The Technical Aspects of International Maritime Boundary Delimitation, Depiction, and Recovery

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The technical aspects of delimiting, depicting, and recovering international maritime boundaries are addressed. Potential sources of error in the delimitation, depiction, and recovery of boundaries are exposed, and recommendations are made for avoiding errors in the future. Recent technological advances in the field of international maritime boundary making are discussed. The technical information provided in international maritime boundary treaties signed between 1940 and 1991 is analyzed.

Keywords combinatorial search algorithm, delimitation, geodetic datum, global positioning system, international, lines, maritime boundary, Mercator's projection, nautical charts

"Good fences make good neighbors."*

State practice indicates that "boundary as fence" is the predominant model in international maritime boundary making.[1] If a boundary is to function effectively as a fence, its location must be apparent to all who pass by. Therefore, it is important that international maritime boundaries be delimited carefully to avoid numerous sources of error, and that they be depicted precisely and in a manner that is fully understood by the states parties to the agreement and other ocean users.[2] In order to avoid confusion about the exact location of a boundary line, the texts of international maritime boundary treaties must contain certain technical information, including (1) the geographical coordinates of turning points, (2) the nature of the line segments connecting these points, and (3) the geodetic datum to which the boundary is referenced. Where these conditions have not been met, there is potential for international conflict over negotiated lines.[3]

The international community of ocean users must know the precise location of negotiated international maritime boundaries. These lines separate national territories con-

*Robert Frost, "Mending Wall," in *Poetry of Robert Frost: The Collected Poems, Complete and Unabridged*, ed. Edward Connery Lathem (New York: Holt, Rinehart and Winston, 1979), 33–34.

Received 26 August 1996; accepted 4 October 1996.

The author acknowledges the valuable assistance provided by the members of his thesis committee at the University of Washington, Seattle: Professor William Burke, Dr. Nicholas Chrisman, and Dr. Edward Miles. Dr. Robert Smith of the U.S. Department of State, Washington, DC, and Dr. Lewis Alexander of the University of Rhode Island, Kingston, RI, also provided helpful input. Special thanks is due Dr. Galo Carrera of Geometrix Inc., Dartmouth, Nova Scotia, Canada, for his constructive criticism and advice throughout this learning process.

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Ocean Development & International Law, 28:167–197, 1997

0090-8320/97 $12.00 + .00

taining valuable resources such as fish, hydrocarbons, and hard minerals. However, unlike a terrestrial boundary, it is nearly impossible to demarcate a maritime boundary. The terrestrial section of the border between the United States and Mexico is an example of a well-demarcated land boundary. The physical constructions and natural features along this border function as markers of the location of the political boundary. Unfortunately, natural features such as rivers and mountain ranges are not available on the featureless surface of the ocean, nor is it feasible to construct fixed physical barriers at sea.[4] The geomorphology of the continental shelf, which does function as a reference point for some maritime boundaries (e.g., the outer edge of the continental margin), is not readily apparent to the typical ocean user. Neither do coastal features provide guidance at a distance of 200 nautical miles. Due to these limitations, the location of an international maritime boundary must be depicted on a chart using geometric points and lines, or by a list of geographical coordinates of turning points which can be referenced to the surface of the earth via mathematically defined ellipsoids that mimic the irregular surface of the ocean. If the required technical information is provided in the treaty text, these abstract depictions, combined with satellite positioning technology, will allow all parties to precisely recover a maritime boundary.

There is an important distinction between the method used to delimit a boundary and the method used to depict the boundary once delimited. In the context of a single boundary agreement, the method of delimitation is significant only to the states parties to the agreement and must satisfy their needs alone.[5] However, it should be noted that equidistance is the principle underlying a large majority of international maritime boundaries, and in places in this article the discussion of delimitation will be specific to equidistant boundaries.[6] The method used to *depict* the location of an international maritime boundary is the more important aspect of boundary making from the perspective of the international community of ocean users. It is this method that will determine the level of precision with which the boundary can be recovered. Although delimitation and depiction are distinct, some of the issues that are raised in this article pertain to both.

The body of this article addresses the technical pitfalls encountered in the processes of delimiting and depicting international maritime boundaries. These include problems with nautical charts such as chart availability, scale, projection, and production, and problems with geographical coordinates of turning points, geodetic datums, and the nature of line segments. Technological advances in maritime boundary making are discussed, and recommendations are made which, if followed, should lead to more precise boundary making in the future. Appendix 1 provides a table of the bilateral and trilateral international maritime boundary treaties signed between 1940 and 1991 and the technical information provided in those treaties.[7] Appendix 1, when read in conjunction with this article, should provide the reader with some idea of the degree of recoverability of maritime boundaries worldwide. Although the majority of this discussion is limited to boundaries between adjacent or opposite states, the issues raised also are relevant to the delimitation and depiction of other lines at sea, such as straight baselines, unilaterally claimed seaward limits, traffic separation lanes, and hydrocarbon lease areas.

United Nations Convention on the Law of the Sea

Although the 1982 United Nations Convention on the Law of the Sea states that an equitable solution shall be the goal of maritime boundary agreements, it does not dictate a specific method of delimitation to achieve equitable results.[8] Article 15 recommends equidistance for the purpose of delimiting the territorial sea between states with opposite or adjacent coasts; however, the provision allows for the use of other methods if "it is necessary by reason of historic title or other special circumstances to delimit the territorial seas of the two States in a way which is at variance therewith."[9] In Articles 74 and 83, regarding the delimitation of the exclusive economic zone and continental shelf, respectively, the Convention is silent as to the method of delimitation, and states only that the boundary "shall be effected by agreement on the basis of international law . . . in order to achieve an equitable solution."[10] This wording leaves states with several methods for delimiting their maritime boundaries, the most popular of which thus far has been equidistance.

The 1982 Convention is clearer on the topic of the depiction of maritime boundaries once they have been delimited. The following language, found in Article 75 of the Convention, addresses the method of depicting the location of the limit of the exclusive economic zone:

> 1. Subject to this Part, the outer limit lines of the exclusive economic zone and the lines of delimitation drawn in accordance with article 74 shall be shown on charts of a scale or scales adequate for ascertaining their position. Where appropriate, lists of geographical coordinates of points, specifying geodetic datum, may be substituted for such outer limit lines or lines of delimitation.
> 2. The coastal State shall give due publicity to such charts or lists of geographical co-ordinates and shall deposit a copy of each such chart or list with the Secretary-General of the United Nations.

Similar language is found in Articles 16 and 84, which deal with the depiction of the limits of the territorial sea and the continental shelf, respectively.

Few of the international maritime boundaries considered in Appendix 1 are depicted on a chart "of a scale or scales adequate for ascertaining their position" without some support from the text of the treaty. Several of the agreements signed since the mid-1970s include a chart to be used for illustrative purposes only.[11] In many of the boundary treaties, it is stated explicitly that the chart annexed to the treaty document is an integral part of the agreement.[12] In other treaties, however, it is unclear what role the chart is intended to play.

Most treaties are not forthcoming about the use of cartometry versus computation in the delimitation process, but it can be assumed that boundaries negotiated prior to the 1978 Norway-United Kingdom continental shelf agreement[13] were delimited graphically on the surface of a chart. Since that time, computer programs have been in use which are designed to calculate equidistance from known basepoints using combinatorial search algorithms. Although charts currently are used less frequently in the delimitation process, and play a less important role in depicting maritime boundaries, they are an important part of many extant boundary agreements and deserve some comment here.

Charts

Several problems arise in the use of charts to delimit and depict international maritime boundaries, particularly with respect to the issues of chart availability, scale, projection, and production.

Availability

In order to cartometrically determine the location of an equidistant turning point on a chart, all relevant sections of coastline and the area of the ocean to be partitioned must be within the frame of the chart. Nautical charts are designed specifically to ensure safe navigation by mariners, and not for the purpose of delimiting international maritime boundaries. The informational needs of the mariner are different from those of the technical adviser in a boundary negotiation. A mariner might require a small-scale (i.e., 1:1,500,000) chart of a region to provide him or her with a general idea of the land configurations and locations of any dangerous waters in the area. Beyond this the mariner will need larger scale, or more detailed, charts of nearshore waters if he or she plans to navigate along a coast. Only one coast is important to the mariner at any given time, and thus, unless the two or more coastlines in question are relatively close together, they will not both appear on the same large-scale chart. Because nautical charts are not designed for the delimitation of maritime boundaries, their coverage is often such that part of the area under consideration is on one chart while the rest of the area is on another, despite the fact that the whole area could fit on a chart of the same, or larger, scale if it were designed with boundary delimitation in mind.[14]

British Admiralty, the United States Defense Mapping Agency Hydrographic/Topographic Center, the French Service Hydrographique et Oceanographique de la Marine, and the former Soviet navy provide worldwide coverage of coastal waters.[15] Many nations do not have the technical or financial capacity to support their own mapping agencies. In this case, they must rely on the charts of their coastal waters which are available through one of these foreign agencies. This may prove to be a politically unpalatable option in some instances. Even if the parties are willing to use the available charts of the region, they still face issues of chart coverage and scale.[16] Unfortunately, any attempt by foreign states to update and improve their charts using ship-based techniques within the exclusive economic zone of another state could be severely inhibited by Part XIII of the 1982 Law of the Sea Convention, which grants the coastal state exclusive rights to marine scientific research within its exclusive economic zone.

Scale

In recognition of the realities of the charting world, the wording in Articles 16, 75, and 84 of the 1982 Convention gives no specific indication as to what is considered an appropriate chart scale. It is likely that the Convention was written in such ambiguous terms to allow for the lack of large-scale charts in various parts of the world. To dictate a minimum scale would exclude many states from negotiating their maritime boundaries simply because there are no large-scale charts available of their coastal waters. Adequate scale depends on boundary length, the distance between basepoints on opposite or adjacent coasts, the type of boundary being delimited (e.g., territorial sea, exclusive economic zone), and the size of the area encompassed by the boundary.

Adequate scale also depends on the cartographic tools employed to draw the boundary. Maling calculated that if dividers (maximum spread 180 millimeters) are used to construct maritime boundaries on nautical charts, the largest practicable scale for constructing the boundary of the territorial sea is 1:125,000 and for the exclusive economic zone 1:1,500,000. The error that can be expected in using this graphical technique translates into ±50 meters and ±600 meters on the ground for the respective zones. If a compass beam is used instead (maximum spread 800 millimeters) the largest practicable scale for constructing the territorial sea is 1:25,000 with a standard error of ±5 meters, and 1:500,000 with an error of ±100 meters for the exclusive economic zone.[17] In other words, the tool cannot be opened wide enough to delimit a 200-nautical-mile-wide zone on a larger scale chart. An error of ±5 meters is probably acceptable for most maritime activities, but the tools of cartography limit that degree of accuracy to lines drawn within 12 nautical miles of the baselines. An error of ±100 meters is less acceptable. Regardless of the limits imposed by the tools of cartography, nautical charts with a scale of 1:25,000 are unavailable for most coastal areas.[18]

Line width is another important factor to consider when addressing problems with chart scale. Lines on charts depicting coastlines are rarely narrower than $\frac{1}{100}$ of an inch. At a scale of 1:1,500,000, a line of that width covers a 381-meter-wide swath on the ground. This is the size (on the ground) of the symbol (on the chart) which the cartographer uses to determine the location of the turning points of a maritime boundary. The location of the turning point can be determined with no more accuracy than that of the reference basepoint, and in fact, probably with less accuracy because it is dependent on two such basepoints, and additionally, is subject to the measurement error discussed above. If the error is biased for some reason, a positional error for the turning point of the boundary could be expected to be nearly 1 kilometer on the ground depending on the tool used. This error would be reduced with a larger scale chart, but so would the extent of the chart coverage.

Another issue that arises when discussing chart scale and its effects on boundary delimitation and depiction is the issue of the smallest significant figure used when providing the geographical coordinates of turning points. Most extant international maritime boundary agreements provide a list of the geographical coordinates of their turning points. The smallest significant figure given for these coordinates can provide clues as to the technique used to determine their locations and the precision with which the boundaries were delimited. The smallest significant figure also helps determine the degree of recoverability of the boundary. The majority of the boundaries listed in Appendix 1 are depicted by giving the geographical coordinates of their turning points to the nearest second (1") of latitude and longitude. However, the range of precision among the 147 boundaries is from the nearest degree (1°) to the nearest one hundredth of a second (.01").[19]

The precision with which the geographical coordinates of turning points can be determined cartometrically on the surface of a chart is limited by the scale of the chart. On a 1:1,500,000 scale chart, 1' of latitude covers only 1.2 millimeters on the surface of the chart. In order to measure a point to the nearest 1" ($\frac{1}{60}$ of 1'), the cartographer would need to be able to divide this 1.2 millimeter length into 60 equal portions of .02 millimeters. Because the width of a narrow line is equivalent to .25 millimeters, this task clearly would be impossible at this scale. This limits the measurement accuracy of both basepoints and turning points, but does not necessarily mean that these points cannot be precisely recovered at sea. If the geographical coordinates of a turning point are given only to the nearest 1", it can be assumed that the point was intended to be at exactly that set of coordinates. In other words, no smaller significant figure was deemed necessary because the turning point happened to fall exactly at the intersection of a parallel and meridian on a grid constructed to the nearest 1". It is more likely that measurement constraints due to chart scale would not allow the states parties to the boundary agreement to determine the locations of their turning points with a higher degree of precision.

If states parties to an agreement are satisfied with this level of precision, then the coordinates of the turning points cannot be disputed. However, the line segments that join pairs of turning points, consisting of an infinite number of points, each of which is theoretically equidistant from basepoints on the opposite or adjacent coasts, do not fit as neatly into this concept. If the points that make up the line segments between turning points are also limited to 1" of accuracy, the line segments will zigzag along the grid of parallels and meridians described above. This is unavoidable unless the line segments are measured, graphically or by computation, with more accuracy than that of the turning points.

Projection

A chart is a planar, Euclidean surface on which the non-Euclidean surface of the earth is represented. To make this possible, the surface of the three-dimensional earth must be "projected" onto a two-dimensional paper chart. There are several different types of projection, all of which distort either angle or scale. Because nautical charts are designed as aids to navigation for mariners who navigate on compass bearings, the preservation of angle is more crucial than the preservation of scale. It is useful for mariners to have a chart on which a line of constant compass bearing on the surface of the ocean is represented as a straight line on the chart. Mercator's projection provides a chart with these qualities by distorting scale, but preserving angle. It thus is the ideal projection for nautical charts, and with only the rare exception, nautical charts are drawn in Mercator's projection.

However, due to the scale distortions of Mercator's projection, it is not the ideal projection for delimiting equidistant boundaries, or any other type of boundary which relies on distance to determine its location. In Mercator's projection, the scale at 60°00' latitude is four times larger than the scale at the equator. In other words, four times more actual area is represented in the same amount of chart space at the equator than is represented at 60°00' latitude. The magnitude of scale distortion increases as one moves away from the equator. The scale at 80°00' is 33.163 times larger than the scale at the equator. Scale distortion is problematic because of the effect that it has on distance on the chart compared with actual distance on the ground.

Because the same area on the chart represents more area on the ground at the equator than the same area on the chart represents at a higher degree of latitude, geometric equidistance on the chart does not represent equidistance on the ground. The only situation in which geometric equidistance on a chart in Mercator's projection will represent equidistance on the ground is when the basepoints are on the same parallel of latitude. In this case, the measurement would be directly east-west and thus would avoid the scale distortions which occur on the north-south axis. With the exception of this rare occurrence, determining the location of equidistant turning points on a nautical chart will favor the nation whose basepoints are closer to the equator. Figure 1 is a simplified illustration of the difference between geometric equidistance on a nautical chart and actual equidistance on the surface of the ocean, which Australia and Indonesia encountered after negotiating their 1971 seabed boundary. According to Prescott,

> [i]t was not realized until long after the boundary had been settled that Points A4-A12 lie south of the strict equidistant line. This occurred because it was not appreciated that the scale of Mercator charts increases away from the equator. This means that the *same lengths* measured north and south of a median line trending east-west will produce *longer distances* on the poleward

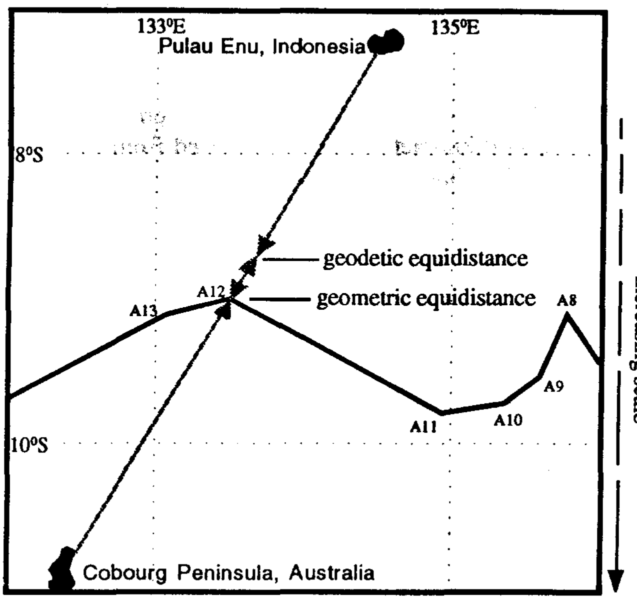

Figure 1. Geometric equidistance versus geodetic equidistance (not to scale). *Sources*: J. R. Victor Prescott, "Australia-Indonesia (Seabed Boundaries)," in *International Maritime Boundaries*, ed. Jonathan I. Charney and Lewis M. Alexander (Boston: Martinus Nijhoff Publishers, 1993), 2: 1195–1201; and Robert D. Hodgson and E. John Cooper, "The Technical Delimitation of a Modern Equidistant Boundary," *Ocean Development and International Law* 3 (1976): 361–388.

> side of the line. It is reported by surveyors that some points were up to 4 n.m. south of the strict line of equidistance [emphases added].[20]

The loss of ocean territory by Australia due to the misuse of a nautical chart in Mercator's projection was significant.

Production

The positional accuracy of the shoreline is a crucial feature on charts used to delimit equidistance turning points, because the shoreline determines the location of the reference baselines and basepoints.[21] Chrisman, Gurda, and Beard investigated the chart compilation and production process of the United States National Ocean Service, the branch of the National Oceanographic and Atmospheric Administration responsible for charting the shorelines of the United States. The main focus of their study was error in chart production. Depending on the techniques used to produce a nautical chart, shoreline positional accuracy could be in error by as much as .61 millimeters on the surface of the chart.[22] This fraction of a millimeter may seem insignificant, but when translated into error on the ground, it becomes clear that an error of this size will have a substantial influence on the final location of an equidistant turning point. At a scale of 1:500,000, this seemingly inconsequential error escalates to the problematic size of 305 meters on the ground. At 1:1,500,000 the error triples to 915 meters.

The above numbers refer to the expected positional error of only one of the two, or perhaps three, coasts involved in a delimitation agreement. If for some reason there is a bias due to systematic errors in the chart production process, the total positional error of the equidistant turning point could be the cumulative sum of several positional errors. Add to this the inaccuracies involved in line width and cartometric error, and it becomes apparent that errors of several kilometers can be expected from the small-scale nautical charts used to delimit maritime boundaries.[23]

Geodetic Datum[24]

If states parties to a treaty choose not to submit a chart to publicize the location of their boundary, then the 1982 Law of the Sea Convention provides that "a list of the geographical co-ordinates of points, *specifying the geodetic datum*, may be substituted" (emphasis added).[25] The geodetic datum supplies the requisite information for anchoring those geographical coordinates, and the points to which they refer, to the surface of a reference ellipsoid which represents the geoid, or magnetic surface of the earth.[26] The geoid is distinct from both the ellipsoid and the topographical surface of the earth (e.g., mountains and trenches [see Figure 2]). The geoid and the topographical surface differ vertically by as much as 9,000 meters on land and 11,000 meters at sea.[27] The geoid, because it approximates the surface of the ocean, is the surface of interest when delimit-

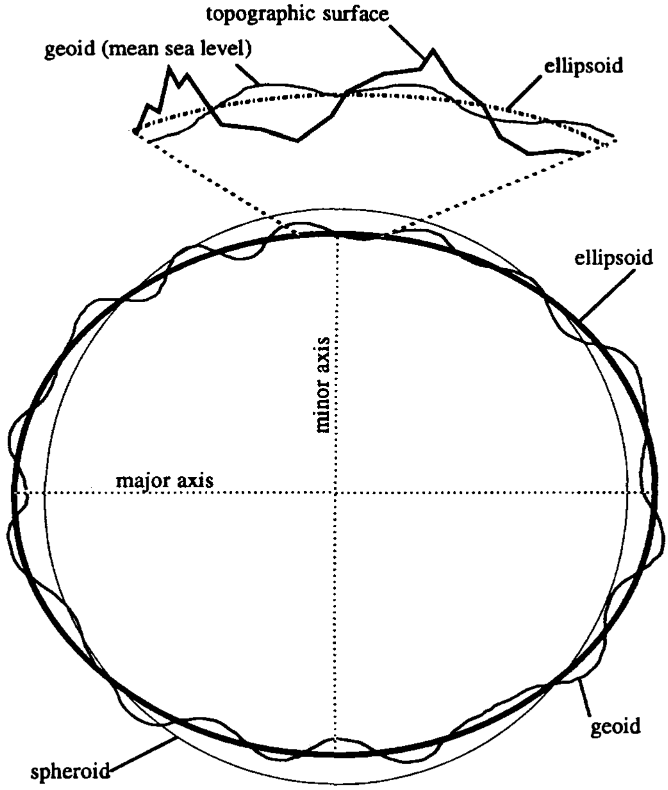

Figure 2. Various surfaces. *Sources*: Robert W. Smith, "A Geographical Primer to Maritime Boundary-Making," *Ocean Development and International Law* 12 (1982): 1–22; and D. Simpson, "Some Observations on the Use of GPS and Charts," *International Hydrographic Review* 70, no. 2 (1993): 29–38.

ing maritime boundaries. It is the surface on which the boundaries exist. However, because the geoid undulates due to the uneven distribution of mass in the earth, it is impossible to define mathematically. Instead, geodesists have developed mathematically defined ellipsoids which closely approximate the surface of the geoid. The vertical discrepancy between these two surfaces (geoid and ellipsoid defined by a geocentric datum) is 0 where they are tangential and approximately 100 meters where they differ most.[28] Ellipsoids are defined by the lengths of their major and minor axes, and by the degree of flattening at the poles.

Local geodetic datums define the dimensions (major and minor axes and degree of flattening) of the ellipsoid which provides the "best fit" for that particular region of the geoid. These local datums also include a point of origin "from which the geographical coordinates of all features of the survey are derived."[29] Although an ellipsoid defined by a local datum provides the "best fit" to the geoid in that particular region, it is unsuitable elsewhere on the geoid. Local datums, which usually are centered on a land mass, become progressively less accurate, or less "well fit," as they move away from their point of origin. Thus, the most serious degradation occurs on the fringes of local datums which usually correspond to coastal and ocean areas. There are over 100 local datums in use around the world, none of whose reference ellipsoid mimics the geoid beyond a localized area.

However, in the 1970s the development of new satellite technology provided geodesists with the tools necessary to define a global, geocentric datum.[30] This type of geodetic datum consists of a reference ellipsoid which closely mimics the surface of the geoid across its full extent. Unlike the local datums, which are referenced to points of origin on the topographic surface, global datums are referenced to the earth's center of mass. The most recent development in the area of global, geocentric datums is World Geodetic System 1984 (WGS84), which currently provides the "best fit" ellipsoid worldwide.[31]

International maritime boundary delimitation and recovery are made problematic by the existence of numerous, unconnected datums. Beazley wrote that "[t]he lack of agreement on a common geodetic datum for the definition of geographical coordinates offers possibly the greatest likelihood of subsequent disputes even though a boundary line has apparently been settled."[32] This is due to the inherent discrepancies among local datums, especially at their fringes, and between local datums and global datums. The result of these discrepancies is that a single point on the surface of the geoid, or ocean, will be defined by different geographical coordinates depending on the datums to which it is referenced. Obversely, a single set of geographical coordinates will represent different points on the geoid if it is referenced to different geodetic datums. Depending on the datums used and the location of the point relative to the datums, the difference may be slight. However, discrepancies of up to 1.5 kilometers can occur on the geoid between points defined by a single set of geographical coordinates referenced to two different geodetic datums.[33]

Articles 16, 75, and 84 of the 1982 Law of the Sea Convention require that if a list of the geographical coordinates of turning points is submitted in place of a chart, the geodetic datum to which those coordinates are referenced must be specified. It is common practice for states to submit a chart and a list of geographical coordinates without any reference to a geodetic datum. By neglecting to specify a geodetic datum, states parties to the boundary agreement imply that the datum to which the chart is referenced is also the datum to which the coordinates are referenced.[34] This practice is problematic both because the intention is rarely stated explicitly and because the geodetic datum to which a chart is referenced is not always stated on the chart itself.[35] Without a specified geodetic datum, maritime boundaries are not recoverable with any degree of precision.

Lines

The discussion above has been limited to the positional accuracy of the turning points of maritime boundaries, both in their initial determination and in their subsequent recovery. Most international maritime boundaries consist of a set of turning points *and* a series of line segments which connect pairs of these points. The problems which arise when the nature of those line segments is not specified in international maritime boundary agreements are addressed below.

There are several different types of lines which can be used to connect the turning points of a maritime boundary. Although they are all, in a sense, "straight lines," each type describes a different line on the surface of the ocean. As a result, the nature of the line segments affects the configuration of national territories. The following are definitions of the various lines commonly used in maritime boundary agreements.[36]

Geodesic/geodetic line: A geodesic is the line of shortest distance between two points on the surface of an ellipsoid and represents the shortest distance between two points on the surface of the earth. It also most closely represents an equidistant line between opposite coasts. Meridians (lines of longitude) and the equator are geodesics, but parallels (lines of latitude) are not. Because of Mercator's projection, a geodesic appears curved on nautical charts. The azimuth, or compass direction, of a geodesic changes along its length.

Loxodrome/rhumb line: A loxodrome appears as a straight line on the surface of a nautical chart. It is the line of shortest distance between two points on the Euclidean surface of a nautical chart. A loxodrome is useful to mariners because it maintains a constant azimuth along its entire length. Although a loxodrome is straight on a nautical chart, on the surface of the earth a loxodrome is represented by a loxodromic curve which spirals toward the pole on a constant bearing. Parallels (including the equator) and meridians also are loxodromes.

Great circle: A great circle is the line between two points on the surface of a sphere which is defined by the intersection of that sphere and a plane that passes through the two points and the center of the sphere. It is a geodesic on a perfect sphere. Meridians and the equator are great circles, but only on a perfect sphere. Because the surface of the earth more closely resembles an ellipsoid, and is so defined, a great circle is not a straight line on the earth's surface.[37]

Small circle: Parallels other than the equator are small circles. Unlike the equator and meridians, parallels are not geodesics. They appear as straight lines on nautical charts.

Azimuth: Technically, an azimuth is not a line, but an angle or bearing. It is the horizontal angle between a meridian and a line intersecting it. Loxodromes (and loxodromic curves) have a constant azimuth, while the azimuth of a geodesic is different at each meridian it intersects.

Nowhere in the 1982 Law of the Sea Convention is the nature of lines mentioned. Although the term "straight line" is used, there is no clarification as to what kind of line is intended.[38] As a result, many treaties either do not specify the type of line segment that connects turning points, or they simply refer to the line segments using the ambiguous term "straight lines" without further clarification.[39] Because the discrepancy in the ocean area encompassed by these different kinds of lines can be substantial, ambiguity must be avoided in order to eliminate disputes in the future over the location of the boundary and what part of the sea it apportions to whom.[40]

Technological Advances

Two new technologies relevant to international maritime boundary making have been developed since the 1970s: (1) satellite networks for positioning at sea, and (2) software programs for computing distance and area on an ellipsoid. These relatively new technologies make possible high degrees of precision and accuracy in the delimitation, depiction, and recovery of international maritime boundaries. These technological advances, along with the increased value and use of ocean resources, also make high degrees of precision and accuracy more necessary. Ocean users can now locate themselves on the surface of the ocean to within 1 centimeter. Prior to the 1970s, and the advent of satellite technology, ocean users out of sight of land could not determine their position with greater accuracy than 1 nautical mile.[41] For many of these ocean users, it is critical that they know their position relative to lines of jurisdictional division.[42] Boundary makers can now compute the location of international maritime boundaries with degrees of precision impossible to attain by using only nautical charts. These technologies already influence the spatial conceptualization of the world's oceans, and this influence will only increase as these technologies become more widely available. They are crucial factors in modern international maritime boundary making and deserve some attention here.

Global Positioning System

A Global Positioning System (GPS) is a network of satellites that can determine the horizontal and vertical location of a receiver on, or relative to, the surface of a "best fit," geocentric ellipsoid. The NAVSTAR network is owned and operated by the United States Department of Defense, and is referenced to the WGS84 ellipsoid. The Global Navigation Satellite System (GLONASS) is Russian owned and operated, and is referenced to the ellipsoid of the Soviet Geodetic System 1985 (SGS85). The NAVSTAR and GLONASS networks each contain 24 satellites. The Department of Defense intentionally degrades the NAVSTAR system by corrupting satellite position and timing information contained in the messages transmitted from the satellites to the receiver. This degradation is called selective availability. Even with the degraded signal caused by selective availability, a civilian using a single, 12-channel, handheld GPS receiver can position himself or herself on the WGS84 ellipsoid with a "horizontal positional accuracy of 100 meters or better at a 95% confidence level."[43] With a receiver designed to receive signals from both NAVSTAR and GLONASS satellites, precision can be doubled due both to the larger number of satellites available to the receiver at any one time and to the undegraded nature of the GLONASS signals.[44]

There are many ways to further improve the positional accuracy of the NAVSTAR system under selective availability without resorting to GLONASS satellites. However, additional precision requires more expensive equipment, and in the case of differential and "on the fly" techniques, requires two receivers (see Table 1). In order to improve the precision of the GPS under conditions of selective availability, the user can switch to differential mode. Differential mode requires two receivers, one of which is a land-based, fixed-point receiver, the other of which is mobile. It is the precise location of the

Table 1
Global Positioning System (GPS) positioning modes, precisions, and costs

Positioning mode	Precision (meters)	Cost per receiver (U.S.$)	Number of receivers required
Standard Positioning System (SPS)	100 m	1,000	1
Precise Positioning System (PPS)	50 m	10,000	1
SPS Differential	10 m	5,000	2
PPS Differential	1 m	10,000	2
Single frequency on the fly carrier phase ambiguity resolution (L1 OTF)	0.1 m	10,000	2
Double frequency on the fly carrier phase ambiguity resolution (L1 L2 OTF)	0.01 m	20,000	2

Source: Galo Carrera, "The Role of GPS, GIS and ECDIS in the Delimitation of Maritime Spaces" (paper presented at International Boundaries Research Unit Workshop on Geographical and Technical Considerations in Maritime Boundary Delimitations, Durham, United Kingdom, July 1996).

mobile receiver that is important to the marine surveyor. With the additional fixed triangulation point provided by the land-based receiver, the position of the mobile receiver can be established to within 10 meters using a Standard Positioning System (SPS) in differential mode, and to within 1 meter using a Precise Positioning System (PPS) in differential mode. Still greater precision can be achieved by using receivers in single or double frequency on the fly (OTF) carrier phase ambiguity resolution mode. In OTF mode, the number of wave lengths between the fixed receiver and the mobile receiver is measured, providing extremely high levels of precision. A receiver in single frequency OTF mode can be positioned to the nearest 0.1 meter and in double frequency OTF mode, to the nearest 0.01 meter.[45]

As a result of industry pressure and a recent Rand Corporation study commissioned by the executive branch of the U.S. government, it is likely that commercial interests in the NAVSTAR system will begin to take precedence over military interests. The restrictions imposed by selective availability inhibit the navigational uses of NAVSTAR for civilian aircraft, ships, and automobiles. Additionally, the possibility that military priorities could suddenly disrupt the navigational capabilities of the system for civilian users has created uncertainties which have inhibited growth in the GPS industry. If selective availability is phased out, more precise positioning can be achieved at lower cost for more users.[46]

Computation

Software programs that use combinatorial search algorithms which can compute the location of equidistant turning points directly on the surface of the reference ellipsoid have been in use since the 1970s. These programs also are capable of computing offshore limits, equidistant boundaries, weighted boundaries, points along a segment of a geodesic defined by its end points, points along an arc of a seaward limit, the size of maritime areas, and transformations between geodetic datums.[47] The required input data are the geographical coordinates of basepoints on opposite coasts, and the dimensions of the reference ellipsoid of the geodetic datum to which those points are referenced. Many nations have developed their own programs for the purpose of computing their boundaries with other states, and the seaward limits of their territorial sea and exclusive economic zone. The algorithms and designs of these programs generally are classified information. However, one such computer program, DELMAR version 1.0, was designed in 1988 with funding from the International Centre for Ocean Development (ICOD) for the purpose of providing developing countries with the technical capacity to delimit precisely their international maritime boundaries.[48]

By computing the location of equidistant turning points directly on the ellipsoid, the areal distortions caused by Mercator's projection are eliminated, as are many of the measurement errors involved in the process of cartometrically determining the location of turning points. The degree of precision with which these computations can be made is virtually limitless.[49] Additionally, because the computations are made on the surface of the ellipsoid, every "straight line" is automatically a geodesic, leaving no room for ambiguity as to the nature of the line segments connecting pairs of turning points. To ensure a high level of clarity, however, the nature of line segments should be explicitly stated in the treaty text.

Although the output (geographical coordinates of turning points) of these computations can be extremely precise, the accuracy of the output ultimately is dependent on the accuracy of the input data (geographical coordinates of basepoints and the dimensions of the reference ellipsoid). Therefore, the method for determining the geographical coordinates of the basepoints is a limiting factor. The measurement errors associated with cartometrically determining the location of equidistant turning points are eliminated through computational methods; however, the errors associated with determining the geographical coordinates of the basepoints from which these turning points are computed are not. All of the measurement errors associated with the use of cartometric tools, and with nautical charts (e.g., line width, scale, positional accuracy of shoreline symbol, production techniques, source material, geodetic datum) would still exist for the measurement of basepoints. The GPS (in differential or OTF mode), used as a surveying tool, is a technology that would eliminate most of the error in the positional accuracy of basepoints. High levels of precision and accuracy can be achieved if GPS and computation are used in the delimitation, depiction, and recovery of international maritime boundaries. As the price of these technologies decreases and the need for precision increases, it is likely that GPS and computation will replace nautical charts and cartometry in the international maritime boundary making process.[50]

Recommendations

Regardless of the method used to delimit an international maritime boundary, the following information is necessary for the accurate recovery of the boundary by states parties to the treaty and by third-party ocean users, and should be included in the text of every international maritime boundary treaty: (1) the geographical coordinates of turning points (preferably to the nearest .1"), (2) the nature of the line segments connecting these points (preferably geodesics as they are the closest to equidistant and easiest to compute), and (3) the geodetic datum to which the boundary is referenced (preferably WGS84 or another global datum in order to avoid transformations to or from local datums). A nautical chart also could be annexed to the treaty to portray the geographical context within which the boundary lies; however, it should be stated explicitly that the chart is for illustrative purposes only and that the language in the text of the treaty predominates. While there is a trend toward providing this necessary information, the majority (60%) of the international maritime boundaries considered in Appendix 1 lack one or more of the three pieces of information necessary for their precise recovery.

Other Considerations

Although absolute accuracy and precision in the delimitation, depiction, and recovery of international maritime boundaries is the presumed goal here, other modifying considerations should be taken into account during the process of creating maritime boundaries. Both the nature of the resource that is being divided and the technological capacity of the ocean users in the area of the boundary should be considered. For instance, it is unnecessary to partition a fugitive resource, such as a highly migratory pelagic finfish population, with the same degree of precision as relatively sedentary resources, such as oil, gas, or hard minerals. While oil companies can locate the corner of a stationary offshore oil platform to within less than a meter, there are many fishing vessels around the world that navigate without the use of nautical charts, much less satellite technology.[51] If fishery resources are the only consideration when delimiting a maritime boundary between two countries with low-technology artisanal fleets, then techniques involving satellite-derived basepoints and equidistant turning points computed to the nearest .01" would indeed be overkill. In this instance, drawing the boundary as an azimuth from a visible point on land probably would be sufficient. However, boundary makers should consider the possibility of other ocean uses in the future, such as the unexpected discovery and exploitation of hydrocarbons in the area of the boundary. Boundary makers also should recognize that a well-delimited, precisely depicted boundary can be made less precise by relaxing the strictness with which it is enforced, while an initially imprecise boundary cannot be improved without further negotiations and surveying. Additionally, they should be aware that it is possible to delimit the continental shelf and the water column with separate boundaries and different levels of precision.

Buffer zones have been created around some international maritime boundaries to deal with the issue of ocean users' capabilities with respect to locating themselves on the surface of the ocean. Ecuador, recognizing that its fishermen might not be able to locate themselves on the ocean relative to its boundaries with Colombia and Peru, has devised a unique boundary-making strategy involving buffer zones. Article 2 of the 1975 Colombia-Ecuador maritime boundary agreement states:

> To establish beyond 12 nautical miles starting from the coast, a special zone, 10 nautical miles in width, on either side of the parallel which is the marine limit between the two countries, for the purpose of insuring that the accidental presence of local fishermen of either country in that zone should not be considered a violation of that marine boundary. This is not recognition of any rights to engage in fishing or hunting activities within said special zone.[52]

This is not a joint development zone, but rather a buffer zone that recognizes the limited technical capacity of the resource users in the area of the boundary. If ocean users in the area of a boundary are unable to locate the boundary precisely, then buffer zones are one sensible solution. However, as the boundary itself is the positional reference for these zones, the accuracy of that boundary is still of the utmost importance.

Johnston and Valencia challenged the current boundary-making paradigm when they posed the question, "[S]hould an ocean boundary always, or even normally, take the form of a line or 'fence'?"[53] There are many excellent arguments as to why cooperative arrangements between states would be more effective than the linear settlements which have been the norm over the past half century of maritime boundary making. One shortcoming of linear settlements is that they rarely reflect the configuration of the natural systems that they divide. International maritime boundaries are artificial legal constructs superimposed on continuous natural systems. Such artificial superimpositions lead, inter alia, to straddling fish stocks and divided fields of oil and gas. Johnston suggested that transboundary issues such as these would be better dealt with through a regime based on functional rationality, involving joint development schemes and the sharing between nations of the costs and benefits of ocean development.[54] Johnston predicted an increase in the use of a "functionalist" approach to ocean boundary making, whereby the efficient use and development of marine resources, rather than greed-motivated territorial claims, would be the driving force behind maritime boundary delimitation.[55] To witness the demise of greed-motivated territorial claims in the international arena would be a welcome surprise. Current state practice on international maritime boundary making, however, indicates that linear settlements still are the predominant method of dividing ocean space and resources.

Conclusion

If in fact international maritime boundary making is a "fence building" activity, as state practice indicates that it is, then it must be conducted in a manner which will allow states parties to boundary agreements to "memorialize their settlement in a technically precise form that would be unchallengeable in the future."[56] Many of the existing international maritime boundaries do not achieve this standard. This is due in large part to the level of technology at the time of their delimitation. However, over the past two decades technological advances, such as GPS and computational software, have given coastal states the ability to more accurately and precisely delimit, depict, and recover their maritime boundaries. These advances also have increased—by five orders of magnitude—the precision with which one's position on the surface of the ocean can be determined, making accurate boundaries that much more important.

As of November 30, 1990, the United States Department of State identified 420 potential international maritime boundaries.[57] Since that time, many more potential international maritime boundaries have been created through the balkanization of the former Soviet Union and former Yugoslavia. In 1990, fewer than one-third of the 420 potential boundary agreements had been negotiated. The treaty texts of many of these boundary agreements do not provide the technical information necessary for the precise recovery of the boundary at sea. Of the 147 boundaries analyzed in Appendix 1, approximately 55% are not referenced to a specific geodetic datum. The nature of some or all of the line segments are not specified for approximately 35% of these boundaries. The smallest significant figure of the coordinates of turning points for approximately 30% of these boundaries is greater than 1". There may be problems in the future due to the unrecoverability of many of these boundaries.

Modern technology, which can be used to delimit, depict, and recover maritime boundaries accurately and precisely, is now relatively affordable and readily available. Technical expertise also is available in the form of commercial surveying companies and geodetic consultancies. There are no longer any excuses for imprecise maritime boundaries. Neither are there any strategic benefits to imprecision. The exploitation of marine resources in disputed areas is a risky undertaking; therefore, the resources in those areas either will be inefficiently exploited or will lie unused until such time as the locations of the boundaries are made clear. The international political stability derived from precise, unchallengeable maritime boundaries will benefit all ocean users in the international community. International maritime boundary making must be a multidisciplinary undertaking that includes legal experts as well as technical experts, such as geographers and geodesists. If international maritime boundaries are to function as fences, then let us build them well.

Appendix 1
Technical Information Provided in International Maritime Boundary Treaties

The international maritime boundaries listed here are existing boundary lines as of 1991. The treaties or International Court of Justice awards in which they are depicted were signed or rendered between 1940 and 1991. The exclusive source of information for this list is *International Maritime Boundaries*, volumes 1 and 2, edited by Jonathan I. Charney and Lewis M. Alexander and published by Martinus Nijhoff in 1993. The author has used their numbering system and geographical regions. Nine of the records from *International Maritime Boundaries* do not appear in this list (i.e., 2-13[1], 2-13[2], 7-1, 7-4, 7-10, 8-10[3], 10-4[4], 10-5, 10-6[2]). Four of these records (7-1, Abu Dhabi-Dubai [1968]; 7-4, Dubai-Sharjah [1981]; 7-10, Sharjah-Umm al Qaywayn [1964]; and 10-5, Federal Republic of Germany-German Democratic Republic [1974]) do not appear in this list because they are no longer international in nature, but rather internal to sovereign states (i.e., the United Arab Emirates and Germany). Two of these records (2-13 [1], Trinidad and Tobago-Venezuela [1942]; and 2-13[2], Trinidad and Tobago-Venezuela [1989]) do not appear in this list because the boundaries depicted in these treaties have been superseded completely by a boundary depicted in a later treaty (i.e., 2-13[3], Trinidad and Tobago-Venezuela [1990]). Three of the *International Maritime Boundaries* records (8-10[3], Turkey-Soviet Union [1987]; 10-4[4], Finland-Soviet Union [1985]; and 10-6[2], Federal Republic of Germany-Poland [1990]) do not appear in this list because they do not change the technical nature of the line. In the case of 10-6(2), Federal Republic of Germany-Poland (1990), the parties simply reaffirm the existence of the line depicted in the treaty found in record 10-6(1), German Democratic Republic-Poland (1989). In both 8-10(3), Turkey-Soviet Union (1987), and 10-4(4), Finland-Soviet Union (1985), the depiction of an earlier line remains the same while the number of maritime zones that the line divides increases. For example, instead of dividing only the continental shelf as stated in the treaty in record 8-10(2), Turkey-Soviet Union (1978), as of 1987 the same line also divides the exclusive economic zone.

There also are several additional records in the list which do not correspond directly to the records found in *International Maritime Boundaries*. These are indicated with a lower case roman letter after the *International Maritime Boundaries* record number. These additional records are necessary if more than one line is described in a single treaty or a single *International Maritime Boundaries* record. This appendix does not list international maritime boundary treaties, but rather the boundaries depicted in those treaties.

Island and territory names are given in parentheses. Other geographical references (e.g., bodies of water) and references to the maritime zones delimited by the boundary (e.g., exclusive economic zone, territorial sea, fisheries zone, continental shelf, historic waters) are given in brackets for the sake of clarity. If no maritime zone is specified, the boundary

Appendix Table
International Maritime Boundaries

International Maritime Boundaries record number	Boundary	Date treaty signed/ award rendered	Chart annexed?	Smallest significant figure in seconds (")	Geodetic datum specified?	Nature of line segments specified?
I. North America						
1-5a	Mexico-United States of America [TS, Gulf of Mexico]	11/23/70	Y	.01"	N	N
1-5b	Mexico-United States of America [TS, Pacific Ocean]	11/23/70	Y	N/A	N	N
1-2	Canada-France (St. Pierre and Miquelon) [TS]	3/27/72	Y	1"	N	Y[b]
1-1	Canada-Denmark (Greenland) [CS]	12/17/73	Y	6"	Y	Y[c]
1-4	Cuba-United States of America	12/16/77	Y	1"	Y	Y[c]
1-5c	Mexico-United States of America [Gulf of Mexico and Pacific Ocean; extension of 1-5a and 1-5b]	5/4/78	N	.01"	Y	Y[c]
1-3	Canada-United States of America [Gulf of Maine]	3/29/79	N	1"	Y	Y[c]
1-6	United States of America-Soviet Union	6/1/90	N	1"	Y*	Y[c,b,i]
II. Middle America/The Caribbean						
2-8	Cuba-Mexico	7/26/76	Y†	.01"	N	Y[g]
2-5	Colombia-Panama [Caribbean Sea and Pacific Ocean]	11/20/76	Y	60"	N	N

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Appendix Table

International Maritime Boundaries (*Continued*)

International Maritime Boundaries record number	Boundary	Date treaty signed/ award rendered	Chart annexed?	Smallest significant figure in seconds (")	Geodetic datum specified?	Nature of line segments specified?
II. Middle America\The Caribbean (*Cont.*)						
2-1	Colombia-Costa Rica [Caribbean Sea]	3/17/77	Y	60"	N	Y[b,e,f]
2-7	Cuba-Haiti	10/27/77	Y†	.01"	N	Y[g]
2-2	Colombia-Dominican Republic	1/13/78	Y	6"	N	N
2-3	Colombia-Haiti	2/17/78	Y	6"	N	N
2-14	United States of America (Puerto Rico, Virgin Islands)-Venezuela	3/28/78	Y†	1"	Y	Y[c,d]
2-12a	Netherlands (Saba Island)-Venezuela (Aves Island)	3/31/78	Y†	1"	Y	Y[g]
2-12b	Netherlands (Aruba, Curacao, Bonaire)-Venezuela	3/31/78	Y†	1"	Y	Y[e,f,g]
2-9	Dominican Republic-Venezuela	3/3/79	Y	1"	Y	Y[c,d]
2-6	Costa Rica-Panama [Caribbean Sea and Pacific Ocean]	2/2/80	Y	1"	N	N
2-11	France (Guadeloupe and Martinique)-Venezuela	7/17/80	Y	10"	N	Y[e]
2-10	France (Martinique)-Saint Lucia	3/4/81	Y	1"	Y	Y[b]
2-4	Colombia-Honduras	8/2/86	Y†	1"	N	Y[c,f,k]
2-15	Dominica-France (Guadeloupe and Martinique)	9/7/87	Y	1"	Y	Y[b]
2-13(3)	Trinidad and Tobago-Venezuela	4/18/90	Y†	1"	Y	Y[c,d,e]

III.	South America					
3-9	Ecuador-Peru	8/18/52	N	N/A	N	Y[f]
3-5	Chile-Peru	8/18/52	N	N/A	N	Y[f]
3-4	Brazil-Uruguay	7/21/72	N	N/A	N	Y[d]
3-2	Argentina-Uruguay	11/19/73	Y	1"	N	N
3-7	Colombia-Ecuador	8/23/75	Y	N/A	N	Y[f]
3-3	Brazil-France (French Guiana)	1/30/81	N	1"	Y	Y[d,b]
3-6	Colombia-Costa Rica [Pacific Ocean]	4/6/84	Y	60"	N	N
3-1	Argentina-Chile	11/29/84	Y	1"	N	Y[b,d,e,f]
3-8	Costa Rica-Ecuador	3/12/85	N	N/A	Y*	Y[c]
IV.	Africa					
4-4	Portugal (Guinea Bissau)-France (Senegal)	4/26/60	N	N/A	N	Y[d]
4-1	Cameroon-Nigeria	6/1/75	Y	1"	N	N
4-2	The Gambia-Senegal	6/4/75	Y	1"	N	N,Y[f]
4-6	Mauritania-Morocco [CS]	4/14/76	Y	3,600"	N	Y[f]
4-5	Kenya-Tanzania	7/9/76	Y	1"	N	N,Y[f,i]
4-3	Guinea-Guinea Bissau	2/14/85	Y	15"	Y*	Y[b]
4-7	Mozambique-Tanzania	12/28/88	Y	1"	N	N,Y[f]
V.	Central Pacific/East Asia					
5-2	United Kingdom (Sarawak, North Borneo, Brunei) [TS, CS]	9/11/58	N	1"	N	Y[d]
5-9(1)	Indonesia-Malaysia [CS]	10/27/69	Y	6"	N	N
5-9(2)	Indonesia-Malaysia [TS]	3/17/70	Y	6"	N	N
5-11	Indonesia-Singapore [TS]	5/25/73	Y	.1"	N	N

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Appendix Table
International Maritime Boundaries (*Continued*)

International Maritime Boundaries record number	Boundary	Date treaty signed/ award rendered	Chart annexed?	Smallest significant figure in seconds (")	Geodetic datum specified?	Nature of line segments specified?
V. Central Pacific/East Asia (*Cont.*)						
5-12a	Japan-South Korea [CS]	1/30/74	Y	6"	N	N
5-12b	Japan-South Korea [JDZ]	1/30/74	Y	6"	N	N
5-3a	Australia-Papua New Guinea [FZ]	12/18/78	Y	1"	Y	Y[c,e,f,i]
5-3b	Australia-Papua New Guinea [TS]	12/18/78	Y	1"	Y	Y[c,i]
5-3c	Australia-Papua New Guinea [PZ]	12/18/78	Y	10"	Y	Y[c,e,f,i,m]
5-3d	Australia-Papua New Guinea [CS]	12/18/78	Y	1"	Y	Y[c,f]
5-13(1)	Malaysia-Thailand [TS, Gulf of Thailand and Straits of Malacca]	10/24/79	Y	6"	N	N
5-13(2)a	Malaysia-Thailand [CS, Gulf of Thailand]	10/24/79	Y	6"	N	N
5-8	France (Wallis and Futuna)-Tonga [EEZ]	1/11/80	N	N/A	N	N
5-5	Cook Islands-United States of America (American Samoa)	6/11/80	N	1"	Y*	Y[c]
5-14	New Zealand (Tokelau)-United States of America (American Samoa)	12/2/80	N	1"	Y*	Y[c]
5-10	Indonesia-Papua New Guinea [CS, FZ/EZ, Pacific Ocean; extension of 6-2(1)b]	12/13/80	Y	5"	N	N
5-1	Australia-France (New Caledonia) [CS, FZ/EZ]	1/4/82	Y	1"	Y*	Y[c]
5-6	Fiji-France (New Caledonia, Wallis and Futuna) [EEZ]	1/19/83	Y†	N/A	Y*	Y[c]

5-7	France (French Polynesia)-UK (Pitcairn, Henderson, Ducie and Oeno Islands) [EZ/FZ]	10/25/83	Y†	1"	Y*	Y[b]
5-15(1)	North Korea-Soviet Union [TS]	4/17/85	Y	60"	N	N
5-15(2)	North Korea-Soviet Union [EEZ, CS]	1/22/86	Y	6"	N	N
5-4	Australia-Solomon Islands [CS, FZ/EEZ]	9/13/88	Y	1"	Y**	Y[c]
5-16	Papua New Guinea-Solomon Islands	1/25/89	Y	1"	N	Y[c]
5-13(2)b	Malaysia-Thailand [JDZ, Gulf of Thailand]	5/13/90	Y	3"	N	N
5-18	Cook Islands-France (French Polynesia)	8/3/90	Y	1"	Y*	Y[b]
5-17	France (New Caledonia)-Solomon Islands	11/12/90	Y	1"	Y*	Y[b]
VI. Indian Ocean/Southeast Asia						
6-2(1)a	Australia-Indonesia [CS, Arafura Sea]	5/18/71	Y	60"	N	N
6-2(1)b	Australia (Papua New Guinea)-Indonesia [CS, Pacific Ocean]	5/18/71	Y	30"	N	N
6-13(1)	Indonesia-Thailand [CS]	12/17/71	Y	6"	N	N
6-12	Indonesia-Malaysia-Thailand [TJ]	12/21/71	Y	6"	N	N
6-2(2)	Australia-Indonesia [CS, Timor and Arafura Seas; extension of 6-2(1)a]	10/9/72	Y	60"	N	N
6-2(3)	Australia (Papua New Guinea)-Indonesia [landward extension of 6-2(1)a]	2/12/73	Y	1"	N	N
6-10(1)	India-Sri Lanka [HW]	6/28/74	Y	.05"	N	Y[g]
6-6(1)	India-Indonesia [CS]	8/8/74	Y	6"	N	N
6-13(2)	Indonesia-Thailand [CS, extension of 6-13(1)]	12/11/75	Y	6"	N	N
6-10(2)	India-Sri Lanka	3/23/76	Y	6"	N	Y[g]
6-9	India-Maldives-Sri Lanka [TJ]	7/31/76	Y	.6"	N	N
6-8	India-Maldives	12/28/76	Y	1"	N	Y[g]
6-6(2)	India-Indonesia [CS; extension of 6-6(1)]	1/14/77	Y	1"	N	N

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Appendix Table
International Maritime Boundaries (*Continued*)

International Maritime Boundaries record number	Boundary	Date treaty signed/ award rendered	Chart annexed?	Smallest significant figure in seconds (")	Geodetic datum specified?	Nature of line segments specified?
VI. Indian Ocean/Southeast Asia (*Cont.*)						
6-11	India-Thailand [CS]	6/22/78	Y	1"	N	N
6-7	India-Indonesia-Thailand [TJ]	6/22/78	Y	1"	N	N
6-5	France (Reunion)-Mauritius [EZ]	4/2/80	Y	1"	N	Y[b]
6-4	Burma-Thailand	7/25/80	Y	1"	N	N
6-2(4)	Australia-Indonesia [FZ (provisional)]	10/29/81	Y	N/A	N	N
6-1	Australia (Heard and McDonald Islands)-France (Kerguelen Islands)	1/4/82	Y	1"	Y*	Y[c]
6-3	Burma-India	12/23/86	Y	1"	N	N
6-2(5)	Australia-Indonesia [JDZ, Timor Gap]	12/11/89	Y	1"	Y	Y[c]
VII. Persian Gulf						
7-3	Bahrain-Saudi Arabia [CS]	2/22/58	Y	1"	N	N
7-7	Iran-Saudi Arabia [CS]	10/24/68	Y	6"	N	N
7-9	Qatar-United Arab Emirates (Abu Dhabi)	3/20/69	N	5"	N	N
7-6	Iran-Qatar [CS]	9/20/69	Y	5"	N	Y[c]
7-2	Bahrain-Iran [CS]	6/17/71	Y	1"	N	Y[c]
7-5	Iran-Oman [CS]	7/25/74	Y	5"	Y	Y[c]
7-8	Iran-United Arab Emirates (Dubai) [CS]	8/31/74	Y	1"	N	Y[c]
VIII. Mediterranean/Black Sea						
8-1	Cyprus-United Kingdom (Akrotiri, Dhekelia) [TS]	8/16/60	Y	N/A	N	Y[d]
8-7(1)	Italy-Yugoslavia [CS]	1/8/68	Y	6"	N	Y[g,i]

8-6	Italy-Tunisia [CS]	8/20/71	Y	6"	N	Y[g,i]
8-10(1)	Turkey-Soviet Union [TS]	4/17/73	Y	.01"	Y	Y[d]
8-5	Italy (Sardinia)-Spain (Menorca) [CS]	2/19/74	Y	6"	N	Y[c]
8-7(2)	Italy-Yugoslavia [TS]	11/10/75	Y	.6"	N	Y[g]
8-4	Greece-Italy [CS]	5/24/77	Y	6"	N	Y[g]
8-10(2)	Turkey-Soviet Union [CS; extension of 8-10(1); EEZ as of 2/6/87]	6/23/78	Y	1"	Y	N
8-3a	France-Monaco	2/16/84	Y	.01"	Y	Y[b]
8-3b	France-Monaco [TS]	2/16/84	Y	.1"	Y	Y[b]
8-8	Libya-Malta [CS]	11/10/86	Y†	1"	Y	Y[g]
8-2	France (Corsica)-Italy (Sardinia)	11/28/86	Y	.1"	Y	Y[b,e,f]
8-9	Libya-Tunisia [CS]	8/8/88	Y†	10"	N	Y[d]
IX. Northern and Western Europe						
9-6	Norway-Soviet Union [TS, CS]	11/29/57	Y	.01"	Y	N
9-11a	Federal Republic of Germany-Netherlands [CS]	12/1/64	Y	1"	N	N
9-15a	Norway-United Kingdom [CS]	3/10/65	Y	2"	Y	Y[g]
9-8a	Denmark-Federal Republic of Germany [CS]	6/9/65	N	.1"	Y	N
9-13	Netherlands-United Kingdom [CS]	10/6/65	Y	1"	Y	Y[g]
9-14	Norway-Sweden [TS, CS]	7/24/68	Y	.1"	Y	Y[b,g]
9-8b	Denmark-Federal Republic of Germany [CS; extension of 9-8a]	1/28/71	Y	.1"	Y	Y[g]
9-11b	Federal Republic of Germany-Netherlands [CS; extension of 9-11a]	1/28/71	Y	1"	Y	Y[g]
9-12	Federal Republic of Germany-United Kingdom [CS]	11/25/71	Y	.1"	Y	Y[g]
9-10	Denmark-United Kingdom [CS]	11/25/71	Y	.1"	Y	Y[g]
9-2a	France-Spain [CS, Bay of Biscay]	1/29/74	Y	1"	N	Y[c]

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Appendix Table
International Maritime Boundaries (*Continued*)

International Maritime Boundaries record number	Boundary	Date treaty signed/ award rendered	Chart annexed?	Smallest significant figure in seconds (")	Geodetic datum specified?	Nature of line segments specified?
IX. Northern and Western Europe (*Cont.*)						
9-2b	France-Spain [TS, CZ, Bay of Biscay]	1/29/74	Y	N/A	N	Y[c]
9-2c	France-Spain [JDZ, Bay of Biscay]	1/29/74	Y	600"	N	Y[c]
9-9	Denmark-Norway [CS]	6/4/74	Y	.1"	Y	Y[g]
9-7	Portugal-Spain [TS, CZ, CS]	2/12/76	Y	1"	N	Y[e,f]
9-3a	France-United Kingdom [CS, western English Channel]	6/30/77	Y	1"	Y	N
9-3b	France-United Kingdom [Channel Islands]	3/14/78	Y	N/A	Y	Y[i]
9-15b	Norway-United Kingdom [CS, extension of 9-15a]	12/22/78	Y	.01"	Y	Y[c]
9-1	Denmark (Faroe Islands)-Norway [CS, FZ/EZ]	6/15/79	Y†	.01"	Y	Y[c]
9-4a	Iceland-Norway (Jan Mayen) [CS, FZ/EZ]	5/28/80	N	N/A	N	Y[i]
9-4b	Iceland-Norway (Jan Mayen) [JDZ]	10/22/81	N	300"	N	Y[e,f]
9-3c	France-United Kingdom [CS, eastern English Channel and North Sea]	6/24/82	Y	1"	Y	Y[b]
9-3d	France-United Kingdom [TS, Straits of Dover]	11/2/88	Y†	.01"	Y	Y[b]
9-5	Ireland-United Kingdom [CS]	11/7/88	Y†	6"	Y*	Y[e,f]
9-16	Belgium-France [TS, CS]	10/8/90	Y†	1"	Y	Y[b]
9-17	Belgium-United Kingdom [CS]	5/29/91	Y†	1"	Y	Y[b]
X. Baltic Sea						
10-4(1)	Finland-Soviet Union [CS, Gulf of Finland; FZ as of 2/25/80; AP as of 2/5/85]	5/20/65	Y	6"	Y	N

10-4(2)	Finland-Soviet Union [CS, Baltic Sea; extension of 10-4(1); FZ as of 2/25/80; AP as of 2/5/85]	5/5/67	Y	6"	Y	N
10-3	Finland-Sweden [CS]	9/29/72	Y	6"	Y	N
10-1	Denmark-Federal Republic of Germany [CS]	6/1/77	Y	.1"	Y	Y[g]
10-7	German Democratic Republic-Sweden [CS]	6/22/78	Y	1"	N	Y[c]
10-4(3)	Finland-Soviet Union [CS, FZ; extension of 10-4(2); AP as of 2/5/85]	2/25/80	Y	1"	Y	N
10-2	Denmark-Sweden [CS, FZ]	11/9/84	Y†	.1"	Y	Y[c]
10-8	Poland-Soviet Union	7/17/85	Y	1"	N	N
10-9a	Sweden-Soviet Union [CS, FZ/EZ]	4/18/88	Y	.06"	Y	Y[b]
10-9b	Sweden-Soviet Union [JDZ]	4/18/88	Y	.06"	Y	Y[b]
10-11	Denmark-German Democratic Republic [CS, FZ]	9/14/88	Y†	.1"	Y	Y[c]
10-10	Poland-Sweden [CS, FZ]	2/10/89	Y	.06"	Y*	Y[c]
10-6(1)	German Democratic Republic-Poland [TS, CS, FZ]	5/22/89	Y	.01"	Y	Y[c]
10-12	Poland-Sweden-Soviet Union [TJ]	6/30/89	N	.06"	Y**	Y[c]

†For illustrative purposes only.
*Global, geocentric datum (i.e., World Geodetic System 1972 or 1984 [WGS72, WGS84]).
**Two or more geodetic datums used, one of which is WGS72 (no asterisk means local datum used).
[b]Loxodrome.
[c]Geodesic.
[d]Azimuth.
[e]Meridian.
[f]Parallel.
[g]Great circle.
[i]Arc with specified radius drawn from specified basepoint.
[k]"Circular line" with unspecified radius drawn from specified point.
[m]Low water line.
Abbreviations: Y, yes; N, no; N/A, information not available to author; AP, all-purpose; JDZ, joint development zone; EEZ, exclusive economic zone; TS, territorial sea; FZ, fisheries zone; CS, continental shelf; CZ, contiguous zone; HW, historic waters; PZ, protected zone; EZ, economic zone; TJ, trijunction point.

is an all-purpose boundary. Additionally, when a boundary is an extension of, rather than a replacement for, a preexisting line, that information is provided (e.g., Mexico-United States of America [Gulf of Mexico and Pacific Ocean; extension of 1-5a and 1-5b]).

Notes

1. Of the 137 extant international maritime boundary treaties in 1990, fewer than a dozen included joint development zones. Jonathan I. Charney and Lewis M. Alexander, eds., *International Maritime Boundaries*, 2 vols. (Boston: Martinus Nijhoff Publishers, 1993). These types of agreements are uncommon and even the joint development zones are "limited to discrete areas that are themselves bounded." Ibid., 1:xxvi.

2. The following definitions will help the reader interpret the author's use of the words demarcate, delimit, depict, and recover.

Demarcate—to mark the limits of. Demarcation is the process of physically marking a boundary on the surface of the earth. A physical structure, such as a fence, wall, or buoy could be used to demarcate one state's territory from that of another.

Delimit—to fix the limits of. Delimitation is the process of determining the location of a boundary. The process might involve negotiations, and marine surveying and cartometric efforts.

Depict—to represent by a picture, to describe. This is the process of conveying the location of a boundary line from one party to another. Depiction of an international maritime boundary can be in the concrete form of a line drawn on a chart, or the abstract form of a set of geographical coordinates referenced to a grid of parallels and meridians (lines of latitude and longitude).

Recover—to find or identify again. Recovery is the process of locating a delimited boundary. Recovering a demarcated boundary is a simple task; however, international maritime boundaries are rarely demarcated. If sufficient information is not provided when depicting a boundary, it is likely that states parties to a boundary will recover conflicting versions of the same line.

3. Peter Beazley, "Technical Considerations in Maritime Boundary Delimitation," in *International Maritime Boundaries*, ed. Jonathan I. Charney and Lewis M. Alexander (Boston: Martinus Nijhoff Publishers, 1993), 1:243–262.

4. In shallow water it is possible to anchor a series of buoys to demarcate the turning points of a boundary. However, this practice is not applicable in deep water and functions only to demarcate the turning points to the exclusion of the linear boundary. In addition, the positional accuracy of a buoy which wanders with the tides and currents might not be a suitable marker for the purpose of demarcating crucial international maritime boundaries.

5. In the larger context of international maritime boundary making, the state practice of using one method of delimitation over another has significance beyond that individual boundary in that state practice can influence the development of international law. This is especially true in an area of international law such as maritime boundary delimitation, many components of which are open for interpretation by coastal states.

6. One hundred three, or 77%, of extant international maritime boundary agreements incorporate some form of equidistance—whether strict, simplified, or modified—in the method used to delimit part or all of the boundary. Leonard Legault and Blair Hankey, "Method, Oppositeness and Adjacency, and Proportionality in Maritime Boundary Delimitation," in *International Maritime Boundaries*, 1:203–241.

7. Charney and Alexander, *International Maritime Boundaries*, is the source of all of the treaties and technical information listed in Appendix 1. Charney explained that, "[w]hile states have delimited their maritime boundaries for centuries, so much has changed in recent years that the most relevant data postdates 1940. . . . The Truman Proclamations of 1945 certainly mark a significant turning point in this new era." Jonathan I. Charney, introduction to *International Maritime Boundaries*, 1:xxvi. Charney lists other important events and changes in the period since 1940 that have affected the practice of international maritime boundary making, such as the three United Nations Conferences on the Law of the Sea; the establishment of legal regimes for the

continental shelf, exclusive economic zone, and territorial sea; increased development of offshore hydrocarbon; and increased management of living marine resources. Ibid., xxvi–xxvii.

The 1991 treaty signed between Belgium and the United Kingdom was the latest when this two-volume work went to press. A third volume, which begins in 1991, is being prepared.

8. United Nations Convention on the Law of the Sea, opened for signature December 10, 1982, UN Doc. A/CONF.62/122 (1982), reprinted in *The Law of the Sea: United Nations Convention on the Law of the Sea, with Index and Final Act of the Third United Nations Conference on the Law of the Sea* (New York: United Nations, 1983), 1–157, and *International Legal Materials* 21 (1982): 1261–1354 [hereinafter 1982 Law of the Sea Convention].

9. 1982 Law of the Sea Convention, art. 15.

10. Ibid., arts. 74 and 83.

11. For example, Article IV, paragraph 2, of the Treaty Between the Republic of Trinidad and Tobago and the Republic of Venezuela on the Delimitation of Marine and Submarine Areas, signed April 18, 1990, reads as follows: "The limits and points previously indicated have been drawn *solely by way of illustration* on the Map accepted by the parties and annexed to this Treaty" (emphasis added). Text reprinted in *International Maritime Boundaries*, 1:687.

12. For example, Article II of the Delimitation Treaty Between the Government of the Republic of Venezuela and the Government of the French Republic, signed July 17, 1980, reads as follows: "For the purpose of this treaty, chart No. 6332 of the hydrographic and oceanographic service of the navy of the French Republic entitled 'from Porto Rico to the Gulf of Paria; (scale 1/1,203,000 at latitude 13 degrees 30 minutes-1963 edition) shall be the reference chart. The said chart is appended to this Treaty and *forms an integral part hereof*" (emphasis added). Text reprinted in *International Maritime Boundaries*, 1:613.

13. Text reprinted in *International Maritime Boundaries*, 2:1887–1889.

14. An example of this problem is found in the 1978 trijunction point agreement in the Andaman Sea between India, Indonesia, and Thailand, for which British Admiralty Chart No. 830 was used. Text reprinted in *International Maritime Boundaries*, 2:1386–1388. The scale of this chart is 1:1,500,000, but only one-third of the area depicted on the chart is relevant to the trijunction agreement. See United Kingdom Hydrographer of the Navy, *Andaman Sea/Bay of Bengal*, BA 830 (Taunton: British Admiralty, 1987). In other words, a more detailed, 1:500,000 scale chart of the same size could have been used in that treaty if the chart had been designed specifically for the delimitation of that trijunction point.

15. D. W. Newson, "Nautical Chart Standardization," *International Hydrographic Review* 61, no. 2 (1984): 111–122. According to both Nicholas Chrisman (Geography Department, University of Washington, Seattle, Washington) and Leonard Shrock (Captain's Nautical Supplies, Seattle, Washington), the hydrographic offices of the United States, Russia, and France rely heavily on source material provided by British Admiralty.

16. For instance, although the United States Defense Mapping Agency produces 1:300,000 scale charts of every coastal zone in the world, charts of a scale larger than 1:300,000 are generally unavailable except for major ports or other high traffic areas. See U.S. Department of Defense, Defense Mapping Agency, *Hydrographic Products: Nautical Charts and Publications*, vol. 1 of *Defense Mapping Agency Catalog of Maps, Charts, and Related Products* (Washington, DC, 1994).

17. D. H. Maling, *Measurements from Maps: Principles and Methods of Cartometry* (New York: Pergamon Press, 1989), 541–542.

18. See note 16 above.

19. Translated into ground length, 1' of latitude = 1 nautical mile = 1,852 meters; 1" of latitude = 31 meters; and .01" of latitude = .31 meters. Unlike units of latitude, units of longitude represent shorter distances on the ground as they move away from the equator. At the equator units of longitude are equivalent to units of latitude, and at the poles they are nil. At 45°00' latitude, 1' of longitude is approximately equal to 1,320 meters on the ground, while 1" of longitude is equal to 22 meters.

20. J. R. Victor Prescott, "Australia-Indonesia (Seabed Boundaries) (1971)," in *International Maritime Boundaries*, 2: 1198–1199.

21. Article 5 of the 1982 Law of the Sea Convention states that "[e]xcept where otherwise provided in this Convention, the normal baseline for measuring the breadth of the territorial sea is the seaward low-water line along the coasts marked on large-scale charts officially recognized by the coastal State." The "seaward low-water line" is the same line from which equidistant turning points are usually measured, and thus the accuracy of this line is critical.

22. This magnitude of error was predicted for a digital database generated from lines manually traced from photographic enlargements and reduced by a Xerox 2080 (the machine in use at the National Ocean Service at the time). A smaller error (.15 mm) is predicted for a digital database generated by the digital scanning of traced shoreline maps. See Nicholas Chrisman, Robert Gurda, and M. Kate Beard, "National Charting Quality Standards," draft report for Office of Charting and Geodetic Services, National Ocean Service, National Oceanic and Atmospheric Administration, U.S. Department of Commerce, Rockville, MD, 1987. However, the original accuracy of the paper shoreline map is not included in this model of error.

23. Consider also the potential error associated with the source material used to compile a nautical chart. The paragraph on British Admiralty Chart No. 830 describing the source material used in its compilation reads as follows: "Various sources, but mainly surveys by the Marine Survey of India between 1850 and 1913 and Admiralty surveys 1888–1900 and 1936–9." This chart was used in the negotiation and delimitation of the trijunction point in the Andaman Sea between India, Indonesia, and Thailand. This trijunction point, agreed to in a treaty signed June 22, 1978, was "defined by geographical coordinates taken from British Admiralty Chart No. 830." Text reprinted in *International Maritime Boundaries*, 2:1387. Possible changes in the coastal geomorphology over the past 150 years, the error associated with the marine surveying methods of this period, and the distortions which arise during transformations from one geodetic datum or projection to another could result in significant differences between the coastline as it is portrayed on the chart and the coastline as it exists on the ground.

24. Geodetic datum is also referred to as horizontal datum. Horizontal datum is distinct from vertical datum which determines the sea level used to define the low water line, and thus the location of baselines and basepoints.

25. 1982 Law of the Sea Convention, arts. 16, 75, and 84.

26. The geoid is the undulating magnetic surface of the earth. Both the geoid, and the mathematically defined ellipsoids used to represent it, bulge at the equator so that the north-south axis (minor axis) is shorter than the east-west axis (major axis). Therefore, the term reference "ellipsoid" is used rather than "spheroid," which implies an object with a constant diameter.

27. D. Simpson, "Some Observations on the Use of GPS and Charts," *International Hydrographic Review* 70, no. 2 (1993): 29–38.

28. Ibid., 30.

29. Beazley, "Technical Considerations," 248. Below is an example of a local geodetic datum: Australian Geodetic Datum 1966; a (semi-major axis) = 6,378,160; c (degree of flattening) = 1/298.25; point of origin-Johnston Geodetic Station in the Northern Territory of Australia at 25°56'54.5515"S and 133°12'30.0771"E; 571.2 meters above the surface of the ellipsoid.

30. Simpson, "Some Observations," 31.

31. WGS84 superseded World Geodetic System 1972 (WGS72), which previously superseded Geodetic Reference System 1967, each time providing a better fit to the geoid. Satellite-derived positions referenced to WGS84 can be transformed with varying degrees of accuracy to other global datum, and to local datum, and vice versa. The United States Defense Mapping Agency sells software for $1.50 which can transform over 100 geodetic datums to WGS84. U.S. Department of Defense, Defense Mapping Agency, *Hydrographic Products*, ii.

32. Beazley, "Technical Considerations," 247. For approximately 55% of the international maritime boundaries considered in Appendix 1, no geodetic datum is specified. However, there is a clear chronological trend toward specifying datum. In some treaties, two geodetic datums are specified and the coordinates of all the turning points are provided for both datums. In other

treaties, a different geodetic datum is specified for each turning point in the boundary (e.g., the 1989 trijunction agreement between Poland, Sweden, and the Soviet Union).

33. Discrepancies of this magnitude are common for islands. Beazley noted that Réunion, an island nation in the Indian Ocean, experienced a shift of 1.5 km when a transformation was made from its local datum to WGS72. Ibid., 248.

A survey conducted in 1993 by the United States Coast and Geodetic Survey of the Northern Mariana Islands, in which the local datum was transformed to WGS84, produced the following results: "Preliminary results of the global positioning survey indicate repositioning of several islands in the Northern Marianas by as much as 1.5 nautical miles to the north. One such island, Farallon de Pajaros, marks the northern limit for the U.S. maritime boundary. The resulting northerly shift . . . increases the territory of the United States and its fisheries rights in that region." Lewis Lapine, "C&GS Conducts GPS Survey of 4,000 Miles of the Pacific," *American Congress of Survey and Mapping Bulletin*, Jan./Feb. 1994, 13.

34. It is stated explicitly in some treaty texts that the geodetic datum of the chart is the one to which the coordinates should be referenced. In others, this is implied by the attachment of a chart to the treaty and a lack of reference in the text of the treaty to a geodetic datum.

35. Chart makers often do not include a reference to the geodetic datum because various source materials, referenced to different datums, have been used to produce the chart (see note 23 above). Therefore, different parts of the chart could be referenced to different geodetic datums. In other instances, the geodetic datum is simply not known. Nigel Gooding stated that British Admiralty charts are referenced to 65 geodetic datum around the world, and that over half of the chart panels are on unknown datums. Cited in Adam J. Kerr, "Geodetic Problems Associated with the Introduction of the Global Positioning System (GPS) with Emphasis on East Asia," *International Hydrographic Review* 71, no. 1 (1994): 21–28.

An example is British Admiralty Chart No. 830, which is not explicitly referenced to a geodetic datum, but rather contains the following caveat: "Positions obtained from satellite navigation systems are normally referred to the World Geodetic System (WGS); adjustments for plotting such positions cannot be determined for this chart but it should *not* be assumed that they are negligible" (emphasis added). The Indian Datum, referenced to the 1830 Everest ellipsoid, is commonly used in this part of the world, and it is likely that most of the source material for British Admiralty Chart No. 830 was referenced to this local datum. However, this is not stated anywhere on the chart itself. British Admiralty Chart No. 830 is an integral part of several boundary treaties in the Andaman Sea.

36. Much of the information in these definitions comes from Beazley, "Technical Considerations"; Charney and Alexander, *International Maritime Boundaries*; Robert D. Hodgson and E. John Cooper, "The Technical Delimitation of a Modern Equidistant Boundary," *Ocean Development and International Law* 3 (1976): 361–388; and Robert W. Smith, "A Geographical Primer to Maritime Boundary-Making," *Ocean Development and International Law* 12 (1982): 1–22.

37. Beazley questioned the continued use of great circles in maritime boundary agreements as recent as the 1986 Libya-Malta agreement. He stated that the use of great circles "presumably either follows a supposed precedent, or is intended to conform to other agreements in the area. It is, however, incompatible with the use of geodetic concepts of positioning and datum, and it is hoped that it will not be used in future agreements." Beazley, "Technical Considerations," 253.

38. Articles 7, 9, and 10 of the 1982 Law of the Sea Convention refer to the drawing of straight baselines, and Article 47 to straight archipelagic baselines. Other articles in the Convention, such as Articles 16, 75, and 84, use the term "line" without further explanation.

39. For approximately 35% of the boundaries considered in Appendix 1, the nature of some or all of the line segments that make up each boundary was unspecified.

40. Milan Thamsborg, in a well-known example, demonstrated the discrepancy in ocean area encompassed by a geodesic and a loxodrome drawn between points A (58°00'N, 0°00'E) and B (62°00'N, 10°00'E). In this example, the ownership of 2,070 square nautical miles of ocean space is left open to future dispute because the nature of the line segment connecting points A and B is not specified. See Milan Thamsborg, "Geodetic Hydrography as Related to Maritime

Boundary Problems," *International Hydrographic Review* 51, no. 1 (1974): 157–173. These lines are approximately 385 nautical miles long and are drawn at relatively high latitudes. The difference between a geodesic and a loxodrome increases as latitude increases. The difference also becomes greater as the azimuth of the loxodrome approaches parallel with the equator. There is no difference between a loxodrome and a geodesic whose azimuth is directly north or south, nor is there a difference between these two lines when they coincide with the equator.

41. Beazley, "Technical Considerations," 244.

42. Fishermen and oil companies are two types of ocean users for whom their position relative to the location of international maritime boundaries is important. Fishing vessels permitted to fish in the exclusive economic zone of one coastal state must know where that state's jurisdiction ends and those of the opposite or adjacent states begin. Similarly, oil companies need to know whose portion of the continental shelf they are over. As the level of uncertainty regarding the ownership of an ocean area increases, so does the level of risk involved in exploiting the living and nonliving marine resources (including space) in that area.

43. Simpson, "Some Observations," 33.

44. This information comes from the author's notes recorded during a presentation by Galo Carrera, "The Role of GPS, GIS and ECDIS in the Delimitation of Maritime Spaces" (paper presented at International Boundaries Research Unit Workshop on Geographical and Technical Considerations in Maritime Boundary Delimitations, Durham, United Kingdom, July 1996). According to Dr. Carrera, Ashtech, Inc., a small company in Sunnyvale, California, is now producing receivers designed to receive signals from both NAVSTAR and GLONASS satellites. Galo Carrera, conversation with author, July 18, 1996, at the International Boundaries Research Unit, Durham, UK.

45. Carrera, "Role of GPS."

46. It should be noted that higher levels of precision in positioning do not eliminate all navigational problems. If precise measurements from a GPS are used in conjunction with a less precise, or less accurate, paper chart or electronic chart display and information system (ECDIS), the GPS measurement will be limited by the precision of the chart to which it is applied. It also is possible that the chart will be referenced to a different geodetic datum than the measurement from the GPS.

The discrepancy in the levels of accuracy between charts (paper and ECDIS) and satellite systems is the topic of several recent papers published in the *International Hydrographic Review*. See Simpson, "Some Observations"; Kerr, "Geodetic Problems"; and F. Mayer, "Cartographic Problems of Global Positioning," *International Hydrographic Review* 70, no. 2 (1993): 63–69.

47. Galo Carrera, "A Method for the Delimitation of an Equidistant Boundary Between Coastal States on the Surface of a Geodetic Ellipsoid," *International Hydrographic Review* 64, no. 1 (1987): 147–159; and Galo Carrera, "DELMAR: A Computer Program Library for the Delimitation of Maritime Boundaries," in *Maritime Boundaries*, World Boundaries Series, vol. 5, ed. Gerald H. Blake (New York: Routledge, 1994), 49–58.

48. "The ultimate purpose of DELMAR is to serve interdisciplinary teams under the leadership of international lawyers as a source of technical information during the analysis, negotiation, and verification of maritime boundary agreements." Carrera, "DELMAR," 49.

49. There are limits to the usefulness of high degrees of precision. For instance, it is not necessary for most ocean activities to know the location of a turning point to the nearest .01", or 30.8 centimeters.

50. Handheld GPS receivers designed for backcountry hiking are now available at sporting goods stores for less than U.S.$200. John Markoff, "Finding Profit Aiding the Lost: A Civilian Industry Is Built on the Military's Locator Technology," *The New York Times*, Mar. 5, 1996, D1. These less expensive receivers do not have as many channels as their more expensive counterparts and therefore cannot track as many satellites at one time, making them less accurate. Nor do they have differential or on the fly (OTF) mode capabilities. However, prices for GPS receivers, regardless of their level of accuracy, have plummeted in recent years and probably will continue to do so as the prices of microelectronic components fall and as more firms enter the GPS market. Ibid.

With regard to how many international maritime boundaries have been delimited using computational methods, Beazley wrote: "The information obtainable from the reports is insufficient to assess with any certainty what proportion of lines which lend themselves to it have actually been computed. In view of the simplicity and accuracy of computation, it would be surprising if most of the more recent boundaries have not been so determined." Beazley, "Technical Considerations," 251.

51. The author has been aboard small- and medium-scale fishing vessels in the waters of Malaysia, Indonesia, the Philippines, and the Turks and Caicos Islands, which had no electronic navigational devices or charts. These boats generally fished within sight of land, although some (medium-sized purse seiners out of Kuala Besut, Malaysia, for instance) fished out of sight of land in the vicinity of disputed ocean areas.

52. Text reprinted in *International Maritime Boundaries*, 1:818.

53. Douglas M. Johnston and Mark J. Valencia, *Pacific Ocean Boundary Problems: Status and Solutions* (Boston: Martinus Nijhoff Publishers, 1991), 1.

54. Douglas M. Johnston, *The Theory and History of Ocean Boundary-Making* (Montreal: McGill-Queen's University Press, 1988).

55. Ibid., 285.

56. Jonathan Charney, "The American Society of International Law Maritime Boundary Project," in *Maritime Boundaries*, 11.

57. U.S. Department of State, Office of Ocean Affairs, *Maritime Boundaries of the World*, Limits in the Seas, no. 108 (Washington, D.C., 1990).