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REPORT

OF THE

COMMITTEE OF INQUIRY

ON THE

COLABA OBSERVATORY.

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REPORT

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COLABA OBSERVATORY.

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From the letter of Lieut.-Colonel Marriott, Secretary to Government (No. 548 of 1864), dated 28th July 1864, it appears that the following are the points on which Government especially desires to be informed:—

"1*st*—The purposes intended by the present operations of the Observatory;

"2*nd*—The degree of accuracy with which the present purposes are fulfilled, including under this head a particular report on the state of the instruments;

"And, 3*rd*—The improvements which are needed, and the extension of the Observatory operations which is desirable, both generally and also with due regard to the class of this Observatory and the resources of the Government."

2. The purposes intended by the present operations of the Observatory are briefly as follows:—

Purposes of the present operations in the different departments.

(1) To keep and give the exact mean time to the extensive shipping in the harbour, to rate ships' chronometers, and to make such extra observations of special astronomical phenomena as may be of use to science.

(2) To register the indications of all the instruments measuring the different elements of the weather and climate, for the purposes of science generally, and with special reference to the bearings of meteorology on sanitary science; and to trace the propagation of the changes in the atmosphere from place to place, and the modifications they undergo in transit, with the special object of ultimately giving warning of sudden and violent changes of weather.

(3) To keep a record of the observed times and heights of tide, and to deduce therefrom the formulæ representing their elements at this port, in order to predict these times and heights in future for the use of the shipping.

(4) To observe and record the variations of the elements of terrestrial magnetism at an important intertropical point of the earth's surface, so as, in conjunction with the operations of other Magnetical Observatories, to assist in educing the laws of the phenomena of magnetic force, both for the direct advancement of this science and its application to others.

3. In accordance with these purposes, the present operations of the Observatory naturally subdivide into four departments:—

1. Astronomical,
2. Tidal,
3. Meteorological,
4. Magnetical.

The Astronomical Department.

Early History of the Observatory.

4. From the information the Committee has been able to obtain, it appears that the Honourable East India Company, pleased with the deserved celebrity and important services of their Observatory at Madras, proposed to establish another at Bombay. The present site was accordingly selected and the ground enclosed in 1823. Mr. Curnin was appointed Honourable East India Company's Astronomer at Bombay, and entrusted with the designing and superintendence of the building, which was erected in 1826, and originally consisted of four roomy offices forming the arms of a cross, with a moveable dome occupying the centre. This has since been altered and, with several additions, forms the present residence of the Superintendent and the astronomical office,—the tower for the time-ball occupying the place of the former dome. The Observer's house was at first at some distance, the Observatory being meant to be occupied exclusively by instruments. Mr. Curnin, however, it appears, complained of the quality of the instruments supplied him, and shipped the greater part of them back to England. The Observatory then continued for some time unoccupied. In July 1832 the Geographical Society of Bombay obtained permission to use one of the empty rooms, and in 1835 it was assigned as a dwelling-house to the Elphinstone Professor of Astronomy, and a few instruments were placed at his disposal. The transit instrument was put up in 1840, and this with a sidereal and two mean-time clocks, the one with a mercurial and the other with a wooden-rod pendulum, are the instruments still used for keeping the time.

The Transit Telescope.

5. The transit instrument is of an old pattern, made by Gilbert, and bearing the date '1826,' with small circles, and mounted on stone pillars, and—although a scientific Observer would prefer an instrument of more modern construction with circle and microscopes to

work with—that in the Observatory might serve tolerably for the purpose for which it is required. It ought, however, to be in a more efficient state in respect to its working condition, as regards the cleanness of its axis, definition of the wires, adjustment of the small circles, perfect isolation of the supports, &c.

The Time Ball.

6. For communicating correct time to the shipping there is a time-ball dropped by electricity every day at 1 P. M.; but the position of the ball is unfavourable for being seen from the shipping. The fall or drop of the ball is too short, and in the upper part of the harbour in hazy weather it is not possible to know whether the ball is up or not without the aid of a telescope, and then, just at the critical moment, some ship's rigging may intervene and prevent the time being observed.

Might be removed to a more convenient position.

7. There is no reason, however, why the time-ball should be dropped at the Observatory; a lofty flagstaff on the new ground in the Government Dockyard, or the Castle flagstaff, might be made available for it; —either would be a good position visible from the shipping in every part of the harbour. Connected with the Observatory by a single wire, the ball could be dropped with as much precision as at present; and the time of the evening gun might then be dispensed with.

State of the Electric Battery.

8. The electric part of the apparatus should be in a more efficient state; the plates of the battery were observed to be coated with a deposit of copper; they are occasionally washed with water, but never amalgamated with mercury. The mode of working the whole apparatus, testing the continuity of the current, &c., should be assimilated to the practice followed in England.

Government Chronometers in store.

9. A large number of chronometers (at present 75) belonging to Government are kept in store, and daily rated at an expenditure of labour which seems to be to little purpose. Such a number in store must

be greatly in excess of any probable demand. For those it is necessary to retain a better depository should be provided, for, stored as they now are in presses resting on the wooden flooring of the room, their rate is probably affected by vibration.

Number of Ships' Chronometers rated.

10. From the information afforded at the Observatory it appears that on an average from twenty to thirty private chronometers are rated monthly, or about 350 per annum,—for each of which a fee of Rs. 5 is charged.

Careful supervision of the rating of Chronometers, &c., necessary.

11. It appears to the Committee a matter of the utmost importance that, in a great commercial seaport like Bombay, ships' captains should be able to have their chronometers carefully rated, and that the correct time should be communicated regularly to the shipping in the harbour. And, as the safety of so many lives, as well as of so much wealth, depends to such an extent on the correctness of the indications of these instruments, the Committee are of opinion that the maintenance of correct time, dropping the time-ball, and rating chronometers, should be under the constant and direct superintendence of a skilled European.

Equipment for extra Astronomical Observations.

12. In addition to the instruments already mentioned Government also supplied to the Observatory two good six-feet telescopes, an altitude and azimuth instrument, and some others. As in other similar Observatories, the object of these seems to have been to take observations of comets, the position of the zodical light, and generally for noting such special phenomena as are of interest to science, whilst no additional staff is required to observe and register them.

State of the Instruments, &c.

13. The altitude and azimuth instrument is out of order; the two telescopes deserve more careful keeping; and the stand, at best but a very clumsy wooden affair, is rotten. In the compound there is a small moveable dome ready to receive an instrument.

14. In the published volumes of observations there are very few such extra observations as those referred to recorded. In the volume for 1858 some positions of the great comet of that year are given with the elements computed from them; but, as the errors in the results amount to a whole week in the time of perihelion-passage and 5° or 6° in the inclination of the orbit, there seems to be little reason for putting much trust in the observations themselves. The comets of 1861 and September 1862, owing to their altitude in this latitude, presented very favorable opportunities for making good observations at Colaba, but no notice is taken of them in the published volumes.* Hence it appears that the Observatory has hitherto failed in making extra astronomical observations. This the Committee would attribute chiefly to the Superintendent having hitherto held another office also, which engrossed the greater part of his time and attention.

The Extra Observations few and of no value.

The Tidal Observations.

15. Early in 1845 the Geographical Society of Bombay presented a memorandum to Government recommending the establishment of a system of tidal and meteorological observations to be made at different points on the west coast of India and at Aden, the Society offering 'to take upon itself as many of the details as it could carry through, especially those as to the providing of instruments and furnishing iustructions and forms for the observations.' This scheme was sanctioned by Government, and the

Establishment of the Tidal Observations.

* In the *Bombay Gazette* of 9th September 1862, along with the meteorological observations, purporting to be sent from the Government Observatory at Colaba, there appeared some 'Remarks on the Comet,' with its positions from August 27th to September 4th, said to have been 'taken with a small altitude and azimuth instrument by Gilbert.' On the 13th it was pointed out that nearly the whole of these observations were identical in times and figures with some rough observations published in the same newspaper on the 6th September by a correspondent at Ahmadnagar. No notice is taken of these observations in the volume for 1862, and it must be supposed the communication to the newspaper was made without the Superintendent's knowledge.

plan was afterwards enlarged by the Court of Directors of the Honourable East India Company. The Secretary to the Geographical Society also induced the Lords of the Admiralty, through their Hydrographer, Admiral Beaufort, to aid the scheme by a grant for instruments to the amount of £ 350. Tide-gauges and other instruments were accordingly supplied through the Society, but in 1847 none of the observations promised to the Society had been forwarded, and, partly owing to the supervision of the Society being ignored, but little advantage seems to have been derived from the scheme it had planned and matured. Had it been intelligently carried out the observations would have been of considerable practical value, and must have added to our knowledge of the tides on this coast.

State of the Tide-Gauge.

16. The tide-gauge at Colaba is one of those brought out for the Geographical Society. For some years past it has been subject to frequent derangements, and does not now afford consistent readings. The pipe leading to low water is reported to be much corroded, but this hardly accounts for the irregularities of the register, which appear to be greatest near the time of high water.

Objection to the locality of the Tide-Gauge.

17. The position of the gauge, moreover, is not such as to afford the time and height of the tide in the harbour, and even if accurately registered a subsidiary series of observations would be necessary to make those collected here of practical value. The accuracy of a part of the past observations has been called in question, but their value as a whole can only be determined by a careful scientific discussion of them, a work of very considerable labour. The results of an attempted reduction are given in the end of the volume for 1862, but they do not appear to be of any practical value, and are quite unworthy of publication. Large sums of money are frequently expended on the reduction of such observations in England and

Bombay Geographical Society's Trans., Vol. xvii., Art. 2.

Reduction of the Observations indispensably necessary.

other European countries, and it seems deserving the consideration of Government whether those taken at Colaba—especially when the gauge was in fair order—ought not to be reduced, and so made practically useful. If the results are found to be satisfactory the observations may then be stopped.

Supplementary Tidal Observations required.

18. To render the observations made at Colaba available for the harbour, another tide-gauge might also be employed in a better situation, where a careful set of observations extending over one year would be amply sufficient for determining all the desiderata at that point.

Meteorological Department.

Begun in 1841.

19. The meteorological observations appear to have been commenced in 1841, at the same time with the magnetical.

Meteorological Instruments at present in use.

20. The following are the meteorological instruments now in use at the Observatory:—(1) In the astronomical room there are an Osler's self registering Anemometer and pluviometer, a pair of thermometers, wet and dry bulb by Newman, a Newman's standard barometer, No. 51,* and a Regnault's hygrometer.* (2) In the magnetic observatory are two Newman's standard barometers, Nos. 48 and 58, and, in an adjoining room, the electroscopic apparatus. (3) Outside is a thermometer-stand shaded from the sun, with three pairs of thermometers, dry and moist bulbs. (4) On the tide-gauge house is a self-registering anemometer. (5) In a shed is the standard thermometer by Newman, graduated to tenths of a degree, five thermometers for underground temperature, one of which is broken, and a moist-bulb thermometer; and (6) in the compound there are two rain-gauges.

* Belong to the Medical Board.

Instruments in store.

21. A list of the instruments in store, meteorological, astronomical, and magnetic, will be found in the appendix.

On the Anemometers.

22. On the instruments in use the Committee remark, that the Osler's wind-gauge has never been well suited for registering sudden changes of the wind, which throw the direction-vane out of gear, and the force is also said to be registered unsatisfactorily. The vane is screened from the direct influence of the wind on one side by the tower of the time-ball, and acted on by the eddies of wind produced by the obstructing tower. The observations registered by this instrument since the erection of the tower must thus be regarded as quite untrustworthy, and the labour bestowed on them thrown away. The wind-gauge on the tide-house is too low ever to have afforded any trustworthy results. Its clockwork, being unprotected from the injurious action of damp and dust, is now corroded and unserviceable. There is a Lind's anemometer in store, and a small gauge by Elliot for measuring the velocity of the wind, in good repair, but not mounted for observation.

One efficient Anemometer enough.

23. The labour of attending to more than one wind-gauge should be discontinued, but that one should be of the most approved construction and in thoroughly effective condition, and constant intelligent attention to its working parts should ensure confidence in the results.

See para. 7.

24. The removal of the time-ball to the Dockyard would allow of the wind-gauge being put upon the tower upon which the ball now drops.

Pluviometers.

25. The elevated rain-gauge on the roof of the astronomical office is near the vane of the anemometer, and like it subjected to eddies of wind which will carry light rain over it. The rectangular shape of the opening has also been somewhat injured by the bending in of the sides. From being made of metal and placed on a blackened terrace, it is liable to get heated in sunshine, and consequently to throw off light rains in the form of vapour. The other rain-gauges (Newman's) appear to be in serviceable condition and are used as checks one against another.

26. The electric room adjoins the Magnetic Observatory. It is about ten feet square inside, and fully forty high. It contain a Volta's electrometer with Henly's electroscope, Ronald's spark measurer, and Bennet's gold leaf electroscope—the latter unserviceable and for some time disused. The electrometer is in working order, but is said to show no effect of electricity during the moonsoon. There is another similar spare instrument in store; but the Observatory might with advantage be supplied with some of the more recently invented instruments for indicating the electric condition of the atmosphere, and electrical observations might be regularly made at stated hours, as well as during electric disturbances.

Electroscopic Apparatus.

Bombay Magn. Meteor. Obs. 1858, Int. to Meteor. Obs. page viii.

Want of additional instruments See para. 58.

27. The indications of the barometers are rendered unstrustworthy by the very abundant oxidation of the mercury contained in the cisterns. The surface of the mercury ought always to be kept so clean as to reflect the image of the ivory point by which the adjustment of the scale is made. In the two standards, Nos. 48 and 58, the mercury is oxidized to such an extent that, for years past their indications can scarcely have possessed any scientific value; for it is evident that if the index is set to an accumulation of dust or oxide the readings must necessarily want that accuracy which can, and ought to be attained in any Observatory. The standard No. 51 is not oxidized to the same extent, but it is not free from it, and a quantity of moisture appears on the inside of the tube. The continued registration of instruments in such a condition, it needed scarcely be added, is worse than useless, it is deceptive. The instruments, however, are otherwise good, and might be rendered trustworthy.

State of the Barometers.

28. The dry bulb thermometers seem to be in serviceable condition, but there does not appear to be any system of comparison and verification practised,

Thermometers. See para. 35.

and, as the zero point has a tendency to shift, there is no security for the correctness of the observations of absolute temperature made at the Observatory.

29. The moist bulb thermometers, although sheltered from the sun, are exposed to all the variations of the wind and the observations now made can possess no value while the evaporating surface is ever being placed under different conditions as regards the breeze. The cloth covering the bulbs of some them is crusted with saline matter which must retard the evaporation and affect the accuracy of the indications to a very considerable extent. Besides, the wet bulb thermometer was formerly observed inside the Magnetic Observatory, and the series of observations made before the change and that made after it will not be comparable one with the other. The Regnault's hygrometer is said to have been in the Observatory since 1856, and seems to be in good order.

Hygrometric obervations unsatisfactory. See para. 58.

The series broken.

30. From the preceding it may be inferred that the Committee think the meteorological department might be in a more efficient state. Meteorological observations, though apparently so simple, if they are to be of any real service to science in determining the facts of local temperature, humidity pressure, &c., are not so easily conducted as is generally supposed, and require not only perseverance but considerable scientific intelligence, and the Committee think the observations should be made under the immediate supervision of a European of scientific education.

Skilled superintendence required.

31. Remarks on the printed observations will be made in connection with those of the magnetic department.

See paras. 36, 37, 38, 48.

Magnetical Department.

32. About 1840 it was proposed to establish a Magnetic Ob-

Establishment of the Magnetic Observatory.

servatory at Aden, to be conducted at the expense of the Honourable East India Company, as were also those at Simla and Madras. The arrangements were not completed, however, and the instruments were sent on to Bombay, where, at the suggestion of Colonel Sykes, they were placed in charge of Mr. Orlebar in March 1841, and a building was immediately erected for their reception. Mr. Orlebar expresses the dismay he felt at finding himself "*not* only without guidance as to the nature of the building, but also as to the parts and objects of many of the instruments." Mr. Caldecott, the Superintendent of the Trevandrum Observatory, however, when passing through Bombay, afforded sufficient instructions to enable Mr. Orlebar to commence without farther delay, and Captain Boileau, of Simla, supplied additional aid. Mr. Orlebar had no time, he says*

Bombay Observations 1845, Int. p. ii.

to determine the best arrrangement for the instruments or to obtain guidance from other quarters, and so disposed them at such distances as one large room would most conveniently admit. His 'numerous avocations,' he adds, 'obliged him to give less time than he could have liked to the work', and numerous difficulties 'occurred through his previous ignorance of the instruments and from destitution of assistance.' Early in September 1841, however, the magnetometers were fixed and observations commenced. The Establishment then sanctioned consisted of three non-commissioned officers from the Sappers and Miners, to which Native Assistants were added as required. Respecting one of the European Assis-

Bombay Obser. 1845, Int. p. iii.

Bombay Obser. 1845, Int. p. iv.

tants Mr. Orlebar expressed his fears to Government that his observations might not be trustworthy and applied for his return to his Corps. On afterwards projecting the

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* In 1841 three non-commissioned officers of the Sappers and Miners were employed as observers, and when suitable men can be obtained from regiments serving in the Presidency it might still be of advantage to secure their services.

curves of this man's observations, however, Mr. Orlebar says he could "see distinctly that no deceit had been used." Mr. Orlebar went to England in May 1842, and the observations previously made do not seem ever to have been published. For the next three years the Observatory was under the charge of Dr. Buist, the Secretary to the Geographical Society, and his observations are published in a separate volume. Mr. Orlebar resumed charge in April 1845, and the observations made since then by him and his successors Commanders Montriou and Fergusson have been regularly published *in extenso* at the expense of Government.

Dr. Buist's Observations, 1842-1845.

33. The instrumental equipment of this department is stated to have originally consisted of—

Magnetical Instruments, Bom. Obs., 1845, Int. p. v.

"1 Unifilar Magnetometer,
1 Bifilar Magnetometer,
1 Induction Magnetometer,*
1 Portable Unifilar Magnetometer,
1 Declination Magnetometer."

In 1844 the Honourable Court of Directors sent out in addition three small Declination magnetometers, one small Horizontal Force, and one Induction magnetometer, for the reception of which a small Observatory was erected at the north-east corner of the large one. There are no windows in it, however, and this, together with the indistinct condition of the scales, renders it very difficult to read the instruments. In 1849 a new Vertical Force Magnetometer and a new dip circle were supplied,—the instruments previously in use not having given very satisfactory results. But, whether from defects in the instruments themselves or want of care and skill in the adjustment and manage-

Additional Instruments, &c.

New Balance Magnetometer and Dip Circle.

* There seems to be some mistake in this list of Mr. Orlebar's, as the vertical Force Magnetometer by Robinson is spoken of in the same volume (Int., p. xlix.) though not mentioned in the list, p. v.

ment of them, the indications of the new instruments seem little superior to those of the older ones they were obtained to supercede. The dip circle is not in perfect repair now, and, as well as the other instruments, is not of the most modern and approved construction.

34. The other instruments, however, are such as ought, with proper management, to give fair results. A new Dip Circle, an Absolute Declination Instrument, and perhaps also a new Balance Magnetometer, are required to put this department on a proper footing as to instruments. The instruments in use ought to be kept more free from spider-webs and dust than they seem to be.

Other instruments.

New instruments required at once.

Operations and Results.

35. In order that an Observatory should discharge its duties with the accuracy absolutely necessary to meet the demands of science, which require the greatest possible consistency of instrumental indications, the instruments employed ought not only to be really good ones, but it is as necessary they should be preserved in a state of constant repair and comparability. Now the Committee have no reason to suppose that the instruments originally supplied were of inferior description; but both in meteorology and magnetism, the condition of the instruments requires constant attention and perpetual revision under skilful superintendence in order to preserve them *absolutely* as well as *relatively* correct. Verification there seems to have been none, nor could anyone be trusted to verify even a thermometer, which requires some special scientific knowledge.

Necessity of verification of the instruments both meteorologic and magnetic.

36. But even if made with instruments of the same kind in a state of perfect repair and comparability, and faithfully and skilfully observed, it ought not to be forgotten that the mere registration of instrumen-

The observations should be regularly reduced. See para. 42.

tal readings is of little or no use until the observations are corrected and reduced in order to elicit from them the laws of the results.

Want of trained scientific direction.

37. In the publication of the numerous large volumes of observations made at Colaba too much appears to have been trusted to mere routine. The instruments having been placed in the Observatory and the prescribed regulations followed, it seems to have been taken for granted that the observations should be 'all right,' and that nothing more could be required: no independent mind has been exercised in varying and co-ordinating the observations. Even in the simplest of the researches the Observatory is expected to carry on, the intelligence of the observer should be applied to vary the observations according to the character of the phenomena:—in the words of M. Biot,

M. Biot's opinion.

'The caprices of physical phenomena cannot be regulated by *ordonnances*; none of their laws have been established by rude observations . . . it is necessary to take them by parts with much instinct and nicety, to follow them and disengage them from the mass according as our subtlest judgment may disentangle them.' This exercise of independent intelligence, the Committee need scarcely add, can only be fairly expected from a Superintendent who can devote the whole of his time and attention to the work of the Observatory.

Bombay Observ. 1845, Int. p. lxx.

38. The only attempts at original research hitherto made at Colaba have been singularly unscientific. Professor Orlebar supposed he had discovered that the humidity derived from the cistern and covering of the wet bulb thermometer had so marked an effect upon the reading of the adjacent dry-bulb that the observations of the latter instrument were useless, and accordingly he did not publish them. Mr. J. Allan Broun, of the Trevandrum Observatory, has lately shown the probable source of this error to have been the confusion of Göttingen and Bombay time in the comparison of old observations. Be-

Bombay Geog. Socy.'s Trans. vol. xvii. art. 9.

fore such a result was published, a series of special experiments ought to have been instituted to verify it. Then, again, the whole of the published observations since 1847 have been corrected for a supposed effect of the atmosphere upon the magnetic intensity of the earth. Such an effect has never been detected anywhere else, and yet the correction for it it has been persisted in at the Observatory. Mr. Broun has shewn* very conclusively that the discrepancy to be accounted for arose from an over-correction for temperature, the correction employed being 3·2† instead of about 1·58 small scale divisions. In subsequent volumes this temperature coefficient is reduced to 2·0 small scale divisions, and it is merely stated that the correction alluded to had been *verified*; but it is certain the results must have been widely different with the smaller temperature coefficient.

Over-correction of the observations.

Bombay Geog. Socy's. Trans. Vol. xvii. Art. 10.

39. The rapidity and regularity with which he Bombay Observations have been published could scarcely be exceeded; but if it were desirable to continue the publication in full of all the horary observations, the forms of the registers appear susceptible of very considerable condensation and improvement. For example, in the 7th, 8th and 9th columns of the Magnetical Observations, the Absolute Horizontal, and Vertical Forces, and the Dip are given as computed from the hourly value registered in the preceding columns: these might as well be omitted;—they must cost much labour that might otherwise be better employed. Besides, no other Observatory puts the variations of Absolute Horizontal Force, &c.

The published volumes of observations.

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* Mr. J. A. Broun also points out the error of the supposed effect of solar white-light on the magnets, alluded to in the Bombay Observations 1845, Int. p. iv.; and 1847, p. xxvi.

† This is printed as 0·32 scale divisions in the Observations,—and it may be here remarked that the divisions for *tens* have been all along read as *units*, and those for *units* as *tenths*. A comparison with the observations made at any other Observatory renders this error apparent.

in such forms and they are comparable with nothing; nor it is certain that the coefficients are accurately enough known and that these computed quantities are really what they pretend to be. The Meteorological observations could also be advantageously condensed. Then the collection of arithmetical mean values, which, under the name of "Results" fill so many tables in each volume is unnecessarily extensive—many of the tables being of no use.

Errors in the arithmetical computations and printed observations.

40. In the formation of these tables, the mere arithmetical operations of addition, subtraction, and division have been but carelessly performed,—many of the quantities being in error. Even in forming one table from another frequent errors have occurred, and there is not a single erratum noticed in any of the volumes. It thus becomes very probable that, besides those that may be detected, there are many errors in the printed observations detracting from their value. There seems to have been none of the usual checks employed to secure correctness—no double computation, no verification.

The local *day* should be adopted in the magnetic department.

41. Differing from the practice of all other British Colonial Observatories, that of Colaba has adopted the Göttingen *day* for the Magnetic, and the local day for the Meteorological observations. Hence the former are stopped at 4 P. M. on Saturdays and resumed at the same hour on Sundays, whilst the latter are continued till midnight on Saturdays and resumed at the midnight following. The consequence of this is, that the magnetic observations of Saturday evenings are lost, and those made on Sunday evenings cannot be compared with any made elsewhere in the East, for no other Observatory makes observations on the local Sunday.

Observations if trustworthy, sufficient for laws of short period.

42. If trustworthy, the observations already made should be sufficient, both in meteorology and magnetism, for all laws of short period,—but if not, no amount of observations amassed on the present system, without constant scientific supervision and with instruments the accuracy of whose indications is unknown, will ever be of

Scientific analysis has been neglected. See para. 36.

any value. What is now most urgently required is careful scientific discussion to discover whether all the observations hitherto collected are deserving of confidence or only some of them. It is to be regretted that the analysis of the observations was not carried on *pari passu* with their publication. Very little, however, has been attempted in this way. Graphical projections have indeed been occasionally employed to illustrate the fluctuations of the physical elements of observation, but not with the effect and success this mode of analysing results is capable of. In no case have mathematical formulæ of reduction been applied to any of the sets of observations for the discovery of the laws to which they conform. Thus what is good, bad, or indifferent among the observations is as yet unknown and cannot well be ascertained till some care has been bestowed on the observations and on the instruments with which they have been made.

The secular constants not determined.

43. So little having been done to analyse the observations for establishing the laws of the variations of the elements observed, it need scarcely be remarked that nothing has been attempted in the way of furnishing the *secular constants* of the local meteorology; so that after collecting observations for nearly a quarter of a century we do not yet know the normal data of the climatology of Bombay. Nor need it be added that the many questions science asks in the departments of meteorology and magnetism have been left unanswered,—but which if answered correctly for one station would clear the way for all further researches into *local* climate, &c., and render their solution attainable in surrounding localities at a *minimum* of labour.

The co-officients for the magnetical instruments should be determined before removing them. See para. 39.

44. The constants for the correction and reduction of the magnetical observations cannot be depended on, and it is easy to understand how valueless any series of observations must be where the value of the units employed are unknown. No attempt has been made to find out whether these coeffi-

sients are correctly determined by employing the most accurate methods,—it being well known that the methods in use five and twenty years ago cannot now be depended upon. The Committee would therefore deprecate the hasty rejection or removal of any of the present instruments until these co-efficients have been carefully determined from them, for if not deduced from them as they still are, the value of the masses of observations which have already cost so much to collect and print must still remain doubtful.

Adjustments possibly defective.

45. It is also possible that some of the instruments may not be in such a state of adjustment as to ensure the correctness of their indications. Wherever a pair of instruments measuring the same element give discordant results it is sufficient proof that one, if not both of them, is in error; and so long as this is the case no single result can be depended on, or will be accepted by men of science.

The Observatory has not advanced with the requirements of science.

46. The maintenance of an establishment for magnetical and meteorological purposes should depend upon whether it keeps pace with the times by contributing its share to the advancement of science. Now it must be confessed that the results of the Bombay observations are far from satisfying this demand. No advance has been made since 1848, every detail of observation and mode of reduction then in use being essentially the same up to the present time;—and this has not arisen from any lack of opportunity, since the progress made, especially in magnetism, has rendered necessary considerable extensions and alterations in the old mode of treatment, and the results of the observations of the British Colonial Observatories abundantly testify to the scope afforded for improvement in the modes of reduction and discussion. Though its equipment is somewhat antiquated now, and thus it is no longer able in some respects to take a prominent place among physical observatories of a similar kind, yet where it really has the means it makes no attempt to do so.

Site of the Observatory.

47. Whilst the locality of an observatory that has once been established should not be changed to avoid trifling disadvantages at the expense of consistency in the results, there appear to be sufficient reasons in the case of the Colaba Observatory, for removing it to a better locality if the Government should be willing to bear the expense of new buildings.

Locality might be changed.

48. One objection will appear from the following. It has been the practice from time immemorial to intimate the arrival of each ship off the Port by firing a gun to warn the pilot to go out to her assistance. This gun was formerly placed on a platform in front of the Light-house, near the wall of the Burying-ground. It was considered that the loss of the ships *Lord William Bentinck* and *Lord Castlereagh* in the monsoon of 1840 might have been averted if a gun had been placed farther out on the prong: to prevent a recurrence of such a disaster, this was accordingly done, but it was found to be attended with much inconvenience owing to the distance from the Lighthouse where all the stores and ammunition were kept, and that, during high tides and heavy weather, it was difficult to get out to the gun. A solid platform was then built near the lighthouse and about 220 yards from the observatory, on which two 18-pounder iron guns were mounted, and these were directed to be used to intimate the approach of any ship. Frequent complaints were made from time to time by the officers in charge of the Observatory, that the firing of these guns had an injurious effect on the instruments, till at last Commodore Wellesley, about the year 1859, ordered a gun of smaller calibre with only a half charge of powder to be fired instead, and this gun was placed on a patch of sand near the N.E. corner of the Burying-ground—the muzzle pointing towards the harbour. This has been found sufficient to give warning to the pilots of the approach of ships. Recently, however, heavy Armstrong guns have been mounted on a

Objection to the site on account of the neighbouring guns and battery.

battery in the immediate vicinity of the Observatory: these will, of course, have to be fired from time to time for exercise, and must prove much more injurious to the magnetometers, chronometers, &c., than even the 18-pounders which were at a greater distance. This alone is a very serious objection to the present site of the Observatory.

49. But there is another independent objection:—The present locality of the Observatory is so isolated from the body of the Island of Bombay that it is by no means adapted for directly ascertaining its general meteorological phenomena. It is a matter of common remark that the rain-fall at the Observatory differs considerably from that at any other part of the island where it has been measured; it is known that the tension of vapour on the sea-shore varies considerably from its value even three miles from it; and it may be reasonably inferred that the temperature, direction and force of the wind, and other meteorological phenomena are different here and in the more northerly and central parts of the island. For the purposes of determining the local meteorology therefore—one of the main objects of the Observatory—the Committee think a more central position very desirable,—such, for instance, as Colangee Hill—on which the Parel flagstaff stands, or that on which the Central flagstaff is placed. Either of these would answer,—each has a clear commanding view, there are no batteries or guns in the vicinity, nor is there much traffic to vibrate the instruments, and they are sites everyway more suitable for all departments of the Observatory than the present one. Of course the more easterly of the two is the preferable one.

Close proximity to the sea objectionable.

See British Association Rep. 1859, Trans. p. 44.

Localities suggested.

Improvements and Extension of Operations desirable.

50. In reply to the third point on which Government desires to be informed, the Committee would remark that there can be no

An efficient Observatory much wanted. See para. 11.

doubt that an efficient Observatory is a great desideratum in Bombay, not only for purely scientific purposes, but for the general public good. The necessity of giving the exact time to the valuable shipping in so great a commercial port is of itself an object of so much material importance as to render the Astronomical department of the Observatory indispensably necessary, and this alone would require the services, and ought to be under the direct and constant superintendence of a European well qualified for the duties of his office and who would require a native assistant; and if competent for the conduct of the other departments also and enabled to devote the whole of his attention to the work of the Observatory, a slight addition of observers and computers on very moderate salaries would enable him to continue the operations of the observatory in meteorology and magnetism; and the continuance of the work of these departments, if even on a slightly reduced scale, in connection with the past work and expenditure would be of much importance to science. But it is not to be anticipated that the present Government will fall behind the late Honourable East India Company in its encouragement of science, nor, in its anxiety to develope the material resources of this great empire, will it forget the advantages of sustaining an interest in the higher sources of human happiness, or of assisting to perfect such departments of knowledge as meteorology and magnetism, which have a very important, if indirect, bearing on physical well-being. The British and some of the Colonial governments have taken a strong interest in the advancement of these sciences and extensively patronised them, and the example set by them has been nobly followed by several European Governments.* 'Great physical theories,' says Sir John Herschel in a

A qualified Superintendent of first importance.

The object deserves the attention of Government.

Properly a national object.

* The Observatory of Neuchatel, established not long ago and furnished with the best instruments, had no higher *material* object than that of giving the time to the watchmakers of the Canton. Norway, though a small and poor state, by a unanimous

memorial to H. M.'s Government from the British Association, 'with their trains of practical consequences, are preeminently national objects, whether for glory or for utility.' The opportunity therefore which now exists for establishing the Observatory on a permanent and satisfactory footing, the Committee thinks, ought not to be neglected.

British Association Report for 1839, p. 39.

51. The observations in Terrestrial Magnetism made at Bombay will in one sense be of increased importance in future, owing to the suppression of the Trevandrum Observatory, inasmuch as, when the past labours of the two observatories have been compared, the continued work of one may be considered to some extent as a continuation of the work of the other. Then the value of any station for such observations is directly proportional to its distance from others where observations are also made. Now Trevandrum is within 400 miles of Madras, whilst Madras, is about 650 miles from Bombay, and as Trevandrum is to be given up, it becomes all the more important that the Bombay observations should be continued with improved instrumental means. More might be added, but the Committee do not think it can be necessary to enlarge on this point.

Increasing importance of the Bombay Observations.

52. It seems exceedingly desirable that the masses of observations Tidal, Meteorological, and Magnetical, already accumulated should be discussed without delay so as to make them available for local and

Discussion of the accumulated observations.

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vote of its Storthing defrayed the expense of Hansteen's journey to which we owe his valuable Magnetic observations over Northern Europe and Asia. The generosity of of the Czars has refused nothing to insnre the success of the numerous Meteorological Observatories located over the whole surface of Russia. 'There has been created there a body, an actual army of Meteorographers, having its general, its officers, its soldiers.' Farther, between the years 1860 and 1863 magnetical observatories were equipped with complete sets of instruments of the most approved construction at Batavia, Coimbra, Lisbon, Florence, St. Petersburg, and Philadelphia. And lastly, the British Association and Royal Society have represented to the British Government the desirability of establishing magnetic observatories at Vancouver's Island, Newfoundland, the Falkland Islands, and Pekin.

scientific purposes; and as the current work of the Observatory would probably occupy nearly the whole of the time and attention of the ordinary staff, special provision would require to be made for a portion at least of this work.

Improved provision for rating Chronometers. See para. 11.

53. To render the rating of chronometers as perfect as possible the Committee think it desirable the Observatory should be in a position to perform this important duty according to the most approved methods under regulated conditions of temperature.

Extension of the operations of the Observatory to observations made at outstations.

54. As the important objects of Meteorology can only be attained by a careful analysis of a long series of well conducted observations made at a central observatory, and combining the observations made in different parts of the neighbouring country,—such a central observatory at Bombay should be made a point of reference and comparison and have the superintendence of all observations meteorological or magnetic made by public authority throughout the Presidency, by which they might be rendered available for practical or scientific purposes. And owing to the special character of terrestrial magnetism, the observations at such a primary station are a necessary check on the accuracy and fidelity of those made at every other.

Warning of the approach of storms.

55. The Meteorological Observatory might also be made of important practical use to the shipping if telegraphic communication were established with the ports on the Katch and Koromandal coasts, by which timely warning of cyclones and heavy weather might be afforded.

Observatory might verify intruments and afford directions for observations at outstations.

56 The Observatory ought to be able to stimulate observation among private amateurs. Instruments might be issued, tested, and verified for them at the Observatory, and the observations they made should be studied, compared, and discussed by the superintendent, who might also make it a part of his

duty occasionally to visit out-stations where such observations were carried on—to examine the localities, give directions for the position of the instruments, and afford instructions likely to secure similarity of methods. For want of such superintendence and assistance the greater part of the observations made by amateurs, at hospitals, &c., is altogether valueless,—the observations of one individual seldom being comparable with those of another for the purpose of deducing any trustworthy scientific inference. Monthly reports of the wind, rain, humidity, temperature, and pressure are now forwarded to the Colaba Observatory from Poona, Belgaum, &c., where they are observed by Europeans whose sole duty it is to do so. By the plan suggested these observations would be made available for affording information respecting the local climate, and much of the detail work of the Presidency might be accomplished at little or no additional expense. And this local meteorology might, in this country, be made of considerable practical importance to the State.

Observatory should be able to verify instruments.

57. It ought also to be a part of the duties of the Observatory to verify thermometers and other meteorological instruments for the use of private observers, hospitals, ships' captains &c., for which a small fee might be charged; and records should be kept of all such work done.

Improvements in the meteorological department. See paras, 22—29.

58. There are many important matters connected with meteorology to which an energetic superintendent, if properly assisted, would no doubt direct his attention. Some of these have already been noticed and it may suffice to mention the following here:—

Humidity. See para. 29.

Careful hygrometric observations are of great importance and should be intelligently conducted in circumstances favourable for obtaining reliable results. Daniell's hygrometer as well as the wet bulb thermometer should be used.

The important subject of Radiation is at present neglected,

Radiation.

but requires attention, and the Actinometer should be in regular use.

Wind. See para. 23.

The velocity and azimuth of the wind ought to be registered by a trustworthy instrument properly placed.

Ozonometric and electrical observation. See para. 26.

Ozonometric Observations have not yet been attempted at the Observatory, but ought to be instituted and collected with great care as being of importance to sanitary science: they might be carried on in special connection with improved electrometric observations.

Instruments required for the Magnetical Department.

59. For the Magnetical department, the Committee consider it necessary the Observatory should be supplied with a new Dip Circle, an Absolute *Declination Instrument*, or—better, an Absolute Horizontal Intensity Instrument of the latest construction which also serves for observations of absolute declination and can be conveniently employed in magnetic surveys. Probably also a new Vertical Force Magnetometer will be required. These instruments should be of the most improved patterns, of the best quality and carefully tested and approved of by some able European magnetician before they are sent out.

Inclination Observations.

60. The Dip Circle observations should be made regularly with at least two needles the agreement of whose results will be to some extent a test of their value.

Probable cost of the instruments required.

61. The cost of these instruments, supposing the new form of Absolute Horizontal Intensity Apparatus is selected, might amount to £ 170 or thereabouts: with the Absolute Declinometer, which would not be so useful and accurate in some respects, the expense would not be much less.

Further operations.

62. The present operations might then be continued without much farther change until the reduction of the accumulated observations extending, as they proba-

bly do, over a double cycle of the decennial period, while no series yet fully discussed has included one complete cycle of that period; and if the Bombay Observations prove satisfactory they may possibly afford a more definite determination of the characteristics of that variation than has yet been obtained. It may then be found convenient to curtail the work in this department and to make only such observations as are required for the discovery of laws of long period.

A very considerable saving may be effected in the publication.

63. The hourly observations published by the Colaba Observatory form one instance among others, of the fact that, unless the labour of discussion is performed as part of the functions of the Observatory, the truths contained in them are not likely ever to be *extracted, and so they* remain useless to magnetical students. Consequently the Committee consider the cost of publication in that form is no longer justified, and that the printing ought to be stopped until it is known whether they are really worth the expense or not. But in future it might even be preferable to print only an abstract containing the results of scientific analyses of the observations, and require the Observatory to keep the registers in triplicate, handing over two of the copies annually to Government, the third being reserved for the use of the Observatory. The expenditure saved by this plan would meet a considerable portion of the extra outlay required to render the Observatory really efficient.

Objection to removing the Observatory. See paras. 47 49.

64. The only objection to removing the Observatory from its present locality is the breaking of the series of magnetic observations, which is much to be regretted, but it might with proper precautions be made but little injurious; and if, as seems desirable, Government is willing to transfer it to a more suitable site, then improvements might be made at no very great expense which would place it on a footing to enable it to take its part along with the most advanced physical observatories in extending our knowledge of this

How to render the magnetic Observatory complete.

most interesting and promising field of research. With this view, in constructing a new room for the differential magnetometers, arrangements should be made for limiting the range of temperature as much as possible, in order that any error in the temperature correction may have a minimum effect upon the results. The room at present used is fully exposed to the heating and cooling effects of every change of temperature, and the variations in the readings of the instruments are frequently in great part due to the range of temperature, while it is most desirable they should represent effects as purely magnetic as possible. Then a first class Observatory should have at least some self-registering instruments for the study of the continuous variations, which can only be done where the records give the magnetic forces for every successive moment of time, instead of their being limited to twenty-four equidistant momentary values in each day. They also save the inconvenience attending the taking of observations with the common instruments by night. But as eminent magneticians have expressed doubts as to the photographic instruments being equal to Lamont's or Grubb's instruments for the investigation of the laws depending on equidistant observations, it might be advisable to retain and employ the present instruments also, as a constant check on the others; the night observations might, however, be interpolated from the photographic traces.

New Magnetometer room.

Photographic self-registering instruments.

65. The probable cost of a complete set of self-registering photographic instruments would be about £500; or if, as recommended for such Observatories by the joint Committee of the Royal Society and British Association, the system of the Observatory included the magnetic survey of the neighbouring country a further sum of £100 would be required. It might not be necessary to procure the whole at first however.

Cost of a complete set.

66. The Superintendent ought to be able to avail himself

The library of the Observatory.

of the most recent literature in Magnetism and Meteorology, and the Committee are informed that provision has been made for this, and that there are already at the Observatory about 150 different publications, contained in upwards of 520 volumes and parts, on Astronomy, Magnetism, and Meteorology, including some of the best works English and Foreign.

67. Lastly the Committee would recommend that the management of the Observatory be transferred from the Marine Department, which has no longer the position it had before the abolition of the India Navy, —and that it be placed under a duly qualified Superintendent;—further that a Committee of Visitors be appointed to inspect the Observatory *annually* and receive a report from the Superintendent on the state of the Observatory and the work done during the year with such suggestions as he may consider necessary,—the Committee to forward the same to Government with such remarks as they may think are required. This Committee of Visitors might consist of the principal Sanitary Officer and the Master Attendant of the Port *ex officio*, with four other members—two appointed by Government and two to be recommended by the Geographical Society of Bombay.

Management to be entrusted to a Committee.

Committee.

W. C. Barker, retired Captain I. N.,
Master Attendant and Conservator of the Port,
President Observatory Commission.

Bombay 10*th January* 1865.

APPENDIX.

1. A List of Instruments belonging to the Astronomical Department of the Government Observatory Bombay.—*Supplied by the Superintendent in charge.*

1 Transit, 5 feet.
1 Sidereal Clock.
1 Telescope for Jupiter's Satellites, in case.
1 Large Telescope, brass tube, on wooden stand.
1 Ditto wooden tube, with wooden stand.
1 Altitude and Azimuth Instrument, 18 inch circle,—defective.
1 Level.
2 Levels for the Transit Instrument.
1 Sextant with stand.
2 Gold pocket Chronometers,—old and stopped.
1 Portable Chronometer by Arnold.
1 Box Chronometer by Arnold and Dent.
1 Do. „ „ Parkinson and Frodsham No. 2346.
1 Do. „ ditto „ No. 2362.
1 Pocket Chronometer by Barrand, No. 855.
1 Mean Time Clock by Cave.
1 Standard Mean Time Clock.
1 Small moveable Collimator.
1 Collimator made in Calcutta.
1 Sextant with Artificial Horizon.

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2. Meteorological Instruments received from the Medical Board.

2 Air thermometers.
3 Wet bulb thermometers.
9 Maximum thermometers.
1 Daniell's Hygrometer.
4 Minimum thermometers.

1 Regnault's Hygrometer.
4 Spare thermometers for Regnault's Hygrometer, &c.
1 Ronald's Hygrometer.
1 Hygrometer.
1 Standard Barometer by Newman, No. 51.
1 Mountain Barometer.
1 Adie's Mountain Barometer.
1 Aneroid Barometer.
2 Rain Gauges.
1 Anemometer,—fixed on the Tide house.

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3. Magnetical and Meteorological Instruments in Store.

1 Portable Declinometer,—suspension tube broken.
1 Apparatus for adjusting Declinometer.
1 Apparatus for adjusting the Horizontal Force Magnetometer.
1 Apparatus for adjusting the Vertical Force Magnetometer.
1 Vertical Force Magnetometer in case.
1 Robinson's Dip Circle by Barrow with two needles.
2 Intensity Needles.
1 Dip Circle and Needle by Narrien and Blunt,—old.
1 Dip Circle by Gilbert.
2 Small levels for Dip Circle.
1 Vibration Needle for Hanstien's apparatus,—rusted.
1 Induction Inclinometer.
1 Copper vessel for magnets.
2 Copper rings for checking vibrations.
1 Horse-shoe Magnet.
2 Large Bar Magnets.
2 Bar Magnets in case.
1 Portable Transit Instrument.
1 Collimator.
1 Large Electrometer.
1 Self-registering Tide gauge.
2 Small Electroscopes,—out of order.

1 Actinometer,—out of order.
1 Mountain Barometer,—broken.
1 Barometer,—with wooden stand.
2 Barometers.
3 Standard Thermometers by Newman.
2 Experimental thermometers—one broken.
1 Ditto „ graduated to 800° Fahr.
1 Wet Bulb Thermometer.
1 Ground Thermometer 12 feet long.
1 Ditto „ —broken.
1 Maximum Thermometer by Newman.
1 Minimum ditto. ditto.
1 Rain-gauge for light showers.
1 Sextant and Artificial Horizon.
1 Sextant and Patent Horizon.
1 Standard Brass yard, in case,—thermometer broken.
1 Brass scale of 2 feet.
2 Lithographic presses (large and small),—out of order.
1 Box Chronometer by Arnold and Dent, No. 1339.
3 Ditto „ by Parkinson and Frodsham Nos. 2370, 2318 and 2376.
1 Wind-gauge by Elliot Brothers.
1 Variation Transit.