A

TREATISE

ON

LAND-SURVEYING:

COMPRISING

THE THEORY

DEVELOPED FROM FIVE ELEMENTARY PRINCIPLES;

AND THE PRACTICE

WITH THE CHAIN ALONE, THE COMPASS, THE TRANSIT, THE THEODOLITE, THE PLANE TABLE, &c.

ILLUSTRATED BY
FOUR HUNDRED ENGRAVINGS,
AND A MAGNETIC CHART.

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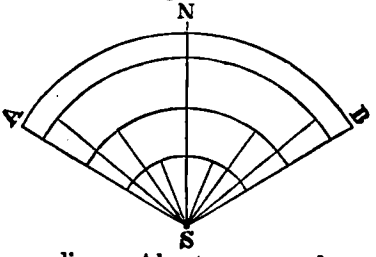
according to the locality. Observations of the amount and the direction of this variation have been made in nearly all parts of the world. In the United States the Variation in the Eastern States is Westerly, and in the Western States is Easterly, as will be given in detail, after the methods for determining the True Meridian, and consequently the Variation, at any place, have been explained.

TO DETERMINE THE TRUE MERIDIAN.

(300) By equal shadows of the Sun. On the South side of any level surface, erect an upright staff, shown, in horizontal projection, at S. Two or three hours before noon, mark the extremity, A, of its shadow. Describe an arc of a circle with S, the foot of the staff, for centre, and SA, the distance to the extremity of the shadow, for radius. About as many hours after noon as it had been before noon when the first mark was made, watch for the moment when the end of the shadow touches the arc at another point, B. Bisect the arc AB at N. Draw SN, and it will be the true meridian, or North and South line required.

Fig. 200.



For greater accuracy, describe several arcs before hand, mark the points in which each of them is touched by the shadow, bisect each, and adopt the average of all. The shadow will be better defined, if a piece of tin with a hole through it be placed at the top of the staff, as a bright spot will thus be substituted for the less definite shadow. Nor need the staff be vertical, if from its summit a plumb-line be dropped to the ground, and the point which this strikes be adopted as the centre of the arcs.

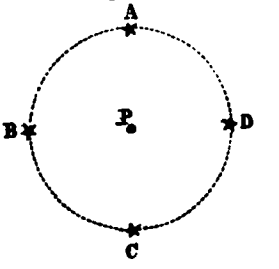
This method is a very good approximation, though perfectly correct only at the time of the solstices; about June 21st and December 22d. It was employed by the Romans in laying out cities.

To get the Variation, set the compass at one end of the True Meridian line thus obtained, sight to the other end of it, and take

the Bearing as of any ordinary line. The number of degrees in the reading will be the desired variation of the needle.

(301) By the North Star, when in the Meridian. The North Star, or Pole Star, (called by astronomers *Alpha Ursæ Minoris*, or *Polaris*), is not situated precisely at the North Pole of the heavens. If it were, the Meridian could be at once determined by sighting to it, or placing the eye at some distance behind a plumb-line so that this line should hide the star. But the North Star is about $1\frac{1}{2}°$ from the Pole. Twice in 24 hours, however, (more precisely 23h. 56m.), it is in the Meridian, being then exactly above or below the Pole, as at A and C in the figure. To know when it is so, is rendered easy by the aid of another star, easily identified, which at these times is almost exactly above or below the North Star, i. e. situated in the same vertical plane. If then we watch for the moment at which a suspended plumb-line will cover both these stars, they will then be in the Meridian.

Fig. 201.



The other star is in the well known constellation of the Great Bear, called also the Plough, or the Dipper, or Charles's Wain.

Fig. 202.

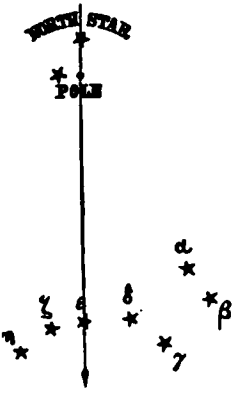
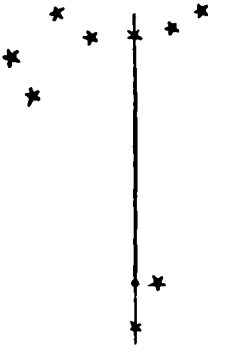


Fig. 203.



Two of its five bright stars (the right-hand ones in Fig. 202) are known as the "Pointers," from their pointing near to the North

Star, thus assisting in finding it. The star in the tail or handle, nearest to the four which form a quadrilateral, is the star which comes to the Meridian at the same time with the North Star, twice in 24 hours, as in Fig. 202 or 203. It is known as *Alioth*, or *Epsilon Ursæ Majoris*.*

To determine the Meridian by this method, suspend a long plumb-line from some elevated point, such as a stick projecting from the highest window of a house suitably situated. The plumb-bob may pass into a pail of water to lessen its vibrations. South of this set up the compass, at such a distance from the plumb-line that neither of the stars will be seen above its highest point, i. e. in Latitudes of 40° or 50° not quite as far from the plumb-line as it is long. Or, instead of a compass, place a board on two stakes, so as to form a sort of bench, running East and West, and on it place one of the compass-sights, or anything having a small hole in it to look through. As the time approaches for the North Star to be on the Meridian (as taken from the table given below) place the compass, or the sight, so that, looking through it, the plumb-line shall seem to cover or hide the North Star. As the star moves one way, move the eye and sight the other way, so as to constantly keep the star behind the plumb-line. At last *Alioth*, too, will be covered by the plumb-line. At that moment the eye and the plumb-line are (approximately) in the Meridian. Fasten down the sight on the board till morning, or with the compass take the bearing at once, and the reading is the variation.†

Instead of one plumb-line and a sight, two plumb-lines may be suspended at the end of a horizontal rod, turning on the top of a pole.

The line thus obtained points to the East of the true line when the North Star is above Alioth, and vice versa. The North Star is exactly in the Meridian about 17 minutes after it has been in the same vertical plane with Alioth, and may be sighted to after that interval of time, with perfect accuracy.

* The North Pole is very nearly at the intersection of the line from Polaris to Alioth, and a perpendicular to this line from the small star seen to the left of it in Fig. 202.

† If a Transit or Theodolite be used, the cross-hairs must be illuminated by throwing the light of a lamp into the telescope by its reflection from white paper.

Another bright star, which is on the opposite side of the Pole, and is known to astronomers as *Gamma Cassiopeiæ*, also comes on the Meridian nearly at the same time as the North Star, and will thus assist in determining its direction.

(302) The time at which the North Star passes the Meridian above the Pole, for every 10th day in the year, is given in the following Table, in common clock time.* The upper transit is the most convenient, since at the other transit Alioth is too high to be conveniently observed.

Times of North Star passing the Meridian.

MONTH.	1st DAY.	11th DAY.	21st DAY.
	H. M.	H. M.	H. M.
January,	6 21 P. M.	5 41 P. M.	5 02 P. M.
February,	4 18 P. M.	3 39 P. M.	3 00 P. M.
March,	2 28 P. M.	1 49 P. M.	1 09 P. M.
April,	0 26 P. M.	11 47 A. M.	11 08 A. M.
May,	10 28 A. M.	9 49 A. M.	9 10 A. M.
June,	8 27 A. M.	7 48 A. M.	7 08 A. M.
July,	6 29 A. M.	5 50 A. M.	5 11 A. M.
August,	4 28 A. M.	3 49 A. M.	3 09 A. M.
September,	2 26 A. M.	1 47 A. M.	1 07 A. M.
October,	0 28 A. M.	11 45 P. M.	11 06 P. M.
November,	10 22 P. M.	9 43 P. M.	9 04 P. M.
December,	8 24 P. M.	7 45 P. M.	7 06 P. M.

* To calculate the time of the North Star passing the Meridian at its upper culmination: Find in the "American Almanac," (Boston), or the "Astronomical Ephemeris," (Washington), or the "Nautical Almanac," (London), or by interpolation from the data at the end of this note, the right ascension of the star, and from it (increased by twenty-four hours if necessary to render the subtraction possible) subtract the Right ascension of the Sun at mean noon, or the sidereal time at mean noon, for the given day, as found in the "Ephemeris of the Sun," in the same Almanacs. From the remainder subtract the acceleration of sidereal on mean time corresponding to this remainder, (3m. 56s. for 24 hours), and the new remainder is the required mean solar time of the upper passage of the star across the Meridian, in "Astronomical" reckoning, the astronomical day beginning at noon of the common civil day of the same date.

The right ascension of the North Star for Jan. 1, 1850, is 1h. 05m. 01.4s.; for 1860, 1h. 08m. 02.8s.; for 1870, 1h. 11m. 16.9s.; for 1880, 1h. 14m. 45.1s.; for 1890, 1h. 18m. 29.2s.; for 1900, 1h. 22m. 31s.

To find the time of the star's passage of the Meridian for other days than those given in the Table, take from it the time for the day most nearly preceding that desired, and subtract from this time 4 minutes for each day from the date of the day in the Table to that of the desired day; or, more accurately, interpolate, by saying: *As* the number of days between those given in the Table *is to* the number of days from the next preceding day in the Table to the desired day, *so is* the difference between the times given in the Table for the days next preceding and following the desired day *to* the time to be subtracted from that of the next preceding day. The first term of the preceding proportion is always *ten*, except at the end of months having more or less than 30 days. For example, let the time of the North Star's passing the Meridian on July 26th be required. From July 21st to August 1st being 11 days, we have this proportion: 11 days : 5 days :: 43 minutes : $19\frac{6}{11}$ minutes. Taking this from 5h. 11m. A. M., we get 4h. $51\frac{1}{2}$m. A. M. for the time of passage required.

The North Star passes the Meridian later every year. In 1860, it will pass the Meridian about two minutes later than in 1854; in 1870, five minutes, in 1880, eight minutes, in 1890, twelve minutes, and in 1900, sixteen minutes, later than in 1854: the year for which the preceding table has been calculated.

The times at which the North Star passes the Meridian *below* the Pole, in its lower Transit, can be found by adding 11h. 58m. to the time of the upper Transit, or by subtracting that interval from it.*

(303) By the North Star at its extreme elongation. When the North Star is at its greatest *apparent* angular distance East or West of the Pole, as at B or D in Fig. 201, it is said to be at its extreme Eastern, or extreme Western, Elongation. If it be observed at either of these times, the direction of the Meridian can be easily

* The North Star, which is now about 1° 28′ from the Pole, was 12° distant from it when its place was first recorded. Its distance is now diminishing at the rate of about a third of a minute in a year, and will continue to do so till it approaches to within half a degree, when it will again recede. The brightest star in the Northern hemisphere, *Alpha Lyræ*, will be the Pole Star in about 12,000 years, being then within about 5° of the Pole, though now more than 51° distant from it

obtained from the observation. The great advantage of this method over the preceding is that then the star's motion apparently ceases for a short time.

(304) The following Table gives the

TIMES OF EXTREME ELONGATIONS OF THE NORTH STAR.*

MONTH.	1ST DAY.		11TH DAY.		21ST DAY.	
	EASTERN.	WESTERN.	EASTERN.	WESTERN.	EASTERN.	WESTERN.
	H. M.	H. M.	H. M.	H. M.	H. M.	H. M.
Jan'y,	0 27 P.M.	0 19 A.M.	11 47 A.M.	11 35 P.M.	11 08 A.M.	10 56 P.M.
Feb'y,	10 24 A.M.	10 13 P.M.	9 45 A.M.	9 33 P.M.	9 06 A.M.	8 54 P.M.
March,	8 34 A.M.	8 22 P.M.	7 55 A.M.	7 43 P.M.	7 15 A.M.	7 04 P.M.
April,	6 32 A.M.	6 20 P.M.	5 53 A.M.	5 41 P.M.	5 14 A.M.	5 02 P.M.
May,	4 34 A.M.	4 22 P.M.	3 55 A.M.	3 43 P.M.	3 16 A.M.	3 04 P.M.
June,	2 33 A.M.	2 21 P.M.	1 53 A.M.	1 42 P.M.	1 14 A.M.	1 02 P.M.
July,	0 35 A.M.	0 23 P.M.	11 52 P.M.	11 44 A.M.	11 13 P.M.	11 05 A.M.
August,	10 30 P.M.	10 22 A.M.	9 51 P.M.	9 43 A.M.	9 11 P.M.	9 03 A.M.
Sept'r,	8 28 P.M.	8 20 A.M.	7 49 P.M.	7 41 A.M.	7 09 P.M.	7 01 A.M.
Oct'r,	6 30 P.M.	6 22 A.M.	5 51 P.M.	5 43 A.M.	5 12 P.M.	5 04 A.M.
Nov'r,	4 28 P.M.	4 21 A.M.	3 49 P.M.	3 41 A.M.	3 10 P.M.	3 02 A.M.
Dec'r,	2 30 P.M.	2 22 A.M.	1 51 P.M.	1 43 A.M.	1 12 P.M.	1 04 A.M.

The Eastern Elongations from October to March, and the Western Elongations from April to September, occurring in the day time, they will generally not be visible except with the aid of a powerful telescope.

* To calculate the times of the greatest elongation of the North Star: Find in one of the Almanacs before referred to, or from the data below, its Polar distance at the given time. Add the logarithm of its tangent to the logarithm of the tangent of the Latitude of the place, and the sum will be the logarithm of the cosine of the Hour angle before or after the culmination. Reduce the space to time; correct for sidereal acceleration (3m. 56s. for 24 hours) and subtract the result from the time of the star's passing the meridian on that day, to get the time of the Eastern elongation, or add it to get the Western.

The Polar distance of the North Star, for Jan. 1, 1850, is 1° 29′ 25″; for 1860, 1° 26′ 12″.7; for 1870, 1° 23° 01″; for 1880, 1° 19′ 50″.4; for 1890, 1° 16′ 40″.7; for 1900, 1° 13′ 32″.2.

The preceding Table was calculated for Latitude 40°. The Time at which the Elongations occur vary slightly for other Latitudes. In Latitude 50°, the Eastern Elongations occur about 2 minutes later and the Western Elongations about 2 minutes earlier than the times in the Table. In Latitude 26°, precisely the reverse takes place.

The Times of Elongation are continually, though slowly, becoming later. The preceding Table was calculated for July 1st, 1854. In 1860, the times will be nearly 2 minutes later; and in 1900, the Eastern Elongations will be about 15 minutes, and the Western Elongations 17 minutes later than in 1854.

(305) Observations. Knowing from the preceding Table the hour and minute of the extreme Elongation on any day, a little before that time suspend a plumb-line, precisely as in Art. (**301**), and place yourself south of it as there directed. As the North Star moves one way, move your eye the other, so that the plumb-line shall continually seem to cover the star. At last the star will appear to stop moving for a time, and then begin to move backwards. Fix the sight on the board (or the compass, &c.) in the position in which it was when the star ceased moving; for the star was then at its extreme apparent Elongation, East or West, as the case may be.

(306) Azimuths. The angle which the line from the eye to the plumb-line, makes with the True Meridian (i. e. the angle between the meridian plane and the vertical plane passing through the eye and the star) is called the *Azimuth* of the Star. It is given in the following Table for different Latitudes, and for a number of years to come. For the intermediate Latitudes, it can be obtained by a simple proportion, similar to that explained in detail in Art. (**302**).*

* To calculate this Azimuth: From the logarithm of the sine of the Polar distance of the star, subtract the logarithm of the cosine of the Latitude of the place; the remainder will be the logarithm of the sine of the angle required. The Polar distance can be obtained as directed in the last note.

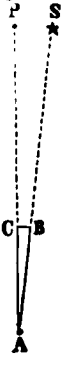
AZIMUTHS OF THE NORTH STAR.

Latitudes.	1854	1855	1856	1857	1858	1859	1860	1870
50°	2° 16¾′	2° 16¼′	2° 16′	2° 15½′	2° 15′	2° 14½′	2° 14¼′	2° 09¼′
49°	2° 14′	2° 13½′	2° 13¼′	2° 12¾′	2° 12¼′	2° 12′	2° 11½′	2° 06½′
48°	2° 11½′	2° 11′	2° 10½′	2° 10¼′	2° 09¾′	2° 09¼′	2° 09′	2° 04′
47°	2° 09′	2° 08½′	2° 08′	2° 07¾′	2° 07¼′	2° 06¾′	2° 06½′	2° 01¾′
46°	2° 06¾′	2° 06¼′	2° 05¾′	2° 05½′	2° 05′	2° 04½′	2° 04¼′	1° 59½′
45°	2° 04½′	2° 04′	2° 03½′	2° 03¼′	2° 02¾′	2° 02¼′	2° 02′	1° 57½′
44°	2° 02½′	2° 02′	2° 01¾′	2° 01½′	2° 01′	2° 00½′	2° 00′	1° 55½′
43°	2° 00½′	2° 00′	1° 59½′	1° 59′	1° 58¾′	1° 58¼′	1° 58′	1° 53½′
42°	1° 58½′	1° 58′	1° 57½′	1° 57¼′	1° 56¾′	1° 56½′	1° 56′	1° 51¾′
41°	1° 56¾′	1° 56¼′	1° 55¾′	1° 55½′	1° 55′	1° 54½′	1° 54¼′	1° 50′
40°	1° 55′	1° 54½′	1° 54′	1° 53¾′	1° 53¼′	1° 53′	1° 52½′	1° 48¼′
39°	1° 53¼′	1° 52¾′	1° 52½′	1° 52′	1° 51¾′	1° 51¼′	1° 51′	1° 46¾′
38°	1° 51¾′	1° 51¼′	1° 51′	1° 50½′	1° 50′	1° 49¾′	1° 49½′	1° 45¼′
37°	1° 50¼′	1° 49¾′	1° 49½′	1° 49′	1° 48¾′	1° 48¼′	1° 48′	1° 44′
36°	1° 48¾′	1° 48¼′	1° 48′	1° 47¾′	1° 47¼′	1° 47′	1° 46½′	1° 42¾′
35°	1° 47½′	1° 47′	1° 46¾′	1° 46¼′	1° 46′	1° 45½′	1° 45¼′	1° 41½′
34°	1° 46¼′	1° 45¾′	1° 45½′	1° 45′	1° 44¾′	1° 44¼′	1° 44′	1° 40¼′
33°	1° 45′	1° 44½′	1° 44¼′	1° 43¾′	1° 43½′	1° 43′	1° 42¾′	1° 39′
32°	1° 44′	1° 43½′	1° 43′	1° 42¾′	1° 42¼′	1° 42′	1° 41½′	1° 38′
31°	1° 42¾′	1° 42¼′	1° 42′	1° 41½′	1° 41′	1° 40¾′	1° 40½′	1° 37′
30°	1° 41½′	1° 41¼′	1° 41′	1° 40½′	1° 40¼′	1° 40′	1° 39½′	1° 36′

(307) Setting out a Meridian. When two points in the direction of the North Star at its extreme elongation have been obtained, as in Art. (**305**), the True Meridian can be found thus. Let A and B be the two points. Multiply the natural tangent of the Azimuth given in the Table, by the distance AB. The product will be the length of a line which is to be set off from B, perpendicular to AB, to some point C. A and C will then be points in the True Meridian. This operation may be postponed till morning.

If the directions of both the extreme Eastern and extreme Western elongations be set out, the line lying midway between them will be the True Meridian.

Fig. 204.

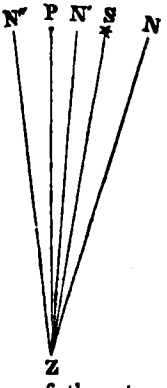


(308) Determining the Variation. The variation would of course be given by taking the Bearing of the Meridian thus obtained, but it can also be determined by taking the Bearing of the star at the time of the extreme elongation, and applying the following rules.

When the Azimuth of the star and its magnetic bearing are one East and the other West, the sum of the two is the Magnetic Variation, which is of the same name as the Azimuth; i. e. East, if that be East, and West, if it be West.

When the Azimuth of the star and its Magnetic Bearing are both East, or both West, their difference is the Variation, which will be of the same name as the Azimuth and Bearing, if the Azimuth be the greater of the two, or of the contrary name if the Azimuth be the smaller.

Fig. 205.



All these cases are presented together in the figure, in which P is the North Pole; Z the place of the observer; ZP the True Meridian; S the star at its greatest Eastern elongation; and ZN, ZN', ZN'', various supposed directions of the needle.

Call the Azimuth of the star, i. e. the angle PZS, 2° East.

Suppose the needle to point to N, and the Bearing of the star, i. e. SZN, to be 5° West of Magnetic North. The variation PZN will evidently be 7° East of true North.

Suppose the needle to point to N', and the bearing of the star, i. e. N'ZS, to be $1\frac{1}{4}$° East of Magnetic North. The Variation will be $\frac{3}{4}$° East of true North, and of the same name as the Azimuth, because that is greater than the bearing.

Suppose the needle to point to N'' and the bearing of the star, i. e. N''ZS, to be 10° East of Magnetic North. The Variation will be 8° West of true North, of the contrary name to the Azimuth, because that is the smaller of the two.*

* Algebraically, always subtract the Bearing from the Azimuth, and give the remainder its proper resulting algebraic sign. It will be the Variation; East if *plus*, and West, if minus. Thus in the first case above, the Variation $= + 2° - (- 5°) = + 7° = 7°$ East. In the second case, the Variation $= + 2° - (+ 1\frac{1}{4}°) = + \frac{3}{4}° = \frac{3}{4}°$ East. In the third case, the Variation $= + 2° - (+ 10°) = - 8° = 8°$ West.

If the star was on the other side of the Pole, the rules would apply likewise.

(309) Other Methods. Many other methods of determining the true Meridian are employed; such as by equal altitudes and azimuths of the sun, or of a star; by one azimuth, knowing the time; by observations of circumpolar stars at equal times before and after their culmination, or before and after their greatest elongation, &c.

All these methods however require some degree of astronomical knowledge; and those which have been explained are abundantly sufficient for all the purposes of the ordinary Land-Surveyor.

"Burt's Solar Compass" is an instrument by which, "when adjusted for the Sun's declination, and the Latitude of the place, the azimuth of any line from the true North and South can be read off, and the difference between it and the Bearing by the compass will then be the variation."

(310) Magnetic variation in the United States. The variation in any part of the United States, east of the Territories, can be approximately obtained by mere inspection of the map at the beginning of this volume.* Through all the places at which the needle in 1840,† pointed to the true North, a line is drawn on the map, and called the *Line of no Variation.* It will be seen to be nearly straight, and to pass in a N.N.W. direction from a little West of Cape Hatteras, N. C., through the middle of Virginia, about midway between Cleveland, (Ohio), and Erie, (Pa.), and through the middle of Lake Erie and Lake Huron. If followed South-Easterly it would be found to touch the most Easterly point of South America. It is now slowly moving Westward.

At all places situated to the East of this line (including the New-England States, New-York, New-Jersey, Delaware, Maryland, nearly all of Pennsylvania, and the Eastern half of Virginia and North Carolina) the Variation is Westerly, i. e. the North end of the needle points to the West of the true North. At all places

* Copied (by permission) from one prepared by Prof. Loomis by the reduction of numerous observations, and originally published in Silliman's "American Journal of Science," for Oct. 1840, Vol. xxxix, p. 41.

† A gradual change in the Variation is going on from year to year, as will be explained in the next Chapter.

situated to the West of this line (including the Western and Southern States) the Variation is easterly, i. e. the North end of the needle points to the East of the true North. This variation increases in proportion to the distance of the place on either side of the line of no variation, reaching 21° of Easterly Variation in Oregon, and 18° of Westerly Variation in Maine.

Lines of equal Variation are lines drawn through all the places which have the same variation. On the map they are drawn for each degree. All the places situated on the line marked 1°, East or West, have 1° Variation; those on the 2° line, have 2° Variation, &c. The variation at the intermediate places can be approximately estimated by the eye. These lines all refer to 1840.

The lines of equal Variation, if continued Northward, would all meet in a certain point called the *Magnetic Pole*, and situated in the neighborhood of 96° West Longitude from Greenwich, and 70° of North Latitude. Towards this pole the needle tends to point.

Another Magnetic pole is found in the Southern hemisphere; but the farther development of this subject belongs to a treatise on Natural Philosophy.

The Variation on the Pacific slope of this country has been very imperfectly ascertained. A few leading points are as below.

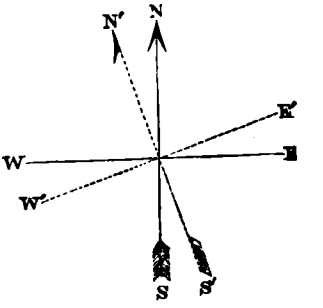
California;	Point Conception,	Sept. 1850, 13° 49½′ E.
	Point Penos, Monterey,	Feb. 1851, 14° 58′ E.
	Presidio, San Francisco,	Feb. 1852, 15° 27′ E.
	San Diego,	Mar. 1851, 12° 29′ E.
Oregon;	Cape Disappointment,	July, 1851, 20° 45′ E.
	Ewing Harbor,	Nov. 1851, 18° 29′ E.
Wash. Ter'y.	Scarboro' Harbor,	Aug. 1852, 21° 30′ E.

(311) To correct Magnetic Bearings. The Variation at any place and time being known, the Magnetic Bearings taken there and then, may be reduced to their true Bearings, by these Rules.

RULE 1. *When the Variation is West*, as it is in the North-Eastern States, the true Bearing will be the *sum* of the Variation and a Bearing which is North and West, or South and East; and the *difference* of the Variation and a Bearing which is North and East, or South and West. To apply this to the cardinal points, a

North Bearing must be called N. 0° West, an East Bearing N. 90° E., a South Bearing S. 0° E., and a West Bearing S. 90° W.; counting around from N′ to N, in the figure, and so onward, "with the Sun."

Fig. 206.

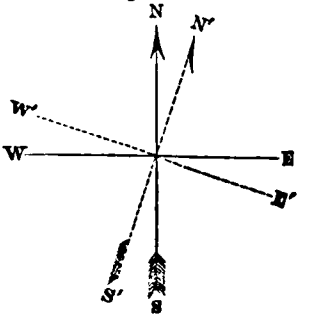


The reasons for these corrections are apparent from the Figure, in which the dotted lines and the accented letters represent the direction of the needle, and the full lines and the unaccented letters represent the true North and South and East and West lines.

When the sum of the Variation and the Bearing is directed to be taken, and comes to more than 90°, the supplement of the sun is to be taken, and the first letter changed. When the difference is directed to be taken, and the Variation is greater than the Bearing, the last letter must be changed. A diagram of the case will remove all doubts. Examples of all these cases are given below for a Variation of 8° West.

MAGNETIC BEARING.	TRUE BEARING.	MAGNETIC BEARING.	TRUE BEARING.
North.	N. 8° W.	South.	S. 8° E.
N. 1° E.	N. 7° W.	S. 2° W.	S. 6° E.
N. 40° E.	N. 32° E.	S. 60° W.	S. 52° W.
East.	N. 82° E.	West.	S. 82° W.
S. 50° E.	S. 58° E.	N. 70° W.	N. 78° W.
S. 89° E.	N. 83° E.	N. 83° W.	S. 89° W.

Fig. 207.



RULE 2. *When the Variation is East*, as in the Western and Southern States, the preceding directions must be exactly reversed; i. e. the true Bearing will be the *difference* of the Variation and a Bearing which is North and West, or South and East; and the *sum* of the Variation and a Bearing which is North and East, or South and West. A North Bearing

must be called N. 0° E., a West Bearing N. 90° W., a South Bearing S. 0° W., and an East Bearing S. 90° E., counting from N′ to N, and so onward, "against the sun." The reasons for these rules are seen in the Figure. Examples are given below, for a Variation of 5° E.

MAGNETIC BEARING.	TRUE BEARING.	MAGNETIC BEARING.	TRUE BEARING.
North.	N. 5° E.	South.	S. 5° W.
N. 40° E.	N. 45° E.	S. 60° W.	S. 65° W.
N. 89° E.	S. 86° E.	S. 87° W.	N. 88° W.
East.	S. 85° E.	West.	N. 85° W.
S. 1° E.	S. 4° W.	N. 70° W.	N. 65° W.
S. 50° E.	S. 45° E.	N. 2° W.	N. 3° E.

(312) To survey a line with true Bearings. The compass may be set, or adjusted, by means of the Vernier, (noticed in Arts. (**229**) and (**237**), and shown in Fig. 148, page 126) according to the Variation in any place, so that the Bearings of any lines then taken with it will be their true Bearings. To effect this, turn aside the compass plate, by means of the Tangent Screw which moves the Vernier, a number of degrees equal to the Variation, moving the S. end of the Compass-box to the *right*, (the North end being supposed to go ahead) if the Variation be Westerly, and *vice versa;* for that moves the North end of the Compass-box in the contrary direction, and thus makes a line which before was N. by the needle, now read, as it should truly, North, so many degrees, West if the Variation was West; and similarly in the reverse case.