Marine Geospatial Software: Generating Economic Benefits from Hydrographic Data and Calculation of Maritime Boundaries

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SUMMARY

With its suite of software specially designed for hydrographic and marine applications, CARIS can help generate economic benefits from marine geospatial data.

Economic benefits will arise from the extension of the maritime states' sovereign territory under the United Nations Convention on the Law Of the Sea (UNCLOS). In this case, CARIS LOTS provides geodetic calculation and analysing tools to better process and interpret bathymetric data. Deep bathymetric data is required to define the 2500 m isobath and the morphological foot of the slope, both of which are used in the definition of criteria for delimiting the extension of the juridical continental shelf under Article 76 of UNCLOS. Once defined or resolved (in the case of disputed boundaries) the maritime limits and boundaries geospatial information can help generate revenue from offshore resources and their management.

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1. INTRODUCTION

Hydrographic survey data is becoming more useful as it becomes the basis for economic geospatial applications. New software tools are necessary to insure that the economic benefits are realized by the countries owning these data.

A tool for calculating maritime boundaries complying with the United Nations Convention on the Law of the Sea is presented as a way to use this survey information to establish or expand the national boundaries of coastal states.

2. GEOSPATIAL TOOL FOR RESOLUTION OF MARITIME BOUNDARY DISPUTES AND EXTENSION OF THE NATIONAL TERRITORY

CARIS LOTS was designed to calculate maritime boundaries in compliance with the United Nations Convention on the Law Of the Sea. These maritime boundaries and limits include bilateral maritime boundaries, the 3 nautical mile (3M) , the territorial sea (12 M), the contiguous zone (24 M) , the exclusive economic zone (200 M) and the extension of the juridical continental shelf beyond 200 M. Calculating and resolving these maritime boundaries clarifies the jurisdiction of the sovereign governments to which they belong.

Requirements of the United Nations Convention on the Law Of the Sea (UNCLOS) call for geodetic tools (United Nations, 1999). Many of the maritime limits and boundaries must be calculated geodetically rather than using map projections coordinates which bias the results.

2.1 Territorial Sea Baseline (TSB) as the Starting Point

A large majority of the maritime boundaries are derived from the territorial sea baseline model. One of the constraints of the juridical continental shelf's extent is directly calculated from the TSB model. This TS baseline model is maintained by national hydrographic offices as part of their surveying mandate. It forms the delimitation between the internal water and the territorial sea. It can use capes, headlands and low water elevations with permanent structures such as light houses as well as low water elevations within 12 M of the coast. More information on the use of low water elevations and their definition is described in the United Nations Convention on the Law Of the Sea (UNCLOS) (United Nations, 1983; United Nations ,1993).

The territorial sea baseline is a vital national limit defined by hydrographic criteria. It is based on published nautical charts data and recognized surveyed and published geographic points.

Two types of TS Baselines are used: straight baselines and normal baselines. To each type of baseline, a geodetic Envelope of Arcs (EoA) tool is associated. Straight segments from straight baselines contribute to the limits whereas each normal baseline point is considered individually to produce the EoA.

Support and maintenance of the Territorial Sea baseline is assured in LOTS by a provision of good data import tools, specialized digitizing tools and raster data display:

- BSB raster nautical charts
- GeoTIFFs of scanned geo-referenced paper charts
- MrSID satellite imagery
- TFW/TIFF georeferenced images

2.2 Resolving Disputed Boundaries

In order to determine a state's extension of its juridical continental shelf, bilateral boundary delineation or boundary dispute resolution may be necessary.

The extension of the national territory beyond 200 M means that new opposing neighbours can now share a boundary or that adjacent neighbours need to consider resolution of disputed boundaries or seaward extension of their bilateral boundaries. LOTS provides a tool for a mathematical solution called the median (for opposite states) or equidistant line (for adjacent states). This theoretical solution uses the TSB of each state to calculate an unbiased bilateral boundary dependant on inflection points of the two TSB models. This theoretical boundary can form the starting basis for boundary negotiations between two states.

Only the major inflection points on the TSB will contribute to the equidistant or median line between two states. Figure 1 (see next page) shows hypothetical median and equidistant lines that can be used for dividing the Arctic ocean beyond the 200 M limit. Figure 1 illustrates the construction lines of an hypothetical equidistant line between the US state of Alaska and Canada. Contributing points must come from both TSBs and have preferably 3 points at the same distance of the common equidistant point, 2 from one TSB and 1 from the other TSB. All distances for the median/equidistant line are calculated geodetically. The TSB for Canada is published on the United Nations internet site for the Division for Ocean Affairs and Law Of the Sea (DOALOS), Office of Legal Affairs. The TSB for Alaska was approximated by digitizing the water line from the raster backdrop of LandSAT TM7 satellite mosaics with resolution of 15 m on the ground. The equidistant line was extended to 600 M to allow for a significant extension of the continental shelf beyond 200 M. In the Canada Basin of the Arctic ocean, this assumption of a significant extension of the continental shelf is based on the large accumulation of sediment associated with the Mackenzie river delta.

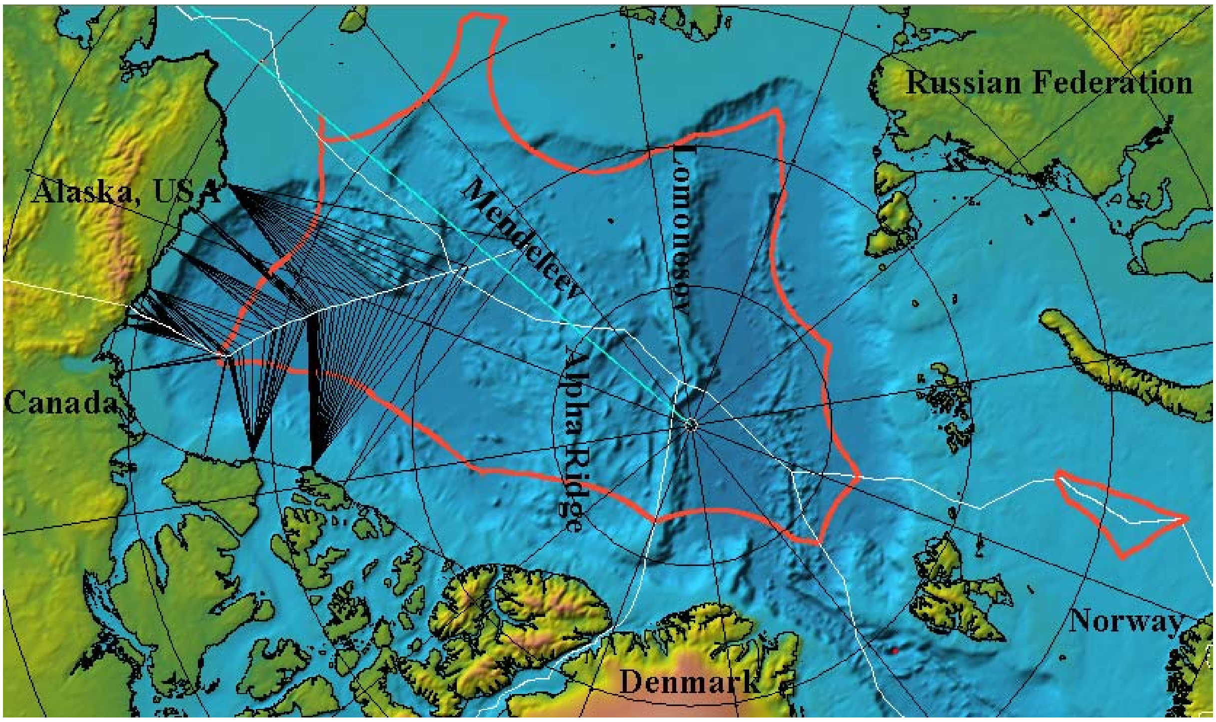

Figure 1 -The 200 M EEZ (in red) in the arctic with hypothetical bilateral median and equidistance lines (in white) separating all arctic states. ETOPO2 bathymetry is shown.

Note that the Blue line along the meridian at 168° 58’ 37”W outlines a boundary agreed between the Russian Federation and the USA (United Nations, 1990). However, this maritime boundary could be disputed by Canada and Denmark where it nears the north pole.

LOTS also provides other alternate tools for bilateral boundary delimitation: the bisector line, the loxodrome and the geodetic line. Some of these tools will also require the contributing points of TSBs from opposing or adjacent countries in their calculations.

2.3 Extension of the Continental Shelf under Article 76

The extension of the juridical continental shelf under article 76 of UNCLOS requires acquisition of new constraining bathymetric and geophysical survey data. Although actual hydrographic data is required as proof for a submission to the United Nations, it is highly recommended to conduct a thorough desktop study using all available national data and public domain data to evaluate the level of effort involved in such a submission..

Coarse bathymetric grids derived from Satellite altimetry and available ship track data can be used within the framework of a desktop study. ETOPO2 and the World Sediment thickness grid available from National Geophysical Data Center in Boulder, Colorado, USA are used to display results obtained with LOTS’s tools.

The extension of the juridical continental shelf beyond 200 M is defined by 2 constraints and 2 formulae:

- The distance constraint: 350 M calculated from the TSB (EoA).
- The depth constraint: 2500 m isobath + 100 M (EoA)
- The distance formula: Foot of the slope (FOS) + 60 M (EoA)
- The sediment formula or Gardiner line, sediment thickness equal to 1% of the distance from the FOS.

As indicated, the Envelope of Arcs geodetic tool plays an important role in the calculations.

2.3.1 Constraints

The distance constraint is based on the TSB. It is calculated as a 350 M geodetic envelope of arcs (EoA) in the same way as the 200 M EEZ was calculated.

The depth constraint is based on the 2500 m isobath. In the desktop study, this isobath can be extracted from a public domain gridded data set such as ETOPO5, ETOPO2 or GEBCO1. An envelope of arcs (EoA) tool is used to calculate the constraint at 2500 m + 100 M. Each point on the 2500 m contour is considered as a normal point for the EoA calculation.

The combination of the seaward-most part of each constraint will form the final constraint beyond which the seafloor and its subsoil cannot be claimed as an extension of the continental shelf. The 2500 m isobath from plateaus and submarine elevations of continental origin may push the constraint seaward as illustrated in Figure 2. Proof of the continental origin must however be provided.

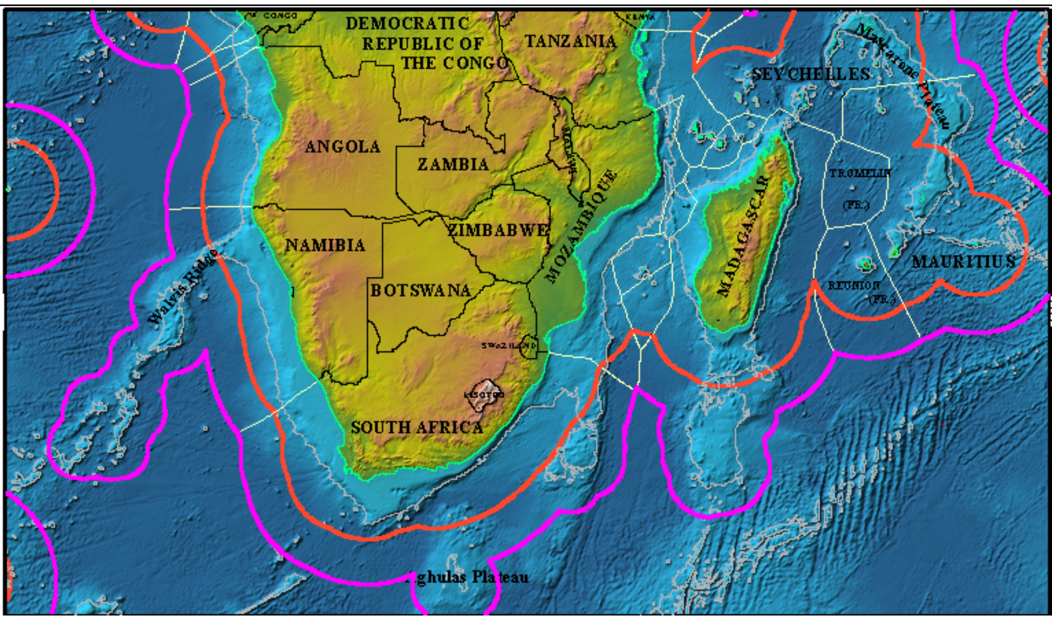

Figure 2 - Hypothetical constraints to limit the extension of the juridical continental shelf beyond 200 M for southern Africa (shown in magenta).

2.3.2 Formulae

The formulae are based on a geo-morphological parameter, the foot of the slope (FOS) which indicates the boundary between the continental slope and the continental rise. UNCLOS defines this FOS as the maximum change in gradient found on the slope. LOTS provides a FOS profile analyzer tool to perform this task.

Note that the work of the analyzer tool to locate the foot of the slope is made easier by the availability of a complete profile covering all the morphological provinces of the continental shelf: the continental plateau, slope, rise and abyssal plain.

LOTS uses bathymetric profiles of the morphological continental shelf to determine the FOS see Figure 3). Two methods of filtering the bathymetric profile allow generalizing the seafloor to remove small wavelength noise and automatically detect candidates for the FOS. The first filter is a Douglas Puecker piecewise linear best fitting solution (blue). The tolerance can be adjusted and some of the noise features can be filtered manually. This filter is indicated in blue and will yield FOS candidates at points of major changes in gradient. The second filter is a Fast Fourier Transform (FFT) which allows to low-pass the long wavelengths. The frequency content of the low-pass filter is adjustable. The second order derivative (gold) of the generalized morphological shelf function (red), shows the rate of gradient change. The highest second derivative’s peak is then the slope’s maximum change in gradient (FOS).

The user can choose the best candidate for his FOS by choosing one of the filters candidates which can define a conservative or an aggressive scenario. Selection of the FOS can also be done manually by dragging a FOS marker selector to the proper position.

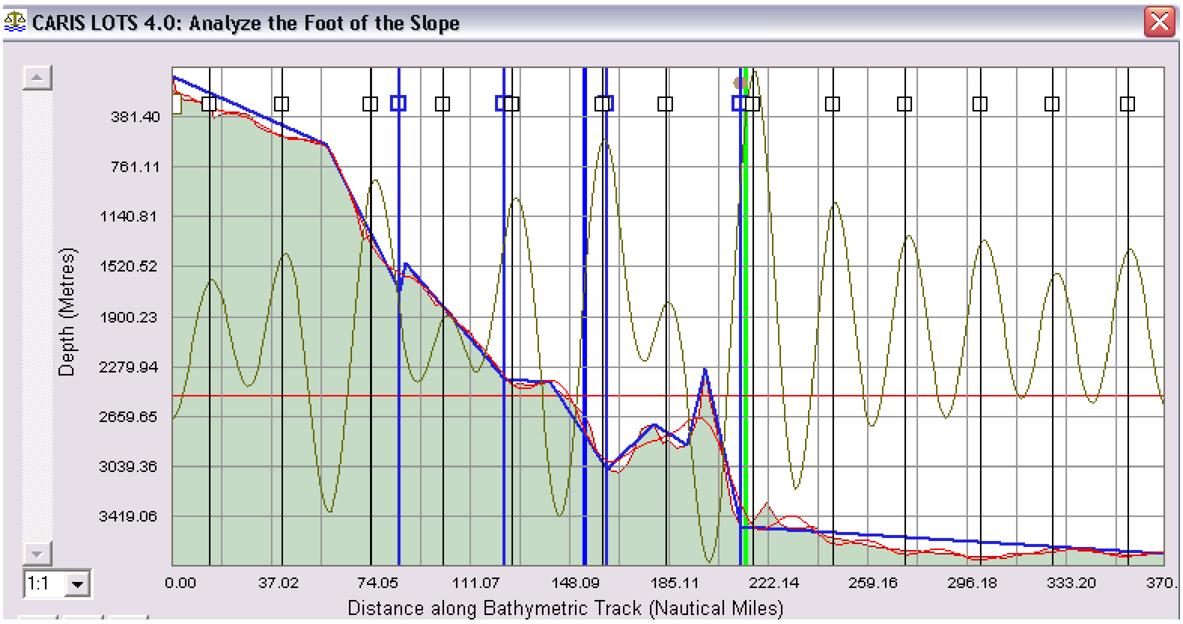

Figure 3 - FOS analyzer showing the two types of filters and the determination of the Foot of the Slope (gold marker).

FOS makers are created on the display and are used to calculate the FOS + 60 M. Strategic location of these FOS on spurs rather than canyons can promote the sovereign country's interests by pushing the formula seaward.

The Gardiner line also uses the FOS markers but requires sediment thickness information from seismic surveys. A special sediment 1% analyzer is used for this. A "sediment 1% marker" is placed where the sediment thickness is equivalent to 1% of the distance from a selected FOS marker. LOTS also provides a SEG-Y analyzer to allow digitizing of sediment sequences with different average seismic velocities to better extract seismic thickness from reflection seismic profiles

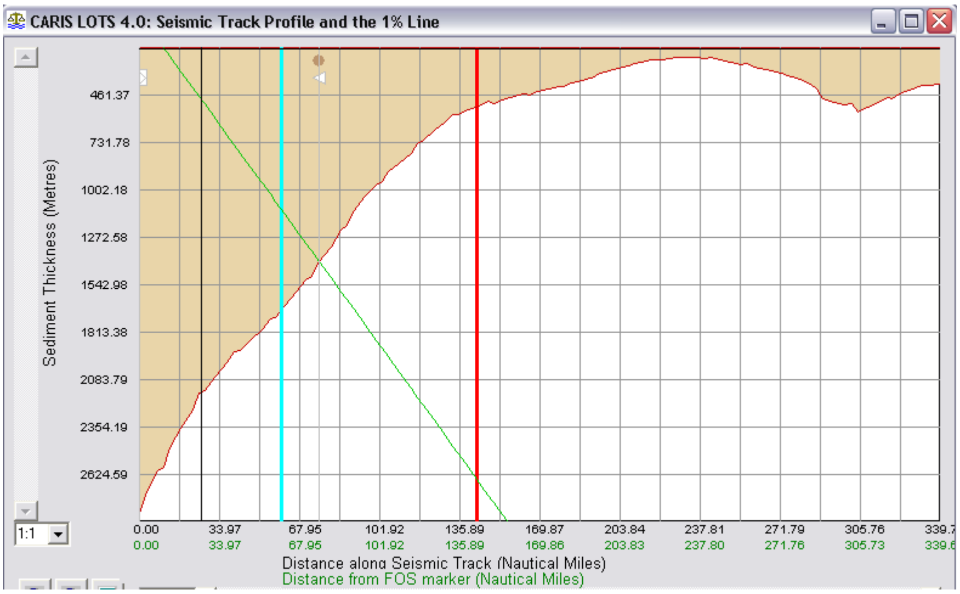

Figure 4 - Sediment thickness analyzer: placement of a marker where the sediment thickness equals 1% of the distance from the FOS (green line intersecting the sediment thickness).

The distance Formula and Gardiner line are combined into the Formulae line. This Formulae line is produced by retaining the seaward-most component of each formula line. Large contributions to area gains are associated with plateaus and submarine elevations of continental origin as seen in Figure 5.

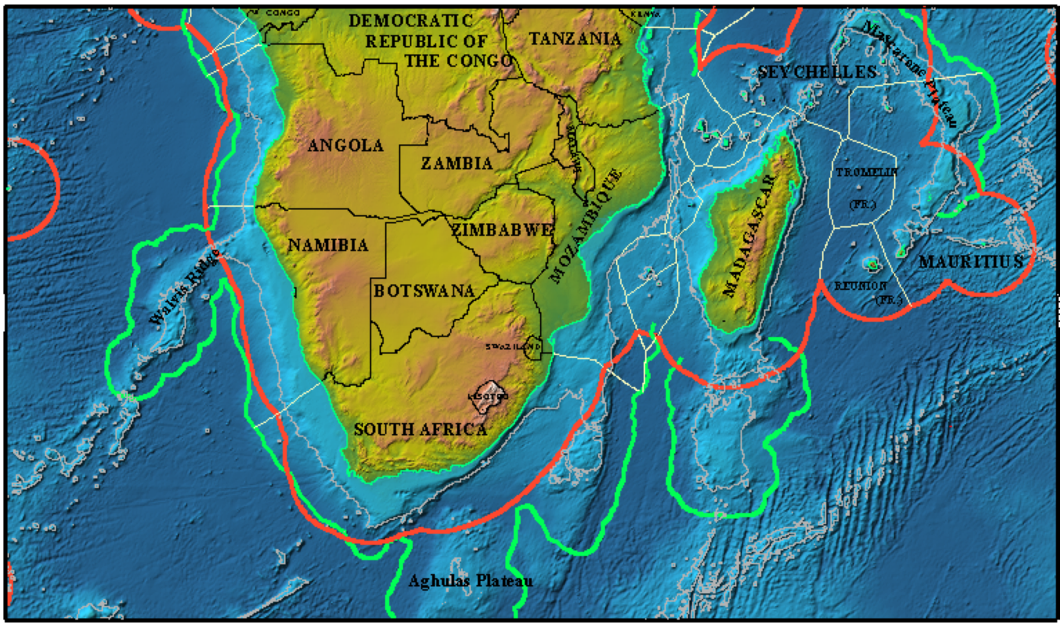

Figure 5 - Hypothetical formulae lines justifying the extension of the continental shelf beyond 200 M for southern Africa (shown in green).

2.3.3 <u>Outer limit</u>

The outer limit of the continental shelf is obtained by combining constraints and formulae.

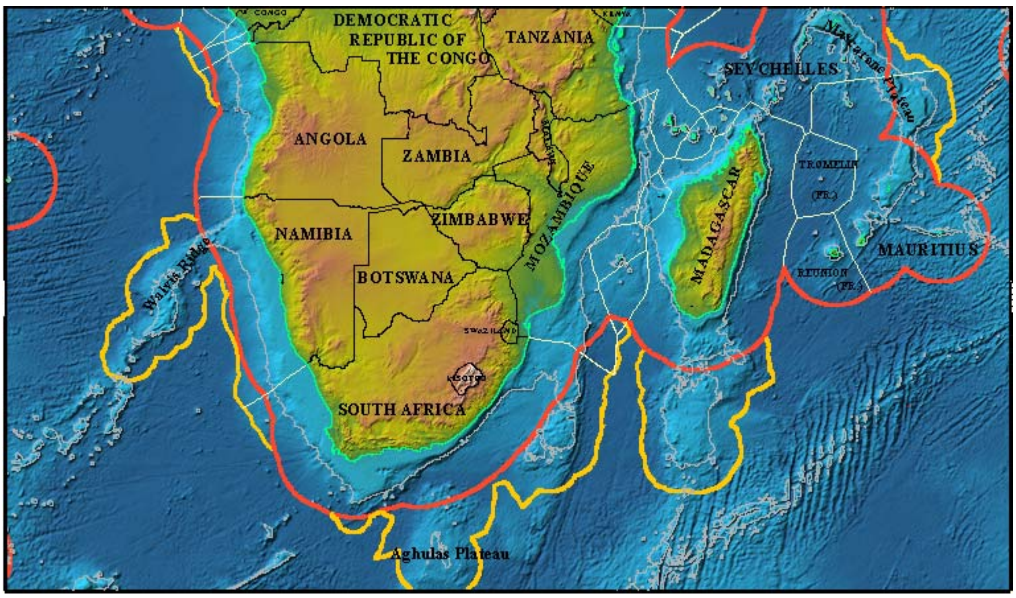

Figure 6 - Hypothetical extension of the continental shelf beyond 200 M for southern Africa (shown in orange).

Figure 6 shows an example of hypothetical outer limits of the juridical continental shelf for southern Africa. The juridical continental shelf can be extended up to the limit justified by the formulae but not beyond the constraint. Combining the landward-most part of the constraints and the formulae lines defines the outer limit of the juridical continental shelf under Article 76 of UNCLOS. Calculated hypothetical areas of continental shelf extension for a desktop study of southern Africa are given in the table below.

Hypothetical continental shelf extension under UNCLOS Article 76 restricted to Figure 6 Results of the geodetic area calculations	
Country	Area to gain (km^2)
Angola	37138.89
Gabon	24544.75
Ile Europa (France)	15196.22
Madagascar	653320.07
Mauritius	282555.78
Mozambique	63453.15
Namibia	663704.07
Seychelles	67099.26
South Africa	782594.77

In the cases where bilateral boundaries are disputed, these area calculation results will certainly change depending on the results of negotiations, treaties or international court rulings. Changes related to better, more accurate and more recent hydrographic and geophysical survey data will also affect the results. These areas of extension of the juridical continental shelf must be supported by accompanying proof of the validity of the continental origin of the associated plateaus and submarine elevations as evidence to the contrary (United Nations, 1983; United Nations 1999).

Once calculated, the claim for the new maritime limits must be submitted with supporting data and reports to the United Nations. After submission and acceptance, the new maritime limits will become national boundaries that can be published and included in official nautical charts. They also become available for inclusion in marine cadastres. These maritime limits and boundaries are then used to define rights and royalties on offshore leasing blocks, thus opening the way to additional national revenues from offshore natural resource exploration and exploitation.

4. CONCLUSIONS

Good quality hydrographic data combined with existing published marine geospatial data are key elements for generating economic benefits from the delineation of maritime boundaries using marine geospatial software such as CARIS LOTS.

Accurate hydrographic and shoreline surveys along with published nautical chart data information are essential to define the territorial sea baseline (TSB) model which impacts many of the maritime boundaries. In the delimitation of the outer limit of the juridical continental shelf, bathymetric data in deep waters is also needed for locating the 2500 m isobath and the morphological foot of the slope (FOS). A coastal state can use the results of the desktop study to investigate improvements to the TSB and to plan necessary bathymetric survey coverage.

Some of the economic benefits generated by the definition of new maritime boundaries or resolution of disputed maritime boundaries are:

- Clarity of boundary definition abating conflict between neighbours
- Clarity of jurisdiction promoting national wealth through management of undisputed offshore natural resource (such as offshore block leasing).
- Acquisition of new national territory under UNCLOS Article 76 where the natural resources of the seafloor and subsoil can be exploited.

As demonstrated in the hypothetical desktop study of southern Africa, significant gain in territory can be expected by many coastal states as a result of a claim for extension of their juridical continental shelf under Article 76 of UNCLOS. This endeavor, however, requires mobilization of resources both human and monetary, as well as the use of the right tools.

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BIOGRAPHICAL NOTES

Mr **José Alexis Primelles Cárdenas**, B.Sc. Geodesy and Cartography. IHO Cat-B Hydrographer, CARIS.

Before joining CARIS as a technical subject matter expert in CARIS marine software products, he worked as a hydrographer and cartographer for the Cuban Hydrographic Service for eight years. Mr. Primelles Cárdenas has been in the Marine GIS industry for 15 years now. Since year 2000 he provides technical support, training and consultation in several languages on hydrographic data management for nautical charting purposes as well as on delimitation of maritime boundaries.

Mr **Serge Lévesque**, B.Sc. Geological Engineering, M.Sc Oceanography, CARIS
Mr Serge Lévesque is Product Manager for CARIS LOTS at CARIS Headquarters in Fredericton, New Brunswick, Canada. As a consultant geophysicist, he worked for the Geological Survey of Canada on geophysical data compilations of the North Atlantic and Arctic oceans and on tectonic plate reconstructions at the Bedford Institute of Oceanography, Nova Scotia. Mr. Lévesque was Reseach Associate at the Atlantic Centre for Remote Sensing of the Oceans from 1993 to 1995. He worked in the private sector on remote sensing airborne surveys and in the offshore before joining CARIS in 1999. His fields of expertise at CARIS are in hydrographic data processing, digital chart production and the LOTS law of the sea software. He provides LOTS training and technical services since 2002.

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