variety of small animals. With regard to the geology of the Selkirks, earlier than the Glacial formation, no rocks later than the Palæozoic seem to be met with in the central range. In the higher ranges, greenish quartzites and micaceous schists are the commonest rocks. The summit of Mount Bonney and the southern and south-western *arêtes* of Mount Sir Donald consist of a beautiful white, smooth quartzite, speckled in the former case with deep brown spots, "probably iron or manganese oxides." Associated with these harder rocks are a number of remarkable silky-looking schists (*phylites* of Prof. Bonney), the result of great squeezing in the movements which upheaved the ranges. Roughly speaking, then, the configuration of this district, with its complexity of valleys, is due to the disintegration and denudation of the softer schists and the permanence of the harder quartzites in mountain-ridges. With regard to age, the rocks range from true Archæan to late Palæozoic, possibly a little later. The presence of very old schists and gneisses would seem, then, to show that though the range called the Rockies, on the Canadian Pacific Railway route, is the water-parting, the Selkirks are geologically the true continuation of the Rocky Mountains of Montana, and the backbone of the continent.

THE Russian Geographical Society has received the following news from Captain Grombchevski, who was sent out to explore the Khanate of Kunjut in the highlands between India and Afghanistan, and for a time was supposed to have been lost. After having left Marghelan in Russian Turkistan, M. Grombchevski crossed the highlands of Alai, and, *viâ* the Pamir lakes, Great Kara-kul, and Rang-kul, he reached the sources of the Amu-daria (the Murghab). Thence he proceeded to the Ak-baital River, and on August 16 he crossed the high ridge on the frontier of Afghanistan. On the southern slope of this ridge the Expedition was overtaken by a violent snow-storm, during which M. Grombchevski's Cossacks succeeded in getting hold of two inhabitants of Turm, from whom they learned that the Expedition was surrounded by Afghan troops, who had been sent out to take them prisoners. In consequence, M. Grombchevski, notwithstanding the snow-storm which was still raging, crossed the mountains again and returned to the Pamir, whence he immediately went across the Hindu-kush through a mountain pass which leads to Kunjut. The journey was so difficult that the Expedition lost one-half of its horses and part of its luggage. Circumstances did not permit M. Grombchevski to stay at Kunjut. He re-crossed the Hindu-kush, and entered East Turkistan at the sources of the Raskem-daria, one of the affluents of the Yarkand River. He followed its course, hoping to reach Karakorum, but was soon compelled to abandon his scheme, and only explored the nephrite mines on the banks of the river. After having surveyed part of the Raskem and Yarkand Rivers, the Expedition returned to Little Kara-kul Lake on the Pamir, and reached Kashgar on November 13. Three weeks later they were at Osh, bringing in a mass of interesting information and numbers of photographic views of the explored region.

THE last volume of the *Izvestia* of the Caucasus branch of the Russian Geographical Society contains a variety of interesting short articles and notes. V. Massalsky's sketches of the regions of Kars and Batum are especially valuable to botanists. M. Konshin gives a most interesting geological and geographical sketch of the Transcaspian region; and two obituary articles (with portraits) devoted to Abich and Von Koschkul contain excellent reviews of their work in the Caucasus. The appendix contains a note on the study of the Caucasian languages, and various papers relating to Persia, Asia Minor, and Afghanistan. The most important of the latter is a report on the work done by the Russian Commissioners of the Afghan Boundary Commission, with a map of the region (13 miles to the inch) brought up to date in 1888. A short paper on the economic conditions of the Russian Transcaspian dominions, and a condensed translation from a "Guide to Armenia," by Bishop Srvandziantz, are also worthy of notice.

ELECTRICAL NOTES.

HALLWACHS (*Ann. Wied.*, vol. xxxiv. p. 731, 1888) is continuing his researches on the connection between light and electricity. He has found that if the light of an arc lamp falls on clean plates of zinc, brass, and aluminium, they are always charged positively, the zinc to a potential of over 1 volt, the brass to 1 volt, and the aluminium to 0·5 volt. The plates become fatigued by constant illumination.

SIR WILLIAM THOMSON gave the Friday evening lecture on February 8 at the Royal Institution, on "Electrostatic Measurement," and described voltmeters and their functions; but the most interesting part of his discourse was his approving and eulogistic reference to Hertz's work, his own measurement of "*v*," which brings it very close to 3×10^{10} centimetres per second, and his long-deferred conversion to Maxwell's electromagnetic theory of light, which he thought had sprung from Maxwell's inner consciousness.

HIMSTEDT (*Ann. Wied.*, vol. xxxv. p. 126), using a condenser, has determined the value of v to be $3{\cdot}0093 \times 10^{10}$.

NAHRWOLD (*Ann. Wied.*, vol. xxxv. p. 107) has shown that platinum rendered incandescent in a closed space is electrified negatively, the air being positive, but the same effect is not to be obtained with hydrogen, or any other pure gas.

MAGNETIC ELEMENTS, Parc Saint-Maur, Paris:—

	January 1, 1889.	1888.
Declination	15° 47′·4	− 4′·7
Dip	65° 15′·7	− 1′·0
H	0·19508	+ 0·00028
V	0·42275	+ 0·0003
T	0·46559	+ 0·00039

E. G. ACHESON in New York (*Electrical World*, January 19) has repeated many of Prof. Oliver Lodge's experiments on the "alternative" path in discharging Leyden jars, but has deduced from them different conclusions. He has avoided the errors due to charging which vitiated Prof. Lodge's early experiments. This is done by using one jar instead of two, and separating the charging system entirely from the discharging. He shows that the effects are due entirely to "extra currents" in the alternative wire dependent on the geometrical form of the current, and modified a little by the electro-magnetic inertia of iron. He has photographed the sparks, and obtains clear traces of oscillation when self-induction is present. His results have little or no bearing on the form of lightning protectors.

WESENDONCK (*Ann. Wied.* vol. xxxv. p. 450) has made the curious observation that if in a long vacuum tube the distance between the electrodes be increased, the resistance is not affected. This does not agree with Varley's conclusions (Proc. R.S. vol. xix. p. 236, 1871), who showed that after the polarization of the electrodes is overcome gases obey Ohm's law.

MEBIUS (*Beiblatter der Physik*, vol. xii. p. 678, 1888) has tried to verify the statement that an electric current diminishes the coefficient of elasticity of metals, and he has come to the conclusion that it has no action on elasticity.

ON THE INTENSITY OF EARTHQUAKES, WITH APPROXIMATE CALCULATIONS OF THE ENERGY INVOLVED.[1]

AS an exact science, seismology is in its infancy. Although great progress has been made during the past ten years, and especially in the development of instruments and methods for a more precise study of seismic phenomena, the results thus far have served rather to reveal the complicated nature of the problems involved; and while encouraging the seismologist to renewed effort, they warn him that his efforts are not to be light. The recent advances of the science have been, and properly, toward the study of the phenomena at hand, the nature and extent of the motion of the earth particle together with the rate at which the disturbance is propagated, in the expectation and hope that in time the location and character of the original cause may be revealed through these.

In the early growth of an exact science one of the obstacles met with is the absence of an exact nomenclature, and seismology furnishes no exception to this rule. Whenever it becomes desirable or necessary to incorporate the meaning of a word in a mathematical expression, it is imperative that the necessary restrictions be placed upon its use. It has long been customary to speak of the *intensity* of an earthquake without any special effort to give the word an exact meaning. Generally it is applied to the destructiveness of the disturbance on the earth's surface, and sometimes to the magnitude of the subter-

[1] By Prof. T. C. Mendenhall, President of the Rose Polytechnic Institute, Terre Haute, Indiana. (From the Proceedings of the American Association for the Advancement of Science, 1888.)

ranean cause of the same. But modern seismology proposes to measure the intensity of an earthquake and to express its value numerically. It is worth while, therefore, to inquire in what sense the term may be used with precision, and what may be accepted as its mathematical equivalent. Evidently it may mean, and in fact it has been made by different writers to mean, the measure of the surface destruction; the energy per unit area of wave-front of a single earthquake wave; the rate at which energy is transmitted across unit area of a plane parallel to the wave-front; and the total energy expended in the production of the original disturbance. The use of well-constructed seismographs has furnished us, within a few years, a good deal of fairly trustworthy information relating to certain elements of earthquake motion, notably the amplitude and period of vibration and the velocity of transmission, by means of which, and aided by a few not very violent assumptions, some of the above quantities may be calculated. They are not identical, numerically or otherwise, and it is manifestly improper to apply the word *intensity* to all of them.

An earthquake wave is generally assumed to be the result of an harmonic vibration. While this supposition is not strictly correct, it is probably not so far erroneous as to materially vitiate the results which follow.

If then—

a = maximum displacement,
t = periodic time,
v_1 = maximum velocity of particle,
V = velocity of wave transmission,
d = density of material through which transmission occurs,

the following are easily obtained:—

(1) Maximum velocity, $v_1 = \frac{2\pi a}{t}$.

(2) Maximum acceleration, $\frac{v_1^2}{a} = \frac{4\pi^2 a}{t^2}$

(3) Energy of unit volume with velocity, $v_1 = \frac{1}{2}dv_1^2 = \frac{2\pi^2 a^2 d}{t^2}$

(4) Energy of wave per unit area of wave-front $= \frac{2\pi^2 a^2 dV}{t^2}$

(5) Energy per second across unit area of plane parallel to wave-front (rate of transmission) $= \frac{2\pi^2 a^2 dV}{t^2}$

It is well known that Mallett and others of the earlier seismologists attempted to find a mathematical expression which should represent the so-called "intensity" of the shock, by means of the velocity of projection of loose bodies as determined by their range, and also through the dimensions of bodies which would be overturned by the shock. The maximum velocity of the earth might be ascertained by the first method with fair accuracy; the second method is nearly, if not quite, worthless in practice, and both are decidedly inferior in design and operation to the modern seismograph, which gives the principal elements of the motion directly.

In a paper by Profs. Milne and Gray, *Philosophical Magazine*, November 1881, the following occurs:—"The intensity of a shock is evidently best estimated from the maximum velocity of translation produced in a body during an earthquake. This is evidently the element according to which the destructive power is to be measured, it being proportional to the maximum kinetic energy of the bodies on the earth's surface relative to that surface during the shock." Now this statement is inconsistent with that which immediately follows, and with their mathematical expression, which is $I \propto \frac{A}{T^2}$, equivalent to the second expression given above. This inconsistency was doubtless quickly and first detected by the authors, and in a copy of the paper received from them I find interlinear corrections in the paragraph quoted above in virtue of which the words "rate of change of" are substituted for the word "maximum" where it first occurs, and "acceleration" for the words "kinetic energy," thus bringing it into agreement with the remainder of the discussion, and at the same time unquestionably better representing the opinion of the authors, who in all subsequent publications have used the maximum acceleration to represent the intensity as shown in the overturning, shattering, and projecting power of the shock.

The same expression, $\frac{v_1^2}{a}$, is used as a measure of intensity by Prof. Holden in his paper on "Earthquake Intensities in San Francisco" (*American Journal of Science*, vol. xxv. p. 427) where he defines it as "intensity of shock defined mechanically = destructive effect = the maximum acceleration due to the impulse." He asserts that "the researches of the Japanese seismologists have abundantly shown that the destruction of buildings, &c., is proportional to the acceleration produced by the earthquake shock itself, in a mass connected with the earth's surface." This statement is hardly justifiable, at least up to the present time. In the Report of the British Association for 1885, the Committee appointed by the Association for the purpose of investigating the earthquake phenomena of Japan, consisting of Messrs. Etheridge, Gray, and Milne, describe among other seismic experiments one which consisted in determining the quantity to be calculated from an earthquake diagram which would give a measure of the overturning or shattering power of a disturbance. The result of this investigation seemed to show that the acceleration, which by calculation from the dimensions of the columns was necessary for overturning, was something between the mean acceleration, represented by $\frac{4v_1}{t}$, and the maximum acceleration, $\frac{v_1^2}{a}$.

The actual destruction caused by an earthquake wave is undoubtedly a function of many variables, but it seems tolerably certain that maximum acceleration is the leading factor, and at the present time no better measure can be found. It appears to me, however, that it is unwise to apply the term "intensity" or "intensity of shock" to this quantity, which might be called the "destructiveness" of the wave, or perhaps its "destructivity," as indicating a little more clearly the power to destroy.

Dutton and Hayden, in their "Abstract of the Results of the Investigation of the Charleston Earthquake," presented to the National Academy of Sciences on April 19, 1887, define intensity as the "amount of energy per unit area of wave-front," but, in the subsequent discussion, use it almost continually as a measure of surface destruction. Upon the first definition they have based a very interesting and novel method for determining the depth of the focus; but in the application of the method to the Charleston earthquake they have used the word in its other and very different sense. A reference to the formulæ given above will show that one of these quantities is inversely as the square of the distance from the origin, as assumed by them in the development of their method, while the other, used in its application, is not so proportional, and this must be admitted to be fatal to their deductions.

In the discussion of a somewhat analogous case, Lord Rayleigh says ("Theory of Sound," vol. ii. p. 16), "The rate at which energy is transmitted across unit of area of a plane parallel to the front of a progressive wave may be regarded as the mechanical measure of the intensity of the radiation." The algebraic expression for this quality, as shown above, is, of course, similar to that of the quantity last considered, differing from it only in the power of "t" in the denominator. Both are very important expressions; neither is very closely related to "surface destruction," and the latter is unquestionably a suitable measure of the "intensity of an earthquake" in the most important sense.

It thus appears that at least four measures for earthquake intensities are and have been in use, which are expressed mathematically in terms of amplitude, period, velocity of transmission, and density of medium in formulæ (1) (2) (4) (5) above. To show more forcibly the necessity of placing some restrictions upon the use of the word, I have compared the "intensities" of two earthquakes, using each of the four expressions. The disturbances compared are those of May 6 and May 11, 1884, at Tokio, Japan, the observations being made by Prof. Milne (Trans. Seis. Soc. Japan, vol. x. p. 27). The same instrument, located in the same place, was used in both, and the interval of time between the two is so small as to forbid any important change in the conditions. That of May 6 is called "A," and that of May 11, "B." The results are as follows:—

$\frac{B}{A}$ ...	(1)	(2)	(4)	(5)
	1·1	1·7	0·9	1·3

from which it is evident that much depends on the measure of intensity adopted.

As stated at the beginning of this paper, the more recent work of seismologists has been in the study of individual disturbances for the purpose of determining the principal elements of motion, amplitude, period, direction, and speed of transmission. In this study much has been learned. From the nature of the case we are almost absolutely restricted to an investigation of surface phenomena, and we are soon forced to admit that what goes on at the surface cannot accurately represent what is going on below. Among other reasons for this conclusion we have, notably, the greatly varying results obtained from the same disturbance at points comparatively very near to each other. The amplitude at one point may be two or three times that at another a few hundred feet away, and not only this, but the periodic times do not agree, and when the maximum acceleration is applied to the disturbance, its so-called intensity or destructiveness will vary greatly within a small area. As a matter of fact, it has long been known that such variations in destructive power do occur in nearly all earthquakes. Not only do the above elements vary, but the speed of transmission, when once the surface is reached, is undoubtedly not constant, although we have no reason to believe that it is not approximately so in the rocks through which it is, in the main, transmitted. Most of these irregularities are doubtless due to the non-elastic character of the materials lying near the surface and to their lack of homogeneity. In spite of their appearance in the phenomena of the surface, it is difficult, if not impossible, to believe that they exist in the rocks below. It is more reasonable to assume that during an earthquake the waves of transmission are, in the main, and until the surface is reached, somewhat regular in their form and approximately constant in certain of their elements. It may also be assumed that in amplitude and periodic time the subterranean wave, although doubtless much less than the surface-wave, cannot differ from it enormously, so that elements of motion obtained by seismometric observations upon the surface may be applied within certain limits to the investigation of the energy involved, the results being considered as rough approximations.

On these assumptions the following calculations have been made:—

Let A be the area of a portion of a wave-front, and l a length measured at right angles to A. Then formula (5) above, which shows the energy per second across unit area, multiplied by $\frac{Al}{V}$ will evidently express the energy required to generate the waves existing at any moment in the volume lA. That is

$$\frac{2\pi^2a^2d\mathrm{V}}{t^2}\cdot\frac{\mathrm{A}l}{\mathrm{V}}$$

$$=\frac{2\pi^2a^2d\mathrm{A}l}{t^2}$$

$$=\frac{2\pi^2a^2}{t^2}\cdot m\,(m = \text{mass of volume } l\mathrm{A})$$

$$=\tfrac{1}{2}mv_1^2.$$

That is to say, the work consumed in generating waves of harmonic type is the same as would be required to give the maximum velocity to the whole mass through which the waves extend.[1] Sir William Thomson, who was probably the first to apply this principle, in his calculation of the mechanical value of a cubic mile of sunlight, concludes that in the case of a complex radiation this value is more likely to reach twice that of the above expression.

On the assumption that the maximum velocity of the particle is known, we may now apply this formula to the calculation of the energy involved in an earthquake. For this purpose I have selected, first, the Japanese earthquake of January 15, 1887, which disturbed over 30,000 square miles of territory, and the elements of which were well recorded on the Tokio seismographs. Assuming a mass of 150 pounds per cubic foot, and taking a cubic mile as the volume to be considered, I find that to put it in vibration required the expenditure of 2,500,000,000 foot-pounds of energy, and this might be called the "mechanical value of a cubic mile of earthquake." Assuming that an area of 100 miles square, with a mean depth of one mile, was thus in vibration at any one instant of time, which is not improbable considering the known rate of transmission and the long duration of the earthquake, the amount of energy thus represented would be 25×10^{12} foot-pounds. This energy might be generated by the fall, under the action of gravity, of a cube of rock 1000 feet on each edge, the mass of which would be 75,000,000 tons, through a vertical distance of about 166 feet.

It would be interesting to apply this method to the Charleston earthquake of August 31, 1886. Unfortunately no seismographic records were made, and the elements of motion are largely matters of conjecture. Messrs. Dutton and Hayden, in the report already referred to, express the opinion that in some localities the displacement must have been as much as 10 inches or 1 foot. This seems to me improbable, but it may be safe to say that over a considerable area it was as much as 1 inch. Nothing is known with certainty as to the period of the oscillations, but as it generally increases with the magnitude of the disturbance, it would probably not be grossly incorrect to call it two seconds. Assuming these magnitudes, I find the energy of a cubic mile of the Charleston earthquake, taken near enough to the epicentrum to be disturbed as above, to be equal to 24,000,000,000 foot-pounds. The speed of transmission of this disturbance has been pretty well determined, by Newcomb and Dutton, to be approximately three miles per second, so that a cubic mile would be disturbed in one-third of a second. To do this would require 130,000,000 horse-power. Assuming as before that an area about the epicentrum 100 miles square was thus disturbed, the energy involved would be 24×10^{13} foot-pounds, and the rate of its expenditure would be that of 1,300,000,000,000 horse-power.

All of these numbers can only be regarded as gross approximations. They probably indicate the order of magnitudes involved, and may be useful until more trustworthy data are furnished.

[1] Lord Rayleigh, "Theory of Sound," vol. ii. p. 17. Sir William Thomson on "The Possible Density of the Luminous Medium."

THE ROYAL HORTICULTURAL SOCIETY.

THE annual general meeting of the Royal Horticultural Society was held on Tuesday, February 12, at the offices, 117 Victoria Street, S.W. The Society is to be heartily congratulated on the great improvement which has taken place in its affairs since it quitted the Gardens at South Kensington this time last year. From the Report of the Council, and the speech of Sir Trevor Lawrence, Bart., M.P., President, in moving its adoption, we glean the following particulars. During the past year 657 Fellows have joined the Society, 81 have resigned, and 48 died, the total number of Fellows on the books being now 1636. The total income from all sources, independent of the "Donation" account (£1125 5*s*.), was £3617 8*s*. 6*d*.; the total expenditure, £3412 14*s*. 4*d*., showing a surplus of £204 14*s*. 2*d*. On January 1, 1888, there was a debit balance of £1152, which has been cleared off by the transfer of of £755 7*s*. 6*d*. from the "Donation" account, and £396 12*s*. 6*d*. from current revenue. The total expenditure on the maintenance of the Society's Gardens at Chiswick was £1501 6*s*. 8*d*., the receipts from the sale of produce, £737 7*s*. 6*d*., brought up by minor items to £810 4*s*. 3*d*., making the net cost of the Gardens to the Society £691 2*s*. 5*d*. The income for 1889 is estimated at £3000, and the expenditure at £2950. The President referred to the great value to the Society of the services of Mr. Dyer, F.R.S., Director of the Royal Gardens, Kew, and Mr. H. Veitch, who were retiring from the Council owing to the pressure of other engagements, and of Mr. Wilson, F.R.S., and Dr. Hogg, who were retiring after having served the Society well and faithfully during very many years. He also paid a well-deserved tribute to the energy, ability, judgment, and devotion to their duties, of the Honorary Secretary, the Rev. W. Wilks, and the Treasurer, Mr. D. Morris, Assistant-Director of the Royal Gardens, Kew. During the past year numerous very interesting exhibitions have been held in connection with the fortnightly meetings of the Society in the Drill Hall of the London Scottish Volunteers, James's Street, Buckingham Gate. A magnificent show was held on May 17 and 18, in the Gardens of the Inner Temple, by the permission of the Treasurer and Benchers, in which, for the first time in the history of such displays, attention was drawn to the excellent horticultural work being done by the market growers of the London district. A conference on apples and pears, held at Chiswick from October 16 to 20, attracted great attention, and the papers read and the discussions raised as to the circumstances and conditions requisite for the successful cultivation of these fruits in the British Isles were of great value. The Society propose to hold this year, in addition to a great show in the Temple Gardens on May 30 and 31, and its usual bi-monthly exhibi-