different stages of this sheared rock recur at intervals according to their position in the plications where they have suffered greater or less pressure.

The dolomite crystals most probably owe their origin to percolating water charged with salts of magnesia derived from the surrounding shales; and perhaps, in the case of the coral limestone, from the corals themselves, as a small quantity of magnesia is often present in the corallum.

Besides forming the intercalated beds of sandstone, silica is abundant in the limestones and clay-slates in the form of minute quartz-grains and crystals; and these would readily dissolve and re-crystallize during and after the processes of contortion and shearing, as is seen in the replacement and fringing of the oolitic grains.

It is interesting to note the close association of the oolitic granules in these beds with masses of the old reef-forming corals, an association similar to that found at the present time in tropical areas.

The patches of limestone in the shales undoubtedly owe their lenticular form to the forces which produced the shearing; but on account of the superior hardness of the limestone the surrounding shales have suffered more in being squeezed out of position, and have been altered into talc on the surfaces of the mass.

In concluding these notes it remains for me to express my obligations and thanks to Professor Judd, F.R.S., for his kind and valuable advice; to Professor Thorpe, F.R.S., for his kindness in supplying me with the analysis of the dolomitic limestone; and to my brother, Mr. R. S. Chapman, for his skill in producing the photographs from which the plate has been made.

EXPLANATION OF PLATE V.

- FIG. 1.—Oolitic limestone of Devonian age, practically unaffected by pressure, from Sampson's Cave. $\times 14$.
 FIG. 1a.—The same rock treated with acid to show the siliceous portion. $\times 14$.
 FIG. 2.—Oolitic limestone with incipient cleavage, from Watermouth Cave. $\times 14$.
 FIG. 3.—Sheared and dolomitized oolitic limestone, from Rillage Point. $\times 14$.
 FIG. 4.—Extreme condition of sheared oolitic limestone, with "eyes" of calcite, and dolomite, from Rillage Point. $\times 14$.
 FIG. 4a.—A portion of the same more highly magnified, to show the dolomite crystals with their centres occupied by ferruginous material. $\times 36$.
 FIG. 5.—Sheared limestone formed of encrinite remains and oolitic grains; the ossicles and stem-joints of the encrinites are almost unaffected by the shearing forces. From Rillage Point. $\times 14$.
 FIG. 6.—Sheared coral limestone, from Watermouth. $\times 4$.

III.—THE SUBMERGENCE OF THE BRITISH ISLES DURING THE GLACIAL PERIOD.

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

THE question of the submergence of the British Isles during, at least, one stage of the Glacial period, is deserving of careful consideration by geologists. Until the visit of the late lamented Prof. Carvill Lewis to this country, no one, as far as I am aware, questioned the view that the British Isles have been submerged to a depth, in some places, amounting to 1300 or 1400 feet—this being the level at which shell-beds are found in some parts of England, Wales, and

Ireland. Prof. Lewis, however, struck out a new theory to account for the existence of these high-level shelly-gravels, which has since been adopted by Mr. Kendall¹ and other geologists, according to which these shell-beds have reached their present altitude by the agency of the great ice-sheet, which is credited with the astonishing power of having carried these deposits from the bed of the Irish Sea, and then of having laid them down in their final resting-place high up amongst the mountain groups of Wicklow, Wales, and Central England. It might be objected to this view, that, in the first place, the matter deposited at the tail of an ice-sheet is moraine matter, not usually stratified shelly gravel and clay; in the second, that in the process of transportation, such deposits, borne along for miles in the body, or at the foot, of the ice-sheet, and carried up the mountain slopes, would be ground into the finest mud or powder; and it seems inconceivable that even a few minute fragments of shells, sufficiently large for identification, should have survived such a destructive process; but this objection is considered invalid, so that we must have recourse to others.

Well then, thirdly, the view advocated supposes either that the ice-sheet in the Irish Sea attained an original thickness of 1300 or 1400 feet in the vicinity of the mountains aforesaid *plus* an additional thickness for the depth of the adjoining sea-bed, or else that it rose up from the sea-bottom and ascended the flanks and valleys of the mountains owing to the *vis a tergo*, or some other force of propulsion. The thickness of the ice-sheet in the latitude of Snowdon must have been over 1500 feet according to this calculation (a very improbable view as it seems to me); or the ice must have pushed the shell-beds several hundred feet up the Welsh and Wicklow slopes; a phenomenon which, as far as I am aware, has no example at the present day. In making this statement, I do not deny the power of glacier-ice to move over low opposing ridges, as in the case of Bray Head, but in such cases the whole of the opposing ridge has been enveloped in the mass of moving ice; and the conditions are very different from those which would occur where the ice-sheet is confronted by the flanks of still higher ridges.

But without insisting too strongly upon this objection I have another to advance which is absolutely fatal to the transportation theory of Prof. Carvill Lewis and his followers. In the case of North Wales, those who are acquainted with its glacial phenomena, or who have studied the writings of the late Sir A. C. Ramsay, are aware that there is no evidence whatever of an ice-movement inwards from the Irish Sea; but that, on the contrary, the ice-movements radiated outwards from the mountain heights. Ramsay, indeed, clearly describes what he calls "the Drift," and shows that it consists of Boulder-clay, sand, and gravel filling the bottoms and sides of the valleys up to a level of about 1300—1400 feet; but that this Drift is of marine origin, formed during a period of submergence, he has no doubt whatever. When describing it as rudely stratified, and containing blocks and boulders carried by floating

¹ Glacial Geology, Old and New. GEOL. MAG. Dec. III. Vol. IX. p. 491.

icebergs, he says with reference to the question of submergence: "From circumstances presently to be mentioned, it is to me certain, that at a time when North Wales was so far submerged that only the higher mountain tops rose as islands, none of them more than about 2000 feet" above the surface, etc. (Old Glaciers of North Wales, p. 96). This is the deliberate opinion of one who, as Director of the Geological Survey, and as taking an active personal part in the work in North Wales for several years, had become familiar with every spot and section where the Glacial deposits were visible; and was investigating the phenomena of glaciation with the enthusiasm which their novelty at the time inspired. It is true that, as Ramsay himself determined, the ice-sheet of the Irish Channel was sufficiently thick to pass across Anglesea, and the low ground adjoining the Menai Straits in a S.W. direction; but there is no evidence whatever that it ascended the mountain slopes around Snowdon to a level of 1400—1500 feet above the present surface. It is in such Marine Drift deposits as those above described that the shells occur, not only at Moel-Tryfan, but in several other places, such as the valleys which descend from Carnedd Llewelyn, at elevations of about 1200—1300 feet and also in Denbighshire.

Then as regards Ireland, the evidence is quite as conclusive. The shell-beds which were discovered by Mr. John Kelly, and the Rev. Maxwell Close, at Caldbeck Castle, at 1300 feet, and in several other localities, not so elevated, amongst the Wicklow Mountains, are by no means solitary representatives of submergence. They are detached portions of the shelly gravels of Wexford which reach levels of 300—400 feet, and of the great deposits of sand and gravel which cover such large tracts of the central plain of Ireland, up to levels of several hundred feet, and in which sea-shells have been found at various elevations, as in the Dargle Valley, at spots west of the Sugarloaf Mountain, and south of Enniskerry, county Wicklow, up to heights ranging from 500 or 600 up to 1000 or 1200 feet according to Jukes (Manual of Geology, 3rd edit. p. 709). They have also been found in more inland places. But the presence or absence of shells in these deposits is of very little consequence; the beds are the same, whether shells have been found in them or not; and it is easy to conceive how shells, originally contained, may have been dissolved out of them by percolating rain-water. That the shell-gravels of the central plain of Ireland are the same deposits as those which contain shells in the higher elevations, and that they are the result of submergence is the clear opinion of the late Prof. Jukes (*Ibid.* p. 710). If they had been formed by an ice-sheet, that ice-sheet must have moved *from the sea* and spread itself over the land-surface of Central Ireland, but this is exactly the reverse of the case, as shown by the glacial striæ and the *roches-moutonnées*. These have all been observed and tabulated in detail over the whole country by Mr. Close, the Geological Surveyors, and others, and will be found laid down on my map of the General Glaciation of Ireland (Phys. Geol. of Ireland, 2nd edit. p. 211), from which it will be seen that the movement of the great ice-sheet was everywhere

from the land outward towards the present sea-coast. The direction of this movement, as determined by numerous observations is, I repeat, fatal to the transportation theory of Professor Carvill Lewis and his followers, which postulates a movement in an opposite direction. For myself I feel satisfied that the submergence view is the only one which meets the requirements of the case. I will only add a few words more in order to remove an erroneous impression to the effect that a submersion of 1300—1400 feet in the latitude of Snowdon and Wicklow involves a similar amount of depression to the north and south of that parallel. There is no such inference required. In the parallel referred to the depression (assuming the level of the ocean to have been constant) appears to have reached its maximum for the British Islands, gradually lessening northwards into Scotland, where, according to Prof. James Geikie, it was over 510 feet, marine shells being found in the Glacial series up to this level; in Norway they are found at 580 feet.¹ In an opposite direction beds of gravel, or scattered pebbles of quartz from the waste of the New Red Sandstone, are found up to a level of about 600 feet amongst the Cotteswold Hills on the borders of Oxfordshire and Gloucestershire.² No ice-sheet ever invaded this part of England, and the occurrence of these pebbles drifted from the north, and lying on the Jurassic table-land can be accounted for in no other way except by submergence. To the same series of Drift deposits are to be referred the "High-level gravels" of Oxfordshire, Wilts, Berks, Dorset, and the Isle of Wight—as also the "Middle Glacial Beds" of Messrs. S. V. Wood and J. L. Rome in the Eastern Counties, reaching elevations of about 200—300 feet. All the phenomena point to an inter-Glacial epoch of deep submergence, and the conversion of the British Isles into an Archipelago of small islets washed by cold water, and sometimes encumbered with ice of local origin.

IV.—THE TRUE HORIZON OF THE MAMMOTH.

By MARK STIRRUP, F.G.S.

IN some recent articles contributed to the GEOLOGICAL MAGAZINE, Sir Henry H. Howorth has sought to establish by a great array of authorities, both British and foreign, the pre-Glacial, or at least pre-Boulder Clay, age of the Mammoth.

As Sir Henry claims to have proved his case—a proposition which probably few geologists will admit—and "calls upon those who still maintain a post-Glacial or inter-Glacial existence of the Mammoth to prove their case," I will attempt, to offer some little evidence to show that the conclusion he has arrived at is scarcely warranted by the facts.

In order not to unduly trespass on the limited space, I do not intend to analyze the value of the British evidence which Sir Henry has

¹ In the Lake District the late Mr. Clifton Ward has traced stratified gravels up to a level of at least 1500 to 1600 feet.—"Geology of the Northern part of the Lake District," Mem. Geol. Survey, p. 94.

² Quart. Journ. Geol. Soc. vol. xi. p. 477.