

Hands-On Data Science with R Maps

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Spatial data is central to many of our tasks as Data Scientists. Identifying patterns and then correlations and relationships between those patterns delivers opportunities for delivering new services. Imagine predicting common routes for travellers this morning, and dynamically routing public transport to meet those needs. Fundamental to the Data Scientist is the ability to process, visualize and then model spatial data. Done right maps can be a very effective communications tool. Numerous R packages work together to bring us a sophisticated mapping and spatial analysis capability.

The required packages for this module include:

```
library(ggplot2)    # Plotting maps.
library(maps)       # Map data.
library(oz)         # Map data for Australia.
library(scales)     # Functions: alpha() comma()
library(ggmap)      # Google maps.
```

As we work through this chapter, new R commands will be introduced. Be sure to review the command's documentation and understand what the command does. You can ask for help using the `? command` as in:

```
?read.csv
```

We can obtain documentation on a particular package using the `help=` option of `library()`:

```
library(help=rattle)
```

This chapter is intended to be hands on. To learn effectively, you are encouraged to have R running (e.g., RStudio) and to run all the commands as they appear here. Check that you get the same output, and you understand the output. Try some variations. Explore.

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1 Google Maps: Geocoding

One of the fundamental things about spatial data and mapping is the geographic coordinate system used to uniquely identify locations. We use longitude (x axis, abbreviated lon) and latitude (y axis, abbreviated lat) for locations on our planet. The longitude is the angle from the meridian through Greenwich and the latitude is the angle from the equator. We can use `ggmap` (?) to `geocode()` street addresses and locations. Here are a few examples.

```
library(ggmap)
geocode("New York")

##           lon           lat
## 1 -74.00594  40.71278

geocode("Qiushi Road, Shenzhen")

##           lon           lat
## 1 113.9751  22.59073

geocode("Canberra")

##           lon           lat
## 1 149.1287 -35.282

geocode("Gus' Cafe, Garema Place, Canberra, Australia")

##           lon           lat
## 1 149.1321 -35.27839

geocode("9 Bunda Street, Canberra")

##           lon           lat
## 1 149.1312 -35.27757

geocode("11 Bunda Street, Canberra")

##           lon           lat
## 1 149.1313 -35.27758
```

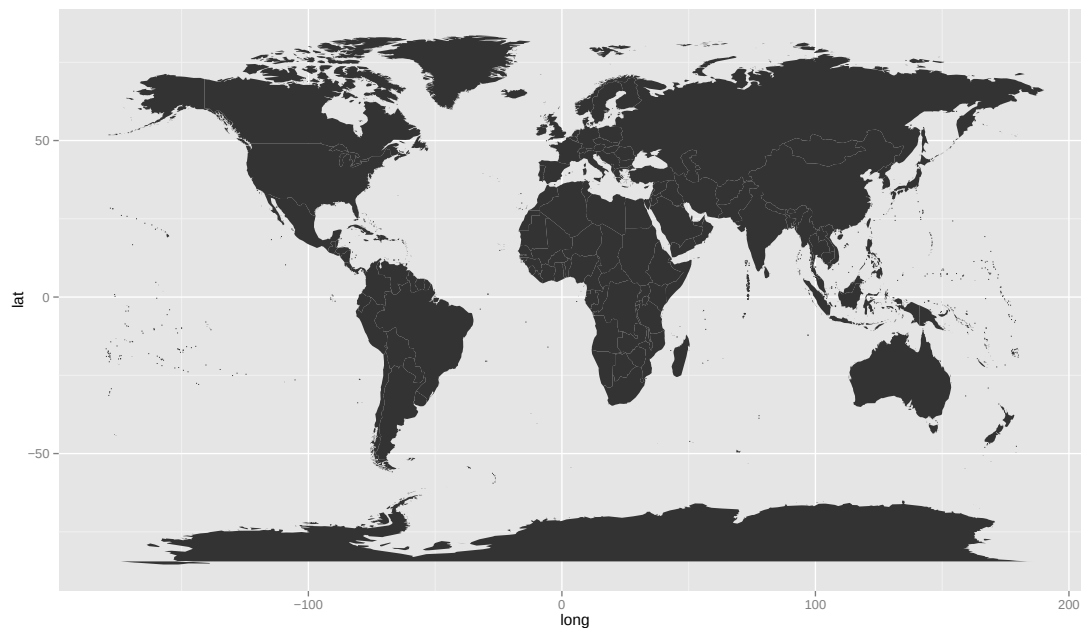
For later use we will save some locations.

```
(syd <- as.numeric(geocode("Sydney"))))
## [1] 151.20699 -33.86749

(cbr <- as.numeric(geocode("Canberra"))))
## [1] 149.1287 -35.2820

sydbb <- c(151.15, -33.88, 151.25, -33.84)
```

2 World Map



The data here comes from the `maps` (Brownrigg, 2014) package. We load the vector data for plotting a world map using `map_data()`.

```
ds <- map_data("world")
class(ds)

## [1] "data.frame"

str(ds)

## 'data.frame': 25553 obs. of 6 variables:
## $ long      : num -133 -132 -132 -132 -130 ...
## $ lat       : num 58.4 57.2 57 56.7 56.1 ...
## $ group     : num 1 1 1 1 1 1 1 1 1 1 ...
## ...

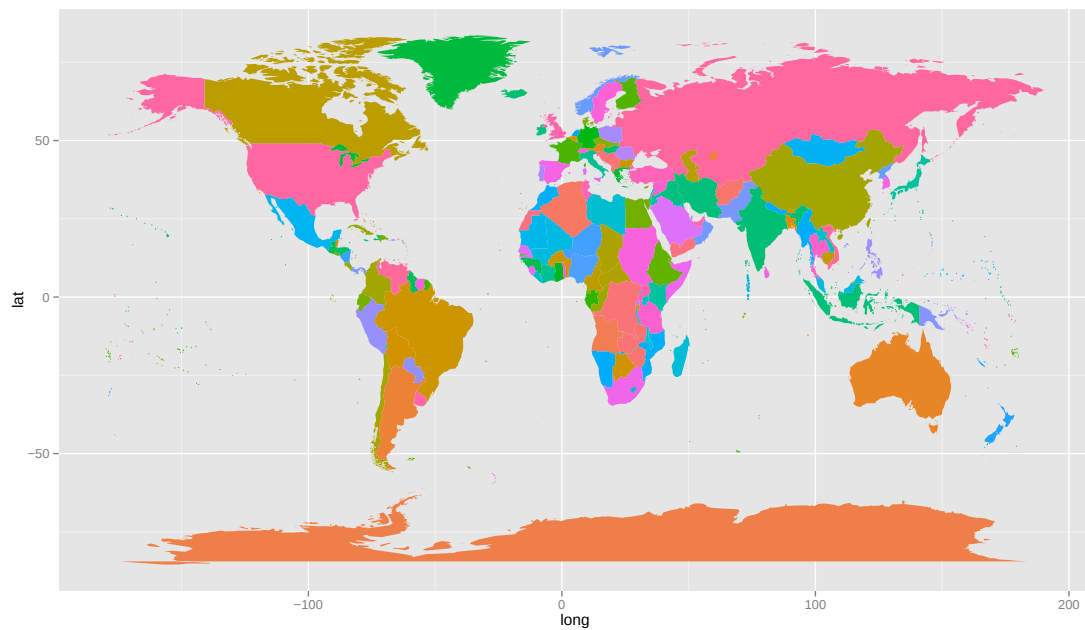
head(ds)

##      long  lat group order region subregion
## 1 -133.4 58.42     1     1  Canada      <NA>
## 2 -132.3 57.16     1     2  Canada      <NA>
## 3 -132.0 56.99     1     3  Canada      <NA>
## ...
```

It is then quite simple to plot the world map using `ggplot2` (Wickham and Chang, 2014).

```
p <- ggplot(ds, aes(x=long, y=lat, group=group))
p <- p + geom_polygon()
p
```

3 World Map with Coloured Regions



We can specify a fill for the map, based on the regions.

```
p <- ggplot(ds, aes(x=long, y=lat, group=group, fill=region))
p <- p + geom_polygon()
p <- p + theme(legend.position = "none")
p
```

Note there are very many regions, and so the legend would be too large, so we turn that off.

```
length(unique(ds$region))
## [1] 234
```


4 Obtain Map Data

Visit <http://www.gadm.org/country> to download administrative vector data for any region of the world. The coordinate reference system is latitude/longitude and the WGS84 datum. The file formats include shapefiles, ESRI data files, Google Earth, and RData files.

From the website: A "shapefile" consist of at least three actual files. This is a commonly used format that can be directly used in Arc-anything, DIVA-GIS, and many other programs. Unfortunately, many of the non standard latin (roman / english) characters are lost in the shapefile. Even if you use the shapefile for mapping, you can use the .csv file that comes with the shapefiles, or the attribute data in the geodatabase for the correct attributes (the geodatabase is a MS Access database that (on windows) can be accessed via ODBC).

An "ESRI personal geodatabase" is a MS Access file that can be opened in ArcGIS (version 10). One of its advantages, compared to a shapefile, is that it can store non-latin characters (e.g. Cyrillic and Chinese characters). You can also query the (attribute) data in Access or via ODBC.

An "ESRI file geodatabase" can be opened in ArcGIS (version 10). It can also store non-latin characters (e.g. Cyrillic and Chinese characters).

A "Google Earth .kmz" file can be opened in Google Earth.

A "RData" file can be used in R (with the sp package loaded). See the CRAN spatial task view

5 Australian Map Data

A data frame version of the Australian map data that comes originally from [oz \(?\)](http://www.elaliberte.info/software) is available at <http://www.elaliberte.info/software>. We load the CSV version of the data frame here.

```
ds <- read.csv(file.path("data", "ozdata.csv"))
dim(ds)

## [1] 5852      7

head(ds, 2)

##   X long   lat group order state border
## 1 1 129.0 -31.58     1     1    WA  coast
## 2 2 128.7 -31.69     1     2    WA  coast

tail(ds, 2)

##           X long   lat group order state border
## 5851 5851 146.9 -43.59     7    660    TAS  coast
## 5852 5852 146.9 -43.59     7    661    TAS  coast

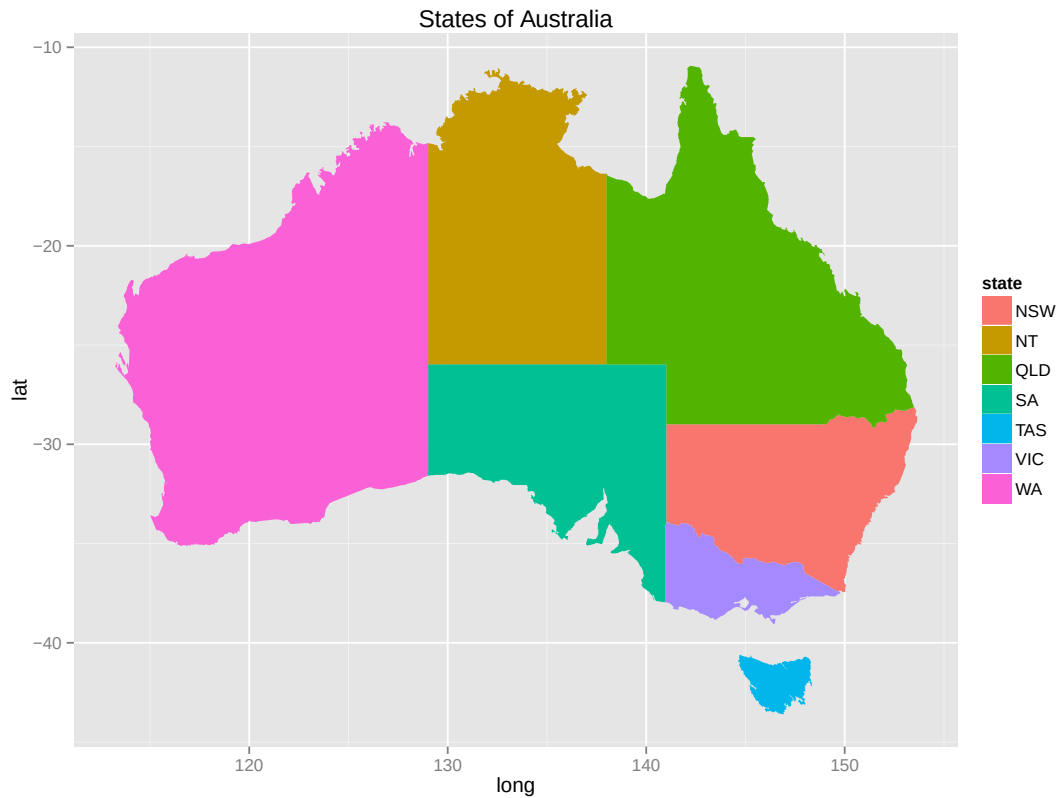
str(ds)

## 'data.frame': 5852 obs. of  7 variables:
##  $ X      : int  1 2 3 4 5 6 7 8 9 10 ...
##  $ long   : num  129 129 129 128 128 ...
##  $ lat    : num  -31.6 -31.7 -31.8 -31.8 -31.9 ...
##  $ group  : int  1 1 1 1 1 1 1 1 1 1 ...
##  $ order  : int  1 2 3 4 5 6 7 8 9 10 ...
##  $ state  : Factor w/ 7 levels "NSW","NT","QLD",...: 7 7 7 7 7 7 7 7 7 7 ...
##  $ border : Factor w/ 19 levels "coast","NSW.QLD",...: 1 1 1 1 1 1 1 1 1 1 ...

summary(ds)

##           X           long           lat           group
##  Min.      :    1      Min.      :113      Min.      : -43.6      Min.      :1.00
##  1st Qu.:1464      1st Qu.:131      1st Qu.: -35.6      1st Qu.:2.00
##  Median :2926      Median :142      Median : -28.9      Median :3.00
##  Mean     :2926      Mean     :139      Mean     : -27.2      Mean     :3.52
##  3rd Qu.:4389      3rd Qu.:147      3rd Qu.: -16.1      3rd Qu.:5.00
##  Max.     :5852      Max.     :154      Max.     : -10.9      Max.     :7.00
##
##           order           state           border
##  Min.      :    1      NSW: 856      coast :4904
##  1st Qu.: 210      NT : 743      NSW.VIC: 282
##  Median : 418      QLD:1118      VIC.NSW: 282
##  Mean     : 459      SA : 504      NSW.QLD: 176
##  3rd Qu.: 648      TAS: 661      QLD.NSW: 176
##  Max.     :1298      VIC: 672      QLD.SA :    3
##           WA :1298      (Other): 29
```

6 Australian Map with States



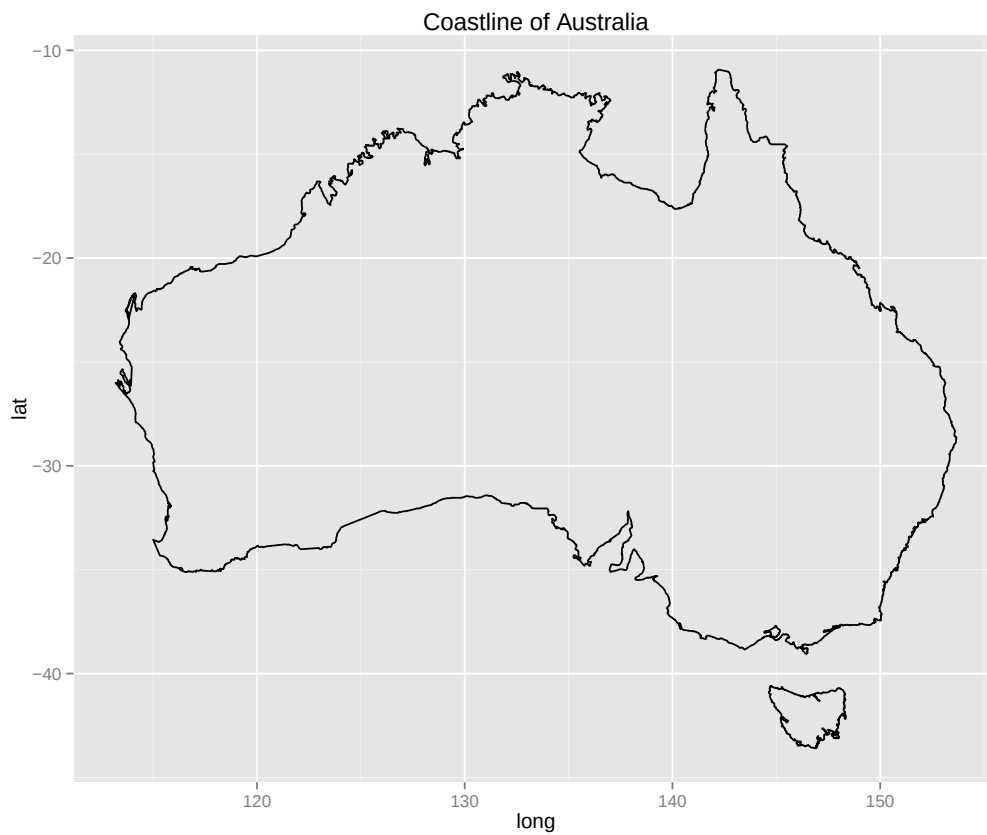
The map is drawn with a different fill colour for each state.

```
p <- ggplot(ds, aes(long, lat, fill=state))
p <- p + geom_polygon()
p <- p + coord_equal()
p <- p + ggtitle("States of Australia")
p
```

Note the use `coord_equal()` to ensure a properly proportioned map.

This example was motivated by the example using `qqplot()` at <http://www.elaliberte.info/software>.

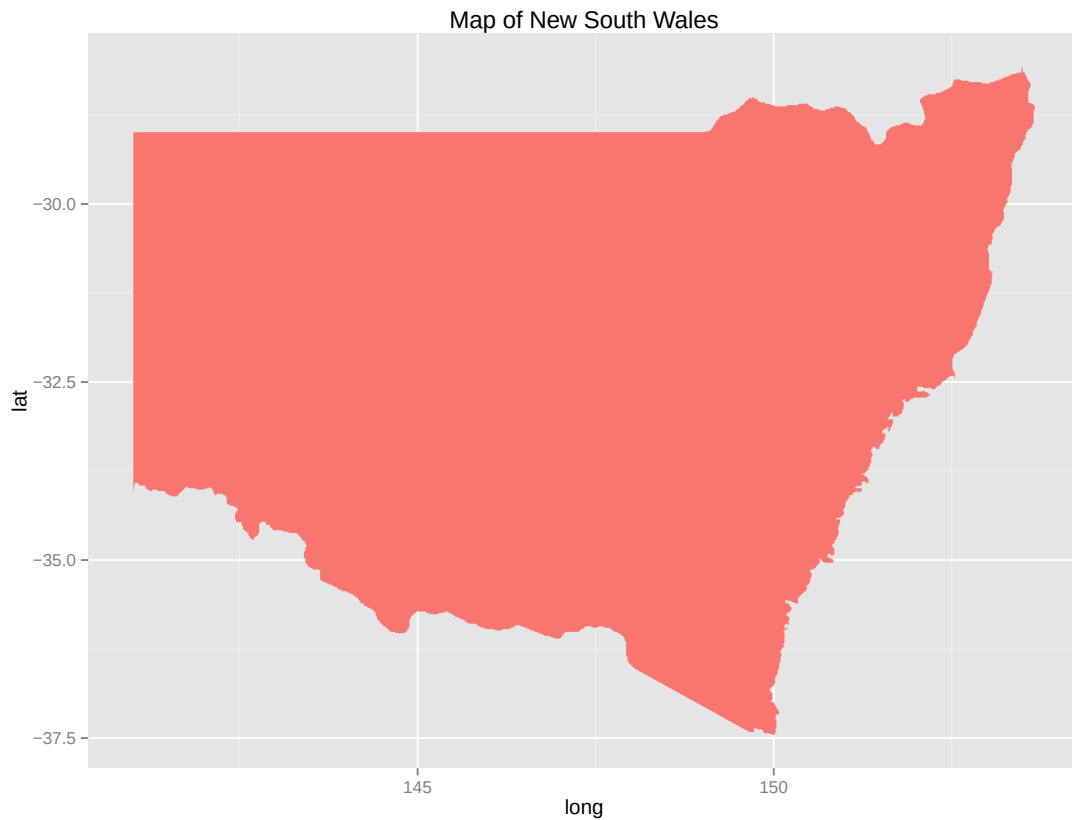
7 Map a Subset — Australian Coastline



```
p <- ggplot(subset(ds, border=="coast"), aes(long, lat, fill=state))
p <- p + geom_path()
p <- p + coord_equal()
p <- p + ggtitle("Coastline of Australia")
p
```

This example was motivated by the example using `qqplot()` at <http://www.elaliberte.info/software>.

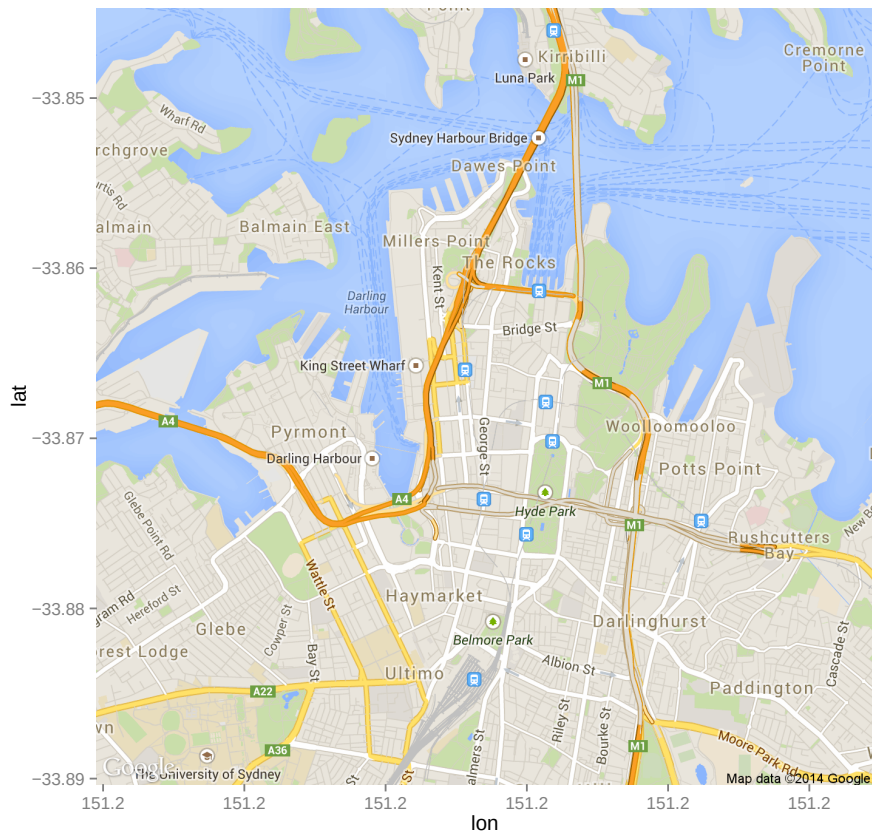
8 Map a Subset — New South Wales



```
p <- ggplot(subset(ds, state=="NSW"), aes(long, lat, fill=state))
p <- p + geom_polygon()
p <- p + coord_equal()
p <- p + ggtitle("Map of New South Wales")
p <- p + theme(legend.position="none")
p
```

This example was motivated by the example using `qqplot()` at <http://www.elaliberte.info/software>.

9 Google Map of Sydney



Here we download the map data for Sydney from Google using `get_map()` from `ggmap` (?). The data is transformed into a raster object for plotting.

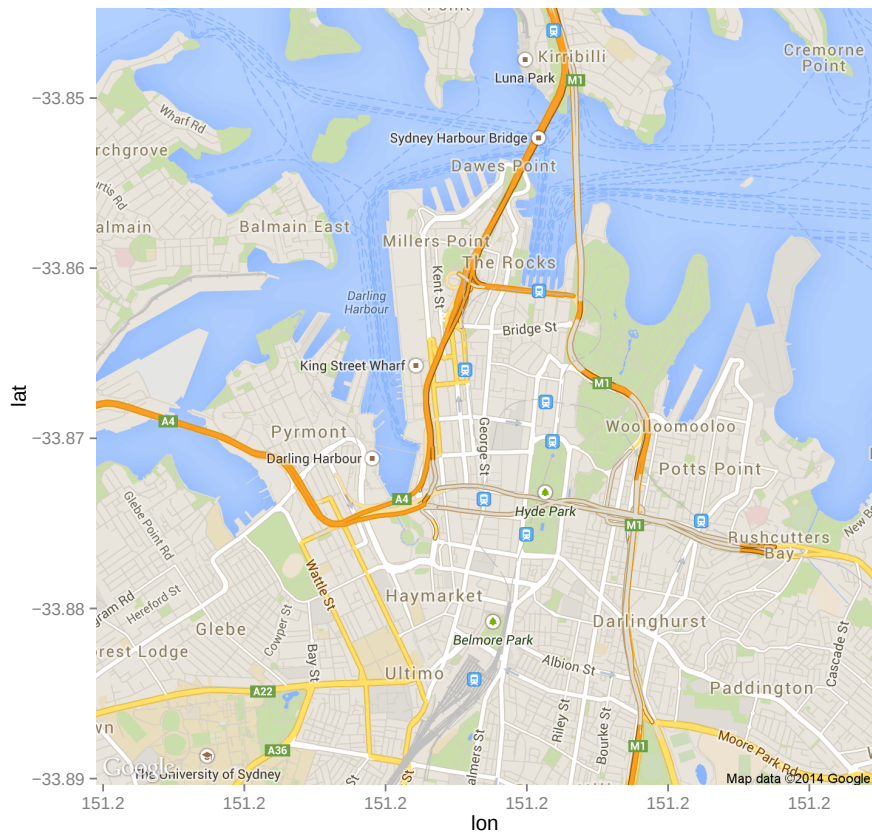
```
map <- get_map(location="Sydney", zoom=14, maptype="roadmap", source="google")
p <- ggmap(map)
p
```

The `zoom=` option is an integer. A value of 0 returns a map of the whole world, centred around the location. The maximum value is 21 and returns a map down to the building. Choosing 4 is usually good for continents, 14 for a city.

Notice that the object returned by `ggmap()` is a `ggplot` object, and so all the usual `ggplot2` (Wickham and Chang, 2014) functions apply.

```
class(p)
## [1] "gg"      "ggplot"
```

10 Google Map by Geocode of Sydney



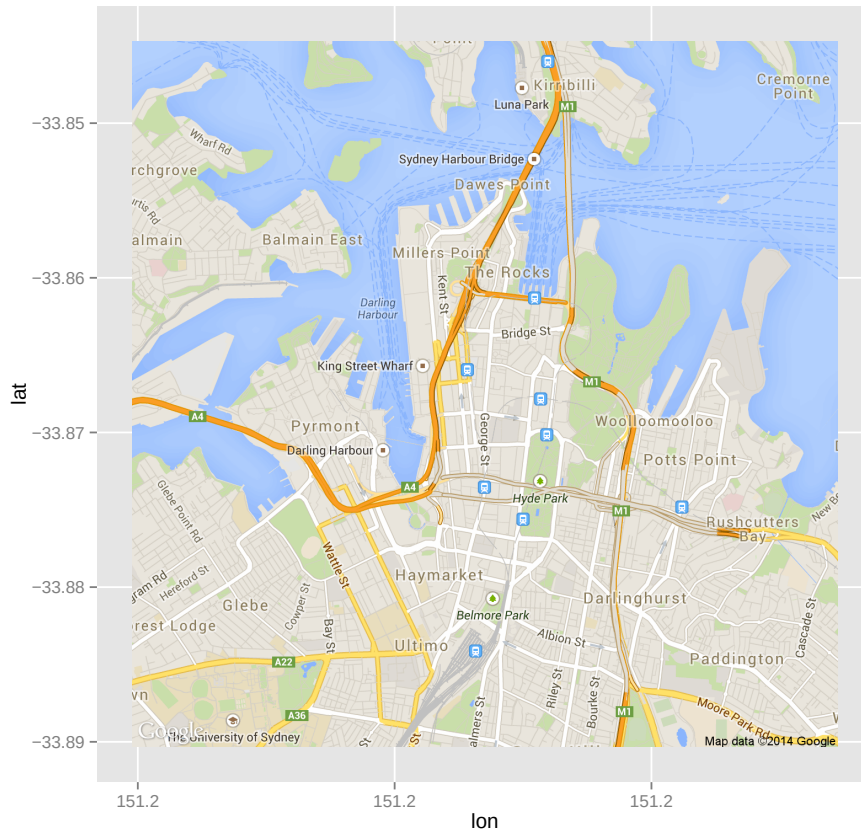
We will generally provide geo-codes to extract maps.

```
map <- get_map(location=syd, zoom=14, maptype="roadmap", source="google")
p <- ggmap(map)
p
```

Notice we have previously saved the location of Sydney into the variable *syd* and we have used that here to extract the same map.

```
(syd <- as.numeric(geocode("Sydney"))))
## [1] 151.21 -33.87
```

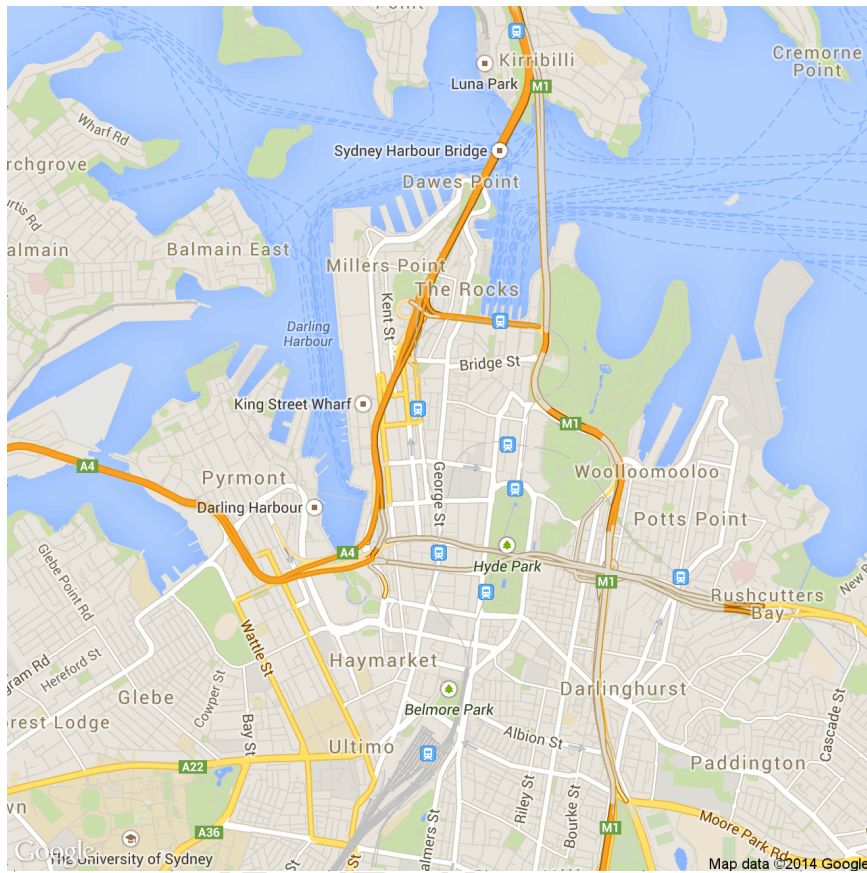
11 Map with Normal Extent of Sydney



```
map <- get_map(location="Sydney", zoom=14, maptype="roadmap", source="google")
p <- ggmap(map, extent="normal")
p
```

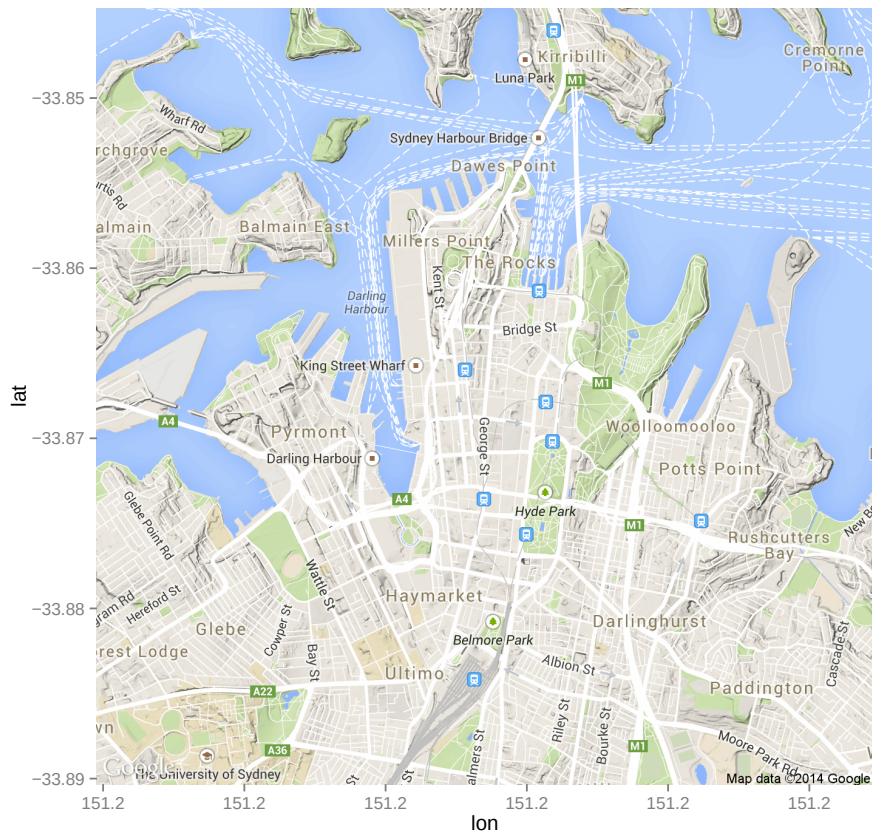
The default is `extent="panel"`.

12 Map with Device Extent of Sydney



```
map <- get_map(location="Sydney", zoom=14, maptype="roadmap", source="google")
p <- ggmap(map, extent="device")
p
```

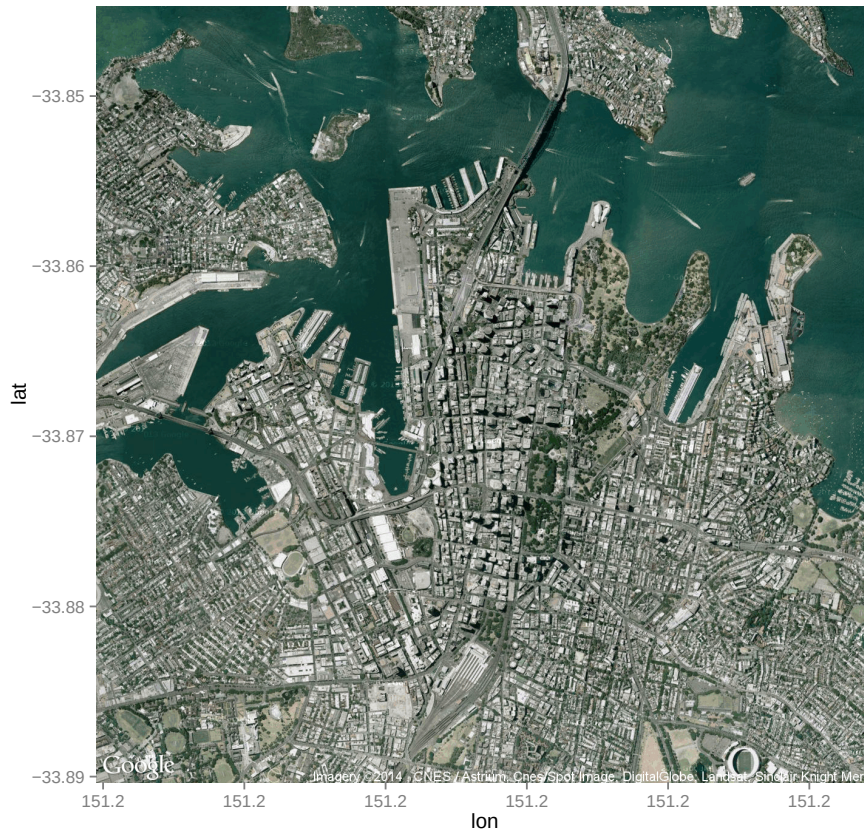
13 Google Terrain Map of Sydney



Here we see another type of map available from Google.

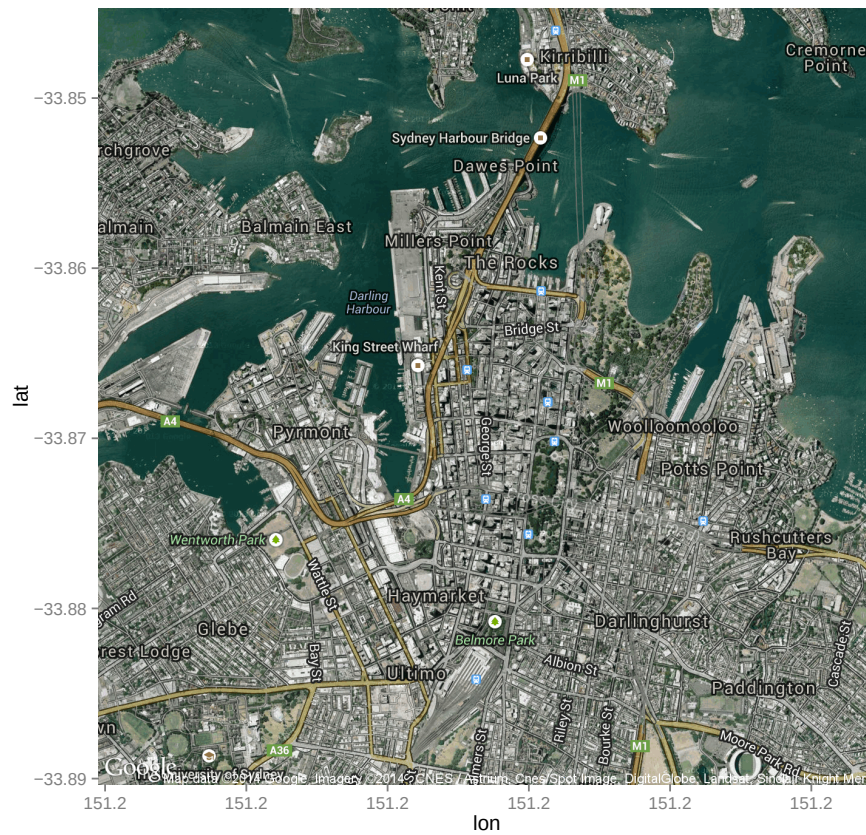
```
map <- get_map(location="Sydney", zoom=14, maptype="terrain", source="google")
p <- ggmap(map)
p
```

14 Google Satellite Map of Sydney



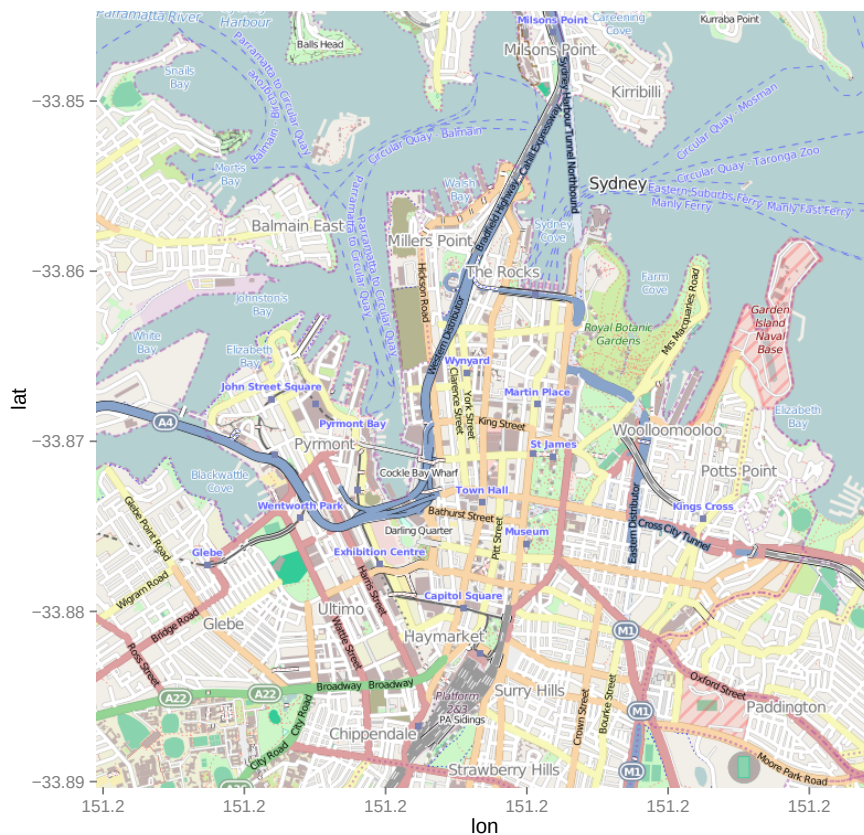
```
map <- get_map(location="Sydney", zoom=14, maptype="satellite", source="google")
p <- ggmap(map)
p
```


15 Google Hybrid Map of Sydney



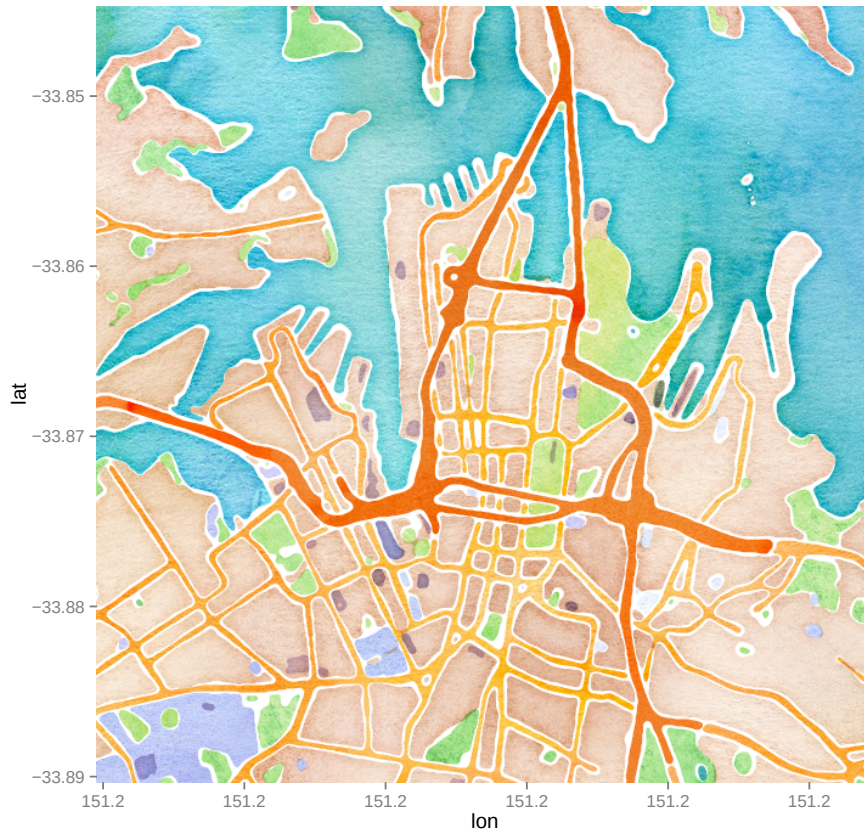
```
map <- get_map(location="Sydney", zoom=14, maptype="hybrid", source="google")  
p <- ggmap(map)  
p
```

16 OpenStreetMap of Sydney



```
map <- get_map(location="Sydney", zoom=14, source="osm")
p <- ggmap(map)
p
```

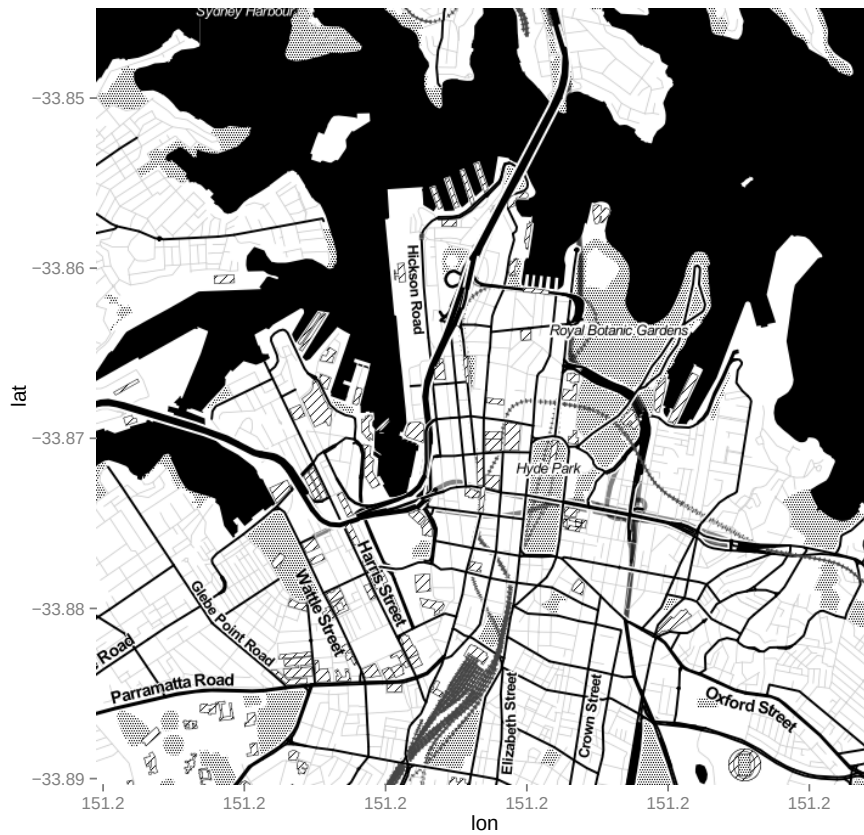
17 Stamen Watercolour Map of Sydney



Here we downloaded the map data for Sydney from other sources. This watercolour comes from [Stamen](#).

```
map <- get_map(location="Sydney", zoom=14, maptype="watercolor", source="stamen")
p <- ggmap(map)
p
```

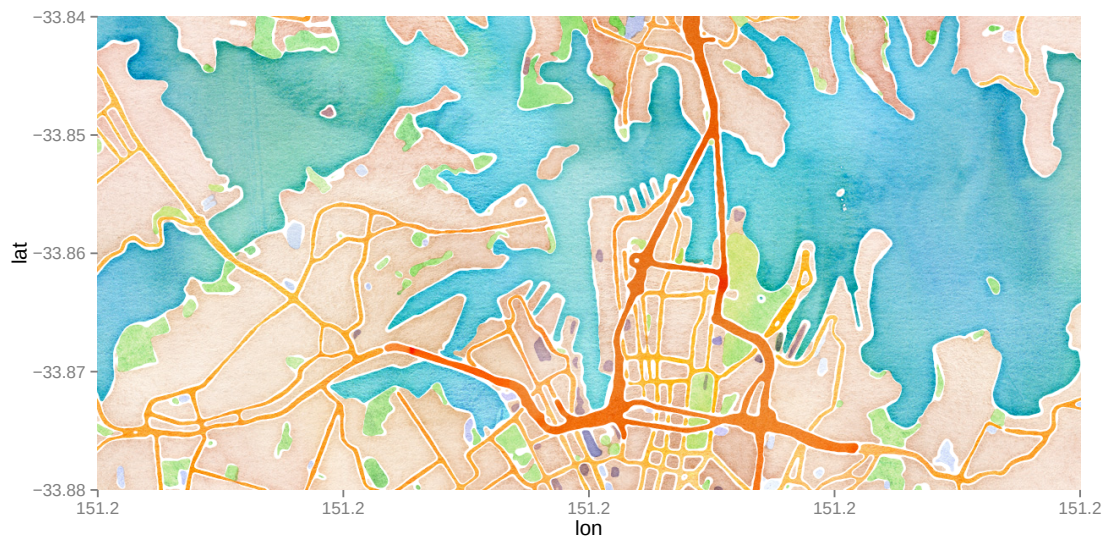

18 Stamen Toner Map of Sydney



```
map <- get_map(location="Sydney", zoom=14, maptype="toner", source="stamen")  
p <- ggmap(map)  
p
```

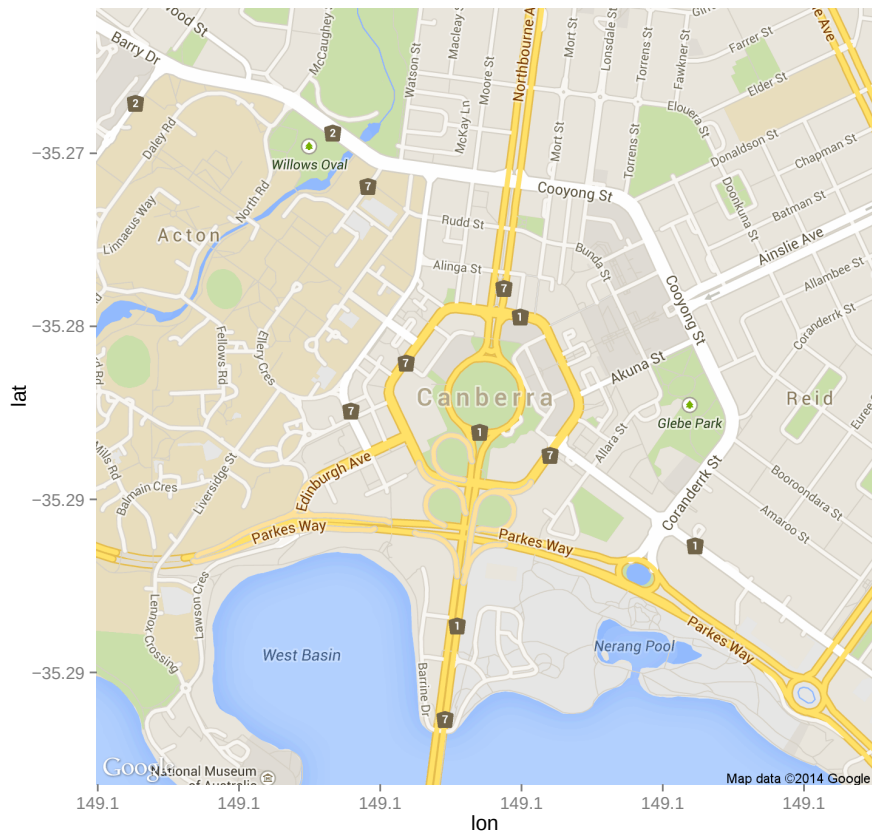
19 Bounding Box to Specify Sydney Map

Some sources also support bounding boxes rather than a centroid and zoom. Stamen, for example, supports bounding boxes, but Google does not. Here we use a bounding box (*sydbb*) that we defined earlier.



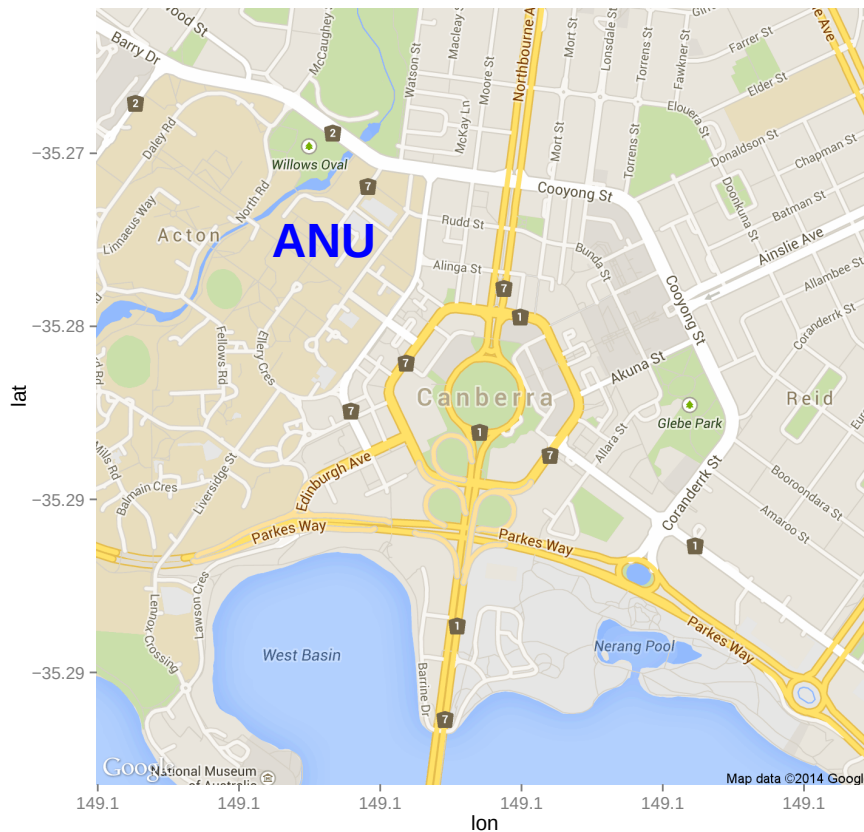
```
map <- get_map(location=sydbb, maptype="watercolor", source="stamen")
p <- ggmap(map)
p
```


20 Google Map of Canberra



```
map <- get_map(location="Canberra", zoom=15, maptype="roadmap", source="google")
p <- ggmap(map)
p
```

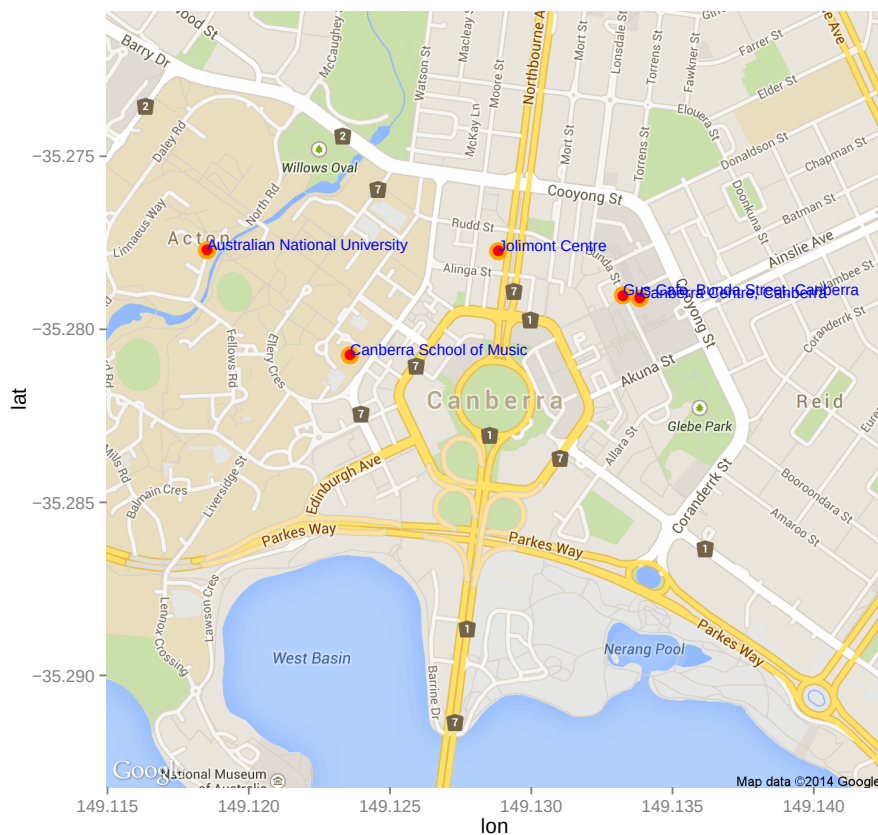
21 Annotating a Map with Text



Here we add a blue ANU label (Australian National University).

```
map <- get_map(location="Canberra", zoom=15, maptype="roadmap", source="google")
df1bl <- data.frame(lon=149.1230, lat=-35.2775, text="ANU")
p <- ggmap(map)
p <- p + geom_text(data=df1bl, aes(x=lon, y=lat, label=text),
  size=10, colour="blue", fontface="bold")
p
```

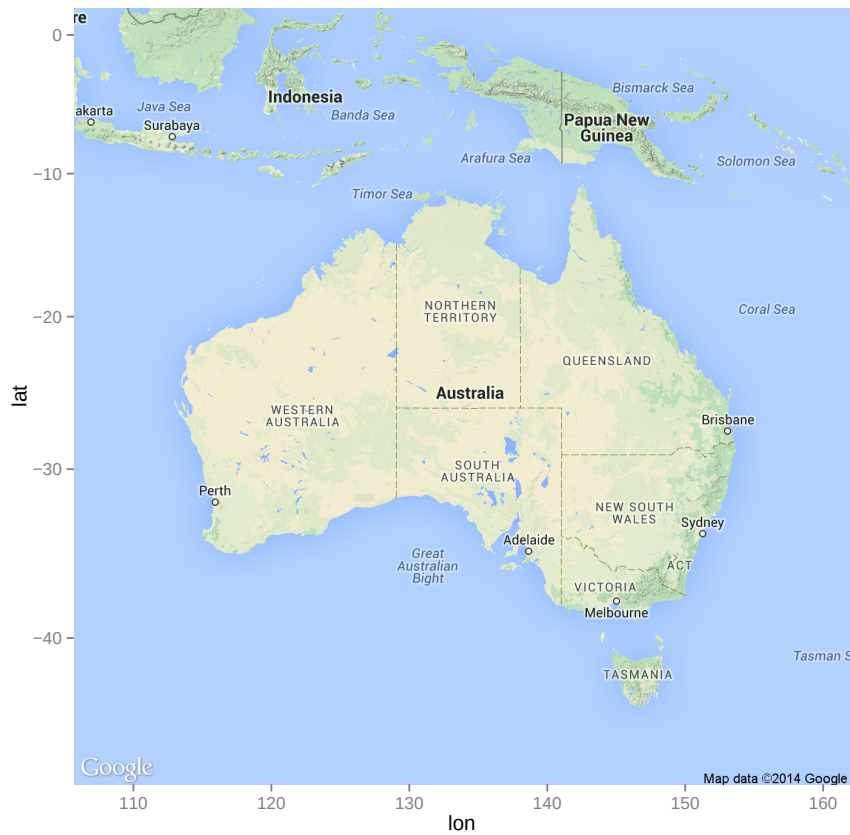
22 Annotating a Map with Landmarks



Here we have geocoded some landmarks and then added them to the map.

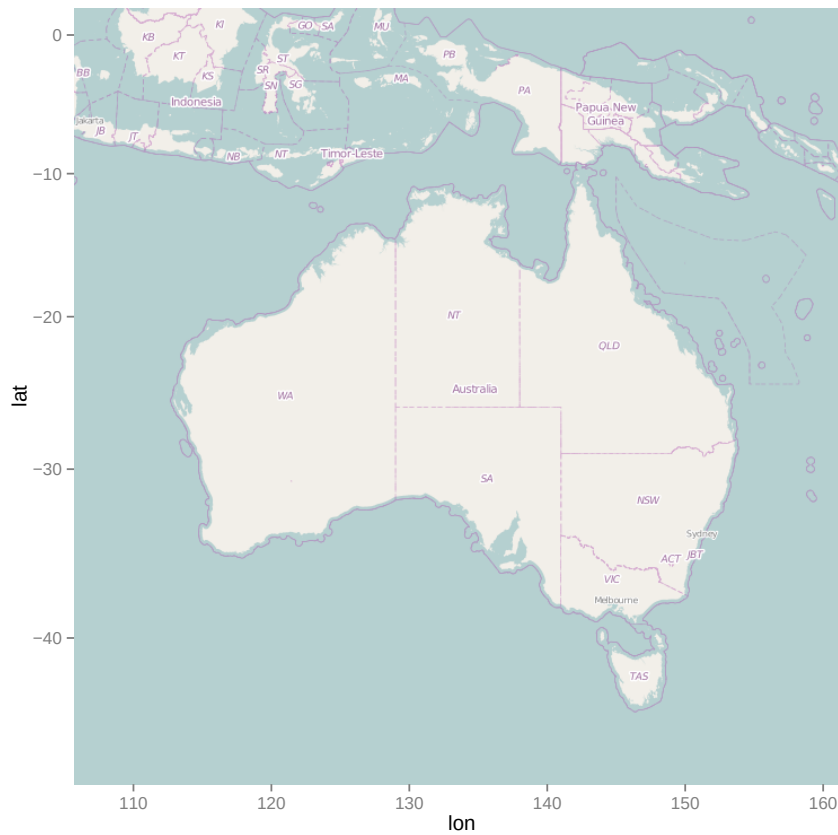
```
landmarks <- c("Gus Cafe, Bunda Street, Canberra", "Canberra Centre, Canberra",
               "Canberra School of Music", "Jolimont Centre",
               "Australian National University")
lbls <- cbind(geocode(landmarks), text=landmarks)
p <- ggmap(map)
p <- p + geom_point(data=lbls, aes(x=lon, y=lat), size=5, colour="orange")
p <- p + geom_point(data=lbls, aes(x=lon, y=lat), size=3, colour="red")
p <- p + geom_text(data=lbls, aes(x=lon, y=lat, label=text),
                  size=3, colour="blue", hjust=0, vjust=0)
p
```

23 Google Map of Australia



```
map <- get_map(location=as.numeric(geocode("Australia")),
               zoom=4, source="google")
p <- ggmap(map)
p
```

24 OpenStreetMap of Australia



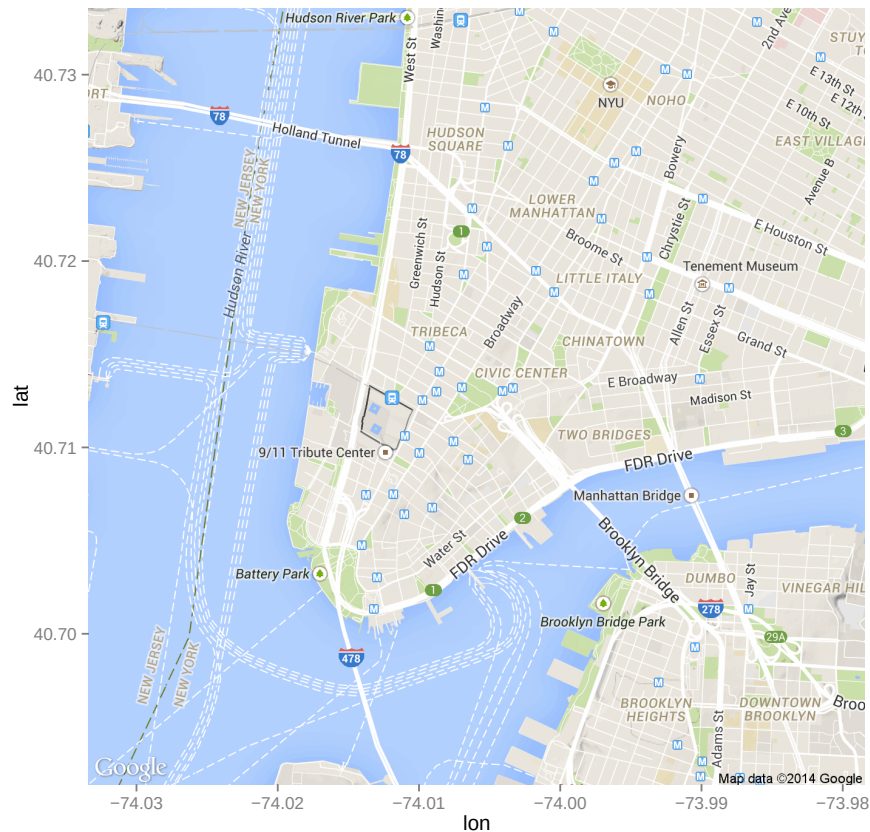
```
map <- get_map(location="Australia", zoom=4, source="osm")
p <- ggmap(map)
p
```

25 Google Map of Europe



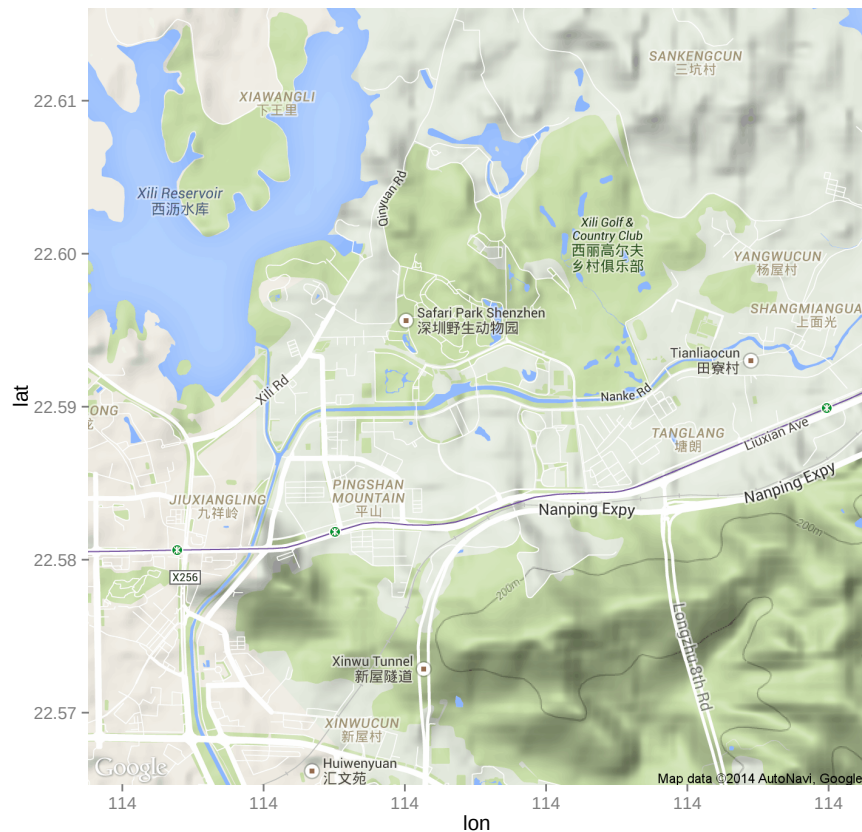
```
map <- get_map(location="Europe", zoom=4)
p <- ggmap(map)
p
```


26 New York: Google Maps



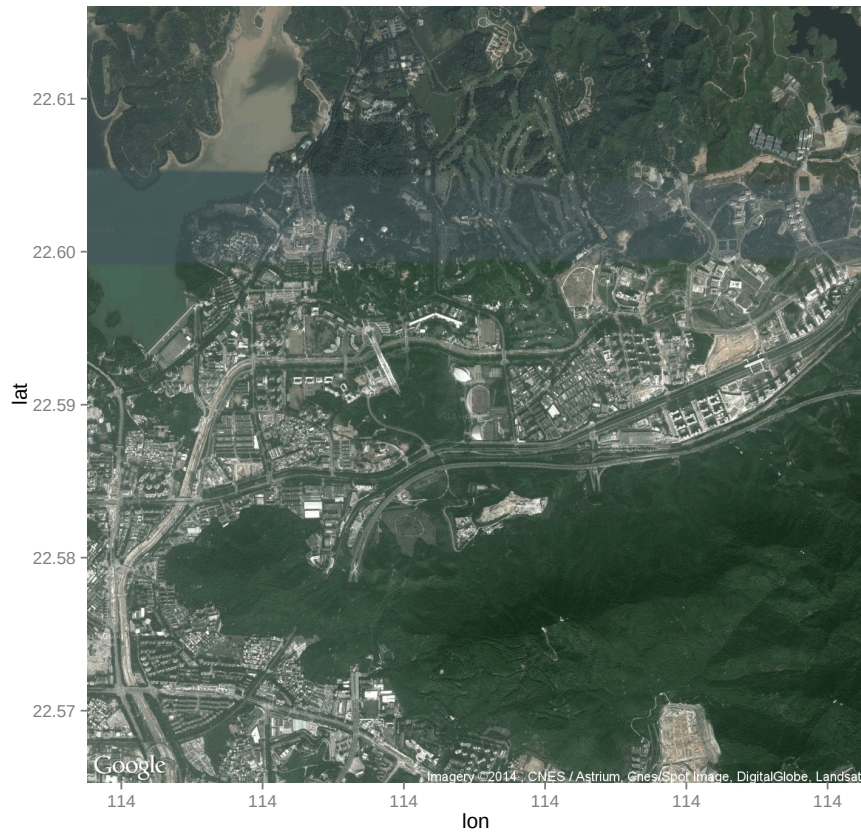
```
map <- get_map(location=as.numeric(geocode("New York")),  
               zoom=14, source="google")  
p <- ggmap(map)  
p
```

27 Google Maps: Shenzhen University Town



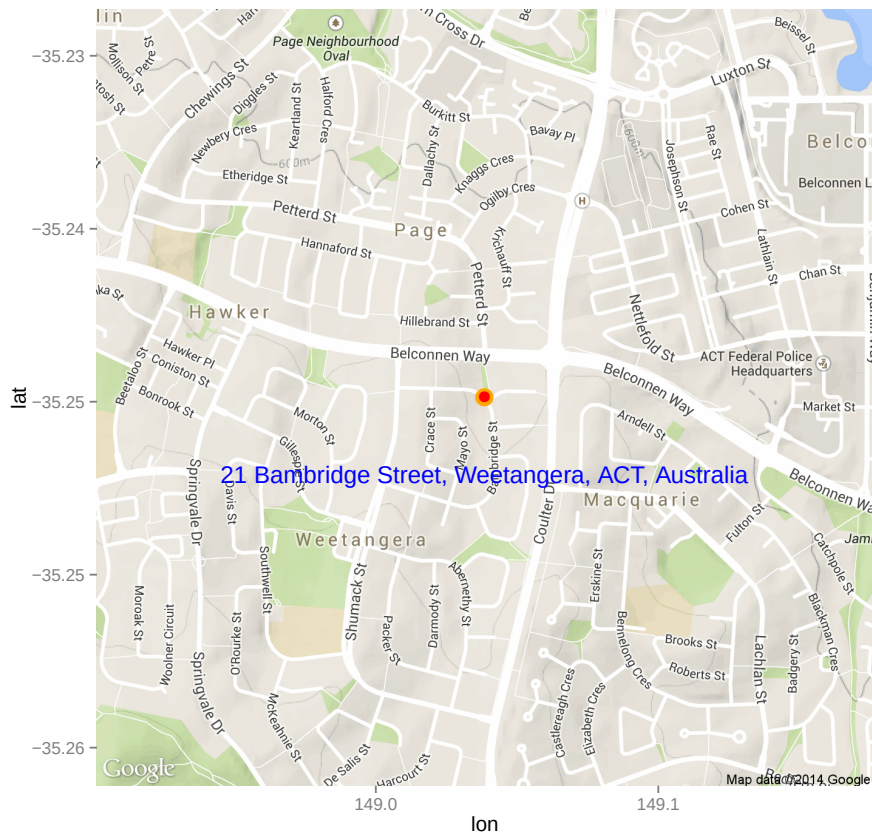
```
map <- get_map(location=as.numeric(geocode("Qiusi Road, Shenzhen")),  
              zoom=14, source="google")  
p <- ggmap(map)  
p
```

28 Google Maps: Shenzhen Satellite



```
map <- get_map(location=as.numeric(geocode("Qiushi Road, Shenzhen")),  
              zoom=14, maptype="satellite", source="google")  
p <- ggmap(map)  
p
```

29 Plot an Address



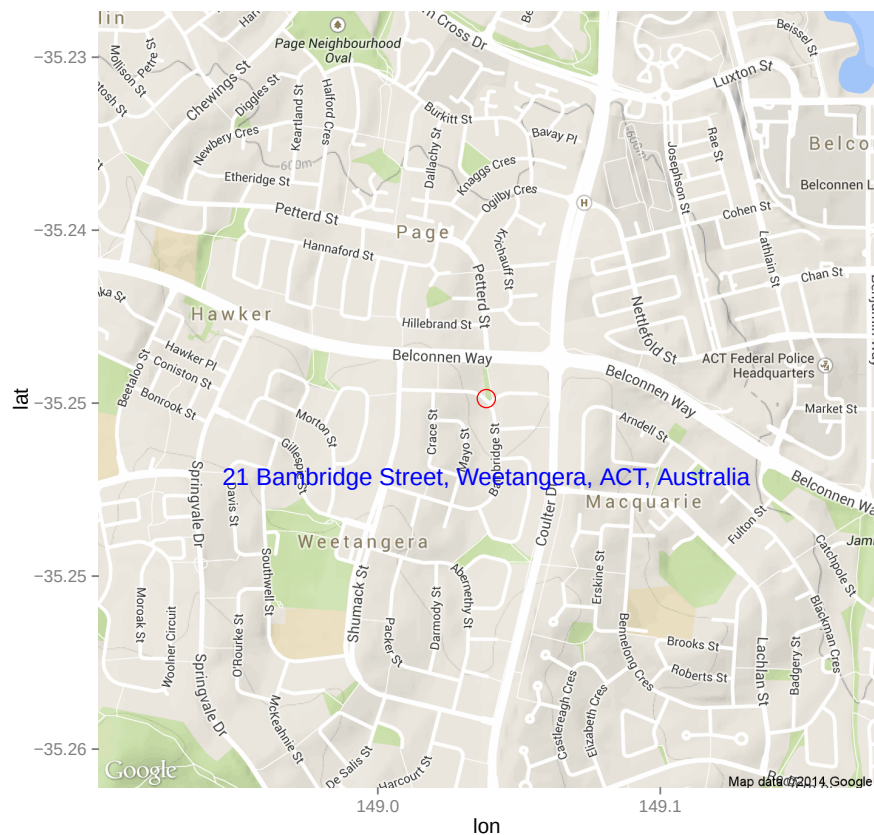
```

addr <- "21 Bambridge Street, Weetangera, ACT, Australia"
loc <- as.numeric(geocode(addr))
lbl <- data.frame(lon=loc[1], lat=loc[2], text=addr)
map <- get_map(location=loc, zoom=15, source="google")
p <- ggmap(map)
p <- p + geom_point(data=lbl, aes(x=lon, y=lat), size=5, colour="orange")
p <- p + geom_point(data=lbl, aes(x=lon, y=lat), size=3, colour="red")
p <- p + geom_text(data=lbl, aes(x=lon, y=lat, label=text),
                  size=5, colour="blue", hjust=0.5, vjust=5)
p

```

The location is pinpointed with a red dot overlaying an orange dot. We also add the actual address to the plot.

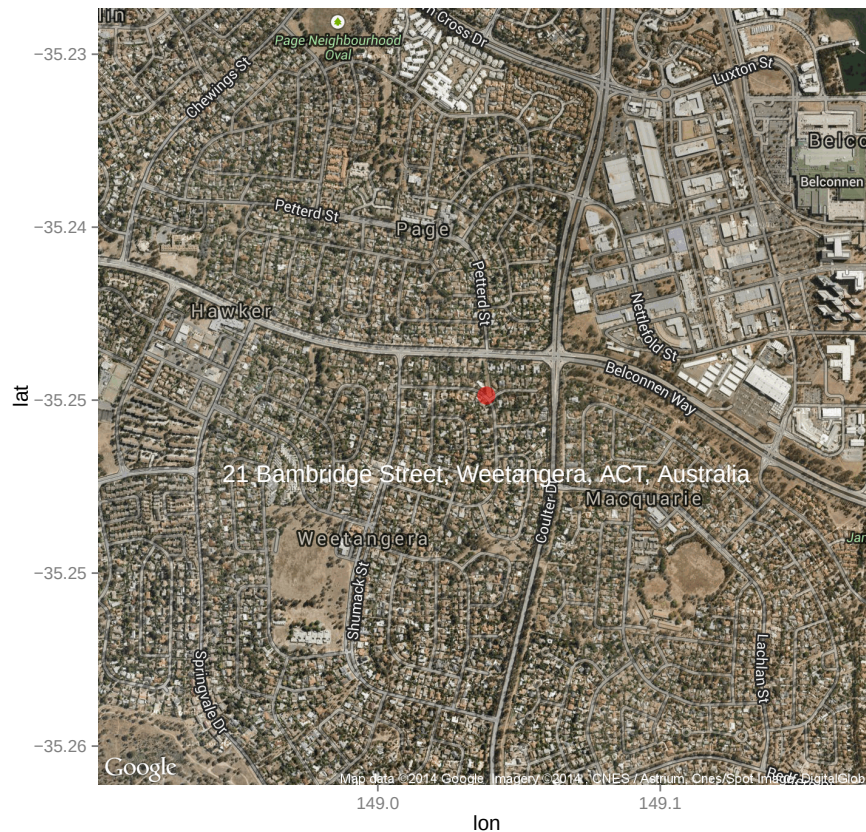
30 Plot an Address Using Circle



```
addr <- "21 Bambridge Street, Weetangera, ACT, Australia"
loc <- as.numeric(geocode(addr))
lbl <- data.frame(lon=loc[1], lat=loc[2], text=addr)
map <- get_map(location=loc, zoom=15, source="google")
p <- ggmap(map)
p <- p + geom_point(data=lbl, aes(x=lon, y=lat), size=5,
                    shape=1, colour="red")
p <- p + geom_text(data=lbl, aes(x=lon, y=lat, label=text),
                  size=5, colour="blue", hjust=0.5, vjust=5)
p
```

Here we have replaced the dot with a circle to pinpoint the location, using `shape=1` to choose a circle rather than a filled dot.

31 Plot an Address on a Satellite Image



```
addr <- "21 Bambridge Street, Weetangera, ACT, Australia"
loc <- as.numeric(geocode(addr))
lbl <- data.frame(lon=loc[1], lat=loc[2], text=addr)
map <- get_map(location=loc, zoom=15, maptype="hybrid", source="google")
p <- ggmap(map)
p <- p + geom_point(data=lbl, aes(x=lon, y=lat),
                    alpha=I(0.5), size=I(5), colour="red")
p <- p + geom_text(data=lbl, aes(x=lon, y=lat, label=text),
                  size=5, colour="white", hjust=0.5, vjust=5)
p
```

The underlying map is now a hybrid satellite and road map, with a transparent red dot to pinpoint the location. The transparency is controlled by `alpha=I(0.5)`.

32 USA Arrests: Assaults per Murder Data

This example comes from the help page for `map_data()` from `ggplot2` (Wickham and Chang, 2014). It shows the number of assaults per murder in each US state, though it is quite easy to modify the code to display various statistics from the data.

First we take a copy of the **USArrests** dataset and lowercase the variables and the state names to make the matching across different datasets uniform.

```
arrests <- USArrests
names(arrests) <- tolower(names(arrests))
arrests$region <- tolower(rownames(USArrests))
head(arrests)
```

##		murder	assault	urbanpop	rape	region
##	Alabama	13.2	236	58	21.2	alabama
##	Alaska	10.0	263	48	44.5	alaska
##	Arizona	8.1	294	80	31.0	arizona
....						

Then we merge the statistics with the spatial data, in readiness for mapping.

```
states <- map_data("state")
head(states)
```

##		long	lat	group	order	region	subregion
##	1	-87.46	30.39	1	1	alabama	<NA>
##	2	-87.48	30.37	1	2	alabama	<NA>
##	3	-87.53	30.37	1	3	alabama	<NA>
....							

```
ds <- merge(states, arrests, sort=FALSE, by="region")
head(ds)
```

##	region	long	lat	group	order	subregion	murder	assault	urbanpop	rape
##	1	alabama	-87.46	30.39	1	1	<NA>	13.2	236	58 21.2
##	2	alabama	-87.48	30.37	1	2	<NA>	13.2	236	58 21.2
##	3	alabama	-87.95	30.25	1	13	<NA>	13.2	236	58 21.2
....										

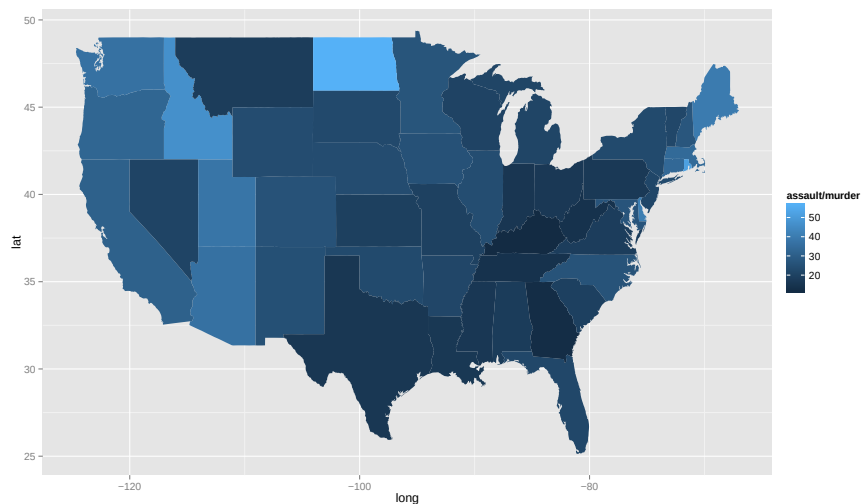
```
ds <- ds[order(ds$order), ]
head(ds)
```

##	region	long	lat	group	order	subregion	murder	assault	urbanpop	rape
##	1	alabama	-87.46	30.39	1	1	<NA>	13.2	236	58 21.2
##	2	alabama	-87.48	30.37	1	2	<NA>	13.2	236	58 21.2
##	6	alabama	-87.53	30.37	1	3	<NA>	13.2	236	58 21.2
....										

33 USA Arrests: Assaults per Murder Map

Once we have the data ready, plotting it simply requires nominating the dataset, and identifying the x and y as long and lat respectively. We also need to identify the grouping, which is by state, and so the fill is then specified for each state to indicate the statistic of interest.

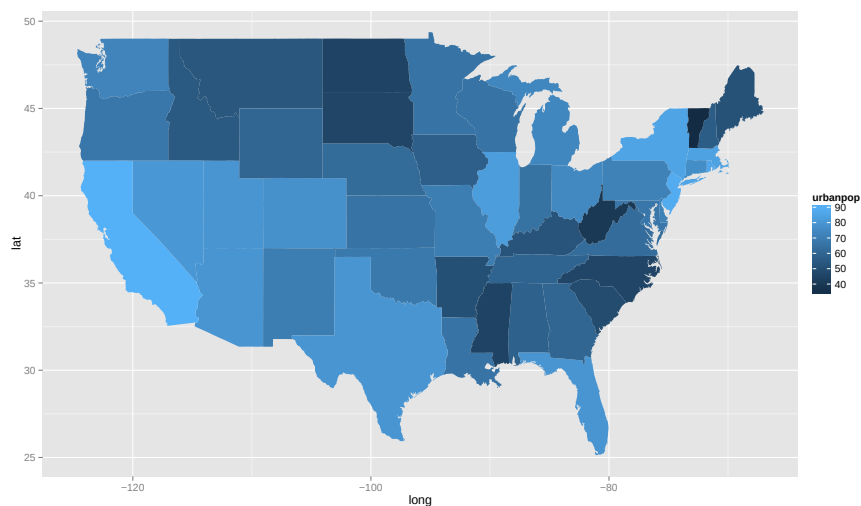
```
g <- ggplot(ds, aes(long, lat, group=group, fill=assault/murder))
g <- g + geom_polygon()
print(g)
```



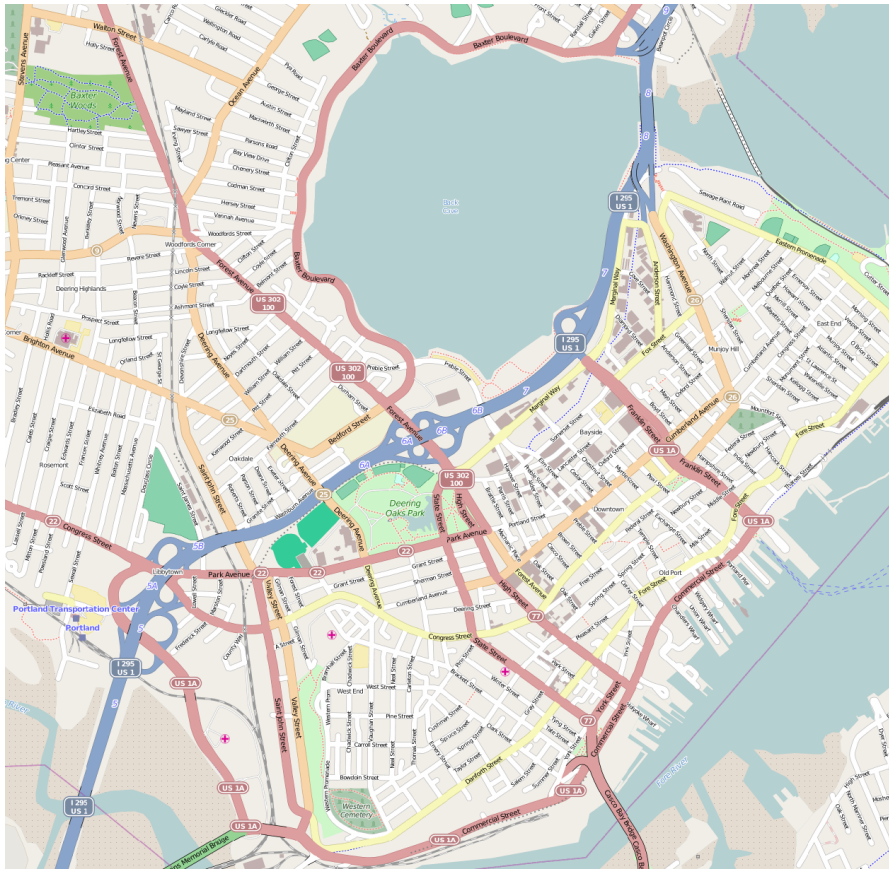
Exercise:
How can
we change
the colour
of the
scale?

We might also be interested in plotting the percentage of urban population in each state.

```
g <- ggplot(ds, aes(long, lat, group=group, fill=urbanpop))
g <- g + geom_polygon()
print(g)
```

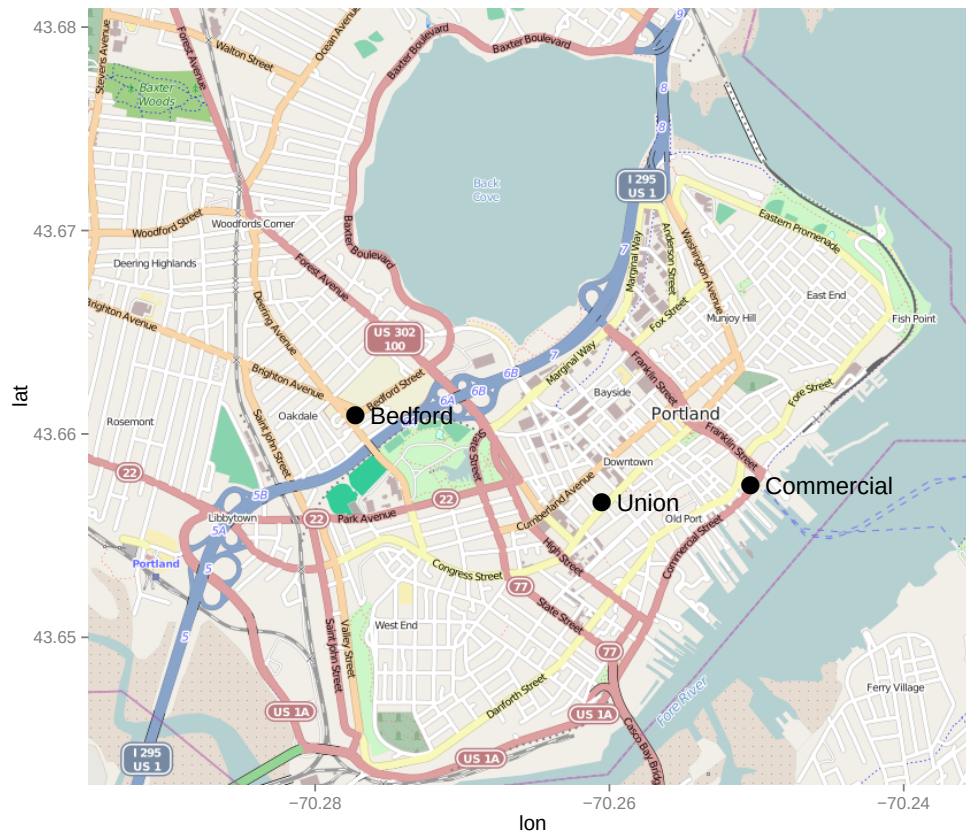


34 Portland: Open Street Maps



```
library(OpenStreetMap)
stores <- data.frame(name=c("Commercial", "Union", "Bedford"),
                     lon=c(-70.25042295455, -70.26050806045, -70.27726650238),
                     lat=c(43.657471302616, 43.65663299041, 43.66091757424))
lat <- c(43.68093, 43.64278)
lon <- c(-70.29548, -70.24097)
portland <- openmap(c(lat[1], lon[1]), c(lat[2], lon[2]), zoom=15, 'osm')
plot(portland, raster=TRUE)
```

35 Portland: Annotated Maps



From <http://stackoverflow.com/questions/10686054/outlined-text-with-ggplot2>

```
stores <- data.frame(name=c("Commercial", "Union", "Bedford"),
                     lon=c(-70.25042295455, -70.26050806045, -70.27726650238),
                     lat=c( 43.65747130261, 43.65663299041, 43.66091757424))
```

```
portland <- c(-70.2954, 43.64278, -70.2350, 43.68093)
```

```
library(ggmap)
map <- get_map(location=portland, source="osm")

g <- ggmap(map)
g <- g + geom_point(data=stores, aes(x=lon, y=lat), size=5)
g <- g + geom_text(data=stores, aes(label=name, x=lon+.001, y=lat), hjust=0)
print(g)
```

36 Portland: Standout Text Annotation



This map uses outlined text to ensure we can better read text on the map.

```
g <- ggmap(map)
g <- g + geom_point(data=stores, aes(x=lon, y=lat), size=5)

theta <- seq(pi/16, 2*pi, length.out=32)
xo <- diff(portland[c(1,3)])/250
yo <- diff(portland[c(2,4)])/250

for(i in theta)
  g <- g + geom_text(data=stores, bquote(aes(x=lon + .001 + .(cos(i) * xo),
      y=lat + .(sin(i) * yo), label = name)),
      size=5, colour='black', hjust=0)

g <- g + geom_text(data=stores, aes(x=lon+.001, y=lat, label=name),
      size=5, colour='white', hjust=0)
print(g)
```


37 Animated Maps

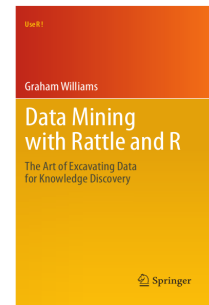
See <http://rmaps.github.io/blog/posts/animated-choropleths/>.

DRAFT

38 Further Reading and Acknowledgements

The [Rattle Book](#), published by Springer, provides a comprehensive introduction to data mining and analytics using Rattle and R. It is available from [Amazon](#). Other documentation on a broader selection of R topics of relevance to the data scientist is freely available from <http://datamining.togaware.com>, including the [Datamining Desktop Survival Guide](#).

This chapter is one of many chapters available from <http://HandsOnDataScience.com>. In particular follow the links on the website with a * which indicates the generally more developed chapters.



Other resources include:

- The packages `RgoogleMaps` (?) and `OpenStreetMap` (?) provide alternative interfaces to Google Maps, etc., whereby we can download maps and annotate them. Much of the functionality we have already seen is provided by `ggmap` (?). `OpenStreetMap` provides `automap()`. `RgoogleMaps` provides `GetMap()` to download a map from Google, and `PlotOnStaticMap()` for displaying the map and overlaying plots on the map.
- The package `osmar` (?) provides an interactive environment based on `OpenStreetMap`.

Tony's ToDo

stats between locations like distance
calculate an area on a map
colour code regions
regions like ABS has
ability to plot graphs either on map or in a new window with stats as meta data
ability to have a region shaded with locations pinpointed on top
dialogue box which describes data on location
have images on a map, and you can filter out, with a simple scroll option.
a 3d options on a property like bing maps has
the ability to make a move to fly through way points on a map
radius zones around a point.
radius points around multiple points, like a distorted ven diagram
stats that change over time like a movie but static location, but graphs change
time change colour for night and day or both

39 References

- Brownrigg R (2014). *maps: Draw Geographical Maps*. R package version 2.3-9, URL <http://CRAN.R-project.org/package=maps>.
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- Wickham H, Chang W (2014). *ggplot2: An implementation of the Grammar of Graphics*. R package version 1.0.0, URL <http://CRAN.R-project.org/package=ggplot2>.
- Williams GJ (2009). “Rattle: A Data Mining GUI for R.” *The R Journal*, 1(2), 45–55. URL http://journal.r-project.org/archive/2009-2/RJournal_2009-2_Williams.pdf.
- Williams GJ (2011). *Data Mining with Rattle and R: The art of excavating data for knowledge discovery*. Use R! Springer, New York. URL http://www.amazon.com/gp/product/1441998896/ref=as_li_qf_sp_asin_tl?ie=UTF8&tag=togaware-20&linkCode=as2&camp=217145&creative=399373&creativeASIN=1441998896.
- Williams GJ (2014). *rattle: Graphical user interface for data mining in R*. R package version 3.0.4, URL <http://rattle.togaware.com/>.

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