Which Way is North?

by Albert J. Hebrank, PLS

EARLY IN MY SURVEY career while starting a boundary survey in Ballard (a Scandinavian neighborhood in Seattle), I was standing on the sidewalk studying the legal description and the city quarter section map to ascertain to what meridian the description referred when a long-time resident of the neighborhood approached me and asked what I was doing. When I replied that I was trying to determine which way was north, he fixed me with a pitiful gaze, pointed up the avenue, and said "I only ban here forty yars, but north ban that–a–way," and wandered off shaking his head. Unfortunately he had not held the pose long enough for me to make an instrument observation along his forefinger, so I was forced to rely on survey interpretation rather than upon his positive knowledge.

Those of you who work with maps and property descriptions and title reports, and you know what north is. You know that it is usually shown on maps with an arrow, and if no arrow is shown, the default position is generally straight up the sheet. You also know that directions based upon the four points of the compass and intervening positions appear in many property descriptions and show an angular relationship between courses. I suspect that many of you also request survey work on occasion and may specify what meridian is to be used in those surveys. And many more interpret or prepare property descriptions which use these directions.

Have you ever noticed that a single line on the county tax assessor's map, for example, may have three or four different directions noted along its length? Or that two adjoining descriptions may have different bearings called along what is presumably a common line? Can all be correct? How did this come about?

Let's take a look at how and why a surveyor uses bearings in ascertaining the geometry of a relatively small parcel of land, "relatively small" meaning sizes of normal ownership as opposed to sizes involved in the mapping of entire cities or counties.

All such land parcels are geometric figures which are defined on a plane surface by angles and distances, as is shown in Figure 1. Even curvilinear figures can be reduced to triangular segments such as you in Figure 2. In order to be certain that the described figure is mathematically correct, or "closes,"as the surveyor says, you check this collection of triangles, one against the other, to see that all dimensions are compatible from one triangle to the next.

But there is an easier way illustrated in Figure 3. If you calculate the triangles enclosing the figure based on the direction of one line of the figure, in this case the one along the left side, you find yourself dealing only with right triangles and no longer have to deal with pesky formulas such as the law of sines or the law of cosines. Also the veracity, or mathematical integrity of the figure is proven if the algebraic sum of all of the "vertical" components is zero and the algebraic sum of all of the "horizontal" components is zero.

In Figure 4, we take this concept one step farther and relate the figure to a pair of axes set perpendicular to each other, and calculate the positions of the various points relative to the point where the two axes intersect. This intersection point is referred to as the origin of the system. Mathematicians would refer then to the position of any point in the figure as being at coordinates x and y; x being the distance along the x-axis from the origin, and y being the distance along the y-axis from the origin. The surveyor prefers to call distances along the y-axis "north" and distances along the x-axis "east." This method of calculation is known as coordinate geometry.

The important concept here is that so long as the axes are constructed perpendicular to one another, their direction relative to the figure is of no importance in the calculations. Therefore, the base direction of the controlling line in the figure may be related to a recognized coordinate system, or it may relate to some other record direction of the line such as the Public Land Survey System or to a plat or to an old deed or a deed being retraced or to a celestial observation or to a recognized map projection, or it may simply be assumed.

A mix of these different "bases of bearings" often accounts for the different directions along the same lines seen on many maps. So long as the base direction is described in the deed or plat, the figure can be computed relative to that document. However, mixing of bearing systems obviously does not work and has resulted not only in confusion over boundary line locations, but even in lawsuits often brought about by the need to ascertain the intent of the author of the description.

You may have noticed that I just skipped very lightly into the use of the term "bearing". Let us look now at Figure 5, which illustrates just what a bearing is. If you construct these same axes just discussed, and then draw some straight lines in random directions through the origin, you can see that the bearing of a line is the angular direction measured from the north–south axis toward the east–west axis. In other words, the bearing north 60 degrees east defines a line that makes an angle of 60 degrees in a clockwise (easterly) direction from north. Similarly, a bearing of south 45 degrees east defines a line that makes an angle of 45 degrees in a counterclockwise (easterly) direction from south. As the directions north and south from the same point of origin define the very same line, but going in opposite directions, so do the bearings north 60 degrees east and south 60 degrees west, and either notation is correct to describe the aspect of that line, although not its absolute direction. This is true of all bearings of the same numerical value that are in opposing quadrants (i.e., northeast and south-

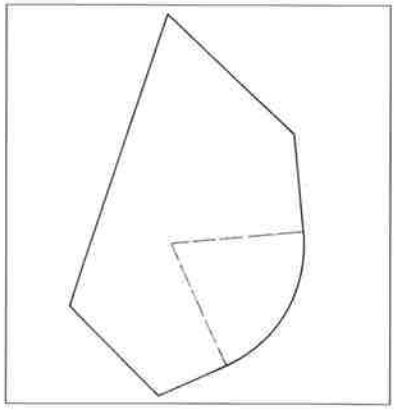

Figure 1

west or northwest and southeast).

In the lower portion of Figure 5 appear two other directional systems often used by surveyors, although seldom in property descriptions. These are known as "azimuth" notation and work the same as bearings except that rather than showing angular direction in quadrants of 90 degrees each, angles (azimuths) extend through the full 360-degree circle and are always measured in a clockwise direction, north azimuths having zero degrees equals 360 degrees at the north position and south

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azimuths having zero degrees equals 360 degrees at the south position. Azimuths are often used in the calculation of coordinates because of the relative ease of addition and subtraction of angles within this system.

The terms "true north" and "magnetic north" are often encountered in requests for surveys and/or mapping specifications. To understand what these terms mean, one must understand the configuration of our planet earth, the location of the north magnetic pole, and map projections often used in surveying and mapping practice.

Contrary to the expressed beliefs of a famous society located in Great Britain, consensus has it that the earth is not flat. While the best generally available map of the earth is a globe, spherical in shape, it is not truly a sphere either. The proper term for the actual shape of the earth is geoid, which can be closely ap-

proximated by an hypothetical ellipsoid. Due to centrifugal force created by the rotation of the earth, its diameter at the equator is greater than that at the poles, so a section of the earth through the poles can be described as an ellipse with a major and minor axis. When this ellipse is rotated about the poles the ellipsoid is generated.

That having been said, let us describe the ellipsoid and geoid in less scientific but more easily comprehended terms. Imagine a basketball on which a rather large basketball player is sitting. Since the player's weight squishes the ball somewhat, it becomes shorter from top (north pole) to bottom (south pole), and increases most in girth halfway between the two. This is a fair description of the ellipsoid, which we will henceforth refer to as the basketball.

Now, onto the basketball, paste lumpy protuberances represented upon the earth as mountains, and form depressions in the basketball such as we see on the earth as oceans, deep lakes, and valleys. The basketball emasculated in this manner now assumes the actual shape of the earth, or geoid, and very much resembles a lumpy old potato. Henceforth we will refer to the geoid as the potato.

The earth, while orbiting the sun, rotates about its axis. The two ends of this axis are the north and south poles.

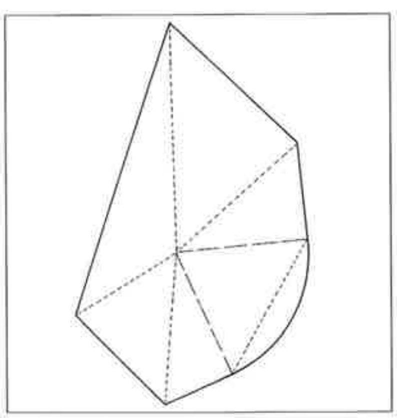


Figure 2

Great circles of the earth running between these two poles are geodetic north–south lines. All geodetic north–south lines when drawn upon the basketball converge at the north and south poles and are most distant from one another at the equator. Obviously, geodetic north–south lines are not parallel to one another.

While international boundaries and boundaries between states often follow lines of latitude and longitude, the types of boundaries here under discussion are based on projection to a plane. The Public Land Survey System, which provides the primary framework for land ownership outside of the original 13 colonies, while taking geodetic convergence into account by providing correction corners at 24-mile intervals and government lots along the north and west tier of each township (6-mile intervals), treated the final product as a plane survey.

I believe that by now every state has adopted a map projection to provide a consistent mapping relationship throughout that particular state which can be easily related to the North American Datum of 1983 and through which plane coordinate positions in latitude and longitude (geodetic positions, or positions defined by horizontal and vertical angles imposed upon the basketball) can be readily calculated. The North American Datum of 1983 is the name for the ellipsoid (basketball) to which the Global Positioning System satellites relate.

The two most common map projections which have been adopted by the various states are known as the Lambert Conformal Conic Projection and as the Transverse Mercator Projection, the first relating to an unfurled cone and the second to an unfurled cylinder. I will describe the Lambert Conformal Conic Projection since that is the one used in my home state of Washington and the one with which I have had some experience. The Mercator projection exhibits the same anomalies in regard to the relationship between grid north and geodetic north, which is what we are here concerned with. The purpose of these projections is to allow us to map the surface on a plane and to describe and locate property using plane geometry.

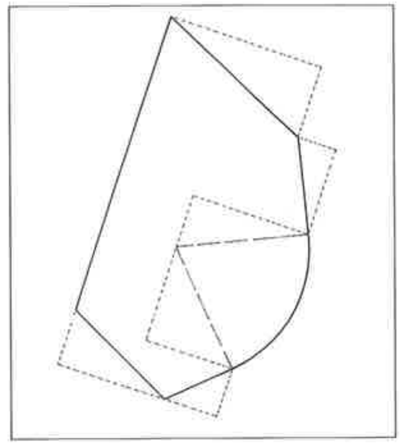


Figure 3

Envision a cone with with its apex on the northerly extension of the earth's axis passing through two lines of latitude, the cone being below the surface of the basketball between these two lines and above the surface outside of these two lines, as shown in the upper left portion of Figure 6. Then consider just that portion of the cone lying between two limiting lines of longitude and cut out that segment of the cone. If that segment of the cone is then laid out flat, the two lines of latitude (east–west lines) are parallel curved lines called standard parallels, and a line of longitude (north–south line) midway between the two limiting lines of longitude is referred to as the central meridian and is the base for the rectangular grid to be imposed on the flattened conical segment. All lines parallel with this central meridian will bear grid north and south, and lines perpendicular thereto bear grid east and west. This is the Lambert Conformal Conic Projection.

Plane survey data based on this system will reference north as being grid north, which as you can see in the lower portion of Figure 6 is identical with geodetic north only at points along the central meridian. However, given the coordinates of points within the plane projection, any competent surveyor can compute not only the latitude and longitude of any point therein, but can also compute the mapping angle, which is the angle between grid north and geodetic north at any point.

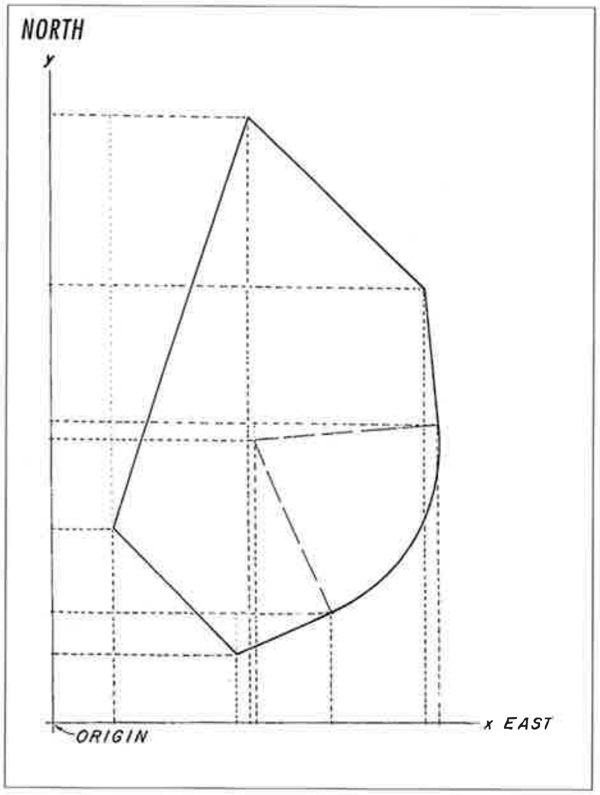
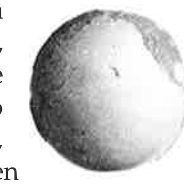


Figure 4

Magnetic north is the direction in which a compass needle will point from any particular place. If no consideration is given to local magnetic attraction, the compass needle will point toward the north magnetic pole which is located in northern Canada. Unless one is located along a line of longitude passing through the north magnetic pole, the compass will not point toward geodetic north. The difference between the two directions is called magnetic declination or variation. In the Seattle area magnetic north is approximately 23 degrees east of geodetic north, and I suspect that in Pittsburgh magnetic north is probably some less degree to the west of geodetic north. In addition, the position of the north magnetic pole changes over time, so magnetic directions must also be adjusted for this change if they are to be used in retracement. The direction the needle will point throughout each day also varies, and this daily variance is known as the diurnal. Furthermore, the diurnal varies from day to day and is dramatically affected by sunstorms as well as cloud cover and temperature.

It should be noted that all distances called in deeds and all distances shown on survey maps are horizontal distances, that is, they are measured along a horizontal line as opposed to along the sloped terrain. While field measurements are often made along a slope, the angle of the slope is also measured and the distance reduced mathematically to the horizontal.

If a survey is presented on a state plane coordinate system, these horizontal measurements are further reduced to their length at sea level and then multiplied by a scale factor so that they will conform to the map projection being used. In the case of a Lambert projection, the scale factor will be unity along the two standard parallels, less than one between the two, and greater than one north or south of them.



Back to true north. Geodetic north is probably what one would most likely consider to be true north, but some folks insist that astronomic north is in fact true north. Unfortunately, these two are not the same due to deflection of the vertical cause by gravitational effects of the geoid (potato) as opposed to the ellipsoid (basketball), which differences vary throughout the earth and can be overcome by applying something called the Laplace correction. In any event, both geodetic and astronomic north are not parallel through two points separated in an east–west direction.

I brought to you what seemed to be a simple question, "Which way is

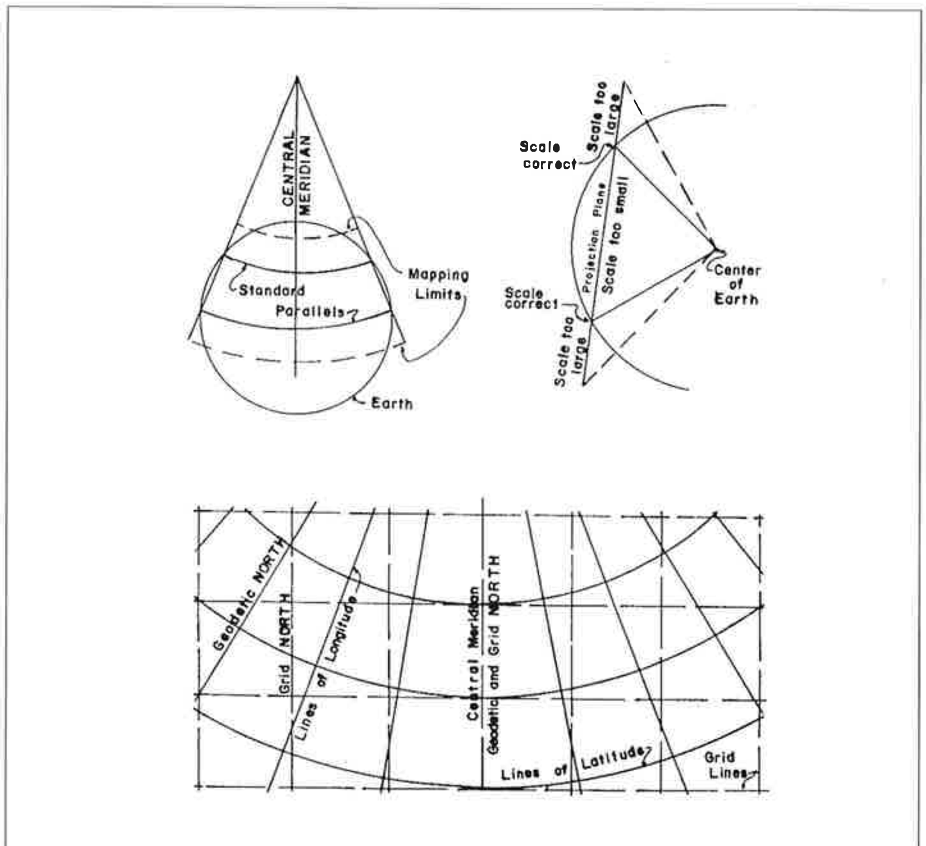


Figure 5

north?" I leave you to ponder the same question with perhaps a better understanding of the use of that term. ❑

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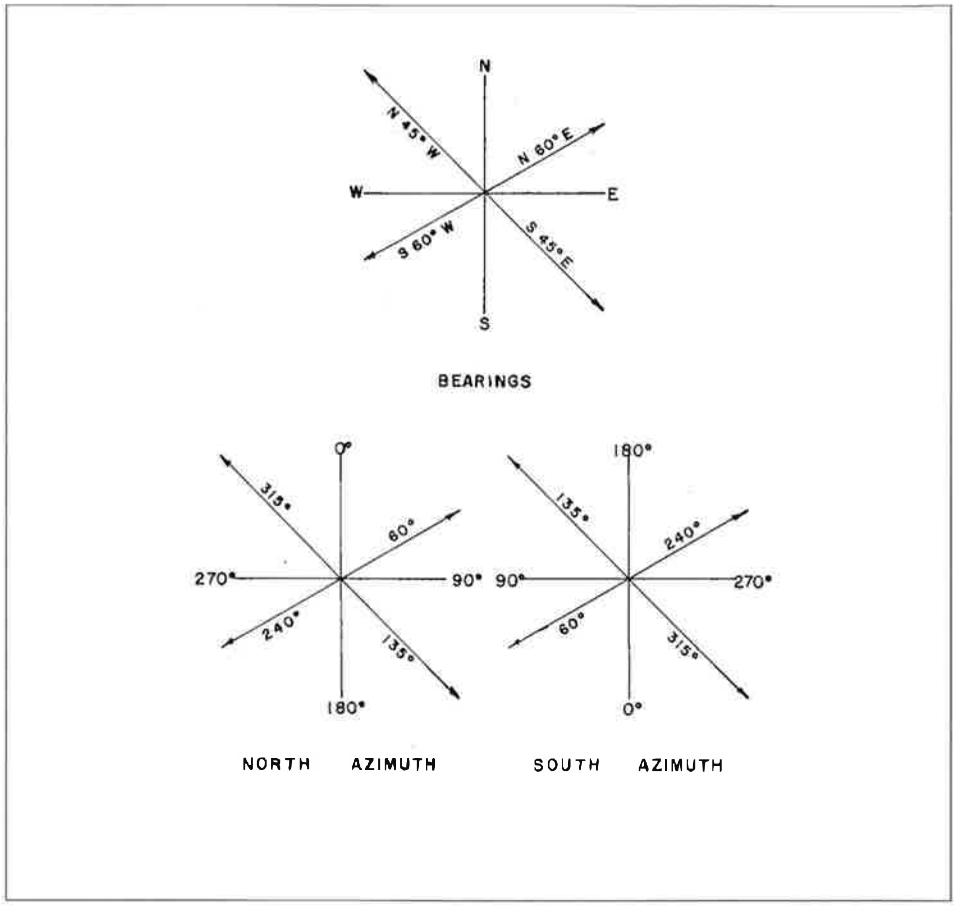

Figure 6