VISUAL CALCULUS OR PERCEPTUAL FRIBBLE? WORLD MAPS WITH CONSTANT SCALE EDGES: A NOVEL PROJECTION METHOD, WELL-SUITED TO OUR ERA

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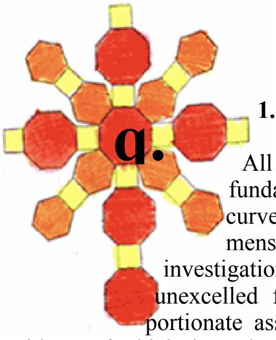
ABSTRACT: I introduce world maps with constant scale edges [**cse**], and show how cse encompasses both conventional projections and a new class of maps—*world maps with* ***constant scale*** *natural boundaries* [**csnb**]. Given context this, apparently, strains mathematics, rejoining a “battle” twixt numbers and geometry thought by some, perhaps, long-settled in favor of algebra. Here geometry betters its cousin, as when numbers, shy the idea of an irrational number, once lost the number-line’s challenge.
The idea of “natural boundary” mapping is simple, and in principle offers substantial advantage for studying natural, globular objects—dynamic and spherical planets like Earth and Venus, and odder things like Eros and Ios. But, such maps are difficult to make, and heretofore suffered the usual drawbacks of maps in general, e.g. distorted periphery and unintelligible edge. Computers would end the tedium of plotting points; and *constant scale* joined to *natural boundary* re-imagines maps.
I paint a methodology of projection-geometry turned inside out. It works from edge to middle rather than (Mercator, 1569) the other way ‘round. This begs no new from software arts. Peripheral distortion yields to peripheral “hinging”; field distortion, unlike customary rubber-sheetings, expresses as shrinkage--balanced along proscribed centrelines.
I trace to Albrecht Durer, and James Clerk Maxwell; I thread through Robert {Lee} Frost, and {Harold Calvin)} Marston Morse.
I tell how csnb may, in some situations, be approximated by equal azimuth projections.
I describe csnb’s novel properties in general and in plate tectonics by example.



1. OVERVIEW

1.1. Hallmarks of our Era

All scientists are familiar with the fundamental problem of representing curved or complex volumes in two dimensions, as on a map. Most investigations use stereographic views, which are unexcelled for small regions, but not for proportionate assessment of global events, issues or ideas--of which these days there’s a lot, and a lot known about them. The problem is making sense of lots of data.

1.2. The News:

csnb projections offer a new perspective on, and new tool to probe--processes and structures of irregular solid surfaces.

1.3. Motivation

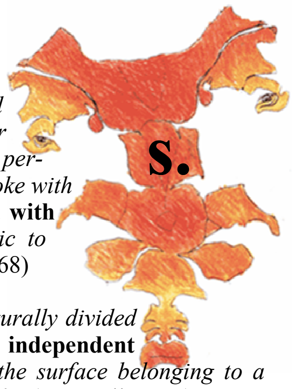
The rub being that digitizing csnb is a large bump in cartography’s road—a big effort of software design, at odds with existing systems, must be done.

2. HISTORY

2.1. some Quotations

“...instead of representing the ‘Archimedean’ solids in perspective or stereographic images, Durer invented the apparently original and, **if one may say so,** prototopological *method of developing them on the plane surface in such a way that the facets form a coherent ‘NET’* (Fig. 1.q) *which, when cut out of paper and properly folded where two or more facets adjoin, will form an actual, three-dimensional model of the solid in question.”* (Panofsky, 1943)

“...452 years ago, at a time when new discoveries had outmoded medieval and ancient maps, and explorations had widened horizons and created a need for better maps...-.Gerard Mercator employed the new principle of perspective to draw up a map which broke with the principles of Ptolemy and which, **with later improvement,** *has been basic to cartography ever since.”* (Boyer, 1968)

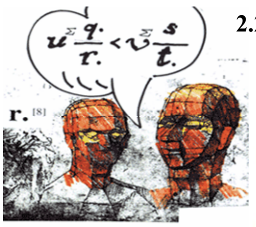


“Hence the whole earth may be naturally divided into...Dales, and also, **by an independent division,** *into Hills, each point of the surface belonging to a certain dale and also to a certain hill.”* (Maxwell, 1870)

“...in mathematics there are those who would like to keep algebra and geometry apart, or would like to subordinate one to the other. The battle became acute when the discovery of analytic geometry by Descartes made it possible to represent all geometry by algebra. The battle between geometry and algebra has been waged ***from antiquity to the present.****”* (Morse, 1950)

2.2. Discussion

If that’s history, that’s also a cryptic leapfrog; but space is dear.



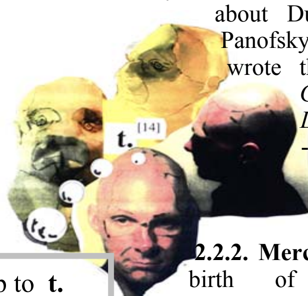


Figure 1: s. folds up to **t.**
A **q.**-like **r.** may be fashioned, but will fall short to **s.**-like continuations of **t.**

2.2.1. Durer: If any art historian could say *prototopological* about Durer, it’d be Princeton’s Panofsky. Marston Morse, who wrote the book on topology--*A Calculus of Variation in the Large,* a k a *Morse Theory*--was Panofsky’s colleague at the nearby Institute for Advanced Study.

2.2.2. Mercator: Boyer describes the birth of modern cartography. Mercator’s invention was soon re-imagined as formula (Wright, 1615), numbers seizing high ground of efficiency from geometry.

2.2.3. Maxwell: Maxwell’s genius for descriptive language sets the stage for Morse. His “independent” *dales* and *hills* are delineated by lines of *watershed* and *watercourse.*

These lines are overlapping systems, and form a grid—a net of strings. This is the vocabulary of cse/csnb.

Investigators vary their images by stepping from one grid to the other at points (*passes* and *bars* to Maxwell, just *passes* to Morse) where the grids intersect.

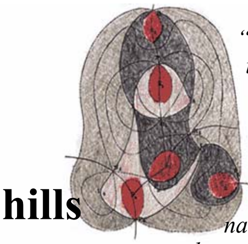
These lines may be any wiggly set one wishes, regardless of altitude: tectonic activity, the planet's largest lines, for example, or meteorology, our most fluid lines.

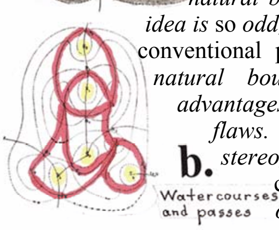
Maxwell's ups and downs have since become fundamental to physics—the "rolling ball" of gravity and electricity. This expands cse/csnb's scope.

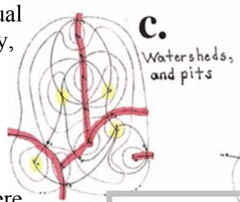
A Molecular Mapping Group (Autschbach, 2000) could make quick use of csnb. Carrying, without regard for a more factual way, the familiar illusion of Mercator into electron-density, merely because csnb is late to the gate, is correctable.

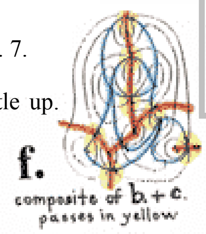
2.2.3.1. Examples: The borders of Figs. 5, 13 & 14 stay not only in Maxwell's topography, but also on *watersheds*. Fig. 4's upper images use *watersheds* and *watercourses* (current divides) as map edge, stepping from one net to the other where land meets ocean.

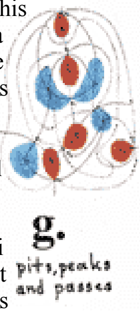
Trenches, in the status of "centreline," make for Fig. 7.











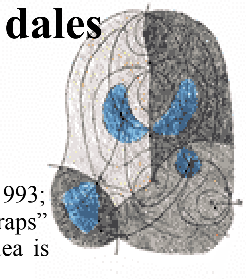


Figure 2: Maxwell's *chart of an inland basin,* rendered.

2.2.4. Morse: Morse was not one to give the battle up. Raoul Bott, his apprentice and later his biographer, said, "[Morse] was in a sense a solitary figure, battling the *algebraic topology,* into which his beloved Analysis Situs had grown."

2.3. World Maps with Natural Boundaries

The idea could be old-- da Vinci made a cloverleaf-shaped map that {should} fold up, and the subject was explored mid-20th century (Spilhaus and Snyder, 1993; Mulcahy, 1999). And, ancient, irregular map "scraps" appear in the light of csnb curious too, as the idea is easy to stumble upon.

2.4. World Maps with Constant Scale Natural Boundaries

A special case of world maps with constant scale edges.

Durer's drawings express planar facets. Durer didn't lay out the unfolded version of Fig.1.**r.** but, given **q.**, that may be imagined; compare it with **s.**, the same form--a human head.

Durer's cue is an exhaustion of planes, csnb's from Maxwell's strings. Both methods approach the ideal, but csnb gets there faster, so to speak.

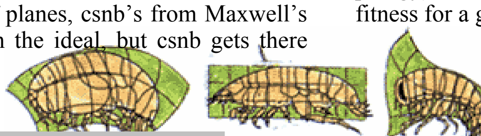
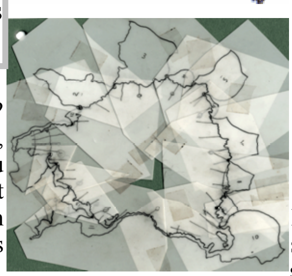


Figure 3: rubber sheets versus *Hinging.*



3. CONTEXT

3.1. Reactions to cse/csnb

"Continental divides for a map's boundary, you did it? I thought of that…couldn't figure out how, though….Centrelines, huh? I don't know what you mean. Ya got a formula?...No, too bad, they won't listen to you," said Athel Spilhaus, along with "I'm eighty-six today, ya know…" when I called to discuss a map I'd sent him.

"Oh, these are just D'Arcy Thompson-isms…" said cartographer Keith Clarke, in response to similar maps (Thompson, 1916).

"There is at present no software of any kind that supports any sort of maps with natural boundary, **especially** *[csnb]. The idea is* so *odd, there's no way to compare* [it to conventional projections]*....Sure, in principle natural boundary maps have intriguing advantages, but they suffer conventional flaws. So, with new, exciting stereography, why bother* [with strict cartographic product]*? ...And, no one's asking for it. If we had requests for natural boundary maps, we'd start making them….On the other hand, that's a difficult thing to do. Scissoring conventional projections, like Spilhaus, is* **extremely** *complicated.* [csnb] *is so different, there's no telling…"* (Mulcahy, 1999)

In 2000, the ACSM *Map Design Competition 2000* declined to premiate Figs. 13 and 14, entered in the category *other*, as "projections." The jury declined to open the discretionary *other* category.

Bott, on reviewing csnb informally, says he sees nothing in cse/csnb of Morse Theory.

Christensen, who defines himself as an analytic cartographer, says about csnb *I see no numbers there.*

3.2. Comment

Apparently, cse/csnb exploits something—a mutual normality betwixt independent divisions, perhaps--in Maxwell's work untouched by Morse.

4. RESPONSE

Apprehension has always been the lure, the charm of maps. It's remarkable that a demonstrably appropriate cartographic system --indeed *any* cartographic projection system, much less one Mercator could understand--is not digitized; remarkable save that maps are hobbled by centuries-old flaws, marginalized by digital stereography, and outpaced by analytic discoveries (topology). That strict cartography--a "mature" discipline--has the fitness for a great leap surprises.

That cse/csnb is not a D'Arcy Thompson-ism (Fig 3-top) is easy to see: his sheet's edge, which varies in length, is nonexistent in csnb. There is, of course, in csnb a reduction of area, 3-D to 2-D, but the anology is to the repair with a heat gun of a bulge in a mylar mirror, rather than the stretch of a rubber sheet.

The process is anamorphic sculpture rather than anamorphic drawing (Clark 1980). See Fig. 17.

Does loose cartography play to the eye's strength? Yes, but only ot the extent the eye sees. That's a limited arena, when global components play. Stereography never shows in one view all the surface of an essentially globular object.

Krantz puts well the present case for maps in a hot–image world (Krantz 1999). In addition, csnb permits regions defined by Maxwell's terms—worthwhile distinctions in principle—to be seen in entirety: Fig. 6 is the basin of Africa and Asia; Fig. 6 is the Antarctic basin.

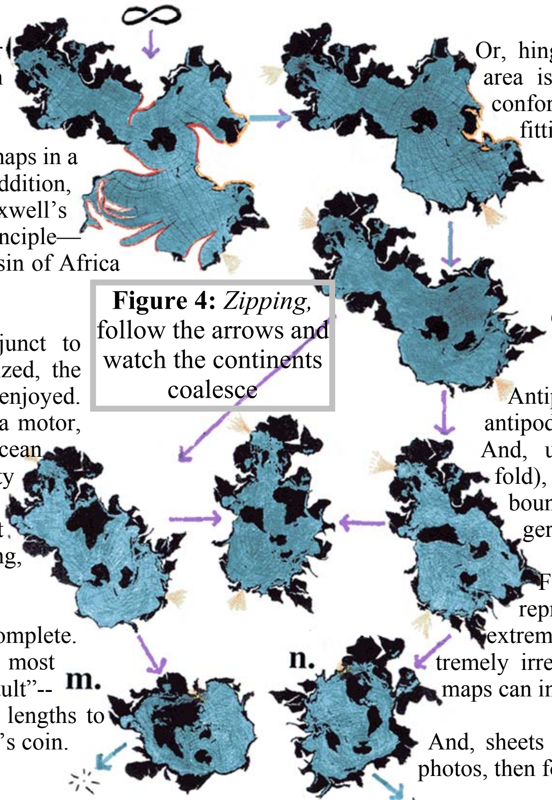


Figure 4: *Zipping,* follow the arrows and watch the continents coalesce

A common map use is as an adjunct to reasoning. Once a pattern is recognized, the map is needed not, though no less enjoyed. Figs. 5 & 6, like an on-axis view of a motor, show how earth's spin drives ocean currents. Yet Fig. 6 displays a subtlety obscure in Fig. 5. The currents clearly have two "ears"—Antarctica's great gulfs--each associated with a strong, northward, basement current.

Is analysis flawed? No, just incomplete. Poincaré and Morse, those most responsible--Morse might say "at fault"--for analysis' advanced state, went to lengths to show that it is but one side of thinking's coin.

5. METHODS

Boundaries never change in length, only in azimuth; boundaries define regions, and hence centrelines of regions. Centrelines change only in length, never in azimuth. If these restrictions were relaxed, and the edge could be any imaginary line (such a line of longitude) *and* could stretch, then conventional, formula-based projections—all of them--would result, as a little thought will show.

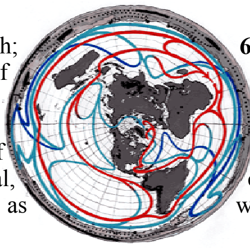


Figure 5: a world map bounded by the South Pole

Fig. 2 illustrates the sophistication of Maxwell's *independent divisions.* Compare the many patterns.

5.1. Zipping

Fig. 4's progression could continue in the zero direction, i.e. beyond **m.** & **n.,** to the limit of a single point, a mountaintop in Malaysia, Fig. 15, for example, where one crosses to the world of conventional projections, in the style of an *equal azimuth* (Unknown, c2000BC) which breaks the sphere at a single point. This suggests something—a cross-over spot between csnb and convention projections. See section **7**.

Conversely, the progression may reverse towards another crossover point, conventional orthography.

Figs.4.m. & n. enlarge as Figs.13.& 14.

5.2. Hinging

Changes in azimuth occur at hinges. It is not immediately clear that overlaps may always be eliminated, but adding hinge-points and altering the hinge-arcs has always worked.

Hinge-arcs may be set so they are as equal as possible, that minimizes enclosed area, and gives a folded model which fits in a sphere.

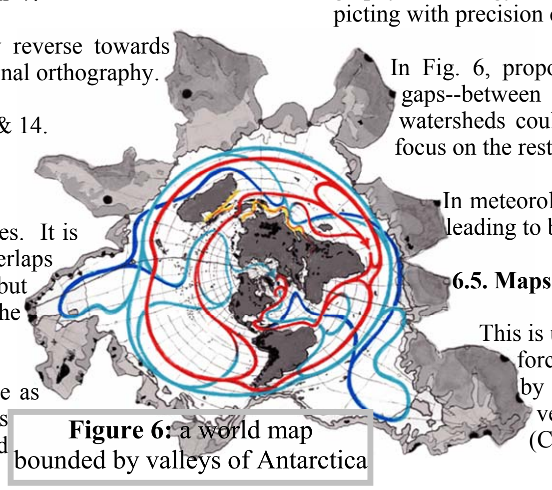


Figure 6: a world map bounded by valleys of Antarctica

Or, hinge-arcs may be set so the enclosed area is at a maximum, which maximizes conformality and produces a folded model fitting an egg.

Hinging is shown in Fig. 3.

6. PROPERTIES

6.1. Maps can be folded up to 3-D replicas

Antipodal geometry is preserved; maps' antipodes are conformal, unlike usual maps. And, unlike geodesic maps (which also fold), csnb's antipodes are naturally bounded, which begets geometry germane to inquiry. (Spilhaus, 1987)

For spheres, globes are the only true representation of the body, but for extremely irregular solids like Eros, or extremely irregular processes like tectonics, csnb maps can in principle be transformed to solids.

And, sheets could be economically printed with photos, then folded into photo-real models.

6.1. leads to **6.2.**

6.2. Maps can be "zipped up," and still folded

This advantage--**large-region unification**--follows from **6.1.** It speaks to csnb's quiddity: these maps may be zipped completely, or completely unzipped--zero and infinity, the basics--without loosing their "prototopological" nature.

6.3. Maps can represent solids with holes or deep fissures

It is difficult to construct a global weather map because of up- and down-welling between stratified altitudes. csnb can handle such problems. Another application, in physical chemistry, might be conformal representation of electron-density. And, in forensic anthropology, csnb might be helpful in identifying tribal affinities for museum-remains repatriation. (Clark, 2002)

6.4. Maps can compare multiple global parameters

In geophysics, csnb might be useful for showing seismic tomography; in biology, for tracking nuances in cell motion, or depicting with precision cell division.

In Fig. 6, proportionate regional differences—laps and gaps--between glacial watersheds and underlying rock watersheds could be clearly compared, without loosing focus on the rest of Earth's surface.

In meteorology, stalled hurricanes could be as clear, leading to better weather predictions.

6.5. Maps permit geometric harmonic analysis

This is useful for exploring natural boundaries of force or motion. A Medial Axis, described by *waterlining,* locates centroids, directs vectors, and assists in measure of distance (Christensen, 1999). See Section 8.

6.6. Highly zipped maps have curious characteristics

When csnb maps are folded up they have weak and strong axes, which may mimic an object's actual conditions, such as at Earth's trenches and spreading ridges.

At molecular orders of volume, this feature promises intriguing models. It implies that, in some sense, a molecule of, a case, hydrogen chloride, modelled in csnb, *inhabits* the solid modelled by the folded map.

csnb works well in pairs—maps with independent, complementary viewpoints. See Figs. 13 & 14.

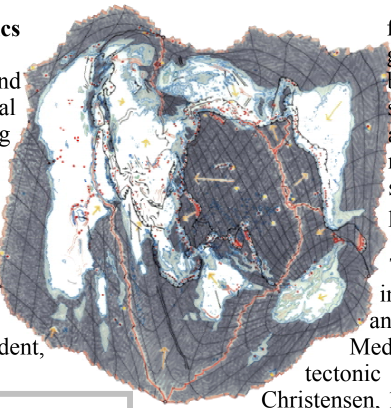


Figure 7: lithospheric stress patterns

7. SUGGESTION

csnb's effectiveness may be tested at Great Points--spots with global consequences or causes, such as big impacts, eruptions, storms, and tidal anomalies—because point-event csnb is logically synonymous with *equal azimuth,* which breaks the sphere at a single point. At relatively little effort, csnb may be tried by investigators.

Contemplate the currents: Fig. 6. has 5.'s data and a readable edge--Antarctica's valleys.

Why it's a good idea not to put map-midst a Great Point is counter-intuitive. Received wisdom says "centre," but this puts an interesting part at the usually obscure periphery. Yet in csnb, this displays as a single, potentially pattern-revealing, shape.

Compare Antarctica's two bays, obscure in Fig. 6., but proportionate in Fig. 5. See Fig. 16 for Key.

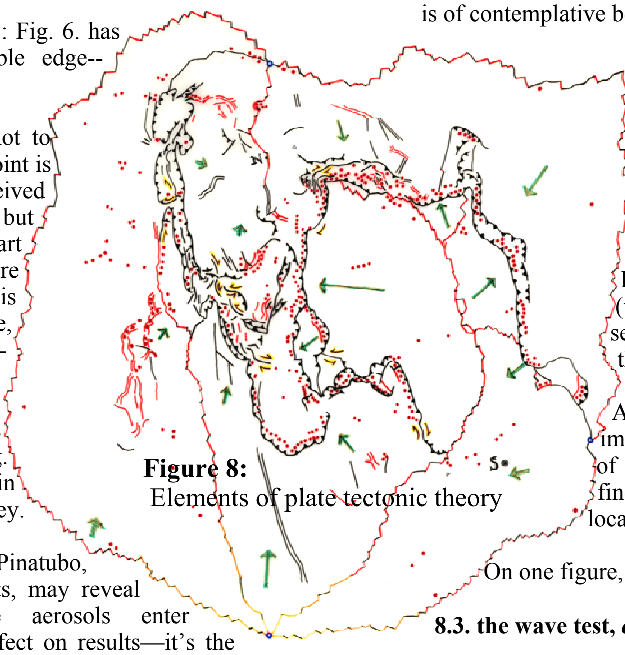


Figure 8: Elements of plate tectonic theory

Maps of Chicxulub and Pinatubo, two famous Great Points, may reveal little, because where aerosols enter stratosphere has little effect on results—it's the insignificance of a gas nozzle in a chamber—it all blends around the equator. However, such effects may be noticeable on bodies without atmosphere.

And, if Tarawa-edged maps make a pattern of tidal nodes, this may help with other, long-rumored anomalies—*great waves* off South Africa, and *maelstroms* off Norway—that might have the same interplanetary cause.

In meteorology, a statistical tie of Malaysian atmospherics and Atlantic hurricanes is also, a pictorial possibility. See Figs. 14 & 15.

8. EXAMPLE, PLATE TECTONICS

8.1. Summary

If the "orientation of the intraplate stress field is largely controlled by the geometry of the plate boundaries," and by "compressional forces," then these stresses may be depicted, animated, and refined by a *Wave Test* on a csnb map. It acts as a sort of graph paper, similar to a 19th century-science wave pool.

The map's boundary generates an initiating wave. Interactive animation—interference resulting from a Medial Axis--permits visual appraisal of tectonic stress patterns. (Zoback, 1992, Christensen, 1999)

And, insight may be gained haptically, by toying with *Mechanical Globes* constructed from csnb.

8.2. the wave test, *beginning*

An appropriate map configuration is reached by zipping and hinging until the resulting "first-order, mid-plate, uni-axial stress vectors" best fit the data. To some extent, especially in a new science like tectonics, this is a subjective choice. The shape is of contemplative benefit in its own right (Lowman, 1999).

For example, Fig. 7 shows at the map's boundary a subset of spreading ridge. Moments may be summed about a point; arrows may collect in a minimum circle; or, something analogous to a Maxwell String Diagram could be examined for equilibrium--tweaks---in the edge.

First-order stresses express as wave fronts (waterlines) inwards from map edge, and second-order stresses as functions carried on the first-order waves.

A map-user, finer tuning the edge to best fit image with experiment, so balances the "ratio of first- and second-order magnitudes," and finds that a "careful evaluation of observed local rotations" has been done.

On one figure, this is very "careful evaluation."

8.3. the wave test, *continuing*

Waterlining establishes the map's Medial Axis—a 2-D polyvector—that may then be merged with fractures, faults and trenches to make a new Medial axis, slightly out of harmony with the map's edge.

The process reverses. A new wave front projects outward from the medial mean, retuning the edge as investigators deem, or experiment dictates. Coulomb stresses can be incorporated, Christensen demonstrates, by varying the x y ratios of the wave fronts.

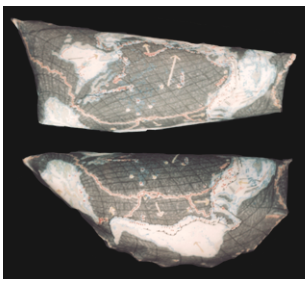


Figure 9: a folded figure 7.

Because of its edge, Fig. 8 (a simplified Fig 7) remains readable without coast- or sialic-lines.

An opposite map from Fig. 7 would put tectonic's least certain portion (continental fracture piles) at csnb's most accurate area—the edge. A *wave tets* on this might give a novel, and careful, evaluation of these fuzzy zones. Stress shadows might be clear.

Where the test fails to follow facts, or one seeks prediction, various scenarios of back- and forecasting could adjust the image; or would, save that csnb does not, in the world of conventional projections, exist.

8.4. Mechanical Globes

Ridges are interlaced, whence manipulable models—pull on the Indian Ocean triple junction and trenches in Indonesia and India subduct.

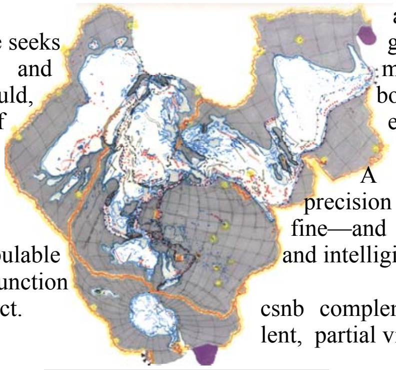


Figure 10: a map zipped midway Figs. 7 & 11

The meaning, if any, of Fig. 9's condensed form is unclear; but (if mathematics relates to nature) the "prototopological" quality of csnb must mean something; a puzzle, tantalizing to those who--as Morse put it in a birthday greeting to Robert Frost--*enjoy, and endure the joys,* of entertaining the unknown. (Morse, 1959)

At an intermediate level of zipping (imagine a coarsely peeled apple) spherical divergence gives folded model strong and weak zones, areas which correspond (perhaps only loosely correspond, but…) to each plate's uni-axial influence, the first-order intraplate stress field. See Fig. 10.

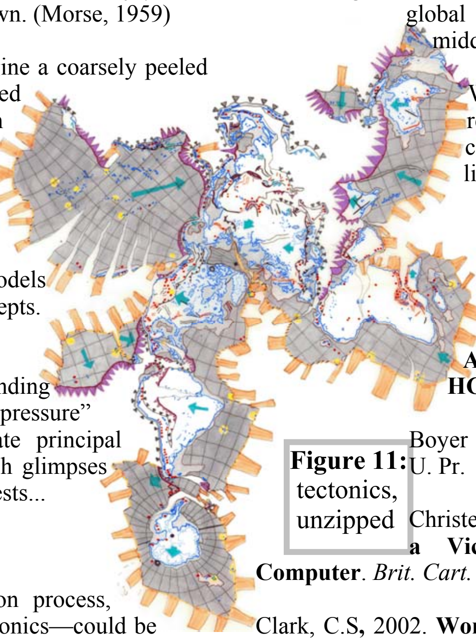


Figure 11: tectonics, unzipped

At minimal levels of zipping, maps and models could be handy explaining basic concepts. See Figs. 11 & 12.

Such models may be helpful for understanding "uncertainties such as hydrostatic pore pressure" and "relative magnitudes of intermediate principal stresses." Perhaps only glimpses, but such glimpses could be plugged back into further wave tests...

8.5. Example *enlarged*

This same sort of cartographic depiction process, applied here to very slow dynamics—tectonics—could be done in much faster meteorological dynamics; or much more complexity as swarms of asteroids, or molecular chemistry.

9. COMPENDIUM

An infrequent use of maps is as an *actual* reasoning method—a tool, like in orienteering, and Mercator's map, showing sailors' rhumb lines as straight. Others have explored conventional world maps with natural boundaries (Spilhaus 1991); csnb has an additional quality of an accurate edge, which admits of novel *actual* uses: a "global orthography" of additional study tactics.

csnb's proportional fidelity and intelligible perimeter--an edge with exact content--also plays to the eye's strength and, up a level, to the mind's strength. We are just not used to thinking of things in a globally proportionate way. Wild-shaped image? Deal with it. What *is,* is a rational string (presumably, or…change the boundary!), a calculus of locales.

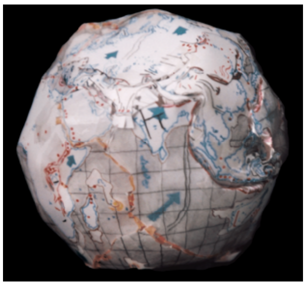


Figure 12: a folded up Figure 7

Tectonicists, discussing regions, don't say such and such plate-shape is unacceptable, irrelevant or avoidable, anymore than astronomers would say some galactic object is too bizarre to contemplate. csnb merely collects that chaos, that reality, within a border more definite than other systems--however extravagant the result.

A strict cartographic product, csnb admits of precision both the equal of convention—the middle is just fine—and the better, because csnb's periphery is accurate and intelligible.

csnb complements--perhaps perfectly—stereography's excellent, partial views.

csnb reduces from three, or conventional best two, to **one** the map number needed for a full look at something.

csnb brings--within a boundary's context---proportionality to global geometry, without degrading a map's middle regions.

With csnb, insight improves as pattern-recognizing capacity increases; and communications improve as images are limited.

10. REFERENCES

Autschbach J., et al, A 2000. **Where do the forces in molecules come from? A Density Functional Study of N2 and HCl.** *J. Phys. Chem.,* 104.

Boyer C. 1968. ***A History of Mathematics***. Pr. U. Pr.

Christensen, A.H.J., Jun 1999. **The Revival of a Victorian Art: Waterlining with a Computer**. *Brit. Cart. Soc.* 36, 1.

Clark, C.S, 2002. **World Maps with Constant Scale Natural Boundaries and the Asteroid Eros.** *Lun. Plan. Sci. XXXIII,* Abstract #1794, LPI., Houston (CD-ROM).

Clark, C.S., 1980, **Anamorphic Dining Room,** *The High Museum of Art,* Atlanta, GA

Durer, A., 1519. **…studies in construction of heads.** the *Dresden Sketchbook,* Saxon State Library, Dresden.

Durer, A., 1538. **"NET" of the Cuboctahedron Truncum.** From the *Fourth Book (on Geometry),* Saxon State Library, Dresden.

Krantz, S.C., 1999. **Conformal Mappings.** *Amer. Sci.,* 84, 436**.**

Lowman P.D., et al., 1999. **A Digital Tectonic Activity Map of the Earth.** *J.l of Geosciences Ed.,* 47, 5, 489.

Maxwell, J.C., 1870. **On Hills and Dales.** *Phil. Mag,* 40, 269. Taylor and Francis Ltd, www.tandf.co.uk/journals.

Mercator G., 1569 ***Nova et Aucta orbis Terrae.***

Morse, H.C.M., Feb 1959, Mathematics and the Arts. Bull Atom. Sci. XV, 2. See especially AUTHOR'S

NOTE, “which might interest Robert Frost.” See also letter to Robert, Mar 22, 1959. (Filed under Harold Morse) Rauner Spec. Coll., Dartmouth.

Mulcahy, K., 1999. *Phone call.*

Olson, D.W., Nov 1987. **The Tide at Tarawa,** *Sky and Tel.,* Sky Pub., Cambr. 22, 526-529.

several sources say, 1998. *“csnb--though debugging would be a nightmare--is in principle nothing but simple c-code.”*

Snyder, J.P. & Voxland P.M. 1989. ***An Album of Map Projections.*** *USGS #1453,* USGPO.

Spilhaus, A.F., and Snyder, J.P., Oct 1991. **World Maps With Natural Boundaries.** *GSIJ-ACSM,* 18, 4.

Panofsky, E., 1943. ***Albrecht Durer.*** Princeton U. Press, p. 259.

Thompson, D’A.W. 1916. ***On Growth and Form.*** Cam. U. Pr.

Unknown, c2000BC. **Equal Azimuth** was used by the earliest Egyptians, *probably for star charts*, say Snyder and Voxland.

Zoback, M.A., July 30, 1992. **First- and Second-Order Patterns of Stress in the Lithosphere: The World Stress Map Project,** *Journal of Geophysical Research,* 97, B8.

11. APPENDIX

11.1. Complementary map-pairs

Section 8.3 describes another type of map-pair, tectonic twins.

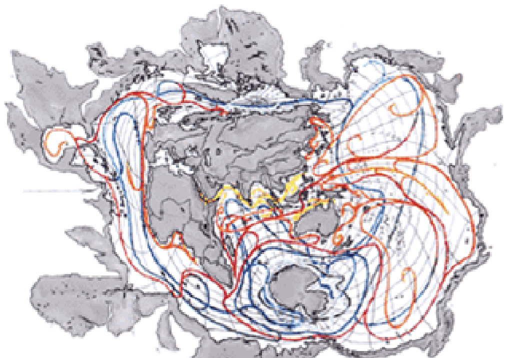


Figure 13: the basin of the Americas.

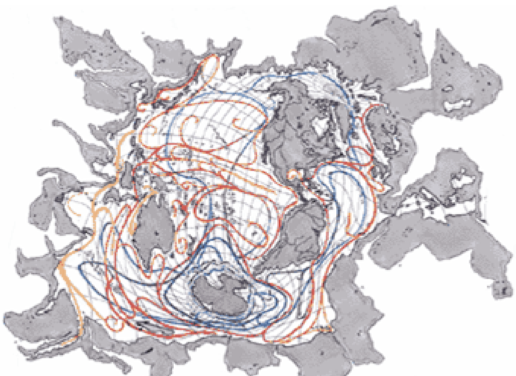


Figure 14: the basin of Africa and Asia

11.2. A Hurricane-chasing map?

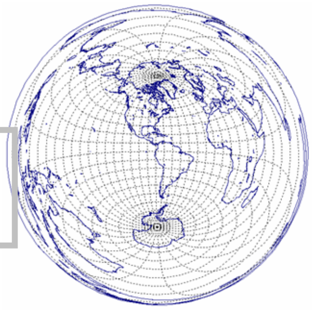


Figure 15: Malaysia-edged *Equal Azimuth*

11.3. Key for Figs. 5 & 6.

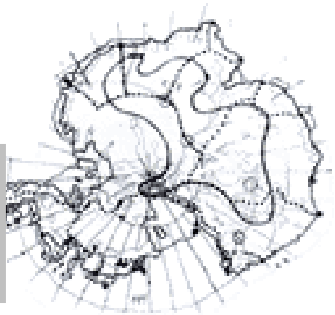


Figure 16: Antarctica—10,000 foot contour shown solid; *water-sheds* shown dotted.

11.4. Anamorphic Sculpture.

Figure 17: Anamorphic sculpture is one dimension more involved than anamorphic drawing.

12. ACKNOWLEDGEMENTS

Poet Robert Lee Frost arranged this toboggan at the top of the hill over 50 years ago; *cartographer* Ralph Freeman, U.S. Army Corps of Engineers, Jacksonville District, broke it free in 1964; *architect* (and *Houston native*) jim hagan gave it an needed nudge in 1990, and continues to contribute. I am grateful for the ride.

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Extraterrestrial Mapping Workshopper Randy Kirk encouraged this paper. For the curious (from Facts on File, and other sources), the word “extraterrestrial” was first recorded, and perhaps invented by H.G. Wells, c1900. The first American use *“…on the form that intelligent extra-terrestrials might have…”* was by L. Sprague de Camp, Design for Life, Astounding Science Fiction, May 1939, Street & Smith Pub., NY.