Mapping and Graphic Stress Analysis for Icy Satellites Using Constant-Scale Natural Boundary Methods. C. S. Clark[1], P. E. Clark[2], [1]Chuck Clark architect, 1100 Alta Avenue, Atlanta, GA 30307, rightbasicbuilding@gmail.com, [2]Catholic University of America/IACS@NASA/GSFC, Greenbelt, MD 20771, clarkp@cua.edu

Introduction: Constant-scale natural boundary mapping [CSNB] transforms the surface of any essentially globular object—spherical, triaxial, irregular—to the 2-dimensional plane in a manner which, unlike conventional projections, preserves proportion and adjacency of natural districts composing the object's surface [1]. This prototopological, i.e., foldable, shape may be usable as an engineering tool to determine stress, after the manner demonstrated by Maxwell [2], using either Eisenlohr projections [3] or CSNB as so-called Maxwell surfaces. Here we apply both methods to icy bodies (See Figure), to test whether CSNB can provide insights into surface morphology and geological activity, such as venting at tiger stripes on Enceladus, distribution of old and young terrain on Ganymede.

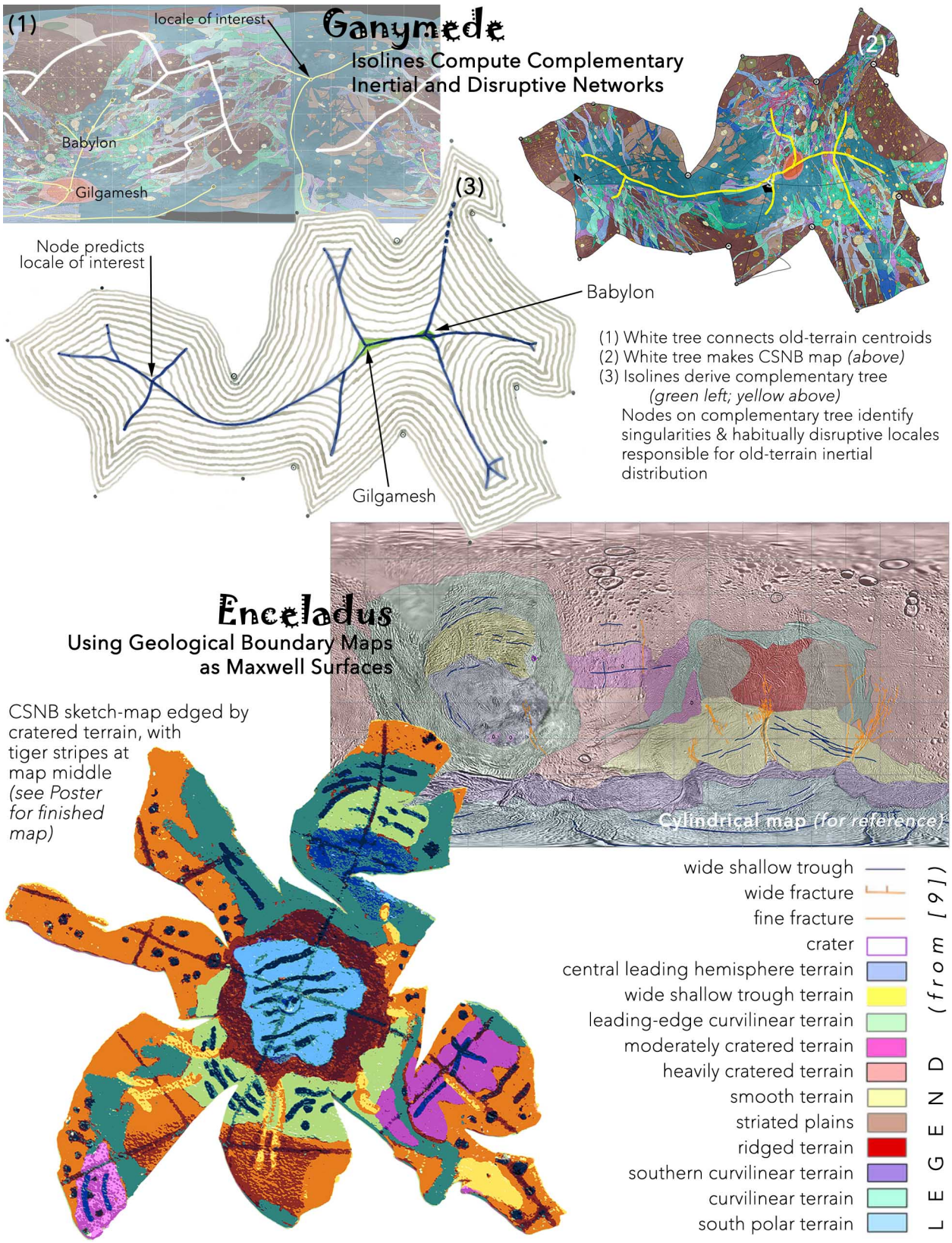
Background: Isolines (waterlines) have been used since Victorian times as both cartographic presentation technique [4] and as a geometric method for determining points of inaccessibility (oceanic points most distant from land). Here we use them as surface projections of boundary shape and force.

Geological Context & Boundary Selection for Icy Satellites Ganymede & Enceladus: The surfaces of these two satellites [5] are shaped by a combination of external and internal forces, including impact cratering resulting in mixing of non-icy and icy crust materials, tectonic episodes, and ongoing cryovolcanic processes stimulated to different degrees by tidal forces. See preliminary CSNB maps, with conventional maps for comparison, below.

Jovian satellite Ganymede's surface [6,7] exhibits two major terrains, 'light' and 'dark,' their boundaries clearly indicated by distinct albedo boundaries. The darker terrain (brown tones) is more heavily cratered and older. Its dark regolith deposits, postulated to be derived from sublimation of underlying ice-rich crust, are found within craters and on slopes of surrounding radial ridges and concentric arcuate structures or furrows (possibly multi-ring basin remnants). The more abundant light terrain (blue/green tones with tan indicating craters) is less heavily cratered and younger, typically consisting of intricate networks of crosscutting lineaments and smooth patches. It is dominated by extensional faulting, formed by cryovolcanic flooding of dark material with ice, and/or tectonic disruption and exposure of underlying ice at fault scarps. Also identified are 'relaxed,' older impact features called palimpsests (greens), and the largest impact basin Gilgamesh (orange). CSNB maps include dark-terrain-bounded and light-terrain-bounded maps, based on 'center lines' through each. Branches are formed from indications of inflections on the isoline map. Note the increased complexity, in terms of the number of branches and shape of dark-terrain-bounded light terrain CSNB map, from left to right. A rare four-branch intersection occurs in the complex Babylon region, an extensive palimpsest surrounded by distinct craters [8], as well as the occurrence nearby of the largest crater along the light terrain centerline.

Saturnian satellite Enceladus [9] exhibits both east-west and north-south asymmetries in terrain distribution, due at least in part to its tidally locked relationship to Saturn. North and south poles are clearly different: the south is actively erupting and resurfacing, whereas the north is an extension of the oldest, most heavily cratered terrain. At mid to low latitudes, heavily and moderately cratered terrain, facing permanently toward and away from Saturn along an oblate axis, alternates (every 90˚) with younger, more deformed terrains including striated, ridged, and curvilinear terrains (see color key) indicating far more complexity, resurfacing, and tensional stresses. We are in the process of creating CSNB maps with southern and northern poles at the center with boundaries representing centerlines of major terrains, as well as using the Eisenlohr projections to predict stresses.

References: [1] Clark P.E. and Clark C.S. (2013) "Constant-Scale Natural Boundary Mapping to Reveal Global and Cosmic Processes" *SpringerBrief,* 116 pp. [2] Maxwell J.C. On Reciprocal Figures, Frames and Diagrams of Forces *Trans. Roy. Soc. Edin.* 26, 1–40 (1869). [3] Snyder J.P. *An Album of Map Projections*, USGS Prof. Paper 1453, p. 184–185 (1989). [4] Christensen A. *Br. Cartogr. Soc.* 36 1 (1999). [5] Clark C.S., World maps with constant scale natural boundaries, http://rightbasicbuilding.com. [6] Collins et al, 2013, USGS Global Geological Map of Ganymede. [7] USGS,http://astrogeology.usgs.gov/search/details/ Ganymede/Geology/Ganymede_SIM3237_Database/ zip, accessed 1/1/15. [8] Collins G. personal communication, *LPS XLV* (2014) [9] Crow-Willard E.N. and Pappalardo R.T. *LPS XLI,* Abstract# 2715.


Ganymede
Isolines Compute Complementary
Inertial and Disruptive Networks
(1)
locale of interest
Babylon
Gilgamesh
(2)
(3)
Node predicts
locale of interest
Babylon
Gilgamesh
(1) White tree connects old-terrain centroids
(2) White tree makes CSNB map (above)
(3) Isolines derive complementary tree
(green left; yellow above)
Nodes on complementary tree identify
singularities & habitually disruptive locales
responsible for old-terrain inertial
distribution
Enceladus
Using Geological Boundary Maps
as Maxwell Surfaces
Cylindrical map (for reference)
CSNB sketch-map edged by
cratered terrain, with
tiger stripes at
map middle
(see Poster
for finished
map)
LEGEND (from [9])
wide shallow trough
wide fracture
fine fracture
crater
central leading hemisphere terrain
wide shallow trough terrain
leading-edge curvilinear terrain
moderately cratered terrain
heavily cratered terrain
smooth terrain
striated plains
ridged terrain
southern curvilinear terrain
curvilinear terrain
south polar terrain