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Delimitatin of the Seaward Extent of United States Jurisdiction over the Mineral Resources of its Continental Shelf

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Delimitation of the Seaward Extent of United States Jurisdiction over the Mineral Resources of its Continental Shelf

by

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Abstract

This thesis provides a seaward delimitation of United States jurisdiction over the mineral resources of its continental shelf. It does not set lateral maritime boundaries between the United States and its neighbors. Despite the abundance of literature regarding the continental shelf concept, United States shelf limits have not been demarcated in any precise detail. In order to encourage efficient utilization of offshore mineral resources and to avoid unnecessary legal problems, such determination is important.

Initially, the conflicting conceptions of the geological and legal continental shelf are discussed. The evolution of the continental shelf as both a physical feature of the earth's crust and a legal-political doctrine is traced through the first three chapters. This development culminates in the most recent embodiment of the principle in conventional and customary international law, as seen in the new convention on the law of the sea.

The fourth chapter examines the current definition of the continental shelf in detail, suggesting amendments and revisions where found necessary. The formulae provided by the definition are then applied to the United States continental margin. Based on these calculations, maps are constructed displaying the various criteria. Comparative analysis of the lines allows demarcation of preferred shelf limits. The implications of these limits upon current assessments of offshore mineral resources are discussed in the final chapter.

Original maps show the limits to shelf jurisdiction around the continental United States, Hawaii, and Alaska. The extent to which jurisdiction embraces the mineral resources of the seabed and subsoil is also demonstrated. The sources for these illustrations are included in the appendix.

Results of the investigation indicate that the internationally-accepted definition of the continental shelf would grant a vast area of seabed and subsoil to United States jurisdiction. Additionally, a substantial portion of estimated offshore mineral resources is encompassed by the seaward limits. Exceptions to this are noted herein. With this information in hand, marine mineral interests may be spurred to explore the potential of continental shelf resources.

Acknowledgments

I thank all those folks who have shared with me their energies and talents throughout this effort. The generous response evoked by my curiosity has made this a remarkable experience. I warmly thank Dr. Lewis Alexander for his humor, tolerance, and guiding wisdom which still serve to both sustain and challenge me. I am very grateful to Dr. Lawrence Juda and Dr. Robert McMaster for their support, advice, and critical review of the manuscript. Dr. David Warren is very much appreciated for enhancing the enjoyable and educational atmosphere of my oral defense. Thanks to the easy nature and typing skills of Clarice Coleman, the preparation of this opus flowed smoothly.

Finally, because I shared my wretchedness at times with a heartful of dear friends, I now share my joy with them... and thank them for sharing both.

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INTRODUCTION

> The institution of the continental shelf has arisen out of the recognition of a physical fact; and the link between this fact and the law, without which that institution would never have existed, remains an important element for the application of its legal regime.[1]

In its 1969 judgment of the North Sea Continental Shelf Cases, the International Court of Justice recognized this link between the physical and legal concepts of the continental shelf. Throughout its evolution, however, the institution of the continental shelf has been so twisted and tangled that this essential link has been broken time and again. As members of the international community have grown to realize the potential benefits to be derived from recovering offshore resources, each has defined the edges of its submerged land mass to suit its own needs. Thus, in the course of the legislative history of the shelf, these politically-derived conceptions have strayed from physical reality. The most recent embodiment of the continental shelf principle into an international law of the sea finally reunites this fact and the law.

On April 30, 1982, the Third United Nations Conference on the Law of the Sea culminated in agreement by a majority of the attendant nations on a set of rules to govern ocean activities. The United States, an active participant in negotiations since the initial gathering in 1968, chose not to accept the final form of the draft treaty. It can be reasonably assumed, however, that the tenets of maritime jurisdiction which have been shaped throughout the past 15 years will remain as customary international law regardless of the achievement of a global treaty. For the purposes of this study, United States jurisdiction over the mineral resources of its continental shelf is described by Article 76 of the draft convention.

The second assumption upon which this thesis is based is the national objective of resource optimization. As society becomes increasingly industrialized and economic activity quickens its pace, demand for the earth's resources soars. Threatening the delicate balance of resource demand and supply - and indeed prompted by it - are the national security considerations held by each state seeking to ensure an adequate resource base without dependence on foreign sources. The United States is no exception. In order to foster such a goal, government must provide a political climate in which the security of private investment can be assured. Ascertained limits to national jurisdiction in areas of resource potential provide a part of such assurance. Thus, in order for the United States to fully and efficiently utilize the wealth of seabed and subsoil resources of its continental margin, clear and fixed boundaries must be established. Development will then be encouraged.

Resource exploration and exploitation depend upon a number of variables, including geologic occurrence, technological expertise, economic conditions, and legal-political considerations. This thesis addresses only the legal and geological aspects of the continental shelf and its resources. Knowledge of the geology, understanding of the law, and assessment of the resources of the continental shelf will provide a sound framework from which government and private industry can approach development of shelf resources. The dynamic forces of economics and technological advances will then determine the growth of the marine mining industry.

CHAPTER I

The Physical Shelf

Plate Boundaries and Continental Margins

The earth's surface is segmented into 12 major and a number of smaller rigid plates in relative motion with respect to one another. The boundaries among these plates can be classified as divergent, convergent, and transform types, dependent upon the direction of motion between these plates. At a divergent boundary, continental lithosphere separates, and accretion of oceanic lithosphere occurs in the void created by the diverging plates. Convergent boundaries display consumption of lithosphere as it is subducted beneath an overriding plate.[2] A transform plate boundary system is characterized by horizontal motion between two plates along a lateral fault zone without significant accretion or consumption of crust.[3]

The tectonic evolution of these plate boundary systems governs the nature of continental margins. Passive margins result from the drifting of lithosphere away from divergent plate boundaries. Active margins may form along convergent and transform types of plate boundaries.[4] (Figure 1)

One objective of recent studies of plate boundary systems and continental margins has been the identification of a contact between thick, low density continental and thin, high density oceanic crust.[5] It is known that the transition from continental to

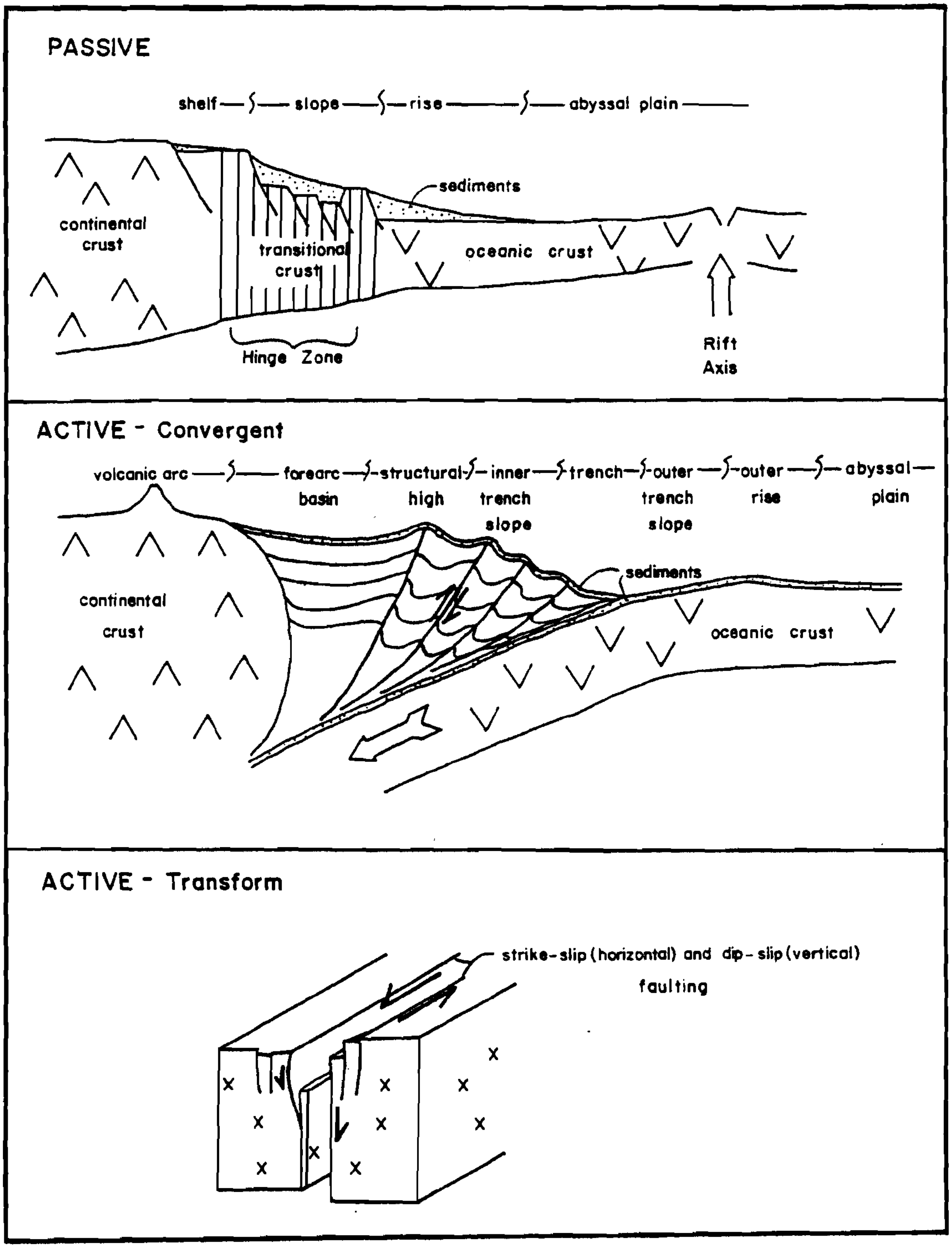

Figure I: Plate Boundaries and Continental Margins oceanic crust across a passive margin occurs within a single plate,[6] while the plate boundary along an active margin approximates the continent - ocean basin juncture.[7] However, a precise and clear delimitation between the two types of crust on either passive or active margins has been unattainable. Instead, a band of transitional crust,[8] corresponding to the characteristics of neither continental nor oceanic crust, has been identified between the continent and ocean basin. Along both passive and active margins, this belt of transitional crust represents the most definitive contact between continental and oceanic crust which can be established today.

Passive Margins

The early stages of rifting at a divergent plate boundary are marked by faulting and volcanism as the plates rupture and spread apart. The newly-formed oceanic crust is bounded by uplifted "hinge zones" encompassing the transition to highstanding continental crust. As these continental margins drift away from the rift axis, they cool and subside, becoming less tectonically active.[9]

Geophysical studies of the subsurface structure of passive margins have revealed a magnetically anomalous zone centering roughly on the continental slope.[10] Identified as transitional crust, this band is taken to represent the rift-stage "hinge zone" of complex faulted structures, volcanic flows, and sediments. This zone of continent-ocean basin contact is as wide as 75 kilometers across the Carolina margin.[11] Examination of the Arctic Alaskan margin has not yet clearly indicated a similar band, although the Chukchi

Continental Borderland, over 300 miles offshore, is inferred to contain fragments of continental crust.[12]

Subsequent evolution of this passive margin is directed by subsidence, sedimentation, ocean circulation, and climate.[13] Subsidence allows the developing margin to construct a sediment wedge upward and outward from the continental block.[13] In contrast, sea level lowstands lead to more active periods of sediment slumping and sliding and submarine canyon cutting[14] on the margin slope. This often results in marked regression of the margin. Hence, a thick sediment section typically covers the transition zone of crustal rocks so that morphological boundaries often differ in position from those of deeper geology.

The morphological divisions of a passive continental margin comprise the shelf, slope, and rise and surficially express the transition from light continental to dense oceanic crust. The uppermost province, the shelf, is a shallow, gently sloping (1:1000; 0°07') surface of low local relief which extends from the upland coastal plain to a relatively sharp break, termed the shelf edge or shelf break.[15] Most of the continental shelf is, in fact, the submerged extension of the coastal plain, and so is part of the continental mass itself, leaving only the outermost part in the zone of the passive continental margin.[16] Ranging in width from a few to more than a thousand kilometers --- as in the Arctic Ocean and Bering Sea off Alaska -- shelves presently constitute 7.6 percent of the total ocean floor.[17] Water depths at the shelf edge range from a few to more than 550 meters and average at 133 meters.[18]

The sharp increase in gradient (1:40; 3°-6°) terminating the shelf marks the advent of the continental slope,[19] "...by far the steepest, longest, and highest topographic feature on the earth's surface."[20] The base of the slope commonly lies at 1500-3000 meter depths.

At the base of the continental slope, in some areas, is a smooth, gently-graded apron of sediments merging into the deep seafloor. Gradients range from 1:100 to 1:700, as high as 1:50 shelfward and as low as 1:1000 seaward, and depths have been measured from 2000 to more than 5000 meters.[21] This province may extend as far as 1000 kilometers seaward before gradients decrease to less than 1:1000[22] on the abyssal plain.

Active Margins

At a convergent plate boundary the crustal rock of one plate descends beneath the crustal rock of another plate. The convergent zone is marked by a deep-sea trench. The trench may exhibit well-developed sequences of sedimentary deposits derived from the adjacent continent and moved downslope by slumping, sliding, and turbidity currents. For example, the turbidite deposits in the Washington Oregon Trench extend beyond the seaward limits of the structural trench, resembling the prograded configuration of a passive margin. Thinner deposits of the eastern Aleutian Trench preserve a flat-floored trench. In contrast, the Kuril-Kamchatka Trench fringing the northwestern Pacific margin lacks a thick sedimentary fill because midslope basins trapped turbidite flow.[23]

In the trench, pelagic sediments resting upon the landward-moving plate are covered by land-derived deposits. As the plate interacts with another plate, these trench deposits are either carried down beneath the overthrusting plate or accreted against the overthrusting plate. Furthermore, on some active margins lacking trench deposits, tectonic erosion is believed to break off rock from the overthrusting plate and drag this material down with the descending plate. This may cause landward retreat of the trench. Conversely, tectonic accretion may build out the active margin seaward by adding offscraped sediments from the descending plate to the overriding crust.[24]

The geomorphology of active margins can be summed up in one important feature: the trench. Landward of this site are typically a steep inner trench slope, structural high, forearc basin, and volcanic arc. Seaward are found an outer trench slope, outer rise, and abyssal plain.[25] The trench slope may plunge to depths as great as 8000 meters as in the western Aleutian Trench, or lie as shallow as 3000 meters as in the sediment-filled Washington-Oregon Trench. It is notable for this study that the subduction margins edging the northwestern United States and southern Alaska reach abyssal depths within 200 miles from shore.

Despite the simple diagrammatic cross-sections depicting continental-oceanic crust abuttal at the trench,[26] the kneading of sediments and rocks at subduction zones precludes delimitation of such a crustal transition. Additionally, most of the research has focused on learning tectonic processes rather than unscrambling the continent-ocean basin juncture at these complex margins.

Further, along a plate boundary, the two interacting plates may slide past one another horizontally. The boundary between the plates may be defined by a simple fault scarp, such as the Queen Charlotte Islands Fault stretching from British Columbia to the eastern Aleutian Trench,[27] or a series of faults, as exemplified by the transform margin off southern California[28] where the irregular topography of the borderland[29] reveals its faulted structure. These two transform margins resemble convergent margin in their configuration: narrow shelf, steep slope, and trench. The trenches are not sites of current subduction, but rather sediment-buried troughs.

Along these complex belts of deformation, slivers of the interacting plates are displaced along the juncture. This serves to obscure the location of the continental-oceanic crust interface, which is perceived as a zone of faults rather than a simple break.[30]

Additional Continental Margin Features

As an enhancement to the simple profile of passive and active margins presented herein, certain additional features commonly edging the continents may be examined. In some places, as off the southern California coast, a continental borderland overlies continental crust and is described by a very irregular topography of ridges, banks, basins, and islands. A marginal plateau, as exemplified by the Blake Plateau off the southeast United States Atlantic coast and the Chukchi Shelf off northwest Alaska, overlies continental crust for the most part and has undergone greater rates of subsidence and nondeposition than the inner part of the shelf. Epicontinental seas are ponded on continental shelves and enclosed either by shallow banks of the shelf or by land. The Gulf of Maine, Gulf of St. Lawrence, and channels of the Bahamas belong to this class. A marginal sea or basin lies at the foot of the slope, and although slightly shallower than ocean basins, an abyssal plain generally occupies part of its floor. The Gulf of Mexico and Bering Sea are examples of this feature.

CHAPTER II

The Legal Shelf

Legislative and Political Evolution of the Continental Shelf

"Because of the uncertainty and variation in the physical description of the shelf, the legal definition has developed somewhat apart from geologic reality."[31] Historically, the concerns of navigation, defense, and commerce in the coastal zones adjacent to nations have superceded any interest in the seabed and subsoil of these areas. The early Roman concept of mare liberum lost popular support during the Middle Ages as "each nation asserted such claims as seen warranted in its own eyes."[32] Late Renaissance reversion to the doctrine of freedom of the high seas later was sustained by embryonic American foreign policy. It was tempered, however, by the late 18th century adoption of the "cannon-shot rule," America's first official claim to a three-mile territorial limit.[33]

Interest in the submerged land mass developed with the growing realization of its potential wealth in natural resources. The economic and technologic feasibility of hydrocarbon and mineral extraction enhanced the already profitable and often essential, fishing industry offshore. This awakening prompted the first attempt to embody a set of principles for a law of the sea at the 1930 Hague Conference. Dealing with both maritime and non-maritime issues, this initial effort adopted no formal agreement, but rather only recommendations and resolutions.[34] In 1942, the bilateral

Anglo-Venezuelan Treaty restricted claims by either party on appropriation of mineral resources across a mutually determined dividing line between British Trinidad and mainland Venezuela. This agreement had no effect on the sovereignty of other nations nor upon the status of superjacent waters.[35]

The Truman Proclamation. The continental shelf most significantly entered the international political arena on September 28, 1945 when President Truman proclaimed the "natural resources of the subsoil and seabed of the continental shelf beneath the high seas but contiguous to the coasts of the United States as appertaining to the United States, subject to its jurisdiction and control." He attributed this bold claim to the "long-range world-wide need for new sources of petroleum and other minerals...and the conservation and prudent utilization" of these resources.[36]

Political concern regarding the continental shelf originally had sprung from United States-Japan discord over fisheries in the Bristol Bay area a decade earlier. During the period from 1936 to 1938, Japanese fishermen caught salmon en route to spawning grounds through these shallow shelf waters. Anxiety within the United States over the possible depletion of salmon fisheries led to a settlement with the Japanese temporarily banning their fishermen from taking this species. With this issue settled, attention turned to property rights to the seabed and subsoil as requests from private interests to explore and exploit offshore multiplied. A 1943 memorandum from the Department of Interior's General Land Office to Interior Secretary Harold Ickes, noting the domestic need for natural resources and promise of the continental shelf, ultimately prompted Presidential action.[37]

A White House Press Release, accompanying the Truman declaration, explained the President's continental shelf as: "generally submerged land which is contiguous to the continent and which is covered by no more than 100 fathoms 182.9 meters of water." It seems that the continental shelf here is intended in the geological sense as an "extension of the land mass...naturally" belonging to the coastal nation. The depth criterion serves to enhance the geological definition of the shelf rather than geographically limit it.

Directly upon the heels of the Truman Proclamation followed a succession of unilateral claims of comparable or expanded scope. Chile and Peru reacted in 1947 by asserting offshore jurisdiction to a 200 mile band. Costa Rica, El Salvador, Honduras, South Korea, and Saudi Arabia followed suit shortly thereafter. Early claims by Mexico, Ecuador, and Nicaragua mimicked the depth criterion chosen by the United States, but later aligned with the fixed distance declarations of these other geologically narrow-shelf nations. Still other countries, such as Argentina and Australia, claimed simply the "continental shelf," while Israel applied a flexible criterion of "exploitability of submarine areas" adjacent to the territorial sea.[38]

The United States filed formal protests against those claims of Mexico, Argentina, Chile, and Peru because they asserted sovereignty over resources other than minerals, as well as overlying waters. Although the United States challenge evoked no accommodating response from these nations, it remained in opposition to sovereign claims beyond three miles.[39] Furthermore, the frequency with which these claims were made and the relative acquiescence with which they were accepted by other states had the cumulative effect of establishing a rule of customary international law, even though no international accord had been reached on the subject.

The Outer Continental Shelf Lands Act. In 1953, the first federal legislation authorizing the leasing of United States offshore lands was enacted. The Outer Continental Shelf Lands Act[40] was adopted as a companion measure to the Submerged Lands Act[41] which vested ownership of navigable waters within three geographical miles of the coastline in the various states. The outer continental shelf includes "all submerged lands lying seaward and outside of the area of lands beneath navigable waters granted to the various states , and of which the seabed and subsoil appertain to the United States and are subject to its jurisdiction and control."[42] As such the Act does not indicate a precise outer boundary to the submerged lands of the United States, but rather merely serves as a legislative implementation of the 1945 Truman Proclamation.[43] The Act also reaffirms the role of the Secretary of Interior as administrator of leasing procedures as originally designated by President Truman in 1945.[44]

The International Law Commission. The national claims to continental shelf jurisdiction following the Truman Proclamation were unilateral and divergent in nature, creating an atmosphere of confusion which the United Nations attempted to dispel through the formation of the International Law Commission (ILC). Established under a General Assembly resolution in 1947 and charged with the task of "codification and development of international law," the ILC in 1950 dealt with the regimes of the Territorial Sea and the High Seas, incorporating the concept of the continental shelf within the latter.[45]

At its third session in 1951, the ILC offered in specific language a proposed treaty on the continental shelf, defining it as:

> the seabed and subsoil of the submarine areas contiguous to the coast, but outside the area of territorial waters, where the depth of the superjacent waters admits of the exploitation of the natural resources of the seabed and subsoil.[46]

Criticism of this vague definition stemmed from the fear that coastal nations would claim title to lands far beyond the geologic shelf or slope. At its fifth session in 1953, the ILC replaced this depth-of-exploitability criterion with a 200 meter depth limit.[47] This change was not meant to abolish rights beyond the 200 meter depth, but rather to indicate that there was no urgency about a provision for exploitation beyond that depth and to provide a practicable formula capable of ready application.[48]

When 20 members of the Organization of American States gathered at the Inter-American Specialized Conference on "Conservation of Natural Resources: Continental Shelf and Marine Waters" at Ciudad Trujillo, Dominican Republic March 15-28, 1956, they found this definition unacceptable. Instead, they, including a United States representative, embraced the "continental shelf, continental and insular terrace, or other submarine areas, adjacent to the coastal state" as an integral, although submerged, part of the continent. The continental terrace, a new term in the legal continental shelf encyclopaedia, comprised the "shelf to the point of declivity...and slope...to the greatest depths."[49]

The members at the Conference recognized the lack of uniformity worldwide in depth, width, and geologic character and composition of the shelf and therefore supported the ILC's 1951 exploitability formula beyond the 200 meter isobath. Interestingly, the American states noted that "the utilization of the resources of the shelf cannot be technically limited." Upon this justification, they extended the limits to resources of the shelf to embrace the terrace (shelf and slope) simply because the "technical utilization" of the resources was unlimited. An "adjacency" factor had replaced that of "contiguity," perhaps in an effort to provide some degree of leeway by substituting "close to" for "adjoining or touching."[50] This definition, the jurists believed, would solve the unequal distribution problem[51] created by the widely varying continental margins of broad- and narrow-shelf states; instead, it served to revive the controversy as to whether there is a technological limit to the exploitation of seabed resources.

Shortly after the close of the Ciudad Trujillo Conference in 1956, the final report from the eighth session of the ILC emerged, reiterating this marriage of depth and exploitability criteria. Dr. F. V. Garcia-Amador of Cuba, who represented his country at Ciudad Trujillo, chaired this final session. Although he managed to retain the language permitting coastal state rights regardless of the existence of a physical continental shelf off its coast, he did let pass the omission of the term "continental terrace" because he was assured that the depth-of-exploitability would bring that area within the general concept.[52] This concluding session also recommeded that an international conference on the law of the sea be convoked by the United Nations. Thus the ILC developed a legal basis for a continental shelf doctrine and supplied the background, framework, and stimulation for the 1958 undertaking at Geneva.[53]

The Geneva Conference on the Law of the Sea. "There is little doubt but that the work of the ILC and the 1958 Geneva Conference represents the greatest advance in the development and codification of the international law of the sea since the 1930 Hague Conference."[54] However, this advance has effected an "existing definition of the outer limit of the continental shelf which possesses so many elastic clauses and phrases as to constitute a meaningless definition of a 'limit'."[55] The Convention on the Continental Shelf is one of four to come out of the Geneva Conference of diplomats, attorneys, and scientists, and it closely parallels the draft articles prepared by the ILC.

Article 1 of the Geneva Convention on the Continental Shelf reflects Article 67 of the ILC's final recommendations:

> For the purpose of these articles, the term 'continental shelf' is used as referring to the seabed and subsoil of the submarine areas adjacent to the coast but outside the area of the territorial sea, to a depth of 200 meters, or, beyond that limit, to where the depth of the superjacent waters admits of the exploitation of the natural resources of the said areas.[56]

Upon an April, 1957 request by the United Nations, a group of geologists, geographers, and fishery experts sponsored by the U.N. Economic and Social Council described the "Scientific Considerations Relating to the Continental Shelf"[57] in September, 1957 in preparation for the Conference. This report supplied definitions of geological terms,[58] pointed out the error in accepting 200 meters as an average depth to the shelf edge, and proposed methods by which to define the boundary of the shelf.[59] With the aim of keeping to the morphological criteria and steering away from that of exploitability, these experts presented a selection of such unworkable definitions as to drive the framers of the Convention back to the simpler, however unstable, depth-plus-exploitability configuration.

Various proposals were advanced in Committee IV deliberating the continental shelf regime, applying measures such as: 550 meter depth, but not greater than 100 miles from the outer limit of the territorial sea; 550 meter depth only; 200 meter depth only; shelf edge or 200 meter depth; shelf edge or 550 meter depth; and depth-of-exploitability only.[60] In addition, such criteria as geologic structure, type of aquatic inhabitants, and geographic delimitation methods were offered for consideration.[61] The need for certainty in any legal concept was answered by the choice of the fixed 200 meter isobath for the average depth of the shelf edge. The need for flexibility in any political concept was answered by the exploitability provision allowing technological development to expand jurisdictional holdings. The need for a natural boundary for this physical feature was left unanswered.

These tactical solutions have generated exhaustive dialogue as to the proper construction of the Convention on the Continental Shelf which may be examined in retrospect. Critics of the 200 meter depth for the shelf break selection note that this change in gradient typically occurs at 133 meters and varies from a few to more than 550 meters. Consequently, the 200 meter depth chosen has no logical basis[62] in the geomorphic conditions of the continental margin. Additionally, the topography of the margin often exhibits several submarine canyons, trenches, or troughs deeper than 200 meters roughly parallelling the coast. Inquiries have been voiced as to whether these interruptions should be considered part of the shelf in which they are embedded.[63] This situation is illustrated by the Forty-Mile Bank off southern California, where a 1340 meter trough separates this shallow area from the mainland.

It seems clear that application of the adjacency criterion will not exclude such shallow submarine areas as evidenced by 1961 leasing permits issued on Forty-Mile Bank.[64] More ambiguous, however, are the status of the extensive shelf off Alaska where the 200 meter isobath lies several hundred miles offshore and the fate of borderlands and plateaus shallower than 200 meters which geomorphically appertain to the shelf. In addition, it is argued that processes of erosion and deposition continually alter the position of the shelf edge, in turn relocating the 200 meter isobath and thus the legal boundary line. Finally, for those nations lacking the technical capability to reach beyond 200 meters, this sole criterion will grant large expanses of jurisdiction to some countries, while very little will accrue to others.[65] Again, this is due to world-wide discrepancies in shelf breadth and depth.

The open-ended exploitability clause is bewildering as a boundary definition, and, in boosting coastal state expectations, renders the 200 meter isobath meaningless as a limit. In the ratification hearings before the United States Senate Foreign Relations Committee in 1960, Ambassador Arthur Dean, who had led the United States delegation at Geneva, spoke on behalf of the State Department: "The Continental Shelf is presumed to be exploitable at a depth of 200 meters beneath the surface of the sea, and may be exploited beyond that depth where technological developments can be shown to make such exploitation possible."[66] (emphasis added) An examination of United States practice reveals a rather liberal interpretation of this limit.

Besides the phosphorite leases on Forty-Mile Bank, the Department of Interior issued oil and gas leases in 1963-1968 in water depths to 457 meters and published leasing maps for depths as great as 1828 meters. In 1967, Humble Oil and Refining Company secured a permit to drill 21 coreholes beneath the Atlantic Ocean "on the continental slope" in depths to 1523 meters, as far as 300 miles from the coast. Similarly, at least two dozen other nations had granted offshore concessions in waters deeper than 200 meters. Despite these claims to great depths and breadths of the continental margin, as of 1969 the maximum water depth in which American commercial production of petroleum had been established was 104 meters.[67] Other commercially recoverable resources were being extracted at considerably lesser depths.[68] Under the auspices of the Joint Oceanographic Institutions for Deep Earth Sampling (JOIDES), as of 1969, a total of 39 exploratory holes had been drilled of which 17 were in water depths of 4572-5486 meters. Does evidence of exploration constitute a "showing" of exploitative knowhow? Is jurisdiction established by virtue of any activity, or is a distinction to be drawn between exploration and exploitation? Although left to speculation, the treaty's inclusion of the phrase "admits of" in the present tense seems to have created a trust in technological capability preserved for future coastal state jurisdiction.

Many coastal states fretted over losing access to their continental shelf resources.[69] It seems that the intent of the drafters of the Convention was to extend jurisdiction to where the "state of the art" - that is, the world's most advanced technology - could reach, even if that technology is not the result of a given coastal state's national effort and achievement.[70] Perceived as such, a coastal state's juridical shelf is protected from the activities of nationals of any other state because the admittance of exploitation assigns that area to the adjacent coastal state.[71]

Finally, in applying the exploitability criterion, there is an absence of a seaward limit to national jurisdiction, except for the indefinite boundary of adjacency. Although the position that the adjacency criterion places no restraint upon the seaward march of exploitation to mid-ocean has been generally discredited, the progress of that march shows that adjacency is not a stringent restriction. As the legal shelf deepens, the incidence of non-contiguous shelf areas such as seamounts are likely to appear.[72]

In speaking before the Senate Subcommittee on Ocean Space in 1969, Malcolm Wilkey, general counsel for Kennecott Copper, remarked:

> It was recognized referring to the ILC and Ciudad Trujillo meeting that what was to be legally defined was not the geologic continental shelf, because this would be inequitable to many states. The object was to define legally an area, with reference to this geologic continental shelf, which would represent a delimiting of the area subject to national sovereignty over the mineral resources of the seabed and subsoil, and by such definition create areas which were roughly equitable for the coastal states of the world.[73]

If this was the legislative intent of those who formulated Article 1, one may rightly question the achievement of their goal. The 200 meter yardstick inaccurately bounds the shelf, inequitably distributing shelf resources; and the inevitable instability of the exploitability formula threatens to remove that outer limit altogether. Essentially, no agreement on a permanent outer boundary was reached through the adoption of Article 1 of the Geneva Convention on the Continental Shelf.[74]

United Nations Unrest. Even by the time of the Convention's ratification by 39 states in 1964, considerable pressure had grown to replace its inherent uncertainties with a precise boundary formula. In 1966, United States initiatives in the U.N. General Assembly resulted in the adoption of a Resolution on Resources of the Sea requesting a survey of the present state of knowledge of and techniques for exploiting the resources of the seas. The Secretary General responded, inter alia, that there existed an urgent need to redefine the continental shelf "which as presently defined is so imprecise as to leave virtually open the important question of where the exclusive rights of riparian countries cease to apply."[75]

At its 22nd session, in 1967, the General Assembly, prompted by a Malatese proposal in August, decided by a 99-0 December vote to establish an ad hoc Committee to Study the Peaceful Uses of the Seabed and Ocean Floor Beyond the Limits of National Jurisdiction.[76] Its represenstatives from 35 nations met throughout 1968 and submitted a final report to the 23rd (1968) session. The Committee viewed its functions as gathering information, clarifying issues, and defining international goals and upon completion presented just that to the General Assembly. The Committee did not design a legal regime for the seabed, but rather suggested that a set of principles --

including a deep ocean floor boundary -- needed further consideration by the international community.[77]

In December of 1968, the General Assembly reactivated this framework of responsibility by forming a permanent Committee on the Peaceful Uses of the Sea-Bed and the Ocean Floor Beyond the Limits of National Jurisdiction. Its mandate was more exacting than that of the ad hoc Committee in requesting the formulation of administrative machinery that should be established for the development of natural resources beyond the limits of national jurisdiction as well as the extent of those limits.[78] These preliminary investigations culminated in the December 1969 resolution requesting the Secretary-General to determine "the desirability of convening at an early date a conference on the law of the sea."[79] Despite vehement opposition by the United States and the Soviet Union and their usual supporting blocs, the measure was passed. Thus the sentiment for a broad-scale conference to achieve international consensus prevailed over uniform, unilateral declarations. The December 17, 1970 Declaration of Principles to convoke a Third Conference on the Law of the Sea "to create an international oceans regime compatible with a changing international order"[80] ensued.

Judicial Affirmation of a Customary Continental Shelf Concept

Elsewhere in the international arena, a 1969 World Court opinion involving the lateral boundaries on the continental shelf between West Germany and the Netherlands and West Germany and Denmark influenced the popular perception of the continental shelf. As held in the North Sea Continental Shelf Cases, the elastic definition of the shelf as contained in the 1958 Convention is separate and distinct from the continental shelf doctrine entrenched in customary international law. The latter is founded in the "natural prolongation of the land territory," borne out of the 1945 Truman Proclamation.[81] The rationale for the natural prolongation concept, without particularizing the extent of this prolongation, at least indicates that the coastal state holds sovereign rights over the resources of its submerged land area by virtue of that area forming a part of the underwater prolongation of such land's territory.[82] Although the International Court of Justice (ICJ) decision further complicates an already complicated situation, it does serve to bring the continental shelf notion back to its "purely geological, geographical, and oceanographical origin."[83]

In its most recent, February 24, 1982, decision on delimitation of continental shelf boundaries between states, the ICJ did not rely upon the precedent of "natural prolongation" to determine title to shelf area. As between the states of Tunisia and Libya, the court held that lateral boundaries be shaped by such factors as historical use and coastline configuration. The jurists described the Tunisia-Libya continental shelf as a single geomorphological feature -- a submerged prolongation of the continent as a whole rather than preferentially of one state's land territory. As held in the North Sea Cases, principles of equity should apply in this lateral boundary dispute according to the Court.[84] It should be noted, however, that no seaward delimitation controversy has come before the Court. However, the opinion held by the Justices in these lateral boundary issues serves to enhance the evolution of the shelf concept.

United States Views

In the United States, the passage in 1966 of the Marine Resources and Engineering Development Act expressed a national purpose to stimulate marine exploration, technology, and financial investment in the resources of the oceans. Two complementary bodies were established: The National Council on Marine Resources and Engineering Development, comprising Cabinet members and marine agency directors advisory to the President; and the Commission on Marine Science, Engineering, and Resources, representing diverse interests from government, industry, and academia placed in a developmental and planning role to guide the nation's marine commitment. The Commission in 1967 appointed seven panels, of which Panel VI dealt with international issues. The 1969 report of the Commission, entitled Our Nation and the Sea,[85] ventures specific recommendations emerging from Panel VI for redefining the continental shelf.

In suggesting that the United States seek to change the existing framework, the International Panel noted that: "private enterprise will be deterred from exploring and exploiting the mineral resources of the seabed and subsoil...unless it is assured of exclusive access to such resources in a large enough area for a long enough time to make the activity profitable."[86] This security was not guaranteed in the Geneva Convention's definition, as perceived by the National Petroleum Council (NPC) in 1968.[87]

This first in a series of periodic reports completed by the NPC as solicited by the Interior Department maintained that sovereign rights over the submerged land mass extend to "at least the landward portions of the geological continental rises." They felt this position to be in keeping with Article 1 of the Convention on the Continental Shelf as expounded by the 1956 Ciudad Trujillo enclosure of the terrace "to the greatest depths". They also drew support from the geomorphological onlap of rise sediments upon the lower slope, the base of which the NPC deemed the edge of the continent. The NPC urged the United States and other nations to promulgate parallel uniform declarations "stating the extent of their rights (and the limitations on those rights) under the 1958 Convention." The precise demarcation of these boundaries, extended from a base-of-slope guideline, would be best assigned to a competent international technical agency for "eventual" resolution. Meanwhile, the existing principles of international law - that is, customary "natural prolongation" to conventional "greatest depths" of exploitability - were construed as adequate by the NPC to govern activities on the seafloor "for some time to come."[90]

The Stratton Commission strongly rejected the conclusions and recommendations of the NPC. The International Panel argued that had the draftsmen of the Convention intended to incorporate the "slope" in Article 1, they would not have confined their language to "shelf" only. The Commission accused the NPC's reliance on the base of the slope as magnifying the inequity between states with broad margins and those whose shelves drop off abruptly to the abyssal plain. The NPC proposal, asserted the Commission, created a danger of encouraging narrow-shelf states to claim rights to the superjacent water column, sea surface, and air space overhead in lieu of shelf mineral riches. Finally, the NPC was scolded for its fear of the "unknown perils of international legal-political arrangements yet to be negotiated," while the Stratton Commission cautioned against the "known perils of the exercise of exclusive authority by coastal nations around the world."[91]

In light of President Johnson's warning against a "race to grab" the sea's resources[92] coupled with the renewed attention at the international level to revise the legal-political framework controlling uses of the seabed, the Stratton Commission redefined the continental shelf. This proposal hemmed in exclusive shelf jurisdiction at the 200 meter isobath, or 50 nautical miles from the baselines used for measuring the breadth of the territorial sea, whichever alternative would give the coastal state the greater area. This depth/distance pairing, it was reasoned, most closely approximated the average depth and width of the world's geomorphological shelves. In the same breath, the Commission designated an "intermediate zone," extending to a 2500 meter/100 mile pairing for the slope foot, to be managed by the coastal state for the benefit of an international authority regulating the bed of the deep seas.[93] This compromise sought to satisfy the expectations of coastal states as encouraged by the 1958 Convention, while at the same time consider the fairness and equity in treating these resources as "the legacy of all human beings."[94]

Another proposal emerged from the United States about this time, employing the 550 meter isobath or 50 miles as a boundary line. This procedure advanced by Senator Claiborne Pell, was soundly denounced by Cecil Olmstead of Texaco:

> One might ask why 550 meters or 50 miles, why not 549 meters or 51 miles?...If the natural line of demarcation provided by the geological distinction between continental mass and abyssal ocean area should be departed from, the decision as to where to

> establish the line would almost undoubtedly be an arbitrary one...in the last analysis, a political horsetrade.[95]

Lastly, in his May 23, 1970 "Statement on United States Oceans Policy," President Nixon supported the Stratton Commission's "trusteeship zone" concept embracing the undefined "continental margins" beyond a depth of 200 meters. This proposal was submitted to the August 3, 1970 meeting of the U.N. Sea-Bed Committee as a document entitled "Draft United Nations Convention on the International Seabed Area."[96] It was received with less than rave reviews, again due to coastal state refusal to renunciate their presumed rights.

These efforts succombed to the general policy of the United States, as manifested by the Department of Interior's leasing policies,[97] notwithstanding the fact that exploration is not necessarily equated with exploitation for purposes of the Convention's definition. Numerous resolutions were introduced in Congress in the late 1960's expressing opposition to the vesting of control over ocean resources in an international body.[98] The lawmakers seemed to agree with the NPC, International Law Association, American Petroleum Institute, and American Bar Association[99] that the seaward perimeter of the legal continental shelf was shaped by modern technology. This then was the nationalistic sentiment prevalent in the United States as it embarked upon the path of international negotiation at the Third United Nations Conference on the Law of the Sea (UNCLOS III).

CHAPTER III

UNCLOS III

Preparations for the Conference

The past few decades have witnessed two important trends with significant side-effects in the oceans regimes. Independence has been achieved by over 60 fledgling countries since 1958, most of these on or within the sea, but few party to the Geneva Conventions.[100] Also, sophistication of technology has reached even greater peaks than those immediately spurred by World War II in the fields of living and nonliving resource exploitation and scientific exploration. The accelerated expansion seaward of national jurisdiction touches upon the sea surface and water column, as well as the seabed and subsoil. Thus, as the problem of designing a regime for seabed minerals has become more pressing, an equitable arrangement -- taking into account the needs of developing nations -- has received considerable attention. Those involved in delimiting the natural prolongation of coastal state jurisdiction are emphasizing a balancing of the demands of coastal states with the requirements of the international community. The recent gatherings of UNCLOS III and the upshot thereof reflect the wrestling of minds with these urgent concerns.

Prompted by the Declaration of Principles regarding the deep seabed adopted by the General Assembly in 1970, UNCLOS III commenced in New York in 1973. This organizational session constructed the scaffolding, modelled after the U.N. Sea-Bed Committee which had been carrying on preparations for the Conference since 1970. Topics were allocated to three subcommittees of the whole, the second having "the broadest and most complex mandate of all." Among other traditional law of the sea issues, the Second Committee addressed itself to the seabed within national jurisdiction.[101]

The Conference Underway

At the first substantive session in Caracas in 1974, no decision on issues nor Article of the future convention emerged from Committee II. However, the status of support for certain principles and positions was clear at this time. With regard to the continental shelf concept, the attention devoted throughout the Conference to the 200 mile economic zone idea is noteworthy. Originally proposed in 1972 at both the Santo Domingo Conference of Caribbean Countries on the Problems of the Sea and the African States Regional Seminar on the Law of the Sea, the offshore economic zone was intended to take in living and nonliving resources, ensuring a share of the oceans' wealth for all coastal nations regardless of their offshore geology or technological capability.

Throughout 1972 and 1973, support for the economic zone proposal was submitted as draft articles to the Sea-Bed Committee by Latin American - not surprising in view of their earlier continental shelf claims - and African states, as well as Canada, India, and Sri Lanka.[102] The United States, whose 1970 draft treaty had "failed to capture the imagination of the Sea-Bed Committee,"[103] indicated a willingness to accept coastal state jurisdiction over an economic zone beyond the territorial sea; nevertheless, it maintained its revenue-sharing recommendation beyond the 200 meter isobath.

The revenue-sharing approach which stemmed from the 1970 trusteeship proposal grew in strength throughout the development of the continental shelf doctrine. It was nurtured by a guiding principle of the Conference: equity. As the diverse segments of the world community sought to establish an equitable set of rules for the oceans, certain land-locked and narrow-margin states complained of the inequity of their geographic situation with respect to coastal and broad-margin states. In their fight for geographically equitable arrangements, these states have come to be known as "geographically disadvantaged."

This demand for geographic equity is a novel one in boundary delimitation: boundary patterns on land generally reveal no such equitable division of territory. Simply, some nations embrace vast expanses while others claim small areas. Likewise, not all nations are edged by broad continental margins facing the sea. However, equitable arrangements have prevailed over geographic and geologic realities in UNCLOS III maritime boundary discussions. Perhaps this is due to the nature of the beast: the oceans are a new, and yet the last, frontier on earth to be divided up. Perhaps it only makes sense that equity should guide the system of law and order for the marine environment.

Revenue-sharing emerged as a means to achieve such geographic equity in determining continental shelf jurisdiction. At the opening session of the Conference, narrow-margin states favored limiting exclusive coastal state jurisdiction to 200 miles. Broad-margin states preferred drawing the line at the outer edge of the margin in hope less would be subject to international sharing. Revenue-sharing served to bridge this gap by creating an intermediate zone - beyond 200 miles to the outer edge - of shared coastal and international benefits. Thus, revenue-sharing, one vehicle of the principle of geographic equity, has in great part shaped the continental shelf definition.

By the 1974 Caracas meeting, over 100 of the attendant 150 states were inclined to describe the regimes of the seas along nationalistic lines. Some believed that the continental shelf should be partially or wholly subsumed within the economic zone, while others with both wide and narrow margins, advocated coastal state jurisdiction beyond 200 miles in order to maximize their degree of control over offshore areas. In this vein, the Soviet Union offered a 500 meter depth maximum beyond 200 miles.[104]

When the Conference reconvened in Geneva in 1975, the question as to whether the shelf would be defined to include continental margin areas beyond 200 miles remained unresolved.[105] The informal Single Negotiating Text drawn up at this session by Committee II suggested coastal state jurisdiction to the edge of the continental margin coupled with revenue-sharing where that edge lay beyond 200 miles. Members of the Committee indicated a need for a precisely defined margin edge and charged an ad hoc group to pursue this goal. Notwithstanding this unfinished task, Article 62 firmly installed the enduring phraseology:

> The continental shelf of a coastal state comprises the seabed and subsoil of the submarine areas that extend beyond its territorial sea throughout the natural

> prolongation of its land territory to the outer edge of the continental margin, or to a distance of 200 miles from the baselines from which the breadth of the territorial sea is measured where the outer edge of the continental margin does not extend up to that distance.[106]

The 1976 and 1977 sessions of the Conference in New York marked an important stage in the development of the continental shelf doctrine. Although not incorporated within either the 1976 Revised Single Negotiating Text (RSNT) or the 1977 Informal Composite Negotiating Text (ICNT), the formula presented by the delegation from Ireland gained a broad base of support. At the seventh session in 1978, seven negotiating groups were appointed to resolve outstanding troublesome issues. Negotiating Group 6 dealt with the delimitation of the outer limit of the shelf while the others handled matters concerning the deep seabed, economic zone, and adjacent and opposite state boundary delimitation. This Negotiating Group 6 noted how the Irish amendment would enhance Article 76 with the following paragraphs:

> 2. The continental margin comprises the submerged portion of the land mass of the coastal State, and consists of the seabed and subsoil of the shelf, the slope, and the rise. It does not include the deep ocean floor nor the subsoil thereof.
> 3. For the purposes of this Convention, the coastal State shall establish the outer edge of the continental margin wherever the margin extends beyond 200 miles from the baselines...by either:
>   (a) A line delineated in accordance with paragraph 4 by reference to the outermost fixed points at each of which the thickness of sedimentary rocks is at least 1% of the shortest distance from such point to the foot of the continental slope; or,
>   (b) A line delineated in accordance with paragraph 4 by reference to fixed points not more than 60 miles from the foot of the continental slope.

> In the absence of evidence to the contrary, the foot of the continental slope shall be determined as the point of maximum change in the gradient at its base.

Paragraph 4 stipulates that the fixed points be located at coordinates of latitude and longitude, describing the boundary by straight lines not exceeding 60 miles in length.[107]

Although some Arab states refused to accept any coastal state jurisdiction over continental shelf resources beyond 200 miles, no other compromise was proffered until the Soviet Union proposal in April, 1978 to eliminate the sediment thickness reference (paragraph 3(a)) and to provide a cut-off on paragraph 3(b) of 100 miles beyond the 200 mile economic zone. Immediate dissension resulted from the Soviet proposal's disregard for the geological basis of the continental shelf doctrine, failure to delimit the shelf edge, and elimination of existing coastal state sovereignty. As with earlier fixed distance proposals, apprehension centered on the possible fostering of a 300 mile economic zone. These two formulae remained in competition at the end of the seventh session as delegates reviewed a comparative study of the various formulae.[108]

Consideration of the continental shelf issue at Geneva in the spring and New York in the summer of 1979 further accomplished definitive work in this struggle to achieve stability, certainty, and predictability in national-international relations across the continental margin. Article 76 of the ICNT/Rev. 1 reaffirmed the widespread support for the Irish formula and revealed the aforementioned inadequacies of the Soviet proposal. The chairman of Committee II and the Negotiating Group 6 selected alternative maximum bounds of 350 miles or 100 miles beyond the 2500 meter isobath, whichever is further seaward, upon those margins wider than 200 miles.[109] Sustained Soviet interest in establishing a cut-off stemmed from their concern to ensure that certain mid-ocean ridges surrounded by a 2500 meter isobath would not be considered part of the continental margins of nearby coastal states.[110] At this session also, Sri Lanka evoked sympathy, but no alteration of Article 76, for the geomorphological conditions off its coast; that is, the foot of the slope and 2500 meter isobath fall nearshore, while an exceedingly broad rise stretches several hundred miles seaward.

Negotiations on the continental shelf principle were concluded at the ninth session in 1980. At the end of the New York meeting in April, the matter of ridges was cleared up by reworking within the ICNT/Rev. 2 the phrase "the deep ocean floor with its oceanic ridges." This was settled following intensive discussions between broad margin states and the Soviet Union on the language to be used in the text. Particular attention was paid to this issue by United States Representative Elliot Richardson to ascertain that features such as the Chukchi Plateau situated north of Alaska with its component elevations and depressions cannot be considered a ridge, but instead part and parcel to the margin and hence bounded by 2500 meters plus 100 miles. No objections were raised. Additionally, it was agreed that a "consensus statement of understanding" would be appended to the Final Act of the Conference stipulating an average thickness of sediment method of delimitation peculiar to Sri Lanka jurisdiction; in this way, reopening of negotiations on the internationally accepted definition of the continental shelf was avoided.[111]

Since the 1980 ninth session therefore, the description of the legal continental shelf has been fixed firmly in the minds of the plenipotentiaries who gathered at Geneva and expressed their consensus in the Draft Convention's Article 76.[112] It has been concluded that the outer limit of the legal continental shelf -- the area comprising the seabed and subsoil over which a coastal state exercises sovereign rights for the purposes of exploration and exploitation of natural resources -- lies at 200 miles from the coast (baseline) or at the outer edge of the continental margin, where that margin extends beyond 200 miles, as defined by the Irish formula, provided it does not reach further seaward than 350 miles or 100 miles beyond the 2500 meter isobath.

It is the coastal state's option, in delimiting the boundary of its legal shelf, to choose either of the two formulae provided by Article 76 paragraph 4 or a combination thereof to maximize its area of jurisdiction. In practicing such "geographic selectivity,"[113] the coastal state must delineate this boundary by straight lines no greater than 60 miles in length, connecting points fixed by coordinates of latitude and longitude. The maximum change-in-gradient criterion is inserted as an explanation of the slope's foot, not as an outer edge to the legal or geological continental shelf.

Finally, this geophysical, geomorphological, and geographical determination, incorporating any embedded irregular features which are natural components of the continental margin and satisfy the Irish formula, is ultimately restrained only by a maximum permissible fixed distance (350 miles) or depth-plus-distance (2500 meters plus 100 miles). Both of these cut-off configurations apply to such marginal components as "plateaux, rises, caps, banks, and spurs." However, only the 350 mile criterion serves to limit jurisdiction over "submarine ridges." In neglecting to explain what is meant by "submarine ridges," the draft treaty invites individual interpretation by the coastal state. This provision, albeit politically flexible, poses a perplexing task of boundary demarcation on these features.

The coastal state is assigned this task of drawing the continental shelf boundary. Article 76 paragraph 8 of the Draft Convention stipulates, however, that an elected Commission on the Limits of the Continental Shelf of geologists and geophysicists be organized according to "equitable geographic representation." Such a Commission will review the coastal state's boundary delineation and "make recommendations" regarding the particulars of such boundary placement. Thereafter the coastal state is to set its limits "on the basis of these recommendations." These limits are to be final and binding. If the Commission disagrees with the coastal state's contention, that state must revise and resubmit a new configuration. The Commission is not a judicial or legislative body.

This provision is interesting to examine because of the transition its language underwent during the ninth session. The April 1980 ICNT/Rev. 2 required only that the Commission's recommendations be taken "into account." Objections to the liberty allowed by such wording resulted in its present form. Even now, however, it is not entirely clear as to the procedure to be followed if the coastal state rejects the Commission's opinion. It seems the Conference continued to assume that the coastal state and the Commission would strive to achieve harmony on an accurate and precise boundary.

The Conference Concluded

An atmosphere of restrained optimism prevailed on March 8, 1982 as UNCLOS III reconvened. Developing countries in particular hoped that this eleventh session would achieve international accord on a set of rules to govern activities in the oceans' sphere. Confronting these hopeful views were the reservations held by the United States regarding certain deep seabed mining provisions. The United States position was manifested a year earlier by its withdrawal from participation in negotiations pending a thorough review of the draft document by the new administration. A revamped United States delegation joined the March 1982 gathering in New York with a deep seabed miner's version of the convention. The April 30th close of the session revealed the reception which these American demands evoked: 130 nations agreed upon the draft text; 17 abstained; and four refused to accept its provisions. The United States stood in the last group, together with Israel, Venezuela, and Turkey.

Although United States consent was thwarted by global differences in opinion regarding deep seabed mining, the issue of maritime jurisdiction on the continental shelf is well-settled in international law. For those states party, in relation to each other UNCLOS III will supercede the Geneva Conventions; for nonsignatory states who participated in negotiations, the tenets of Article 76 will rule as customary international law. Longstanding practice or acceptance of a rule by members of the world community establishes that rule as customary law. This may stand between or among two or more states or apply to the international community as a whole. The definition of the continental shelf, emerging from 15 years of UNCLOS deliberation, has been molded into its present form by the framers of the Draft Convention. Although yet to be put into practice by any nation, the acceptance which the language has received within the international community effects its status as customary law. Consequently, it can be reasonably assumed that United States jurisdiction over the mineral resources of its continental shelf may be determined by the application of Article 76 to its continental margin.

At the first conference of the Law of the Sea Institute in 1966, John Mero, then President of Ocean Resources, Inc., noted:

> The outer edge of the continental shelf, or at least the distance in the sea to which a nation may lay claim to the resources of the seafloor, should be fixed and stated and not left indefinite for future adjustments that may be protested. There is nothing that companies or groups fear more than having political boundaries moved back and forth over a property in which they have invested a great deal of money to develop.[114]

This need for an attractive investment climate is of even greater importance today. Mineral exploration and extraction costs increase dramatically with technological advances to deeper waters and greater distances from shore. A "fixed and stated" boundary would ensure the legal-political security of this growing investment.

Oddly enough, despite its introduction in 1976, the so-called Irish formula has not been determined in any precise detail along the United States margin. Throughout negotiations, the thrust of the United States had been one of areal maximization without a clear are used interchangeably to describe the bottom of the slope. Consequently, by positioning the maximum gradient change at the base, Article 76 defines the foot of the slope as the foot of the slope.

Hedberg has noted dissatisfaction with the draft definition "as it merely shifts the problem of defining the 'foot' to that of defining the 'base'. Instead, he considers the toe of the geomorphic continent to lie at: "the lowest point in the oceanwardmost major course of downward inclination in the generally descending profile of the continental slope, beyond which the gradient either flattens very gently to merge eventually with the abyssal plain, or reverses to form the other side of an oceanic trench."[117] This offering does not elucidate the observe provision of Article 76, but rather serves as a separate definition. As such, it too fails to make clear the seaward extent of the "descending profile." The continental rise, albeit of more gentle grade, is a continuation of "downward inclination" from the slope; and so, the "lowest point" in inclination may fall on, or at the foot of, the rise.

It is apparent that a standard definition of the foot of the slope is still needed. As learned during the shelf edge debate, the employment of a depth contour as a legal-political boundary, however simple, proves geomorphically inaccurate and geographically inequitable on a global scale. Perhaps a solution to this dilemma may be found in a coupling of Hedberg's recommendation with paragraph 4(b):

> The foot of the continental slope may be determined as the point of maximum change, or the median among more than one nearly equal major changes, in gradient in the generally descending profile of the continental slope (3° -6°; < 1:40) of the rise or reverses to form the other side of a marginal trench.

If the definition is geomorphically accurate, and yet flexible enough to accommodate the multifarious margins edging the continents, the phrase "in the absence of evidence to the contrary" supplied by paragraph 4(b) seems unnecessary.

Seaward Jurisdictional Belt. The base of the slope is not a sharp enough feature to serve directlv as a political boundary, and so Hedberg proposed a boundary zone of "uniform, internationally prescribed width, adjacent oceanward to the best approximate position of the base of slope."[118] His suggested minimum width of 100 kilometers (54 miles) corresponds roughly to the 60 figure -- the linear distance equal to one degree of latitude -- currently set forth in Article 76. The language of the Draft Convention does not provide for a boundary zone, however, rather setting 60 miles as the maximum seaward placement of the boundary from the slope toe. Further, Hedberg's early work stipulated the drawing of this boundary by way of straight lines joining coordinates of latitude and longitude. Article 76 does also. Through this approach, the coastal state would enjoy the privilege of delimiting its offshore shelf jurisdiction, within internationally agreed requirements and subject to the approval of an "International Marine Boundary Commission" of oceanographic experts.[119]

As can be seen, many of the tenets of this "base of slope-boundary zone formula" have been adopted by the lawyers and geologists tracing the outlines of national-international domains on the ocean floor. As chairman of the Technical Subcommittee of the NPC's Committee on Petroleum Resources Under the Ocean Floor, Hedberg gained industry backing for his naturally-based, scientifically-sound, and practicable boundary. The evolution of and support for this formula is evident throughout the series of periodic NPC reports[120] because it encompasses the onlapping sediments of the upper rise which appeal to oil and gas interests. Thus it comes as little surprise that the cardinal points of this formula have withstood the deliberations of the Law of the Sea Conference.

Sediment thickness. The Irish delegation's 1976 submittal presented a perplexing alternative to the "base of slope-boundary zone" formula. The thickness of sediment test is intended to take into account the maximum area of sedimentary rocks sufficiently thick for potential hydrocarbon and mineral accumulations, while at the same time avoiding a "last grain of sand"[121] misinterpretation of what is meant by the continental rise. Thus this method of delimitation also finds scientific support in its utilization of geophysical techniques to estimate the furthest reach of eroded continental debris. It does not presume to identify crustal character, and appropriately so as the continental-oceanic crust transition generally holds little relation to the overlying sediments.

The sediment thickness test poses some serious difficulties in its practical application: available quantitative information on sediment thicknesses in the ocean is as yet scant; sediment thicknesses are spotty and irregular in distribution, exhibiting a directional variability of change; igneous and sedimentary rocks are often interbedded, especially along the rift-stage zone, and complicate the measurement of depth to true basement; where sediments are too thick or absorptive, profiles fail to indicate a clear definition of basement, while where too thin, calculation of velocity regression equations is precluded; and finally the tremendous cost of geophysical data gathering -- that is, deepwater drilling coupled with seismic reflection and refraction techniques -- hinders an adequate determination of a precise, linear worldwide boundary.[122]

smoothing

Because of the density of trackline control, requiring a smooting technique over basement terrain irregularities, and the uncertainty in the application of the velocity function to reflection time data, a 10% ($\pm$) error in any sediment thickness value is not unrealistic.[123] Nevertheless, statistical determinations of velocity estimates and velocity regression equations are used to convert seismic reflection time in the sediments to thickness in each of the sampled areas. From these calculations are constucted isopach maps whereon the contours present a synthesis of intermediate- to large-scale trends in sediment thickness and basement irregularities. Such isopach maps were used in this study to delimit the outer edge of the continental margin where the sediment thickness at a given point does not exceed 1% of the distance from that point to the base of the slope. An adequate number of points are determined so that the straight lines connecting them do not exceed 60 miles in length.

Submarine ridges. The 100 miles beyond the 2500 meter isobath cutoff is delimited by straight lines, while the 200 and 350 mile arcs are measured from the baselines from which the breadth of the territorial sea is measured. Again, it is the option of the coastal state which cutoff criterion to employ in maximizing jurisdiction, excepting the exclusive application of 350 miles to submarine ridges. The rationale for this ridge provision is clear when one considers, for example, the potential Icelandic gain in following the

2500 meter contour as it spans the north and south Atlantic basins. The framers of the treaty failed to pursue this reasoning to its conclusion, however, in a clear and universally applicable definition of a submarine ridge.

A number of questions are borne out of this legislative void. Is the coastal state entitled to a ridge by virtue of its intersection with and extension beyond the 200 mile arc, or must the ridge stem from the continental margin? What criterion determines the continuity of a ridge as it traverses the ocean floor, a bathymetric contour, secomic activity, lithologic character or crustal structure, heat-flow measurements, or simply geographic identification as a "ridge"? Where ridges are adjoining, can a domino-like chain of jurisdiction reach 350 miles, where is its seaward limit drawn? Finally, where are lateral boundaries to be placed?

In an effort to resolve these problems, it seems a standard definition of a submarine ridge must be devised. A ridge in marine geology is an elongate elevation of the seafloor, having rough, often faulted topography. It may be a single, linear feature or a mountain range of numerous ridges.[124] The terms "rise" and "ridge" have been used interchangeably in reference to this feature. "Fracture zones" also have been regarded as ridges because they appear as long, thin bands conspicuously more mountainous than the surrounding seafloor.[125] Third, submarine volcanoes in a linear grouping pattern may establish themselves as a ridge. A ridge is "primarily a tectonic feature, expressed in surface relief;"[126] therefore, an examination of the tectonically different rise, fracture zone, and submarine volcano features may land to a clear understanding of the diversity of "submarine ridges." H.W. Menard has thoroughly discussed these features, and the following summary draws upon his work.[127]

Rises worldwide exhibit such variability as to preclude setting measurement standards. However, certain characteristics are common: faulted topography, with normal faulting parallel to the rise and transverse wrench faulting; high heat flow over the center and low heat flow on the flanks; widespread volcanism; a seismically active central belt; and a linear, symmetrical pattern of magnetic anomalies or disturbances on both sides of the axial raise crest. Rises are formed as upward bulges of the mantle, rifted and separated by a rising plume of hot magma along the axis. The accreting oceanic crust cools with distance from the crest, reflecting the field of the Earth's magnetism at the time of its solidification. Hence the symmetrical anomalous lineations. Horizontal movement of the flanks away from the crest causes normal tension faults paralleling the axis, and transverse wrench faults between the migrating crustal blocks.

The mid-oceanic ridge is a continuous system of median ridges running the length of the North and South Atlantic Oceans, Indian Ocean, and South and Mid-Pacific Oceans. It measures about 1500 kilometers in width, more than 84,000 kilometers in length, and 1-3 kilometers in elevation above the ocean floor. Magnetic anamaly and heat-flow patterns and earthquake epicenters have been found to follow its crest. Two such median elevations, the Juan de Fuca and Gorda Ridges constitute sections of the East Pacific Rise portion of the broad, fractured swell.

Fracture zones exhibit high elevated relief similar to that of rises of a few kilometers, although these tectonic features are generally more narrow, not as long, and remarkably straight. In contrast to the volcanic construction of a rise, a fracture zone is uplifted by the faulting associated with differential motion of crusted blocks away from spreading centers. Topography makes obvious vertical movement on fracture zones, while relative straightness and offset of magnetic anomaly patterns indicate horizontal movement. Seismicity appears more intense along fracture zones where they intersect with the crest of a rise, evidence of the tectonically acative nature of the fracture. The Mendocino and Blanco Fracture Zones off the United States northwest Pacific margin illustrate such features, offsetting the crest of the East Pacific Rise.

Finally, ocean basin volcanoes, grouped in an elliptical or linear design, can build a submarine ridge. Where the centers of eruption, generated by "hot spots" from the mantle, are sufficiently close to pond the outflow of volcanic material, the bases of the volcanoes overlap. Development of this process migrating along a lineation results in a prominent topographic feature such as the Hawaiian Island ridge.

Notwithstanding their tectonic origin, ridges worldwide cannot be adequately defined by seismicity, heat flow, or magnetic anomalies. Certain submarine volcanoes and paleorifts, with associated fracture zones, remain as distinguishable topographic features which long ago ceased to be tectonically active. Consequently, reliance upon current or recent geophysical data may prove misleading in identifying a submarine ridge. At the same time, a fixed height or length criterion would provide an arbitrary definition, as well as an inaccurate one in many cases.

A submarine ridge in the arena of international law of the sea may be suggested as: a rugged, elongate elevation or group of elevations rising or arching upward at least 1000 meters or more from the seafloor, the linear continuity of which either butts against or continues beneath a continent or extends until the downward inclination of its slope flatten to merge with the ocean floor. Relief on the flanks of a ridge may smooth steeply or gently to the gradient of the abyssal plain. Therefore, the base of the ridge slope may be found at the point of maximum change, or median among more than one nearly equal major changes, in gradient in the downward inclination of the ridge flank profile, beyond withich the gradient flattens (0°) as the abyssal plain. Sedimentation is sparse in the deep ocean, unlike that characterizing continental margins, and so placement of the toe of the ridge slope commonly is not obscured by overlapping or slumping sediments.

Jurisdiction over a submarine ridge may be granted to the coastal state by virtue of the extension of the ridge seaward beyond the 200 mile zone. Where the ridge can be traced on the ocean floor more than 350 miles from the coast, jurisdiction thereon is discontinued at that distance. Where the ridge falls short of this cutoff, it is suggested here that its terminal boundary be located by straight lines no more than 60 miles in length connecting fixed points no further than 30 miles from the base of the ridge slope. Similarly, lateral boundaries of the ridge may be demarctaed by straight lines no further than 30 miles from the base along its length.

Thus, Article 76 offers to the coastal state a plethora of alternative methods, linked to the physical fact of the continental shelf, by which it can legally delimit precise seaward bounds to its jurisdiction over mineral resources. The flexible language of the draft convention leaves many blanks to be filled - perhaps appropriately so - by the individual coastal nation, subject to approval by the aforementioned International Boundary Commission established by the Convention. In undertaking the application of the formulae to the United States continental margin, the physical and legal feasibility of areal maximization and resource optimization will be determined.

Delimitation by Article 76

Methodology. The delimitation of the continental shelf of the United States entails the regional demarcation of several lineations as dictated by Article 76: 200 and 350 miles, 100 miles beyond the 2500 meter isobath, base of slope, 60 miles beyond the base of slope, and sufficient sediment depths beyond the base of slope. The boundary lines drawn herein do not represent the definitive statement on United States shelf boundaries, but rather intend to serve as precise, and accurate to the degree possible, limits to shelf mineral jurisdiction. Error is inherent in present geophysical surveying and data compilation techniques, especially in areas where information is meager as in the Arctic. However, based upon that which has been generated, this thesis presents a viable delimitation of United States continental shelf jurisdiction. The design and construction of maps displaying this demarcation required extensive coordination

States continental shelf jurisdiction. The design and construction of maps displaying this demarcation required extensive coordination of numerous source maps, geological and geophysical literature, and original calculations. Following is an introduction to Plates 1-6.

The 200 and 350 mile arcs are extended from the baselines from which the breadth of the territorial sea is measured. Their placement has been checked with other sources. Base maps depicting the 2500 meter isobath were chosen for this study in order to most accurately measure points 100 miles seaward. The frequency of these determinations, measured perpendicular to the 2500 meter contour, is such that straight lines connecting them do not exceed 60 miles in length.

The base of slope is calculated on those margins whose outer edges lie beyond 200 miles from shore. This situation occurs on the broad passive margins of the Atlantic Coast and Arctic Coast of Alaska. On the former, two 'bases' are shown: an 'approximate' and a 'proposed'. Although scientific thought is not entirely concurrent on the regional location of the Atlantic slope's foot, it is fairly well-settled among marine geologists and geophysicists familiar with this margin that the maximum change in gradient designating the base of slope cuts across bathymetric contours ranging generally from 1500-2500 meters, and dropping to an extreme of 5000 meters. The 'approximate' base shown here corresponds to this generally-accepted placement.[128] (Plate 1) Original calculations roughly agree with this approximation.

Accompanying this is the base of the continent as directed by Hedberg. He places this feature at depths from 4000-5000 meters, on what has become known in marine geology as the "upper continental rise." Hedberg discounts distinguishing between an "upper" and "lower" continental rise, declaring instead that the notch separating the two marks, in fact, the foot of the slope.[129] This proposal recently has been submitted to the U.S. Geological Survey for consideration as a viable determination of this feature;[130] hence its inclusion here.

Along the Arctic Coast of Alaska, the base of slope is fixed where original rise:run calculations indicate the maximum change in gradient. The slope is steep as it skirts the Chukchi Shelf, making its termination easily identifiable; however, the Mackenzie Delta introduces more gently grading topography and so a contour-cutting trace of the slope's foot. Here medians among major changes in gradient depict its location.

As extended perpendicular to the base of slope, the 60 mile-distant points are placed so as to be joined by straight lines no longer than 60 miles. Similarly, coordinating sediment depth (isopach) maps with the base maps employed, those points of appropriate sediment thickness were connected by straight lines of length not exceeding 60 miles.

Altantic Coast. Along the thickening and prograding wedge of sediments bordering the northwest Atlantic basin, the base of slope centers on the 2400 meter isobath from Georges Bank to the northern reaches of the Baltimore Canyon Trough. It can be traced to shallower depths of 1800 meters off New Jersey and Cape Hatteras, NC. Following the tread of the slope foot further south, it takes a jog southeast off Cape Fear, NC, dropping more than 1000 meters. It skirts the Blake Plateau and Outer Ridge to depths of 4400-4800 meters. Then the slope-rise juncture to the east and south of the Blake Spur is abrupt at 4400-5000 meters. (Plate 1)

The base of slope as perceived by Hedberg follows the 4500 meter contour south from Georges Bank until, east of Cape Hatteras, it swings seaward around a seafloor spur and continues south along the 5000 meter isobath. Upon reaching the southeast tip of the Blake Outer Ridge, it turns sharply northwest to 4400 meters. Like the 'approximate' slope foot, this 'proposed' toe then follows the 5000 meter contour south of the Blake Spur (Plate 1).

Extended from the 'approximate' base of slope, the sediment thickness boundary everywhere lies beyond the 60 mile band. It also falls seaward of 200 mile arcs, save east of Cape Hatteras. The cutoff provided by 100 miles beyond the 2500 meter isobath is landward of 350 mile arcs, and so the latter serves as the maximum seaward extent of shelf jurisdiction on the Atlantic Coast. Specifically, one area of shelf as defined by paragraph 4(a)(ii) is cutoff by the 350 mile arc: the Blake Plateau Outer Ridge. Sediments are sufficiently thick nearly 100 miles southeast of the Ridge nose to place the outer edge of the margin at that distance. So, shelf jurisdiction via the 'approximate' foot is described by sediment thickness, except as cut off by the 350 mile arc and enlarged by the 200 mile arc (Plates 1 & 6).

Measured from the 'proposed' slope foot, the sediment thickness formula again surpasses the 60 mile band, excepting a lengthy stretch east of Cape Hatteras. Title to the thick sediments, which everywhere reach seaward beyond 200 miles, is bounded by 350 mile arcs in three areas: immediately south of the Canadian border (American claim), east of Cape Hatteras, and across the nose of the Blake Outer Ridge. Thus, the 'proposed' geographic selection of formulae would include both the sediment depth test and 60 mile measure, as restricted by a 350 mile maximum distance from shore. (Plates 1 & 6)

At either end of this passive margin lie the as yet undetermined lateral boundaries with Canada and the Bahamas. The former is at present in dispute; hence the indication of geographic claims. The latter has yet to be discussed with the Bahama Islands, and so a hypothetical equidistant line is utilized here. Both lateral boundaries are extended to meet shelf limits.

Gulf Coast. On May 4, 1978, a draft treaty was signed between the United States and Mexico establishing a maritime boundary regarding claims over the waters and seabed of the Gulf of Mexico. The agreement was pigeon-holed upon reaching the Senate floor because of discontent expressed by United States oil and gas interests.[131] Despite this halt in treaty proceedings, the mutually agreed boundaries remain in tact in United States policy pending the reopening of negotiations between the two states.

The apparently generous grant to Mexico is due to the weighting of the shelf islets off the Yucatan coast with the same value as the mainland in delimiting maritime jurisdiction. Two gaps remain where the drawing of 200 mile arcs leave patches of international marginal sea. The sediments of the Gulf are of sufficient thickness to negate an outer edge to the margin as defined by Article 76; at the same time, 350 mile arcs drawn from the baselines everywhere overlap one another. Recall that as a marginal sea, the Gulf of Mexico is a geological component of the continental margin. Consequently, it is evident that negotiation of lateral boundaries is demanded by this shared feature. Herein hypothetical equidistant lines bridge these two gaps. (Plate 2)

Pacific Coast. Delimitation of the seaward extent of United States jurisdiction over its western continental shelf presents a challenge vis-a-vis submarine ridges tracing a zig-zag pattern across the seafloor. This active margin exhibits a shelf width minimum of less than five miles off Monterey, CA, widening to nearly 50 miles southwest of Newport, OR. The margin profile plunges dramatically to depths greater than 2500 meters within 90 miles of the northern and central California coast, steepening further off Monterey, CA where the 2500 meter isobath lies about 30 miles offshore. Because of this narrow-margin situation, paragraph 4 is not applicable; rather, 200 mile arcs describe the limit of continental shelf jurisdiction (Plate 3).

Delimitation by means of 200 mile arcs is interrupted by the Mendocino Ridge off northern California and the ridge and trough complexes off Oregon and Washington. On these submarine ridges, jurisdiction is discontinued at 350 miles where the ridges extend to that distance. The Mendocino Ridge is a steep-sided escarpment where the northern oceanic crustal block towers more than 2500 meters above the nearly 5000 meter deep southern block. It reaches seaward like an appendage from the continental margin and intersects the 200 mile limit. The irregular relief of this fracture zone smooths to abyssal depths several hundred miles from shore. Jurisdiction is bounded seaward by a 350 mile arc and laterally by 30 mile measures.

The northernmost tail of the East Pacific Rise is composed of the system of rifts and fracture comes north of the Mendocino Ridge. Off Oregon, the Gorda Ridge is a northeast-trending, seismically active rift lying entirely within the 200 mile zone. This mountainous chain of ridges and valleys displays 700 meter depressions among peaks reaching 1500 meters above the seafloor. Depths average at 3000 meters on the surrounding plain.

The Gorda Ridge is interrupted, both tectonically and topographically, by the Blanco Fracture Zone, offsetting the rise crest along a northwesterly trend. Although a less dramatic feature than the Mendocino Ridge, the Blanco faults similarly exhibit a 500-1000 meter upthrust of the northern block above the down-slipped southern province.

Nearly 300 miles from shore, the Blanco Ridge fissures the crest of the Juan de Fuca section of the East Pacific Rise. Like the Gorda Rift, the Juan de Fuca trends northeast and is actively spreading the Pacific and North American plates. This collection of ridges and troughs overlaps the northwest corner of the 200 mile zone and spans west and north more than 1500 miles from the 200 mile limit. Continuing into Canadian shelf jurisdiction, the mid-ocean ridge system is obliterated at 50° N by transverse faulting. Thus, jurisdictional boundaries are set at: north lateral, a United States-Canada hypothetical equidistance line to 350 miles from shore; seaward, 350 mile arcs; and south lateral, a 30 mile measure from the ridge base.

Hawaiian Islands. The volcanic origin of the Hawaiian Islands effects a chain of mountains rising up to sea level from the deep ocean floor. These mountains have virtually no continental shelf, and hence jurisdiction is determined by an encircling of 200 mile arcs. The Necker Ridge extends southwest from Necker Island, and its terminal slope merges with the abyssal plain within the 200 mile zone of the United States Johnston Atoll. Jurisdiction over this submarine ridge may be granted according to the definition suggested herein (Plate 4).

Arctic Coast of Alaska. The northern edge of the Pacific plate dips beneath the North American plate at the Aleutian Trench. At this active margin, terrane drops abruptly to abyssal depths within 50 miles of the Aleutian Islands. Two hundred mile arcs set the reach of United States mineral control. To the west, the 1867 United States-Russia Convention Line provides a negotiated maritime boundary - shown here as a great circle as advanced by the United States - for the Bering and Chukchi Seas. The former, a marginal sea, holds such a volume of sediments as to negate an outer edge to the margin as defined by paragraph 4(a)(ii); therefore it is appropriate, as in the Gulf of Mexico, that the boundary thereon be resolved by negotiation in accordance with the principles of maritime boundary delimitation.

The Chukchi Shelf, like the Blake Plateau, is a feature of the continental margin. As such it is bounded on the west by the 1867 Line and on the north and east by Article 76. The base of slope is calculated herein at depths nearing 3600 meters around the plateau and eastward toward the Mackenzie Cone shallowing to less than 3000 meters before jurisdiction is stopped by a hypothetical equidistant line with Canada. Extended from this suggested base of slope, a 60 mile band everywhere falls seaward of 200 miles from shore. More importantly, from the data generated thus far, albeit not entirely conclusive, it can be derived that the volume of sediments in this Arctic basin is sufficient to employ a paragraph 4 cutoff. The delta from the northwest flowing MacKenzie River thins westward to about 4.5 kilometers at the Chukchi Shelf and Borderland,[132] where northern flowing Asian rivers maintain a steady sediment supply. This pattern of westward-thinning deposition continues at least 200 miles from the Alaskan coast and can be inferred to reach further. Hence the satisfaction of the sediment depth test. Weather and ice conditions permitting, further geophysical surveying beyond 250-300 miles will enhance the knowledge of Beaufort Sea geology and ascertain the placement of the sediment depth test.

From the extended hypothetical Canadian boundary, taking into account a 350 mile Canadian shelf zone, the United States shelf boundary is described by 350 mile arcs westward until intersection with the 100 miles beyond the 2500 meter isobath. Thereupon, this cutoff criterion serves as the boundary circumscribing the Chukchi Plateau. The 1867 United States-Russia Convention Line is elongated to meet this shelf limit (Plate 5).

CHAPTER V

Mineral Resources of the Continental Margin

Resources and Undiscovered Resources

The 1945 Truman Proclamation and its legislative implementation in 1953 served to stimulate and support multiplying claims to mineral resources of submerged lands. This Federal approval enhanced the security of offshore investment, although the subsequent Geneva Convention clouded its outer edges. At the same time, increased domestic mineral consumption spurred by World War II outpaced domestic mineral supplies. This strained the international trade balance and national security of the United States. These forces have encouraged development of technology in the offshore exploration and extraction of fuel and non-fuel minerals.

Continental margin deposits include such produced or potentially producible minerals as: petroleum and natual gas, gas hydrates, tin, titanium, gold, monazite, manganese, nickel, cobalt, copper, phosphates, and sand and gravel.[133] Energy materials - oil and gas - have received the greatest attention as escalating demand has sustained economic and technologic expenditures. Hard minerals - although mined to some extent nearshore - have failed to draw efforts seaward. This has been credited, not only to adequate land sources, both foreign and domestic, but also to an executive decision in 1968 to ban offshore hard mineral leasing in federal waters.[134] Recent policy decisions of the present administration may promise a turnaround for the marine mining industry.

The availability of a resource is dependent upon such factors as: certainty of its legal status (ownership); knowledge of its geologic occurrence; technologic recoverability; and economic conditions. A resource is a known accumulation of a source of supply which is now or could be conventionally recoverable. A resource becomes a reserve when geological and engineering studies demonstrate the deposit to be recoverable from known or partially defined reservoirs under existing economic and operating conditions. Undiscovered resources comprise a tentative estimate of mineral quantity, presumed to exist based on regional geological analyses and statistical models. This calculation disregards present accessibility and economics in figuring the mineral's conventional recovery and sale.[135]

This thesis addresses two variables in the potential recovery and sale of continental margin resources: geologic occurrence and legal status. Technological innovations and market forces, subject to rapid fluxes, are not included here because they require a different time frame of consideration. Although much can still be learned of the geochemical and geological properties of many offshore minerals, to date there exists a sound foundation of knowledge regarding their nature, occurrence, distribution, and associations. Therefore, by plotting these geological resource assessments on the suggested legal shelf, the extent to which the United States holds title to the mineral resources of its margin can be derived. In this way, the protection of claims is indicated by way of locating a "fixed and stated" boundary for which John Mero pleaded more than 15 years ago.

Hydrocarbons

Oil and gas originate from organic matter that is deposited along with sands and fine-grained muds in relatively anoxic sedimentary basins of continental margins. As the sediments are buried, the increased pressure and temperature at greater basin depths thermally alter the hydrocarbons over time to form oil or gas. Natural gas is a late-stage product in the maturation of hydrocarbons, dependent upon a more terrestial source of organic material, greater heat flow, and a prolonged period of alteration. With increasing pressure, the petroleum migrates from fine-grained source rocks to coarse-grained reservoir sands. The hydrodynamics of these porous reservoir rocks allow oil to move upward until it accumulates in structural or stratigraphic traps and is sealed overhead. Structures such as faults, anticlines (deformed sediment layers), sediment-draped diapirs, and pinch-outs of sand or gravel within fine-grained material may act as traps. Stratigraphic changes in lithology also will pond petroleum.[136] Consequently, even if basinal sediments are thick enough to thermally generate hydrocarbons, the absence of structural or stratigraphic traps will prohibit the accumulation of commercial quantities of oil or gas.

In 1980, offshore production accounted for 12.5 percent of the oil and 26.5 percent of the natural gas for the United States.[137] Estimated undiscovered recoverable crude oil and natural gas are calculated at 34.1 percent and 28.1 percent, respectively, of the United States total.[138] For this study, the continental shelf and slope to the 2500 meter contour are divided into four areas: Atlantic Coast, Gulf Coast, Pacific Coast, and Alaska Offshore.

Hawaii is not included because its volcanic terrane is considered unsuitable for hydrocarbon accumulation. Excluded from this petroleum resource assessment are heavy oil deposits, tar deposits, gas in impermeable "tight" reservoirs, gas in geopressured shales and brines, and natural gas hydrates.[139]

Altantic Coast. Along the Atlantic outer continental shelf (OCS), the first lease sale was held in 1976 in the Mid-Atlantic region.[140] Until drilling began, the Atlantic OCS was viewed as a frontier area and expectations ran high. This optimism was inspired by thick sediments coupled with promise of traps associated in Baltimore Canyon - and numerous salt diapirs. Early surveys and estimates have proved overzealous, however, as a single oil find and abounding gas shows have resulted in the Mid-Atlantic region,[141] while the North Atlantic has yielded no discoveries for the United States.

As spirits began to sink, interest was sparked by the paleo-shelf edge reef complex below the present slope. This porous structure is flanked seaward by organic-rich sediments[142] and may provide appropriate reservoirs, traps, and seals for migrating fluids. High marine organic productivity, relatively reducing bottom conditions, and intermediate sedimentation rates on slopes and rises favor petroleum yields.[143] Further seaward, traps become more important as sediments thin. Two kilometers of sediment are considered the minimum within which the geothermal gradient can effect hydrocarbon maturation. Pinch-outs, faults, turbidites, and unconformities are sought especially in this province of nearly horizontal strata.[144]

As shown on accompanying Plate 6, potential source and reservoir rocks are designated in accordance with the foregoing discussion: shelf gas, thermally-generated oil and gas, reef-associated accumulations, salt deposit pockets, and deep-water speculation to a two kilometer sediment depth. Extended from the 'approximate' base of slope, the shelf boundary denies title to the "unknown potential" petroleum province on the Blake Outer Ridge and north of Cape Hatteras. On the other hand, the entirety of this province is encompassed by the 'proposed' shelf limit excepting, again, the Blake Outer Ridge. An estimate of undiscovered resources in these excluded areas is unrealistic at this time.

Gulf Coast. The first Federal offshore lease sale following the 1953 passage of the OCS Lands Act offered tracts off Louisiana in the Gulf of Mexico in 1954. Cumulative production to 1975 measured 4.1 billion barrels oil and 32.1 trillion cubic feet gas to the 200 meter isobath.[145] Prolific production and potential accumulations in this marginal basin result from thick sediments coupled with extensive salt deposits, providing adequate reservoirs and traps (Plate 2).

Maritime boundary delimitation with Mexico will determine the extent of control held by the United States over this petrolliferous marginal sea. A method of joint or shared exploitation may be required in order to efficiently extract those deposits lying across the boundary.

Pacific Coast. The narrow shelf and steep slope of the Pacific margin contribute little to the petroleum resources of the United States. Production off the coast of California commenced in 1968[146] and, by 1975, reached a cumulative total of 1.5 billion barrels oil and 1.4 trillion cubic feet gas.[147] The entire geologic and geomorphic continental margin and any petroleum potential therein of the Pacific coast is incorporated within the legal concept of the continental shelf (Plate 3).

Alaska Offshore. Development and production of petroleum in Alaska began in Cook Inlet in the early 1960's and spread into the Gulf of Alaska shortly thereafter. Production of oil and gas by 1975 was negligible. Recent geophysical surveying and exploratory drilling, however, have boosted hopes for offshore Alaska tremendously. Specifically, estimates for the Beaufort and Chukchi shelves exceed those for any other offshore region. These quantities are dependent upon enabling technology, a condition not yet met.

The Alaskan margin can be approached - in terms of geology and petroleum potential - as three unique provinces. The steeply plunging slope of the Aleutian Trench to the south is discouraging to the petroleum geologist and well within the 200 mile zone of shelf jurisdiction. The sedimentation and thermal history of the Bering shelf, slope, and deepwater Aleutian basin are adequate for oil and gas generation. Geophysical work has indicated the presence of traps throughout these exceptionally thick sediments.[148] The Norton and Navarin Basins are scheduled for leasing within the next two years, an indication of perceived promise. Both of these are bounded on the west by the 1867 United States-Russia Convention Line. As in the Gulf of Mexico, boundary-straddling deposits will demand special attention.

Finally, the Atlantic-type Arctic margin of Alaska is thickly covered with marine and terrigenous debris from the many Canadian, American, and Asian rivers. Beneath the Chukchi and Beaufort shelves of favorable sedimentary rocks extends the Arctic coastal plain of northern Alaska wherein "every major stratigraphic unit...has been found to contain commercial or potentially commercial pools, or strong shows, of oil and gas."[149] The outer limits to these petrolliferous shelves are drawn as directed by Article 76. This shelf boundary embraces a vast area of mineral jurisdiction for the United States. That petroleum prospects well beyond the 2500 meter isobath are promising is ascertained; however, that these suitable source, reservoir, and trap rocks continue to and beyond the edge of the legal shelf can only be speculated. The United States clearly benefits from this progradation from the Canadian margin -- both in shelf delimitation by way of the sediment thickness test and in petroleum potential.

Gas Hydrates

Gas hydrates are a type of inclusion compound or clathrate in which natural gas molecules - mainly methane - are trapped within an ice-like, crystalline lattice of host water molecules. In general, gas hydrates form at high pressures and low temperatuares if gas is available at saturation concentration. Because both pressure and the geothermal gradient increase with depth of sediment, clathrates have been found at sediment depths of only 1/2 kilometer beneath a water column ranging from a few to a few thousand meters. The presence of salt lowers the temperature of hydrate formation, facilitating its occurrence at shallower depths, while impurities enlarge the field of hydrate stability.[150]

Bottom-simulating reflectors - indicators of possible hydrate horizons - have been identified along the Atlantic Coast, in the Gulf of Mexico and Bering Sea, and on the Arctic Coast of Alaska. Note the association of these occurrences with either salt deposits or low subsurface temperatures. Although an ideal gas hydrate would contain the equivalent of about 170 cubic meters of free methane gas,[151] in nature the lattice chambers are not completely filled. However, this unique structure may offer large quantities of natural gas (also serving as an impermeable seal to underlying free gas) in the upper few hundred meters of sediment and will demand innovative technologies to produce.

Of the offshore gas hydrate accumulations which have been discovered (Plates 2, 5, 6), only that in the crest of the Blake Outer Ridge is vulnerable to continental shelf delimitation. Anomalous reflecting horizons have been traced seaward to water depths of 4600 meters[152] while the 350 mile cutoff falls at 4200 meters. Although its geographical extent has not yet been ascertained, a patch of approximately 100 square miles will accrue to the international seabed area. Resource estimates on this unknown are not feasible yet.

Hard Minerals

Keeping company with produced and potentially producible offshore hydrocarbon resources are more than a dozen other minerals which currently are being extracted or hold tremendous potential for extraction from the continental margin. Although marine mining of hard minerals did not flourish like the energy industry, its recorded history dates back to 2200 B.C. when the Chinese evaporated sea water to procure salt. Recovery of sand and gravel from the English Channel over 100 years ago[153] marked the birth of the aggregate industry, currently the most important offshore mineral exploited other than oil and gas.[154]

In the United States, land sources, both foreign and domestic, had been deemed adequate to satisfy the nation's demand with only sporadic attention to exploring submerged lands. Within the past 25 years, prompted perhaps by depletion of certain land sources and growing concern with dependence upon foreign suppliers, hard minerals offshore began to attract interest. By the 1960's, however, environmental concerns superceded the fledgling marine mining industry, and a 1968 executive decision placed a moratorium on hard minerals leasing in Federal waters.[155]

Interest seemed to diminish quickly as companies were unable to obtain leases and received no action from the government. However, in 1977, the Geological Survey and NOAA undertook a survey to determine interest in hard minerals offshore. Response was strong for sand and gravel and phosphorites, and a lease request was pending as of 1979 for ferromanganese nodules on the Blake Plateau. The Task Force concluded that sufficient national interest and economic incentives existed to support commercial hard mineral mining in selected areas of the OCS.[156]

On January 19, 1982, Secretary of the Interior James Watt promulgated the first hard minerals program on the OCS since its legislative authorization 30 years earlier.[157] Early sales will be located on the Blake Plateau for manganese nodules and along the Arctic Coast of Alaska for sand and gravel. Future sales may encourage production of the following resources. For the purposes of this study, assessment is brief because practically all hard minerals of the continental margin known thus far are within shelf jurisdiction as regionally determined. One exception will be examined.

Sand and gravel and shells. Aggregates are sand, gravel, and shells which are used in the construction and, to a lesser degree, glassmaking and other industries.[158] Adequate supply for the high-consumption Atlantic coast can be furnished by: calcium carbonate sand and shells of the western Florida shelf and south of Cape Hatteras; quartz sand north of this point; and gravel off the northeastern states.[159] In Alaska, offshore gravel sources are coveted by the petroleum industry for platform construction; depletion of and restrictions upon other sources will impel early leasing here. Gravel and limey sands have attracted interest off California, although the only commercial aggregate mining along the Pacific coast occurs in San Francisco Bay. Penguin Bank, southwest of the Hawaiian Islands, offers a large quantity of sand to this volcanic chain in short supply.[160]

Salt deposits. Salt is multifaceted as a valuable resource: sulphur is currently mined from salt domes in the Gulf of Mexico; Gulf and Atlantic coast deposits may contain evaporate minerals such as bromine, potash, and potassium; salt beds and diapirs are sought as reservoirs and traps for oil and gas accumulations; and, finally, recent research points to the energy potential of "osmotic pressure gradients" of brine solutions.[161]

Phosphorite. Phosphorite, or phosphate rock, is an authigenic mineral (precipitated from seawater) commonly occurring in nodules and encrustations. Its primary market is the agricultural industry; and only recently the basins of the southern California borderland, the surficial sediments off the southeast Atlantic Coast, and grains and pellets of the Gulf Coast of Florida have been assessed for their phosphorite potential. Water depths at the Gulf deposits are generally less than 200 meters; along the Atlantic Coast as, deep as 1000 meters; and off California at approximately 200 meters.[162]

Ferromanganese nodules and concretions. Accompanying the phosphorite concretions on the Blake Plateau are manganese nodules, pavements, and encrustations. These assay well below the nickel and copper values of favored Pacific Ocean nodules, but compare in cobalt concentrations. Additionally, the Blake Plateau nodules are claimed to have the highest concentrations of platinum of all studied oceanic nodules; and, perhaps most importantly, these nodules and crusts are found at 600-1000 meter depths within United States shelf jurisdiction. Deposits off the southern/central California coast have also been reported.[163]

Barite. Marine barite crystals, nodules, and concretions found in seafloor sediments are attributed to the concentration of barium in the marine biological cycle.[164] These authigenic concentrations of primarily barium sulphate are recovered by subsea quarrying off the southern California coast and southeastern Alaskan shore.[165]

Placers. Gold, platinum, and tin occur in relict beaches, buried river channels, and nearshore gravels off Alaska, Washington, Oregon, and California. Alaska is considered the most promising of these areas. Because placers commonly are found near to their source, oftentimes the best indication of an offshore deposit is an onshore occurrence.

Chromite, titanium, zircon, monazite, and magnetite sands reflect the character of their parent rock. Titanium dominates Atlantic Coast heavy mineral sands, along with zircon and monazite, indicative of granitic weathering. Chromite sands characterize the Pacific Coast basaltic eroded bedrock. Little is known of the geographic extent of these deposits because of the leasing moratorium.[166]

Polymetallic Sulfides. Investigations of metallogenesis at oceanic spreading centers have led to the recent discovery of polymetallic sulfides in the Juan de Fuca Ridge off the northern Pacific Coast.[167] These hydrothermal precipitates are found in association with submarine volcanic activity,[168] and so further deposits are sought in the rift valleys of the Gorda Ridge. Rich in zinc, iron, copper, and economically significant amounts of silver and cadmium, the Juan de Fuca sulfides occur as massive deposits on or beneath the seafloor. Smaller 'globules' of minerals bubble the basaltic crust and line chimney vents from which the hydrothermal fluids escape.[169]

The massive, metal-enriched sulfides of the Juan de Fuca Ridge were sampled at 2200 meter water depths approximately 250-270 miles west of Oregon and Washington. Indications of hydrothermal activity and ore formation are apparent as close as 100 miles to shore.[170]

Conservative estimates on the mass of the Juan de Fuca deposit place it at 100,000 cubic meters, although no systemic surveys of the volume and grade have yet been undertaken.[171]

The frequent observations in the mid-1970's of sulfide segregations on mid-oceanic ridges coincide with -- but do not appear to have incited -- the agitation at UNCLOS III deliberations to affix a limit on submarine ridge jurisdiction other than 100 miles beyond the 2500 meter isobath. The resolution of this issue allows the appropriation of these deep ocean features and any mineral resources thereon to a distance of 350 miles from shore by the adjacent coastal state. The United States holds title to the mineral resources of the entire Gorda Ridge and Blanco Fracture Zone, and a substantial portion of the Juan de Fuca Ridge. The potential sulfide mineral wealth to be gleaned is vast.

Conclusions

> As Robert Frost said, 'Good fences make good neighbors,' and certainly the converse is also true - uncertain and ill-conceived boundaries will be a constant source of dissatisfaction and trouble, and moreover, once imposed, they will be extremely difficult to change by peaceful processes.[172]

Although Hollis Hedberg may appear to be a lone voice crying out for revision of Article 76, this thesis supports his plea for a simple, consistent, and naturally-based boundary formula governing national-international mineral jurisdiction. However, this study acknowledges the political realities of international law-making which temper such reconsideration.

The motivation for resource control is political, ensuring a broad domestic resource base and national security. As pressures upon limited resources increase world-wide - and especially in the ocean frontier - coastal states seek to maximize title to the mineral resources of their submerged land masses. Thus it is not surprising that what is meant by the 'continental shelf' in international ocean law is not the geomorphological shelf. Rather, the limits to shelf jurisdiction promise to lie for seaward of the geological continent - ocean basin juncture.

Embodied in the recent UNCLOS III agreement, the continental shelf doctrine is firmly installed in conventional law of the sea. More importantly for the United States, the evolution of this doctrine over the past 40 years effects its stance as customary international law. Consequently, delimitation of United States shelf jurisdiction as formulated by Article 76 is within internationally-accepted guidelines. The United States should make clear the seaward extent of its claim upon the limited mineral resources of its continental margin without delay. In so doing, advancement of mining technology to greater depths and distances would be encouraged, and "good fences" would be established.

The delimitation of the United States continental shelf presented in this study reveals the complexities of fixing a naturally-based boundary which strives for political flexibility. The geographic selection of formulae on the broad Atlantic and Alaskan Arctic margins consistently prefers the sediment thickness test to define the outer edge of the margin. As noted, the error inherent in geophysical surveying and data compilation makes this formula imprecise as a boundary determination, particularly in areas of sparse information as in the Arctic. However, because the sediments of the margin have been targeted for resource potential, this sediment-based criterion has remained in shelf delimitation thinking. The margin's edge as found by this formula is bounded by Article 76-imposed cutoffs in two places: along the Atlantic Coast, on the Blake Outer Ridge; and everywhere along the Alaskan Arctic Coast.

With respect to mineral resources, continental shelf jurisdiction embraces the entirety of: oil and gas resources, excepting certain deep-water "unknown potential" areas of the Atlantic and Alaskan Arctic margins; gas hydrates, save those accumulations on the Blake Outer Ridge; and hard minerals, excluding those potential polymetallic sulfide deposits on the Juan de Fuca Ridge falling under Canadian or international control.

As stated in the introduction, the purpose of this thesis was to delimit the seaward extent of United States jurisdiction over the mineral resources of its continental shelf. To this end, it has demonstrated that the United States continental shelf is broadly described by Article 76, incorporating jurisdiction over submarine ridges as well as prograding margin sediments. It cannot be stated conclusively that resource optimization is achieved by this geographic selection of boundary formulae. Although economic and technologic forces will influence the eventual recoverability of the excluded resources, their potential has been indicated and it is this potential which is beyond United States reach. In light of this analysis, the United States is encouraged to ascertain the extent of national title to the mineral resources of the seabed and subsoil beneath its bordering seas.

CHAPTER IV

Article 76

Elaboration of Article 76

Base of slope. As early as 1968, Hollis Hedberg, a Princeton geologist and former Gulf Oil executive, addressed the developing jurisdictional regimes in the oceans with respect to petroleum industry interests. This first public expression[115] of reliance upon the foot of the slope as a guide to a major world boundary bases its rationale on: "The slope is the single most impressive and most extensive geomorphic feature of the earth's surface."[116] It approximately marks the fundamental change from low density continental to high density oceanic crust and thus provides a geologically, geomorphically, and geographically natural boundary.

Once authorized to serve as a guide for the national-international continental shelf boundary, the base of slope must be located. Article 76 paragraph 4(b) provides a circuitous definition whereby the foot of the slope is described as the "maximum change in gradient at its base." (emphasis added) The irregular topography of the continental margin exhibits a number of major gradient changes, often nearly equal in degree, making the choice of a "maximum" difficult. In geologic terminology, 'base' and 'foot' are used interchangeably to describe the bottom of the slope. Consequently, by positioning the maximum gradient change at the base, Article 76 defines the foot of the slope as the foot of the slope.

Hedberg has noted dissatisfaction with the draft definition "as it merely shifts the problem of defining the 'foot' to that of defining the 'base'. Instead, he considers the toe of the geomorphic continent to lie at: "the lowest point in the oceanwardmost major course of downward inclination in the generally descending profile of the continental slope, beyond which the gradient either flattens very gently to merge eventually with the abyssal plain, or reverses to form the other side of an oceanic trench."[117] This offering does not elucidate the obscure provision of Article 76, but rather serves as a separate definition. As such, it too fails to make clear the seaward extent of the "descending profile." The continental rise, albeit of more gentle grade, is a continuation of "downward inclination" from the slope; and so, the "lowest point" in inclination may fall on, or at the foot of, the rise.

It is apparent that a standard definition of the foot of the slope is still needed. As learned during the shelf edge debate, the employment of a depth contour as a legal-political boundary, however simple, proves geomorphically inaccurate and geographically inequitable on a global scale. Perhaps a solution to this dilemma may be found in a coupling of Hedberg's recommendation with paragraph 4(b):

> The foot of the continental slope may be determined as the point of maximum change, or the median among more than one nearly equal major changes, in gradient in the generally descending profile of the continental slope (3° -6°; 1:40), beyond which the downward inclination either flattens to a gentle gradient (0.5°; >1:40) of the rise or reverses to form the other side of a marginal trench.

If the definition is geomorphically accurate, and yet flexible enough to accommodate the multifarious margins edging the continents, the phrase "in the absence of evidence to the contrary" supplied by paragraph 4(b) seems unnecessary.

Seaward Jurisdictional Belt. The base of the slope is not a sharp enough feature to serve directly as a legal-political boundary, and so Hedberg proposed a boundary zone of "uniform, internationally prescribed width, adjacent oceanward to the best approximate position of the base of slope."[118] His suggested minimum width of 100 kilometers (54 miles) corresponds roughly to the 60 mile figure -- the linear distance equal to one degree of latitude -- currently set forth in Article 76. The language of the Draft Convention does not provide for a boundary zone, however, rather setting 60 miles as the maximum seaward placement of the boundary from the slope toe. Further, Hedberg's early work stipulated the drawing of this boundary by way of straight lines joining coordinates of latitude and longitude. Article 76 does also. Through this approach, the coastal state would enjoy the privilege of delimiting its offshore shelf jurisdiction, within internationally agreed requirements and subject to the approval of an "International Marine Boundary Commission" of oceanographic experts.[119]

As can be seen, many of the tenets of this "base of slope-boundary zone formula" have been adopted by the lawyers and geologists tracing the outlines of national-international domains on the ocean floor. As chairman of the Technical Subcommittee of the NPC's Committee on Petroleum Resources Under the Ocean Floor, Hedberg gained industry backing for his naturally-based, scientifically-sound, and practicable boundary. The evolution of and support for this formula is evident throughout the series of periodic NPC reports[120] because it encompasses the onlapping sediments of the upper rise which appeal to oil and gas interests. Thus it comes as little surprise that the cardinal points of this formula have withstood the deliberations of the Law of the Sea Conference.

Sediment thickness. The Irish delegation's 1976 submittal presented a perplexing alternative to the "base of slope-boundary zone" formula. The thickness of sediment test is intended to take into account the maximum area of sedimentary rocks sufficiently thick for potential hydrocarbon and mineral accumulations, while at the same time avoiding a "last grain of sand"[121] misinterpretation of what is meant by the continental rise. Thus this method of delimitation also finds scientific support in its utilization of geophysical techniques to estimate the furthest reach of eroded continental debris. It does not presume to identify crustal character, and appropriately so as the continental-oceanic crust transition generally holds little relation to the overlying sediments.

The sediment thickness test poses some serious difficulties in its practical application: available quantitative information on sediment thicknesses in the ocean is as yet scant; sediment thicknesses are spotty and irregular in distribution, exhibiting a directional variability of change; volcanic and sedimentary rocks are often interbedded, especially along the rift-stage zone, and complicate the measurement of depth to true basement; where sediments are too thick or absorptive, profiles fail to indicate a clear definition of basement, while where too thin, calculation of velocity regression equations is precluded; and finally the tremendous cost of geophysical data gathering -- that is, deepwater drilling coupled with seismic reflection and refraction techniques -- hinders an adequate determination of a precise, linear worldwide boundary.[122]

Because of the density of trackline control, requiring a smoothing technique over basement terrain irregularities, and the uncertainty in the application of the velocity function to reflection time data, a 10% (±) error in any sediment thickness value is not unrealistic.[123] Nevertheless, statistical determinations of velocity estimates and velocity regression equations are used to convert seismic reflection time in the sediments to thickness in each of the sampled areas. From these calculations are constructed isopach maps whereon the contours present a synthesis of intermediate- to large-scale trends in sediment thickness and basement irregularities. Such isopach maps were used in this study to delimit the outer edge of the continental margin where the sediment thickness at a given point does not exceed 1% of the distance from that point to the base of the slope. An adequate number of points are determined so that the straight lines connecting them do not exceed 60 miles in length.

Submarine ridges. The 100 miles beyond the 2500 meter isobath cutoff is delimited by straight lines, while the 200 and 350 mile arcs are measured from the baselines from which the breadth of the territorial sea is measured. Again, it is the option of the coastal state which cutoff criterion to employ in maximizing jurisdiction, excepting the exclusive application of 350 miles to submarine ridges. The rationale for this ridge provision is clear when one considers, for example, the potential Icelandic gain in following the

2500 meter contour as it spans the north and south Atlantic basins. The framers of the treaty failed to pursue this reasoning to its conclusion, however, in a clear and universally applicable definition of a submarine ridge.

A number of questions are borne out of this legislative void. Is the coastal state entitled to a ridge by virtue of its intersection with and extension beyond the 200 mile arc, or must the ridge stem from the continental margin? What criterion determines the continuity of a ridge as it traverses the ocean floor, a bathymetric contour, seismic activity, lithologic character or crustal structure, heat-flow measurements, or simply geographic identification as a "ridge"? Where ridges are adjoining, can a domino-like chain of jurisdiction reach 350 miles, where is its seaward limit drawn? Finally, where are lateral boundaries to be placed?

In an effort to resolve these problems, it seems a standard definition of a submarine ridge must be devised. A ridge in marine geology is an elongate elevation of the seafloor, having rough, often faulted topography. It may be a single, linear feature or a mountain range of numerous ridges.[124] The terms "rise" and "ridge" have been used interchangeably in reference to this feature. "Fracture zones" also have been regarded as ridges because they appear as long, thin bands conspicuously more mountainous than the surrounding seafloor.[125] Third, submarine volcanoes in a linear grouping pattern may establish themselves as a ridge. A ridge is "primarily a tectonic feature, expressed in surface relief;"[126] therefore, an examination of the tectonically different rise, fracture zone, and submarine volcano features may lend to a clear understanding of the diversity of "submarine ridges." H.W. Menard has thoroughly discussed these features, and the following summary draws upon his work.[127]

Rises, or midoceanic ridges, worldwide exhibit such variability as to preclude setting measurement standards. However, certain characteristics are common faulted topography, with normal faulting parallel to the rise and transverse wrench faulting; high heat flow over the center and low heat flow on the flanks; widespread volcanism; a seismically active central belt; and a linear, symmetrical pattern of magnetic anomalies or disturbances on both sides of the axial rise crest. Rises are formed as upward bulges of the mantle, rifted and separated by a rising plume of hot magma along the axis. The accreting oceanic crust cools with distance from the crest, reflecting the field of the Earth's magnetism at the time of its solidification. Hence the symmetrical anomalous lineations. Horizontal movement of the flanks away from the crest causes normal tension faults paralleling the axis, and transverse wrench faults between the migrating crustal blocks.

The mid-oceanic ridge is a continuous system of median ridges running the length of the North and South Atlantic Oceans, Indian Ocean, and South and Mid-Pacific Oceans. It measures about 1500 kilometers in width, more than 84,000 kilometers in length, and 1-3 kilometers in elevation above the ocean floor. Magnetic anomaly and heat-flow patterns and earthquake epicenters have been found to follow its crest. Two such median elevations, the Juan de Fuca and Gorda Ridges constitute sections of the East Pacific Rise portion of the broad, fractured swell.

Fracture zones exhibit high elevated relief similar to that of rises of a few kilometers, although these tectonic features are generally more narrow, not as long, and remarkably straight. In contrast to the volcanic construction of a rise, a fracture zone is uplifted by the faulting associated with differential motion of crusted blocks away from spreading centers. Topography makes obvious vertical movement on fracture zones, while relative straightness and offset of magnetic anomaly patterns indicate horizontal movement. Seismicity appears more intense along fracture zones where they intersect with the crest of a rise, evidence of the tectonically active nature of the fracture. The Mendocino and Blanco Fracture Zones off the United States northwest Pacific margin illustrate such features, offsetting the crest of the East Pacific Rise.

Finally, ocean basin volcanoes, grouped in an elliptical or linear design, can build a submarine ridge. Where the centers of eruption, generated by "hot spots" from the mantle, are sufficiently close to pond the outflow of volcanic material, the bases of the volcanoes overlap. Development of this process migrating along a lineation results in a prominent topographic feature such as the Hawaiian Island ridge.

Notwithstanding their tectonic origin, ridges worldwide cannot be adequately defined by seismicity, heat flow, or magnetic anomalies. Certain submarine volcanoes and paleorifts, with associated fracture zones, remain as distinguishable topographic features which long ago ceased to be tectonically active. Consequently, reliance upon current or recent geophysical data may prove misleading in identifying a submarine ridge. At the same time, a fixed height or length criterion would provide an arbitrary definition, as well as an inaccurate one in many cases.

A submarine ridge definition in the arena of international law of the sea is suggested here as: a rugged, elongate elevation or group of elevations rising or arching upward at least 1000 meters or more from the seafloor, the linear continuity of which either butts against or continues beneath a continent or extends until the downward inclination of its slope flattens to merge with the ocean floor. Relief on the flanks of a ridge may smooth steeply or gently to the gradient of the abyssal plain. Therefore, the base of the ridge slope may be found at the point of maximum change, or median among more than one nearly equal major changes, in gradient in the downward inclination of the ridge flank profile, beyond which the gradient flattens (0°) to the abyssal plain. Sedimentation is sparse in the deep ocean, unlike that characterizing continental margins, and so placement of the toe of the ridge slope commonly is not obscured by overlapping or slumping sediments.

This interpretation grants jurisdiction over a submarine ridge to the coastal state by virtue of the extension of the ridge seaward beyond the 200 mile zone. Where the ridge can be traced on the ocean floor more than 350 miles from the coast, jurisdiction thereon is discontinued at that distance. Where the ridge falls short of this cutoff, it is suggested here that its terminal boundary be located by straight lines no more than 60 miles in length connecting fixed points no further than 30 miles from the base of the ridge slope. Similarly, lateral boundaries of the ridge may be demarcated by straight lines no further than 30 miles from the base along its length.

Thus, Article 76 offers to the coastal state a plethora of alternative methods, linked to the physical fact of the continental shelf, by which it can legally delimit precise seaward bounds to its jurisdiction over mineral resources. The flexible language of the draft convention leaves many blanks to be filled - perhaps appropriately so - by the individual coastal nation, subject to approval by the aforementioned International Boundary Commission established by the Convention. In undertaking the application of the formulae to the United States continental margin, the physical and legal feasibility of areal maximization and resource optimization will be determined.

Delimitation by Article 76

Methodology. The delimitation of the continental shelf of the United States entails the regional demarcation of several lineations as dictated by Article 76: 200 and 350 miles, 100 miles beyond the 2500 meter isobath, base of slope, 60 miles beyond the base of slope, and sufficient sediment depths beyond the base of slope. The boundary lines drawn herein do not represent the definitive statement on United States shelf boundaries, but rather intend to serve as precise, and accurate to the degree possible, limits to shelf mineral jurisdiction. Error is inherent in present geophysical surveying and data compilation techniques, especially in areas where information is meager, as in the Arctic. However, based upon that which has been generated, this thesis presents a viable delimitation of United

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APPENDIX

Sources of Data Used in Map Construction

Plate 1

- Base from Richard M. Pratt, Atlantic Continental Shelf and Slope of the United States - Physiography and Sediments of the Deep-Sea Basin, Geological Survey Professional Paper 529-B (1968), mercator projection.
- Position of 'approximate' base of slope from:
  William Dillon and John Grow, Branch of Atlantic - Gulf of Mexico Marine Geology, USGS, Woods Hole, MA, personal communication, April 1982;
  K. O. Emery, Geology and Geophysics, WHOI, Woods Hole, MA, personal communication, April, 1982;
  William Ryan, Lamont-Doherty Geological Observatory, Palisades, NY, perosnla communication, February, 1982;
  Elazar Uchupi, Geology and Geophysics, WHOI, Woods Hole, MA, personal communication, April, 1982;
  original calculations - that is, the maximum of or median among changes in gradient (rise:run).
- Position of 'proposed' base of slope from Hollis D. Hedberg, "Ocean Floor Boundaries," Science, 204 (April 13, 1979), 141.
- Sediment thickness data from B. E. Tucholke, R. E. Houte, and W. J. Ludwig, "Isopach Map of Sediments in the Western North Atlantic Ocean," Lamont-Doherty Geological Observatory, 1980.
- 200 nautical mile measures correlated with National Ocean Survey (NOS), "Bathymetric Maps," National Oceanic and Atmospheric Administration (NOSS) (1981), 13003, 11009.
- All miles are nautical miles.
- Area from 'approximate' base = 458,427.6 square nautical miles.
- Area from 'proposed' base = 546, 207.8 square nautical miles.

Plate 2

- Base from Elazar Uchupi, "Bathymetric Atlas of the Atlantic, Caribbean, and Gulf of Mexico," WHOI Reference No. 71-72 (December 1971), mercator projection.
- Sediment thickness information from William Ryan, Lamont-Doherty Geological Observatory, Palisades, NY, personal communication, February 1982.
- Maritime Boundaries from Office of the Geographer, "Cuba-United States Hypothetical Equidistance Line" and "Mexico-United States Maritime Boundaries," U.S. State Department.
- Extended maritime boundaries are calculated hypothetical equidistance lines.

- Resources from: G. L. Dolton, et al, Estimates of Undiscovered Recoverable Resources of Conventionally Producible Oil and Gas in the United States, USGS Open-File Report 81-192 (1981);
  Keith A. Kvenvolden and Mark A. McMenamin, "Hydrates of Natural Gas: A Review of Their Geologic Occurrence," Geological Survey Circular 825 (1980);
  Frank T. Manheim, "Potential Hard Mineral and Associated Resources on the Atlantic and Gulf Continental Margins," in Program Feasibility Document, OCS Minerals Leasing, OCS Mining Policy II Task Force, National Technical Information SErvice (1979);
  ________ and Harold D. Hess, "Hard Mineral Resources Around the U.S. Continental Margin," Offshore Technology Conference Preprints, 4131 (1981);
  V. E. McKelvey and F. H. Wang, World Subsea Mineral Resources, USGS Miscellaneous Investigations Map I-632 (1969).
- All miles are nautical miles.
- Area = 295,909.0 square nautical miles.

Plate 3

- Base from T. E. Chase et al, "Offshore Topography of the Western United States," USGS Open File Map 81-443 (1981), mercator projection;
  T. E. Chase, H. W. Menard, and J. Mammerickx, "Topography of the North Pacific," Geological Data Center, Scripps Institution of Oceanography and Institute of Marine Resources (1977), mercator projection.
- Maritime Boundaries from:
  Office of the Geographer, "Mexico-United States Provisional Maritime Boundary," U.S. State Department map 503193, 12-76;
  Original calculations.
- 200 nautical mile measures correlated with NOS, "Bathymetric Maps," NOSS (1981), 530, 531, 18007, 18020.
- 350 nautical mile measures, extended maritime boundaries, and submarine ridge limits from original calculations.
- Resources from:
  Dolton et al, "Estimates of Undiscovered Recoverable Resources;"
  Manheim and Hess, "Hard Mineral Resources;"
  McKelvey and Wang, "Subsea Mineral Resources;"
  OCS Mining Policy Task Force, "OCS Minerals Leasing."
- All miles are nautical miles.
- Area = 390,745.0 square nautical miles.

Plate 4

- Base from NOS, "Bathymetric Maps - San Diego to Aleutian Islands and Hawaiian Islands," NOSS (1980), 530, mercator projection.
- 200 nautical mile measures correlated with NOS, "Bathymetric Maps," 530, 540.
- Submarine ridge limits from original calculations.

- Resources from:
  Manheim and Hess, "Hard Mineral Resources;"
  OCS Mining Policy Task Force, "OCS Minerals Leasing."
- All miles are nautical miles.
- Area = 943,021.4 square nautical miles.

Plate 5

- Base from American Geographical Society (AGS), "Map of the Arctic Region," (1975), stereographic projection.
- Base of slope from original calculations.
- Sediment thickness data from A. Grantz, S. Eittreim, and O. T. Whitney, "Geology and Physiography of the Continental Margin North of Alaska and Implications for the Origin of the Canada Basin," The Ocean Basins and Margins, 5, ed. by A. E. Nairn, M. Churkin, and F. G. Stehli (New York: Plenum Publishing Corp., 1981), 439-492;
  Arthur Grantz, Branch of Pacific-Arctic Marine Geology, USGS, Menlo Park, CA, personal communication, March, 1982.
- Maritime Boundaries from: NOS, "Bathymetric Maps," 500, 513, 514, 531, 16003; AGS, "Map of Arctic Region."
- 200 nautical mile measures correlated with NOS, "Bathymetric Maps," 500, 513, 514, 531, 16003.
- Resources from:
  Dolton et al, "Estimates of Undiscovered Recoverable Resources;"
  Kvenvolden and McMenamin, "Hydrates of Natural Gas;"
  Manheim and Hess, "Hard Mineral Resources;"
  McKelvey and Wang, "Subsea Mineral Resources."
- All miles are nautical miles.
- Area = 1,451,742.0 square nautical miles.

Plate 6

- Base from Richard M. Pratt, "Atlantic Continental Shelf and Slope of the United States."
- 'Approximate' continental shelf limits comprise, north to south: sediment thickness test, 200 mile arc, sediment thickness test, 350 mile arc.
  'Proposed' continental shelf limits comprise, north to south: sediment thickness test, 60 mile measure, sediment thickness test, 350 mile arc, 60 mile measure, sediment thickness test, 350 mile arc.
- Maritime boundaries from Office of Geographer "The Bahamas-United States Hypothetical Equidistance Lines" and Canada-United States Maritime Boundary Claims," U.S. State Department.
- Extended maritime boundaries from original calculations.

- Resources from:
  William Dillon, John Grow, and Charles Paull, "Unconventional Gas Hydrate Seals May Trap Gas off Southeast U.S.," Oil and Gas Journal (January 7, 1980), 124-130;
  Dolton et al, "Estimates of Undiscovered Recoverable Resources;"
  Manheim, "Atlantic and Gulf Reources;"
  ________ and Hess, "Hard Mineral Resources;"
  R. E. Mattick, Marine Geology, USGS, Reston, VA, unpublished map (1982);
  Brian Tucholke, George Bryan, and John Ewing, "Gas-Hydrate Horizons Detected in Seismic-Profiler Data from the Western North Atlantic," AAPG Bulletin, 61, 5 (1977), 698-707.
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