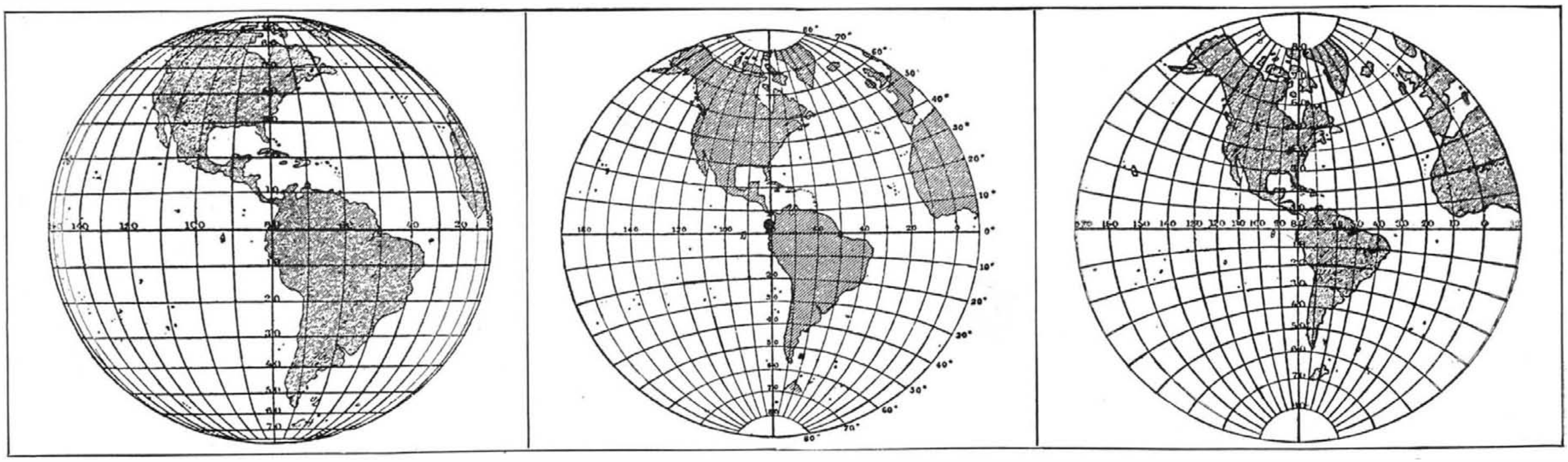


Left: Orthographic projection. *Center:* Globular. *Right:* Stereographic

Three different schemes of mapping the earth, and their results when applied to a hemisphere

A Map's Other Name Is Ananias

The Various Projections Used in Representing the Earth's Surface, and What They Do to the Facts

By C. H. Claudy

DO you know what a map is? It sounds like a foolish question. You will probably contend that every school boy knows. If pressed for a definition you will probably say "a map is a drawing which exactly represents a portion of the earth's surface, the distances between points upon the map being proportional to distance between the points upon the earth represented" or some similar explanation.

But this is only partly true. There is only one kind of map in existence which will truthfully fit such a definition, and that is a map made upon a globe. No flat map, large or small, "exactly represents" any portion of the earth's surface, and only on a globe are the distances between all points truly proportional to distances between points on the earth represented.

In other words all flat maps are distorted. All flat maps tell only a part of the truth. All flat maps to some extent misrepresent the facts.

This is not due to any lack of moral sense on the part of the map makers. They can't help it. The nature of a globe is such that there is no process by which its surface can be flattened out without tearing, stretching, cutting or compressing. And the earth is a globe (slightly flattened at the poles.

If the earth had happened to be a cylinder, maps would all be truthful. A cylinder can be slit lengthwise and, with the ends removed, its surface flattened out into a square or oblong plane. Had the earth chanced to be a cone, maps of it could be made with perfect accuracy, for a cone, like a cylinder, can be slit and unrolled. Or had the earth been a cube or a polygon, we could make accurate maps of what was upon its many sides.

Nature, however, decreed that the earth should be a globe (nearly). Any flat map we make on paper (as opposed to one constructed on a ball) must represent a part or the whole of this globe. As it is impossible to flatten a part or the whole of a globe without stretching, tearing or compressing, any map of any part or the whole of the globe must be distorted.

We can control this distortion. We can make our maps, for instance, fairly accurate as to the apparent outline of countries or lakes or of oceans. When we look up and see the full moon, it appears to our eyes as a flat bright disk, with markings upon it. If we actually draw these outlines on flat paper, we have a map of the moon which is truthful in outline to what we see.

But the distances, as shown on our lunar map, will not be truthful. Such a map must show the center as distant from the rim of the moon an amount equal to half its diameter, while the center is actually distant an amount equal to one-fourth the circumference. And what is true of the central point as compared to the rim is true of any other two points.

If we make an accurate outline map of North America, so that the countries appear to the eye as they would to an observer on the moon, the distances will not "measure true." And the closer to the rim of our circular map we get, the greater the "compression" and the less the accuracy.

There are a great many methods of making maps—a great many different "projections" as they are called. This name is used for the basis on which maps are made, because "projecting" is the process. Let us suppose a globe of glass, with a tiny but strong light in its center. On the outside of the globe of glass we draw with dark opaque paint, the land surface of the globe. Let us suppose that we curl a sheet of white paper into a cylinder which fits close to the illuminated globe, in such a position that its sides are parallel to the axis, drawn through the poles. Upon the paper, then, will appear a shadow of the countries we have painted on the glass globe. If we now draw these shadows on the paper, and then unroll the paper, we have a "cylindrical projection" of the land contours of the earth. In regions near the equator they are almost, if not quite, accurate. But as we look farther north or south, we find them more and more distorted. And no matter how long our cylinder is, it can never be long enough to get in *all* the map because, as the line joining the poles is parallel to the sides of the cylinder, the polar land (if there is such) could never cast a shadow on the paper.

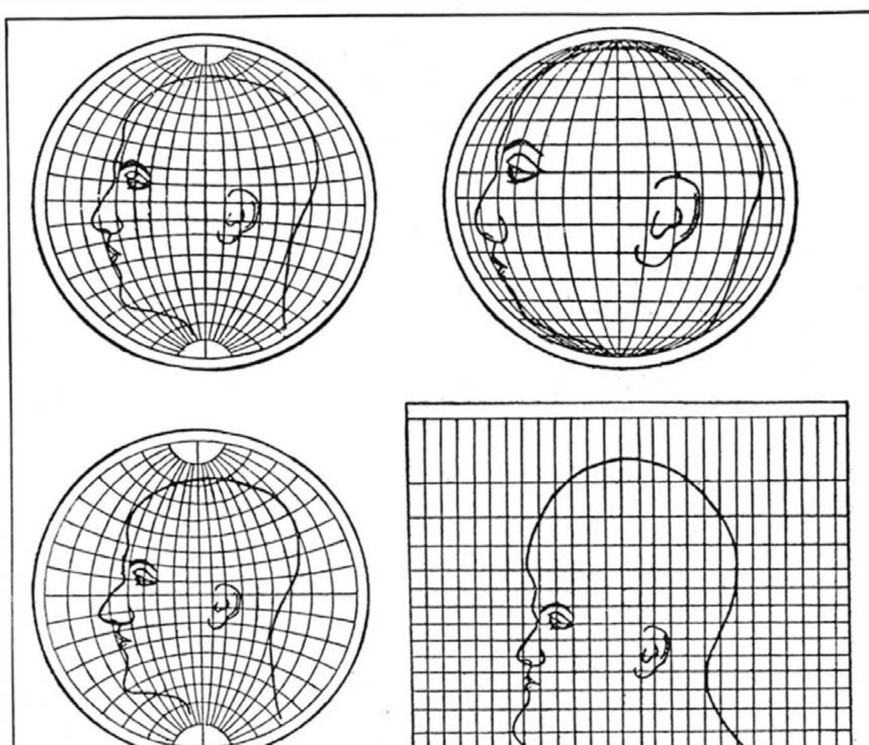
Such a projection is the base of the familiar Mercator projector which is in every atlas. The Mercator projector is what is known as a "conformal" one; the "sketching" of the polar regions is arbitrarily limited, usually to an amount not exceeding the "stretching" east and west.

But the Mercator projection is only one of many. There are many different "projections" because of many different needs of maps for many different purposes. The ideal map, if it could be constructed, would show areas of true shape, areas would have perfect proportion to one another, as in nature, distances from place to place on the map would be truly proportioned to distances between the places on the earth, all great circles on the earth (a great circle is the shortest distance between any two points) would be straight lines on the map, and latitudes and longitudes on the map would be the true latitudes and longitudes of the places on the earth.

No flat map can give all these things in perfection. Many different projections give some of them correctly, the others distorted. We select the requirement we need in a map, and construct our maps accordingly. Thus, in the Mercator projection the great circle is a straight line. The Mercator projection, then, is much used in sailing the seas because it is easy to plot a course on it. It prevaricates badly as to distances; the mariner checks his actual position, and distance of his run, by other means than visual examination of his Mercator projection.

There are many different possible projections. We may consider the earth as a nearly globular body formed of small sections of the bases of cones. We can consider it as having a surface formed of small quadrangles. We can consider a "stereographic" projection, in which our little light in the center of the sphere is moved to the south pole and projects shadows on a plane parallel to the equator. We can make an "orthographic" projection, in which the projection point is infinitely distant—the moon map we drew in imagination early in this story is an "orthographic" one. We can make a "globular" projection, in which the outer meridian and the central one are divided into equal parts by the parallels, which are arcs of circles. This is a much less misleading projection for common use in schools or homes, than is the Mercator projection. In other words it looks and "measures" much more nearly true to nature than the Mercator projection.

All this may appear somewhat difficult of understanding, but reference to the accompanying figures should make it very plain, particularly the four little drawings which show what happens in dis-



Upper left: Globular. *Upper right:* Orthographic. *Lower left:* Stereographic. *Lower right:* Mercator

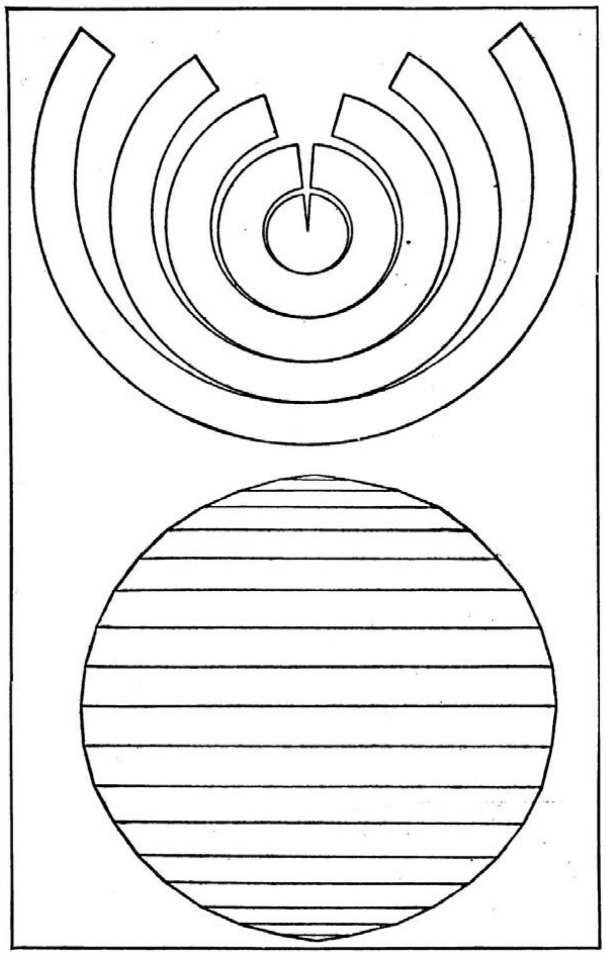
What four commonly used projections do, as shown on a human head

tortion, when an area is pulled out of shape by one or another projection. Here is a man's head, drawn on a globular projection. If from this we make an orthographic projection, we spread him out, and make him fat and big and bulgy. If we use a stereographic projection, we do not alter his chin and neck and forehead and upper head so much, but we somewhat "mash in" his profile and his lower head. And what we do to him when we put him on a Mercator projection is frightful to behold. We strech him all out of shape.

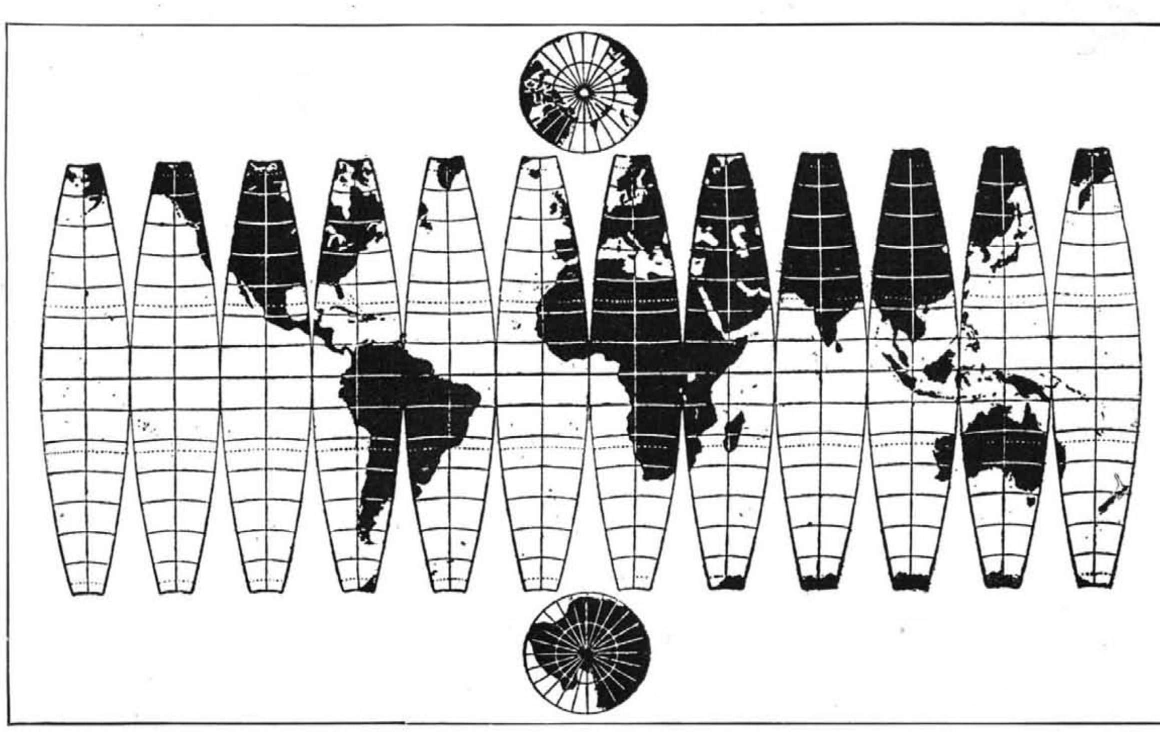
Yet the "latitude" and the "longitude" of every part of his face is the same on all four projections.

The reader is warned not to consider from this that the globular projection is any better or more accurate than any of the others. Had we at first drawn the head correctly on a Mercator projection and then transferred it to the others by comparing "latitude" and "longitude" of points on the face, we should have other and as drastic distortions.

Of course, for all small areas—a city, a county, half a state, even a whole state if it isn't too big—the flat map is sufficiently accurate in all ways for all practical purposes. One does not need a globe for short distances and small areas. But for large areas and great distances, no map is truthful in all ways, and he is the wise student and the well-informed reader, who either consults a globe when in need of accurate map information or uses his projection, whatever it may be, with a full consciousness of just how and where it distorts reality.



If the earth were made up of a series of conical frustums, these would open out into plane sections to make a map



When we try to flatten out the spherical earth into a map, this is what happens

Rock Crystal Balls

By Herbert Whitlock

Curator of Mineralogy, American Museum of Natural History

AMONG the semiprecious stones there is none, with the exception of jade, which has been so extensively used as a material for carved objects as rock crystal. From Italy and France have come the graceful vases, chalices, bowls, and drinking vessels of classic beauty, of fine and rich ornamentation; from Russia art objects of more severe and geometric treatment, as well as exquisite statuettes and figurines in this limpid medium; and from the Orient the odd-shaped vases and snuff bottles characteristic of Chinese art.

Among all of these, however, there are probably no series of objects fashioned of rock crystal which are more striking than the spheres made by the lapidary artists of Japan. The best of these are cut from flawless quartz crystals, clear and absolutely colorless, and are usually mounted on bronze wrought into decorative forms, such as dragons, storks, tortoise, and grotesque human figures. The clear, polished ball, contrasting with its dark bronze mounting, is preeminently an artistic object, lending itself with especial facility to the Japanese taste, which sets aside one beautiful thing as sufficient to contemplate and admire in an entire room. Groups of these balls delicately balanced in their mountings have been frequently employed in that land of earthquakes to give warning of shocks, effected by the slight preliminary tremors shaking them from their balanced poises.

Rock crystal spheres have, moreover, been since very acient times the especial stock in trade of the occult foreteller of events. Gazing into the still depths of these bits of earth's clearest substance, these seers of the future, so they tell us, can conjure up pictures impossible of production from commonplace glass. It is this alleged occult property which has raised the rock crystal sphere from a place of preeminent beauty to one of even higher romance and of unreality and woven around it an intricate web of legendary mysticism.

Dr. Dee, a crystal gazer of the seventeenth century, has handed down in his diary a very elaborate and complete description of the methods employed by occulists of that period, which are practically the same as those in use today. The crystal ball is supported upon a background of neutral tone, preferably black, in a room hung with similar draperies and lit only with candles or lamps which concentrate what little light there is present on the crystal. The operator fixes his gaze upon the brilliant spot of light reflected from the polished surface of the crystal until consciousness of his surroundings is replaced by subconscious "vision." It is significant that, in all descriptions of these "visions," what we may call the critical period is marked by the fading away of the image of the ball itself from conscious sight and its replacement by a thin cloud or mist upon which the prophetic "images" appear.

In a certain sense no less marvelous than the alleged occult powers of the crystal ball are the simple means employed by the Japanese artisans in producing them. This art, which, it is said, has been handed down from father to son for generations, consists of manual dexterity carried to a superlative degree. Armed with only two primitive tools, the lapidary shapes from an angular quartz crystal a sphere of perfect roundness and high polish. The quartz crystal is first roughly shaped to the form of a ball by chipping and abrading it with a piece of steel about twelve inches long and one-half inch wide, which has a concave cutting edge somewhat like a carpenter's gouge. When by means of this treatment the mass has been made round and approximately smooth, a joint of bamboo is used to complete the polishing, quartz dust, which lodges in the pores of the bamboo and, finally, rouge, furnishing the abrasives.

This all sounds extremely simple and no doubt is, to one who is trained to do it, but let the reader undertake it himself if he doubts the wonderful manual skill of these Orientals. Of course, in the lapidary shops of Europe and America where the grinding and polishing of crystal balls are undertaken, the lathe and the casting of just the right curvature for a ball of required diameter render the task infinitely more simple; but even with these aids the production of a rock crystal ball of a diameter of, say, three inches is a matter of weeks.

Inasmuch as the labor expended on a crystal ball of even modest size renders it a very costly object, continues the *Journal of the American Museum of Natural History*, the question which naturally presents itself is how can a purchaser be sure he is buying quartz and not glass? There are two very good ways of distinguishing quartz from its much more plebeian imitator. In the first place, almost every piece of glass large enough for a ball of even small size is reasonably sure to contain one or more round bubbles. Although extremely minute, these may be detected with a good "loop" or hand lens. And inasmuch as quartz never contains round cavities, the presence of these latter will at once stamp the ball in which they are found as spurious.

There is, moreover, a much more exact test, which the writer has found to be applicable to balls from about one and one-half inches diameter up. Quartz has the optical property, called double refraction, of exhibiting two images of everything which is viewed through it in a certain direction. It therefore becomes a very easy matter to apply the test by drawing a cross of fine lines on a piece of paper and then resting the ball on this cross and shifting it until a double image of the lines appears to the eye through the ball. It is impossible for a glass ball to produce this effect. So we come at the end to an actual vision which any one can see by gazing into a rock crystal ball.

Acetylene As Auto Motor Fuel

SWITZERLAND has turned to acetylene for use as a motor fuel, calcium carbide being a native product, while petroleum products are imported. Acetylene, however, has not proved as satisfactory as gasoline, for when F. Haber, a prominent German chemist, visited Switzerland in the fall of 1919, he did not find any cars running on acetylene, all having been reconverted to use liquid fuel. Haber was engaged by the German Government to investigate the possibilities of acetylene as a motor fuel and he conducted a series of experiments. According to Keel, a Swiss authority on acetylene and its use, 1 kg. of acetylene gave as much energy as 2 kg. or 2.5 kg. of benzol, though the heats of combustion are only as 6:5. The reason for this Haber found to be that there is always an excess of air in the benzol fuel mixture, while acetylene can be burned with its theoretical air allowance. The combustion of benzol was shown to be incomplete; in tests that of acetylene proved to be complete.

As regards the variation of the acetylene percentage in the air mixture, Keel stated that owing to the high pressures, and temperatures produced in the cylinder, the advisable limits ranged from 1.5 per cent to 7.5 per cent of acetylene; Haber sets these limits at 3 per cent and 5 per cent. With mixtures deficient in acetylene, there was noisy back-firing; with rich mixtures, pinking. The pinking is generally ascribed to spontaneous pre-ignition of the mixture by compression.