

Spatial Data as Vectors

HES 505 Fall 2022: Session 7

Matt Williamson

Today's Plan

Map
— OF THE MINING SECTIONS OF —
IDAHO & OREGON
— embracing the GOLD and SILVER mines of —
BOISE & OWYHEE
— BY GEO. WOODMAN —
— compiled chiefly from notes of his travels and surveys, —
— during the last 18 months —
— PUBLISHED BY A. GENSOUL —
— 511 Montgomery St. San Francisco. —

REFERENCE.
— Wagon Roads —
— Trails —
— Railroads —
— Towns and Ranches —
— Forts —
— Springs —

Objectives

- Articulate the role of the data model in geographic information systems
- Describe the key elements of vector data
- Use the **sf** package to read and manipulate vector data
- Define **geometry** in the context of vector objects and troubleshoot common problems

What is a data model?

- **Data:** a collection of discrete values that describe phenomena
- Your brain stores millions of pieces of data
- Computers are not your brain
 - Need to organize data systematically
 - Be able to display and access efficiently
 - Need to be able to store and access repeatedly
- Data models solve this problem

2 Types of Spatial Data Models

- **Raster:** grid-cell tessellation of an area. Each raster describes the value of a single phenomenon. More next week...
- **Vector:** (many) attributes associated with locations defined by coordinates

The Vector Data Model

- **Vertices** (i.e., discrete x-y locations) define the shape of the vector
- The organization of those vertices define the *shape* of the vector
- General types: points, lines, polygons

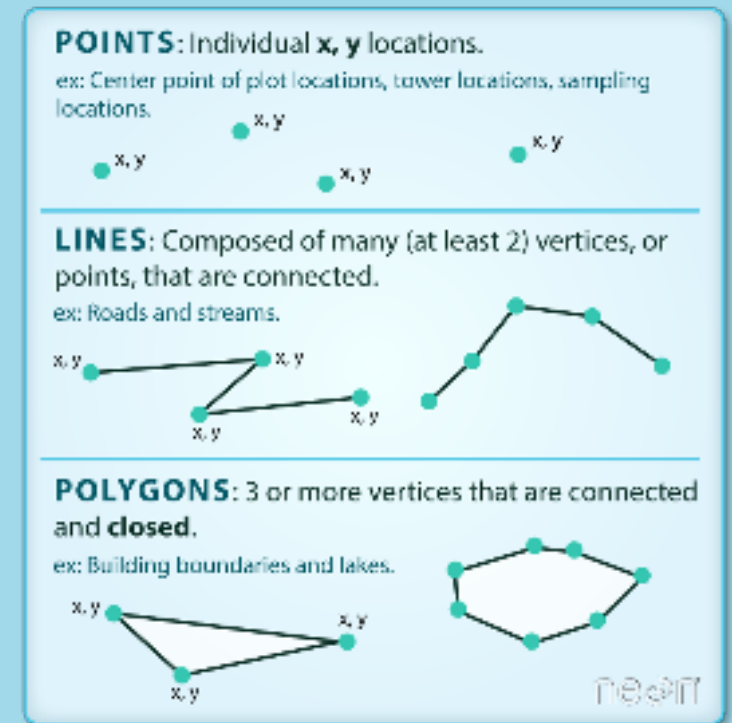
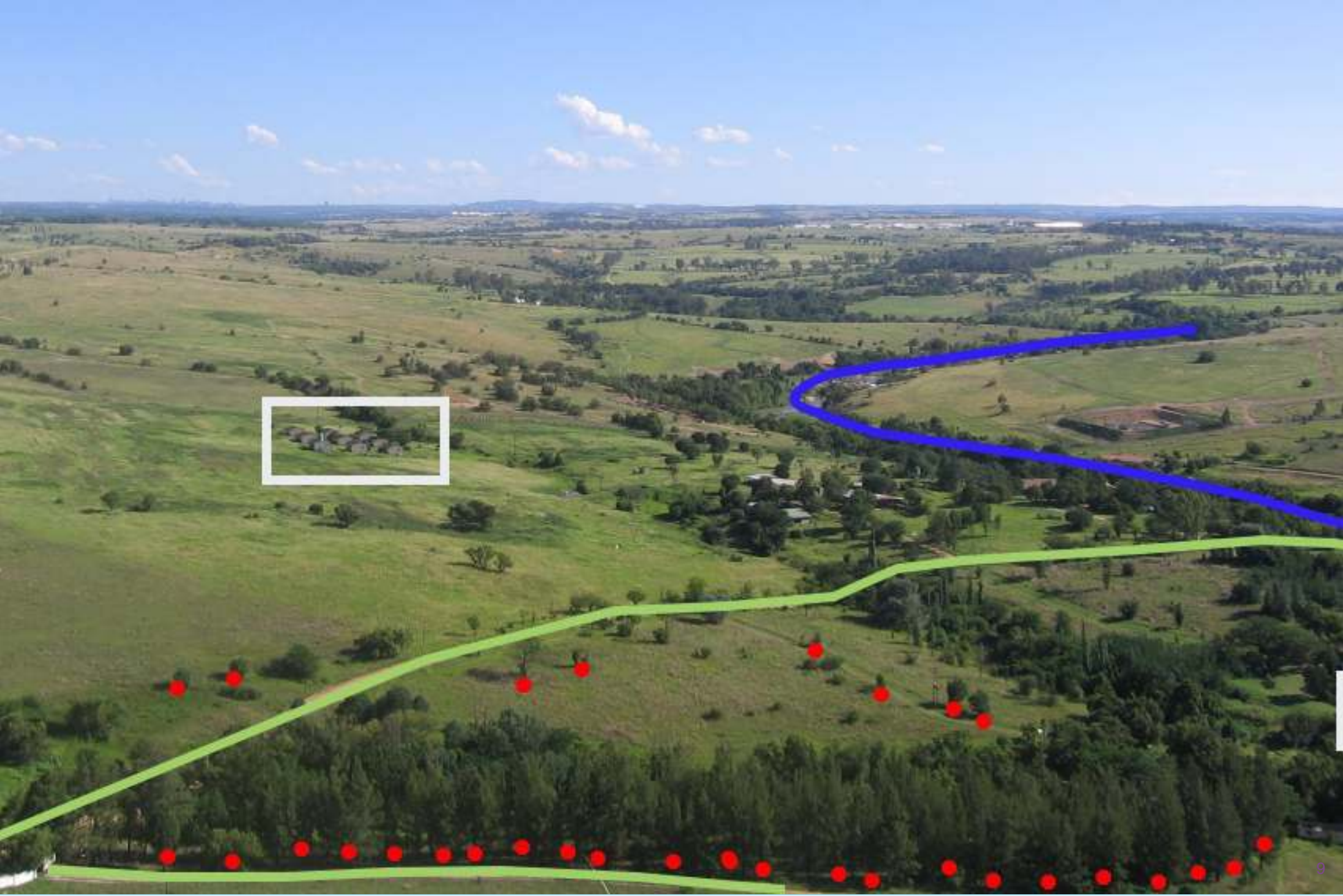


Image Source: Colin Williams
(NEON)



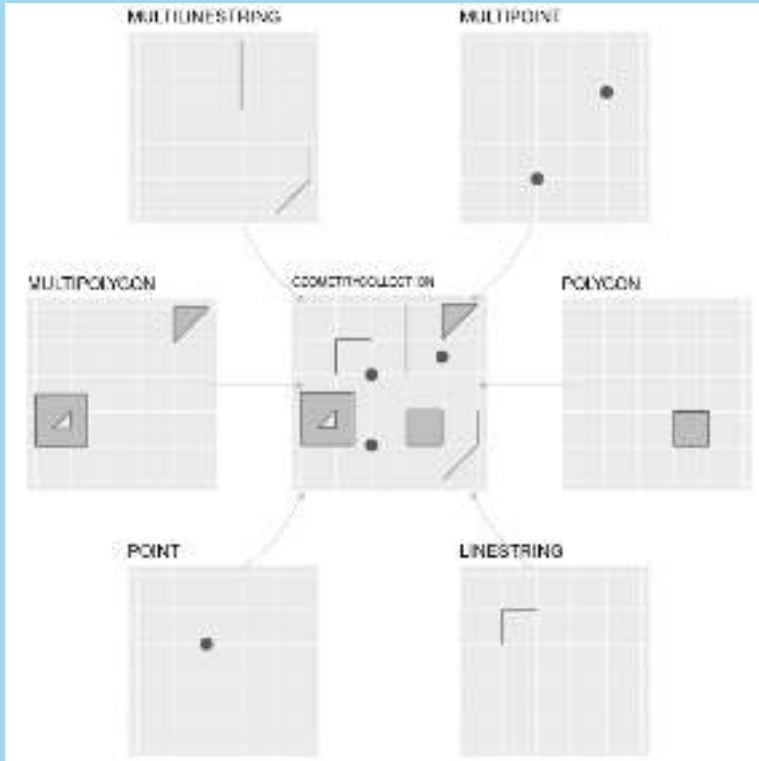
Vectors in Action

- Useful for locations with discrete, well-defined boundaries
- Very precise (not necessarily accurate)
- Not the same as the **vector** data class



Vectors in R

Representing vector data in R



- **sf** hierarchy reflects increasing complexity of geometry
 - **st_point**, **st_linestring**, **st_polygon** for single features
 - **st_multi*** for multiple features of the same type
 - **st_geometrycollection** for multiple feature types
 - **st_as_sfc** creates the geometry list column for many **sf** operations

From Lovelace et al.

Points

```
1 library(sf)
2 proj <- st_crs('+proj=longlat +datum=WGS84')
3 long <- c(-116.7, -120.4, -116.7, -113.5, -115.5, -120.8, -119.5, -113.7, -
4 lat <- c(45.3, 42.6, 38.9, 42.1, 35.7, 38.9, 36.2, 39, 41.6, 36.9)
5 st_multipoint(cbind(long, lat)) %>% st_sfc(., crs = proj)
```

Geometry set for 1 feature

Geometry type: MULTIPOINT

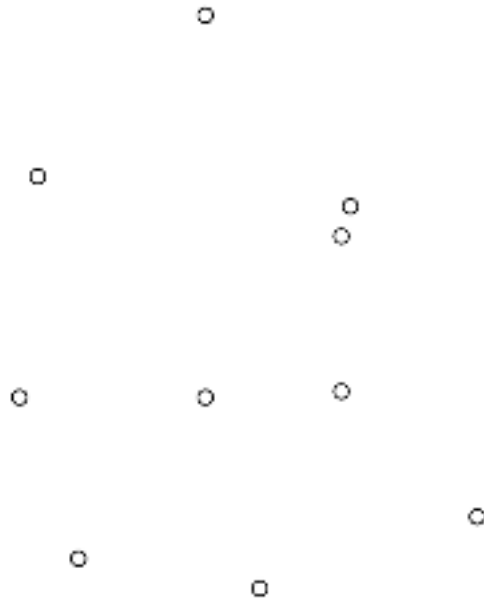
Dimension: XY

Bounding box: xmin: -120.8 ymin: 35.7 xmax: -110.7 ymax: 45.3

Geodetic CRS: +proj=longlat +datum=WGS84

Points

```
1 plot(st_multipoint(cbind(long, lat)) %>%  
2       st_sfc(., crs = proj))
```



Lines

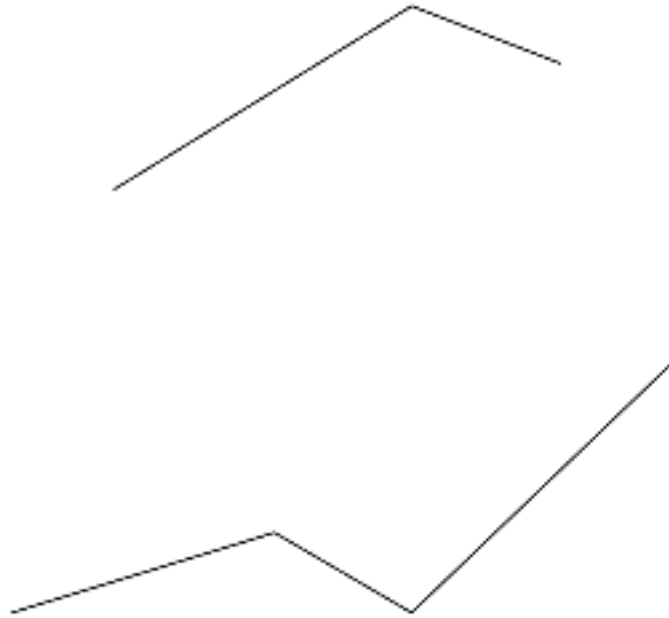
```
1 lon <- c(-116.8, -114.2, -112.9, -111.9, -114.2, -115.4, -117.7)
2 lat <- c(41.3, 42.9, 42.4, 39.8, 37.6, 38.3, 37.6)
3 lonlat <- cbind(lon, lat)
4 pts <- st_multipoint(lonlat)
5
6 sfline <- st_multilinestring(list(pts[1:3,], pts[4:7,]))
7 str(sfline)
```

List of 2

```
$ : num [1:3, 1:2] -116.8 -114.2 -112.9 41.3 42.9 ...
  ..- attr(*, "dimnames")=List of 2
  .. ..$ : NULL
  .. ..$ : chr [1:2] "lon" "lat"
$ : num [1:4, 1:2] -111.9 -114.2 -115.4 -117.7 39.8 ...
  ..- attr(*, "dimnames")=List of 2
  .. ..$ : NULL
  .. ..$ : chr [1:2] "lon" "lat"
- attr(*, "class")= chr [1:3] "XY" "MULTILINESTRING" "sfg"
```

Lines

```
1 plot(st_multilinestring(list(pts[1:3,], pts[4:7,])))
```

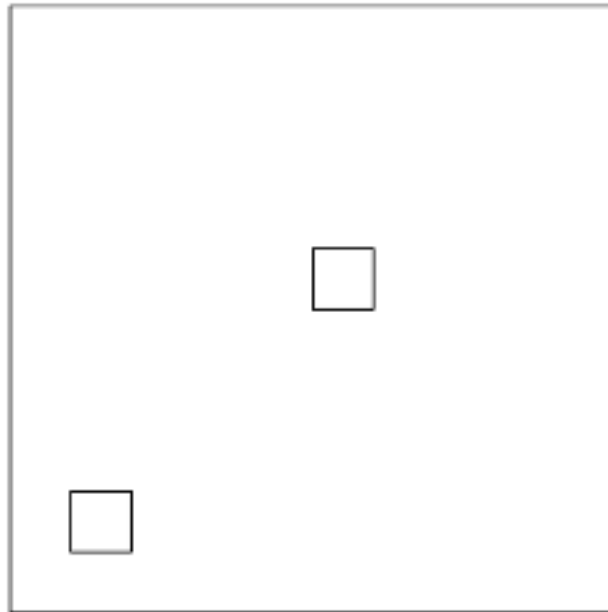


Polygons

```
1 outer = matrix(c(0,0,10,0,10,10,0,10,0,0),ncol=2, byrow=TRUE)
2 hole1 = matrix(c(1,1,1,2,2,2,2,1,1,1),ncol=2, byrow=TRUE)
3 hole2 = matrix(c(5,5,5,6,6,6,6,5,5,5),ncol=2, byrow=TRUE)
4 coords = list(outer, hole1, hole2)
5 pl1 = st_polygon(coords)
```

Polygons

```
1 plot(pl1)
```



But what about actual data?

Convert a data frame to **sf** object

- Useful for situations where point locations given as columns in spreadsheet
- Requires that you the projection used when the data were collected
- Using the **meuse** dataset (use **?sp::meuse** to learn more about it)

```
1 library(sp)
2 data(meuse)
3 head(meuse, n=3)[,1:10]
```

	x	y	cadmium	copper	lead	zinc	elev	dist	om	ffreq
1	181072	333611	11.7	85	299	1022	7.909	0.00135803	13.6	1
2	181025	333558	8.6	81	277	1141	6.983	0.01222430	14.0	1
3	181165	333537	6.5	68	199	640	7.800	0.10302900	13.0	1

Convert a data frame to **sf** object

- Using the **x** and **y** columns in the data
- **agr** defines the attribute-geometry-relationship
- **constant**, **aggregate**, and **identity**

```
1 meuse_sf = st_as_sf(meuse, coords = c("x", "y"),  
2                       crs = 28992, agr =  
3                       "constant")  
4 meuse_sf[1:2, 1:10]
```

Simple feature collection with 2 features and 10 fields

Attribute-geometry relationships: constant (10)

Geometry type: POINT

Dimension: XY

Bounding box: xmin: 181025 ymin: 333558 xmax: 181072 ymax: 333611

Projected CRS: Amersfoort / RD New

cadmium copper lead zinc elev dist om freq soil lime

1	11.7	85	299	1022	7.909	0.00135803	13.6	1	1	1
2	8.6	81	277	1141	6.983	0.01222430	14.0	1	1	1

geometry

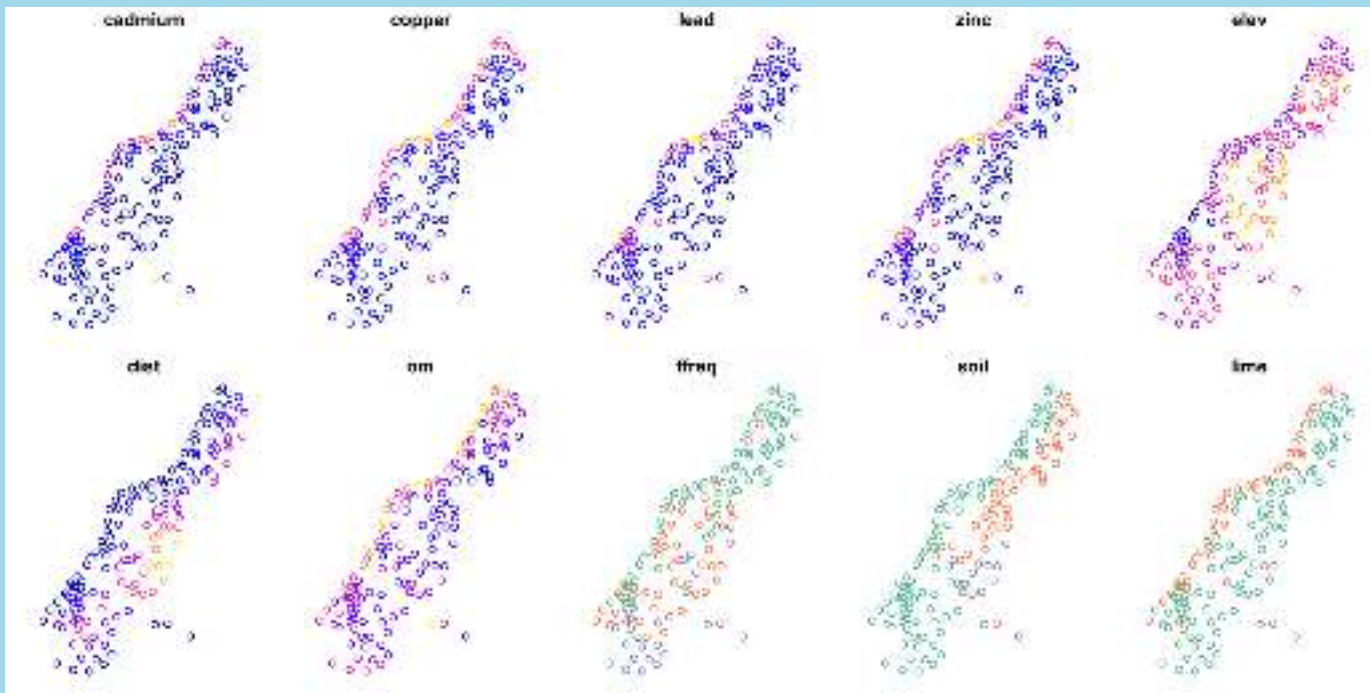
1 POINT (181072 333611)

2 POINT (181025 333558)

Plotting **sf** objects

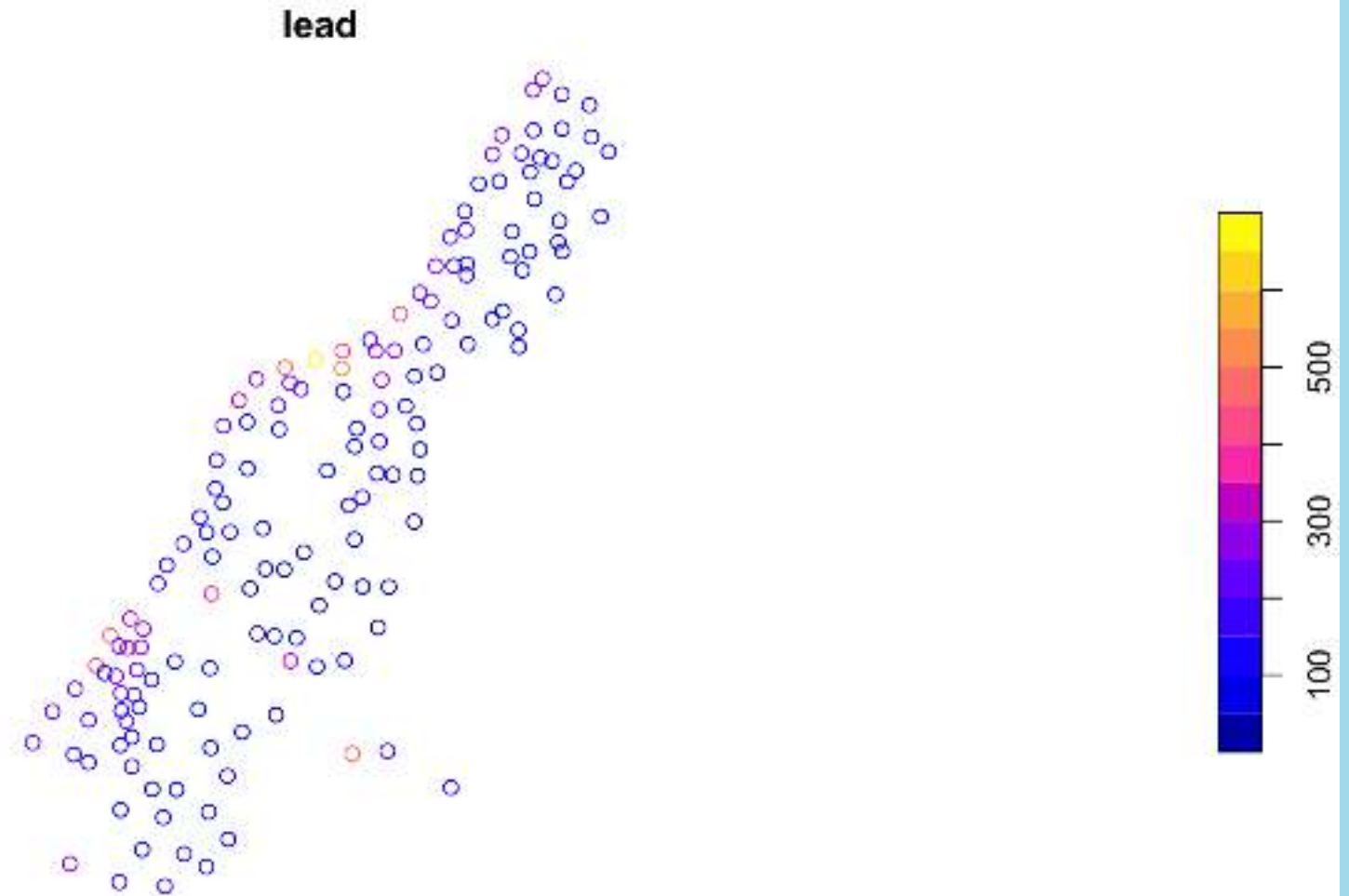
- Quick way to check your data
- Remember that **sf** has **geometry** and **attributes**

```
1 plot(meuse_sf)
```



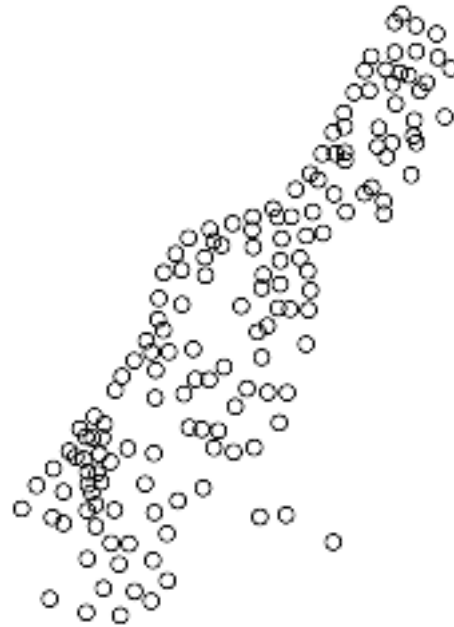
Plotting **sf** objects

```
1 plot(meuse_sf[ 'lead' ])
```



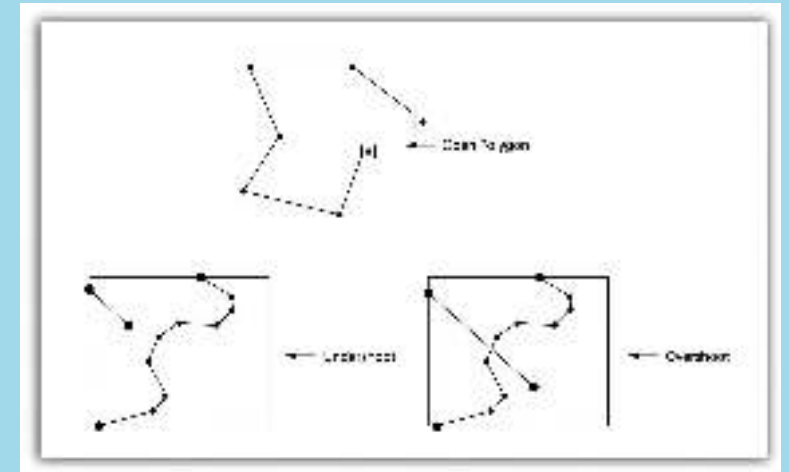
Plotting **sf** objects

```
1 plot(st_geometry(meuse_sf))
```



Common Problems with Vector Data

- Vectors and scale
- Slivers and overlaps
- Undershoots and overshoots
- Self-intersections and rings



Topology Errors - Saylor Acad.

We'll use `st_is_valid()` to check this, but fixing can be tricky

Fixing Problematic Topology

- `st_make_valid()` for simple cases
- `st_buffer` with `dist=0`
- More complex errors need more complex approaches

A Note on Vectors

Moving forward we will rely primarily on the **sf** package for vector manipulation. Some packages require objects to be a different class. **terra**, for example, relies on **SpatVectors**. You can use **as()** to coerce objects from one type to another (assuming a method exists). You can also explore other packages. Many packages provide access to the ‘spatial’ backbones of **R** (like **geos** and **gdal**), they just differ in how the “verbs” are specified. For **sf** operations the **st_** prefix is typical. For **rgeos** operations, the **g** prefix is common.

