ASTRONOMICAL PHENOMENA FOR THE WEEK 1886 DECEMBER 12-18

(FOR the reckoning of time the civil day, commencing at Greenwich mean midnight, counting the hours on to 24, is here employed.)

At Greenwich on December 12

Sun rises, 7h. 59m.; souths, 11h. 53m. 58·0s.; sets, 15h. 49m.; decl. on meridian, 23° 6′ S.: Sidereal Time at Sunset, 21h. 14m.

Moon (one day past Full) rises, 16h. 34m.*; souths, 0h. 29m.; sets, 8h. 27m.; decl. on meridian, 18° 57′ N.

Planet	Rises h. m.	Souths h. m.	Sets h. m.	Decl. on meridian ° ′
Mercury	6 15	10 43	15 11	18 3 S.
Venus	8 12	12 4	15 56	23 30 S.
Mars	10 10	14 6	18 2	23 1 S.
Jupiter	3 14	8 26	13 38	10 7 S.
Saturn	18 6*	2 9	10 12	21 33 N.

* Indicates that the rising is that of the preceding evening.

Occultations of Stars by the Moon (visible at Greenwich)

Dec.	Star	Mag.	Disap. h. m.	Reap. h. m.	Corresponding angles from vertex to right for inverted image ° °
14	3 Cancri	6	1 42	2 46	100 237
14	B.A.C. 2731	6½	6 54	near approach	207 —
14	54 Cancri	6½	21 26	22 9	85 181

Dec.	h.	
13	6	Mercury stationary.
13	17	Saturn in conjunction with and 2° 59′ north of the Moon.

Variable Stars

Star	R.A. h. m.	Decl. ° ′		h. m.
U Cephei	0 52·2	81 16 N.	Dec. 13,	1 25 *m*
			,, 18,	1 5 *m*
T Arietis	2 42·0	17 2 N.	,, 16,	*m*
S Tauri	4 23·0	9 42 N.	,, 18,	*M*
R Leporis	4 54·4	14 59 S.	,, 12,	*M*
S Cancri	8 37·4	19 27 N.	,, 17,	2 24 *m*
W Virginis	13 20·2	2 47 S.	,, 15,	21 0 *M*
δ Libræ	14 54·9	8 4 S.	,, 16,	4 50 *m*
U Coronæ	15 13·6	32 4 N.	,, 13,	22 15 *m*
β Lyræ	18 45·9	33 14 N.	,, 15,	2 30 m_2
δ Cephei	22 24·9	57 50 N.	,, 16,	4 50 *m*
			,, 17,	19 20 *M*

M signifies maximum; *m* minimum; m_2 secondary minimum.

Meteor-Showers

Moonlight interferes with meteor observation during the early part of the week, which is also less fruitful of meteors than are the first few days of the month. Amongst the radiants which have supplied meteors at this season are one in the constellation of the Lynx, R.A. 108°, Decl. 63° N., and one in Quadrans, R.A. 221°, Decl. + 53° N.

THE LAW OF STORMS IN THE EASTERN SEAS[1]

I. IN the Eastern seas the earliest signs of a typhoon are clouds of the cirrus type—looking like fine hair, feathers or small pale white tufts of wool—travelling from the east or thereabout, their direction backing towards the north, a slight rise in the barometer, clear and dry but hot weather, and light winds. This fine weather lasts for days, and the existence of a typhoon at a great distance contributes therefore to the safety of ships at sea,—a fact that is not sufficiently appreciated by mariners.

The cirrus clouds, which frequently assume fantastic shapes, make their appearance within 1500 miles of the centre of a typhoon, the barometer is generally rising beyond from 600 to 1000 miles of the centre, and the mean of the twenty-four hours' temperature rises in Hong Kong above 81°.

A swell in the sea is noticed within from 300 to 500 miles of the centre, but this depends greatly upon the situation of the nearest land. Halos round the sun and the moon, phosphorescence of the water, and also glorious sunsets appear to be frequently noticed before typhoons.

Within about 800 miles of the centre the sky is generally half covered with cumulus clouds, above which cirro-cumulus are usually seen. South and south-west of the centre, thunderstorms and cumulo-stratus clouds are observed. On approaching nearer to the centre the cloudiness increases, the temperature falls in consequence, and the mercury begins to descend in the barometer. Then the air becomes oppressive from the increasing dampness, a slight haze is observed during the morning hours, and the sky presents a threatening and vaporous appearance. Within 300 miles of the centre the temperature falls quickly owing to the cumulus, roll-cumulus, or nimbus clouds, with which the sky is nearly completely overcast. And meantime the wind has risen and blows generally with the force of a strong breeze about 300 miles from the centre. But this depends also upon the bearing of the centre, the wind being usually strongest in the right hand semicircle. Within 150 miles of the centre the sky is densely overcast with nimbus clouds accompanied by heavy rain, and within 60 miles it generally pours down in torrents, while the wind blows so hard that no canvas can withstand it; but there is no thunder and lightning. The temperature at sea is frequently about 76°, and on shore about 78°.

Within from 2 to 15 miles of the centre the wind either calms down or blow only moderate breezes, and the sky clears, being now covered only by very light clouds. The sea is as a rule mountainous, but in some reports it is stated that the sea had calmed down to some extent when the wind fell. Quantities of sea-birds, and near land also butterflies and other insects, cover a ship situated in the bull's eye of a typhoon. It is possible that the central calm does not quite accurately coincide with the centre of the typhoon.

The angle between the direction of the wind and the direction of the radius (the straight line between the observer and the centre of the typhoon) is, on an average, between 10° and 25° latitude, 43° in front of the centre and 53° behind the centre; between 33° and 35° latitude, 65° in front and 85° behind; and between 10° and 35° it is about 49° in front and 62° behind the centre. The angle appears to be smaller near the shore for off-shore winds, and far out at sea the difference between the angle in front of and behind the centre appears to be small. The following rule for finding, on board ship in the China seas, the bearing of the centre of a typhoon is, therefore, approximately correct: Stand with your back to the wind, and you will have the centre on your left side, but 3 points in front of your left hand; *i.e. the centre bears about* 11 *points from the wind.* If your ship is in a very low latitude the centre may lie as much as 4 points in front of your left hand, *i.e.* bear 12 points from the wind, and if you are in a high latitude it may bear only 9 points from the wind. Once the wind has reached the force of a strong breeze, the average angle between the wind and the direction of the centre does not appear to change at all, but the wind, which blows in great gusts in a typhoon, may oscillate to both sides of the true value. There does not appear to be any foundation at all for the belief that the wind near the centre blows in circles round the centre. To act according to this rule might prove disastrous to a ship experiencing a typhoon.

Very low clouds in a typhoon move with the wind, but if the clouds are high they are frequently seen to move in a different manner, and the following rule may then occasionally be of use: If right in front of the centre, stand with your back towards the direction whence the clouds are coming, and you will have the centre from 1 to 2 points in front of your left hand; and if straight behind the centre you may have it a point or two to the left of the direction in which you are looking.

Once the bearing of the centre has been ascertained, the master of a vessel in a typhoon requires to know in which semicircle, looking in the direction towards which the typhoon is moving, he is situated: If *in the right hand semicircle, the wind will veer, i.e.* shift with the sun; and if *in the left hand semicircle, it will back, i.e.* shift in the opposite direction. But this rule is strictly applicable on board of a vessel only when hove-to, or at any rate proceeding at a slower rate than the typhoon. For a vessel moving at a faster rate than and in the same direction as a typhoon, the rule may be reversed. In case of doubt it may therefore become advisable to heave-to in order to be quite sure of the semicircle in which you are situated. But we have seen that the wind moves in spirals towards the centre, and

[1] By Dr. W. Doberck, Hong Kong Government Astronomer. Reprinted from the *Hong Kong Telegraph.*

it is therefore dangerous to lie-to in a typhoon, particularly before you are sure that the centre is past. Vessels near the coast of China, or in the Formosa Channel, generally seek refuge in the nearest typhoon harbour indicated in the Directory.

The wind shifts faster the nearer the centre you are. If the barometer falls rapidly and the wind does not change its direction, and when the gusts continue to increase in force, your ship is in danger of entering into the central calm of the depression with its mountainous and confused seas, which is by all means to be avoided, as it is the high cross seas that do the most damage, and not the force of the wind. When once you are caught in a typhoon you should make no sail, except what may be necessary to steady the ship, till the gusts continue to decrease in force and the barometer has risen for some time. Very deceitful lulls are reported to occur during the raging of a typhoon. The master of a sailing-vessel is said to have put up topgallant sails after getting into the central calm. Of course he could have had no reliable barometer on board.

In storms encountered in higher latitudes, where the incurvature of the wind is not so great as in a tropical hurricane, the right-hand semicircle is termed the dangerous semicircle, as a ship running before the wind is in more danger of crossing the path of the storm in front of the centre and perhaps be overtaken by it; but in a typhoon there is not much to choose between the semicircles. A dismasted ship is in danger of being carried into the centre from any quarter.

However, the right-hand semicircle is also in a typhoon generally more dangerous than the other, both with regard to the risk of crossing the path in front of the centre, and also, as remarked above, with regard to the force of the wind and consequent greater sea disturbance. A ship experiencing a northerly gale and a falling barometer in the China Sea in the typhoon season is generally in greater danger than another experiencing a south-westerly gale.

When you have ascertained in which semicircle your vessel is situated, you should, if in the right-hand semicircle, keep the wind as long as possible on the starboard tack; and if in the left-hand semicircle, you should run on the starboard tack, or heave-to on the port tack, so as to let the ship come up as the wind backs and run no risk of being taken aback. As explained further on, a typhoon encountered in a low latitude moves so slowly that a steamer or fast sailing-ship has a fair chance of running away from it, but farther north, when the centre proceeds at the rate of thirty or forty miles an hour, it requires careful management even supposing you have ample sea-room.

Typhoons are dangerous on the open sea, but they are still more to be feared in open anchorages or near lee shores. Along the south-west coast of Formosa and elsewhere, a ship must in the south-west monsoon be prepared to run to sea at very short notice, as in some of the harbours you could not lie with any chance of riding out a typhoon. A steamer at anchor should get up steam as soon as the wind rises above the force of a strong breeze, and a sailing-vessel should take down the top-masts. The direction in which the wind is going to shift must early be determined so as to select a sheltered anchorage. If the centre passes very near the anchorage, the berth may have to be changed to the other shore during the lull, before the wind shifts to the opposite quarter.

A ship moored by a single anchor with her head to the wind, will swing with the sun in the right-hand semicircle and against the sun in the left-hand semicircle. If two anchors are dropped, the anchor on the advancing bow should be let go first, therefore a ship in the right-hand semicircle of a typhoon should first drop the port anchor and afterwards the starboard, in order that she may ride with open hawse. And a ship in the left-hand semicircle should first drop the starboard anchor. But ships have to ride with a long scope in a typhoon, and as they are liable to drag the anchors, some prefer to drop the second anchor to veer upon if the first should not hold.

II. The force of the wind and the appearance of the sky do not always furnish a reliable guide to determine how far you are from the centre of a typhoon. The dimensions are different in different typhoons, and near land the strong winds are often so irregularly distributed that in a place near the centre less wind may actually be experienced than at some distance farther away from it. Also the 11-point rule for ascertaining the bearing of the centre fails near some shores if the centre is not near at hand; thus there often blows a steady easterly gale along the southern coast of China when a typhoon is crossing the China Sea, and the gale blows often steady from north-east about the northern entrance to the Formosa Channel when there is a typhoon in a more southern latitude.

The surest of all warnings is furnished by the standard barometer on shore and the compensated aneroid on board ship; you are all right if you can put your vessel on the tack that will keep your barometer rising. But in order to understand the indications of the barometer you will have to keep a regular meteorological register. The master of a vessel who does not look at his aneroid till he is in a typhoon, does not derive half the benefits from his observations that he would have enjoyed had he watched it beforehand. He might perhaps have avoided the weather he is now experiencing, or even have benefited by the favourable winds and sailed round the typhoon. No doubt the time is approaching when underwriters will stipulate that the indications of an aneroid or a marine barometer must be regularly registered on board a vessel insured by them.

On the other hand, it would not be fair to ask the mariners to keep complete meteorological records, such as are kept in the lighthouses out here. Some seamen have a taste for this kind of work and make very useful and fairly accurate observations, but, for instance, the readings of dry and damp bulb thermometers taken on many vessels are of very little use.

The tube of the marine barometer has to be so much contracted to stand the incessant pumping and danger of breakage, that the instrument is sluggish and often reads half an inch or more too high near the centre of a typhoon. Some cheap wooden barometers cannot be registered below a certain height, the cistern being too small to hold the mercury that comes out of the tube. Of course some cheap aneroids are no better, and even a first-class compensated instrument requires to be thoroughly verified, as the scale is never quite correct, but they act nearly as quickly as first-class standard barometers, and for use on board ship the instrument that is quickest in its indications must be preferred. The objection to the use of the aneroid is founded on the fact that its index-correction changes gradually; but then this can be determined and allowed for by reading it off as often as the vessel enters a port, such as Hong Kong, where correct meteorological observations are constantly being made.

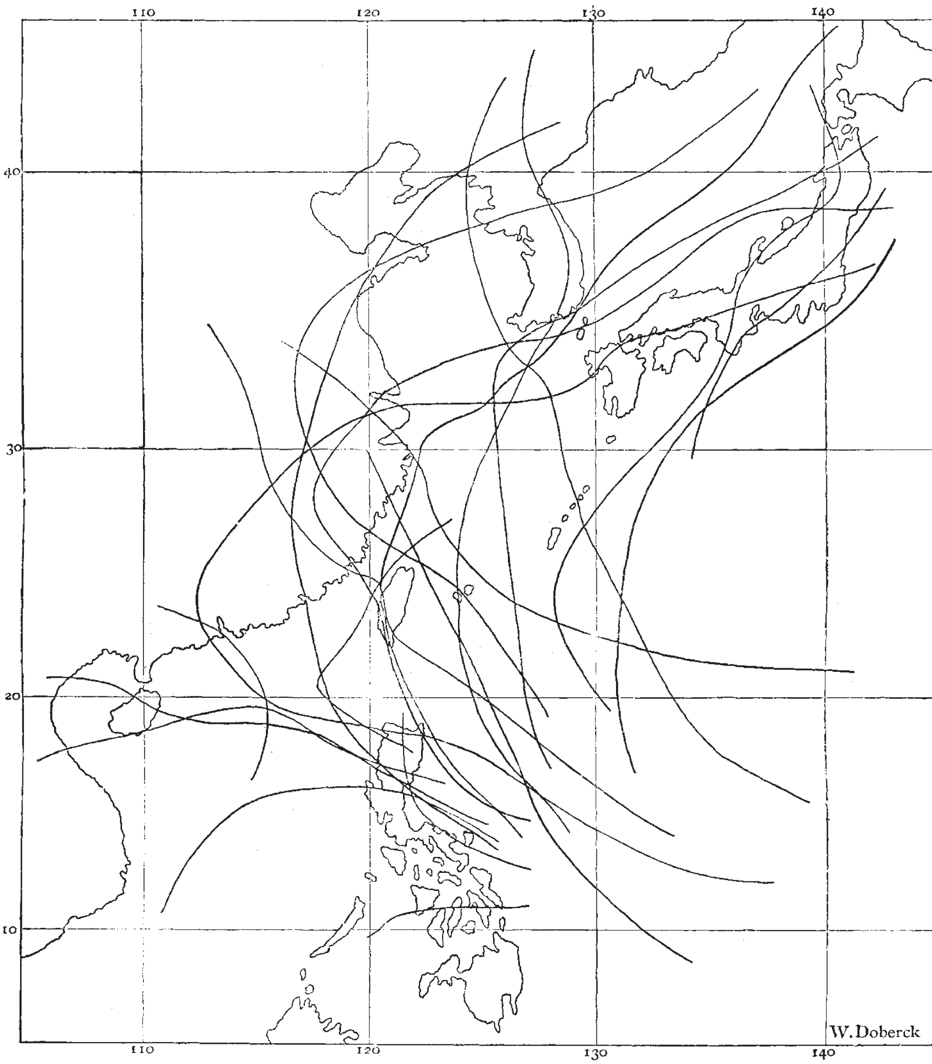
The best hours for making observations are 4 a.m., 8 a.m., &c., up to midnight inclusive. The observations should consist in readings of the aneroid, temperature (this is no use except when the thermometer is placed well forward so as to be exposed to the wind, though in a position sheltered from the sun and the rain), direction and force (0-12) of the wind, direction whence coming of the clouds, amount (0-9) of sea-disturbance, and weather (Beaufort's notation). For further particulars the "Instructions for making Meteorological Observations, prepared for use in China," published in 1883 by the writer, may be consulted.

From 4 a.m. to 10 a.m. the barometer is rising, falling from 10 a.m. to 4 p.m., rising from 4 p.m. to 10 p.m., and falling from 10 p.m. to 4 a.m. It reads highest at 10 a.m. and lowest at 4 p.m. During the approach of a typhoon this regular daily variation may be masked, but it goes on all the same, and must be taken into account when the barometer begins to fall before a typhoon. Thus if it has fallen a certain amount between 10 a.m. and 4 p.m. you must subtract the normal descent between these hours in order to know how much of the fall is due to the approach of the typhoon, and if it were between 4 p.m. and 10 p.m. that it fell, you must add the normal rise for the same purpose.

In many typhoons, the barometer, reduced to 32° Fahrenheit, and to sea-level, does not fall below 28·80 inches. In others it falls as low as 28·50. Lower readings of the barometer appear to be rare, but it has been stated to have fallen much lower. The rate at which your barometer is falling depends upon your approach to the contre, and in consequence upon the rate at which this is travelling. For this reason it is not safe to draw conclusions concerning the amount of wind to be expected from the rate at which the barometer is falling, but to some extent, of course, this may be done. Remember, that, when the barometer has fallen to its lowest reading and begins to rise, you may expect to experience as much bad weather as you have already gone through.

The wind blows from a region where the barometric pressure is higher, towards one where it is lower, being, however, deflected towards the right in a typhoon, and the force of the wind depends upon the difference of pressure between one place and another situated in the direction of the greatest barometric slope or gradient. This is expressed in hundredths of an inch per fifteen nautical miles. Now, the gradient corresponding to a certain force of the wind is somewhat uncertain, particularly when the force of the wind exceeds a whole gale, but on an average a gradient of 0·02 inches in 15 miles corresponds to a force of wind equal to 6 on Beaufort's scale, 0·03 to 7, 0·04 to 8, 0·05 to 9, 0·07 to 10, 0·10 to 11, and where the gradient is above a tenth of an inch in fifteen miles it generally blows with full typhoon force. In low latitudes the gradient occasionally exceeds one inch in fifteen miles.

Curved lines drawn on a map through the places from which the same height of the barometer (reduced) is reported, or between those that report a higher and a lower barometer, are called isobars. The gradient lies at a right angle to the isobar. These are the most important elements in forecasting the weather. Thus during the south-west monsoon the barometer as a rule reads higher over Luzon than along the China coast, the gradient being directed from about south-east towards north-west, indicating southerly winds as prevailing over the China Sea according to the 12-point rule. But when, as occasionally happens in the typhoon season during the south-west monsoon, readings reported from stations along the south-eastern coast of China are higher than those reported from Luzon, the gradient is found to be reversed, being directed towards south-east, thus indicating northerly winds. At such times a typhoon may be expected, and the probability is increased if the barometer is falling in Luzon and rising slowly in Northern China and Japan, and if cirrus clouds have previously been observed to come up from east or north.



Principal Typhoons of 1884 and 1885.

III. Nearly all the typhoons appear to have their origin east or south-east of the Philippine Archipelago, in a part of the ocean south of the high-pressure area that covers the Northern Pacific in the summer season, which part of the ocean is characterised by high sea-surface temperature. Typhoons are sometimes formed in the China Sea, but then they seldom develop much energy, as they usually move quickly northwards and enter the mainland of China or Formosa. Owing to their small dimensions they are easily avoided by such ships as may fall in with them. The sea-disturbance is nothing terrible, and only whole gales of wind were reported in those cases that have been investigated here. If, however, a typhoon of this kind passes northwards up through the Formosa Channel, it soon becomes as formidable as any of those that originate in the tropical Pacific. We have not traced typhoons nearer to the equater than about 9°. But it appears that they may possibly in some cases originate nearer than that to the equator, as hurricanes have been encountered in a lower latitude.

It frequently happens that a vessel encountering a typhoon in, say, 12° north latitude and 135° longitude east of Greenwich, does not experience any strong wind or bad weather till within a hundred miles or so of the centre, and as the typhoons are most violent in that locality, it is very important to look out for the premonitory signs referred to in the first section of this article, taking into account that the dimensions of a typhoon are so small there. On the other hand, they move at so slow a rate that you may run away from them if you are aware of the danger in time, so much more as you may be sure that a typhoon in that locality is directing its course to somewhere about west-north-west or north-west, and most likely in the first-named direction. So it is better to get to the eastward of it. Nearer the Philippine Archipelago the typhoons usually take a more northerly course, moving north-west or north-north-westward. But frequently they continue their course west-north-westward and cross the islands to enter the China Sea. In spring and autumn they have even been found to move westward and turn south-westward after entering the China Sea. But when you are east of the Philippines you should try to get your ship south-east of the typhoon by crossing the path behind the centre, if possible. If you are going northwards, you will then benefit by the fresh south or south-west breezes, taking care not to approach too near to the typhoon, whose progressive motion may not be more than six miles an hour. You will probably have squally and wet weather.

When all the paths of the typhoons that have been investigated by the writer in the course of the last three years are laid down on a map of the Far East, the picture looks much like a fan, the paths, with a few stray exceptions, radiating from the locality referred to above, and running in all directions between west and north, but most of them at first westward and then north-westward. In a higher latitude they generally recurve and pass off to the north-east, after first, of course, having turned northwards. Every typhoon does not recurve; in fact, as stated above, some of them finally disappear in the China Sea after turning to the south-west. The others recurve betwen 20° and 40° latitude, and 115° and 130° longitude. The Middle Dog Lighthouse is situated in the centre of the region of recurvature.

The normal path is therefore, roughly speaking, a parabola, whose axis lies from east to west, and whose apex is turned westward and lies within the region indicated above. But each path individually is anything but a regular parabola, and the deviations are evidently due to the influence of the coast-line of the mainland of Asia and to the mountainous islands (especially the high mountains of Formosa) as well as to the prevailing winds. For there is no doubt that the progression of a typhoon is the effect of the wind prevailing at the time, not necessarily at the surface of the earth, but at a somewhat higher level in the atmosphere, which agrees with the direction of the clouds, that have, as explained in the first section of this article, been found to move nearly straight towards the centre in the posterior semicircle. If, however, the wind at the surface of the earth is strong, it is at times plainly seen to blow the typhoon before it. The typhoons do not appear to move south-westward in the China Sea except when the north-east monsoon is strong, and in the summer of 1885, when the south-west monsoon was strong, most of the typhoons moved northwards while yet to the east of Formosa. This is then the reason why the typhoons depend upon the season of the year. They are likewise deflected from their previous path when exposed to strong winds blowing out of open channels, such as the Formosa or Corea Channels, in which case the speed of their progress is sometimes abruptly increased.

The average rate of progress of the centre of a typhoon in 11° latitude is 5 miles an hour. In 13° it is 6½, in 15° it is 8, in 20° it is 9, in 25° it is 11, in 30° it is 14, and in 32½° latitude it is 17 miles an hour. The rate of progress does not vary perceptibly in case of typhoons south of 13° latitude, so it is well for masters of vessels to know this, but it is more variable the farther north you go. In 32½° latitude it ranges between 6 and 36 miles an hour, so that you cannot at all be sure that a typhoon, which you may happen to be near, will travel at anything like the average rate of progress in that latitude.

In "Observations and Researches made at the Hong Kong Observatory in the year 1884," the writer suggested the division of typhoons into four classes according to the paths which they usually follow. Of course abnormal instances, such as for instance are presented by the typhoons that originate in the China Sea, occur occasionally in China as well as elsewhere, but they are comparatively rare.

Typhoons of the first class occur at the beginning and the end of the typhoon season. They cross the China Sea and travel either in a west-north-westerly direction from the neighbourhood of Luzon towards Tonquin, passing south of or crossing the Island of Hainan, or, if pressure is high over Annam, they travel first westward and subsequently south-westward. They can generally be followed for between five and six days.

Typhoons of the second class are the most frequently encountered, and their paths can be traced farthest. They generally travel north-westward while in the neighbourhood of Luzon, and either strike the coast of China south of the Formosa Channel, in which case they as a rule abruptly lose the character of a tropical hurricane, recurve in the interior of China, re-enter the sea somewhere between Shanghai and Chefoo (thereby regaining some of their past violence), pass across or near to Corea, and are finally lost sight of in their motion towards about east-north-east; or they pass up through the Formosa Channel, recurve towards north-east, and pass along the coasts of Japan; or they may strike the coast of China north of Formosa. Typhoons following the latter path originate further east of the Philippines than the others. They either continue their motion north-westward, in which case they are soon lost, or recurve and pass north-eastward near Corea. Typhoons of the second class occur from June to September inclusive, but are most common in August and September. It appears that a third of the typhoons belong to this class. They can be followed on an average 7 days, or rather between 5 and 12 days.

Typhoons of the third class are probably the most numerous of all, but are not encountered so frequently as the typhoons of the second class, and therefore the existence of a typhoon of this class is sometimes only suspected, although it of course influences the weather along the eastern coast of China through the fine weather area with which it is surrounded. They pass to the east of Formosa, travelling northwards. After recurving, they generally pass near Japan, but sometimes a typhoon of this class continues to move north-north-westward and does not recurve till west of Corea. They prevail in the same season as typhoons of the second class, and may be traced on an average during 7 days, or more correctly between 3 and 12 days. A typhoon of this class frequently follows after one of the second class. It is a well-known fact that depressions are attracted towards places which have just been traversed by a depression.

Typhoons of the fourth class pass south of Luzon, travelling westward, or first in this direction and then south-westward. They occur at the beginning and the end of the typhoon season, while the north-east monsoon is strong, namely in April and late in autumn, but are very rare. They are said to be more violent in autumn than in spring. Existing in so low a latitude, their dimensions are, of course, very limited. The writer has not been able to follow them for more than a day or two.

The number of typhoons that are known to have occurred in each month of the year, expressed in percentages of the total number of typhoons, is as follows:—January 2, February 0, March 2, April 2, May 5, June 5, July 10, August 19, September 27, October 16, November 8, and December 3. These figures prove that typhoons are most frequent during the month of September, but they also show that, strictly speaking, there scarcely exists a well-marked typhoon season. On an average there are 15 typhoons every year, but typhoons in different years exhibit some variations.

IV. The writer on his arrival in the colony in 1883 found that meteorological observations were received from a few of the Treaty ports, &c., and were published in the local papers; and seeing that these returns would only have to be corrected and reduced, as well as slightly extended, in order to be of great value to the shipping, he took upon himself to effect this. Subsequently, as the official work of the Observatory was fully started, he would have had to give up this purpose had not the Government decided to support it. Thus originated the *China Coast Meteorological Register*, which is published daily from here. It contains, at present, observations of the principal meteorological elements, which are received through the co-operation of the great telegraph companies from Manilla, Bolinao (Luzon), Haiphong, Hong Kong, Amoy, Foochow, Shanghai, Nagasaki, and Vladivostock, but the number of the stations might with advantage be extended. It gives also information about the weather prevailing in the Far East, and more or less rough intimations concerning such typhoons as happen to be indicated by the telegraphic returns, as well as by local observations. Subsequently more or less extensive monthly meteorological returns are received from about fifty land stations in the Far East, and the examination of the log-books of ships calling at this port, as well as observations received from commanders of men-of-war and masters of vessels trading in these seas, furnish a perhaps unequalled amount of material for scientific discussion, the results of which, as far as they go, are from time to time published in the *Government Gazette*. But no funds are available for this work, the Observatory being supposed to make and investigate only local observations, and with reference to weather-intelligence to warn the colony of storms by which it may be threatened, as far as may be possible through local observations. Some distinguished individuals having the welfare of the colony at heart would gladly see the little Observatory extended into a Meteorological Office for the Far East, for which it would be so peculiarly adapted owing to its central position, extensive telegraphic connections, &c.; but where the money is to come from has not yet been suggested. The Meteorological Office in London is allowed over ninety thousand dollars a year. The area in question is considerably larger than the area covered by the United Kingdom. The annual cost of the local Observatory was estimated to begin at ten thousand dollars, and it was remarked that additional clerical help would certainly be needed if it were resolved to undertake a thorough investigation of the monsoons of the China Sea. But actually only about six thousand dollars a year are expended in connection with the Hong Kong Observatory.

The Colony itself is warned by means of the *typhoon gun*, placed at the foot of the mast for hoisting signals beside the time-ball tower. It is fired one round whenever a strong gale of wind is expected here, and two rounds whenever the wind is expected to blow with typhoon force. It will be fired again, if possible, when the wind is likely to suddenly shift round. In 1885 it was fired also as a mail gun, but this practice has been discontinued, and as long as the typhoon gun is not fired in future, one may be sure that no typhoon is expected here. During the approach of a typhoon, and at other times when it appears desirable, special messages are telegraphed from the Observatory to be distributed in Hong Kong in such manner as the Government may from time to time see fit to direct, but as soon as they are issued from here the writer's responsibility in the matter ceases. This arrangement will, however, be found to be of very little use until the Observatory is placed in direct communication with the telegraph offices in Hong Kong, as the connections between the police stations generally break down in bad weather, when there is no boat-communication with the other side of the harbour, and thus the colony may expect that communication with the Observatory will sometimes be interrupted just at such times when the intelligence issued from here would be particularly useful. As soon as direct communication with the telegraph offices is established, the daily returns from the Treaty ports will be telegraphed across the harbour, and the *China Coast Meteorological Register* can then be issued at an early hour, by which its utility will be very much increased.

In the course of the summer of 1884 the writer invented and started a system of *meteorological signals*, which continue to be hoisted on the mast beside the time-ball tower at Tsim-sha-tsui. As these signals could not be hoisted without friendly co-operation with the officials of foreign Governments, they are, of course, unofficial, using this word in the sense in which it is understood by scientific men. The utility of these signals is confined to the shipping and to those interested in ships about to leave the harbour, or out in the China Sea. *The colony itself is warned by means of the typhoon gun.*

A red drum is hoisted to indicated the existence of a typhoon felt in the China Sea in a longitude more easterly than the colony. Steamers, if bound for northern, western, or southern ports, should lose no time in starting, and may then expect more or less fine weather. Those bound for the Philippines should take precautions to avoid the typhoon, and observe the rules set forth in the first section of this article. Sailing-vessels bound for western or southern ports should lose no time in starting, but those that are bound for northern or eastern ports ought to remain in the harbour awaiting further information, as they may expect to fall in with calms or contrary breezes after starting, even should the wind be westerly here at the time. The day after the drum has been hoisted the *China Coast Meteorological Register* should be consulted, taking into account that typhoons east and south east of Hong Kong generally travel at the rate of from six to fourteen miles an hour.

A red cone pointing upwards indicates that a typhoon exists in a latitude more northern than the colony, or that it is progressing towards the north. More or less persistent south-west winds, at times accompanied by thunderstorms, may then be expected, and ships leaving the harbour are not at all likely to run any risk from the typhoon. Sailing-vessels bound for the north should start as soon as convenient, so as to benefit by the favourable breeze to run through the Formosa Channel and avoid the way round Formosa. By following the latter route a sailing-vessel, moreover, runs the risk of encountering the next typhoon east of Formosa, particularly during the months of August and September.

A red cone pointing downwards indicates that a typhoon exists in a latitude more southern than the colony, or that it is progressing towards the south. As such a typhoon is likely to travel in a northerly direction, ships desirous of avoiding bad weather should await further instructions, or remain in port till the barometer begins to rise. Then the danger is past.

A red ball indicates that the typhoon exists in a longitude more westerly than the colony. Ships starting for northern, eastern, or southern ports may expect breezes from east round by south to south-west. Those starting for western ports run no risk as long as the barometer is rising. If it should happen to fall, they may heave-to, and subsequently, if necessary, take refuge in some typhoon anchorage, such as St. John's harbour, but this will rarely occur. If a vessel in the Formosa Channel experiences an increasing south-westerly gale and a falling barometer, the typhoon has very likely recurved. All you have to do in that case is to lie-to, when the weather will quickly improve, and you may expect a pleasant voyage.

V. As the typhoons during their entire course are nearly always moving northwards, or rather into a higher latitude, a ship situated in the southern semicircle is on the whole in a safer position than north of the centre. East of Luzon typhoons move west-north-westward, or thereabout, and a ship must shape its course so as to reach the quadrant south-east of the centre. As a general rule, they move north-westward in that part of the China Sea between Hong Kong, Luzon, and Formosa, and east of the latter island they generally travel in some direction between north-west and north. So your vessel is safest when south of the centre, where you must heave-to till the weather improves, particularly if bound for one of the northern ports. If bound for the south, you may run across the path in front of the centre with the north-westerly breeze, but if you are not in time you may lose your boats and sustain other damage.

About 30° latitude, between China and Japan, you are liable to fall in with a typhoon travelling in any direction between west-north-west, north, and east-north-east. Here you are as a rule safest when south of the centre, but if the typhoon is travelling north-eastward this is in the dangerous semicircle. However, the investigations of the writer, though he has paid less attention to typhoons near Japan than elsewhere, nevertheless indicate with some degree of probability that the wind is less incurving behind the centre in that locality than elsewhere. North of this latitude you would of course prefer to be west of the centre.

Suppose that after leaving Singapore bound for Hong Kong the south-west monsoon begins to blow fresher and the barometer to fall, and you suspect that a typhoon is raging in a latitude more northern than where you are at present (the phenomena mentioned would not necessarily indicate the existence of a typhoon, if they were not accompanied with some of the other signs enumerated in the first section of this article), you will, of course, set your course to the east in order to sail round the typhoon and benefit by the south-easterly backing to east winds which you may expect to fall in with; but if the season is late in the year, you had better assure yourself that the typhoon is not travelling south-westward, in which case you might possibly be overtaken by the centre. These typhoons are often the cause of high seas even in the Gulf of Siam; but as their progressive motion is usually rather slow, you may heave-to in order to make observations without losing ground perceptibly. Supposing a typhoon in the China Sea does not make itself felt till you have reached a higher latitude, and that it is passing westward in a latitude south of your ship; being in the dangerous semicircle, where the wind is, moreover, stronger than south of the centre, you may have to cross the path in front of the centre to arrive in the anterior left-hand quadrant; or, if the typhoon is yet distant, the wind light, and your ship thoroughly sea-worthy and in good trim, you may possibly put her on the port tack and run north-eastward, but be ready to change the tack as soon as it becomes advisable.

Many of the anchorages along the south-eastern coast of China and the south-western coast of Formosa afford excellent shelter against north-east winds, but would prove to be much worse than the open sea during a heavy southerly gale. If you observe a northerly gale and a falling barometer, by far the surest signs of an approaching typhoon, and appearances are rapidly getting worse, then occasions may possibly occur when you may be under the dire necessity of running southwards with the northerly gale, against the rules laid down by meteorologists, and bring your ship into a most dangerous position in front of the centre. But you may happen to be better off there after gaining ample sea-room, than in the snug anchorage, where your vessel would be smashed against the rocks as soon as she began to drag her anchors when the storm burst upon her from the south, although the south-west storms experienced along the south-eastern coast of China during a typhoon that enters the mainland are as a rule less violent or protracted than the preceding storm from the north.

Suppose that after leaving Hong Kong bound for a northern port you were to ascertain the existence of a typhoon about to cross your course in front of your vessel, and you experience, say, a strong breeze from the west-north-west. If you do not alter your course, you may, from the fact of its subsequently appearing to be a hanging gale and seeing the mercury falling in the barometer, draw the erroneous conclusion that you are on the path of the centre of a typhoon coming down on you from the east-north-east. In such a case it does not appear to be advisable to scud before the wind, it being decidedly wiser to heave-to. Then if the gale is observed to begin to back towards south-west, you may run southwards and shape your course so as to sail round the typhoon. Masters of steamers leaving Hong Kong while the red drum is hoisted generally lose no time in running southwards as soon as the typhoon is observed to have taken a north-western course, and suffer very little delay in consequence.

Steamers bound for Shanghai are, while between Foochow and Ningpo, liable to experience the northerly gales that precede a typhoon of the second class travelling north-westward and about to strike the coast in that locality. Not wishing to expose their ships to the high cross seas round northern Formosa, the masters generally take them into the nearest typhoon harbour in order to wait till the centre has entered the mainland, and then run northwards with the southerly gale.

These few examples will be sufficient, the more so as the further consideration of the subject would lead into details with which the writer is not familiar, being possessed of no further knowledge of navigation than the little that can be gleaned from the inspection of log-books and from occasional conversations with masters of vessels of many years' standing. The writer has invariably found these gentlemen ready to recount their experiences and to communicate any information, as soon as they found that it was required for scientific purposes exclusively. The master of a vessel, after encountering a severe typhoon, has often to undergo the vexation of seeing every manœuvre of his subjected to the comments of those unaware of the hundreds of things he has to take into consideration besides the law of storms, and who were comfortably ensconced in their houses while he was experiencing the typhoon with its fierce gusts, interrupted by the, if possible, more ominous lulls, during which he cannot see three ship's lengths before him, the mountainous waves in which his good ship is but a "cock-boat," the loudest shouting inaudible, drowned in the roar of the tempest, boats and everything movable having been washed overboard, rudder gone, and perhaps one of the masts thumping at her bottom, while the seas threaten at every moment to swamp the ship.

VI. The origin of a typhoon is not quite understood, but appears to be connected with an abnormally high temperature and humidity in some place in comparison with the neighbourhood. Over such a place the hot air expands, ascends, and is thereby cooled. But the heat liberated by the consequent condensation of water-vapour retards the rate at which it cools on rising in the atmosphere, and enables it to rise still further. When the air has risen to a high level, it effects there an increase of barometric pressure, in consequence of which the upper air is set in motion out towards the circumference of the area in question. Thus a fall in the barometer at the surface of the sea in the middle of the hot and damp region is effected, and the surrounding air is impelled in towards the centre. The motions inwards at the surface of the sea, and outwards at a high atmospheric level, are, of course, contemporaneous, and one is assisted by the other. But air in motion is deflected towards the right in the northern hemisphere, owing to the rotation of the earth, except at or very near the equator; whence typhoons do not exist in that locality, for if the wind continues to blow into the depression it is soon filled up. Owing to its deflection towards the right, the wind is caused to move in a curved path in towards the centre, and the centrifugal force, developed in the curvilinear motion, deflects it still further from the straight line leading into the centre. The friction between the wind and the greatly disturbed sea-surface likewise retards the entrance of the air at the sea-surface into the central parts of the depression. But the air at a higher level in the atmosphere is subject to little friction, and escapes therefore at a greater speed from the central high-pressure area at that level. It is, therefore, apparent that once a cyclonal motion is started under circumstances favourable for its continuation, it tends to increase and to spread outwards.

There is, however, this important difference between a typhoon and a tornado, that the latter is taller than it is broad, whereas a typhoon perhaps does not reach above an altitude of four miles, while its horizontal diameter may amount to upwards of a thousand miles. Moreover, it is not at all likely that the centre at a higher level lies vertically above the central calm at the earth's surface, or even that the centres at different altitudes are situated in a straight line. We are, therefore, scarcely entitled to speak of an axis in a typhoon.

The spirals described by the air particles approaching the centre in a typhoon are known as logarithmic spirals, but unless a typhoon is stationary, which is perhaps never the case in Nature, new portions of air are constantly set in motion in front of the centre and others left behind by the typhoon.

As already remarked, the progressive motion of typhoons is evidently caused by the wind prevailing, if not at the surface of the earth, at any rate at a higher level. That the principal part of the disturbance is situated high above the surface of the earth is proved by the fact that the centres of typhoons pass across mountains several thousand feet high, and also by the circumstance that the difference between the temperature at the Hong Kong Observatory and at Victoria Peak is not perceptibly affected by the approach of a typhoon, for we cannot very well assume that the temperature of a vertical column of air is lower near the centre than outside the cyclone. The mountains referred to are situated on islands, and while crossing them the typhoon derives its store of water-vapour from the surrounding sea, for as soon as the centre has entered the coast, and is on all sides surrounded by dry land, it ceases to exist as a tropical storm, and can only be traced in the registers through a slight fall in the barometer, a freshening of the wind, perhaps amounting to a moderate gale at stations crossed by the centre, and wet weather. Inland in China the bull's eye of a typhoon does not appear to be observed.

As the wind blows more straight into the centre the nearer the equator you are, it follows that more air enters the typhoon from the southern semicircle than from the northern, and this is one of the reasons why typhoons nearly always move in a northerly direction. Moreover, the difference increases together with the dimension of the typhoons, which explains why they expand and accelerate their progressive motion at the same time.

The foregoing observations contain the principal practical results of investigations of about forty typhoons, continued during a period of three years. The mariner into whose hands this article may fall is advised to determine for himself the direction in which the centre of a typhoon, which he is experiencing, is travelling; for although typhoons of the classes enumerated are by far the most common, he never can be quite sure that he has not to do with an exceptional case, and quite possibly a case that is not found among the forty typhoons referred to above. By the time that we shall be in possession of full and trustworthy investigations of a couple of hundred typhoons, we may expect to have complete lists of the sub-classes of the four classes of typhoons, and to be better acquainted with cases of rare occurrence, for, after all, the typhoons are of a simpler construction and their paths more regular than is the case with storms in Europe. Typhoons are so violent near their centre that the whole disturbance is evidently ruled thereby, whereas storms in the North Atlantic and in Europe appear to be made up of a lot of local eddies, some of which are by degrees detached from the chief disturbance and form subsidiary depressions. The writer has not been able to ascertain the existence of a subsidiary depression in the China Seas during the last three years, and it is therefore doubtful whether such ever occur.

A great advance in our knowledge of typhoons in the China Sea will no doubt follow on the construction of a lighthouse on the dangerous Pratas Shoal, such as has for many years been talked about. Our storm-warnings would gain still more in value, and the cost of construction need not exceed the loss caused by a single disastrous typhoon.

EARTHQUAKE IN SIERRA LEONE

THE following correspondence has been forwarded for publication by Mr. R. H. Scott, F.R.S., Secretary, Meteorological Office :—

Government House, Sierra Leone, October 29, 1886

SIR,—I have the honour to transmit a copy of a communication received from Mr. J. M. Metzger, Manager of the Western District, in which he reports that an earthquake was felt at Sennehoo, in the Bompeh River, about the middle of last month.

(2) In the third and fourth paragraphs of his letter, Mr. Metzger draws attention to the fact that the shock in question was almost simultaneous with those experienced in other quarters of the globe, and that the latitude of the Bompeh District is within a few degrees of Charleston, America, where their effects lately proved so disastrous.

I have, &c.,

(Signed) J. S. HAY,
Administrator-in-Chief

The Right Hon. Edward Stanhope, M.P.,
&c., &c., &c.

I HAVE the honour to state, for the information of His Excellency the Administrator-in-Chief, that on the return of the District boat from the Bompeh River on the 16th inst., the coxswain reported that he had been informed at Sennehoo that about the middle of last month an earthquake was felt at that place and in the upper parts of the country; in consequence of which, many of the natives, who interpreted the event as prognostic of coming war, hastened down to the water-side to procure arms and powder in preparation for hostilities, which they regarded as imminent.

(2) The shock is said to have been continuous, accompanied with a rumbling noise as of some heavy-laden cart being moved along, resulting in the cracking and falling down of the mud plaster on the walls of the houses at Sennehoo. What happened in the upper parts of the country is, of course, not known, but the force must have been sufficiently severe to impress the people and influence them as they appeared to have been.

(3) It is remarkable that these vibrations, which seemed to have been extensive throughout the Bompeh District, and which seemed to have been so distinct, are almost simultaneous with those experienced in some places in the Mediterranean Sea, in Greece, and notably at Charleston, on the Atlantic coast of America, where their effects were so disastrous.

(4) The Bompeh, like the Ribbee and Cockborough Rivers, runs into Yawry Bay, which is an arm of the Atlantic, and the Bompeh District, on the eastern side of this ocean, is opposite to, and not many degrees of latitude below, the scene of the late disasters in America.

(5) I think it my duty to make this communication, as the information might possibly be of use to scientists engaged in the study of the facts connected with the range and transmission of these seismic disturbances.

(Signed) JOS. M. METZGER, Manager

Kent, Western District, October 20, 1886

SCIENTIFIC SERIALS

American Journal of Science, November.—The higher oxides of copper, by Thomas B. Osborne. The oxides here dealt with are copper dioxide and copper sesquioxide; but being unable to continue the subject, at least for some time, the author publishes the incomplete results so far obtained, in the hope that they may be of use to others wishing to continue this line of investigation. —The structure of the Triassic formation of the Connecticut Valley, by William Morris Davis. It is shown that disturbance has taken place after the period of deposition; that it was not caused by overflow or intrusion of trap-sheets; that it was not a simple monoclinal tilting; and that there is evidence for occurrence of unseen faults. The probable character of the disturbing force, its action on the fundamental schists, with consequent monoclinal faulting of overlying Triassic strata, and generally the area and depth of the disturbance, are questions also discussed in this elaborate paper.—Researches on the lithia micas, by F. W. Clarke. Descriptions and exhaustive analyses are given of the lepidolites of Rumford, Hebron, Auburn, and other parts of Maine, and of the iron-lithia micas of Rockfort granite-quarries near Cape Ann, Massachusetts.—The thickness of the ice in North-Eastern Pennsylvania during the Glacial epoch, by John C. Branner. So far from rising only 2200 feet above sea-level, as hitherto supposed, the ice is shown to have covered the twin peaks of Elk Mountain (2700 and 2575 feet), and no doubt also the Sugar Loaf, Ararat, and the other loftiest summits of this region during the Glacial epoch. A sheet of ice 1500 feet or less in thickness could never have flowed across such a mountainous region, so regardless as the great glacier was of its marked topographical features.—On the time of contact between the hammer and string in a piano, by Charles K. Wead. Owing to the uncertainty attending the theory developed by Helmholtz regarding the action of the hammer on a piano-string, the author has attempted to measure directly the time of contact by a simple process with results here tabulated.—Photographic determinations of stellar positions, by B. A. Gould. This is a reprint of the paper presented at the late Buffalo meeting of the American Association, and containing a brief history of stellar photography, and of the results so far obtained by the author in this department of practical astronomy.—Lucasite, a new variety of vermiculite, by Thomas M. Chatard. A description and full analysis is given of this substance, specimens of which have been found associated with corundum at Corundum Hill, Macon County, North Carolina. It has been named lucasite in honour of Dr. H. S. Lucas, so well known in connection with the Chester emery mine, Massachusetts.—Crystallographic notes, by W. G. Brown. An account is given of certain artificial copper crystals, of artificial crystallised cuprous oxide (cuprite), and of crystallised lead carbonate (cerussite) found under circumstances here described.—On the chemical composition of ralstonite, by S. L. Penfield and D. N. Harper. A comparative table is given of the analyses made by Nordenskjöld, Penfield, and Brandle of this rare mineral, which was found associated with thomsenolite at Arksuk Fjord, Greenland. —Analyses of the thomsenolite by the same chemists.—Mineralogical notes, by Edward S. Dana. Descriptive analyses are given of columbite from Standish, Maine, of diaspore from Newlin, Pennsylvania, of zincite from Stirling Hill, New Jersey, and of some native sulphur from Rabbit Hollow, Nevada, interesting because of its complex crystalline form.

Rivista Scientifico-Industriale, October.—On the cause of the magnetic rotatory polarisation, by Prof. Augusto Righi. Fresnel's hypothesis having been proved inadequate by recent experiment, the author has resumed the subject, with the view of ascertaining whether it may be explained by the reflected or transmitted vibrations of bodies endowed with rotatory power. If the incident polarised ray on penetrating a body is really decomposed into two inverse circular rays endowed with different velocities, the intensity of the two rays must also vary both in the reflected and transmitted light. The ray possessing greatest velocity of propagation, and consequently a lower index of refraction, must possess least intensity in the reflected and greatest in the transmitted light, assuming the two indices to be greater than unity, as in the opposite case the result would be reversed. Hence both the reflected and transmitted ray will become elliptical; and Prof. Righi has succeeded in determining this ellipticity by employing iron, the body endowed with the greatest rotatory power. The elliptical vibration of the reflected ray is in the opposite direction to that of the magnetising current, while that of the transmitted ray is in the same direction. In a future communication it will be shown that this agrees with the hypothesis of double circular refraction.—On the tests of fatty substances, and especially of olive oil, by Professors G. B. Bizio and L. Gabba. This paper contains a critical inquiry into the methods of testing the purity especially of olive oil, and it concludes that none of the processes now in use are absolutely trustworthy. Even that of Bechi fails to distinguish with certainty between olive and cotton oil.