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Scientific Considerations Relating to the Continental Shelf

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SCIENTIFIC CONSIDERATIONS RELATING TO THE CONTINENTAL SHELF

MEMORANDUM BY THE SECRETARIAT OF THE UNITED NATIONS EDUCATIONAL, SCIENTIFIC AND CULTURAL ORGANIZATION

(Preparatory document No. 2)

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CONTENTS

Introduction

1. The United Nations Organization requested on 18 April 1957 the preparation of a working document on the subject of: Topographical and Geological description of the Continental Shelf and Other Submarine Regions adjacent to the Coast; the document being envisaged for use during an International Conference of Plenipotentiaries charged with examining the Law of the Sea.

2. To meet this request of the United Nations, UNESCO convened a meeting of experts (Drs. A. Guilcher, Nancy, France; P. H. Kuenen, Groningen, Netherlands; F. P. Shepard, La Jolla, California, United States of America — Dr. V. P. Zenkovitch, Moscow, Union of Soviet Socialist Republics, also invited but unable to attend), to whom a preliminary draft text prepared under contract by Dr. Guilcher, with the advice of Drs. P. Tchernia and M. Eyriès, was submitted for review. The present paper is the result of the combined work of the above experts,[1] who collaborated in bringing about amendments to the preliminary draft.

3. It appeared to the experts that a document carrying precisely the requested title would not be the most useful that could be conceived for the projected Conference. It is not so much a systematic description that should be furnished (such a description would be in any case either very long or very incomplete), as the elements that could lead to such a definition, and permitting the plenipotentiaries to choose, in full awareness of all the circumstances, the borderlines or criteria for the borderlines, which they require, as well as the elements for evaluating the part of the sea-bottom situated beyond the continental shelf for their juridical status.

4. For this reason, it was thought useful to modify the title and the substance of the requested document, and to adopt the one used in the heading. It will be found that the report includes a descriptive part, or more exactly, that precise examples are given with reference to each aspect of the problem to be examined. It is in fact necessary, since natural topographical features are concerned here, to go beyond abstractions. However, in principle, the report is not primarily descriptive.

5. The following items are treated: the continental shelf as a legitimate concept; the problem of the borderline between the shelf and the slope; the problem of irregularities of the topography of the shelf; the problem of "other submarine regions adjacent to the coast", and of isolated submarine rises in the sea.

I. CONTINENTAL SHELF AS A LEGITIMATE CONCEPT

6. Attention is first drawn to the definitions adopted by the International Committee on the Nomenclature of Ocean Bottom Features, published by Wiseman and Ovey (Definitions of features on the deep-sea floor, *Deep-Sea Research,* Vol. I, No. 1, Oct. 1953, p. 11-16).

"*Continental shelf, shelf edge and borderland.* The zone around the continent, extending from the low-water line to the depth at which there is a marked increase of slope to greater depth. Where this increase occurs, the term shelf edge is appropriate. Conventionally, its edge is taken at 100 fathoms, or 200 metres, but instances are known where the increase of slope occurs at more than 200 or less than 65 fathoms. When the zone below the low-water line is highly irregular, and includes depths well in excess of those typical of continental shelves, the term continental borderland is appropriate.[2]

Continental slope. The declivity from the outer edge of the continental shelf or continental borderland into great depths.

[1] It should be noted that the experts limited themselves to purely scientific considerations and that the memorandum should not be considered as a statement of the views of UNESCO regarding the legal questions involved.

[2] This point will be discussed further in paragraph 40.

Continental terrace. The zone around the continents, extending from the low-water line, to the base of the continental slope.

Island shelf. The zone around an island or island group, extending from the low-water line to the depths at which there is a marked increase of slope to greater depths. Conventionally, its edge is taken at 100 fathoms, or 200 metres.

Island slope. The declivity from the outer edge of an island shelf into great depths."

7. In French, "continental shelf" is translated equally often *plateau continental* and *plateforme continentale*. "Continental slope" is traditionally translated *talus continental,* but it seems better to say *pente continentale,* an expression which does not prejudge the origin of this relief, which is still disputed and which no doubt is not invariable. In fact, *talus* seems to imply a built-up declivity. "Continental terrace", which comprehends both continental shelf and continental slope, can be rendered by *marge continentale* (Bourcart, *Géographie du fond des mers,* Paris, 1949; Guilcher, *Morphologie littorale et sous-marine,* Paris 1954); besides, the expression "continental margin" is used in English (e.g. Umbgrove, *The Pulse of the Earth,* The Hague, 1949); this term seems to us even preferable in that language. The equivalents of other terms are:

"Shelf edge": *bord de la plate-forme*;

"Borderland": *bordure continentale*;

"Island shelf and slope": *plate-forme and pente insulaire.*

8. In spite of the difficulties of defining the borderline between the continental shelf and the continental slope (see under section II below), it is incontestable that the concept of continental shelf corresponds to a real feature. As a general rule, there exists in fact a shallowly submerged zone along the edge of continents, of which the mean slope is markedly less steep than beyond, leading to the deep-sea floor. The reality of this feature can be demonstrated by the percentages of terrestrial surface occupied by three depth zones of the oceans (according to Svendrup, Johnson and Fleming, *The Oceans,* New York, 1942).

From 0 to 200 metres:	7.6 per cent	8.5 per cent
„ 200 to 1000 metres:	4.3 per cent	
„ 1000 to 2000 metres:	4.2 per cent	

9. Since the area covered by bottoms lying between 0 and 200 metres is only slightly less than that between 200 and 2,000 metres, a range of depth that is nine times as great, it is evident that the average slope is much steeper beyond 200 metres than nearer shore. These figures are liable to be somewhat modified by continued soundings in years to come, but it can be affirmed that they will not change significantly, and that the general conclusions drawn from them will not be altered.

10. The outer limit of the continental shelf will be discussed in section II. Meanwhile the depthline of 200 metres will be retained as the margin. Thus defined the shelf is very unequally distributed around the continents. It can be of a width of several hundred kilometres, as off the Guianas, and, in other cases, can be limited to 1 or 2 kilometres or even be completely lacking (western coast of Corsica, and off the Alpes-maritimes, on the south-east coast of France). It is important however to emphasize that total absence of the continental shelf is a rare feature, and that the shelf usually exists not only off flat coasts like north Siberia or south Argentina, but also off a number of mountainous coasts like that of Galicia on the north-west side of the Iberian Peninsula, where the shelf extends to a width of about twenty kilometres in spite of the fact that immediately inland there are found heights reaching from 400 to 600 metres. It is however true that is is particularly off mountainous coasts that the shelf may be missing (principle of the continuity of subaerial and submarine topographies).

11. It seems unnecessary to include in this report separate consideration of island shelves, since the juridical problems raised by the continental shelf apply also to them.

12. Finally the existence should be noted of shallow seas between islands and/or continents. These areas incontestably form parts of the continental shelf. In some cases the islands form the raised margin of the continental shelf (e.g. Farilhoes off Portugal, Taiwan off China, Aru Islands south of New Guinea). In other cases the area can be considered a flooded part of the continent (e.g. Gulf of Paria; Baltin; White Sea; North Sea; Persian Gulf; sea between the Sunda Isles, Malacca and Gulf of Siam; Yellow Sea; Gulf of Tartary; sea between New Guinea and Australia). Those areas merge imperceptibly and without any change in character morphologically or geologically with the adjoining shelves facing the wide oceans. Hence no doubt can arise as to their belonging to the shelf.

II. The problem of the borderline between the continental shelf and the continental slope

13. Here the concern is with an essential problem: is it legitimate to fix the limit of the continental shelf along the 200 metre line (or 100 fathom line which comes to almost the same thing) based on topographic data? Can one adopt a line of demarcation topographically or otherwise, that would be universally valid?

14. An examination of this problem applied to the seas of the world as a whole was made by Shepard (*Submarine Geology,* New York, 1948). Shepard reached the following conclusions (p. 143-144): the edge of the shelf, that is to say, the depth at which the greatest change in the slope occurs, on the average at 72 fathoms (133 metres); the average slope of the shelf is 0° 07′, and is a little steeper in the inner half than in the outer; on the continental slope, on the other hand, the average slope is 4°17′ for the first 1000 fathoms of the slope (*ibid.*, p. 187). It appears therefore, according to these data, that the traditional limit of 200 metres is too deep, at least for an average.

15. However, actual figures can depart considerably from this average, and it is certain that the continental shelf reaches depths varying very much from place to place, and can in certain cases attain relatively great depths. Thus, around the Antarctic, "a depth of two to three hundred fathoms (370 to 555 metres) is commonly found before the break of slope which marks the edge

of the continental shelf" (Ewing and Heezen, in *Antarctica in the International Geophysical Year,* American Geophysical Union, Washington, 1956, p. 75). Off western and north-western Australia, the Sahul Shelf descends to a depth of 555 metres (300 fathoms) in certain places, whereas in other places the shelf edges are much shallower (R. W. Fairbridge, The Sahul Shelf, Northern Australia, *Journ. Roy. Soc. West. Australia,* XXXVII, 1953, p. 1-33.—M. A. Carrigy et R. W. Fairbridge, Recent sedimentation, physiography and structure of the continental shelves of Western Australia, *ibid.,* XXXVIII, 1954, p. 65-95). Other poorly sounded areas which may represent deep shelves could possibly be included in continental borderlands which are discussed later (para. 40). The continental shelf off Norway, where depths are fairly variable even in the relatively flat parts, can be considered as a "glaciated shelf", which is a special type also discussed later (para. 20).

16. Furthermore, Bourcart has emphasized the great difficulty sometimes encountered, according to his view, of defining the outer edge of the shelf (Note *sur la définition des formes du terrain sous-marin,* Deep-sea Research Vol. 2, January 1955, p. 140-144). He admits that there exists sometimes a very marked line of demarcation occurring at depths varying from place to place, as has already been seen. The example can be cited of the Arabian shelf in the Red Sea, 200 kilometres south of Jidda, which is only 50-80 metres deep, and which suddenly drops off beyond this with a very sharp discontinuity of slope to depths of 640 to 730 metres, where there is a second step (Nesteroff and Guilcher, *Morphologie et géologie du Banc Farsan, Annales de l'Institut Océanographique,* Vol. 30, 1955, p. 1-100). However, Bourcart also says: "*La côte française de la Méditerranée ne nous donne aucun exemple de plateau continental qui soit limité par un abrupt net. Le seul case est celui des abrupts par où se terminent vers le haut les canyons*". Thus, he continues, in the Gulf of Lions we have "*une pente convexe qui débute vers 100 mètres et passe par un maximum à 500-600 mètres. Elle devient concave vers 2000-2100 mètres*". He concludes that in many cases the distinction between the continental shelf and the continental slope is either difficult or impossible.

17. This difficulty pointed out by Bourcart does certainly exist in certain regions, but these are quite exceptional. Even in the Gulf of Lions (Frenche Mediterranean coast), the charts published by Bourcart himself (*Contribution à la connaissance du socle sous-marin de la France le long de la côte méditerranéenne, Comptes rendus du 19e Congrès Géologique International,* Alger, 1952, Section IV, p. 25-63) show that in this region the shelf and the slope can be separated. In the north-west Gulf of Mexico, of which a fine chart in two sheets has been published by Mrs. Gealy (Topography of the continental slope in north-west Gulf of Mexico, *Bull. Geol. Soc. America,* Vol. 66, 1955, p. 203-228), the slope shows a rapid increase beyond about 75 fathoms (140 metres), and there again, the limits could be traced with sufficient accuracy. The Porcupine Bank, off Ireland, is a much more delicate case, over which soundings as yet unpublished have been made recently (March 1957). This bank has, generally speaking, a long slope that is regularly convex towards the great depths of the Atlantic, which extends at least to a depth of 800 metres. This feature may be seen also, for the south-western tip of this Bank, in the Chart of the north-east Atlantic published by Hill (*Deep-Sea Research,* Vol. 3, No. 2, April 1956). To define the edge of this bank would be a difficult operation. This is an extreme case.

18. The difficulties seem to proceed in large measure from the fact that the continental margins (shelves and slopes) do not appear to have the same origin, and as a consequence to have the same structure. For the problem of origins, reference for details is made to Shepard, *op. cit.*, Bourcart, *Géographie du fond des mers,* Kuenen, Marine Geology, New York, 1950, Guilcher, *op. cit.* A first type, of which the existence is established beyond doubt, is that formed by sedimentation of a few thousand metres thick on a subsiding foundation. A representative case is the shelf off the east coast of the United States, well explored by means of seismic prospecting methods. The base of the Cretaceous deposits, which is 900 metres below sea-level at the entrance of Chesapeake Bay, is found to be at a depth of 3,900 metres at the outer edge of the shelf, with younger sediments on top in the shape of a wedge forming the terrace. Likewise, the coastal shelf of the northern Gulf of Mexico, also well studied by many deep wells and by seismic prospecting, is formed by a mass of Tertiary sediment many thousands of metres thick. Salt rises up through these sediments from below in the form of salt domes, forming slight mounds at the surface. These cases of built-up shelves are not among those whose outlines are difficult to define.

19. A second type is due primarily to erosion, the cutting by waves of coastal terraces during times of lowered sea level caused by glaciers on the continents. The terraces were formed at various levels down to about 100 metres below the present sea level. After the sea level returned the terraces have been partly smothered by sediment but can still be found by an acoustic probe which shows the thickness of surficial sediments. Shelves of this type are mostly very narrow, a few kilometres wide. Examples are found off southern California and probably in many other areas.

20. A third type occurs off most glaciated coasts (Shepard, *op. cit.* chap. 5). These shelves are very irregular, containing many basins and troughs which have depths greater than 200 metres even near the coasts. (H. Holtedahl, *On the Norwegian continental terrace, primarily outside Möre-Romsdal,* Bergen, 1955; O. Holtedahl, *The submarine relief off the Norwegian coast,* Oslo, 1940). Shallow banks, including islands are found on the outer parts of these shelves. These banks are important sources of fish, for example the Grand Banks.

21. A fourth type is that of flexured continental margins, caused by the bulging up of the continent and concomitant downwarping of the submerged part. According to Bourcart (*op. cit.*) and Jessen (*Die Randschwellen der Kontinente, Ergänzungsheft 241 zu Petermanns Mitteilungen,* Gotha, 1943), this type is seen along many coasts of the world, and in particular in various points on the African coast: mountains found

along the periphery of this continent for instance in Gabon and in Angola, would represent the projecting parts of the flexure, and at least for the case of Angola, this explanation appears to be correct. Bourcart believes that the south-eastern coast of France (Provence, Niçois) is of the same type. He has proposed the same for the Atlantic coast of Morocco, but there his conclusions have been challenged by various authors. However this may be, the flexured continental margins are not in principle built up, at least not to the same degree as the preceding type ; very gentle convexity of this edge may be encountered.

22. A fifth type is that of margins consisting of a series of step faults, probable examples of which are found along the coasts of Queensland in Australia, and possible examples along the Arabian coast on the Red Sea, at least in certain places (Nesteroff and Guilcher, *op. cit.*). In this case, one finds immediately at the foot of the shelf a deeper area of varying depth, intermediate between the shelf and the deep-sea floor. Sedimentation on this stepped area can obliterate the steps to a greater or smaller degree according to the case, but the sedimentation is not as thick as in the first type. The difficulties of delineation would often be quite small.

23. A sixth is the basin and range type, where the topographic relief is formed by blockfaulting and possibly folding. These basins and ranges run parallel or nearly parallel to the coast. The most typical example is found along the southern coast of California. (Shepard and Emery, *Submarine Topography off the California Coast,* 1941, Special paper No. 31 - Geological Soc. of America). The question remains as to how far the whole area consisting of crests and depressions forms part of the continental shelf: we will return to this question in par. 40. In other regions folds may perhaps play a more important rôle than faults. It has been suggested by Bourcart and Glangeaud (*Morphotectonique de la marge continentale nord-africaine, Bull. Soc. Géol. de France,* (6) IV, 1954, p. 751-772) that recent folds may have contributed to form the Algerian coast.

24. In spite of these diversities of origin the continental shelf has a remarkably even marginal depth, usually lying between 100 and 150 metres. This uniformity is probably the result of wave erosion during glacial stages of low sea level and in part delta building at these same stages. Some scientists believe that the depths represent the lowest level at which the waves can transport sediments at present. Many shelves have been affected somewhat by crustal warping, particularly by slow subsidence. Others have been built up since the Ice Age by deposition. In the coral sea areas as in Northern Australia the growth of corals has greatly decreased shelf depths.

25. Faced with these difficulties, should one adopt a non-morphological and non-bathymetrical criterion, and base it for instance on the geological nature of the bottom or upon the aquatic inhabitants ? This does not appear feasible. As regards the nature of the bottom, it follows from the foregoing remarks how extreme the differences in composition must be. Rock of all kinds, coarse fragmentary matter, sand, coral reefs, mud covering, etc., are all known to occur extensively. As to bottom inhabitants, numerous organisms have a wide range covering most of the shelf and the upper part of the slope.

26. It does not seem advisable on the other hand to propose a definition of boundaries corresponding to the technical possibilities of exploitation of the soil and submarine sub-soil, and this for two reasons. Firstly, rapid technical advances of exploiting the mineral resources of the sea are being made so that the limit thus defined would be on the outward move all the time. Moreover, this limit would depend on local current and wave conditions, so that there would be the greatest confusion concerning the suggested definition. Secondly, the possibility, already realized, of exploitation by oblique drilling and mining from the land deprive the suggested definition of all meaning.

27. In spite of the above, is it still possible to propose to jurists a general rule for defining the boundaries ? It is suggested to keep to the morphological criteria, notwithstanding the difficulties encountered in this domain. A few criteria are proposed that are at the same time almost universally valid and in accordance with the actual bottom relief.

Proposed Method for Defining the Boundary of the Continental Shelf

Case 1 : The soundings are insufficient for tracing the depth contours : in this case the continental shelf is limited by agreement to the depth of 100 metres until the establishment of charts with precise contours.

Case 2 : Soundings are sufficient, that is to say, there are no points in the area in question which are more than 5 kilometres distant from a line not parallel to the coast along which the depth is known in a continuous manner.

Case 2 a : The great majority of continuous echo sounding profiles running from the coast to oceanic depths show a clearly marked break in slope at the outer edge of the shelf at less than — 600 metres. Often this break is seen to be double, with the most marked angularity found in the deeper of the two. This point (in the case of two, the one most pronounced) marks the edge of the shelf.

Case 2 b : If any doubt exists as to the position or existence of such a break at less than — 600 metres, the following procedure should be followed : The contours are traced at depth intervals of 50 metres (or 25 fathoms) in the range between — 50 and — 800 metres. A set of lines normal to the contour is drawn, spaced at 10 kilometres intervals measured along the 200 metre contour. The *two shallowest* consecutive contours are selected satisfying the following condition : The distance between the two contours, measured along the line of maximum slope, is less than 1/10th of that, similarly measured, between the two extreme contours of — 50 and — 800 metres. A border point is then marked on each of the lines mentioned, midway between the shallowest of those two contours and the next one on the shallow side. The outside limit of the continental shelf is defined by the broken line, traced on a chart based on the Mercator projection, formed by joining by straight lines the border points obtained in the above manner.

28. *Remarks :* In case 1, the 100 metre depth is

chosen because it is the shallowest normally found at the break of slope in imprecise charts. In case 2 *b*, the proposed rule would appear to permit the definition of borderlines even where the outer edge of the shelf is gently rounded, that is, where a clear break in slope is lacking. They can be applied validly also to island shelves, whether they may be small islands or continental islands of the Madagascar type.

The above rules are so devised as to provide an incentive for carrying out sounding surveys in less well chartered areas of the shelf.

III. The problem of irregularities in the shelf

29. The term shelf or platform does not necessarily imply an absolutely flat relief, but only a configuration where, except in glaciated areas, the unevenness is not very considerable: 100 metres at most, and usually of lesser order. If we were to insist on absolutely flat areas between the coast and the outer limits suggested above, we would not find very many continental shelves in the world. Besides, isolated rises and depressions of a much greater scale can be found on the shelves; but in continental terminology, it is admitted that such heights and depressions do not form part of the platform.

30. Shallowly embedded submarine valleys (some 40 or 50 metres deep) that are found on the shelves in different parts of the world should certainly be considered as integral parts of the shelves. Examples are found on the shelf off the mouth of the Hudson River, in the Java Sea between Java, Sumatra and Borneo, in the Arafura Sea, north of Australia, and in front of Guinea. These valleys (so-called shelf channels), cut by subaerial rivers during the Pleistocene period at a time when glaciation caused a lowering of the sea level, are but a witness of the fact that the shelf is a borderline area alternately submerged and exposed, a true extension of the neighbouring continents. Another evidence of the mixed origin of the shelves is the existence on various shelves of hills of glacial origin and of Quaternary Age (north-east coast of North America, North Sea, Baltic Sea). There are also channels of fluviatile or other origin, which have been excavated to greater or lesser extent by tidal current scour.

31. The case of isolated and narrow but deeper depressions is more controversial. Such depressions are found scattered in certain seas, examples being the Hurd Deep in the English Channel (172 metres), and the multitude of small trenches in the North Sea (Devil's Holes, Swatch Way, Fladen Trough etc. — with depths up to 274 metres), whose origin is not yet well known. In the Baltic Sea also, there exist such isolated depressions, examples being the Ulvö Trough, the Åland Sea Trough (Giere, *Die Entstehung der Ostsee,* Königsberg, 1938), with depths reaching 250 metres and in exceptional cases even exceeding 300 metres (355 metres in the Åland Trough, according to the Union of Soviet Socialist Republics' Atlas, 2nd Edition, Moscow, 1955). It will no doubt be unanimously agreed that these isolated deeps form part of the shelf in which they are embedded, so long as they do not occupy more than a very small part of the sea bottom and are encircled by much shallower depths.

32. However, certain continental shelves are marked by much deeper and bigger depressions than those cited above. Three categories can be distinguished: *a*) the depressions that communicate with the deep sea beyond the outer edge of the shelf only over a sill at the level, or nearly at the level of the shelf floor; *b*) wide flat-floored troughs lacking a sill in the outer part; *c*) the narrow canyon-like valleys which slope out to the deep-sea floor.

a) The depressions of the first kind are frequent on continental shelves in higher latitudes that have been glaciated. They are sometimes longitudinal and thus form a kind of large trough parallel to the general direction of the coast, for example around Norway (O. Holtedahl, *op. cit.*; H. Holtedahl, *op. cit.*), sometimes transversal, and thus correspond to the openings of fjords, for example, the coast of British Columbia (Shepard, *op. cit.*). The glaciers of the Ice Age are evidently responsible for the modelling.

b) The depression of the second type so far as known are all off glaciated coasts, for example the Cabot Strait Trough, south of Newfoundland, discussed below (para. 35).

c) Depressions of the third type, much more numerous but narrower, are the submarine canyons, concerning which a considerable literature is in existence (see general works already cited): they are valleys with a V-shaped cross-section, often ramified, deeply embedded in the shelf, with relative depths of several hundred metres, sometimes even exceeding 1,000 metres. They are thus distinguished from the "shelf channels" described in para. 30. Furthermore, they have a very steep and irregular longitudinal profile, but, generally, without very marked counter-slopes. Many submarine canyons only cut into the fringe of the continental shelf without penetrating deeply into it; but others traverse it almost completely and nearly reach the coast or even enter the mouths of certain rivers, as is the case of the Congo Canyon on the west coast of Africa, the Gouf de Cap Breton, off the south-western coast of France; and the canyons off California.

33. The problem whether these various depressions do or do not form part of the continental shelf is one which will arise in many areas since submarine canyons exist in a considerable number of regions; they are known to be found on the coasts of both Americas, many Mediterranean coasts, coasts of east and west Africa, off the entrance of the English Channel, in the Beaufort Sea, around the Philippines, Japan, etc. (chart of canyons known in 1939 in Shepard, *op. cit.*, p. 210; this chart has now become very incomplete. Many other examples of canyons in the works, already cited, of Kuenen, Shepard, Bourcart, Guilcher). Though the exploitation by man of their bottom and sides are not as yet begun nor envisaged, it is foreseen that jurists will one day be faced with this problem.

34. From the morphological point of view, when a depression of the first type mentioned above is concerned, that is, one communicating with the ocean over a sill nearly level with the shelf, it would seem reasonable to consider this depression as constituting a part of the shelf, even if the depression is very deep. In this case the depression is perhaps anamalous to the

shelf, it is true, but totally enclosed therein. It is suggested that the depressions in the Norwegian shelf should not be dissociated therefrom because they form an integral part of the shelf from the morphogenetic point of view and many continue far inside the coast-line as fjords. It is also suggested that the Norwegian Trough forms part of the North Sea Shelf because of its sill.

35. A more difficult problem arises concerning depressions of the second type, that is, extending across to the break in slope without a sill. A type example is provided by the trough coming out of the Gulf of St. Lawrence through Cabot Strait. The depths along the entire length of this trough are in excess of those of the shelf on either side, and the trough has a width of about 100 kilometres. On the other hand, the trough is morphologically related to the shelf. Furthermore, the depths are not in excess of many of the basins on other glaciated shelves and it would be difficult to draw a line between this trough and the numerous other troughs of the glaciated shelves. However, the problem of the inclusion of this kind of trough in the continental shelves is more controversial than the preceding case.

36. The situation is very different from that of submarine canyons which tend to slope continuously out from their head to the deep-sea floor, thus forming part of the continental slope. The narrow upper part of submarine canyons, although belonging technically more to the slope than to the surface of the terrace, could nevertheless be considered part of the surrounding shelf from the point of view of convenience for international legislation.

37. In this regard, the notion of the straight baseline might be taken into consideration. This is the baseline from which the width of territorial waters are calculated in the case of deep coastal indentations.[3] The question would then be to know what would be the width of the indentation in the shelf beyond which a straight line should be drawn from one side to the other, to define the limits of the shelf at this point. The critical width to be adopted should be discussed by jurists.

IV. The problem of "other submarine regions adjacent to the coast"

38. An attempt to furnish the scientific elements that would serve to define such regions puts one in a difficult position, since what "regions" exactly are in question? The commentaries concerning the article 67 of the Articles concerning the Law of the Sea[4] might throw some light on the matter. It is stated in para. (2) of the commentary on article 67 that the International Law Commission had envisaged the use of an expression other than "continental shelf" for the case where "technical developments in the near future might make it possible to exploit the resources of the seabed at a depth of over 200 metres...".

39. The considerations discussed above make it clear that only confusion could arise from such a procedure. If, notwithstanding, the future Conference on the Law of the Sea should not limit legislation to the continental shelf, it is obvious that morphological considerations would then no longer play any part.

40. A special problem arises in the case of the continental borderlands, concerning which the area off southern California provides the type example. Here the basins and troughs are quite different from those of the glaciated shelves. They are clearly due to block-faulting and their depths are intermediate between shelf and deep sea. On the other hand, some of the ridges rise to shelf depths and even include islands. It is also important to note that the feature corresponding to the continental slope lies seaward of the continental borderland. A case somewhat comparable to the borderland is found in the Bahama Banks where even deeper troughs than those off California are found in between some of the island banks.

41. If the legislation is not limited to the shelves and borderlands, it might be useful to attempt to define here the notion of the continental slope, that is to say, the part of the sea bottom immediately adjacent to the shelf, and constituting together with it the continental margin. The definition of the International Nomenclature Committee was given in section I. As in the case of the shelf, the question of the outer boundary is posed. This boundary is relatively easy to draw if one keeps to general lines; but if an exact borderline has to be traced, serious difficulties are encountered, even greater than in the case of the shelf. This stems from the state of our knowledge and from the nature of things.

42. Our knowledge of the sea bottom is the less precise as the depth and the distance from the coast increase. At first the approaches of the coasts were sounded to meet the requirements of surface navigation; then the adjacent shelf was explored for fishing, for submarine navigation, with the view to eventual exploitation of the sub-soil, or because the scientific study thereof was fairly easy; going deeper, the available data rapidly dwindles due to the fact that the above reasons do not apply, or at least do not apply to the same degree. It is today quite in the domain of fancy to think of defining exactly the outline of the base of the continental slope, except in rare and particularly favourable cases. We will not even venture to quote a reference figure for the depth, since this varies in a range very much wider than in the case of the outer edges of the shelf.

43. In the favoured regions where precise soundings have been made, the slope appears to terminate in a fairly gradual fashion, that is to say, with a concave profile and an easing off of the slope. This is not encouraging for those who would wish to trace a line of demarcation separating the slope from the great depths. This arises, at least in part, from the existence of very numerous submarine canyons cutting the slope. These canyons are the places where sediment slumping and turbidity currents (spasmodic currents, formed of water charged with sediments) occur, sometimes the two together (numerous works of Kuenen on this subject;

[3] See article 5 of the Articles concerning the law of the sea in the report of the International Law Commission covering the work of its eighth session, *Official Records of the General Assembly, Eleventh Session, Supplement No. 9* (A/3159), p. 13.

[4] *Ibid.*, p. 41.

similarly those of Shepard, with somewhat differing conclusions), which have either cut the canyons or at least maintain them open by periodically evacuating the sediments that tend to fill them. The two cases perhaps coexist: certain canyons can be attributed to other causes than turbidity currents in their origin (subaerial erosion by rivers prior to submersion), specially where they cut through hard rock.

44. Great fans exist beyond some of the canyons. These are in general gentle sloping and smooth, but are cut by shallow valleys. Some of the latter are continuations of the submarine canyons.

45. It must be said, however, that the study of the slope is very useful for the knowledge of the shelf. In fact, the exploitation of the whole body underlying the shelf and slope, which comes to the same as saying the exploitation of the continental margin, can certainly profit greatly not only from drilling results, but also from geophysical studies (which are made on the surface and do not require boring); but the latter can also be backed up by exploration of the natural sections constituted by the canyons, where samples may be taken which reveal the internal structure of the margin.

46. It could also be said that the upper part of the slope is susceptible to exploitation from the viewpoint of fisheries, but possibly not the whole slope. Off western Europe, it does not seem profitable to trawl at depths exceeding 600 to 700 metres. This limit, however, may not be the same everywhere.

47. Finally, another question is raised: that of isolated rises and ridges occurring in oceanic basins. These accidents of topography are very numerous, and they sometimes cover considerable surfaces. When they are situated very far from continents or islands, and when they are at the same time separated from them by depths of several thousand metres, they would probably not pose questions for the jurists, and it is not considered useful to discuss them here. But all are not of this kind.

48. Thus, there exist rises isolated by great depths but relatively near to exposed lands that are inhabited and appropriated. This is the case of the Rockall Bank, situated in the Atlantic, 57°N., separated from the British Isles by depths exceeding 1,000 metres over a width of several hundred kilometres, but located less than 400 kilometres away from the Outer Hebrides and less than 300 from St. Kilda. This bank is covered by less than 200 metres of water over a very wide area, and from it emerges a steep rock that is almost unapproachable, and is only suitable for a lighthouse-type building (which has never been built). The United Kingdom is said to claim sovereignty over this rock (this must be verified by jurists) and in this case the Rockall Bank would be likened to an island shelf. To the north-east of the Rockall Bank there exists another bank (see Hill, Chart of the North East Atlantic cited earlier), separated from the former by depths of 700 to 800 metres, whose slopes do not seem to be very steep, and this bank too extends over a wide area at less than 500 metres depth. The question is to know how far the bank to the north-east of Rockall can be considered "adjacent to the coast" if the Rockall Bank is admitted to be an island shelf; and if Rockall does not have the status of an island, could its bank be considered to be adjacent to the British Isles from its proximity to it, in spite of the depths that separate it? The same question can be raised for the Rosemary Bank, 59°N (north-west of the Scottish coast). There again the problem is not of a nature to be discussed here and solved, but mention of their existence is made for the reference of jurists, and some topographical and bathymetrical elements are provided for their guidance. Comparison in this case should be made with the southern California borderland, where similar ridges exist.

49. As regards the ridges traversing oceanic basins, a good example is that of the Iceland-Faeroe Ridge, knowledge of which has recently been improved (Dietrich, *Ueberströmung des Island - Färöer Ruckens in Bodennähe ... Deutsche Hydrographische Zeitschrift*, Vol. 9, 1956, pp. 78-89). This ridge, of a length of about 300 kilometres, is covered throughout by less than 500 metres of water, and in certain parts over the Rosengarton Bank by less than 300 metres. The ridge is, however, separated by a marked slope from the island shelves of Iceland and of the Faeroes, which do not descend below 200 metres. The question therefore is to know whether they are not to be considered as an extension of those two shelves, and this would be a reasonable conclusion if the rule 2 b proposed earlier for defining the limits of the continental shelf is adopted. If the ridge is considered to be an extension of the shelf, it would mean that the criterion based on the break in the slope is to be abandoned when dealing with these island shelves. This leads to a new difficulty, that of stepped continental fringes: should the limit be at the edge of the first step, or the second? If the second lies below 600 metres, it would be natural to leave it out, and this has been done for the coast of Saudi-Arabia on the Red Sea (see section II); but in the case of the Iceland-Faeroe Ridge, one may well hesitate because the depth is less.

50. In conclusion, the problems which the jurists will be facing will often be very complicated and very difficult to solve because a great variety of particular cases will be encountered. Nature does not lend itself — in fact, it is very far from lending itself — to classification and to definition of strict borderlines as desired by man, and that is why some of the questions raised in this paper have been left open.

51. The report has summarized what is now known about the continental shelf, but it should be emphasized that this knowledge is very incomplete. Despite extensive recent investigation of the sea floor, the need for unrestricted research along biological, geological, geophysical and hydrographic lines is very acute. The answers to the foregoing problems as well as the intelligent utilization of the resources of the shelf are dependent on free investigations with as much international co-operation as possible.

ADDENDUM

52. Professor V. Zenkovitch, of the Institute of Oceanology, Academy of Sciences of the USSR, who was unable to take part in the discussions held between the experts during the preparation of the paper, later submitted comments on the paper; these comments are reproduced in this addendum. His comments were

circulated to the authors of the paper, who submitted counter-comments, the substance of which is also set forth below.

Comments by Professor V. Zenkovitch

53. It seems that the method of defining the limits of the continental shelf proposed in paragraph 27, No. 2, is not suitable. There exist shelves which descend abruptly from the coast down to depths from 150 to 200 metres and then extend in a broad flat platform. Shelves of this nature are known in the Barents Sea and the Sea of Okhotsk. If they were to be defined according to the proposed method these platforms at depths of between 200 and 400 metres would be excluded. In such complicated cases as these (where the borders of the shelf do not have a clear profile curve), it would no doubt be better to define the border by means of conventional isobaths of 100 to 200 metres.

54. Furthermore, in order to solve the question of irregularities of other sea bottoms (troughs, isolated rises, depressions, including canyons), that would necessitate inclusion in the area of the shelf, the jurists would have to know to what extent such irregularities are frequent, and what are their average and maximum dimensions. It seems that the absence of such information is a shortcoming of the presented document, and that the specialists should be able to provide the necessary data within a relatively short time.

Substance of counter-comments by Professor André Guilcher, Professor P. H. Kuenen and Dr. F. P. Shepard

55. Professor Guilcher considers that the transmission of Professor Zenkovitch's comments to the United Nations should serve to fill gaps remaining in the report, at least partly, particularly in the case of the first comment. With regard to the second, Professor Guilcher's opinion is that sufficient explanations are given in paragraphs 31 to 35 of the report.

56. Professor Kuenen writes as follows:

" Professor Zenkovitch has drawn attention to an important point in our UNESCO shelf report, concerning the definition in paragraph 27.

It seems to me that the deep platforms he mentions will not give trouble in cases falling under 2*a*. For if there is a clearly marked outer edge then this edge will be adopted as the outer margin. But if the outer edge of such a deep shelf is ill defined case 2*b* arises and Professor Zenkovitch is right that in such a case the definition would exclude this shelf, which in my opinion is clearly not the intention of our report. Perhaps one could add after ' — 800 metres ' in the first sentence of case 2 *b* : ' but leaving out of account the slope from the platform to the adjoining coast and thus only considering the outer margin of the shelf '.

I have no charts on which to judge this problem, but I hope this addition would largely satisfy Professor Zenkovitch's objections, without upsetting the plan of the report."

57. Dr. Shepard's views are that, with regard to the first comment, the cases 2 *a* and 2 *b* dealt with in the proposed method of defining the shelf edge amply cover the case of double break in slope to which Professor Zenkovitch draws attention. Dr. Shepard further points out that the situation of a shelf with depths between 200 and 400 metres has been given due consideration in the report.

58. With regard to the second comment, the opinion is given that the details suggested for inclusion in the report by Professor Zenkovitch would be extremely difficult to give, and if they were provided in full, they would prove to be too voluminous to be convenient for reference by the participants in the International Conference.