STA286 Lecture 01

Neil Montgomery

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admin

contact, notes

date format	YYYY-MM-DD – *All Hail ISO8601!!!*
instructor	Neil Montgomery
email	`neilm@mie.utoronto.ca`
office	BA8137
office hours	W11-1
website	portal (announcements, grades, suggested exercises, etc.)
github	`https://github.com/sta286-winter-2017` (lecture material, code, etc.)

Lecture notes and other course timing matters will be organized by *lecture number* and not *lecture date*, due to two lecture sections.

evaluation, book, tutorials

what	when	how much
midterm 1	TBA	25%
midterm 2	TBA	25%
exam	TBA	50%

The book is Walpole, R.E., Myers, R.H., Myers, S.L., Ye, K., 2012. *Probability & statistics for engineers & scientists.* 9th edition.

I will suggest exercises from this book each week. Your TA will work through some of them in tutorial each week.

Tutorials start TBA.

software

The course begins and ends with data analysis, with a long stretch of probability theory in the middle.

Data analysis requires a computer. Also, some concepts can be illustrated using simulation, which also requires a computer.

We will be using `R`. It's pretty good at data analysis.

language	interpreter	integrated development environment
`R`	`R`	`RStudio`

Some detailed instructions and suggestions for installation and configuration appear on the course website.

I will try to impart some data analysis workflow wisdom throughout the course. Some already appears in the detailed instructions.

MATLAB SUCKS!

what is a dataset?

most datasets are rectangles

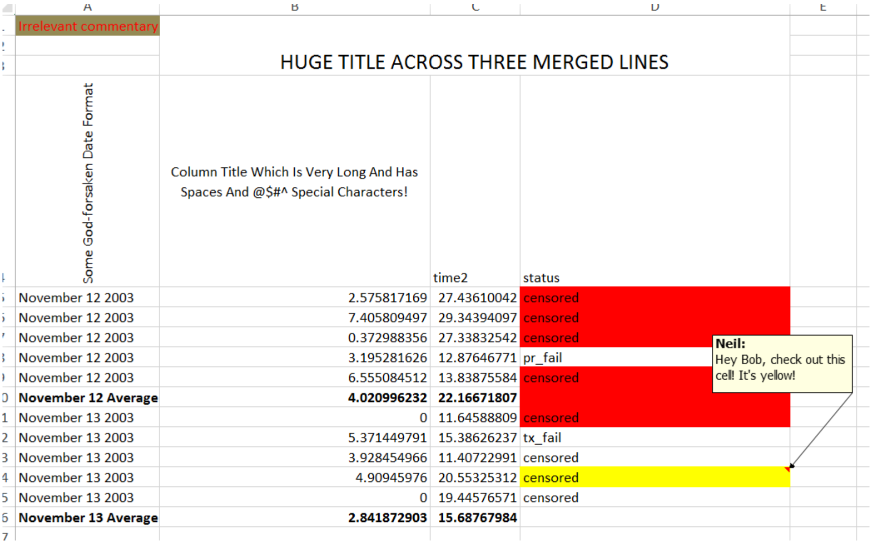
Columns are the *variables*.

The top row has the names of the variables; possibly chosen wisely.

Rows are the *observations* of measurements taken on *units*.

There are no averages, no comments (unless in a “comment” variable), no colors, no formatting, no plots, no capes!

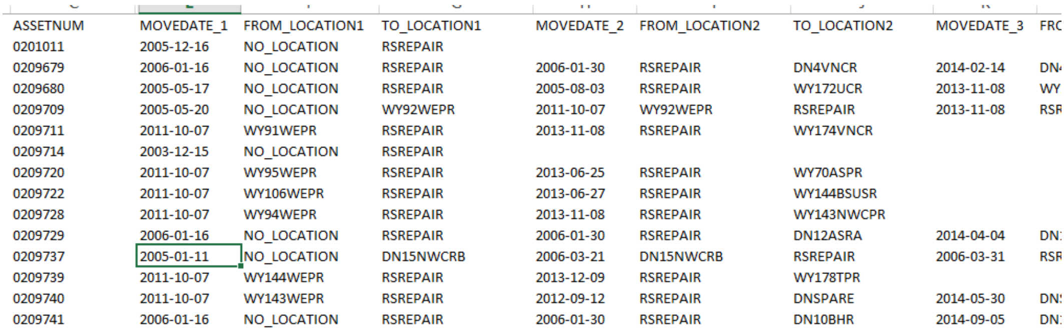
not a dataset



A	B	C	D	E
Irrelevant commentary	HUGE TITLE ACROSS THREE MERGED LINES			
Some God-forsaken Date Format	Column Title Which Is Very Long And Has Spaces And @$#^ Special Characters!	time2	status	
November 12 2003	2.575817169	27.43610042	censored	
November 12 2003	7.405809497	29.34394097	censored	
November 12 2003	0.372988356	27.33832542	censored	
November 12 2003	3.195281626	12.87646771	pr_fail	
November 12 2003	6.555084512	13.83875584	censored	
November 12 Average	**4.020996232**	**22.16671807**		
November 13 2003	0	11.64588809	censored	
November 13 2003	5.371449791	15.38626237	tx_fail	
November 13 2003	3.928454966	11.40722991	censored	
November 13 2003	4.90945976	20.55325312	censored	
November 13 2003	0	19.44576571	censored	
November 13 Average	**2.841872903**	**15.68767984**		

Neil:
Hey Bob, check out this cell! It's yellow!

not a dataset



ASSETNUM	MOVEDATE_1	FROM_LOCATION1	TO_LOCATION1	MOVEDATE_2	FROM_LOCATION2	TO_LOCATION2	MOVEDATE_3	FRO
0201011	2005-12-16	NO_LOCATION	RSREPAIR					
0209679	2006-01-16	NO_LOCATION	RSREPAIR	2006-01-30	RSREPAIR	DN4VNCR	2014-02-14	DN
0209680	2005-05-17	NO_LOCATION	RSREPAIR	2005-08-03	RSREPAIR	WY172UCR	2013-11-08	WY
0209709	2005-05-20	NO_LOCATION	WY92WEPR	2011-10-07	WY92WEPR	RSREPAIR	2013-11-08	RSR
0209711	2011-10-07	WY91WEPR	RSREPAIR	2013-11-08	RSREPAIR	WY174VNCR		
0209714	2003-12-15	NO_LOCATION	RSREPAIR					
0209720	2011-10-07	WY95WEPR	RSREPAIR	2013-06-25	RSREPAIR	WY70ASPR		
0209722	2011-10-07	WY106WEPR	RSREPAIR	2013-06-27	RSREPAIR	WY144BSUSR		
0209728	2011-10-07	WY94WEPR	RSREPAIR	2013-11-08	RSREPAIR	WY143NWCPR		
0209729	2006-01-16	NO_LOCATION	RSREPAIR	2006-01-30	RSREPAIR	DN12ASRA	2014-04-04	DN
0209737	2005-01-11	NO_LOCATION	DN15NWCRB	2006-03-21	DN15NWCRB	RSREPAIR	2006-03-31	RSR
0209739	2011-10-07	WY144WEPR	RSREPAIR	2013-12-09	RSREPAIR	WY178TPR		
0209740	2011-10-07	WY143WEPR	RSREPAIR	2012-09-12	RSREPAIR	DNSPARE	2014-05-30	DN
0209741	2006-01-16	NO_LOCATION	RSREPAIR	2006-01-30	RSREPAIR	DN10BHR	2014-09-05	DN

an oil readings dataset (wide version)

```
## # A tibble: 612 × 17
##     Ident                Date WorkingAge   TakenBy    Fe    Al    Cu
##     <chr>              <dttm>      <dbl>     <chr> <dbl> <dbl> <dbl>
## 1  448576 1999-05-10 19:00:00        243 EMPL_0917    13     5    14
## 2  448576 1999-07-26 19:00:00        569 EMPL_0917    18     6    25
## 3  448576 1999-09-29 19:00:00        830 EMPL_9375    26     6    35
## 4  448576 1999-10-08 19:00:00        862 EMPL_0917    15     9    14
## 5  448576 1999-11-02 19:00:00        946 EMPL_9375    14     4    19
## 6  448576 1999-12-09 19:00:00       1088 EMPL_0917    18     5    23
## 7  448576 1999-12-27 19:00:00       1157 EMPL_9375    24     8    25
## 8  448576 2000-01-14 19:00:00       1238 EMPL_9375    27     9    34
## 9  448576 2000-02-15 19:00:00       1376 EMPL_9375    16     8    17
## 10 448576 2000-03-11 19:00:00       1492 EMPL_0917    20     8    20
## # ... with 602 more rows, and 10 more variables: Cr <dbl>, Si <dbl>,
## #   Pb <dbl>, Ph <dbl>, Ca <dbl>, Zn <dbl>, Mg <dbl>, Mo <dbl>,
## #   Sn <dbl>, Na <dbl>
```

oil readings with Ident and TakenBy properly treated

```
## # A tibble: 612 × 17
##     Ident                Date WorkingAge   TakenBy    Fe    Al    Cu
##    <fctr>              <dttm>      <dbl>    <fctr> <dbl> <dbl> <dbl>
## 1  448576 1999-05-10 19:00:00        243 EMPL_0917    13     5    14
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```

oil readings dataset (long version)

```
## # A tibble: 7,956 × 6
##     Ident                Date WorkingAge   TakenBy element   ppm
##    <fctr>              <dttm>      <dbl>    <fctr>   <chr> <dbl>
## 1  448576 1999-05-10 19:00:00        243 EMPL_0917      Fe    13
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## 10 448576 2000-03-11 19:00:00       1492 EMPL_0917      Fe    20
## # ... with 7,946 more rows
```

the main questions

- where did the data come from?

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  - were the units chosed randomly from a population?
  - were the units randomly assigned into groups?
- what are the (joint) *distributions* of the data?

random sample, experiment, observational data

Sometimes the data come from a *random sample* from a larger *population*, in which case statements about the sample can apply to the population using laws of probability.

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Sometimes data come from an *experiment* where units are randomly assigned to different *levels* of one or more *factors*, in which cause cause-and-effect can be inferred using laws of probability.

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Sometimes data come from an *experiment* where units are randomly assigned to different *levels* of one or more *factors*, in which cause cause-and-effect can be inferred using laws of probability.

Often the data are just some records of what happened. Grander inferences might be made, but only on a subject-matter basis.

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through a process called *exploratory data analysis*

a taxonomy of variables

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  - Lots of grey areas even in this classification!
    - Categories can have an inherent order
    - "Likert scale" (strongly disagree coded as 1 and so on. . .)
- Numerical variables could be discrete (counting something) or continuously measured.

numerical summaries of dataset variables — definitions first with examples after

sample measures of “location”

The dataset is often called the “sample” (no matter where the data came from).

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For a particular numerical variable in the sample with observations:

$$\{x_1, x_2, \ldots, x_n\}$$

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$$\overline{x} = \frac{1}{n} \sum_{i=1}^{n} x_i$$

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Could be sensitive to extreme observations.

sample medians, sample percentiles

Order the observations:

$$x_{(1)} \leq x_{(2)} \leq \cdots \leq x_{(n)}$$

A number that divides the observations into two groups is called a *sample median*. For example:

$$\tilde{x} = \begin{cases} x_{((n+1)/2)} & : n \text{ odd} \\ \left(x_{(n/2)} + x_{(n/2+1)} \right)/2 & : n \text{ even} \end{cases},$$

which is harder to write out than it is to understand.

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which is harder to write out than it is to understand.

A *sample p^{th} percentile* has p% of the data below or equal to it. Special cases include (sample. . .): quartiles, quintiles, deciles, and indeed the median itself.

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Very (too?) simple measure: *sample range* which is just $x_{(n)} - x_{(1)}$.

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Summing up over all the observations gives the *sum of absolute deviations* (aka SAD) and the *sample variance* respectively. Notation and formula:

$$s^2 = \frac{\sum\limits_{i=1}^{n} (x_i - \overline{x})^2}{n-1}$$

sample standard deviation

s^2 is essentially the average squared deviation. (More on $n-1$ later in the course.)

The sample variance is good for theory but has an inconvenient unit. More practical is the *sample standard deviation*:

$$s = \sqrt{s^2}$$

numerical summaries for categorical variables

The oil readings data has one categorical variable, the Ident variable which is just a serial number.

```
## # A tibble: 5 × 17
##    Ident                Date WorkingAge   TakenBy    Fe    Al    Cu
##   <fctr>              <dttm>      <dbl>    <fctr> <dbl> <dbl> <dbl>
## 1 448576 1999-05-10 19:00:00        243 EMPL_0917    13     5    14
## 2 448576 1999-07-26 19:00:00        569 EMPL_0917    18     6    25
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## 4 448576 1999-10-08 19:00:00        862 EMPL_0917    15     9    14
## 5 448576 1999-11-02 19:00:00        946 EMPL_9375    14     4    19
## # ... with 10 more variables: Cr <dbl>, Si <dbl>, Pb <dbl>, Ph <dbl>,
## #   Ca <dbl>, Zn <dbl>, Mg <dbl>, Mo <dbl>, Sn <dbl>, Na <dbl>
```

tables of counts (or proportions)

A categorical variable could also be called a *factor* variable with *levels*, and to tabulate the frequency of each level is the way to summarize.

```
## # A tibble: 25 × 3
##      Ident     n proportion
##     <fctr> <int>      <dbl>
## 1   448572    31 0.05065359
## 2   448574    31 0.05065359
## 3   448576    36 0.05882353
## 4   448577    29 0.04738562
## 5   448578    34 0.05555556
## 6   448579    36 0.05882353
## 7   448580    28 0.04575163
## 8   448581    31 0.05065359
## 9   448582    41 0.06699346
## 10  448583    42 0.06862745
## # ... with 15 more rows
```

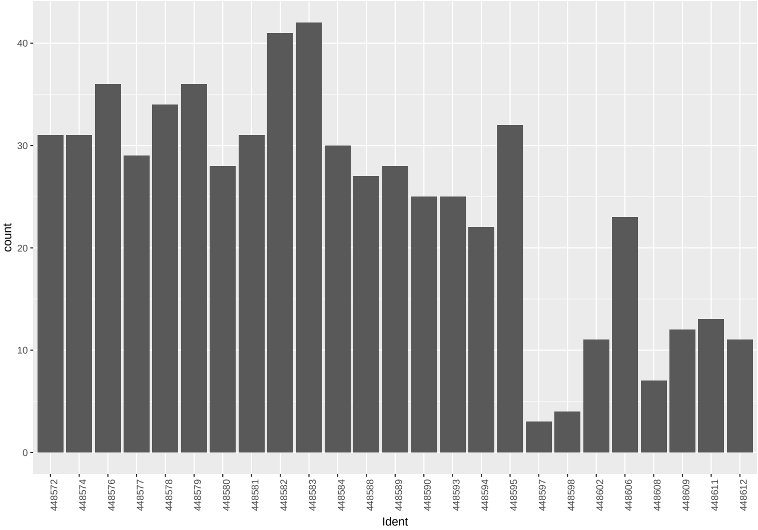
two-way classification with Ident and TakenBy

```
##             Ident
## TakenBy     448572 448574 448576 448577 448578 448579 448580 448581 4485
##   EMPL_0592     18     16      0      0     12      0      0      7
##   EMPL_0917      0      0     18     11      0     22     10      0
##   EMPL_2095      8      8      0      0      8      0      0      7
##   EMPL_4925      0      0     10      9      0      6     10      0
##   EMPL_9134      5      7      0      0     14      0      0     17
##   EMPL_9375      0      0      8      9      0      8      8      0
##             Ident
## TakenBy     448583 448584 448588 448589 448590 448593 448594 448595 4485
##   EMPL_0592      0      0      0     10      0     10      0      0
##   EMPL_0917     24      9     11      0     13      0     10     18
##   EMPL_2095      0      0      0     12      0      7      0      0
##   EMPL_4925     10     11     11      0      7      0     10     10
##   EMPL_9134      0      0      0      6      0      8      0      0
##   EMPL_9375      8     10      5      0      5      0      2      4
##             Ident
```

graphical summaries

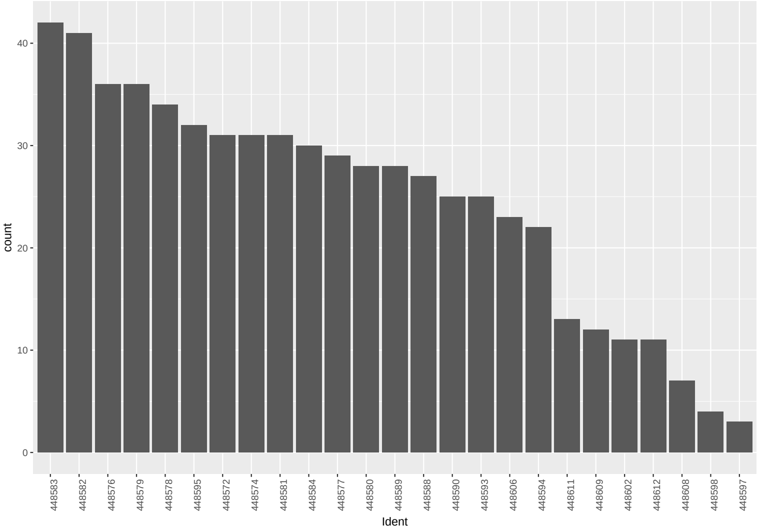
barchart

A barchart is a table of counts, in graphical form.

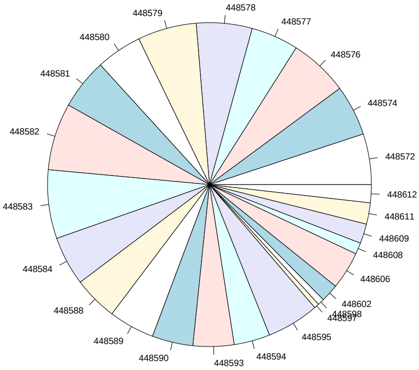


“Pareto” chart

Ordered by count.



piecharts are problematic

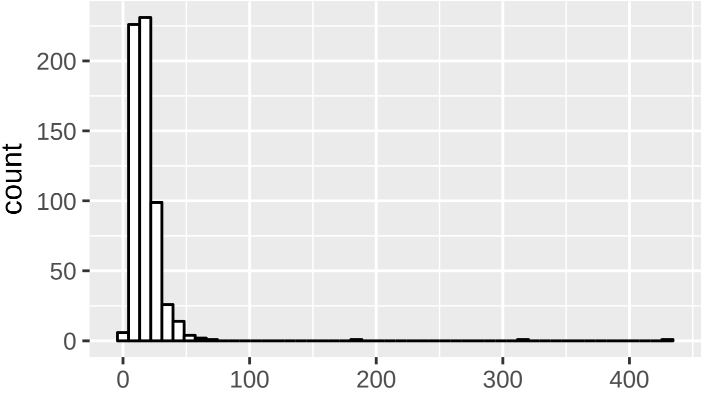


histograms

A histogram is a special case of a barchart.

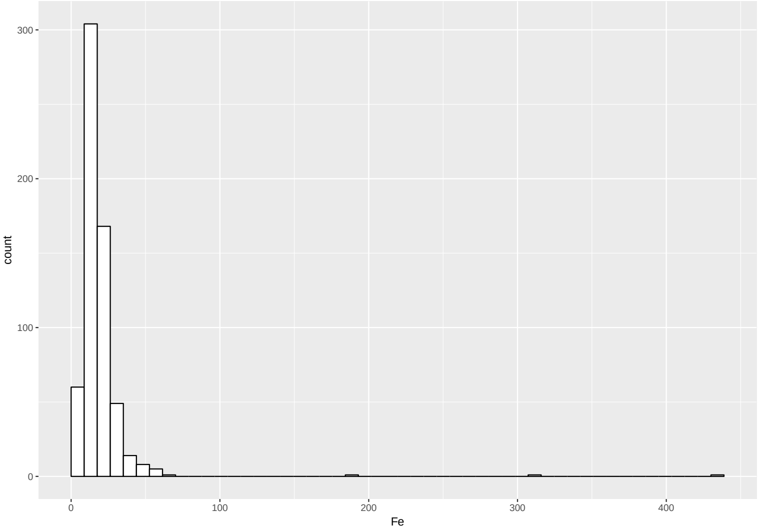
A numerical variable is split into classes and a barchart is made from the table of counts of obvservations within each class.

Histograms are done by the computer. Always play around with the number of classes.

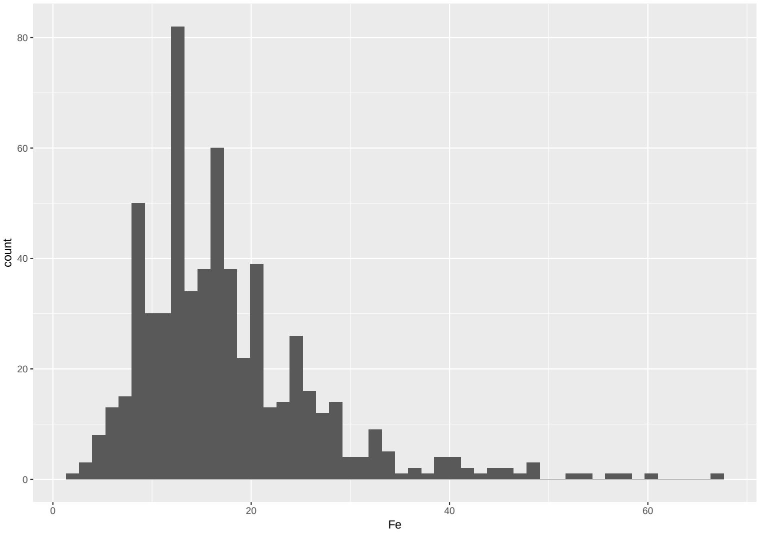


histograms are hard to implement!

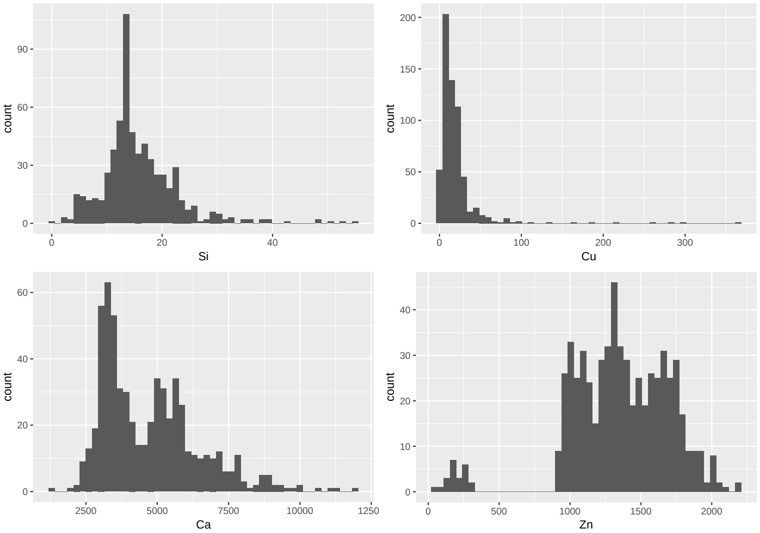
Better picture around 0. Possibly not important for EDA?



histogram without those really big values

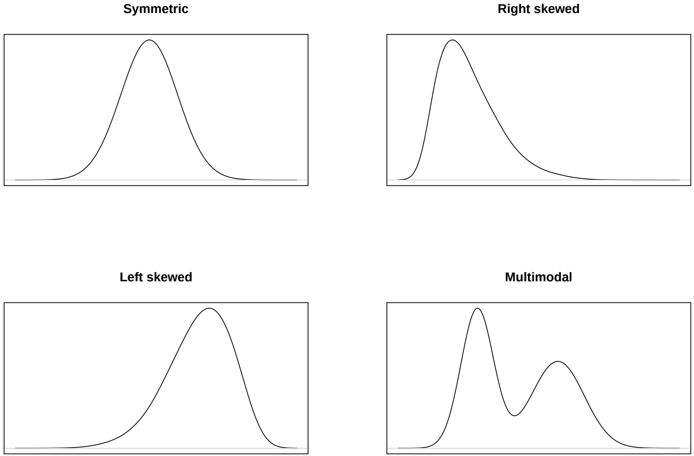


a few more ppm histograms



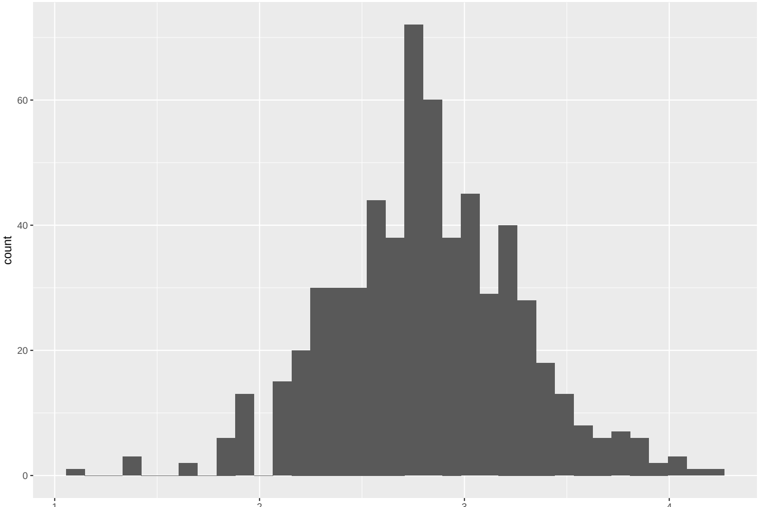
“shapes” of “distributions”

To use a histogram, *glance* at it and look for any of the following (without getting fooled by plot artefacts):



transforming variables

Apply log or square root to a variable will change the shape of the empirical distribution, e.g. transform right-skewed to symmetric.



boxplots

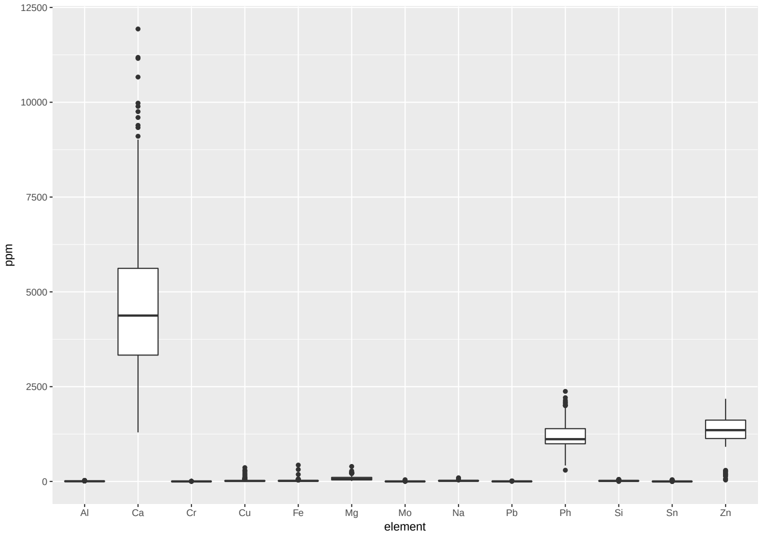
A special plot of these (or similar) five numbers:

min $\quad$ 25th percentile $\quad$ median $\quad$ 75th percentile $\quad$ max

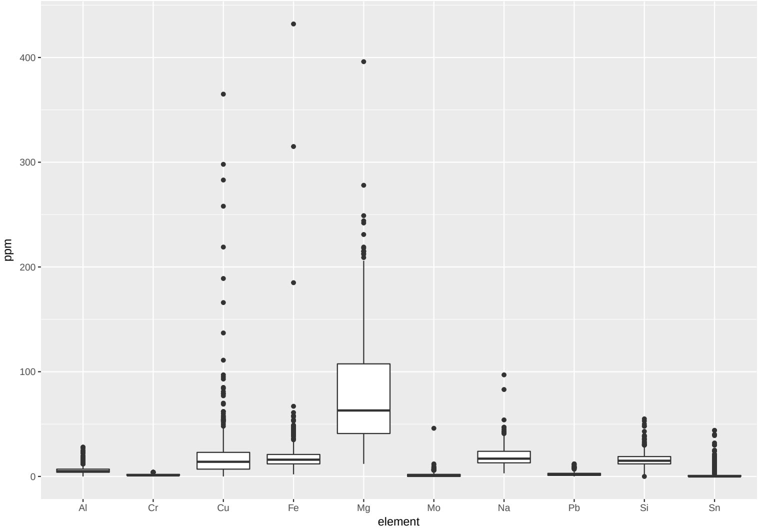
is called a *boxplot*. Often the extreme values are shown individually (see documentation for the (irrelevant) details.)

Best as *side-by-side* boxplots with more than one varaible on the same scale.

boxplot example - I

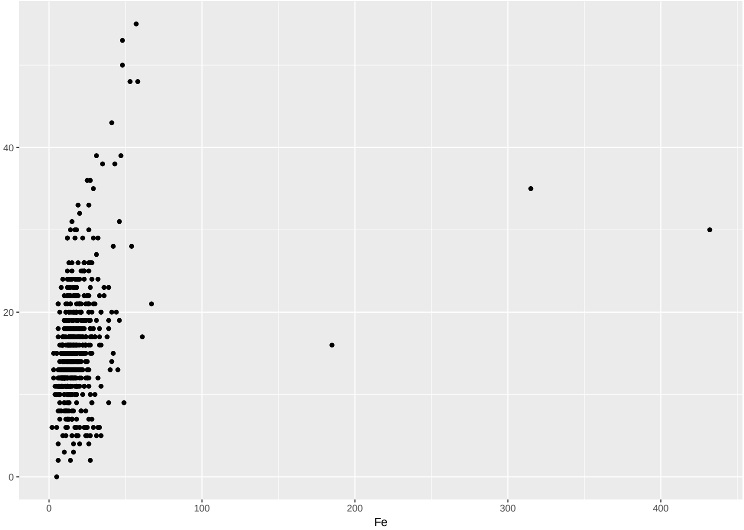


boxplot example - II

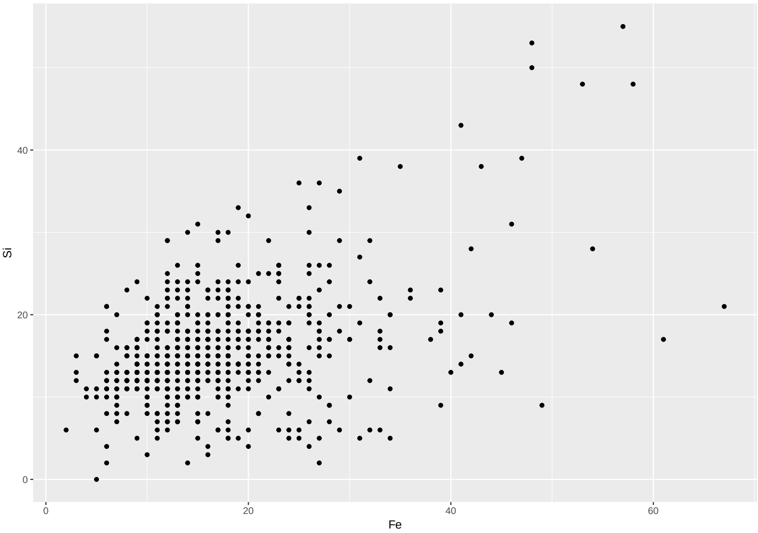


scatterplot

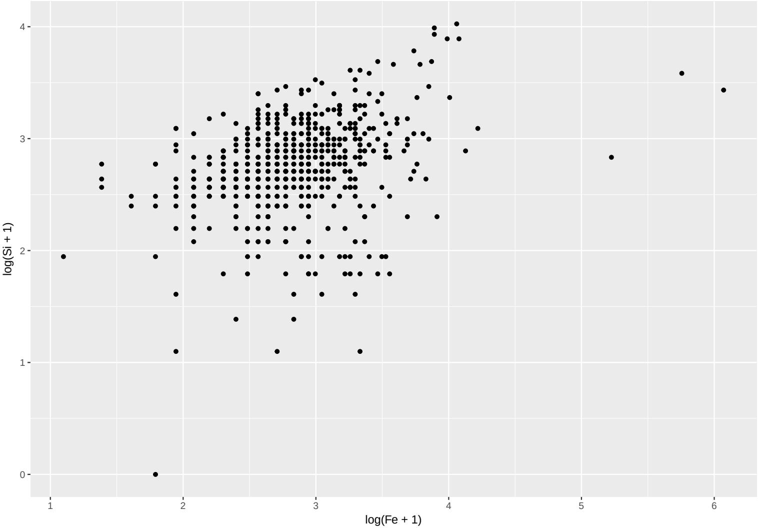
A graphic for two numerical variables, e.g. `Fe` and `Si`



Fe vs Si without the “outliers”

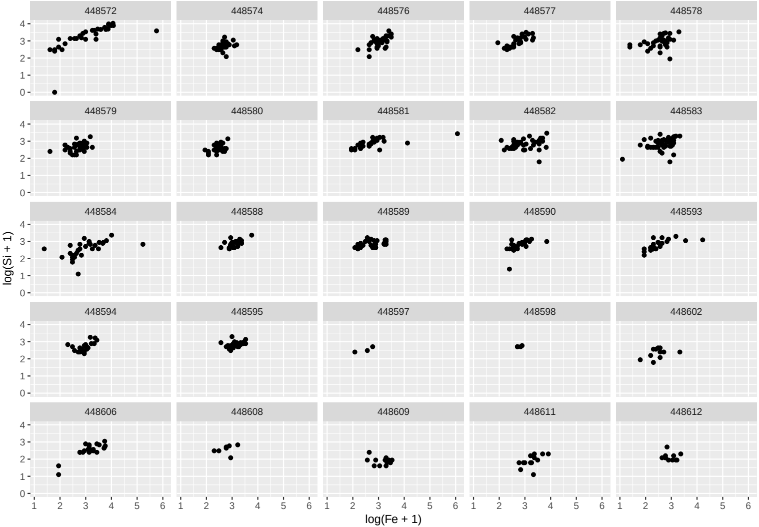


alternatively, on a log-log scale

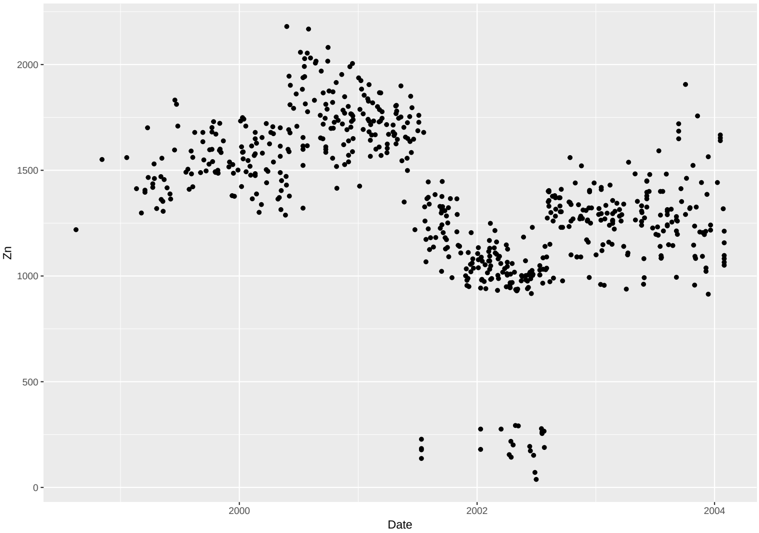


“small multiples” through faceting

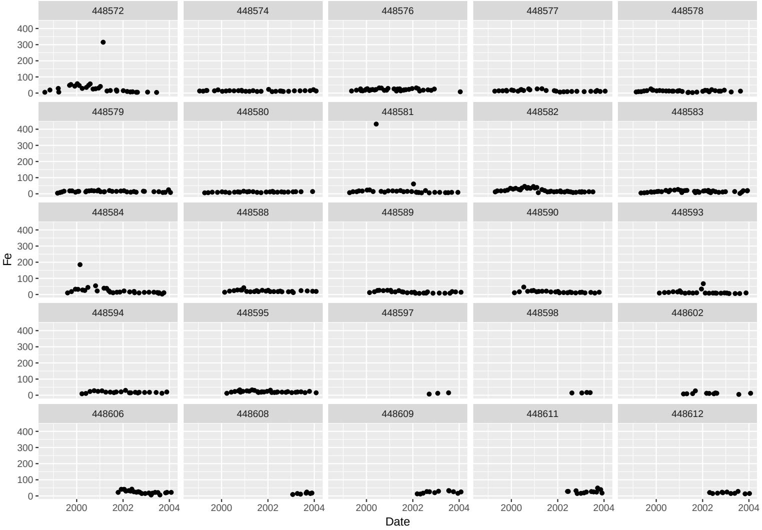
A powerful exploratory tool is to make a grid of small plots on subsets of the data.



what about that “Date” variable. . . (!)



Fe versus Date, facet by Ident


Fe
Date