consolidation than both orthoclase and plagioclase, as crystals of both are enclosed within it.

The white mica is stated by Professor Haughton to be margarodite, and the black mica, lepidomelane. The latter occurs in plates and lamellae, which are of a deep chestnut-brown when the long axis of the lamellae coincides with the short diagonal of the polarizing nicol, and pale yellow in a direction at right angles to this. This mineral is often altered along the periphery and between the lamellae into a pale green chlorite.

Professor Haughton† gives the following as the average of eleven analyses of the Leinster granite :—

SiO_2	= 72·07
Al_2O_3	= 14·81
Fe_2O_3	= 2·22
CaO	= 1·63
MgO	= ·33
K_2O	= 5·11
Na_2O	= 2·79
Loss by ignition	= 1·09
	100·05

In the N.W. of Sheet 139, there are several outlying patches of granite, of which the one near Aughrim may be taken as a type. It is

* Trans. Roy. Irish Acad. Vol. XXIII. (1859), p. 589.
† Loc. cit., page 600.

well exposed in a railway cutting near the station, where it is quarried for building purposes. It is an evenly and somewhat finely grained rock of a greyish white colour, speckled with scales of black mica.

This rock is remarkable under the microscope for the perfect idiomorphism of its felspar. The rectangular crystals of this mineral are, so to speak, embedded in a groundmass of pure allotriomorphic quartz. The sharpness of outline which characterizes these crystals, appears to be due to a secondary enlargement they have undergone since their first formation, each crystal being surrounded by a narrow rim of clear substance which can be easily distinguished from the turbid, kaolinized interior of the original crystal. That the clear substance is also felspar is shown by the fact that it extinguishes simultaneously with the crystal it surrounds.

The felspar crystals are loaded with decomposition products. Besides the usual opaque specks (kaolin), which are sufficiently abundant to produce turbidity, there are thin lamellæ of mica, developed along the cleavage planes. Some of the crystals, too, contain irregular granules of a colourless mineral with a high refractive index and strong double refraction. This mineral is probably epidote, although no sign of pleochroism could be detected. In addition to the turbid felspar, a small quantity of clear microcline is also present. It is of later consolidation than the orthoclase.

The mica is mostly of the brown variety; muscovite is rare. Resulting from the alteration of the mica are patches of chlorite, in which are embedded granules of sphene and minute doubly terminated crystals of zircon, the latter with pleochroic borders.

Aplite-Veins in the Granite.—The Leinster granite is often traversed (as at Killiney Hill) by veins of a white, finely grained, or even compact, rock, which has hitherto been described as eurite. Microscopic examination shows that these rocks are aplites, consisting of a microcrystalline aggregate of quartz, orthoclase, plagioclase, microcline, and white mica or muscovite. As accessory constituents occur abundant needles of tourmaline and, more rarely, rounded and corroded grains of garnet.

V. Contact-metamorphism in the neighbourhood of the Granite.

The metamorphism of the slates in contact with the granite of the main axis cannot be so conveniently studied in Sheet 138 as in the corresponding one to the N. (Sheet 130), where the development of mica-schist (often much crumpled and contorted) can be well followed along the valleys of the Avonbeg and Glendasen rivers. Above Drumgoff Bridge in Glenmalure (the valley of the Avonbeg) garnet and staurolite-schist occur in patches included in the granite.

But in the neighbourhood of the small outlying patches of granite in Sheet 139 the metamorphism is equally strikingly developed, and can be studied with greater convenience. For instance, every step in the alternation from a normal Lower Silurian slate right up to the massive crystalline rock in contact with the granite can be traced in the excellent section made by the railway cutting at Aughrim Station on the line running from Woodenbridge to Shillelagh.

I will describe this section in detail. At a distance of 135 yards from the contact the rock is a gray laminated slate, just beginning to show a faintly spotted character. Under the microscope only a few minute flecks and needles of crystalline material can be seen. At a

distance of 90 yards the laminated character of the rock is much modified, and the dark gray micaceous matrix is crowded with black prisms of andalusite. Under the microscope this mineral presents itself in large well-developed crystals which, when sufficiently thick, give a deep red colour for rays vibrating parallel to the long axis ($c = \gamma$), it is associated with a considerable quantity of black carbonaceous material (graphite?). As the junction with the granite is approached the rock becomes more and more massive. At the actual contact it is much injected with granitic material, and does not contain andalusite. It consists partly of patches made up of fine mica scales and quartz granules, partly of a more coarsely-grained aggregate of quartz and felspar derived from the granite.

Andalusite is also well developed in a dark-coloured micaceous schist, occurring in Drimingall Wood, S. of Coolboy crossroads, $2\frac{1}{2}$ miles E. of Shillelagh. This rock bears all the characteristic signs of contact-metamorphism, and, although granite is not exposed at the surface at this place, there can be little doubt that a ridge or boss of the rock is not far distant.

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