WORLD MAPS WITH CONSTANT-SCALE NATURAL BOUNDARIES: CSNB 2007

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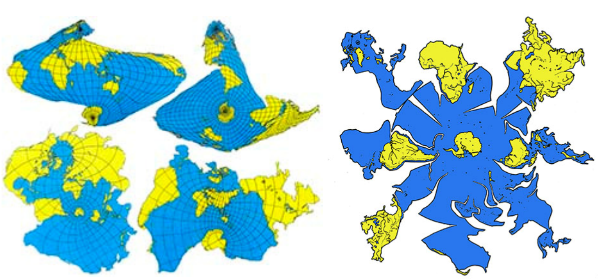
Introduction: Background and methods of world maps with constant-scale natural boundaries (CSNB) have been presented earlier [1, 2 & 3]; likewise its applications to extra-terrestrial bodies [4, 5, 6, 7, 8, 9 & 10]. Here, I illustrate CSNB's background, elaborate its methods, outline its uses for planetology, and discuss its mathematical implications.

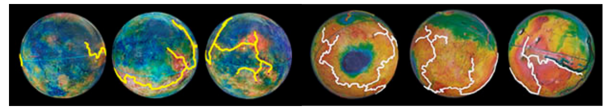
Background: With the invention of artificial satellites, notably Landsat, the 20th Century saw the introduction of AP Colvocoresses' and JP Snyder's space oblique Mercator projection [11]. Snyder, never one to take on a project unless its objective was perfectly clear [12], also found time to work with AF Spilhaus on a radical innovation in cartographic content: World maps with natural boundaries [13], as in Fig. 1 [14]. CSNB is a radical formal break with convention because, in shifting constant-scale to map edge, it abandons the xy "sheet goods" precedent (followed since the 16th century [15]) in favor of a simpler and apparently more fundamental model of a tree at constant scale, the tree being the cartographic interruption of surface. This shift in metaphor shifts the underlying mathematics a half step from geometry towards topology, specifically the realm of proto-topology (a term coined by E Panofsky in 1943 to describe certain constructions of the 16th Century polymath Albrecht Dürer [16]), because CSNB maps have the same delightful property as Dürer's once-novel developments of platonic solids: They always fold to a closed volume. CSNB's outputs are remarkable, as Fig. 1 right, but its methods challenge no draftsman--only techniques familiar to Mercator were used making these outlines—but CSNB would no doubt befuddle Edward Wright and his algebraic mapmaking descendants.

Mapping procedure: In CSNB, researchers choose map edges—natural boundaries--that constrain regions of interest. In contrast to the usual way of projection selection—finding a best (or least worse) mating of formal mathematical properties with the map's purpose—this edge selection leads directly to the map. By visual inspection or automated extraction [17] we divide a world's surface by a one dimensional, tree-like system (see Fig. 2) that is then transformed to the plane surface from the globe by tracing (when working by hand). Fig. 3 shows some flattened trees. The tree is bifurcated, endpoints acting as hinges, its branches swinging round to reconnect, and enclose a shape, a mapping of the surface. Each closed shape is then geometrically adjusted in its cross dimensions in ratio to respective great circle cross dimensions. Next, each shape is subdivided into graticles to fit local proportions. Fig. 3 illustrates these steps. Finally, digital content is pasted in, completing the maps (e.g., Fig. 4). This bifurcated-and-zigzag-wire analogy is quite different from the customary peeled-orange analogy because that fails to reduce things as far as CSNB does: Two dimensions in the orange peel versus one dimension in the tree. Thus from the standpoint of the advance of mathematics, CSNB may be an unavoidable tool for planetary science, regardless of the difficulties to come in merging it with traditional standards. Taken in hand-plotted totality, CSNB is cumbersome and tedious, like the binary system. Fig. 3 (top image) makes this quite clear. But, like the binary system, CSNB is amenable to digital capabilities.



Spilhaus world maps [14]
Images courtesy American Philosophical Society
A CSNB world map (1992)

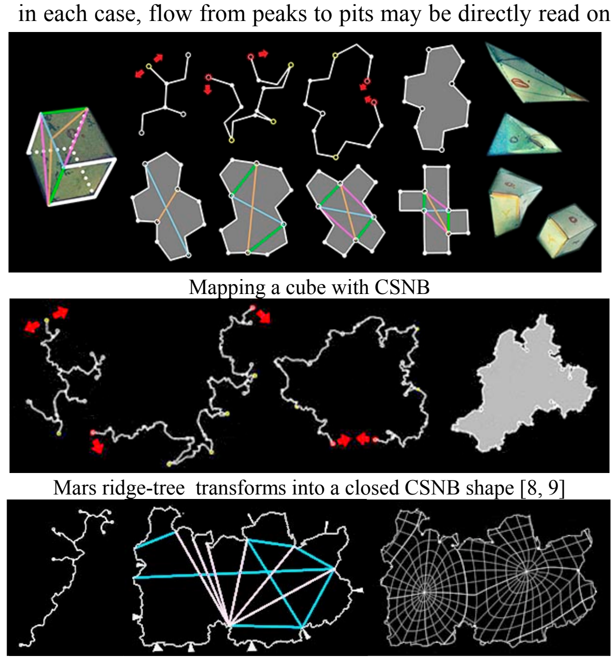
Figure 1: Conventional world maps with natural boundaries compared with CSNB



Venus ridges Mars ridges

Figure 2: Natural boundaries on globes, i.e., at constant-scale (see also Fig. 5 top left)

CSNB and comparative planetology: CSNB maps are useful when global patterns are at issue, and when, as with asteroids, objects are non-spherical. Curious planetary scientists might like to try Fig. 4's Mars, Venus, and Earth maps. They all have this précis: Ridges on topography above planetary mean (sea level on Earth) make their map's edge. For Earth the edge-set lies within an east-west hemispherical dichotomy; for Mars, within a north-south hemispherical dichotomy; for Venus, in contrast, it girds the Equator. Yet in each case, flow from peaks to pits may be directly read on



Mapping a cube with CSNB

Mars ridge-tree transforms into a closed CSNB shape [8, 9]

Venus-tree cross-map dimensions Gridded outline

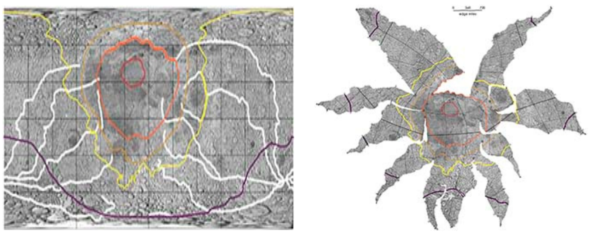
Figure 3: Various stages in making CSNB maps—what might be called: Applied descriptive proto-topology

the CSNB maps. The maps' overall shapes and outline articulations bespeaks differences in their planetary evolutions.

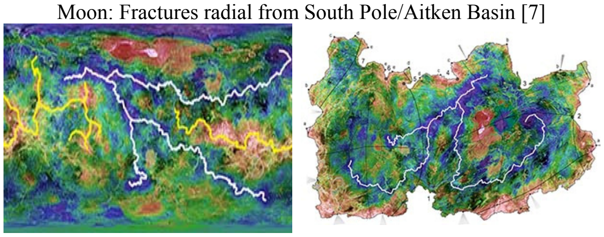
Fig. 4's Moon map is a sophisticated display of fracture patterns in the lunar crust. Conventional cartographic compactness is forgone in favor of a "splat" format that preserves proportions and shapes of antipodal fracture districts [7].

The CSNB mapping of Eros (a non-spherical world) achieves the customary cartographic objective--a compact shape--that, unlike the cylindrical map, is nowhere greatly distorted. See this map folded up in Fig. 5.

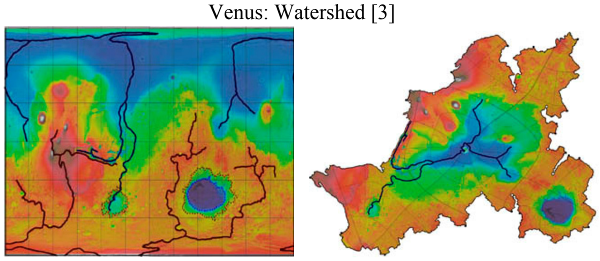
Prototopological forms: During the folding, the paper somehow always---without the slightest tearing or stretching—manages to keep up with the constant-scale edge. Sometimes, CSNB maps fold to volumes closely replicating the originating object (Fig. 5 top). Other times, when boundary systems have limited compass, CSNB maps fold to volumes highly truncated from their originating object (Fig. 5 lower rows). There is great educational power in this Eros model, and great huh-that's-funny mystery in these odd-shaped Mars and Venus examples: Anecdotal evidence that CSNB is indeed a novel development in the mature discipline of cartographic projection.



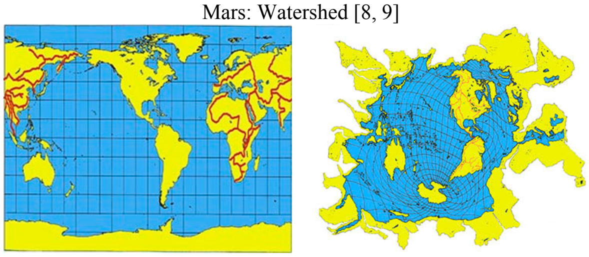
Moon: Fractures radial from South Pole/Aitken Basin [7]



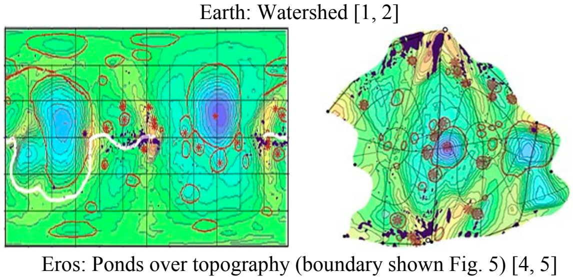
Venus: Watershed [3]



Mars: Watershed [8, 9]



Earth: Watershed [1, 2]



Eros: Ponds over topography (boundary shown Fig. 5) [4, 5]

Figure 4: Simple cylindrical and CSNB formats compared (CSNB edges are bold lines in left column maps)

Summary: These odd looking maps may appear arbitrary or weakly controlled, but the twin formal requirements of a) edge at constant scale and b) proportionate cross-map dimensions, insures that these seemingly wild shapes are precisely those shapes necessary to preserve both peripheral and mid-map local proportions, thus giving researchers a clearer and more germane picture of a global surface.

Future directions: Enceladus and Kleopatra are likely subjects for current methods, as well as updating existing CSNB Eros maps to show improved photomosiac [18]. In weather and climate studies, the CSNB edge can animate, i.e., change with changing conditions. Digital programming must be introduced for the idea to become widely practical. Fortunately, modern computers are more adept at mimicking graphical than algebraic methods.

References: [1] Clark CS (2003) *ISPRS WG IV/9* 34, XXX. [2] Clark CS et al. (2006) *LPS XXXVII*, Abs. #1207. [3] Clark CS and PE Clark (2007) *LPS XXXVIII*, submitted. [4] Clark CS (2002) *LPS XXXIII* Abs. #1794. [5] Clark CS and PE Clark (2006) *LPS XXXVI*, Abs. #1189. [6] Clark PE and CS Clark (2005) LPS *XXXVI*, Abs. #1432. [7] Clark PE and CS Clark (2006) *LPS XXXVII*, Abs. #1153. [8] Clark CS (2004) *Workshop on Hemispheres Apart, LPI Contri. No. 1213*, 9-10. [9] Clark CS (2005) *LPS XXXVI*, Abs. #2189. [10] Clark PE et al. (2007) *ISPRS WG IV/9*, submitted. [11] Snyder JP (1981) *USGS Bull. 1518*. [12] Colvocoresses AP (2006) telephone chat. [13] Spilhaus AF and JP Snyder (1991) *CGIS* 18, 4, 246-254. [14] Spilhaus AF (1991) *Memoirs Amer. Phil. Soc.* 196. [15] Boyer C (1968) A History of Mathematics, *PUP*, p. 329. [16] Panofsky E (1943) The Life and Art of Albrecht Dürer, *PUP*, p. 259. [17] Topological Data Structures for Surfaces (2004) *JW & S*, Rana S, ed. [18] Stooke PJ (2007) *LPS XXXVIII*, Abs. #1167.

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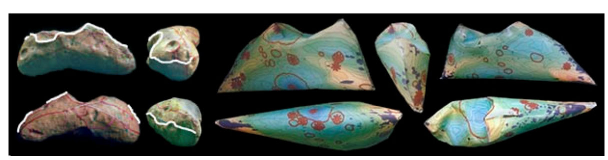
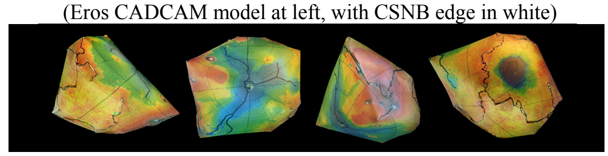
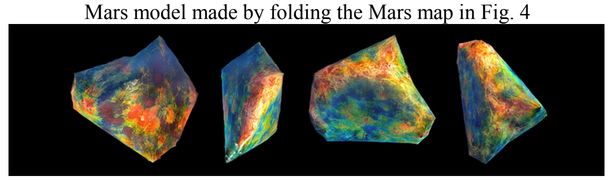


Eros model made by folding the CSNB Eros map in Fig. 4
(Eros CADCAM model at left, with CSNB edge in white)



Mars model made by folding the Mars map in Fig. 4



Venus model made by folding the Venus map in Fig. 4

Figure 5: Proto-topological forms made with CSNB maps