



The Alps during the glacial peeioid

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This strange manufacture is one of the most extraordinary sights in South America, and was witnessed by me near Buenos Ayres. Having in company with a friend reached the suburb of Barracas by a short railway, we ferried over a filthy stream whose banks were in some places literally formed of the refuse of slaughtered cattle. We were now on the premises of the Saladero, one of many situated close together on the banks of the stream. I was struck by the silence that prevailed in a place where I knew that a frightful slaughter was going on.

Having thus followed the ox from his native plains to his final destruction at the Saladero, I shall conclude with a few words about sheep. Until thirty or forty years ago the native sheep was such a wretched creature that the very dogs would not eat it, and its chief value seems to have been as fuel in the treeless interior. Now by foreign enterprise millions of sheep, improved by attention to breeding and the introduction of European races, are found, particularly on the lands near the towns, whence they have almost expelled the cattle. As yet, however, as in the case of the cattle, the want of a good market for the meat reduces their value far below European prices.

In the towns beef and mutton sell at a penny the pound or less. In the country I have bought an excellent fat sheep for three shillings, and have known a flock sold at an average of 10d. a head. As it is impossible to drive sheep hundreds of miles to be boiled down at the sea coast like oxen, on many large farms in the interior they boil down 8000 or 10,000 sheep every year, but as no grease can be obtained from the most fleshy and best eating parts, these are thrown away, and I have seen 10,000 beautiful legs of mutton lying rotting on the plain at once. I cannot help thinking that some method of preserving this immense supply of meat for our use in these overcrowded and pauper-stricken islands may ere long be discovered, and the traveller may be spared the pain of seeing such a lamentable waste of food in one part of the world while thousands of hard-working people in other parts can scarcely keep themselves from starvation.

THE ALPS DURING THE GLACIAL PERIOD.¹

AMONG the most conspicuous evidences of formerly widespread ice-action in the Alpine Lands are the large travelled blocks or *erratics*, so lavishly scattered everywhere. From an early period these attracted the attention of intelligent travellers, some of whom expressed surprise when they saw that the isolated blocks did not consist of the same kind of rock as that of the mountains on which they rested. The numerous gigantic erratics—some as big as cottages—that strew the flanks of the Jura looking towards the Alps, are often referred to as specially remarkable.

¹ *Die Alpen im Eiszeitalter*. Von Albrecht Penck, Professor an der Univ. Berlin, u. Eduard Brückner, Professor an d. Univ. Wien. In drei Bänden. Pp. 1199. Leipzig: Tauchnitz, 1909. Price 55 marks.

Obviously these had been carried to where they are now found—but by what mysterious agency? Some—probably all—had come from the Alps, and had therefore travelled many miles. Amongst other vague conjectures it had been suggested that the transporting agent may have been water—that the blocks might have been swept down from the Alps by powerful débâcles or cataclysms. Such views, however, were considered unsatisfactory—a more reasonable explanation of the phenomenon had yet to be found. It is interesting to Scotsmen to know that the first to discover the solution of the problem—to divine the true origin of the erratics—was a fellow-countryman, John Playfair, formerly Professor of Natural Philosophy in the University of Edinburgh, and a devoted disciple of James Hutton, one of the great founders of the present system of Geology. During a visit to Switzerland in 1815, Playfair was much impressed with the great wandered blocks of the Jura. One of these—a mass of granite—he estimated to weigh 2520 tons, and his sagacious reflections are worth quoting, inasmuch as his recognition of the glacial origin of the erratics of the Jura was in point of fact the first step taken to work out the history of the Ice Age. “When we consider,” he remarks, “that the present point where the granite is to be found in its native place is at a distance of 70 miles, it will appear no easy matter to assign a conveyance by which this block could have performed such a journey over hills and valleys without considerable injury. A current of water, however powerful, could never have carried it up an acclivity, but would have deposited it in the first valley it came to, and would in a much less distance have rounded its angles, and given to it the shape so characteristic of stones subjected to the action of water. A glacier which fills up valleys in its course, and which conveys the rocks on its surface free from attrition, is the only agent we now see capable of transporting them to such a distance, without destroying that sharpness of the angles so distinctive of these masses.”

Some fifteen years, however, were to elapse before the study of the glacial formations of the Alps began to be seriously attacked by scientific men. It is to Venetz, Charpentier, and L. Agassiz that we owe the first clear outline of the several phenomena which unite to prove beyond any question that the Alpine glaciers were formerly much more extensive. These early observers indeed may be truly said to have laid the foundations of glacial geology. During the many years that have passed since the results of their investigations were given to the world, hosts of geologists from every country have visited the Alpine lands and increased our knowledge of their glaciation. But the next most notable advance was made when Morlot in 1854 and Heer in 1858 discovered that there had been more than one great extension of the glaciers. To these two investigators belongs the honour of having been the earliest to recognise the existence of certain accumulations which have come to be known as “interglacial” formations. Still later it was reserved for a Scotsman—Andrew Crombie Ramsay—to demonstrate that the great Alpine lakes occupy basins of glacial erosion. His views were for many years pertinaciously contested, but many of his opponents, who thought that he had greatly exaggerated

glacial erosion, are to-day compelled to admit that glaciers are much more effective agents of erosion than Ramsay himself had suspected. In short, it is now maintained that the larger valleys of the Alps have been throughout widened and greatly deepened by glacial action, and that the present rock-basins, profound and capacious as they may be, are yet of subordinate importance—being relatively shallow depressions hollowed out in the bottoms of valleys already over-deepened by glacial scour and excavation.

Many other questions connected with the glacial history of the Alpine Lands have interested geologists since the appearance of Ramsay's paper, "On the glacial origin of certain lakes in Switzerland," but important as these are, it must be admitted that by the work of the earlier observers the fundamental conclusions of glacial geology had already been established. Shortly stated, these conclusions are as follows: (a) the former greater extension of the glaciers; (b) the periodical return of such extensive glaciation; and (c) the effective action of glacier-ice as a modifier of the earth's surface. Nearly thirty years ago Dr. Penck, in his well-known work on the glaciation of the German Alps, recognised that these conclusions summed up the chief results of glacial research hitherto obtained, and in his and Professor Brückner's recent great work—*Die Alpen in Eiszeitalter*—the same opinion is expressed with regard to the present position of glacial geology. It is needless to say, however, that the problems considered by the earlier observers have since their time been looked at from other points of view, and treated in a different manner, while many subsidiary problems of much interest and importance have been discussed. Only those who are conversant with the literature of the science can realise the great advances made within the past thirty or forty years. By the following of new lines of research and the employment of improved methods of investigation, our knowledge of the history of the Ice Age of Europe has been in a manner revolutionised. And no researches of the kind have been more fruitful in results than those pursued in the Alpine Lands.

In the elaborate work by Penck and Brückner we have a complete and detailed summary of all that is at present known of the glacial phenomena of the Alps. They have themselves devoted many years to the study, during which they have explored, one may say, the entire chain from end to end. From time to time each has given some account of his labours and the views he has been led to hold as to the glacial history of the regions examined by him. In the masterly work before us these independent researches are combined, so as to form the most important contribution to glacial geology which has appeared for many years. It represents the labours of nearly a quarter of a century, carried on only during academic vacations, and largely if not entirely at the authors' own expense. This speaks volumes for the enthusiasm of these distinguished glacialists, and for their personal vigour—only men who are strong both mentally and bodily could have accomplished what they have done. The publication of their work has been spread over several years—the first part appearing in 1901, and the last at the close of 1908. The first volume is by Dr. Penck, and discusses the glacial phenomena of the

northern "East Alps." In this volume the author summarises the results obtained by his colleague in the Salzach district. The glaciation of the northern "West Alps" is discussed in the second volume, to which both authors contribute, while the third volume is devoted to the "South Alps" and the eastern slopes of the great chain, which are drained by the Mur, the Drave, and the Save, and is in like manner the work partly of Penck and partly of Brückner. The authors cover so wide an area and treat their subject in such detail that it is quite impossible in a magazine article to deal with their accounts of particular districts. We may, therefore, confine ourselves to a short and necessarily imperfect summary of some of the chief results obtained. These are set forth more or less fully by Professor Penck in the concluding chapters of Vol. III.

The Alpine glaciers of the Ice Age attained gigantic proportions as compared with their puny successors of to-day, but it must not be supposed that the mountain-land was ever so continuously covered with ice as is the case with Greenland. The ancient glaciers did not, like the vast Arctic glaciers, draw their supplies from one uninterrupted snowfield—each was fed from its own particular *névé*-basin. Nevertheless neighbouring glaciers were in many cases not so independent, so sharply separated from each other as in our day. Not infrequently they coalesced across what are now dividing watersheds. This was especially the case on the northern slopes of the chain, as in Switzerland, North Tyrol, and Upper Bavaria. In those regions the glaciers reached the low forelands, where they united to form a continuous ice-sheet. It was otherwise, however, with the glaciers that descended from the higher Alps towards the east and south-west. These were clearly separated from each other, and did not coalesce even upon the low grounds—indeed, many dropped their terminal moraines well within their mountain-valleys. The same to some extent was the case with the ice-flows that drained the southern flanks of the chain. Several of these, however, deployed upon the forelands—the glaciers that occupied the sites of the great lakes, Maggiore, Lugano, and Como, uniting outside of the mountain-valleys to form a continuous ice-covering. It would appear, therefore, that the middle section of the Alps, between Switzerland and Upper Bavaria on the one hand, and the region of the Italian lakes on the other, was the area of maximum glaciation. The elevated central part of that area was covered with continuous ice from which glaciers flowed north while others trended south. It is worthy of note, however, that the ice-shed separating those two sets of streams nowhere coincided with but lay north of the watershed. The same fact has been observed in connection with the glaciation of the Scandinavian Peninsula and the Scottish Highlands—in neither of those regions did the ice-shed of glacial times coincide with the watershed.

In general terms it may be said that the glaciers of the Ice Age were simply exaggerations of their present successors. The latter are fed from the same *névé*-basins as those from which the glaciers of the Ice Age drew their supplies. It would appear, moreover, that these basins were not as a rule more deeply filled in the Ice Age than they are now. The Alps above the existing snowline, therefore, must have much the same

appearance as in glacial times. If this be the case, then it would seem that the former vast development of glaciation was due not so much to increased precipitation of snow, as to a lower rate of ablation or melting. In other words, extreme glacial conditions were the immediate result of a general lowering of the temperature. It is further notable that the precipitation of glacial times bore a close relation to that of the present. The areas of maximum and minimum precipitation during the Ice Age and in our own day are the same—the existing snow-line running approximately parallel to that of the glacial period, but at an average elevation of 1200 metres above it.

The general facies of the organic remains, met with here and there in the moraines and fluvio-glacial gravels of the period, are quite in keeping with these conditions. On the north side of the Alps the great confluent glaciers terminated in a dreary Tundra-like region, lying some 400 to 600 metres below the depressed snow-line. From the ice-front escaped numerous glacial streams which distributed broad sheets of shingle and gravel over the low forelands. During the short summer these gravel-flats would be traversed by a network of watercourses which in winter time would be mostly dried up. The foreland of the Alps would thus seem to have resembled the tracts extending outwards from the Vatnajökull in Iceland—a desolate region, yet sufficiently clothed with vegetation to tempt thither the mammoth, the woolly rhinoceros, and the reindeer. The conditions on the south side of the Alps were less forbidding. There the snow-line was higher, and forests extended up to a height of 800 to 1000 metres, so that many of the glaciers must have invaded the tree-covered areas, and it is even quite likely that trees may here and there have grown upon the moraine-covered glaciers themselves, just as is the case to-day in Alaska and the Himalaya.

The gravel-flats spreading out in front of the southern ice-flows were not so sterile as those on the opposite side of the mountains. In certain places, not liable to be flooded by the glacial waters, a somewhat rich molluscan fauna flourished. Forests, however, did not extend everywhere along the foot of the mountains—on the contrary, wide stretches of marsh and peat-bog covered considerable tracts, the pools in which nourished alpine diatoms. The great mammals that roamed the Tundras on the north side of the chain would seem not to have frequented the forest-lands of the south. The teeth of mammoth, which are not uncommon fossils in the northern gravel-beds, occur very rarely in the south—one specimen alone having been obtained—while remains of the reindeer have been met with only at Mentone on the west and in Carinthia on the east side of the Alps. Of the woolly rhinoceros no trace has occurred. It is further notable that the Arctic element, so conspicuous in the glacial fauna of the north, is not present in the south, where the fauna is characteristically alpine—chamois, ibex, alpine hare, and marmot having ranged far south in the peninsula. The southern foreland of the Alps, therefore, must have resembled the south coast-lands of Alaska rather than the drearier wastes of Iceland. Towards the east and south-west extremities of the chain the larger glaciers must likewise have descended into forest-clad land. Many of the smaller ice-

flows of those regions, however, were confined to the upper reaches of the mountain-valleys. The general aspect of middle Scandinavia probably reproduces not inaptly the conditions that characterised the two ends of the Alpine chain during glacial times—the summits of the South-West Alps appearing then not unlike the present snowy heights in the interior of New Zealand.

The glacial and interglacial deposits of the Alpine Lands are wholly of Pleistocene or Quaternary age. Nowhere throughout the whole region have any passage-beds been discovered which might serve to link on the Pleistocene to the preceding Pliocene period. Should such passage-beds exist they must lie buried under the enormously thick alluvial accumulations that cumber the valley of the Po.

During the Pleistocene or Quaternary period the Alps witnessed several remarkable climatic changes—epochs of extensive glaciation alternating with epochs of milder and even genial conditions, during which the glaciers retired to the inner recesses of the mountains. That such oscillations occurred has of course long been recognised, not only for the Alps, but for all the glaciated regions of Europe and North America. It is true that the evidence of those changes has now and again been called in question and attempts made to explain it away. For example, the occurrence of fossiliferous freshwater deposits interstratified with morainic accumulations, within the peripheral areas of the glaciated tracts of Northern Europe, has been accounted for by temporary advances and retreats of one and the same great *mer de glace*. And similar explanations have been given of the appearance of fossiliferous beds intercalated in the glacial deposits of North America. There are many phenomena, however, connected with those interglacial beds which the theory referred to does not and cannot account for. If the organic remains were always of such a character as to lead to the belief that the plants and animals they represent might have flourished in the immediate proximity of a great ice-sheet, there would be something to say for the theory in question. But so far is this from being the case that many interglacial deposits have yielded the remains of a fauna and flora strongly indicative of more genial climatic conditions than now obtain in the same regions. Not only so, but abundant evidence is forthcoming to show that interglacial epochs were of protracted duration;—in a word, the alternation of glacial and interglacial deposits points not to mere temporary advances and retreats of the glaciers but to secular climatic oscillations. The evidence adduced by MM. Penck and Brückner is so full and clear that it is impossible to misunderstand it. They recognise four distinct glacial epochs, separated the one from the other by more or less prolonged interglacial epochs. Each glacial stage is marked by a great series of moraines with their accompanying fluvio-glacial gravel-terraces. The interglacial stages, on the other hand, are distinguished by the presence of fossiliferous deposits, and by the evidence of long-continued and profound river erosion, of extensive sedimentation, and protracted atmospheric action. Not infrequently, when one series of moraines and moraine gravels has been superimposed directly upon another, the line of separation between the two series is nevertheless

very marked—the older deposits having obviously been long exposed to “weathering,” and even in many cases converted into hard rock-masses by the action of infiltrating water, before they were covered up by younger accumulations.

The several glacial epochs recognised by Penck and Brückner are named after localities where they are typically developed. Thus, beginning with the oldest, we have the Günz, the Mindel, the Riss, and the Würm epochs. During the first and last of these epochs the glaciation was less extensive than during the Mindel and the Riss epochs. It is remarkable that the Riss glaciers in certain valleys were larger than those which occupied the same valleys in the preceding Mindel epoch. In other valleys, however, the reverse was the case—the Mindel glaciers having attained a greater development than their successors in the Riss epoch. In the valleys of the Inn, the Salzach, and the Iller, for example, the Mindel glaciers were the greatest, but such was not the case with the Isar glacier, which was most extensive in the Riss epoch. So again in the Rhine region, in Switzerland, in the French Alps, and in the Po valley the Riss glaciation was the most extensive. It is thought that not unlikely these differences may have been the result of those differential crustal movements which are admitted to have affected the Alps during glacial times. If Switzerland experienced a movement of elevation in the interglacial epoch that followed the Mindel glaciation, the Riss glaciers in the West and South-West Alps would naturally attain larger dimensions than their predecessors of the earlier glacial epoch. Should subsequent research establish this conclusion, it would follow that the greatest depression of the snow-line must have taken place in the Mindel epoch—in other words, we should assign the maximum cold of the glacial period to the Mindel stage.

Although the phenomena of the great moraines and the fluvio-glacial terraces of the Alpine forelands clearly shows that these tracts have experienced four successive glaciations, yet they do not tell us to what extent the glaciers retreated during the interglacial epochs. For such evidence we must turn to the fossiliferous interglacial deposits themselves, and they leave us in no doubt that the deglaciation was not less extensive than the glaciation. There were times when the glaciers retreated to the innermost recesses of the mountains, and the Alpine valleys experienced a warmer climate than the present. Among the most notable interglacial accumulations is the Höttinger Breccia, which occurs in the vicinity of Innsbrück. The rich flora obtained from this deposit has close affinities with a flora which flourishes to-day as far south as the southern coasts of the Black Sea. When the Pontic rhododendron and its associates flourished on the lofty mountain-slopes of the Inn Valley, the snow-line must have been some 400 metres at least higher than now. The climate, in short, could not have been less genial than that experienced at present upon the flanks of the Alps in Italy. There are certain contrasts between the interglacial floras of the northern and southern sides of the Alpine chain which are worth noting. The forests that clothed the mountain-slopes in the north were of the Baltic type, consisting mainly of conifers, oaks, maples, birches, and

hazels. Along with these, however, were the yew, the box, the water-chestnut, etc., from the presence of which it may be inferred that the snow-line could not have been lower than it is to-day. On the south side of the Alps the flora had a marked Illyrian aspect: the chestnut flourished at a height of 800 metres, the vine grew, as it does to-day, along the banks of Lake Iseo, the box abounded, and the Pontic rhododendron (no longer an Alpine plant) was likewise very widely distributed. Nowhere was this interglacial flora associated with arctic-alpine types. The most notable animals of the time were extinct forms of elephant (not the mammoth) and rhinoceros (not the woolly species) and stag.

It would seem that the interglacial epochs were of unequal duration. This is indicated by the relative amount of geological work accomplished during the several epochs. Thus it would appear that the genial interval that separated the Mindel and the Riss glaciations, greatly exceeded in duration the earliest interglacial epoch—that namely which came between the Günz and the Mindel glaciations. This conclusion is based on the fact that much more geological work was done during the Mindel-Riss than during the Günz-Mindel interglacial epoch. Unless, therefore, we are to assume that during the former epoch the agents of geological change acted with much more energy than in earlier interglacial times, which is highly improbable, we must conclude that the second interglacial stage was the most prolonged. On like grounds MM. Penck and Brückner believe that the third or Riss-Würm interglacial epoch was considerably shorter than the earliest or Günz-Mindel epoch.

For various reasons it is more difficult to determine the relative duration of the cold or glacial epochs. The extent of their respective moraines and fluvio-glacial gravels might lead one to infer that the Riss epoch was longer than the Würm epoch. But there are so many other considerations to be kept in view that such inferences cannot be advanced with much confidence.

The passing away of excessive glacial conditions in the Alps is indicated by a succession of large moraines and associated river-gravels, which seem to show that the final retreat of the last great glaciers was interrupted by at least three long pauses or "Rückzugsstadien." The moraines in question are separated from one another by what are termed "interstadial" deposits, which resemble in character and position true interglacial accumulations. Our authors are very guarded in their interpretation of these phenomena, but are clearly of opinion that the moraines indicate successive advances of the glaciers, each advance having been preceded by a retreat of unknown extent. Named from places at which they are typically displayed, the three series (beginning with the oldest) are known as the Buhlstadium, the Gschnitzstadium, and the Daunstadium. From many observations we learn that during the earliest of these stadia the average height attained by the snow-line was 900 metres below its present level, while in the subsequent stadia it rose successively—reaching in the Gschnitzstadium a height of 600 metres below the existing snow-line, and in the Daunstadium rising some 300 metres higher.

The interstadial stages imply long periods of time during which the glaciers retired up their valleys for considerable, if indeterminate, distances. So far, therefore, they are comparable to the interglacial epochs. In like manner, the moraines of the Bühl, Gschnitz, and Daun stadia are comparable to the similar moraines of the preceding glacial epochs, since each series of moraines, old and young alike, indicates a distinct readvance of the glaciers. The authors fully recognise all this, and are even willing to admit that certain interstadial accumulations may eventually come to be recognised as of interglacial importance. In general, however, the evidence is not decisive—the “interstadial” deposits are wanting in any clear indications of interglacial conditions. Their plant-remains have not yet been exhaustively studied, and until this work has been done it is considered safer to look upon the deposits in question as indicating less important climatic changes than the true interglacial accumulations. It is to be hoped, therefore, that the plant-bearing beds will ere long receive the careful attention of competent botanists.

Until we are better informed as to the extent of the climatic oscillations in Post-Würm times it will be impossible to correlate the last chapters of Alpine glacial history with the contemporaneous records of the Ice Age in other parts of Europe. One can hardly doubt that the climatic changes which took place in North-West Europe in late glacial and so-called “postglacial” times, are the counterparts of those that marked the closing phases of the Quaternary period in the Alps. And if this should be the case, as seems in the highest degree probable, it would be advisable to drop the use of the term *postglacial* altogether. The word ought to have a definite meaning, and yet it is applied in different countries to deposits which are not of the same age. Properly speaking, there are no “postglacial” formations in the Alps. The deposits so named belong to Post-Würm times, and contain the records of the closing stages of the Pleistocene or Quaternary period. The minor fluctuations—the successive advances and retreats of the Alpine glaciers, as indicated by the “Rückzugsstadien” and the interstadial deposits—may well have been of as pronounced a character as the climatic oscillations that took place in North-West Europe towards the end of Pleistocene times.

At present the absolute duration of the Ice Age cannot be determined in the absence of an exact chronological basis, such as might be supplied by Astronomy. All the geologist can attempt to do is to ascertain the relative duration of the several epochs of the period. The amount of geological work accomplished during those epochs varied considerably, as we have seen. If it be not unreasonable to infer that the greatest amount of work required the longest time for its accomplishment, then it would appear that the Riss epoch must be three times further removed from the present than the Würm epoch, while the Mindel may be twelve times older than the latter—the Günz being perhaps one and a half times as old as the Mindel epoch. On various grounds the Würm glaciation is conjectured to have reached its maximum rather over 20,000 years ago. If this estimate be taken as some indication of the duration of the two last interglacial epochs, then the Riss-Würm interglacial epoch must have lasted for 60,000 years or

thereabout, and the preceding Mindel-Riss epoch for not less than 240,000 years. Although such estimates do not pretend to be more than rough approximations, they nevertheless help one to realise how greatly extended are the periods of time embraced by glacial history. If indeed we keep in view merely the enormous amount of denudation and sedimentation accomplished during glacial times, we shall be prepared to admit that the inception of the Ice Age may well date back for several hundred thousand years. The Quaternary deposits occupying the great valley of the Po have been derived from the tear and wear of the Alps, and attain a thickness so extraordinary that to supply all this material the rivers must have lowered their drainage areas by at least 100 metres. Those two rapid rivers, the Kandar and the Reuss, having succeeded in lowering their drainage area by one metre in 3000 to 4000 years, we can hardly assign a shorter period than 300,000 or 400,000 years for the denudation of the Southern Alps and the filling-up of the Po Valley by fluvial action.

In glacial times an arctic-alpine fauna—including the mammoth, the woolly rhinoceros, and the reindeer—flourished on the north side of the Alps; subsequently it was replaced by an interglacial fauna, but after the latter had disappeared, the arctic-alpine forms returned. These faunas acquire a fresh interest when we learn that prehistoric man was associated with them. Human relics belonging to the Mousterian stage of culture occur along with the remains of the earliest arctic-alpine fauna, and bespeak the presence of man during the Riss glacial epoch. The same stage of culture persisted into the succeeding Riss-Würm epoch, when the arctic-alpine forms had retreated and an interglacial fauna had succeeded. How genial the conditions were at this stage is shown by the evidence derived from the recently discovered cave of Wildkirchli at a height of 1500 metres on the Ebenalp near Säntis. The mountains appear to have been clothed at that time with a thick vegetation, and the climate could not have been less temperate but was probably even more genial than the present. Mousterian man lived in caves high up on the mountain-slopes, where he followed the chase. The Riss-Würm interglacial epoch with its characteristic fauna passed away, to be succeeded by the Würm glacial epoch and the reappearance of the arctic-alpine fauna. The stage of culture had now advanced from the Mousterian to the Solutrian, and finally, in Post-Würm times, to the Magdalenian.

While the arctic-alpine fauna plays a most important rôle on the north side of the Alps, it is otherwise on the south side of the mountains. There a well-marked forest fauna flourished during both the Riss-Würm and the Mindel-Riss interglacial epochs. But in none of the southern interglacial beds have any traces of man yet been discovered. Should these eventually be met with we should expect to find the Mousterian types in the Riss-Würm, and the Chelleian in the Mindel-Riss deposits.

An arctic-alpine fauna, as we have seen, is associated with the two younger glacial epochs, and a "warm" fauna with the two younger interglacial epochs. Whether the same was the case with the two older glacial

epochs and the intervening Günz-Mindel interglacial epoch is not known. Fossils are of very rare occurrence in the older glacial accumulations, while deposits which can be with certainty assigned to the Günz-Mindel interglacial horizon have not yet been detected. All that can be asserted is that the latter epoch was of prolonged duration, but whether the climatic conditions were as genial as those of the later interglacial epochs we cannot tell. Not improbably the Günz glaciation may have witnessed the advent of the arctic-alpine fauna, while during the succeeding Günz-Mindel epoch the region may have been occupied by the characteristic interglacial fauna. Certain it is that the older and younger arctic-alpine faunas and the older and younger interglacial faunas which alternated with each other in the later stages of the period remained much the same throughout. Some notable changes, however, did occur. Thus the southern elephant (*E. meridionalis*) and the cave-bear, which played a conspicuous part in the earlier stages, either disappeared or were very sparingly present towards the close of the long cycle of climatic oscillations. And doubtless many modifications of the faunas may have taken place, of which no record has been preserved. Nevertheless when we reflect on the prolonged duration and the many pronounced climatic changes of the glacial period—inducing as the latter must have done great migrations—we may well be surprised that the faunas seem to have undergone so little modification. It was not quite the same, as we have seen, with our own race—for during the period man passed through all the successive stages of culture, from the very primitive Chellean to the relatively advanced Magdalenian type.

There are many other topics discussed in the 1190 pages of MM. Penck's and Brückner's treatise which we should like to have indicated, but space forbids. We shall have written to little purpose, however, if some notion of the general scope of the work cannot be gathered from our imperfect sketch. That our authors' results will have a strong influence on glacial research in other lands cannot be doubted. We shall now probably be spared the frequently reiterated statement that glacier-ice is a most ineffective eroding agent. Probably also the reality of the recurrence of alternating glacial and genial epochs throughout the Ice Age will no longer be so confidently disputed.

The book is well illustrated with numerous geological sections, maps, and photographs, and with the aid of these the reader should have no difficulty in following the descriptions and discussions of the text. It might have been well, however, if our authors could have seen their way to prepare a general map (preferably coloured) to show the distribution of the glacial and fluvio-glacial deposits of the several epochs and stadia.

JAMES GEIKIE.