

VIII. *Magnetic Survey of Belgium in 1871.* By the Rev. STEPHEN J. PERRY.
Communicated by General Sir EDWARD SABINE, F.R.S.

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PREVIOUS to the year 1871 few observations had been made in Belgium for determining the elements of terrestrial magnetism, if we except the series which has been carried on without interruption at the Royal Observatory since 1828. Before this latter date the Intensity and Dip had never been ascertained, and there existed only two reliable measures of the Declination, viz. that of $20^{\circ} 35'5$ for Ostend, which PIGOT observed in 1772, and the other for Nieuport, which, at about the same date, was found by MANN to be $19^{\circ} 48'5$. Since 1828 the observations made at any other station besides Brussels have not been numerous. In 1854 the Dip was measured at Antwerp, Courtray, Ghent, Mons, and Ostend; the Horizontal Force was found at Liège and Louvain in 1829, 1850, and 1854, and also at Namur in 1829; and the three elements were observed in 1859 at Ghent and Mechlin. The results of these various observations are collected in the work entitled “*La Physique du Globe,*” by M. A. QUETELET, and in Dr. LAMONT’S ‘*Untersuchungen über die Richtung und Stärke des Erdmagnetismus in Belgien,*’ &c. The above being the only determinations of the magnetic elements, there is an obvious want of a complete series of observations at a sufficient number of stations, and the survey which forms the subject of the present paper was undertaken with the view of supplying the required series of connected values of the three elements.

The instruments employed in this survey were the BARROW dip-circle, the JONES unifilar, and the FRODSHAM chronometer of Stonyhurst Observatory, and an excellent theodolite by TROUGHTON and SIMMS for determining the azimuth of the fixed points for the Declination. For this last instrument I was indebted to the kindness of JAMES SHOOLBRED, Esq., C.E. All necessary information respecting the magnets and instruments will be found in the paper on the Magnetic Survey of the West of France printed in the *Phil. Trans.* of 1870.

The methods of observation and reduction were identical with those adopted in the preceding surveys.

At all the stations in Belgium the Dip was observed by Mr. W. CARLISLE, the readings for each needle being never less than 32; the remaining elements were determined by myself.

In forming the equations of condition for the determination of the lines of equal Dip, Declination, and Intensity, the Royal Observatory of Brussels has been chosen as the origin of coordinates.

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TABLE I.

| Station. | Latitude. | Longitude. | Difference in miles of | | Place of observation. |
|----------------------|------------|------------|------------------------|-------|------------------------------------|
| | | | Lat. | Long. | |
| | | m s | | | |
| Aix-la Chapelle..... | 50° 46' 0" | 6 51 | - 6.0 | +75.1 | 18 Aurelius Strasse. |
| Alost | 50 56 18 | 1 19 | + 5.9 | -14.4 | Garden of the College. |
| Antwerp | 51 13 15 | 0 8 | +25.4 | + 1.4 | Courte rue Neuve. |
| Arlon | 49 41 0 | 5 39 | -80.8 | +63.6 | Rue du Luxembourg 46. |
| Bruges | 51 12 30 | 4 35 | +24.6 | -49.8 | Rue Flamande 60. |
| Brussels | 50 51 11 | 0 0 | 0.0 | 0.0 | Royal Observatory, 131 rue Royale. |
| Courtray | 50 49 0 | 4 21 | - 2.5 | -47.6 | Garden near Church of St. Michael. |
| Ghent..... | 51 3 12 | 2 34 | +13.8 | -28.0 | Rue d'Assaut 26. |
| Liège | 50 39 0 | 4 51 | -14.0 | +53.4 | Collège St. Servais. |
| Lierre..... | 51 7 0 | 0 47 | +18.2 | + 8.5 | Vineyard close by Parish Church. |
| Louvain..... | 50 53 27 | 1 19 | + 2.6 | +14.3 | Rue des Récollets 11. |
| Mechlin..... | 51 1 45 | 0 26 | +12.2 | + 4.7 | Boulevards des Arbalétriers 83. |
| Mons | 50 27 0 | 1 41 | -27.9 | -18.6 | Collège St. Stanislas. |
| Namur | 50 28 2 | 1 56 | -26.7 | +21.3 | Collège N. D. de la Paix. |
| Ostend | 51 13 47 | 5 48 | +26.0 | -63.0 | Garden near the Church. |
| Spa | 50 29 0 | 5 55 | -25.5 | +65.2 | Rue de Wauxhall 43. |
| Tournay | 50 36 22 | 3 55 | -17.1 | -43.1 | Collège Notre Dame. |
| Tronchiennes..... | 51 3 12 | 2 49 | +13.8 | -30.8 | Ancienne Abbaye. |
| Turnhout | 51 19 0 | 2 11 | +32.1 | +23.7 | Collège St. Joseph. |
| Verviers..... | 50 36 0 | 5 55 | -17.5 | +65.1 | Collège St. François Xavier. |

A comparison of the large atlases of FERRARIS, PHILIP, and the Useful Knowledge Society have supplied the required data for the above geographical latitudes and longitudes, whenever these could not be obtained directly from the 'Connaissance des Temps.'

The Magnetic Dip.

As this element has been observed almost invariably with each of the three needles employed throughout the survey, any very accurate comparison of the readings obtained with the several needles is thus rendered unnecessary. It may suffice to remark that needles Nos. 2 & 3 give mean results which are scarcely perceptibly at variance, whilst the readings of No. 1 are about 1.5 in excess of the mean of the other two.

TABLE II.

| Station. | Date. | G.M.T. | Dip. | | | |
|-------------------------------|-----------------|------------|---------------|---------------|---------------|------------|
| | | | Needle No. 1. | Needle No. 2. | Needle No. 3. | Mean. |
| Antwerp | 1871. Aug. 5 | h m | 67° 4' 29" | 67° 0' 8" | 66° 59' 19" | 67° 1' 19" |
| | | 9 5 A.M. | | | | |
| | | 10 50 " | | | | |
| Brussels, 131 rue Royale..... | " 8 | 3 15 P.M. | 67 5 57 | 67 12 34 | 67 8 50 | 67 9 7 |
| | | 10 15 A.M. | | | | |
| | | 3 15 P.M. | | | | |
| Brussels Observatory | " 9 | 4 50 " | 66 56 34 | 67 1 34 | | 66 59 4 |
| | | 10 50 A.M. | | | | |
| | | 12 15 P.M. | | | | |
| Louvain | " 11 | 10 10 A.M. | 66 58 12 | 66 54 11 | 66 53 38 | 66 55 12 |
| | | 2 55 P.M. | | | | |
| | | 4 55 " | | | | |
| Mechlin | " 14 | 8 10 A.M. | 66 47 39 | 66 40 36 | | 66 44 8 |
| | | 9 55 " | | | | |
| | | 4 0 P.M. | | | | |
| Lierre..... | " 14 | 8 5 A.M. | 66 59 30 | 66 54 47 | 67 0 19 | 66 58 12 |
| | | 9 55 " | | | | |
| | | 10 20 " | | | | |
| Turnhout | " 16 | 4 15 P.M. | 67 10 6 | 67 6 2 | 67 7 56 | 67 8 1 |
| | | 5 44 " | | | | |
| | | | | | | |

TABLE II. (continued).

| Station. | Date. | G.M.T. | Dip. | | | |
|-------------------------------|------------------|-----------|---------------|---------------|---------------|-------------|
| | | | Needle No. 1. | Needle No. 2. | Needle No. 3. | Mean. |
| Verviers | 1871. Aug. 23 | h m | | | | |
| | | 8 40 A.M. | 66° 47' 8" | | | |
| | | 10 15 " | ..... | 66° 40' 55" | | |
| Liège | " 25 | 11 35 " | | | 66° 44' 49" | 66° 44' 17" |
| | | 7 45 " | 66° 29' 47" | | | |
| | | 2 50 P.M. | ..... | 66° 28' 28" | | |
| Aix-la-Chapelle..... | " 26 | 9 35 A.M. | | | 66° 28' 45" | 66° 29' 0" |
| | | 4 30 P.M. | 66° 38' 17" | | | |
| | | 5 45 " | ..... | 66° 43' 49" | | |
| Spa..... | " 28 | 9 10 A.M. | | | 66° 36' 8" | 66° 39' 25" |
| | | 8 10 " | 66° 40' 34" | | | |
| | | 9 30 " | ..... | 66° 41' 11" | | |
| Arlon..... | " 31 | 11 0 " | | | 66° 39' 15" | 66° 40' 20" |
| | | 8 45 " | 65° 56' 23" | | | |
| | | 10 10 " | ..... | 65° 55' 17" | | |
| Namur | Sept. 2. | 11 10 " | | | 65° 55' 4" | 65° 55' 35" |
| | | 8 40 " | 66° 35' 34" | | | |
| | | 9 40 " | ..... | 66° 29' 19" | | |
| Mons | " 4. | 10 50 " | | | 66° 35' 21" | 66° 33' 25" |
| | | 2 45 P.M. | 66° 33' 29" | | | |
| | | 3 50 " | ..... | 66° 38' 39" | | |
| Tournay..... | " 6. | 4 50 " | | | 66° 34' 20" | 66° 35' 29" |
| | | 3 10 " | 66° 42' 15" | | | |
| | | 4 20 " | ..... | 66° 38' 34" | | |
| Courtray | " 7. | 5 25 " | | | 66° 36' 4" | 66° 38' 58" |
| | | 3 30 " | 66° 41' 25" | | | |
| | | 4 35 " | ..... | 66° 38' 19" | | |
| Ghent | " 8. | 7 45 A.M. | | | 66° 45' 38" | 66° 41' 47" |
| | | 3 20 P.M. | 67° 13' 34" | | | |
| | | " 10. | 8 0 A.M. | | 67° 14' 12" | |
| Ostend | " 11. | 9 18 " | | | 67° 15' 15" | 67° 14' 20" |
| | | 4 35 P.M. | 67° 14' 20" | | | |
| | | 5 25 " | ..... | 67° 16' 26" | | |
| Bruges | " 12. | 4 15 " | | | 67° 10' 19" | 67° 13' 42" |
| | | 9 16 A.M. | 67° 14' 35" | | | |
| | | 11 10 " | ..... |  | 67° 7' 21" | |
| Tronchiennes | " 14. | 4 40 P.M. | | 67° 9' 4" | | 67° 10' 20" |
| | | 3 30 " | 67° 21' 35" | | | |
| | | 4 30 " | ..... | 67° 22' 35" | | |
| Alost | " 16. | 8 55 A.M. | | | 67° 23' 47" | 67° 22' 39" |
| | | 3 14 P.M. | 67° 15' 28" | | | |
| | | 4 15 " | ..... | 67° 11' 12" | | |
| Brussels, 131 rue Royale..... | " 19. | 9 34 A.M. | | | 67° 14' 0" | 67° 13' 33" |
| | | 4 50 P.M. | 67° 9' 8" | | | |
| | | " 20. | 8 35 A.M. | | 67° 6' 39" | |
| Brussels Observatory | " 23. | 7 45 " | | | 67° 2' 51" | 67° 6' 13" |
| | | " 25. | ..... |  |  |  |
| | | 10 35 " | 67° 1' 21" | | | |
| | " 22. | 2 0 P.M. | | 66° 58' 12" | | |
| | | 3 5 " | ..... |  | 67° 1' 2" | 67° 0' 12" |
| | | | | | | |

Expressing the mean values in decimals of a degree, and subtracting 65° from each, we obtain the equations required for determining the distance apart, and the inclination to the meridian, of the lines of equal Dip.

$$\begin{aligned}
 1.657 &= \delta - 75.1x - 6.0y \\
 2.226 &= \delta + 14.4x + 5.9y \\
 2.022 &= \delta - 1.4x + 25.4y \\
 0.926 &= \delta - 63.6x - 80.8y \\
 2.172 &= \delta + 49.8x + 24.6y \\
 1.696 &= \delta + 47.6x - 2.5y \\
 2.239 &= \delta + 28.0x + 13.8y
 \end{aligned}$$

$$\begin{aligned}
1.484 &= \delta - 53.4x - 14.0y \\
1.970 &= \delta - 8.5x + 18.2y \\
1.920 &= \delta - 14.3x + 2.6y \\
1.736 &= \delta - 4.7x + 12.2y \\
1.591 &= \delta + 18.6x - 27.9y \\
1.557 &= \delta - 21.3x - 26.7y \\
2.228 &= \delta + 63.0x + 26.0y \\
1.672 &= \delta - 65.2x - 25.5y \\
1.650 &= \delta + 43.1x - 17.1y \\
2.378 &= \delta + 30.8x + 13.8y \\
2.134 &= \delta - 23.7x + 32.1y \\
1.738 &= \delta - 65.1x - 17.5y
\end{aligned}$$

The solution of these equations of condition, found by the method of least squares, is $\delta = 1.87299$, $x = 0.0013762$, $y = -0.0104147$.

The computed value of the Dip at the central station is therefore $66^{\circ}.87299$, the direction of the Isoclinals being from N. $82^{\circ} 28' 19''.4$ E. to S. $82^{\circ} 28' 19''.4$ W., and the distance between stations, whose Dips differ by $0^{\circ}.5$, 47.6 miles.

The Dip at the several stations obtained from this calculated data, and compared with the observed mean values, furnishes the following Table of errors:—

TABLE III.

| Station. | Observed Dip. | Computed Dip. | Errors. |
|----------------------|---------------|---------------|---------|
| Aix-la-Chapelle..... | 1.657 | 1.708 | -0.051 |
| Alost | 2.226 | 1.954 | +0.272 |
| Antwerp | 2.022 | 2.136 | -0.114 |
| Arlon | 0.926 | 0.943 | -0.017 |
| Bruges | 2.172 | 2.198 | -0.026 |
| Courtray | 1.696 | 1.912 | -0.216 |
| Ghent..... | 2.239 | 2.056 | +0.183 |
| Liège | 1.484 | 1.654 | -0.170 |
| Lierre..... | 1.970 | 2.051 | -0.081 |
| Louvain..... | 1.920 | 1.880 | +0.040 |
| Mechlin..... | 1.736 | 1.994 | -0.258 |
| Mons | 1.591 | 1.608 | -0.017 |
| Namur | 1.557 | 1.566 | -0.009 |
| Ostend | 2.228 | 2.229 | -0.001 |
| Spa..... | 1.672 | 1.517 | +0.155 |
| Tournay..... | 1.650 | 1.754 | -0.104 |
| Tronchiennes | 2.378 | 2.059 | +0.319 |
| Turahout | 2.134 | 2.174 | -0.040 |
| Verviers..... | 1.738 | 1.601 | +0.137 |

The probable error at any one station will therefore be ± 0.10445 , whilst that of the mean Dip at the central station is ± 0.02185 .

Referring now to previous observations, we shall be able to ascertain approximately the secular variation of the Dip. The only determinations of this magnetic element for stations out of Brussels are those of M. MAHMOUD EFFENDI in 1854 and of Dr. LAMONT in 1858, and these will serve to form the following Tables.

TABLE IV.

| Station. | Dip, 1854. | Dip, 1871. | Diff. of Epoch. | Diff. of Dip. | Yearly rate. |
|----------------|------------|------------|-----------------|--------------------|--------------|
| Antwerp..... | 67° 875 | 67° 022 | 17 | -0.853 | -0.050 |
| Courtray | 67° 655 | 66° 696 | " | -0.959 | -0.056 |
| Ghent..... | 67° 833 | 67° 239 | " | -0.594 | -0.036 |
| Mons | 67° 383 | 66° 591 | " | -0.792 | -0.047 |
| Ostend | 68° 047 | 67° 228 | " | -0.819 | -0.048 |
| Brussels | 67° 663 | 66° 994 | " | -0.669 | -0.039 |
| | | | | Mean for 1862.5... | -0.046 |

TABLE V.

| Station. | Dip, Jan. 1, 1858. | Dip, Sept. 1, 1871. | Diff. of Epoch. | Diff. of Dip. | Yearly rate. |
|----------------------|--------------------|---------------------|-----------------|--------------------|--------------|
| Aix-la-Chapelle..... | 67° 445 | 66° 657 | 13½ | -0.788 | -0.058 |
| Ghent..... | 68° 002 | 67° 239 | " | -0.763 | -0.056 |
| Mechlin | 67° 643 | 66° 736 | " | -0.907 | -0.066 |
| Brussels | 67° 663 | 66° 994 | " | -0.669 | -0.049 |
| | | | | Mean for 1864.8... | -0.0573 |

The values for Ghent and Brussels in the first column of figures of Table IV. do not inspire much confidence, as the latter is identical with LAMONT's value for 1858; and the former is much smaller than the corresponding number in Table V., although observed four years previously.

Table V. gives a secular variation which lies about midway between the values -0.062 and -0.054 found respectively for the West and East of France. Table IV. would make the secular variation -0.050, if we neglected the two doubtful quantities.

Dr. LAMONT gives -0.0417 as the annual decrease for 1858, which would indicate an acceleration of the yearly rate. We know, however, from the continuous series of observations made at the Brussels Observatory, and published in its 'Annuaire' by the eminent Director, M. A. QUETELET, that the annual decrease has been gradually diminishing from 0° 0527 in 1830 to 0° 0194 in 1865, the yearly variation being 0.00095. The extreme values of the Dip observed at the Royal Observatory at Brussels were 68° 56' 5 in 1827.8, and 67° 8' 0 in 1871.5.

The Magnetic Intensity.

TABLE VI.

| Station. | Date. | G.M.T. | Distance of centres of magnets. | Temp. | Observed deflection. | Log $\frac{m}{X}$. | Date. | G.M.T. | Temp. | Time of one vibration. | Log mX . |
|------------------------------|-----------------|------------|---------------------------------|-------|----------------------|---------------------|--------------|-----------------------|---------|------------------------|------------|
| Antwerp..... | 1871. Aug. 5 | 4 3 P.M. | 1.0 | 67.1 | 13 26 52 | 9.06882 | Aug. 5 | h m s 1 56 11 P.M. | 75.5 | 5.371295 | 0.25704 |
| | | 4 26 | 1.3 | 65.8 | 6 5 33 | 9.06927 | | 8 26 46 | 76.7 | 5.35285 | 0.25997 |
| Brussels Observa- tory. | " 9 | 11 2 A.M. | 1.0 | 76.9 | 13 20 52 | 9.06638 | " 9 | 12 42 6 | 81.1 | 5.35230 | 0.26039 |
| | | 11 28 | 1.3 | 77.8 | 6 1 51 | 9.06578 | | 12 51 56 | 81.5 | 5.35120 | 0.26060 |
| Brussels, 131 rue Royale. | " 10 | 4 36 P.M. | 1.0 | 78.0 | 13 26 58 | 9.06970 | " 10 | 7 25 11 A.M. | 70.6 | 5.37560 | 0.25591 |
| | | | | | | | | 8 12 50 | 72.3 | 5.376085 | 0.25595 |
| Louvain..... | " 11 | 10 43 A.M. | 1.0 | 78.9 | 13 20 18 | 9.06624 | " 11 | 8 23 47 | 74.0 | 5.37571 | 0.25613 |
| | | 11 14 | 1.3 | 79.7 | 6 2 31 | 9.06674 | | 3 34 42 P.M. | 80.4 | 5.349085 | 0.26084 |
| Turnhout..... | " 16 | 4 58 P.M. | 1.0 | 74.8 | 13 21 4 | 9.06633 | " 11 | 3 43 37 | 80.3 | 5.34900 | 0.26085 |
| | | 5 26 | 1.3 | 73.5 | 6 3 9 | 9.06701 |  | ..... | 76.8 | 5.35183 | 0.26011 |
| Liège..... | " 24 | 11 6 A.M. | 1.0 | 72.4 | 13 8 42 | 9.05950 | " 12 | 8 32 24 A.M. | 76.5 | 5.353795 | 0.25978 |
| | | 11 31 | 1.3 | 71.6 | 5 57 12 | 9.05972 | | 8 26 46 | 76.7 | 5.35285 | 0.25997 |
| Aix-la-Chapelle... | " 28 | 9 25 | 1.0 | 62.9 | 13 12 15 | 9.06073 | " 17 | 8 36 12 | 81.2 | 5.35436 | 0.26004 |
| | | 9 49 | 1.3 | 63.0 | 5 58 27 | 9.06059 | | 9 31 46 | 71.3 | 5.31033 | 0.26656 |
| Spa..... | " 29 | 9 40 | 1.0 | 66.1 | 13 6 17 | 9.05773 | " 24 | 7 46 4 | 62.8 | 5.31292 | 0.26615 |
| | | 10 6 | 1.3 | 66.7 | 5 57 0 | 9.05911 | | 7 55 55 | 62.8 | 5.31196 | 0.26561 |
| Arlon..... | " 31 | 4 5 P.M. | 1.0 | 71.9 | 12 48 10 | 9.04820 | " 28 | 7 46 4 | 62.8 | 5.309335 | 0.26604 |
| | | 4 34 | 1.3 | 70.2 | 5 48 1 | 9.04832 | | 7 55 55 | 62.8 | 5.31196 | 0.26561 |
| Namur..... | Sept. 2 | 8 28 A.M. | 1.0 | 73.9 | 13 13 12 | 9.06205 | " 29 | 8 12 45 | 62.7 | 5.30525 | 0.26667 |
| | | 8 56 | 1.3 | 75.1 | 5 58 50 | 9.06196 | | 8 34 54 | 80.1 | 5.32917 | 0.26418 |
| Mons..... | " 4 | 2 41 P.M. | 1.0 | 78.0 | 13 7 32 | 9.05929 | " 31 | 10 36 13 | 77.7 | 5.24971 | 0.27710 |
| | | 9 44 A.M. | 1.0 | 67.2 | 13 8 54 | 9.05922 | | 10 45 33 | 75.2 | 5.24888 | 0.27706 |
| | " 5 | 10 8 | 1.3 | 67.7 | 5 56 54 | 9.05906 | Sept. 2 | 9 34 44 | 80.1 | 5.32917 | 0.26418 |
| | | | | | | | | 8 24 10 | 81.1 | 5.325875 | 0.26479 |
| Tournay..... | " 6 | 3 58 P.M. | 1.0 | 81.5 | 13 8 29 | 9.06009 | " 5 | 7 54 21 | 66.4 | 5.321795 | 0.26427 |
| | | 4 23 | 1.3 | 81.0 | 5 56 59 | 9.06017 | | 8 24 10 | 66.2 | 5.32092 | 0.26443 |
| Courtray..... | " 8 | 8 16 A.M. | 1.0 | 66.2 | 13 11 34 | 9.06059 | " 6 | 5 3 40 P.M. | 78.4 | 5.334665 | 0.26303 |
| | | 8 38 | 1.3 | 66.1 | 5 58 12 | 9.06052 | | 5 25 35 | 77.6 | 5.332125 | 0.26340 |
| Ghent..... | " 9 | 4 10 P.M. | 1.0 | 67.0 | 13 26 35 | 9.06866 | " 7 | 5 33 27 | 77.0 | 5.33175 | 0.26342 |
| | | 4 37 | 1.3 | 65.9 | 6 5 5 | 9.06874 | | 3 23 43 | 71.2 | 5.32100 | 0.26483 |
| Ostend..... | " 11 | 5 55 | 1.0 | 69.1 | 13 27 30 | 9.06931 | " 9 | 3 32 35 | 71.0 | 5.319665 | 0.26505 |
| | | 10 22 A.M. | 1.0 | 67.8 | 13 27 8 | 9.06901 | | 2 44 46 | 71.6 | 5.38500 | 0.25463 |
| Bruges..... | " 13 | 10 45 | 1.3 | 67.6 | 6 5 12 | 9.06900 | " 11 | 2 53 44 | 70.1 | 5.38271 | 0.25490 |
| | | 8 52 | 1.0 | 63.2 | 13 23 43 | 9.06687 | | 4 42 40 | 70.2 | 5.38850 | 0.25395 |
| | " 13 | 9 16 | 1.3 | 63.5 | 6 3 54 | 9.06715 | " 13 | 4 51 38 | 70.1 | 5.38596 | 0.25436 |
| | | | | | | | | 10 11 34 A.M. | 67.2 | 5.369495 | 0.25665 |
| Tronchiennes..... | " 17 | 9 0 | 1.0 | 57.3 | 13 31 30 | 9.07055 | " 14 | 10 20 31 | 68.2 | 5.36480 | 0.25748 |
| | | 9 26 | 1.3 | 57.9 | 6 7 2 | 9.07046 | | 4 15 8 P.M. | 63.1 | 5.35975 | 0.25786 |
| Alost..... | " 18 | 3 4 P.M. | 1.0 | 58.8 | 13 20 49 | 9.06500 | " 16 | 4 24 3 | 62.5 | 5.358125 | 0.25808 |
| | | 3 28 | 1.3 | 58.1 | 6 2 37 | 9.06523 | | 10 37 5 A.M. | 71.7 | 5.39492 | 0.25299 |
| Brussels Observa- tory. | " 22 | 2 16 | 1.0 | 59.7 | 13 17 13 | 9.06315 | " 17 | 10 46 5 | 70.3 | 5.391335 | 0.25346 |
| | | 2 41 | 1.3 | 60.3 | 6 1 4 | 9.06353 | | 10 6 4 | 61.1 | 5.39083 | 0.25279 |
| Brussels, 131 rue Royale. | " 23 | 9 38 A.M. | 1.0 | 56.0 | 13 27 53 | 9.06856 | " 18 | 10 15 3 | 61.9 | 5.39064 | 0.25286 |
| | | 10 7 | 1.3 | 57.1 | 6 5 26 | 9.06852 | | 4 8 3 P.M. | 59.8 | 5.356335 | 0.25822 |
| | | | | | | | 4 15 28 | 59.2 | 5.35571 | 0.25829 | |
| | | | | | | | 3 30 16 | 60.4 | 5.34995 | 0.25945 | |
| | | | | | | | 4 25 34 | 57.4 | 5.34281 | 0.26039 | |
| | | | | | | | 11 1 57 A.M. | 62.2 | 5.37873 | 0.25485 | |

This Table, combined with the preceding determinations of the Dip, furnishes us with the means of calculating the components of the earth's magnetic intensity, and the magnetic moment of the vibration-needle.

TABLE VII.

| Station. | H. F. | V. F. | T. F. | <i>m.</i> |
|--------------------------|--------|--------|---------|-----------|
| Aix-la-Chapelle..... | 4·0045 | 9·2792 | 10·1064 | 0·46052 |
| Alost | 3·9503 | 9·4054 | 10·2049 | 0·45887 |
| Antwerp..... | 3·9274 | 9·2623 | 10·0606 | 0·46031 |
| Arlon | 4·1157 | 9·2121 | 10·0896 | 0·45991 |
| Bruges | 3·8934 | 9·2495 | 10·0355 | 0·45949 |
| Brussels Observatory ... | 3·9595 | 9·3252 | 10·1310 | 0·45956 |
| Brussels, rue Royale ... | 3·9189 | 9·2899 | 10·0827 | 0·45948 |
| Courtray | 4·0011 | 9·2889 | 10·1139 | 0·45999 |
| Ghent..... | 3·9180 | 9·3382 | 10·1268 | 0·45892 |
| Liège | 4·0126 | 9·2211 | 10·0563 | 0·46024 |
| Louvain..... | 3·9544 | 9·2799 | 10·0873 | 0·46073 |
| Mons | 4·0048 | 9·2507 | 10·0804 | 0·45897 |
| Namur | 3·9923 | 9·2066 | 10·0349 | 0·46052 |
| Ostend | 3·9136 | 9·3226 | 10·1112 | 0·45881 |
| Spa..... | 4·0221 | 9·3267 | 10·1570 | 0·45976 |
| Tournay | 3·9958 | 9·2556 | 10·0813 | 0·45889 |
| Tronchiennes | 3·9016 | 9·3626 | 10·1430 | 0·45896 |
| Turnhout | 3·9522 | 9·3715 | 10·1708 | 0·46062 |

The second members of our original equations remaining each unchanged, but being three fewer in number, Table VII. will enable us at once to form the equations of condition for determining the nature of the lines of equal Horizontal Force. Their solution leads to the following values: H. F. = 3·96649, $x = -0·00030302$, $y = 0·0015808$.

Hence we find that there is a distance of 62·13 miles between the lines, indicating a difference of 0·1 in the Horizontal Force, and that this system of lines is inclined at an angle of 79° 8' 55"·7 to the meridian, the direction being from N. 79° 8' 55"·7 E. to S. 79° 8' 55"·7 W. The differences between the observed results and those computed from the above data furnish a Table for calculating the probable errors.

TABLE VIII.

| Station. | Observed. | Computed. | Obs. — Comp. |
|----------------------|-----------|-----------|--------------|
| Aix-la-Chapelle..... | 4·0045 | 3·9988 | +0·0057 |
| Alost | 3·9503 | 3·9529 | -0·0026 |
| Antwerp | 3·9274 | 3·9268 | +0·0006 |
| Arlon | 4·1157 | 4·1138 | +0·0019 |
| Bruges | 3·8934 | 3·9126 | -0·0192 |
| Courtray | 4·0011 | 3·9562 | +0·0449 |
| Ghent..... | 3·9180 | 3·9363 | -0·0183 |
| Liège | 4·0126 | 4·0950 | +0·0076 |
| Louvain..... | 3·9544 | 3·9668 | -0·0124 |
| Mons | 4·0048 | 4·0052 | -0·0004 |
| Namur | 3·9923 | 4·0153 | -0·0230 |
| Ostend | 3·9136 | 3·9064 | +0·0072 |
| Spa..... | 4·0221 | 4·0267 | -0·0046 |
| Tournay | 3·9958 | 3·9807 | +0·0151 |
| Tronchiennes | 3·9016 | 3·9355 | -0·0339 |
| Turnhout | 3·9522 | 3·9230 | +0·0292 |

This gives us as the probable error for the mean at a single station $\pm 0·01327$, whilst that at the central station is $\pm 0·00332$.

In order to determine the secular change of the Horizontal Intensity, I have collected together, and reduced to English units, all the previous observations with which I am acquainted. The values for 1858 are taken from Dr. LAMONT's 'Erdmagnetismus,' and those for 1839 and 1854 may be found scattered in the introduction to the same work.

The numbers for 1829 and 1850 have been calculated from the data given in M. A. QUETELET'S treatise 'Sur la Physique du Globe;' and for 1850 I have made the supposition, which I find to be most consonant with the observations cited in the same work, that the ratio between the values of Horizontal Force at Paris and Brussels is on the whole nearly constant, that ratio being 0.961.

TABLE IX.

| | 1829. | 1839. | 1850. | 1854. | 1858. |
|----------------------|--------|----------|----------|--------|--------|
| Aix-la-Chapelle..... | 3.7661 | 3.8357 | 3.8796 | 3.9138 | 3.9349 |
| Antwerp..... | ..... | ..... | ..... | 3.8570 | ..... |
| Ghent..... | ..... | ..... | ..... | 3.8208 | 3.8553 |
| Liège..... | 3.7984 | 3.8316 | 3.8755 | 3.8971 | ..... |
| Louvain..... | 3.7355 | [3.8375] | [3.8835] | 3.8730 | ..... |
| Mechlin..... | ..... | ..... | ..... | ..... | 3.9077 |
| Namur..... | 3.8208 | ..... | ..... | ..... | ..... |
| Ostend..... | ..... | ..... | ..... | 3.8056 | ..... |

Neglecting the two observations enclosed within brackets as being evidently too large, we find, by comparing these numbers with those given in Table VIII., the following values of the secular variation:—

TABLE X.

| Epoch..... | 1850. | 1855. | 1860.5. | 1862.5. | 1864.8. |
|-----------------------|---------|---------|---------|---------|---------|
| Secular variation . . | 0.00502 | 0.00547 | 0.00624 | 0.00552 | 0.00484 |

These results give $+0.00542$ as the mean value of the yearly change of the Horizontal Force for the epoch 1858.56. If we compare this with the annual increase deduced from the numerous observations made at Brussels between the years 1828 and 1860, we obtain a strong confirmation of the approximate correctness of the above value. HANSTEEN, LAMONT, and QUETELET have each expressed the law of increase of the Horizontal Force at Brussels in an analytical form, and these formulæ give respectively, for the epoch 1850, 0.005422, 0.005183, and 0.005617, as the secular increase. The mean of these differs from the result found above only by 0.000031. The acceleration for the same date given by HANSTEEN'S formula is $+0.000037$; but QUETELET makes the increase of the yearly rate considerably more rapid. The concluded value of the secular variation of the Horizontal Force for Belgium is slightly in excess of that found for France from the surveys of 1868 and 1869.

We will now pass on to the discussion of the results obtained from the combined observations of the Dip and Horizontal Force at the several stations. Instead of forming new equations of condition with the values given in Table VII., and then solving them by the method of least squares, we can find the Intensity at each station by combining directly the computed as well as the observed values in Tables III. and VIII., and thence deduce the probable errors. Calling the Intensity deduced immediately from the observed Horizontal Force and Dip the observed Intensity, and that formed from the computed values the computed Intensity, we thus obtain the following results:—

TABLE XI.

| Station. | Observed T. F. | Computed T. F. | Observed—Computed. |
|----------------------|----------------|----------------|--------------------|
| Aix-la-Chapelle..... | 10·1064 | 10·1129 | —0·0065 |
| Alost..... | 10·2049 | 10·0976 | +0·1073 |
| Antwerp..... | 10·0606 | 10·1064 | —0·0458 |
| Arlon..... | 10·0896 | 10·0917 | —0·0021 |
| Bruges..... | 10·0355 | 10·0958 | —0·0603 |
| Courtray..... | 10·1139 | 10·0886 | +0·0253 |
| Ghent..... | 10·1268 | 10·0974 | +0·0294 |
| Liège..... | 10·0563 | 10·1064 | —0·0501 |
| Louvain..... | 10·0873 | 10·1024 | —0·0151 |
| Mons..... | 10·0804 | 10·0882 | —0·0078 |
| Namur..... | 10·0349 | 10·0965 | —0·0616 |
| Ostend..... | 10·1112 | 10·0927 | +0·0185 |
| Spa..... | 10·1570 | 10·1052 | +0·0518 |
| Tournay..... | 10·0813 | 10·0859 | —0·0046 |
| Tronchiennes..... | 10·1430 | 10·0966 | +0·0464 |
| Turnhout..... | 10·1708 | 10·1125 | +0·0583 |

The probable error at any station would thus be $\pm 0\cdot0321$, whilst that of the mean is $\pm 0\cdot0080$.

If we examine carefully the above figures, we find that the intensity increases as we proceed Northwards, but that the computed and observed values do not agree as to the Eastward or Westward tendency of the lines. The observed values in the West are greater than those in the East; but when the distance of each station from the meridian of Brussels is taken into account, the isodynamics are found to lie N.W. and S.E. This result is confirmed by combining the observed values by the method of least squares, which gives 10·10525 as the Total Force at the central station, and for the direction of the lines N. $70^{\circ} 3' 34''\cdot6$ W. to S. $70^{\circ} 3' 34''\cdot6$ E. That this is not caused by mere accidental errors at certain stations may be clearly shown; for, casting out those stations whose values are abnormal, and then recalculating the position of the lines of equal Intensity, we obtain a very similar result, even when as many as the six least reliable values are omitted. It is unfortunate that LAMONT'S survey of 1858 does not afford sufficient data for computing the isodynamics in Belgium alone for that epoch; but if we take his stations in Belgium and Holland, along with the neighbouring positions of Aix-la-Chapelle and Emden, we obtain nine equations of condition, which furnish lines of equal Intensity common to the two countries, and the direction of these is from N. $57^{\circ} 6' 6''\cdot3$ E. to S. $57^{\circ} 6' 6''\cdot3$ W. The probable errors are very nearly the same as those given above, being $\pm 0\cdot031582$ for a single station and $\pm 0\cdot010527$ for the mean. Of the three stations common to the two surveys the error for Aix-la-Chapelle is positive, whilst those of Ghent and Mechlin are negative. We have therefore indications of the existence of some great disturbing cause, which, by increasing the intensity at the eastern stations, tends to alter the direction of the isodynamics, and to remove further apart the lines passing through points whose Total Force differs by a constant quantity. A centre of local magnetic force may therefore not unnaturally be sought for in the eastern portion of Belgium, and the geological map of the country presents at once a ready answer to the inquiry. Starting from the neighbourhood of Mons, the vast coal tracks of Belgium, rich in iron ore, stretch across the eastern provinces, enveloping

Namur, Liège, and Aix-la-Chapelle, whilst the remainder of the country appears to be wholly devoid of all ferruginous wealth.

As a further series of observations in this region might throw considerable light on the subject of local magnetism, I purpose, unless the work is previously undertaken by others, again to observe the magnetic elements at closer stations within this interesting area.

If the disturbing cause is unchangeable, it will probably not interfere much with the determination of the secular variation of the Intensity as given in the annexed Table.

TABLE XII.

| Station. | T. F., Jan. 1, 1858. | T. F., Sept. 1, 1871. | Diff. of Epoch. | Yearly change. |
|----------------------|----------------------|-----------------------|--------------------|----------------|
| Aix-la-Chapelle..... | 10·2586 | 10·1064 | 13 $\frac{2}{3}$ | -0·01114 |
| Ghent..... | 10·2923 | 10·1268 | " | -0·01211 |
| Brussels..... | 10·2869 | 10·1310 | " | -0·01141 |
| | | | Mean for 1864·8... | -0·01155 |

The Magnetic Declination.

In the observations for determining this element the azimuth of the fixed mark was found by taking transits of the sun with a transit-theodolite by SIMMS, kindly placed at my disposal for this survey by J. SHOOLBRED, Esq., C.E.; and the angular distance between the mark and the magnetic meridian was read on JONES'S unifilar. The same tripod served for both instruments. Before observing the sun, the fixed mark was bisected by the wire of the telescope, when the verniers of the azimuth-circle read 0° and 180°; thus the figures in the 6th column of Table XIV. are either the means of the readings as taken, or their defect from 360°.

The same magnet was used for all the observations, and each entry is the mean of the readings with erect and inverted scale. The scale-coefficient is 2' 9''·805. For the observations at the Royal Observatory, Brussels, on the 9th of August, the zero-mark was not determined by observed transits with the theodolite, but a plumb-line was suspended in the meridian in front of the magnetic hut by aid of the large transit instrument of the observatory, and then the unifilar was adjusted in the meridian as accurately as this method would permit. The chronometer used was FRODSHAM'S No. 3148. The following Table contains the results of the comparisons made at Brussels and Stonyhurst:—

TABLE XIII.

| Station. | Date. | G. M. T. | Error. | Daily Rate. |
|------------------------------|----------|-----------|-----------|-------------|
| | 1871. | h m | m s | |
| Stonyhurst Observatory | July 31 | 7 30 P.M. | +28 44·62 | +3·09 |
| Brussels Observatory | Aug. 9 | 7 30 " | +29 15·10 | +3·39 |
| " | Sept. 22 | 7 30 " | +32 21·90 | +4·25 |
| Stonyhurst..... | " 29 | 11 0 " | +32 45·01 | +3·24 |
| " | Oct. 3 | 10 0 " | +32 55·69 | +2·69 |

For the comparisons at the Brussels Observatory I am indebted to the kindness of M. E. QUETELET.

It was not possible to compare the chronometer oftener; but this is less to be regretted, as the behaviour of the instrument during the French surveys showed that it is not liable to any great change of rate whilst travelling, if carried always with care. As it was previously found that the rate of the chronometer could be more securely trusted than the deduced rates from observed altitudes of the sun, the latter were not observed in Belgium.

TABLE XIV.

| Station. | Date. | Chronometer. | Error at Noon. | Daily Rate. | Azimuthal distance of sun from mark. | Azimuthal reading of magnet. | Azimuthal reading of mark. |
|--------------------------|---------|-----------------|----------------|-------------|--------------------------------------|------------------------------|----------------------------|
| | 1871. | h m s | m s | s | ° ′ ″ | | |
| Antwerp | Aug. 5 | 10 2 14.5 A.M. | +29 0.49 | +3.39 | 44 47 30 | | |
| | | 10 18 4.1 | ..... | ..... | 39 52 15 | | |
| | | 10 42 9 | ..... | ..... | ..... | 244 54 37.0 | |
| | | 10 49 5 | ..... | ..... | ..... | 244 54 56.5 | 256 35 30 |
| Brussels Observatory ... | " 9 | 4 3 30 P.M. | 29 14.04 | | | | |
| | | 4 20 | | | | | |
| Brussels, 131 rue Royale | " 10 | 8 14 42.8 A.M. | 29 18.02 | +4.245 | 47 34 0 | | |
| | | 8 22 0.9 | ..... | ..... | 45 59 30 | | |
| | | 9 25 | ..... | ..... | ..... | 171 19 42.35 | |
| | | 9 30 | ..... | ..... | ..... | 171 19 42.35 | 159 11 40 |
| Louvain..... | " 11 | 10 1 57.1 | 29 22.26 | | 53 36 0 | | |
| | | 10 11 23.6 | ..... | ..... | 50 42 45 | | |
| | | 8 44 0 | ..... | ..... | ..... | 199 10 10.0 | |
| | | 8 49 30 | ..... | ..... | ..... | 199 8 58.2 | |
| | | 8 56 30 | ..... | ..... | ..... | 199 6 35.4 | 220 16 6.7 |
| Turnhout | " 16 | 10 56 31.4 | 29 43.49 | | 145 43 45 | | |
| | | 11 9 14.3 | ..... | ..... | 150 18 30 | | |
| | | 11 28 52.8 | ..... | ..... | 157 38 45 | | |
| | | 11 34 39.8 | ..... | ..... | 159 52 10 | | |
| | | 12 10 5 P.M. | ..... | ..... | ..... | 117 1 33.9 | |
| | | 12 16 47.5 | ..... | ..... | ..... | 117 3 24.3 | |
| Liège | " 24 | 2 50 44.1 | 30 17.45 | | 104 17 45 | | |
| | | 4 37 29.5 | ..... | ..... | ..... | 163 20 59.9 | |
| | | 4 44 51.5 | ..... | ..... | ..... | 163 20 8.0 | 129 26 20 |
| Aix-la-Chapelle..... | " 26 | 3 56 18.9 | 30 25.94 | | 24 36 45 | | |
| | | 4 7 31.5 | ..... | ..... | 27 5 0 | | |
| | | 4 15 37.9 | ..... | ..... | 28 50 0 | | |
| | | 4 50 45 | ..... | ..... | ..... | 219 25 3.5 | |
| | | 4 58 15 | ..... | ..... | ..... | 219 23 26.2 | |
| | | 5 6 30 | ..... | ..... | ..... | 219 21 16.4 | 101 26 30 |
| Spa..... | " 29 | 11 16 25.3 A.M. | 30 38.67 | | 66 1 30 | | |
| | | 11 21 46.4 | ..... | ..... | 67 56 45 | | |
| | | 11 27 46.3 | ..... | ..... | 70 6 30 | | |
| | | 11 49 30 | ..... | ..... | ..... | 192 44 23 | |
| | | 11 55 0 | ..... | ..... | ..... | 192 43 57 | 124 20 45 |
| Arlon | " 31 | 2 14 19.0 P.M. | 30 47.16 | | 91 14 45 | | |
| | | 2 19 41.5 | ..... | ..... | 92 48 30 | | |
| | | 2 25 4.3 | ..... | ..... | 94 20 30 | | |
| | | 3 9 30 | ..... | ..... | ..... | 230 54 23.6 | |
| | | 3 16 30 | ..... | ..... | ..... | 230 51 47.8 | |
| | | 3 22 30 | ..... | ..... | ..... | 230 50 17.0 | 199 45 15 |
| Namur | Sept. 2 | 11 37 16.1 A.M. | 30 55.65 | | 60 42 30 | | |
| | | 11 43 55.5 | ..... | ..... | 63 6 30 | | |
| | | 11 48 42.1 | ..... | ..... | 64 50 30 | | |
| | | 11 7 51 | ..... | ..... | ..... | 235 51 13 | |
| | | 11 12 0 | ..... | ..... | ..... | 235 50 54 | 180 28 25 |
| Mons | " 4 | 4 12 5.8 P.M. | 31 4.14 | | 187 55 15 | | |
| | | 4 17 55.6 | ..... | ..... | 189 11 30 | | |
| | | 4 24 23.1 | ..... | ..... | 190 34 30 | | |
| | | 4 31 10.8 | ..... | ..... | 192 0 0 | | |
| | | 4 56 0 | ..... | ..... | ..... | 268 53 4.8 | |
| | | 5 1 0 | ..... | ..... | ..... | 268 56 53.4 | |
| | | 5 6 0 | ..... | ..... | ..... | 268 56 27.5 | 168 31 40 |

TABLE XIV. (continued).

| Station. | Date. | Chronometer. | Error at Noon. | Daily Rate. | Azimuthal distance of sun from mark. | Azimuthal reading of magnet. | Azimuthal reading of mark. |
|--------------------------|------------------|-----------------|----------------|-------------|--------------------------------------|------------------------------|----------------------------|
| Tournay..... | 1871. Sept. 6 | h m s | m s | | ° ′ ″ | | |
| | | 2 41 11.3 P.M. | +31 12.63 | | 98 36 0 | | |
| | | 2 46 41.8 | | | 100 5 0 | | |
| | | 2 52 1.6 | | | 101 30 30 | | |
| | | 2 57 20.1 | | | 102 54 45 | | |
| Courtray | " 7 | 3 22 0 | | | | 125 17 57.5 | 91 37 15 |
| | | 3 28 0 | ..... | ..... | ..... | 125 18 16.9 | |
| | | 11 13 38.6 A.M. | 31 16.88 | ..... | 96 9 45 | | |
| | | 11 18 59.0 | ..... | ..... | 97 56 30 | | |
| | | 11 25 2.8 | ..... | ..... | 99 59 0 | | |
| Ghent..... | " 9 | 11 30 57.5 | | | 102 0 30 | | 153 6 5 |
| | | 12 3 30 P.M. | ..... | ..... | ..... | 253 23 21.0 | |
| | | 12 9 0 | ..... | ..... | ..... | 253 23 1.5 | |
| | | 11 31 1.4 A.M. | 31 25.37 | ..... | 28 50 30 | | |
| | | 11 42 56.0 | ..... | ..... | 24 46 30 | | |
| Ostend | " 12 | 11 51 58.1 | | | 21 39 30 | | 122 5 30 |
| | | 12 9 0 P.M. | ..... | ..... | ..... | 270 2 22.3 | |
| | | 12 13 0 | ..... | ..... | ..... | 270 3 20.7 | |
| | | 1 27 0 | ..... | ..... | ..... | 269 53 23.0 | |
| | | 1 31 30 | ..... | ..... | ..... | 269 52 44.0 | |
| Bruges | " 14 | 8 58 23.4 A.M. | 31 38.10 | | 13 55 52 | | 237 37 15 |
| | | 9 3 53.1 | ..... | ..... | 15 14 22 | | |
| | | 9 10 5.6 | ..... | ..... | 16 45 22 | | |
| | | 9 15 59.0 | ..... | ..... | 18 11 22 | | |
| | | 9 58 0 | ..... | ..... | ..... | 112 17 20.9 | |
| Tronchiennes..... | " 16 | 10 2 30 | | | | 112 16 42.0 | 237 12 5 |
| | | 3 8 6.5 P.M. | 31 46.69 | ..... | 19 17 45 | | |
| | | 3 17 18.4 | ..... | ..... | 21 34 0 | | |
| | | 3 26 49.9 | ..... | ..... | 23 52 0 | | |
| | | 4 0 30 | ..... | ..... | ..... | 186 1 46.6 | |
| Alost | " 19 | 4 5 30 | | | | 186 1 40.1 | 94 1 10 |
| | | 8 55 36.4 A.M. | 31 55.08 | ..... | 58 44 30 | | |
| | | 9 1 37.8 | ..... | ..... | 60 10 15 | | |
| | | 9 6 41.1 | ..... | ..... | 61 23 30 | | |
| | | 9 10 51.1 | ..... | ..... | 62 24 0 | | |
| Brussels, 131 rue Royale | " 20 | 9 50 30 | | | | 192 31 21.4 | 240 31 35 |
| | | 9 57 0 | ..... | ..... | ..... | 192 30 24.2 | |
| | | 10 1 0 | ..... | ..... | ..... | 192 31 42.1 | |
| | | 9 12 2.1 | 32 7.81 | ..... | 24 10 30 | | |
| | | 9 17 14.8 | ..... | ..... | 22 52 45 | | |
| Brussels Observatory ... | " 22 | 10 33 0 | | | | 251 28 6.7 | 261 28 50 |
| | | 10 38 30 | ..... | ..... | ..... | 251 28 52.2 | |
| | | 10 44 0 | ..... | ..... | ..... | 251 29 24.6 | |
| | | 2 12 39.5 P.M. | 32 12.06 | ..... | 17 24 0 | | |
| | | 2 21 46.5 | ..... | ..... | 14 54 15 | | |
| " 22 | " 22 | 2 57 30 | | | | 188 13 38.6 | 192 25 0 |
| | | 3 3 0 | ..... | ..... | ..... | 188 13 38.6 | |
| | | 9 55 45.8 A.M. | 32 20.55 | ..... | 32 42 45 | | |
| | | 10 0 56.0 | ..... | ..... | 31 18 15 | | |
| | | 10 51 30 | ..... | ..... | ..... | 181 57 24.2 | |
| " 22 | " 22 | 10 58 30 | | | | 181 55 14.4 | 192 47 37.5 |
| | | 11 13 44.4 | ..... | ..... | 10 17 45 | | |
| | | 11 19 11.5 | ..... | ..... | 8 35 15 | | |
| | | 11 49 30 | ..... | ..... | ..... | 181 42 30.6 | |
| | | 11 54 0 | ..... | ..... | ..... | 181 40 46.8 | |

To complete the determination of the Declination at the different stations, it is necessary to compute the azimuth of the sun at the times of observation. The mean result for each station is contained in the following Table, along with the Declination corrected for Scale-reading, as well as for Daily Range, and for any irregular perturbation that may have occurred at the moment of observation. Fortunately the magnet was always very quiet during the hours of observation, and hence the greater part of the correction in each case is due to Daily Range, which can be estimated more correctly than could the effect of any great disturbance. In order to calculate this correction, I have been obliged to make

use of the magnetograms of Stonyhurst Observatory, as no continuous records have as yet been obtained in Belgium of the magnetic elements. The differences between the ordinates of the curve at the absolute times of observation, and the mean ordinate for July, August, September, and October, multiplied into $28' 38''\cdot9$, the scale-coefficient of the Declination Magnetograph, give a close approximation to the correction required for reducing the results to September 1st for Stonyhurst. To apply these to observations made in Belgium I have introduced the factor 0·69, as I find from the mean values obtained at the Brussels Observatory for 9 A.M., noon, 3 P.M., and 9 P.M., compared with those deduced at Stonyhurst for the same hours, that the movements are in the ratio of 0·69 to 1. This will of course give only a first approximation, but the data will scarcely admit of greater exactness.

TABLE XV.

| Station. | Azimuth of Sun. | Observed W. Declination. | Declination corrected for Range and Disturbance. |
|-------------------------------|-----------------|---|--|
| Antwerp..... | 48° 9' 41"·2 | 17° 30' 41"·7 17 30 22·2 | 17° 33' 16" 17 31 33 |
| Brussels Observatory ..... | ..... | 18 3 49·5 18 4 46·0 | 17 59 52 18 1 0 |
| Brussels, 131 rue Royale..... | 76 2 47·7 | 17 8 0·4 17 8 0·4 | 17 12 45 17 12 57 |
| Louvain..... | 47 49 41·1 | 16 46 15·3 16 47 27·1 16 49 49·9 | 16 50 12 16 51 48 16 55 10 |
| Turnhout | 22 4 5·1 | 17 13 13·7 17 11 23·3 | 17 5 32 17 3 5 |
| Liège | 54 6 53·1 | 16 16 12·0 16 17 3·9 | 16 16 0 16 17 16 |
| Aix-la-Chapelle..... | 72 21 10·3 | 16 30 51·2 16 32 28·5 16 34 38·3 | 16 28 29 16 30 19 16 32 39 |
| Spa..... | 17 5 47·9 | 16 43 44·9 16 44 10·9 | 16 39 59 16 40 25 |
| Arlon..... | 45 8 52·8 | 16 29 35·4 16 32 11·2 16 33 42·0 | 16 23 51 16 26 51 16 28 34 |
| Namur | 10 10 14·0 | 17 40 36·0 17 40 55·0 | 17 34 52 17 34 59 |
| Mons | 72 7 29·5 | 17 21 24·7 17 22 36·1 17 23 2·0 | 17 13 43 17 15 41 17 16 42 |
| Tournay..... | 49 15 37·1 | 17 50 14·2 17 49 54·8 | 17 43 43 17 43 59 |
| Courtray | 18 47 53·8 | 17 54 32·8 17 54 52·3 | 17 47 14 17 48 9 |
| Ghent..... | 11 1 26·5 | 17 59 4·3 17 58 5·9 17 59 3·5 17 59 32·5 | 17 54 8 17 52 46 17 49 58 17 50 4 |
| Ostend | 56 45 19·0 | 18 6 57·6 18 7 36·5 | 18 7 34 18 8 35 |
| Bruges | 54 43 41·9 | 18 1 11·5 18 1 18·0 | 17 58 25 17 58 32 |
| Tronchiennes..... | 55 47 49·1 | 17 55 41·5 17 56 38·6 17 55 20·7 | 17 55 53 17 53 53 17 52 47 |
| Alost | 51 54 1·1 | 17 25 51·8 17 25 6·4 17 24 34·0 | 17 23 53 17 22 44 17 22 35 |
| Brussels, 131 rue Royale..... | 39 40 30·1 | 17 25 33·8 17 25 33·8 | 17 23 0 17 23 12 |
| Brussels Observatory | 39 25 24·6 | 17 52 30·3 17 54 40·1 | 17 54 5 17 56 15 |
| „ „ | 16 25 10·1 | 18 3 46·9 18 5 30·8 | 18 3 47 18 5 31 |

The figures in column 3, which are obtained directly from the unifilar, furnish the first members of the equations, whose solution is

$$\begin{aligned}x &= 0\cdot0119696, \\y &= -0\cdot0012255, \\D &= 17^{\circ}3881.\end{aligned}$$

Thus the position of the isogonics will be N. $5^{\circ} 50' 46''\cdot2$ E. to S. $5^{\circ} 50' 46''\cdot2$ W., and the distance between lines, differing by $30'$, $41\cdot56$ miles.

If, on the other hand, we use the corrected values of column 4 in the formation of our equations, the solution becomes

$$\begin{aligned}x &= 0\cdot0115492, \\y &= -0\cdot0022202, \\D &= 17^{\circ}3368;\end{aligned}$$

and then the isogonics lie at an angle of $10^{\circ} 52' 54''\cdot7$ to the astronomical meridian, and their distance is $42\cdot51$ miles. The corrections have therefore altered very considerably the direction of the isogonics without affecting much their distance apart. We may judge from the following Table how far these corrections have diminished the probable error in the results.

TABLE XVI.

| Station. | Uncorrected Declination. | | Error. | Corrected Declination. | | Error. |
|----------------------|--------------------------|-----------|--------|------------------------|-----------|--------|
| | Observed. | Computed. | | Observed. | Computed. | |
| Aix-la-Chapelle..... | 0·544 | 0·483 | +0·061 | 0·508 | 0·457 | +0·051 |
| Alost | 1·420 | 1·567 | -0·147 | 1·384 | 1·516 | -0·132 |
| Antwerp..... | 1·509 | 1·402 | +0·107 | 1·540 | 1·377 | +0·163 |
| Arlon | 0·530 | 0·528 | +0·002 | 0·440 | 0·424 | +0·016 |
| Bruges | 2·021 | 2·014 | +0·007 | 1·975 | 1·967 | +0·008 |
| Courtray | 1·912 | 1·954 | -0·042 | 1·795 | 1·880 | -0·085 |
| Ghent..... | 1·983 | 1·740 | +0·243 | 1·862 | 1·691 | +0·171 |
| Liège | 0·277 | 0·732 | -0·445 | 0·277 | 0·690 | -0·413 |
| Louvain..... | 0·797 | 1·220 | -0·423 | 0·873 | 1·178 | -0·305 |
| Mons | 1·373 | 1·576 | -0·203 | 1·256 | 1·490 | -0·234 |
| Namur | 1·677 | 1·100 | +0·577 | 1·582 | 1·032 | +0·550 |
| Ostend | 2·121 | 2·173 | -0·052 | 2·135 | 2·120 | +0·015 |
| Spa..... | 0·733 | 0·577 | +0·156 | 0·670 | 0·528 | +0·142 |
| Tournay..... | 1·835 | 1·882 | -0·047 | 1·731 | 1·796 | -0·065 |
| Tronchiennes..... | 1·932 | 1·773 | +0·159 | 1·903 | 1·723 | +0·180 |
| Turnhout | 1·205 | 1·144 | +0·061 | 1·072 | 1·125 | -0·063 |

The probable errors at any station will therefore be $\pm 0\cdot16585$ for the uncorrected and $\pm 0\cdot15234$ for the corrected values, whilst those of the mean are respectively $\pm 0\cdot04146$ and $\pm 0\cdot03809$.

The direction of the isogonics, when the corrected numbers are employed, approaches nearer to that found for France than when the uncorrected observations are used, but it is still considerably in defect. There is scarcely any difference between the closeness of the lines in Belgium and in the West of France.

For the calculation of the secular variation of the Declination, the only available observations made out of Brussels are those of LAMONT in 1858, since the two observations of last century mentioned at the beginning of this paper would not help us to

ascertain the actual yearly change of this element. Dr. LAMONT observed at Aix-la-Chapelle, Ghent, and Mechlin; but as I did not take the Declination at Mechlin, the comparison is confined to two stations.

TABLE XVII.

| Station. | Declination, Jan. 1, 1858. | Declination, Sept. 1, 1871. | Secular variation. |
|-----------------------|-------------------------------|--------------------------------|-----------------------|
| Aix-la-Chapelle | 18·243 | 16·544 | -0·124 |
| Ghent..... | 19·560 | 17·983 | -0·115 |
| | Mean for epoch 1864·8 ... | | -0·1195 |

If we use the corrected values for September 1, 1871, the secular variation becomes -0·1255. LAMONT gives -0·1267 for 1858.

From the long series of observations made at the Royal Observatory of Brussels by MM. A. and E. QUETELET, from 1828 to 1871, I find the following values of the secular variation :—

| | |
|-------------------------|----------|
| Epoch 1838·75 | -0·0896 |
| „ 1849·5 | -0·1065 |
| „ 1860·25 | -0·1234. |

The yearly acceleration is therefore constant, and = -0·00158.

The observations at Brussels give very unsatisfactory results, when we regard the absolute values, and not merely the yearly change at a permanent unaltered station. In 1858 LAMONT found a difference of 28' between the Declination at the observatory and that at a station not far distant; E. QUETELET confirmed this result the same year, the difference being 30'; and now, at positions so close together as the observatory and 131 rue Royale, I find a still greater mean difference. The Declination observations made at Brussels during this survey were as follows:—

| | Uncorrected values. | Corrected values. |
|----------------------------------|---------------------|-------------------|
| Computed results | 17°·3881 | 17°·3368 |
| Observatory, August | 18·0716 | 18·0072 |
| „ September | 17·8931 | 17·9195 |
| „ „ | 18·0775 | 18·0775 |
| „ Error of mean | + 0·6260 | + 0·6646 |
| 131 rue Royale, August | 17·1334 | 17·2125 |
| „ September | 17·4261 | 17·3850 |
| „ Error of mean | - 0·1083 | - 0·0380 |

The station near the observatory, though apparently not free from disturbing influences, gives from the corrected values a result almost identical with the computed quantity, since it is within the range of its probable error, whilst the result for the observatory itself is more than half a degree in excess. This difference of Declination,

combined with the fact that the errors of the observed Dip at both stations are positive and their errors of H. F. both negative, might justify the assumption that the disturbing cause is situated at no great distance from the observatory, and probably at some depth and to the W. of the N. meridian. The probable errors of the observed Dip and H. F. at the observatory were not very large, being respectively $+7' 15''$ and -0.0070 .

It may be of advantage, in particular for the discussion of the errors of the Total Force, to present here in a tabular form a geological description of the stations of observation. The data in this Table are taken from the excellent map of M. ANDRÉ DUMONT, a copy of which was kindly presented to me for this purpose by his son.

TABLE XVIII.

| Station. | Geological formation. |
|----------------------|--|
| Aix-la-Chapelle..... | Terrain crétacé, système Aachenien. E.S.E. houille. |
| Alost | Terrain tertiaire, eocène, glauconie. |
| Antwerp..... | " " pliocène, système Scaldisien. |
| Arlon | " " jurassique, système liasique. |
| Bruges | " " tertiaire, miocène, argile verte et sable marin. |
| | " " eocène, glauconie supérieure. |
| Brussels | " " glauconie; sable et grès de Beauchamp. |
| Courtray | " " glauconie moyenne. |
| Ghent..... | " " glauconie supérieure. |
| Liège | E., W., N. houille. S. terrain anthraxifère, système Eifelien, quartzoschisteux. |
| Lierre..... | Terrain tertiaire, pliocène, système Diestien. |
| Louvain..... | " " N. miocène, argile verte et sable marin; S. glauconie supérieure; E., W. pliocène, système Diestien. |
| Mechlin | " " miocène, argile verte, sable marin, et grès de Fontainebleau. |
| Mons | E., N.E., S.W. houille. S. terrain tertiaire, eocène, glauconie moyenne. |
| Namur | Terrain anthraxifère. N. système Condrusien, calcaireux; S. houille. |
| Ostend | Alluvions. |
| Spa | Terrain Ardennais. N.W. terrain Rhéna, système Gedinnien. |
| Tournay..... | " " tertiaire, eocène, glauconie. S.E. terrain anthraxifère, système Condrusien, calcaireux. |
| Tronchiennes..... | Terrain tertiaire, eocène, glauconie supérieure. |
| Turnhout | " " miocène, système Bolderien. |
| Verviers..... | " " Ardennais, système Salmien; et terrain Rhéna, système Gedinnien. |

The three maps annexed to this paper (Plates XIX.–XXI.) show the general direction of the lines of equal Dip, H. F., and Declination. The broken lines for 1871 are calculated on the supposition of the isoclinals, isodynamics, and isogonics being approximately straight, and the observed mean values are attached to each station in order to show how nearly these straight lines represent the actual curves.

This has also been made more evident by introducing the curves of equal values, which are represented by continuous lines. The method adopted in drawing these lines is shown in the map of the isodynamics; and the shaded portions of the same map indicate the position and extent of the coal-beds of Belgium, which lie, for the most part, along the banks of the Meuse.

The greatness of the accidental errors, as well as the narrow limits of the tract of country under consideration, renders it very difficult to trace, with any great degree of accuracy, the probable curvature of the actual lines of equal Dip, Declination, and Intensity. But bearing in mind that in all cases the errors arising from defects of station or of observation mask to a great extent the real nature of these curves, we may still clearly

perceive two apparent centres of disturbing action,—the one situated in the N.W. centre, and manifested by a great increase of the Dip and a diminution of the Horizontal Force, and the other, more extended and less intense, stretching along the Coal-measures, and giving evidence of its existence by a diminution of the Dip and an increase of the Horizontal component of the Intensity.

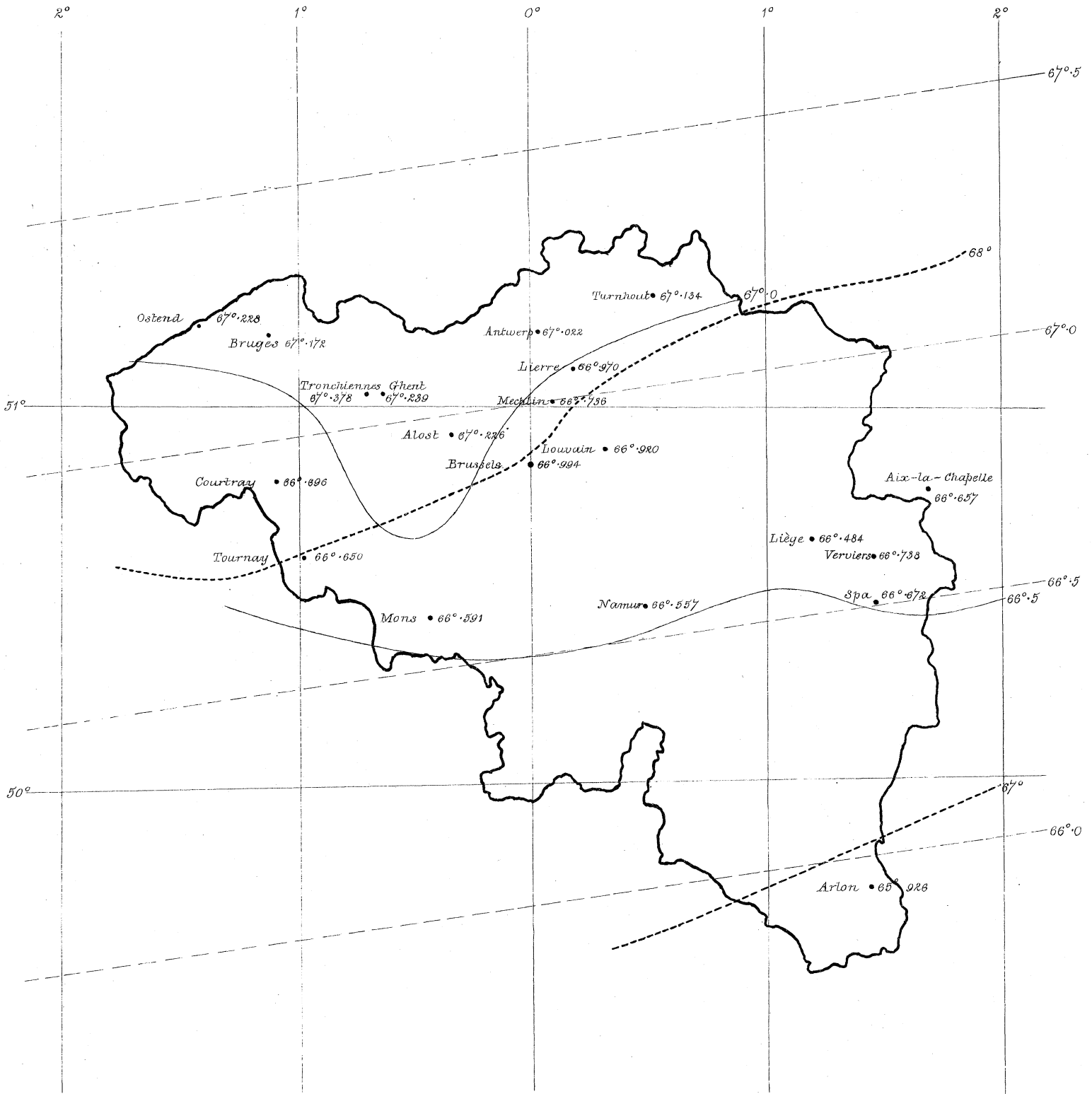
The dotted lines are an enlarged reproduction of the curves on LAMONT'S maps; and from being enlarged they will naturally give a somewhat exaggerated idea of the lesser inequalities, though the general curvature be perfectly correct.

I will now conclude this paper with a list of the magnetic elements at the several stations, the observations being all reduced to the common epoch, January 1st, 1872. In this reduction I have adopted the yearly changes determined by the survey, viz. $-0\cdot0573$, $+0\cdot00542$, $-0\cdot01155$, and $-0\cdot1255$ respectively for the Dip, H. F., T. F., and the corrected Declination.

TABLE XIX.

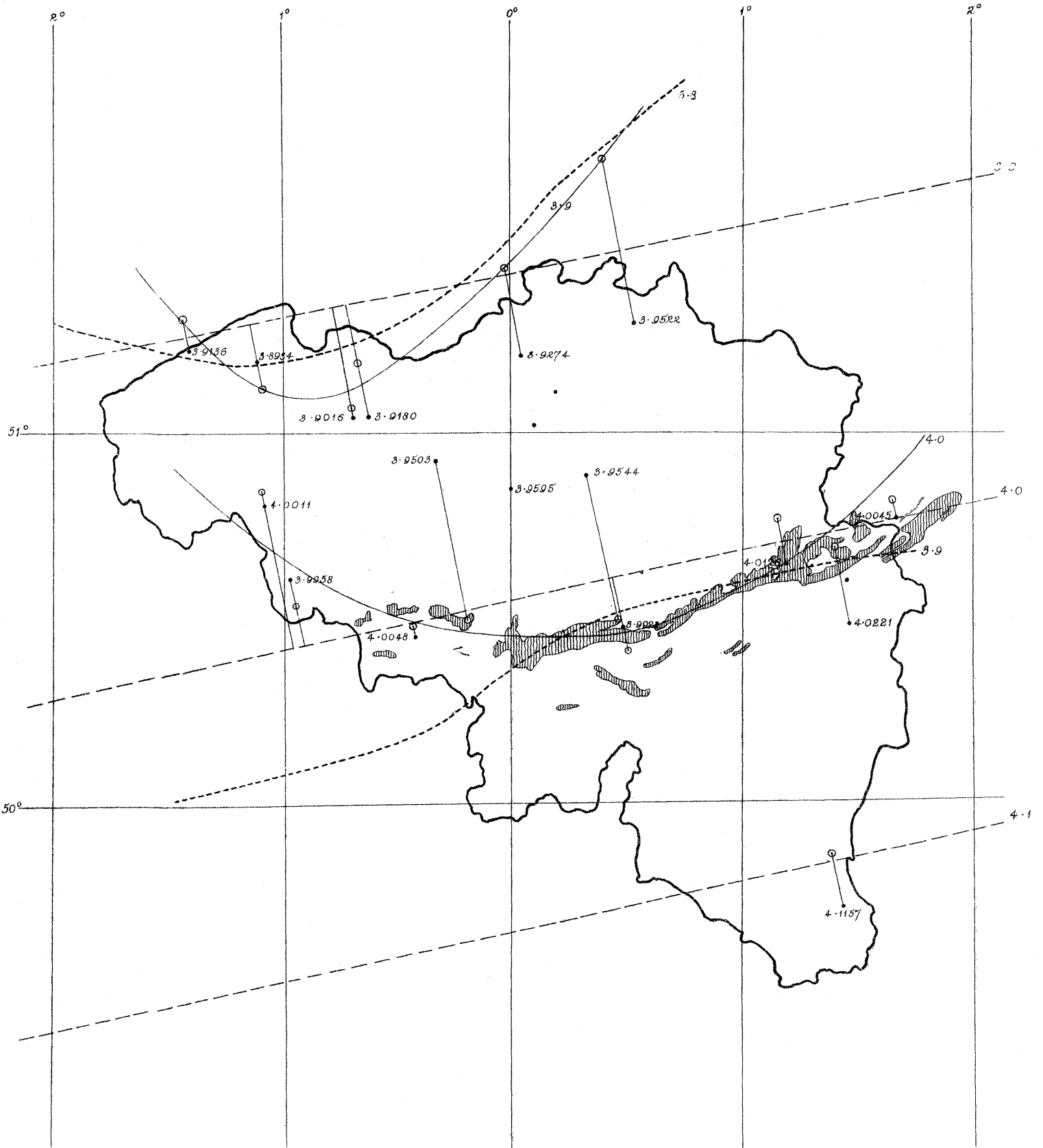
| Station. | Declination. | Dip. | Horizontal Force. | Total Force. |
|----------------------|---------------------|---------------------|-------------------|--------------|
| Aix-la-Chapelle..... | 16 ³ 464 | 66 ⁶ 637 | 4-0064 | 10-1025 |
| Alost | 17-349 | 67-210 | 3-9518 | 10-2016 |
| Antwerp | 17-489 | 66-999 | 3-9296 | 10-0559 |
| Arlon..... | 16-398 | 65-907 | 4-1175 | 10-0857 |
| Bruges | 17-938 | 67-155 | 3-8950 | 10-0321 |
| Brussels..... | 17-959 | 66-975 | 3-9613 | 10-1271 |
| Courtray | 17-756 | 66-678 | 4-0028 | 10-1103 |
| Ghent..... | 17-823 | 67-221 | 3-9197 | 10-1232 |
| Liège | 16-233 | 66-464 | 4-0145 | 10-0522 |
| Lierre..... | ..... | 66-948 | ..... | ..... |
| Louvain..... | 16-824 | 66-898 | 3-9565 | 10-0828 |
| Mechlin..... | ..... | 66-714 | ..... | ..... |
| Mons..... | 17-216 | 66-573 | 4-0065 | 10-0767 |
| Namur | 17-541 | 66-538 | 3-9941 | 10-0311 |
| Ostend | 18-097 | 67-211 | 3-9152 | 10-1077 |
| Spa..... | 16-627 | 66-653 | 4-0239 | 10-1531 |
| Tournay..... | 17-691 | 66-632 | 3-9975 | 10-0776 |
| Tronchiennes | 17-867 | 67-361 | 3-9032 | 10-1397 |
| Turnhout | 17-025 | 67-113 | 3-9542 | 10-1665 |
| Verviers..... | ..... | 66-718 | ..... | ..... |

Magnetic Dip.



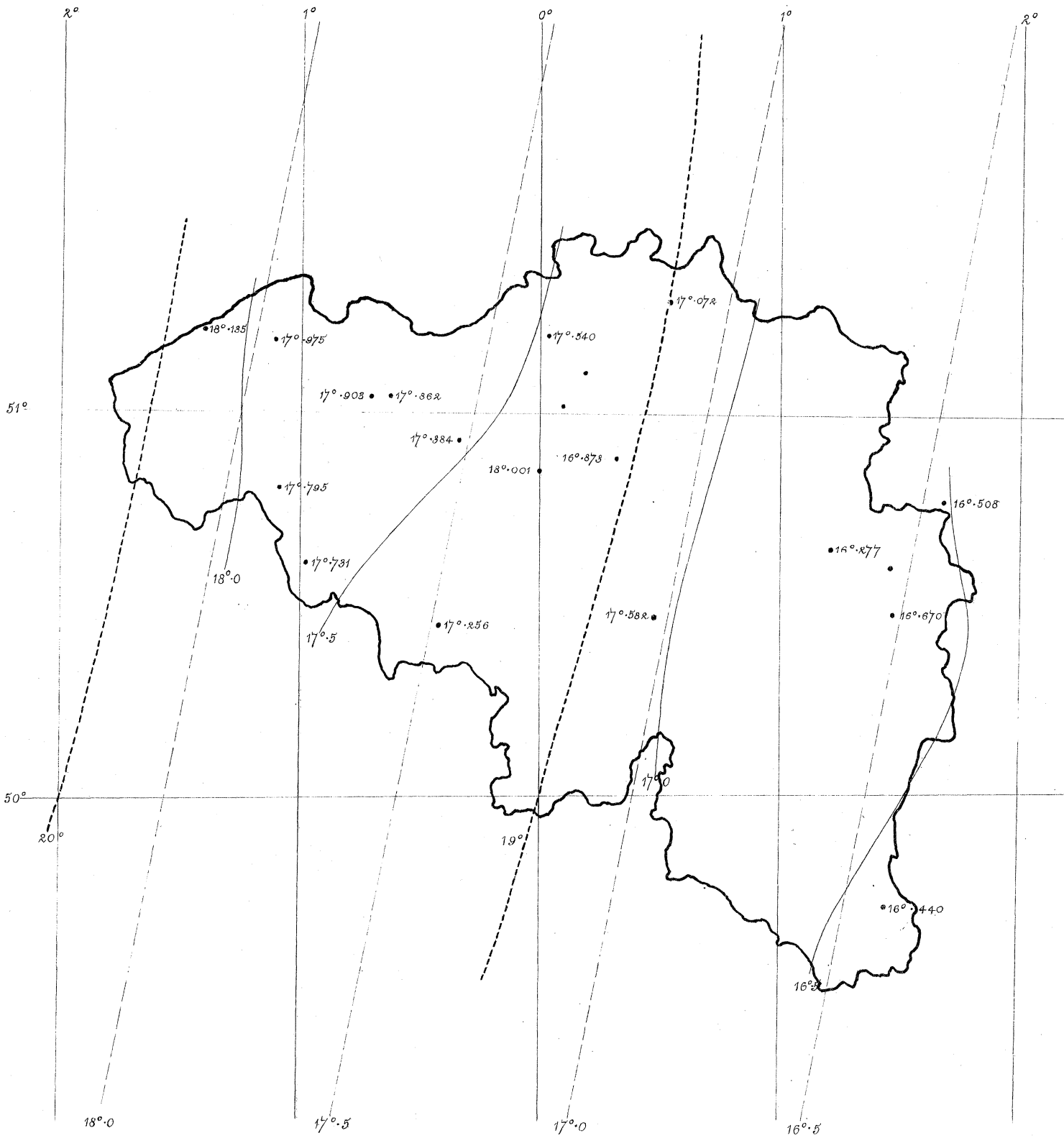
Isoclinals Epoch 1871 —————
 " " 1849 - - - - -

Magnetic Intensity.



Lines of equal Horizontal Force. Epoch 1850 -----
 " " " 1871 -----

Magnetic Declination.



Isogones. Epoch 1848 -----
 " " 1871 - - - - -