UTILIZATION OF THE EARTH'S INTERNAL HEAT.

A DISCUSSION AT THE SEISMOLOGICAL SOCIETY OPENED BY J. MILNE.

[*February 23rd, 1882.*]

Mr. Milne's remarks upon the above subject have been extracted from the columns of the *Japan Weekly Mail*, as follows:—

Fifty years ago Sir John Herschel told us that the Sun's rays are the ultimate source of almost every motion which takes place on the surface of the earth. By its calorific effects winds are generated; waters drawn up from the ocean to the mountains, whence they fall in streams to turn our mills; vegetables enabled to derive their support from inorganic matter; chemical decompositions produced to which we owe our stores of peat and coal: turn in short, where we may, some process traceable to solar heat is discovered. It was the sun—philosophers have recently informed us—that originally fractured the moon from the surface of our earth, and so the sun ultimately becomes responsible for the tides—another source of power which those living by the margin of tidal rivers have often utilized. Similarly, if we carry our analysis back far enough, all the working forces we possess on the surface of

the globe are found to be derived from sources external to it. But are those external sources the only available energies? If, by the lowering of some giant extinguisher, the sun's heat was gradually withdrawn from us, let us picture to ourselves the consequences. Little by little, man would retreat towards equatorial regions, followed or preceded by all sentient creatures; and, in the ensuing battle between life and climate, the species would die out one by one, until as Adam with his garment of fig-leaves was the Alpha of humanity, an Esquimaux clad in skins, with his pack of starving dogs, would roam in the torrid zone as the Omega. And with the final fall of the giant extinguisher, would this miserable Omega also be extinguished? With the darkening of the sun's face would "all wordly shapes melt in gloom," or might there not be some loophole through which a few favoured beings could escape to wait for better days? The supply of external heat being cut off, might it not be possible to draw on the internal store with which our planet is so bountifully supplied? Not far from Yokohama, at an elevation of several thousand feet, when solar caloric was at a minimum and snow and sleet falling fast, the writer of this article remembers to have warmed his hands and feet over a cauldron of molten rock. So too, when our hypothetical extinguisher had descended, the shivering Omegas of humanity might perhaps congregate round the craters and geysers of the globe, and save themselves from the fate of the Siberian mammoth. But we do not insist upon this point. The event might, or might not, be so. Our intention is only to demonstrate that in the internal heat of the world—almost completely disregarded as it has hitherto been—there is a vast mine of wealth which may yet be utilized.

For some years past the members of one of the most important sections of the British Association have been

engaged in investigating this heat; but unfortunately they are working in a country which compared with Japan, is old and cold. There, however, experiments have shown that the sun's heat dives into the earth, to a depth of about fifty feet, after which its effect become difficult to trace. It descends in waves, and travels so slowly that, at the maximum depth, the annual variation of temperature is about a year in arrears:—That is to say, the heat of this summer will not be fully felt until next. Going still deeper, the surface effects cease to be perceptible; the region of the earth's internal store of energy is reached; and thence, for each fifty feet of descent, approximately, an increase of 1° F. takes place. This fact, taken in conjunction with hot springs, volcanoes and other cognate phemonena, enables us to predict that at a certain depth there would be found a temperature greater than anything existing in the cupola of a foundry. In a word, within the globe exists an unlimited supply of energy which has never yet been drawn on.

To the scientists of England the utilization of this heat is a problem whose practical solution presents very much greater difficulties than to the inhabitants of such countries as Iceland or Japan. In these latter places experiments probably will show that, on the average, the heat gradient is much steeper than in Europe:—that is to say, a descent of fifty feet will give an increment of temperature considerably greater than one degree. In some districts we have a temperature of molten rock actually on the surface; in others, that of boiling water, while in the neighbourhood of the numerous solfataros, although the surface may be cold, one need only scrape away a little soil to burn one's fingers. Japan has, therefore, a well-nigh infinite store of power in many cases within easy reach.

But can this power be utilized, and, if so, how? In the vicinity of hot springs country-folk sometimes use it for

purpose of cooking and washing, but that is all: the idea of transmitting it to the cities has not been entertained, enormous as would be the resulting gain. Hot water, flowing through wooden pipes and very soon parting with all its caloric, is the first notion that presents itself. But might it not be possible to contrive huge thermopiles—to convert the heat existing about volcanic centres into a power capable of being transmitted along wires as electricity? It is true that with the thermopiles at present in use a difference of temperature equal to that of the boiling water at the junctions gives but a feeble current. Yet thermo-electric currents have yielded sparks and exhibited all the phenomena of currents obtained in other ways. Is there any reason why thermopiles should not be improved, and their size increased; so that when heated by the hot springs they might yield a considerable electro-motive force? Clamond has shown how to construct a thermo-electric battery which can be used for lighting and telegraphic purposes, and even in the present state of knowledge it would seem an easy matter to run our feeble currents into batteries like those which Faure has placed at our command and from the stores accumulated during the day light up our towns at night. If these speculations can be realized the time may not be far distant when from stores thus accumulated during the day, Tokiyo itself may be lighted—a city illuminated, its bells rung, its machinery moved and its locomotives propelled by means of its hot springs! Certainly in her hot springs Japan has a great advantage over many other countries, and sooner or latter she will turn it to account.

Besides these, which may be described as ordinary boiling springs, there are also, at places within tolerably easy reach, cauldrons of boiling weak sulphuric acid. Here then is another source from which power may be derived by chemical activity. Supply Kusatsu, for example, with

sheets of metal and good conductors and Kusatsu will supply power to drive all the engines in Japan. Truly to leave these stores of wealth unexploited seems little short of national suicide.

An unequal distribution of the internal heat of our globe in relation to its surface, has given certain countries, like Japan, a reputation for volcanic and seismic phenomena, and has consequently been regarded by many as a source of danger and destruction. Volcanoes and earthquakes have indeed done much to justify this view by the terrible mischief they have wrought from time to time. But volcanoes are not always abused. By some they have been called the "safety valves of our globe," whence apparently we are to infer that without Etnas and Fujiyamas, our planet would long ago have burst and been dissipated with its inhabitants as meteoric dust. If this be so they have much reason on their side who worship such beneficient mountains. Others again inform us that volcanic agencies, being so intimately connected with the phenomena of upheaval, are to be regarded as the compensators of the denuding agencies of our globe. In that case the Japanese may congratulate themselves that their islands are being gradually raised about the sea level, while Great Britain and such worn out kingdoms are being slowly washed away.

The part that volcanic forces perform in the economy of nature, as here illustrated, is, however, a matter better suited to the speculative philosopher than to the wants of an age which is daily becoming more and more practical. In this latter context it may be said that the only uses hitherto served by volcanoes have been to cast at our feet sundry articles of commercial value, as borax, sulphur, sal-ammoniac and so forth. At one time a bold projector went so far as to suggest that leaden chambers should be erected over the principal fissures in the crater of an

Italian volcano for the purpose of collecting and condensing the various vapours emitted; and chemical works were actually established in this crater, though a change in the condition of the volcano prevented the erection of leaden chambers. Again, at the fumerolles of Mount Cerboli in Tuscany, the heat supplied by the steam issuing from the ground has been applied to cause evaporation from liquids contained in pans during the process of manufacturing boracic acid. This, indeed, is little more than the culinary application of volcanic force made by almost every peasant living in the neighbourhood of an active crater: nevertheless it shows that the utilization of the internal heat of the globe is not, merely a romance.

Having now briefly discussed the feasibility of utilizing the internal heat of our globe by recourse to those portions of it, which, in the form of hot springs, solfataros and volcanoes, crop out upon the surface, offering their services to those who have the necessary ingenuity to apply them, let us turn for a moment to the question of regions which, although themselves without any visible evidences of subterranean caloric, nevertheless from the position they occupy with regard to such evidences elsewhere, justify an inference that there, too sources of similar energy may possibly exist at no very great depths below the surface.

Such a region is the district in which Yokohama and the Eastern Capital of Japan are situated. A circle described with either of these place as centre, and a radius of a hundred miles, would include within every one of its quadrants, several outcrops of the earth's unused stores of heat. To enumerate the positions of such outcrops in the province of Idzu alone, would be no slight undertaking. Nor indeed is there any cause to be surprised at the fact that we are thus surrounded by outlets of subterranean energy, seeing that the district in which we live lies at the juncture of two giant lines of volcanoes — the one stretching from Kam-

schatka in the north-east to beyond the Philippines in the south-west, and the other from central Japan in the north through the Bonins and Ladrones in the south. We dwell among the tumuli of buried Vulcans, never knowing the day when some unwary motion of these monsters may bring our houses tumbling about our ears; and yet even in the very proximity of this peril, man's ingenuity may find before long a new source of inexhaustible profit.

Having regard then to the evironment of this region, we have reason to imagine that sensible heat exists at a point much nearer the surface than is the case in countries like England where volcanic fires have long become extinct. Probably, if a bore-hole were sunk at Tokiyo or Yokohama, it would be found that each fifty feet of descent gave an increase of temperature considerably more rapid than that indicated by the general law. As an instance of this we may mention the case of the Comstode Lode, where at depths below 2,000 feet the increase in temperature is 1° F. for every 25 feet of descent. Thus the heat in the mines situated in the Lode is so great, that, notwithstanding all the modern appliances for ventilation and for providing bountiful supplies of ice water, there is every probability that before long a limit will be reached beyond which the valuable materials contained in the mines will cease to be accessible. A parallel case is recorded of the Besshi copper mines in Japan, and another remarkable instance is at Monte Massi in Tuscany, where there is an increase of 1° F. for every 24 feet of descent. Under such conditions as these, water ought to boil at a depth of 1,200 yards.

To what distance it might be necessary to sink in this district in order to reach a temperature of boiling water is of course a matter of conjecture. Twelve hundred inches might suffice or twelve hundred yards be too little. All we can predict with any confidence, is a rapid development of heat for a comparatively small increase of depth, but to

bore for hot water on that hypothesis alone might not, after all, be such a very chimerical undertaking. We are not without actual experience in the matter. When the rail-road between Yokohama and Tokiyo was in process of construction, steam was observed to issue from the rocks, and some of us remember convincing ourselves by actual contact that there was sensible caloric in the newly exposed stones. So too the springs of fresh water which are said to rise in the harbour here, have a significance not to be overlooked, and it is probable that, if the bed of the sea were subjected to a thermometric examination at convenient places in Yedo Bay, valuable information might be garnered.

Suppose then that we had sunk a bore-hole at some carefully selected site in the neighbourhood of Tokiyo or Yokohama, what are the results we might look to derive from success?

First we might obtain a perpetual supply of hot water for the convenience of a nation which uses more of that commodity than any equal number of persons on the face of the globe—a nation where men are talking seriously to-day of laying iron pipes from the sulphur springs at Kusatsu to the Park of Uyeno, a distance of more than one hundred miles! A natural source of hot water for a city would not however, be altogether a novelty, seeing that the city Buda Pesth at present receives a vast supply from underground reservoirs, so that we have at any rate one precedent to warrant our speculation. With hot water we should of course have the means of heating our houses as well as of filling our baths and the possibility of developing a source of energy to drive our machinery and of light to take the place of candles or gas.

The process here suggested—this tapping of the globe and drawing off draughts of subterranean energy—sounds in truth a somewhat romantic undertaking, but the rewards it

offers are sufficiently great to prevent it being thrust out of court without a hearing. A closer examination will disclose other benefits which might be realized in the attempt, even though the original idea—access to the earth's store-house of caloric—were impracticable.

Thus, in the first place, we should undoubtedly derive valuable knowledge of the strata beneath our feet, and facts of the utmost importance to geologists might be established. Again, as we descended, it is by no means impossible that coal might be discovered. In the rocks amid which our operations would be commenced, fragments and small seams of lignite are exposed; while in the same series of rocks—as for instance in the silk district near Tomioka and also at other places in the Yedo plain—there exist seams of coal at present productive; and at a short distance beyond the Kubo-toge Pass are found valuable deposits of fuel, large quantities of which have been imported into Yokohama by enterprising merchants. In a word, our proposed bore-hole would descend through coal-bearing strata, and this consideration alone renders the undertaking rational and legitimate.

But if coal thus crops out at so many points within our circle of a hundred miles radius, how does it happen—some may ask—that mining is not more extensively carried on? The explanation is no doubt to be found in difficulties of transport. In a country where pack-horses are the only means of transport, a distance of ten or twenty miles from any centre of trade is sufficient to stifle enterprise. But if, on the other hand, coal were obtainable in the immediate vicinity of either Yokohama or Tokiyo, if the mine and the market were identical—then though the products of the former were of inferior quality there would be no question as to their value.

Should it so happen, again, that our boring exploitation neither struck coal nor tapped the earth's internal store-

house of energy, still we should not be entirely without reward. For we could at any rate determine the heat gradient of the Yedo plain and so add Japan's unit to the vast store of facts that are daily garnered all over Europe. Further it would be possible to employ means—thermo-electric say—for measuring changes of temperature at the bottom of the bore hole, and thus determining whether thermometric fluctuations due to subterranean causes take place at considerable depths, after a fashion similar to those traceable to the transmission of solar heat near the surface. We should thus be *en route* to determine whether in volcanic regions a steady flow of heat proceeds upwards from the interior, or whether that flow varies; and if the latter, whether the variation is in any way connected with volcanic action—whether it produces expansion and contraction in rocks and so gives birth to earthquakes. Furnished with the data these investigations might supply, it is possible that in the careful examination of subterranean temperatures we should find a means of predicting and perhaps providing against those phenomena which often cause us so much alarm.

We refrain from entering into other points which suggest themselves in connection with such an undertaking, as for example, the investigation of the subterranean circulation of water, the question of under-ground tides produced by rain; the possibility of establishing an interrestrial system of meteorology, and so forth. What we have written in this context is intended merely to illustrate our original proposition, that Japanese philosophers have every inducement to essay the paths of original research. The nature of our subject has constrained us to omit minutiæ, neither is it for us to predict what new forces of nature, human ingenuity may gradually bring into subjection to human uses. But the plummet of perseverance is daily sinking farther and farther into the depths of science; and the day

may not be far distant when, instead of drawing only on the resources which the fierce energy of the great central furnace has brought within our reach in bygone cycles, we may dip into the giant alembic itself, and make its power subservient to a thousand well-ordered purposes. The instrumentality through which this end is achieved, will win no small measure of gratitude and fame; and Japan seems to be endowed with special facilities for the attempt. We wish her all success! Her students may possibly fancy that we propose to them a chimerical undertaking; but philosophy has proved itself well-nigh omnipotent; and, for the rest, our purpose in writing is to arouse, not to direct, the spirit of original research.

After the reading of Mr. Milne's paper upon this novel and interesting subject there was a long discussion lasting until dark.

Professor Ewing dwelt at length upon the amount of power which could be practically derived from one pound of water at a temperature of 212° Fah., and as the result of a calculation showed that out of every three pounds of water flowing away from a hot spring every minute we ought practically to obtain about one horse power. He also made comparisons between the power contained in every pound of water which falls over Niagara (which may be represented by about one-quarter of a degree Fahrenheit) and the 150° which water at 212° temperature has to dispose of. In short, as a source of energy, a very hot spring was equal to a very large waterfall.

Professor Paul spoke of the economical transmission of electric energy, and as it was more economical to transmit currents of high electro motive force, it would be well to use Accumulators for the currents derived from the springs near to the springs themselves, and then from time to time discharge them along the lines to the cities.

Mr. Knipping spoke of the distribution of temperature

in the earth, pointing out the fact that the law which governs the increase of temperature near the surface need not be constant at great depths.

The discussion was concluded by remarks from Messrs. Chaplin, Mayet, and Hattori.