THE LAMBERT CONFORMAL CONIC PROJECTION

A Hortatory Introduction

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Chaos is a wonderful thing[1]. Only in the tumultuous dialectic between chaos and order, between Tiamat and Marduk, can a world be born; it is this tumult alone that makes creation possible. Nietzsche's Zarathustra insists, in the inspired (in this passage at least) rendering of R.J. Hollingdale (Penguin Classics, 1961): "One must harbor chaos in order to be able to give birth to a dancing star"; to an outsider it appears that the world of Assyriology harbors, nurtures, gives space to plenty of chaos — the dancing star is obviously just around the corner, to be expected at any moment.

It is, however, finally not of chaos that we should speak, but of the defeat of chaos, the triumph of Marduk, the imposition of order in defiance of entropy; the great work of scholarship, after all, is the heroic war against the second law of thermodynamics. And the particular chaos I have in mind at this moment is literally the original chaos, that which was there before there was world, before the world was.

A personal anecdote may make this clearer: some time ago my wife, who is an Assyriologist, decided to write a book. Many people, of course, have had this experience, but in this case the idea arose that some maps would make certain elements of the argument clearer, and, since my profession involves drafting and the use of computer database and drawing tools, I rashly volunteered to produce these maps. The initial topography was easy; the American Civilian Intelligence Agency had already developed and made available to the public all the raw materials necessary for an outline map of any part of the world, or indeed the whole world. To this I added mountains and a few modern cities from readily available maps produced by the US Defense Mapping Agency. It was the work of only a few minutes to distin-

[1] A version of this paper was given in the *Geography Workshop* at *Assyria 95. The 10th Anniversary Symposium of the Neo-Assyrian Text Corpus Project*, on September 9, 1995.

guish between modern and ancient placenames by using different type, so everything seemed well in hand.

The informed reader, however, will immediately realize that such confidence could only be illusory, that the real difficulty lay in locating the requisite ancient places on the map. The latitude and longitude for some places, of course, could be found in the *Répertoire Géographique*, some detailed locations could be found in excavation reports, but some ancient sites could be found only on other maps, whether very small-scale maps in the *Fischer Weltgeschichte* or the admirable map produced here in Helsinki by the *State Archives of Assyria* Project.

It was, paradoxically, the cities shown on other maps that gave us the greatest problems; the problem seemed simple in the abstract —after making a photocopy to the appropriate scale, one had only to align two known points and the other points would fall into place— but as is so often the case, what seemed simple in theory did not work out in practice. One might, for example, align Nineveh and Babylon on both maps, but nothing else would coincide. Even the rivers would appear to run different courses. This problem, of course, was finally solved, and the maps produced as required, but the proximate cause of our difficulties was clear; because the various maps were all made to different projections, copying them to the same scale did not make them identical — or even close enough for easy comparison.

The difficulty faced by all cartographers is that the world is round (it is actually slightly flattened at the poles and therefore elliptical, but that we can leave to the sub-committees), the world is round but we wish to represent a part of its surface on a flat piece of paper. The image of a blue marble spinning away in space is familiar to many of us from space photography; perhaps we remember as well the lower-tech orange-on-a-stick from school. When we skin this orange, we find that the skin does not conveniently spread out flat without tearing, which means that, if we are to transfer an image of the earth to our flat paper, we must project that image. If, for example, we imagine the earth now as a translucent ball, with the oceans painted blue and the continents and other details in pleasing pastel colors, a light at the center of the ball might project details from the surface onto a piece of paper wrapped around the ball. Just how to wrap the paper, whether in a cylinder, or a cone, or perhaps simply flat, forms a large part of the cunning of cartographers and has been a fertile source of debate for centuries. Maps are not, of course, actually produced in this way; the required cartesian coordinates for the paper map are derived mathematically from angular coordinates (latitudes and longitudes) on the earth, but the image is conceptually valid.

The chosen projection makes a great difference in the effect of a map, and in its comparability with other maps. We are all familiar, for example, with the maps that show Greenland as larger than South America and with the controversies engendered by those maps, now considered politically incorrect. In our immediate context, however, we are more concerned with comparability than with political correctness, so we shall look now at the problem of comparing dissimilar maps.

In Figure 1, our first example, we have the Middle East presented in the Mercator Projection[2]. This, of course, is familiar territory and looks much as we might expect it to. Figure 2 shows approximately the same area in the Lambert Conformal Conic Projection; again the area is familiar, and (except for the curved parallels of latitude) there is little apparent difference between the two maps, largely because both projections are "conformal", which means roughly that they show areas in approximately the correct shape, or, to put it more precisely, the relative local angles about every point are correct.

In Figure 3, however, we see that there is indeed a difference; while alignment between the two views is fairly close in the vicinity of Calah, it ranges elsewhere from poor (as in the area of Babylon) to non-existent (as on the Mediterranean coast). Although one could establish a local correspondence around each area of interest in turn, it would clearly be difficult to transfer data from either map to the other, and it would be especially difficult to have much confidence in the results. If data are to be transferred routinely from one map to another, it is essential that both maps be in the same projection.

The next question, of course, is which projection we are to use. A commonly-used manual of map projections contains equations and data for some twenty-seven distinct projections, many more (hundreds) have been developed but are not now used, and there is literally an infinite number that could be devised[3]. While it might seem that there is little difference between our two projections, that either map is as good as the other, there is a significant difference in the extent to which the scale is constant over the whole map. In any map produced by the Mercator projection, the scale is increasingly distorted at higher latitudes as the meridians (converging toward the poles on earth) are forced to lie parallel on the map. This difference in east-west scale must also be reflected in north-south distortion in order to keep the map conformal. The effect of this is clear even in small areas; in our Mercator map of the Middle East there is almost a 16% difference in scale from the bottom of the map to the top. In the Lambert projection of the same area, by contrast, there is less than 0.22% difference in scale from top to bottom of the map, and the total scale difference between the two standard parallels used to make the map (32°20' and 38°40') is just over 0.1%. Now, there is nothing wrong with the Mercator projection for many purposes; it is the standard projection for nautical charts, for example, but would not

[2] In the spoken lecture, two maps were handed out at this point, one on paper and one on acetate; by overlaying one map on the other, the differences between projections were readily made apparent.

[3] J.P. Snyder, *Map Projections — A Working Manual*, U.S. Geological Survey Professional Paper 1395 (U.S. Government Printing Office: 1989).

normally be used for a map such as ours because of the scale differences just mentioned. It was chosen for this demonstration to make the effect of the choice of projection clearer; if another projection had been chosen, the differences would be less obvious, but the Lambert Conformal projection would still show similar advantages in uniformity of scale, and is recognized for this reason as a superior projection for regions (like the Middle East) that have primarily an east-west orientation. Indeed, it is the projection chosen by the British Defence Ministry (and following them the U.S. Defense Mapping Agency) for maps of the Middle East.

In a properly organized world, the projection used for published maps would be a matter of publication style, even as the form of citation in footnotes is today, and all maps illustrating Assyriological data would be made to the same projection and therefore comparable; in the best of all worlds, that projection for Assyriological maps would be the Lambert Conformal Conic Projection. If this were the case, it would be possible, even easy, to see relationships between published data displayed on different maps, even to ask questions that the authors of the maps themselves had not thought of.

In the very best of all possible worlds, however, we would not have to rely on photocopying and scaling published maps, but could find the necessary data instead in a computer database. If the well-known Assyriologist of the future, Professor Robinson, wanted to compare the distribution of pottery types, for example, established by Professor Brown, with the cereals found in different locations by Professor Jones, she would only have to load the relevant data files into her computer and display them as an overlay on a standard map to see whether there is any relationship, and adding a third dataset would be equally simple. The speed of the computer, and the general availability of excellent vector-based drawing and display programs, makes it possible even today to ask questions of spatial data that would have been prohibitively time-consuming ten years ago.

In sum then, if Marduk is to triumph, if the kind of history that is beginning to emerge from the cross-pollination of textual and archaeological evidence is to flower, if we are to even hold the hands of giants, let alone stand on their shoulders, one facilitating condition is obviously a standard projection for maps; for several technical reasons, that standard for Assyriological maps should be the Lambert Conformal Conic Projection.

Addendum (July, 1998)

Sailing Directions Toward a Digital Map

1. *A Brief History*

Although it concludes with a call for a completely digitized map, this talk at Helsinki concerns itself primarily with the standardization of printed maps. Such standardization remains a desirable goal, one that must not be lost sight of, but the project has expanded as new software has opened up coasts previously uncharted (except, perhaps, on large mainframe computers) to exploration by standard desktop PCs.

Shortly after the Helsinki meeting, a preliminary specification was drawn up, outlining a cooperative venture between the *State Archives of Assyria* Project and the Casco Bay Assyriological Institute to produce a new map of the Middle East in the Neo-Assyrian period; although certain aspects of that specification have changed, the objectives defined at that time remain current in their essentials:

To develop a geographical database that:

1. Can be used on a PC and manipulated with reasonably inexpensive software;
2. Does not require an extensive custom programming effort;
3. Allows the production of paper maps (either in color or black-and white) ranging in scale from 1:1,000,000 to 1:10,000,000 or above, and in size from about 36' × 48' to 4'× 6' (or as required for illustrations in books, articles, etc.);
4. Allows the inclusion of non-graphic data such as population, dates, bibliography, evidence for location, etc.
5. Allows manipulation of data (presumably by computer) in other than visual ways (e.g. which points of a given data set fall within 35 kilometers of the Tigris River?; or how long is the road from Nineveh to Arbela?);
6. Allows the inclusion of data sets from any source, provided only that these are geo-referenced — that each item, place, or inflection point on a road is tagged with its latitude and longitude.
7. Allows the future possibility of graphic access to the non-graphic parts of the database, *i.e.*, allows that a user, looking at the map in AutoCAD, could click on (say) a city and retrieve such data as are available in a "text box".
8. Allows the possibility of future expansion into an automated mapping program (this is a stretch, but it is a direction the computerized cartography world is going, and one day it might be possible —perhaps even for a specific class— to instruct a PC to produce a map of the Assyrian Empire in 725 and get a plot on a laser printer with places labeled in an appropriate type size, etc.).
9. NOTE that there is no mention of "definitive" or "unique" in these objectives; if there are three possible locations for a given city, for example, the structure must be

able to accommodate them all, and similarly, if there is more than one name for a given location we expect to handle that, as well.

The ever-increasing power of new PCs, together with the software advances mentioned above, have vastly increased the sophistication that can reasonably be expected from a geographical database, and it is the purpose of this addendum to explore some of the implications and potential of these new capabilities.

2. *The Present Situation*

As it has developed, the Digital map of the Middle East (I avoid the common term "GIS" because it has effectively been preempted in the PC world by the Arc INFO family of programs) already meets many of the original objectives, in particular those principal and most immediate; it allows the production of paper maps to various scales, and it allows the map on a computer screen to be used as an index into a database that goes far beyond geographic or spatial matters.

To date, the topographic base has been established, together with the mechanism for linking the map to a database, and work is underway to develop an exhaustive list of Neo-Assyrian toponyms, link them to specific locations, and establish those locations exactly, both on the visual map and in the database. The graphic part of the Digital map exists as a drawing in AutoCAD (a powerful computer drafting program); one important reason for this choice is that entities in an AutoCAD drawing are accessible to manipulation by a number of other programs, most notably Visual Basic[4]. This accessibility allows analytic tools to be developed with relatively little programming effort, so that potential uses of the Digital Map are limited only by the user's imagination.

3. *Potential and Desiderata*

Two projects currently underway may show something of the Digital Map's potential as an analytic tool: in the first, road segments are being combined into what is called a network topology, and in the second a program is being written to draw a polygon with ten addressable vertices and the properties of maintaining a constant (given) area and a minimum mean distance between the vertices and the (given) center. If these statements are not self-explanatory, or the advantages of these capabilities are not obvious, read on.

In a network topology, connected line segments have information attached to them indicating that they are (for example) road segments, each linking two points, or "nodes". With this information, the computer can literally find its way from, for example, Nineveh to Babylon, or give us the shortest distance by road from Calah to

[4] There are programming interfaces to C++ and Delphi (among others) as well, but Visual Basic is probably the most easily available language and requires the least programming skill.

Til Barsip. Each of these road segments can also be assigned a "resistance" property (the metaphor is from the analysis of electric circuits) which could be translated into kilometers per day, with the result that we could ask, for example, how far an army could move (in any direction) from Nineveh in ten days, an ability that might be very useful in analyzing campaign descriptions or other itineraries.

The second project, the polygon program, speaks to the situation where we postulate a need for a certain area, perhaps the amount of arable land necessary to support a city of a certain size, but cannot simply draw a circle because of constraints in one direction or another. The program initially draws a regular program of the given area about the given center, but when the user moves particular vertices to reflect constraints (unusable land, for example, or the proximity of another city), the program adjusts the positions of the other (unconstrained) vertices to maintain the given area and minimize the mean distance of all vertices from the given center. In this way, we get a representation not only of the area a city would have to control in some sense in order to maintain a certain size, but also of the shape this area might plausibly have taken. The program is not confined to cities, but could be used in the same way to address other problems involving areas.

These applications are currently being developed using the Visual Basic interface to AutoCAD; they are discussed here as examples of, and proxies for, the literally unlimited possibilities for spatial analysis afforded by the digital Map.

While the current cooperative endeavor between the *State Archives of Assyria* Project and the Casco Bay Assyriological Institute is focussed on the Neo-Assyrian period, there is no inherent reason the database could not be expanded. The Digital Map exists as a structure into which data of any sort or period can be poured; in time we might be able to ask it for a specific map of the Middle East in 1250 BC, or as it appeared to the Hurrians, or as it appears to the modern archaeological tourist.

The questions researchers ask depend in large part on the kinds of answers available, and the computer, in shortening by several orders of magnitude the time required to get certain kinds of answers, has already made a qualitative difference in the kinds of question that can be asked. Just as the original specification has evolved in response to experience with the map and with the potential offered by new software and faster computers, so we may expect that the Digital Map and its associated database(s) will continue to evolve in ways that none of us can yet foresee. We cannot, in short, discern more than the vaguest outline of that distant digital shore, but if we do not foreclose options, if we have as open a structure as possible, if we allow for indexing and searching in every conceivable way, there can be no doubt that we shall eventually arrive.

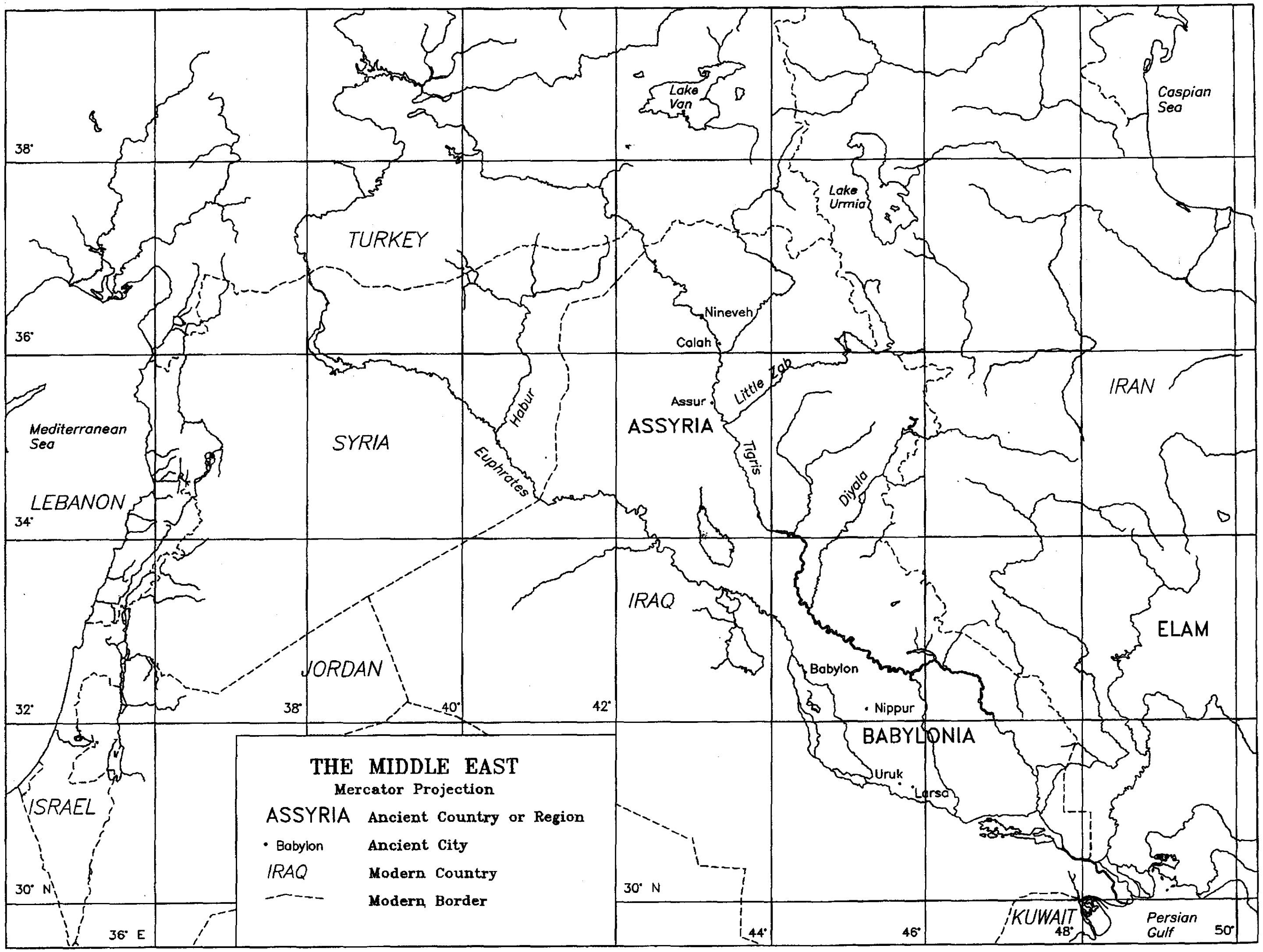

Fig. 1. The Mercator Projection.

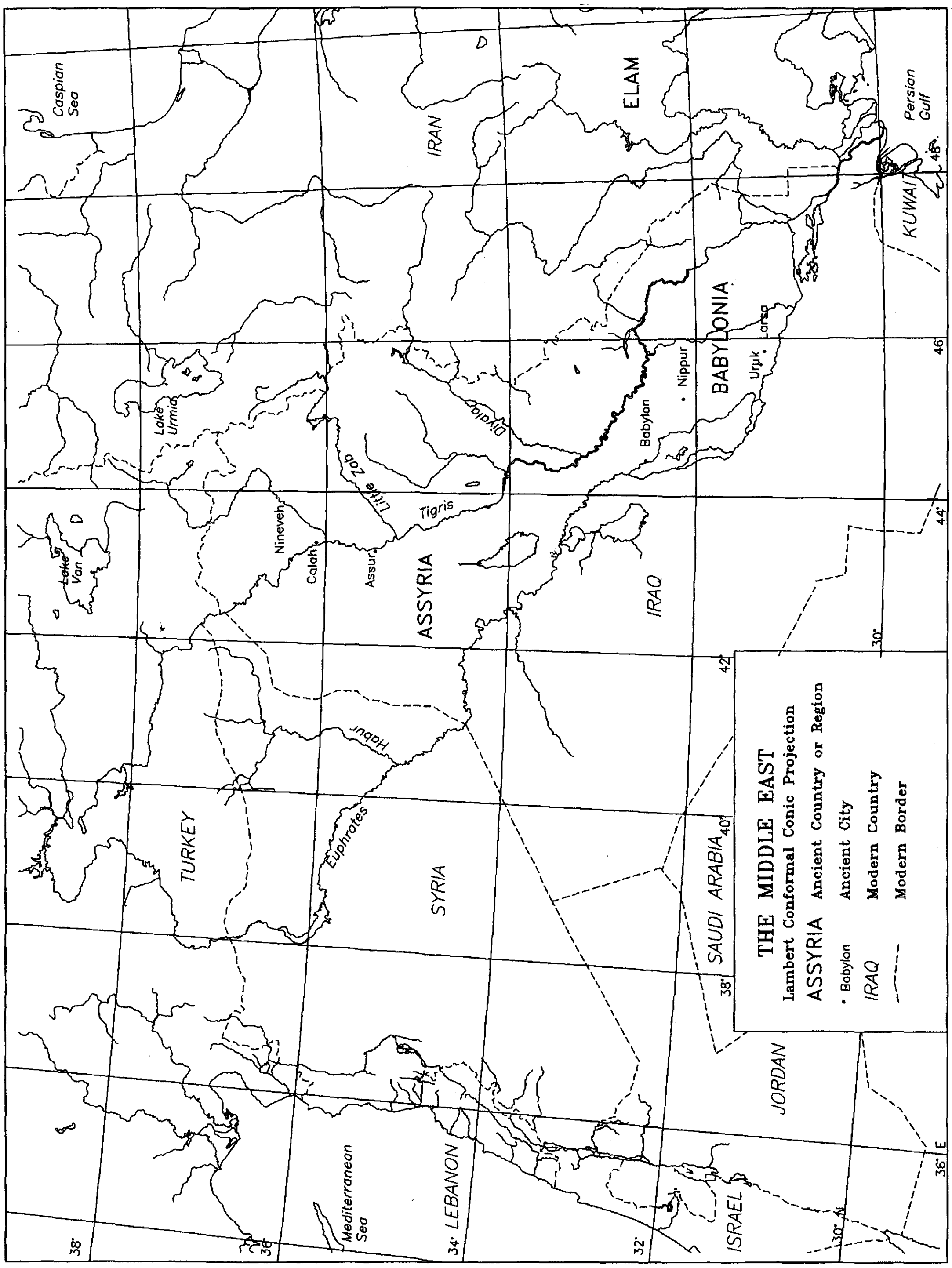

Fig. 2. The Lambert Conformal Conic Projection.

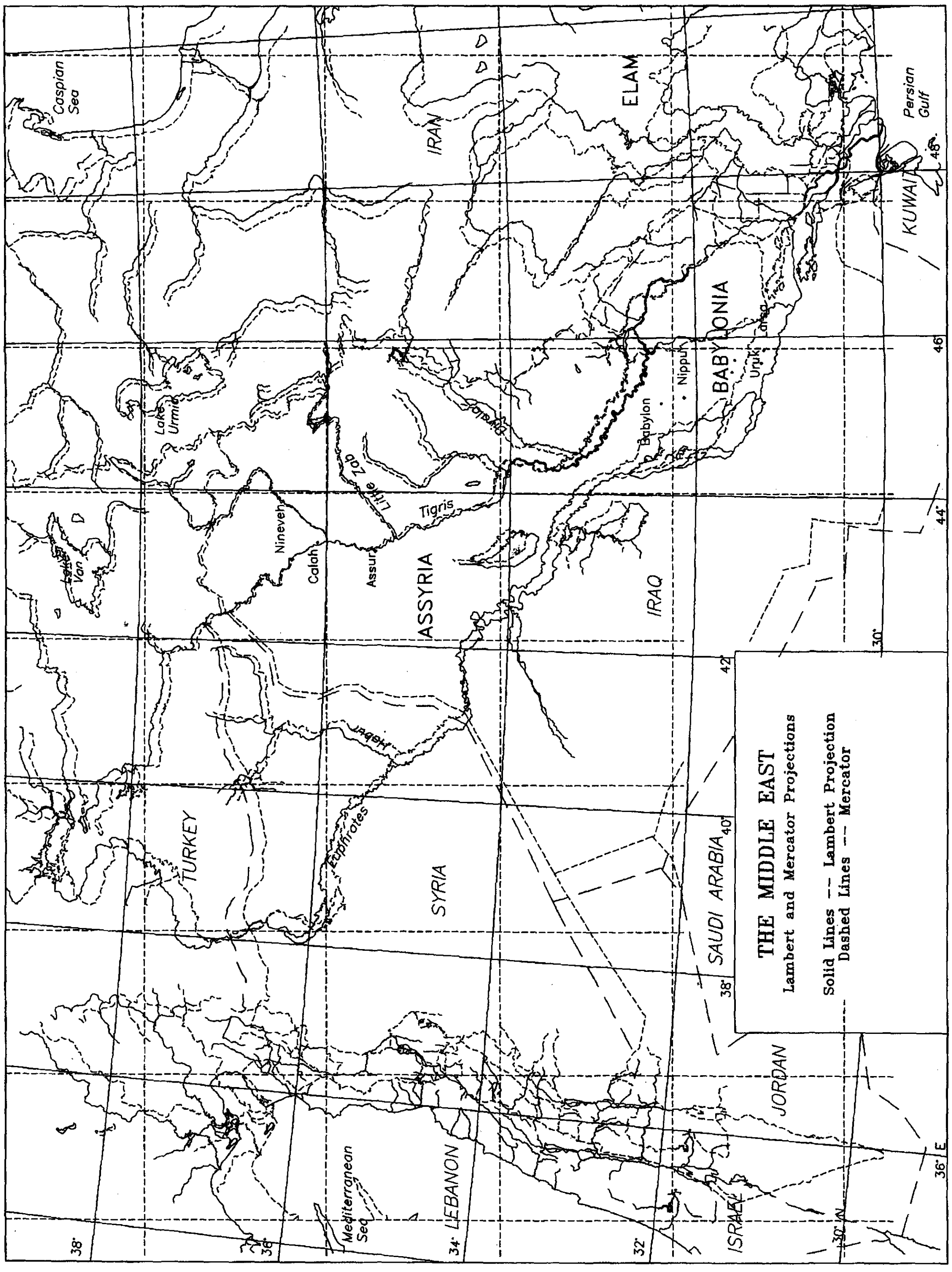

Fig. 3. The Lambert and Mercator Projections.