Göñez, Albaner Com. (4) Greenstone-trachyte (Richthofen), Unter Fernezely, N.E. Nagy Banya, Szathmarer Com. (5) Greenstone trachyte, Trapategy, S.W. Bereghsasz, Beregher Com. I may say that in no single instance have I observed the characteristic pleochroism of the hypersthene in any monoclinic augite. I would therefore ask, with Mr. Whitman Cross, whether it is not possible that the strongly-pleochroic "augite" extracted by Herr Oebbeke¹ from an andesite from the Sierra de Mariveles, Luxon, may not be hypersthene, and whether this pleochroic mineral may not occur in association with a non-pleochroic or differently pleochroic augite.

III.—ON ACCUMULATION AND DENUDATION, AND THEIR INFLUENCE IN CAUSING OSCILLATION OF THE EARTH'S CRUST.

By CHARLES RICKETTS, M.D., F.G.S.

(Continued from p. 306.)

THE Carboniferous Limestone of the north-west of England was formed in a bay separated from another marine area farther south by a narrow isthmus² and promontory never submerged, extending, as Professor Jukes pointed out, in "a band of country running east and west across England from Leicestershire, through Warwickshire, South Staffordshire, North Shropshire into Montgomeryshire,"³ and to the mountainous district of North Wales.

The limestone is situated in and fills up valleys formed in Silurian and other rocks, and there has evidently been a progressive depression during the whole period of its formation; from the time when conglomerates and sandstones derived from the neighbourhood were distributed over the bottoms of these valleys,⁴ forming the so-called "Upper Old Red Sandstone" of the Survey Maps, though considered by the Members of the Geological staff as forming in such cases the base of the Carboniferous series;⁵ and this progressed whilst the flanks of these valleys were being gradually submerged, the basement beds of the limestone being very frequently composed to a great extent of fragments of Silurian rock in a matrix of limestone. This subsidence continued during the whole period in which the strictly marine series, represented by the Carboniferous Limestone, was being deposited; until and beyond the time when that

¹ Oebbeke, Beiträge zur Petrographie der Philipinen und der Palan-Inseln, Neues Jahrbuch, I. Beilage Band, p. 451.

² That portion of this isthmus, situated between Coalbrookdale and the Clee Hills, was sixteen miles wide at the termination of the deposition of the Carboniferous Limestone, and was reduced to twelve miles during that of the Millstone Grit.

³ Memoirs of the Geological Survey, The South Staffordshire Coal-field; by J. Beete Jukes, F.R.S., p. xii. See also Jukes's Manual of Geology, second edition, p. 518.

⁴ Professor J. Phillips recognized that "they were confined to *valleys* in the slate formation, and never follow that rock to its escarpments on high ground."—Geology of Yorkshire, part ii., p. 13.

⁵ Mem. Geol. Survey, Geology of Kendal, etc., W. T. Aveline, F.G.S., p. 14; [Prof.] T. McK. Hughes, F.S.A., p. 15; of Kirkby Lonsdale [Prof.] Hughes, p. 16. On the Carboniferous Conglomerates of the Basin of the Eden, by J. G. Goodchild, Quart. Journ. Geol. Soc. vol. xxx. p. 396.

great change occurred, whereby waters, bringing down soluble silicate, mud, sand, and pebbles, were diverted into this area; the distribution of which produced, according to the conditions prevailing in different periods and localities, in the first place siliceous and carbonaceous materials characterizing the Upper Limestone, afterwards the varieties of strata characterizing the Yoredales and Millstone Grit, and at a later period the Coal-measures.

A modern event which must produce effects comparable with,—at least causing as great a contrast as the changes which occurred in the Carboniferous strata above the Limestone,—took place about 1852, when the muddy waters of the Whang-Ho were diverted from the Yellow Sea into the land-locked Gulf of Pe-Che-Lee, the present outlet being removed a distance of not less than 640 miles along the coast-line, around the rocky promontory of Shan-tung (East Mountain).¹

A very great variation in the *thickness* of the Carboniferous Limestone occurs in different places, and often within very short distances. In the Coalbrookdale district the southern boundary of this formation extends no farther than Little Wenlock, near which village, at Oldfield Quarry, it is 25 feet thick; and a little further northward, at Steeraway, it is 40 feet,² but does not exceed 100 feet. It is evident the Carboniferous Sea did not extend over the Silurian rocks to the south, or over those of the Longmynd towards the west; for any strata resting upon them and belonging to that era are referred to the Coal-measure series.

At Llanymynech, 25 miles north-west of Coalbrookdale, the nearest locality where the Carboniferous Limestone now exists, the precipitous escarpment of Llanymynech Hill rises from a basement of Wenlock shale. Mr. G. H. Morton estimates the thickness of this mass of limestone at 450 feet.³ This gets thinner towards the north, and at Grug-fryn, nine miles distant, it exists along such a narrow space, resting on Wenlock shale and having sandstone above, that the limestone seems to be not more than 100 feet, or perhaps only 50 feet in thickness.⁴

Near Llangollen, where it overlies beds of sandstone and conglomerate, the Carboniferous basement beds previously alluded to, the limestone forms the magnificent escarpment of the Eglwyseg ridge, and is exposed throughout its whole extent. Its entire thickness according to Mr. Morton, is 1200 feet. This forms a remarkable contrast to the exposure on the opposite bank of the River Dee. Within a distance of four miles, at Fron-y-Cysyllte, where the limestone rests on Wenlock shale, there are wanting no less than 873 feet of the lower strata as developed in the Eglwyseg ridge.⁵

In North Derbyshire near Buxton the thickness of the Carbon-

¹ The Double Delta of the Whang-Ho, by Samuel Mossman, *Geographical Magazine*, vol. v. p. 92.

² Geological Survey, Vertical Sections, No. 23.

³ The Carboniferous Limestone and Cefn-y-fedw Sandstone between Llanymynech and Minera, by G. H. Morton, F.G.S., p. 122.

⁴ Morton *op. cit.*, p. 81. ⁵ Morton, *op. cit.* pp. 39 and 75.

iferous Limestone has been ascertained to the amount of 1580 feet;¹ but it may be considerably more, for the base can nowhere be determined. Its thickness diminishes towards the north. From nine to twelve miles north-east of Settle, "in the vicinity of Arncliffe and Kettlewell, it is probably not less than 1000 feet thick." To the west of Arncliffe six and twelve miles respectively, "under Penigent and Ingleborough it is from 400 to 600 feet thick, and along the Pennine chain from Kirkby Stephen northward a less thickness may be assigned to it."²

Judging from such facts as these, there can be no question that the Carboniferous Limestone has been deposited on surfaces of unequal elevation, in valleys and gorges excavated in the older rocks, and that it has been almost throughout its whole extent precipitated slowly and equally, or been otherwise derived from the waters of the sea. The variation in thickness in different localities is very greatly owing to its having been deposited in the vacant spaces which formed these pre-Carboniferous valleys; at all events the evidence by itself is not sufficiently conclusive to decide that, though the accumulation has been greater in one place than in another, therefore the subsidence has been caused by this increase of pressure.

Though the subsidence has been almost entirely continuous during the whole period of the deposition of the limestone, the sea-bed formed was at no time situated at any great depth, for the valves of Mollusks are frequently separated, and the stems and joints of Encrinites have been washed from each other, as by the action of waves or currents. The water therefore having been shallow, a sufficiently correct base-line is afforded to determine the effects produced by the inundation of this submarine plain by large accumulations (derived from distant sources) which constitute the later Carboniferous rocks, whether a greater or less amount of subsidence occurred locally according to the amount deposited.

In the Coalbrookdale district the thickness of the Millstone Grit, where it lies upon the Limestone at Steeraway, is 80 feet;³ a little beyond it rests upon Upper Silurian strata; whilst six miles further towards the south none has ever existed, the Coal-measures lying immediately upon Silurian rocks. At Llangollen according to Mr. Morton it increases in thickness to 723 feet.⁴ Including with it the Yoredales, it extends in North Derbyshire to more than 3000 feet, with a greatly varying thickness, being of that amount near Sheffield, but it is only 1500 feet near Belper, a distance of less than 30 miles.⁵ Beds of Coal occasionally recurring in these strata indicate low-lying land surfaces, posterior to the formation of which there has occurred subsidence with the accumulation many times greater in extent than its whole thickness near the southern margin.

¹ Mem. Geol. Survey, North Derbyshire, p. 18.

² Geology of Yorkshire, by John Phillips, F.R.S., part ii. p. 176.

³ Geological Survey, Vertical Sections, No. 23.

⁴ Under the local definition of Cefn-y-Fedw Sandstone, *op. cit.* p. 51.

⁵ Fig. 37, Comparative Sections of the Millstone Grit and Yoredale Rocks, Mem. Geol. Survey, North Derbyshire, p. 139.

Similar variation in the thickness of deposits occurs also in the Coal formation. Coalbrookdale again affords an example where the accumulations and the changes of level are small compared with other districts; probably because it was situated at a distance from the sources from which the detritus was conveyed, and therefore could not receive the same amount of deposit. The strata in which the profitable beds of coal are situated range from "Little Flint Coal," situated immediately above the "Farewell Rock" (Millstone Grit) to the "Top Coal," and amount to only 180 feet; the gross average thickness of the beds of coal being about 40 feet,¹ that of the beds of workable coal according to Professor Hull 27 feet; the entire thickness of the Coal-measures amounts to 1200 feet.² In Denbighshire the Middle Coal-measures, the only ones worked, have a thickness of 800 feet, with from 27 to 30 feet of workable coal. The Lower Measures amount to 1000 feet, with several coal-seams varying from two to three feet. The aggregate thickness of these Coal-measures is about 3000 feet.³ Again a very great increase is observed in the Coal-measures of the Lancashire district, where, including the Gannister beds, they attain a maximum thickness of 7300 feet.⁴

Taking Leicestershire as a starting-point, the different series of Upper Carboniferous strata attain a very moderate thickness; but a great and progressive increase occurs when passing thence in a north-westerly direction to North Lancashire. Professor Hull has demonstrated this in the following Table of

"COMPARATIVE VERTICAL SECTIONS OF THE CARBONIFEROUS STRATA FROM NORTH LANCASHIRE TO LEICESTERSHIRE.

N.N.W.	S.S.E.			
	Burnley district.	Mottram district.	North Staffordshire.	Leicestershire.
Coal-measures	8460	7635	6000	3000
Millstone Grit	5500	2500	500	50
Yoredales	4675	2000	2300	50
	18,635	12,135	8800	3100."

Commenting on the above sections, Professor Hull remarks, that "it will be observed the beds which attained so prodigious a development in North Lancashire dwindled down to one-sixth of their volume in Liecestershire."⁵ The Coal series varies considerably in limited areas in different localities, and there is in Lancashire a general increase of thickness of the sedimentary materials, such as sandstones and shales, towards the N.N.W. Thus the *same* coal-seams are farther apart at St. Helens than at Prescott, and at Wigan than at St. Helens.⁶ This difference in the thickness of the Coal-measures occurring within restricted areas has been confirmed by Messrs. De Rance and Strahan, who prove the amount

¹ Geological Survey, Vertical Sections, No. 23.

² The Coalfields of Great Britain, by Edward Hull, F.G.S., second edition, p. 96.

³ Hull, *op. cit.* p. 99.

⁴ Hull, *op. cit.* p. 123.

⁵ Quart. Journ. Geol. Soc. vol. xxiv. p. 322.

⁶ Hull, Coal-fields of Great Britain, p. 123.

between certain identical beds of coal to be one-third greater at Standish, near Wigan, than at Prescott, an interval of 13 miles.¹

A most remarkable example of increase in the sedimentary strata occurs in the "Thick" or "Ten Yard" coal of Dudley, which in the southern portion is thirty feet thick, having only two to four feet of partings;—that is, during the whole period of its formation it remained constantly or nearly at the same level, being that of the great Carboniferous plain or delta. Professor Jukes proved that this thick bed of coal at a distance of five miles from Bilston in a northerly direction, in the neighbourhood of Bentley, is divided into ten or twelve separate beds, whose gross thickness is the same, but including the intermediate measures has increased to not less than 406 feet.²

DIAGRAM OF THE DIVISIONS NEAR BENTLEY OF THE "THICK COAL" OF DUDLEY AND BILSTON.

a. Thick Coal at Bilston, 30 feet.

b. Divisions of same at Bentley, 406 feet.

c. Heather Coal.

Length of Section 5 miles. *Altered from Prof. Jukes.*

Conclusion.—From all these facts it may safely be inferred, wherever there has been a great accumulation, there also has supervened a great amount of depression. Such is the record of the present and every geological era. There must needs be a cause for the simultaneous occurrence of these phenomena being thus universal, inseparable, and in about the same relative proportion. As depression could only permit and by no possibility cause accumulation, the only reasonable explanation is that accumulation over considerable areas is, through the pressure exerted by its weight, the true cause of subsidence. This presupposes a comparatively thin crust to the earth resting upon a fluid or semifluid substratum.

If subsidence occurs in one place, there must, to maintain the equilibrium, be elevation in another. Some examples might be adduced, both in former geological periods and also at present, where elevation has ensued without any reasonable evidence that there has been a local withdrawal of pressure. Elevation would more certainly supervene upon the removal of pressure, and probably occur to a greater extent in the locality whence the detritus has been removed the transfer of which has caused subsidence.

Reference has already been made to the results subsequent to the

¹ Geological Survey, Vertical Sections, No. 61.

² Memoirs of the Geological Survey, The South Staffordshire Coal-field, by J. Beete Jukes, F.R.S., p. 25, etc.

dissolution of the snow which, during the Glacial period, enveloped the British Isles, Northern Europe, and North America. The re-elevation of the land to a certain height was ascribed to the removal of the pressure by the melting of this load of ice and snow; but in consequence of the accumulation of Boulder-clay which remained, it was not raised to so great an extent as before the submergence. The present gradual rise of the land in Norway and Spitzbergen may also be attributed to the partial removal of once greatly augmented snow-fields.

The immense amount of material removed, and the depth and width of valleys formed, indicate, not only the erosion to which strata have been subjected, but likewise that there has been a rising of the land to expose it to the action of subaerial agencies. If the land sinks as a consequence of the deposition of strata, there will be little difficulty in attributing upheaval to the effects of denudation, when the many thousands of feet of strata which have been removed are taken into consideration. The enormous amount of denudation to which Palæozoic strata in South and North Wales have been subjected was made apparent in the well-known sections by (Sir) A. C. Ramsay, in which the mass of material displaced has been illustrated by contour lines,¹ and may be recognized as having taken place to a greater or less extent in all the older rocks.

Captain C. E. Dutton states that "those areas in the Colorado district which have been uplifted most have been most denuded; he thinks we ought to turn the statement round and say that those regions which have suffered the greatest amount of denudation have been elevated the most; thereby assuming the removal of the strata as the cause and the uplifting as the effect."²

An examination of hilly districts demonstrates that Captain Dutton's remarks have a general application in different areas in our own country. Where denudation has been greatest, elevation prevails to the greatest extent, and the oldest deposits not unfrequently form the highest ground; or hills, sculptured during a previous geological era, and subsequently depressed beneath accumulated strata, have again risen as these deposits have been removed, and the former crest stands conspicuous as the summit of a mountain.

In North Derbyshire, near Buxton, the highest portion of the Carboniferous Limestone, forming the "water parting" between the east and west of England, is 1500 feet above the sea-level, and is surmounted in the neighbourhood by ridges only, composed of Millstone Grit, some of which run up to 1800 or even to 2000 feet.³ The whole thickness of later Carboniferous strata,—the Yoredales, Millstone Grit and Coal-measures, amounting to more than 5000 feet,—has been removed by denudation; but on every side such strata dip away from the dome-shaped mass to lesser elevations.

In the district of Craven in Yorkshire the Carboniferous Limestone

¹ Memoirs of the Geological Survey, vol. i. plates 4 and 5, vol. iii. plate 28. Referred to by Fisher, *op. cit.* p. 222.

² The Geological History of the Colorado River, *Nature*, vol. xix. 1879, p. 251.

³ Memoirs of the Geological Survey, North Derbyshire, p. 2.

rests horizontally on eroded edges of greatly contorted Silurian strata which, at the commencement of its formation, were situated at the then sea-level, their fragments, consisting of large blocks (some being 3 or even 5 feet in their longest diameter, with pebbles and smaller particles entering largely into the composition of the lower beds of limestone.¹

The curvatures in the Silurian rocks having been formed previous to the commencement of the deposition of the limestone, it is evident the agency which caused them has had no influence in producing the present elevation of the land. The limestone, which is 600 feet thick, continued to subside under the accumulation of later Carboniferous strata, of the Yoredales, Millstone Grit, and Coal-measures, which has been estimated to reach a depth of at least 3500 feet. North of the Great Craven fault, not only have all these strata been removed by denudation, but the Carboniferous Limestone forms a plateau, now raised to about 1400 feet above the sea-level; the elevated ridges resting conformably upon it; such as Penigent (2273 feet), Ingleborough (2375 feet), and Wharfedale (2414 feet), being mere remnants of strata, formed subsequently to the limestone, which have resisted destruction.

Another illustration may be given of subsidence occurring whilst deposition was in progress, and of rising of the land during denudation. The metamorphic rocks which constitute the Malvern range were sculptured nearly to their present contour, but formed an island during the deposition of Upper Silurian strata; this was demonstrated by Miss A. Phillips, whose discovery proved that their base consisted of "a conglomerate full of Silurian shells, the pebbles being fragments of the rock-masses of the Malvern Hills."² Deposition progressed, and the land must have sunk to a great extent to permit the formation of the Upper Silurian and Old Red Sandstone strata, so greatly developed in the neighbourhood. But these, in a much contorted state, were again uplifted, and at the same time greatly denuded; but the elevation or formation of the hill is in nowise dependent on the foldings of these rocks, for the ridge again stood forth as an island from what may have been a near approach to the sea-level of the time, when, upon the upturned and eroded edges of these Silurian and other rocks, conglomeratic breccia,³ and sandstones were deposited during the New Red Sandstone period, depression of the land occurring simultaneously. The land has since undergone a great amount of denudation, and the district has been raised to its present elevation. Such or similar methods of interpretation appear to be generally applicable in assigning a cause for the formation of mountains or other elevated ground.

The cause more generally assigned for subsidence of the crust of the earth is secular cooling of its mass. This cannot also account

¹ On a group of Slate Rocks, between the Rivers Lune and Wharfe, by John Phillips, F.G.S., Trans. Geol. Soc. second series, vol. iii. pp. 10 and 13.

² Memoirs of the Geological Survey, The Malvern Hills, etc., by John Phillips, F.R.S., vol. ii. part I, p. 66.

³ Hafield Conglomerate of Phillips.

for the accumulations which so constantly accompany it, nor is it conceivable that the continuance of the same agency would occasion its re-elevation. If in any case depression has been due to such influence, it may be looked for in the extreme depths of the ocean, where the constant temperature nearly approaches the freezing-point; certainly not in the Arctic regions, where the mean annual temperature is very much lower; for though Greenland is sinking, Norway and Spitzbergen are rising; so also are extensive districts near to or within the Arctic circle—Labrador, Hudson's Bay, the Arctic Archipelago and the shores of Behring's Straits¹—affording unmistakable testimony to elevation of the land within a recent period; in some cases affording evidence that such is now in progress. It has recently been estimated that the shores of Hudson's Bay have risen in places from five to ten feet within the century.²

Near the mouths of large rivers, in deltas and in bays, and during former geological periods, where strata have been deposited, depression has been persistent, even though such a thick covering has been overlaid as would retain the central heat and exclude the external cold.

Deposition and subsidence having been constant and contemporaneous during all geological periods, the phenomena can only be attributed to and associated together as cause and effect. Whether it be strata laid down in the sea, those forming deltas near the mouths of large rivers, or a thick covering of snow that has fallen on the land, the accumulated weight presses down the crust of the earth.

It is also nearly as certain that elevation of continents is to be attributed to denudation to which the land has been subjected, causing a relief of pressure, whether by the disintegration of the rocky mass or by dissolution of glaciers; in the former case it might be further assisted by the transfer of the molten substratum as a consequence of depression in another area.

In an address delivered at Sheffield more than three years ago, having reference to the Coal formation, it was remarked that "the more the subject is considered, the more astonishing does it become for the regularity of the subsidence; and its amount must have kept pace with the thickness of the accumulating deposits;"³ but these concurrent phenomena demand more than wonder, they require serious and careful attention such as is yet to be bestowed upon them. This is the more necessary, as in them may be found the great motive power which not only produces changes of level in the earth's crust, but also permits and induces many other alterations in its physical condition.

Mr. H. B. Woodward, F.G.S., quite recently, in the Transactions

¹ Recent Elevation of the Earth's Surface in the Northern Circumpolar Region, by Henry H. Howorth, Arctic Manual, 1875, Reprinted from the Journal of the Royal Geographical Society, vol. xliii. 1873.

² The Times, Jan. 14, 1880.

³ President's Address to Section C, at Sheffield, by Professor P. Martin Duncan, F.R.S., British Association Report, 1879, p. 330.

of the Norfolk and Norwich Naturalists' Society,¹ has specially alluded to my opinions respecting the dependence of upheaval and of subsidence upon the denudation and the deposition of materials; and has also re-directed attention to the subject in a favourable manner by a letter in the *GEOLOGICAL MAGAZINE*.² Having formerly (1873) criticized my views adversely, these recognitions of them must be considered to be greatly enhanced in value.

IV.—TRACES OF A GREAT POST-GLACIAL FLOOD.

PART 6. THE EVIDENCE OF THE ROLLED GRAVELS AND THE SANDS.

By HENRY H. HOWORTH, F.S.A.

IN a previous paper of this series I endeavoured to show that the so-called Marine Drifts found at high levels, on both sides of the Irish Sea and elsewhere, are proved by their testaceous contents to have had no connection with the Glacial Age; while the mode of their distribution shows that ice in no form can have distributed them as we find them, nor yet are they consistent with the submergence of the land for any considerable time beneath the sea; and I concluded that the only power known to us capable of distributing them is a wide-spread flood of water. I now propose to carry my argument considerably further, but before doing so, as it is so easy to be misunderstood, I must guard myself against the supposition that in what I have said or mean to say I am minimizing the Great Glacial Age.

Any one who will cursorily examine the present distribution of the Pliocene deposits, their disintegrated and broken character, the wide areas which are now entirely free from them, and yet the very specialized fauna and flora which characterize the broken fragments, will agree that a gigantic denuding agency has swept over the whole northern hemisphere, occupied by a continuous land surface in Pliocene times. This apart altogether from the more direct evidence of denuding forces we have in the products of the Glacial age. That Glacial age which intervenes between Pliocene and Post-Glacial times, and is such a marked and complete barrier between them, was no doubt the distinctive era when not only Pliocene but earlier Tertiary beds were scoured out and torn to mere shreds of their former extension. As we cannot suppose that the forces of Nature working on the same materials could have worked in a different fashion to that they work in now, we are driven, in view of the very greatness of the effects, to postulate that these forces, although precisely like those now current in form, were immensely different in degree. This is quite plain, whether we belong to the extreme school of Glacialists or no. It seems equally clear that a large portion of the work done was done by ice: we know of no other agency competent to do it. The smoothed and rounded rocks and other proofs of denudation that prevail so widely in the landscapes of the high latitudes of Europe and America are explainable

¹ The Scenery of Norfolk, vol. iii. p. 460.

² Dec. II. Vol. X. p. 93, 1883.