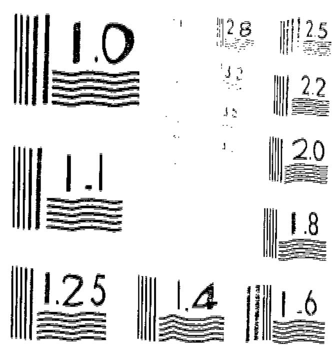
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ABSTRACT

In order to visualize relationships of space for teaching mathematical geography, this booklet shows how the globe may be used as a model of the earth in space. Its purpose is to stimulate the teaching of mathematical principles in secondary-school geography and earth science through a survey of basic principles of global usage. The introduction on using the globe discusses what it is, its advantages, its limitations, types of globes, and types of mountings. A discussion of the lines on a globe includes number and spacing of grid lines, parallels of latitude, meridians of longitude, direction in latitude and longitude, finding locations on a globe, and the great and small circles. How the earth is illuminated by sunlight involves its position in space. The discussion about illumination covers artificial illumination of the globe, summer solstice, winter solstice, equinoxes, length of day and night, subsolar point, tropic lines, natural illumination, sunrise and sunset, and location of the subsolar point. The concept of time is presented in relation to light and space by describing earth as a timepiece, noon and the meridian, equation of time, analemma, time and longitude, standard time, effect of repeated time changes, international date line, and time changes on the globe. (ND)

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DO IT This Way

GEOGRAPHY

VIA USE OF

THE GLOBE

WILLIAM M. McKINNEY
Wisconsin State University,
STEVENS POINT, WISCONSIN

NATIONAL COUNCIL FOR GEOGRAPHIC EDUCATION

2

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FOREWORD

To many people the word "geography" brings to mind only the location and description of places upon the surface of the earth. To those who deal with this subject on the more advanced levels, geography requires that we explain as well as describe the distribution of things. To do this with thoroughness, a number of subdivisions of the field have been created, including mathematical, physical and human geography.

Like many of our basic tools, the globe can be used to demonstrate geographic principles on all levels. In addition to showing the simple locations of political and physical features, it can also be used in the teaching of *mathematical geography*. This topic, which treats the earth as a planet, has been the least appreciated area of geography, mainly because of the difficulty that students have in visualizing relationships of space. It is hoped that this booklet, which shows how the globe may be used as a model of the earth in space, will stimulate the teaching of mathematical principles in secondary school geography and earth science.

The author wishes to acknowledge the help of the Denoyer-Geppert Company in granting permission to use figures 1, 2, 3, 6 and 12, of Dr. John W. Morris in organizing the project, of my wife in typing the manuscript, and of my many teachers, from Mr. Horsman to Dr. Raisz, in giving their knowledge of of the geography of spatial relationships.

William M. McKinney

CONTENTS

INTRODUCING THE GLOBE

What Is A Globe?

The common globe, or *terrestial globe*, is a sphere, upon the surface of which is placed a representation of the land and water bodies of the earth. Other types of globes have been made, such as the celestial globe, but in the study of geography we are primarily concerned with the terrestial type.

A sphere is a round body, so constructed that all points upon its surface are the same distance from its center. It is the three-dimensional equivalent of a circle.

You may have read that the earth is not a perfect sphere. It has been known for more than two hundred years that it is slightly oblate, or flattened at the poles, and more recent discoveries have indicated a slight "pear shape" of our planet. However, most people overestimate these deviations from a spherical shape. On a fifteen-inch globe, the amount of "flattening" at the poles would amount to only one-twentieth of an inch, and the bulges due to the "pear shape" are even less significant. For our purposes, the earth can be treated as if it were a true sphere, and thus manufacturers have made their globes on a spherical pattern.

Advantages of Globes.

Since they are almost perfect representations of the earth's surface, globes have certain advantages over maps:

1. Distances, areas, directions, and true shape will appear in their correct relationship to one another upon a globe. This will not always be true in the case of maps, in which the round surface of the earth must be "stretched" and distorted to fit upon a flat piece of paper.

2. The globe is the best instrument for conveying the illusion of the earth as seen from space.

3. The globe is an excellent device for illustrating certain principles of mathematical geography, such as the length of great circle routes, or the variations in the length of the day. Upon a globe, problems of this nature can be solved directly by *graphical methods*, in terms that can be readily understood by the average secondary school student, rather than by the more advanced methods of spherical trigonometry.

Limitations of Globes.

After reading the paragraph above, one might wonder why flat maps are used at all. Actually, there are also several disadvantages of globes, which must be understood by anyone using them:

1. Globes, being bulky, are difficult to handle and to store.
2. Globes are much more expensive than maps. Further, as they become larger in size, their prices increase sharply. This explains why the early globes were so small, and why globes larger than thirty inches in diameter are still rarely encountered.

Fig. 2 — Horizon Ring

3. While it is possible to show all, or almost all, of the earth's surface upon a single map, no globe can show as much as one-half of the earth's surface to the viewer at any one time.

Thus, globes are not a complete substitute for all other types of representations of the earth's surface. They are designed specifically for special purposes.

Types of Globes.

Globes may be classified in two different ways. One is to arrange them by the types of information printed on their surfaces; the other is to arrange them according to the ways in which they are mounted for use.

In the first type of arrangement we have political, physical, and slated globes. The *political* globe, which shows mainly the nations and principal cities of the world, plus, perhaps, the states and provinces of Anglo-America, is the type with which we are most familiar. Most globes for home use are of this type. The various political divisions are usually portrayed in bright colors.

For classroom purposes, the *physical* globe may be more useful. In this type more attention is given to the relief features and drainage systems of the earth, and the colors employed are more natural and subdued. The majority of such globes are not strictly physical, but a compromise type called physical-political, in which the boundaries and cities are printed over the colors indicating relief. An interesting example of a purely physical type of globe is the *relief* globe, in which the mountains and valleys are actually indicated on the surface in three-dimensional relief. In order to make these features stand out on a small globe, it is necessary to exaggerate their height and depth, so that they are actually not true models of the earth's surface.

A third type, the *slated* globe, is either completely blank, or has blank outlines of the land and sea areas upon its surface (Fig. 1). It is covered with a surface material upon which one may draw with chalk, as if on a blackboard. These globes are extremely valuable in demonstrating basic mathematical relationships to a class, such as the principles underlying latitude and longitude.

Types of Mountings.

There are two principal types of mountings for globes, the axial and the cradle mountings. The axial mounting is the more common of the two; in this case the globe is mounted so that it may be rotated on an axis passing through its poles. This axis is usually inclined 23½ degrees away from the vertical, just as the earth's axis is inclined toward the plane of its orbit. The axis may be suspended from a large vertical circle or semi-circle, termed the *meridian ring*. Axial mountings are ideal for demonstrating the rotation of the earth and the different ways in which the earth may be illuminated during the seasons.

In the cradle mounting the globe lies freely within its mounting so that it may be turned to any position, or even removed entirely from the cradle. Often the top of the cradle is furnished with a horizontal circle, graduated in degrees, termed the *horizon ring* (Fig. 2). The cradle mounting is especially useful for showing the various hemispheres of the earth, for measuring great circles, and, above all, for rectifying the globe.

LINES ON THE GLOBE

Number and Spacing of the Grid Lines.

Most globes are covered with a network of lines which serve as reference points for the user. The typical globe will have thirty-three such lines, twenty-nine of which will be solid and four of which will be dotted. Twelve of these lines will be meridian circles, and twenty-one (including the four dotted ones) will be parallels of latitude. A slated globe will not have these lines on its surface, but may have markings placed at convenient intervals so that lines may be drawn on the surface at will.

These lines are, of course, purely imaginary. Their spacing and location are based upon a variety of reasons, some of which are related to natural phenomena, and some of which are more arbitrary in nature. The meridians have been spaced fifteen degrees apart along the equator, and the parallels (excepting the four dotted ones) have been spaced ten degrees apart along the meridians. Occasionally globes will be found which have their lines spaced according to different intervals; in fact, an infinite number of such lines could be drawn. But in general, the thirty-three line globe is preferred as it has enough lines for convenience, but not so many that a "cluttered" appearance results.

Parallels of Latitude.

The parallels of latitude are ultimately based upon the North and South Poles. These two points are the two places on the earth's surface which do not move during the daily rotation, and are located where the axis of rotation intersects the surface.

Midway between these poles is the *equator*, which contains all those points on the earth's surface which are equally distant from the two poles. The equator is the basic reference line for determining latitude, and thus latitude is indirectly based upon the natural phenomenon of the earth's rotation.

The reference lines for determining latitude are not referred to as "latitudes" but as *parallels of latitude*. Like parallel lines drawn upon a flat, plane surface, they can never cross one another.

Latitude refers to the angular distance of any place upon the earth's surface from the equator, as measured in degrees or fractions of a degree. To determine this distance accurately, it must be measured by the shortest possible course, along one of the north-south meridians. The equator is thus the zero parallel, every place along the tenth parallel will be ten degrees from the equator, and so forth.

Meridians of Longitude.

The basic reference line for determining longitude is more arbitrary. Many lines have been used for this purpose, but in 1884 the *prime meridian*, which passes through the British Royal Observatory at Greenwich, near London, was chosen by international agreement.

The reference lines for determining longitude are referred to as *meridians of longitude* (not "longitudes"). They differ from parallels in that they are not parallel to each other but meet at the poles. They are drawn in this fashion so that the meridans and parallels will always form right angles, and thus point north-south and east-west, at their intersections. Furthermore, they are not full circles, but only semi-circles running from pole to pole. When a meridian is extended beyond each pole to form a full circle, it is termed a *meridian circle*.

Longitude refers to the angular distance of any place on the earth's surface from the prime meridian, as measured in degrees or fractions of a degree. To determine this distance accurately, it is measured along a parallel. The prime meridian is thus the zero meridian, every place along the tenth meridian will be ten degrees from the prime meridian, and so forth.

Direction in Latitude and Longitude.

If we merely identify a line as the tenth parallel, or the tenth meridian, there still exists the possibility of some confusion. Obviously, two tenth parallels could be drawn, one north and one south of the equator. Similarly, two tenth meridians could be drawn, one east and one west of the prime meridian.

To avoid this confusion, the parallels are further designated as being *north or south* of the equator, and the meridians as being *east* or *west* of the prime meridian. Thus, there will be only one tenth parallel north, and every point along this line can be said to have 10° north latitude. Similarly, there will only be one tenth meridian west, and every point along this line can be said to have 10° west longitude.

It is not necessary to indicate north or south when referring to latitude 0° (the equator), or to indicate east or west when referring to longitudes 0° and 180°. This is because the equator is the dividing line between north and south latitude, and the meridian circle composed of the 0° and 180° meridians is the dividing line between east and west longitude.

Finding Locations On the Globe.

Let us take a given location as defined in terms of latitude and longitude, say, 40°N and 90°W, and locate it on the globe according to the principles given above. We know it must lie somewhere along the circular 40th parallel north, and somewhere along the semicircular 90th meridian west. Each of these lines contains innumerable points, but there will only be *one* point which is contained in *both* circles, and this is located where the two cross. This intersection will be found in western Illinois.

This demonstration is particularly appropriate for the slated globe. The parallel can be drawn by steadying the chalk against the meridian ring, touching it to the mark placed on the globe at 40°N, and rotating the globe through one complete turn. The meridian can be drawn by rotating the globe until the meridian ring is in line with the mark for 90°W, then using the ring as a guide to draw the line from pole to pole.

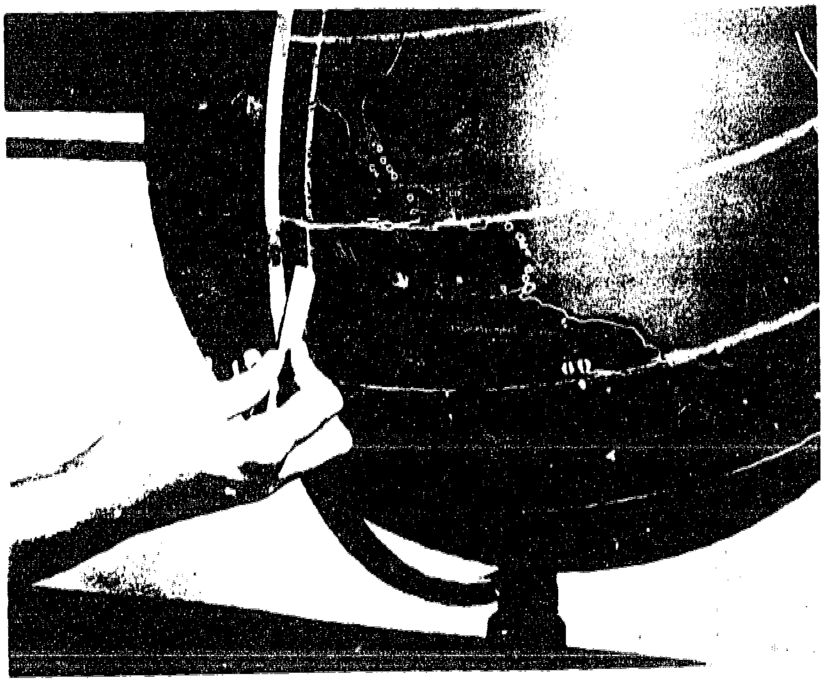

Fig. 3 — Locations on the Globe

Of course, by choosing reference points between the standard mark-gins, other locations could be shown, such as 18°N, 87°W (Fig. 3). Further, by drawing more lines upon the globe, the student can be shown why it is necessary to specify north or south latitude, or east or west longitude, if we are to define a single location. If, as in a previous example, both of the 40th parallels and both of the 90th meridians were drawn, the globe would show four lines intersecting at four different locations: western Illinois, western China, the eastern Pacific, and the eastern Indian Ocean.

Great and Small Circles.

If you will study the parallels and meridians of your globe, you will note that they are not all of the same size. The equator, and the meridian circles, are the largest circles that you can draw upon a globe. If you were to cut through the globe along one of these circles, you would cut through the center of the globe and divide it into two equal halves. Further, you will notice that each of these circles crosses every other circle of this type, and that, when two such circles cross, their crossings are located on the opposite sides of the globe. Circles of this type are called *great circles* (Fig. 4A).

On the other hand, the parallels (excepting the equator) are not the largest circles that could be drawn on the globe. They become smaller as they get farther from the equator, diminishing to single points at the poles. If you were to cut through the globe along such a circle, you would not cut through the center, and the globe would be divided into two unequal parts. Further, they can be drawn so that they do not meet one another. Circles of this type are called *small circles* (Fig. 4B).

The larger the circle, the more closely a portion of this circle will resemble a straight line (Fig. 5). Thus, a route laid along the path of a great circle will be shortest distance between two points on the surface of a sphere. The shortest distance of all, a straight line, would pass below the surface of a sphere.

In addition to the meridians and the equator, innumerable other great circles may be drawn on the globe. They are used in air and sea navigation to save distance in traveling. The simplest method of locating a great circle route between two points is to anchor a tape or string in one location, draw it tight, and then pass it over the other location. If the globe is freely mounted in a cradle with a horizon ring, the globe may be turned so that the two points are located along this ring. In this position the horizon ring follows the great circle route.

Since most parallels are not great circles, they are usually not followed in east-to-west navigation. In the northern hemisphere, the great circle route lies to the north of the parallel; in the southern, it lies to the south of the parallel. As one goes farther north, the parallel circles become smaller, and they deviate more and more from the great circle routes. Thus, using the string or tape, you can demonstrate how the shortest distance from North America to Scandinavia will pass through the polar regions. (Fig. 6).

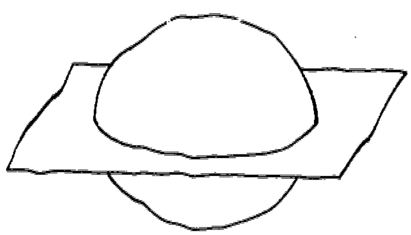

Fig. 4A — Great Circles

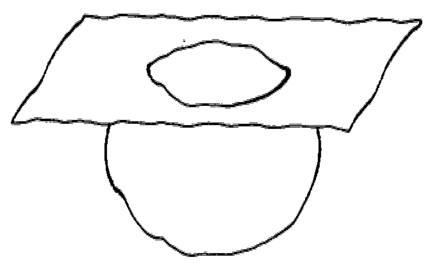

Fig. 4B — Small Circles

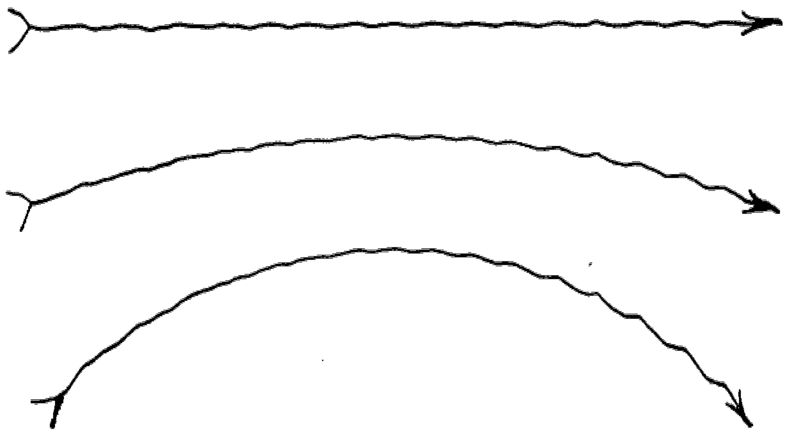

Fig. 5 – Straight Line

The great circle distance between two points on the globe can be measured in inches, either directly with a tape measure, or by comparing the length of string used with a ruler. If you know the diameter of the globe and remember that the earth's diameter is about 8,000 miles, these measurements can be converted into statute miles. Thus, on a twelve-inch globe, one inch will represent about 670 miles, and on a sixteen-inch model, one inch will represent about 500 miles. For greater accuracy, the final answer in miles should be reduced by one percent.

Another method involves the use of nautical miles. In this case the length of string or tape is not measured in inches, but is subsequently laid along the equator, with one end at the prime meridian. The great circle distance can thus be measured in degrees. With a cradle mounting and a horizon ring, the number of degrees can be read directly from the ring. Since a nautical mile is equal to one minute of a great circle, each degree of length will be equivalent to sixty nautical miles. Thus, if the distance were found to be twenty degrees, this would represent 20 x 60 nautical miles, or 1,200. The distance in nautical miles can be converted to statute miles by multiplying again by 1.15.

THE ILLUMINATION OF THE GLOBE

Illumination of the Earth in Space.

The earth in space is illuminated by only one strong point of light, the sun. Coming from an average distance of 93,000,000 miles, the sun's rays are almost parallel to each other, and thus illuminate only half the earth at one time. The boundary between the dark and light halves is called the *circle of illumination;* like the equator and meridian circles, it is a great circle.

If the earth's axis were at right angles to the plane of its orbit, the circle of illumination would always pass through the poles. Since the axis is, in reality, tilted 23½° away from the vertical, the circle of illumination passes through the poles only twice each year, and at other times may be as much as 23½° away from the poles.

Artificial Illumination of the Globe.

The illumination of the earth can be demonstrated by darkening the room and turning a flashlight or spotlight upon the globe. (A slide projector will make a good improvised spotlight.) The rays of light should be horizontal, parallel to the floor, and they should be aimed directly toward the center of the globe. The globe should be mounted so that its axis is inclined 23½° away from the vertical.

Two basic positions of the earth should be illustrated by this technique: that of the solstices, which occur on approximately June 21st and December 21st, and that the equinoxes, which occur approximately March 21st and September 23rd.

Summer Solstice.

To demonstrate the June solstice, which will be the summer solstice for the northern hemisphere, the north polar end of the axis should be pointed directly toward the source of light (Fig. 7). In this position, the circle of illumination will not pass through either pole, but will be a full 23½° away at its closest approaches. At the upper and lower ends of the globe this circle will just touch the two dotted parallels which encircle the poles. These parallels, located at latitudes 66½°N and 66½°S, are termed the *Arctic* and the *Antarctic Circles.*

If you rotate the globe one complete turn around its axis, from west to east, you will notice that the entire area from the Arctic Circle to the North Pole remains continuously illuminated. This, then, is the "Land of the Midnight Sun." Immediately south of the Arctic Circle, locations on the globe will pass through a small portion of shadow during the rotation. As one goes farther south on the globe, the proportion of shadow, as compared with the proportion of light, will increase. At the equator, a point will spend half the time in shadow, half in light, during the single rotation.

Winter Solstice.

South of the equator, the earth is experiencing the winter solstice on June 21st. In the southern hemisphere, each location will spend more time in darkness than in light during the rotation about the axis. The

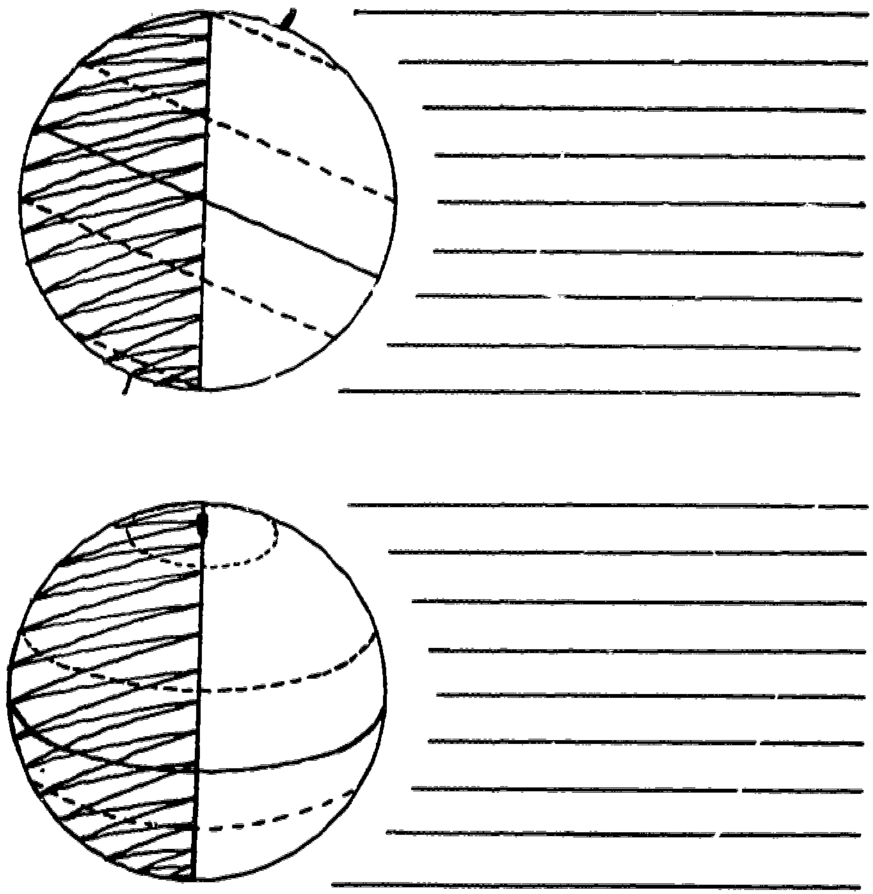

Fig. 7 — Solstice and Equinox

proportion of darkness will increase as one goes farther south until, from the Antarctic Circle to the South Pole, we reach the zone where night lasts a full twenty-four hours.

To illustrate the December solstice, the north polar end of the axis should be pointed away from the source of light. At this time the conditions of illumination will resemble those of the June solstice, except that the conditions in each hemisphere will be exactly *reversed*. Thus, the northern hemisphere will show the conditions of the winter solstice, with darkness exceeding daylight, while the southern hemisphere will show those of the summer solstice, with daylight exceeding darkness.

Equinoxes.

To demonstrate illumination at the time of the equinoxes, the globe should be turned so that the axis turns neither toward nor away from the source of light (Fig. 7). In this position, the circle of illumination will pass through both poles. Every point on the globe, except the two poles, will spend half its time in darkness, half in light, as the globe is spun. This condition will be the same for either equinox; thus, one demonstration will suffice.

Length of Day and Night.

From the foregoing, the following points will become apparent to the viewer:

1. When it is summer in your hemisphere, days must exceed nights in length; when it is winter, nights must exceed days.
2. The maximum length of daylight, or of darkness, increases as you travel toward the pole. Twenty-four hours of daylight or darkness are only possible when you reach the polar circles.
3. When one hemisphere experiences summer, the other has its winter.
4. At the equator, midway between the contrasting hemispheres, days and nights are always twelve hours each in length, regardless of season.

Subsolar Point.

At any given time, there will be only one point on the earth's surface where the sun's rays will be coming down vertically. At this location, termed the *subsolar point*, the sun will appear directly overhead, and a vertical pole will cast no shadow.

The subsolar point is always at the center of the illuminated half of the globe. Thus, in the foregoing demonstration, it will appear at the center of the path of the spotlight beam, and will be equally distant from all parts of the circle of illumination.

Tropic Lines.

The location of the subsolar point changes from hour to hour due to the earth's rotation, and from season to season due to the tilting of the axis. It will always, however, be located between two lines on the globe. On June 21st, it will be over the dotted parallel 23½° north of the equator, termed the *Tropic of Cancer*. On December 21st, it will be over the dotted parallel 23½° south of the equator, termed the *Tropic of Capricorn*. Thus, the two tropic lines, like the other two dotted parallels of the polar circles, are not spaced arbitrarily like the solid-line parallels. Their location has been determined by the conditions of the illumination of the earth.

After each solstice, the subsolar point moves back toward the other tropic. Halfway on this journey, at the times of the equinoxes, the point will lie over the equator.

Natural Illumination of the Globe.

Another basic series of demonstrations involves the use of the naturally illuminated globe. In these cases, the globe is so arranged that it is a true model of the earth in space. Its axis will be parallel to that of the earth, and locations upon the globe's surface will correspond to the same locations on the earth. When placed in direct sunlight, such a globe will be illuminated as the earth is illuminated at the same given time (Fig. 8).

Technique of Rectification.

A globe, when placed in such a position, is termed a *rectified globe.* Globes with a cradle mounting, or with an adjustable meridian ring, may be rectified by the following technique:

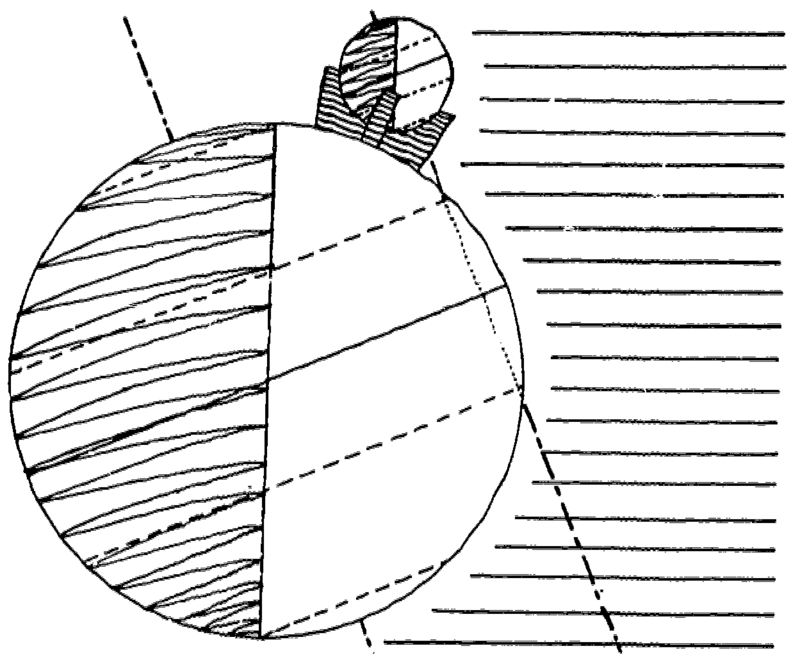

Fig. 8 — Illumination of Globe

1. Turn the globe around its axis until your local meridian of longitude is at the top.
2. Adjust the inclination of the axis so that your particular parallel of latitude is at the top of the globe.
3. Turn the entire globe stand around so that the axis is pointed directly north. If you are using a magnetic compass, make sure that you allow for declination east or west. In some communities, the streets and even some public buildings have been laid out according to the points of the compass, making it easier to locate due north.

The rectification of the globe may be checked in the following manner:

1. Your own locality must be located at the very top of the globe.
2. If the globe has a horizon ring, trace a line from the top of the globe, through the pole, to the ring. Where this line meets the ring, the latitude should be equal to ninety degrees minus the latitude of your community. Thus, if you were at Chicago, 42°N, the horizon ring should pass directly below the North Pole at latitude 90° — 42° or 48°N (Fig. 9).

A third check will be discussed under the topic of the analemma.

Natural Illumination by Seasons.

Since the rectified globe cannot be shifted in position during a demonstration, a complete yearly sequence of earth-sun relationships cannot be shown in one lecture. For example, to show the earth at the time of the

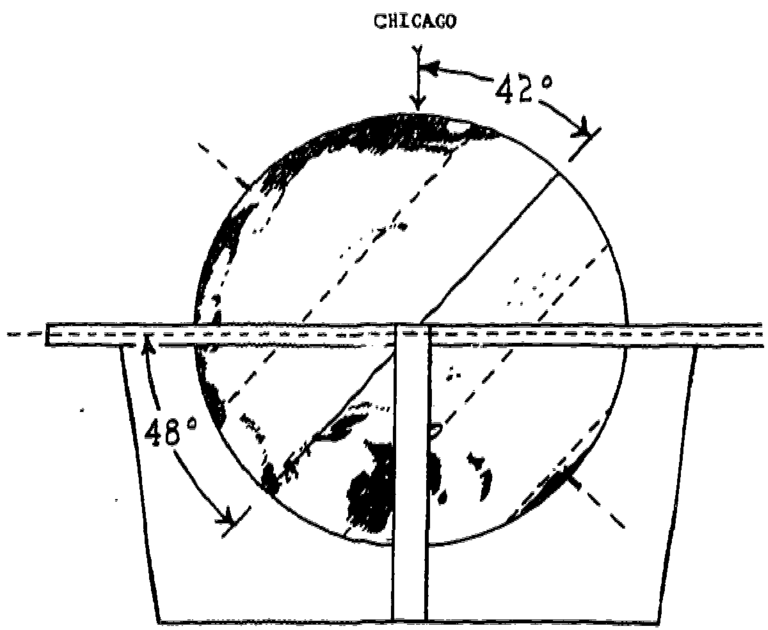

Fig. 9 — Rectified Globe

solstice, one must wait for the solstice. This disadvantage is compensated by the fact that the student can see how the earth would appear illuminated to an observer in space at the very moment of the very day that the demonsration is given (Fig. 10).

Sunrise and Sunset.

The earth turns upon its axis in a west-to-east direction. Since the circle of illumination remains more or less stationary during this rotation, it appears to move, with respect to the earth, in an east-to-west direction.

On the rectified globe, the circle of illumination will determine the lines of sunrise and sunset. If the demonstration lasts for any length of time, the relative position of the circle will change so that new areas to the west will come under illumination. In that portion of the globe, the circle represents the line of sunrise. During the same period, an equivalent area to the east will have fallen into shadow, and in this region the circle represents the line of sunset.

Length of Day.

Day and night are caused by the rotation of the earth. Since the earth turns a full circle (360°) in twenty-four hours, it will turn 15° in one hour ($360° \div 24 = 15°$.) This principle gives an easy method of determining how long daylight will last at your latitude on the date that you have rectified the globe. Using the meridians as a guide, measure the number of degrees along the illuminated portion of your local parallel, from one edge of the circle of illumination to the other. This number of degrees, divided by fifteen, will equal the number of hours from sunrise to sunset.

For example, on June 21st, there should be 225 degrees in the illuminated portion of the 40th parallel on a rectified globe. $225° \div 15 = 15$ hours, the length of time between sunrise and sunset at that latitude.

You will note that, regardless of the date of rectification, half the equator will always be in light, half in darkness. This is because the equator and the circle of illumination, being great circles, must intersect at opposite ends of the globe, 180° apart. $180° \div 15 = 12$ hours, the invariable length of day at the equator.

Locating the Subsolar Point.

As mentioned previously, at the subsolar point a vertical pole will cast no shadow. This principle can be used to locate this point upon a rectified globe.

For the vertical pole, substitute a common pencil. Taking care to keep it pointed toward the center of the globe, hold it above the globe and move it about until its shadow becomes the smallest possible spot. (To avoid interference from the shadow of our hand, the pencil may be held by a pin thrust in its side.) If the globe is correctly rectified, the pencil will then be over the subsolar point (Fig 11).

TIME AND THE GLOBE

Earth as a Timepiece.

The earth is a natural timepiece. Time is directly related to many types of phenomena relating to the earth, including, among others, the daily rotation about the axis, and the seasonal movement of the subsolar point from tropic to tropic.

Noon and the Meridian.

For convenience, the day is divided into two parts. The dividing time was originally taken to be *local noon*, the time of day when, for a particular locality, the sun was highest in the heavens and was due south of the observer if he lived north of the Tropic of Cancer. At that time the sun would be directly overhead somewhere along the local meridian. Before the sun reached this point the time was *Ante Meridiem* (A.M.); after it had passed, the time was *Post Meridiem* (P.M.).

Equation of Time.

However, it was later discovered that, due to certain aspects of the earth's motion about the sun, it was not always exactly twenty-four hours from one local noon to the next. For convenience in setting mechanical timepieces, these slight differences were averaged so that each day was always twenty-four hours in length. This averaged time was called mean solar time, or, more popularly, *clock time*. The difference between local noon, sun time, and noon, clock time, is called *the equation of time*.

Analemma.

It is thus obvious that, if we use clock time, the sun will not always be "on the meridian" when our watches read noon. Thus, if we could graph the different daily locations of the subsolar point with respect to the meridian, we could determine the equation of time for any day of the year.

Such a graph is called an *analemma*. On many globes it can be found as a graph shaped like a figure eight, running from tropic to tropic along the meridian of 120°W (Fig. 12) It could be located along any meridian, but, in the eastern Pacific Ocean, it has been found possible to draw a complete analemma without obscuring details of the land areas of the earth.

The analemma, which has been marked according to the days of the year, may be used for the following purposes:

1. To determine the latitude of the subsolar point. The analemma touches the Tropic of Cancer at the point marked June 21st, the Tropic of Capricorn at December 21st. At the times of the equinoxes the graph crosses the equator. These basic locations of the subsolar point are, of course, well known, but the analemma permits us to locate the point for other dates of the year. For example, for February 15th we will find the subsolar point at 13°S; for August 1st, at 18°N.

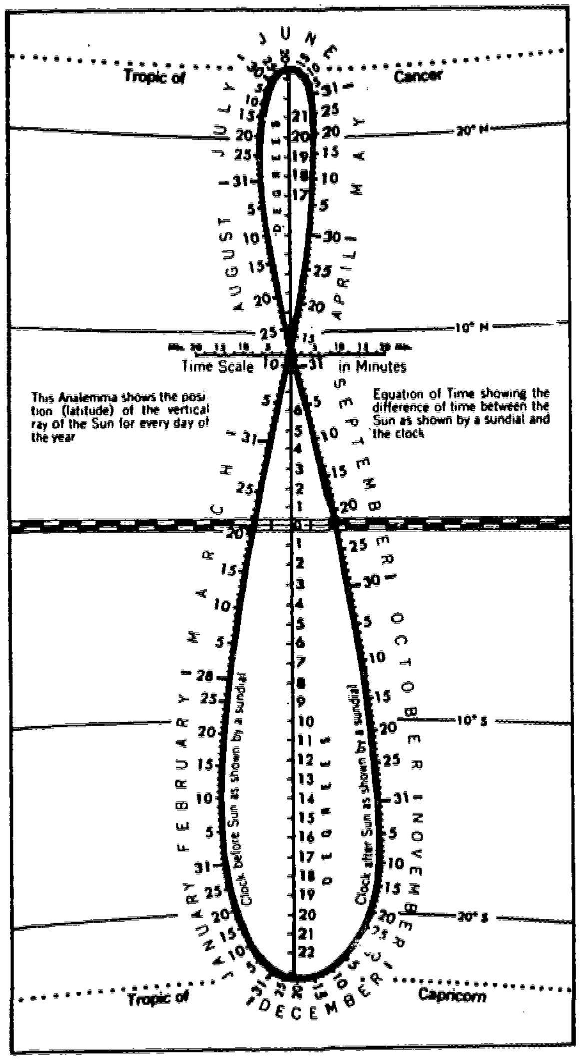

Fig. 12 — The Analemma

2. To determine the equation of time. When the sun has not yet reached the meridian at noon, clock time, the analemma for that day will be located to the east of 120 degrees. On such days we state that the sun is *slow*, compared with clock time. When the sun has already passed the meridian at noon, the analemma for that day will be located to the west of 120 degrees, and we state that the sun is *fast* for that day. These daily variations from east to west give the analemma its characteristic figure-eight shape. The variations can be read on the globe in degrees, and these can be converted into minutes of time by allowing four minutes for each degree of longitude ($60 \div 15 = 4$). On some globes the task is made simpler by a scale reading directly in minutes. Four times during

the year, around April 16th, June 15th, September 1st, and December 26th, the analemma crosses the 120th meridian. When this happens, sun time and clock time will be the same, and the equation of time will be zero.

This use of the analemma was important when people had to check their timepieces by the sun, and thus analemmas were placed upon sundials. With the advent of radio and telephone time signals, many people have forgotten the purpose of the analemma.

3. To check upon the rectification of the globe. The analemma shows the different locations of the subsolar point for each day at noon, clock time, along the 120th meridian. This is the same as 12 noon, Pacific Standard Time; 1 P.M., Mountain Standard Time; 2 P.M., Central Standard Time; 3 P.M., Eastern Standard Time; or 4 P.M., Atlantic Standard Time. For Yukon, Alaska · Hawaii, and Bering Standard Times, subtract 1, 2, or 3 hours, respectively, from 12 Noon.

At the appropriate time, as given for your time zone, locate the subsolar point on your rectified globe by the shadow method. The subsolar point should then be located directly over the analemma, at the point on the graph marked for the given day of the year (Fig. 11). If this does not happen, the globe should be moved north-south along the local meridian, or rotated east-west around its axis, until the two points coincide. Then, and only then, will the globe be properly rectified.

Time and Longitude.

Since local noon is determined by the sun's position with respect to the local meridian, it will be obvious that there will be a different local time for each meridian. Time thus varies according to one's longitude.

This can be shown on the rectified globe by means of a pocket sun dial, or "sun watch." The pocket dial is placed at the top of the globe, the location of your home community. Remember to elevate the gnomon, or shadow stick, of the dial the same number of degrees above the face of the dial as your latitude. When the gnomon is pointed due north, along the local meridian, the pocket dial will indicate local time. It is best to conduct this demonstration when the equation of time is close to zero, *otherwise the dial may be as much as a quarter-hour from clock time.*

If you slide the dial over the globe eastward along your local parallel, taking care to keep the gnomon pointed toward the pole of the globe, the dial will indicate a later time. If you move the dial westward, it will indicate an earlier time.

Standard Time.

Local time, of course, is rarely used now. Late in the Nineteenth Century the needs of the transportation industry forced the adoption of *standard time.*

When standard time was created, North America was divided into a series of zones running north-to-south over the continent. Through each of these zones runs a *standard meridian*, and the longitude of this meridian will be a multiple of 15°. Standard time for each zone is taken to be the local clock time along the standard meridian, thus eliminating the need for numerous resettings of the watch as one travels east or west.

If you are living some distance from the standard meridian of your zone, the time will change noticeably as you move the pocket sun dial from your locality to this meridian. Also, by moving the dial from one standard meridian to another, it can be shown how the time of each zone differs from that of the others, and how a movement through fifteen degrees of longitude produces a difference in time of one hour.

Effect of Repeated Time Changes.

If you continued to travel eastward, by the time you had traveled completely around the globe and returned to your starting point, you would have set your watch *ahead* one hour for each fifteen degrees of longitude traversed. Since there are 360 degrees in a complete circle, this procedure will occur twenty-four times during a trip around the world ($360° \div 15° = 24$). Thus, your own personal time would have advanced twenty-four hours, or one complete day, ahead of the time at the place of your departure and arrival.

If, on the other hand, you traveled westward, you would have set your watch *backward* one hour for each fifteen degrees of travel. Upon completing your circuit of the earth, your own personal time would be one complete day behind the time at the place of your departure and arrival.

International Date Line.

To avoid such occurences, the *International Date Line* was created about the same time that our standard time zones and prime meridian were adopted. This will appear on your globe as a line, dark red or black in color, running approximately along the 180th meridian, but deviating to east or west occasionally so that it may pass through the unpopulated open seas.

The International Date Line is the place where the traveler makes an adjustment for the steady gain or loss of hours occasioned during a world voyage. Since this line represents the only place where he can compensate for the loss or gain, he must take full advantage of it and make an adjustment of a full twenty-four hours in one operation.

Further, the nature of the adjusment in days must be the opposite from the small hourly adjustments that he has been making. Thus, he is bound by the following rules:

1. Traveling east:
   a. Set the watch *ahead* one hour for each 15° traversed, but,
   b. Set the calendar *back* one day upon crossing the Date Line.
2. Traveling west:
   a. Set the watch *back* one hour for each 15° of longitude traversed, but,
   b. Set the calendar *ahead* one day upon crossing the Date Line.

Time Changes on the Globe.

The above principles can be shown by the use of the globe. Turn the North Pole toward the class, and set the pointer on the standard meridian for your time zone, noting your present standard time and date as you do so. (Avoid the use of daylight time, which will only add to the confusion). Then point to the standard meridian for the time zone to the east, and note that the time there will be one hour later.

If one continued in this fashion, by the time the pointer had returned to the meridian used as a starting point, the time would have been advanced one whole day. However, if you take care to set the calendar back one day at the Date Line, you will return at the same time that you started, plus whatever few moments have been occupied in the demonstration.

For example, if you started from the 90th meridian west at 10:30 A.M. Tuesday, by the time you reached the 180th meridian, the time would have advanded to 4:30 A.M. Wednesday. But, upon crossing the Date Line, the calendar is set back to Tuesday, and when one arrives back at 90°W, it is still Tuesday, shortly after 10:30 A.M., C.S.T.

The same demonstration can be made by moving the pointer from east to west around the globe, except that you must set the clock back, and the calendar ahead, at the appropriate locations along the way. The teacher can enliven the discussion by mentioning Jules Verne's fictional account of the journey of Phileas Fogg, who gained a day traveling eastward around the world, or the true story of the ship Victoria of Magellan's expedition, which lost a day traveling westward.

ADDENDUM

A booklet of this length is intended as a survey of the basic principles of globe usage, treating those topics of mathematical geography which are most likely to be covered in the typical secondary classroom. As one might well suspect, more demonstrations than the foregoing are possible, particularly with the rectified globe. If the reader is interested in pursuing the subject further, he might turn to the following references:

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