word, the subject for research is whether one of the last two theories will apply to the case in question. You will notice, moreover, that each of these theories presumes a geological cause. It is in part, I think, this idea of the connection between earthquakes and the movements far below the surface, that has influenced the Academy of sciences in choosing a geologist to examine the phenomenon.

In my turn, — and for the same reason as the Academy of sciences, — I have taken geologists as collaborators. Those who accompany me are Messrs. Michel Lévy and Marcel Bertrand, members of the geological survey of France, and mining engineers of great competence. The third who accompanies me is Professor Barrois, of the Faculty of science at Lille, an eminent geologist, who is well acquainted with the Spanish soil.

I have, then, as my associates, three geologists, perfectly competent to study all the facts that are usually investigated in earthquakes, — the propagation of the motion, the direction of the shock, and the place of greatest intensity. They are also capable of determining the relations which exist between the superficial action of an earthquake and that which may be going on at great depths. Geologists, when they travel over the surface of a piece of ground, see not only the superficial beds, but, by a sort of instinct, they divine the character of the deeper extensions. Sometimes they are mistaken, — they are not infallible, — but still, in the most cases, they are able to determine the constitution of the deep strata. This, then, is one special point which we shall endeavor to determine.

We wish, from the study of the superficial deposits, to deduce its geological structure at a certain depth. On the other hand, with the means which we possess to-day, it is possible to determine approximately the depth from which an earthquake shock originates. We have two methods for this. One, which is founded upon very precise and delicate observations, has been proposed by Mr. Seebach: it is based upon the determination of a series of points, in which the oscillations are felt at the same moment. These observations are extremely difficult to obtain.

There is another, older method, due to the English physicist, Mallet. The system of observations proposed by him is based upon the examination of the cracks in the land after an earthquake. These fractures are, in nearly every case, normal to the direction of the shock; and, when one studies them carefully, the direction of these normals is sufficient to fix their points of convergence, and hence the origin of the shock.

The methods of which I have spoken are not purely theoretical: they have been applied five or six times by Germans, Italians, and English; but, unfortunately, the French have not yet used them. They have given very interesting results; as, for instance, in the last earthquake at Ischia, it has been shown that the cause of the concussions came from a depth of from twelve hundred to eighteen hundred metres at the most. Between twelve hundred and eighteen hundred metres there is certainly a considerable range; but one would have expected to find that the shock came from a much greater depth. Consequently much is already accomplished, when we can limit the origin of the phenomenon to a space so restricted.

I said that we were able to apply these two methods, the one certainly, the other probably. We may thus ascertain the depth of the earthquake's centre. If, on the other hand, we are able to determine by geological observations the constitution of the earth at this point, we shall have obtained a datum extremely important, and we may be able to accept one of the two theories, or so to limit one or the other as to make it agree better with the facts.

These are the objects of our mission, these the things we count on accomplishing. You will see that it is very simple. I hope that we shall obtain satisfactory results. I do not dare to promise that we shall; but I do promise you that we shall study Andalusia, or a portion of this province, with care, and that we shall bring back data of geological interest and importance from this very curious country.

SEISMOLOGICAL NOTES.

THE earthquakes of the last year in England have, like those in this country, aroused an interest in seismometry; and the committee of the Scottish meteorological society, who have charge of the Ben Nevis observatory, have asked Professor Ewing (whose work in Japan we recently noticed [vol. iv. p. 516], and who is now professor of engineering in University college, Dundee) to institute earthquake observations on the top of Ben Nevis. Professor Ewing has received a grant of a hundred pounds from the committee controlling the government grant for scientific investigation, and will proceed to set up apparatus to detect, and probably to record, minute earth-tremors, and also slow changes of level of the ground.

In connection with the recent Spanish earthquakes, it is interesting to note that we have accidentally brought into prominence a new kind of seismoscope. In *Nature*, vol. xxxi. p. 262, Mr. Ellis of the Royal observatory at Greenwich states that the continuous photographic records of the declination and horizontal force magnetometers both show a simultaneous disturbance, different from the ordinary magnetic disturbances, occurring on the evening of Dec. 25, a few minutes after the reported time of the severe earthquake in Spain on that date. No ordinary magnetic disturbances were recorded on this and neighboring dates, and the earth-current registers showed no change; so that there would seem to be little if any reason to doubt that the unusual disturbances recorded were caused by the swinging of the magnets on their suspending fibres, due to the shaking of the points of suspension by the Spanish earthquake. If some method were devised of photographing the lateral swing of the magnets in two azimuths at right angles, in addition to the present torsional swing as magnetometers, these instruments could, perhaps, be made very sensitive seismoscopes as well, and the accuracy of the time-record would only depend upon the velocity given to the strip of photographic paper. Of course, as *seismometers*, they would be as worthless as all stable pendulums must be; but as *seismoscopes*, they might be quite sensitive, and the expense and requisite attention need not add greatly to that already necessary with the magnetometer.

In Japan, Professor Milne keeps up his active work in seismology. During the last summer, he spent five days on the top of Fujiyama, attempting to detect diurnal changes in the level of the ground. The results have not yet been published. This mountain — a wonderfully symmetrical volcanic cone, about twelve thousand feet high, and the most striking object in all Japan — is the one on whose summit Professor Mendenhall made a determination of the force of gravity and of the values of the magnetic elements; and it will always be an interesting point for scientific observations of all kinds, rising as it does in complete isolation out of a plain.

In vol. vii. part 2, of the *Transactions* of the seismological society of Japan, Professor Milne contributes a paper upon three hundred and eighty-seven earthquakes observed in northern Japan between October, 1881, and October, 1883. A map is given for every quake, showing by its colored portion the approximate area covered by the shock, as determined by Professor Milne's system of tracking down earthquakes by a system of postcards distributed to all important places in the hands of observers who send in weekly reports of the occurrence or non-occurrence of any disturbances. In this way Professor Milne has had the northern part of Nippon and the southern part of Yezo covered for several years with a network of forty-five observers, besides those in Tokio and Yokohama. At five of these stations quite accurate time-observations of the disturbances were frequently obtained by the help of good clocks compared several times per week with the daily telegraphic noon signal from Tokio. A catalogue of the individual observations of each of the three hundred and eighty-seven shocks is also given. Some of the results are worth noting. As regards geographical distribution, it is remarkable that only two out of the three hundred and eighty-seven shocks appear to have extended to the west of the range of mountains running up the western side of the island of Nippon, being apparently stopped by that barrier, while about eighty-four per cent seem to have originated either out under the ocean or very near it on the eastern side of the islands. Commenting on this, Professor Milne says, —

"The district which is most shaken is the flat alluvial plain of Musashi following the line of the river Tonegawa. . . . This area forms one of the flattest parts of Japan. The large number of earthquakes which have been felt on the low ground, and the comparatively small number which have been felt in the mountains, is certainly remarkable.

"It must also be observed, that, in the immediate vicinity of active or extremely recent volcanoes, the seismic activity has been small. . . . It may also be remarked that the side of Japan on which earthquakes are the most frequent is the side which slopes down steeply beneath an ocean which at a hundred and twenty miles from the coast has a depth of about two thousand fathoms, whilst on the opposite side of the country, at the same distance from the shore, the depth is only about a hundred and forty fathoms. Another point not to be overlooked is the fact that the district where earthquakes are the most numerous is one where there is abundant evidence of a recent and rapid elevation.

"In all these respects the seismic regions of Japan hold a close relationship to similar regions in South America, where we have earthquakes originating beneath a deep ocean at the foot of a steep slope on the upper parts of which there are numerous volcanic vents, whilst, on the side of this ridge opposite the ocean, earthquakes are rare. With regard to the Musashi area, it may also be remarked that sediments brought down by numerous rivers from the higher parts of the country are accumulating on it at a very rapid rate."

The distribution of the three hundred and eighty-seven earthquakes for the four quarters of the years was as follows, — January - March, 195; April - June, 70; July - September, 39; October - December, 83, — thus confirming the greatest activity in the coldest, and least in the hottest, months of the year, which had been shown before for the Tokio district alone for a long period of years.

With respect to the measurement of the motion of the ground, most of the facts deduced by Professor Milne are substantially the same as those summarized by Professor Ewing in his memoir referred to above. The following, however, which is partly, at least, new, deserves quotation here: —

"Inasmuch as it will be observed that different instruments give different results for the same earthquake, in order that the reader may not regard such diagrams as conflicting, the following results, which have been obtained from the earthquakes here referred to, and which have been confirmed by many observations made subsequently, may be enumerated:

"1. An ordinary earthquake, although having a general direction of propagation, has at a given point many directions of vibration. If there is a decided shock in a disturbance, this particular movement may be indicated in the same manner at adjacent stations.

"2. The amplitude of motion as observed at two adjacent stations, even if only a few hundred feet apart, may be extremely different.

"3. The period of motion may vary like the amplitude, the instruments being in all cases as similar as it is possible to construct them.

"At present I am carrying on observations by means of three similar instruments placed at the corners of a triangle the sides of which are about eight hundred feet in length. When these instruments are side by side, they practically give *similar* diagrams. At their present positions, they always give *different* diagrams. If these instruments were in the hands of distinct observers, each of these observers would give a totally different account of the same earthquake. Judging from the quick period and large amplitude of motion always observed at one particular corner of my triangle, I can say with confidence that at this corner there might be sufficient motion to shatter a building, whilst at the other corners similar buildings would not be damaged."

He does not state whether there is any difference in elevation or in character of soil at the corners of this triangle; but, if there is none, then this observed difference of motion is highly interesting and important, and should be tested and verified in every possible way by interchange of instruments, resetting of supports, etc., in order to be sure in every way that there is no local peculiarity of instrument or method of attachment to the soil. Doubtless this will have been fully attended to in Professor Milne's continuation of these interesting experiments.

H. M. PAUL.

A RECENT DISCUSSION OF THE AXIOMS OF MECHANICS.

THE logic of the physical sciences will always remain a fascinating field for the philosophic inquirer, and doubtless also for the special student of those sciences. The recent efforts towards a 'reform in logic' in Germany have not left this field untouched; and one of the first in importance, among the books that bear on the general topic, is the work whose title is given below. The author has qualified himself for the task by a lengthy study of the history of the development of his science, and he has the power to suggest much more than he directly says. In short, we have here a man who combines definiteness with depth of thought; and his book, whether useful or not to the specialists in mechanics, is surely very suggestive to the student of logic.

The author represents in his way the new empiricism of Germany, — a doctrine that has grown up out of a study of Kant and the English philosophy combined, and that as certainly points back again into the realm of specially philosophic discussion as it appears anxious to be forever beyond that realm. This new empiricism is much more suggestive than the older empiricism of J. S. Mill. He had founded all inductive interpretation of nature on the causal principle, and the causal principle itself again on an inductive interpretation of nature. The new empiricism escapes from this circle by assuming a relatively *a priori* principle in all induction, but seeks to remain empiricism still by making this principle no abstract axiom, but a sort of ultimate form or tendency of intelligence, viz., the tendency *to conceive of the facts of experience in the most economical way*. This interest in economy of thought shall, in the new empiricism, take the place of the old axiom of causality, and, in fact, of all the mysterious axioms of past logicians. This tendency to economy is to be the true *a priori* that Kant sought. It is to give us no knowledge transcending experience, but only a necessary presupposition concerning experience. What for bare experience would seem a confused mass, becomes for the scientific thinker, by virtue of this tendency to economy, a world of law. All the laws are indeed statements of empirical fact; but the statements never could assume this form save by virtue of the effort to economize thought.

Such is the general statement of the new empiricism. Our author, for the most part, confines his use of it to his special task, and lets general philosophy as much as possible alone. Yet he cannot but constantly suggest to the reader the philosophic problems peculiar to his method. For the rest, he lays claim in the preface to considerable relative originality in the development of his own doctrine. Before Kirchhoff and Helmholtz applied to mechanical science the general theories of the new empiricism, Mach had outlined his views in a published essay. He is thus entitled to individual credit, and open to separate criticism.

Applied to mechanical science, the new empiricism, as our author and Kirchhoff have expressed it, takes the form of declaring the purpose of mechanics to be, "the simplest possible description of the motions that are in the world." Thus at a stroke the science is to be freed from all mysterious elements. Those old ideas of force, of inertia, and the rest, are to be defined afresh in such a way as to conform to this logical theory. The science is to have its two perfectly plain bases; viz., experience of motion, of velocity, of direction, etc., and the effort to think this experience with the least effort and the greatest unity.

The historical form that Mach gives to his doctrine makes it especially attractive and enlightening; and we hope for much good effect from this element in the book. Mechanical science, as Mach frequently repeats, had its origin very plainly in the need of men whose handiwork, owing to its technical complexity, was difficult to describe to those new in the craft. The learner must be enabled to see the permanent elements of the experience of his craft beneath, and in all their endlessly various applications; he must be brought to an 'übersichtliche erfassung der thatsachen:' hence the need of quite general and simple descriptions, applying to fundamentally important facts. Economy of description thus from the first becomes the artistic principle, as it were, of this technical instruction.

If this is the origin and general method of the science in its embryonic stage, the origin

Die mechanik in ihrer entwickelung historisch-kritisch dargestellt. Von E. MACH, professor an der Universität zu Prag. Leipzig, *Brockhaus*, 1883. 10+483 p., illustr. 8°.