my father considered might be Upper Freshwater only from their eastward position (pointing out that the shells in them were the same as in those beneath the marine bed), they have shown nothing beyond, or contrary to, what he stated; and it is obvious that it will require further excavations between the two points to determine whether the Freshwater beds a third of a mile to the east are, or are not, beneath the marine bed which this party opened. If such be done, and Mr. Keeping's view that they are beneath it is confirmed, this, so far from showing my father to have been wrong, will show him to have been right in so cautiously guarding himself against any more positive assertion as to the geological position of these freshwater beds to the east of the ravine, than appears from the extracts which I have given from his paper.

IV.—ON THE CAUSES OF CHANGE OF CLIMATE FROM WARM TO COLD, AND COLD TO WARM, DURING LONG PERIODS, AND ALSO OF COINCIDENT CHANGES OF THE FAUNA AND FLORA.¹

By JOHN GUNN, M.A., F.G.S.

IT is a trite observation that truths which lie at our feet may be overlooked by the wise, and discovered by mere accident, or the chance step of some casual passer-by.

This appears to be the case with the phenomena of the so-called Glacial epoch, and the causes of the change of temperature on the earth's surface. The depth and the height of science have been searched through heaven and earth, while the grand and simple agency of nature, which has been operating alike through all time, may have been overlooked, or not duly consulted.

To enter upon the subject at once: it may be asked, if the elevation of mountain ranges be productive of cold, why may not the converse be true, and the wearing down and levelling of those heights be the cause of a warm temperature?

This is not a matter of conjecture, but from its very nature it ought to be a subject of observation, and to admit of actual verification.

In pursuing this inquiry, it is not necessary to enter into the question, how the inequalities of the earth's surface may have originated, nor to refer to astronomical agencies, such as the Precession of the Equinoxes, which are perpetually and uniformly at work alike under all conditions of elevation or depression; but I will claim in support of my proposition, the effect produced by the alterations of the course of the Gulf Stream, through changes in the level of the land, and also by the transport and melting of icebergs and glaciers.

With these provisos, I will commence my observations with the Carboniferous epoch. There is evidence of a quiescent state during which coal was deposited. Not a single instance, that I am aware, can be adduced of the occurrence of bouldered rocks, certainly not of

¹ A Paper read before the Geological Section of the Meeting of the British Association at Southport, 1883.

ice-scratched boulders, in the Coal-measures; but a mild and sub-tropical climate seems to have prevailed.

If we pass on to the Permian, the change both of Fauna and Flora appears to be coincident with that of the level of the land. A great and general disturbance took place, and glaciated and striated rocks prove the reality of a Glacial period. This was first observed and announced by Professor Ramsay. It was exposed in many places to such an extent as to excite surprise that it had not been noticed before.

From that epoch, to and throughout the Oolitic, a gradual and general levelling took place, and no striated boulders nor any indication of ice-action have been discovered.

If in the Chalk, as pointed out by Mr. Godwin-Austen in his elaborate treatise¹ a mass of granitic rock has been found at Croydon imbedded, it exhibits no more than the wasting of the land by floods, or inroads of the sea, or it may have been carried, as he suggests, by sea-coast ice from Polar regions, but such masses are rounded and afford no proof of local glaciation.

In no parts of this country, we might say of Europe, are there equal facilities offered for observation, as in the eastern counties of England, and this arises from the continuous and unbroken succession of the strata: consequently the relations of cause and effect are very minutely and extensively disclosed, and we cannot fail to see how changes of climate and of the Fauna and Flora follow step by step on the elevation or depression of the land.

It can be demonstrated that throughout the Norwich Crag series, and the Stony-bed, which dates from the surface of the Chalk, to the present day, and through the Forest-bed series, the Laminated series, which includes the Chillesford clays and sands, and through the Westleton beds, and the entire Quaternary formations commencing with the lower Boulder-clay, and ending with the Post-Glacial deposits, all the changes of climate and of fauna and flora have gone *pari passu* with the changes of the level of the land.

Thus the *Mastodon arvernensis*, whose remains are found in the Bone-bed in Suffolk beneath the Red Crag, and in the Stony-bed beneath the Norwich Crag, occurs in certain Antwerp-beds at a lower level than that in which the remains of *Elephas meridionalis* are found.

That Elephant succeeded the *Mastodon arvernensis*, and appears in the Estuarine-bed of the Anglo-Belgian basin without the Mastodon, which had ceased to exist in that district at least.

A change of level then took place; the Forest began to grow upon *terra firma*, and there was a concurrent change in animal life; the *Elephas meridionalis* either disappeared altogether, or else the rugosity of the enamel-plates was so modified, and the number increased, as to be scarcely recognizable.

Another and distinct species, or rather form of Elephant appeared. This was named by Dr. Falconer *E. (Euelephas) antiquus*, and it is supposed to have undergone many variations with respect to the

¹ Quart. Journ. Geol. Soc. vol. xiv. p. 252.

width of the teeth, as observed by the late Professor Leith Adams, (Palæont. Monograph, *E. antiquus*, p. 31) during the Forest-bed series.

The effect produced by the continued upraising of the bed of the Estuary is very remarkable. As its result, we have on one side the remains of an Estuary without a river, and on the other side the remnant of the magnificent Rhine without its Estuary.

The extent to which this severance of the estuary from the river has been carried through the elevation of the land is truly marvellous. This is shown by the dispersion of Elephants and other animals on either side.

Prof. Goldfuss, of Bonn, has noticed several teeth derived from a diluvial deposit on the banks of the river Ruhr in Westphalia, with well-marked rhombs, similar to those of the existing African elephant,¹ and he inferred thence that the valley of the Rhine was formerly inhabited by a species of Elephant, which more nearly resembled the existing African species than the *E. primigenius* does the existing Indian.

A tooth of the *Elephas (Loxodon) priscus* is also mentioned by Dr. Falconer, *loc. cit.* p. 96, to have been derived from Gray's Thurrock, in the valley of the Thames, differing slightly from the *E. Africanus*, and another found on the beach at Palling on the Norfolk coast, described by him, *loc. cit.* pp. 98 and 99; a third from the Stony-bed at Horstead, now in the Norwich Museum, and also a well-pronounced specimen in Mr. Savin's Collection; these all prove the same or a very similar species of Elephant to have existed on either side of the valley of the Rhine.

We may go far beyond these limits, and observe that these fossil remains are found not only on both sides of the Rhine-valley, but also beyond the Alpine mountain ranges intervening.

There is an unquestionable correspondence, I might say identity, between the fossil remains on the west and on the east side of the Alps and Sub-Apennines. At the Museum of Florence there are magnificent specimens of the *E. meridionalis* rivalling those of our Forest-bed, associated with the *E. antiquus*, so that I could not but feel quite at home there, and that I was treading on like ground to that of my native country. This coincidence is not confined to one single district beyond the Alpine regions; when at Rome, Mr. Ponzi showed me, among other teeth, one which resembled those of the intermediate *Elephas giganteus*, found at Mundesley, in Norfolk. At Monte Mario, near Rome, I obtained a specimen of the *E. meridionalis*, which I placed in the Norwich Museum. Thus these denizens of the Forest-bed, with which we are so familiar, are found on the other side of the Alpine ranges in like abundance, and of the same colossal stature.

A question arises, how could they have crossed those mountains supposing they were raised to their present height? Judging from accounts given of their powers of locomotion in India, there can be little doubt that the height alone would have offered no obstacle, but

¹ Fauna Antiqua Sivalensis, vol. ii. p. 94.

the increasing cold, arising from the elevation of the land, would not only have prevented their passage over, but have caused the extermination of all the Elephants, except indeed the *E. antiquus* and *E. primigenius*.

With respect to the Molluscs, the same story is told by them. Sir C. Lyell¹ has identified specimens from the Red Crag at Walton-on-the-Naze, in Essex, with some now living in the Mediterranean, and the *Cyrena* or *Corbicula fluminalis*, once common in the Norfolk Crag-beds, is now not to be found nearer than in the warm waters of the Nile.

It thus appears that both Mammals and Molluscs have had an extensive range before the mountain heights were upheaved, and intercommunication cut off. It may seem startling to affirm that the Alps have been interposed at so late a geological period. We are accustomed to regard them as monuments of the highest geological antiquity, on account of their sub-strata of Primary rocks; but nevertheless, as Sir Roderick Murchison has shown² in his able paper on the "Structure of the Alps," they have been comparatively recently elevated, so that not only Miocene, but Pliocene formations rest upon their present summits; and probably still more recent deposits have been laid upon them, and have been worn down by the process of glaciation.

The effects produced by the elevation of the Alpine ranges is obvious. The extreme cold induced culminated in the almost entire change of the fauna. The *Elephas primigenius* and the *Rhinoceros tichorhinus* survived and superseded the other and more southern types; the *Cervus elephas*, *C. tarandus* and the *C. capreolus* survived the profusion of Deer whose remains are yielded by the Forest-bed, and also a host of other Mammals, which succumbed to the cold.

The Glacial epoch, so called, was thus introduced, and the mountain heights, when they attained their highest point of elevation, spread their refrigerating influence far and wide by an ice-sheet, or glaciers, descending into the plains. This was necessarily limited by, and proportioned to the degree of latitude, while near to the Pole, the ice would be continuous, and icebergs, carried down into the sea, would extend the cold into otherwise warmer regions.

The reality of this cause of cold is best shown by the effect produced by the opposite system of depression and the gradual diminution of the regions of perpetual ice and snow.

Every traveller in Switzerland, Savoy, Italy and Greece remarks the traces of former glaciation and of retreating glaciers. In France the return to a genial climate is evident, as in Dordogne, where the Reindeer and the *Elephas primigenius* once lived, and have left their relics, and their unmistakable portraits, or figures carved by the hands of former natives.

Such are some of the indications of the change of climate from cold to warmth due to the gradually diminishing height of mountain

¹ Elements of Geology, p. 207, 6th edition.

² Quart. Journ. Geol. Soc., vol. v. p. 244.

ranges; and there is no reason to doubt but that, if the depression continued in a sufficient degree, there would be a return to the temperature of more genial periods, to the Purbeck or the Oolite; or on the contrary, if the engine may be said to be sufficiently reversed, there would be a return to the Glacial epoch.

The most remarkable evidence to this effect may be adduced from the variations of the course of the Gulf Stream.

Mr. William Hopkins shows¹ that the present Gulf Stream flowing through the Straits of Bahama, and thence in its north-eastern direction towards the North Sea and the coasts of Europe, is a current reflected from the shores of the Gulf of Mexico, in consequence of the impossibility of its continuing the north-western course by which it reaches the Gulf. In his masterly paper he proves that its course has not always been, as at present, through the Straits of Bahama, and that it would not continue to be so, if a depression of the North American Continent to the amount of 2000 feet were to take place; that such a depression would convert the valley of the Mississippi into a great arm of the sea, of which the present Gulf of Mexico would form the southern extremity; and which would communicate at its northern extremity with the waters occupying the submerged district, which he described as the great valley now occupied by the chain of lakes. A direct communication would be thus produced between the Gulf of Mexico and the Arctic Sea along the eastern base of the Rocky Mountains.

Such would be the necessary consequence of this submergence, and further Mr. Hopkins affords a very strong proof that such a course of the Gulf Stream has actually existed between the Gulf of Mexico and the regions of North America by the discovery made by Professor E. Forbes of plants which belong to the Pleistocene period along the flanks of the Rocky Mountains, and between them and Hudson's Bay, being the very region in which the temperature would be expected to be affected by the warm current from the Gulf of Mexico.

Such, no doubt, has been the effect produced by the change of level of the North American Continent, and it is a striking fact that this altered current of the Gulf Stream would have flowed in the direction of Melville Island, the Miocene coal-bearing country in the Arctic regions.

I do not mean to affirm that this extraordinary phenomenon would be thus satisfactorily accounted for, but the conjoint actions of depression of the land and influx of the Gulf Stream appear to offer an explanation of this most extraordinary phenomenon of the existence of a Miocene flora in so northerly a latitude. Without this joint agency, we may affirm that no change in the configuration of land and water, so ably advocated by Sir C. Lyell, could have produced that effect.

In addressing the Members of the British Association, I have not thought it necessary to enter more fully into the particulars of the changes of level and climate during the several periods mentioned.

¹ Quart. Journ. Geol. Soc., vol. viii. p. 89.

I hope I have pointed out sufficient to prove that the relation between cause and effect is borne out, as I proposed to show, and that the levelling of mountain ranges may on good grounds be considered to be the cause of warmth of climate, just as their elevation is productive of cold.

V.—ON THE STRUCTURE OF TRILOBITES.

By HENRY WOODWARD, LL.D., F.R.S.

IN the GEOLOGICAL MAGAZINE for July, 1871, Plate VIII. pp. 289–294, I published an article on the above subject, giving my views of the appendages of Trilobites, and reproducing the figure of *Asaphus platycephalus*, Stokes, showing traces of eight pairs of locomotory appendages, discovered by Mr. Billings in the Trenton Limestone, city of Ottawa, and described and figured by him (in Quart. Journ. Geol. Soc. 1870, pp. 479–486, and plates xxxi. and xxxii.). I also appended a note to Mr. Billings's paper (*op. cit.* 1870, pp. 486–488) on a palpus of *Asaphus* from the same locality, which is as follows:—"Having been requested by Sir William Logan to examine the Trilobite sent over by Mr. Billings from Montreal, I was led to compare it with certain specimens in the British Museum collection, presented by Dr. J. J. Bigsby, F.R.S., some years since.

I was at once attracted by a specimen of *Asaphus*, from the Black Trenton Limestone (Lower Silurian), which has been much eroded

Buccal organs of *Asaphus platycephalus*, Stokes.

h. hypostome ; *p.* palpus ;
m. maxilla.

on its upper surface, having the hypostoma, and what appear to be the appendages belonging to the first, second, and third somites, exposed to view, united along the median line by a longitudinal ridge.

The pseudo-appendages, however, have no evidence of any articulations. But what seems to me to be of the highest importance, as a piece of additional information afforded by the Museum specimen, is the discovery of what I believe to be the *jointed palpus* of one of the maxillæ (Fig. 1), which has

left an impression upon the side of the hypostoma—just, in fact, in that position which it must have occupied in life, judging by other Crustaceans which are furnished with an hypostoma, as *Apus*, *Serolis*, etc.

The palpus is 9 lines in length; the basal joint measures 3 lines, and is 2 lines broad, and somewhat triangular in form.

There appear to be about seven articulations in the palpus itself, above the basal joint, marked by swellings upon its tubular stem which, is one line in diameter.

There can be no reason to doubt that the Trilobita possessed antennules, antennæ, mandibles, maxillæ, and maxillipeds, as we find