

Equal-area Projections and the Azimuthal Equidistant Projection in Maps of Disease

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THE recent increase in the study of tropical medicine has resulted in the increased study and production of maps which portray the distribution of disease. To physicians not specially trained in cartography the term "map" almost invariably suggests the familiar schoolroom map of the world on the Mercator projection, in which the terrestrial globe is represented as a cylinder. Experienced geographers, although not willing to abandon the Mercator projection,¹ recognize that it has several limitations or disadvantages. Those limitations which are of importance in world maps of the so-called tropical diseases may be summarized as follows²⁻⁴:

1. The Arctic and Antarctic regions are greatly exaggerated. According to a traditional example, on the Mercator projection Greenland appears to be larger than South America, although in actual fact Greenland (839,782 square miles) has approximately one-ninth the area of South America (7,045,047 square miles).

2. Since the Arctic and Antarctic regions are exaggerated, the equatorial zones appear disproportionately small. For the portrayal of tropical diseases—and especially for the portrayal of the world distribution of such diseases—this is a serious shortcoming.

3. Territories which are of equal size on a Mercator map are not necessarily equal in area. On Mercator's projection Dutch Borneo and Iceland seem to be approximately equal in size. Actually Dutch Borneo (208,000 square miles) is more than five times as large as Iceland (39,700 square miles).

4. Although Mercator maps are useful to navigators and others who desire to plot the course of a ship, most *distances* are distorted.

Despite these and other disadvantages, the Mercator projection continues to be extremely useful and is not likely to give way under the attacks to which it has been subjected. It is still of great value to navigators—for whom it was originally designed. Moreover, because of its familiarity it is destined to remain in use for such ordinary purposes as the location of places, for war maps in newspapers, and for miscellaneous diagrams. In medical work the Mercator projection can be employed when it is desirable to prepare a "spot map," e.g., a map showing the location of sporadic outbreaks of a disease, if it is not important to indicate the size of areas in which the disease has occurred. The Mercator projection also can be employed for disease maps of small areas, in which distortion is negligible.

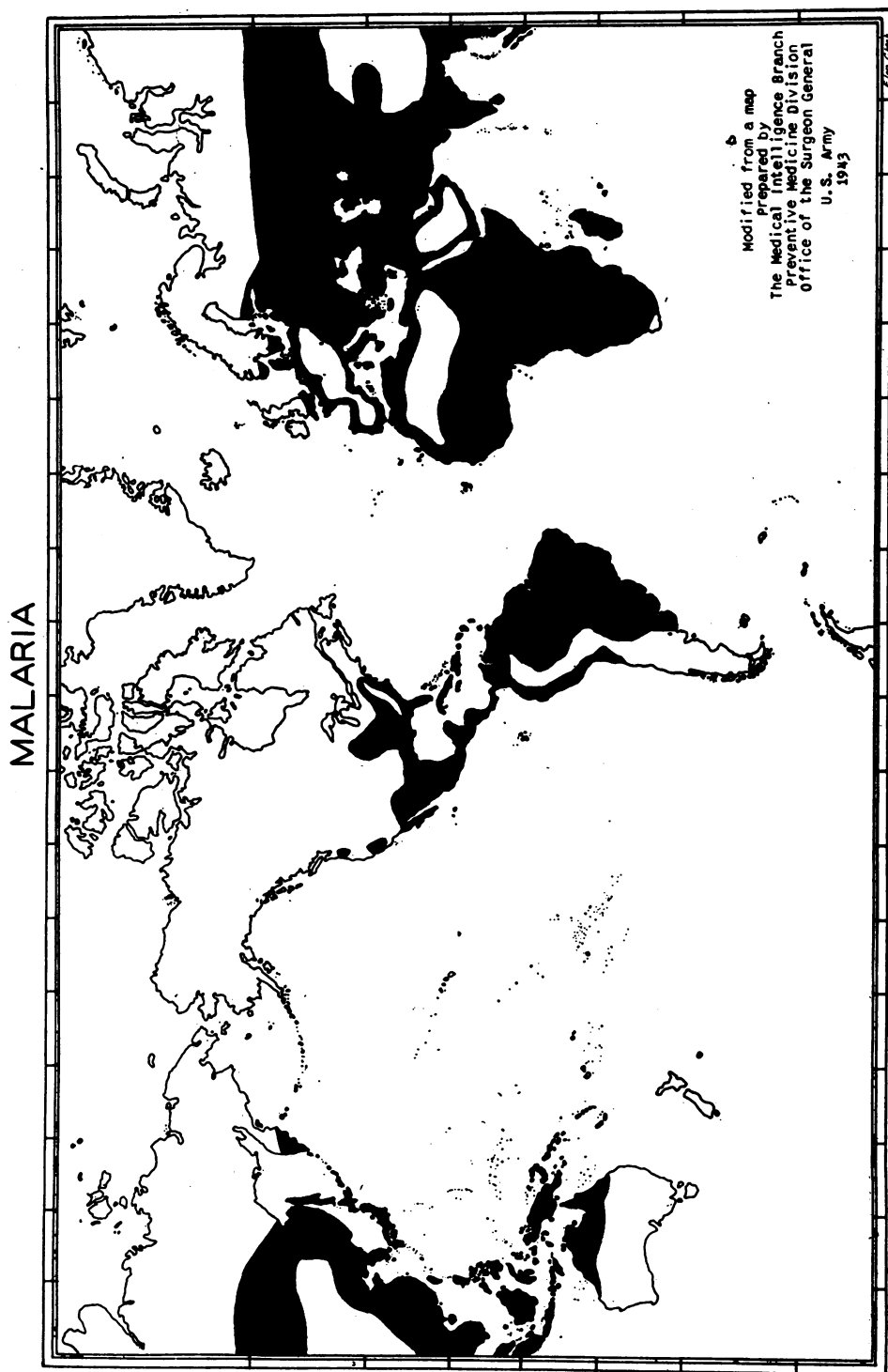


FIGURE 1.—World Distribution of Malaria. Mercator Projection. Adapted from an official War Department map. (See reference.⁹) The original showed degrees of endemicity which have been suppressed in this simplified adaptation. Compare with Figure 2. The epidemiological data shown in this map are not to be regarded as necessarily representing the most recent or most accurate information available.

For *world* maps intended to depict the size of areas in which a disease prevails, the Mercator projection should be supplanted by projections exhibiting the "equal-area" property. In maps of this kind, if any number of pennies is spread out over various parts of the map, the territory covered by each penny will be exactly equal in area to the territory covered by any other penny. If on a map of this type one were to depict the malarious areas of the world, each area would be represented in exact proportion to its size. Hence the areal extent of the disease in any two countries could be compared by inspection of the map. Such comparisons would be misleading if attempted on a Mercator map. Mollweide's projection,^{5, 8} the sinusoidal projection,⁶ and Goode's homolosine projection⁷ all possess the equal-area property. Equal-area maps have been used by certain European students of epidemiology⁸ but have been largely neglected by American workers in this field.

The usefulness of equal-area projections in tropical medicine is revealed by a comparison of Figure 1 and Figure 2, which depict the malarious regions of the world.* Figure 1 was drawn on the Mercator projection and is adapted from an official American map⁹ (this map as originally published indicated various degrees of endemicity which are suppressed in this reproduction). In Figure 2 the same data were plotted on Goode's homolosine projection,¹⁰ which has the equal-area property. It will be observed that in Figure 2 the non-malarious frigid zones are reduced to their correct proportions. As a corollary the regions nearer the equator, also shown in correct proportion, appear

larger than in Figure 1. Consequently the malarious regions of the world are shown to be much larger than is apparent from Figure 1. The discrepancy is even more striking when the malaria zone of North America is compared on the two maps.

The azimuthal equidistant projection is another cartographic tool which should be added to the physician's kit. As far as can be ascertained from a survey of the literature, this useful projection has never before been used for maps of the distribution of disease.

The azimuthal equidistant projection shows the *distance* between one focal point and all other points on the earth's surface. This projection is suitable for world maps of diseases which have a relatively small and continuous or nearly continuous realm of distribution. Examples of such diseases are cholera, scrub typhus (*tsutsugamushi*), Russian spring-summer encephalitis, filariasis caused by *Wuchereria malayi*, and *fièvre boutonneuse*. In diseases such as cholera, which tend to spread from a more or less well defined focus, the azimuthal equidistant projection makes it possible to emphasize the important factor of distance. For the technical details of construction the reader is referred to the standard treatises of Deetz and Adams,¹¹ Raisz,¹² and Herz.¹³

In the application of this projection certain principles must be observed. (1) Every map drawn on this projection is centered on a definite point, usually a city. A map centered on Tokio should not be used for a disease which emanates from Berlin. (2) Distances are correct between the point on which the map is centered and every other point on the map. The distance between two points neither of which is the central point of the map cannot be read off directly. (3) Maps drawn on the azimuthal equidistant projection do not possess the equal-area property.

* The maps used in the present paper are intended merely as illustrations of cartographic methods. The epidemiological data given in these maps are NOT to be regarded as necessarily representing the most recent or most accurate information available.

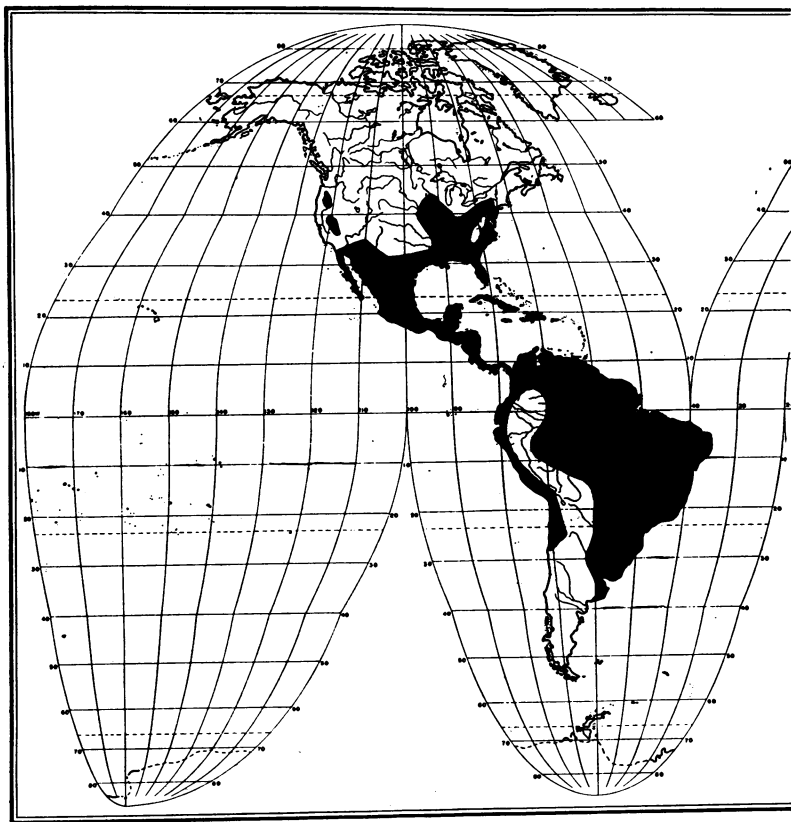
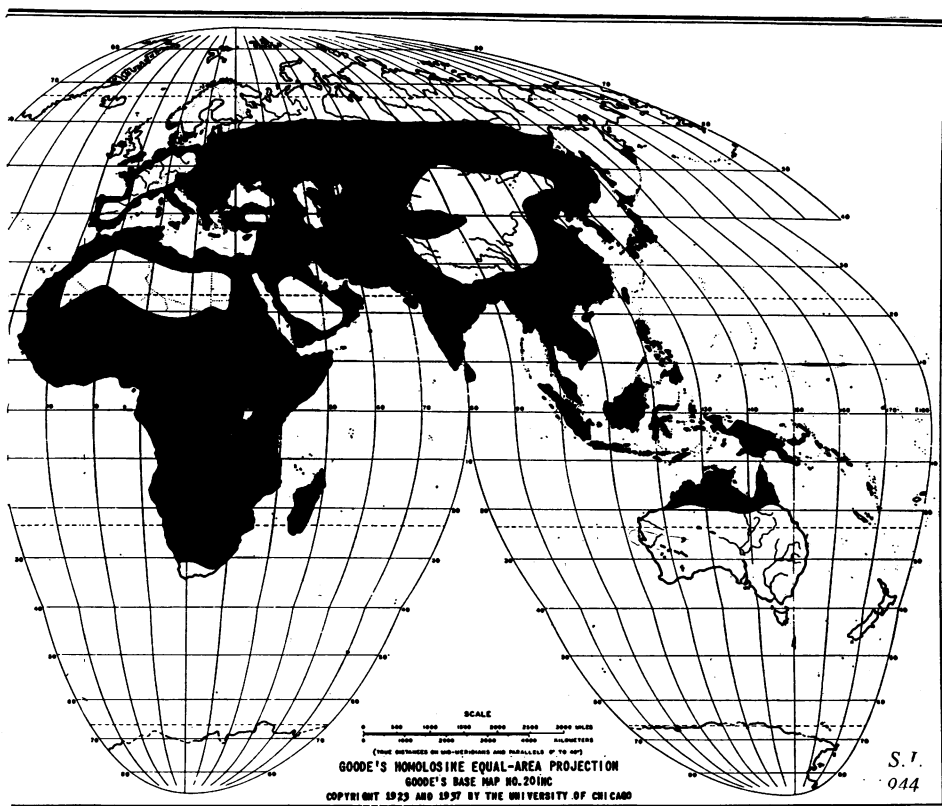


FIGURE 2—Malaria. Goode's homolosine projection. Base map by courtesy of University of Chicago. The frigid zones are reduced to their correct proportions. In consequence the equatorial zones appear larger than

In Figure 3 the distribution of cholera is shown on a map drawn on the azimuthal equidistant projection centered on the equator at 80° east longitude. This point was selected arbitrarily, chiefly for convenience, as the center point. With equal or greater propriety, the city of Calcutta ($22^{\circ} 34' N.$, $88^{\circ} 24' E.$) might have been assumed to be the center of the cholera regions of the world. Figure 3 emphasizes the factor of proximity in the spread of the disease. It should be studied in comparison with Figure 4, which is adapted from an official United States Army map¹⁴ drawn on Mercator's projection.

Figure 3 shows that all the cholera

areas in the world can be included in a circle which has a radius of 4,000 miles. A circle having a radius of only 3,000 miles encompasses almost all the cholera areas, including those adjacent to the Persian Gulf and in Celebes. The distribution of cholera is thus relatively compact as compared with the world distribution of such diseases as malaria and dengue. It will be observed that the aforementioned 3,000 mile circle includes much more water than land. It is further noteworthy that the cholera-free regions at the northern limit of this circle are in and beyond the Himalaya Mountains. Thus it is apparent that two of the chief barriers to the extension of



in Figure 1. Hence the malarious regions of the world, here shown in true proportion, appear larger than in Figure 1. *The epidemiological data shown in this map are not to be regarded as necessarily representing the most recent or most accurate information available.*

cholera are the ocean and the mountains.

Since cholera at the present time is limited to one hemisphere, in the preparation of Figure 3 it was deemed unnecessary to represent the entire world on the chart.

For the depiction of yellow fever, which is a disease of continents bordering on the south Atlantic Ocean, one may employ a complete world map drawn on the azimuthal equidistant projection centered on Ascension Island (Figure 5). In the same way, a map of the distribution of scrub typhus (*tsutsugamushi*) could be centered arbitrarily on Singapore, and a map of the famous outbreak of dengue which occurred in 1926 could be centered on

Athens. The azimuthal equidistant projection also could be used to depict the spread or threatened spread of species of plants or animals. It likewise could be used by an anthropologist who wished to show the dissemination of a culture or process. Like any other projection—including the Mercator—it must be used with exact awareness of its properties and limitations.

SUMMARY

1. The Mercator projection, although of broad general usefulness, is not generally suitable for world maps of disease. It is especially unsuitable for world maps of tropical diseases.

2. Equal-area projections such as Goode's homolosine projection are in general greatly superior to the Mercator for world maps of disease.

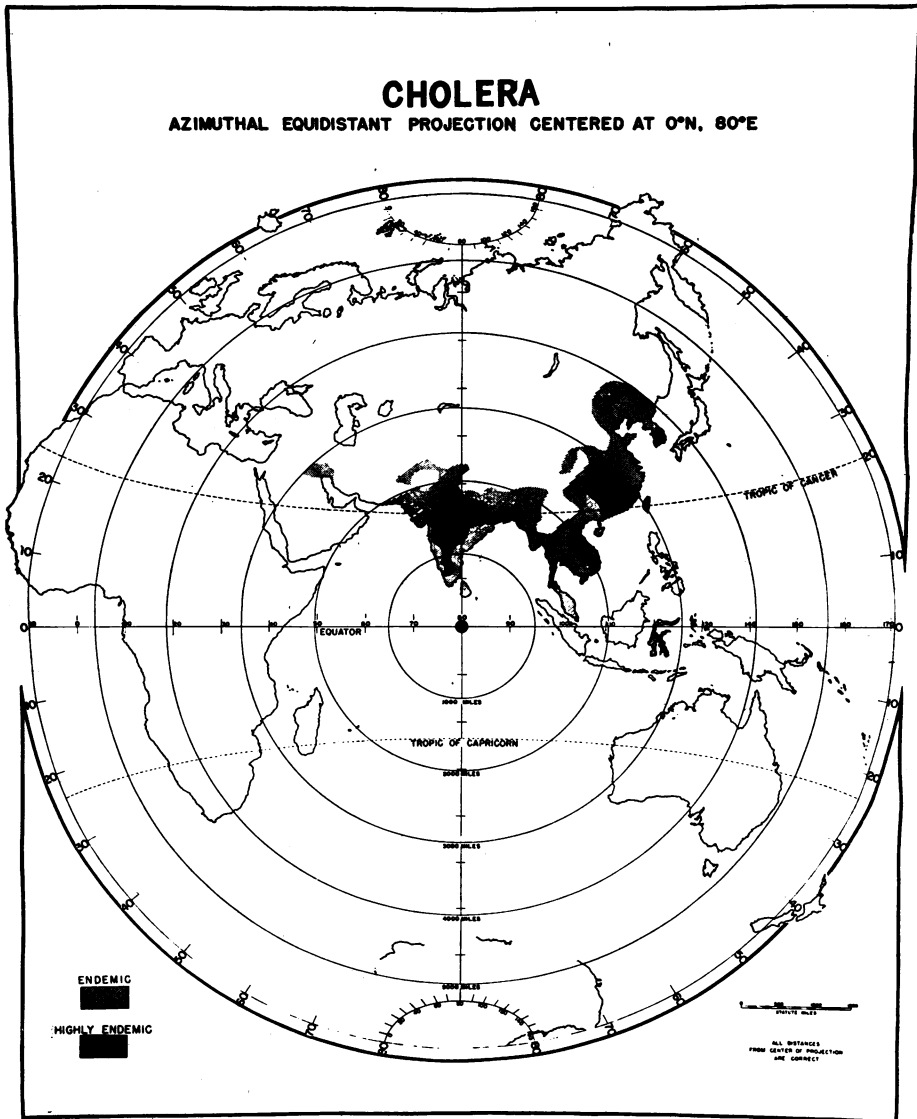


FIGURE 3—Cholera. Azimuthal equidistant projection centered on the equator at 80° east longitude. Compare with Figure 4. *The epidemiological data shown in this map are not to be regarded as necessarily representing the most recent or most accurate information available.*

3. For diseases which have a relatively restricted or coherent distribution, an appropriately centered map drawn on the azimuthal equidistant projection provides illuminating insight into the important aspects of distance and proximity.

4. The text is accompanied by five maps. *The reader is cautioned that these maps are intended merely as illustrations of carto-*

graphic method. The epidemiological data given in these maps are not to be regarded as necessarily representing the most recent or most accurate information available.

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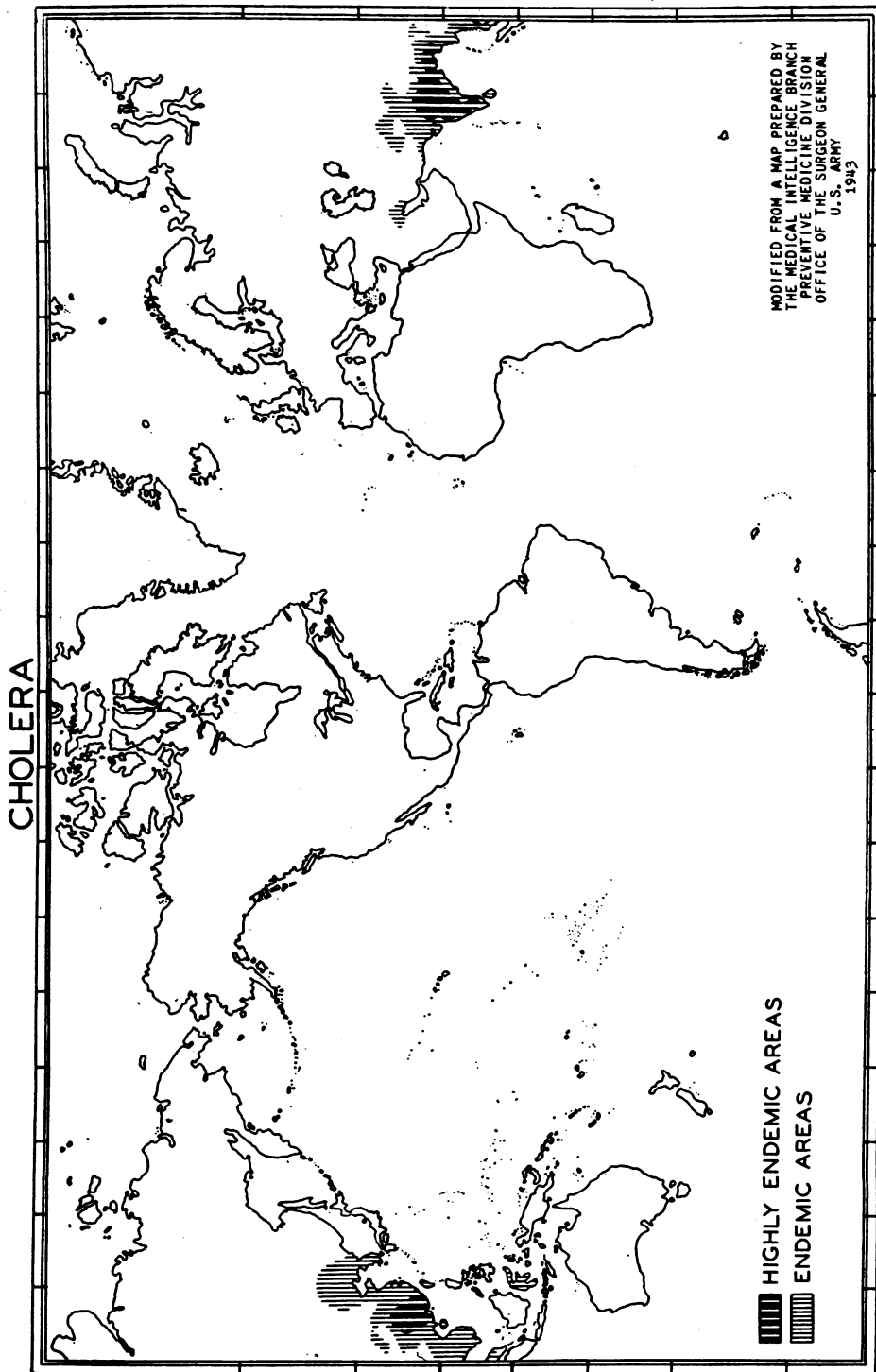


FIGURE 4—Cholera. Mercator projection. Modified from an official United States Army map. (See reference.¹⁴) This map contains the same data as Figure 3. *The epidemiological data shown in this map are not to be regarded as necessarily representing the most recent or most accurate information available.*

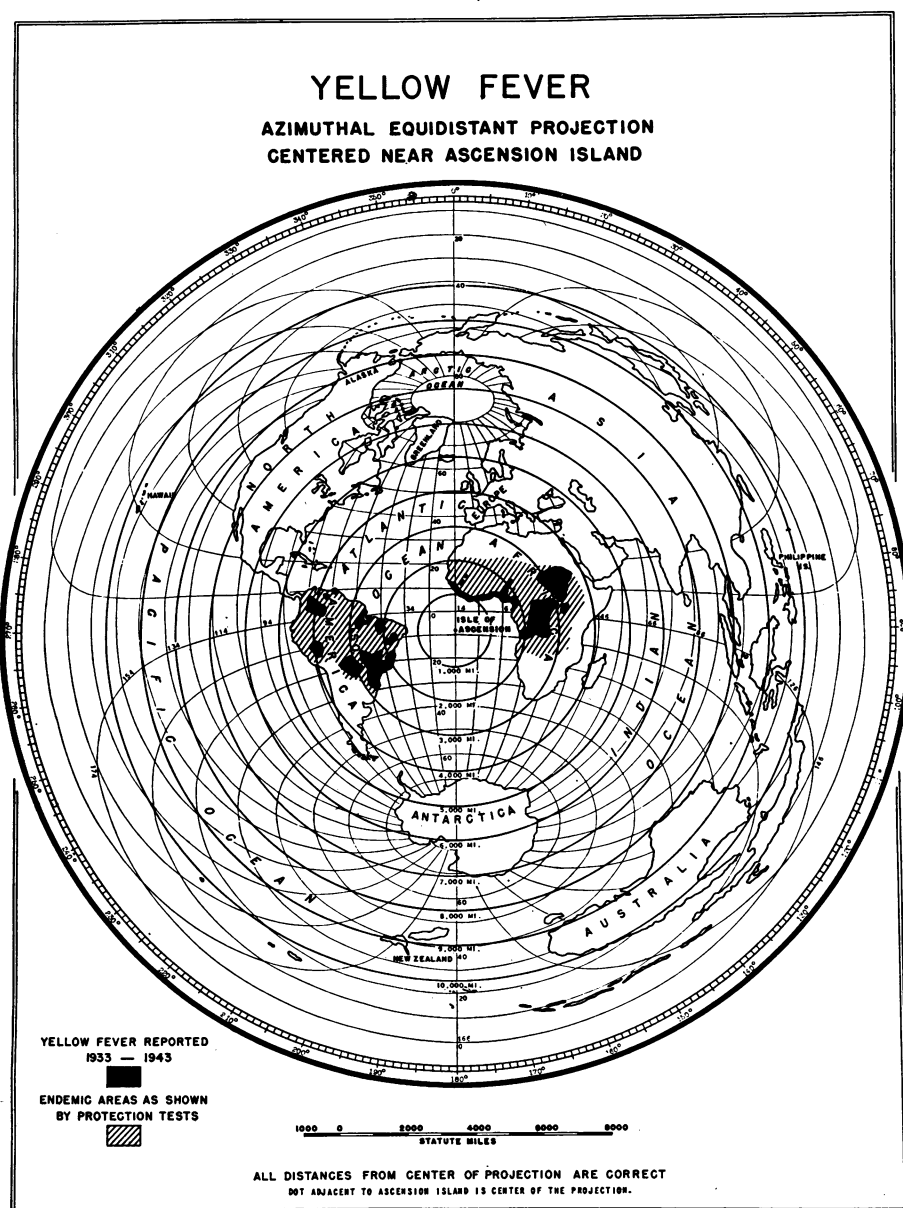


FIGURE 5—Yellow Fever. Azimuthal equidistant projection centered on Ascension Island. This map emphasizes the fact that yellow fever is a disease of continents bordering on the south Atlantic Ocean. It also shows the true distances of all other territories. Data replotted from official U. S. Army map on Mercator projection.

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10. The Outline map for this illustration is No. 201 HC in *Goode's Series of Base Maps*. For permission to use this outline the author is indebted to the University of Chicago.
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Status of Medical Facilities in the Philippine Islands

A communication from the Philippines reports the destruction by recent action of the Medical School and Library, the Cancer Hospital and the Outpatient Buildings at the University of the Philippines. All of the clinical records of the Philippine General Hospital, Manila, were destroyed and only a few broken test tubes and specimen jars were left in the laboratory.

Members of the staff who have survived the Japanese occupation are devoting their full time to the treatment of any and all who are sick and cannot

be treated at home. There is a shortage of everything and many diagnoses are made on physical findings alone. Serologic tests are made by one of the Army laboratories. Limited blood counts are done in the hospital but bacteriologic studies are not possible at present, it was stated. There is a great need for books and periodicals for the medical school and hospital and the library. The communication credited the great skill of the Filipino physicians in the present emergency.