III.—ON THE RELATION BETWEEN THE OLDER AND NEWER PALÆOZOICS OF WEST CORNWALL.¹

By J. B. HILL, R.N., of the Geological Survey.

(PLATE XIV.)

Introductory.

THE author, who has long been engaged on the Palæozoics of West Cornwall, divided the killas extending westward from Gerrans Bay into four groups that formed a natural sequence.² Moreover, as they included definite Lower Silurian horizons, as characterized by the fossiliferous quartzite of Carne, these divisions were linked with the Lower Palæozoics. They consist of the Veryan, Portscatho, Falmouth, and Mylor groups. On the latest issues of the old Survey maps the area occupied by the first of these divisions is coloured as Silurian, and the region occupied by the remainder as Devonian. That colouring, however, was not adopted by De la Beche, who surveyed the region, nor was it the result of any subsequent survey of the area. In the original Geological Survey map of Cornwall the killas was separated by De la Beche into two divisions, viz., a grauwacke group and a carbonaceous series. Thus, the former lying below the Culm-measures was undifferentiated for the reason, as explained in his Report,³ that the progress of geology at that time only warranted the broadest generalizations. He moreover expressed the opinion that the terms Cambrian and Silurian should be restricted to the areas that gave rise to the prolonged researches of Murchison and Sedgwick, and deprecated the extension of that nomenclature to districts that had not received the same detailed investigations. In a later and undated issue of the map the grauwacke group is divided into Devonian and Silurian, presumably by the authority Sir Roderick Murchison. The Devonian colour was not only applied to fossiliferous strata in East and Mid Cornwall, but was extended over the unfossiliferous strata in the west. The Silurian tint, on the other hand, was restricted to a zone that had yielded organic remains. Murchison, however, was of opinion that the older zone extended far beyond those limits into the barren strata coloured as Devonian,⁴ and it is evident that the latter tint was adopted as a matter of convenience, as no re-examination of the area seems to have been undertaken. The known Silurian region was confined to the coastal belt between Chapel Point and Gerrans Bay, a boundary connecting those localities admitting of the ready isolation of that zone from the rest of the country. That such a broad generalization, however, was only regarded as provisional may be inferred from the absence of a line on the map between the two divisions. It will be seen, therefore, that the subdivision of the killas, as the result of the

¹ Communicated by permission of the Director of the Geological Survey.² Summary of Progress, 1898, p. 97, and Trans. Roy. Geol. Soc. Cornwall, vol. xii (1901), pt. 6.³ "Report on the Geology of Devon, Cornwall, and West Somerset," pp. 38–41.⁴ Trans. Roy. Geol. Soc. Cornwall, vol. vi, p. 322.

recent survey, neither invalidates the map published by De la Beche nor the subsequent conclusions of Murchison. It has, on the other hand, not only brought their generalizations within more definite limits, but has carried the investigation a step farther by demonstrating the relations between the older and newer Palæozoics of Cornwall.

As the lithological characters, the structural features, and the mutual relations of the divisions into which the killas has been differentiated have already been the subject of former communications, both to the Royal Geological Society of Cornwall¹ and to the Summaries of Progress of the Geological Survey,² they will only be treated briefly in this paper. They will, moreover, be fully described in the Survey memoirs, but, as the results of recent investigations constitute an important advance in the elucidation of the geology of the West of England, it will be convenient to present at once an outline of these conclusions, as the official publications will not be immediately forthcoming.

The main object of this paper is to demonstrate the existence of an important unconformity dividing the Upper and Lower Palæozoic formations of West Cornwall. Evidence will also be submitted pointing to the natural sequence of the four divisions of the Lower Palæozoics, and to the Lower Devonian age of the conglomeratic series of Manaccan and Grampound.

Lithology of the Lower Palæozoic divisions.

The lithological characteristics of the divisions will now be briefly touched upon.

Vernan Series.—This group consists of blue and grey slate with sandy alternations, thin dark limestones, and dark-coloured cherts. Notwithstanding the occurrence of chert and limestones the sandy interlamination are frequently coarse, but being largely composed of soft grains are readily cleaved. This series, which also includes the Carne quartzite, is further characterized by the presence of manganese, which stains the slate.

Portscatho Series.—These consist of blue and grey clay slates, alternating with harder beds showing every gradation from a sandy slate to a fairly strong grit. The latter are characterized by the predominance of quartz and the comparative abundance of elastic mica. The marked feature, however, which distinguishes them from the Vernan Series is the absence of limestone, except at their mutual junctions. This dearth of calcareous material also applies to the Falmouth and Mylor divisions.

Falmouth Series.—This series consists of argillaceous and fine sandy alternations, varying in colour from green to grey and buff, although blue argillaceous beds sometimes appear. The contrasting tints produce a variegated appearance common to this group. Their mode of decomposition is equally characteristic. The sandy seams become readily friable, are unctuous to the touch, and weather into

¹ See paper already cited.

² From 1897 onwards.

a deep buff colour. The material is of finer texture than the Portscatho Beds, and the coarse structure often seen in the latter is not represented. The presence of zones of strongly contrasted purple and green slate is likewise a distinctive characteristic of this group.

Mylor Series.—This division consists of blue argillaceous and fine-textured sandy beds. The latter are often very siliceous, and occasionally thin quartzites are developed. The most distinguishing feature of this series is its striped and ribbon-like appearance, due to fine alternations of siliceous and argillaceous material, or to argillaceous laminae varying in composition and colour. This composite structure, while a marked characteristic of this division, is frequently developed both in the Portscatho and Falmouth divisions. In this series it has often contributed to the production of pseudo-conglomerates, following conditions of stress.¹

Natural sequence of the Lower Palæozoic divisions.

The four divisions already referred to pass uninterruptedly into one another without any stratigraphical break. The junction between the Vryan and Portscatho groups is well exposed at Pendower in Gerrans Bay. Although the two groups there occupy adjoining horizons, and the former are coloured as Silurian and the latter as Devonian in the old map to which attention has been drawn, their natural sequence is demonstrated by the gradual dying out of the Vryan limestones to the west, and which are still represented in an attenuated form within the Portscatho Series, thus serving as a connecting link between the two groups. Not only do the Vryan Series pass uninterruptedly into the Portscatho group, but these latter also graduate imperceptibly into the Falmouth Series, which in their turn merge insensibly into the Mylor Beds. Notwithstanding the comparative absence of palæontological data the researches of Mr. Howard Fox and Dr. Hinde on the Radiolaria tend to confirm the unbroken sequence of these deposits. The Radiolarian remains have been determined by Dr. Hinde from localities scattered throughout these divisions, but these organisms have not been detected on any known Devonian horizon. Besides Radiolaria, Crinoidal and other fragments are occasionally found in these divisions,² but their occurrence is extremely rare. The quartzite of Carne in Gerrans Bay, which has yielded Caradoc fossils, was included within the Vryan Series, as it appeared to fall naturally into that division.³ The detailed investigation of that area has been subsequently undertaken by Mr. Reid, whose results do not invalidate that sequence.

Relations of the Newer and Older Palæozoics in the Manaccan area.

Having now given a brief outline of the Lower Palæozoic divisions, in so far as they have been investigated by the author,

¹ An account of these structures will be found in the *Trans. Roy. Geol. Soc. Cornwall*, vol. xii (1901), pt. 6.

² Excluding the Carne quartzite.

³ J. B. Hill: *Trans. Roy. Geol. Soc. Cornwall*, vol. xii (1901), pt. 6.

their precise relations with the Devonian formation will now be discussed. While engaged last season on the survey of the tract bordering the Helford basin, the killas was carried south to Porthallow and westward as far as Tregidden. At Porthallow a fault divides the killas on the north from mica-schist on the south. The rocks lying to the south of that disturbance are not dealt with in this paper.

The sedimentary divisions from the Carnmenellis granite, on the north-west, to Porthallow on the south-east, occur in the following topographical order:—

Mylor Series.

Falmouth Series.

Portscatho Series.

Manaccan Series.

Veryan Series, including the Quartzite.

Of these groups the Manaccan Series represents the Newer Palæozoic,¹ and the remainder are confined to the Older Palæozoic. The strike of the latter is about north-east and south-west, while that of the former is slightly oblique and approximates to an east and west direction.

The Mylor Series, through which the granite has intruded, occupies a band gradually widening in a south-westerly direction from Porthnavas to Gweek. Excellent coast sections across the entire band are afforded by Polwheveral Creek, showing the whole metamorphic aureole as well as the zone beyond.

The Falmouth division that succeeds to the south-east forms a narrow band, but widening likewise in a south-west direction. It extends from Mawnan Smith to Mawgan Creek, and is almost entirely confined to the north side of Helford River. Besides the main zone, infolded lenticles occur in the vicinities of Helford, Durgan, and Bream Cove. Excellent transverse sections are exhibited along the coast at Calamansack.

The Portscatho Series succeeds the Falmouth group to the south-east and forms the coastline as far south as St. Anthony. To the westward it practically monopolises the southern side of Helford River, and the northern shore as far as Porthnavas Creek. It also reappears as a small strip at Porthallow, where it is separated from metamorphic rocks of the Lizard type by a fault.

The Manaccan Series.—The natural sequence represented by these three Lower Palæozoic groups is now broken, and another assemblage makes its appearance, which may be designated the Manaccan Series. It rests unconformably on the Portscatho and the Veryan divisions (including the Carne quartzite), and is largely made up of their detritus. The group occupies a band extending westerly from the coast at Nare Point, whence it has been mapped, as far as St. Martin. Passing to the north of Manaccan it is seen along the shores of Gillan Creek, and around the Nare Point to a little beyond the Nare Head. Its southern margin from the coastline to Treglossack skirts the Veryan Series, and thence to the

¹ The evidence in support of this assumption will be given later.

westward is in contact with the Lizard group. Besides this main outcrop small infolds also occur amongst the Vryan Series. Lithologically, the group consists of conglomerate, sandstone, and clay slate, the two latter being often calcareous, and they are all so clearly interbedded that their natural sequence is obvious. The most important member is undoubtedly the conglomerate, from the evidence it affords of the derivation of the group. Its character and main constituents have been given in a former publication,¹ since which it has yielded chert, mica-schist, and possibly serpentine. The latter ingredient, however, being obtained from a road section, the evidence is possibly not conclusive. At its northern margin, where the conglomerate is in close relation with the Portsatho Series, it is almost entirely composed of fragments derived from that group. This is admirably exhibited at Gillan harbour, where the magnitude of the boulders, often exceeding a foot in size, enables their ready identification with the Portsatho Beds in their immediate vicinity, in which practically every type of the latter is seen to be incorporated. The fact, moreover, that the fragments were veined with quartz prior to such incorporation sufficiently indicates the magnitude of the break represented by this unconformity. The conglomerate is likewise seen in contact with the Portsatho Beds on the coastal shelves at Men-aver Point and Nare Point. It has been remarked that the conglomerate varies with the nature of the underlying rock from which it is derived. Whereas at Gillan Creek, where it rests on the Portsatho Series, fragments of that group preponderate, as the Vryan Series and quartzite horizons are approached it partakes more of the character of those types, and the foreign fragments derived from the Lizard rocks increase in a similar direction. The conglomerate is by no means continuous, but the base of the formation is frequently of fine texture. This is shown by the protruding bosses of quartzite, some of which are encircled by the sandstone beds of the Manaccan Series. There is, moreover, a tendency for the coarser deposits to die out in a westerly direction, as was long ago recorded by De la Beche,² the frequent absence of which presents difficulties in the demarcation of the Manaccan Series from the older Palæozoics that underlie them, and especially where good sections are not available.

The Manaccan Series present a less advanced type of metamorphism than that of the Lower Palæozoic divisions amongst which they occur. This difference in deformation between the older and newer Palæozoics, although not always of a very marked type, was early recognized by the author as a significant factor, more especially in the comparison of the killas of Mid Cornwall with that occupying the western regions, which pointed to the conclusion that the latter represented conditions of stress that were either not experienced by the former or prevailed in a less vigorous degree. In the Manaccan area this contrast is admirably illustrated by the comparatively unaltered condition of the clay slates associated with the

¹ J. B. Hill: *Trans. Roy. Geol. Soc. Cornwall*, 1901.

² "Report on the Geology of Cornwall, Devon, and West Somerset," 95.

conglomerate and the more advanced type of deformation represented by the adjoining Portscatho and Vryan divisions. Mr. John Pringle has obtained numerous plant remains from these rocks, together with a few corals and brachiopods, but beyond indicating a marine fauna they throw no light on their geological age. The argillaceous members were searched for graptolites, but without success.

The Manaccan Series is also characterized by the presence of a basic lava that occupies a well-marked horizon between Roskruge and Tregidden. Its contemporaneous nature is clear, not only from its having been involved with the coarser deposits, and frequently partaking of a conglomeratic margin, but scoriaceous boulders clearly derived from it have been incorporated with the adjacent conglomerate. The rock is a very fine-grained basalt, often andesitic, and belongs to the 'pillow lava' class. As this rock is the sole greenstone in West Cornwall that can be definitely separated from the intrusives, it is possible that the contemporaneous greenstones are restricted to the Devonian.¹ Moreover, its comparatively undeformed condition still further illustrates the less advanced metamorphism presented by the Devonian rocks to that of the Lower Palæozoics.

The Vryan Series of Meneage.—The quartzite is almost entirely hidden beneath the Manaccan Series, through which it emerges in numerous lenticles from Penare on the east to Trevaddra on the west. Besides being veined with quartz it is often extremely brecciated, but in this condition loses nothing in compactness, the interstices being filled up with silica. This character was attained prior to the formation of the overlying conglomerate.

The Vryan Series is exposed along the coast from a little north of Nare Cove to Porthallow Cove, whence it extends inland as far as Treglossack, and is there overlain by the Manaccan Series. This small tract is highly disturbed, while local thrusts and brecciation with production of pseudo-conglomerate are prevalent, and it is, moreover, not solely confined to the Vryan group. The quartzite appears between Nelly's Cove and Porthallow Cove. Thin limestones are seen from Nelly's Cove to Nare Cove. Radiolarian cherts are distributed over the section, and are strongly developed at Nelly's Cove. The Portscatho Series and strips of the overlying conglomerate can also be detected, more especially at the south of Porthallow Cove, where the former is contiguous to the Lizard group. It is probable also that this highly disturbed tract may contain representatives of other zones,² but the Vryan Series undoubtedly preponderates. At Gallentreath, between Nelly's Cove and Porthallow Cove, a greenstone of pillow lava type is seen that recalls the pillow lava of Mullion Island. Another highly silicified igneous rock that is closely adjacent resembles a similar band mapped by Mr. Reid at Perhaver. Like the rock at Mullion Island, the Gallentreath

¹ The evidence pointing to the Devonian age of the Manaccan Series will follow.

² *Geol. Mag.*, 1904, No. 481, in which Mr. C. D. Sherborn has referred fossils obtained from this district to Ludlow age.

greenstone is in close proximity to Radiolarian cherts, but the evidence is insufficient to decide whether it is intrusive or contemporaneous.

The Devonian base on the Grampound and Probus horizons.

The evidence obtained from the Manaccan area, where the Upper Palaeozoic rocks occur as a great outlier amongst the Lower Palaeozoic group, has thrown light on the nature of the junction further to the north that marks the main boundary between those formations. The fine-grained conglomerate of Grampound and Probus was recognized in 1902 as the equivalent of the conglomerate of the Manaccan Series. This inference was amply confirmed by microscopical determination undertaken by Dr. Flett. It contains a similar assemblage of rock fragments, resembling one another so closely as practically to preclude the possibility of their derivation from different sources, or from the same source at widely different periods. It was at the same time recognized that it might represent an unconformity between the Silurian and Devonian rocks of Cornwall, an inference which the recent detailed investigation of the Manaccan area has shown to be correct. This fine-grained conglomerate is associated with slightly calcareous sandstones and clay slates, and the whole assemblage is precisely equivalent to that represented by the Manaccan Series, except that in the latter, besides the fine-grained conglomerates like those of Probus and Grampound, these beds frequently present an extreme coarseness, many of the included boulders exceeding a foot in size. As already remarked, the conglomerate of that area is by no means continuous, but the base of the formation is frequently of fine texture. There is, moreover, a tendency for the conglomerate to die out in a westerly direction, so that the demarcation of the Manaccan Series from the older Palaeozoics is attended with difficulty in the cultivated areas. These conditions are exactly reproduced in the Probus horizon. The coarse conglomerates, analogous to those of Manaccan, occurring only in the district further to the east, where they have been mapped by Mr. Reid in the Gorran Sheet (353), while in the western direction towards the Bristol Channel even the fine-grained conglomerates of Probus and Grampound disappear. The rock series of Probus likewise corresponds in strike with that of Manaccan, having a general east and west trend and oblique to that of the adjoining Lower Palaeozoic strata. The southern boundary extends from Porth Towan on the west to Probus on the east, whence it has been traced by Mr. Reid to the north of Tregoney, where it sweeps to the south, and thereafter follows an irregular course to the coast at St. Michael Caerhayes.

The Grampound and Probus Beds have hitherto yielded no organic remains except at Ladock, where an indeterminable brachiopod has recently been discovered. To the north, however, the work of Messrs. Reid and Scrivenor shows that they link on with Lower Devonian fossiliferous horizons in the Newquay district. They, moreover, have close affinities to the Devonian, not only in their

prevailing strike, but also in lithological type and metamorphic condition. For these reasons they are taken to represent the basement beds of that formation.

Relative deformation of the Older and Newer Palæozoics.

It has already been pointed out that the Lower Palæozoic rocks exhibit a greater degree of deformation than do the overlying Devonian. It can be shown by the included boulders in the Devonian conglomerate that the Caradoc quartzite was brecciated and the interstices cemented by silica prior to their incorporation in that deposit. It has likewise been shown from the same evidence that the Portscatho Beds had been welded into solid rock and veined with quartz before the formation of that conglomerate. The Lower Palæozoic beds, therefore, must have been buried deep within the crust and compressed into solid rock, and subsequently upheaved to form the floor of the Devonian seas. At the close of the Carboniferous period these rocks, in common with the overlying Devonian, were again brought within the influence of crustal disturbance, by which they were folded, fractured, and cleaved. As a result of this twofold experience in the subterranean depths almost all traces of organic life appear to have been obliterated. So far as the Mylor, Falmouth, and Portscatho divisions are concerned, and even the Veryan Series if we exclude the quartzite, the sole relic of life that has survived, except an occasional crinoid fragment, is confined to the Radiolaria, the preservation of their casts being in no small measure due to the minuteness of these tiny creatures, and to the siliceous nature of the cement in which they are usually encased.

Age of the Lower Palæozoic divisions.

The age of the Lower Palæozoics cannot be precisely defined. The Quartzite is of Lower Silurian age, and palæontologists are agreed that the fauna is Caradoc.¹ If its inclusion in the Veryan group be correct—and there is no evidence at present pointing to a discordance in the sequence—there is a natural succession from the Quartzite on the one hand to the Mylor Series on the other. The discovery of Upper Silurian fossils by Messrs. Upfield Green, Sherborn, and Reid in areas closely adjoining to the Caradoc Quartzite would appear to indicate a downward succession, of which the Mylor Series represents the base, and that the Lower Palæozoic divisions referred to in this paper are Lower Silurian. As the survey, however, of the older Palæozoics in the Meneage peninsula has not yet been completed, it will be safer to defer further consideration of this subject until the evidence has been exhausted. It will be sufficient for the present to have demonstrated the limits of the Devonian, and to have shown that the killas of West Cornwall is chiefly restricted to the Lower Palæozoics, of which at least one member is of Caradoc age.

¹ The Lower Silurian age of this quartzite was proved by the late Mr. Charles W. Peach, to whose palæontological researches Cornish geology owes so much. Murchison noted that the Gorran fossils were Upper Caradoc, and those of Gerrans Bay (Carne quartzite) were even younger (*Trans. Roy. Geol. Soc. Cornwall*, vol. vi).

Work of other observers in the district.

The geological literature of West Cornwall is so voluminous that it would be impossible within the compass of this paper to do justice to the work of previous observers. In 1821 the Nare Point conglomerate was referred to by Sedgwick, who noted its mechanical origin and its passage into the ordinary grauwacke of the district.¹ It is evident from a perusal of De la Beche's Report, that had he differentiated the Silurian strata from the Devonian, he would have included among the former some of the killas in the Meneage peninsula. As already remarked, Murchison expressed the opinion in 1846 that much of the strata between Gerrans Bay and Falmouth would prove to be of Silurian age. The killas of West Cornwall has formed the subject of various papers by Mr. J. H. Collins, whose researches, extending over many years, prove the zeal and enthusiasm with which he attacked this thorny problem. In 1881 Mr. Collins published a sketch-map with his paper on the Geology of Central and West Cornwall,² in which he not only divided the killas into numerous units, but assigned them respectively to the Devonian, Upper Silurian, Lower Silurian, and Cambrian formations, that were separated from each other by unconformities. Although Mr. Collins' general conclusions cannot be sustained, he subsequently correlated the conglomeratic series of Meneage with the Ladock Beds (the latter being, in part at least, equivalent to the Grampound and Probus grits), and assigned them to the Lower Devonian.³ He recognized also that the killas of West Cornwall was mainly of Lower Palæozoic age, and had he confined himself to that broad generalization his paper would have ensured a more lasting recognition. He also placed the Ponsanooth Beds, which to some extent represent the Mylor Series, at the base of the killas, which may probably be correct. Mr. A. Somervail⁴ controverted some of Mr. Collins' conclusions, but agreed with him as to the Pre-Devonian age of a large part of the killas, and assigns a Lower Silurian age to the slates from Gerrans Bay to the vicinity of Penryn, most of which had been similarly classified by Mr. Collins, and Mr. Somervail suggested that they were of Llandeilo age. In 1891 Mr. Ussher published a sketch-map with his paper,⁵ dealing with the Devonian rocks as described by De la Beche and supplemented by his own researches on that formation. In that map Mr. Ussher has likewise shown the western killas (now representing the Mylor, Falmouth, and Portscatho Series) as (?) Pre-Devonian, and has placed the Grampound grits at the base of the series classed as undoubted Devonian. Mr. Upfield Green has claimed the beds represented by the Mylor, Falmouth, and Portscatho Series as Lower Devonian, of which the Dartmouth slates represent the upper member, while the base is marked by the conglomerate

¹ Trans. Cambridge Phil. Soc., vol. i.

² Journ. Roy. Inst. Cornwall, vol. vii, p. 17.

³ Journ. Roy. Inst. Cornwall, vol. viii, p. 186.

⁴ Journ. Roy. Inst. Cornwall, vol. vii, pp. 262-273.

⁵ Trans. Roy. Geol. Soc. Cornwall, 1891.

of Meneage, etc.¹ Mr. Green's conclusions were criticized by Mr. Ussher, who contended that the superposition of the Dartmouth slates to the Mylor, Falmouth, and Portscatho Series was not supported by proof.² Mr. Ussher recalled that although he formerly correlated the Grampound grits with the Gedinnien, he would now hesitate to do so, the inference apparently being that they might occupy a higher horizon. In that paper Mr. Green refers to the Portscatho and associated series as consisting "chiefly of grits varying much petrologically, but mostly felspathic," and correlates them with arkose or felspathic grits that occur next to the conglomerate on the Continent. As the conglomerate is now shown to be unconformable to the Portscatho Beds, it is of little importance to point out that the latter are more properly defined as siliceous grits, in which felspathic constituents play only a subordinate part, so that their correlation with the Continental arkose referred to cannot be supported on petrological grounds. In 1894 Mr. Clement Reid pointed out that towards Gorran Haven "shore conglomerates, belonging probably to upper part of Lower Devonian, rest directly on Ordovician or still older rocks."³

Finally, the researches of Mr. Howard Fox on the Radiolarian cherts of West Cornwall, and the assistance he has received in their determination by Dr. Hinde, must be referred to. Mr. Fox has shown that not only are these organisms confined to the horizon of the pillow lavas, which indicates such a remarkable association with Lower Silurian horizons in the south of Scotland and elsewhere, but he has proved their existence throughout the Silurian sequence of West Cornwall. The fact, moreover, that the most patient search has failed to detect their presence in the Devonian strata has furnished additional evidence in support of the differentiation of those systems in this region. On the assumption that the Old Red Sandstone was deposited in great inland basins it is possible that the British Devonian rocks, being so closely adjacent to the Welsh lake basin, were laid down in a partially enclosed sea like the Mediterranean, from which the oceanic organisms might have been almost entirely excluded.

Summary and Conclusion.

The main conclusions may be epitomised as follows:—

1. The Lower Palæozoic divisions, including the Veryan, Portscatho, Falmouth, and Mylor groups, form a natural sequence.
2. The Upper Palæozoic, represented by the Manaccan Series, rests unconformably on the Lower Palæozoics, and its constituents have been largely derived from the Veryan and Portscatho groups.
3. The Veryan and Portscatho groups were consolidated and veined with quartz, prior to their denudation and incorporation in the Manaccan conglomerate.

¹ *GEOL. MAG.*, 1904, p. 403.

² *GEOL. MAG.*, 1904, p. 590.

³ Summary of Progress of Geological Survey for 1904, pp. 22–23.

Geological Sketch-map of the district bordering the Helford Basin.

4. The Manaccan Series are repeated on the horizons of Probus and Grampound, from which they extend across the county to either coast.

5. The Manaccan Series represent the basement beds of the Lower Devonian, and the Lower Palæozoic groups include Lower Silurian of Caradoc age, but whether the succession is ascending or descending has not been definitely proved, although the evidence suggests a descending sequence.

Before concluding, it may be remarked that the facts, herein presented, involved such a complete change in the colouring and interpretation of the old geological maps that a special investigation of the evidence on which the conclusions are based was undertaken at the request of the Director by Mr. H. B. Woodward and Mr. Clement Reid. As the result of that investigation they were satisfied that the conglomerate was partly derived from the underlying Vryan and Portscatho Beds, and that those groups, together with the associated Falmouth and Mylor Series, are of Pre-Devonian age. The conclusions, therefore, which form the subject of this communication not only embody the opinions of the author, but command the support of his official superiors of the Geological Survey.

EXPLANATION OF PLATE XIV.

Sketch-map to illustrate the geology of the Manaccan district.

IV.—FOSSIL ECHINOIDEA FROM SINAI AND EGYPT.

By J. W. GREGORY, D.Sc., F.R.S., F.G.S.,
Professor of Geology, Glasgow University.

(PLATES X AND XI.¹)

THE collections of Echinoidea described in the following report were made by Messrs. Barron, Beadnell, and Hume during their work for the Egyptian Geological Survey, and were entrusted to me for description by the Director, Captain Lyons, R.E.

The collections belong to three main series—(1) Cretaceous, (2) Eocene and Miocene, and (3) Pleistocene. The Cretaceous Echinoids come from the massif of Abu Roash, and from Sinai. The specimens from Abu Roash were collected by Mr. H. J. L. Beadnell, and mostly came from the eastern end of the massif near the village of Abu Roash. The best known fossil from this horizon is *Coptosoma abbatei* (Gauth.), and the bed from which it comes has been assigned to both the Cenomanian and the Turonian. The sections published by Fourtau² show that the beds belong to the older part of the Cretaceous massif of Abu Roash; but he places the *C. abbatei* beds in the Turonian³ or Lower Senonian.⁴ Walther,

¹ [Plate XI will appear with the second part of Professor Gregory's paper in the June Number of the GEOLOGICAL MAGAZINE.—EDITOR.]

² Fourtau: Notes Echin. foss. Egypte, 1900, p. 17.

³ Fourtau: *ibid.*, p. 21; and Crét. massif Abu Roash, C.R., vol. cxxxi (1900).

⁴ Fourtau, Révision Echin. foss. Egypte: Mém. Inst. Egypt., vol. iii, fasc. 8 (1899), pp. 607, 623.