could the exact age of a number of trees be determined. This has been planned for future work and will be executed at the earliest possible date. The fact, however, that these trees have acted as silent guards for centuries over these slopes and have recorded with unerring accuracy the rate of erosion is apparent, and as soon as the data can be secured, there will be a valuable factor for converting geological time into years.

By approximating the various estimates in connection with the date the following may be of interest: The Hole where the observations were made was about six miles wide. The trees were 300 years old and there had been on an average of three feet of rock removed from their roots. This would require one hundred years to remove a foot of the formation. Considering that the erosion started in the center of the Hole, there has been three miles removed from either side, which at the rate of one foot per century would require 1,584,000 years. Without question this erosion commenced at the close of the Miocene and hence represents the entire Pliocene and Pleistocene Epochs. The exact time relation of the Pliocene, and Pleistocene in relation to Eocene and Miocene has not been established; but if the Pliocene and Pleistocene Epochs represent 1,584,000 years it would not be out of the way to estimate Cenozoic time at 4,000,000 years. If this value be substituted in the ratios of geological time suggested by Dana:—Paleozoic: Mesozoic: Cenozoic as 12 : 3 : 1 then all geological time since the beginning of the Cambrian would be represented by 64,000,000 years. This estimate is not inconsistent with some already made; but when founded on absolute data may vary much from this. Nevertheless, whatever the results may be when found upon a complete investigation of this subject, they will furnish valuable scientific data that will aid materially in giving us a better understanding of geological time in terms of years.

Wilbur C. Knight.

Geological Laboratory
University of Wyoming,
October 2, 1899.

SCIENTIFIC BOOKS.

La géologie expérimentale. Par Stanislas Meunier, Professeur de Géologie au Museum d'histoire naturelle de Paris. With 56 figures in the text. Paris, Ancienne librairie, Germer Bailliére et cie. 1899. Pp. 311. (Bibliothèque Scientifique Internationale, XCII.). Price, 6 frs.

Just twenty years have elapsed since Daubrée brought out his famous work *Études synthétiques de géologie expérimentale*, and laid thereby the foundations of the school of French experimentalists. This book was translated into German in the following year, 1880, but never found an English interpreter. That such an edition was needed is shown by the reference in Dana's Manual of Geology to an alleged experiment of Daubrée with plates of *ice*, which should have been rendered plates of *glass*.

The mantle of Daubrée seems to have been taken up by M. Stanislas Meunier, who enjoys the distinction of having reduced the odds and ends of experiments, performed in the imitation and illustration of geologic processes, to a system of lectures for the entertainment and instruction of a large class of students. The present book is a *résumé* of these lectures as given in the year 1898 at the Museum of Natural History in Paris.

The scope of the work is general, in that the experiments described relate to a wide range of phenomena, *e. g.*, the formation of rain-prints, stream channels, deltas, solution furrows, weathering, disintegration and decomposition of rocks, the striation of rocks, sedimentation under varied conditions, the production of faults, folds, and systems of fracture and displacement. The treatment of the subject, however, is somewhat narrowed by the fact that the author deals almost altogether with his own experiments, with only incidental reference to the work of others. The book cannot be said, therefore, to represent fairly or comprehen-

sively the state of experimental geology. The critical student to whom experiments are the last resort will find from footnotes that most of the author's tests are more completely described in the *Comptes rendus de l'Academie des Sciences.*

The grouping of the subject matter is good, experiments relating to epigene processes coming first and those pertaining to the theory of hypogene actions following. An introductory chapter of 34 pages is an apology for and defense of 'La Geologie experimentale,' a frank statement that the methods and its results are scorned in certain quarters. While this admission seems not inappropriate, the frequent references in the body of the work to the distinction between experimental geology and geology as ordinarily pursued, appear somewhat pathetic and out of place in a book designedly published in the interests of science and for the popularization of this subject. Notwithstanding the fact that many of the author's attempted explanations of natural phenomena would probably not be accepted by geologists, it cannot but be instructive to many who have not grasped the facts of the earth's structure to see how by some simple mechanical contrivance phenomena simulating mountains, the action of volcanoes, the effects of earthquakes and the like may be produced. However far removed the apparatus employed may be from the exact processes in nature, analogies described in the text must displace much misconception which prevails in the popular mind concerning the operations of the earth forces.

It is to be regretted that the author did not state the principles governing experimentation and something of the limitations of the method. Though the objections to certain experiments are briefly referred to, there is much which has been said on the subject of which we find no echo in this book. A text-book giving a comprehensive view of the subject with critical notes would be a welcome addition to our geological laboratories.

As for the experiments, many of them illustrate everyday changes which it is customary in all favorably situated colleges to demonstrate in the field where the natural process and its product may be seen under more favorable circumstances than in the laboratory. That experimentation without accurate knowledge of the facts to be explained is not infallible, is well illustrated by the different conclusions reached by Daubrée and Meunier in regard to the rectangular courses of rivers. Daubrée, it will be recalled, sought to explain the right-angled courses of streams by postulating preëxistent faults as guiding lines for the drainage. At the time he did his work this explanation had many adherents. It is manifestly no difficult matter for a clever artisan to devise a model in which the conditions of the hypothesis and the expected results are satisfactorily demonstrated. Professor Meunier, evidently familiar with the current view that such rectangular courses arise in the development of a river system upon certain geological structures unaffected by faults, performs an experiment through which he comes to disbelieve in Daubrée's conclusion. Incidentally the phenomena of the headwater gnawing of streams, the recession of falls, and river-capture, are artificially reproduced. It is to be noted that in the discussion the reference to 35,000 years as the time required for the recession of Niagara Falls indicates an oversight on the part of the author of all recent investigations on that subject.

Some of the experiments intended to illustrate the phenomena of meanders in streams seem hardly legitimate, or at least there is no endeavor to imitate nature in the employment of a stream of mercury and in the production of meanders on a slope of 20 degrees! The object of the experiment seems here to have been lost sight of! Likewise the agitation of a flexible cord, substituted for a stream with meanders, in the attempt to illustrate the control of the meander is amusing, but it may be questioned whether it is convincing.

Other experiments are described as designed to prove the competency of running water to excavate valleys and with the further purpose of combating the lingering notion in France that 'we are now in a period of geologic tranquility.'

Under the head of marine and lacustrine denudation, M. Stanislas Meunier treats of the mechanical action of waves and the chemical action of water. The experiments with wave

action are seemingly very incomplete in that no mention is made of the formation of shore-bars, spits, hooks, etc. It seems likely that the scalloped beaches described by Jefferson (*Journal of Geology*, Chicago, VII., 1899), might have light thrown on their origin by proper experimentation.

"Glacial geology offers an extended field for experiments, and in this connection our author proceeds to imitate the formation of crevasses, employing stearin placed on a band of rubber. Tension is applied and crevasses are formed. To demonstrate glacial erosion by the striation of rock fragments, the simple friction experiment of Daubrée and others is repeated. It should be said that this experiment does not offer a very close analogy to the conditions in a glacier on account of the 'plasticity' of ice. But it is in regard to recurrent occupation of a field by glaciers that M. Stanislas Meunier makes his most novel suggestion. His proposition may be given in nearly his own words:

"Given a glacier, and everything else remaining in equilibrium, it tends to diminish in spite of seasonable changes, by reason of the progressive lowering of its basin of supply [because] the materials which it transports in such great quantities along with the water which is associated with it, reduce the relief of the ground. It then recedes, and behind its abandoned frontal moraine vegetation is established. But, comparable at all points with rivers, it gnaws back progressively at its head, and it is possible for this recession to reach the point by destroying the rocky arête which separates its basin from that of a neighboring glacier, where it is permitted to divert this glacier to its own basin. Thereupon an increase of substance ought to provoke a return to the dimensions formerly held, and from that time the products of the fossilization of the plants established upon the first glacial terrane will be covered with a second morainal extension."

It is our author's view that this phenomenon of capture of glaciers by being reciprocal and recurrent, accounts for the so-called successive glacial periods in the Pleistocene. He necessarily attempts to refute the theory that these epochs of glaciation and deglaciation are 'general and simultaneous.' While the oscillations of glaciers in a region of valleys such as the Alps might very plausibly be affected by changes of this kind, it is not so apparent that the broad marginal oscillations of the ice-sheet of North America, for instance, can be explained in this manner.

We next find a brief chapter on the work of underground water. Several simple and readily devised means are adopted for imitating the leading features in the production of water-worn channels, tunnels and the striation of pebbles *en masse* through movements initiated by the washing out of supporting materials. The author indulges in some animadversions upon the nature of the scratched drift of the pre-alps of Europe and holds to the opinion that much of the so-called glacial drift of that region is really material striated in mud-flows—of which subject there is more to follow.

Eolian denudation is passed over with a few references to the geological work of the winds and to the well-known experiments of Thoulet. The term *abrasion* employed in a technical sense for wind erosion has not so extended a use among English-speaking writers as the author evidently thinks. Walther's term *deflation* is the only one apparently commanding anything like general use.

The processes of sedimentation receive a well-deserved attention. In this connection the author devotes several pages to the subject of mud-flows, a feature of many moist mountain regions which has been given evidently too little attention by geologists, but which is hardly so important a factor as the author intimates. There are a number of experiments described to show the rate of falling particles in water; and small points bearing on the criteria of horizontality in the deposition of certain strata are brought out. None of these precautions, however, appear to have escaped the attention of field geologists and the author here, as elsewhere, seems to have been forestalled in many of his discoveries. The statement that floating trees in large rivers sink root downward and thus may be buried upright giving the appearance of buried forests appears to pertain to observational geology. There are experiments to show the amount of water included in sediments. A frequent defect of the book is the

mere reference to experiments which are not described, as, for instance, in the case of deltas. The deposition of sediments in the subterrane is treated experimentally and chemical alterations inducing color bands are imitated.

M. Stanislas Meunier has successfully reproduced fossil footprints by blowing sand upon the tracked surface covered with a slight depth of water. He conceives, therefore, that fossil footprints cannot have been preserved by the rise of water spreading sand over the surface on which tracks were made. It remains for some clever manipulator to prove [the converse of this proposition as equally effective. The author's point is a good one, however, and the numerous instances in the older strata in which mud-tracked surfaces are covered with sand is a strong argument in favor of his theory.

Dessication of strata and their torsion are next taken up. The author concludes from his experiments that regular rhomboidal jointing is not to be explained by torsion as Daubrée labored to prove. Neither Daubrée nor the author have imitated with any degree of accuracy the conditions in which the stratum is placed when it yields to the jointing strain, and critical experiments are much needed in the elucidation of an old but not yet satisfactorily solved problem.

A very brief reference to the origin of the crystalline rocks deals mainly with the work of Messrs. Fouqué and Lévy on the igneous rocks. An even shorter discussion of metamorphism touches only some of the concomitants of metamorphism, such as the carbonization of wood tissue. The experiments of Sénarmont and a few others are referred to in the explanation of metalliferous veins, and a few words are given on the subject of kaolinization and serpentinization.

Our author now plunges boldly into experiments designed to elucidate the origin of the primitive crust of the globe. He assumes that beneath the *débris* of the surface there exists a granitic zone, under which occurs a shell of which silica, magnesia and iron constitute the greater part, citing, as evidence of this latter rock, dunite, and the dolerite with native iron at Ovifak. This shell is supposed to have been formed by a precipitation from the nebular gas. The author has obtained in a porcelain tube the synthesis of the principal silicates of magnesia without the intervention of fusion in illustration of this conception. He concludes from his experiments that the solid shell of the globe which was first formed and which had analogies with the solar photosphere, consists of magnesium silicate rocks with an abundance of metallic concretions of which the genesis is related to the phenomena still evident in the material of tin-bearing veins and even in the chimneys of volcanoes. There results, he goes on to state, a relative distribution, in which the consideration of the density of the bodies studied at ordinary temperatures plays no part. Metallic iron, for instance, no "longer appears as constituting a massive nucleus, but on the contrary as forming a true shell below which have been congealed in later times the rocks of which eruptions have procured for us specimens in every geologic epoch."

In part second of this book over 50 pages are devoted to the application of the experimental method to the problems of deep-seated mechanical action. The remarks on the effects of weight or gravity appear not to be suggested by experiments, but to have risen out of the general philosophy of geology. Indented pebbles are ascribed to pure pressure without chemical solution.

An experiment is described with the design of showing the supposed effects of the centrifugal force upon the original crust of the earth. The substances employed in a rotating glass bottle of spherical shape arrange themselves about the equator in the inverse order of their densities contrary to what would be expected from gravity alone. This experiment is largely relied upon for some of the conclusions previously stated regarding the nucleus of the earth.

An experiment to illustrate the formation of volcanic cones reproduces such little burst steam bubbles as one sees in the paint-pots of the Yellowstone Park. Laccoliths are also, it is stated, reproducible by means of melted wax injected between sheets of plaster having a slight degree of plasticity.

Professor Meunier attempts also the famous problem of introducing water into the interior

of the earth, in short, into his infra-granite zone. He holds that the water which comes out in volcanoes cannot be original, because the temperature of the globe is constantly decreasing and that past conditions were still less favorable than the present ones for the maintenance of water in the interior. He thinks, therefore, that the water is of recent introduction.

"The solution of the question," states our author, "appears to result from some very simple experiments of M. Stanislas Meunier." Without describing the experiment which in no way duplicates the condition of the earth's crust at a depth, the author supposes that the water is brought into the infra-granitic zone as water of consolidation and crystallization embodied in fragments of rock which fall down along fault-planes and zones of crushing. The 'falling' of these hydrated rocks into the heated regions of the globe is supposed to give rise to volcanic explosions and as is stated in the next chapter to earthquakes also. The author very frankly states that he is obliged to note the profound astonishment which the first publication of his views elicited.

In the experiments on folds some interesting points are dwelt upon concerning the intersection of planes of fracture which arise, but these artificial faults are not compared with those of any particular region. Under the head of schistosity are described experiments which appear in reality to have induced a kind of cleavage as that term is understood in English. Fractures are produced by compression in some experiments which lead the author to reject Daubrée's famous radiating fractures produced by torsion, seemingly on the ground that such fractures have 'not anywhere been observed.'

The general distribution of mountains upon the globe last of all comes in for experimentation in the clever methods of the author. A small hemispherical shell has stretched over it a rubber layer coated with plaster, in such a manner that when the foundation, which represents the contracting nucleus of the globe, is allowed to retreat, the contraction of the rubber layer induces compression of the plaster. This stress is relieved by circumpolar lines of shearing and displacement, the overthrust being poleward in direction. The author points out the analogies which seem to exist between this model and the arrangement and orogenic movements of the mountain systems of Europe. The researches of Suess on the northwesterly movement of the Eurasian thrusts should be noted as favoring this hypothesis, but it is difficult to see in what way the view is exemplified on the North American continent.

The book is closed with a 'Postface' or statement, with which most geologists will probably agree, that this volume sets forth facts amply sufficing to justify the *raison d'être* of experimental geology. Whatever misgivings one may entertain concerning the decisive character of some of the experiments, there can be no doubt of the suggestiveness of the original and ingenious methods which the author has brought to bear upon some of the largest questions of dynamical geology. The book is illustrated with a few good cuts and is well printed. A list of contents takes the place of a good index. The publishers have taken the liberty of appending 35 pages of advertising matter which might have been omitted.

J. B. W.

Leçons sur la détermination des orbites professées à la Faculté des Sciences de Paris. Par F. Tisserand; redigées et développées pour les calculs numériques par J. Perchot; avec une préface de H. Poincaré. Paris, Gauthier-Villars. 1899. 4to. Pp. xiv + 124.

These lectures formed a part of the course in mathematical astronomy delivered at the Sorbonne by the late Professor Tisserand, but the important question of the determination of cometary and planetary orbits was not treated in his well-known treatise on celestial mechanics. The only work in the French language devoted to the numerical elements of orbits is the translation of Oppolzer's treatise, which is a most useful book to the computer, but neither easy nor attractive to the reader; on the contrary the lectures of Tisserand exhibit the clearness of exposition and the simplicity and elegance of method which uniformly characterize his writings, so that all devotees of mathematical science will be indebted to M. Perchot for this edition of the unedited lectures of his lamented master. Professor Poincaré's pre-