SMITHSONIAN CONTRIBUTIONS TO KNOWLEDGE.

OBSERVATIONS

ON

TERRESTRIAL MAGNETISM

IN

MEXICO.

CONDUCTED UNDER THE DIRECTION OF

BARON VON MÜLLER,

WITH NOTES AND ILLUSTRATIONS OF AN EXAMINATION OF THE VOLCANO POPOCATEPETL AND ITS VICINITY.

BY

AUGUST SONNTAG.

[ACCEPTED FOR PUBLICATION, MAY, 1859.]

COMMISSION

TO WHICH THIS MEMOIR HAS BEEN REFERRED.

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COLLINS, PRINTER,
PHILADELPHIA.

PREFACE.

In 1856, Baron von Müller, of Germany, undertook an exploration in reference to the natural history of Mexico, and proposed to the Smithsonian Institution to make in its behalf a magnetic survey of the same country.

The offer having been accepted by the Institution, an appropriation was made to pay a portion of the salary of Mr. Sonntag, the assistant of Baron von Müller; and the magnetic instruments were intrusted to him which had previously been lent to Dr. Kane, and used by Mr. Sonntag himself, as one of the assistants of this lamented explorer in his last expedition.

Several records of observations, made at various places in Mexico, were at different times forwarded by Baron von Müller previous to his return to Germany, after which the Institution was informed by him that the instruments had been captured and destroyed by robbers.

No final report having been furnished by Baron von Müller, the crude observations made previous to the loss of the instruments have been reduced for publication at the expense of the Institution, by Mr. Sonntag, and the results given in the following pages.

Appended to the magnetical observations will be found a series of notes by Mr. Sonntag, upon the volcano of Popocatepetl and its vicinity.

The present memoir was critically examined by Mr. C. A. Schott, of the Coast Survey, and has been submitted to Professors Guyot and Alexander, of Princeton, as a commission of reference.

JOSEPH HENRY,
Secretary S. I.

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PART I.

OBSERVATIONS

ON

TERRESTRIAL MAGNETISM IN MEXICO.

MAGNETICAL OBSERVATIONS.

INSTRUMENTS AND METHODS OF MAKING THE OBSERVATIONS.

The following observations were made with a set of magnetic instruments, furnished to Baron Von Müller by the Smithsonian Institution. The set contained a small theodolite, a declinometer, and a unifilar-magnetometer, made by Jones, and a Barrow dip-circle. The last-mentioned instrument I had formerly used in Dr. Kane's Arctic expedition, where it was subjected to some rough usage; and although it had been carefully adjusted before it was taken out to Mexico, the axis of the needles proved not to be as perfectly cylindrical as was desirable.

The determinations of absolute declination were made by means of the small theodolite and the declinometer. The azimuth circle of the first named instrument reads to thirty seconds by means of three verniers. It carries also a vertical circle, reading to single minutes. On its transit from Vera-Cruz to Potrero it suffered much, and the clamping-screws and the arms which carry the verniers were bent; this accounts for the great differences in the readings of the single verniers after the first observations. This instrument was used to determine the true [astronomical] and the magnetical azimuth of a mark, for the purpose of obtaining the magnetic declination. The first of these operations consisted in observing the mark and the first and second [western and eastern] limb of the sun, and in determining the error of the chronometer, by which the time of the solar observations was noted.

This error of local time was found generally by double altitudes of the sun, taken either with the theodolite or by means of a pocket-sextant, reading to single minutes, and a mercurial horizon. As the level attached to the vertical circle of the theodolite was not sufficiently sensitive, it was generally thought best to observe also with this instrument the reflected image of the sun. An equal number of observations of the upper and lower limb of the sun were always taken. A pocket-chronometer of Parkinson & Frodsham was used, and its rate on mean time continued always very small.

The declinometer carried a wooden box with a glass-tube of ten inches in length for suspending the magnet. This box was fastened to a table of the same material. After bringing the sides of the box nearly into the magnetic meridian and levelling it, the torsion was taken out of the silk thread by means of a brass collimater, containing a very weak magnetic needle, and the torsion-circle turned until the collimater stood parallel to the box. Then the magnet was put in the place of the collimater and adjusted in height and illumination. It was of cylindrical form and hollow, the north-end being closed by a lens, and the south-end by a plane-glass into which a fine scale was cut.

The theodolite was mounted about one foot to the northward of the declinometer, and so adjusted that the scale on the magnet appeared distinctly. The vertical wire was put near the centre division, and after a set (generally three) of readings had been made, the magnet was turned 180° around its axis, so that the numbers of the scale, if they had appeared upright before, were now inverted. The first position of the scale is always marked *D.* (direct), the second *R.* (reversed). This operation was several times repeated, and the scale-division, corresponding to the axis of the magnet, determined by combining the means of the 1st and 3d set with the mean of the middle set. Next, the angle between the axis of the magnet and the mark was measured by means of the theodolite; and thus the magnetic azimuth of the mark was determined. By these observations the telescope of the theodolite was always several times reversed, so as to eliminate the error which might arise from a deviation of the optical axis, which changes with the focal length.

The declinometer was also used for observing the vibrations in the determination of horizontal intensity. For this purpose two wooden arms were attached to it, one carrying a telescope and ivory scale, the other a counterpoise-weight. After levelling the instrument and taking the torsion out of the supension-threads by means of the plummet, the magnet *D* 3 was suspended. It was of cylindrical form and 3.87 inches in length, and carries a small mirror (intended to reflect the ivory scale), the plane of which was perpendicular to the axis of the magnet. A thermometer was placed in the box and read after each set of observations. The magnet was steadied and the instrument turned in azimuth until the vertical wire of the telescope covered the centre division of the reflected scale. The magnet was found to hang so nearly horizontally, that it was not necessary to use a balance-ring. All vertical motion was carefully checked and the magnet deflected from 100 to 180 scale-divisions from the meridian by means of another small magnet, and then left to vibrate. The time of a passage of the central-division over the wire of the telescope was now observed, and recorded as the time of commencement or 0 vibration, and afterwards the time, when the centre-division passed the wire again at the completion of the 10th, 20th, 30th, 40th, and 50th vibrations, was accurately noted. The 100th, 200th, and 300th vibrations were also noted, and generally the extreme scale readings were recorded at the same time. After the 300th again every 10th to the 350th vibration was observed, thus obtaining six values for the time, in which the magnet made 300 vibrations, viz., from 0 to 300, from 10 to 310, etc.

Occasionally the coefficient of torsion was determined by reading at first the torsion-circle and the scale, then turning the torsion-circle 90° and reading the scale again, then turning it 180° in the opposite direction, and finally turning it back 90° to its original position, and reading the scale each time. It remained always nearly the same and was very small.

The unifilar-magnetometer was only used for experiments of deflection. The horizontal circle of this instrument read to 20 seconds. It supported a heavy copper box, which quieted the magnet, suspended in it, to a considerable extent. To this box were fastened two arms, of about 1.5 feet in length, with grooves, in which the deflecting magnet rested. One of these arms carries also the telescope and the scale, which was reflected from a small mirror, attached to the magnet in such a manner that its axis was parallel to the plane of the mirror. The deflecting magnet was the same used in the vibration experiments. After the instrument was levelled, and the torsion taken out of the silk thread, a magnet of somewhat smaller dimensions than the deflecting magnet was suspended. This last one was placed in the groove on the eastern arm at the distance of one foot, and the instrument turned until the middle of the scale appeared behind the vertical wire of the telescope. Then the circle was read and the magnet placed on the western arm at the same distance and the same pole pointing in the same direction (so that the opposite pole was now turned towards the deflected magnet), when the circle was read off again, and the south pole of the deflecting magnet placed where its north pole was before, without altering the distance. The instrument was now turned until the middle of the scale was again behind the vertical wire and the circle-reading noted. Then the magnet was placed on the eastern arm, at the same distance, and without changing the poles, etc. Afterwards the distance was increased to 1.3 feet, and the operation repeated. At the end of each set the temperature of the deflecting magnet was noted. In the observations with the dip-circle the instrument was brought into the meridian by turning the horizontal circle in azimuth until the dipping-needle indicated 90°. Then the circle was read and turned about 180°, when the needle was brought again into a vertical position and the horizontal circle was read once more. By means of these readings the needle was put in the magnetic meridian. The poles of the needles were reversed at each observation.

OBSERVATIONS AT VERA-CRUZ.

Description of Station No. 1.—The instruments were mounted in the centre of a room, situated on the first floor, and in the northern corner of a villa or cottage, called "la Guacca," two hundred yards outside of the walls of Vera-Cruz, and on the south side of this city. The floor was of marble, and no basement below it. There was no iron in the neighborhood, the locks and hinges of the doors, etc., being of brass. On the walls of the city, two hundred yards to the north, were several heavy iron guns. The grounds near the villa consisted of sand and clay. The instruments were elevated about fourteen feet above the level of the sea, which is only five hundred yards distant.

Station No. I. Vera Cruz, villa "La Guacca."
Latitude 19° 12′. Longitude 96° 9′ W. of Greenwich.

Absolute magnetic declination. True azimuth of the mark A.[1]
1856. August 8, A. M. Small theodolite.

Circle to the left.			Circle to the right.		
Object.	Chronometer.	Circle reading.	Object.	Chronometer.	Circle reading.
⊙ Ist limb	0h 59m 6s	118° 20′ 30″	Mark A	1h 16m —s	356° 34′ 30″
		18 0			36 0
		19 30			34 45
IId limb	1 3 9	118 2 30	⊙ Ist limb	1 18 42	88 41 0[2]
		1 30			39 30
		0 30			41 0
Mark A	1 8 —	356 34 0	⊙ IId limb	1 21 39	88 20 30
		35 15			19 30
		34 30			20 0
Mark A	1 27 —	326 16 45	Mark A	1 24 —	325 16 30
		18 0			16 30
		16 0			15 0
⊙ Ist limb	1 29 20	89 27 0	———	———	———
		26 0			
		27 0			
⊙ IId limb	1 31 32	89 2 0	———	———	———
		1 0			
		2 30			

Absolute magnetic declination. Altitudes of the sun, for the determination of time.
1856. August 8, A. M. Small theodolite.

Direct.			Reflected.		
Sun's limb.	Chronometer.	Circle reading.	Sun's limb.	Chronometer.	Circle reading.
	2h 9m 22s	29° 0′[3]		2h 4m 58s	332° 15′
Upper	10 21.5	15	Lower	5 57	0
	11 27	33		7 4	331 45
	2 13 40	29 30		2 18 46.5	328 30
Lower	14 40	45	Upper	19 50	15
	15 47	30 0		20 52	0
	2 27 24	33 15		2 22 4	328 15
Upper	28 27.5	30	Lower	23 7	0
	———	———		24 12	327 45
Lower	3 1 38	40 45	Lower	2 57 16	320 0
	2 43	41 0		58 20	319 45
Upper	3 4 44	42 0	Upper	3 8 54	316 45
	5 44	42 15		10 4	30

Index error assumed + 0° 8′.6.
Temperature of the air 7h 0m A. M., 80°.5 F.
" " 9 0 A. M., 83.0 F.
Barometer 9h 0m A. M., 29.98 inches.
Attached thermometer 84°.0 F.
Chronometer slow of Greenwich mean time + 2m 57s.7.
Daily rate 6s.3 slow.

[1] The mark A is the cross on the dome of the "Parroquia" [Parish Church], situated on the south side of the "Plaza de Armas," Vera Cruz. It is 2,310 feet distant from the Station No. I.

[2] After 1h 10m (Chron.) the sun had risen too high to be visible from the station, the theodolite was, therefore, put at another place, 12 feet distant, and bearing east by north (magn.) from the station.

[3] In these observations only one vernier of the vertical circle was read.

Zero point of the scale of the collimating magnet.
1856. August 7. Declinometer.

Chronometer.	Scale D.	Chronometer.	Scale R.	Chronometer.	Scale D.
$5^h\ 41^m$	68 6 68 6 68 8	$5^h\ 52^m$	75.0 74.9 75.0	$5^h\ 58^m$	68.8 68.7 68.6
	68.7		75.0		68.7

Zero point 71.8 on the scale. 1 division of the scale = 2′.1.

Absolute magnetic declination. Magnetical azimuth of the mark A.
1856. August 7. Theodolite and declinometer.

CIRCLE EAST.			CIRCLE WEST.		
Object.	Scale reading.	Circle reading.	Object.	Scale reading.	Circle reading.
Scale D $6^h\ 4^m$	71.8 72 0 72.0	294° 38′ 15″ 38 15 37 30	Scale R $6^h\ 27^m$	72.1 72.1 71.9	294° 42′ 30″ 43 0 42 0
Mark A	71.9 ———	294 38 0 62 17 30 17 10 16 30	Mark A	72.0 ———	294 42 30 62 24 0 23 50 23 0
Mark A	———	62 17 3 62 23 30 23 30 23 0			62 23 37
Scale D $6^h\ 40^m$	72.1 72.1 72.1	62 23 20 294 43 45 44 30 43 40			
	72.1	294 43 58			

Mark A bears N. 52° 20′ 57″ W. Mark A bears N. 52° 18′ 53″ W.
" " 20 38
Magnetical azimuth of mark A, N. 52° 19′ 50″ W.

Horizontal intensity. Experiments of vibration.
1855. August 7, A. M. Magnet D 3 suspended.

No.	Chronometer.	No.	Chronometer.	Time of 300 vibrations.
0	$2^h\ 12^m\ 30^s.5$	300	$2^h\ 25^m\ 38^s.0$	$13^m\ 7^s.5$
10	12 56.3	310	26 4.5	8 2
20	13 23.5	320	26 30.7	7.2
30	13 49.0	330	26 57.0	8 0
40	14 16.0	340	27 23.5	7 5
50	14 41.5	350	27 49.5	8 0
100	16 52 5	200	21 15.5	
				13 7.73

Extreme scale readings.

0	8	52
50	10	50
100	12	48
200	16	44
350	19	41

Temperature 81° 5 F.

Time of 1 vibration $2^s.6258$.

The chronometer, by which the time was noted, was $6^h\ 22^m$ fast of mean local time.

Horizontal intensity. Experiments of vibration.

1856. August 7, A. M. Magnet D 3 suspended.

No.	Chronometer.	No.	Chronometer.	Time of 300 vibrations.
0	2^h 32^m 17^s 5	300	2^h 45^m 25^s.0	13^m 7^s.5
10	32 43 3	310	45 50 7	7 4
20	33 9.7	320	46 17.5	7 8
30	33 36 0	330	46 43.5	7.5
40	34 2.5	340	47 10.0	7 5
50	34 28.3	350	47 36.0	7.7
100	36 39.7	200	41 2 0	
				13 7.57

Extreme scale readings.

0	11.0	49 0
50	12 5	47 0
200	17.8	42.2
300	19 7	40 5
350	21.0	39.0

Temperature 81°.5 F.

Time of 1 vibration 2^s.6252.

1856. August 7, A. M. Magnet D 3 suspended.

No.	Chronometer.	No.	Chronometer.	Time of 300 vibrations.
0	2^h 49^m 34^s.0	300	3^h 2^m 41^s.5	13^m 7^s.5
10	50 0.0	310	3 7.5	7.5
20	50 26 3	320	3 34 0	7 7
30	50 52.5	330	4 0 5	8 0
40	51 19 0	340	4 26 5	7.5
50	51 45 0	350	4 52.5	7.5
100	53 56 9	200	2 58 19 0	
				13 7.62

Extreme scale readings.

0	9 0	51.0
100	13.0	47.0
200	16 0	44 0
300	18.0	42.0
350	18 8	41.2

Temperature 82° F.

Time of 1 vibration 2^s.6254.

1857. August 8, A. M. Magnet D suspended.

No.	Chronometer.	No.	Chronometer.	Time of 300 vibrations.
0	5^h 21^m 34^s.0	300	5^h 34^m 42^s 0	13^m 8^s.0
10	22 0.0	310	35 9.0	9.0
20	22 26.5	320	35 34.0	7.5
30	22 53.0	330	36 0.5	7 5
40	23 19.0	340	36 27 0	8.0
50	23 45 0	350	36 53.5	8 5
100	25 56.5	200	30 20.0	
				13 8 08

Extreme scale readings.

0	8.0	52.0
50	10 0	50 0
100	12.0	48.0
200	16.0	44.0
350	19.0	41.0

Temperature 84°.2 F.

Time of 1 vibration 2^s 6269.

Horizontal intensity. Experiments of vibration.

1856. August 8, A. M. Magnet D 3 suspended.

No.	Chronometer.	No.	Chronometer.	Time of 300 vibrations.
0	5h 42m 2s.0	300	5h 55m 9s 0	13m 7s 0
10	42 28.0	310	55 36.0	8 0
20	42 54.0	320	58 2 0	8.0
30	43 21.0	330	56 28 5	7.5
40	43 47 0	340	56 54.5	7.5
50	44 13.0	350	57 21.0	8 0
100	———	200	———	
				13 7.67

Extreme scale readings.

0	10.0	50 0
50	12.0	48 0
100	13.0	47.0
200	17.0	43.0
350	20.0	40.0

Temperature 84°.3 F.

Time of 1 vibration 2s6256.

1856. August 8, A. M. Magnet D 3 suspended.

No.	Chronometer.	No.	Chronometer.	Time of 300 vibrations.
0	5h 59m 23s.0	300	6h 12m 30s.2	13m 7s.2
10	59 49.0	310	12 56 2	7.2
20	6 0 15 0	320	13 23.5	8.5
30	0 41.2	330	13 49.0	7 8
40	1 7.3	340	14 16.0	8.7
50	1 34.2	350	14 42 0	7.8
100	3 45.0	200	8 7.5	
				13 7.87

Extreme scale readings.

0	14.0	46.0
50	16.0	44.0
100	17.3	42.0
200	18.3	40.0
350	22.0	37.5

Temperature 84°.4 F.

Time of 1 vibration 2s.6262.

Experiments of deflections. Distance 1 foot.

1856. August 7, 1h 48m to 2h 20m P. M. Deflecting magnet D 3.

Magnet.	North pole.	Circle reading.	Mean.	2 u.	Temp.
E.	E.	143° 40′ 50″	40′ 40″		85°.0 F.
		40 30			
"	E.	143 40 40	40 30		
		40 20			
"	E.	143 41 0	41 20		
		41 40			
"	W.	128 48 20	48 5	14° 52′ 52″	
		47 50			
"	W.	128 48 20	48 5		
		47 50			
"	W.	128 48 0	47 45		
		47 30			

Horizontal intensity. Experiments of deflections. Distance 1 foot.
1856. August 7, 1^h 48^m to 2^h 20^m P. M. Deflecting magnet D 3.

Magnet.	North pole.	Circle reading.	Mean.	2 u.	Temp.
W.	E.	128° 39′ 45″	39′ 37″		
		39 30			
"	E.	128 39 50	39 40		
		39 30			
"	E.	128 39 50	39 40		
		39 30		15° 19′ 38″	
"	W.	143 58 40	58 25		
		58 10			
"	W.	143 59 50	59 50		
		59 50			
"	W.	143 59 40	59 35		85 0
		59 30			
			Mean	15 6 15	

Experiments of deflections. Distance 1.3 feet.
1856. August 7, 2^h 23^m to 2^h 38^m P. M. Deflecting magnet D 3.

Magnet.	North pole.	Circle reading.	Mean.	2 u.	Temp.
E.	E.	139° 40′ 30″	40′ 15″		85°.2
		40 0			
"	E.	139 40 30	40 20		
		40 10		6° 48′ 45″	
"	W.	132 52 0	51 40		
		51 20			
"	W.	132 51 50	51 25		
		51 0			
W.	E.	132 49 20	49 10		
		49 0			
"	E.	132 49 30	49 15		
		49 0		6 55 25	
"	W.	139 44 35	44 22		
		44 10			
"	W.	139 45 10	44 55		85.2
		44 40			
			Mean	6 52 6	

Experiments of deflections. Distance 1 3 feet.
1856. August 7, 5^h 33^m to 5^h 52^m P. M. Deflecting magnet D 3.

Magnet.	North pole.	Circle reading.	Mean.	2 u.	Temp.
E.	E.	139° 38′ 40″	38′ 22″		84°.5
		38 5			
"	E.	139 38 40	38 25		
		38 10			
				6° 50′ 47″	

Horizontal intensity. Experiments of deflections. Distance 1.3 feet.
1856. August 7, 5h 33m to 5h 52m P. M. Deflecting magnet D 3.

Magnet.	North pole.	Circle reading.	Mean.	2 u.	Temp.
E.	W.	132° 47′ 55″ 47 10	47′ 32″		
"	W.	132 48 0 47 20	47 40		
W.	E.	132 48 40 48 20	48 30		
"	E.	132 48 30 48 15	48 22		
"	W.	139 40 0 39 40	39 50	6° 51′ 31″	
"	W.	139 40 20 39 50	40 5		84.5
			Mean	6 51 9	

Experiments of deflections. Distance 1 foot.
1856. August 7, 5h 57m to 6h 17m P. M. Deflecting magnet D 3.

Magnet.	North pole.	Circle reading.	Mean.	2 u.	Temp.
W.	E.	128° 42′ 50″ 42 20	42′ 35″		84°.2
"	E.	128 43 10 42 30	42 50		
"	W.	143 52 40 52 0	52 20	15° 9′ 36″	
"	W.	143 52 30 52 5	52 17		
E.	E.	143 44 10 43 40	43 55		
"	E.	143 44 5 43 40	43 52		
"	W.	128 40 5 39 30	39 47	15 4 7	
"	W.	128 40 0 39 30	39 45		84.2
			Mean	15 6 52	

Magnetic inclination.

1856. August 8, 0^h 15^m P. M. Needle No. 2. A. North pole.

CIRCLE EAST.				CIRCLE WEST.			
Face east.		Face west.		Face east.		Face west.	
46° 49′	45° 7′	47° 13′	45° 16′	134° 45′	133° 20′	134° 49′	136° 16′
55	16	19	22	32	6	34	135 58
46 52	45 11.5	47 16	45 19	134 38.5	133 13.0	134 41.5	136 7
46 1.7		46 17.5		133 55.7		135 24.3	
46 9.6				134 40.0			
45 44.8							

1856. August 8, 0^h 15^m P. M. Needle No. 2. A. South pole.

CIRCLE WEST.				CIRCLE EAST.			
Face west.		Face east.		Face west.		Face east.	
138° 8′	140° 7′	136° 58′	138° 40′	43° 50′	42° 5′	43° 18′	41° 50′
137 51	139 50	41	23	44 1	15	30	59
137 59.5	139 58.5	136 49.5	138 31.5	43 55.5	42 10.0	43 24.0	41 54.5
138 59.0		137 40.5		43 2.7		42 39.3	
138 19.7				42 51.0			
42 15.6							

1856. August 8, 0^h 40^m P. M. Needle No. 1. A. South pole.

CIRCLE EAST.				CIRCLE WEST.			
Face east.		Face west.		Face east.		Face west.	
45° 34′	44° 0′	42° 55′	41° 9′	135° 18′	137° 2′	137° 13′	139° 5′
44	9	43 4	19	2	136 46	136 56	138 47
45 39.0	44 4.5	42 59.5	41 14.0	135 10.0	136 54.0	137 4.5	138 56.0
44 51.7		42 6.7		136 2.0		138 0.2	
43 29.2				137 1.1			
43 14.0							

1856. August 8, 0^h 40^m P. M. Needle No. 1. A. North pole.

CIRCLE WEST.				CIRCLE EAST.			
Face west.		Face east.		Face west.		Face east.	
133° 30′	135° 8′	137° 23′	139° 21′	48° 38′	47° 0	45° 13′	43° 46′
16	134 51	8	5	47	8	20	51
133 23.0	134 59.5	137 15.5	139 13.0	48 42.5	47 4.0	45 16.5	43 48.5
134 11.2		138 14.2		47 53.2		44 32.5	
136 12.7				46 12.9			
45 0.1							

Magnetic inclination.

1856. August 8, 1h 5m P. M. Needle No. 2. A. South pole.

CIRCLE EAST.				CIRCLE WEST.			
Face east.		Face west.		Face east.		Face west.	
44° 20′	42° 14′	44° 0′	42° 27′	138° 35′	136° 48′	138° 19′	140° 7′
31	22	9	37	18	32	4	139 50
44 25.5	42 18.0	44 4.5	42 32.0	138 26.5	136 40.0	138 11.5	139 58.5
43 21.7		43 18.3		137 33.2		139 5.0	
43 20.0				138 19.1			
42 30.5							

1856. August 8, 1h 5m P. M. Needle No. 2. A. North pole.

CIRCLE WEST.				CIRCLE EAST.			
Face west.		Face east.		Face west.		Face east.	
134° 53′	136° 23′	134° 30′	136° 30′	46° 32′	44° 51′	45° 53′	44° 14′
38	7	14	13	44	45 5	46 6	27
134 45.5	136 15.0	134 22.0	136 21.5	46 38.0	45 58.0	45 59.5	44 20.5
135 30.2		135 21.8		45 48.0		45 10.0	
135 26.0				45 29 0			
45 1.5							

OBSERVATIONS AT POTRERO.

Description of Station No. II.—Potrero is the first large sugar estate on the road from Vera Cruz to Orizaba, about twenty miles to the east of the last-mentioned town. Its elevation above the level of the Mexican Gulf was found 1,988 English feet (by barometrical observations). The magnetical observations have been made in a shed or barn, consisting of a roof of palm leaves supported by a number of poles. There is no iron within several hundred yards of it. The shed is situated about eighty yards to the N. N. W. of the store. A tree, nearly four miles to the west of the station, was used for a mark (A) in the determination of the absolute declination.

STATION NO. II. POTRERO.

Latitude 18° 56′. Longitude 96° 48′ W. of Greenwich.

Absolute magnetic declination. True azimuth of the mark A.

1856. August 18, A. M. Small theodolite.

CIRCLE TO THE LEFT.			CIRCLE TO THE RIGHT.		
Object.	Chronometer.	Circle reading.	Object.	Chronometer.	Circle reading.
⊙ Ist limb	1^h 3^m 48^s	249° 25′	⊙ IId limb	1^h 27^m 7^s	250° 40′
		26			33.5
		30			35
⊙ Ist limb	6 48	249 44	⊙ Ist limb	28 46	251 19
		38			13
		38			14
⊙ IId limb	8 31	249 19	Mark A	———	94 14
		13			20
		13.5			27
⊙ IId limb	10 17	249 25	Mark A	———	94 18
		21.5			20
		20			26
Mark A	———	94 14	⊙ Ist limb	1 37 10	251 55
		18			47
		23			47
Mark A	———	94 17	⊙ IId limb	39 14	251 26
		18			22
		23			20
⊙ Ist limb	1 18 22	250 31			
		26			
		23			
⊙ Ist limb	20 16	250 40			
		34			
		33.5			
⊙ IId limb	21 50	250 12			
		9			
		7			
⊙ IId limb	23 20	250 19.5			
		14			
		14			

Altitudes of the sun, for the determination of time.

1856. August 17, P. M. Small theodolite.

REFLECTED.			DIRECT.		
Sun's limb.	Chronometer.	Circle reading.	Sun's limb.	Chronometer.	Circle reading.
Upper	10h 1m 49s	38° 25′	Upper	10h 14m 53s	324° 21′
		26			20.5
Upper	3 9	38 5.5	Upper	16 11	324 38
		6			38
Upper	6 59	37 13.5	Upper	17 15	324 55
		13			54

Absolute magnetic declination. Altitudes of the sun, for the determination of time.

1856. August 17, P. M. Small theodolite.

REFLECTED.			DIRECT.		
Sun's limb.	Chronometer.	Circle reading.	Sun's limb.	Chronometer.	Circle reading.
Lower	10h 8m 9s	36° 23′.5	Lower	10h 18m 0s	325° 36′
		24			36
Lower	10 7	35 56	Lower	18 45	325 47
		56			47
Lower	11 46	35 31	Lower	19 30	325 58
		30			58

Temperature of air 77° F. Barometer 28.17 English inches. Attached thermometer 76° F. During the observations the sun was often obscured by clouds.

1856. August 18, A. M. Small theodolite.

DIRECT.			REFLECTED.		
Sun's limb.	Chronometer.	Circle reading.	Sun's limb.	Chronometer.	Circle reading.
	1h 51m 36s	23° 30′[1]		1h 57m 2s	334° 20′
Lower	52 17	40	Upper	57 45	10
	53 0	50		58 27	0
	1 54 15	24 40		2 0 3	334 10
Upper	54 57	50	Lower	0 42	0
	55 43	25 0		1 27	333 50
	2 8 3	27 20		2 2 51	333 30
Lower	8 52	30	Lower	3 28	20
	9 30	40		4 7	10
	2 10 47	28 30		2 5 24	332 20
Upper	11 23	40	Upper	6 6	10
	12 4	50		6 47	0

Temperature of air 75°.0. Barometer 28.10 English inches. Attached thermometer 74°.0.

[1] In these observations only one vernier of the vertical circle was read.

Absolute magnetic declination. Magnetical azimuth of the mark A.

1856. August 17, A. M. Theodolite and declinometer.

CIRCLE TO THE RIGHT.

Chronometer.	Scale.	Chronometer.	Scale.	Circle reading.	Mean.	Bearing of A.
0h 52m	71 8	0h 57m	71.7	180° 29′	180° 28′.3	
	71.8		71.7	31		
D	72 0	R	71.7	25		
Mark A	—	—	—	277 31	277 24.3	N. 83° 4′.0 W.
				20		
				22		
1 3	71 5	1 27	71.8	180 27	180 27.5	
	71.4		71.8	31.5		
R	71.4	R	71.8	24		
Mark A	—	—	—	277 29	277 21.7	83 5.8
				16		
				20		
2 0	71.8	2 3	71.6	180 22	180 22.3	
	71.7		71.6	27		
D	71.7	D	71.6	18		
Mark A	—	—	—	277 27.5	277 21.2	83 1.1
				16		
				20		
					Mean	83 3.6

1856. August 17. A. M. Theodolite and declinometer.

CIRCLE TO THE LEFT.

Chronometer.	Scale.	Chronometer.	Scale.	Circle reading.	Mean.	Bearing of A.
1h 33m	71.8	———	———	180° 29′	180° 28′.7	
	71.7			32		
R	71.7			25		
Mark A	—	—	—	277 32.5	277 26.2	N. 83° 2′.5 W.
				22		
				24		
1 42	71.8	———	———	180 19.5	180 18.8	
	71.8			23.5		
R	71.8			13.5		
Mark A	—	—	—	277 27	277 20.3	82 58.5
				15		
				19		
1 49	72.0	1h 55m	72.4	180 23	180 23.0	
	72.0		72.5	27		
R	72.0	D.	72.4	19		
Mark A	—	—	—	277 28	277 21.0	83 2.0
				15		
				20		
					Mean	83 1.0

Magnetical azimuth of mark A, N. 83° 2′.8 W.

Horizontal intensity. Experiments of vibration.

1856. August 16, P. M. Vibrating magnet D 3.

No.	Chronometer.	No.	Chronometer.	Time of 300 vibrations.
0	6h 55m 17s.0	300	7h 8m 23s.0	13m 6s.0
10	55 43.0	310	8 49.5	6 5
20	56 9 5	320	9 15.0	5.5
30	56 35.5	330	9 41.5	6 0
40	57 1.5	340	10 8.0	6.5
50	57 28.0	350	10 34.0	6 0
100	59 38.5	200	4 0.5	
				13 6.08

Extreme scale readings.

0	13.0	47.0
100	16.4	43.6
200	19.4	41.0
350	22.0	38.0

Temperature 77°.0 F.

Time of 1 vibration 2s.6203.

Horizontal intensity. Experiments of vibration.

1856. August 16, P. M. Vibrating magnet D 3.

No.	Chronometer.	No.	Chronometer.	Time of 304 vibrations.
0	7h 16m 23s.0	304	7h 29m 39s.5	13m 16s.5
10	16 49.0	314	30 6.0	17.0
20	17 15.0	324	30 32.0	17.0
30	17 41.0	334	30 58.0	17.0
40	18 7.5	344	31 24.5	17.0
50	18 33.5	354	31 51.0	17.5
100	20 44.5	200	25 7.0	
				13 17.0

Extreme scale readings.

50	13.0	47.0
100	14.5	45.5
200	17.0	42.5
354	20.5	39.0

Temperature 78°.0 F.

Time of 1 vibration 2s.6217.

1856. August 17, A. M. Vibrating magnet D 3.

No.	Chronometer.	No.	Chronometer.	Time of 300 vibrations.
0	2h 53m 10s.0	300	3h 6m 16s.0	13m 6s.0
10	53 36.0	310	6 42.0	6.0
20	54 2.0	320	7 8.5	6.5
30	54 28.5	330	7 34.5	6 0
40	54 55.0	340	8 0 3	5.3
50	55 21.0	350	8 26.7	5.7
100	57 32.0	200	1 54.0	
				13 5 92

Extreme scale readings.

0	20 0	40.0
50	21 5	38.5
100	22.0	38.0
200	23.0	36.7
300	24 5	35.5
350	25.0	35.0

Temperature 78°.0 F.

Time of 1 vibration 2s.6197.

Horizontal intensity. Experiments of vibration.

1856. August 17, A. M. Vibrating magnet D 3.

No.	Chronometer.	No.	Chronometer.	Time of 300 vibrations.
0	3h 10m 34s.0	300	3h 23m 39s.7	13m 5s.7
10	11 0.2	310	24 6.0	5.8
20	11 26.3	320	24 32.0	5.7
30	11 52.1	330	24 58.0	5.9
40	12 19.0	340	25 25.0	6.0
50	12 45.0	350	25 50.4	5.4
100	14 55.8	200	19 17.8	
				13 5.75

Extreme scale readings.

0	18.0	42.0
50	20.0	40.0
100	20.5	39 5
200	22.0	38.0
300	23.5	26.5
350	25.2	34.8

Coefficient of torsion.

Torsion circle.	Scale.
190°	298.5
100	293.2
280	304.1
190	297.8

Temperature 78°.0 F. Time of 1 vibration 2s.6192.

Experiments of deflections. Distance 1 foot.

1856. August 17, 0h 50m P. M. Deflecting magnet D 3.

Magnet.	North pole.	Circle reading.	Mean.	2 u.	Temp.
W.	E.	219° 36′ 20″	36′ 10″		81°.0
		36 0			
"	E.	219 36 20	36 5		
		35 50		14° 56′ 16″	
"	W.	234 32 10	32 2		
		31 55			
"	W.	234 33 0	32 45		
		32 30			
E.	E.	234 40 20	40 10		
		40 0			
"	E.	234 40 35	40 22		
		40 10		15 4 15	
"	W.	219 36 25	36 10		
		35 55			
"	W.	219 36 10	35 52		
		35 35			81.0
			Mean	15 0 16	

Horizontal intensity. Experiments of deflections. Distance 1.3 foot.

1856. August 17, 1h 15m P. M. Deflecting magnet D 3.

Magnet.	North pole.	Circle reading.	Mean.	2 u.	Temp.
W.	W.	230° 33′ 0″	32′ 45″		80°.7
		32 30			
"	W.	230 32 55	32 42		
		32 30		6° 47′ 7″	
"	E.	223 45 50	45 37		
		45 25			
"	E.	223 45 50	45 35		
		45 20			
E.	W.	223 45 30	45 15		
		45 0			
"	W.	223 45 40	45 20		
		45 0		6 50 49	
"	E.	230 36 20	36 5		
		35 50			
"	E.	230 36 20	36 7		80.7
		35 55			
			Mean	6 48 58	

Magnetic inclination.

1856. August 17, 11h 25m A. M. Needle No. 2. A. North pole.

Circle east.				Circle west.			
Face east.		Face west.		Face east.		Face west.	
45° 27′	43° 41′	44° 57′	43° 18′	135° 53′	136° 43′	135° 16′	136° 39′
40	54	45 11	34	41	32	1	26
45 33.5	43 47.5	45 4.0	43 26.0	135 47.0	136 37.5	135 8.5	136 32.5
44 40.5		44 15.0		136 12.2		135 50.5	
44 27.7				136 1.3			
44 13.2							

1856. August 17, 11h 25m A. M. Needle No. 2. A. South pole.

Circle west.				Circle east.			
Face east.		Face west.		Face west.		Face east.	
138° 32′	140° 2′	139° 5′	140° 23′	42° 21′	40° 36′	43° 2′	41° 13′
17	139 50	138 54	12	36	50	15	28
138 24.5	139 56.0	138 59.5	140 17.5	42 28.5	40 43.0	43 8.5	41 20.5
139 10.3		139 38.5		41 35.7		42 14.5	
139 24.4				41 55.1			
41 15.3							

1856. August 17, 0h 5m P. M. Needle No. 1. A. North pole.

Circle east.				Circle west.			
Face east.		Face west.		Face east.		Face west.	
41° 37′	39° 47′	46° 51′	44° 58′	139° 32′	140° 51′	133° 0′	135° 20′
51	40 3	47 5	45 12	14	33	132 42	3
41 44	39 55	46 58	45 5	139 23	140 42	132 51	135 11.5
40 49.5		46 1.5		140 2.5		134 1.3	
43 25.5				137 1.9			
43 11.8							

1856. August 27, 0h 5m P. M. Needle No. 1. A. South pole.

Circle west.				Circle east.			
Face west.		Face east.		Face west.		Face east.	
136° 5′	137° 31′	139° 23′	140° 45′	46° 46′	45° 2	42° 28′	40° 17′
135 46	13	5	27	47 0	15	43	34
135 55.5	137 22.0	139 14.0	140 36.0	46 53.0	45 8.5	42 35.5	40 25.5
136 38.7		139 55.0		46 0.7		41 30.5	
138 16.8				43 45.6			
42 44.4							

OBSERVATIONS AT ORIZABA.

Description of Station No. III.—The instruments were mounted under a roof of palm leaves, in the garden of Mr. Thomas Grandison, at Cocolapam, about a thousand yards to the south of the town of Orizaba. A few hundred yards west of the magnetic station rises a huge mountain ridge, of ancient volcanic rock, to a height of 1,500 to 2,000 feet above the plain. This may possibly cause some small local disturbance.

The elevation of the station above the level of the sea was found by barometrical observations 4,042 English feet.

In the determination of absolute declination a break in a distant mountain ridge to the eastward was used as a mark (A).

No experiments of deflection have been made at Orizaba.

Station No. III. Cocolapam near Orizaba.
Latitude 18° 53′. Longitude 97° 4′ W. of Greenwich.

Absolute magnetic declination. Zero point of the scale of the collimating magnet.
1856. August 27, A. M. Declinometer.

Chronometer.	Scale R.	Chronometer.	Scale D.	Chronometer.	Scale R.	Chronometer.	Scale D.
$3^h\ 54^m$	71 8	$4^h\ 0^m$	70 9	$4^h\ 6^m$	72.5	$4^h\ 13^m$	71.6
	71.8		70.9		72.5		71.5
	71.8		70.9		72.5		71.5
	71.8		70.9		72.5		71.5

Zero point on the scale 71.7.

Absolute magnetic declination. Magnetical azimuth of the mark A.
1856. August 27, A. M. Theodolite and declinometer.

CIRCLE TO THE LEFT.

Chronometer.	Scale.	Circle reading.	Mean.	Bearing of A.
$4^h\ 17^m$	71.7	98° 44′	98° 47′.8	
	71.7	47		
D	71 6	52.5		
Mark A	—	358 23	358 21.0	N. 79° 33′.2 E.
		13		
		27		
4 42	71 6	98 42	98 46.3	
	71 7	45		
R	71.7	52		
Mark A	—	358 23.5	358 21.0	79 34.7
		12		
		27.5		
			Mean	N. 79 34 0 E.

1856. August 27. A. M. Theodolite and declinometer.

CIRCLE TO THE RIGHT.

Chronometer.	Scale.	Circle reading.	Mean.	Bearing of A.
4h 32m	71.6	98° 41′	98° 45′.3	
	71 7	44		
	71.7	51		
Mark A	—	358 18	358 15.0	N. 79° 29′.7 E.
		6		
		21		
4 35	71.7	98 41	98 45.3	
	71 7	44		
	71.7	51		
Mark A	—	358 21.5	358 18.7	79 33.4
		10.5		
		24		
			Mean	N. 79 31.6 E.

Magnetical azimuth of mark A, N. 79° 32′.8 E.

Horizontal intensity. Experiments of vibration.

1856. August 26, P. M. Vibrating magnet D 3.

No.	Chronometer.	No.	Chronometer.	Time of 300 vibrations.
0	10h 47m 32s.8	300	11h 0m 39s.0	13m 6s.2
10	47 59.0	310	1 5.2	6.2
20	48 25.0	320	1 31.4	6.4
30	48 51.0	330	1 58.0	7 0
40	49 17.0	340	2 24.0	7.0
50	49 43.5	350	2 50.5	7.0
100	51 54.5	200	10 56 17.0	
				13 6.63

Extreme scale readings.

0	10.0	50.0
100	14.0	46.0
200	16.0	44.0
300	18.0	42.0
350	20.0	40.0

Temperature 76° F.

Time of 1 vibration 2s.6221.

1856. August 26, A. M. Vibrating magnet D 3.

No.	Chronometer.	No.	Chronometer.	Time of 300 vibrations.
0	11h 4m 59s.0	300	11h 18m 5s.0	13m 6s.0
10	5 25.0	310	18 32.0	7.0
20	5 51.0	320	18 57.2	6.2
30	6 18.0	330	19 23.8	5.8
40	6 44 0	340	19 50 0	8.0
50	7 10.0	350	20 16.0	6.0
100	9 20.8	200	13 43.0	
				13 6.17

Extreme scale readings.

0	14.0	46.0
100	16.0	44.0
200	19.0	41.0
350	22.0	38.0

Temperature 76° F.

Time of 1 vibration 2s.6206.

Horizontal intensity. Experiments of vibration.

1856. August 26, P. M. Vibrating magnet D 3.

No.	Chronometer.	No.	Chronometer.	Time of 300 vibrations.
0	11^h 25^m $15^s.0$	300	11^h 38^m $21^s.0$	13^m $6^s.0$
10	25 41.0	310	38 47.0	6.0
20	26 7.0	320	39 13.5	6.5
30	26 33.2	330	39 40.0	6.8
40	26 59.0	340	40 5.8	6.8
50	27 26.0	350	40 32.0	6.0
100	29 36.8	200	33 58.8	
				13 6.35

Extreme scale readings.

0	20.0	39.0
100	22.0	38.0
200	24.0	36.0
300	25.0	35.0
350	25.5	35.5

Temperature 75°.6 F.

Time of 1 vibration $2^s.6212$.

Horizontal intensity. Experiments of vibration.

1856. August 26, P. M. Vibrating magnet D 3.

No.	Chronometer.	No.	Chronometer.	Time of 300 vibrations.
0	11^h 43^m $2^s.8$	300	11^h 56^m $9^s.0$	13^m $6^s.2$
10	43 28.8	310	56 35.0	6.2
20	43 54.5	320	57 1.0	6.5
30	44 21.0	330	57 28.0	7.0
40	44 47.3	340	57 53.8	6.5
50	45 14.0	350	58 20.0	6.0
100	47 25.0	200	51 46.5	
				13 6.40

Extreme scale readings.

0	18.0	41.0
50	20.0	39 5
100	20.3	39.0
200	22.0	38.0
300	23.0	36.0

Temperature 75°.0 F.

Time of 1 vibration $2^s.6213$.

Magnetic inclination.

1856. August 26, 3h 30m P. M. Needle No. 2. A. South pole.

CIRCLE EAST.				CIRCLE WEST.			
Face east.		Face west.		Face east.		Face west.	
43° 21′	42° 34′	42° 41′	42° 0′	139° 57′	140° 18′	138° 52′	139° 24′
36	48	35	41 54	39	1	35	6
43 28.5	42 41.0	42 38.0	41 57.0	139 48.0	140 9.5	138 43.5	139 15.0
43 4.7		42 17.5		139 58 7		138 59.3	
42 41.1				139 29.0			
41 36.1							

1856. August 26, 3h 30m P. M. Needle No. 2. A. North pole.

CIRCLE WEST.				CIRCLE EAST.			
Face west.		Face east.		Face west.		Face east.	
136° 28′	136° 25′	136° 19′	136° 27′	45° 1′	44° 20′	45° 21′	44° 24′
11	7	4	11	14	30	36	38
136 19.5	136 16.0	136 11.5	136 19.0	45 7.5	44 25.0	45 28.5	44 31.0
136 17.7		136 15.3		44 46.2		44 59.8	
136 16.5				44 53 0			
44 18.3							

1856. August 26, 6h 0m P. M. Needle No. 1. A. North pole.

CIRCLE EAST.				CIRCLE WEST.			
Face east.		Face west.		Face east.		Face west.	
44° 43′	43° 48′	46° 7′	45° 5′	138° 30′	138° 41′	138° 13′	138° 23′
55	44 3	20	20	13	23	137 53	5
44 49.0	43 55.5	46 13.5	45 12.5	138 21.5	138 32.0	138 3.0	138 14.0
44 22.2		45 43.0		138 26.7		138 8.5	
45 2.6				138 17.6			
43 22.5							

1856. August 26, 6h 0m P. M. Needle No. 1. A. South pole.

CIRCLE EAST.				CIRCLE WEST.			
Face west.		Face east.		Face west.		Face east.	
46° 8′	45° 3′	40° 34′	39° 47′	136° 33′	136° 33′	141° 5′	141° 12′
20	18	49	40 3	17	17	140 47	140 53
46 14.0	45 10.5	40 41.5	39 55.0	136 25.0	136 25.0	140 56.0	141 2.5
45 42.2		40 18.2		136 25.0		140 59.2	
43 0.2				138 42.1			
42 9.1							

OBSERVATIONS AT SAN ANDRES CHALCHECOMULA.

Description of Station No. IV.—The town of San Andres is situated in a plain at the foot of the Peak of Orizaba, and this volcano rises, to the east of it at a distance of about ten miles, to the height of 10,000 English feet above the plain, which is elevated 7,800 English feet above the level of the Mexican Gulf.

The instruments were mounted in the yard of the house of Mr. Canto. The azimuth of a very distant tree (A) was originally determined by observations of the sun, but after the declinometer had been mounted this tree was obscured by fog, and the magnetic azimuth of another, nearer mark (B), having nearly the same direction as A, was determined. Afterwards the angle between A and B was measured and found A 32′.3 to the right of B. This quantity has to be *added* to the circle readings of B to get the corresponding readings for the mark A.

Deflections have not been observed at this station.

Station No. IV. San Andres.

Latitude 18° 59′. Longitude 97° 15′ W. of Greenwich.

Absolute magnetic declination. True azimuth of the mark A.
1856. September 17, A. M. Small theodolite.

CIRCLE TO THE LEFT.			CIRCLE TO THE RIGHT.		
Object.	Chronometer.	Circle reading.	Object.	Chronometer.	Circle reading.
⊙ Ist limb	1h 52m 13s	266° 18′	⊙ Ist limb	2h 5m 17s	267° 28′
		3			14
		6			18.5
⊙ IId limb	54 24	265 52	⊙ IId limb	6 42	267 1
		37			266 47
		41			51
Mark A	———	167 30	Mark A	———	167 24
		33			27.5
		27			21.5
Mark A	———	167 29	Mark A	———	167 24
		32			28
		26			22
⊙ Ist limb	2 0 47	267 8.5	⊙ Ist limb	2 11 10	268 3
		266 53.5			267 48.5
		58.5			52
⊙ IId limb	2 50	266 45.5	⊙ IId limb	12 46	267 37.5
		31			23
		35			25.5

Altitudes of the sun, for the determination of time.

1856. September 17, A. M. Small theodolite.

CIRCLE TO THE LEFT.			CIRCLE TO THE { LEFT.[2] RIGHT.		
Sun's limb.	Chronometer.	Circle reading.	Sun's limb.	Chronometer.	Circle reading.
Upper. D.[1]	2h 21m 18s	330° 20′	Lower. R.	2h 34m 46s	33° 10′
Upper. D.	21 57	10	Lower. R.	35 34	20
Upper. D.	22 38	0	Lower. R.	36 22	30
Lower. D.	2 23 36	330 20	Upper. D.	2 42 48	35 30
Lower. D.	24 14	10	Upper. D.	43 33	40
Lower. D.	24 57	0	Upper. D.	44 15	50
Upper. R	2 32 32	33 10	Lower. D.	2 45 48	35 40
Upper. R.	33 13	20	Lower. D.	46 37	50
Upper. R.	33 53	30	Lower. D.	47 22	36 0

Temperature of air 65°.5. Barometer 581.5mm. Attached thermometer 69° 0.

Absolute magnetic declination. Altitudes of the sun, for the determination of time.

1856. September 18, A. M. Small theodolite.

CIRCLE TO THE LEFT.			CIRCLE TO THE RIGHT.		
Sun's limb.	Chronometer.	Circle reading.	Sun's limb.	Chronometer.	Circle reading.
Upper	1h 57m 24s	335° 10′	Upper	2h 4m 17s	25° 40′
Upper	58 5	0	Upper	5 0	50
Upper	58 48	334 50	Upper	5 43	26 0
Lower	1 59 41	335 10	Lower	2 6 33	25 40
Lower	2 0 21	0	Lower	7 11	50
Lower	1 2	334 50	Lower	7 57	26 0

Temperature of air 64°.3. Barometer 582.1mm. Attached thermometer 67°.0.

Zero-point of the scale of the collimating magnet.

1856. September 17, A. M. Declinometer.

Chronometer.	Scale.	Chronometer.	Scale.	Chronometer.	Scale.	Means.	
6h 10m	71.9	6h 15m	75.7	6h 19m	72.6	71.6	
	71.5		75.7		72.4	75.7	
R	71.4	D	75 8	R	72.6	72.5	73 9
6 23	76.5	6 27	72.7	6 33	76.1	76.6	74.3
	76 6		72.3		76.2	72.5	74.5
D	76 6	R	72.4	D	76.4	76.2	74.4
6 37	73 5	6 41	75.6	6 47	72.7	73.5	74 6
	73.5		75 8		72.7	75.8	74.7
R	73 5	D	75.9	R	72.8	72.7	74.4
						Mean	74.4

[1] D. denotes direct, R. reflected observations.

[2] Between 2h 36m and 2h 42m the instrument was reversed.

Magnetic azimuth of the mark A.
1856. September 17, P. M. Theodolite and declinometer.

CIRCLE TO THE RIGHT.

Chronometer.	Scale.	Circle reading.	Mean.	Bearing of A.
6^h 52^m	74.5	280° 24′	280° 16′.2	
	74.4	9.5		
R	74.4	15		
Mark B	———	89 2	89 4.3	N. 10° 39′.6 W.
		1		
		10	+ 32.3	
Mark B	———	89 1	89 4.0	10 44.2
		1	+ 32.3	
		10	280 20.5	
7 3	74.4	280 28.5		
	74.4	13		
R	74.4	20		
			Mean	N. 10 41.9 W.

Absolute magnetic declination. Magnetical azimuth of Mark A.
1856. September 17, P. M. Theodolite and declinometer.

CIRCLE TO THE LEFT.

Chronometer.	Scale.	Circle reading.	Mean.	Bearing of A.
7^h 8^m	74.4	280° 23′	280° 15′.7	
	74.4	9		
R	74.5	15		
Mark B	———	88 58.5	89 1.3	N. 10° 42′.1 W.
		59.5		
		89 6	+ 32.3	
Mark B	———	88 57.5	89 1.3	
		89 0		
		89 6.5	+ 32.3	10 35.6
7 15	74.5	280 18	280 9.2	
	74.4	2.5		
R	74.5	7		
			Mean	N. 10 38.9

Magnetical azimuth of mark A, N. 10° 40′.4 W.

Horizontal intensity. Experiments of vibration.
1856. September 17, P. M. Vibrating magnet D 3.

No.	Chronometer.	No.	Chronometer.	Time of 300 vibrations.
0	7^h 44^m $41^s.8$	300	7^h 57^m $48^s.0$	13^m $6^s.2$
10	45 7.9	310	58 14.4	6.5
20	45 34.0	320	58 40.8	6.8
30	46 0.4	330	59 7.0	6.6
40	46 26.8	340	59 33.3	6.5
50	46 52.8	350	59 59.2	6.4
100	49 3.8	200	53 26.4	
				13 6.50

Extreme scale readings.

0	20.0	40.0
100	22.0	38.0
200	23.0	37.0
300	24.0	35.0
350	24.5	35.0

Temperature 71°.9 F.

Time of 1 vibration $2^s.6217$.

Horizontal intensity. Experiments of vibration.

1856. September 17, P. M. Vibrating magnet D 3.

No.	Chronometer.	No.	Chronometer.	Time of 300 vibrations.
0	8h 3m 29s.8	300	8h 16m 36s.1	13m 6s.3
10	3 55.6	310	17 2.3	6.7
20	4 22 0	320	17 28 8	6 8
30	4 48.2	330	17 54 8	6 6
40	5 14 4	340	18 21 2	6.8
50	5 40 8	350	18 47 2	6.4
100	7 51.8	200	12 13.6	
				13 6.60

Extreme scale readings.

0	12.0	48.0
100	15.0	45.0
200	17.0	43.0
350	20.5	39 5

Temperature 71°.8 F.

Time of 1 vibration 2s.6220.

1856. September 17, P. M. Vibrating magnet D 3.

No.	Chronometer.	No.	Chronometer.	Time of 400 vibrations.
0	8h 25m 5s.2	400	8h 42m 34s.0	17m 28s.8
10	25 31.4	410	43 0.2	28 8
20	25 57 5	420	43 26 6	29 1
30	26 24.0	430	43 52.8	28.8
40	26 49 9	440	44 19 2	29.3
50	27 16 2	450	———	———
100	29 27.5	300	38 11.0	
				17 28.96

Extreme scale readings.

0	13 0	47.0
100	17.0	43.0
300	20 0	39.5
440	23 0	37.0

Temperature 68°.7 F.

Time of 1 vibration 2s.6224.

1856. September 17. Vibrating magnet D 3.

No.	Chronometer.	No.	Chronometer.	Time of 300 vibrations.
0	9h 17m 40s.2	300	9h 30m 46s.8	13m 6s.6
10	18 6 4	310	31 13.1	6 7
20	18 33.0	320	31 39 4	6.4
30	———	330	32 5.6	———
40	19 25 0	340	32 31.6	6 6
50	19 51.3	350	32 58.0	6.7
100	22 2.4	200	26 25.0	
				13 6.60

Extreme scale readings.

0	16.0	44.0
100	18 7	41.3
200	20 2	39 8
350	22 8	37.2

Coefficient of torsion.

Torsion circle.	Scale.
300°	302.8
210	299.4
30	306 7
300	303.0

Temperature 66°.0 F. Time of 1 vibration 2s.6220.

Magnetic inclination.

1856. September 18, 8h A. M. Needle No. 1. A. North pole.

CIRCLE EAST.				CIRCLE WEST.			
Face east.		Face west.		Face east.		Face west.	
44° 36′	45° 56′	44° 45′	45° 35′	136° 37′	136° 18′	137° 25′	137° 30′
45 16.0		45 10.0		136 27.5		137 27.5	
45 13.0				136 57.5			
44 7.7							

1856. September 18, 8h A. M. Needle No. 1. A. South pole.

CIRCLE WEST.				CIRCLE EAST.			
Face west.		Face east.		Face west.		Face east.	
139° 5′	139° 20′	140° 0′	140° 27′	40° 53′	42° 0′	42° 22′	42° 47′
139 12.5		140 13.5		41 26.5		42 34.5	
139 43.0				42 0.5			
41 8.7							

NOTE.—In these observations only one vernier of the dip circle was read.

OBSERVATIONS AT MIRADOR.

Description of Station No. V.—Mirador is a large sugar estate, situated on the eastern foot of the high volcanic ridge, which connects the Peak of Orizaba and the Coffre of Perote. Its elevation above the level of the sea is about 2,400 English feet. The soil is compact red clay, containing some iron.

The instruments were mounted under the veranda (porch) of the house of the proprietor, MR. SATORIUS, about 10 feet to the east of the entrance.

A distant tree, bearing E. by S. (magn.) was used for a mark at the determination of absolute declination.

STATION No. V. MIRADOR.

Latitude 19° 13′. Longitude 96° 37′ W. of Greenwich.

Absolute magnetic declination. True azimuth of the mark A.

1856. October 10, A. M. Small theodolite.

CIRCLE TO THE LEFT.			CIRCLE TO THE RIGHT.		
Object.	Chronometer.	Circle reading.	Object.	Chronometer.	Circle reading.
Mark A	———	89° 19′	Mark A	———	89° 16′
		20			18.5
		28			25
⊙ Ist limb	0h 37m 8s	78 52.5	⊙ Ist limb	0h 47m 0s	79 40
		55			40.5
		79 5			51.5
⊙ IId limb	0 39 17	78 33	⊙ IId limb	0 49 0	79 19.5
		33			20
		43			29.5
Mark A	———	89 19	Mark A	———	89 14.5
		20			18.5
		29.5			25

Altitudes of the sun for the determination of time.

1856. October 10, A. M. Small theodolite.

Sun's limb.	Chronometer.	Circle reading.	Sun's limb.	Chronometer.	Circle reading.
Upper. D.	2h 48m 8s	324° 10′	Lower. R.	2h 56m 15s	36° 0′
Upper. D.	48 52	0	Lower. R.	57 0	10
Upper. D.	49 41	323 50	Lower. R.	57 46	20
Lower. D.	2 50 38	324 10	Upper. D.	3 0 33	321 30
Lower. D.	51 22	0	Upper. D.	1 21	20
Lower. D.	52 9	323 50	Upper. D.	2 8	10
Upper. R.	2 53 41	36 0	Lower. D.	3 3 4	321 30
Upper. R.	54 29	10	Lower. D.	3 52	20
Upper. R.	55 12	20	Lower. D.	4 40	10

Temperature of air 71°.0. Barometer 695.7mm. Attached thermometer 71°.5.

Zero-point of the scale of the collimating magnet.

1856. October 10, A. M. Declinometer.

Chronometer.	Scale.	Chronometer.	Scale.	Chronometer.	Scale.	Means.	
0h 41m	71.2	0h 48m	76.9	0h 51m	71.2	71.2	
	71.2		77.0		71.1	77.0	
R	71.2	D	77.1	R	71.2	71.2	74.1
0 54	77.5	0 58	71.2	1 1	76.2	77.5	74.2
	77.5		71.2		76.3	71.2	74.2
D	77.4	R	71.2	D	76.3	76.3	74.0
1 4	71.8	1 8	77.0			71.8	73.9
	71.8		77.0			77.0	74.2
R	71.9	D	77.0				
						Mean	74.1

Absolute magnetic declination. Magnetical azimuth of the mark A.

1856. October 10, A. M. Theodolite and declinometer.

CIRCLE TO THE RIGHT.

Chronometer.	Scale.	Circle reading.	Mean.	Bearing of A.
1h 16m	74.1	182° 2′.5	182° 1′.2	
	74.1	5		
D	74 1	181 56		
Mark A	—	103 48.5	103 51.5	N. 101° 50′.3 E.
		51		
		55		
Mark A	—	103 48.5	103 50.8	101 49.3
		50		
		54		
1 28	74 0	182 2.5	182 1.5	
	74 1	5		
D	74.0	181 57		
			Mean	N. 101 49.8 E.

1856. October 10. Theodolite and declinometer.

CIRCLE TO THE LEFT.

Chronometer.	Scale.	Circle reading.	Mean.	Bearing of A.
1h 23m	74.2	182° 6′.5	182° 7′.3	
	74 3	8.0		
D	74 2	1.5		
Mark A	—	103 53.5	103 56.0	N. 101° 48′.7 E.
		55.5		
		59.0		
Mark A	—	103 53.0	103 55.8	101 50.5
		56 0		
		58.5		
1 38	74.1	182 6.0	182 5.3	
	74.1	8.5		
D	74.1	1.5		
			Mean	N. 101 49.6 E.

Magnetical azimuth of the mark A, N. 101° 49′.7 E.

Horizontal intensity. Experiments of vibration.

1856. October 9, A. M. Vibrating magnet D 3.

No.	Chronometer.	No.	Chronometer.	Time of 300 vibrations.
0	5h 37m 22s.4	300	5h 50m 33s.2	13m 10s.8
10	37 48.8	310	50 59.6	10.8
20	38 15 0	320	51 26.1	11.1
30	38 41.2	330	51 52.7	11.5
40	39 7.6	340	52 18 8	11.2
50	39 34.0	350	52 45 6	11.6
100	41 45.6	200	46 9.2	
				13 11 17

Extreme scale readings.

0	19.0	41.0
200	22.3	37.7
350	24 3	35.7

Temperature 76°.0 F.

Time of 1 vibration 2s.6372.

Horizontal intensity. Experiments of vibration.

1856. October 9, A. M. Vibrating magnet D 3.

No.	Chronometer.	No.	Chronometer.	Time of 200 vibrations.
0	9h 0m 43s.6	200	9h 9m 31s.6	8m 48s.0
10	1 9 8	210	9 57 9	48 1
20	1 36 3	220	10 24.6	48.3
30	2 2.8	230	10 50.6	47 8
40	2 29 2	240	11 17.0	47 8
50	2 55.6	250	11 43 2	47.6
100	5 7.6	260	12 9 6	
				8 47 93

Extreme scale readings.

0	17 0	43 0
100	19.0	41 0
250	22.0	38.0

Temperature 75°.5 F.

Time of 1 vibration 2s.6396.

1856. October 9, P. M. Vibrating magnet D 3.

No.	Chronometer.	No.	Chronometer.	Time of 300 vibrations.
0	10h 46m 5s.8	300	10h 59m 16s 9	13m 11s.1
10	46 32 1	310	59 43.1	11.0
20	46 58.4	320	11 0 9.4	11.0
30	47 25.0	330	0 35 8	10.8
40	47 51 3	340	1 2 2	10 9
50	48 17.5	350	1 28.8	11.3
100	50 29.2	200	10 54 53.2	
				13 11.02

Extreme scale readings.

0	22.5	37 5
100	24.0	36.0
200	25.0	35.0
350	26 0	34.0

Temperature 72°.0 F.

Time of 1 vibration 2s.6367.

Horizontal intensity. Experiments of vibration.

1856. October 9, P. M. Vibrating magnet D 3.

No.	Chronometer.	No.	Chronometer.	Time of 204 vibrations.
0	11h 4m 39s.8	204	11h 13m 38s 0	8m 58s.2
10	5 6 0	214	14 4 2	58.2
20	5 32.8	224	14 30 6	57 8
30	5 59.0	234	14 57 0	58 0
40	6 25 8	244	15 23 2	57 4
50	6 51.8	254	15 49 4	57 6
104	9 14.0	264	16 15 8	
				8 57 84

Extreme scale readings.

0	21.0	39 0
104	22.7	37.3
264	24.0	36 0

Temperature 71°.6 F.

Time of 1 vibration 2s.6366.

Experiments of deflection. Distance 1.3 foot.

1856. October 10, A. M. Deflecting magnet D 3.

Magnet.	North pole.	Circle reading.	Mean.	2 u.	Temp.
W.	N.	263° 26′ 10″	26′ 10″		76°.2
		26 10			
"	N.	263 26 0	25 55		
		25 50			
"	N.	263 24 0	24 0		
		0			
"	S.	270 18 40	18 45		
		18 50			
"	S.	270 18 40	18 40	6° 53′ 21″	
		18 40			
"	S.	270 18 40	18 45		
		18 50			
E.	N.	270 13 40	13 35		
		13 30			
"	N.	270 13 30	13 30		
		13 30			
"	N.	270 13 45	13 47		
		13 50			
"	S.	263 27 50	27 45	6 46 34	
		27 40			
"	S.	263 27 50	27 45		
		27 40			
"	S.	263 25 50	25 40		
		25 30			77.6
			Mean	6 49 57	

Horizontal intensity. Experiments of deflections. Distance 1 foot.

1856. October 10. Deflecting magnet D 3.

Magnet.	North pole.	Circle reading.	Mean.	2 u.	Temp.
W.	S.	274° 25′ 0″	25′ 0″		77°.0
		0			
"	S.	274 25 5	25 2		
		0			
"	S.	274 25 45	25 42		
		25 40			
"	N.	259 16 35	16 35	15° 8′ 53″	
		16 35			
"	N.	259 16 25	16 20		
		16 15			
"	N.	259 16 10	16 10		
		16 10			
E.	S.	259 21 0	21 0		
		21 0			
"	S.	259 20 40	20 38		
		20 35			
"	S.	259 20 30	20 30		
		20 30			
"	N.	274 9 25	9 22	14 50 2	
		9 20			
"	N.	274 9 20	9 15		
		10			
"	N.	274 13 45	13 48		
		13 50			77
			Mean	14 59 27	

Magnetic inclination.

1856. October 11, 8h A. M. Needle No. 1. A. North pole.

CIRCLE EAST.				CIRCLE WEST.			
Face east.		Face west.		Face east.		Face west.	
42° 42′	43° 29′	43° 52′	44° 31′	133° 0′	136° 1′	136° 20′	136° 23′
43 5.5		44 11.5		136 0.5		136 21.5	
43 38.5				136 11.0			
43 43.7							

1856. October 11, 8h A. M. Needle No. 1. A South pole.

CIRCLE WEST.				CIRCLE EAST.			
Face west.		Face east.		Face west.		Face east.	
136° 1′	135° 27′	136° 13′	136° 18′	43° 31′	44° 17′	43° 23′	44° 8′
135 41.0		136 15.5		43 54.0		43 45.5	
135 59.8				43 49 8			
43 55.0							

NOTE.—In these observations only one vernier of the dip circle was read.

Magnetic inclination.

1856. October 10, 1h 50m P. M. Needle No. 2. A. South pole.

CIRCLE EAST.				CIRCLE WEST.			
Face east.		Face west.		Face east.		Face west.	
41° 57′	42° 44′	42° 15′	43° 11′	137° 48′	137° 17′	137° 44′	137° 12′
42 12	43 0	30	25	37	6	32	1
42 4.5	42 52.0	42 22.5	43 18.0	137 42.5	137 11.5	137 38.0	137 6.5
42 28.2		42 50.2		137 27.0		137 22.2	
42 39.2				137 24.6			
42 37.3							

1856. October 10, 1h 50m P. M. Needle No. 2. A. North pole.

CIRCLE WEST.				CIRCLE EAST.			
Face west.		Face east.		Face west.		Face east.	
136° 16′	136° 2′	134° 41′	134° 28′	43° 34′	44° 31′	46° 0′	46° 46′
1	135 46	26	12	48	46	14	47 1
136 8.5	135 54.0	134 33.5	134 20.0	43 41.0	44 38.5	46 7.0	46 53.5
136 1.2		134 26.8		44 9.8		46 30.2	
135 14.0				45 20.0			
45 3.0							

OBSERVATIONS AT THE CITY OF MEXICO.

Description of Station No. VI.—The instruments were mounted on the arched roof of the church in the Convent San Augustin. This is the same place where Baron von Humboldt made his observations about fifty-seven years ago. The roof is entirely of bricks, and there is no iron within fifty feet of the station, farther off are some iron railings, etc.

The station is 75 feet above the ground, or 7,550 English feet above the level of the sea.

A church steeple, about fifteen miles west of the station, was used for a mark (A) at the determination of absolute declination.

Station No. VI. Mexico, Convent San Augustin.

Latitude 19° 26′. Longitude 99° 5′ W. of Greenwich.

Absolute magnetic declination. True azimuth of the mark A.

1856. December 11, A. M. Small theodolite.

Circle to the left.			Circle to the right.		
Object.	Chronometer.	Circle reading.	Object.	Chronometer.	Circle reading.
Mark A	———	150° 55′	Mark A	———	150° 35′
		151 0			38
		0.5			40
⊙ IId limb	$7^h\ 55^m\ 13^s$	11 51	⊙ Ist limb	$8^h\ 19^m\ 37^s$	15 24
		40 5			16
		12 2			37
⊙ Ist limb	57 30	12 42	⊙ IId limb	8 21 22	14 59
		34			51
		54			15 12.5
⊙ Ist limb	59 12	12 54	Mark A	———	150 44
		44.5			49
		13 7 5			50 5
⊙ IId limb	8 0 23	12 29	Mark A	———	150 45
		20			52
		41			51
Mark A	———	150 55	⊙ Ist limb	8 29 14	16 50 5
		151 1			40.5
		1			17 2
Mark A	———	150 51	⊙ IId limb	30 33	16 29
		57			20
		55			42
⊙ Ist limb	8 7 33	13 56 5	Mark A	———	150 43
		47.5			50
		14 8			49
⊙ IId limb	8 8 44	13 31	———	———	———
		22.5			
		43 5			

Note—The chronometer was $+0^m\ 43^s.5$ slow of mean Mexican time. Its daily rate was $+3^s.6$ (losing).

Zero point of the scale of the collimating magnet.

1856. December 11, A. M. Declinometer.

Chronometer.	Scale.	Chronometer.	Scale.	Chronometer.	Scale.	Chronometer.	Scale.
9h 57m D	74.7 74.6 74.6	4h 59m R	72.9 73.0 73.0	10h 2m D	74.7 74.7 74.6	10h 4m R	72.9 73.1 73.1
Mean	74.6		73.0		74.7		73.0

Zero point 73.8 on the scale.

Absolute magnetic declination. Magnetical azimuth of the mark A.

1856. December 11, A. M. Theodolite and declinometer.

CIRCLE TO THE LEFT.

Chronometer.	Scale.	Circle reading.	Mean.	Bearing of A.
10h 7m	73.8 73.8 73.8	79° 42′.5 46.5 80 1.5	79° 50′.2	
Mark A	———	153 24 31 29	153 28.0	N. 106° 22′.2 W.
Mark A	———	153 30.5 36 34	153 33.5	106 24.3
10 17	73.7 73.6 73.6	79 51 54 80 8.5	79 57.8	
10 19	73 8 73.7 73.7	79 51 54 80 8	79 57.7	
Mark A	———	153 32 38 35	153 35.0	106 22 7
			Mean	N. 106 23.1 W.

1856. December 11, A. M. Theodolite and declinometer.

CIRCLE TO THE RIGHT.

Chronometer.	Scale.	Circle reading.	Mean.	Bearing of A.
10h 23m	73.7 73.7 73 7	79° 39′ 42 58	79° 46′.3	
Mark A	———	153 21 28 26	153 25.0	N. 106° 21′.3 W.
Mark A	———	153 22 28.5 27	153 25.8	106 22.7
10 30	73.9 74.0 74.0	79 42 43.5 80 0	79 48.5	
			Mean	N. 106 22 0 W.

Magnetical azimuth of the mark A, N. 106° 22′.6 W.

Horizontal intensity. Experiments of vibration.

1856. December 10, P. M. Vibrating magnet D 3.

No.	Chronometer.	No.	Chronometer.	Time of 300 vibrations.
0	1^{h} 48^{m} 7^{s}.1	300	2^{h} 1^{m} 17^{s} 0	13^{m} 9^{s}.9
10	48 33.6	310	1 43.5	9.9
20	48 59 8	320	2 9.4	9.6
30	49 26.5	330	2 35.8	9 3
40	49 52.5	340	3 2.0	9.5
50	50 18.8	350	3 28.3	9.5
100	52 30.4	200	1 56 53.5	
				13 9.62

Extreme scale readings.

0	21.4	38.6
50	22.2	37.8
100	22.8	37.2
200	24.0	36.0
350	25.3	34.7

Temperature 68°.2 F.

Time of 1 vibration 2^{s}.6321.

1856. December 10, P. M. Vibrating magnet D 3.

No.	Chronometer.	No.	Chronometer.	Time of 300 vibrations.
0	2^{h} 6^{m} 24^{s}.9	300	2^{h} 19^{m} 34^{s}.4	13^{m} 9^{s}.5
10	6 51.0	310	20 0.4	9.4
20	7 17.4	320	20 26 8	9.4
30	7 43.5	330	20 53.1	9.6
40	8 9 6	340	21 19.7	10.1
50	8 36.6	350	21 46.0	9.4
100	10 48.0	200	15 11.4	
				13 9.57

Extreme scale readings.

0	18 0	42.0
50	19.2	40.8
100	20 1	39.9
200	21 7	38.3
350	23.5	36.5

Temperature 68°.6 F.

Time of 1 vibration 2^{s}.6319.

1856. December 10, P. M. Vibrating magnet D 3.

No.	Chronometer.	No.	Chronometer.	Time of 300 vibrations.
0	1^{h} 12^{m} 11^{s}.0	300	1^{h} 25^{m} 21^{s}.6	16^{m} 10^{s}.6
10	12 37.5	310	25 47.8	10.3
20	13 4 0	320	26 14.2	10 2
30	13 30.2	330	26 40 6	10.4
40	13 56 5	340	27 7 0	10.5
50	14 23.2	350	27 33.4	10 2
100	16 34 5	200	20 58.0	
				13 10 37

Extreme scale readings.

0	17.0	43 0
200	20 3	39.7
350	22.0	38.0

Temperature 69°.5 F.

Time of 1 vibration 2^{s}.6346.

Horizontal intensity. Experiments of vibration.
1856. December 10, P. M. Vibrating magnet D 3.

No.	Chronometer.	No.	Chronometer.	Time of 300 vibrations.
0	1h 31m 13s.5	300	1h 44m 23s 6	13m 10s.3
10	31 39.6	310	44 49.8	10.2
20	32 6.0	320	45 16.0	10 0
30	32 32.7	330	45 42.4	9.7
40	32 58.8	340	46 8.7	9 9
50	33 25.1	350	46 35.3	10.2
100	35 37.0	200	40 0.0	
				13 10 10

Extreme scale readings.

0	14.5	45.5
100	16.0	44 0
200	18.2	41.8
350	21.0	39.0

Temperature 68°.8 F.

Time of 1 vibration 2s.6337.

Experiments of deflection. Distance 1 foot.
1856. December 10. Deflecting magnet D 3.

Magnet.	North pole.	Circle reading.	Mean.	2 u.	Temp.
E.	W.	157° 16′ 20″	16′ 0″		68°.5
		15 40			
"	W.	157 16 30	16 5	14° 45′ 30″	
		15 40			
"	E.	172 1 50	1 30	45 25	
		1 10			
"	E.	172 1 45	1 30		
		1 15			
W.	W.	172 14 25	14 7		
		13 50			
"	W.	172 13 50	13 25	15 0 22	
		13 0			
"	E.	157 14 10	13 45	14 59 32	
		13 20			
"	E.	157 14 5	13 53		
		13 40			
E.	E.	171 58 50	58 30		
		58 10			
"	W.	157 17 40	17 20	14 41 10	
		17 0			
W.	E.	157 16 15	15 52	14 51 0	
		15 30			
"	W.	172 10 0	9 52		68.8
		9 45			
			Mean	14 51 0	68.6

Horizontal intensity. Experiments of deflections.

1856. December 10. Deflecting magnet D 3.

Magnet.	North pole.	Circle reading.	Mean.	2 u.	Temp.
E.	E.	168° 5′ 45″	5′ 25″		67°.9
		5 5			
"	E.	168 05 55	5 32	6° 41′ 17″	
		5 10			
"	W.	161 22 0	21 40	43 45	
		21 20			
"	W.	161 21 30	21 15		
		21 0			
W.	E.	161 20 50	20 30	6 49 20	
		20 10			
"	E.	161 21 30	21 12	48 33	
		20 55			
E.	W.	161 21 50	21 32		
		21 15			
"	E.	168 1 40	1 45	6 40 13	
		1 50			
W.	W.	168 6 15	5 48	45 21	
		5 20			
"	E.	161 20 40	20 27		
		20 15			
"	W.	168 10 0	9 50		
		9 40			
"	W.	168 10 0	9 45		67.9
		9 30			
			Mean	6 45 15	67.9

Magnetic inclination.

1856. December 17, 0h 50m P. M. Needle No. 1. A. South pole.

CIRCLE EAST.				CIRCLE WEST.			
Face east.		Face west.		Face east.		Face west.	
41° 55′	39° 36′	41° 39′	39° 50′	139° 27′	137° 31′	139° 36′	137° 24′
42 11	50	54	40 8	10	16	18	5
42 3.0	39 43.0	41 46.5	39 59.0	139 18.5	137 23.5	139 27.0	137 14.5
40 53.0		40 52.8		138 21.0		138 20.8	
40 52.9				138 20.9			
41 16.0							

1856. December 17, 1h 40m P. M. Needle No. 1. A. North pole.

CIRCLE WEST.				CIRCLE EAST.			
Face west.		Face east.		Face west.		Face east.	
139° 50′	137° 42′	138° 41′	136° 37′	41° 52′	39° 51′	42° 17′	40° 25′
34	24	24	20	42 9	40 5	34	41
139 42.0	137 33.0	138 32.5	136 28.5	42 0.5	39 58.0	42 25.5	40 33.0
138 37.5		137 30.5		40 59.2		41 29.2	
138 4.0				41 14.2			
41 35.1							

Magnetic inclination.

1856. December 17, 1^h 50^m P. M. Needle No. 2. A. North pole.

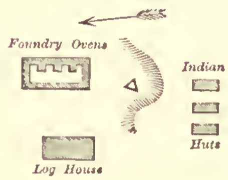
CIRCLE EAST.				CIRCLE WEST.			
Face east.		Face west.		Face east.		Face west.	
41° 37′	39° 43′	41° 46′	39° 55′	139° 14′	137° 14′	139° 10′	137° 14′
54	40 0	42 3	40 11	138 56	136 56	138 53	136 56
41 45.5	39 51.5	41 54.5	40 3.0	139 5.0	137 5.0	139 1 5	137 5.0
40 48.5		40 58.7		138 5.0		138 3.2	
40 53.6				138 4.1			
41 24.7							

1856. December 17, 2^h 30^m P. M. Needle No. 2. A. South pole.

CIRCLE WEST.				CIRCLE EAST.			
Face west.		Face east.		Face west.		Face east.	
139° 34′	137° 29′	139° 16′	137° 24′	42° 11′	40° 26′	41° 50′	40° 8′
18	12	1	7	25	42	42 5	23
139 26.0	137 20.5	139 8.5	137 15.5	42 18.0	40 34.0	41 57.5	40 15.5
138 23.2		138 12.0		41 26.0		41 6.5	
138 17.6				41 16.2			
41 29.3							

OBSERVATIONS AT RANCHO TLAMACAS.

Description of Station No. VIII.[1]—The magnetic station was established at the sulphur foundry, called Rancho Tlamacas, on a small depression of the ground between the foundry ovens (to the north) and three Indian huts (to the south and southwest.)



The height of the station above the level of the Mexican Gulf is 12,750 English feet.

A pointed rock on the northeast side of the volcanic cone, a little below the limit of perpetual snow, was used for a mark (A) in the determination of absolute declination.

Station No. VIII. Rancho Tlamacas.

Latitude 19° 3′. Longitude 98° W. of Greenwich.

Absolute magnetic declination. True azimuth of the mark A.
1857. January 25, P. M. Small theodolite.

CIRCLE TO THE LEFT.			CIRCLE TO THE RIGHT.		
Object.	Chronometer.	Circle reading.	Object.	Chronometer.	Circle reading.
Mark A	——	179° 59′.5	Mark A	——	180° 15′.5
		61.5			17.0
		57.0			12.5
Mark A	——	179 59.5	Mark A	——	180 15.0
		60.5			17.0
		57.0			12.5
⊙ Ist limb	$4^h\ 16^m\ 51^s$	268 42.0	⊙ Ist limb	$4^h\ 30^m\ 44^s$	270 35.0
		26.0			18.0
		35.0			26.5
⊙ IId limb	19 21	268 26.5	⊙ IId limb	32 6	270 11.0
		10 0			269 54.0
		19.5			270 2.0
⊙ Ist limb	20 58	269 21.5	⊙ IId limb	33 17	270 19.0
		5.0			2.5
		14.5			12 0
⊙ IId limb	22 37	268 59.5	⊙ Ist limb	34 47	271 2 5
		44.0			270 45.0
		53.0			55.0
Mark A	——	180 7.0	Mark A	——	180 20 0
		10.0			21.0
		6.5			18.0
Mark A	——	180 7.0	Mark A	——	180 20
		10.5			21.5
		6.5			17.5

[1] There has also been made a complete set of magnetical observations at the town of Chalev, in the valley of Mexico (latitude 19° 18′, longitude 98° 51′ west of Greenwich), and this station is called No. VII. The results of these observations only will be given in the following pages, as the record of them was lost.

Absolute magnetic declination. True azimuth of the mark A.

1857. January 26, A. M. Small theodolite.

CIRCLE TO THE RIGHT.			CIRCLE TO THE LEFT.		
Object.	Chronometer.	Circle reading.	Object.	Chronometer.	Circle reading.
Mark A	———	303° 41′.0	Mark A	———	303° 39′.0
		23.3			18.5
		38.5			38.0
Mark A	———	303 41.5	Mark A	———	303 39.0
		23.0			19.0
		38.5			38.5
⊙ Ist limb	7^h 50^m 54^s	276 32 0	⊙ Ist limb	8^h 15^m 7^s	270 28 5
		15.5			11.0
		24.5			22.0
⊙ IId limb	53 11	267 14.0	⊙ Ist limb	16 58	270 42 0
		266 59.9			27.0
		267 6.0			38.0
⊙ Ist limb	56 32	268 13.5	⊙ IId limb	19 0	270 23 0
		267 56.0			7 5
		268 4.0			18 0
⊙ IId limb	58 33	267 52.0	⊙ IId limb.	20 46	270 38.0
		35.5			22.0
		43.0			32 0
Mark A	———	303 44.5	Mark A	———	303 41 5
		25.5			22.0
		40.0			40.0
Mark A	———	303 44.5	Mark A	———	303 42.0
		25.0			23.0
		40.0			39.0

Absolute magnetic declination. Zero-point of the scale of the collimating magnet.

1857. January 25. Declinometer.

Chronometer.	Scale.	Chronometer.	Scale.	Chronometer.	Scale.	Means.	
11^h 53^m	74.0	11^h 57^m	77.7	0^h 2^m	74.0	74.0	
D	74.0	R	77.9	D	73.9	77.8	75 9
	74.0		77.8		73.9	73.9	75.7
0 7	77 2	0 11	73.1	0 16	77.5	77.2	75.3
R	77.2	D	73.1	R	77.4	73.1	75.2
	77.2		73.0		77.4	77.4	75 3
0 20	73.3	0 25	77.4	0 29	73.3	73.2	75.3
D	73 1	R	77.5	D	73.3	77.4	75.3
	73.1		77.4		73 3	73.3	
						Mean	75.4

Absolute magnetic declination. Magnetical azimuth of Mark A.

1857. January 25, P. M. Theodolite and declinometer.

CIRCLE TO THE LEFT.

Chronometer.	Scale.	Circle reading.	Mean.	Bearing of A.
Mark A	———	323° 45′.0	323° 58′.3	N. 145° 6′.3 E.
		46.0		
		64.0		
0h 46m	75.3	358 54.5	358 52.0	
D	75 4	40.5		
	75.3	61.0		
0 51	75 5	358 53.5	358 51.8	
D	75.4	41.0		
	75.5	61.0		
Mark A	———	323 65.0	323 58.5	154 6.7
		46.5		
		64.0		
Mark A	———	180 1.0	180 2.3	145 5.0
		4.5		
		1.5		
1 6	75.2	214 60.0	214 57.3	
	75.2	56.5		
	75.2	55.5		
1 14	75.5	214 60.0	214 56.3	
	75.5	55.0		
	75.3	54.0		
Mark A	———	180 2.0	180 3.2	145 6.9
		5.5		
		2.0		
			Mean	N. 145 6.2 E.

1857. January 25, P. M. Theodolite and declinometer.

CIRCLE TO THE RIGHT.

Chronometer.	Scale.	Circle reading.	Mean.	Bearing of A.
Mark A	———	179° 57.′0	179° 57′.2	N. 145° 7′.0 E.
		59.5		
		55.0		
1h 22m	75.5	214 54.0	214 50.2	
	75.5	49.0		
	75.5	47.5		
1 24	75.5	214 54 0	214 50 0	
	75.5	49.0		
	75.3	47.0		
Mark A	———	179 59.0	179 58 2	145 8.2
		60 0		
		55.5		
Mark A	———	179 59.0	179 58.3	145 8.8
		60.5		
		55.5		
1 33	75.5	214 53.0	214 49.5	
	75.4	49.0		
	75.3	46.5		
1 37	75 2	214 53.0	214 49.8	
	75.2	49.0		
	75.3	47.5		
Mark A	———	179 59.5	179 59.3	145 9 5
		61.5		
		57.0		
			Mean	145 8.4

Magnetical azimuth of mark A, N. 145° 7′.3 E.

Horizontal intensity. Experiments of vibration.

1857. January 25, P. M. Vibrating magnet D 3.

No.	Chronometer.	No.	Chronometer.	Time of 300 vibrations.
0	3h 20m 3s.6	300	3h 33m 13s.8	13m 10s.2
10	20 29.8	310	33 40.2	10.4
20	20 56.2	320	34 6.4	10.2
30	21 22.6	330	34 32.9	10.3
40	21 48.8	340	34 59.3	10.5
50	22 15.2	350	35 25.6	10.4
100	24 27.2	200	28 50.5	
				13 10.33

Extreme scale readings.

0	20.0	40.0
100	21.7	38.3
200	24.0	36.3
350	27.8	31.6

Temperature 11°.5 C.

Time of 1 vibration 2s.6344.

1857. January 25, P. M. Vibrating magnet D 3.

No.	Chronometer.	No.	Chronometer.	Time of 300 vibrations.
0	3h 39m 28s.2	300	3h 52m 38s.6	13m 10s.4
10	39 54.4	310	53 4.9	10.5
20	40 20.8	320	53 31.2	10.4
30	40 47.2	330	53 57.6	10.4
40	41 13.4	340	54 23.9	10.5
50	41 40.0	350	54 50.2	10.2
100	43 51.7	200	48 15.2	
				13 10.40

Extreme scale readings.

50	20.0	40.0
200	22.2	37.8
300	23.6	36.4
350	24.2	35.9

Temperature 12°.2 C.

Time of 1 vibration 2s.6347.

1857. January 25, P. M. Vibrating magnet D 3.

No.	Chronometer.	No.	Chronometer.	Time of 300 vibrations.
0	3h 56m 39s.7	300	4h 9m 50s.1	13m 10s.4
10	57 6.2	310	10 16.5	10.3
20	57 32.6	320	10 42.8	10.2
30	57 58.9	330	11 9.2	10.3
40	58 25.3	340	11 35.4	10.1
50	58 51.8	350	12 1.7	9.9
100	4 1 3.3	200	5 27.8	
				13 10.20

Extreme scale readings.

0	19.0	41.0
100	20.7	39.3
200	22.5	37.5
300	23.6	36.2

Temperature 5°.5 C.

Time of 1 vibration 2s.6340.

Experiments of deflection. Distance 1 foot.

1857. January 26, 11h 6m A. M. Deflecting magnet D 3.

Magnet.	North pole.	Circle reading.	Mean.	2 u.	Temp.
E.	W.	78° 49′ 0″	48′ 30″		9°.7 C.
		48 0		14° 27′ 17″	
"	E.	93 16 10	15 47		
		15 25			
W.	W.	93 48 50	48 45		
		48 40		15 21 8	
"	E.	78 28 10	27 37		
		27 5			
"	E.	78 28 45	28 17		
		27 50		15 19 8	
"	W.	93 47 45	47 25		
		47 5			
E.	E.	93 16 25	16 7		
		15 50		14 27 27	
"	W.	78 49 0	48 40		
		48 20			9.7
			Mean	14 53 45.0	

Horizontal intensity. Experiments of deflections.

1857. January 26, 11h 25m A. M. Deflecting magnet D 3.

Magnet.	North pole.	Circle reading.	Mean.	2 u.	Temp.
E.	W.	82° 49′ 40″	49′ 30″		9°.7 C.
		49 20		6° 33′ 15″	
"	E.	89 23 10	22 45		
		22 20			
W.	W.	89 33 35	33 12		
		32 50		6 51 17	
"	E.	82 42 20	41 55		
		41 30			
"	E.	82 39 5	38 47		
		38 30		6 54 23	
"	W.	89 33 30	33 10		
		32 50			
E.	E.	89 23 15	22 47		
		22 20		6 36 57	
"	W.	82 46 20	45 50		9.7
		45 20			
			Mean	6 43 58	

Magnetic inclination.

1857. January 25, 9h 45m A. M. Needle No. 2. A. North pole.

CIRCLE EAST.				CIRCLE WEST.			
Face east.		Face west.		Face east.		Face west.	
43° 41′	42° 23′	44° 4′	42° 36′	138° 69′	137° 21′	139° 17′	136° 47′
52	36	15	47	58	5	1	31
43 46.5	42 29.5	44 9.5	42 41.5	139 3.5	137 13.0	139 9.0	136 39.0
43 8.0		43 25.5		138 8.2		137 5.4	
43 16.8				138 1.1			
42 37.8							

1857. January 25, 9h 45m A. M. Needle No. 2. A. South pole.

CIRCLE WEST.				CIRCLE EAST.			
Face west.		Face east.		Face west.		Face east.	
138° 39′	136° 63′	138° 35′	136° 51′	43° 45′	41° 54′	44° 12′	42° 2′
21	47	19	35	56	65	23	14
138 30.0	136 55.0	138 27.0	136 43.0	43 50.5	41 59.5	44 17.5	42 8.0
137 42.5		137 35.0		42 55.0		43 12.8	
137 38.8				43 3.9			
42 42.6							

1857. January 25, 10h 40m A. M. Needle No. 1. A. South pole.

CIRCLE EAST.				CIRCLE WEST.			
Face east.		Face west.		Face east.		Face west.	
44° 7′	41° 59′	43° 48′	41° 34′	138° 53′	136° 68′	138° 69′	137° 38′
17	70	58	45	38	53	54	23
44 12.0	42 4.5	43 53.0	41 39.5	138 45.5	137 0.5	139 1.5	137 30.5
43 8.2		42 46.2		137 53.0		138 16.0	
42 57.2				138 4.5			
42 26.4							

1857. January 25, 10h 40m A. M. Needle No. 1. A. North pole.

CIRCLE WEST.				CIRCLE EAST.			
Face west.		Face east.		Face west.		Face east.	
138° 54′	137° 26′	138° 24′	136° 43′	43° 57′	41° 37′	43° 34′	41° 22′
37	10	8	28	70	50	48	37
138 45.5	137 18.0	138 16.0	136 35.5	44 3.5	41 43.5	43 41.0	41 29.5
138 1.8		137 25.8		42 53.5		42 35.3	
137 43.8				42 44.4			
42 30.3							

RESULTS OF THE MAGNETICAL OBSERVATIONS.

MAGNETIC DECLINATION.

STATION No. I. VERA CRUZ.

Magnetic azimuth of the mark A	N. 52° 19′.8 W.
Astronomical " " "	N. 44 2.9 W.
Magnetic declination, 1856, August 7, at noon	8 16.9 E.

STATION No. II. POTRERO.

Magnetic azimuth of the mark A	N. 83° 2′.8 W.
Astronomical " " "	N. 74 23.6 W.
Magnetic declination, 1856, August 17, $7^h\ 13^m$ A. M.	8 39.2 E.

STATION No. III. COCOLAPAM NEAR ORIZABA.

Magnetic azimuth of the mark A	N. 79° 32′.8 E.
Astronomical " " "	N. 88 1.1 E.
Magnetic declination, 1856, August 27, $10^h\ 8^m$ A. M.	8 28.3 E.

STATION No. IV. SAN ANDRES CHALCHECOMULA.

Magnetic azimuth of the mark A	N. 10° 40′.4 W.
Astronomical " " "	N. 2 27.6 W.
Magnetic declination, 1856, September 17, $0^h\ 40^m$ P. M.	8 12.8 E.

STATION No. V. MIRADOR.

Magnetic azimuth of the mark A	N. 101° 49′.7 E.
Astronomical " " "	N. 109 51.3 E.
Magnetic declination, 1856, October 10, $7^h\ 12^m$ A. M.	8 1.6 E.

STATION No. VI. CITY OF MEXICO.

Magnetic azimuth of the mark A	N. 106° 22′.6 W.
Astronomical " " "	N. 97 36.1 W.
Magnetic declination, 1856, December 11, $10^h\ 19^m$ A. M.	8 46.5 E.

STATION No. VIII. RANCHO TLAMACAS.

Magnetic azimuth of the mark A	N. 145° 7′.3 E.
Astronomical " " "	N. 153 35.7 E.
Magnetic declination, 1857, January 25, $1^h\ 19^m$ P. M.	8 28.4 E.

HORIZONTAL INTENSITY.

The constants K and q for the magnet D 3, which was exclusively used in the experiments of vibrations and deflections, had been determined in 1855 by Mr. CHAS. A. SCHOTT, U. S. Coast Survey, and found:—

Moment of inertia $K = 2.6072$, at temperature 76°.2.

Coefficient of temperature $q = 0.00022$.

The value of $log.\ \pi^2 K$ was computed for the following temperatures:—

At temp. 76° $log.\ \pi^2 K = 1.41047$.
" 50 $log.\ \pi^2 K = 1.41032$.

Change of $log.\ \pi^2 K$ for 1° F., 0.6 units of the 5th decimal.

The observations of deflection at distances of 1 foot and 1.3 feet, and at five different stations, give the value of the induction-coefficient P:—

Station I.	1856, August 7 . . .	$P = + 0.0004$
" II.	1856, August 17 . . .	— 0.0007
" V.	1856, October 10 . . .	— 0.0085
" VI.	1856, December 10 . . .	— 0.0037
" VIII.	1857, January 26 . . .	+ 0.0118
	Mean . . .	$P = — 0.0001$

This value of P is so small that it was neglected in the computation of the intensity.

The experiments of vibrations and deflections at the same five stations give for the magnetic moment m of magnet D 3.

Station I.	1856, August 7 . .	$m = 0.4952$,	temp. 83°
" II.	1856, August 17 . .	0.4945,	" 78
" V.	1856, October 9 . .	0.4915,	" 74
" VI.	1856, December 10 . .	0.4899,	" 69
" VIII.	1857, January 25 . .	0.4895,	" 50

The means of the 1st and 2d, and of the 3d and 4th values give:—

1856, August 12 . . .	$m = 0.4948$,	temperature 80°
1856, November 9 . . .	$m = 0.4907$,	" 72

Loss of magnetism for ten days 0.00046.[1]

From these the values of m were interpolated for the two stations, at which no experiments of deflections have been made, viz:—

Station III.	August 26	$m = 0\ 4942$
" IV.	September 17	0.4931

m and X are expressed in feet and grains.

Station No. I. Vera Cruz.

	Time of 1 vibration.	Temp.
August 7.	2s.6258	81°.5
" 7.	.6252	81.5
" 7.	.6254	82.0
" 8.	.6269	84.2
" 8.	.6256	84.3
" 8.	.6262	84.4
Mean	2.6258	83.0
Corr. for rate	+ 2	
	$T' = 2.6260$	

Angles of deflection.

	Distance.	u.	Temp.
August 7.	1 foot	7° 33′ 17″	84°.7
" 7.	1.3 feet	3 25 49	85.0

Horizontal intensity, August 7 and 8.
$X = 7.533$.

Station No. II. Potrero.

	Time of 1 vibration.	Temp.
August 16.	2s.6203	77°.0
" 16.	.6217	78.0
" 17.	.6197	78.0
" 17.	.6192	78.0
	$T' = 2.6202$	77.8

Angles of deflection.

	Distance.	u.	Temp.
August 17.	1 foot	7° 30′ 8″	81°.0
" 17.	1.3 feet	3 24 29	80.7

Horizontal intensity, August 16 and 17.
$X = 7.574$.

[1] Mr. Chas. A. Schott found 1855, September 13, $m = 0.5104$, which gives the loss in 334 days = 0.0156, or the loss in 10 days 0.00047, showing a very regular decrease of the magnetism of D 3.

STATION NO. III. COCOLAPAM NEAR ORIZABA.

	Time of 1 vibration.	Temp.
August 26.	2ˢ.6221	76°.0
" 26.	.6206	76.0
" 26.	.6212	75.6
" 26.	.6213	75.0
	$T' = 2.6213$	75.6

No deflections observed.
m assumed 0.4942.

Horizontal intensity, August 26.
$X = 7.579$.

STATION NO. IV. SAN ANDRES CHALCHECOMULA.

	Time of 1 vibration.	Temp.
September 17.	2ˢ.6217	71°.9
" 17.	.6220	71.8
" 17.	.6220	66.0
" 17.	.6224	68.7
	$T' = 2.6220$	69.6

No deflections observed.
m assumed 0.4931.

Horizontal intensity, September 17.
$X = 7.589$.

STATION NO. V. MIRADOR.

	Time of 1 vibration.	Temp.
October 9.	2ˢ.6372	76°.0
" 9.	.6396	75.5
" 9.	.6367	72.0
" 9.	.6366	71.6
	$T' = 2.6375$	73.6

	Distance.	Angles of deflection. u.	Temp.
October 9.	1 foot	7° 29′ 44″	77°.0
" 9.	1.3 feet	3 24 58	76.9

Horizontal intensity, October 9.
$X = 7.522$.

STATION NO. VI. CITY OF MEXICO.

	Time of 1 vibration.	Temp.
December 10.	2ˢ.6321	68°.2
" 10.	.6319	68.6
" 10.	.6346	69.5
" 10.	.6337	68.8
	$T' = 2.6331$	68.8

	Distance.	Angles of deflection. u.	Temp.
December 10.	1 foot	7° 25′ 30″	68°.6
" 10.	1.3 feet	3 22 38	67.9

Horizontal intensity, December 10.
$X = 7.576$.

STATION NO. VIII. RANCHO TLAMACAS.

	Time of 1 vibration.	Temp.
January 25.	2ˢ.6344	11°.5 C.
" 25.	.6347	12.2 C.
" 25.	.6340	5.5 C.
	$T' = 2.6344$	9.7 C.
		= 49.5 F.

	Distance.	Angles of deflection. u.	Temp.
January 25.	1 foot	7° 26′ 52″	9°.7 C.
" 25.	1.3 feet	3 21 59	9.7 C.

Horizontal intensity, January 25.
$X = 7.571$.

MAGNETIC INCLINATION.

STATION NO. I. VERA CRUZ.

	Needle No. 1.	Needle No. 2.	Needle No. 2.
A. North pole	45° 0′.1	45° 44′.8	45° 1′.5
A. South pole	43 14.0	42 15.6	42 30.5
Mean	44 7.0	44 0.2	43 46.0

Resulting dip, August 8, 43° 57′.7.

STATION NO. II. POTRERO.

	Needle No. 1.	Needle No. 2.
A. North pole	43° 11′.8	44° 13′.2
A South pole	42 44.4	41 15.3
Mean	42 58.1	42 44.3

Resulting dip, August 17, 42° 51′.2.

STATION NO. III. COCOLAPAM NEAR ORIZABA.

	Needle No. 1.	Needle No. 2.
A. North pole	43° 22′.5	44° 18′.3
A. South pole	42 9.1	41 36.1
Mean	42 45.8	42 57.2

Resulting dip, August 26, 42° 51′.5.

STATION NO. IV. SAN ANDRES CHALCHECOMULA.

	Needle No. 1.
A. North pole	44° 7′.7
A. South pole	41 8.7
Resulting dip, September 18 . . .	42 38.2

STATION NO. V. MIRADOR.

	Needle No. 1.	Needle No. 2.
A. North pole	43° 43′.7	45° 3′.0
A. South pole	43 55.0	42 37.3
Mean	43 49.4	43 50.2

Resulting dip, October 10 and 11, 43° 49′.8.

STATION NO. VI. CITY OF MEXICO.

	Needle No. 1.	Needle No. 2.
A. North pole	41° 35′.1	41° 24′.7
A. South pole	41 16.0	41 29.3
Mean	41 25.6	41 27.0

Resulting dip, December 17, 41° 26′.3.

STATION NO. VIII. RANCHO TLAMACAS.

	Needle No. 1.	Needle No. 2.
A. North pole	42° 30′.3	42° 37′.8
A. South pole	42 26.4	42 42.6
Mean	42 28.4	42 40.2

Resulting dip, January 25, 42° 34.′3.

RECAPITULATION OF RESULTS OF THE MAGNETICAL OBSERVATIONS.

No. of station.	Name.	Lat. N.	Long. W. of Greenwich.	Date.	Declination east.	Dip N.	Horizontal intensity.	Height above the sea.
								English feet.
I.	Vera Cruz	19° 12′	96° 9′	1856, Aug. 7–8	8° 17′	43° 58′	7.533	14
II.	Potrero	18 56	96 48	" " 16–17	8 39	42 51	7.574	1,988
III.	Cocolapam	18 53	97 4	" " 26–27	8 28	42 51	7.579	4,042
IV.	San Audres	18 59	97 15	" Sept. 17–18	8 13	42 38	7.589	7,800
V.	Mirador	19 13	96 37	" Oct. 10–11	8 2	43 50	7.522	2,400
VI.	City of Mexico	19 26	99 5	" Dec. 10–17	8 46	41 26	7 576	7,550
VII.	Chalco	19 18	98 51	1857, Jan. 6	9 3	43 12	7.540	7,480
VIII.	Tlamacas	19 3	98 39	" " 25	8 28	42 34	7.571	12,750

PART II.

NOTES

ON THE

VOLCANO POPOCATEPETL AND ITS VICINITY.

GENERAL REMARKS.

Within the last three years several ascensions have been accomplished of the volcano Popocatepetl, and also two or three attempts made to reach the highest point of the Ixtaccihuatl. Mr. Walker Fearn, Secretary U. S. Legation in Mexico, and Dr. Crawford, U. S. A., who ascended these mountains in January, 1857, have published such excellent general descriptions of them, in different journals, that little is to be added on this subject. I confine myself therefore to a geographical and geological description,[1] and give a few notes in regard to the difficulties of the ascent and the necessary precautions to be observed in the undertaking, which may perhaps prove of use to travellers, hereafter attempting the exploration of these or similar mountains.

The Popocatepetl and Ixtaccihuatl are the highest peaks of a mountain ridge, having a mean breadth of about fifteen and a length of forty English miles; running from Lat. 18° 55′ to Lat. 19° 30′ N., in a direction nearly N. 10° W., at a distance of thirty-five to fifty miles east of the city of Mexico. The average height of the ridge is about 5000 feet above the plateau from which it rises, or 13,000 English feet above the level of the sea; the Popocatepetl forms its southern termination, and to the south of it the plateau also falls off—at many places abruptly—several thousand feet.

To the east of this ridge is the alluvial plain of Amecameca, 8200 feet above the sea, and separated from the valley of Mexico, which is 700 feet lower, only by a low ridge of volcanic origin—containing several cones with extinct craters—the height of which above the plain does not exceed a thousand feet; the waters from the west side of this ridge run into the lakes, which occupy the centre of the valley of Mexico.

On the east side the mountains are bounded by the valley of Puebla, which is about 7500 feet above the level of the sea; and the waters from this and the south side run into the "Rio Mescal," a river which passes through the city of Puebla and empties into the Pacific Ocean. To the north the ridge decreases gradually in height until it loses itself in the plains of Apam (los llanos de Apam),

[1] I take this opportunity to express my obligations to Prof. Monross, who kindly furnished me with some valuable notes on the geology of Popocatepetl, after we ascended the volcano together in June, 1857. Free use of these notes has been made in the present description.

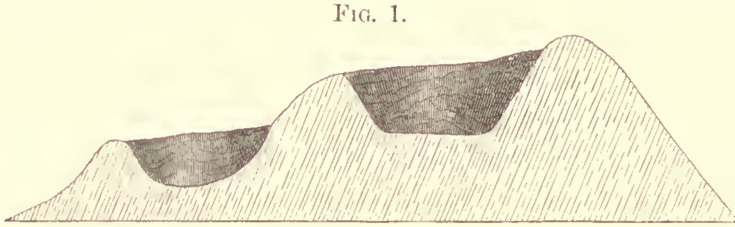
which have nearly the same elevation above the level of the sea as the plain of Amecameca.

The most convenient starting point for ascending the mountains is the town of Amecameca, situated in the plain which takes its name from it, at the eastern base of a hill, called "Sacremonte." A chapel stands upon the summit and another on the eastern slope of this hill, which is about 400 feet above the plain. At the town seven or eight Indians should be engaged as guides and to man the capstan, by which, with a rope attached, the traveller is lowered down into the crater. The first spurs of the ridge are reached a mile east of the town. They rise very gently for a considerable distance, but gradually become steeper and steeper. Where they are intersected by small ravines or gullies, washed out by the torrents, there appear just beneath the surface alternate layers of yellow pumice and black volcanic sand, in which boulders of feldspathic and porphyritic lava are entirely or partially imbedded. The surface in the upper regions is covered with a long wiry grass, and studded with pine-trees. Boulders of various sizes and shapes are scattered over it in all directions.

No lava streams appear to have run down on the west side of the mountain, and the absence of such streams is explained by the fact, that the western wall of the crater is nearly 600 feet higher than the eastern rim. A similar elevation of the western or southwestern wall above the opposite, as far as I have noticed, exists in all recent Mexican craters. It is particularly well defined on the peak of Orizaba, where even from Vera Cruz a horizontal black line is seen just below the highest point, strongly contrasting with the snow around it: this line is the western wall of the crater.

The volcano of the Colima, and the volcano of Toluca also, have their highest points at the west sides of their craters. The same peculiarity marks the outline of a volcano of very extraordinary form, situated in the valley of Mexico, about twelve miles S. E. by E. from the city, near the village of Ayotla, and called the volcano of San Isidro: it has two distinct craters; the eastern is much lower than the western, and divided from it by a wall of very compact lava; the highest point—about 1500 feet above the level of the lakes—is W. S. W. from the western crater. The bottoms of the craters of this volcano are at present cornfields.

Fig. 1.



VOLCANO OF SAN ISIDRO, SEEN FROM N. N. W.

I might add many more instances, in which I have observed the western walls of the craters of Mexican volcanoes to be considerably higher than their eastern edges, but it will be sufficient to state that, in no case, have I seen a volcanic cone whose crater is of recent formation, the east side of which was higher than the west side, nor do I recollect to have seen one, the east and west sides of which had the same elevation. But this singular law holds good not alone for volcanic cones.

On the plain of Perote, near a silver mine called "La Preciosa," there are three small lakes of nearly circular form, which are evidently of volcanic origin. The one nearest to the mine is the largest; its longest diameter runs from N. 31° E. to S. 31° W., and measures nearly 2000 yards. The surface of the water is about twenty-five feet lower than that of the surrounding plain, and the banks are perpendicular. The Director of the mine informed me that he had attempted to sound the lake, but found no bottom at 250 fathoms. The water is brackish, and its temperature was 69°.2, while the temperature of the air in shade was 65°.0 (noon, Sept. 20, 1856). The two other lakes are of similar form, but somewhat smaller. No one of them has an outlet, nor do any streams empty into them, as it does not rain more than four or five times a year in their vicinity. Nevertheless the water is perfectly clear, and of the dark color of sea-water in deep soundings. The shores of these three lakes on the east side, are not elevated above the general level of the surrounding plain, but on the west side they rise into hills (the one at the larger lake being about 160 feet high) sloping gently towards the plain, but falling off abruptly towards the lake, presenting the appearance of an excavation, of which the material was thrown up on its western banks. The surface of the hill consists of coarse sand. The trade-winds, which are prevalent in these regions and blow from E. N. E., may, perhaps, furnish an explanation of this peculiar elevation of the western walls of the more recent craters above their eastern rims.

As stated before, no lava is seen at the surface of Popocatepetl on its northern and eastern slopes; but at rare intervals, in the deeper ravines (barrancas), solid ledges of very compact lava are to be found. Passing around the volcano from the north through east to the south, the first lava-stream on the surface is met with on the eastern slope of the cone, commencing a little below the limit of perpetual snow; this stream has probably its origin at or near the present crater, but the upper part of it is covered by volcanic sand and snow. It is soon joined by another and larger stream, the outlines of which are distinctly defined above the snow-mantle of the cone up to the edge of the crater, where it forms a point projecting a little above the general profile of the mountain, when seen from the north. The altitude of this point was determined trigonometrically, and in the following observations it is distinguished by the name of the "eastern peak," from the highest or "western peak." The stream is called "el espinazo del diablo" (the devil's backbone), and extends about three miles down, losing itself near the eastern base of the mountain.

On the southeastern and southern slopes large lava-streams extend from the crater down to the edge of the plateau (from which the volcano rises ten thousand feet vertically), and cover a space of many square miles. The surface of the lower and nearly horizontal parts of these lava-fields (pedregals) is studded with boulders of all dimensions, mostly approaching to a globular form, or to segments of globes, and containing much iron and nickel. The lava of these fields is sometimes of a red (cinnabar) or brownish, but more generally of a dark gray, color, and not rarely perfectly black, sometimes with a glazed surface not unlike obsidian.

Within six or seven miles from the crater, the layers of volcanic sand and pumice become very regular, as seen at all places where they are exposed on the sides of the ravines and gullies. The stratum immediately beneath the surface is a layer of coarse, black sand, three feet thick, then succeeds a layer of reddish-yellow pumice, only one quarter of this thickness, then again a layer of sand, and so on alternately; showing that at the last eruptions a shower of pumice first issued, which covered the ground from three inches to a foot in thickness, to a distance of six or seven miles from the crater; this was followed by a shower of gray or black sand, the deposit from which reached a thickness of from three to six feet. An interesting proof that the last eruption was at no very remote date is afforded by the trunk of a pine-tree, which was found, when I last ascended the volcano, in company with Prof. Monross, in June, 1857, imbedded in the last layer of pumice, below the uppermost strata of volcanic sand, more than three feet below the surface. The outside or sapwood of the tree had decayed, but the interior wood being impregnated with turpentine was still perfectly fresh and well preserved. Certainly not many centuries can have passed since this tree was buried.

About three miles from the point where the trunk of the pine-tree was found, we reached the highest human residence in this part of the world. It consists of a few Indian huts and a log house, in front of which are the ovens for purifying the sulphur which is brought down from the crater. The place is called "Rancho Tlamacas," and has an elevation of nearly 12,800 English feet above the level of the sea. Here the traveller can remain for the night, and, leaving early the next morning, may reach the edge of the crater about noon without much exertion.

About half a mile to the west of this "rancho" we crossed a ridge of rock, which runs from the "Pico del fraile," situated on the west side of the highest peak, to the Ixtaccihuatl, rising at several points into irregular peaks. This ridge is not a stream of lava from the present crater, but a dike of ancient volcanic rock (gray stone), upheaved by the later action of the volcano. About 400 feet above the rancho, or at nearly 13,200 feet of absolute height, the last stunted pine-trees are seen, and this may be assumed as the limit of vegetation; some wiry grass, only, growing in bunches, is found for a short distance higher up. During the summer months, or, more properly, the rainy season, the snow often extends on the north and west side of the volcano down to this limit, or even lower, as we experienced during the latter part of June, having been for three days enveloped in a dense fall of snow, at the Rancho Tlamacas, which covered the ground nearly twelve inches deep, although much of it melted immediately. This snow-storm extended at least a thousand feet further down, terminating at a height of from 11,700 to 11,800 feet.

The limit of perpetual snow is about 1000 feet higher than the limit of vegetation, or, on the north and northwest side of the mountain, 14,200 feet. On the south and southeast side it is much higher, and from below there can be traced black lines, which are in reality lava-streams, up to the edge of the crater (17,200 feet). The snow extends much lower down during the summer (from June to September) than during the winter months (from October until May). This is caused by the supply of moisture from the clouds, in which the mountain tops are wrapt almost constantly during the rainy (or summer) season. Snow falls the greater part of this time, and though the sun is very powerful, it rarely breaks through the clouds. The snow, melted by the heat, is replaced almost immediately by a fresh fall, whilst in winter, when the sky is generally clear, the accumulated snow is melted to a great extent by the direct rays of the sun.

Before reaching the limit of perpetual snow, there appears a layer of transparent ice beneath the upper strata of black sand. I observed the first traces of this ice at a height of 14,000 feet. I could not ascertain its average thickness, although this is evidently considerable. The sand lies from two to four feet deep above it. In an attempt to ascend the peak of Orizaba, in September, 1856, I also noticed, near the limit of perpetual snow, a layer of similar ice beneath the first stratum of sand. This seems to prove that, at the time when the last eruption occurred, the snow extended as low or lower down than the ice does at present. The ejected sand, still warm when it reached the ground, would melt the surface of the snow, and the water, thus produced, penetrating into the lower layers of snow, would freeze again, changing the strata with which it is mixed into a kind of glacier ice. This ice, protected from the solar heat by the covering of sand, is not liable to thaw, and that part of the rain or melted snow, which filters every year through the layer of sand, freezes as soon as it comes in contact with the stratum of ice, thus increasing its bulk; and, as at this height the mean temperature of the year is below the freezing point, it is not probable that it would ever melt again.

A deep gully or ravine, the head of which is about 16,000 feet above the level of the sea, issues from between the highest or western peak and the "Pico del fraile." It runs for some distance in a N. N. E. direction, turning afterwards more to the east. This gully exposes the strata as they were deposited just on the foot of the volcanic cone by many successive eruptions. The lower beds are of a light brownish-red or of a yellowish-white color, and consist of pumice and scoriæ, while the last six layers are alternately pumice and black sand. From this it would appear that the vast mantle of black sand, which covers the cone as well as the slopes of the mountain for many miles, is the product of the last efforts of the expiring volcano.[1]

After leaving the "Rancho Tlamacas" it is still possible to ride for a considerable distance on horseback, and travellers generally dismount and leave their horses only a few hundred yards below the limit of perpetual snow. The animals can, of course, only make slow progress in ascending the steep slopes of the mountain, as they are obliged to walk in deep sand, affording no secure footing, and often slide back as much as they advance; but the traveller, in riding, saves his strength meanwhile for the toil of ascending the last 3500 feet.

It is always best to get upon the snow as soon as possible after leaving the horses, because this affords a much better footing than the loose sand. The eyes should

[1] This passage was copied from one of Prof. Monross' notes.

now be protected by colored glasses or by a green veil. In consequence of neglecting this precaution when I attempted to reach the crater of the peak of Orizaba in September, 1856, I suffered severely for several days with snow blindness. It is well to send four or five of the Indians ahead that they may tread steps into the snow, or where the surface is hard, cut them in with a hatchet. By means of these steps the ascent is rendered at once safe, easy and short, as, the average slope being about 30°, about one foot is gained in height for every two feet of distance. I found ice spurs and long iron-pointed sticks or boat-hooks entirely unnecessary, only encumbering the traveller, and followed, in my second and third ascent of this volcano, the example of the Indians, who use nothing but a common rude walking-stick, notwithstanding that each one carries a load of from twenty-five to fifty pounds on his back. I did not pass or see a single dangerous spot, and consider myself very fortunate in not encountering any of those places, where "one slip of the foot or a single false step would precipitate the wanderer into the fearful abyss which yawns beneath him," such as some travellers, who ascended the mountain a short time before I did, found on their road, although it must have coincided nearly with the one I took. On the peak of Orizaba, however, and also on the Ixtaccihuatl, I have seen crevices in the snow which might well prove fatal to the careless mountaineer.

A very unpleasant sensation is experienced in approaching the summit of a high mountain, in consequence of the difficulty of breathing during the ascent. It is not felt as much while walking as during the intervals of rest, which become necessary every fifteen or twenty minutes, and is so much like choking, that the traveller is sometimes impelled to tear the veil from his face and to throw off his neckcloth to obtain air.

But, although I have been five times on heights exceeding that of Mont Blanc—between 16,400 and 17,400 English feet, and generally accompanied by eight or more persons, I have never seen an instance of blood rushing from the nose, mouth and ears, as observed by many travellers; and my opinion is, that whenever it occurs, the cause of it is more the exertion than the rarefied air. Neither have I ever experienced the painful sensation in the limbs, often mentioned, and ascribed to the relaxation of atmospheric pressure upon the joints.

The slope of the snow-covered part of the volcano on its east and north side is very uniform, and the surface is only slightly undulating, so that it approaches the form of a regular cone. When half way up, the sulphurous odor with which the air above is impregnated is sensibly perceived.

On reaching the crater the snow-mantle breaks off abruptly, showing that here (on the north side) its thickness does not exceed five, at many places scarcely three, feet. The sides of the crater at the place where it is entered, fall off with an inclination of about 40° for the first hundred feet. The steep slopes are covered with black volcanic sand of the same nature as that which covers the surface at the foot of the cone. Above the sand project huge rocks of a very compact, dark gray or black lava, most of which present a rounded surface, except where they have been split after their formation. Thirty-two feet (perpendicularly) below the point where the crater is entered, is an overhanging rock, against which the Indians, who carry the sulphur, have placed a few boards. This place is called by them "la cueva" (the cave). and it affords a little protection, at least, against the piercing winds and the snow. Here I slept two nights, in January and February, 1857, on one of these the thermometer going down as low as —11°.8 C. (February 9, at 4 o'clock A. M.).

About thirty feet below "la cueva" is placed a rudely-constructed capstan of wood, by means of which the sulphur is raised. It is also used in lowering persons down the vertical part of the crater, which has here the least height, but which still amounts to about 250 feet. From this point there is a magnificent view of the crater, the southern and western walls of which indicate, by their shelved or terraced form, that the lava must have accumulated in successive thick and irregular beds.

Fig. 2.

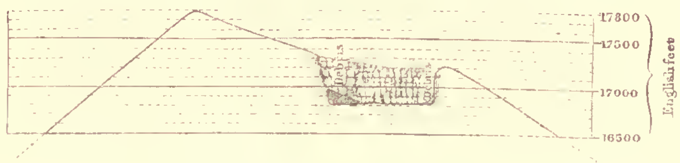
SECTION OF CRATER FROM EAST TO WEST.

The accompanying sections of the crater and the upper part of the cone may, perhaps, serve to illustrate its general structure. The nucleus of the cone is composed of compact lava, which, at least in the upper parts, is arranged in nearly vertical beds. This has little or nothing of the light, spongy or scoriaceous character of that seen in some volcanoes; as, for instance, in the modern crater of Jorullo (according to Prof. Monross), but is hard and very heavy, mostly of a dark-red, or bluish-black color. These beds nowhere show a basaltic or columnar structure. The nucleus of the cone is covered by a thick mantle of sand, scoria, and pumice, where it is not too precipitous.

In descending into the crater, the traveller is usually preceded by an Indian, and there is some danger of being hurt by the stones which are constantly falling from above him. The action of the frost is doubtless a principal agent in detaching these stones. The sun shining on the snow which covers the edge of the crater, and the shelves or narrow terraces, melts a part of it, the water penetrates into the minute crevices of the rocks, where it freezes again, and, expanding while it changes into ice, has an effect similar to that of gunpowder.

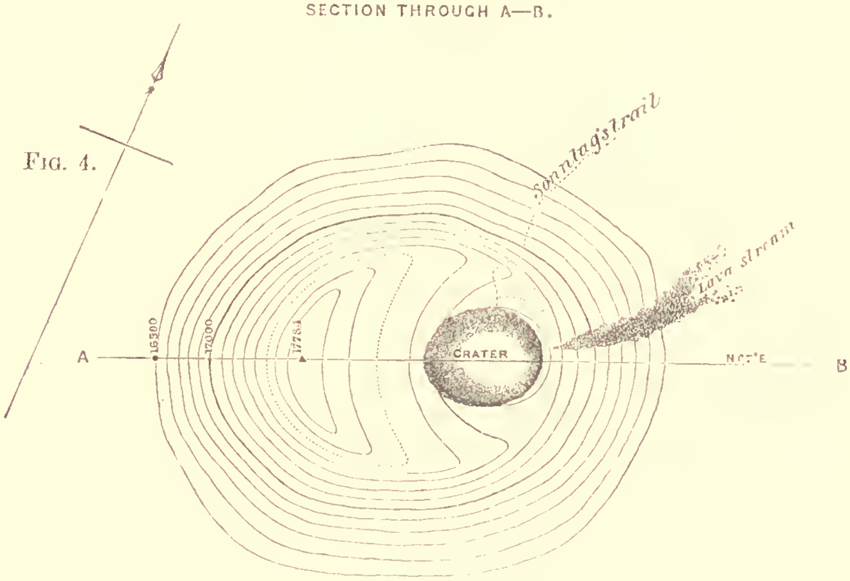
One of the guides, who had been many times in the crater, asserted that the bottom of it rises six feet annually by the accumulation of the detached stones. This is certainly an exaggeration; nevertheless, the amount of rise is considerable, since at least ten stones fall per hour, of more than two feet diameter, or certainly more than 2000 cubic feet in a day (probably double this quantity). If now we assume the diameter of the bottom of the crater, including the *debris* on which many of the falling stones remain—(the horizontal part of the bottom has a diameter of only 750 feet)—to be 1200 feet, the surface will be 1,130,000 square feet, and the quantity of stones falling annually at the rate of 2000 cubic feet for a day, amounts to 730,000 cubic feet, so that, if the bottom was covered uniformly, it would rise about 0.65 of a foot in a year. But as the stones do not reach the middle, the sides or *debris* must increase considerably more rapidly. This would indicate that the crater must fill up, and the height of the cone sensibly decrease within a thousand years if the volcano should remain inactive. The diminution of depth will, however, be less and less every year, in proportion as the upper part of the crater expands and the depth diminishes. (Figs. 3 and 4 exhibit a section and plan of the summit.)

Fig. 3.



SECTION THROUGH A—B.

Fig. 4.



SUMMIT AND CRATER of POPOCATEPETL.

Scale 1:20000.

Besides stones of smaller sizes a large quantity of sand is continually falling which tends to fill up the empty spaces left between the larger stones. It is set in motion by the wind, which generally blows very fresh on the summit, and by falling stones. Very little is required to disturb the sand, as it is deposited on the steep walls of the crater.

After being detached from the rope, and while continuing the descent of the talus, we were several times compelled to take refuge from the falling stones behind a large boulder or a vertical wall. In January and February the *debris* was nearly clear of snow, but in June we found it covered with a thick layer, the surface of which was so hard that we were obliged to cut steps in it with a hatchet by which to descend. Our guide, whilst engaged in this work, at one time lost his footing, and slid down about thirty paces before he succeeded in stopping himself.

The horizontal part of the bottom of the crater is covered with snow, above the surface of which rise only a few large boulders. In February, I noticed on the northeast side, at a place where the snow was wanting, some water of a bluish-white color and a sour taste. In June this water had disappeared, and the surface was covered uniformly with snow, except in the vicinity of the chimneys, called by the guides "respiradores." These exhibit the last, feeble evidence of the former activity of the volcano, but its main throat has been so effectually choked up by the rubbish, which has fallen into it, that at the lowest and central part of the bottom no vapors issue. The present vents are a little way up the slope, and from the two largest of these, one on the east, the other on the south side, rise volumes of vapor which extend to the edge of the crater, and sometimes in clear, calm weather are seen above it. The noise of these jets may be heard at the top of the crater, where it sounds much like the roaring of the wind, which may have given rise to the belief common among the Indians, that a passage exists between the crater and the surface of the cone near the top of "Pico del fraile," through which the wind whistles. At the "respiradores" the steam issues from the crevices between the stones, which, as well as the sand in their vicinity, are covered with crystalline sulphur.

The principal vent on the south side is about thirty feet in diameter, and filled up with stones of all sizes, which are entirely encrusted with sulphur, and decomposed by its action to such a degree, that small pieces of them may be crumbled to powder between the fingers. The large vent to the east does not cover so much ground, but the steam issues under a higher pressure; stones of eight or nine inches in diameter, when cast upon one of the crevices, through which the vapor escapes, are thrown back with such force as to fall to the ground several feet from the opening. When we removed one of the larger stones from the vent, by the aid of a long pole, sand, small stones, and sulphur, which had been covered by it, were thrown up more than ten feet into the air. We tried also to measure the temperature of the vapor issuing from the "respiradores," but the thermometer being graduated only to 160° F., burst from the heat, which exceeded this temperature.

There is not much sulphur seen in the crater except near the vents, where it is precipitated from the vapor and deposited on the rocks and the ground. This may be accounted for by the fact that the falling stones and the *debris*, which is constantly renewing the surface of the bottom of the crater, must certainly cover any old beds of sulphur which may exist. The vapor which escapes consists of steam, highly charged with sulphur in the form of sulphuretted hydrogen and of free sulphur in vapor. Very little sulphurous acid issues, although this acid as well as sulphuric is found in the air of the crater, as is proved by the sour taste of the icicles and by incrustations of sulphate of lime on some of the rocks. As already mentioned, the air not only in the crater, but outside half way down the cone, is impregnated with sulphur, proving that a very large quantity of it is discharged.

At the time of our explorations, in June, there was a cloud resting on the top of the mountain while we were at the bottom of the crater. The combined effect of this and the vapor on the light was very interesting. While standing near the chimneys, we noticed that every light object was tinged with a reddish color; patches of snow appeared of a pink hue; a white pocket handkerchief was of a light rose-color, and the gold of a watch-case resembled copper.

The last part of the ascent of the volcano, from the snow line to the crater, is generally accomplished in four hours and a half; the vertical height of this part of the cone is 3300 feet, and therefore only a little over twelve feet in height is gained in one minute. The same distance is descended in an hour or an hour and a half. The horses were left at an elevation of 14,000 feet, and the edge of the crater, where we descended into it, is 17,300 feet above the sea.

The lower part of the Ixtaccihuatl has a more cheerful appearance than the corresponding parts of the Popocatepetl. The soil, less covered with volcanic sand, is more favorable to vegetation; while nothing but pine-trees are seen on the slopes of the "smoking mountain" (the meaning of the Aztec word "Popocatepetl"), the spurs of the Ixtaccihuatl (Aztec for "white woman") are covered to a considerable height with a variety of flowers and trees of luxuriant foliage. Nevertheless, this mountain is also entirely of volcanic formation, and its upper parts are nearly as much covered with volcanic sand as the Popocatepetl, which probably has been thrown thus far by the latter volcano, since the entire ridge which connects the two mountains is covered with the same material, and their distance does not exceed ten miles. Many persons are of opinion that there has formerly been a crater between the highest and the northern peak of the Ixtaccihuatl, the walls of which are now broken down and have filled up the cavity. The appearance of the northern side favors this hypothesis. I regret much that I had not an opportunity of approaching the north and east sides of this mountain near enough to decide whether the beds of dark-colored rock seen there are streams of lava or upheaved ancient volcanic rock. The south and west sides, which I explored, are of graystone formation. Passing a perpendicular wall of this material a little below the line of perpetual snow, I noticed, near some crevices in the rock, yellow spots, having exactly the appearance of crystalline sulphur; the spots were, however, so high up the wall that I could not reach them. If the Ixtaccihuatl has ever been an active volcano, a much longer time must certainly have elapsed since its last eruption than since that of the Popocatepetl.

The ascent of the Ixtaccihuatl offers much greater difficulties than that of "Popocatepetl," on account of its steep sides and deep fissures in the snow, which are sometimes concealed by a thin crust, and in that case they become very dangerous to the explorer. I doubt, indeed, whether the highest point of this mountain has ever been reached, although I am convinced that it might be attained by parties properly prepared. The last point which I reached (in February, 1857) was 600 feet vertically below the highest peak. To this I ascended without much exertion, following for the greater part of the way a ridge of boulders on the north side of the deep ravine, which, starting near the top, on the west side of the mountain, extends in a westerly direction and loses itself in the plain of Amecameca.

The enormous size of the boulders on the western slope of this mountain must always attract the attention of the traveller. Many of the blocks are from twenty-five to thirty feet in diameter, not rounded, like those on Popocatepetl, but having plane faces and angular edges. They are sometimes isolated, but more generally in ridges running down the slopes of the mountain, and commencing often far above the line of perpetual snow.

HYPSOMETRICAL DETERMINATIONS.

BAROMETRICAL AND TRIGONOMETRICAL MEASUREMENTS OF HEIGHTS.

Determinations of the heights, derived from one or even from several barometrical observations, are liable to a considerable error, if they are continued only for a few hours at the upper station, and if the lower station is very distant; but for a sojourn of several days at a height of nearly 18,000 English feet above the sea—though within the tropics—preparations on an extensive scale become so necessary, that I could not think of adopting this plan, although it would have been very interesting in many respects.

I concluded, therefore, to make a series of barometrical observations extending over several days, at the highest convenient point; to determine the elevations of the different peaks above this point trigonometrically; and to observe barometers at the highest points to which I might ascend, so that the two measurements would check each other.

For the lower station I took the city of Mexico as the nearest place of known altitude, at which I could obtain corresponding observations. The most convenient places I found for trigonometrical stations were; on the base of the cone of the Popocatepetl; the "Rancho Tlamacas," which is 5000 feet below the highest peak, and a little more than 5000 feet above the city of Mexico; and on the base of the Ixtaccihuatl, a small plain, 11,600 English feet above the sea. At the two latter stations a French syphon-barometer was employed, and before and afterwards compared with two barometers, which were observed simultaneously in Mexico.

This barometer could not be used at much greater heights than those of the trigonometrical stations, and several other French and English syphon-barometers which were at that time at my disposal were also rendered useless at these great elevations: the mercury in the long arm retreating into the brass tube, or below the limit of the scale; and in the short arm rising above the divisions. Besides this, it was very difficult to transport long glass tubes, filled with mercury, over such rough ground as the upper part of these mountains presents. I took, therefore, two barometer tubes of large diameter, and cut them off, one to the length of 500 and the other to 440 millimetres. The open end was then heated under the blowpipe, and the aperture reduced to so small a size that it could be easily closed air-tight by the point of the finger; to each of the tubes a scale of dry cedar-wood was attached, on which minute divisions might be read without difficulty, and which extended over the entire length of the tube. In addition to the empty tubes and the scales, I carried with me two small wooden vessels or cisterns each of two inches diameter, and two inches deep, together with a quantity of mercury. On arriving at the point to be measured, the two cisterns were filled to the depth of an inch and a half, and the tubes entirely, with pure mercury; care being taken to expel the small bubbles of air by slight shaking. The aperture of each tube was then closed with the finger, and the whole inverted with the open end below the surface of the mercury in the cistern. After the mercury had settled in the tube, the scale was read at the top, and also at the level of the quicksilver in the cistern. The difference of these readings gave the length of the mercurial column. This should be reduced for temperature, on account of the expansion of mercury and the wood, but the correction, arising from the latter, was neglected, being very small. At the trigonometrical station on the Ixtaccihuatl, at a temperature of +9°.6 C., the longer of the tubes was found to agree perfectly with the syphon-barometer. In Tlamacas the difference scarcely exceeded $0^{mm}.2$, showing that the result, obtained by this simple barometer, has claims to a considerable degree of accuracy.

The instrument used for measuring the vertical angles, and for the triangulation, was made by Ertel, of Munich. It had a repeating circle, which could be mounted vertically for measuring altitudes, or horizontally for azimuths; and by means of four verniers it read to 10″. When the circle was in a horizontal position it carried a telescope with broken axis; for observations of altitudes an extra telescope had to be attached as well as a level, and so many adjustments were required, that much time was consumed in mounting it vertically. The instrument belonged to the Mining School, in Mexico, and was kindly lent to me by that institution. It had been treated rather roughly before, and, owing to this as well as to its complicated construction, it required great care and much patience in using it. The readings when the telescope had been moved from the left to the right, or from above downwards, were always different from the readings when it had been moved from the right to the left, or from below upwards. This difference, sometimes amounting to more than two minutes, was the principal cause of the want of agreement among the single measurements, and I have on this account given them, in full detail. The observations were, however, so arranged, that all constant errors, which might arise from torsion, or from tension, and collimation, were eliminated.

The standard used in measuring the base-line was a brass scale, the length of which was determined in Mexico, and found to be 622 millimetres, at a temperature of +15° C. With the aid of this standard the length of a rod used in measuring the base-line was accurately determined. The direction of the line was carefully marked by a thin rope, stretched, and at several places supported, so as to form very nearly a straight line. Besides the wooden rod, a steel-tape of ten metres length was used, and the two measurements of the base, obtained with these instruments, agreed in both cases within 0.06 of a metre.

Corresponding barometrical observations were made in Mexico by Mr. Diaz-Covarrubias, at a temporary observatory near the gate "San Lazaro," and by Mr.

Poole, at the Hotel Iturbide. The barometer of Mr. Diaz-Covarrubias stood $0^{mm}.20$ lower than the instrument I used, and a correction for this has been taken into account in the computation of the observations. Mr. Poole's barometer and my own agreed perfectly. I give his observations, which he kindly communicated to me, in the following pages, together with my own. The observations of Mr. Diaz-Covarrubias I am not able to give at present.

The direction of the wind is not given, as it is difficult to determine its true course with any accuracy among the mountains, where it follows the direction of the valleys and ravines. Generally the weather is nearly calm in the mornings, and at two o'clock P. M. a fresh easterly wind sets in, which continues to blow until seven or eight o'clock P. M., when it becomes calm again. The atmosphere during the observations was mostly clear, and is always nearly so from November till May, except when northerly winds blow.

OBSERVATIONS OF BAROMETER AND TEMPERATURE.

CITY OF MEXICO.—Barometer 55.5 English feet above the ground. Observer W. POOLE.

1857.	Hour.	Temperature of air.	Barometer.	Attached thermometer.	Reduction.	Barometer at freezing point.
Jan. 23	4h.1 P. M.	—	587mm.25	17°.6 C.	—1mm.67	585mm.58
23	7.0 P. M.	—	587.65	14.7	1.40	6.25
25	2.0 P. M.	—	588.65	12.2	1.16	7.49
30	9.0 A. M.	12°.0 C.	587.10	12.0	1.13	5.97
30	10.0 A. M.	14.0	587 10	14.0	1.32	5.78
30	12.0 M.	17.0	586.07	17.0	1.60	4.47
30	2.0 P. M.	18.0	585.10	18.0	1.70	3.40
30	3.5 P. M.	16 2	584 70	16.2	1.53	3.17
30	4.0 P. M.	16.1	584.66	16.1	1.52	3.14
30	6.0 P. M.	14.8	585.15	14.8	1.41	3.74
30	8.7 P. M.	10.5	587.15	16.5	—1.57	5 58
30	10.0 P. M.	9.0	586.66	13.5	1.28	5.38
30	11.0 P. M.	8.0	586.57	13.7	1.30	5 27
31	8.0 A. M.	7.1	587.59	7.2	0.69	6.90
31	9.0 A. M.	10.6	588.22	10.8	1.03	7.19
31	11.5 A. M.	14.8	588.00	14.8	1.41	6.59
31	12.0 M.	16.2	587.73	16.2	1.54	6.19
31	1.5 P. M.	17.3	587.00	17.3	1.63	5.37
31	3.5 P. M.	17.3	586.54	17.3	1.64	4.90
Feb. 1	9.0 A. M.	8.5	588.31	8.2	0.78	7.53
.1	0.5 P. M.	17.0	588.22	17.0	—1.61	6.61
1	3.0 P. M.	16.8	587.02	16.8	1.58	5.44
4	5.5 P. M.	—	588.45	15.3	1.46	6.99
5	8.8 A. M.	10.0	588.35	13.6	1.29	7.06
5	10.2 A. M.	14.0	588.95	14.0	1.33	7.62
5	11.5 A. M.	15 5	588.40	15.0	1.43	6.97
5	5.6 P. M.	13.5	586.30	15.0	1.42	4.88
6	5 9 A. M.	—	583.35	15.5	1.46	1.89
7	10.0 A. M.	13.7	584.75	13.7	1.29	3.46
7	5.2 P. M.	—	584.70	16.4	1.55	3.15
7	6.7 P. M.	—	584.35	14.0	—1.32	3 03
8	9.0 A. M.	8.0	586.25	11.7	1.10	5.15
8	0.2 P. M.	15.2	585.80	15.2	1.44	4.36
8	2 0 P. M.	17.0	585.45	19.0	1.79	3.66
8	3.8 P. M.	15.1	585.70	19.6	1.85	3.85
8	7.8 P. M.	11.0	586.75	10.6	1.00	5.75
9	8.0 A. M.	6.1	587.65	6.1	0.58	7.07
9	9.0 A. M.	8.8	587.85	8.8	0 84	7.01
9	10.0 A. M.	11.1	588.10	11.1	1.06	7.04
9	11.0 A. M.	12.8	588.05	12.8	1.22	6.83
9	12.0 M.	15 3	587.90	15.3	—1.46	6.44
9	12.7 P. M.	16.3	587.80	16.3	1.55	6.25
9	3.3 P. M.	17.9	587.55	17.9	1.70	5.85
9	5.2 P. M.	17.0	587.85	17.0	1.61	6.24
9	6.0 P. M.	15.6	588.10	15.6	1.48	6.62
9	7.0 P. M.	13.8	588.25	13.8	1.31	6.94
9	11.0 P. M.	6.8	588.10	6.8	0.65	7.45
11	1.0 P. M.	14.3	589.94	14.3	1.36	8.58
11	2.0 P. M.	16 3	589.39	16.3	1.55	7.84
11	3.0 P. M.	17.1	588.85	17.1	1.63	7.22
11	4.0 P. M.	17.1	588.50	17.1	—1.63	586.87
11	6.0 P. M.	13.5	591.42	13 7	1.30	90.02
11	7.0 P. M.	—	590.43	13.7	1.30	89.13
12	10.0 A. M.	12.0	592.58	12.7	1.22	91.36
12	11.0 A. M.	14.8	593 65	14.8	1.42	92.23
12	12.0 M.	16.2	593.67	16.2	1.55	92.12
12	1.0 P. M.	17.7	593.23	17.7	1.69	91.54
12	2.0 P. M.	18.3	592.91	18.3	1.75	91.16
12	3.0 P. M.	18.6	592.58	18.6	1.78	90.80
12	4.0 P. M	—	592.38	18.3	1.75	90.63
12	5.0 P. M.	—	592.15	1.77	1.69	90.46

TOWN OF AMECAMECA, Public Square [Plaza].—Barometer 2 feet above the ground. Observer A. SONNTAG.

1857.	Hour.	Temperature of air.	Barometer.	Attached thermometer.	Reduction.	Barometer at freezing point.
Jan. 19	$1^h.8$ P. M.	16°.3 C.	$574^{mm}.08$	18°.5 C.	$—1^{mm}.72$	$572^{mm}.36$
19	3.0 P. M.	14.4	73.61	16.3	1.51	2.10
19	4.0 P. M.	13.0	73.41	15.0	1.39	2.02
20	7.0 A. M.	8.0	74.02	9.9	0.92	3.10
20	7.8 A. M.	9.0	73.76	9.0	0.83	2.93
27	7.5 P. M.	6.0	73.70	13.0	1.21	2.49
27	10.0 P. M.	2.0	73.93	11.0	1.02	2.91
28	8.0 A. M.	5.0	73.96	11.3	1.05	2.91
28	4.0 P. M.	11.5	73.93	12.2	1.13	2.80

SACRE MONTE, near Amecameca.—Barometer 2 feet above the roof of the upper chapel.

Jan. 28	11.0 A. M.	15.4	566.42	15.4	—1.40	565.02
28	0.30 P. M.	16.0	565.99	19.0	1.73	564.26

RANCHO TLAMACAS.—The barometer 2 feet above the ground. Observer A. SONNTAG.

1857.	Hour.	Temperature of air.	Barometer.	Attached thermometer.	Reduction.	Barometer at freezing point.	Place of observation.
Jan. 20	$3^h.5$ P. M.	+ 8°.0 C.	$485^{mm}.39$	+ 9°.1 C.	$—0^{mm}.71$	$484^{mm}.68$	Indian huts.
20	4.5 P. M.	+ 5.9	484.50	+ 5.9	—0.46	84.04	〃
20	5.5 P. M.	+ 1.4	484.32	+ 1.4	—0.11	84.21	〃
20	6.5 P. M.	— 0.3	484.73	— 0.3	+0.02	84.75	〃
20	7.5 P. M.	— 2.0	485.94	+10.7	—0.84	85.10	〃
23	11.0 A. M.	+ 6.0	484.42	+ 8.2	—0.64	83.78	Station A.
23	12.0 M.	+ 6.3	483.88	+ 6.4	—0.50	83.38	〃
23	5.0 P. M.	+ 3.2	482.80	+ 3.4	—0.26	82.54	〃
23	7.5 P. M.	— 3.0	484.33	+ 8.6	—0.67	83.66	Indian huts.
24	8.5 A. M.	+ 1.5	485.18	+11.2	—0.88	84.30	〃
24	10.0 A. M.	+ 4.0	484.71	+ 8.0	—0.63	84.08	Station A.
24	11.5 A. M.	+ 6.0	485.15	+10.0	—0.78	84.37	Indian huts.[1]
25	8.5 A. M.	+ 1.5	485.48	+11.5	—0.90	84.58	〃
25	11.2 A. M.	+ 5.5	485.54	+11.7	—0.92	84.62	〃
25	2.0 P. M.	+10.0	484.81	+10.5	—0.82	83.99	〃
25	6.0 P. M.	— 3.5	484.94	+11.0	—0.86	84.08	〃
26	6.0 A. M.	— 4.5	—	—	—	—	〃
26	7.0 A. M.	— 2.0	485.40	+10.5	—0.82	84.58	〃
26	0.7 P. M.	+10.0	485.64	+12.0	—0.94	84.70	〃
26	5.2 P. M.	+ 1.2	485.69	+ 6.5	—0.51	85.18	〃
27	9.0 A. M.	+10.2	486.37	+14.5	—1.14	85.23	〃
Feb. 7	5.5 P. M.	+ 1.6	482.07	+ 2.0	—0.16	81.91	〃
7	8.0 P. M.	— 1.0	483.05	+ 8.0	—0.63	82.42	〃
7	9.0 P. M.	— 3.1	483.43	+ 6.0	—0.47	82.96	〃
9	1.5 P. M.	+ 8.0	485.36	+ 8.0	—0.63	84.73	〃

CERO TLAMACAS.—The barometer on a level with the highest point.

Jan. 24	1.0 P. M.	8.5	474.44	12.8	—0.98	473.46
24	2.8 P. M.	9.0	473.95	10.5	—0.81	73.14
24	3.5 P. M.	9.0	473.78	10.0	—0.77	73.01

At THREE CROSSES on the road from Amecameca to Puebla.[2]—The barometer 2 feet above the ground.

Jan. 27	12.0 M.	10.0	496.31	10.0	—0.80	495.51

POINT OF JUNCTION of the roads from Puebla and Tlamacas to Amecameca.—The barometer 2 feet above the level of the water, where the two creeks join.

Jan. 27	0.5 P. M.	11.5	508.44	14.5	—1.19	507.25

[1] Station A is 8 metres above the Indian huts.

[2] This is the highest point of the road, and at the same time the lowest point of the summit of the ridge, which connects the Popocatepetl and Ixtaccihuatl.

Foot of the Ixtaccihuatl. Trigonometrical Station B.—The barometer 2 feet above the ground.

1857.	Hour.	Temperature of air.	Barometer.	Attached thermometer.	Reduction.	Barometer at freezing point.	
Feb. 3	$2^h.5$ P. M.	9°.2 C.	$506^{mm}.16$	9°.2 C.	—$0^{mm}.75$	$505^{mm}.41$	(1)
3	3.5 P. M.	8.4	505.88	10.0	0.81	5.07	(2)
4	8.0 A. M.	5.0	507.09	10.6	0.86	6.23	
4	9.0 A. M.	7.2	507.31	7.2	0.59	6.72	
4	10.0 A. M.	9.0	507.38	9.1	0.74	6.64	
4	11.0 A. M.	10.5	507.53	13.0	1.07	6.46	
4	1.0 P. M.	12.0	507.24	12.0	0.98	6.26	
4	3.0 P. M.	12.0	506.63	13.7	1.12	5 51	
4	5.0 P. M.	6.0	506.49	10.3	0.83	5.66	
4	6.0 P. M.	4.0	506.04	5.0	0.41	5.63	
Ixtaccihuatl, at the top of the cascade, where the Indian "Nieveros" cut ice to supply the City of Mexico.							
Feb. 3	5.5 P. M.	4.0	483.60	9.0	—0.70	482.90	
Ixtaccihuatl.—Rock projecting above the snow, about 600 feet (vertical) below the highest peak.							
Feb. 5	1.0 P. M.	1.0	422.5	+1.0	—0.07	422.43	Cistern bar. I.
5	1.0 P. M.	1.0	422.3	+1.0	0.07	22.23	" II.
5	1.1 P. M.	1.0	422.0	+1.0	0.07	21.93	" I.

Popocatepetl.

1857.	Hour.	Temperature of air.	Barometer.	Attached thermometer.	
Bottom of the crater.					
February 8	2.0 P. M.	+2°.0 C.	416.0	+7°.5 C.	Cistern barometer I.
8	2.1 P. M.	+2.0	416 0	+7.5	" " II.
Cave ("la cueva") in the crater.					
February 8	4.0 P. M.	—2.0 C.	406.5	—2.0	Cistern barometer I.
8	4.1 P. M.	—2.0	406.0	—2.0	" " II.

Observations of Temperature on the Popocatepetl.—The observations were made at "la cueva," in the crater.

1857.	Hour.	Temperature.	1857.	Hour.	Temperature.
January 21	$4^h.0$ P. M.	—2°.5 C.	February 8	$8^h.0$ P. M.	—7°.5 C.
22	7.0 A. M.	—9.0	9	4.0 A. M.	—11.8
22	8.0 A. M.	—7.0	9	6.0 A. M.	— 9.0
February 8	4.0 P. M.	—2.0	9	7.0 A. M.	— 7.0
8	6.0 P. M.	—4.0	9	8.0 A. M.	— 5.8

1 The longer cistern barometer (I.) read $506^{mm}.3$ at temperature +9°.2 C.

2 The cistern barometer I. read $505^{mm}.8$ at temperature +10.0 C.

OBSERVATIONS OF HORIZONTAL AND VERTICAL ANGLES.

All observations of altitudes and horizontal angles, except the measurement of the elevation of the highest peak above the edge of the crater, were made with the instrument of Ertel, before described. One division of the level of this instrument corresponds to three seconds.

For the determination of the elevation of the highest peak of "Popocatepetl" above the crater, a small theodolite, belonging to the set of Smithsonian magnetic instruments, was used. It had a vertical circle reading to single minutes.

OBSERVATIONS OF VERTICAL ANGLES.

Rancho Tlamacas, January 23, 1857.—Ertel's altitude and azimuth instrument.

Station A.					
Object.	Position of circle.	Level.	Circle reading.	Means.	
Popocatepetl, West peak.	Right	6.2	20° 19′ 25″	19′ 26″.2	
			5		
		7.2	35	Level +1.5	
			40		
					20° 19′ 12″.0
"	"	6.8	20 18 60	18 56.3	
			75		
		6.8	50	0.0	
			40		
"	Left	6.0	338 57 25	57 47.5	
			55		
		7.2	70	+ 1.8	
			40		
					338 57 36.9
"	"	6.0	338 57 40	57 23.7	
			35		
		6.5	10	+ 0.8	
			10		
Point of zenith on the circle					359 38 24.4
Altitude of West peak					20 40 47.6
Popocatepetl, East peak.	Right	6.0	18 57 25	57 25.0	
			30		
		7.3	20	+ 1.9	
			25		
					18 57 33.2
"	"	6.5	18 57 40	57 38.8	
			30		
		6.9	30	+ 0.6	
			55		
"	Left	5.8	310 18 60	18 50.0	
			70		
		7.3	30	+ 2.2	
			40		
					340 18 55.0
"	"	7.0	340 18 70	18 58.8	
			75		
		6.3	40	— 1.0	
			50		
Point of zenith on the circle					359 38 14.1
Altitude of East peak					19 19 19.1

Station A—Continued.					
Object.	Position of circle.	Level.	Circle reading.	Means.	
Pico del Fraile.	Right	6 3	19° 5′ 40″	5′ 25″.0	
			20		
		6.7	10	+ 0.6	19 5 25.6
			30		
"	Left	6.5	340 10 65	10 53.8	340 10 54.2
			70		
		6.8	40	+ 0.4	
			40		
	Point of zenith on the circle				359 38 9.9
	Altitude of Pico del Fraile				19 27 15.7
Cerro Tlamacas.	Right	6.3	12 18 40	18 15.0	
			10		
		6.8	0	+ 0.7	12 18 15.7
			10		
"	Left	5.8	346 58 10	58 3.8	
			25		
		7.6	0	+ 2.7	346 58 6.5
			57 40		
	Point of zenith on the circle				359 38 11.1
	Altitude of Cerro Tlamacas				12 40 4.6

Station B.

Object.	Position of circle.	Level.	Circle reading.	Means.	
Station A (3.9 feet	Right	7.5	356° 14′ 60″	14′ 51″.2	356 14 49.0
above the ground).			30		
		6.0	40	Level 2.2	
			75		
"	Left	6.0	1 34 45	34 53.7	1 34 55.5
			60		
		7.2	80	+ 1.8	
			30		
Point of zenith on the circle					358 54 52.2
Depression of Station A					2 40 3.3
East peak.	Right	6.4	18 0 40	0 20.0	18 0 21.0
			10		
		7.1	0	+ 1.0	
			30		
"	Left	6.0	339 50 25	50 28.7	339 50 30.5
			50		
		7.2	10	+ 1.8	
			30		
Point of zenith on the circle					358 55 25.7
Altitude of East peak					19 4 55 3
West peak.	Right	6.7	19° 31′ 50″	31′ 40″.0	19° 31′ 40″.3
			35		
		6.9	20	+ 0.3	
			55		
"	Left	7.5	338 20 30	20 5.0	338 20 2 8
			20 0		
		6.0	19 50	— 2.2	
			20 0		
Point of zenith on the circle					358 55 51.5
Altitude of West peak					20 35 48.8
Pico del Fraile.	Right	6.8	18 23 40	23 40.0	18 23 40 0
			30		
		6.8	35	0.0	
			55		
"	Left	6.8	339 26 50	339 26 31.2	339 26 31.2
			50		
		6.8	10	0.0	
			15		
Point of zenith on the circle					358 55 5.6
Altitude of Pico del Fraile					18 28 34.4

OBSERVATIONS OF HORIZONTAL ANGLES.

Rancho Tlamacas, January 24, 1857.—Ertel's altitude and azimuth instrument.

Station A.

Object.	Circle readings.				Means.	
Station B.	119° 6′ 20″	7′ 15″	6′ 50″	6′ 20″	119° 6′ 27″.5	119° 6′ 48″.1
	30	15	50	25	7 23.7	
	40	35	65	45	6 53.7	
	20	30	50	20	6 27.5	
Pico del Fraile.	39 44 20	45 20	43 20	43 50	39 44 33.7	39 44 10.6
	40	0	0	40	45 11.2	
	30	10	10	40	43 11.2	
	45	15	15	55	43 46.2	
West peak.	32 3 15	2 15	1 10	0 65	32 3 15.0	32 1 48.7
	10	0	0 50	50	2 6.2	
	20	0	0 50	50	0 57.5	
	15	10	1 0	60	0 56.3	
East peak.	20 52 10	50 40	49 40	49 50	20 52 8.7	20 50 30.2
	0	30	25	40	50 35.0	
	5	30	30	40	49 33.7	
	20	40	40	45	49 43.7	

Angle B, Pico del Fraile	79° 22′ 37″.5	B to the right.	
" B, West peak	87 4 59.4	"	"
" B, East peak	98 16 17.9	"	"

Station B.[1]

Object.	Circle readings.				Means.	
Station A.	177° 24′ 45″	24′ 30″	23′ 25″	24′ 30″	177° 24′ 51″.7	177° 24′ 22″.7
	50	30	30	40	24 33.3	
	60	40	33	40	23 29.3	
					24 36.7	
East peak.	256 35 35	34 40	34 40	34 20	256 35 35 0	256 34 50.4
	30	40	50	20	34 36.7	
	40	30	40	40	34 43.3	
					34 26.7	
West peak.	267 51 30	50 50	52 20	51 50	267 51 26 7	267 51 35.0
	30	50	30	40	50 46.7	
	20	40	20	40	52 23 3	
					51 43.3	
Pico del Fraile.	275 0 5	0 0	0 50	—	275 0 1.7	275 0 16.1
	0	10	40		0 3.3	
	0	0	40		0 43.3	

Angle A, East peak	79° 10′ 27″.7	A to the left.	
" A, West peak	90 27 12.3	"	"
" A, Pico del Fraile	97 35 53.4	"	"

Length of base line 173^{m}.206 ± 0^{m}.066.
Direction of base line N. 95° 32′ W. (true).

[1] At this station only 3 verniers were read.

OBSERVATIONS OF VERTICAL ANGLES.

PLAIN ON THE IXTACCIHUATL, February 4, 1857.—Ertel's altitude and azimuth instrument.

STATION A.					
Object.	Position of circle.	Level.	Circle reading.	Means.	
Ixtaccihuatl, Highest peak.	Right	6.6	16° 12′ 30″	12′ 12″.5	
			0		
		6.9	10	Level + 0.4	
			10		
"	"	6.4	16 12 20	12 7.5	16° 12′ 10″.5
			11 55		
		6.8	12 5	+ 0.6	
			10		
"	Left	6.4	341 40 85	40 58.8	
			40		
		6 9	45	+ 0.7	
			65		341 41 2.5
"	"	6.2	341 40 90	41 3.8	
			45		
		7 3	45	+ 1.6	
			75		
	Point of zenith on the circle				358 56 36.5
	Altitude of HIGHEST PEAK				17 15 34.0
Ixtaccihuatl, South peak.	Right	6.4	13 31 55	31 36.2	13 31 37.1
			20		
		7.0	30	+ 0.9	
			40		
"	Left	6.3	344 21 50	21 15.0	344 21 16.2
			20 55		
		7.1	21 0	+ 1.2	
			15		
	Point of zenith on the circle				358 56 26.6
	Altitude of SOUTH PEAK				14 35 10.5
Popocatepetl, West peak.	Right	6.4	5 27 55	27 37.5	
			30		
		7.2	25	+ 1.2	
			40		5 27 35.0
"	"	6.4	5 27 45	27 30.0	
			10		
		7.2	25	+ 1.2	
			40		
"	Left	7.3	352 27 25	26 28.8	352 26 27 2
			26 0		
		6 2	10	— 1.6	
			20		
	Point of zenith on the circle				358 57 1.1
	Altitude of POPOCATEPETL				6 30 33.9

Station B.[1]					
Object.	Position of circle.	Level.	Circle reading.	Means.	
Ixtaccihuatl, Highest peak.	Left	5.8	341° 33′ 50″	33′ 25″.0	
			0		
		7.1	20	Level + 1.9	
			30		
					341° 33′ 24.2″
"	"	5.4	341 33 40	33 18.8	
			0		
		7.2	15	+ 2.7	
			20		
"	Right	7.2	16 18 70	18 55.0	
			30		
		5.4	50	— 2.7	
			70		
					16 18 55.4
"	"	6.8	16 18 80	19 0.0	
			30		
		5.8	50	— 1.5	
			80		
Point of zenith on the circle					358 56 9.8
Altitude of the Highest peak					17 22 45.6
Ixtaccihuatl, South peak.	Left	6.3	344 21 60	21 32.5	344 21 32.8
			20		
		6.5	20	+ 0 3	
			30		
"	Right	6.3	13 29 90	30 5.0	13 30 4.4
			50		
		5.9	45	— 0.6	
			75		
Point of zenith on the circle					358 55 48.6
Altitude of South peak					14 34 15.8
Popocatepetl, West peak.	Left	7.3	352 30 10	29 55.0	
			29 40		
		5.1	29 50	— 3.3	
			30 0		
					352 29 43.1
"	"	8.0	352 30 10	29 40.0	
			29 10		
		4.3	29 35	— 5.5	
			29 45		
"	Right	5.3	5 23 30	23 8.7	
			22 40		
		7.0	23 10	+ 2.5	
			23 15		
					5 23 37.5
"	"	6.3	5 24 10	24 3.8	
			23 20		
		6.4	24 20	+ 0.1	
			24 25		
Point of zenith on the circle					358 56 40.3
Altitude of Popocatepetl					6 26 57.2

[1] The altitude of this station, seen from station A, is 2° 45′.

OBSERVATIONS OF HORIZONTAL ANGLES.

Plain on the Ixtaccihuatl, February 4, 1857.—Ertel's altitude and azimuth instrument.

Station A.

Object.	Circle readings.				Means.	
Station B.	49° 22′ 60″	23′ 35″	23′ 30″	23′ 10″	49° 23′ 1″.2	
	50	30	20	5	23 36.2	
	75	40	40	25	23 30.0	
	60	40	30	25	23 16.2	
						49° 23′ 13″.4
"	49 23 10	22 45	22 50	23 30	49 23 8.8	
	0	30	40	45	22 41.2	
	15	55	65	45	22 53.8	
	10	35	60	40	23 40.0	
Ixtaccihuatl, Highest peak.	113 12 40	12 45	12 45	12 35	113 12 25.0	
	25	40	50	30	12 37.5	
	30	45	70	65	12 48.8	
	5	20	30	25	12 38.8	
						113 12 26.8
"	113 12 40	12 35	12 20	11 70	113 12 30.0	
	30	25	10	50	12 26.2	
	40	35	25	60	12 11.2	
	10	10	11 50	50	11 57.5	
Ixtaccihuatl, South peak.	130 37 50	37 50	37 60	37 70	130 37 47.5	130 37 54.7
	50	40	60	60	37 51.2	
	45	70	65	75	37 56.2	
	45	45	40	50	38 3.8	
Popocatepetl, West peak.	197 55 20	55 20	55 55	55 70	197 55 15.0	
	25	20	50	60	55 12.5	
	5	0	30	40	55 43.7	
	10	10	40	60	55 57.5	
						197 55 36.0
"	197 55 40	55 50	55 60	55 50	197 55 30.0	
	35	40	55	40	38.8	
	15	30	40	25	52.5	
	30	35	55	35	37.5	

Station B.

Object.	Circle readings.				Means.	
Station A.	91° 14′ 10″	14′ 20″	14′ 5″	13′ 60″	91° 14′ 10″.0	
	5	15	20	50	14 21.2	
	20	30	30	70	14 17.5	
	5	20	15	60	14 0.0	
						91° 14′ 6″.7
"	91 14 20	14 20	13 50	13 50	91 14 12.5	
	5	10	50	40	14 16.2	
	20	25	60	45	13 50.0	
	5	10	40	50	13 46.2	
Popocatepetl, West peak.	60 3 10	3 5	3 35	3 0	60 3 11.2	
	0	0	35	10	3 6.2	
	20	15	50	30	2 40.0	
	15	5	40	10	3 12.5	
						60 2 52.2

STATION B—Continued.

Object.	Circle readings.				Means.	
Popocatepetl, West peak.	60° 3′ 10″	2′ 20″	2′ 10″	3′ 0″	60° 3′ 5″.0	
	2 50	20	10	0	2 27.5	
	3 10	40	20	10	2 12.5	
	3 10	30	10	0	3 2.5	
Ixtaccihuatl, South peak.	353 55 20	54 40	55 40	54 65	353 55 10.0	353° 55′ 2″.2
	0	20	15	40	54 33.8	
	10	35	35	50	55 30 0	
	10	40	30	65	54 55.0	
Ixtaccihuatl, Highest peak.	336 30 30	30 40	30 45	30 50	336 30 25.0	
	20	30	30	25	30 30.0	
	25	20	20	50	30 31.2	
	25	30	30	30	30 38.8	
						336 30 23.2
"	336 30 35	29 60	30 40	30 45	336 30 21.2	
	10	30	20	15	29 45.0	
	20	40	20	20	30 25.0	
	20	50	20	40	30 30.0	

At STATION A.

Angle B, Highest peak . . . . . . 63° 49′ 13″.4
Angle B, South peak 81 14 41.3
Angle B, Popocatepetl 148 32 22.6

At STATION B.

Angle A, Popocatepetl 31 11 14.5
Angle A, South peak 97 19 4.5
Angle A, Highest peak 114 43 43.5

Length of base line $150^{m}.433 \pm 0^{m}.062$.
Direction of base line N. 7° 0′ E. (true).

ALTITUDE OF THE WEST PEAK OF POPOCATEPETL ABOVE THE CAVE IN THE CRATER.
February 8, 1857. Small theodolite (3.5 feet above the ground).

STATION A.

Depression of the cave in the crater . . . . . 32° 20′
Distance of the cave from station A $20^{m}.4$.
Angle B, West peak 44 11
Altitude of West peak 15 43
Altitude of station B 9 23

STATION B.

Angle A, West peak 129 37
Altitude of West peak 16 4.5

Length of base line $73^{m}.40$.

COMPUTATION OF HEIGHTS.

POPOCATEPETL.—Only a few of the barometrical observations in the city of Mexico were made at exactly the same time as the observations at Tlamacas, and at the trigonometrical station of the Ixtaccihuatl. For this reason all barometer readings made on the same day have been reduced to the mean height of the mercurial column at the freezing point for that day, and the differences of level deduced from the means of the observations thus corrected. The reduction was made by means of the following tables.

CORRECTION TO BE APPLIED TO THE HOURLY READINGS TO REDUCE THEM TO THE MEAN HEIGHT OF THE BAROMETER DURING THE DAY, FROM JANUARY 20 TO FEBRUARY 10.

Hour.	Correction.	Hour.	Correction.	Hour.	Correction.	Hour.	Correction.
CITY OF MEXICO.							
8^h A. M.	—0^{mm}.55	12^h M.	—0^{mm}.14	4^h P. M.	+1^{mm}.19	8^h P. M.	—0^{mm}.60
9 A. M.	—0.93	1 P. M.	+0.11	5 P. M.	+0.80	9 P. M.	—0.80
10 A. M.	—0.65	2 P. M.	+0.44	6 P. M.	+0.30	10 P. M.	—0.89
11 A. M.	—0.40	3 P. M.	+0.85	7 P. M.	—0.24	11 P. M.	—0.76
RANCHO TLAMACAS AND TRIGONOMETRICAL STATION ON THE IXTACCIHUATL.							
8 A. M.	—0.15	12 M.	—0.20	4 P. M.	+0.60	8 P. M.	—0.46
9 A. M.	—0.55	1 P. M.	—0.04	5 P. M.	+0.66		
10 A. M.	—0.51	2 P. M.	+0.20	6 P. M.	+0.36		
11 A. M.	—0.43	3 P. M.	+0.42	7 P. M.	—0.06		

The table for the city of Mexico has been deduced from observations of days on which the mean height of the barometer was nearly the same as on the preceding and following days.

The other table has been interpolated from observations at Tlamacas, and at the foot of the Ixtaccihuatl.

Barometrical observations, which I made at very different heights in several parts of the Mexican Republic, seem to indicate that the daily maximum and minimum set in later in proportion as we ascend higher, at the rate of about six minutes for every thousand feet change in elevation. I computed, therefore, from the table of corrections for the city of Mexico, a table corresponding to a height of 12,500 feet, by supposing the time of maximum and minimum at this height half an hour later than in Mexico, and reducing the corrections; then interpolated from the table for the city of Mexico, in proportion to the mean daily range of the two stations, which was assumed to be 0.615. In this way the following table was obtained.

CORRECTION OF HOURLY OBSERVATIONS, CORRESPONDING TO A HEIGHT OF 11,600 TO 12,800 ENGLISH FEET.

Hour.	Correction.	Difference.	Hour.	Correction.	Difference.	Hour.	Correction.	Difference.
8^h A. M.	$-0^{mm}.22$	$+0^{mm}.07$	12^h M.	$-0^{mm}.17$	$-0^{mm}.03$	4^h P. M.	$+0^{mm}.68$	$-0^{mm}.08$
9 A. M.	—0.50	—0.05	1 P. M.	—0.01	—0.03	5 P. M.	+0.67	—0.01
10 A. M.	—0.54	+0.03	2 P. M.	+0.17	+0.03	6 P. M.	+0.34	+0.02
11 A. M.	—0.32	—0.11	3 P. M.	+0.39	+0.03	7 P. M.	+0.02	—0.08

The column headed "Difference" shows the differences of the values in this table from those in the table interpolated from actual observations. These differences would have been much greater and more irregular, if the time of maximum and minimum had been assumed to be the same at both elevations.

The heights have been computed by the tables of Gauss; some of them were recomputed by Delcros' tables, published in the Smithsonian Miscellaneous Collections. It was found that in a single case only the difference between the two tables amounted to three feet, hence it was not thought necessary to alter the results found by Gauss' tables.

The height upon which all other elevations are based, namely, the—

City of Mexico (plaza) was assumed above the Mexican gulf to be . . . . 7472.8 Eng. feet.

This value is the mean between Humboldt's determination and my own, deduced from two month observations by myself, in Mexico, and from corresponding observations by Dr. Berendt, in Vera Cruz. There is a difference of only three feet between the two values.

The observations at the Rancho Tlamacas give—all reduced to the trigonometrical station A—

Tlamacas, trigonometrical station A, above Mexico . . 5319.6 feet.
" " " " above the Mexican gulf . 12792.4 "

The barometrical observations at the bottom of the crater give—

Bottom of crater, above Mexico . . . . 9322.7 feet.
" " above the Mexican gulf . . . . 16795.5 "

And the observations at the cave in the crater give—

Cave in the crater, above Mexico . . . . 9830.0 feet.

The computation of the depression of the cave, measured at station A, near the edge of the crater, gives—

Cave, below station A . . . . 32.3 feet.

And the small triangle, measured at the edge of the crater, gives—

Highest peak of Popocatepetl, above station A . . . 482.5 feet.
" " " " above Mexico . . . 10344.8 "
" " " " above the Mexican gulf . . 17817.6 "

The triangulation at Rancho Tlamacas gives two values for the height of each point of the Popocatepetl, one for each station. The reduction of the heights, observed at station B, to those of station A, is + 26.42 feet. This correction applied, the results are—

HEIGHTS ABOVE STATION A.

From observations—	Western peak.	Eastern peak.	Pico del Fraile.
At station A	4985.05	4387.07	3766.43
At station B	83.34	87.32	65.70
Mean	4984.20	4387.20	3766.06
Correction[1]	+7.07	+6.78	+5.78
Height above station A	4991.27	4393.98	3771.84

HEIGHTS ABOVE THE LEVEL OF THE MEXICAN GULF.

POPOCATEPETL, Highest (Western) peak	17783.7	English feet.
" Eastern peak	17186.4	" "
" Pico de Fraile	16564.2	" "

The highest peak is, according to this triangulation, 33.9 feet lower than it was found from the barometrical measurement at the cave in the crater, but the smaller value is probably the more accurate, and has been adopted. These heights, as also those of the Ixtaccihuatl, differ several feet from those found by a first computation, and communicated by me to Baron von Müller[2] and M. Leverrier, who published them in Dr. Petermann's "Geographische Mittheilungen," and other periodicals. The difference was caused by an error in the former reduction of the base line to the horizon, and some other accidental error.

IXTACCIHUATL.—The height of the trigonometrical station B on the foot of the Ixtaccihuatl was found to be 4124.4 feet above the city of Mexico, or—

STATION B, above the Mexican gulf . . . . 11597.2 Eng. feet.

The reduction of station A to station B was found to be 23.68 feet. This gives the elevations of the three points, of which the altitudes have been observed, as follows:—

HEIGHTS ABOVE STATION B.

From observations—	Highest peak.	South peak.	Popocatepetl.
At station A	5470.88	5049.25	6089.13
At station B	68.85	49.49	6103.41
Means	5469.86	5049.37	6096.27
Correction	+9.82	+11.30	+63.50
Height above station B	5479.68	5060.67	6159.77

HEIGHT ABOVE THE LEVEL OF THE MEXICAN GULF.

IXTACCIHUATL, Highest peak	17076.9	English feet.
" South peak	16657.9	" "
POPOCATEPETL, West peak	17757.0	" "

[1] This correction includes the effect of curvature, terrestrial refraction, and the height of the instrument above the ground.

[2] Baron von Müller has, by mistake, given the height of the Eastern peak [Espinazo del diablo] for that of the Western or highest peak [Pico mayor].

This makes the Popocatepetl 26.7 feet lower than the determination at Tlamacas, a quantity within the limits of error, to which the last determination is liable, as the two lines, drawn from the Popocatepetl to the ends of the base line *A B* on the foot of the Ixtaccihuatl, form an angle of only 16′ 23″ with each other.

MISCELLANEOUS HEIGHTS.—The barometrical observations at Amecameca give—

AMECAMECA (plaza) above the city of Mexico . .	709.0	Eng. feet.
" above the Mexican gulf	8181.8	"

The observations at Sacremonte, if compared with those made at Amecameca on the same day, after applying the correction for the hours of observation, give—

SACREMONTE, above Amecameca	420.6	Eng. feet.
" above the Mexican gulf	8602.4	"

The lowest depression in the ridge, connecting the Popocatepetl and Ixtaccihuatl, which is identical with the highest point of the road from Puebla to Amecameca, was found to be 12,118 English feet above the sea.

The junction of the roads from Puebla and Tlamacas to Amecameca is 11,485 English feet above the level of the sea, and the absolute height of a cascade on the Ixtaccihuatl, where ice remains all the year, was found to be 12,788 Eng. feet.

The height of Cerro Tlamacas is . . . . 13,359 "

Vegetation does not extend within 200 feet of the top of this mountain.

The heights of a considerable number of points on the western slope of the mountain ridge have been determined for the purpose of constructing a map. The method employed consisted generally in taking bearings from the point itself to two known objects, one of these was always Sacremonte, near Amecameca, which is very prominent, the other, either the Ixtaccihuatl or the Popocatepetl. The position of the point was thus fixed. Afterwards the small theodolite was mounted on Sacremonte, and the altitudes of the different points determined, which were easily recognized by the bearings, formerly taken from them to Sacremonte. The heights, obtained by this method, are sufficiently accurate for the purpose for which they were intended.

To render comparisons with other determinations of the principal heights more convenient, the results have been changed into metres and collected in the following table:—

HEIGHTS ABOVE THE LEVEL OF THE MEXICAN GULF.

POPOCATEPETL.		IXTACCIHUATL.	
Western (Highest) peak	5420^{m}.4	Highest peak	5204^{m}.9
Eastern peak	5238.3	South peak	5077.2
Pico del Fraile	5048.7	Trigonometrical station B	3534.8
Bottom of crater	5119.2	Highest point reached	5010.9
Trigonometrical station at Tlamacas	3899.2		

AMECAMECA (plaza)	2493.8
MEXICO CITY (plaza)	2277.7

This height of Mexico is sixty metres different from the height determined by Messrs. Truqui and Craveri (Petermann's Geogr. Mittheilungen, 1856, page 360). The difference seems to be caused by an extremely low period of the barometer in

Vera Cruz during the time in March, when Mr. Craveri was observing. He gives as the mean height of the barometer $759^{mm}.16$ at the temperature 24°.79. If we suppose this to be Centigrade, the mean height, reduced to the freezing point, would be $756^{mm}.12$, or reduced to the level of the sea, $757^{mm}.12$ (the barometer being $11^{m}.5$ above the sea). But the mean height of the barometer in March is, in the northern tropics, above the annual mean, which is at Vera Cruz (reduced to the level of the sea and to the freezing point) $760^{mm}.5$, according to the observation of Dr. Berendt, which have been continued for nearly three years. If we suppose (as is the case in Havana) the mean height of the barometer in March to be $0^{mm}.7$ above the mean of the year, this height would become $761^{mm}.2$, or $4^{mm}.08$ higher than that M. Craveri observed; this would make the city of Mexico 46.3 metres higher, and come within 14 metres of Humboldt's determination and my own.

GEOGRAPHICAL POSITIONS.

At the Rancho Tlamacas I made several sets of circum-meridian observations of the sun for determining the latitude, and also observations of equal altitudes in the forenoon and afternoon for obtaining the local time; as I had only one pocket chronometer, the rate of which was rather irregular in consequence of being transported on horseback, the last observations are of no value for the determination of the difference of longitude between the Popocatepetl and the city of Mexico. I have, therefore, given the longitudes of the different points, as deduced from the triangulation, upon the western or highest peak of the Popocatepetl. The observations were made with the instrument of Ertel, the circle being mounted vertically.

The latitude from two sets of circum-meridian observations of the sun, was found to be for—

RANCHO TLAMACAS, trig. station A. 19° 3′ 0″.0 N.

The co-ordinates of the principal points of the Popocatepetl, taking station A as zero point and supposing X positive when west, Y when north of A, were found to be for—

	Western peak.	Eastern peak.	Pico del Fraile.
X	— 603 feet.	— 2986 feet.	+ 945 feet.
Y	13193 "	—12152 "	—10621 "

From the first two sets of co-ordinates, combined with the difference of height of the eastern and western peak (597.3 feet), was computed the—

Upper diameter of the crater	2668 Eng. feet.
Direction of this diameter	S. 66° 24′ W. (true).

The diameter of the level part of the bottom of the crater, running from north to south, was estimated by pacing to be 750 feet.

The co-ordinates of the principal points determined at the trigonometrical station on the Ixtaccihuatl, referred to station B as zero point, are—

	IXTACCIHUATL. Highest peak.	IXTACCIHUATL. South peak.	POPOCATEPETL. Western peak.
X	—16643 feet.	—19425 feet.	—22123 feet.
Y	+ 5322 "	+ 107 "	—49254 "

Or, if all co-ordinates are referred to the western peak of the Popocatepetl as zero point, the results are as follows:—

	X { + West / — East }.	Y { + North / — South }.
Popocatepetl, Western peak . . .	0	0
" Eastern peak . . .	— 2383	+ 1041
" Pico del Fraile . . .	+ 1548	+ 2572
Tlamacas, station A	+ 603	+13193
Ixtaccihuatl, Highest peak . . .	+ 5480	+54576
" South peak . . .	+ 2698	+49361
" station B	+22123	+49254

These co-ordinates, changed into minutes and seconds of arc, give the following—

GEOGRAPHICAL POSITIONS.

	Longitude.	Latitude N.
Popocatepetl, Western peak . .	0″.0	19° 0′ 49″.2
" Eastern peak . . .	24.8 E.	19 0 59.6
" Pico del Fraile . .	16 1 W.	19 1 14.7
Rancho Tlamacas	6.3 W.	19 3 0.0
Ixtaccihuatl, Highest peak . . .	57.1 W.	19 9 50.2
" South peak . . .	28.1 W.	19 8 58.5
" station B . . .	3′ 50.7 W.	18 8 57.4

MISCELLANEOUS NOTES.

In ascending from the low-lands, which are elevated but little above the level of the sea, into the higher mountainous regions, the interval between two successive respirations decreases in proportion as the air becomes more rarefied. This fact may be accounted for by assuming that the lungs always require nearly the same quantity of air in weight, and this quantity increases in volume in the same ratio, as the density of the air decreases, but we cannot draw a larger volume of air in a single breath on a high mountain than at the level of the sea.

In Mexico, near the level of the sea, I found that I breathed from twenty-two to twenty-three times in a minute (the barometer standing at 760 millimetres or 30 inches), while in the city of Mexico, with the barometer at 588 millimetres or 22.5 inches, the number of respirations in a minute was increased from twenty-seven to thirty; at the Rancho Tlamacas the barometer at 484 millimetres, the number was from thirty-three to thirty-six, and at the crater of the Popocatepetl with the barometer at 406 millimetres, the respirations were from forty to forty-four.

Another series of observations of a similar character relative to the frequency of the pulse, gave the following results: Near the level of the sea I counted from sixty-four to seventy-four; at a height of 7500 English feet above the sea from seventy-five to eighty-four; at 12,800 English feet elevation from eighty-six to ninety-four, and at the crater of the Popocatepetl, 17,300 feet above the level of the sea, from ninety-six to one hundred pulsations in a minute.

The observations on the frequency of respiration and on the pulsations, were made only when I felt perfectly well, and was not in the slightest degree excited; generally after several hours' rest, and in the crater of the Popocatepetl early in the morning, before rising, after I had been sleeping ten hours or more. Persons who are accustomed to live in low countries, experience considerable inconvenience for some time after their arrival on the high plateau, in consequence of this acceleration of respiration, which is particularly felt at every exertion, for instance in walking up hill, or only up stairs, in raising heavy weights, etc.; but after they have lived for several months at these elevations, their breathing and pulsations again become slower. The natives of the high table-lands probably do not breathe any faster or have more frequent beats of the pulse than the natives of the countries near the coast, owing perhaps to an increased capacity of the lungs.

Similar observations have also been made on different animals, particularly on horses and dogs, which had been imported from the low countries. Race horses and gray hounds for instance, brought over from the United States and England, have not the same speed on the high plains of Mexico as in their native country. This, however, does not affect the fleetness of their offspring, if born and raised on the high lands.

At an elevation of more than 11,000 feet, a person in a good state of health never perspires, not even after great exertions; and in an artificially increased temperature, only a feverish heat is experienced. Even at the height of the city of Mexico, anything more than a slight perspiration is rarely felt. It has been before stated, that I never observed a case of bleeding of the nose, whilst ascending very high mountains, but generally headache, accompanied by a painful sensation in the eyes, which swell out considerably, is felt. The odor of sulphur, besides the rarefied air, is one of the principal causes of this pain, as it is much more severe at the bottom of the crater of the Popocatepetl than near its edge or outside.

During the rainy season, from June to September, the tops of the higher mountains are rarely seen, as they are almost constantly enveloped in clouds or fog, produced by the contact of the warm air (at this season, nearly saturated with humidity) with the cold, partially snow-covered surface of the mountains. The chilled air is not able to contain the same quantity of aqueous vapor, and part of it becomes visible as fog or snow. From June 18 to 22, 1857, I was delayed at the Rancho Tlamacas on the foot of the Popocatepetl, at an elevation of 12,800 feet, for three days, the fog being so dense that we could scarcely see at twenty yards distance; an image of the camp-fire, at night time, being reflected from it. It snowed continually, while the thermometer during the day was about two degrees F. above, and at night as much below the freezing point.

During the dry season, from October till May, the atmosphere of the high-lands is always clear, except when northerly winds blow; but generally about nine or ten o'clock in the mornings, mist begins to form around the highest mountain peaks and accumulates rapidly, so that at eleven o'clock those parts of the mountains, which are elevated more than 13,000 feet, are entirely wrapped in clouds. Small floating clouds, which form sometimes in the vicinity, in calm weather generally unite with the larger masses which envelope the peaks. In the afternoon these clouds sink lower down, and the upper snow-covered part becomes visible again above them a short time before sunset. At this time they appear most beautiful, tinged with a rosy, or sometimes of a reddish golden color, but immediately after sunset these brilliant tints change into a dull lead color (bluish gray), and the clouds entirely disperse about this time, only occasionally a light mist being noted in the valleys and on the meadows during the evening. There are, however, times, particularly in January and February, when not a cloud is seen near the mountains for two or three days in succession.

The cumulus-clouds never extend much above the highest mountain-peaks, and their greatest height probably does not exceed 20,000 English feet. At greater elevations cirrus-clouds only are observed, which appear here of a purer white color than when they are seen from the low-lands. This lighter appearance is probably caused in a great measure by their contrast with the sky, which is here of a darker blue than near the level of the sea. I had no means of estimating accurately the height of the cirrus-clouds, but from their size and appearance, which do not differ sensibly from that which they exhibit near the level of the sea, as also from their slow motion, it would appear that they were at least from three to five miles above the station of observation, or from six to eight miles above the level of the sea.

A sensible effect of the rarefaction of the air on the duration of the twilight is also observed; twenty minutes after sunset, stars of the fifth magnitude become visible, and fifteen minutes later the last traces of twilight disappear on the western horizon. If the air is calm the stars appear in a quiet, planetary light, and lose very little of their brightness as they approach the horizon. Stars of the sixth magnitude may be still distinguished at an altitude of five degrees.

I have never observed any striking electrical phenomena in heights above 13,000 feet, and during my stay on the high plateau of Mexico, thunder and lightning occurred very rarely. On the plains it rained, during the rainy season, on an average, not more than every third day, and generally only in the afternoon from three to five o'clock, but at this time the fall was occasionally very heavy. The two last seasons (1857 and 1858) were, however, considered by the natives as unusually dry. In the higher mountain ridges (from 10,000 to 13,000 feet elevation) a drizzling rain falls, sometimes for days in succession, increasing generally in the afternoon.

My observations on the limits of animal life are so restricted as to be of little value.

Several classes of birds, among which I noted the raven, are found near the limits of vegetation (13,200 feet), and great numbers of parrots were noted on the western slopes of the peak of Orizaba, at more than 10,000 feet of altitude. Wolves ascend as high, or even higher, than the ravens; and I have seen deer 12,000 feet above the level of the sea.