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ART. XXXIII.—*Geological Horizons as determined by Vertebrate Fossils*;* by O. C. MARSH. With Plate XII.

IN 1877, the author endeavored to bring together some results of his researches in the Rocky mountain region and in other parts of the country, relating to the succession of vertebrate life.† This led to a comparison of the relative value of the three different groups of fossils; plants, invertebrates, and vertebrates, in marking geological time. In examining the subject with some care, the author found that, for this purpose, plants are not satisfactory witnesses; that invertebrate animals are much better; but that vertebrates afford the most reliable evidence of climatic and other geological changes. The subdivisions of the latter group, and, in fact, all forms of animal life, are of value in this respect, mainly according to the perfection of their organization, or zoölogical rank. Fishes, for example, are but slightly affected by changes that would destroy Reptiles or Birds, and the higher Mammals succumb under influences that the lower forms pass through in safety. The special applications of this general law, and its value in geology, readily suggest themselves.

In accordance with this principle, the author next attempted to define the principal geological horizons in the West which he had personally investigated, and then taking in each the largest and most dominant vertebrate form which characterized it, used the name for the horizon. In the same way, some of the principal horizons of the East were named, and the whole brought together in a section to illustrate vertebrate life in America.‡

The names thus given to various horizons were not intended to replace those already applied, but merely to supplement them, and by new evidence, to clear up those in doubt. The same principle had long before been found to work admirably in Europe, where certain characteristic invertebrate fossils, especially Ammonites, had served to mark definitely various subdivisions of a single formation. The wider application of the principle to vertebrate fossils, from their earliest known appearance to the present time, has already helped to complete the record of vertebrate life in America, and rendered an equal service to systematic geology.

Since this method of defining geological horizons by vertebrate fossils was first used by the author in 1877, many important

* Abstract of Communication made to the International Geological Congress Washington, D. C., August 28th, 1891.

† Introduction and Succession of Vertebrate Life in America. Address before the American Association for the Advancement of Science, Nashville, Tenn., August 30, 1877.

‡ The same address, Frontispiece.

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discoveries have been made, especially in the West, and much information bearing on the subject has been obtained from various quarters. In 1884, the author revised and extended the first section for his monograph on the *Dinocerata*, and it seems fitting on the present occasion to bring together once more some of the later evidence, and place on record the more important horizons now known to the author by personal exploration, or by other investigations which he has verified.

The accompanying section, Plate XII, is designed to represent in outline, in their geological order, the successive horizons at present known with certainty from characteristic vertebrate fossils. The correlation of these horizons with those determined on other evidence is important, and considerable progress in this direction has already been made, but the results cannot be presented here.

In comparing the present section with the one first published by the author, it will be noticed that no vertebrates are yet known in the Archæan or Cambrian, but a single fortunate discovery in Colorado has recently carried back the first known appearance of Fishes, from the lower Devonian to the lower Silurian, or more specifically, from the Schoharie Grit to the Trenton.

The next point of importance is in the Triassic, in the horizon of the Connecticut river sandstone where so many foot-prints have been found, and attributed to Birds. Recent discoveries in these beds have shown that at least three distinct forms of carnivorous Dinosaurian reptiles, all of moderate size, lived at that period, and doubtless did their share in leaving foot-prints behind them. In two of the skeletons secured, the bones of the hind feet are still in position, and in life could have made some of the foot-prints previously discovered.

Near the base of the Jurassic, a new horizon may now be defined as the Hallopus beds, as here alone remains of the remarkable reptile named by the author *Hallopus victor* have been found. Another diminutive Dinosaur, *Nanosaurus*, occurs in the same strata. This horizon is believed to be lower than the Baptanodon beds, although the two have not been found together. The Hallopus beds now known are in Colorado, below the Atlantosaurus beds, but quite distinct from them.

The Baptanodon beds have been found at many localities, in Dakota, Wyoming, and northern Utah, everywhere beneath the Atlantosaurus beds, and having below them, at various localities, a series of red beds, which may, perhaps, contain the Hallopus horizon, but are generally regarded as Triassic.

Beside the two species of *Baptanodon* described by the author, the next vertebrate in importance, in the same horizon, is a small Plesiosaur, which may be called *Parasaurus striatus*. One specimen only has been found in northern Wyoming.

The Atlantosaurus beds of the upper Jurassic are now known to be one of the best marked horizons yet discovered. They have been traced for more than four hundred miles along the eastern flank of the Rocky mountains, and nearly everywhere contain great numbers of fossil vertebrates, especially gigantic Dinosaurs and other reptiles, as well as many diminutive mammals of primitive types. The same deposits have been found on the western slope, with the Baptanodon beds beneath them.

The most remarkable of the new horizons recently determined are the Ceratops beds in the Laramie series, at the top of the Cretaceous. This horizon is as strongly marked as that of the Atlantosaurus beds, and has now been traced for nearly eight hundred miles along the eastern base of the Rocky mountains. Toward the north, it is underlaid by marine Cretaceous strata containing Fox Hill fossils, but further south, various older formations are found immediately beneath it. The overlying strata, when present, are usually of Tertiary age. The Fort Union Eocene beds on the upper Missouri, the Brontotherium beds of the Miocene in Wyoming, and further south in Colorado the Pliohippus beds of the Pliocene, may be seen immediately above. The vertebrate fauna of the Ceratops beds is remarkably rich and varied. The gigantic horned Dinosaurs named by the author the *Ceratopsidæ* especially abound, and determine the horizon with accuracy. Other Dinosaurs are numerous; and a few Birds, and various Mammals of Mesozoic types have also been secured.

In the various horizons of the Tertiary, as repeated in the present section, no changes of importance have been required, as more recent discoveries fully confirm their value and accurate determination.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *On the Absorption Spectrum of Liquid Oxygen.*—In a preliminary examination of the absorption spectrum of liquified oxygen, Olszewski observed four bands corresponding to the wave lengths 628, 577, 535 and 480, these bands being the same as those noted by Liveing and Dewar in the spectrum of gaseous oxygen at high pressures, in addition to two bands in the ultra red agreeing with the Fraunhofer lines A and B. More recently Olszewski has prepared liquid oxygen in larger quantity and has examined its absorption spectrum more critically. Using a layer

30 mm. thick and 50 mm. high, contained in a thin glass vessel surrounded by three glass beakers to protect it from outside heat, it was found possible to maintain it at atmospheric pressure at its boiling point −181·4° for half an hour or more; and thus to submit it to observation for that time. The four absorption bands above mentioned were observed, and in addition a fifth band corresponding to the Fraunhofer line A, more intense than the band of wave length 535 but less so than the others. No absorption band corresponding to the line B was seen. In 1883 liquid oxygen was described as colorless; but with larger quantities, the author has noticed that in a layer of greater thickness than 15 mm., it has a distinct blue color by transmitted light. Since special care was taken in the purification of the gas, and since ozone was proved to be absent, the author believes this color to be characteristic of liquid oxygen. Moreover, he suggests that the blue color of the sky may be due to the oxygen in the atmosphere.—*Ann. Phys. Chem.*, II, xlii, 663; *J. Chem. Soc.*, lx, 773, July, 1891. G. F. B.

2. *On the Production of Ozone in Rapid Combustion.*—The statement of Ilosvay that ozone is not produced in rapid combustion having been questioned, he has reëxamined the matter and concludes that the tests by which the presence of the ozone was established by Loew and Cundall were not satisfactory. He finds that neither in the products of combustion nor in the air taken from around a flame is any substance present which (1) gives the odor of ozone, (2) renders thallous oxide paper brown, or (3) permanently decolorizes a solution of sulphophenyl-azo-α-naphthylamine so that naphthylamine no longer restores the color. By carefully depriving the gas used of sulphur compounds, he obtained in only a single experiment a reaction with thallous oxide paper; and this after about seven hours. Taking special precautions to keep the temperature of the flame low, however, and employing a special collecting apparatus, he obtained the thallous oxide reaction in about 4 to 5 minutes and the other reaction in 10 to 15 minutes. Examined in this way the author finds the flame of methane to give less, the flames of hydrogen and carbon monoxide more ozone than that of illuminating gas. Moreover it appears that the relative amounts of nitrous acid and ozone formed by a flame depend upon its temperature and upon its surface; the ozone formation being favored by a low temperature. Oxygen did not give as good results as air. Even if the oxygen is partially converted into ozone by blowing a current of this gas or of air on a flame, this fact the author thinks does not contradict his statement that ozone is not formed during rapid combustion. These results agree with those of Dewar and those of Elster and Geitel. The former chemist ozonized oxygen by passing it over white hot platinum. Since therefore the conditions essential to the production of ozone are not present in ordinary combination, this cannot be the source of the ozone of the atmosphere.—*Bull. Soc. Chim.*, III, iv, 707; *J. Chem. Soc.*, lx, 798, July, 1891. G. F. B.

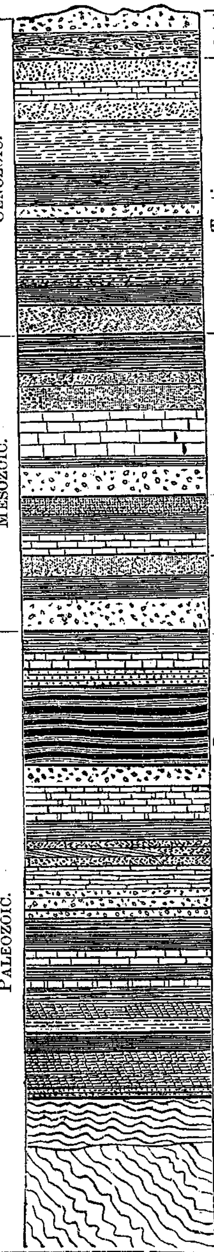
Entomological Club.

L. O. HOWARD: The Encyrtinæ with branched antennæ.
H. G. HUBBARD: Insect life in the hot springs of Yellowstone National Park.
E. A. SCHWARZ: Preliminary notes on the insect fauna of the Great Salt Lake, Utah.
J. A. LINTNER: On the occurrence of the Pear midge, Diploris pyrivora. Notes on the Pear tree Psylla, Psylla pyricola, in the Hudson River Valley. On the eye-spotted bud moth, Tinetocera ocellana, in Western New York. On some of our Orgyias. Exhibition of the luminous females of Phengodes, species.
J. B. SMITH: Note on the habits of Xyleborus dispar. Habits of Volucella fasciata. Notes on the classification of the Lepidoptera. A revision of the genus Cucullia. Staining insect structures.
E. W. CLAYPOLE: Means of preserving larvæ for class use. A substitute for cork.
H. E. WEED: Screw worm feeding on vegetable matter.
D. S. KELLICOTT: Notes on two borers destructive of mountain ash.
B. P. MANN: The bibliography on Entomology.
C. V. RILEY: Notes on Sphecius speciosus. Some interesting Phylloxeræ. Notes on the larval habits of Megaphycis.
M. E. MURTFELDT: Longevity and vitality of Ixodes and Trombidium. Modification of habit in paper wasps.

2. *The British Association.*—The meeting of the British Association was opened at Cardiff, Wales, on Wednesday, the 19th of August. The able address of the President, Professor William Huggins, treating of the progress of Astronomy through spectroscopic observations, is published in full in Nature of August 20th. The reader is referred to this and the following numbers of Nature for the addresses, also of the Presidents of Sections, and for abstracts of the more important papers presented. The next meeting will be held at Edinburgh, under the Presidency of Sir Archibald Geikie, commencing on the 3d of August, 1892.

OBITUARY.

WILLIAM FERREL, the eminent meteorologist, died at his home in Kansas City, Missouri, on the 18th of September, at the age of seventy-four. He commenced his active scientific career in 1857, when he was made assistant in the office of the American Ephemeris and Nautical Almanac. This position he held for ten years, when he was appointed to the staff of the U. S. Coast Survey. In 1882 he was made assistant, with the rank of professor, in the Signal Service Bureau, where he remained until October, 1886. Some of his most important work was was done in connection with the Coast Survey; he invented the maxima and minima tide-tide predicting machine, which is now used in predicting the tides. His list of published works include a number of volumes devoted to researches on the tides, meteorological problems, etc.; of these, a volume on Recent Advances in Meterology was published in 1883, and a Popular Treatise on the Winds—a work of marked value—in 1889. The recent volumes of this Journal contain a number of important memoirs by Mr. Ferrel upon thermal radiation, cyclones, tornadoes and related subjects, chiefly in terrestrial physics.



CENOZOIC.	Recent. Quaternary.			Tapir, Peccary, Bison, Llama. *Bos*, *Equus*, *Megatherium*, *Mylodon*.
	Tertiary	Pliocene.	Equus Beds.	*Equus*, *Tapirus*, *Elephas*.
			Pliohippus Beds.	*Pliohippus*, *Tapiravus*, *Mastodon*, *Procamelus*, *Aceratherium*, *Bos*, *Morotherium*.
		Miocene.	Miohippus Beds.	*Miohippus*, *Diceratherium*, *Thinohyus*.
			Oreodon Beds.	*Oreodon*, *Eporeodon*, *Hyænodon*, *Hyracodon*, *Moropus*.
			Brontotherium Beds	*Brontotherium*, *Brontops*, *Allops*, *Titanops*, *Titan-therium*, *Protoceras*, *Mesohippus*, *Elotherium*.
		Eocene.	Diplacodon Beds.	*Diplacodon*, *Epihippus*, *Amynodon*.
			Dinoceras Beds.	*Dinoceras*, *Tinoceras*, *Uintatherium*, *Palæosyo* *Orohippus*, *Hyrachyus*, *Colonoceras*.
			Heliobatis Beds.	*Heliobatis*, *Amia*, *Lepidosteus*.
			Coryphodon Beds.	*Coryphodon*, *Eohippus*, Lemurs, Ungulates, Tillodonts, Rodents, Serpents.
MESOZOIC.	Cretaceous.		Laramie Series, or Ceratops Beds.	*Ceratops*, *Triceratops*, *Hadrosaurus*, *Dryptosaur* Mammals, *Cimolomys*, *Dipriodon*, *Selenacod* *Nanomys*, *Stagodon*. Birds, *Cimolopteryx*.
			Fox Hill group.	
			Colorado Series, or Pteranodon Beds.	Birds with Teeth, *Hesperornis*, *Ichthyornis*. Mosasaurs, *Edestosaurus*, *Lestosaurus*, *Tylosaur* Pterodactyls (*Pteranodon*). Plesiosaurs.
			Dakota Group.	
	Jurassic.		Atlantosaurus Beds Baptanodon Beds. Hallopus Beds.	Dinosaurs, *Brontosaurus*, *Morosaurus*, *Diplodoc* *Stegosaurus*, *Camptonotus*, *Allosaurus*. Mamm *Dryolestes*, *Stylacodon*, *Tinodon*, *Ctenacodon*.
	Triassic.		Otozoum, or Conn. River, Beds.	First Mammals (*Dromatherium*). Dinosaur Footprints. *Anchisaurus*, *Ammosaurus*. Crocodiles (*Belodon*).
PALEOZOIC.	Permian.		Nothodon Beds.	Reptiles (*Nothodon*, *Sphenacodon*).
	Carboniferous		Coal Measures, or Eosaurus Beds.	First Reptiles (?) *Eosaurus*.
			Subcarboniferous, or Sauropus Beds.	First known Amphibians (Labyrinthodonts), *Sauropus*.
	Devonian.		Dinichthys Beds.	*Dinichthys*.
			Lower Devonian.	
	Silurian.		Upper Silurian.	
			Lower Silurian.	First known Fishes.
	Cambrian.		Primordial.	
	Archæan.		Huronian.	No Vertebrates known
			Laurentian.	

SECTION TO ILLUSTRATE VERTEBRATE LIFE IN AMERICA.