XII. *Magnetic Survey of the Eastern Archipelago. By Captain* C. M. Elliot, *of the Madras Engineers. Communicated by Lieut.-Col.* Sabine, *V.P. Treas. R.S. &c.*

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In accordance with instructions received from the Honourable the Court of Directors of the East India Company, and at the recommendation of the Royal Society, I commenced, in the month of January 1846, the Magnetic Survey of the Eastern Archipelago.

As, in the prosecution of this work, I was left entirely to my own discretion, I may be permitted to state, that the principal object of the Survey appeared to me to consist in determining the position of certain magnetic lines which were included within the space I had to traverse; such, for instance, as the line of no dip, and of the maximum horizontal component of the force; from these, to determine the line of minimum intensity; and finally, the line of no variation and its direction. The determination of these lines I considered to be the principal object; but in addition, I was anxious to take hourly observations of the elements of the earth's magnetism, in order to ascertain whether the changes of declination and of magnetic intensity were uniformly similar over so large an area. The fixed stations for this latter purpose were sixteen in number, and the time employed at each station varied from a few days to several months. The fixed stations were spread over an area of 28° of latitude and of 45° of longitude, viz. from 16° latitude north to 12° latitude south, and from 80° to 125° longitude east. With reference to the line of no dip, which in this part of the globe coincides very nearly with the line of minimum intensity, I may state, that of the sixteen stations, nine were to the south, three to the north, and four in its immediate vicinity. With reference to geographical position, four were in the islands adjacent to Singapore; one in Borneo; one in the island of Java; two in Sumatra; one in the island of Mindanao; one in Celebes; one at the Cocos or Keeling Islands, which was the most southern station to which I could venture; one at Penang, and one in its immediate vicinity; one at Nicobar, in the bay of Bengal; one at Moulmein, which was my most northern; and, finally, one at Madras, which was my most western station. The Survey is however incomplete, as it would have been desirable to extend it considerably more to the eastward, in order to lay down with greater certainty the continuation, of the line of no dip and of the line of minimum intensity; and likewise I should have wished to proceed more to the northward, to ascertain with greater exactitude, at what distance north of the line of minimum intensity, the magnetic declination changes those periods of extreme easterly and extreme westerly variation, by which it is characterized in the southern magnetic hemisphere.

In January 1846 I started from Singapore, and after visiting some islands in the vici-

nity, which I was enabled to do through the kindness of Colonel Butterworth, C.B., the Governor of the Straits, I proceeded, in May 1846, to Borneo, where I remained some time with my friend Sir James Brooke, K.C.B., and making Sarāwak my head-quarters, I took observations at several of the Dutch settlements on the western coast. From Borneo I proceeded to Java, where I passed ten months, and went on to Sumatra in August 1847; but from severe illness brought on through over-exertion in the magnetic survey of part of that island, I was forced to return to Singapore for medical advice in February 1848. At Singapore I remained for some weeks; during which time I was able to take a considerable number of observations of dip and of horizontal intensity; and early in April 1848 I again left Singapore, and visited successively, Pulo Labooan, Sambooanga in the island of Mindanao, and Keemah in the Celebes. From Keemah I proceeded to the Keeling or Cocos Islands, and from the Cocos returned to Batavia, whence I was on the point of proceeding to the eastward and to New Guinea; when I received instructions which induced me to return to Madras, in consequence of having unfortunately very much exceeded the time allotted to me; and thus an end was put to the Survey, which the liberal patronage of the Court of Directors of the East India Company had enabled me to undertake, and which I had hoped to render complete. I returned to Singapore at the close of the year 1848; and here let me gratefully acknowledge, the kind and hospitable treatment I received everywhere from the Dutch authorities. No restrictions were placed on my movements; I was allowed to proceed wherever I chose, and I rejoice at the opportunity thus afforded me of recording my sense of their uniform liberality; nor can I omit mentioning my obligations to His Excellency Baron Rochussen, the Governor-General of the Dutch Possessions in the East; to His Excellency General Van der Weyck, the Commander-in-Chief in Java, and to Captain Smitz, the Hydrographer, who rendered me very great service in his superintendence of the magnetic observatory during my occasional absence from Batavia.

Quitting Singapore for the last time, I stopped at Penang on my way to Nicobar Island, which I was anxious to visit from its being in the immediate vicinity of the line of no dip and of minimum intensity.

I then visited Moulmein, and from Moulmein proceeded to Madras, which I reached in June 1849, from which time till the month of October I was employed there in taking a complete set of absolute determinations, and of hourly magnetic observations, in which latter duty I received the kind aid of Captain Jacob, the Honourable East India Company's Astronomer. Madras was my last station, and I there concluded the Survey. Having then to reduce and bring into shape an enormous mass of work, it occurred to me that the difficulties I should encounter in publishing in India a system of observation, combining the details of a fixed observatory with those of a magnetic survey, would be very great. I therefore applied for furlough, and came to England for the sole purpose of publishing my observations, after reducing them into as condensed a form as was consistent with perspicuity.

Since my arrival in England I have been in constant communication with Colonel

SABINE, R.A., to whose zealous superintendence and advice I am indebted, on almost every point connected with the reduction of the observations; I have likewise to express my obligations to Dr. LLOYD for his advice and for many acts of kindness; from their joint Report on the Magnetic Isoclinal and Isodynamic Lines in the British Islands, I have laid down, in a manner similar to the method there adopted, the different magnetic lines on the Chart of the Eastern Seas; while to the "Magnetical Instructions for the use of Portable Instruments," drawn up by Captain RIDDELL, R.A., I am indebted for the abstracts and forms in which the different instruments are registered.

I do not therefore pretend to any originality in my plan; and the only merit I lay claim to is, that these observations, taken under many difficulties, were made with the earnest desire to do credit to the Royal Society, who recommended the Survey, and to the East India Company, whose munificence enabled me to undertake it.

The Survey consisting; first, of the observation of the differential changes of magnetic and meteorological phenomena at sixteen stations; secondly, of absolute determinations of dip, intensity, and variation in Java, Sumatra, Borneo and other islands of the Archipelago; thirdly, of magnetic and meteorological observations at sea,—it will perhaps be best to treat of each separately, and I shall therefore commence with the observatories.

The following Table contains the names of the different stations at which observatories were established, commencing with the most northerly. The first column contains the stations; the second and third, the latitudes and longitudes; the fourth and fifth, the materials with which the observatories were constructed; the sixth, the nature of the soil; the seventh, the number of days of observation; the eighth, the year and month; and the ninth, the place of observation.

Station.	Latitude.	Longitude.	Materials with which the Observatories were constructed.		Nature of soil.	No. of days observation.	Year and Month.	Places of observation.
			Roof.	Walls.				
Moulmein ...	16° 26′ 49″ N.	97° 45′ 30″ E.	Double thickness of canvas.	Cotton-cloth ...	Clay	7	April 1849	Near Captain BERDMORE's house.
Madras	13 04 09	80 16 30	Cotton-cloth ...	Cotton-cloth ...	Clay and sand.	34	Aug. and Sept. 1849.	At the fixed Magnetic Observatory.
Nicobar	9 10 12	92 48 23	Double thickness of canvas.	Cotton-cloth ...	Coral and sand.	5	February 1849.........	Near the sea-shore.
Sambooanga.	6 54 20	122 13 45	Double thickness of canvas.	Canvas............	Clay and sand.	6	May 1848	Near the sea-shore.
Penang	5 25 36	100 24 30	Double thickness of canvas.	Folds of cotton-cloth.	Clay and sand.	5	January 1849	Near the sea-shore.
Pulo Dinding	4 12 47	100 32 52	Double thickness of canvas.	Folds of cotton-cloth.	Clay.........	3	January 1849	Near the sea-shore.
Sarāwak	1 33 54	110 29 00	Thatched with leaves of Neepa.	Leaves of the Neepa palm.	Clay.........	72	June, July and August 1846.	Near Sir J. BROOKE's house.
Keemah, Celebes.	1 21 55	125 07 59	Canvas............	Canvas............	Clay.........	10	June 1848	In the village, not far from the shore.
Pulo Peesang	1 27 53	103 19 15	Canvas............	Canvas............	Clay and sand.	5	January 1846	Close to the sea-shore.
Singapore ...	1 18 32	103 56 30	Thatched with leaves of Neepa.	Wood and sun-burnt bricks.	Sand upon blue clay.	30	Nov. and Dec. 1848.	At the fixed Magnetic Observatory.
Carimon......	0 59 22	103 27 00	Canvas............	Canvas............	Sand	6	January 1846	Close to the sea-shore.
Pulo Booāya.	0 09 09	104 21 00	Canvas............	Canvas............	Sand	4	February 1846.........	On the sea-shore.
Padang, Sumātra.	0 58 58 S.	100 31 15	Double thickness of canvas.	Canvas............	Ferruginous sand.	78	Oct., Nov., Dec., 1847 and Jan. 1848.	Near the sea-shore.
Batavia	6 09 52	106 58 00	Thatched with leaves of Neepa.	Thick bamboo matting.	Clay.........	199	From Nov. 1846 to July 1847.	In the midst of a vast plain of rice-fields.
Cocos or Keeling Islands.	12 05 38	96 50 30	Double thickness of canvas.	Cocoa-nut leaves	Fragments of coral.	27	August and September 1848.	Close to the sea-shore.

The instruments in use at the observatories were the following:—

No. I. Portable Declination Magnetometer, showing changes of declination or of variation.

No. II. Induction Inclinometer, showing likewise changes of declination.

No. III. JONES' new Declinometer, in use during the latter period of the Survey, showing likewise changes of declination.

Nos. IV. and V. Portable Bifilar Magnetometer with Thermometer, showing changes of horizontal intensity.

Nos. VI. and VII. Barometer and Thermometer; NEWMAN'S Standard Barometer was in use during the first part of the Survey; and latterly, a Portable Instrument by CARY.

Nos. VIII. and IX. Dry and Wet-bulb Thermometers.

No. X. Standard Thermometer.

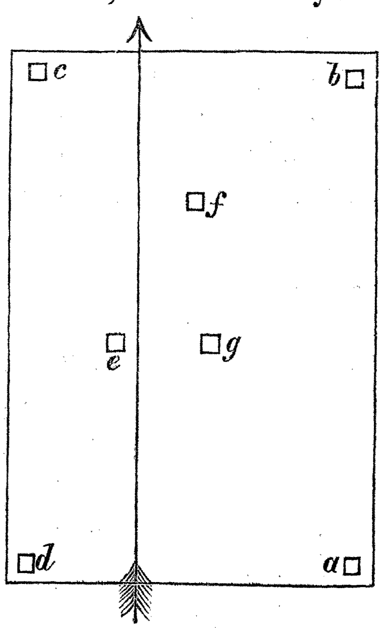
Nos. XI. and XII. Maximum and Minimum Thermometers.

Observatories, Position of the Instruments, &c.

As all the observatories were constructed upon the same principle, it will not be necessary to give the positions and adjustments of the instruments at more than two of the stations; the details of the rest being precisely of a similar nature; for this purpose the position of the instruments, their adjustments and the dimensions of the observatories on Direction Island, Cocos; and at Batavia, are given.

Observatory on Direction Island, Cocos or Keeling Islands.

The observations at the Cocos or Keeling Islands were made on Direction Island, with the usual magnetic and meteorological instruments. The soil on Direction Island consists of a few inches of vegetable soil, and of several feet in depth of fragments of coral. The observatory tent was pitched in the midst of a thick plantation of cocoa-nut trees about 8 feet above the level of low-water mark, and about 50 yards from the sea.



Dimensions of the tent 19 × 13 feet. Tent consisted of a double lining of canvas, and the walls of cocoa-nut leaves.

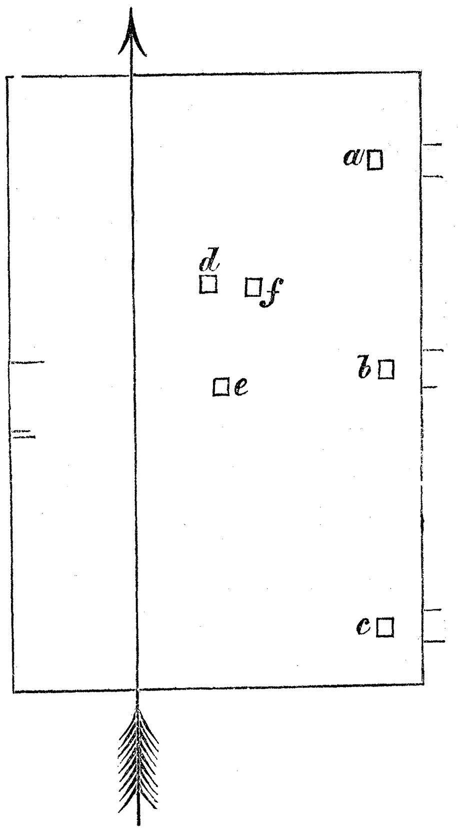
a. Declinometer No. I.
b. Declinometer No. II.
c. Declinometer No. III.
d. Bifilar and Thermometer.
e. Barometer and Thermometer.
f. Dry and Wet Bulb.
g. Standard Thermometer.

The magnetic instruments were placed at the four corners as remote from one another as the dimensions of the tent would permit. The Standard Thermometer was attached to one of the poles of the tent. The Barometer fixed to a detached post firmly imbedded in the

ground. The Dry and Wet-Bulb Thermometers were placed on a small table, 5 feet above the ground.

Observatory at Batavia.

The dimensions of this building were 42×28 feet, and almost wholly constructed of bamboo; the walls were 12 feet in height, composed of thick bamboo matting, and the roof was thatched with leaves of the Neepa palm. The soil was a very stiff clay, and the spot selected was in the midst of extensive rice-fields.



a. Bifilar Magnetometer, on a pillar constructed of sun-dried bricks, capped by a slab of granite.

b. Declinometer No. II. on a wooden stand.

c. Declinometer No. I. on a pillar of sun-dried bricks.

d. Standard Barometer with its Thermometer.

e. Dry and Wet Bulb.

f. Standard Thermometer.

The Bifilar at the N.E. angle, the scale facing the south; Declinometer No. II. at the point *b*, and Declinometer No. I. at the point *c*, both facing the east, the instruments being about 18 feet apart; the Dry and Wet Bulb on a table at *e*; the Standard Barometer attached to a post firmly imbedded in the earth at *d*; the Standard Thermometer fixed to a post at *f*.

Times of Observation.

Having during the greater part of the Survey but one assistant, I limited the observations to nineteen hours daily, viz. hourly observations from 3 A.M. to 9 P.M. To this arrangement there are exceptions; as at Sarāwak and during the first four months at Batavia, when I had three assistants; and then observations were taken hourly during the twenty-four hours. By astronomical time, therefore, the observations generally commenced at fifteen hours, and terminated at nine hours.

Order in which the Instruments will be noticed.

The instruments will be noticed in the following order:—The Declinometers, the Bifilar, the Dry and Wet-Bulb Thermometers, the Barometer, the Standard Thermometer, and the Maximum and Minimum Thermometers.

Declinometers.

There were never less than two declinometers observed at the same station, and subsequently, when JONES's declinometer was received, all three were put in adjust-

ment and observed. At Pulo Peesang, Carimon, Pulo Booāya, Sarāwak, Batavia, Poolo Bay, Padang and Sambooanga, Nos. I. and II. were employed; at Moulmein, Nos. II. and III.; at Keemah, the Cocos, Pulo Dinding, Penang, Nicobar, and Madras, Nos. I. II. and III.; and at Singapore, in November and December 1848, not only were the three above-mentioned observed, but two in addition, viz. No. IV., a small cylindrical magnet 3 inches in length, in use for deflection in a separate building, and No. V., the large 15-inch bar in the observatory.

Declinometer No. I.—Declinometer No. I. is the Portable Declination Magnetometer described in Captain RIDDELL's work on Magnetic Instruments; the magnet is a solid cylinder 3 inches in length and suspended by a filament of untwisted silk; the former enclosed in a copper box, the latter in a glass tube. A scale being fixed above the telescope and reflected by a mirror attached to the stirrup in which the magnet is placed, the changes in the position of the magnet are shown by the mirror reflecting different portions of the ivory scale, and are read off by the telescope attached to the instrument. The mirror is immediately below the magnet and parallel to its longer axis; the scale faced the east, and increasing readings denote a movement of the north pole east. The ratio of the torsion force to the magnetic directive force, or the value of $\frac{H}{F}$, varied from ·000207 to ·000278. The value of one scale division in arc value is $a'=3437{\cdot}75\times\frac{l}{2r}=1'{\cdot}00$, where $l=\frac{1}{100}$th of an inch=·01 and $r=17{\cdot}19$ inches.

Declinometer No. II.—Declinometer No. II. is the Induction Inclinometer described at page 12 of RIDDELL's work. The magnet is of the same length as No. I., but hollow. The adjustments are precisely similar. The mirror is parallel to and immediately below the longer axis of the magnet. The value of one scale division is exactly the same as for No. I., viz. 1′ of arc. The coefficient of torsion varied from ·000139 to ·00025, and is therefore not worth taking into account, except for large angles of deflection.

Declinometer No. III.—Declinometer No. III., or JONES's Declinometer, is precisely similar in principle to the two others; the magnet being a solid cylinder 3 inches in length. The mirror, instead of being parallel to the longer axis of the magnet, is at right angles to it, so that the scale, instead of facing the east, being to the south of the magnet, faced the north. Increasing scale readings denote a movement of the north pole east. The value of one scale division is $1'{\cdot}0036$; the coefficient of torsion ·00031.

Contents of Abstracts of Table A. *referring to the Declinometers.*

In the abstracts of Table A. are given, from page i to page xi inclusive, the oscillation, or more properly the variation of the declination* at the different stations in

* In order to obviate confusion as much as possible, I have substituted in Table A. for hourly variation the word oscillation, which is meant to express the extreme range or swing of the needle from its most western to its most eastern position: the term hourly variation has not been used in Table A., as it might be con-

the Eastern Archipelago; pages ii and iii contain the mean oscillation of the declination, the range extending from the most westerly declination assumed as zero, to the most eastern position of the magnet. As increasing readings denote a movement of the north pole of the magnet eastward, the lowest number will of course be the most western position or zero, the highest number being the most eastern position. As these tables contain the mean oscillation for several months, the oscillations at those stations where observations have been taken for more than one month are given in pages iv to vii inclusive.

In addition to the three Portable Declinometers, No. IV., a small 3-inch cylinder used as the deflected magnet in the determination of the absolute horizontal intensity, and No. V., the 15-inch observatory bar, were observed at Singapore. The oscillations of these two instruments are given at pages iv and v, reduced to minutes of angular space, and the mean results are included in the Table of Declinometer No. III. at pages ii and iii. It occurred to me constantly whilst at the observatory to note, that not only did the large magnet differ from the smaller magnets in its time of changing, but the range or oscillation was not the same; the time of change differed but slightly it is true; but it was not identically the same*. I determined therefore to use on the Survey never less than two magnets; one a solid, the other a hollow cylinder, for the changes of declination; and on my return to Singapore in 1848, I took nearly simultaneous observations of as many declination magnets as could be observed together.

On inspection of the Tables of the mean oscillation of the declination at pages ii and iii, I was struck with the dissimilarity of the times of occurrence of minimum westerly declination at the different survey stations; and as the observations were taken at all seasons of the year, it appeared to be exceedingly desirable to have some fixed observatory to refer to, to ascertain what changes might be due to geographical position and what changes to the time of the year. I have, therefore, at pages viii, ix, x and xi, given the mean hourly oscillation of the magnetic declination at the Singapore Observatory, for each season being the mean of three years; the mean of each of the months; and finally, the mean of each of the three years, showing the

founded with the angle α, or the angle which the magnetic meridian forms with the true meridian, and which is usually called the variation of the needle; but to prevent mistakes, for the angle α, the term magnetic declination has been substituted, in accordance with the method now generally adopted.

* I attributed at the time this difference of range, and the turning points not being exactly simultaneous, to the method of suspension by filaments of silk, and the constant change to which the force of torsion was liable from the hygrometric properties of the silk. The large observatory 15-inch bar was suspended by eighteen fibres of untwisted silk; and when a fresh adjustment became necessary from the threads breaking, a brass bar was swung, in order to take the torsion out of the new suspension thread: after getting the brass bar accurately into the magnetic meridian, it would remain in the same position for several hours; but, if adjusted during the day, it would be found, after the lapse of a night, forming some angle with the magnetic meridian; thus, from some cause, hygrometric or otherwise, the plane of detorsion was no longer in the same position in which it had previously been in adjustment.

remarkable similarity of one year with another. As the sole object in giving these Singapore tables, was to determine the times of extreme easterly and westerly declination, in the southern magnetic hemisphere near the line of minimum intensity, the results of the Singapore Observatory magnet are not in this instance given in minutes of arc, but in scale divisions; one scale division being equal to 40''·7 of arc.

Table A.—Pages xii to xlvii contain the results of the declinometers at the sixteen stations in the Archipelago. The stations are given proceeding from the most northern to the most southern: the observations themselves are omitted. At the top of every double page is printed the name of the station, with its latitude and longitude; the mean astronomical time at the station; and the value of one scale division in minutes of arc, multiplied by the coefficient of torsion or $1+\frac{H}{F}$; the value of which is so trifling as not to affect the small diurnal changes of the magnet; and the zero of the month, which is the scale division of the magnet at that hour at which the absolute determination of the magnetic declination was made, usually at 9 A.M. The results of each instrument are contained in five lines; the first, the sums of the scale readings; the second, the means; the third, the diurnal changes, from the mean of the month*; the fourth, the range or oscillation of the needle, from its minimum or most western position; and the fifth, the diurnal declination.

Curves.

The curves of the declinometer are given in Plates IV., V. and VI. Part 1 of Plate IV. contains the curves of the declinometer at those stations where observations were made during the spring and summer; Part 2 of Plate IV. and Part 1 of Plate V. the winter curves; Part 2 of Plate V. the equinoctial curves. The two Plates are drawn to a scale of 1' of arc to 0·35 of an inch, and Plate VI. contains the Singapore curves, which are drawn on a scale of 0'·68 of arc (the value of one scale division) to 0·35 of an inch. In the three Plates the zero line is the line of the magnet's most westerly position. The curve rising denotes a movement of the north pole of the magnet eastward. The curves themselves show, by the description of dotting, to which season they belong.

As the station curves have to be compared separately with Singapore, it will be preferable to consider first the principal changes of the Singapore curves shown in Plate VI. In Part 1 of Plate VI., which gives the mean curve of each month for three years, it appears that the minimum or westerly declination occurs at Singapore in December at 19 hours; in January at 20; in February at 21; in March (equinoctial month) a slight retrogression to 20; in April at 21; in May at 23; in June at 21;

* The mean of the month being the mean of the whole number of observations; where there are but nineteen hours of observation, and these principally in the daytime, the mean of these for a mean temperature would unquestionably be too high; five of the hours of the night being omitted, the mean of the nineteen observed hours would be greater than the true mean; but this is not the case with the magnetic declination, the range being exceedingly small at night, and usually close upon the mean position of the needle.

in July and August at 23; in September at 22; in October at 21; and in November at 20 hours. If the seasons are projected in curves as in Part 2 of Plate VI., we find in winter the minimum at 20 hours; in spring at 21 hours; in summer at 23 hours; and in autumn back to 21 hours; agreeing in this with the spring curve, but differing very materially as regards the progression of the needle eastward in the afternoon; autumn and winter agreeing in this latter respect, and also spring and summer. The oscillation of the curve exhibits a much greater range during the winter months*; the autumn curve is next in extent of range and in the afternoon preserves a certain degree of parallelism with the winter curve; and both these curves have the afternoon maximum more decidedly expressed, and have also a higher maximum than in the morning. The reverse of this is the case with the spring and summer curves.

The mean curves of the three years exhibit a wonderful uniformity and almost total resemblance. There are two most decided maxima at 18 and at 3 or 4 hours, and one minimum at 21. There are besides two other minima at 10 and at 17 hours more faintly expressed. If we turn to the seasons, we find only one strongly defined maximum and minimum or a single progression in winter; in spring two strongly expressed maxima and one minimum; in summer and in autumn two maxima and two minima; and as these maxima and minima occur at different periods, the mean annual curve thus blends the leading characteristics of all, and presents accordingly a double, if not a triple progression.

On an inspection of the Plates, and on comparing them with the Singapore curves, we find that in Part 1 of Plate IV. the Moulmein April curve resembles no single curve in any one month at Singapore. The curve is that described by Declinometer No. III.; there are two minima at 17 and 1, and two maxima at 20 and 5 hours. Moulmein is about 8° north of the line of minimum intensity.

The next two in Part 1 of Plate IV. are the Sambooanga May curves of Declinometers Nos. I. and II.; comparing them with the same period at Singapore, we observe a certain degree of similarity, the morning maximum being at the same hour, the minimum being one hour later; the curves of the two declinometers differ slightly with each other: Sambooanga is on the line of minimum intensity.

The next curves are those of Batavia during the spring months; their resemblance to the spring curve of Singapore given in Part 2 of Plate VI. is very striking; the morning and afternoon maxima and the morning minimum being at the same hours at both places: Batavia is 14° south of the line of minimum intensity.

The next curves in Part 1 of Plate IV. are the Sarāwak summer curves; there is a considerable resemblance to the curves at the same period at Singapore, the morning minimum being one hour later; the position of Sarāwak is exactly the same as Singapore relatively to its position south of the line of minimum intensity. The

* The sun is longer to the south of the line of minimum intensity than it is to the north. Singapore is in north latitude 1° 18′, and as the line of minimum intensity crosses the meridian of Singapore in about 8° north latitude, the sun is to the south of it considerably more than half the year.

last three curves of Plate I. are the Keemah curves of the latter end of June or commencement of July; their morning maximum and minimum at 19 hours, and at noon, correspond with the same periods at Singapore.

At the top of Part 2 of Plate IV. containing the winter stations, the curves of the five declinometers are drawn to the same scale, viz. 1′ of arc to 0·35 of an inch: there may be seen from these curves, the extreme difference likely to occur amongst instruments observed nearly simultaneously; whilst these curves are similar, they are not identically the same; the observations were not taken at the same instant, but one after the other in the order of the declinometers*. The curves of Pulo Peesang in the same Plate, are similar to the Singapore February curve. The Carimon and Booāya curves are similar to one another, but the maximum in the afternoon is earlier than the corresponding maximum at Singapore. Part 1 of Plate V. is the continuation of the winter curves; the curves of the three declinometers at all the stations of Nicobar, Penang, Pulo Dinding, Batavia and Padang, agree well with the same winter period at Singapore.

In Part 1 of Plate V., at the hours of 6 and 7, there is observable in some instances a want of uniformity in the progression of the curve; in some instances no difference is perceptible, in others a minimum. On referring to Plate V. we find there is a minimum at Singapore in January, exactly similar to the minima shown in some of the curves of Part 1 of Plate V., and at the same hours.

In Part 2 of Plate V. are given the curves of the stations where the instruments were observed during the equinoctial months, both in spring and in autumn. The Madras curve, when compared with the Singapore curve, has its morning maximum and minimum at 20 hours and at noon; at Singapore at 18 and at 22 hours, two hours earlier. Madras is near the line of minimum intensity.

The observations at Bencoolen were taken for a few days at the end of August and at the commencement of September, it is therefore difficult to say to which month they belong; they agree well with the Singapore August curve. The next curves in the Plate are those of Batavia in March; they are exactly similar to the Singapore curve in March.

The Cocos curves taken in September agree well with the Singapore September curve; the form of the morning curve is identical, and the time of the afternoon maximum; but they differ in the afternoon maximum at the Cocos, having a greater range than the morning maximum; the progression of the magnet westward being subsequently more rapid till between the hours of six and seven, when there is the same faint minimum expressed as in the January curve at Singapore. Noting therefore those curves which are in accordance or differing but slightly from the Singapore

* The observation of No. IV. at 3 A.M. has been omitted in the curve, as on referring to the observation book the series was found to be broken on one day in November; but the observation at 3 A.M. was entered, and as the scale reading was unusually low, it has reduced the mean reading at 3 A.M., or at 15 hours lower than it should be.

curves during similar periods, we find only two which differ materially from the Singapore curves at similar periods of the year; one of the stations, Moulmein, being considerably to the north of the line of minimum intensity, the other, Madras (not differing so much), in its immediate vicinity. Sambooanga and Nicobar are indeed likewise close upon the line of no dip or minimum intensity, yet they agree generally with the Singapore curves. It is to be observed, that as we proceed north and approach the line of minimum intensity, the similarity to the Singapore curves becomes more faint; this may be seen on inspection of the Plates, where the most southerly stations, the Padang, Batavia and Cocos curves, agree exceedingly well with those at Singapore at similar periods*.

Bifilar Magnetometer.

The bifilar magnetometer is described at page 11 of RIDDELL's work; the apparatus is not very dissimilar to the unifilar; it consists of a tripod base with a fixed circular plate 5 inches in diameter, graduated so as to be read off by verniers to single minutes, carrying an upper revolving plate and two projecting arms for supporting the reading telescope and counterpoise weight; the magnet and bifilar suspension are inclosed, the former in a copper box, the latter in a suspension tube, 10 inches in length, carrying a circular plate, torsion circle and right and left hand screw-cylinder at its upper extremity, and the circle divided so as to be read off by verniers to $5'$: the magnet is suspended by two portions of the same thread, and is maintained by a rotation of the upper extremities in a position at right angles to the magnetic meridian. The principal adjustments are the following, for the purpose of bringing the magnet, when suspended by the double thread, into a position at right angles to the magnetic meridian:—1st. To bring the line of detorsion of the threads to coincide with the magnetic meridian. This is effected by suspending the magnet by a single filament of untwisted silk; the telescope is turned until the centre division of the scale is on the wire; the instrument is clamped; the magnet is then introduced carefully with its bifilar suspension; the vernier of the torsion circle is turned until the centre division is again on the vertical wire of the telescope, and the plane of detorsion is in the magnetic meridian. The telescope which is fixed to the instrument is then turned 90° in azimuth; the vernier of the torsion circle is turned in the same direction through an angle (v) equal to 60°. The centre division of the scale is brought on the vertical wire by increasing or diminishing the interval of the threads; which is effected by turning the milled head of the screw-cylinder. The telescope is then turned back 90°; the torsion circle being turned back through the angle v; if the adjustment has been made correctly, the line of detorsion is again in the magnetic meridian;

* Some want of similarity to the Singapore curve at those stations where any difference is observable, may possibly arise in some degree from want of the observations extending over a sufficient number of days; but not altogether, for at Madras, where a difference is perceptible, the declinometers were observed for more than a month.

the accuracy of the adjustment is tested by turning the telescope 180° in azimuth, so as to reverse the direction of the magnet, or bring its north end to the south. The telescope is again turned 90° at right angles to the magnetic meridian, so that increasing readings denote a decrease of force; the vernier of the torsion circle is turned till the central division of the scale is again on the vertical wire. The magnet is then perpendicular to the magnetic meridian, and the instrument is in adjustment. Thus much was necessary for understanding the following adjustments; those at the Cocos and at Batavia only are given; the adjustments at the rest of the stations being precisely similar, since the same angle of torsion $v=60°$ was selected for every station.

Adjustment of the Bifilar at Batavia.

The bifilar was adjusted in the afternoon of the 8th of November 1846 at 3 P.M. With the single suspension thread, the scale read 100; the horizontal circle 82° 23′. The bifilar apparatus was then carefully substituted.

	Horizontal circle.	Torsion circle.	Scale.
Magnet direct	82° 23′	53° 50′	100
Magnet direct	172 23	113 50	100
Magnet direct	82 23	53 50	99
Magnet reversed	262 19	53 50	99
Magnet direct	172 23	113 50	92·3

Before taking down the instrument a fresh series was taken on the 7th of August 1847: premising that the reading 82° 23′ on the circle is direct, or the north end of the magnet to the north, and 262° 23′ is reverse, or the north end of the needle to the south; the following is the readjustment:—

	Horizontal circle.	Torsion circle.	Scale.
Magnet direct	172° 23′	113° 50′	132·8
Magnet direct	82 22	53 52	95·0
Magnet reversed	262 20	53 52	73·0
Magnet direct	82 30	53 40	85·0
Magnet reversed	262 50	53 40	78·0
Magnet direct	82 50	53 40	79·0
Magnet direct	172 50	113 40	121·0
Magnet direct	172 50	113 30	115·0
Magnet reversed	262 40	53 45	110·0
Magnet direct	82 40	53 45	99·5
Magnet direct	172 20	113 50	110·0

This small change of numbers is satisfactory, considering that the portable bifilar had been up for more than eight months.

Adjustment of the Bifilar at the Cocos.

The bifilar magnetometer was adjusted on the 27th of August, 1848. In the unifilar suspension the scale read 100·2; the bifilar suspension was then substituted.

	Horizontal circle.	Torsion circle.	Scale.
	° ′	° ′	
Magnet direct	50 27	233 55	99·3
Magnet direct	140 27	293 55	100·0
Magnet direct	50 27	233 55	96·5
Magnet reversed . . .	230 27	233 55	85·5
Magnet direct	140 17	293 55	95·3

The angle v or angle of torsion $=60°$. Thermometer $82°·6$.

Value of a, *or of one Scale Division in terms of Radius.*

The variations of the horizontal intensity are obtained by multiplying the differences of the scale readings, or of their mean values (corrected for changes of temperature) by a constant coefficient

$$k=a\,.\cot v,$$

where a is the value of one scale division in terms of radius; as the horizontal circle by means of verniers read off to single minutes, I ascertained the value of a directly.

The first series gave the value of a' .	$=1'·45$
The second series gave the value of a'	$=1·38$
The third series gave the value of a' .	$=1·43$
The fourth series gave the value of a'	$=1·44$
Mean . .	1·433

The other method consisted in knowing the length, of one division of the scale, and of the radius,

where $$a'=\frac{l}{2r}\times 3437'·75,$$

$$l=\frac{1}{70} \text{ of an inch},$$

$$r=17·19 \text{ inches},$$

$$a'=\frac{1}{70}\times\frac{3437·75}{34·38}=\frac{100}{70}=1'·43.$$

$1'·43$ has been the angular value assumed, and the value of a in terms of radius is

$$·0002909\times 1'·43=·000415987,$$

and $k=a\,.\cot v=·0002402$ the value of one scale division in terms of the force. The scale readings or mean values are corrected for temperature according to the formula

$$f=f'-(t'-t)\frac{q}{k},$$

where f' and $f=$ observed and corrected readings,
t' and $t=$ observed and standard temperature,
$q=$ change of magnetic moment of the bar for 1° of FAHR.
$k=a\,.\cot v$, given above.

Coefficient of Temperature.—Determination of the Value of q.

The value of q was determined directly at all the principal stations by heat being gradually applied to the box at the time the instrument was in adjustment; by adopting this method before sunrise, the thermometer being at the lowest temperature, and the changes of force very trifling, I could ascertain at once the changes in the readings of the scale corresponding to the changes of the thermometer, and from thence the coefficient of temperature in terms of the force; a piece of cotton steeped in spirits of wine, ignited and applied carefully to the bottom of the box, gradually raised the interior temperature as indicated by the inclosed thermometer.

The following are the results at the commencement of August 1847 at Batavia; the results of the experiments at that station and at the Cocos are alone given, the results at all the other stations being precisely similar.

Coefficient of Temperature at Batavia.

Thermometer.	Differences.	Scale divisions.	Differences.
77°·6		76·8	
	5·0		6·3
82·6		103·1	
	2·4		0·9
85·0		104·0	
	3·5		3·2
88·5		107·2	
	1·0		0·9
89·5		108·1	
Sum	11·9		11·3

or one degree of temperature FAHR. for one scale division very nearly: this result agrees exactly with similar observations made at other stations.

Coefficient of Temperature at the Cocos.

To determine q or the coefficient of temperature the morning that the instrument was taken down, a piece of cotton dipped in spirit and ignited, was carefully applied to the bottom of the box, between 5 and 6 A.M., when the thermometer was at the minimum temperature and the changes of force but small, with the following results:—

Bifilar.		Thermometer.	
Scale.	Differences.	FAHR.	Differences.
86·1		75°·9	
	4·7		3·9
90·8		79·2	
	5·7		10·7
96·5		89·9	
	2·0		0·7
98·5		90·6	
	3·2		0·0
101·7		90·6	
Sum	15·6		15·3

Descending Scale.

97·0 92·0 89·6 87·3	4·7 5·0 2·4 2·3	83·6 79·6 77·6 76·6	7·0 4·0 2·0 1·0
Sum	14·4	Sum	14·0

Although the partial differences do not agree exactly, yet at the two extremes there is but little difference either in the ascending or descending scales of temperature. In the former, for an increase of 15°·3 of temperature the scale reading increased 15·6 divisions, and then fell back 14·4 scale divisions with a decrease of 14°; q therefore =·0002402 of the force. As these results are strictly in accordance with similar observations made at other stations, viz. at Sarāwak, Padang, &c., I have not had the least hesitation in assuming the value of q equivalent to one scale division: increasing scale readings denote an increase of temperature or decrease of force.

Oscillation or Variation of the Bifilar.

From page xlviii to lv inclusive, are given the oscillation, or more properly, the range of the horizontal intensity, given in detail in Table B; first, the mean oscillation of the horizontal intensity at all the stations comprised in the Survey; and at those stations where observations have been taken for more than a month, as at Batavia, Sarāwak, and Padang, the mean oscillation has been found from the monthly oscillations. At pages l and li are given the comparison of the observatory with the portable bifilar; but these are in scale divisions, and their values in terms of the force are different. The maximum range in the one case is 5·91×·000240=·0014, and in the other case 8·23×·000197=·0016 of the force; and the mean range is, of the portable bifilar, 2·48×·000240=·000595, and of the observatory bifilar 2·87×·000197 =·000565 of the force*.

Singapore a Station for Comparison.

In order to have a fixed station where the hours of maxima and minima and extreme range may be known, the oscillation of the observatory bifilar is given in scale divisions at pages lii and liii for each of the seasons, for each of the months, and finally, the mean of each year.

* It is evident that the great difference between the portable and observatory bifilar magnetometers takes place in the morning, or when the atmosphere is most saturated with moisture. The observatory bifilar magnet being well protected, and suspended by silver wire, would not be affected by humidity. The portable bifilar, on the other hand, being more exposed, and the magnet suspended by filaments of silk, it is to be presumed that the thread would be somewhat affected by damp. It may here be observed, that the same silk threads for the bifilar suspension were in use during nearly the whole period of the Survey; the suspension thread was formed by placing three filaments of silk together, their torsion having been previously taken out, and after running them through a very weak solution of gum and water, wiping them quite dry; the threads thus treated lasted for more than three years.

Table B.

From page lvi to lxxxv are contained the results of the bifilar at each of the sixteen stations in the Archipelago; the stations are given from the most northern proceeding to the most southern, the observations themselves being omitted.

At the top of each page is printed the name of the station and the astronomical time; then follow the coefficients, the value of one scale division, and the value of q (the change of magnetic moment of the magnet for 1° of temperature in terms of the force); X the value of the absolute horizontal intensity; the zero of the month, which is the mean of the month uncorrected; and the standard temperature, to which the mean of the month is corrected. The results of the bifilar at each station are given in horizontal columns: the first contains the sums of the scale readings; the second the means; the third the temperature correction to the lowest mean reading of the thermometer; and as increasing scale readings denote a decrease of force, the corrections will be all subtractive; the fourth contains the corrected means; the fifth contains the variation of the force in scale readings, the highest scale reading being the minimum of force and considered as 0; and the sixth contains these scale divisions in terms of the force, one scale division being =·0002402 of the force. The last vertical column, or $\frac{\delta X}{X}$, is retained, since it is the difference between the zero and the mean value of the daily means corrected to 80°. Immediately below this table is given the mean results of the thermometer, the bulb of which is inserted in the copper box containing the bifilar magnet; the first column includes the sums; the second the means; and the third column the differences from the lowest mean temperature.

Curves.

Part 1 of Plate VII. contains the curves of the Bifilar at the Singapore Observatory for each month of the year in scale divisions, each scale division being ·000197 of the force drawn to 0·35 of an inch.

Part 2 of Plate VII. is drawn to the same scale, and contains the mean of the four seasons, the mean of each year, and the general mean of the three years. The general march of these curves is exceedingly simple, having but one single progression; the maximum occurs at either 22 or 23 hours, the autumn and winter curves having generally their maximum at the former, the spring and summer curves at the latter hour. The minimum occurs at 10 or 11 hours, the minimum in autumn and in winter being likewise one hour earlier than the minimum in spring and summer; the extreme range in spring and autumn being greater than in summer and in winter.

Plate VIII. contains the curves at the stations where the portable bifilar was observed; three stations having been omitted, as the curves of these instruments observed but for a few days would cause some confusion by crowding the Plate: there appears to be exactly the same similarity observable between these and the Singapore curves to which they are referred, the maximum occurring sometimes as late as noon;

but the curves at the winter stations, as at Singapore during the same period, being distinguished by the intensity reaching its maximum earlier by one hour than in spring.

The curves in Parts 1 and 2 of Plate VIII. are both drawn to the same scale, viz. one scale division (=·000240 of force) to 0·29 of an inch. The curve rising denotes an increase of force. The curves of the bifilar showing the changes of horizontal intensity, appear to partake, every one, of the same character as the horizontal intensity at Singapore.

Table C.—*Dry and Wet Bulb.*

The dry and wet bulb instrument was made by CARY; it was small but accurate, and was in use throughout the Survey; but the wet-bulb thermometer was broken in crossing from Moulmein to Madras, and at the latter station another thermometer was substituted in lieu of it.

Explanation of Table C.

The results of the dry and wet-bulb thermometers are contained in Table C, from page lxxxvi to cvii inclusive. The mean variation or range of the dry thermometer is given in the General Table at pages lxxxvi and lxxxvii. At pages lxxxviii and lxxxix are given the mean variation of the wet thermometer.

At pages xc and xci are given the mean variation of the tension and vapour, and at pages xciv and xcv the mean degree of humidity of the air at the different stations.

The Tables containing only the mean results of the observations commence at pages xcvi and xcvii. The dry and wet-bulb thermometers at each station are given in succession.

In the first line of each set is given the mean of the number of days observed, in the second line the diurnal variation; then follows the mean of the wet-bulb thermometer, the diurnal variation, and lastly, the tension or elastic force of vapour in inches of mercury. The formula for the tension of vapour at the dew-point is

$$f''=f'-\frac{d}{88},$$

where d is the difference between the dry and wet bulb, and f' the tension of vapour at the temperature of the wet bulb. The value of f' is given in Table V. of the Report of the Committee of Physics and Meteorology of the Royal Society. The quantity of humidity in the air is found by dividing the tension of vapour at the temperature of the dew-point by the tension of vapour at the temperature of the air, and the result gives the number of proportional parts of in humidity the atmosphere; and it is by this method that the Table at pages xciv and xcv is constructed. The Tables of the dry and wet bulb are concluded at pages cvi and cvii.

Curves.

The curves corresponding to these Tables are laid down in Plate IX.; but the standard thermometer for the dry bulb is substituted. The curves are drawn to a scale of 10° of temperature to 0·35 of an inch.

Remarks.

The curve of the dry thermometer consists but of a single progression, the minimum being usually at 6 A.M., the maximum at noon. The curve of the wet thermometer consists likewise but of a single progression, its maximum and minimum occurring at the above times; the diurnal variation of the tension of vapour at pages xc and xci at the different Survey stations is very irregular; the curve usually consists of but a single progression, and is very similar to the wet bulb. The minimum is usually at 6 A.M., the maximum being at noon; the greatest range extending from 0·1 to 0·26 of an inch of the barometer. The irregularity occasionally indicated may be owing to the shortness of the period during which the instrument was observed. At those places where the dry and wet bulb were observed for more than a month the curve is regular. Throughout the Archipelago the minimum of tension of vapour usually occurs at 6 A.M., the maximum being at noon; a remarkable exception to this takes place at Madras, where the minimum is observed at noon; it appears to be explicable from the circumstance of the remarkable dryness of the air at Madras in August and September compared with that of the Archipelago generally; the dry thermometer at Madras ranges 15°·5 during the day from 6 A.M. to noon, or 1 P.M.; at which time it is at its maximum, as also the difference between the dry and the wet bulb. After 1 P.M. the dry thermometer gradually falls, and the difference between the dry and wet bulb diminishes, whilst the wet-bulb thermometer is still rising, very slowly, till 3 P.M.; consequently the tension of vapour increases so that the minimum elastic force occurs at noon, and the maximum some time in the afternoon.

The mean elastic force of the tension of vapour varies from 0·8 to 0·9 of an inch of the mercurial column.

The range of the humidity in the atmosphere, given at pages xciv and xcv, shows a single progression only, the minimum being at noon, the maximum early in the morning; in some instances the air is saturated with moisture at 6 A.M.

At Moulmein and at Madras, where the air was driest, and just previous to the N.E. monsoon at the latter and the S.W. monsoon at the former place, the mean quantity of humidity varied from 66 to 68 parts, complete saturation being 100; in the space included in the Survey the air is always loaded with moisture, and it is a tolerable approximation to the truth to state, that throughout the Archipelago the minimum quantity of humidity is 0·75, the maximum 0·85, and the mean quantity 0·80; complete saturation being $=1·0$.

The following Table contains the stations, their latitudes and longitudes; the mean

date of observation; the number of days and the number of hours of each day the instruments were observed; the mean of the dry and wet thermometer, and of the tension of vapour; determined in two ways,—1st, by dividing by the number of hours during which the instruments were observed, and 2nd, by the system of equal intervals, a method for determining the mean value where the continuity of hourly observation is broken during the day, as generally occurred in the present instance.

Dr. LLOYD, in a paper on the mean results of observation, has shown that the error committed by taking the mean of any three equidistant hours as the mean temperature of the day, does not exceed 0°·26. In the following Table, in the column containing the mean by equal intervals, three sets of equidistant hours have been taken for finding the mean, viz. 3, 4, and 5 A.M.; 11 A.M., noon, and 1 P.M.; 7, 8, and 9 P.M. At those stations, where the instruments were observed during the twenty-four hours, a direct comparison can be instituted for ascertaining the correctness of this mode of finding the mean; at Sarāwak for three and at Batavia for four months, the means by each method are nearly identical. The mean temperature, as shown by the dry bulb, is about 80°; the mean of the wet bulb is between 76° and 77°; and the mean elastic force or tension of vapour throughout the space included in the Survey, varies from 0·8 to 0·9 of an inch of the barometric column.

Table showing the Means of the Dry and Wet Thermometers and of the Tension of Vapour, by Dr. LLOYD's method of equal intervals, and by dividing by the number of hours observed, and the difference in each case.

Station.	Latitude.	Longitude.	Mean date corresponding to the	No. of days.	No. of hours.	Dry Thermometer.			Wet Thermometer.			Tension of Vapour.		
						Mean by equal intervals.	Mean by number of hours.	Diff.	Mean by equal intervals.	Mean by number of hours.	Diff.	Mean by equal intervals.	Mean by number of hours.	Diff.
Moulmein ...	16° 29′ 46″ N.	97° 45′ 30″ E.	Mid. of April.	7	19	86·1	88·3	+2·2	78·0	78·5	+0·5	·853	·846	−·007
Madras	13 04 09	80 16 00	Begin. of Sept.	34	19	84·3	85·2	+0·9	76·6	76·6	0·0	·811	·801	−·010
Nicobar	9 10 12	92 48 23	Begin. of Feb.	5	19	79·3	80·5	+1·2	75·8	76·6	+0·8	·839	·855	+·016
Sambooanga.	6 54 20	122 13 45	End of May.	6	19	80·5	82·2	+1·7	76·4	77·6	+1·2	·847	·877	+·030
Pulo Penang.	5 25 36	100 24 38	End of Jan.	5	19	80·6	81·2	+0·6	77·0	77·3	+0·3	·873	·876	+·003
Pulo Dinding	4 12 48	100 32 52	End of Jan.	3	19	82·7	83·2	+0·5	76·6	77·1	+0·5	·838	·844	+·006
Sarāwak......	1 33 54	110 29 00	Mid. of June.	26	24	79·8	79·6	−0·2	77·8	77·7	−0·1	·913	·911	−·002
			Mid. of July.	27	24	79·0	78·9	−0·1	76·9	76·9	0·0	·886	·885	−·001
			Mid. of Aug.	19	24	79·0	78·8	−0·2	76·7	76·6	−0·1	·877	·874	−·003
Keemah	1 21 55	125 07 59	End of June.	10	19	80·4	81·1	+0·7	76·6	77·0	+0·4	·863	·865	+·002
Pulo Peesang	1 27 53	103 19 15	Mid. of Jan.	5	18	80·6	80·8	+0·2	77·5	77·9	+0·4	·892	·905	+·103
Singapore ...	1 18 32	103 56 30	End of Nov.	16	19	80·3	80·3	0·0	77·1	76·9	−0·2	·876	·869	−·007
			Begin. of Dec.	14	19	80·2	80·1	−0·1	76·4	76·2	−0·2	·851	·843	−·008
Padang	0 58 58 S.	100 31 15	End of Oct.	13	19	78·5	79·7	+1·2	75·9	75·7	−0·2	·816	·828	+·012
			Mid. of Nov.	26	19	79·2	80·2	+1·0	75·4	76·0	+0·6	·828	·835	+·007
			Mid. of Dec.	26	19	79·5	80·6	+1·1	75·3	75·9	+0·6	·820	·826	+·006
			Begin. of Jan.	13	19	79·8	80·9	+1·1	76·1	76·7	+0·6	·848	·855	+·007
Bencoolen ...	3 53 54 S.	102 28 45	Begin. of Sept.	5	19	78·1	79·3	+1·2	76·3	77·0	+0·7	·869	·865	−·004
Batavia	6 09 52	106 58 00	Mid. of Nov.	19	24	80·3	80·2	−0·1	76·8	76·8	0·0	·866	·866	·000
			Mid. of Dec.	26	24	79·7	79·7	0·0	76·6	76·5	−0·1	·866	·859	−·007
			Mid. of Jan.	25	24	79·5	79·8	+0·3	76·3	76·4	+0·1	·852	·854	+·002
			Mid. of Feb.	24	24	79·5	79·5	0·0	76·8	76·8	0·0	·875	·874	−·001
			Mid. of March	27	19	80·5	81·2	+0·7	77·2	77·6	+0·4	·882	·888	+·006
			Mid. of April	26	19	80·5	81·1	+0·6	77·0	77·3	+0·3	·874	·877	+·003
			Mid. of May	26	19	80·2	80·9	+0·7	76·5	76·8	+0·3	·858	·859	+·001
			Mid. of June	26	19	80·0	80·7	+0·7	75·4	75·7	+0·3	·815	·817	+·002
Cocos	12 05 38	96 50 30	Mid. of Sept.	26	19	79·6	79·5	−0·1	75·0	75·0	0·0	·802	·803	+·001

Some doubts have arisen as to the value of the dry and wet bulb as an instrument

for measuring approximately the degree of humidity in the atmosphere; and Colonel SYKES, F.R.S., has mooted the question in a very interesting paper on the Meteorology of India, which has been lately published in the Philosophical Transactions: one of the sources of error supposed to be peculiar to this instrument, although easily remedied if discovered, is the too close proximity of the wet bulb to the dry bulb, the consequent depression of the latter, the difference of the two thermometers or the value of *d* consequently diminishing, and the resulting tension of vapour greater than it ought to be. I do not know the exact distance that the two bulbs were apart in CARY's little instrument; at most 2 to 2½ inches, and both fixed to one stem. The following are the results of a comparison between the Standard Thermometer and Dry-Bulb Thermometer at all the stations; and it will be seen, on inspection of the following Table, how very slight are the differences between the two thermometers*.

Station.	Month.	Mean by the number of hours.		Difference.
		Standard Thermometer.	Dry Thermometer.	Standard—Dry Thermometer.
Moulmein	April	88·4°	88·3°	+0·1°
Madras	September	85·2	85·2	0·0
Nicobar	February	80·9	80·5	+0·4
Sambooanga	May	82·5	82·2	+0·3
Pulo Penang	January	81·7	81·2	+0·5
Pulo Dinding	January	82·6	83·2	−0·6
Sarāwak	June	79·6	79·6	0·0
	July	78·8	78·9	−0·1
	August	78·7	78·8	−0·1
Keemah	June	81·5	81·1	+0·4
Pulo Peesang	January	81·5	80·8	+0·7
Singapore	December	79·8	80·2	−0·4
Padang	October	80·5	79·7	+0·8
	November	80·8	80·2	+0·6
	December	81·3	80·6	+0·7
	January	81·7	80·9	+0·8
Bencoolen	September	79·3	79·3	0·0
Batavia	November	80·3	80·2	+0·1
	December	79·8	79·7	+0·1
	January	80·1	79·8	+0·3
	February	79·6	79·5	+0·1
	March	81·3	81·2	+0·1
	April	81·3	81·1	+0·2
	May	81·2	80·9	+0·3
	June	81·0	80·7	+0·3
Cocos	September	79·2	79·5	−0·3

Standard Barometer and Portable Barometer, and Adjustments.

At the principal stations the large Standard Barometer was in use; but at some the Portable Barometer was observed, from the greater trouble and risk attending

* At Padang the differences are the greatest, and as these appear to be constant at the same station, they are probably due more to the relative position of the Standard Thermometer and Dry Bulb, than to the proximity of the latter to the Wet Bulb.

the carriage of the Standard. The Standard was used at the following places:—at the Cocos, at Batavia, at Padang, at Singapore, at Keemah, at Sarāwak, and at Sambooanga.

The Standard Barometer was made by NEWMAN; diameter of the tube $0''\cdot532$; the correction to be applied for capillary action $+\cdot003''$. The zero-point consists of a fine conical point brought to touch the surface of the mercury; this is an adjustment which we are instructed to make at each observation; but throughout the Survey the conical point or zero-point, being once accurately adjusted, was never subsequently touched; the capacity of the cistern is so much greater than that of the tube, that the variation of the barometer in the Tropics being not more than $\frac{1}{10}$th of an inch, the level of the cistern would be but little affected thereby. The internal diameter of the cistern is about 4 inches; the relative areas of the tube and cistern are as 0·25 to 16, or as 1 to 64; and as the barometric column varies to the extent of $\frac{1}{10}$th of an inch, the cistern would be affected to $\frac{1}{640}$th of an inch, and the quicksilver therefore would rise above or sink below the mean position $\frac{1}{1280}$th of an inch; a space which a very accurate observer might be able to detect between the conical point and a very bright surface, but not with the quicksilver in the barometer now in question, as the surface was covered with a thick film, and the glass cistern was somewhat dingy; for this reason, after one adjustment very carefully made at noon, this being about the time of the mean, the zero point of the barometer was not further touched during the whole series of observations; and I never could detect at the hour of maximum and minimum, viz. at 9 or 10 A.M., and at 3 or 4 P.M., any difference in the relative position of the conical point to the surface of the mercury, and therefore no correction has been applied to the neutral point determined at noon.

The Standard Barometer was by no means tight, and therefore imperfectly portable: when moving from one place to another, the quicksilver was constantly escaping by the wooden collar at its junction with the tube; this loss was supplied with fresh mercury, strained through leather and poured into the cistern; and as no air could ever be detected in the tube, the instrument was perfectly serviceable throughout the whole of the Survey. The leakage at the collar was by no means peculiar to this barometer, as I have discovered it in others by the same maker.

The Portable Barometer, made by CARY, was in use at a few stations during the Survey; I had filled it very carefully at Singapore; in the comparisons made with it and the Singapore Standard Barometer, it was generally a little lower; but as it had not exactly the same range, the correction would not be constant, and therefore no correction has been applied. The diameter of the tube, which dimension I obtained from Mr. CARY, is between 0·27 and 0·28 of an inch; the correction to be applied for capillary action $=+0''\cdot023$; the scale is marked on brass to the twentieth of an inch, and can be read off by a vernier to the thousandth of an inch, being similar in this respect to the Standard Barometer. The gauge-point or zero-point is a slit in the iron cistern at its upper surface; the quicksilver, being pressed up by means of a screw applied to the leathern bottom of the cistern, is raised till the light is no longer seen

through the slit, and the level of the quicksilver in the cistern is then at that point from which the scale is laid off; there is therefore no correction for neutral point: this instrument was well made and well finished, and has yielded at all times exceedingly satisfactory results.

Explanation of the Table D.

The observations made with the barometer are contained in Table D. from page cviii. to cxxi inclusive.

At pages cviii and cix are given the mean variation or oscillation of the barometer; at pages cx and cxi the mean variation of the gaseous pressure or dry column of air.

From page cxiv to cxxi inclusive, are contained the mean results of the barometer at each station: each set contains in the first line the mean of the barometer uncorrected; then the barometer corrected to 32°; and thirdly, the gaseous pressure which is deduced by subtracting from the barometric column the tension of vapour.

Curves.

The curves of the barometer corrected to 32°, are contained in Plate X. The curves are drawn to a scale of ·01 of an inch of barometric pressure to 0·30 of an inch linear measure: the curve rises with the increase of pressure.

Plate XI. contains the curves of the variation of gaseous pressure drawn to the same scale, viz. ·01 of an inch of barometric pressure to 0·30 of an inch linear measure: the curve rises with increase of pressure.

Remarks.

The barometric curve has a double progression, a principal maximum and minimum at 9 A.M., and at 3 and 4 P.M.; and a secondary maximum and minimum at 10 P.M. and 4 A.M. The intervals between the successive maxima and minima are nearly equal, and the degree of parallelism between all the curves is very striking; the range or variation appears to be nearly similar, and the hours of maxima and minima are identical; one exception occurs at Madras, the maximum taking place at the same time, but the minimum at 5 P.M., two hours later than the minimum generally throughout the Archipelago.

The variation of the gaseous pressure is given in Plate XI.; it appears to have, like the barometric curve, a double progression, but the principal maximum and minimum occur earlier; the A.M. minimum is more faintly expressed, with an interval of three or four hours only between the morning minimum and the morning maximum. The curve is likewise more irregular than the barometric, and the range is greater; only a few of the curves are given, to prevent confusion from over-crowding, and those places have been selected where observations have been taken for upwards of a month.

The following Table contains, by Dr. LLOYD's method of equal intervals, the means of the barometer uncorrected, the barometer corrected to 32°, and the mean of the gaseous pressure; each mean being the result of three sets at equidistant hours, viz. 3, 4, 5 A.M.; 11 A.M., noon, 1 P.M.; 7, 8. and 9 P.M. The mean throughout the Archipelago, of the barometer corrected, is 29·80 to 29·90 English inches; the range or variation being a little more than a tenth of an inch. The mean of the gaseous pressure is about 29 inches; the variation being nearly double that of the barometric pressure, and amounting to about two-tenths of an inch.

Station.	Latitude.	Longitude.	Mean date corresponding to the	No. of days.	No. of hours.	Mean of the barom. uncorrected.	Mean of the barom. corrected to 32°.	Mean of gaseous pressure.
						28 English inches + the numbers in the Table.		
	° ′ ″	° ′ ″				in.	in.	in.
Moulmein ...	16 29 46 N.	97 45 30 E.	Middle of April	7	19	1·897	1·766	0·913
Madras	13 04 09	80 16 00	Beginning of September	34	19	1·807	1·681	0·806
Nicobar	9 10 12	92 48 23	Beginning of February	5	19	2·052	1·937	1·098
Sambooanga	6 54 20	122 13 45	End of May	6	19	1·997	1·863	1·013
Pulo Penang	5 25 30	100 24 38	End of January	5	19	2·005	1·885	1·013
Pulo Dinding	4 12 48	100 32 52	End of January	3	19	2·114	1·994	1·156
Sarāwak	1 33 54	110 29 00	Middle of June	26	24	1·997	1·864	0·952
			Middle of July	27	24	1·985	1·854	0·968
			Middle of August	19	24	2·009	1·879	1·002
Keemah	1 21 55	125 07 59	End of June	10	19	2·016	1·880	1·018
Pulo Peesang	1 27 53	103 19 15	Middle of January	5	18	2·074	1·955	1·080
Singapore ...	1 18 32	103 56 30	End of November	16	19	2·050	1·914	1·038
			Beginning of December	14	19	2·037	1·905	1·053
Padang	0 58 58 S.	100 31 15	End of October	13	19	2·045	1·912	1·097
			Middle of November ...	26	19	2·040	1·907	1·079
			Middle of December ...	26	19	2·005	1·873	1·053
			Beginning of January...	13	19	2·017	1·883	1·035
Bencoolen ...	3 53 54	102 28 45	Beginning of September	5	19	1·974	1·862	0·993
Batavia	6 09 52	106 58 00	Middle of November ...	19	24	1·994	1·860	0·992
			Middle of December ...	26	24	1·995	1·862	0·996
			Middle of January	25	24	2·001	1·868	1·016
			Middle of February ...	24	24	1·988	1·856	0·981
			Middle of March	27	19	2·015	1·876	0·994
			Middle of April	26	19	2·010	1·875	1·001
			Middle of May	26	19	2·009	1·873	1·016
			Middle of June	26	19	2·003	1·868	1·054
Cocos	12 05 38	96 50 30	Middle of September ...	26	19	2·089	1·958	1·155

Standard Thermometer.

This instrument, made by NEWMAN, was used in the observatory at Singapore till the end of the year 1845, and I then took it with me on the Survey. The scale is marked off to half-degrees, each degree being 0·11 of an inch, so that the thermometer is read off easily to tenths. In marking off the scale, an error has been committed in omitting one degree from 90° to 95°, so that 95° is only 94°; the divisions of the scale are all equal, and therefore the mistake occurring in the numbering only, one degree has always been deducted from the observed reading of the thermometer when it stood at 95° or above that temperature. The standard thermometer

was usually attached to the pole of the tent, or else to the back of the post to which the standard barometer was fixed.

Explanation of Table E.

The results of the observations with the Standard Thermometer are contained in Table E., from page cxxii to cxxix inclusive. At pages cxxii and cxxiii are given the diurnal variation of the Standard Thermometer. The remainder of Table E. contains the mean results of the Standard Thermometer; each set contains, in two lines, the mean hourly readings and the diurnal variation of the Standard Thermometer.

Curves.

The curves of the Standard Thermometer have already been noticed in speaking of the dry bulb.

Remarks.

There is but one maximum and one minimum in the twenty-four hours, viz. at 2 and at 18 hours. The oscillation or range varies, but the smallest is at Singapore, where the standard thermometer was placed inside the observatory, but exposed to a current of air passing through the building. The range was greatest at Moulmein and at Padang; but as at these observatories the observations were taken under canvas only, the direct influence of the sun's rays was very great. At Moulmein the temperature of the observatory was so hot as to be nearly unbearable, although the thermometer only reached 105°: at the commencement of the Introduction I gave a short statement of the materials with which each observatory was constructed, that, in recording the height of the thermometer, the circumstances under which it was observed should be taken into consideration: the difficulty in tropical climates of ascertaining correctly the temperature of the air is very great; the most difficult points to be determined appear to be; the size of the building, the height of the roof and the nature of the materials of which it is composed, in order that the thermometer shall give only the temperature of the air, and not in addition that of the building in which it is placed. If the building is small, if the roof is low and of good conducting materials, such as slates or tiles, the thermometer is too high by day, and probably too low at night; the only condition appears to be a lofty room, of large size, well-ventilated, and double-roofed with non-conducting materials. The observatories at Sarāwak, Singapore and Batavia were excellent in this respect: at all other stations the thermometer was not sufficiently screened from the above liabilities to error, and therefore the daily curve at some of the stations is too high, whilst the mean temperature is nearly correct.

Solar and Terrestrial Radiation Thermometers.

In addition to these thermometrical observations, there was likewise in use, at the conclusion of the Survey, a Solar Radiation Thermometer, the bulb of which was

tinged of a dark purple colour, although not absolutely black. This instrument was placed on a table outside the tents and freely exposed to the sun. After the instruments in the tent were observed, the solar radiation thermometer was read off hourly, from 7 A.M. to 4 or 5 P.M., and the maximum of the day recorded, with the time at which it was observed, being generally 11 A.M., noon, or 1 P.M.

The minimum self-registering thermometer was placed on a table outside the tent at night, and the minimum temperature shown by the index read off at 7 A.M.

The subjoined Table contains the maximum solar radiation, and the mean at each station; the minimum and the mean of the self-registering thermometer exposed at night; and lastly, the mean of the standard thermometer, by dividing by the number of observations, and likewise by Dr. LLOYD's method of equal intervals, each result being the mean of three sets, at 3, 4, 5 A.M.; 11 A.M., noon, 1 P.M.; and 8, 9, 10 P.M.

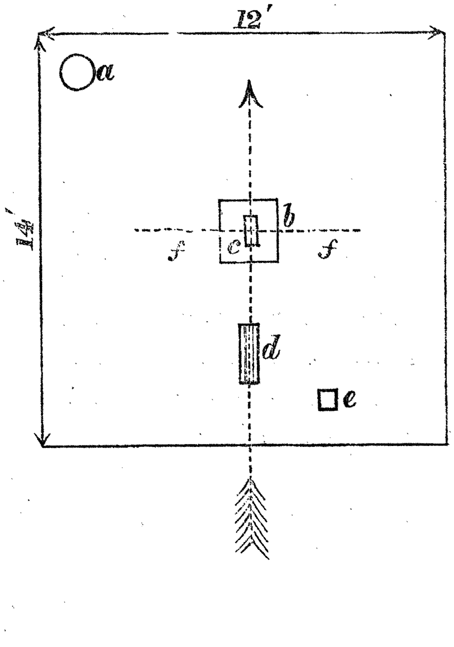
Station.	Latitude.	Longitude.	Mean date corresponding to the	No. of days.	No. of hours.	Solar Radiation.		Terr. Radiation.		Standard Thermometer.		
						Maximum.	Mean.	Minimum.	Mean.	Mean by equal intervals.	Mean of the whole set.	Diff.
Moulmein	16° 29′ 46″ N.	97° 45′ 30″ E.	Middle of April.	7	19	111°·5	110°·0	70°·2	71°·9	86°·0	88°·4	+2°·0
Madras	13 04 09	80 16 00	Beginning of Sept.	34	19	115·0	104·7	74·0	76·6	84·3	85·2	+0·9
Nicobar	9 10 12	92 48 23	Beginning of Feb.	5	19	102·0	98·9	67·7	68·4	79·9	80·9	+1·0
Sambooanga	6 54 20	122 13 45	End of May.	6	19	104·7	102·6	71·4	72·3	80·7	82·5	+1·8
Pulo Peenang......	5 25 30	100 24 38	End of January.	5	19	105·8	103·0	70·8	71·9	81·3	81·7	+0·4
Pulo Dinding......	4 12 48	100 32 52	End of January.	3	19	113·8	110·9	70·6	72·2	82·4	82·6	+0·2
Sarāwak	1 33 54	110 29 00	Middle of June.	26	24	......	......	......	......	79·8	79·6	−0·2
			Middle of July.	27	24	......	......	68·6	71·8	79·0	78·8	−0·2
			Middle of August.	19	24	......	......	69·3	71·6	78·8	78·7	−0·1
Keemah	1 21 55	125 07 59	End of June.	10	19	112·2	108·6	68·3	70·3	80·9	81·5	+0·6
Pulo Peesang	1 27 53	103 19 15	Middle of January.	5	18	......	......	......	......	81·3	81·5	+0·2
Singapore	1 18 32	103 56 30	Beginning of Dec.	30	19	107·7	98·3	67·6	71·1	79·8	79·8	0·0
Padang	0 58 58 S.	100 31 15	End of October.	13	19	......	......	69·4	70·6	79·2	80·5	+1·3
			Middle of November.	26	19	......	......	69·8	71·1	79·7	80·8	+1·1
			Middle of December.	26	19	......	......	68·5	70·8	80·3	81·3	+1·0
			Beginning of Jan.	13	19	......	......	......	......	80·5	81·7	+1·2
Bencoolen	3 53 54	102 28 45	Beginning of Sept.	5	19	......	......	69·8	71·2	78·4	79·3	+0·9
Batavia	6 09 52	106 58 00	Middle of November.	19	24	......	......	69·2	72·4	80·5	80·3	−0·2
			Middle of December.	26	24	......	......	69·8	72·6	80·3	79·8	−0·5
			Middle of January.	25	24	......	......	68·5	71·1	80·0	80·1	+0·1
			Middle of February.	24	24	......	......	70·7	72·6	79·6	79·6	0·0
			Middle of March.	27	19	......	......	69·2	72·9	80·9	81·3	+0·4
			Middle of April.	26	19	......	......	69·2	71·5	80·8	81·3	+0·5
			Middle of May.	26	19	......	......	67·4	69·9	80·7	81·2	+0·5
			Middle of June.	26	19	......	......	......	......	80·5	81·0	+0·5
Cocos or Keelings	12 05 38	96 50 30	Middle of September.	27	19	105·5	99·5	72·2	74·9	79·2	79·2	0·0

Survey, and Instruments employed.

The observations connected with the Survey relate to absolute determination, such as latitude, longitude, dip, horizontal intensity, and variation or magnetic declination, and this is the order in which the subject will be treated; but previously, it may be as well to state in a few words, how the Survey on land was conducted. On my arrival at a station I had my small tent pitched, for the reception of the magnetic instruments; this was generally put up the evening of my arrival; and the next morning at daybreak I commenced observing. The instruments in use were a 6-inch dip circle, a portable declinometer for magnetic declination and intensity, an altitude

and azimuth instrument, made by ROBINSON, and sent out on the first establishment of the observatories, and a chronometer (824), ARNOLD and DENT, which had been so long in use, that it was not to be trusted for a fixed rate. The first instrument set up was the portable declinometer; this instrument was tedious to adjust, in consequence of the suspension thread, to support the collimator magnet, being stronger than there was occasion for so as to obviate the necessity of frequent renewal; the stirrup with the brass weight attached to the suspension thread, was allowed to swing for more than a couple of hours; the opportunity was taken during the interval of determining the dip with four needles. At $8\frac{1}{2}$ A.M. the dip observations being completed, the stirrup of the portable declinometer, by frequent small twists of the torsion circle having been brought to rest in the magnetic meridian, was finally in adjustment. The brass weight for taking the torsion out of the threads was removed, and the collimator magnet placed in the stirrup. The altitude and azimuth instrument was adjusted in rear of the collimator magnet, and in the direction of its axis, but always to the south of it, at a distance of about 4 feet. By 9 A.M., this instrument being also in adjustment, the copper damper was placed carefully in the oaken box containing the collimator magnet, by which the latter in a few minutes was brought to rest. During this short interval three or five altitudes of the sun were taken with the sextant and artificial horizon, and the corresponding times with the chronometer.

At $9\frac{1}{2}$ A.M., the collimator magnet being at rest, altitudes of the sun were observed with the altitude and azimuth for magnetic declination or variation; these being finished, observations for horizontal intensity, both of deflection and vibration, were proceeded with and generally finished at $11\frac{1}{2}$ A.M. At noon circummeridional altitudes of the sun were observed for latitude, and in the afternoon, if fine, equal altitudes were taken to confirm the morning sights. The tent was then taken down, the instruments packed up, and generally sent off in the evening, if practicable, to the next station.



The following is a rough diagram (not drawn to scale) of the relative positions of the instruments in the tent:—

a. The dip circle, removed at $8\frac{1}{2}$ A.M.

b. Declinometer-box, with deflecting arms, *f*, *f*, for the determination of the absolute horizontal intensity.

c. Collimator magnet, in declinometer-box, suspended by three or four fibres of untwisted silk.

d. Telescope of altitude and azimuth.

e. Position of table on which the chronometer was placed.

Dimensions of the tent 12×14 feet.

Latitude.

The observations for latitude were usually taken, if the weather permitted, a few minutes both before and after noon: the instrument being previously in adjustment, the altitudes and times corresponding were taken immediately before or at noon, three times with the vertical circle direct, and three times at or immediately after noon with the vertical circle reversed; the latitude was found from these altitudes reduced to the meridian.

A Table of the Latitudes at the Cocos or Keeling Islands is subjoined, merely as a specimen of the working of the instrument; it is necessary to state, that in the observations for latitude by taking altitudes of the sun, the error of collimation was corrected by the reversal of the telescope on its axis; but in finding the latitude from altitudes of the stars, the instrument was clamped in the meridian, the altitude of the star taken as it passed the centre wire, and a correction applied for the error of collimation.

Date.	Latitude ☉	Date.	Latitude ✱.	Name of ✱.
August 26......	12° 05′ 21″ S.	August 28	12° 05′ 18″ S.	α Herculis.
27......	06 15		05 32	α Ophiuchi.
31......	06 10	September 10	05 07	γ Aquilæ.
September 7......	05 30		05 30	α Aquilæ.
15......	05 46		05 40	ε Aquarii.
23......	05 19		05 20	μ Aquarii.
26......	06 07	12	06 20	p Piscium.
27......	05 58		05 40	s Piscium.
		13	05 10	s Piscium.
		14	05 30	μ Ceti.
			05 30	o Piscium.
		15	05 45	ζ 2 Ceti.
			05 20	μ Ceti.
		16	05 10	λ Tauri.
		17	05 28	γ Aquilæ.
			05 30	α Aquilæ.

Longitudes.

The longitudes were found chiefly from sights; but I am afraid they are not much to be depended upon, in consequence of the rate of the chronometer frequently changing; the following is the method I adopted, at any two places far apart, where I was able to determine the rate. I took the mean rate and applied it to the observations for longitude at the intermediate stations. At some of the principal points, where I remained for a considerable time, I was able to obtain sights of moon-culminating stars for longitude, as well as lunar distances; the longitudes obtained from moon-culminating stars with the altitude and azimuth instrument, were necessarily very rough, but they served as a check upon the chronometer.

The following observations were taken at the Cocos:—

Date.	Stars and Moon.	Mean difference between Greenwich and Cocos, ✱ and ☾.	Resulting Longitude East.
		m s	h m s
Sept. 6......	θ Ophiuchi, ☾ I, μ Sagittarii, λ Sagittarii	14 09·86	6 27 18
8......	o and π Sagittarii, ☾ I, α 2 Capricorni	14 49·08	6 28 36
9......	α 2 Capricorni, ☾ I, ε and μ Aquarii	15 00·13	6 26 31
10......	ε and μ Aquarii, ☾ I, γ and δ Capricorni	15 11·14	6 27 48
12......	☾ I, p and s Piscium	15 20·05	6 27 05
13......	s Piscium, ☾ II.	15 27·42	6 26 45
14......	☾ II., μ and o Piscium	15 44·21	6 28 23
15......	o Piscium, ☾ II., ζ, ε and μ Ceti.....................	15 59·04	6 27 43
		Mean Longitude	6 27 22

The mean longitude resulting from nine sets of lunar distances, was $6^h\ 26^m\ 47^s$; but these were not to be trusted, as the sum of the distance and the true altitudes of the ☉ and ☾ at each observation amounted to 180°, very nearly. I consider it my duty, however unsatisfactory may be the observations, to publish one set in detail, as their value, small or large, may thus be inferred; although but little could be expected from a small altitude and azimuth on an ordinary table stand, as a substitute for a transit instrument, it was better to depend upon these observations than upon the chronometer, which had been long in use, and which yielded such rates, on successive days at the Cocos, as the following:—

$+7^{s}\cdot7$, $+9^{s}\cdot1$, $+11^{s}\cdot4$, $+8^{s}\cdot8$, $+7^{s}\cdot8$, $+6^{s}\cdot7$, $+6^{s}\cdot7$, $+8^{s}\cdot4$, $+8^{s}\cdot9$,
$+8^{s}\cdot7$, $+8^{s}\cdot9$, $+9^{s}\cdot1$, $+9^{s}\cdot5$, $+12^{s}\cdot2$, $+10^{s}\cdot4$, $+9^{s}\cdot9$, $+8^{s}\cdot6$, $+8^{s}\cdot9$;

the mean rate being $+8^{s}\cdot19$; of course no dependence could be placed upon such rates as these for the longitude.

Dip or Inclination of the Needle.

The Dip Observations are contained in Table F., from page cxxx to cxxxix inclusive.

On commencing the Survey in 1846 I was not furnished with a dip circle; a Fox's dip circle had been stolen from the observatory at the latter end of 1845, and three dip circles had been sent, in 1844, to England to Mr. Barrow, but they had not then reached Singapore, having been detained at Bombay through some mistake.

In March 1846 I received a dip circle with four needles from Mr. Taylor, the then astronomer at Madras: the needles were very inferior; one of them, A 1 L, having a difference of 24° reading on the reversal of the poles: the observations with this needle should perhaps have been omitted. The correction to be applied to A 1 L was 28′, with only half the value assigned to it, which has been given to each of the other needles, and each recorded observation with the Madras circle is the mean of forty-eight readings. With the Madras dip circle I took observations at Singapore, in

Borneo, at Batavia, and the western portion of the island of Java; these observations are included in pages cxxx and part of cxxxi.

On my return to Batavia at the latter end of the year, I found the three dip circles, which, having been thoroughly repaired, had been sent out by Mr. BARROW; the observations are contained in pages cxxxii and cxxxiii*.

Before commencing the survey of part of Sumātra, I determined to make use of needles with their poles unchanged, and to apply a correction, if necessary, for the true dip, as the large magnets for reversing the poles were often brought in dangerous proximity to the small cylindrical magnets used on the Survey. Having determined the true dip at Padang with nine needles, I fixed upon Dip Circle No. 1 with three needles, A 1, A 1 L and A 2 L, by first combining A 1, A 1 L, and subsequently A 1 L with A 2 L.

The mean result gave me as a correction . . .	$+8'\cdot9$
The mean of the nine needles with the poles changed .	$=-18^\circ\ 31'\cdot7$
With the three combined as above and the poles unchanged	$18^\circ\ 40'\cdot6$
	$+8'\cdot9$

So that in the Survey in Sumātra, at page cxxxv in the last column, is given the corrected dip by subtracting $8'\cdot9$ from the mean of the three needles.

This series of three needles with poles unchanged and correction $+8'\cdot9$, terminates at Nātal in Sumātra.

On my return to Singapore in February 1848, a long series of observations was taken, to determine by direct means the difference in the inclination A.M. and P.M., the former being taken with four needles at 10 and 11 A.M., the hours of maximum horizontal intensity, and the latter at 4 P.M., the hour of minimum horizontal intensity; the poles of the needles employed were changed at the commencement or the termination of each day's observation, so that the A.M. and P.M. observations were taken with the needles under the same magnetic condition; two days consequently were necessary for the determination of the true dip. From the mean result at page cxxxiv, there is a difference of $0'\cdot8$ increase in the afternoon, whilst the probable error of the mean value of each set is the same, viz. $\pm0'\cdot4$.

At the Cocos or Keeling Islands, the poles of the needles of Box No. 1 being unchanged, the correction to be applied to the three needles was as follows:—for A 1, $-3'\cdot0$; for A 1 L, $-6'\cdot0$; and for A 2 L, $-3'\cdot0$; equal value in determining the mean has however been given to these needles, as double the number of readings have been taken.

At Pulo Dinding the poles of the needles of Dip Circle No. 1 were again changed,

* There were originally four needles, A 1, A 2, A 1 L, A 2 L, to each dip circle numbered 1, 2 and 3; but three of the needles having soon become rusty, there were left three needles with Dip Circle No. 1, four needles with Circle No. 2, and two needles with Circle No. 3; and it was in consequence of Dip Circle No. 2 being complete, that it was used for the survey of Java.

when it appeared that for A 1, poles direct and poles reversed were nearly the same; for A 1 L, the correction to be applied to poles direct was − 16′·3, and for A 2 L, the correction to be applied was — 2′·0; and these have been the corrections made use of at page cxxxv for Dip Circle No. 1 at Singapore.

Inclination or Dip at Sea.

The observations at sea were made with a Fox's Dip Circle; the separate observations are not given, as they would occupy too much space; but the mean results are contained in a General Table at page cxxxvii, where the observations at sea have been corrected for the direction of the ship's head, for index correction (the poles being unchanged), and corrected with the whole of the dip observations to a mean epoch, viz. January 1, 1848. The details of swinging the ship, of finding the index correction, are not included in this report, but one example is given of swinging the Schooner at Keemah.

Correction for Direction of Ship's Head.

There were in all thirteen observations: from north to east, three; east to south, three; south to west, three; and west to north, four.

	Ship's Head.	Dip.	Mean Dip.
North to East	N.	11° 37′·5	11° 37′·2
	N.E.	11 35·0	
	E.N.E.	11 39·1	
East to South	E. by S.	11 33·7	11 33·6
	E.S.E.	11 40·8	
	S.S.E.	11 26·2	
South to West	S. by W.	11 29·7	11 33·7
	S.W.	11 33·3	
	W. by S.	11 36·2	
West to North	W. by N.	11 31·1	11 35·5
	W.N.W.	11 34·5	
	N.W.	11 39·5	
	N. by W.	11 36·8	

On shore, at Keemah, the mean of five observations by Fox's Dip Circle was 11° 28′·0, and as the Schooner bore E.S.E. the correction for distance would be − 1′; the dip by this instrument at the ship would be − 11° 29′, and the correction, therefore, for the direction of the ship's head and of local attraction, is, from north to east + 8′·2; east to south + 4′·6; south to west + 4′·7; west to north + 6′·5.

Index Correction.

True dip on shore from nine needles . . .	11° 02′·7
Dip from needle B. (Fox) as above	11° 28′·0
Index correction	+25·3

This instrument Colonel SABINE, R.A. had the kindness to send out to me, and I used it whenever an opportunity offered, but the Schooner was so small that it was difficult to take observations of inclination when there was any sea on. The needle B. was never removed from the box, and advantage was taken at every station of applying to the dip a fresh index correction. Fox's Dip Circle, sent out overland, was very roughly handled on its way out, so that the circle was no longer concentric to the axis of the needle. The observations were taken on a gymbal stand, the dip circle being leveled as accurately as possible, and twenty readings taken with the face of the circle to the east, and the same number with the face of the circle to the west. The inclinations at sea contained in the General Table, are the means of several groups of observations; for the dip being observed whenever it was calm, three or even five observations were taken repeatedly during the day when the weather permitted.

General Table, and Reduction of Observations to one common Epoch.

The General Table of Inclination on shore and at sea is given at pages cxxxvii, cxxxviii and cxxxix. The whole of the observations are reduced to one common epoch, viz. the 1st of January, 1848. At the Singapore Observatory observations were taken at two different periods, and with great care.

At the commencement of 1848 the dip was	−12° 56′·8
At the commencement of 1849 the dip was	−12° 59′·4
The difference nearly, of one year . . .	= −2′·6

These are valuable chiefly from the superior character of the instruments and dipping-needles. But going back to the first establishment of the observatory, the mean dip of the needle was—

At the end of 1841	−12° 43′·3
At the end of 1848, or commencement of 1849 . .	−12° 59′·4
	−16′·1

giving for the yearly change −2′·3.

The secular change at Madras can likewise be determined; for from the mean of twenty-two observations taken in July 1840,

The mean dip of the needle was	+7° 13′ 40″ N.
Twenty-nine observations in July and August 1849, gave	+7° 37′ 42″
Total difference in nine years	+24′ 02″

being $2'{\cdot}7$ per annum increase, or $0'{\cdot}22$ per mensem. This rate of $0'{\cdot}22$ per mensem is assumed as the correction to be added to observations taken prior to January 1848 to correct them to that epoch, and subtracted from observations taken subsequent to that date. This change at Madras is I believe strictly in accordance with the observations of Captain LUDLOW of the Madras Engineers, the talented director of the magnetic establishment at that station. As the south end of the needle dips at Singapore and the north end at Madras, and the inclination is increasing at both stations, there must be at some intermediate spot a point of contrary flexure.

The method of observing on shore after the reception of the three new dip circles was never altered with those needles whose poles were changed; the circle being always in the magnetic meridian; two sets of readings were taken in each position of the needle, the usual eight positions being observed for the correction of instrumental error as follows: viz. needle direct and reversed for the non-coincidence of the magnetic axis with the axis of form; the circle east and the circle west for the correction of the zero of the vertical limb, and the same four positions with the poles changed to correct the error arising from the centre of gravity not coinciding exactly with the axle of the needle.

With a view of ascertaining the value of the observations of the inclination, I drew up the following Table of the probable error of a single determination, and of the probable error of the mean value of the inclination at some of the principal points of the Eastern Archipelago.

The first column contains the year and month; the second, the name of the station; the third, the number of needles; the fourth, the number of dip circles observed; the fifth, the number of observations; the sixth, the mean value of the dip; the seventh, the probable error of a single determination; and the eighth, the probable error of the mean value.

Year and Month.	Name of Station.		No. of Needles.	No. of Dip Circles.	No. of observations.	Mean value of the Dip.	Probable error of a single determination.	Probable error of the mean value.
March, 1846	Singapore		3	1	21	−12 47·7	±4′·3	±0′·9
July, 1846	Sambas	Borneo	3	1	6	14 26·5	4·2	1·7
	Pantiānak ...	Borneo	3	1	9	14 41·0	3·3	1·1
May and June ...	Sarāwak	Borneo	3	1	27	11 09·7	4·9	0·9
September, 1846	Batavia	Java.	3	1	9	27 03·7	3·1	1·0
November		Java.	6	3	6	27 02·4	2·0	0·8
November	Tegu	Java.	12	3	19	28 42·5	1·8	0·4
November	Top of Gedé	Java.	5	2	6	29 42·7	1·8	0·7
December	Chunjūr	Java.	12	3	12	28 23·1	2·4	0·7
December	Sidang Bārang	Java.	4	1	8	30 12·1	1·3	0·4
December	Bandong	Java.	11	3	15	28 31·1	2·9	0·8
December	Garoet	Java.	6	2	6	28 58·5	0·7	0·3
December	Permangpek	Java.	4	1	8	30 11·8	0·9	0·3
February, 1847 ...	Soorabāya ...	Java.	4	1	8	28 50·2	3·8	1·3
March, 1847	Sūmenap	......	4	1	12	27 43·5	1·3	0·4
April	PuloKuneeang	......	4	1	12	27 23·6	2·3	0·7
May	Kedeeri	......	4	1	12	29 50·0	2·1	0·6
July	Batavia	......	9	3	44	27 08·2	1·8	0·3
September	Bencoolen		9	3	17	23 53·1	1·9	0·5
October	Padang		9	3	9	18 31·7	3·9	1·3
February, 1848 ...	Singapore, A.M.		4	1	28	12 56·4	2·0	0·4
	P.M.		4	1	28	12 57·2	1·9	0·4
			4	1	56	12 56·8	2·0	0·3
May	Pulo Labooan		9	3	9	2 53·2	1·7	0·6
	Sambooanga		9	3	9	+ 1 19·3	1·6	0·5
June	Keemah		9	3	9	−11 02·7	1·7	0·4
August	Cocos		9	3	36	39 20	1·3	0·2
November	Singapore		9	3	80	12 59·4	2·8	1·3
January, 1849 ...	Malacca		9	3	9	11 27·9	0·9	0·3
January	Pulo Dinding		9	3	9	7 33·9	2·2	0·7
January	Penang		9	3	9	4 55·5	1·6	0·4
February	Nicobar		9	3	9	+ 1 17·8	1·1	0·4
March	Hastings' Island		9	3	9	4 32·3	1·9	0·6
April	Moulmein		8	3	8	17 49·1	2·5	0·9
July	Madras		9	3	29	7 37·7	1·5	0·3

Horizontal Intensity.

The horizontal intensity was determined from four declinometers, viz. the small Observatory Declinometer at Singapore; the Induction or No. II; JONES's or No. III; and the Portable Declinometer.

The Observatory Declinometer with apparatus, consisted of a small gun-metal box, in which was suspended a needle 3 inches in length with mirror attached: two deflecting bars at right angles to the box, were marked off to 0·05 of a foot. A telescope and scale detached from the instrument, and put on a separate pillar, completed the apparatus, which was placed in a building near the magnetic observatory.

2nd. *The Induction or No.* II. *Declinometer.*—This instrument has already been described; the apparatus for deflection consists of two arms fixed at right angles to the box; they were of insufficient length, as the greatest distance at which the deflecting magnet could be placed was 1·4 foot. On measuring the angles of deflection,

the ivory scale was always made use of instead of the horizontal limb of the instrument; and the advantage gained by this was rapidity of observation.

JONES'S, or No. III Declinometer, was received at the termination of the Survey; it was liable to derangement from the difficulty of clamping the limb securely; in other respects the instrument was a very great improvement upon No. II. Declinometer; the ivory scale had a greater range; the deflecting bar at right angles to the instrument was a strong brass scale, supporting a moveable stirrup on its upper edge, on which the deflecting magnet was placed, so that it could be moved backwards and forwards by sliding the stirrup along the scale: the great advantage of this arrangement consisted in the deflecting magnet never being touched, nor affected by the heat of the hand.

Six deflecting needles were used with the three declinometers, D 5, D 6, A 7, A 8, A 9 and A 10. D 6 was lost at Padang in Sumātra.

The Portable or No. IV. Declinometer, was used both for variation and for horizontal intensity; so that after altitudes of the sun and the magnetic axis of the collimator magnet had been observed, the instrument became available for observations of deflection and vibration; C 15 a collimator magnet, being suspended, and C 7 the deflecting needle. The angles of deflection were read off on the glass scale of the suspended magnet, the divisions of which were very coarsely cut.

Explanation of Table G.

The observations are contained in Table G. from page cxl to page cliii. The results are given in eleven columns. The first contains the date; the second, the station; the third and fourth, the suspended and deflecting magnets; the fifth and sixth, the distances at which the magnets were placed, with the corresponding angles of deflection; the seventh, the observed time of 300 vibrations; the eighth, the Declinometer; O standing for the Observatory, I for the Induction, J for JONES'S, and P for the Portable Declinometer; the ninth and tenth, the values of m and X, m being the moment of free magnetism of the deflecting bar, and X the horizontal component of the earth's magnetic force; and the eleventh, the mean value of X.

Mode of Observation in determining the Horizontal Component of the Force.

The position of the deflected magnet was read off without the deflecting magnet, both at the commencement and at the end of the observations, and the change which had occurred in the declination in the interval was thus shown without the necessity of a subsidiary instrument. The change of declination observed was spread over the observations, on the supposition that it had been uniform. The deflecting magnet was placed on the brass scale to the west of the declinometer, and moved successively to four or eight distances, with the marked end of the needle to the west and to the east. The needle was then placed to the east of the deflected magnet, and a similar operation performed. This concluded the experiments of deflection.

To determine the time of one vibration, 360 were observed, and care was taken that the vibrations of the deflecting needle should be limited to an exceedingly small arc.

Formulæ for the Determination of m and X.

Deflection.—The value of $\frac{m}{X}$ is found for each distance by the formula

$$\frac{m}{X}=\frac{1}{2}r^3\tan a.\frac{1}{1+\frac{P}{r^2}},$$

where

$$P=-\frac{r^2r_{\prime}^5\tan a_{\prime}-r_{\prime}^2r^5\tan a}{r_{\prime}^5\tan a_{\prime}-r^5\tan a},$$

r and $r_{\prime}$ being two distances at which the deflecting magnet is placed, a and $a_{\prime}$ the corresponding angles of deflection.

Vibration.—From the experiments of vibration,

$$mX=\frac{\pi^2k}{T^2},$$

where π is the ratio of the circumference of a circle to its diameter, k the moment of inertia of the magnet and stirrup, T the time of one vibration.

To obtain the value of k, a cylindrical brass weight is attached at each end of the magnet,

and

$$k=k_{\prime}\frac{T^2}{T'^2-T^2};$$

where $k_{\prime}$ is the moment of inertia of the magnet and attached weights, T the time of vibration with the magnet and stirrup only, T′ the time with the weights attached,

and

$$k_{\prime}=\left(\frac{1}{2}l^2+r^2\right)p;$$

in which l=the interval between the points of suspension of the weights, r the radius of the brass cylinders, and $2p$ their weight.

Determination of the Coefficients.

In finding the values of m and X, it is necessary to determine certain constants; such as (1) the value of one division of the scale of the suspended magnet; (2) the coefficient of temperature of the deflecting magnet; (3) its moment of inertia; (4) the value of P.

(1.) *Value of one division of the scale.*—In the Singapore Observatory Declinometer, the value of one scale division was determined by the formula

$$a'=\frac{l}{2r}\times 3437'\cdot747:$$

the results alone are given.

November 22, 1845.—Value of one scale division . . . . . . $=1'{\cdot}002$

$$1+\frac{H(=\text{torsion force})}{F\,(=\text{magnetic directive force})} \quad . \; . \quad =1{\cdot}0004$$

March 21, 1846.—Value of one scale division . . . $=59''{\cdot}983=1'$ nearly,

$$1+\frac{H}{F} \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \quad =1{\cdot}0004$$

March 7, 1848.—Value of one scale division . . . . $=1'{\cdot}0081$

$$1+\frac{H}{F} \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \quad =1{\cdot}0007$$

On returning to the observatory, in December 1848, after an absence of several months, I found that the pillar supporting the instrument was slightly inclined, the foundation having been undermined, probably by white ants; I rebuilt the pillar, and the instrument being readjusted, the value of one scale division $=1'{\cdot}0005$.

The value of one scale division of the Induction Inclinometer has been already stated $=1'{\cdot}0$.

The value of one division of No. III. Declinometer was determined at Samboo-anga, May 31, 1848.

By measuring the scale, with the aid of the horizontal circle, the value of one scale division has been ascertained . . . . $=1'{\cdot}0036$

and $1+\frac{H}{F}$ . . . $=1{\cdot}00037$

The value of one division of C 15, the suspended collimator magnet of the Portable Declinometer, was determined from time to time; but the following are the results with two theodolites.

By the large altitude and azimuth, value of one scale division .	$=2'{\cdot}904$
By the small theodolite	$=2{\cdot}900$
Mean value	$2{\cdot}902$

The value of one scale division of C 7 the deflecting collimator magnet, was found to be $=2'{\cdot}342$.

(2.) *Coefficient of Temperature.*—The coefficient of temperature, or value of q, was determined by vibrating the needles in an oak box, and increasing the temperature of the room in which the magnets were vibrated. Perhaps the coefficient of temperature has not been sufficiently well determined; but as the standard temperature to which the magnets are reduced is 80°, and the temperature of the deflecting magnets never differed materially from this, a slight error in the determination of the coefficient would make no perceptible difference in the resulting value of X.

Experiments were carried on at Woolwich, at the end of last year, with one of the needles; the coefficient of temperature was determined for the cylindrical magnet

D 5 by the method of deflection, and the result coincided with the value of q found by vibration.

The following Table contains the determination of the value of q, or of the coefficient of temperature of the small magnets.

$q=\frac{T'-T}{T(t'-t)}$, in which t' and t are the two temperatures, and T′ and T the corresponding times of vibration.

Date.	No. of magnet.	No. of vibrations.	T.	t.	No. of vibrations.	T′.	t'.	$t'-t$.	T′−T.	Value of q.	
1844.											
June 7.	D 5	720	86·5	341·635	3600	121·3	343·05	34·8	1·415	·000119	Mean of the solid magnets $q=$·000105.
May 28.	D 6	1080	86·6	339·47	1440	116·8	340·252	30·22	0·7825	·000076	
	A 7	720	86·25	254·725	720	118·3	256	32	1·275	·0001565	
May 30.	A 8	720	86·5	315·08	1080	119	316·33	32·5	1·25	·000122	Mean of the hollow cylindrical magnets $q=$·000322.
May 30.	A 10	720	87	266·755	1080	120	267·637	33	0·882	·0001	
June 7.	H 9	360	87	180·3	360	113·8	182	26·8	1·7	·000352	
June 14.	H 10	360	86·8	181·92	720	126	183·805	29·2	1·885	·000355	
June 27.	H 11	360	87	172·96	360	103	173·66	16·0	0·701	·000253	
1845.											
April 7.	C 7	756	88·5	423·1	360	109·7	427·00	21·2	2·28	·00025	

(3.) *Moment of Inertia.*—The moment of inertia was determined at different periods. The following Table contains the moments of inertia prior to the commencement of the Survey at the Singapore Magnetic Observatory.

Date.	Magnet.	Small weights.		Length of magnet in feet.	p, or weight of cylinder in grs.	r, or radius of cylinder in feet.	Moment of inertia $k_{,}=\frac{1}{2}l^2p+r^2$ $k=k_{,}\frac{t^2}{t'^2-t^2}$.	Large weights.		p, or weight of cylinder in grs.	r, or radius of cylinder in feet.	Moment of inertia $k_{,}=\frac{1}{2}l^2p+r^2$ $k=k_{,}\frac{t^2}{t_{,}^2-t^2}$.	Radius of magnet in feet, or $r_{,}$.	Weight of magnet in grs., or $p_{,}$.	Moment of inertia $k_{,}=\frac{1}{12}l^2p_{,}+\frac{1}{4}r_{,}^2p_{,}$.
		Time of 1 vibration from 360. Needle loaded, t'.	Time of 1 vibration from 360. Needle unloaded, t.					Time of 1 vibration from 360. Needle loaded, t'.	Time of 1 vibration from 360. Needle unloaded, t.						
1845.															
March 7.	D 5	6·9316	3·7	·3033	210	·01335	3·863	9·0289	3·7	414	·01675	3·862	·0125	497	3·8294
May 1.	......	6·9678	3·7202	......	......	......	3·865	9·0379	3·7202	......	......	3·862			
March 15.	D 6	7·025	3·7266	......	......	......	3·7972	9·1661	3·7266	......	......	3·7934	......	490	3·7751
May 2.	......	7·0221	3·7249	......	......	......	3·7931	9·1526	3·7249	......	......	3·7995			
1844.															
August ...	......	6·7881	3·6097	......	......	......	3·8236	8·87276	3·6097	......	......	3·798			
	......	6·7964	3·6082	......	......	......	3·8056	8·8728	8·6082	......	......	3·7955			
	......	6·7933	3·607	......	......	......	3·8158	8·877	3·607	......	......	3·7882			
March 17.	A 5	5·355	2·6958	·2522	......	......	2·2798	7·0458	2·6958	......	......	2·2779	......	418	2·232
1845.															
March 18.	A 6	6·1154	3·0733	......	......	......	2·2693	8·0533	3·0733	......	......	2·2641	......	416·5	2·224
19.	A 7	5·4478	2·74	......	......	......	2·2742	7·18	2·74	......	......	2·2641	......	416·5	2·224
22.	A 8	6·5843	3·2933	......	......	......	2·2408	8·2758	3·2933	......	......	2·2366	......	411·5	2·197
24.	A 9	5·657	2·81	......	......	......	2·1998	7·4661	2·81	......	......	2·1920	......	405·5	2·165
25.	A 10	5·7172	2·8664	......	......	......	2·2551	7 5372	2·8664	......	......	2·2458	......	415	2·216
26.	C 7	5·7533	4·4194	·3350	......	......	17·014	6·8027	4·4194	......	......	17·191			

The following Table contains the results of the values of π^2k found for each needle; the mean value of π^2k determined from observations prior to 1847 being considered as of value equal to those taken subsequently.

Date and Station.	Value of π^2k for the cylindrical magnets and the collimator magnet.					
	D 5.	A 7.	A 8.	A 9.	A 10.	C 7.
Singapore, prior to 1847	38·225	22·485	22·281	21·818	22·394	168·14
Batavia, July, 1847	38·265	22·443	22·140	21·882	22·363	167·30
Singapore, February, 1848	38·482	22·353	22·124	21·797	22·385	166·94
Singapore, December, 1848	38·423	22·296	22·126	21·783	22·307	167·25
Madras, September, 1849	38·208	22·884	21·846	21·813	22·383	

The mean value of π^2k has been employed in determining the value of X; that is to say, the value of π^2k found at a station is added to the results determined at previous periods, and a mean assumed as the true value of π^2k.

(4.) *Value of* $P=-\frac{r^2r_i^5\tan a_i-r_i^2r^5\tan a}{r_i^5\tan a_i-r^5\tan a}$.—The value of P was determined for each needle, from the mean of many angles of deflection at the same distances. The following are the results of the mean value of P for the different magnets and the four declinometers.

March, 1846, at Singapore, the value of P for D 5 and D 6, determined by the Observatory Declinometer, was —·00309.

June, 1846, at Sarāwak, by the Induction Inclinometer,—

The value of P for D 5 was	+·00320
D 6	+·00169
A 6	—·024157
A 7	—·007276
A 8	—·00726
A 9	—·00335
A 10	—·00335
C 7	—·00361

June, 1848, at Sambooanga, in the island of Mindanāo, by No. III. Declinometer,—

The value of P for D 5 was	—·00148
A 7	—·01642
A 8	—·00900
A 9	—·01218
A 10	—·01407

December, 1848, at Singapore, by No. III. Declinometer, the value of P for

A 8 was . .	—·00930
A 9 was . .	—·01059
A 10 was . .	—·00932

and by the Observatory Declinometer the value of P for A 8 was —·00751.

Remarks.—The observations of deflection are exceedingly numerous, and it is to be regretted that some of the time expended on them was not bestowed on the more complete determination of the coefficients; but, as the angles of deflection were exceedingly small, it was deemed advisable to multiply observations for the value of $\frac{m}{X}$ as much as practicable. The needle was not always vibrated on the same day on which the experiments of deflection were observed, yet care was taken that it should be vibrated at the same time at which the deflection was observed; and in low latitudes, subject to trifling disturbances, there is a greater change in a few hours on the

same day, than there will be after the lapse of some time at the same hours; thus there would be a much greater difference in the time of vibration of a needle at 11 A.M. and 5 P.M. on the same day, than if it were vibrated at 11 A.M. on different days.

The following Table contains the probable error of a single determination, and also of the mean value of the horizontal intensity, at each station in the Eastern Archipelago.

Year and Month.	Name of Station.	No. of observations.	Number of deflecting needles.	Number of instruments.	Mean value of the horizontal intensity.	Probable error	
						Of a single determination.	Of the mean value.
1845	Singapore	179	2	2	8·095	±·009	±·0007
March, 1846	Singapore	55	7	2	8·121	·0095	·0013
March, 1848	Singapore	199	5	2	8·116	·0090	·0006
December	Singapore	300	5	3	8·114	·0103	·0006
January, 1846	Pulo Peesang	18	7	1	8·092	·0070	·0017
January	Carimons	15	6	1	8·077	·0090	·0056
February	Lingin	16	6	1	8·062	·0070	·0017
June	Sarāwak	43	7	1	8·186	·007	·001
September	Batavia	56	7	1	7·894	·010	·0014
July, 1847	Batavia	218	6	1	7·891	·0084	·0006
August	Lampongs, Sumātra	24	6	1	7·916	·0070	·0014
September	Bencoolen	24	6	1	7·913	·0053	·0011
October	Padang	24	6	1	7·962	·011	·002
March, 1848	Ophir, near Malacca	20	5	1	8·255	·017	·0038
May	Pulo Labooan	20	5	1	8·240	·0052	·0012
May	Sambooanga	60	5	2	8·162	·0110	·0015
June	Keemah	60	5	2	8·253	·0120	·0015
August	Cocos	120	5	2	7·274	·010	·0009
February, 1849	Nicobar	60	5	2	8·155	·011	·0014
January	Pulo Dinding	20	5	1	8·117	·006	·0014
January	Pulo Penang	20	5	1	8·159	·007	·0015
March	Hastings' Island	20	5	1	8·177	·007	·0015
April	Moulmein	59	5	2	8·119	·0085	·0011
August	Madras	127	5	2	8·078	·0085	·0007

Table H.

Table H, at pages cliv and clv, contains the absolute determinations of Total Force, and of the Horizontal Component, of Inclination and of Variation.

Explanation of Table H.—The first five columns require no explanation. The sixth column contains the horizontal intensity deduced from observations made with the four declinometers; the values of the horizontal intensity given by the portable declinometer, are less than those found by means of the other three declinometers; this has arisen from the shrinking of the oak deflecting bar of the portable declinometer, by which the values of r, r', &c., the distances of the deflecting from the suspended magnet, are less than they should be, consequently the angles of deflection are greater than they ought to be; $\frac{m}{X}$ is therefore greater and X less than its true value; but this shrinking must have happened before the Survey; for the ratio of the true horizontal

intensity deduced from the three declinometers, to the horizontal intensity found by means of the portable declinometer, is constant.

As the instrument was left at Madras, I have no means of measuring the true values of r, r', &c.; but if four stations be taken, Singapore at the commencement, Batavia and the Cocos during the Survey, and Madras at its termination, we find the comparison to be as follows:—

	Horizontal intensity from three declinometers.	Horizontal intensity from portable declinometer.	Ratio.
Singapore, 1845	8·0947	7·9495	1·0182
Singapore, 1846	8·121	7·951	1·0214
Singapore, 1848	8·114	7·991	1·0154
Batavia, 1847	7·897	7·784	1·0145
Cocos, 1848	7·2745	7·167	1·0150
Madras, 1849	8·0784	7·951	1·0160
		Mean ratio . . .	1·0167

by which ratio 1·0167, all the values of the horizontal intensity found by means of the portable declinometer, are multiplied for the true value.

The seventh column contains the total intensity. The total intensity has not been determined by direct observation, but from the formula $h=f\cos\delta$,

or
$$f=\frac{h}{\cos\delta}=h\,.\sec\delta,$$

where h is the horizontal intensity,
δ the dip,
and f the total intensity.

The eighth column contains the variation or magnetic declination, found by means of the altitude and azimuth instrument and collimator magnet. The following Table is given in explanation of the manner in which the variation was determined, the station being on Direction Island at the Cocos; each observation is the mean of three sets of altitudes and azimuths, with the vertical limb in the direct and reversed positions.

Date.	Time.	Reading of the true meridian on the limb. Limb direct. 1.	Limb direct. 2.	Limb direct. 3.	Limb direct. Mean.	Limb reversed on its axis. 1.	Limb reversed on its axis. 2.	Limb reversed on its axis. 3.	Limb reversed on its axis. Mean.	Mean of the two sets, or true meridian on the limb.	Mean of magnetic axis on the limb.	Mean magnetic variation. West.
Aug. 28.	A.M.	211 18 30	211 17 10	211 18 00	211 17 53	211 34 10	211 34 40	211 34 00	211 34 17	211 26 05	210 16 28	1° 09′ 37″
29.	A.M.	211 29 47	211 29 27	211 30 17	211 29 50	211 32 23	211 30 13	211 32 57	211 31 51	211 30 50	210 18 06	1 12 44*
31.	A.M.	211 27 40	211 26 50	211 27 10	211 27 13	211 26 00	211 25 04	211 25 00	211 25 21	211 26 17	210 16 16	1 10 01
Sept. 7.	A.M.	211 23 53	211 23 23	211 25 27	211 24 14	211 30 07	211 29 53	211 29 53	211 29 58	211 27 06	210 17 06	1 10 00
9.	A.M.	211 25 30	211 25 16	211 26 20	211 25 42	211 29 40	211 27 30	211 28 03	211 28 24	211 27 03	210 17 20	1 09 43
19.	A.M.	211 28 05	211 28 14	211 30 54	211 29 04	211 23 40	211 25 40	211 23 59	211 24 26	211 26 45	210 18 37	1 08 08
27.	A.M.	212 10 17	212 10 40	212 12 44	212 11 14	212 08 30	212 07 40	212 09 47	212 08 39	212 09 50	210 55 18	1 14 38†
									Mean of the variation			1 10 42

* New spider's web, and instrument readjusted.

† New level put on the vertical limb, and position of the altitude and azimuth changed.

The eleventh column contains the altitudes of the stations above the sea level. Unfortunately, during the survey of Java, I had no barometer with me.

Table I.

Table I contains the observations made at sea; the inclination determined by Fox's Dip Circle have already been noticed. The meteorological observations, consisting of the temperature of the air and of the sea, were taken when practicable, at 15, 18, and 21 hours, at noon, and at 3, 6, and 9 P.M. The observations of the temperature of the sea were made in the following manner:—the thermometer was placed in a bucket of sea-water, allowed to stand for a few minutes whilst the other instruments were observed, and the thermometer was read off whilst its bulb was still immersed.

The Table contained at pages clvi and clvii requires no explanation.

On the Direction of the Isoclinal and Isodynamic Lines, and the Lines of Equal Variation or Magnetic Declination.

On the Isoclinal Lines.—The observations of dip or inclination have been combined for the position of the isoclinal lines, their mean direction, and their mean distance apart; they have been formed into four different groups.

1st Group.—Singapore, Borneo, and Java, afford forty stations; and if we call δ the dip at the central position, u the angle which the isoclinal line passing through the central position makes with the meridian, and r a constant coefficient, which determines the rate of increase in a direction perpendicular to the isoclinal line; and we put

$$r \cos u = x$$
$$r \sin u = y,$$

we may make equations of condition of the following form:

$$ax + by = \delta - \delta',$$

where a and b are coordinates of distance in longitude and latitude of the several stations from the mean, expressed in geographical miles; δ' the inclination at these several stations, and δ the mean dip.

Then from this group we obtain, the results alone being given,

At a mean latitude .	=	6°	17′ South.
Mean longitude	=	108	55 East.
And mean dip . .	= −	27	01·5 South.

$$x = -0{\cdot}132 \qquad y = +1{\cdot}935$$
$$r = +1'{\cdot}940 \text{ and } u = -86^\circ\ 06'.$$

The axes of coordinates are throughout assumed positive when taken to the north and west; so that as we proceed to the north, the dip increases at the rate of $1'{\cdot}940$ perpendicular to the isoclinal line which forms an angle of N. 86° 06′ E. to S. 86° 06′ West.

2nd Group.—Sumātra contains thirty stations; the resulting equations give—

At a mean latitude . = 0° $08'$ South.
At a mean longitude . =100 31 East.
And mean dip . . = 16 $36'\cdot6$ South.
$x=+0\cdot230$; $y=+2\cdot008$
$r=+2'\cdot021$ and $u=83^\circ\ 28'$.

We have therefore, the isoclinal line in Sumātra forming an angle of N. 83° 28′ W. to S. 83° 28′ East, and the line at right angles to it increasing at the rate of 2′·021; and as the central station, through which this line passes, is only 8 miles to the south of the equator, we may assume this to be the rate at which the dip increases at nearly right angles to the terrestrial equator in longitude 100° 31′ East.

3rd Group.—From the third group we have thirty observations taken at sea.

The resulting equations give—

At a mean latitude . = 2° $38'$ North.
At a mean longitude =110 05 East.
And mean dip . . . = 9 11·7 South.
$x=+0\cdot089$; $y=+1\cdot991$
$u=87^\circ\ 26'$; $r=+1'\cdot993$.

We have, therefore, the isoclinal line running N. 87° 26′ W. to S. 87° 26′ East, and the line at right angles increasing at the rate of +1′·993 for each geographical mile.

4th Group.—In the fourth group are contained the principal stations in the Magnetic Survey, extending from the 80th to the 125th degree of east longitude, and from $16\frac{1}{2}^\circ$ North to 12° South.

From the resulting equations we obtain—

At a mean latitude . = 0° $09'$ North.
At a mean longitude =104 44 East.
And mean dip . . = 14 40·4 South.
$x=+0\cdot114$ $y=+1'\cdot947$
$u=86^\circ\ 39'$; $r=+1'\cdot953$.

The isoclinal line runs therefore N. 86° 39′ W. to S. 86° 39′ East, and the line at right angles to it increases at the rate of 1′·953 for each geographical mile.

On the Lines of Equal Horizontal Intensity.

For the lines of equal horizontal intensity the equations of condition have been combined in the same manner by the method of least squares.

From one group of forty stations

At a mean latitude of . . . . 0° $38'\cdot5$ North.
At a mean longitude of . . . . 102 26 East.
$x=+\cdot000312076$; $y=+\cdot000765277$
$r=+\cdot0008249$; $u=67^\circ\ 48'$.

The line of equal horizontal intensity forms an angle of N. 67° 48′ W. to S. 67° 48′ E. with the meridian, and on the line perpendicular to this the horizontal intensity increases at the rate of ·0008249 the geographical mile.

From a second group of seventy-seven stations, comprising all those at some distance to the south of the line of maximum horizontal intensity, we obtain

At a mean latitude	=	3° 40′	South.
At a mean longitude	=	106 33·0	East.

$x=+\cdot00028453$; $y=+\cdot0005117$

$u=60^\circ\ 57'$; $r=+\cdot000585439$.

The line of equal horizontal intensity forms an angle of N. 60° 57′ W. to S. 60° 57′ E. with the meridian, and the horizontal intensity on a line perpendicular to this increases at the rate of ·0005855 the geographical mile.

Lines of Total Intensity.

The total intensity has been determined by the formula $h=f\cos\delta$,

or
$$f=\frac{h}{\cos\delta}=h\sec\delta,$$

where h is the horizontal intensity,

δ the dip,

f the total intensity ;

eighty equations of condition of the following form,

$$ax+by=f-f',$$

have been combined by the method of least squares, so as to assume the form of the two following equations :—

$$a^2x+aby=a(f-f')$$
$$abx+b^2y=b(f-f'),$$

a and b being the coordinates of distance in longitude and latitude from the mean station for any station, and f' its intensity ; f the mean total intensity $=8\cdot745$.

Then by adding together the equations of condition for each station, we obtain the following :—

$$r=-\cdot001073,$$
$$u=85^\circ\ 36',$$

at a mean latitude of 3° 05′ S. and a mean longitude of 106° 47′ E.

The angle which the line of equal total intensity forms with the meridian is N. 85° 36′ W. to S. 85° 36′ E., and increases southerly at the rate of ·001073 the geographical mile. The line of least intensity in that part of the Archipelago over which I have carried the Survey, agrees nearly with the line of no dip. On looking over the list of stations, we find Sambooanga, Nicobar, and Madras, with the least total inten-

sity. Sambooanga and Nicobar are about forty miles north of the line of no dip. The angle which the line of least intensity makes with the meridian is nearly a right angle.

Lines of Variation.

The first attempt which I made to determine the lines of equal variation was unsatisfactory. From 120 equations of condition combined by the method of least squares, I obtained results quite at variance with the actual fact.

I then broke up the observations into three groups, one to the extreme west, comprising the observations taken in Sumātra, one in the centre comprising the observations taken in Java, and the third group to the east. The results thus obtained are more satisfactory, for the line of equal variation in the longitudes and latitudes over which the Survey extended is a straight line for a very short distance only.

1st, or Eastern group:—

At a mean latitude.	=	2° 03′	North.
At a mean longitude	=	113 53	East.
And mean variation	=	1 23	East.

The line of equal variation forms an angle of N. 52° 51′ E. to S. 52° 51′ W. with the meridian, and the rate of progression, or the value of r, is $-0'{\cdot}0346$ the geographical mile.

2nd, or Sumātra group:—

At a mean latitude.	=	1° 36′	North.
At a mean longitude	=	100 36	East.
At a mean variation	=	1 35	East.

$$u = -82°\ 06',$$
$$\text{and } r = +{\cdot}0545\,;$$

so that the variation increases as we proceed northerly, at the rate of $+{\cdot}0545$ the geographical mile; the line of equal variation forming an angle of N. 82° 06′ E. to S. 82° 06′ W.

3rd, or Java group:—

At a mean latitude.	=	7° 03′	South.
At a mean longitude	=	108 51	East.
At a mean variation	=	+0 35	East.

$$\text{The value of } r = 0'{\cdot}145.$$
$$\text{The value of } u = -89°\ 24',$$

so that the line of equal variation in Java forms with the meridian an angle of N. 89° 24′ E., and proceeds at the rate of 0′·145 the geographical mile.

The lines have been laid down on the charts nearly in accordance with the foregoing results.

The line of equal inclination forms an angle of 86° 40′ with the meridian, and changes in a direction perpendicular to it at the rate of 1′·970 the geographical mile.

The line of equal horizontal intensity forms an angle of nearly 65° with the meridian. For the position of the central line of maximum horizontal intensity, I have taken stations north and south of this line having the same horizontal intensity, and have divided the distance between them; and in laying down the rate of decrease of the horizontal intensity, I have fixed upon the Java group, which has the greatest number of stations, as decreasing at the rate given me by the equations of condition; but since the horizontal intensity at the Cocos shows a much more rapid decrease when at some distance from the line of maximum horizontal intensity, I have gradually increased the rate of progression to the Cocos, and decreased it in the same proportion northwards from Java to the line of maximum horizontal intensity.

The lines of total intensity are laid down in strict conformity with the resulting equations of condition. The direction of the lines is between 85° and 86°, and proceeds at the rate of ·001073 the geographical mile. There is much less difficulty in laying down the total intensity lines than the lines of horizontal intensity; for the former, and the rate of progression in a direction normal to them, are functions of the dip and horizontal intensity; and since the dip changes very rapidly, whilst the horizontal intensity is nearly stationary in the immediate vicinity of the maximum horizontal intensity, it follows, first, that the line of minimum total intensity will coincide nearly with the line of no dip; and secondly, that its rate of progression, or the value of r, will be as uniform and as constant as the lines of dip, for it has been shown that over the space of 28° of latitude over which this Survey extends, the dip changes at the rate of nearly two miles for every mile of latitude.

In laying down the lines of variation, I have been guided partly by the equations of condition, but to be directed by these alone would lead to very unsatisfactory results. I have, in the Java group and in the Eastern group, conformed to the results of the equations of condition combined by the method of least squares, whilst in the western group I have simply connected together by lines the stations having the same variation.

Explanation of Plates XII. *and* XIII.

Plate XII. contains the isoclinal lines or lines of equal magnetic dip and lines of equal magnetic declination, as well as the central lines of minimum total intensity and of maximum horizontal intensity.

Plate XIII. contains the isodynamic lines or lines of equal horizontal intensity and of equal total intensity; and in addition, the line of no magnetic declination and the line of no dip.

Pimlico Lodge, Westminster,
November 15, 1850.