The Fundamental Laws of GIScience

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Tests of a law

- An empirical statement
  - verifiable with respect to the real world
  - the Law of Utility Maximization
- Always true
  - deterministic?
  - does a single counterexample defeat a law?
  - the Second Law of Thermodynamics
  - Newton’s Laws of Motion

Can there be laws in the social sciences?

- Not if a single counterexample can defeat a law
- Ernest Rutherford: “The only result that can possibly be obtained in the social sciences is: some do, and some don’t”
  - a candidate for the First Law of Social Science

Proposed tests of laws in GIScience

- Based on empirical observation
  - observed to be generally true
  - with sufficient generality to be useful as a norm
  - deviations from the law should be interesting
- Dealing with geographic form rather than process
  - to distinguish laws of GIScience from laws of geography, ecology, hydrology, …

"On laws in geography"

- Golledge and Amadeo (1968) *Annals of the Association of American Geographers* 58(4): 760-774.
  - cross-section laws
  - equilibrium laws
  - historical laws
  - developmental laws
  - statistical laws

The value of laws

- Teaching
  - laws allow courses to be structured from first principles
- System design
  - laws provide the basis for predicting performance, making design choices
- Physics envy
  - an asset of a strong, robust discipline

Tobler’s First Law

- “All things are related, but nearby things are more related than distant things”
  - W.R. Tobler, 1970. A computer movie simulating urban growth in the Detroit region. *Economic Geography* 46: 234-240
  - implies process as much as form
  - “nearby things are more similar than distant things”

Validity

- “Nearby things are less similar than distant things”
  - negative spatial autocorrelation
  - possible at certain scales
    - the checkerboard
    - retailing
  - but negative a/c at one scale requires positive a/c at other scales
  - smoothing processes dominate sharpening processes

Formalization

- Geostatistics
  - variogram, covariogram
  - measuring how similarity decreases with distance
  - parameters vary by phenomenon
    - does this make TFL less of a law?

Utility

- Representation
  - GI is reducible to statements of the form <**x**,**z**>
  - the atomic form of GI is unmanageable, encountered only in point samples
  - all other GI data models assume TFL
- Spatial interpolation
  - IDW and Kriging implement TFL

If TFL weren't true

- GIS would be impossible
  - a point sample is useful only with interpolation
- Life would be impossible

Expanding the horizons

- Other spaces
  - are there spaces for which TFL is not true?
  - digits of π
  - genome
- Other laws of GIScience

Candidate laws

- All important places are at the corners of four map sheets
- Montello and Fabrikant, “The First Law of Cognitive Geography”
  - “People think closer things are more similar”

A second (first) law

- TFL describes a second-order effect
  - properties of places taken two at a time
  - a law of spatial dependence
  - is there a law of places taken one at a time?
- Spatial heterogeneity
  - non-stationarity
  - uncontrolled variance

Corollaries of the second law

- There is no average place on the Earth's surface
- Sampling is problematic
  - one must visit or map all of it to understand its full complexity
- Results depend explicitly on the bounds of the study
- The Noah effect
  - there is a finite probability of an event of any magnitude
  - to observe an event of a given magnitude it is simply necessary to wait long enough

A GIScientist's Noah effect

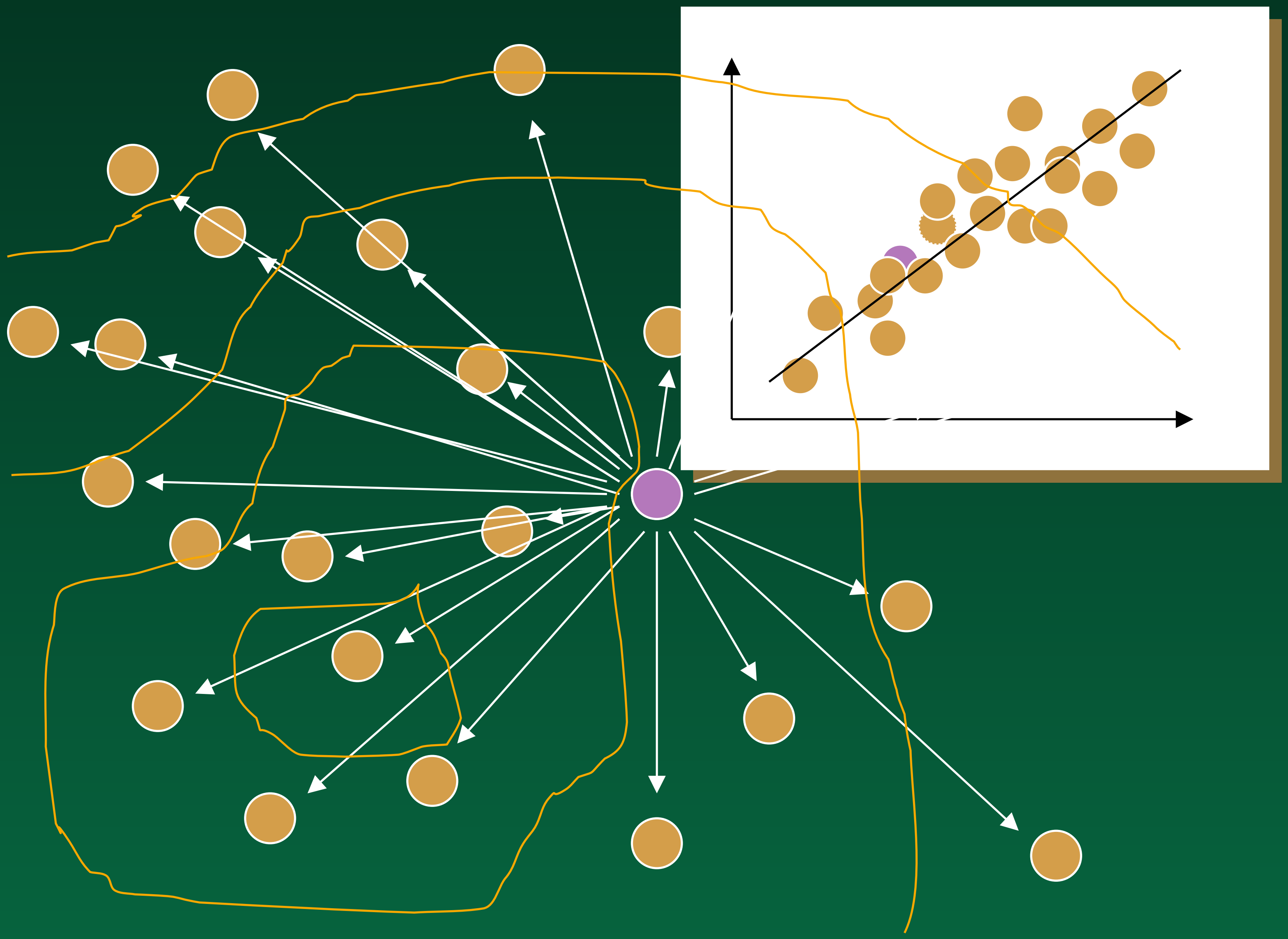
- The Eden effect
  - El Dorado
  - to find a feature of any magnitude it is sufficient to look far enough
    - but unlike time, the Earth's surface is limited
- The Pareto distribution or rank-size rule
  - plot log rank against log size
  - a model of the extreme upper tail of distributions
  - fits well to the world's largest:
    - cities by population
    - lakes by area
  - but not mountains by elevation

Practical implications of the second law

- A state is not a sample of the nation
  - a country is not a sample of the world
- Classification schemes will differ when devised by local jurisdictions
- Figures of the Earth will differ when devised by local surveying agencies
- Global standards will always compete with local standards

Implications for analysis

- Strong argument for place-based analysis, local statistics, geographically weighted regression
  - a middle ground in the nomothetic/idiographic debate

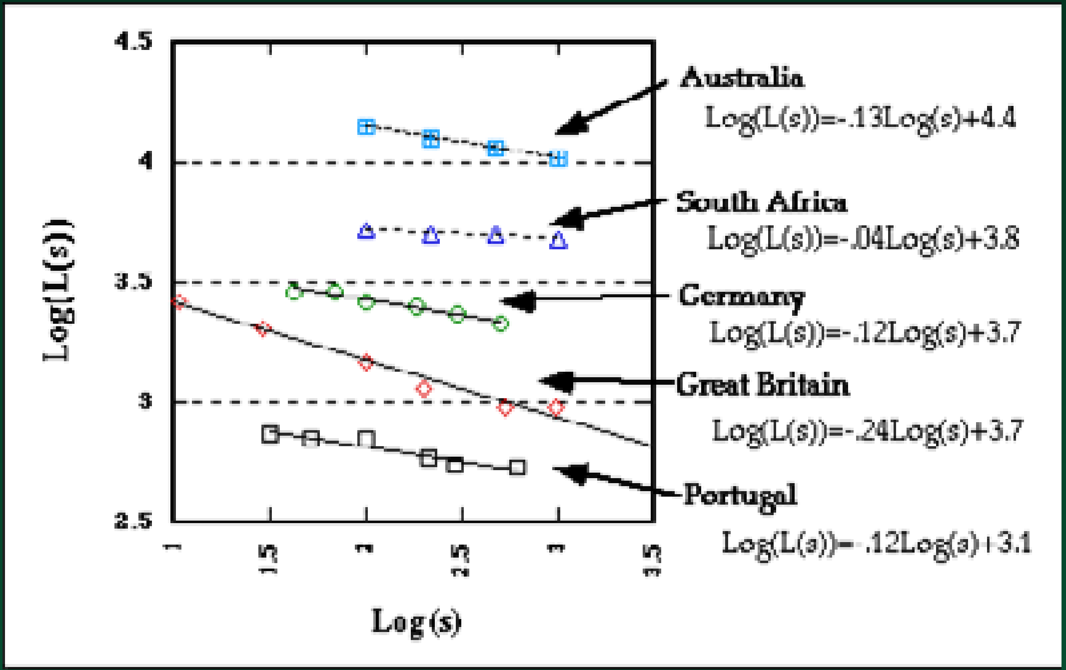


Possible corollary of the heterogeneity law

- For every conceivable pattern in two (three) dimensions there exists an instance on the Earth's surface
  - for every GIS algorithm/indexing scheme/data model there exists a data set for which that algorithm/indexing scheme/data model is optimal
  - "There are more things in Heaven and earth, Horatio, than are dealt with in your philosophy"

3) A fractal principle

- The closer you look the more you see
  - and for many natural phenomena the rate is orderly
  - Richardson plots
  - lengths of national boundaries
    - Spain and Portugal
    - context of 1920s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Germany
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Great Britain
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Portugal
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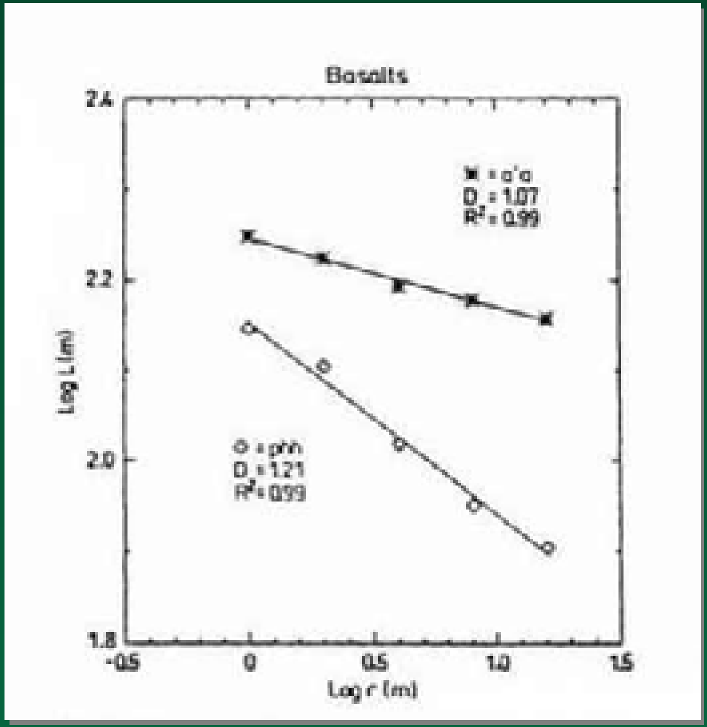
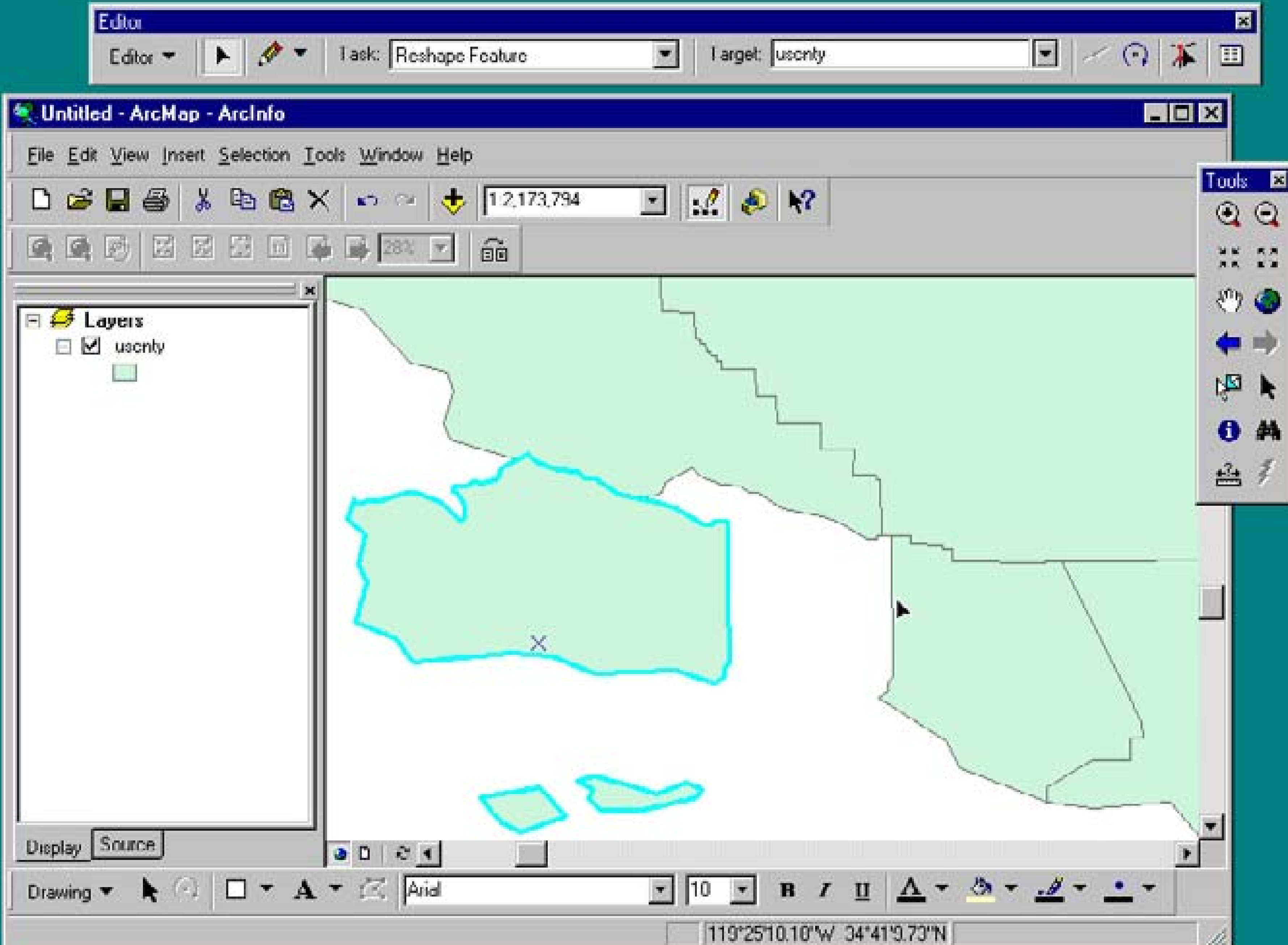

Basalts
Log L (m)
Log r (m)

Practical implications

- Indexing schemes, quadtrees
  - partitioning of information at different scales
- Length is a function of spatial resolution
  - and variously under-estimated in GIS
  - as are many other properties
    - slope
    - soil class
    - land cover class
  - spatial resolution should always be explicit in GIS analysis
    - easy in raster
    - much more difficult in vector

4) Objects and fields

- There are two ways of conceptualizing geographic variation
  - as discrete, countable objects littering an otherwise empty table-top
  - as a collection of continuous fields, functions of location



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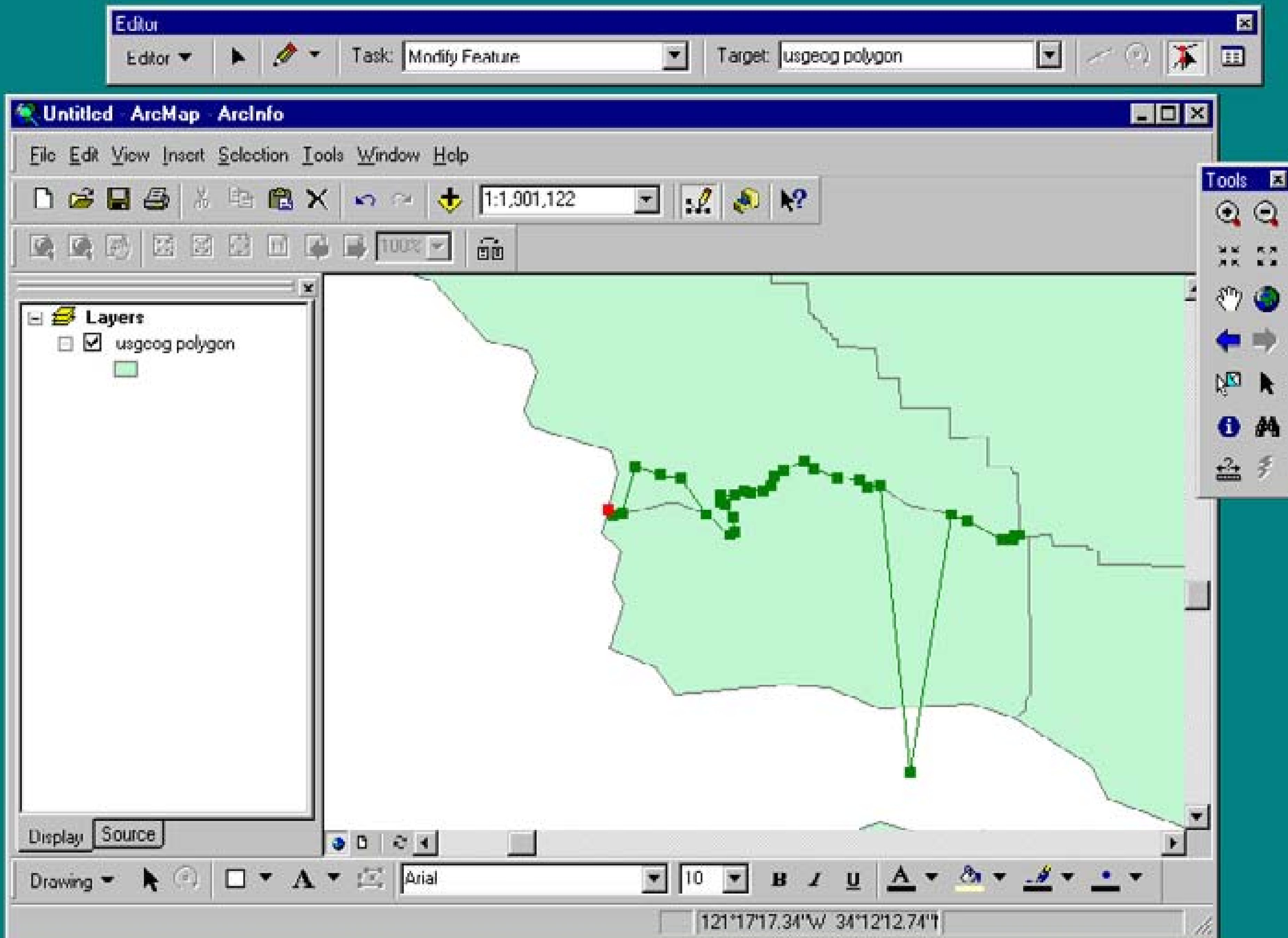
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121°17'17.34"W 34°12'12.74"N

5) The uncertainty principle

- No representation of the Earth's surface can be complete
  - no measurement of position can be perfect
  - a GIS will always leave doubt about the true nature of the Earth's surface


display.june.stp - Display
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Practical implications

- Store measurements not coordinates
  - measurement-based GIS
- Allow topology to trump geometry
- Never test for equality of position

Derivative principles

- Principles that can be derived by combining fundamental ones
- TFL and the principle of uncertainty
  - errors will be spatially autocorrelated
  - relative accuracy will be better than absolute accuracy
  - a map whose absolute positional accuracy is no better than 50m will still show objects in their correct relative location
  - elevations that are accurate to no better than 7m can still be used to estimate slope

Conclusions

- Laws exist in GIScience
  - and should be stated
  - formally or informally?
- Generalizations about the geographic world can be blindingly obvious
  - but stating them is important
- Laws have practical value in GIScience
- Laws have pedagogic value
  - the nature of geographic information
  - how special is spatial?