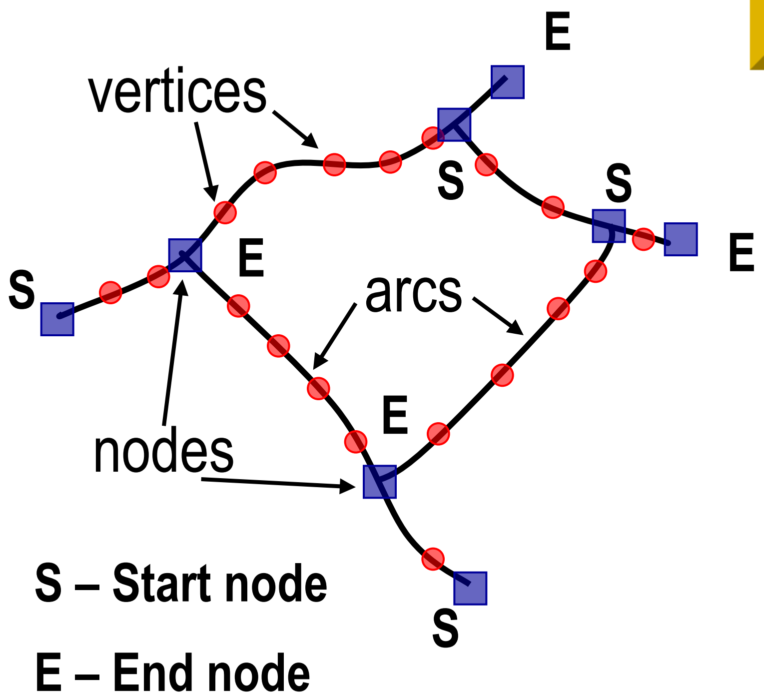
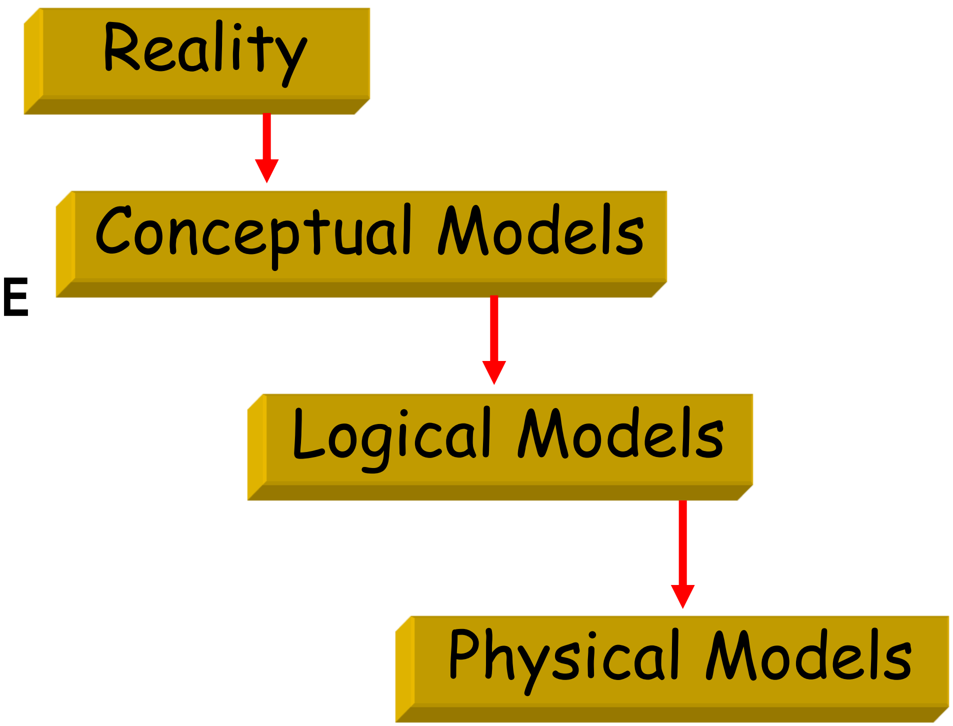
Maps as Numbers: Data Models





The Task

- An accurate, registered, digital map that can be queried and analyzed.

Translate:

Real World, Paper Map ➡ Computer Files

Spatial Data Models, Topology

Entity Info. ➡ Queriable Database Files

Relational or Object-Oriented Databases

Relate Spatial Coordinates to Entity Info.

"Spatial DBMS" software = GIS software

Data Models

- How is reality abstracted and codified?

Abstraction

Codification

Reality — Wells produce from rocks that contain oil and gas

↓

Conceptual Models — Wells are points, rock units are polygons (both are objects)

↓

Logical Models — Well A penetrates Fm. 1; produces oil. Well B penetrates Fm. 3; produces gas. Fm 3 overlies Fm. 1.

↓

Physical Models — Store well location with a particular file structure, production stats. in a dBase table. Associate table with location.

Conceptual Models

Characterized all features or phenomenon as:

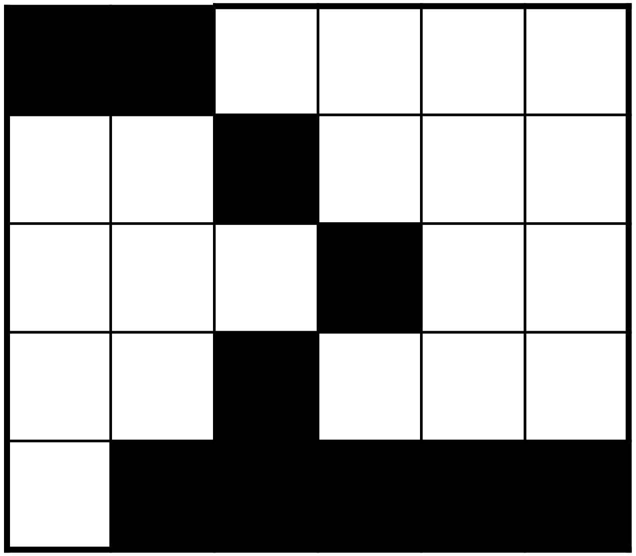
- Discrete objects; e.g. wells, roads, rock bodies, etc.
  - ***Object-based models***
- Continuous phenomena; e.g. gravity, topography, temperature, snowfall, soil pH, etc.
  - ***Field-based models***

Logical Models

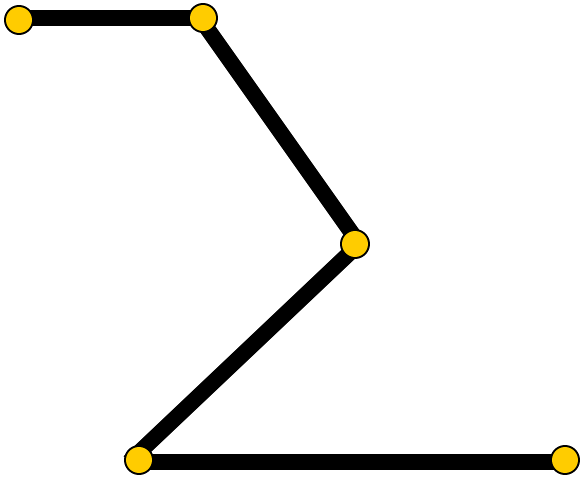
- **VECTOR MODEL**
  - Discrete objects are represented by points and vectors, continuous fields by irregular tessellations of triangles (TINs)
- **RASTER MODEL**
  - Discrete objects and continuous fields are represented by an array of square cells (pixels)

Logical Models

⌘ How should discrete objects be coded?

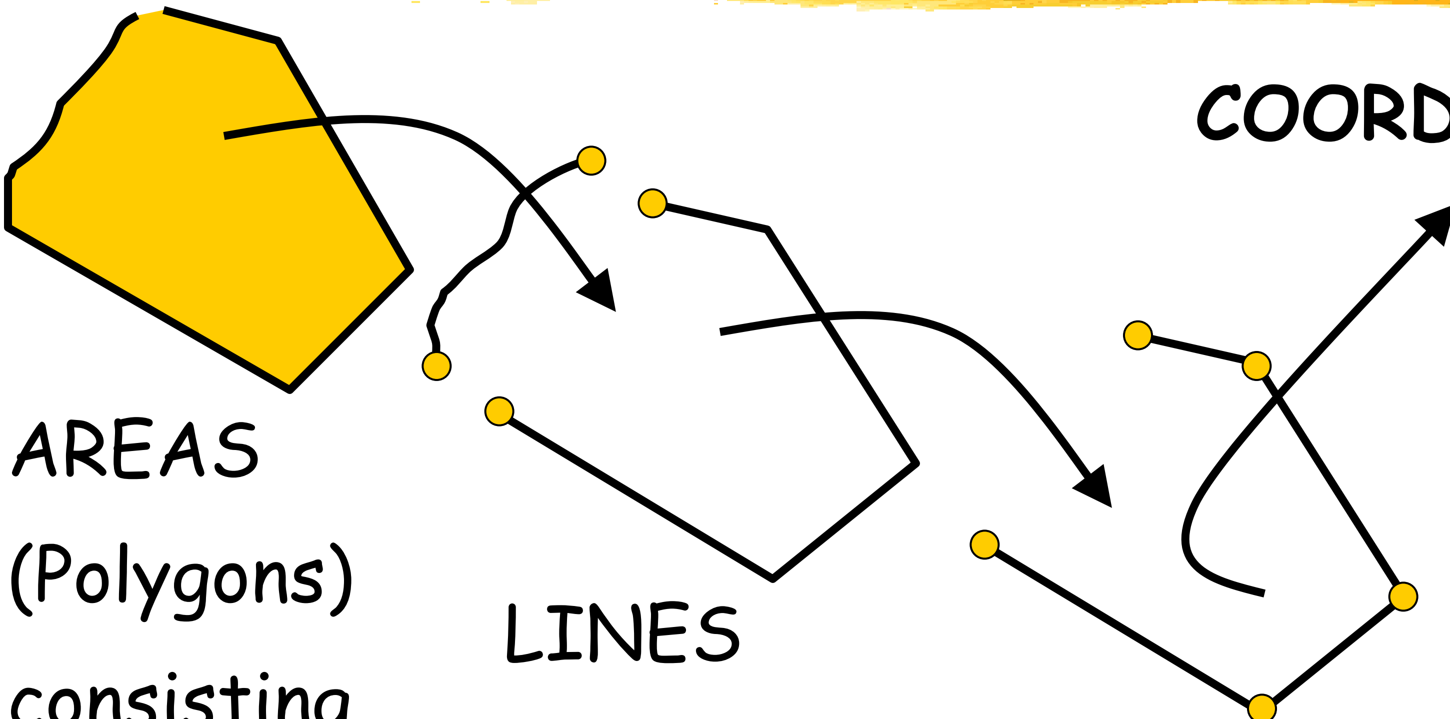


Raster Model



Vector Model

Vector Model



AREAS

(Polygons)

consisting of.........

LINES

(Arcs)

consisting of.........

POINTS

consisting of.........

COORDINATES

<u>(x, y)</u>

(1, 5)

(5, 1)

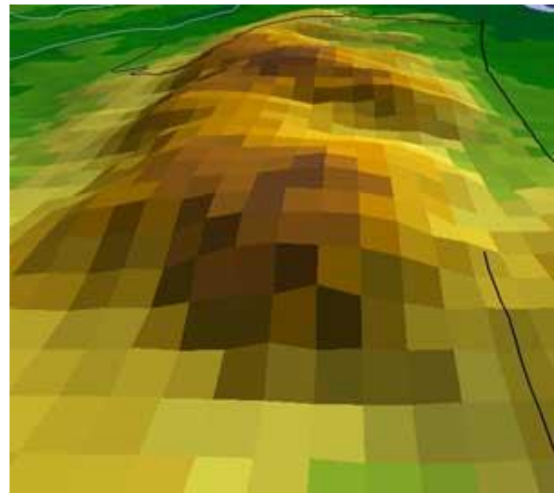
(7, 2)

(5, 7)

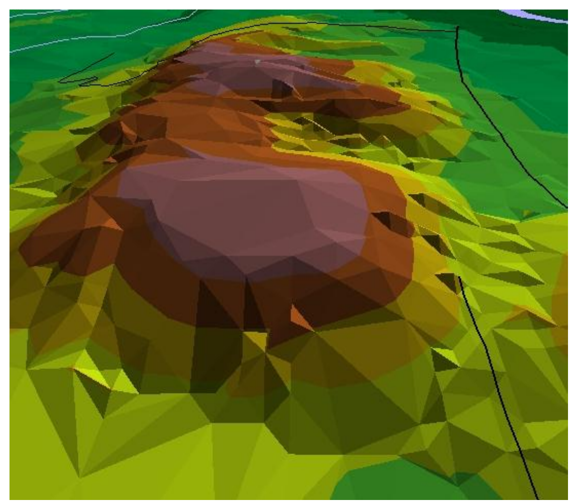
(3, 8)

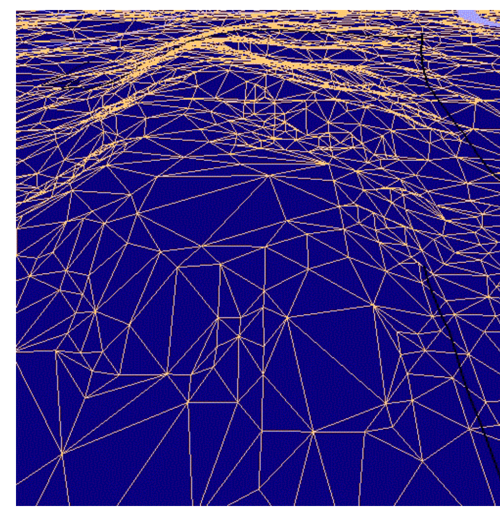
Continuous phenomena as surfaces

- Raster
  Topography
  - Regular tessellations, e.g. DEM



- Vector
  Topography
  - Irregular tessellations, e.g. T.I.N.





Simple Vector Data Structure

Vector Line

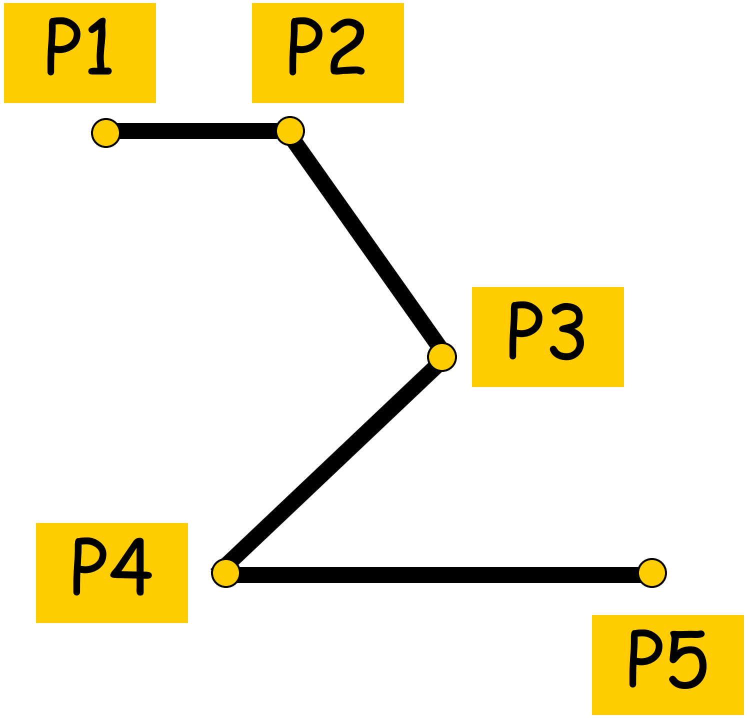


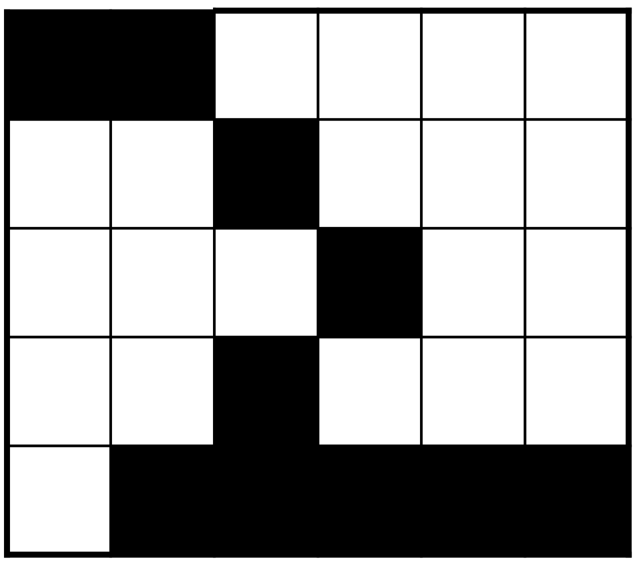
Table of Points

ID	X	Y
P1	503200	3200522
P2	503250	3200522
P3	503300	3200460
P4	503245	3200410
P5	503350	3200410

(in UTM coordinates)

Simple Raster Data Structure:

Raster Line



Equivalent Flat File

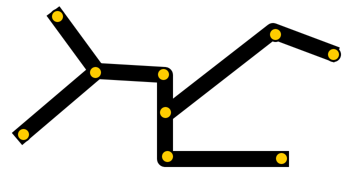
1 1 0 0 0 0
0 0 1 0 0 0
0 0 0 1 0 0
0 0 1 0 0 0
0 1 1 1 1 1

Vector Models

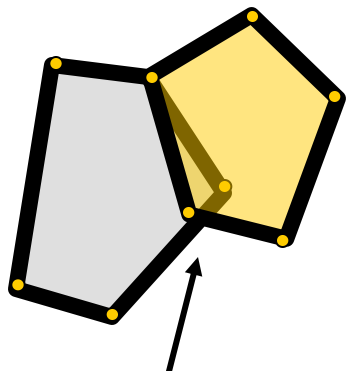
- Graphical
- Topologic/georelational
- T.I.N.
- Network

Graphical Vector Model

- Lines have arbitrary beginning and end, like spaghetti on a plate



- Common lines between adjacent polygons duplicated



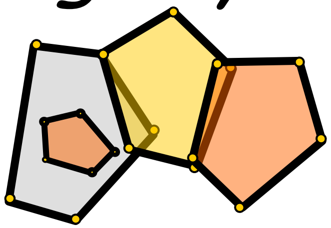
  - Can leads to "slivers" of unassigned area = "sliver polygons"

Graphical Vector Model

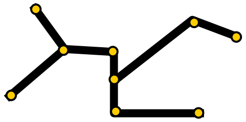
- Shortcomings for maps:
  - No real world coordinates
  - No identification of individual objects; no way to attach attributes
  - Details of relationships among object (e.g. what's adjacent) not stored, but needed for spatial analysis.

Graphical Vector Structure

- Contains no explicit information about *adjacency*, *containment* or *contiguity* i.e.
  - Which polygons are adjacent?



  - Which polygons are contained within other polygons?



  - Which lines are connected? Where are they connected? Where do lines begin and end?

= "*Spaghetti Data Model*"

Topological Vector Model

- Store pts. as x,y geographic coordinates
- Store lines as paths of connected pts.
- Store polygons as closed paths

Also explicitly store ....

- Where lines start and end (connectivity)
- Which polygons are to the right and left side of a common line (adjacency)

Topology

- The geometric relationship(s) between entities (e. g. points, lines, areas); where is one thing with respect to another?

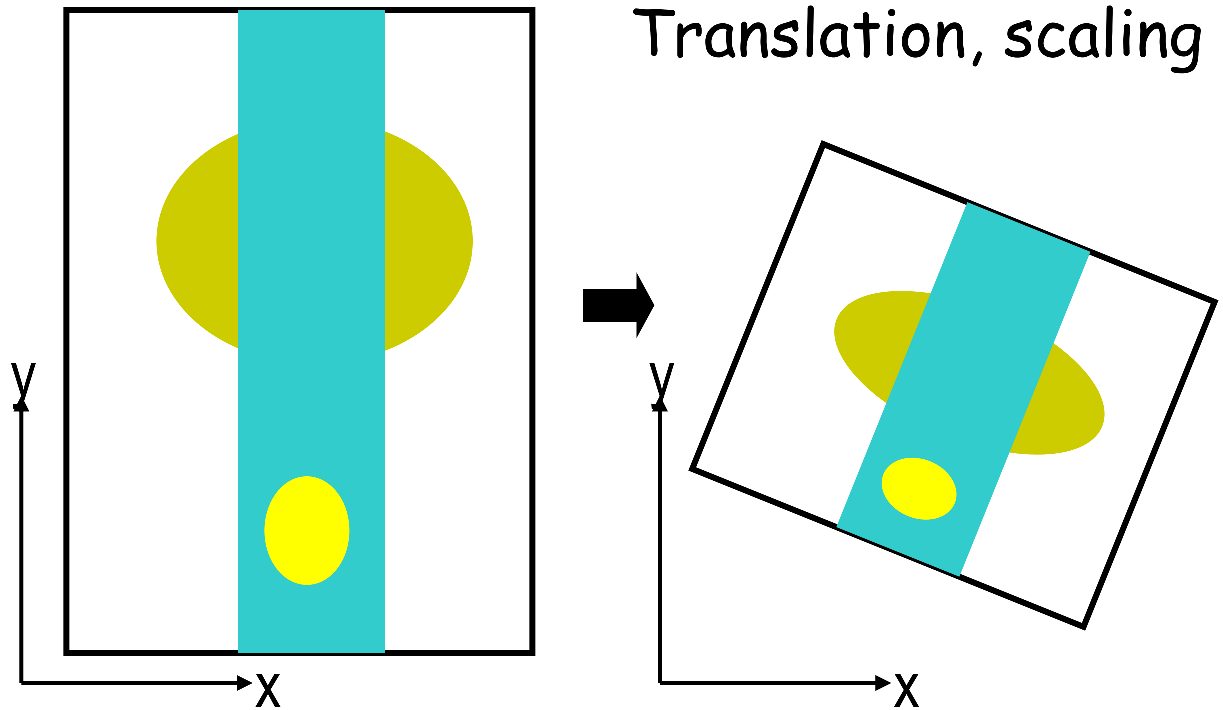
Topological Properties

- Spatial characteristics that are unchanged by transformations like scaling, rotation and translation
  - **Non-topological**: x, y coordinates, area, distance, orientation, area
  - **Topological**:
    - **Contiguity** – what's adjacent
    - **Connectivity** – what's connected
    - **Containment** – what's inside or outside of a region

Topological Properties

- **Contiguity**: Adjacency
- **Connectivity**: What's connected
- **Containment**: What's inside or outside of a region

Translation, scaling



⌘Unchanged by translation, scaling, rotation

Lines: Graphic vs. Topologic

- Graphic (Spaghetti)

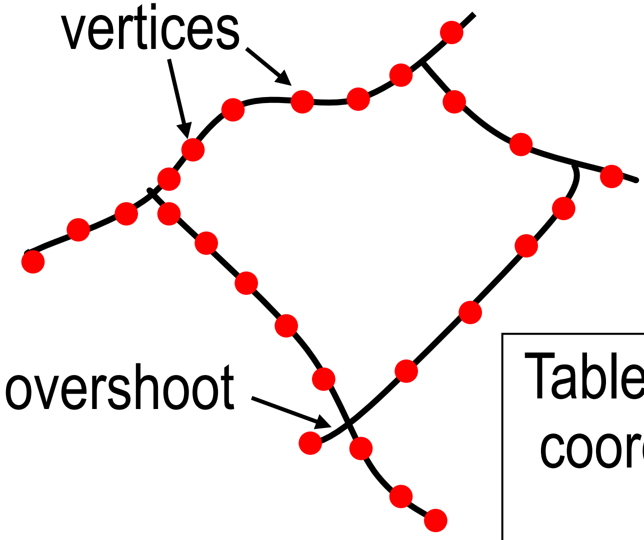
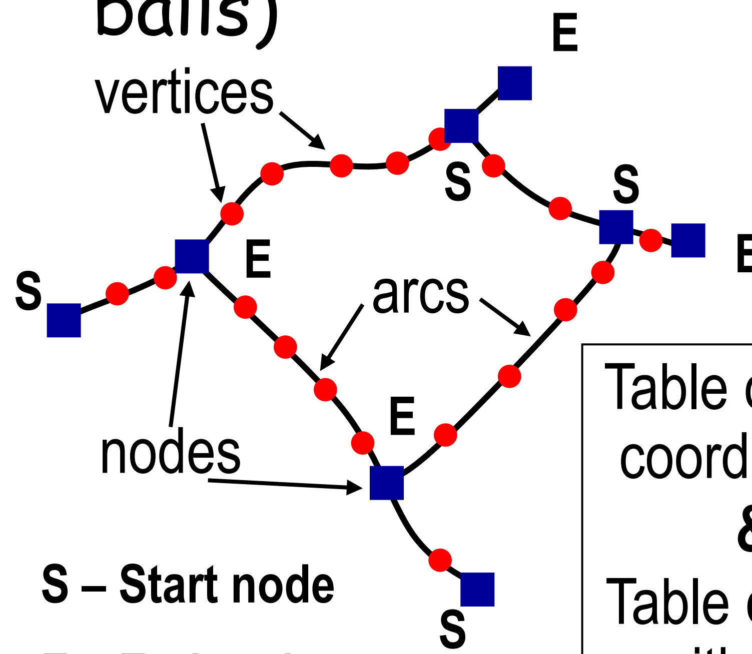


Table of (x,y) coordinates

- Topologic (with meat-balls)



S – Start node

E – End node

Table of (x,y) coordinates
&
Table of arcs with IDs, starting and ending nodes

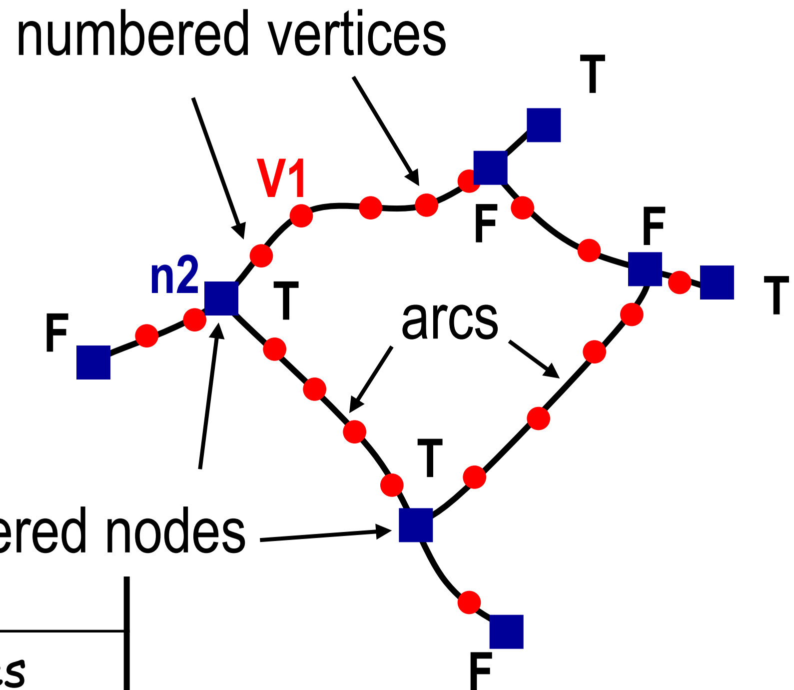
Lines: Arc-Node Topology

Vertex Table

ID	x	y
1	0	0
.	.	.
.	.	.
19	3	5

Node Table

ID	x	y
1	0	0
.	.	.
.	.	.
8	3	5



Arc Table

ID	FID	F Node	T Node	Vertices
1	100	1	2	1, 2
2	102	3	2	3, 4, 5, 6, 7
3	103	3	4	null

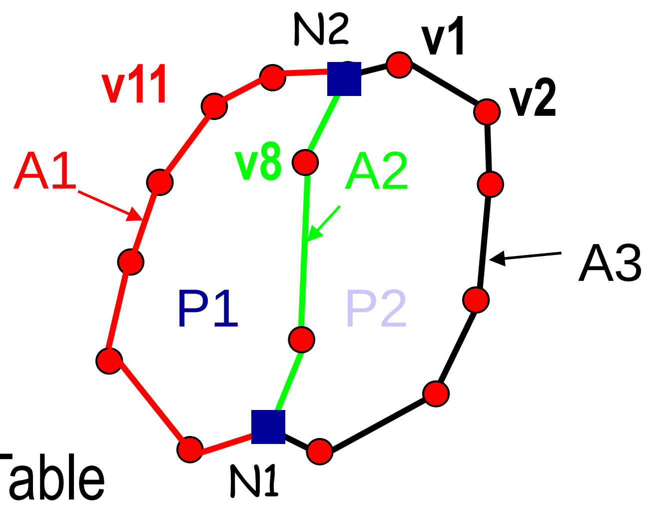
F ="Start" node (F –"From" node)

T = End node or (T – "To" node)

Polygons: Polygon-Arc Topology

Arc Table

Arc ID	L. Poly	R. Poly	F Node	T Node
A1	World	P1	N1	N2
A2	P1	P2	N2	N1
A3	P2	World	N2	N1



Polygon Table

Poly ID	FID	Arcs.
P1	100	A1, A2
P2	102	A2, A3

Arc Coordinates Table

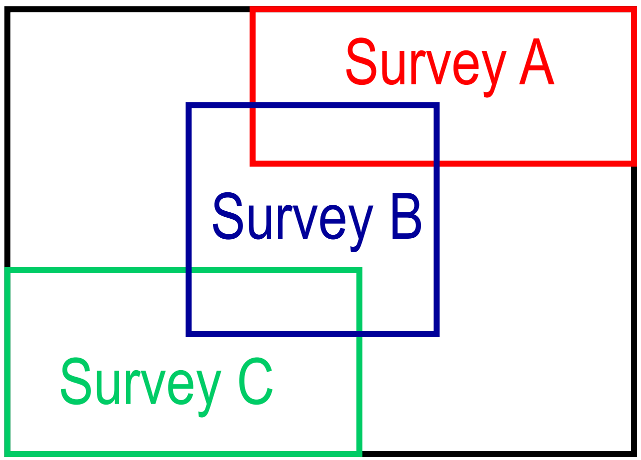
Arc	Start	Vertices	End
A1	N1	v7, …,v11, …	N2
A2	N2	…, v8	N1
A3	N2	v1, v2, …,v6	N1

Topology - Planar Enforcement

- One and only one feature at every x, y location
  - Lines cross at nodes; polygons space-filling, exhaustive, mutually exclusive (no overlaps)
  - Sum of the area of all individual polygons equals the area of extent of all polygons
  - Common boundaries stored only once
- A PLANAR GRAPH meets these conditions
- Allows spatial queries for adjacency, containment and rapid what-is-where
- All raster data is of this sort

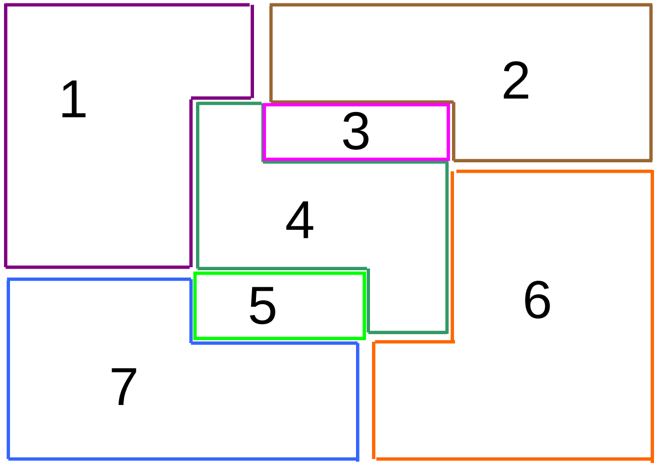
Non-Planar vs. Planar Graphs

- Spaghetti



after Bonham-Carter, 1994

- Topologic



Polygons	1	2	3	4	5	6	7
Survey A	0	1	1	0	0	0	0
Survey B	0	0	1	1	1	0	0
Survey C	0	0	0	0	1	0	1
None	1	0	0	0	0	1	0

Why bother with topology?

- Provides a way of error trapping and geometry validation after data entry
  - All lines must meet at nodes, all polygons must close, polygons can't overlap, all lines in a network must join
- Permits spatial queries, precise measurements

What kind of queries does topology permit?

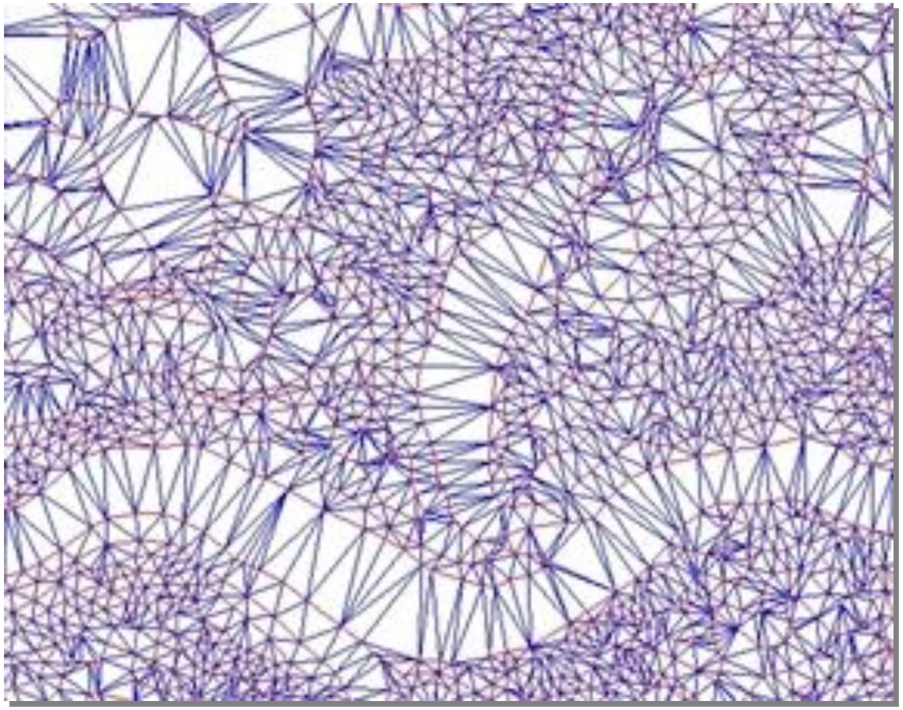
- Connectivity
  - What is shortest path between features or locations? (networks, flow)
  - Find all fault trace intersections
- Contiguity
  - What's adjacent: e.g. Show all granite/limestone contacts
  - Combine all contiguous units with a specific attribute (e.g. lithology) into a single unit
- Containment (= "Area Definition")
  - What proportion of an area is underlain by a specific rock type?
  - What is spatial density of specific feature(s)?

Vector Models

- ⌘ Graphical ✓
- ⌘ Topologic/"georelational" ✓
- ⌘ T.I.N. ←
- ⌘ Network

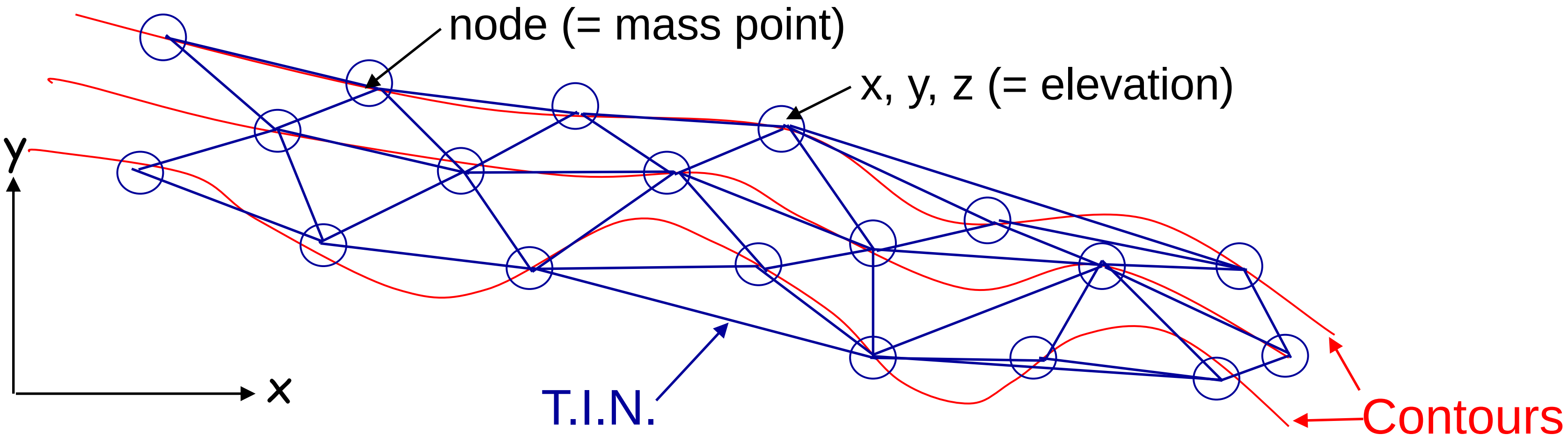
Triangulated Irregular Network -TIN

- Topological 3-D model for representing continuous surfaces using a tessellation of triangles

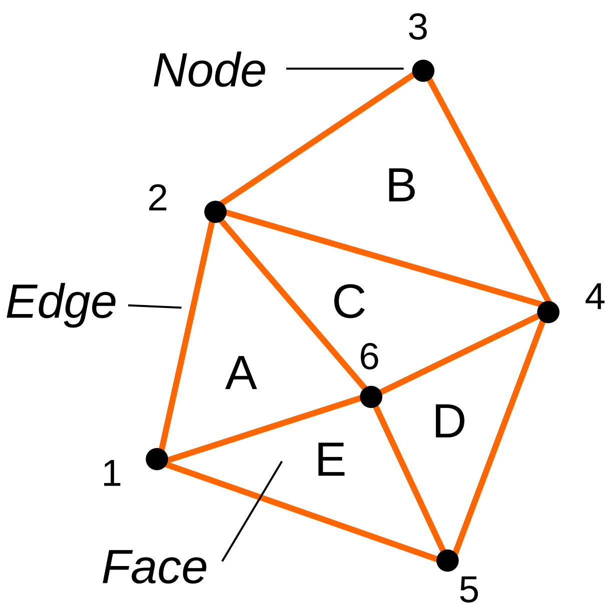


Triangular Irregular Network

- Network of interlocking triangles from irregularly spaced points with x, y and z values
- Density of triangles varies with density of data points (e.g. spacing of contours) - c.f. raster with uniform data density
- Triangle sides are constructed by connecting adjacent points so that the minimum angle of each triangle is maximized
- Can render faces, calculate slope, aspect, surface shade, hidden-line removal, etc.



TIN Topology



Node Table

Node	x	y	z
1	3	5	5
2	5	9	12
3	11	12	16
4	15	5	3
5	13	3	44
6	10	7	50

Node Elevations

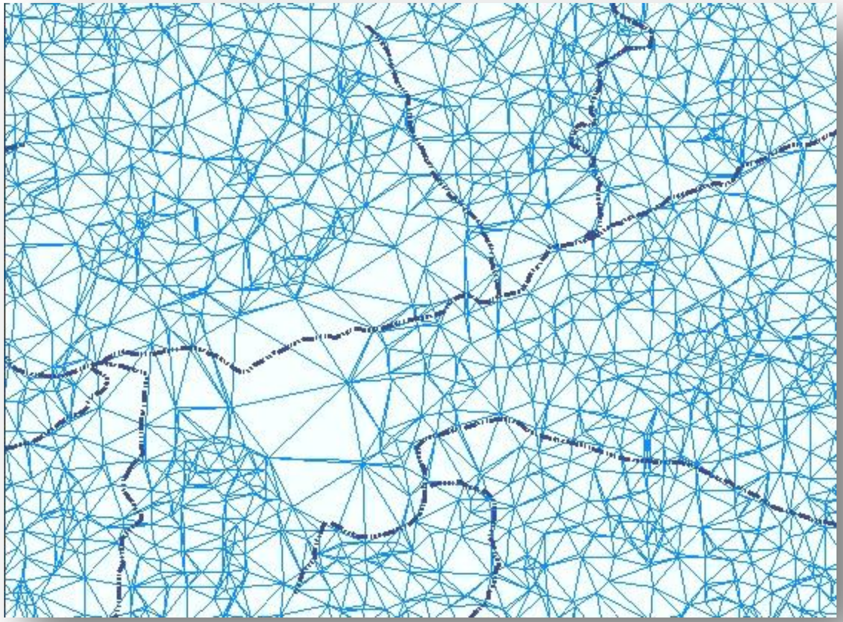
Tin Topology Table

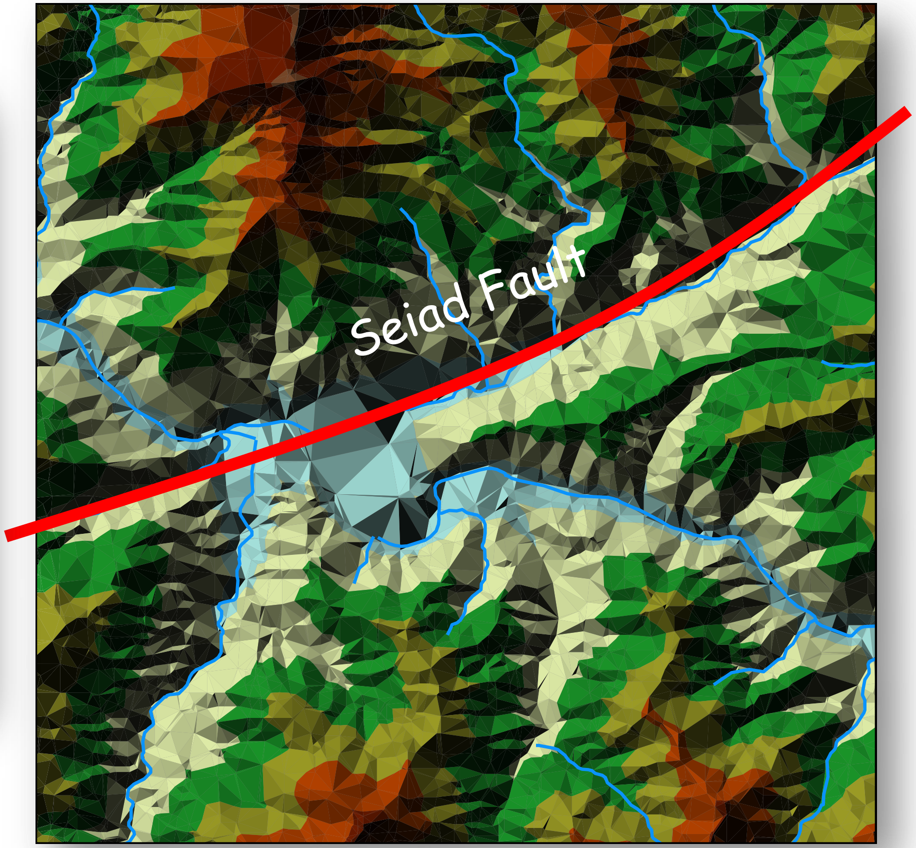
Triangle	Node list	Neighbors
A	1, 2, 6	-, C, E
B	2, 3, 4	-, -, C
C	2, 4, 6	B, D, A
D	4, 5, 6	E, C, -
E	5, 1, 6	A, C, D

After Zeiler, Modeling our World, p. 165

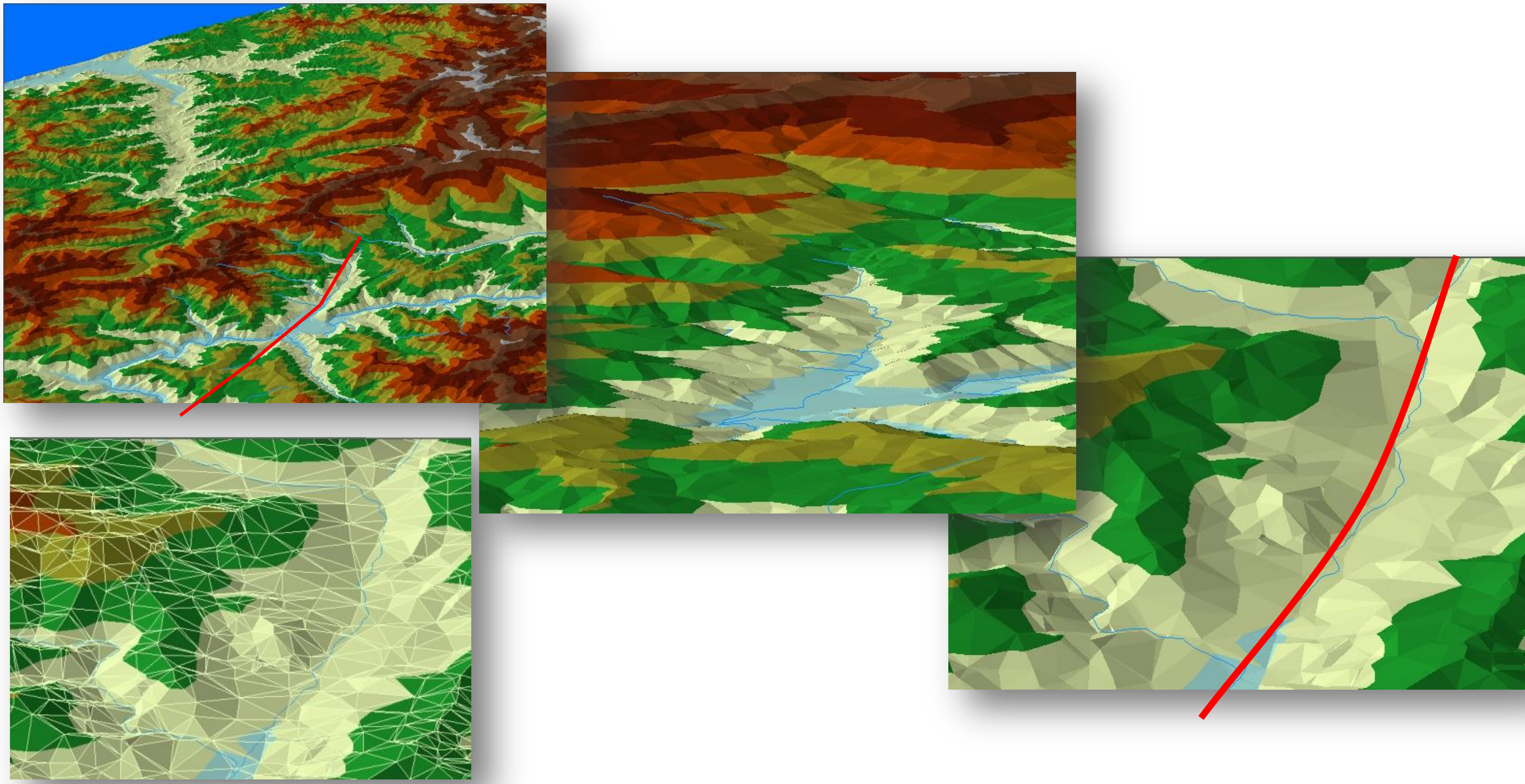
TIN for Seiad Valley, CA

- Triangle edges symbolized
- Faces symbolized for elevation & aspect

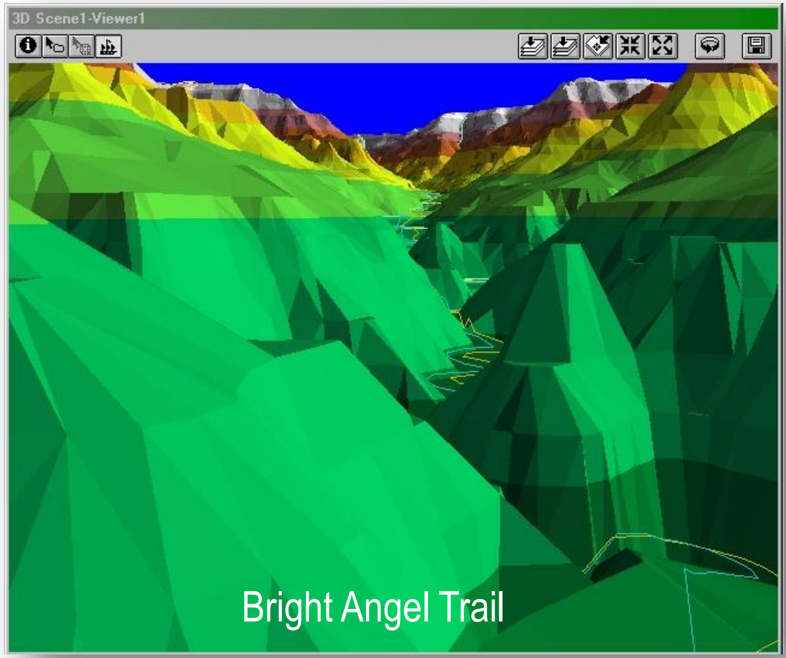


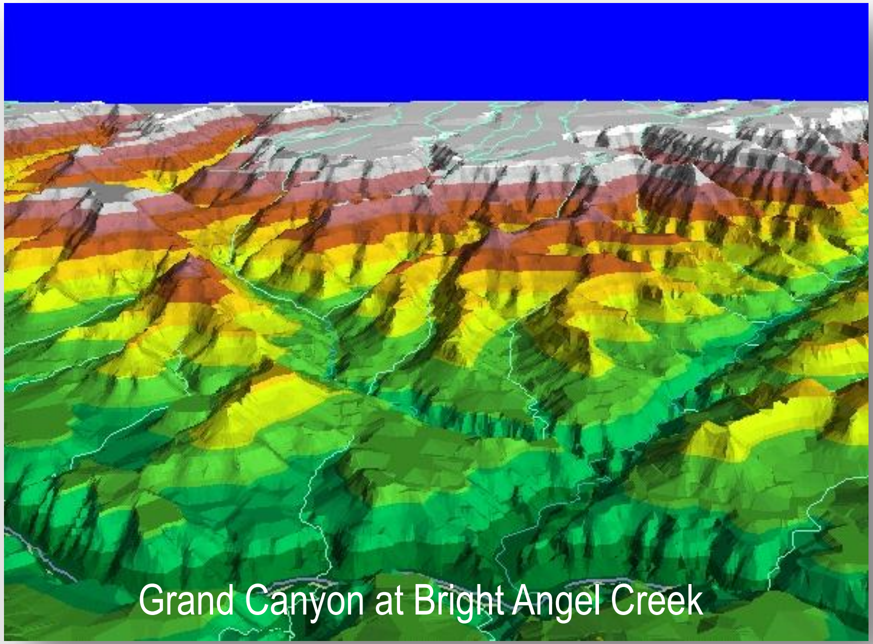


3-D TIN Scenes of Seiad Valley fault



3-D TINS, Grand Canyon





Vector Models

- Graphical ✓
- Topologic/"georelational" ✓
- T.I.N. ✓
- Network - not discussed, see Help files