TABLE VIII.

Earthquakes.	Mean length of focus in miles.
Strong . .	$12\frac{1}{4}$
Moderate . .	13
Slight, *a* . .	12
,, *b* . .	$4\frac{1}{4}$

Slight earthquakes are obviously divisible into two sub-classes, the first in which the focus is 9 miles or more in length, the second in which the focus is 6 miles or less in length.[1] The above Table gives the reason why the sound should be of nearly the same character in strong, moderate, and the first division of slight earthquakes. Thus, the intensity of all but the slightest earthquakes depends, not on the magnitude of the focus, so much as on the amount of relative displacement along the surface of the fault.

British earthquakes, according to the nature of the shock, are divisible into two classes, simple and twin, and this classification corresponds to a difference in origin. Simple earthquakes are due to continuous slips, as a rule along strike faults; twin earthquakes are caused by rotation of the median limb of a crust-fold along a transverse fault, the two foci coinciding with the crest and trough of the fold, the interfocal region with the practically undisplaced portion of the median limb about which the rotation takes place. In this connexion, it is worthy of notice that the average distance between the epicentres of British twin earthquakes is 10 or 11 miles, which agrees closely with the average distance of 9 to 12 miles between the crests of the great crust-folds in France.

The average length of the focus in twin earthquakes is about 12 miles. Thus, the average length of focus in twin earthquakes and in other earthquakes, whether strong or moderate or, in certain cases, slight, is nearly the same, and is probably equal to, or it may be slightly more than, the average distance between the crests of the crust-folds. In other words, the magnitude of the crust-folds seems to determine the length of fault-slips along strike faults as well as along transverse faults.

NOTICES OF MEMOIRS.

I.—THE SIGNIFICANCE OF EARLY AND OF PLEISTOCENE GLACIATIONS.[2]

By MARSDEN MANSON, Ph.D.

THE objects of this paper are to point out the significant differences between the preceding, accompanying, and succeeding phenomena of early glaciations and the corresponding phenomena of Pleistocene

[1] In determining the average for the second sub-class, a large number of very slight shocks were unavoidably omitted; their inclusion would, of course, lower the average considerably.

[2] Being an abstract of a paper read before the Eleventh Session of the Int. Geol. Congress, Stockholm, August, 1910.

and present glaciation. One of the broadest and most recent summaries on the subject is that of Professor T. W. Edgeworth David, F.R.S.[1] He finds that in the following horizons the presence of evidences of extensive ice-action is quite firmly established:—Lower Cambrian, Devonian, Permo-Carboniferous, Pleistocene.

Professor A. P. Coleman also reviews the whole subject very clearly, and finds four periods of extensive glaciations—(1) Lower Huronian, left its effects over hundreds of thousands of square miles;[2] (2) Early Cambrian, in widely separated regions; (3) Permo-Carboniferous, for large parts of the world; (4) Pleistocene, very general. We therefore accept, for the purposes of this discussion, that ice-action of great extent occurred in these periods.

Cambrian Glacial Action.—Evidences of the action of ice in Cambrian time have been observed from Arctic, through north temperate and tropical, and in south tropical latitudes. Evidences of Cambrian life have been found which are of wide distribution as to latitudes and indicative of warm seas. "The testimony of the fossils, wherever gathered, implies nearly uniform climatic conditions, not only over our own continent, but throughout all the earth where records of the Cambrian Period are found."[3] The extremely wide range of life in Cambrian time justified Dana in saying, "There was no frigid zone, and there may have been no excessively torrid zone."[4]

Evidences of Glacial Action in the Devonian Era.—When the evidences of glacial action in the Devonian era are compared it is found that they embrace nearly as wide a distribution in latitude as do the evidences of the life of that era, and that, like the distribution of temperature and of life in the preceding Silurian and succeeding Carboniferous era, both life and glacial action were distinctly non-zonal in distribution, and the former indicated warm temperate or tropical conditions.

Permo-Carboniferous Ice-sheets.—During Permo-Carboniferous time extensive sheets of ice were laid down in the tropical latitudes of both hemispheres. During this period the life was indicative of temperate conditions rather than Arctic, and its distribution was worldwide. "The Permian Period lies in the midst of geological history, with periods of great uniformity and remarkable Polar geniality both before and after it."[5]

It must be recognized at once that zones of temperature did not prevail immediately before, during, nor immediately after the Permo-Carboniferous glaciation; that whatever part solar radiation played in the climatic distribution of that age it was not the controlling part, as at present, and that to attempt to fit such a distribution of temperature to solar radiation involves suppositions and hypotheses which have not been made to harmonize with present conceptions of solar-controlled climates. The volcanic heat liberated at the close of this era, and that

[1] See Trans. Tenth Int. Geol. Cong., Mexico, vol. i, pp. 437–82, 1906.

[2] Bull. Geol. Soc. Am., vol. xix, pp. 347–69, November, 1908. See also Davis, ibid., vol. xvii, p. 414, August, 1906.

[3] Chamberlin & Salisbury, *Geology*, ii, p. 273.

[4] Manual, 4th ed., p. 484.

[5] Chamberlin & Salisbury, ii, p. 656.

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slowly brought into effect from cooling lava and radio-active substances by subsequent denudation, would tend to raise the temperature of the air, from which it could escape only by slow processes[1] under the powerful conservative influences of solar radiation. The widespread geniality of the succeeding period may be, in part at least, attributed to this accession of heat—the geniality compared with that of the preceding period, when tropical life flourished at all latitudes. Taking the three epochs in succession, Carboniferous, Permian, and Triassic, it appears that the Permian was a period of marked temperature depression in a series of non-zonal climates.[2]

Pleistocene Glaciation and Conditions.—Pleistocene glaciation followed a period during which cold temperate forms of life were for the first time distinctly developed over wide ranges of latitude, which, during the immediately preceding period, were occupied by temperate forms. For the first time also marine life of Arctic habit took possession of oceans previously supporting more temperate forms only. The cold became so general as to be 'worldwide' in its effects.

A Review and Comparison of these Glaciations and of Life.—When the distribution in latitude of the evidences of early glaciations and of life are compared with Pleistocene glaciations and the distributions of modern life, it is observed—

1. That both early and late glaciations and all life prior to the modern era were distributed over extreme ranges of latitude and apparently without regard to exposure to solar radiation.

Pleistocene glaciation may have reached its maxima progressively at different latitudes, that is, whatever may have been the maximum extension of glaciation in the latitude of the tropics, this maximum was apparently reached prior to the maximum in, say, latitudes 45 to 55 degrees; similarly, glacial maxima in these latitudes may have preceded maximum glaciations in Polar latitudes. But taken as a whole, Pleistocene glaciations were not laid down in accordance with present zonally distributed climates.

2. That early glaciations were preceded, accompanied, and followed by a widespread distribution of tropical and temperate forms of life and by warm oceans, while Pleistocene glaciation was 'phenomenal', was preceded by a period of widespread cold temperate life, and accompanied by colder oceans than had previously prevailed.

3. That the earlier glaciations were followed by periods of widespread tropical or temperate life, while Pleistocene glaciation was followed by a period in which life and temperatures were restricted to zones distinctly dependent upon solar radiation for their establishment and maintenance.

A deduction which seems fully justified is that up to the culmination of Pleistocene glaciation zones of temperature were scarcely perceptible, if at all, which deduction is confirmed by both the wide distributions of life and the evidences of glacial action in low latitudes in the pre-Pleistocene eras.

The absence of distinct zones of climate is highly significant, and

[1] Chamberlin & Salisbury, ii, p. 672.

[2] Neumayr held that there were climatic zones in Jurassic and Cretaceous times; see W. T. Blanford, Address to Geol. Soc., 1890, p. 55.—Ed. Geol. Mag.

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clearly established the fact that a solar control of climates similar to that at present existing did not prevail prior to the modern era,[1] or that some factor was active which did not admit of the zonally distributed climates of solar control.

The distribution of ice and of fossil life during Huronian, Cambrian, and Permo-Carboniferous time, and during preceding and succeeding eras to the close of Pleistocene time, are so widely at variance with a solar-controlled distribution of temperatures like the present that it seems impossible to assign these phenomena merely to variations in solar radiation. Under solar control, for instance, what would become of Polar and mid-latitude life while tropical latitudes were glaciated nearly or quite to sea-level?

The phenomena of geological and present climates may be interpreted under the hypothesis that prior to the Recent or Human Epoch the earth was more continuously clouded, and thereby deprived of the zonal temperature control of solar radiation.[2]

When these evidences of ice-action and the phenomena of life are broadly compared, under this hypothesis, it appears to the writer—(1) That accordingly ice-fields were laid down generally without regard to latitude, although Pleistocene glaciation reached its maximum along the broadest land areas under the north temperate rain-belt, and this maximum may have been reached after the inauguration of solar control in tropical latitudes. (2) That the earlier glaciations were contemporaneous with tropical and temperate land and marine forms, and that the greater exposure of the continents to loss of heat, and their low specific heat and conductivity, caused them to cool more readily, thus frequently forcing land animals to seek warmer conditions in the oceans, and from these permanently marine forms of life have descended. (3) That Pleistocene glaciation followed an extremely gradual although fluctuating refrigeration of the earth as a whole when its crustal condition became more stable than ever before and its oceans for the first time fully and completely chilled, and that the stress of cold was so general that the oceans did not then offer more congenial conditions to even the cold temperate land life of the immediately preceding period; that this stress was first relieved in regions of least cloudiness by the penetration of solar radiation to the surface, and that more moderate conditions spread thence into the solar-controlled, zonally distributed temperatures of to-day; that the accession of heat through continuous exposure and the trapping of solar radiation, converted into long wave-length rays, is a cumulative process which has recorded and is yet recording its gradual but irregular progressiveness by the removal of Pleistocene glacial conditions and the corresponding advance of life. (4) That only after the culmination of this marked and phenomenal glaciation did temperatures and life pass from a non-zonal to a zonal distribution, which manifests itself in zones of life and of climates, and marks

[1] There is an apparently zonal distribution of the very much mixed groups of Pliocene life which may have resulted from a similar di-tribution of temperatures, but exceptional conditions warn us against too implicit an acceptance of this conclusion.

[2] See Trans. Tenth Int. Geol. Cong., Mexico, vol. i, pp. 349–405, 1906.

Pleistocene time as the most significant transition epoch of the climatic history of the earth.

There seems to be a tendency in recent years to fall back upon the hypothesis of variations in the emissive power of the sun to account for the variations of surface temperatures indicated by ice formations.[1]

It is certainly quite possible and even probable that the sun's emission has altered within geological time, but neither the distribution of fossil life nor the evidences of ice formations occur with that zonal arrangement in harmony with solar-controlled climates, so that to the writer it seems necessary to attribute geological climates to a uniformly distributed source of heat, and to eliminate solar control by the reasonable assumption of persistent cloudiness. It is not implied that the clouds were so thick as to prevent the transmission of light such as is now received on overcast days, but a far less thick layer than that would suffice to screen off most of the solar-heating effects. Moreover, under the hypothesis that solar radiation was interrupted by a thin but continuous stratum of cloud, there is no reason why glaciers should not flow into the sea at any latitude.

When cloud densities decreased to approximately present conditions the tropical zones of downcast currents and minimum cloudiness were the regions first affected, and in these solar radiation first reached the surface. Thus solar radiation which, with a continuously cloudy sky, fixed the tropical zones as regions most exposed to cold downcast currents and to glaciation, also fixes them, with present cloudiness of 52 per cent. of the earth's surface, as regions of maximum exposure to solar radiation. The great continental glaciers of the northern hemisphere were grouped about the North Polar region for the reason that continents are so grouped, and for the additional reason that atmospheric circulation fixes latitude 50° N. as one of the belts of maximum storm circulation and precipitation.

Solar climatic control distinctly manifests itself by a zonal arrangement of temperatures and of life; under this control the disappearance of Pleistocene ice-sheets is taking place. The earth is therefore not in an era of senility or decrepitude, but in the springtime of a new life in which nobler, higher types of life are being developed.

The difficulties attendant upon the previous explanation of climatic phenomena appear to the author to be due to false premises, namely, (1) that solar radiation controlled the climates of Pleistocene and previous eras; and (2) that effective earth heat, under the extremely slow processes of loss and bringing into effectiveness and the powerful processes of conservation, was entirely lost prior to the era of zonally disposed climates. Upon a rejection of these assumed premises we may freely admit that ice has been a geologic agent from the earliest ages, particularly upon land masses of low specific heat and extremely low conductivity, and that the regions of cold downcast currents were, prior to the Pleistocene, most exposed to cold downcast currents and to consequent local glaciation; and that as the supply of earth heat fluctuated, ice formed under favourable conditions over large geographic areas in any latitude and during many eras, to disappear from an

[1] Professor David, Trans. Tenth Int. Geol. Cong., Mexico, vol. i, pp. 481–2, 1906.

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increase of available earth heat or a lowering of elevation. These earlier ice formations were, however, not accompanied by cold seas, nor upon their disappearance were zonally distributed climates established.

The approaching, culminating, and succeeding phenomena of the Ice Age were therefore far more remarkable and significant than the corresponding phenomena accompanying the occurrences of ice as a geologic agent in the earlier ages. The worldwide distribution of cold temperate life just preceding the equally worldwide phenomena of Pleistocene glaciation, and the succeeding era of zonally distributed temperatures and life distinctly dominated by solar control, mark a profound change in the climatic history of the earth, and make it manifest that but once have the oceans chilled to that degree of cold which warrants the use of the term Ice Age.

Summary.—The phenomena of the earlier glaciations and the preceding, accompanying, and succeeding distributions of temperatures and of life appear to warrant the conclusions—(1) That these phenomena did not occur during eras of solar climatic control; (2) that there were apparently marked fluctuations in the amounts of available earth heat; (3) that during periods of deficiency and upon elevated areas, and particularly in zones of downcast atmospheric currents, local glaciers of great extent formed; (4) that these glaciations disappeared or varied from one of several causes, (*a*) accessions of heat from the crust, (*b*) variations in the elevation of the crust, (*c*) possible intermittent thinnings of the denser cloud formation of earlier eras in the regions of minimum cloud formation, permitting solar radiation to reach the earth's surface in these latitudes; (5) that these glaciations were not of the same order of magnitude nor did they mark the climacteric era of the evolution of climates as did the Ice Age.

II.—Royal Society.—The Lignite of Bovey Tracey. By Clement Reid, F.R.S., and Eleanor M. Reid, B.Sc. Read June 16, 1910.

In 1863 Heer and Pengelly published in the *Phil. Trans.* an account of these lignite beds and their flora. Heer classed the lignite as Lower Miocene, considering it equivalent to the Aquitanian of France and to the Hamstead Beds of the Isle of Wight. These latter are now referred to the Middle Oligocene.

A statement by Starkie Gardner, that Heer's Bovey plants are the same as those found in the Bournemouth Beds (Middle Eocene), has caused the Bovey Beds to be classed as Eocene in recent textbooks and on recent maps of the Geological Survey, leaving a great gap in the geological record in Britain. Our researches have not supported this view, but tend to show that Heer was right, the Bovey lignite being highest Oligocene, or perhaps lowest Miocene. We could find in the Bournemouth collection nothing to support Gardner's view, and he does not appear to have collected at Bovey, his comments referring to the collection now in the Museum of Practical Geology.

We therefore made a collection in the Bovey deposits, as far as the state of the lignite pit would allow, in order to settle if possible the true age. The results were unexpected, for by using new methods we obtained a considerable number of species, mainly identical with

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well-known plants of the lignite of the Wetterau, which is generally classed as Upper Oligocene. In certain cases better specimens showed also that Heer's supposed peculiar species of Bovey belong to well-known forms of the Rhine lignite—his *Vitis britannica*, for instance, being only a crushed seed of *Vitis teutonica*. Several curious new species were discovered, including the earliest known *Rubus*, a peculiar *Potamogeton*, and a new genus of Boragineæ.

A study of the cone and leaf of *Sequoia couttsiæ* proves that it is a true *Sequoia*, and not a species of *Arthrotaxis*.

III.—Edinburgh Geological Society.

A GEOLOGICAL work by Dr. Ogilvie Gordon, entitled *The Thrust-masses in the Western District of the Dolomites* in South Tyrol, has just been published by the Edinburgh Geological Society in a Special Part of their *Transactions*, vol. ix; price 7*s*. The text extends to 91 pages, and is illustrated by 2 geological maps, 18 coloured geological sections, and a number of original photographs and sketches. Mrs. Gordon describes a series of gigantic thrust-masses composed, in that district, of Permian, Triassic, Jurassic, and Cretaceous rocks that have travelled from east to west above the older crystalline rocks of the Central Alps, and have subsequently been downthrown along with the older rocks and suffered further deformation in the region of the Dolomites. The base of the series is composed of brecciated rock-material belonging to the floor over which the subjacent mass has passed and to the lower layers of the subjacent mass. The lower layers of each mass differ from place to place, as they were masses that had been already plicated in east and west direction, and in the course of the overthrust movements new plicational forms were superinduced both in north and south and in east and west directions. Similarly the cross-faults intersect, or coalesce with, the E.–W., E.N.E.–W.S.W., and W.N.W.–E.S.E. faults, and form fault-networks which completely isolate the adjacent areas in the crust. The chief Dolomite mountains, such as the Langkofl and Plattkofl Massive and Sella Massive, are areas of inthrow surrounded by faults, within which the higher thrust-slices have been preserved.

One of the geological maps shows four successive thrust-masses—(1) a basal thrust-mass mainly composed of the Permian Quartz Porphyry and Gröden Sandstones, the Lower Trias, and the *Calcareous facies* of Muschelkalk and Marmolata Limestone; (2) a thrust-mass comprising fragments of the older strata and widely extended exposures of the *porphyritic lavas and tufaceous and dolomite facies* of Middle Trias; (3) a thrust-mass belonging to the same facies as (2), but mainly composed of Schlern Dolomite, with varying thicknesses of the lavas and tuffs below it and of Upper Trias and younger horizons above it; (4) a thrust-mass mainly composed of Upper Triassic Dolomite associated with infolds of younger Mesozoic strata. The other geological map shows the detailed stratigraphy of the Langkofl and Plattkofl Massive. This mountain has been regarded as a 'Coral-Reef' of Middle Triassic age, but the supposed 'reef' peculiarities are interpreted by Mrs. Gordon upon the basis of the overthrust structures typical of the whole area. The outstanding deformational feature of all the thrust-slices is the rapid variation in the thickness of the various horizons of strata. Other features are the brecciated or nodular structure of the rock-material in the crush-zones, passing into gneissose and schistose structure, and the close cleavage penetrating the rocks in intersecting directions. The outward dip of the strata noticeable in the chief mountain-massives is a dip participated in by the subjacent thrust-masses and associated with steep flexures towards leading faults of the later period of downthrowing and horizontal displacements. Mrs. Gordon interprets the leading strike in the district as a curve round the north, west, and south, and the transversal directions as N.N.W.–S.S.E., N.–S., and N.N.E.–S.S.W., the system being essentially an interference system produced in virtue of the coalescence of plicational effects during the interaction of north-south and east-west pressures.

REVIEWS.

I.—The Sub-Antarctic Islands of New Zealand.

Reports on the Geophysics, Geology, Zoology, and Botany of the Islands lying to the south of New Zealand. Edited by Professor Charles Chilton, M.A., D.Sc., F.L.S. Published by the Philosophical Institute of Canterbury. 2 vols. 4to; pp. xxxv, 848. Wellington, N.Z. London: Dulau & Co., 1909.

THE observations recorded in these two volumes are the results of an expedition made in November, 1907, with the co-operation of the New Zealand Government, to the more important islands that lie to the south of New Zealand.

The geology of Campbell Island and the Snares is described by Professor P. Marshall and Mr. R. Browne, and that of the Auckland, Bounty, and Antipodes Islands by Mr. Robert Speight and Mr. A. M. Finlayson.

In Campbell Island the oldest rock formation is a mass of gabbro. Somewhat larger areas are occupied by oceanic limestone, with foraminifera, occasional grains of glauconite, some flints, but no detritus: it is regarded as probably of Miocene age. The main mass of the island is formed of volcanic breccias and lavas (trachyte, phonolite, and basalt), the terraced features being due to the outcrop of nearly horizontal flows of lava, separated by less resistant scoria beds. Abundant evidence of glaciation was observed, but the formation of glaciers on the island is regarded as the result of a general cause of refrigeration and not as specially due to elevation. The absence of raised beaches and rock-shelves indicates that there has been no recent elevation, but it seems probable that a movement of depression is in progress.

The Auckland Islands exhibit evidence of "a moderately severe glaciation", and there are indications that it was probably more intense at an earlier date. Considerable elevation of the land must have occurred during those times, but the upheaval is not regarded as