THE DEFINITION OF THE BOUNDARIES OF MARINE MINING AREAS IN INTERNATIONAL WATERS

by G.L. HASKINS(*)

SYNOPSIS

This paper describes in simple terms for non-technical people how the boundaries of marine mining areas can be logically defined, confidently identified whilst operating in the area and the activities therein uniformly mapped. Technical detail and complexities are specifically omitted.

1. INTRODUCTION

The lessons learned from the past when boundaries have been defined for the limits of areas allocated for mineral exploration, appraisal and production show that three simple rules should be followed:

(i) The written description of the boundary should be unequivocal, i.e. allow for only one interpretation.

(ii) The accuracy of the physical establishment of the boundaries on site should be compatible with the technology that exists at the time of allocation, and this technology should not subsequently be changed. (See note in Appendix 2).

(iii) The enclosed areas should be amenable to some logical and equitable form of subdivision in order to permit practical relinquishment and reallocation of relinquished areas.

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It follows that there are two main elements to the problem which must be carefully considered:

The first is to select a suitable method of splitting the area into subdivisions. The second is to decide how to establish the limits of the subdivisions themselves when on the ground (or water) at the site of the boundary.

2. THE SUBDIVISIONS

2.1. The geographical subdivision

The International Sea-Bed Authority (ISBA) is responsible for administering the sea-bed and its resources beyond the limits of national jurisdiction. Thus the first subdivision is the world, minus the land masses, continental shelves, Exclusive Economic Zones, territorial and inland waters. The zones outside of national jurisdiction can be treated in a logical and mathematical fashion so that their definition, description and mapping are founded upon a universally understood, homogeneous and suitably systematic set of rules.

Conventional geographical techniques provide a traditional grid of position information by means of parallels of Latitude (φ) and meridians of Longitude (λ). These need little explanation except to refresh the memory regarding the terminology.

It is thus convenient to take as a starting point the universally accepted concept of φ and λ as being a good basis for a grid of subdivisions for international waters. Some nations also use the concept for managing the subdivision of their own waters; others do not. These latter often extend a land subdivision network system into the sea areas, usually because it is an existing legal basis for such subdivision; however, this usually leads to cartographic problems and is not a constraint that is imposed upon the ISBA.

It can be seen from Figure 1 that the area of the "block" or "panel" enclosed by, say, 1 degree of φ (δφ = 1°) and 1 degree of λ (δλ = 1°), decreases the nearer the "panel" gets to the pole until, at δφ = 90° – 89° the "panel" becomes a triangle.

2.2. The geographical grid

It is relatively simple to apply the geographical coordinates φ and λ to the problem of defining a sea-bed mining site of maximum size of 150 000 sq. kilometres. What is this area expressed in terms of a block or panel having equal sides in both φ and λ (δφ=δλ)?
In figure 2 a block of equal sides in both $\phi$ and $\lambda$ is shown, i.e. $\delta \phi = \delta \lambda = n$ in unitary terms. In fact the actual distance of the northern side (in the northern hemisphere above the Equator) is less than the southern side. The converse is the case in the southern hemisphere. The actual distance $\delta \lambda$ (termed departure in latitude units) is given by Gardner (ref. [3]) and is a function of the latitude parallel across which it is measured, such that

$$\text{Departure} = \text{diff. Longitude} \times \cos \text{Latitude} \ (\text{approx}).$$

**FIG. 1.** — The world showing parallels and meridians of Latitude and Longitude.

**FIG. 2.** — Geographical block with sides having the same degree values of $\phi$ and $\lambda$. 

$\delta \phi = \delta \lambda = n$; $\phi_1 = \text{Latitude (} \phi \text{) of centre of block}$
A tabulation of the computation of area versus latitude is as follows:

**TABLE A**
Areas (km²) of blocks, dimensions versus latitude

<table>
<thead>
<tr>
<th>Values of sides</th>
<th>Area (sq. km) at ( \varphi_i ) (degrees)</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \delta \varphi = \delta \lambda ) (degrees)</td>
<td>( \varphi_i = 0^\circ )</td>
</tr>
<tr>
<td>1</td>
<td>12347</td>
</tr>
<tr>
<td>2</td>
<td>49391</td>
</tr>
<tr>
<td>3</td>
<td>111129</td>
</tr>
<tr>
<td>4</td>
<td>197562</td>
</tr>
<tr>
<td>5</td>
<td>308691</td>
</tr>
<tr>
<td>6</td>
<td>444516</td>
</tr>
<tr>
<td>7</td>
<td>605035</td>
</tr>
<tr>
<td>8</td>
<td>790250</td>
</tr>
<tr>
<td>9</td>
<td>1000000</td>
</tr>
<tr>
<td>10</td>
<td>1234765</td>
</tr>
</tbody>
</table>

This table shows that the area of a block decreases as \( \varphi \) increases. Up to about Lat. 40°, 150 000 sq. km is contained by blocks of sides between 3° and 4°; at 60° the blocks would have over 4° sides; at 80° the blocks would have sides of between 8° and 9°.

A tabulation of dimensions in \( \delta \varphi \), \( \delta \lambda \) (when \( \delta \varphi = \delta \lambda \)) of an area of 150 000 sq. km shows:

**TABLE B**

<table>
<thead>
<tr>
<th>( \varphi_i ) (degrees)</th>
<th>Dimensions of blocks</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>150 000 sq. km is 3°29'08&quot; ( \delta \varphi, \delta \lambda )</td>
</tr>
<tr>
<td>20</td>
<td>&quot;</td>
</tr>
<tr>
<td>40</td>
<td>&quot;</td>
</tr>
<tr>
<td>60</td>
<td>&quot;</td>
</tr>
<tr>
<td>80</td>
<td>&quot;</td>
</tr>
</tbody>
</table>

In this case, a standard area enclosed by sides \( \delta \varphi = \delta \lambda \) has ever-increasing values of \( \delta \varphi \) and \( \delta \lambda \) as the value of \( \varphi \) increases away from the Equator.

2.3. Selection of the dimensions of a primary block

The size of one primary block should be such that a mine-site of 150 000 km² could possibly fit within the block, or lie across up to not more than four blocks. It follows, therefore, that the primary block should have an area greater than 150 000 km².

An additional factor to be taken into consideration is the shape of the primary block. Since mine-sites may take any shape and may have axes in any direction, the primary block should be as "square" as possible on the surface of the globe. To this end it is worth noting that a ratio of 2 \( \lambda \) : 1 \( \varphi \) provides a 2 : 1 (E : N) shape
at the Equator and 1:1 shape at Latitude 60°. It is therefore logical to select a primary block of ratio \(2 \lambda : 1 \varphi\), with dimensions which will contain a mine-site of 150,000 km\(^2\).

**TABLE C**

<table>
<thead>
<tr>
<th>(\varphi) (degrees)</th>
<th>Area of block (km(^2))</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>220,257</td>
</tr>
<tr>
<td>20</td>
<td>208,854</td>
</tr>
<tr>
<td>40</td>
<td>170,260</td>
</tr>
<tr>
<td>60</td>
<td>111,129</td>
</tr>
<tr>
<td>80</td>
<td>38,595</td>
</tr>
</tbody>
</table>

Table C shows the areas of a block with sides of \(\delta\lambda = 6°\) and \(\delta\varphi = 3°\) \((2:1)\) computed for Latitude values from 0° to 80°. Unfortunately, the area decreases below 150,000 km\(^2\) at about Latitude 45°. Another disadvantage is the large number of blocks to cover the globe — 60 blocks East-West and 60 blocks North-South, or 3,600 in all. Figure 3 shows the coverage.

By doubling the dimensions to \(\delta\lambda = 12°\) and \(\delta\varphi = 6°\) the area remains in excess of 150,000 km\(^2\) to above latitude 80° as shown in Table D.

![Figure 3](image_url)
This result provides a network of primary blocks within which any mining site of 150 000 km$^2$ will possibly fit either in one block, across two blocks or at the junction of four blocks. The total number of such primary blocks to cover the world will amount to 900; thus we have a suitable size, an equable shape, and a convenient number of primary blocks if they have a dimension of $\delta \lambda = 12^\circ$, $\delta \varphi = 6^\circ$.

### 2.4. The division of primary blocks into sub-blocks

Having established a suitable primary network of parallels and meridians of $\delta \lambda = 12^\circ$, $\delta \varphi = 6^\circ$ it is necessary to consider how these may be subdivided to cover the actual mining site. One way would be into $6 \times 12$ one degree sub-blocks, each having an approximate area as shown in Table A, depending upon the latitude of the primary block. A number of these sub-blocks can be selected to enclose as tightly as possible the actual area of geological interest, see figure 4.

In figure 4 the area of geological interest is enclosed by an irregular perimeter line, and the sub-blocks ($1^\circ \times 1^\circ$) which could be allocated to the mining site are shown by a pecked line; they total 28.

Using a mean latitude of $33^\circ$, the approximate area enclosed by the pecked line containing 28 sub-blocks, is:

$$28 \times (111.12)^2 \cos 33 = 289,957 \text{ km}^2$$
which is twice the permitted area of one site; it will therefore need to be reduced into two parts, each of 14 blocks:

\[ 14 \times (111.12)^2 \cos 33 = 144,979 \text{ km}^2. \]

### 2.5. The identification of blocks and sub-blocks

For the effective management of marine minesites allocated by means of a system of blocks, it is necessary to devise a suitable means of readily identifying the blocks chosen. There are a number of ways to do this:

a) The first means of identification could be by numbering the primary blocks, in the case shown above, from 1 to 900, and the sub-blocks from 1 to 72. Thus 617/15 would be **primary block 617, sub-block 15**. It is then necessary to refer to a diagram to identify firstly the **primary block**: in this case (see fig. 3) it is the 17th block along row 21.

Row 21 is bounded by \( \varphi = 30^\circ \text{N} \) to \( \varphi = 36^\circ \text{N} \) and the 17th block thereof has limits \( \lambda = 12^\circ \text{E} \) to \( \lambda = 24^\circ \text{E} \).

The **sub-block** is 15, which is the third sub-block of the second row, i.e. is bounded by \( \varphi = 31^\circ \text{N} \) to \( \varphi = 32^\circ \text{N} \) and \( \lambda = 14^\circ \text{E} \) to \( \lambda = 15^\circ \text{E} \).

This method of identification requires reference to diagrams and does not readily enable quick identification of the geographical limits of the block.

b) The use of the values of the block limits is the next alternative. The primary block would then be 30N012E comprising the \( \varphi, \lambda \) values of the lower left (SW) corner. The sub-block would be 0102, the increments of one degree to obtain the lower left (SW) corner of the sub-block.

The whole identifier would then become 30N012E0102, a total of eleven alphanumerical indicators.

c) A third alternative would be simply to identify the sub-block only with the same identifier used for the primary block in (b) above, i.e.

\[ 31N014E. \]

This has the attraction of being simple, but entirely neglects the useful advantages of having primary blocks.

Referring to figure 4, the western-most of the two selected minesites would be defined in terms of the three alternatives above as:

a) **Primary block 617; sub-blocks 16-19, 28-31, 40-43, 55, 56; or,**

\[ 617/16-19, 28-31, 40-43, 55, 56. \]

b) **Primary blocks 30N012E; sub-blocks 0103, 0104, 0105, 0106, 0203, 0204, 0205, 0206, 0303, 0304, 0305, 0306, 0406, 0407; or,**

\[ 30N012E/0103-06, 0203-06, 0303-06, 0406, 0407. \]

c) **Blocks 31N015E, 31N016E, 31N017E, 31N018E, 32N015E, 32N016E, 32N017E,**

\[ 32N018E, 33N015E, 33N016E, 33N017E, 33N018E, 34N018E, 34N019E; or **31N015E - 31N018E, 32N015E - 32N018E, 33N015E - 33N018E, 34N018E, 34N019E.** \]

These are all somewhat complicated and cumbersome. It is therefore worthwhile examining some of the other world global grid systems based on
parallels and meridians, to see if any can be adapted for the use of minesite management.

2.6. Global geographical grids

There are a number of geographical grid systems that have been used or propounded in the past. Humphris in reference [2] provides a good source of information regarding some of them.

- The International Hydrographic Organization’s *Index of Patterns of Ocean Sounding Sheets*: a series of scale 1:1,000,000 and 1:250,000 Mercator plotting sheets used to compile ocean sounding data which are subsequently presented on the General Bathymetric Chart of the Oceans (GEBCO). GEBCO is a series of 18 sheets on scale 1:10,000,000.

  The limits of the plotting sheets vary with latitude and the numbering breaks at the boundaries of the continental masses. (See fig. 5). This system is not suitable for the purpose under discussion.

- GEO-CODE, used for international postal coding, and without any obvious merit for any other use.
GEOREF, a system of 15° Latitude and 15° Longitude panels having a lettered main reference and sub-divisions into degrees, minutes and hundredths of a minute. It is used by the U.S. Air Force. The panels, however, become awkwardly shaped near the poles, and alphabetical indicators complicate calculation processes.

MARSDEN SQUARES, a system of 10° Latitude and 10° Longitude panels widely used in meteorology and oceanography. Whilst at first sight this system looks reasonable, Humphris lists six valid reasons why it is unsuitable for marine management purposes, the main one being that it seems impossible to devise a simple spot reference system which can be related to the panels (see fig. 6).

Humphris has devised a fully decimalised global location system: the Humphris Global Grid (fig. 7), which has many advantages over other systems. A full explanation is contained in reference [2] and a précis is shown in Appendix 1.

The system has the following advantages:

(i) It is logical.
(ii) Areal distortion is minimized. At the Equator the sides are relatively 2 λ to 1 φ. At 60° the panels are approximately square; beyond this point the north-south dimensions progressively exceed the east-west dimensions but only at the polar caps will they become unsuitably proportioned for general use.
(iii) The conversion from simple and informative panel coordinates to conventional Latitude and Longitude values is linear. Computations for approximate areas (hectares, etc.) are straightforward, and readily adapted to computer processing.
(iv) It is applicable to the whole of the Earth’s surface.
(v) The positions of the limits of national jurisdiction can be expressed in global grid coordinates.
Fig. 7. — Humphris Global Grid — a decimalised numerical location system for all globes including Earth and Moon. Each globe panel is similarly divided and subdivided to produce smaller panels and finer spot references.

Thus two of the three rules expressed in paragraph 1, (i) and (iii), are fully complied with by the use of the global grid.

2.8. Use of the Humphris Global Grid

Referring again to figure 4, the same area of geological interest shown is within global grid panel 56 and lies across secondary panels 47, 48, 57, 58, 59, 68 and 69. These are shown in figure 8.

An enlargement is made in order to show the tertiary panels in figure 8. The area can now be closely bounded by the resultant closely spaced tertiary grid. The area thus enclosed consists of 312 tertiary panels as follows:

<table>
<thead>
<tr>
<th>Secondary</th>
<th>No. of Tertiaries</th>
</tr>
</thead>
<tbody>
<tr>
<td>47</td>
<td>42</td>
</tr>
<tr>
<td>48</td>
<td>75</td>
</tr>
<tr>
<td>57</td>
<td>35</td>
</tr>
<tr>
<td>58</td>
<td>97</td>
</tr>
<tr>
<td>59</td>
<td>36</td>
</tr>
<tr>
<td>68</td>
<td>12</td>
</tr>
<tr>
<td>69</td>
<td>15 = 312</td>
</tr>
</tbody>
</table>

The approximate total area in km$^2$ = AREA

\[ = 312 \times (111.12)^2 \times 0.18 \times 0.36 \cos 33.5 = 208171 \text{ km}^2. \]
Fig. 8. — Showing part of global grid panel 56, and secondary/tertiary panels.

The area so divided may be then allocated as required either as whole secondary or tertiary blocks whichever is the most convenient.

The Notes at Appendix I explain in more detail the principles of the Humphris Global Grid.

3. POSITIONING MINING ACTIVITIES

3.1. Having selected a suitable and convenient method of dividing the international oceanic areas into sub-divisions for allocation to operating organisations, rule 1 (ii) should be investigated. There must be some means of ensuring that mining activities are accurately located within the allocated sub-divisions. On land, such boundaries can be surveyed and marked by monuments, but at sea this is impractical. A well-known advertisement for its radio positioning systems by Teledyne Hastings-Raydist illustrates the problem very well (see fig. 9).

Unluckily, radio positioning systems tend to become decreasingly accurate the further away from land they are used. Since the areas under consideration are all more than 200 miles offshore, it is necessary to determine some other reliable method.

3.2. We are fortunate that present technology permits a high order of accuracy in determining position on the surface of the Earth by the use of satellites placed in position in space for the purpose. A suitably equipped observer can readily establish his whereabouts in three dimensions in terms of the geographical grid (φ, λ). The U.S. Navy Satellite System (USNSS) uses polar orbiting satellites which can
provide a position within 100 metres at intervals from a minimum of approximately every 40 minutes to a maximum of about 7 hours (given certain known parameters such as accurate ship’s course and speed over the ground). The Global Positioning System (GPS NAVSTAR) now being introduced will provide 24-hour continuous positioning using a family of satellites which are already being launched into position in space. Accuracy may be better than 50 metres. Accuracy is to some extent dependent upon cost. USNSS receivers providing two-dimensional solutions \((\phi, \lambda)\) are available at around $2,000 and have an accuracy of about 300 metres. The GPS hardware will be more costly, certainly at first, but has already been developed and is undergoing rigorous testing within the limited coverage at present available.

Thus the means is to hand for a reasonable solution to the positioning of mobile ship-borne activities. It is now necessary to go rather more deeply into the question of what these measurements really mean.

3.3. The Earth is not a sphere. It has an irregular but approximately spheroidal shape, which precludes simple mathematical calculations or expressions from being used to define its surface. To overcome this drawback the geodetic scientist uses a reference spheroid which is obtained by rotating a reference ellipsoid, defined by two measurements, the major and minor axes (see fig. 10), about either of the two axes.

The regular shape of the reference spheroid now lends itself to mathematical treatment for computing distances, directions, positions, and height above or below its surface.

The size and dimensions of the reference spheroid are chosen to give as close a fit as possible to the actual shape of the Earth in the area in which work will take place. In fact, it closely approximates to the geoid, which is the theoretical surface
which would be taken up by Mean Sea Level if there were no land masses and the Earth's surface were covered by sea.

There are thus three surfaces under consideration (see fig. 11):

(i) Topography — the Earth's surface;
(ii) The geoid — which undulates under the influence of variation in gravity;
(iii) The spheroid — closely fitting (ii): a uniform surface upon which computations can be made.

Satellite systems compute positions relative to the Earth's centre of mass, and hence : the geoid.

3.4. There are a number of reference spheroids in use, chosen to suit local conditions. However, with the advent of satellite positioning it was necessary to choose one that would be suitable for the whole world; in 1972 the World Geodetic System (WGS 72) was brought into use for this purpose and provides for a spheroid with the following properties:

\[
\begin{align*}
a &= 6378135 \text{ metres} \\
b &= 6356750.5 \text{ metres}
\end{align*}
\]

fig. 10. — The meridian ellipse.

fig. 11. — The three surfaces — topography, geoid, spheroid.
The elevation of the geoid above or below this surface is termed geoidal separation (see fig. 11).

Satellite positioning therefore has an important property pertinent to rule 1(ii):

*Any number of observers, with any number of satellite receivers, who occupy the same point on the Earth's surface, and use the same principles of computation, should obtain from their observations the same value for the position of that point.*

Any differences will be caused by inaccuracies of the values for the movement of the station (vessel) relative to the ground (sea bottom) during the period of observation.

If the station is fixed (i.e. on land or a fixed structure), and observations are conducted over a period of some days, and using certain techniques of verification, sub-metre agreement can be achieved.

It must be noted at this point that the GPS system will be referred to WGS 84 not WGS 72. However, for the purposes of boundary establishment in an offshore environment aboard a vessel there is no significant difference in the results obtained using WGS 72 or WGS 84.

Now that we have a global grid system, and the means for accurate navigation in terms of WGS, how can we display this graphically?

### 4. MAPPING

A visual representation of position can be made on a scaled-down model of the reference spheroid. It will, of course, have a curved surface which is not a very convenient medium to carry around. To overcome this, the parallels and meridians ($\varphi, \lambda$) can be subjected to a mathematical distortion in order to draw them on a flat sheet. This process is termed a *projection*. The larger the area displayed, the greater will be the distortions created by the projection. None are perfect and they all have one or more adverse properties, among which are:

- shapes are distorted;
- straight lines appear as curves;
- curves appear as straight lines;
- true direction varies with the position on the projection;
- scale varies with the position on the projection, etc.

There are many projections that have been devised for particular and general applications by cartographers. Three of these, used widely by surveyors and navigators, are:

**Transverse Mercator**: which possesses all the drawbacks, but in a minimal form; the scale error increases East-West, but is constant North-South.

**Mercator**: used by navigators because lines of constant bearing (which are actually curves on the Earth's surface) appear as straight lines — a most useful property for the navigator.
LAMBERT: a surveyor's projection in which the scale error increases in the North-South direction but is constant East-West.

Any of these projections, and several others, are suitable for mapping mining activities in the ocean. Their selection is made on the basis of the use to which the map is to be put and the extent of the area to be mapped. In any case, positions derived from satellite observations can be displayed, as can the boundaries of the allocated operating area.

5. CONCLUSION

This paper outlines the basic principles that can be used in managing the allocation of sea areas for mineral exploration and recovery of resources.

The meridians and parallels expressed as latitude and longitude, or as the Humphris Decimalised Global Grid, would provide an unequivocal means of describing the boundaries of allocated areas and their subdivisions.

Satellite navigation in terms of WGS will ensure uniform positioning of the sea-borne activities by readily available means and avoid overlaps or gaps between adjacent minesites.

Long established map projection systems, proven over the past to be practical, can be used to document the work.

All three: descriptive coordinates, navigation systems and maps, can be linked by computer to digital data banking and electronic data transmission. No new techniques have to be assimilated by surveying personnel who have come from the hydrocarbon industry in continental shelf waters. What has not been addressed, and is the new technology now under development, is the accurate transfer of surface position to the sea-bed by deep-water acoustic navigation systems; however, it is already certain that any inaccuracies that may arise therefrom will be well within the tolerances of the safety zones described in Appendix 2.

REFERENCES

NOTES ON HUMPHRIS' DECIMALISED GLOBAL GRID

The objective of the global grid is to provide a convenient and logical world geographical reference system. It is based upon meridians of longitude ($\lambda$) and parallels of latitude ($\varphi$) and reduces the distortion of unitary panels which is inherent in using conventional geographical sub-divisions into full degrees and minutes.

For instance, a 10 degree "panel" would be approximately square at the Equator, and the North-South edge would become increasingly greater in relation to the East-West edge with distance northward (or southward) from the Equator. The subdivisions into minutes of angular measures are not decimal.

The Humphris Global Grid (see figure 7) uses a unitary measure of $\delta\lambda = 36^\circ$ and $\delta\varphi = 18^\circ$. The origin is $\lambda = 180^\circ$ West and $\varphi = 90^\circ$ South. The grid has many useful properties:

(i) The 100 primary panels are numbered from 00 to 99, avoiding any number greater than two figures. All values are positive.

(ii) Each primary panel may be sub-divided any number of times into 100 sub-panels. For instance, 63 99 is sub-panel 99 of main panel 63; 63 99 24 is sub-panel 24 of sub-panel 99 of main panel 63.

(iii) Spot references may be designated. The lower left hand corner of 63 99 24 is

Easting 6 9 2
Northing 3 9 4

(iv) Conversions to geographical coordinates are simple:

Easting $6.92 = 36 (6.92 - 5) \text{ DMS} = 69^\circ07'12''$ East Long.
Northing $3.94 = 18 (3.94 - 5) \text{ DMS} = 19^\circ04'48''$ South Lat.

(v) The dimensions of panel 63 99 24 are:

$\delta\lambda \times \delta\varphi = 0.36^\circ \times 0.18^\circ = 21'36'' \times 10'48''$

check: the upper right hand corner of 63 99 24 is:

63 99 35

which converts to $36 (6.93 - 5) \text{ DMS} = 69^\circ28'48''E = 69^\circ07'12'' + 21'36''$

check
18 (3.95 - 5) DMS = 18°54'00''S = 19°04'48'' - 10'48''

check.

(vi) The geographical limits of 63 99 24 are, therefore (see fig. 1A):
(vii) The global grid lends itself to digital data handling and at the same time is readily referenced to conventional angular units for plotting on a map of any projection.

(viii) Areas may be defined by one or more whole panels of convenient size from, say 216 nautical miles $\times$ 108 n.m. to, say, the fourth reduction of 2 n.m. $\times$ 1 n.m. (approximately). Alternatively, the corner points of selected areas may be defined by global grid coordinates (although this rather negates the benefits of the system — one might just as well use conventional geographical terms).

The dimensions of whole panels are (in nautical miles).

<table>
<thead>
<tr>
<th>Primary</th>
<th>2160 $\times$ 1080 (at the Equator)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>216 $\times$ 108 &quot;</td>
</tr>
<tr>
<td>3</td>
<td>21.6 $\times$ 10.8 &quot;</td>
</tr>
<tr>
<td>4</td>
<td>2.16 $\times$ 1.08 &quot;</td>
</tr>
<tr>
<td>and so on.</td>
<td></td>
</tr>
</tbody>
</table>

(ix) Accuracy to 2 decimals of a second is achieved at the 8th term or $10^{-7}$ reduction. That is, 8 terms are required for this degree of accuracy, i.e.

$$E1.2345670 = 135°33'20".12$$ West Longitude

Thus high accuracy point positions can be expressed in fewer terms than are used in geographical units.

(x) The shape of the panels varies with latitude:

- At the Equator the proportion is 2:1 (EW: NS)
- At Latitude $60^\circ$ the proportion is 1:1
- Above $60^\circ$ the NS dimension increases, but only at the polar caps do the panels become unreasonably distorted.

It may be argued that a geographical primary panel of, say $\Delta \lambda = 20^\circ; \Delta \varphi = 10^\circ$ could be suitable both for decimalised sub-division and with regard to shape, but the identification of the primary panel is a problem to be addressed.

The world would be covered by 18 NS units and 18 EW units = 324 units at level 1. The identifiers would have to be either 3 figure numbers, or a combination of alpha-numeric which is both confusing and incompatible with
digitized processing. The advantage might be that the boundaries of subdivided panels at level 2 would still be full degree values, but this argument is not very strong since the Humphris system is so readily converted to plotting units; below level 2, the boundaries are just as irregular in unitary terms.

It therefore follows that the global grid provides a series of convenient subdivisions for many marine and terrestrial management purposes, and specifically it is useful for managing mining activities in both national and international waters.

APPENDIX 2

NOTE ON THE ACCURACY OF BOUNDARY ESTABLISHMENT

In the hydrocarbon industry it has been and still is common practice for governments to prohibit, without special permission, activities within defined distances from the declared boundaries of operating areas awarded to companies. The purpose of this is to ensure that activities controlled by the available positioning systems are actually within the area allocated.

In the case of very distant offshore operations controlled by satellite systems on board ships and floating plant, these limits should be reasonable, and declared, say, as 500 metres.

It is by no means certain (1984) that GPS will be enabled by the U.S. Government to operate at its full potential accuracy. This question is still under consideration. If full accuracy use is eventually permitted, then the 500 metre "safety zone" could be reduced.

APPENDIX 3

COMPUTATIONS ON THE HUMPHRIS GLOBAL GRID

1. To compute Latitude (\(\varphi\)) and Longitude (\(\lambda\)) from global grid coordinates

<table>
<thead>
<tr>
<th>Given GG coords:</th>
<th>33</th>
<th>84</th>
<th>20</th>
<th>55</th>
<th>17</th>
<th>91</th>
</tr>
</thead>
<tbody>
<tr>
<td>(level)</td>
<td>(2)</td>
<td>(3)</td>
<td>(4)</td>
<td>(5)</td>
<td>(6)</td>
<td>(7)</td>
</tr>
<tr>
<td>Easting</td>
<td>3</td>
<td>8</td>
<td>2</td>
<td>5</td>
<td>1</td>
<td>9</td>
</tr>
<tr>
<td>Northing</td>
<td>3</td>
<td>4</td>
<td>0</td>
<td>5</td>
<td>7</td>
<td>1</td>
</tr>
</tbody>
</table>
Latitude = 18(3.40571-5) = -28°697220
= 28°41'49"99 South (φ)
Longitude = 36(3.82519-5) = -42°293160
= 42°17'35"38 West (λ)

2. To compute global grid coordinates from Latitude (φ) and Longitude (λ)

Given geographical : φ = 28°41'49"99 South
λ = 42°17'35"38 West
Northing = 5 + (φ/18) = 5 + \left(\frac{-28.697219}{18}\right)
= 3.40571
Easting = 5 + (λ/36) = 5 + \left(\frac{-42.2931611}{36}\right)
= 3.82519
GG coords are 33 84 20 55 17 91

3. Approximate area computation

For a quick check on the area enclosed by a global grid panel after the geographical limits have been calculated, this can be done by a Mercator approximation, using the basic formula :

\[ \text{Area} = (φ_1 - φ_2) \left(\deltaλ \left(\cosφ_1 + \cosφ_2\right)\right) \times 1800 \]

where :
φ₁ = Lat. of upper parallel
φ₂ = Lat. of lower parallel
λ₁ = Long. of right meridian
λ₂ = Long. of left meridian
\( \deltaλ = λ₁ - λ₂ \).

FIG. 2A. — Area computation.