II. *Contributions to Terrestrial Magnetism.—No.* II.

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§ 3. *Captain* BELCHER'S *Observations on the west Coast of America, and the adjacent Islands.* § 4. *New Determination of the Magnetic Elements at Otaheite.*

§ 3. *Captain* BELCHER'S *Observations on the west Coast of America, and the adjacent Islands.*

THE observations, an account of which is now presented to the Society, were made by Captain EDWARD BELCHER, R.N. and the officers of H.M.S. Sulphur, employed in the years 1837 to 1840 in surveying portions of the west coast of North America. The account has been drawn up from the official reports transmitted to the Admiralty, and placed in my hands by the Hydrographer, Captain BEAUFORT. The services which Captain BELCHER and his officers may be expected to render to magnetical science are not terminated, as the Sulphur has not yet returned to England: but the portion now communicated forms a complete series, comprising the results of their labours up to the period of their final departure from the coast of America. The zeal, perseverance, and care with which these have been conducted will be best appreciated by an examination of the details.

Horizontal Intensity.—Captain BELCHER joined the Sulphur at Panama in the spring of 1837, receiving from his predecessor, Captain BEECHEY, a six-inch inclination instrument by ROBINSON, and several needles for experiments on the horizontal intensity by the method of vibration. He had taken with him from England a nine-inch altitude and azimuth instrument with attached needles, and a five-inch theodolite, both by CARY, which he had employed in former surveys in determining declinations, and had had reason to confide in. Before his departure from Panama on a surveying cruize, which might furnish opportunities of magnetic observation at several stations on the west coast of America between Behring Strait and Peru, the times of vibration of the horizontal needles, eleven in number, were carefully observed, in March 1837, at a convenient spot near the ruins of the Convent of St. Francisco; and these observations were repeated at the same spot on the return of the Sulphur to Panama in October 1838, after an absence of eighteen months. By comparing the times of vibration in March 1837 and October 1838, as given in the subjoined Table, it will be seen that the magnetism of several of the needles had greatly altered in the interim:

TABLE I.—Comparison of Intensity Needles at Panama in March 1837, and October 1838. Commencing arcs 40°.

Periods.	Designation of the Needles.										
	1.	3.	4.	5.	6.	7.	8.	9.	11.	12.	13.
	s	s	s	s	s	s	s	s	s	s	s
March 1837	625·1	600·9	775·7	472·7	512·6	532·7	470·4	434·3	453·9	373·8	375·2
October 1838....	673·1	608·6	864·0	475·2	514·6	536·8	471·4	439·5	475·8	403·7	395·5

Nos. 5. 6. 7. and 8. had each undergone a small and comparatively insignificant loss of force; but the changes sustained by the other needles, especially by Nos. 1. 4. 11. 12. and 13, were too great to justify the deduction of results, either from a mean of the times of vibration at the two periods, or on the principle of an uniform loss corresponding to equal intervals of time. Unfortunately, Nos. 1. 3. and 4. were amongst those which had been most frequently employed at the stations visited in the cruize; and as an attentive examination of the observations made with them has not furnished, as it sometimes does, the means of discovering when and in what manner the alterations of magnetism took place, I have not attempted to draw from these observations conclusions which could not be otherwise than unsatisfactory. Happily several of the stations were revisited in 1839, when the apparatus was in more perfect order, and the observers having improved by practice, the results are such as leave no other regret for the failure on the first occasion, than what is due to the loss of time and pains. At those stations of the first cruize which were not subsequently visited, we may still derive results from the observations with Nos. 5. 6. 7. and 8, which, though not entitled to equal confidence in respect to precision with the determinations made in the subsequent voyage, are nevertheless well deserving of regard and record. It may be convenient, however, in the relation, to invert the order of succession, and to commence with an account of the second, or principal *magnetic*, voyage.

Having occasion to remain at Panama and its neighbourhood for some months after the needles had been vibrated as above noticed in October 1838, Captain BELCHER repeated the observations with the needles specified in the next Table a third time, at the same place as before, on the 16th of March 1839. The times of vibration inserted in this Table were on both occasions in arcs commencing with 40°, which had been the uniform practice with all the needles at the stations visited in the first voyage. Having heard from Captain BEAUFORT of the attention which Captain BELCHER and his officers were giving to magnetic observations, and having been permitted to examine the reports of the observations of the first voyage which had reached the Admiralty on the 1st of January 1839, I wrote to Captain BELCHER to recommend that in future he should commence the vibrations at an arc of 20°. This letter was received in Panama early in March, and a double series of observations were made in consequence on the 16th of March, one series commencing with 40° to compare with those of October 1838, and a second commencing with 20°, to correspond with all the observations which should be subsequently made. The times of vibration commencing with 40° are those inserted in this Table; the series commencing with 20° will be found in its due succession.

Table II.—Comparison of the Intensity Needles at Panama in October 1838, and March 1839*.

Periods.	Designation of the Needles.						
	5.	7.	8.	9.	11.	12.	13.
	s	s	s	s	s	s	s
October 1838....	475·2	536·8	471·4	439·5	475·8	403·7	395·5
March 1839	476·3	536·1	471·4	438·2	474·8	404·6	394·5

This comparison having shown that the seven needles specified in the Table were in a steady magnetic state, Captain Belcher despatched Nos. 7. 8. and 9. to England, to have their times of vibration observed there, and to be returned to him on the coast of California; purposing by this means to attach his series of relative determinations to the great body of results obtained by other observers. The needles were received by me in August 1839, and were vibrated on the 12th and 13th of August at a suitable place near Woolwich, where I also observed the dip at the same time. They reached Captain Belcher again in the following November at Mazatlan. In the meantime the Sulphur had quitted Panama, having on board Nos. 5. 11. 12. and 13, and had visited successively Cocos Island, Oahu one of the Sandwich Islands, Kodiack and Sitka on the north-west coast of America, Fort Vancouver and Baker's Bay in Columbia River, Port Bodega, San Francisco, Monterey, Sta Barbara, San Pedro, San Diego, San Quentin, San Bartholomew, Magdalena Bay, and St. Lucas Bay, arriving at Mazatlan in November. At each of the above-named stations the times of vibration of one or more of the needles were observed, and occasionally of all the four. On the arrival of the three needles which had been sent to England, their times of vibration were observed, in comparison with the others, first at Mazatlan, and a few days afterwards at San Blas, where, more time being available, the comparison was repeated on two different days, viz. on the 6th and 19th of December. From San Blas

* Nos. 1. 3. and 4. are not included in this Table, because the observations on the 16th of March 1839 showed that they were still losing magnetism, and they were not therefore subsequently employed. No. 6. is also omitted, and the cause is explained by a memorandum of Captain Belcher's to the following effect: "No. 6. kept well during the first twenty-one months, and changed suddenly during an excursion to Conchagua in November and December 1838. It was vibrated on the 20th and 22nd of November, and gave consistent results: on the 27th it was carried on horseback up the Amapola hill, 3000 feet above the sea, and on its return on the 22nd of December was found to have lost magnetism equivalent to upwards of 12 seconds in 510 seconds. The surface rock on the Amapola hill was so highly magnetic that no satisfactory observations could be obtained there with the needle." An examination of the subsequent observations of No. 6, compared with those of the other needles, shows that its magnetism was unsteady for many months after this accident, becoming gradually weaker. I have not, therefore, taken into account the observations with this needle, as they do not yield independent results of equal value with the other needles, and there are enough consistent determinations without them.

the Sulphur proceeded to the islands of Socorro and Clarion, to Martins Island one of the Marquesas, and lastly to Bow Island, with which the stations on the west coast of America and its adjacent islands may be considered to have terminated.

To have made this series of magnetic determinations thoroughly complete, the needles should have been taken back to Panama, and their times of vibration should have been re-examined there at the close of the operations; but this proceeding did not consist with other duties. We are, therefore, without that direct evidence of the steady magnetism of the needles, subsequently to the observations at Panama in March 1839, which might have been furnished thereby; but where so many needles are employed, evidence of scarcely inferior weight may be obtained by their inter-comparison; especially at stations where the opportunities of observation are favourable, and the probable error of the result with each needle is further diminished by its being derived from repetitions on different days. The observations at Mazatlan and San Blas, on the return of Nos. 7. 8. and 9. from England, furnish one good occasion of this nature; and we may take as a second the observations at Martins Island, being the last station at which they were repeated on different days.

If we divide the squares of the times of vibration of the several needles at Panama by the squares of their times of vibration at Mazatlan, we obtain quotients, which, if the needles were unchanged relatively to each other in the interim, should be identical; or as nearly so as the ordinary errors of observation permit, including therein the diurnal and irregular variations of the magnetic force itself. The times of vibration at San Blas and Panama, similarly treated, supply a similar comparison, in which, however, the quotients will differ in absolute value from the preceding ones, inasmuch as the horizontal intensity of the earth's magnetism is not precisely the same at Mazatlan and San Blas*; but the degree of accordance *with each other* of the second series of quotients will furnish, as in the former case, the required evidence; which is of greater weight in the instance of San Blas than in that of Mazatlan, because the times of vibration at San Blas were derived from observations on two different days, and at Mazatlan from those of a single day only.

TABLE III.—Intercomparison of the Intensity Needles at Mazatlan and San Blas.

	Quotients.								
	5.	7.	8.	9.	11.	12.	13.	Mean, omitting No. 8.	Weights†.
Panama and Mazatlan	0·930	0·930	0·923	0·924	0·931	0·928	0·925	0·928	2
Panama and San Blas	0·951	......	0·950	0·956	0·959	0·962	0·956	0·958	3
Difference of each needle from the mean	+ ·002	+ ·002	− ·005	− ·004	+ ·003	·000	− ·003	Panama and Mazatlan.	
	+ ·001	....	− ·008	− ·002	+ ·001	+ ·004	− ·002	Panama and San Blas.	
Mean difference...............	+ ·001	+ ·002	− ·007	− ·003	+ ·002	+ ·002	− ·002	Allowing the respective weights.	

* The quotients are, in fact, in the two cases, the respective values of the horizontal intensity at Mazatlan and San Blas relatively to the force at Panama taken as unity.

† These are arbitrary weights, assigned according to the number of *days* employed in each comparison.

No. 8. is the only needle which presents a difference from the other needles exceeding in value a five-hundredth part of the time of vibration. If therefore the magnetism of Nos. 5. 7. 9. 11. 12. and 13. suffered any change in the interval comprehended by the comparison, the alteration must have taken place to an equivalent amount in each of the needles: a coincidence the less probable, because they had all been previously exposed to greater extremes of natural temperature than were experienced at the stations visited between Panama and San Blas.

The difference which No. 8. presents from the mean of the other needles is equivalent to $1^{s}\cdot7$ in 480 seconds, its time of vibration, or to a proportional loss of magnetism. It does happen occasionally that results with the same needle corrected for temperature, will differ from each other to this amount, in cases when the subsequent return to the original time of vibration manifests that the magnetism of the needle has undergone no change, or at least no permanent change: but as the difference exceeds the probable error of observation, as will be presently shown, and as moreover nearly the same difference appears at all the subsequent stations, when the results with No. 8. are compared with those of the other needles, I have regarded it as an indication of an actual loss of magnetism sustained by No. 8., at some time between the observations at Panama in March 1839, and those at Mazatlan in November of the same year, rendering that needle less fit than the others for intermediate deductions: and I have allowed for this loss at all the stations subsequently to San Blas, by deducting ·00312 from the logarithm of the square of its time of vibration.

The observations at Mazatlan with No. 7, for the comparison of its time of vibration with that of the other needles, were made on the 29th of November. On the 30th of November and 2nd of December, this needle was employed in experiments to ascertain the effect on its time of vibration of differences of temperature, by vibrating it in air of the natural temperature, and in air heated by means of boiling water. No memorandum has accompanied the observations of any accident having occurred, either in putting the needle away after the conclusion of the observations of the 29th, or before the commencement of those of the 30th, but a comparison of the results on the three days manifests that the magnetism of the needle sustained an alteration in that interval:

November 29. Corrected time of vibration 550·9 seconds
November 30. Corrected time of vibration 556·7 seconds
December 2. Corrected time of vibration 555·9 seconds.

The observations at the next station, San Blas, confirm this direct evidence of a change, as is seen in the following statement, which shows the quotients of No. 7. at Mazatlan and San Blas compared with the mean quotients of the other needles.

	1839.	Needle 7.	Mean of the Needles.	Difference.
Mazatlan	Nov. 29	0·934	0·933	+ 0·001
	Nov. 30 and Dec. 2	0·916	0·933	− 0·017
San Blas	Dec. 6 and Dec. 19	0·940	0·959	− 0·019

I have allowed, therefore, a loss of magnetism in this needle equivalent to 5^{s}·4 in 556 seconds at all the stations subsequent to Mazatlan, and have accordingly deducted ·00848 from the logarithms of the squares of the times of vibration of No. 7. at those stations.

We now proceed to a similar general intercomparison of the needles at Martins Island.

Table IV.—Intercomparison of the Intensity Needles at Martins Island.

	Quotients.							
	5.	7.	8.	9.	11.	12.	13.	Mean.
Panama and Martins Island	0·975	0·983	0·981	0·981	0·981	0·983	0·978	0·980
Differences from the Mean	− ·005	+ ·003	+ ·001	+ ·001	+ ·001	+ ·003	− ·002	

Here, with the exception of No. 5, which appears to have sustained a slight loss of magnetism, the agreement of the quotients shows the general steadiness of the magnetic condition of the needles. In the case of No. 5. the difference does not exceed the limits of *occasional* error of observation; the results with this needle subsequently to San Blas may not deserve to be regarded as *fully* equal in value to those of the other needles; but the amount of error in the final determinations hazarded by retaining its results independent of correction is insignificant.

As this Table includes the whole interval between the observations at Panama in 1839, and those at Martins Island in 1840, we may regard it as substantiating the general steady magnetic condition of the needles in the whole of that interval, with the exception of the changes already noticed in Nos. 7. and 8, which have been traced to the period of their occurrence, and their amount examined and allowed for.

The times of vibration at all the stations visited subsequently to March 1839 were taken in arcs commencing with 20°: the time of the chronometer was noted at every 10th vibration during 300, and the mean time of 200 vibrations derived from ten partial results, i. e. from the 0th and 200th, the 10th and 210th, the 20th and 220th.

No satisfactory experiments having been made to determine the individual coefficients in the correction for temperature of these needles, I have taken an arbitrary coefficient for that purpose, being the arithmetical mean of the coefficients experimentally ascertained for the twenty-nine needles specified in the following list:—

·000165	Hansteen			Phil. Trans., 1828. Art. I.
·00019	Lenz	Needle .	1	Mém. de l'Acad. Imp. de St. Pétersbourg, 1824.
·00025	Lenz	Needle .	5	
·00026	Lenz	Needle .	2	
·00029	Lenz	Needle .	4	
·00016	Lloyd	Needle	L (4)	Trans. R. I. A., vol. xvii.
·000254	Lloyd	Needle	L (*a*)	Brit. Assoc. Report, 1835.
·000248	Lloyd	Needle	L (*b*)	

·00022	SABINE	Needle	L (3)	Account of the Euphrates Expedition. App.
·00027	SABINE	Needle	L (4)	
·00038	SABINE	Needle	E (1)	
·00041	SABINE	Needle	E (4)	
·000068	SABINE	Needle	FITZROY'S.	Voyage of the Beagle. App.
·00030	SABINE	Needle	(3)	Phil. Trans., 1840. Art. IV.
·000055	Ross and SABINE.	Needle	R L (4)	Brit. Assoc. Report, 1838.
·000436	BACHE	Needle	. (1)	Trans. Am. Phil. Soc., 1836.
·000423	BACHE	Needle	. (2)	
·000277	BACHE . . .	Needle	. (3)	
·000117	BACHE	Needle	. (A)	
·000052	BACHE	Needle	. (C)	
·000357	BACHE	Needle	(3 B)	
·000359	CHRISTIE . . .	Needle	. (1)	Phil. Trans., 1836. Art. XIX.
·000302	CHRISTIE . . .	Needle	. (3)	
·000177	CHRISTIE . . .	Needle	Lozenge	
·000227	CHRISTIE . . .	Needle	. II	
·00036	DUPERREY . . .	Needle	. I	Mém de L' Acad. Roy. de Bruxelles, tom. xiii.
·000625	QUETELET . . .	Needle	. II	
·00020	FORBES . . .	Needle	. I	Trans. R. S. Edin., vol. xiv.
·00013	FORBES . . .	Needle	Flat	
·00026				

Whence,

$$T' = T\,[1 + \cdot 00026\,(60^\circ - t)],$$

in which T is the time of vibration at any station, t the actual temperature in degrees of FAHR., and T' is the equivalent time at the temperature of 60°.

The application of this correction gives the "corrected time" in Table V. In the few cases where the rate of the chronometer exceeded an insignificant amount, a correction for the rate is also included in the "corrected time," and a memorandum of the rate itself is inserted in the column of remarks.

Table V. contains an abstract of the observations at the different stations with the needles which have been specified: it includes every observation recorded to have been made with these needles between the 16th of March 1839 at Panama, and the 22nd of March 1840 at Bow Island, except, 1st, two incomplete observations, one with No. 11. at Fort Vancouver, and one with No. 13. at San Francisco, in which either the vibration was interrupted, or the needles came to rest, before the usual and requisite number of vibrations had been made; and 2nd, some observations at Tepic in the neighbourhood of San Blas and at Mazatlan, in which the needles, for the sake of experiment, were vibrated in air artificially heated, or alternately in the sun and in the shade.

TABLE V.—Abstract of observations with the Intensity Needles between the 16th of March 1839, and the 22nd of March 1840.

Station.	1839.	Needle.	Time.	Therm.	Corrected Time.	Remarks.
			s	°	s	
Panama	March 16.	5	472·6	84	469·4	
	March 16.	5	472·3	85		
	March 16.	7	535·2	80	531·3	
	March 16.	7	534·1	88		
	March 16.	8	470·2	88	466·2	
	March 16.	8	468·9	86		
	March 16.	9	437·8	80	433·8	
	March 16.	9	435·5	90		
	March 16.	11	473·3	87	470·0	
	March 16.	12	403·2	87	400·4	
	March 16.	13	393·2	88	390·4	
Cocos Island	April 8.	5	466·4	83	463·9	
	April 8.	5	466·9	82		
	April 8.	11	465·6	78	463·5	
	April 8.	11	465·8	78		
	April 8.	12	397·4	77	395·6	
	April 8.	12	397·5	78		
	April 8.	13	390·0	78	388·2	
	April 8.	13	390·0	78		
Oahu	June 4.	5	512·1	80	510·3	
	June 4.	5	513·8	90		
	June 9.	5	514·6	89		
	June 9.	5	515·2	91		
	June 8.	11	515·5	79	512·6	
	June 8.	11	515·8	88		
	June 8.	12	439·8	87	436·5	
	June 8.	12	439·4	88		
	June 8.	13	430·0	87	427·5	
	June 8.	13	430·9	87		
Kodiack	July 7.	5	688·5	79	685·1	
Sitka	July 18.	5	730·3	61	730·1	
	July 18.	11	730·4	62	730·1	
	July 18.	12	624·0	64	623·4	
	July 18.	13	611·2	67	610·1	
Woolwich	Aug. 12 and 13	7	766·4	66	766·2	Observed by Lieut.-Colonel SABINE.
	Aug. 12 and 13	7	766·8	66		
	Aug. 12 and 13	7	767·6	61		
	Aug. 12 and 13	8	670·7	68	669·7	
	Aug. 12 and 13	8	669·9	68		
	Aug. 12 and 13	8	671·7	63		
	Aug. 12 and 13	9	627·3	65	626·9	
	Aug. 12 and 13	9	627·8	61		
	Aug. 12 and 13	9	627·0	62		
Fort Vancouver	Aug. 13	5	616·8	59	616·9	Chron. G. 8^s·5
	Aug. 13	5	619·8	72		Chron. G. 8^s·5
	Aug. 14	5	616·9	65		Chron. G. 8^s·5
	Aug. 14	5	617·1	69		Chron. G. 8^s·5
	Aug. 14	5	619·8	69		Chron. G. 8^s·5
	Aug. 15	5	617·5	63		Chron. G. 8^s·5
	Aug. 15	5	617·2	63		Chron. G. 8^s·5
	Aug. 15	11	620·7	66	619·8	Chron. G. 8^s·5
	Aug. 13	12	527·5	82	526·9	Chron. G. 8^s·5
	Aug. 15	12	530·1	66		Chron. G. 8^s·5
	Aug. 13	13	515·6	81	515·2	Chron. G. 8^s·5
	Aug. 15	13	518·5	66		Chron. G. 8^s·5
Baker's Bay	September 13	5	622·4	60	622·6	
	September 13	5	624·4	70		

Table V. (Continued.)

Station.	1839.	Needle.	Time.	Therm.	Corrected Time.	Remarks.
			s	°	s	
Bodega	September 25	5	560·4	63	559·9	
San Francisco	September 30	5	556·8	76	555·0	
	September 30	5	557·2	71		
	September 30	11	558·7	64	558·1	
	September 30	12	476·4	62	476·2	
Monterey	October 5	5	549·7	65	549·0	
S^ta^ Barbara	October 10	5	539·0	77	536·6	
San Pedro	October 12	5	538·4	74	536·5	
San Diego	October 17	5	528·2	70	526·8	
San Quentin	October 24	5	515·3	77	513·1	
San Bartholomew	October 29	5	503·3	74	501·5	
Magdalena Bay	November 1	5	490·1	73	488·5	
Bay of St. Lucas	November 21	5	487·9	83	485·0	
Mazatlan	November 28	5	488·1	71	486·7	
	November 28	11	488·5	72	487·0	
	November 28	12	416·9	72	415·6	
	November 28	13	407·3	72	406·0	
	November 29	7	552·8	73	550·9	
	November 30	7	557·7	72	556·4	
	November 30	7	559·4	73		
	December 2	7	558·2	76		
	November 29	8	485·1	72	485·3	
	November 30	8	487·8	73		
	December 2	8	488·1	76		
	November 29	9	452·8	73	451·3	
	November 30	9	453·3	71		
	December 2	9	452·6	76		
San Blas	December 6	5	482·3	88	479·5	
	December 19	5	482·5	78		
	December 6	7	550·3	85	548·4	
	December 19	7	551·8	78		
	December 19	7	551·8	78		
	December 6	8	480·4	87	478·4	
	December 19	8	481·9	77		
	December 6	9	445·9	86	443·6	
	December 19	9	446·2	76		
	December 6	11	482·7	86	480·0	
	December 19	11	483·1	81		
	December 6	12	410·5	81	408·3	
	December 19	12	411·0	84		
	December 6	13	401·3	81	399·2	
	December 19	13	402·0	84		
Socorro Island	December 26	5	478·1	83	474·9	
	December 26	5	477·7	85		
Clarion Island	December 29	5	481·4	84	478·7	
	December 29	5	482·0	85		
	1840.					
Martins Island (Marquesas)	January 23	5	477·5	88	475·4	
	January 23	5	477·9	89		
	January 28	5	479·2	85		
	January 28	5	480·1	86		
	January 29	5	479·0	86		
	January 25	7	545·0	86	541·0	
	January 27	7	544·6	88		
	January 25	8	476·0	87	472·5	
	January 27	8	475·7	83		
	January 25	9	441·5	90	438·1	
	January 27	9	440·8	86		

TABLE V. (Continued.)

Station.	1840.	Needle.	Time.	Therm.	Corrected Time.	Remarks.
			s	°	s	
Martins Island (Marquesas	January 25	11	477·8	90	474·6	
	January 27	11	478·1	88		
	January 25	12	406·9	87	403·6	
	January 27	12	406·2	88		
	January 25	13	397·7	88	394·8	
	January 27	13	397·4	88		
Bow Island..........	February 6 ..	5	484·1	87	480·5	
	February 6 ..	5	483·6	87		Village.
	February 22 ..	5	483·4	82	480·1	
	February 22 ..	5	483·5	89		Observatory.
	February 25 ..	5	485·6	90		
	February 25 ..	5	485·8	90	482·1	S.E. Cocoanut Grove.
	February 26 ..	5	485·0	81		
	February 26 ..	5	485·3	88	481·7 } 480·9	Chron. L. 5·3.
	February 26 ..	5	484·9	88		West Cocoanut Grove.
	February 27 ..	5	484·1	85		
	February 27 ..	5	484·0	83	480·8	West Rock.
	February 28 ..	5	484·4	86		
	February 29 ..	5	483·5	87	479·8	
	February 29 ..	5	482·8	81		Village.
	March 20 and 21	5	484·3	83	481·4	Mean of 22 sets. Observatory.
	March 22......	7	550·7	75		Chron. G. 5·8.
	March 22......	7	551·1	76	548·9	
	March 22......	7	551·9	76		
	March 22......	8	480·8	76		
	March 22......	8	482·6	77	479·4	
	March 22......	8	481·5	76		
	March 22......	8	481·2	78		
	March 22......	9	446·4	79		
	March 22......	9	446·6	81	443·9	
	March 22......	9	446·4	86		
	March 22......	11	482·8	87		
	March 22......	11	483·1	82	479·5	
	March 22......	11	482·6	87		
	March 22......	12	411·0	86		
	March 22......	12	411·1	87	408·2	
	March 22......	12	411·2	88		
	March 22......	13	402·2	87		
	March 22......	13	401·9	87	399·1	
	March 22......	13	401·8	85		

By means of the observations in the preceding Table, we obtain the ratio of the horizontal intensity at each station to that at each of the others specified in the Table. The *absolute* horizontal intensity was nowhere observed, because Captain BELCHER was not furnished with an instrument for the purpose, and no such instrument has yet been carried to any of the stations which he visited. For the purpose of expressing the ratio determined by the observations, we may select any one of the stations as a base-station, and assign an arbitrary value for the horizontal intensity at that station. I have chosen Panama, and have made the horizontal intensity there = 1000, because that is the value which it bears at Panama in M. GAUSS's theoretical map of this element*, and those who may desire it will thus be enabled to

* Atlas des Erdmagnetismus nach den elementen der theorie entworfen, Plate XI.; and Taylor's Scientific Memoirs, vol. ii. Plate XXII.

compare *directly* the horizontal intensities observed by Captain Belcher, with the computed intensities of M. Gauss's theory. Table VI. exhibits the observed values.

Table VI.—Observed Values of the Horizontal Intensity.

Station.	Needle.	Corrected Time.	Horizontal Intensity.		Number of Needles.	Number of Days.	Number of Observations.
		s.					
Panama	5	469·4	1000	1000	7	1	11
	7	531·3	1000				
	8	466·2	1000				
	9	433·8	1000				
	11	470·0	1000				
	12	400·4	1000				
	13	390·4	1000				
Cocos Island	5	463·9	1024	1022	4	1	8
	11	463·5	1028				
	12	395·6	1025				
	13	388·2	1012				
Oahu	5	510·3	846	841	4	3	10
	11	512·6	841				
	12	436·5	841				
	13	427·5	834				
Kodiack	5	685·1	470	470	1	1	1
Sitka	5	730·1	413	412	4	1	4
	11	730·1	414				
	12	623·4	413				
	13	610·1	410				
Woolwich	7	766·2	480·9	480	2	2	6
	9	626·9	478·8				
Fort Vancouver	5	616·9	579	576	4	3	12
	11	619·8	575				
	12	526·9	577				
	13	515·2	574				
Baker's Bay	5	622·6	569	569	1	1	2
Bodega	5	559·9	703	703	1	1	1
San Francisco	5	555·0	716	711	3	1	4
	11	558·1	709				
	12	475·4	707				
Monterey	5	549·0	731	731	1	1	1
Sta Barbara	5	536·6	765	765	1	1	1
San Pedro	5	536·5	766	766	1	1	1
San Diego	5	526·8	794	794	1	1	1
San Quentin	5	513·1	837	837	1	1	1
San Bartholomew	5	501·5	876	876	1	1	1
Magdalena Bay	5	488·5	924	924	1	1	1
Bay of St. Lucas	5	485·0	937	937	1	1	1
Mazatlan	5	486·7	930	928	6	3	11
	7	550·9	930				
	9	451·3	924				
	11	487·0	931				
	12	415·6	928				
	13	407·3	925				
San Blas	5	479·5	959	958	5	2	10
	7	548·4	957				
	9	443·6	956				
	11	480·0	959				
	12	408·3	962				
	13	400·2	956				
Socorro Island	5	474·9	977	977	1	1	2

TABLE VI. (Continued.)

Station.	Needle.	Corrected Time.	Horizontal Intensity.		Number of Needles.	Number of Days.	Number of Observations.
		s					
Clarion Island....	5	478·7	962	962	1	1	2
Martins Island	5	475·4	975				
	7	541·0	983				
	8	472·5	981				
	9	438·1	981	980	7	5	17
	11	474·6	981				
	12	403·6	984				
	13	394·8	978				
Bow Island....	5	480·9	953				
	7	548·9	955				
	8	479·4	953				
	9	443·9	955	957	7	8	55
	11	479·5	961				
	12	408·2	962				
	13	399·1	957				

In this Table each needle has been given an equal influence on the mean result, without reference to the number of observations made with it. Where the observations do not afford certain and independent evidence of the unchanged state of each of the needles in respect to magnetism, weights assigned from other considerations must necessarily be arbitrary and uncertain. For example, at the last station in the Table, Bow Island, thirty-six observations were made with No. 5, and not more than three or four with each of the other six needles. But we have already seen, on intercomparison, reason to suspect that No. 5. may have sustained a slight loss of magnetism at the station preceding Bow Island, and it is the only needle in which any change of the kind is indicated subsequently to the general comparison at San Blas. Whilst, therefore, on the one hand, we might not be justified, without more clear and decided evidence, in altogether setting aside the result with No. 5, so on the other hand we should not obtain the most probable final deduction, by giving to that result a weight, in comparison with that of each of the other needles, proportioned to the number of observations, and resting on the probable error of a single observation,—apart from changes of magnetism in the needle itself.

We will now revert to the stations visited in the first voyage which were not subsequently revisited, and at which the values of the horizontal intensity may be derived by means of Nos. 5, 6, 7, or 8. Table VII. contains an abstract of the observations with these needles, in all of which the times of vibration were obtained in arcs commencing with 40°. The column entitled "Corrected Times," shows the mean time of vibration reduced to a standard temperature of 60°. The arithmetical mean of the times at Panama in March 1837, October 1839, and March 1839, has been taken as the approximate time of vibration at Panama throughout the interval; and the ratio of the horizontal intensity at the other stations has been computed accordingly, as shown in Table VIII. In this Table, as in Table VI., each needle has been given an equal influence on the general mean, without reference to the number of observations which were made with it.

TABLE VII.—Abstract of observations with the Intensity Needles, Nos. 5, 6, 7, and 8, at the undermentioned Stations.

Station.	1837.	Needle.	Time.	Therm.	Corrected Time.	Remarks.
			s	°	s	
Panama	March 10	5	471·7	79	470·4	
	March 10	5	473·7	79		
	March 10	6	512·5	80	510·4	
	March 10	6	512·6	72		
	March 12	7	532·7	71	531·2	
	March 12	8	470·4	76	468·4	
Port Etches	August 28	5	736·7	50	738·7	Chron. L. $8^{s}\cdot6$.
	August 28	6	792·4	50	794·5	Chron. L. $8^{s}\cdot6$.
	1838.					
Acapulco	January 17	6	508·1	88	504·5	
	January 17	7	530·7	91	526·5	
Callao	June 20 and 21	5	487·1	68	486·1	Mean of 80 observations.
	June 25	6	525·0	79	522·4	
	June 27	7	546·1	72	544·6	
	June 27	8	483·8	70	482·6	
Puna Island (Guayaquil)	September 23	5	476·1	78	473·7	Mean of 90 observations.
	September 23	6	514·3	79	510·5	Pt Spanola.
	September 23	6	515·3	78		
	September 17	6	517·5	99		Pa Arena.
	September 17	6	517·4	99		
	September 19	6	517·1	93		Pt Barranca.
	September 20	6	509·7	86		Town of Puna.
	September 20	6	510·8	88		
Panama	October 28	5	475·3	82?	472·6	Therm. not recorded.
	October 28	6	514·6	82?	511·7	
	October 28	7	536·8	82?	533·7	
	October 28	8	471·4	82?	468·7	
	1839.					
Panama	March 16	5	476·4	84	473·2	
	March 16	5	476·1	85		
	March 16	7	536·8	80	532·9	
	March 16	7	535·3	88		
	March 16	8	471·8	88	468·1	
	March 16	8	471·0	86		

TABLE VIII.—Observed values of the Horizontal Intensity.

Station.	Needle.	Corrected Time.	Horizontal Intensity. Panama = 1000.		Remarks.
		s			
Port Etches	5	738·7	408	411	
	6	794·5	414		
Acapulco	6	504·5	1026	1024	
	7	526·5	1023		
Callao	5	486·1	943	950	
	6	522·4	957		
	7	544·6	957		
	8	482·6	942		
Puna Island	5	473·7	993	998	
	6	510·5	1002		

At four of Captain BELCHER's stations in North America, he was preceded in observations of the horizontal intensity by Mr. DAVID DOUGLAS, who visited California and the Columbia River in the years 1830 to 1833. It may not be out of place to examine here the degree of accordance in the results obtained by the two experimenters at the four stations, Fort Vancouver, San Francisco, Monterey, and S^ta^ Barbara; and the comparison will be found instructive. Mr. DOUGLAS's observations were made with two pairs of needles, which, before his departure for America, were vibrated in the environs of London, at intervals of several months, with consistent results. One pair of needles, numbered 3. and 4, were returned to England from San Francisco in 1831 to have their magnetic state re-examined: they arrived safely, and were vibrated in 1836, when, on a comparison with their rates in 1828 and 1829, No. 3. was found to have slightly gained, and No. 4. to have slightly lost magnetism; the consequence, probably, of their having been kept in constant contact with each other (No. 4. being a more powerful magnet than No. 3.), except when used in observation, when both needles were always vibrated, and their combined results considered as one determination. The mean of the times of vibration of these needles in 1828–1829, and in 1836, consequently furnishes a satisfactory London rate for the intervening years. The second pair of needles, numbered 5. and 6, were in Mr. DOUGLAS's possession at the period of his untimely death at Owhyhee in 1834, as his letters contain the notice of observations made with them at the summit of Mowna Kaah, and in the crater of Kiraueah, but they have not been found amongst his effects sent to England. The steadiness of this pair of needles can only be judged of, therefore, by their accordance everywhere with the results of Nos. 3. and 4.

Mr. DOUGLAS's papers are in the Colonial Office; an account of his magnetic observations, which I drew up at the request of Lord GLENELG, then Secretary of State for the Colonies, was presented by His Lordship to the Royal Society, and was read in May 1837, but was not printed. The results of the horizontal intensity which will be now referred to, are taken from that account; they are also immediately deducible from the Table of the *total* intensities and dips observed by Mr. DOUGLAS in North America, published in 1838 in my memoir on the magnetic Intensity of the Earth, in the Seventh Report of the British Association for the Advancement of Science: they are as follows:

Horizontal intensity: London = 1000.

	Nos. 5. and 6.		Nos. 3. and 4.	
Fort Vancouver	1830	1238;	1830	1220
San Francisco	1831 and 1833	1517;	1831	1511
Monterey	1831 and 1832	1566;	1831	1542
S^ta^ Barbara	1831	1636;	Not observed.	

or, if we regard London and Woolwich as identical in respect to the value of the horizontal intensity, and express this value by 480, which Captain BELCHER's observations give as its ratio in August 1839 to 1000 at Panama, we have Mr. DOUGLAS's determinations in immediate comparison with those of Captain BELCHER as follows:

	DOUGLAS, 1830, 1833.		BELCHER, 1839.
Fort Vancouver	Nos. 5. and 6. 594;	Nos. 3. and 4. 586 . . .	576
San Francisco	Nos. 5. and 6. 728;	Nos. 3. and 4. 726 . . .	711
Monterey .	Nos. 5. and 6. 752;	Nos. 3. and 4. 740 . . .	731
Sta Barbara .	Nos. 5. and 6. 785;	Nos. 3. and 4. not obsd.	765

It has been assumed in this comparison that the horizontal intensity in London had the same representative value in the years to which Mr. DOUGLAS's observations correspond as in the year to which Captain BELCHER's correspond. But we know that the secular decrease of the dip in London causes a corresponding increase in the horizontal magnetic force at that station, and we are sufficiently acquainted with the average amount of the yearly diminution of the dip to introduce it as an element of calculation. Mr. DOUGLAS's observations with Nos. 5. and 6. correspond to November 1828, when those needles were vibrated in London; and with Nos. 3. and 4. to January 1832, being the middle time between the observations before his departure, and those made with the same needles in June 1836, when returned to England. Captain BELCHER's determination corresponds to August 1839, when his needles were vibrated at Woolwich. Taking the annual decrease of the dip in London in the interval at 2'·6*, and the value of the horizontal intensity at 480·0 in August 1839, we have its value 472·7 in January 1832, and 469·7 in November 1828; omitting the consideration of the secular change of the intensity itself, of which we know extremely little at present. Adopting these values of the horizontal intensity at the respective epochs, the American determinations become as follows, being all relative to 480 in August 1839.

	DOUGLAS.		BELCHER.
Fort Vancouver	Nos. 5. and 6. 581;	Nos. 3. and 4. 577 . .	576
San Francisco .	Nos. 5. and 6. 712;	Nos. 3. and 4. 714 . .	711
Monterey . .	Nos. 5. and 6. 736;	Nos. 3. and 4. 729 . .	731
Sta Barbara . .	Nos. 5. and 6. 768;	Nos. 3. and 4. not obsd.	765

There are still involved in the comparison the secular change of dip at the American stations, and the secular changes of the total intensity both there and in London: none of these are known sufficiently to make them proper elements of calculation, though we have reason to believe that the effect of each of these causes on the comparative numbers would be considerably less than that of the decrease of dip in London†. But enough has been said to show the large proportion which in such

* Eighth Report of the British Association, pp. 62. 66.

† By comparing Captain BELCHER's observed inclinations with M. HANSTEEN's map of that element in 1780, we perceive that the inclination is annually increasing on the west coast of North America, but the amount of the annual change is apparently considerably less than that of the annual decrease in Europe:—with an annual increase of inclination we should have a decrease in the horizontal intensity; this corresponds with the remaining differences between the determinations of Captain BELCHER and Mr. DOUGLAS.

determinations, the "corrections for epoch" and the uncertainties consequent thereupon, bear to the probable amount of the combined instrumental differences and observation errors of independent careful observers; and, consequently, the importance of the *synchronism* so much insisted upon, of the observations which are to concur in determining the magnetic state of the globe at the present period.

Inclination.—The inclinations contained in Table IX. were observed with a six-inch instrument by Robinson, with a needle by the same artist. The poles of the needle were reversed on every occasion, and the observations were repeated in the eight different positions of the circle and needle. Usually five repetitions were made in each position, and the arcs at both ends of the needle being read, the inclinations in the Table are generally a mean of eighty readings.

Table IX.—Observations of the Inclination.

Station.	Date.	Poles. Direct.	Poles. Reversed.	Inclination.	Inclination. (mean)	Remarks.
	1837.					
Panama	March 8	30° 58′·8	32° 53′·2	31° 51′·0	31° 51′·9	Near the Ruins of the Convent of San Francisco.
	March 8	30 54·6	32 51·0	31 52·8		
Magnetic Island	March 20	30 27·5	32 01·5	31 14·5	31 11·9	
	March 22	30 08·5	32 10	31 09·3		
Oahu	July 20 and 24	40 43·4	42 27·6		41 35·1	
Port Etches	August 26 and 28	76 02·2	76 03·6		76 02·9	
Sitka	September 20	75 47·5	75 53·8	75 50·6	75 51·5	Observation Island.
	September 22	75 49·1	75 55·5	75 52·3		
San Blas	December 21	44 20·2	46 30·2	45 25·2	45 24·3	Palm Island.
	December 22	44 12·8	46 34·0	45 23·4		
	December 22	43 59·2	45 26·3		44 42·7	Beach near the Arsenal.
San Francisco	December 29	61 18·9	62 28·7		61 53·8	Yerba Buena.
	1838.					
Acapulco	January 18	36 51·2	39 03·7		37 57·4	Near the Castle.
Realejo	March 19 and 21	33 13·6	36 00·2		34 36·9	Cardon Island.
Cocos Island	April 6	22 29·2	24 36·9		23 33·2	
Callao	June 19 and 23	−4 20·9	−8 07·7		−6 14·3	Plaza de los Muertes.
Puna Island (Guayaquil)	September 17	8 09·4	9 11·1		8 40·2	Punta Arena.
	September 20	8 58·1	10 15·8		9 36·9	Town of Puna.
	September 21	8 22·3	10 27·9	9 25·1	9 08·0	Pt Spanola.
	September 24	8 10·5	9 31·2	8 50·9		
	1839.					
Cocos Island	March 7	21 26·6	24 24·9		22 55·7	
Oahu	June 1	40 24·9	42 15·0	41 19·9	41 16·8	
	June 6	40 12·5	42 09·7	41 11·1		
	June 7	40 36·2	42 02·6	41 19·4		
Kodiack	July 7	72 28·1	72 57·6		72 42·9	Near Pt Greville.
Sitka	July 19	75 43·4	75 54·9		75 49·1	
Baker's Bay	September 13	69 27·5	69 26·2		69 26·9	
Fort Vancouver	August 12	69 15·9	69 23·6	69 19·8	69 22·2	
	August 12	69 20·2	69 28·9	69 24·6		
Port Bodega	September 25	62 50·6	62 56·2		62 53·4	On the Sandy Neck.
San Francisco	September 30	61 50·2	62 16·0	62 03·1	62 05·0	
	September 30	61 37·1	62 16·0	61 56·6		
	October 1	61 52·3	62 25·7	62 09·0		
	October 1	61 52·3	62 22·9	62 07·6		
	October 2	61 50·2	62 25·7	62 08·0		

TABLE IX. (Continued.)

Station.	Date.	Poles. Direct.	Poles. Reversed.	Inclination.	Inclination. (mean)	Remarks.
	1839.					
Monterey	October 5	60° 59′·6	61° 07′·5		61° 03′·6	
S^{ta} Barbara......	October 10	58 53·2	58 55		58 54·1	
San Pedro	October 12	58 14·7	58 28·1		58 21·4	Fossil Island.
San Diego	October 17	56 49·5	57 22·7		57 06·1	
San Quentin	October 24	54 01·9	54 58		54 29·9	
San Bartholomew	October 29	51 12·7	52 09·4		51 41·0	
Magdalena Bay	November 1 ..	45 22·1	47 40·5	46 31·3	46 34·0	
	November 1 ..	45 37·5	47 36·0	46 36·7		
San Lucas Bay ..	November 21 ..	44 37·5	46 41·0		45 39·3	
Mazatlan	November 29 ..	45 42·7	47 30·0	46 36·3	46 38·5	
	December 2 ..	45 43·6	47 37·7	46 40·7		
	December 6 ..	43 34·5	45 22·8	44 28·7	44 32·5	Beach.
	December 19 ..	43 40·8	45 31·7	44 36·3		
	December 8 ..	43 39·9	45 39·4	44 39·6		
San Blas......	December 8 ..	43 38·4	45 39·4	44 38·9		
	December 10 ..	43 42·7	45 29·9	44 36·3	44 38·3	Tepic.
	December 10 ..	43 39·9	45 29·9	44 34·9		
	December 11 ..	43 42·7	45 40·6	44 41·6		
Socorro Island ..	December 26 ..	39 31·8	41 55·5		40 43·7	
Clarion Island ..	December 29 ..	35 21·4	38 44·6		37 03·0	
	1840.					
	January 23	−13 20·2	−14 53·6	−14 06·9		
Martins Island	January 25	−13 12·3	−14 50·6	−14 01·5	−14 06·0	Anna Maria Bay.
	January 27	−13 22·5	−14 56·5	−14 09·5		
	February 6....	−30 13·9	−30 19·7	−30 16·8	−30 19·0	Entrance Village.
	February 29....	−30 18·0	−30 24·4	−30 21·2		
	February 25....	−30 07·1	−31 08·6		−30 37·9	S.E. point.
	February 26....	−30 00	−30 38·2		−30 19·1	S.W. point.
Bow Island....	February 27....	−29 43·4	−30 08·2		−29 55·8	Western extreme.
	February 22....	−30 04·8	−30 13·4	−30 09·1		
	March 14......	−29 44·6	−30 37·5	−30 11·1	−30 15·3	Observatory.
	March 20......	−29 27·7	−31 11·1	−30 19·4		
	March 21......	−29 28·7	−31 14·8	−30 21·7		

Total Intensity.—The values of the total intensity of Captain BELCHER's American stations are deducible from the values of the horizontal intensity in Table VI., and of the inclination in Table IX., by the formula

$$I' = I \cdot \frac{h' \sec i'}{h \sec i},$$

where i, h, and I are the inclination, horizontal and total intensities at Woolwich, and i', h', and I′ the values of the same at any other station. Regarding Woolwich and London as identical, we have I = 1·372, the conventional number by which the total intensity in London is usually expressed. The values of the total intensity in Table X. have been thus computed.

Declination.—The declinations were observed with a nine-inch altitude and azimuth instrument by CARY, having a four-inch magnetic needle attached, which was read at both extremities. Each determination is stated to be the mean result of several observations, both of the true meridian, and of the magnetic direction.

TABLE X.—General Table of the Results of Captain BELCHER's Magnetic Observations on the West Coast of America, and the adjacent Islands. The longitudes in this Table are east of Greenwich; the declinations east; the values of the horizontal intensity are expressed relatively to 1000 at Panama; and the total intensities relatively to 1·372 at London.

Station.	Date.	Latitude.	Longitude.	Declination.	Inclination.	Intensity. Horizontal.	Intensity. Total.	Remarks.
		° ′	° ′	° ′	° ′			
Port Etches	1837	+ 60 21	213 19	31 38·5	+ 76 02·9	411	1·728	
Kodiack	1839	+ 57 20	207 09	26 43·5	+ 72 42·9	470	1·603	
Sitka	1837	+ 57 03	224 34	27 42·0	+ 75 51·5			
Sitka	1839	+ 57 03	224 38	29 32·5	+ 75 49·1	412	1·704	
Baker's Bay	1839	+ 46 17	235 58	19 11·0	+ 69 26·9	569	1·643	
Fort Vancouver..	1839	+ 45 37	237 24	19 22·0	+ 69 22·2	576	1·657	
Port Bodega	1839	+ 38 18	236 58	15 20·0	+ 62 53·4	703	1·563	
San Francisco ..	1837	+ 37 48	237 37	15 20·0	+ 61 53·8			
San Francisco ..	1839	+ 37 48	237 37	15 20·0	+ 62 05·8	711	1·540	
Monterey	1839	+ 36 36	238 07	14 13·0	+ 61 03·6	731	1·531	
Sta Barbara	1839	+ 34 24	240 19	13 28·0	+ 58 54·1	765	1·501	
San Pedro	1839	+ 33 43	241 45	13 08·5	+ 58 21·4	766	1·480	
San Diego	1839	+ 32 41	242 47	12 20·6	+ 57 06·1	794	1·482	
San Quentin	1839	+ 30 22	244 02	12 06	+ 54 29·9	837	1·461	
San Bartholomew	1839	+ 27 40	245 07	10 46	+ 51 41·0	876	1·432	
Magdalena Bay..	1839	+ 24 38	247 53	9 15	+ 46 34·0	924	1·362	
Mazatlan	1839	+ 23 11	253 36	9 24	+ 46 38·5	928	1·370	
San Lucas Bay ..	1839	+ 22 52	250 07	8 37·5	+ 45 39·3	937	1·359	
San Blas........	1837	+ 21 32	254 44	8 34	+ 45 24·3	....	....	Palm Island.
San Blas........	1839	+ 21 32	254 44	9 00	+ 44 32·5	958	1·362	Beach.
Oahu Island	1837	+ 21 17	202 00	10 39·5	+ 41 35·1			
Oahu Island	1839	+ 21 17	202 00	....	+ 41 16·8	841	1·134	
Socorro Island ..	1839	+ 18 43	249 06	....	+ 40 43·7	977	1·307	
Clarion Island ..	1839	+ 18 21	245 19	....	+ 37 03·0	962	1·222	
Acapulco	1838	+ 16 50	260 05	8 23	+ 37 57·4	1024	1·316	
Realejo	1838	+ 12 28	272 48	7 53·5	+ 34 36·9			
Panama	1837	+ 8 37	280 31	....	+ 31 51·9	1000	1·193	
Magnetic Island..	1837	+ 8 04	278 15	7 37·5	+ 31 11·9			
Cocos Island	1838	+ 5 53	272 58	8 24	+ 23 33·2			
Cocos Island	1839	+ 5 53	272 58	....	+ 22 55·7	1022	1·125	
Puna Island	1838	— 2 47	280 05	8 56	+ 9 08	998	1·024	
Martins Island ..	1840	— 8 56	220 20	....	— 14 06·0	980	1·024	
Callao..........	1838	— 12 04	282 52	....	— 6 14·3	950	0·968	
Bow Island......	1840	— 18 05	219 07	....	— 30 16·0	957	1·123	

The declination was observed by Captain BELCHER at Socorro, Clarion, Martin, and Bow Islands, but the record of the observations has not yet been sent home: an early opportunity will be taken of supplying this deficiency in the Table when the observations shall have been received.

§ 4. *New Determination of the Magnetic Elements at Otaheite.*

In M. Gauss's "General Theory of Terrestrial Magnetism*," there is a note to the following effect:—"Otaheite is a station of the highest importance for the future improvement of the magnetic elements: the difference between the two determinations of intensity made there by different observers, viz. Erman 1·172 in 1830, and FitzRoy 1·017 in 1835, is much greater than can with any degree of probability be attributed to yearly changes, and considerably exceeds the greatest difference between the computed and observed intensities at the eighty-six stations at which the theory has been compared with observations."

The importance which M. Gauss attached to a more exact determination of the magnetic elements at Otaheite was communicated to Captain Belcher in a letter from Captain Beaufort, which also conveyed to him permission from the Admiralty to touch at that Island on his homeward voyage. Quitting Bow Island in March 1840, Captain Belcher arrived at Otaheite in April, and made there the observations contained in Tables XI. and XIII., of which the results are given in Tables XII. and XIV.

Table XI.—Observations with the Intensity Needles at Otaheite.

1840.	Needle.	Time.	Therm.	Corrected Time.	1840.	Needle.	Time.	Therm.	Corrected Time.
		s	°				s	°	
April 4	5	483·9	87		May 6	8	478·9	88	
April 4	5	483·7	87		May 6	8	479·1	86	s 476·3
April 4	5	484·2	88		May 7	8	479·6	77	
May 3	5	482·8	90		May 7	8	478·6	76	
May 3	5	482·1	90	s	May 6	9	443·3	85	
May 4	5	480·8	74	479·5	May 6	9	443·4	84	441·6
May 4	5	482·3	86		May 7	9	444·2	75	
May 4	5	482·2	88		May 6	11	480·6	72	
May 4	5	482·2	89		May 6	11	480·4	80	478·0
May 5	5	481·6	76		May 6	11	480·7	89	
May 6	5	481·3	73		May 6	12	408·8	72	
April 17	5	480·1	77	478·2†	May 6	12	409·1	85	406·8
April 17	5	480·6	77		May 6	12	409·2	88	
May 6	7	547·9	94		May 6	13	399·8	73	
May 6	7	547·9	94	544·2	May 6	13	400·7	86	398·2
May 6	7	548·4	77		May 6	13	400·6	86	

* Resultate für 1838, I.

† Observed at Papeite: the other observations with No. 5, as well as all the observations with other needles, were made at Point Venus.

Table XII.—Observed values of the Horizontal Intensity at Otaheite.

	Needle.	Corrected Time.	Horizontal Intensity.	
		s		
Point Venus ..	5	479·5	958·6	965·4
	7	544·2	971·8	
	8	476·3	965·1	
	9	441·6	965·1	
	11	478·0	966·8	
	12	406·8	968·9	
	13	398·2	961·4	
Papeite	5	478·2	963·8	

Table XIII.—Observations of the Inclination at Otaheite.

1840.	Poles		Inclination.		Place of Observation.
	Direct.	Reversed.			
May 2	29° 48′·4	30° 54′·0	30° 21′·2	30° 17′·7	Point Venus.
May 2	29 46·7	30 52·7	30 19·7		
May 4	29 45·0	30 46·2	30 15·6		
May 5	29 48·0	30 43·9	30 15·9		
May 6	29 50·4	30 41·3	30 51·9		
April 11	26 17·0	28 01·0	....	27 09	Papeite.

Table XIV.—General Results of Captain Belcher's magnetic observations at Otaheite.

Place of Observation.	Declination.	Inclination.	Intensity.	
			Horizontal.	Total.
Point Venus .	6° 30′ E.	+ 30° 17′·7	965	1·133
Papeite	not observed.	+ 27 09	964	1·098

Horizontal Intensity.—Captain BELCHER's determination of the horizontal intensity falls between those of MM. ERMAN and FITZROY.

Horizontal Intensity according to	ERMAN	1005
	FITZROY . . .	874
	BELCHER . . .	965

But the differences of the three determinations far exceed in amount the errors, either instrumental or of observation, to which such experienced observers, provided with needles of steady magnetism, are liable; neither should we be justified in ascribing them to fluctuations in the magnetic force itself, especially at a station where the dip is small, and its variations have comparatively little influence on the horizontal intensity. The only known cause to which we can, with any degree of probability, attribute them, is to *station error*, in an island of which the basis is a volcanic rock: and to the same cause we must also refer the difference of three degrees in the inclination observed by Captain BELCHER at Papeite and Point Venus, stations within seven geographical miles of each other, with an instrument of which the probable error, as derived from the observations at Point Venus, does not exceed the same number of minutes. In such localities it is well known to observers, that disturbing influences, producing differences as great as and even greater than those above stated, frequently occur at places not many yards apart. We know the intensity observations at Point Venus, with Captain BELCHER's seven needles, to have been made at one spot, and it is worth while, therefore, to examine the degree of accordance with each other which their results present. Assuming the horizontal intensities determined by each of these needles to have an equal and independent value, and taking, therefore, the arithmetical mean as their most probable result, we have the errors of the needles as follows:—

No. 5.	Horizontal Intensity 958·6;	Error − 6·8
No. 7.	Horizontal Intensity 971·8;	Error + 6·4
No. 8.	Horizontal Intensity 965·1;	Error − 0·3
No. 9.	Horizontal Intensity 965·1;	Error − 0·3
No. 11.	Horizontal Intensity 966·8;	Error + 1·4
No. 12.	Horizontal Intensity 968·9;	Error + 3·5
No. 13.	Horizontal Intensity 961·4;	Error − 4·0
	Mean . . . . . 965·4	

Consequently the mean error ε_2* is

$$\varepsilon_2 = \sqrt{\frac{117 \cdot 59}{6}} = 4 \cdot 425,$$

whence the *probable error*, *r*, of a determination with one needle is

$$r = \varepsilon_2 . \varrho \sqrt{2} = 0 \cdot 674489 \, \varepsilon_2 = 3 \cdot 0,$$

and the probable error of a determination with seven needles $\frac{r}{\sqrt{7}} = 1 \cdot 1$.

* ENCKE, Astron. Jahr. 1834, and Scientific Memoirs, vol. ii. Art. X.

M. Erman's determination differs 40·0, and Captain FitzRoy's 91·0 from Captain Belcher's; the former thirteen times, and the latter thirty times, the probable error of a determination with a single needle of steady magnetism, *where the spot of observation is the same.*

We have considered Captain Belcher's seven needles as giving *equal* and *independent* results for the ratio of the horizontal intensity at Otaheite and Panama; but the result with No. 8. is not strictly an *independent* one, inasmuch as at San Blas that needle received a small correction assigned from its comparison with the others; and the claim of the result of No. 5. to be considered as of *equal* value with that of each of the remaining needles is impaired by the probability of that needle having sustained a slight loss of magnetism at or before Martins Island (page 16.). If, therefore, we were to exclude the results of Nos. 5. and 8, and to derive the horizontal intensity at Otaheite from the five needles, which we may consider as of strictly independent and equal authority, we should have as their mean 966·8, with a probable error of 1·2, and the probable error of a determination with a single needle 2·6. It is true that the number of partial results from which this amount of the probable error is derived is small; but the probability of its being an approximately just representation of the errors of instrument and observation in this method, with needles of steady magnetism, is strengthened, if we examine in the same manner the results with the same five needles at the four stations preceding Otaheite; by so doing we obtain the probable error of a single needle from each as follows:—

Bow Island . . .	2·2
Martins Island . .	1·6
San Blas	1·5
Mazatlan	2·2

The integers in these quantities represent hundredth parts of the space comprised between two adjacent lines of horizontal intensity in M. Gauss's theoretical map of that element.

Uncertainties in respect to the magnetism of needles need no longer prove a source of vexatious anxiety and embarrassment even to travelling observers; with the simple apparatus described by M. Weber* the magnetic state of a needle may be examined at pleasure, and its magnetism may be altogether eliminated in the result.

With this advantage, however,—and it will be scarcely less valued by the confidence it creates whilst the observations are in progress, than by the independency it confers on their results,—and with a probable error of observation of extremely small amount, the magnetic traveller has still two serious sources of error to contend with: 1st, the values of the magnetic elements which he determines may not be *mean values*, by reason of the periodical or irregular fluctuations of the magnetic direction or

* Resultate für 1837, and Scientific Memoirs, vol. ii. Art. IV.

force possibly prevailing at the time of observation; and, 2nd, they may not be true measures of the magnetic elements corresponding to the geographical position in which the observations are made, by reason of those local disturbing magnetic influences which are included under the name of station error.

For the first of these sources of error a remedy is presented, whenever the observations can be made in connexion with those of a fixed magnetic observatory, situated within such distance that the magnetic elements are subject to the same periodical and irregular variations. The particular advantage possessed by the absolute determinations of the fixed observatories,—that of being *mean* values of the quantities sought,—may thus be indefinitely extended.

Against the more formidable evil of *station error* the connexion with a fixed observatory affords the magnetic traveller no security; nor can it furnish him with a correction,—for to error from this source the absolute determinations of fixed observatories are themselves no less liable; and no continuance, or frequency of repetition at the spot itself, will lead to its discovery or assign its correction. The magnetic survey of the British Islands, and more especially of its Scottish and Irish portions, has shown that such disturbances are not confined to localities, which, like Otaheite, consist chiefly of volcanic rocks, but may exist unsuspected and productive of error of serious amount, wherever the igneous rocks rise through, or approach the superficial soil. It is this source of error which presents a practical difficulty to the determination of the elements of the theory of terrestrial magnetism from exact observations at a few chosen positions on the globe. The remedy is to be found in the combination of fixed magnetic observatories and magnetic surveys; the observations of the survey being based on and executed in concert with the regular observations of a fixed observatory; the country surveyed being also sufficiently extensive to neutralise district anomalies, as well as those of a more local nature. The observations of the survey, corrected to mean determinations by their connexion with those of an observatory, and combined in the manner described by Mr. LLOYD in the third section of the Survey of the British Islands, will furnish in their turn the correction for the station error, if any, of the fixed observatory.

Total Intensity.—From the value of the total intensity at Otaheite as now determined by Captain BELCHER, we learn that the *southerly inflection* of the isodynamic lines, in and about the meridian of the Society Islands,—which was pointed out as one of the characteristic features of the general configuration of those lines in the southern hemisphere*,—is even more strongly marked in the latitude of those islands than I had ventured to draw it, under the circumstances of the unusual discordance in the only observations which we then possessed.

* Seventh Report of the British Association, p. 73.

Declination.—I have collected in the subjoined Table all the recorded observations of the declination at Matavai Bay with which I am acquainted, from the earliest discovery of the island to the present time.

Table XV.—Declination observed at Matavai Bay, Otaheite.

Year.	Month.	Observer.	Declination. (East.)	Year.	Month.	Observer.	Declination. (East.)
1765	June........	Byron	5° 00′	1792	January	Vancouver	6° 12′
1767	July........	Wallis..........	5 36	1823	May........	Duperrey........	6 40
1769	June........	Cook	4 46	1824	March	Kotzebue........	6 50
1773	August......	Wales and Bayley	5 40	1826	April	Beechey	7 33
1774	April and May	Wales and Bayley	5 46	1835	November ..	FitzRoy	7 34
1777	December ..	Cook	5 34	1840	May........	Belcher	6 30

A first glance at these observations shows that the easterly declination has been increasing at Otaheite from the time of the first discovery of that island. It is scarcely probable that the progression has been strictly uniform throughout the whole period, but the deficiency of determinations in the years that form the middle portion of the interval, renders the data that we possess unsuitable for deducing the variation in the rate of the secular change; and we must be content with that approximate representation which may be given by an uniform rate. Assuming, therefore, the change of declination to be proportional to the time, I have computed by the method of least squares from the data contained in the Table, the following formula for the declination δ at Otaheite:

$$\delta = 6^\circ \; 11'{\cdot}85 + 1'{\cdot}656 \, t,$$

t being the interval of time elapsed since January 1, 1800, expressed in terms of a year.

The declinations computed according to this formula, and the differences from the observed declinations, are as follows:—

	Computed.	Differences.		Computed.	Differences.
1765 . . .	5° 15′	+ 15′	1792 . . .	5° 59′	− 13′
1767 . . .	5 18	− 18	1823 . . .	6 51	+ 11
1769 . . .	5 21	+ 35	1824 . . .	6 52	+ 2
1773 . . .	5 28	+ 12	1826 . . .	6 55	− 38
1774 . . .	5 29	− 17	1835 . . .	7 12	− 22
1777 . . .	5 35	+ 1	1840 . . .	7 19	+ 49

It will be seen that the discordances with each other of the observations of recent date are as great, and even greater, than those of the earlier observers; which ought to be an indication that the larger discrepances are occasioned rather by local disturbing influences than by errors of observation. The probable error of a single determination, as resulting from the tabulated differences, would be about fifteen minutes.

Inclination.—The observations of the inclination made in the voyages of Captain Cook are entitled to much consideration, in respect both to the experience and skill of the observers, and to the goodness of their instruments. The English dipping needles of that period were made with much more care, and were much superior, especially in their axles, to those subsequently supplied to the government expeditions up to a very recent date. I have therefore placed in the subjoined Table the observations of Mr. Bayley in 1773, 1774, and 1777; and have combined them with the determinations of recent observers, for the purpose of exhibiting the secular change of the inclination at Otaheite, as deduced from the most unexceptionable data that we possess.

Table XVI.—Observations of the Inclination at Point Venus, Otaheite.

Year.	Month.	Observer.	Inclination.
			° ′
1773	August....	Bayley..	−29 43
1774	May......	Bayley..	−29 59
1777	December..	Bayley..	−29 47
1823	May......	Duperrey	−30 03
1830	September	Erman..	−30 29·5
1835	November	FitzRoy	−30 14·5
1840	April	Belcher	−30 17·7

Whence, by the method of least squares, we obtain for the inclination the formula

$$I = -30° 01'{\cdot}1 - 0'{\cdot}447\,t,$$

t being, as before, the interval of time elapsed since January 1, 1800, expressed in parts of a year. The inclination in January 1840, computed by the formula, is $-30° 19'{\cdot}0$.

No observation recorded to have been made at Otaheite by Captain Belcher or his officers, has been omitted in the foregoing account: the manuscript records of the observations on the west coast of America and the adjacent islands, as well as those at Otaheite, are deposited in the Hydrographic Office of the Admiralty.