Messrs. STEVENSON, having been intrusted by the Board of Trade to advise as to establishing a lighthouse system for the coasts of Japan, and to select and recommend for appointment engineers, foremen-mechanics, and trained lightkeepers to carry out their recommendations, desired, through the Secretary, to acknowledge the valuable services of Mr. Brunton, who had been selected for the office of Chief Engineer, in carrying out their designs. The Author of the Paper had not adverted to certain preliminary matters (probably because they occurred in 1867, before his appointment), which explained correctly what led to the adoption in the first instance of catadioptric instead of dioptric apparatus, and rendered it unnecessary to offer any observations on what the Author had said as to the comparative advantages of the dioptric and catadioptric systems of illumination, as to which lighthouse engineers did not differ in opinion.

These preliminary matters referred to the authenticated effects of earthquake shocks, to which attention had been drawn in all the reports sent from Japan to the British Government. In transmitting these reports to the Messrs. Stevenson, the Board of Trade specially requested them to consider in what way the anticipated injury to the apparatus could be ameliorated. The Elder Brethren of the Trinity House, who had also been consulted by the Board of Trade, suggested the employment of Holophotal reflectors as the safest apparatus that could, under the circumstances, be employed, a recommendation in which Messrs. Stevenson entirely concurred. As an additional safeguard they proposed the introduction of an 'aseismic' arrangement. This, as applied to the apparatus, consisted of a slight alteration of the table on which the reflector frame and machine rest, at a cost of about £90 for each lighthouse.¹ Messrs. Stevenson were confirmed in their recommendation of this simple expedient from satisfactory experiments made in this country, which proved that violent shocks applied to the lower part of the table, failed to affect apparatus resting on it, so long as the aseismic joint was in operation; but that whenever the table was screwed down, so as to form a rigid mass, the same shocks not only threw off the lamp-glasses, but in some cases extinguished the lights. Fig. 1 was a section in which the upper table bearing the holophotal reflectors was shown in hatched lines. This table rested on balls contained in cups formed in the upper and lower tables. Fig. 2 was a plan

¹ *Vide* Transactions of the Royal Scottish Society of Arts, vol. vii., p. 557.

showing the points of support which, for ease of adjustment, had been made at three places dividing the circumference of the table into three equal arcs. The same arrangement had been pro-

FIG. 1.

FIG. 2.

posed on a larger scale for the foundations of conical towers of plate iron. The vessel containing these towers was unfortunately wrecked, and no experience of their action existed.

In further illustration of the subject, and particularly of what had been done in Japan, Messrs. Stevenson gave the following quotation from their Report to the Japanese Government made in June 1876, after the authorized works had been completed:¹ "In all of the documents," the report states, "which were submitted to us for consideration by the Board of Trade in 1867, whether from the French, American, or English authorities, great prominence was given to the prevalence of earthquakes, and their anticipated effects on the proposed lighthouse works. Captain Bullock, R.N., calls attention to the frequent volcanic shocks, and says, 'Engineering skill will be required to provide against them.' The French naval officers report that earthquakes, so frequent in Japan, 'would prevent the use of stone structures,' and the Trinity House report 'that perhaps the greatest difficulty of all will be found in the constant volcanic disturbances common in Japan.' To meet the difficulty which had been raised Mr. David Stevenson suggested the use of an 'aseismic joint' in the table supporting the lighting apparatus, so contrived as to admit of a certain amount of horizontal movement taking place in the lighthouse without affecting the table on which the apparatus rests. This arrangement was proved on experimental trials made in this country to be successful, and it was introduced into the Japanese lighthouse apparatus. It would appear, however, that from some dislike to the unsteadiness of the apparatus during the process of cleaning, the aseismic joint was secured so as to prevent it from acting; and, with the apparatus in this state, the only recorded earthquake which has affected any of the lights occurred at Segami, which is lighted by twenty-one holophotal reflectors. The shock had the effect of throwing the whole of the lamp-glasses out of their places, and disarranging the working of the machine, and the opportunity of testing the effect of the apparatus (as an amelioration of an earthquake shock) was thus lost. The experience obtained since the lighthouses were established has certainly gone to prove, that earthquake shocks have neither been so frequent nor severe as was represented; but it should be kept in view that such visitations are extremely uncertain, and may return at any time with renewed frequency and increased vigour. We should, therefore, suggest that if it be desirable to make the tables *less sensitive*, that this could easily be arranged without rendering them incapable of motion; or if it be considered desirable to screw up the tables

¹ Report to the Imperial Government of Japan, relative to lighthouses by D. and T. Stevenson, Civil Engineers, Edinburgh, 21 June, 1876.

while the apparatus is being cleaned, the screws should be made so as to be undone when that operation is completed, so that the responsibility for the action of the aseismatic apparatus should lie with the lightkeeper and not with the lighthouse authorities. The serious damage of any of the lighting apparatus by earthquake shocks, would entail undesirable responsibility if it should occur in a case where the aseismatic joint was found to have been permanently screwed up so as to prevent its acting."

Messrs. Stevenson had great pleasure in saying how much they were assisted by the valuable advice of Admiral Bedford, of the Board of Trade, in determining the positions and the characteristics of the most important of the sea lights; as well as in arranging the various details for giving the Japanese authorities the aid asked from the Government of this country in establishing their lighthouse system.

Mr. DOUGLASS observed that, this being a case of the first lighting of a large extent of coast line, he should be glad to hear some explanation as to the large proportion of fixed to revolving or flashing lights. It was well known that revolving or flashing lights had an accumulative power from five to ten times greater than fixed lights, with the same consumption of oil; in other words, the annual cost for oil with a revolving or flashing light was from one-fifth to one-tenth of that of a fixed light of the same power. In first lighting a coast like Japan, an essential consideration would, therefore, seem to be to introduce as many revolving or flashing lights as possible, having due regard for the necessary distinctions to prevent one light being mistaken for another. The fixed light was considered to be the least distinctive, and should only be adopted where it was desirable to use coloured arcs to cover local dangers; but that appeared, from the Paper, to have been done only in three cases. Out of thirty-four lights only five were revolving. He thought that, as a provision against earthquakes, a light wrought iron, or wooden, structure would be preferable to one of stone. If the stone structure were low, as in some of the instances described, it might, no doubt, withstand a heavy shock; but, for a tower 80 or 100 feet high, a light iron structure, or one constructed of local timber, would have been less costly and more stable. If the earthquake shocks in Japan were as serious as had been represented, he should prefer the old catoptric revolving light. With this light the consumption of oil for the same amount of light would be greater than with a dioptric revolving light, but less than with a dioptric fixed light, while the first cost of the apparatus would be much less than that of a dioptric light, either

revolving or fixed. With earthquake shocks these lights would be as safe as any building that an engineer could design. Evidence of this had been furnished by the forty-seven light-vessels in the service of the Trinity House. These vessels were all fitted on the catoptric system. In some collisions, the lantern and illuminating apparatus had fallen from the mast-head to the deck, a height of 30 feet, but in no instance had the apparatus been entirely destroyed. Under such circumstances, a dioptric apparatus would have been completely broken to pieces. A fixed catoptric apparatus was almost out of the question, except where very small arcs were required to be illuminated, because it was impossible to produce a well-defined cut between white and coloured arcs. It was stated in the Paper, that in the Doty burner, "volume for volume, mineral oil is superior to colza oil to the extent of one-fourth more light in the first order lamps, two-fifths more in the second, one-half more in the third, and four-fifths more in the fourth order lamps."¹ From his experience with the Trinity House lamps—with which the highest recorded photometric results with the greatest economy of working had been obtained—he had found that volume for volume there was no superiority in the best mineral oil over the best colza, but rather a small percentage in favour of colza; moreover, with colza oil these lamps burned almost uniformly for sixteen hours, with only the usual occasional regulation of the damper, but without any trimming of the wicks. The only known advantages of mineral oil over the best vegetable oils, including cocoa-nut, which was as good as colza, were its readiness of ignition, its flame more rapidly rising to the maximum power, and in some cases its low price—the present price in this country being about two-thirds that of colza.

Mr. W. LLOYD said, having had some experience in the construction of lofty buildings in countries liable to earthquakes, he thought there was a great deal more fear with regard to the effects of those shocks than was at all justified. He should like to give two instances that had come under his own observation bearing on the movable joint that had been proposed. As he understood it, this would allow of a limited horizontal movement, and of a free vertical movement. The first case was that of a church-tower in Mendoza, which had been almost entirely destroyed in the year 1861. Two storeys out of three remained after the earthquake. The lower storey was more or less intact, except that there was a large crack in it. The upper storey was entirely destroyed;

¹ *Ante*, p. 17.

but the middle storey, by some horizontal movement, was turned round nearly one-half upon the lower storey, so that the angles of the upper storey corresponded more or less with the centre of the side of the lower storey. That showed an amount of horizontal movement which would be dangerous with a joint of the description proposed. With regard to the vertical movement in the case of an earthquake, he would cite an instance that occurred in Valparaiso in 1851. A family party were sitting in a room after dinner, and on the table was one of the old-fashioned oil lamps, with a large globe and a chimney-glass within it. An earthquake took place, the family rushed out, and on their return they found the globe on the ground; it had been thrown over the chimney-glass, which remained in its place. One could easily imagine, therefore, what the effect would be in a lighthouse, if the joint had a vertical movement. The lantern might be destroyed. From his experience of the structures erected by the Spaniards, he believed that the more solid the structures, the better they resisted earthquake shocks. In Panama there was a single-stone arch of an old Spanish church, spanning 40 or 50 feet, and it remained to the present day. On the Pacific coast, numerous bridges had been built by the Spaniards with solid stone arches, which had resisted every earthquake, not a crack being visible in them. He believed that Nature had pointed out the best course to pursue in structures of that kind. In the lighthouses described, so far as he could judge from the illustrations, there was one defect—a want of batter. Every structure that he had erected in an earthquake country had a great deal more batter than would be given to a similar structure in England. The broader the base the better. An analogy might be found in the buttress-tree, which spread out on all sides in a manner remarkably like buttresses.

Dr. POLE could testify, from correspondence he had had with Japan, how highly Mr. Brunton himself and his work were valued by the Japanese, and by his brother engineers in that country. He had placed upon the wall a Japanese map on a large scale, which had been recently sent to him by Mr. Boyle, the Chief Resident Engineer of the railways, who had marked upon it the lines executed and projected. He thought, at some future time, a Paper upon Japanese railways might be interesting to the members of the Institution. He had also placed upon the table some photographs of railway works in Japan. The country was no doubt a land of earthquakes. Near Yokohama there was a celebrated conical mountain, Fusi Yama, always seen in Japanese lacquer-work, very high, and visible at a long distance. It was a volcano,

which had been in action within the historical era, but it was now extinct. The volcanic influence, however, remained, and the country, especially in that particular neighbourhood, was very subject to earthquakes. He need not say that that liability had attracted the attention of the railway authorities, who had endeavoured to make their works strong enough to withstand the shocks. A great many bridges were required, and many of them had been constructed of iron sent out from England. In their design the probable effects of earthquakes had also been considered. But there had been no shocks of importance since the railways had been opened, and experience had therefore yet to be gained.

Mr. ABERNETHY, Vice-President, observed that probably there was something special in the character of the Inland Sea, otherwise he could not agree to the principle laid down by the Author, to put no lights where the headlands were bold and well defined, or where no danger existed. In this country the most important class of lights were those placed upon salient headlands, in order that during on-shore gales vessels might have a good offing, and ascertain their proximity to land as early as possible. The system of lighthouses might be divided in three parts: 1, the lighthouse upon prominent headlands; 2, lights to define the position of harbours; and 3, guiding and leading lights to guide vessels into harbour. He could not gather from the Paper that this order had been observed. With reference to the effect of earthquakes, he was of opinion that weight and solidity, and not slightness of structure, were best adapted to meet shocks of that description. An extraordinary example was that of the great aqueduct from Cintra to Lisbon, which at one point was at least 250 feet in height, and which was within the zone of the great earthquake that destroyed nearly all the principal buildings, when this structure was uninjured and remained intact to the present day. This fact among others led him to believe that, in order to meet the shock of earthquakes, solidity and weight were essential elements.

Mr. Woods said he had been engaged in the construction of buildings for Peru, where earthquakes were very prevalent, and he had always understood, from the information he had received, that buildings of slight construction, whether of wood or of iron framing, were better adapted to resist earthquake shocks than more solid erections. He could mention cases in which light structures had stood very severe earthquake shocks. For instance, at Pisco, a small town on the coast of Peru, exposed to the action of the sea with heavy surf, there had been built from his designs, about

twenty-five years ago, a light wrought-iron pier, with screw piles, extending 2,400 feet out to sea. Six or seven years ago a great earthquake occurred, by which the city of Arica was overwhelmed. A wave of the sea rushed into the town, carrying with it a gun-brig $\frac{1}{2}$ mile inshore, where she now lay high and dry. The pier sustained the shock of the earthquake. The motion of the platform was so severe, that persons could not stand steadily upon it, but the pier suffered no injury whatever, the undulations passing through it without affecting its stability in any way. He believed the pier was now as sound as when it was first erected. He might mention another instance, that of a building erected at Payta, also on the coast of Peru. It had a light iron framework, lined with wood, and it had been in existence twenty-five or thirty years, after sustaining every shock that had occurred in that part of the country. He did not know whether there had been sufficient experience to test the effects of earthquakes on the solid lighthouses in Japan, but he was inclined to think that a severe shock might occasion them considerable disturbance. With regard to the proposal to fit the lighthouse with lantern tables, he thought an elastic fixing would be as serviceable as the method described in the Paper. If the platform to receive the lanterns were secured to a proper table, by means of intervening springs, he believed all the effect supposed to be obtained by a ball and socket joint would be obtained.

Mr. BEAUMONT said with reference to the partial revolution of one portion of a building upon another, it had been shown by Mallet, in his various works on the phenomena of earthquakes, that it was due to the difference between the frictional adhesion of one part of the building and that of the other, the inertia of the building allowing that part that was not as well fastened as the other to remain nearly still while the other part or parts moved backwards or forwards in the first or second phase of the shock.¹ In the case of lighthouse structures, where the different courses were properly dovetailed one into another, of course that would not take place; neither would structures built of iron be subject to any such movements.

Mr. BRUNTON, in reply, said one reason for the large proportion of fixed lights was their greater simplicity, a matter of importance in a country like Japan; but it should be understood that only part of the scheme for the illumination of the coast had at present been carried out; in order to introduce the necessary distinctions,

¹ *Vide* Transactions of the Royal Irish Academy, vol. xxi., p. 51; and Reports of the British Association for the Advancement of Science, 1847-1858, *passim*.
[1876-77. N.S.]

the lights still to be established would be chiefly revolving. The natives would by that time have gained experience, and might be intrusted with a revolving machine; but, at the commencement of the undertaking, the importance of having a simple apparatus could not be exaggerated.

Doty's burner was adopted in Japan in 1872, on account of the difficulty experienced in procuring suitable vegetable oils, and because at the time no other suitable mineral oil burner was available. Subsequent improvements in burners by Mr. Douglass tended to show that good colza oil could be consumed to give equally as good results, photometrically, as mineral oil; but this was not universally admitted. The standard power of each size of flame, fixed for the purpose of testing the oils used in Japan, and the standard consumption to attain these powers, were as follows:—

	Power.	Rate of Consumption of 1 Gallon.
4-wick colza oil lamp =	255 candles,	4 $\frac{3}{4}$ hours.
4-wick mineral „ =	270 „	5 „
3-wick colza „ =	150 „	9 „
3-wick mineral „ =	190 „	9 $\frac{1}{4}$ „
2-wick colza „ =	50 „	17 „
2-wick mineral „ =	75 „	17 $\frac{1}{2}$ „
1-wick colza „ =	10 „	86 $\frac{1}{2}$ „
1-wick mineral „ =	19 „	92 „

Flames of these strengths were invariably maintained in the Japan lighthouses. These figures were the result of repeated, independent experiments. Allowing that only 23 per cent. more heat was evolved by mineral oil, yet the accumulation of that extra heat in a lantern during a calm tropical night was, in his opinion, sufficient to produce the effects he had stated.

The Japan Lights had been thus classified in the Paper:—
1. Lights required by the treaty powers, which were principally ocean lights; 2. Lights for the Inland Sea; 3. Local lights, these being mostly harbour lights; 4. Ocean lights established by the Government. These, in his opinion, included the three divisions named by Mr. Abernethy. He had not advocated as a general principle “to put no light where the headlands were bold and well defined, or where no danger existed;”¹ but it was one which had been adopted, after many consultations with nautical men, in reference solely to the lighting of the Inland Sea, where the circumstances were peculiar.

The Paper was necessarily of a general character, because it

¹ *Ante*, p. 4.

described a system of lighthouses and not any one in particular; but as many details of construction had been given as were deemed to be of interest. He had consulted all available authorities regarding the nature of the structures best calculated to resist earthquakes; and there seemed to be a general approval of solidity, weight, and strength, as opposed to lightness and flexibility. He accordingly adopted that principle. A lighthouse was a simple erection, and he had given in the Paper the form of each, the thickness of the walls, the sizes of the stones, and the manner in which they were arranged. The batter of the walls was in every case considerably greater than would have been thought necessary in this country.

Many violent earthquakes had occurred since the lighthouses had been erected. But, on account of the inconveniences occasioned by the unsteadiness of the upper part of the aseismic arrangement, as designed by Messrs. Stevenson, it was found necessary to secure it, and so prevent its acting. From a desire to give the design as full a trial as possible, he had repeatedly given instructions to lightkeepers at different stations to keep the tables free to act, and to report to him the result. In every instance their reports showed that the movements caused by the operation of trimming the lamps, or of performing the various other duties connected with the light—and in an apparatus having twenty-eight separate burners these were frequent—seriously deranged the flames, and prevented the machinery in revolving lights working smoothly. Under these circumstances, it became, in his opinion, imperative to prevent the tables acting. The opinion of the Messrs. Stevenson, that the tables might easily be made less sensitive without rendering them incapable of motion, was precisely the problem still to be worked out. The degree of sensitiveness to be attained was one which, while unaffected by ordinary disturbances, would afford a free motion in earthquakes. Probably to attain this might present some difficulty. An earthquake had recently displaced the glass cylinders of the twenty-one reflector lamps at Tsurugisaki lighthouse. These merely stood on their bases, and were not supported in any way. This was the only damage done at the time in the lighthouse. The earthquake, though apparently not so severe as some previously experienced, had a peculiar motion. It turned the upper six or seven courses of the stonework of one of the chimneys of the keeper's house—a column of ashlar masonry about 2 feet by 3 feet, and 10 feet high—half round, and left it in a diagonal position to the lower part, without other fracture or displacement. Mr. Mallet, in his "History of the

Neapolitan Earthquake of 1857," and Mr. Lloyd, both mentioned that they had observed similar twisting movements. In close proximity to Tsurugisaki there were three dioptrical lights, viz., Noshima, Kannonsaki, and Jôkashima, where the earthquake had been as severely felt. In these, the large glass cylinders for the single flames were secured both at the top and at the bottom, but no derangement whatever had occurred. So far as the experience—which was not very extensive, however, in Japan—went, dioptric apparatus was as little liable to derangement from earthquakes as catoptric. Mr. David Stevenson, in his Paper read before the Royal Scottish Society of Arts, said that any sudden lateral motion of the earth on which a building rests, must be transmitted through the rigid and unyielding material of the structure to the summit, where the violence of the shock would be aggravated. Having regard to the vibratory character of the movement in an earthquake, the motion being as much backward as forward; and also to the fact that no building material was absolutely rigid, or unyielding, it was clear that a shock would gradually lose in intensity as it left the foundation and approached the summit of a structure. As a matter of fact, earthquakes, which had been sufficiently severe to frighten the lightkeepers and their families out of their dwellings, had not been felt at the summits of the higher lighthouse towers in Japan. This was of great importance in the construction of buildings in earthquake countries. Recent destructive earthquakes in Japan had invariably indicated a vertical motion only; and the destruction to erections had occurred on the sharp downward movement which always followed the upheaval. Messrs. Stevenson's aseismic tables did not provide for such a movement.

The Author begged to acknowledge the facilities which were afforded him by the Messrs. Stevenson, before he proceeded to Japan, for obtaining a detailed and accurate knowledge of lighthouse construction. The records of their office were placed at his disposal, and they personally assisted him in every way, especially as regarded the design and construction of the optical apparatus, in which matters they were pre-eminent. He also mentioned the assistance he had received at one time from H.E. Mr. Wooyeno, Minister in England for Japan, who, almost at the outset, was the commissioner appointed by the Government to take charge of the work. By his energy and high intelligence he succeeded in extricating the work from serious difficulties in which it was involved, owing to the peculiarities of the native workmen. Unfortunately his Excellency only remained in the Lighthouse Department for a

short time, by which the assistance of a willing and an able colleague was lost, just at the time when such services were most needed.

Mr. W. D. CAY referred, through the Secretary, to the advantages of the use of gas for lighthouses in situations occasionally inaccessible. He had recently completed the works for lighting, in this manner, the lighthouse at the seaward extremity of the New South Breakwater at Aberdeen, the tower of which had been already described at the Institution.¹ The lightkeeper was unable to pass along that breakwater during storms on account of the waves, so that it was necessary to have a constant light; and it had been so arranged that this was kept low during the day, and the full pressure was turned on at sunset by a cock placed on the shore. The gas was brought from the town of Aberdeen in a 2-inch pipe, upwards of $2\frac{1}{2}$ miles long, crossing the river Dee by the Suspension Bridge in a lead pipe, and was carried along the breakwater in a wrought-iron pipe sunk in a groove cut in the concrete, and covered with a pitch-pine beam. A gasholder, inclosed in a house, was provided at the shore end of the breakwater, holding a week's supply of gas; and a dry gas-meter, placed on the pipe from the town, prevented the return of gas towards the town, when through any cause the pressure in the supply pipe should be less than the pressure in the holder. These arrangements had been completed, and tested, and had been found to work in a satisfactory manner. The total cost, including the lighthouse which had been built of concrete in 1873, the light-room, lanterns, gas supply works, &c., would be about £2,200.

Mr. J. J. COLEMAN remarked, through the Secretary, that it was only within the last few years that mineral oil had been used for lighthouse purposes. Previous to 1868 the possibility of using mineral oil in lighthouses had been considered by the Trinity House, but the then existing lamps were not found suitable for its application. In the month of March of that year Captain Doty submitted to the Trinity House authorities a burner with a concentric wick, which he asserted would answer the purpose. This, however, was a crude affair; and the Deputy Master lent Captain Doty a lamp of the first order as a model. Another and more perfect burner was constructed, and sent in the course of the same year to the Trinity House. Professor Tyndall examined it, and did not advise its adoption; but, during the two ensuing years,

¹ *Vide Minutes of Proceedings Inst. C.E., vol. xxxix., p. 123.*

experiments were made by Mr. J. N. Douglass, M. Inst. C.E., who altered the existing Trinity House burners, so as to adapt them for burning mineral oils. A first order light so altered was used successfully at Flamborough Head in 1871.¹ In the meantime, Captain Doty had succeeded in introducing his burner, and the use of mineral oil for lighthouse purposes, into France; the late Emperor of the French taking considerable interest in the subject. He was also successful in interesting the Commissioners of Northern Lighthouses, through their Engineers, Messrs. D. and T. Stevenson. Dr. Stevenson Macadam examined the photogenic power of mineral oil when burnt in Captain Doty's lamp, and made an exhaustive report to these gentleman on the 31st of December, 1870. Assuming a given weight of colza oil to yield a light denoted by 1,000, Dr. Macadam stated that an equal weight of mineral oil furnished in

First order of lamp, a light equivalent to	1,184
Second " " " "	1,544
Third " " " "	1,734
Fourth " " " "	2,040

and concluded thus:—"I am of opinion that paraffin oil, consumed in Doty's lamps, alike from readiness in trimming and lighting up, from steadiness of flame, and from high photogenic power, possesses decided advantages over colza oil for lighthouse illumination."² In April of the same year, Dr. Macadam reported that he had got still more favourable results with the first and second order of lamps, by an alteration of the wicks. These experiments were simultaneous with practical trials of the oil at Girdleness, Pladda, and Pentland Skerries lighthouses. In December 1871 appeared a report by Professor Tyndall,³ who had been employed by the Trinity House to examine into the relative merits of the lamp used by the Trinity House and that introduced by Captain Doty. Dr. Tyndall's experiments lasted fifteen days, and he thus concluded an elaborate report on the matter:—"With oil No. 1, which appears to be more suitable for lighthouse purposes than any other, the Doty lamp shows a small but distinct superiority. As regards this oil, the simple changes introduced by Mr. Douglass into the Trinity burner appear to be almost as effective as the more elaborate devices of a central button and an external jacket introduced by Captain Doty. But as regards the combustion of oils

¹ *Vide* P. P. Correspondence relative to the substitution of mineral oils for colza oil in lighthouses, p. 7, 6 February, 1872.

² *Vide ibid.*, pp. 13 *et seq.*, 28 June, 1871.

³ *Vide ibid.*, p. 23, 6 February, 1872.

richer in carbon, and, therefore, more liable to produce a smoky flame, the Doty lamp possesses, within certain limits, a distinct advantage. On the whole, therefore, I should pronounce the Doty lamp the more effective of the two." Mr. Douglass' alterations of the old colza burner were as follows, according to Dr. Tyndall :— Altering the tips of the wick cases, introducing a perforated disc at the centre of the flame, and modifying the form of the glass chimney, also altering the level of the oil (an expedient previously adopted by Captain Doty). The issue of this report was followed by a voluminous correspondence, extending from 1871 to 1874, between the Trinity House, the Board of Trade, the Northern Commissioners, Messrs. D. and T. Stevenson, and Captain Doty, relating to certain claims on patent rights and proposals to settle the same.¹ In reference to this report, the question of vegetable oils *versus* mineral oil was considered by Dr. Tyndall to have been settled by previous reports of Dr. Macadam, Mr. Valentine, of the Royal College of Chemistry, Mr. Douglass, and Messrs. D. and T. Stevenson. After quoting the report of Mr. Douglass to the Trinity House, that with mineral oil used in a single-wick lamp an economy of 72·7 per cent., and with a four-wick burner of 60·5 per cent., had been gained, as against the results obtained by the use of colza oil, Dr. Tyndall remarked :—" This consensus of evidence leaves no doubt upon the mind that, as regards cost and illuminating power, the paraffin light really possesses the advantages claimed for it." Meanwhile, the French Government had been actively at work, and by the year 1872 sixty-nine light-house stations in France were being supplied with paraffin oil. In 1873 M. Reynaud reported to the Foreign Office² that Captain Doty had been awarded 10,000 francs by the French Government in recognition of his services ; and in the same year the Duc de Broglie reported, through Lord Lyons,³ that two kinds of burners were giving good results, viz., the Doty and a modified form of Fresnel lamp, made by M. Henry Lepaute ; and that they cost the administration the same price, viz. :—

	Francs.
Five meshes	60
Four „	50
Three „	40
Two „	32

¹ *Vide* P. P. Correspondence relative to the substitution of mineral oils for colza oil in lighthouses, *passim*, 27 June, 1872 ; 6 February and 1 August, 1873, and 22 May, 1874.

² *Vide ibid.*, p. 30, 1 August, 1873.

Vide ibid., p. 1, 22 May, 1874.

In 1874 the Trinity House reported to the Board of Trade that paraffin oil was used in nineteen English lighthouses, and they recommended its introduction into twenty more, and a contract was entered into with Messrs. De Mille and Co. for burners, the prices being as follows¹:—

	£.	s.
Five wicks	10	15
Four „	8	0
Three „	6	0
Two „	4	10

In the same year, also, the Board of Trade sanctioned the Northern Commissioners introducing (through Messrs. D. and T. Stevenson) the Doty burner and mineral oil into all Scotch lighthouses. As regarded the economy of mineral oil for lighthouse purposes, its cost had always been under that of colza, or other fatty oils; frequently only one-quarter, and never more than one-half the price. In foreign stations, it would appear from the Paper that it was also economical, notwithstanding the expense of packages and freight. Mr. Brunton had remarked correctly, that much care was required in the selection of the oil, and in freeing it from the volatile constituents which were always present in crude or imperfectly refined mineral oils. If a standard of 145° to 150° flash point were too low, it would be easy to manufacture an oil having a flash point even as high as 250°, which was the quality of oil supplied for the use of saloon lamps of marine steamers. There was one point which the Author seemed to think of importance, viz., the heat produced during the combustion of mineral oil, as compared with that evolved during the combustion of vegetable oils. To use the words of the late Professor Rankine: “The total heat of combustion of any compound of carbon and hydrogen is the same as the quantities of heat which the hydrogen and carbon contained in it would produce separately by their combination with oxygen, and when hydrogen and oxygen exist in the compound in proper proportion to form water, these constituents have no effect on the total heat of combustion.”

The average constitution of vegetable oils was:

Carbon	76
Hydrogen	12
Oxygen	12
	<hr/>
	100
	<hr/>

¹ *Vide* P. P. Correspondence relative to the substitution of mineral oils for colza oil in lighthouses, p. 17.

Applying the above rules, the available carbon and hydrogen for producing heat in say 100 lbs. of the oil would be :

Carbon	lbs. 76
Hydrogen	10½

Again, the average composition of mineral oils was :

Carbon	lbs. 85
Hydrogen.	15
	<hr/> 100

Now the number of British heat units produced by burning 1 lb. of hydrogen was 62,032, and by burning 1 lb. of carbon 14,500, therefore the following calculation would show the total heat of combustion of vegetable *versus* mineral oils :—

Vegetable oils	{ Carbon 76 × 14,500 =	1,102,000
	{ Hydrogen 10½ × 62,032 =	651,336
		<hr/> 1,753,336
Mineral oils	{ Carbon 85 × 14,500 =	1,232,500
	{ Hydrogen 15 × 62,032 =	930,480
		<hr/> 2,162,980

Thus mineral oils evolved 23 per cent. more heat in burning than vegetable oils ; but, on the other hand, taking into consideration the increased light they gave, the amount of heat evolved per unit of light was actually less with mineral oils than with vegetable oils, when the average results of various burners were taken as the basis of calculation. It appeared probable that the breakage of glass chimneys, observed by the Author, was owing to the fact that a mineral oil flame was generally more concentrated than that of a vegetable oil, thus localising the heat produced. He would suggest that if this difficulty caused too much trouble, the form of the chimney, or the construction of the burner, should be altered so as more effectually to spread the flame.

GEOLOGY OF JAPAN.

At this meeting the PRESIDENT directed attention to an interesting series of 123 specimens of the Mineral Products of Japan,—a gift to the Institution from the Government of that Empire ; whereupon it was