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 ($\delta\varphi = 1°$) and 1 degree of λ ($\delta\lambda = 1°$), decreases the nearer the "panel" gets to the pole until, at $\delta\varphi = 90° - 89°$ the "panel" becomes a triangle.

2.2. The geographical grid

It is relatively simple to apply the geographiical 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 ($\delta\varphi = \delta\lambda$) ?

In figure 2 a block of equal sides in both φ and λ is shown, i.e. $\delta\varphi = \delta\lambda = n$ *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

Departure = diff. Longitude × cos Latitude (approx.).

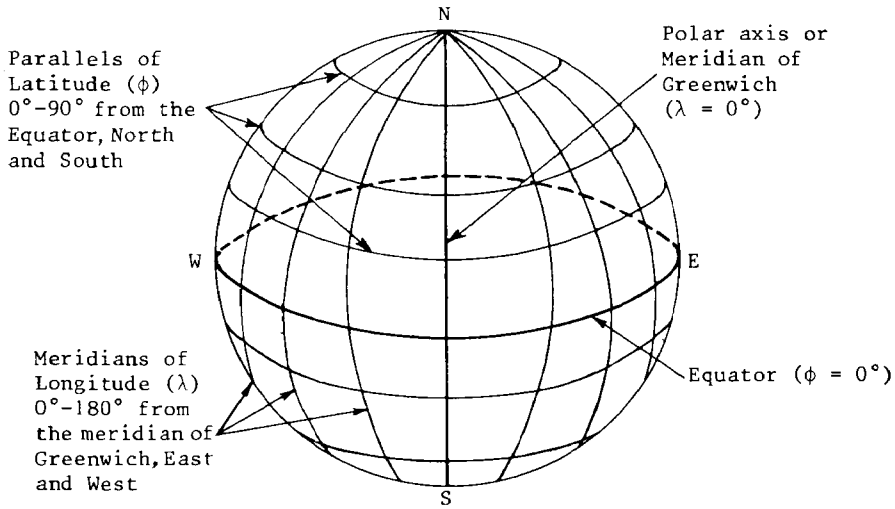FIG. 1. — The world showing parallels and meridians of Latitude and Longitude.

$\delta\varphi = \delta\lambda = n$; φ_1 = Latitude (φ) of centre of block
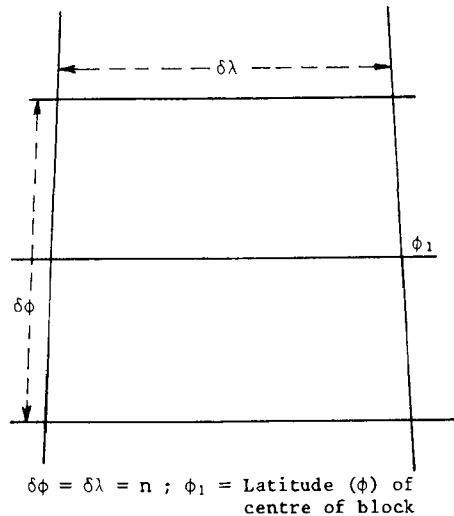
FIG. 2. — Geographical block with sides having the same degree values of φ and λ.

A tabulation of the computation of area versus latitude is as follows :

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

Values of sides	Area (sq. km) at φ_1 (degrees)				
$\delta\varphi = \delta\lambda$ (degrees)	$\varphi_1 = 0°$	$\varphi_1 = 20°$	$\varphi_1 = 40°$	$\varphi_1 = 60°$	$\varphi_1 = 80°$
1	12 347	11 603	9 459	6 174	2 144
2	49 391	46 412	37 835	24 695	8 577
3	111 129	104 427	85 130	55 564	19 297
4	197 562	185 648	151 342	98 781	34 306
5	308 691	290 075	236 471	154 346	53 603
6	444 516	417 708	340 519	222 258	77 189
7	605 035	568 547	463 484	302 518	105 063
8	790 250	742 592	605 365	395 125	137 225
9	1 000 000	939 843	766 167	500 080	173 676
10	1 234 765	1 160 300	945 885	617 383	214 415

This table shows that the area of a block decreases as φ 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

φ_1 (degrees)	Dimensions of blocks
0	150 000 sq. km is 3°29'08" $\delta\varphi, \delta\lambda$
20	" " 3°35'44" "
40	" " 3°58'56" "
60	" " 4°55'45" "
80	" " 8°21'51" "

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 φ 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 λ : 1 φ 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 λ : 1 φ, with dimensions which will contain a mine-site of 150 000 km².

TABLE C

φ_1 (degrees)	Area of block (km²)
0	220 257
20	208 854
40	170 260
60	111 129
80	38 595

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 km² 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 km² to above latitude 80° as shown in Table D.
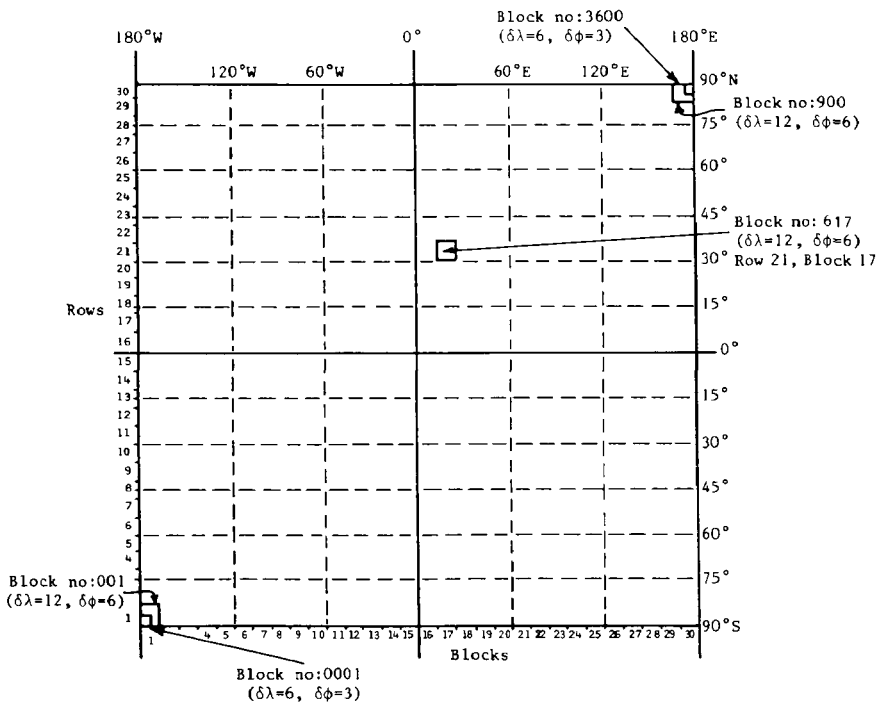

FIG. 3. — The world divided into blocks having dimensions $\delta\lambda = 12$, $\delta\varphi = 6$ and $\delta\lambda = 6$, $\delta\varphi = 3$.

TABLE D

Area of blocks having dimensions

$\delta\lambda = 12°, \ \delta\varphi = 6°$

φ_1 (degrees)	Area of blocks (km^2)
0	889 031
20	835 415
40	681 037
60	444 516
80	154 379

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 $\delta\lambda = 12°, \ \delta\varphi = 6°$.

2.4. The division of primary blocks into sub-blocks

Having established a suitable primary network of parallels and meridians of $\delta\lambda = 12°, \ \delta\varphi = 6°$ it is necessary to consider how these may be subdivided to cover the actual mining site. One way would be into 6 × 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° × 1°) which could be allocated to the mining site are shown by a pecked line; they total 28.

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

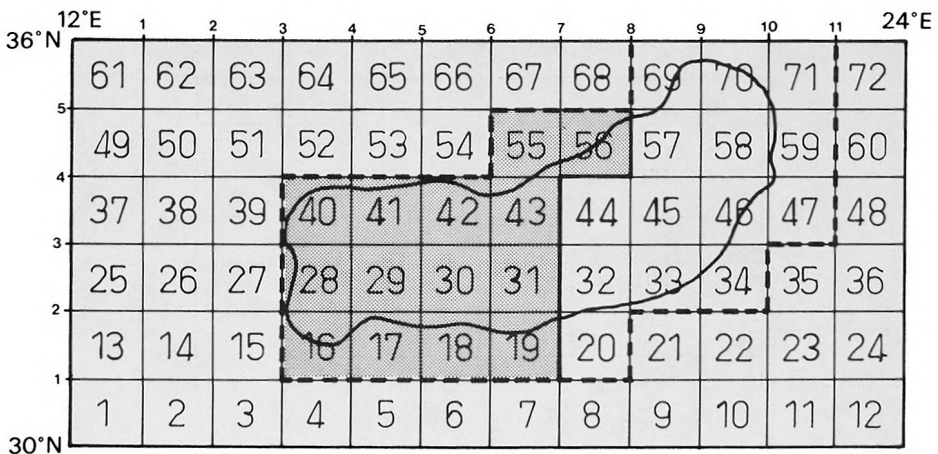$$28 \times (111.12)^2 \cos 33 = 289 \ 957 \ km^2$$

FIG. 4. — Block 617 showing area of geological interest.

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 $\varphi = 30°$ N to $\varphi = 36°$ N and the 17th block thereof has limits $\lambda = 12°$ E to $\lambda = 24°$ E.

The *sub-block* is 15, which is the third sub-block of the second row, i.e. is bounded by $\varphi = 31°$ N to $\varphi = 32°$ N and $\lambda = 14°$ E to $\lambda = 15°$ 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 φ, λ 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.
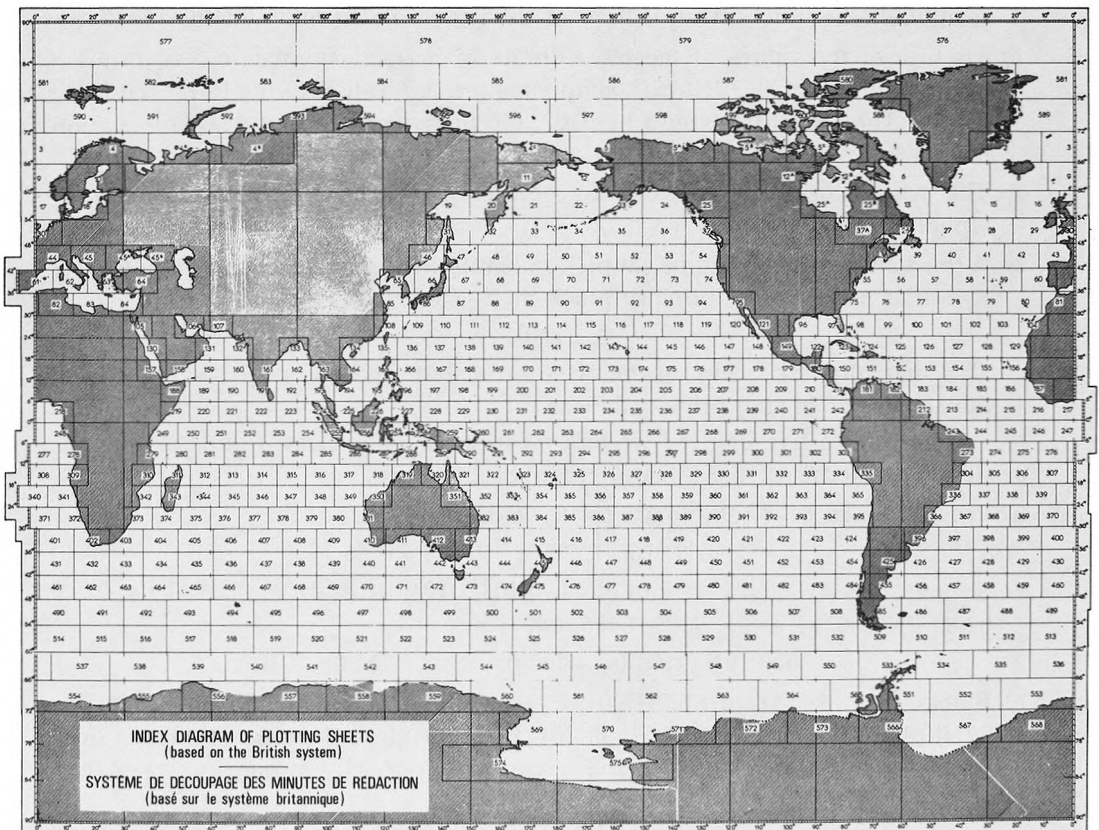

FIG. 5.

● 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).
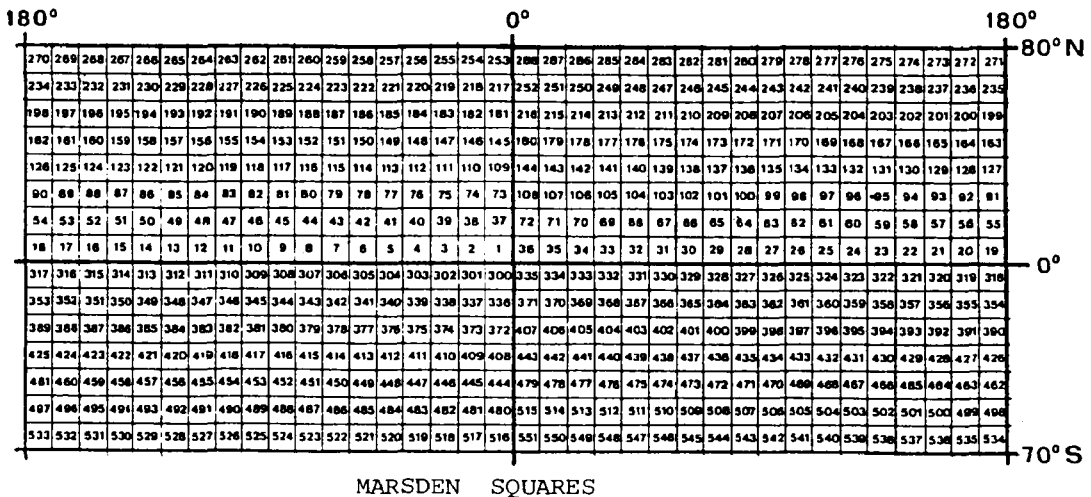
180°   **0°**   **180°** — **80°N**

270	269	268	267	266	265	264	263	262	261	260	259	258	257	256	255	254	253	288	287	286	285	284	283	282	281	280	279	278	277	276	275	274	273	272	271
234	233	232	231	230	229	228	227	226	225	224	223	222	221	220	219	218	217	252	251	250	249	248	247	246	245	244	243	242	241	240	239	238	237	236	235
198	197	196	195	194	193	192	191	190	189	188	187	186	185	184	183	182	181	216	215	214	213	212	211	210	209	208	207	206	205	204	203	202	201	200	199
162	161	160	159	158	157	156	155	154	153	152	151	150	149	148	147	146	145	180	179	178	177	176	175	174	173	172	171	170	169	168	167	166	165	164	163
126	125	124	123	122	121	120	119	118	117	116	115	114	113	112	111	110	109	144	143	142	141	140	139	138	137	136	135	134	133	132	131	130	129	128	127
90	89	88	87	86	85	84	83	82	81	80	79	78	77	76	75	74	73	108	107	106	105	104	103	102	101	100	99	98	97	96	95	94	93	92	91
54	53	52	51	50	49	48	47	46	45	44	43	42	41	40	39	38	37	72	71	70	69	68	67	66	65	64	63	62	61	60	59	58	57	56	55
18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	36	35	34	33	32	31	30	29	28	27	26	25	24	23	22	21	20	19
317	316	315	314	313	312	311	310	309	308	307	306	305	304	303	302	301	300	335	334	333	332	331	330	329	328	327	326	325	324	323	322	321	320	319	318
353	352	351	350	349	348	347	346	345	344	343	342	341	340	339	338	337	336	371	370	369	368	367	366	365	364	363	362	361	360	359	358	357	356	355	354
389	388	387	386	385	384	383	382	381	380	379	378	377	376	375	374	373	372	407	406	405	404	403	402	401	400	399	398	397	396	395	394	393	392	391	390
425	424	423	422	421	420	419	418	417	416	415	414	413	412	411	410	409	408	443	442	441	440	439	438	437	436	435	434	433	432	431	430	429	428	427	426
461	460	459	458	457	456	455	454	453	452	451	450	449	448	447	446	445	444	479	478	477	476	475	474	473	472	471	470	469	468	467	466	465	464	463	462
497	496	495	494	493	492	491	490	489	488	487	486	485	484	483	482	481	480	515	514	513	512	511	510	509	508	507	506	505	504	503	502	501	500	499	498
533	532	531	530	529	528	527	526	525	524	523	522	521	520	519	518	517	516	551	550	549	548	547	546	545	544	543	542	541	540	539	538	537	536	535	534

— **0°** (at mid-grid, right side)   — **70°S** (bottom right)

MARSDEN   SQUARES

FIG. 6.

2.7. Humphris Global Grid

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.
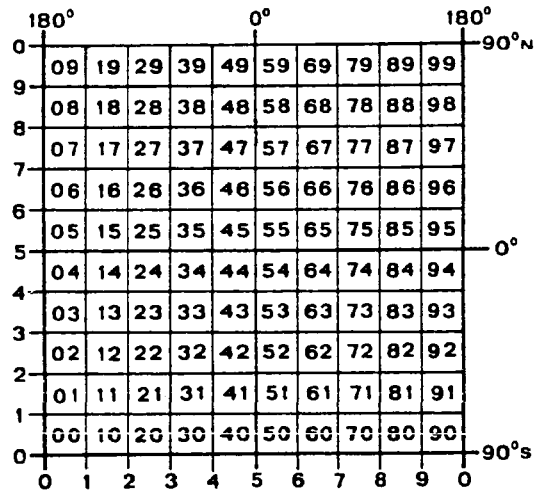
FIG. 7. — Humphris Global Grid — a decimalised numerical location system for all globes including Earth and Moon. Each globe panel is similarly divided and subdivided to produce smaller panels and finer spot references.

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 E

Secondary	No. of Tertiaries
47	42
48	75
57	35
58	97
59	36
68	12
69	15 = 312

The approximate total area in km² = AREA

$$= 312 \times (111.12)^2 \times 0.18 \times 0.36 \cos 33.5 = \textit{208 171 km}^2.$$
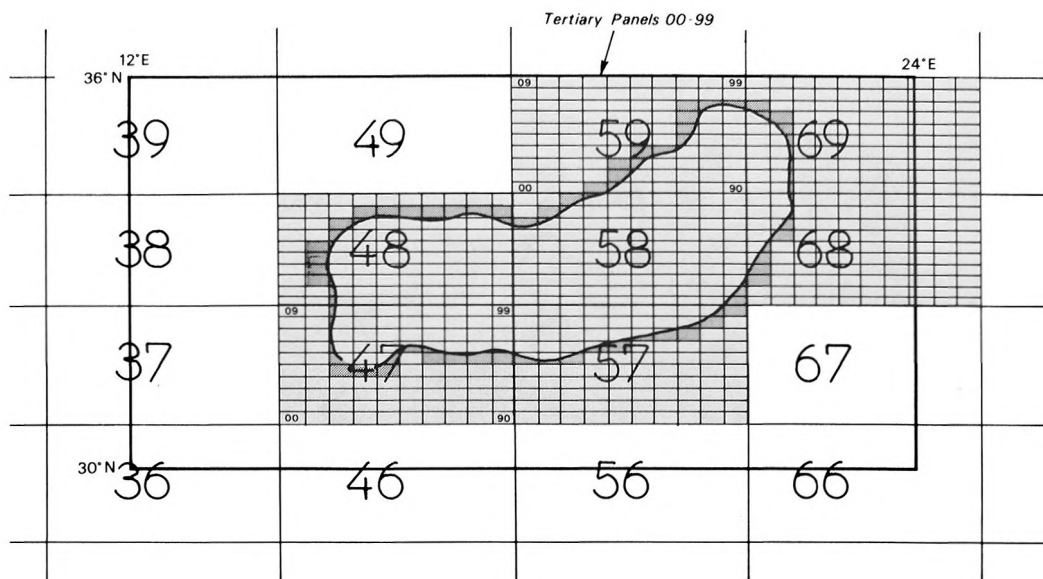
FIG. 8. — Showing part of global grid panel 56, and secondary/tertiary panels.

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 1 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
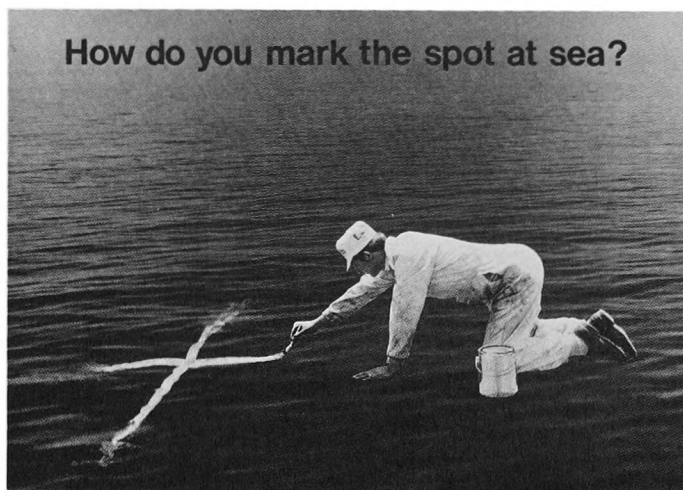
FIG. 9. — (Reproduced by kind permission of Teledyne Hastings-Raydist).

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 (φ, λ) 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
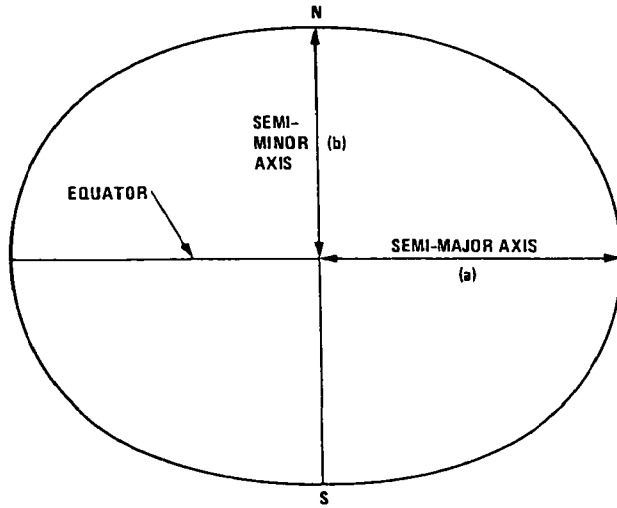
FIG. 10. — The meridian ellipse.

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 :

$$a = 6378135 \text{ metres}$$
$$b = 6356750.5 \text{ metres}$$
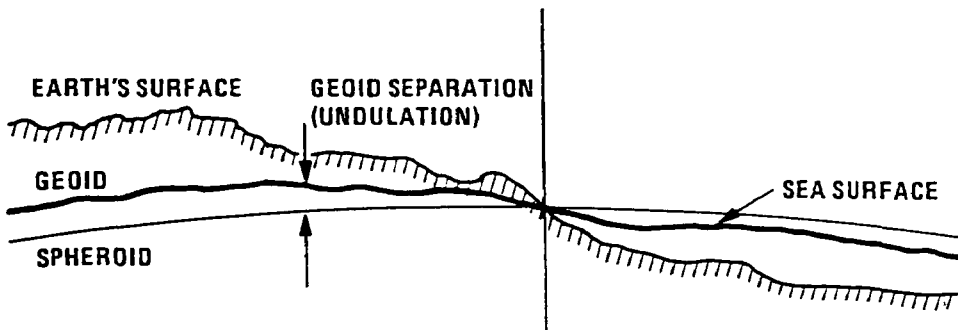
FIG. 11. — The three surfaces — topography, geoid, spheroid.

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 (φ, λ) 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

[1] Satellite Surveying, Gregory J. HOAR, Ph.D., Magnavox Advanced Products and Systems Co., February 1982.

[2] Marine Planning, its incorporation into town and country planning, Norman W. HUMPHRIS, FRICS, published in *Surveyor*, 19 February 1971.

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APPENDIX 1

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 (λ) and parallels of latitude (φ) 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 $\delta\lambda = 36°$ and $\delta\varphi = 18°$. The origin is $\lambda = 180°$ West and $\varphi = 90°$ 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) DMS = 69°07'12" East Long.
Northing   3.94 = 18 (3.94 − 5) DMS = 19°04'48" South Lat.

(v) The dimensions of panel 63 99 24 are :
$\delta\lambda \times \delta\varphi = 0.36° \times 0.18° = 21'36" \times 10'48"$
check : the upper right hand corner of 63 99 24 is :
63 99 35
which converts to 36 (6.93 − 5) DMS = 69°28'48"E = 69°07'12" + 21'36"
check
18 (3.95 − 5) DMS = 18°54'00"S = 19°04'48" − 10'48"
check.

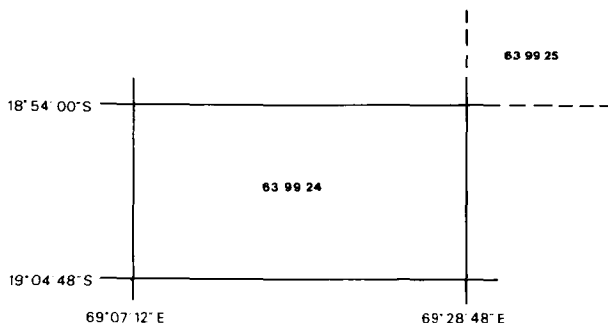(vi) The geographical limits of 63 99 24 are, therefore (see fig. 1A) :

FIG. 1A. — Geographical limits, panel 63 99 24.

(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 × 108 n.m. to, say, the fourth reduction of 2 n.m. × 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).

Primary	2 160 × 1 080 (at the Equator)
2	216 × 108 "
3	21.6 × 10.8 "
4	2.16 × 1.08 "
and so on.	

(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.

$$E1.2345670 = 135°33'20''.12 \text{ West Longitude}$$

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° the proportion is 1:1

— Above 60° 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 $\Delta\lambda° = 20°: \Delta\varphi = 10°$ 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-numerics 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.

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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.

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APPENDIX 3

COMPUTATIONS ON THE HUMPHRIS GLOBAL GRID

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

Given GG coords :	33	84	20	55	17	91
(level)	(2)	(3)	(4)	(5)	(6)	(7)
Easting	3 . 8	2	5	1	9	
Northing	3 . 4	0	5	7	1	

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 geographicals : φ = 28°41'49".99 South
λ = 42°17'35".38 West

$$\text{Northing} = 5 + (\varphi/18) = 5 + \frac{(-28.697219)}{18}$$

$$= 3.40571$$

$$\text{Easting} = 5 + (\lambda/36) = 5 + \frac{(-42.2931611)}{36}$$

$$= 3.82519$$

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 :

Departure = D' Long Cos Mid Latitude
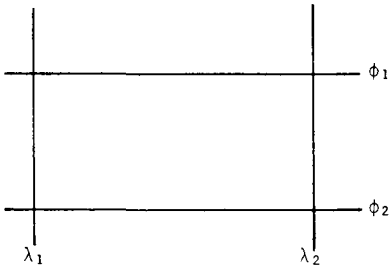
Area = $(\varphi_1 - \varphi_2)$ $(\delta\lambda$ $(\cos\varphi_1 + \cos\varphi_2))$ 1800
where :
φ_1 = Lat. of upper parallel
φ_2 = Lat. of lower parallel
λ_1 = Long. of right meridian
λ_2 = Long. of left meridian
$\delta\lambda$ = $\lambda_1 - \lambda_2$.

FIG. 2A. — Area computation.