ART. LII.—*Daubrée's Experimental Geology: Part II, Experimental Study of Meteorites with reference to certain Cosmical Phenomena*; noticed by J. LAWRENCE SMITH.

Études Synthétiques de Geologie Expérimentale; par A. Daubrée, Deuxième partie—application de la methode expérimentale a l'étude de divers phénomènes cosmologiques.

THE first part of Professor Daubrée's valuable work on experimental geology appeared several months since.* The second part, embracing about 350 pages, is exclusively devoted to an experimental study of the structure and genesis of meteoric minerals, and to the bearing of the facts on the constitution of the universe.

The first chapter of the part before us is devoted to the study of the phenomena attending the fall of Aerolites and to their classification. The statement is reaffirmed, "that the two months, August and November, remarkable for showers of shooting stars, have no particular prominence over other months as regards the number of falls of meteoric stones." It is important that this fact should be clearly stated and reiterated, since many scientists are disposed to connect these two classes of phenomena; until shooting stars and meteoric stones are treated of wholly independently, no approach will be made to a correct theory in regard to the origin of the latter.

* This Journal, August, 1879, p. 150.

The composition of meteorites is reviewed, and the well-established fact that but few minerals enter into the constitution of these bodies, however different they may be in physical characters.

The metallic iron, forming either the entire mass or disseminated in small particles through the stones, is invariably a nickeliferous iron, containing a little cobalt and a trace of copper. The stones commonly consist almost entirely of bronzite* or enstatite (sometimes with magnesia as the only protoxide element) and olivine in various proportions, with particles of iron in smaller or greater quantity disseminated through the mass. The next most abundant non-metallic mineral is anorthite, which is found in that class of meteorites called eukrite. Besides these, a few other minerals are more or less constant, but usually in small quantities and some of them in minute proportions, such as troilite, schreibersite, chromite, daubréelite, etc. Other well-known physical and chemical characters are referred to in the same chapter.

The most interesting part of Professor Daubrée's labors relates to the fusion of meteorites and their artificial imitation. In the first class of experiments the results show that the fusion of meteoric stones does not alter materially the character of the minerals contained in them, except that the crystals of the minerals become better characterized, as seen by examination under the microscope.

The fusion of the eukritic meteorites present some remarkable features; "they yield a product wholly different from the other magnesian meteorites, namely: a vitreous mass sometimes striped by a commencement of devitrification, but without crystals of olivine or enstatite." "In the same experiments, a substance is obtained that does not appear to have been seen in the magnesian meteorites; this is titanium (in the state of carbo-azotide) recognized by its characteristic color and by its not being attacked by acids.

The imitation of meteorites by the reduction of terrestrial rocks was successfully made by fusing rocks consisting principally of pyroxene (a mineral closely related to enstatite) and olivine. In operating upon olivine and lherzolite in large quantities, by fusing them in a crucible *brasqué*, buttons of iron were obtained giving regular figures when etched, and containing nickel and cobalt. In another series of experiments, hydrogen instead of carbon was used as the reducing agent on lherzolite and pyroxene, and the decomposition was effected at a low red heat. The oxide of iron was reduced to metallic iron, and the phosphates to phosphides, the products having a close

* The enstatite, also called bronzite, in its chemical character is a magnesian pyroxene.

chemical analogy to what is found in meteorites. A portion of this part of the volume contains a minute description of the San Catharina meteoric iron, which possesses much interest and is worthy of a still more extended study.

In the second chapter, the deep-seated rocks of our globe are compared with meteorites. There is much that is interesting in the statements in regard to olivine and the transformation of serpentine into olivine. In this connection, Professor Daubrée makes some interesting statements with reference to the association of platinum with serpentine. The presence of metallic iron in native platinum is a distinguishing characteristic and would lead us to infer some connection between the rock matrix of platinum and meteorites.

Daubrée's observations and experiments in regard to the cosmic bodies from which meteorites are derived is of considerable interest, embracing as they do the supposable conditions under which the minerals were formed. In regard to what he considers minerals of reduction—as the iron and schreibersite—he is inclined to attribute their reduction to an atmosphere of hydrogen acting on the rocks at a more or less elevated temperature; how high the temperature was it is impossible to decide. He says: "It was without doubt an elevated temperature, because the anhydrous silicates, as olivine and pyroxene, are the products; yet at the moment of solidification and crystallization, the temperature appears to have been inferior to that which I employed in my previous experiments [those of fusing the meteorites]. Two facts would lead us to this conclusion." "The elevated temperature, produced in the laboratory, resulted in the formation of distinct and large crystals, such as are never found in meteorites. It is worthy of note that the siliceous substances which compose ordinary meteorites are always in small confused crystals, notwithstanding the extreme tendency of the minerals to crystallize. Beside this production of small confused crystals, there is a manifest tendency for them to assume a globular form."

The author compares meteorites with the rocks of our globe and brings out the contrast in a striking manner, showing their entire dissimilarity with our sedimentary rocks; and also with granite, gneiss, mica schist and other rocks of this family, whose minerals, as tourmaline and other silicates, are never present in meteorites. It is only below the granites that we encounter rocks at all analogous to meteorites; and in these occur all the elements and many of the minerals that are to be found in them. This, in connection with what the spectroscope has developed, points to a unity in the origin of celestial bodies and in the constitution of the universe, a fact illustrated in various lights by the author.

He observes: "Whatever their origin and orbits, the meteorites that fall on our planet show us one of the great methods of change carried on in the universe, consisting in the distribution of the fragments, derived from the destruction of certain stars, planets or asteroids, among other suns and planets. Such occurrences are not accidental or exceptional phenomena, but facts under a law of the universe. In establishing a close relation between meteorites and the deep-seated rocks of our globe, we not only unravel remote phases in the history of our own globe, but establish the intimate relation that exists between the different parts of the universe." "It is thus that geology, taken in its broadest sense, has an intimate relation to physical astronomy, for if it receives light, it also contributes light."

The second section of this part of Professor Daubrée's work treats of the mechanical phenomena connected with meteorites. Under this head are included the globular structure which characterizes many of the minerals, the polyhedral forms of meteorites, and the pitting on their surface. This last characteristic is treated at great length, and is attributed to sudden heating in connection with great gaseous pressure. Numerous examples are given of experiments on stone, iron and steel with gunpowder and dynamite; and over forty pages of the work are devoted to the details connected with them.

In the application of this part of the subject, Professor Daubrée says: "Those meteorites, which have a fragmentary structure and are very often polyhedral in form, exhibit on their surface the effects of the action of compressed and heated gases, the indentations affording evidence of a wearing action by air in a cyclonic movement." When meteoric masses have been isolated from each other after entering the atmosphere their surface, during their course, has been exposed to compressed and incandescent gases, from the time that they became luminous to that when they have exploded, at which time the incandescence ceases. The track of a meteorite while thus incandescent is often over one hundred and twenty-five miles, and takes several seconds. During this time, it certainly cannot preserve, in the midst of powerful erosive action, its polyhedral form, with well defined angles and edges." These deductions are certainly reasonable. It is evident that the powerfully compressed air is the cause of their frequent explosions attended with rupture of the mass; for the compression of the air may be supposed to reach 1000 atmospheres, and the bolides are turned and twisted in every direction in the midst of this condensed gas.

In the latter part of this work the other peculiar physical characters of meteorites are considered: the black veins, the

marbled structure of the coating of some of them, and also the pulverulent variety of meteorites, or, as it is sometimes called, meteoric dust, etc.

I have thus given a statement of some of the prominent features of this most admirable work on the mineral and geological study of meteorites, embracing not merely descriptions, but also the results of well directed experiments, and comprehensive philosophical conclusions. We have nothing like it in our scientific literature; and being the result of the labors of so distinguished a geologist as Professor Daubrée, one who has devoted much thought and labor to the subjects of which he treats, it deserves the closest study. The first part of the work I have not referred to, for it has been made known to us briefly in a former notice in this Journal, and quite fully in Professor Dana's recent edition of his *Manual of Geology*, which work cites many of the facts and conclusions, and some of its excellent illustrations.

In the preparation of both parts of this volume, the publisher has done his part most thoroughly, the paper and typography being such as are rarely equalled in scientific publications, and the illustrations in the text, which are very numerous, being of unusual beauty. The work is one that should find its way to the library of every geologist.