Spatial Data as Vectors

HES 505 Fall 2022: Session 7

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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
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Sage Desert
Humboldt Mines
Salt Lake City

Today's Plan

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

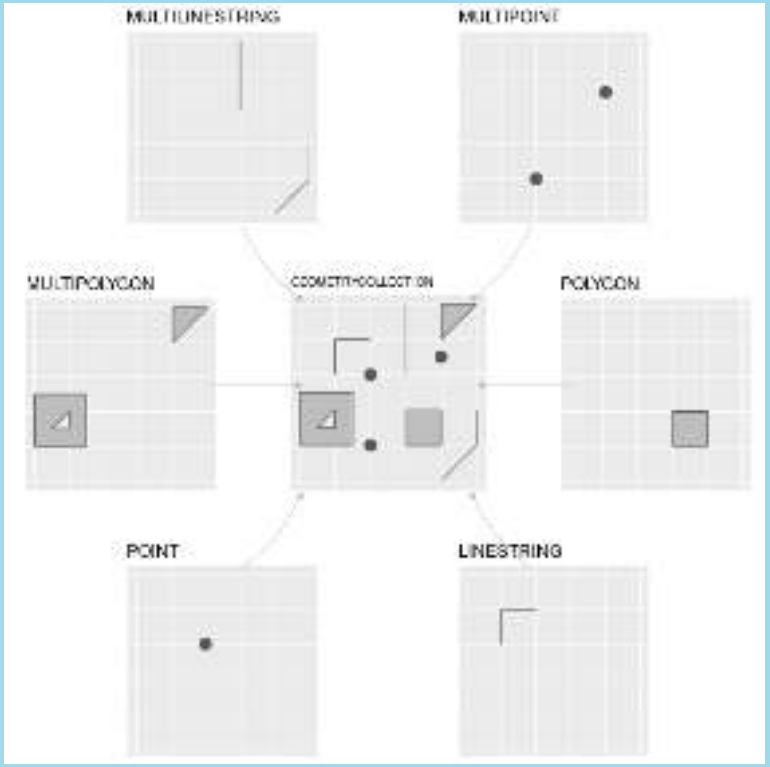
- **Vertices** (i.e., discrete x-y locations) define the shape of the vector
- The organization of those vertices define the *shape* of the vector
- General types: points, lines, polygons

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



From Lovelace et al.

- `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

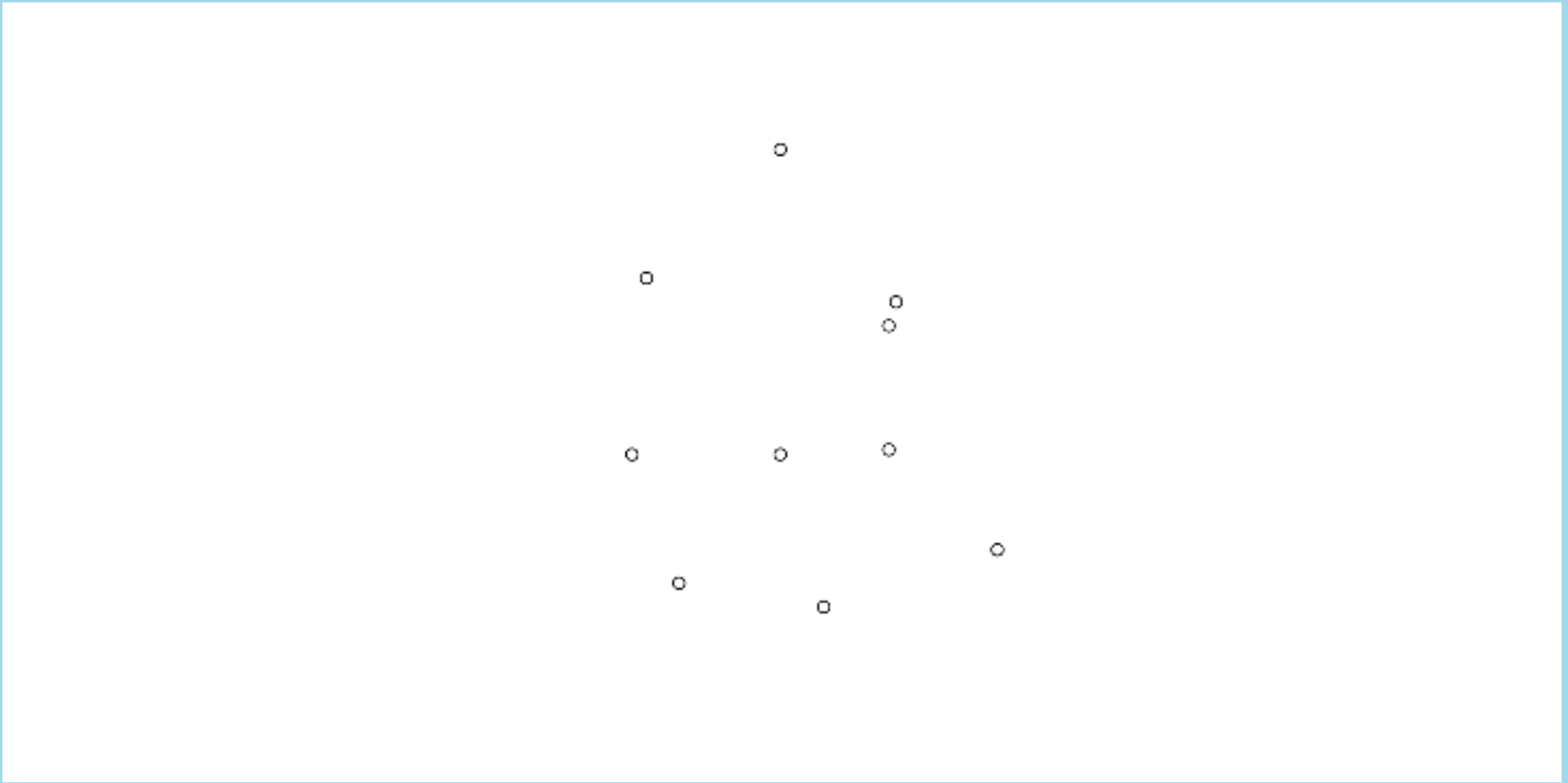
Points

```
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

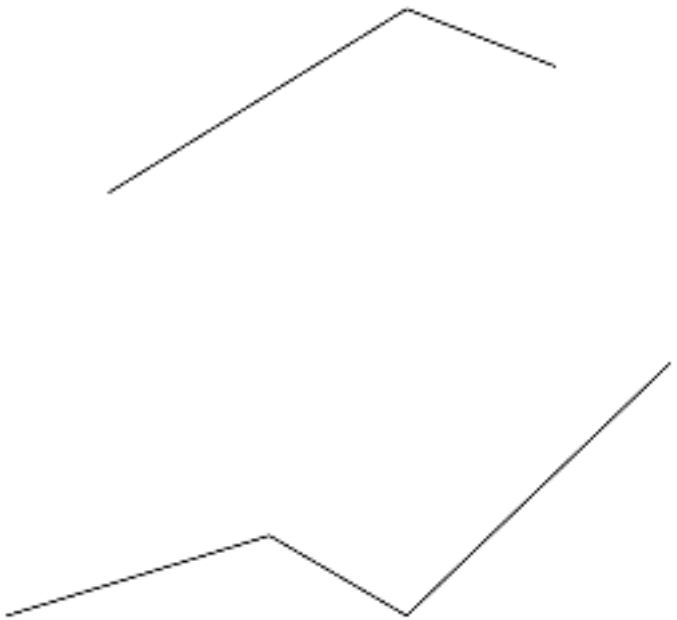
```
lon <- c(-116.8, -114.2, -112.9, -111.9, -114.2, -115.4, -117.7)
lat <- c(41.3, 42.9, 42.4, 39.8, 37.6, 38.3, 37.6)
lonlat <- cbind(lon, lat)
pts <- st_multipoint(lonlat)

sfline <- st_multilinestring(list(pts[1:3,], pts[4:7,]))
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,])))
```

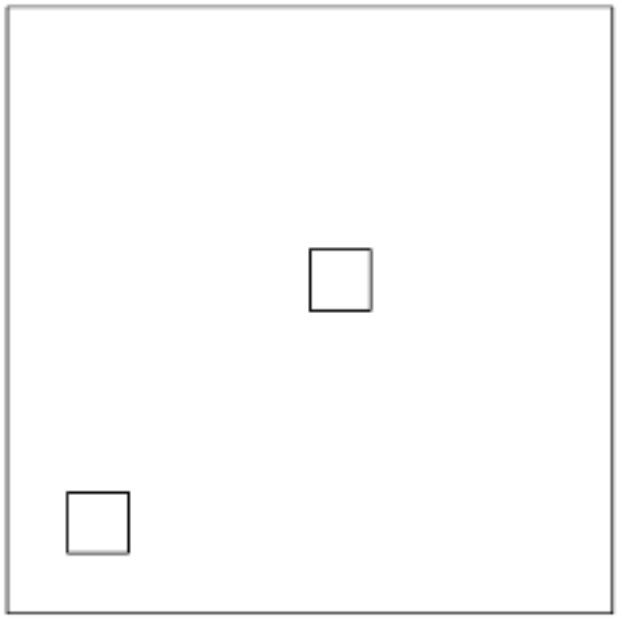


Polygons

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

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

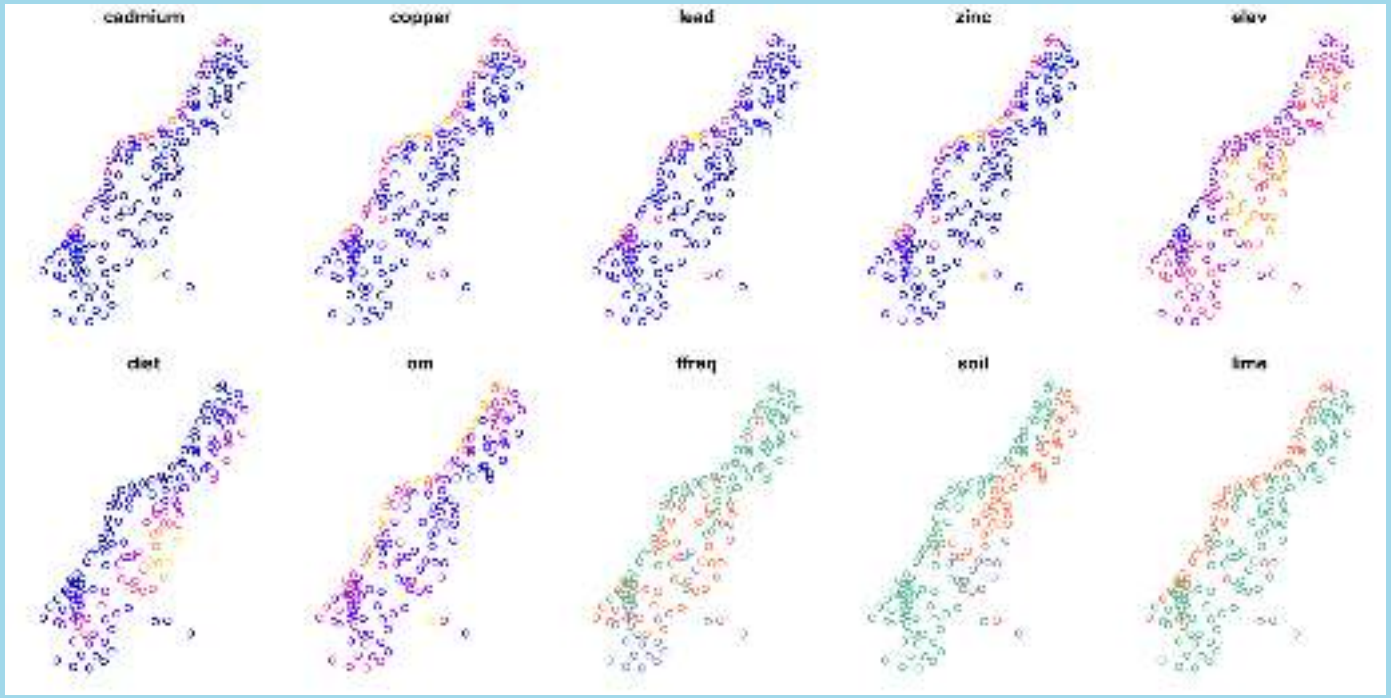
```
Simple feature collection with 2 features and 10 fields
Attribute-geometry relationships: constant (10)
Geometry type: POINT
Dimension:     XY
Bounding box:  xmin: 181025 ymin: 333558 xmax: 181072 ymax: 333611
Projected CRS: Amersfoort / RD New
  cadmium copper lead zinc  elev       dist   om ffreq 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

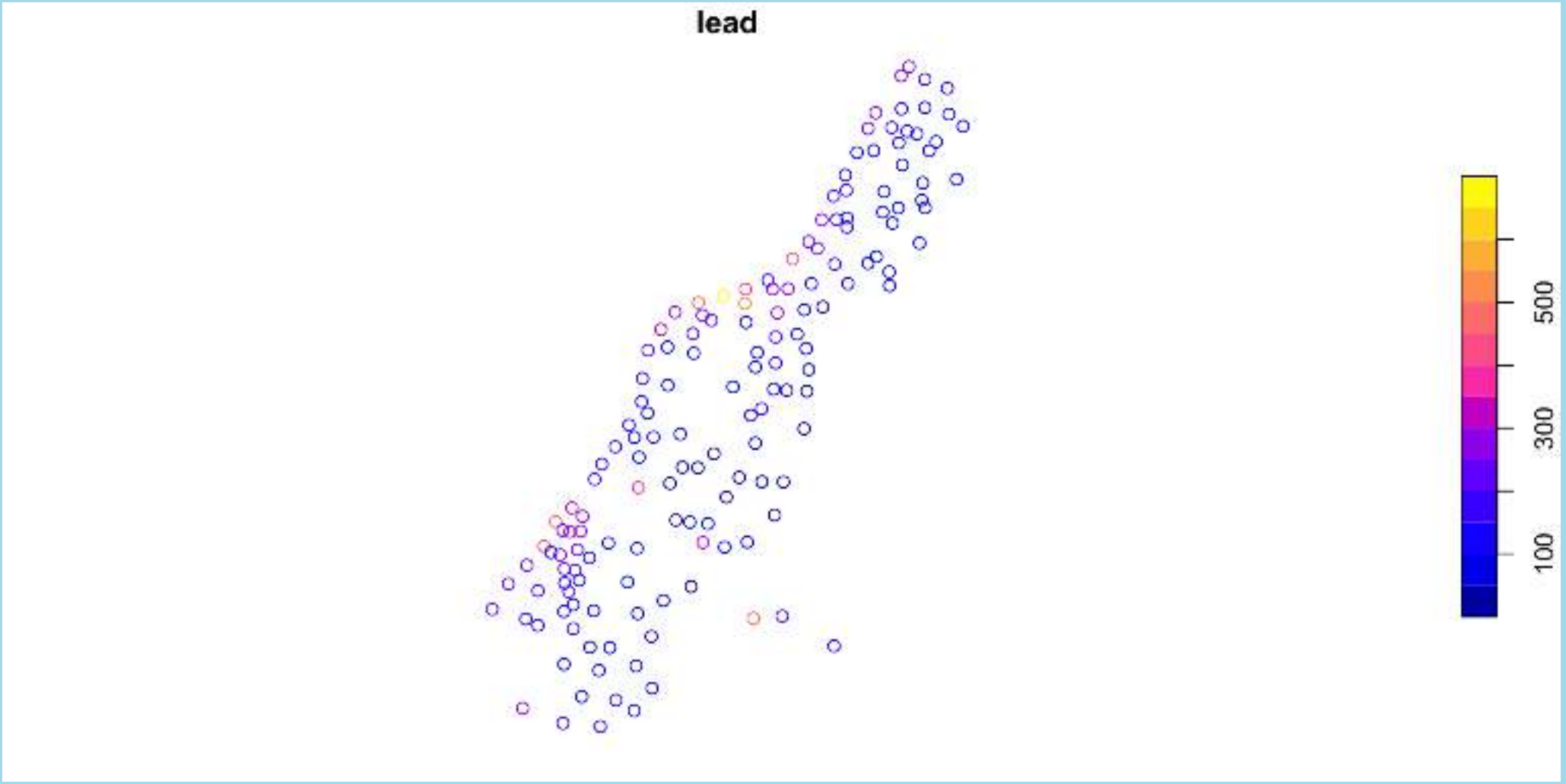
- Quick way to check your data
- Remember that `sf` has `geometry` and `attributes`

```
1  plot(meuse_sf)
```



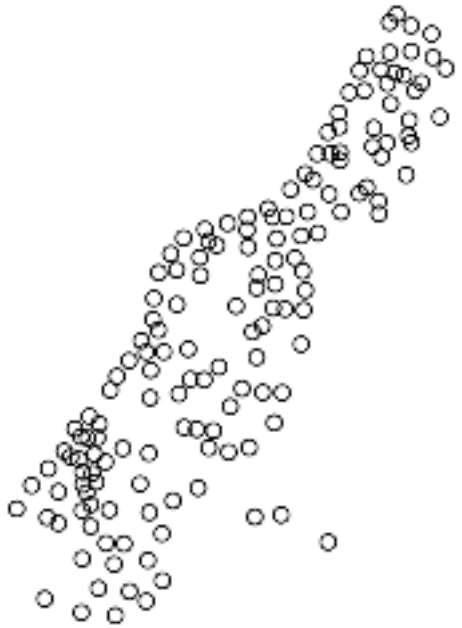
Plotting `sf` objects

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



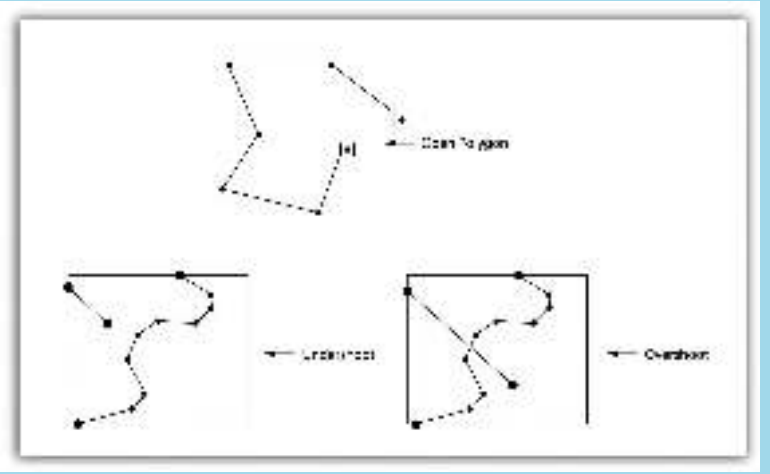
Plotting sf objects

```
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.