Data Bootcamp Final Project - Paleontology Database Analysis

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Backend

Installations and Imports

In [ ]:

```
pip install geopandas
```

In [ ]:

```
# imports
import requests
import pandas as pd
import io
import matplotlib
import matplotlib.pyplot as plt
import numpy as np
import plotly.express as px
import geopandas as gpd
import math
import seaborn as sns
from math import radians, cos, sin, asin, sqrt
from sklearn.ensemble import RandomForestRegressor as rf
from sklearn.model_selection import train_test_split
from sklearn.model_selection import cross_val_score
pd.set_option("display.max_columns", 200)
pd.options.mode.chained_assignment = None
```

In [ ]:

```
# importing data via api call (can take around 5 minutes)
url = requests.get('https://paleobiodb.org/data1.2/occs/list.csv?cc=NOA&show=attr,class,g
enus,subgenus,img,plant,abund,ecospace,taphonomy,etbasis,pres,coll,coords,loc,paleoloc,pr
ot,strat,stratext,lith,lithext,env,geo,timebins,timecompare,methods,refattr,crmod').conte
nt
occs = pd.read_csv(io.StringIO(url.decode('utf-8')))
# clean data
occs['avg_ma'] = (occs['min_ma'] + occs['max_ma']) / 2
occs.drop(columns=['reid_no','flags','record_type','accepted_attr','late_interval','plant
_organ','plant_organ2','reproduction','reproduction_basis','collection_subset','protected
','localbed','localorder','regionalsection','regionalbed','regionalorder','lithadj2','lit
hification2','minor_lithology2','fossilsfrom2','lithology2.1','lithadj2.1','lithification
2.1','minor_lithology2.1','fossilsfrom2.1','rock_censused','collectors','collection_dates
'],inplace=True)
```

```
/usr/local/lib/python3.6/dist-packages/IPython/core/interactiveshell.py:2718: DtypeWarnin
g:

Columns (3,14,26,27,28,36,37,42,43,46,47,48,65,68,71,74,76,77,78,79,80,82,87,88,89,90,91,
92,93,98,99,100,101,102,103,105,106,115,116,117,118,119,121) have mixed types.Specify dty
pe option on import or set low_memory=False.
```

Functions and Formulas

In [ ]:

```
# haversine - formula used to calculate distance in between two geographic coordinates
def haversine(lat1, lng1, lat2, lng2):
    lat1, lng1, lat2, lng2, = map(np.deg2rad, [lat1, lng1, lat2, lng2])
    dlng = lng2 - lng1
    dlat = lat2 - lat1
    a = np.sin(dlat/2)**2 + np.cos(lat1) * np.cos(lat2) * np.sin(dlng/2)**2
    return 2 * np.arcsin(np.sqrt(a)) * 6371
```

In [ ]:

```
# area of a spherical sector of the earth
def spherical_sector_area(proximity_value):
  x = 2*proximity_value/6371
  x = 6371*(1-math.cos(x/2))
  x = 2*math.pi*6371*x
  return x
```

In [ ]:

```
# find distance in between points and every entry in df using numpy vectorization
def distances(data, lat, lng, filter_dis):
  data['dis'] = haversine(lat, lng, data['lat'].values, data['lng'].values)
  return data.loc[data['dis']<filter_dis].sort_values(by=['dis'])
```

In [ ]:

```
# filter based on column and string, simplified .loc function
def filter(data, column, value):
  return data.loc[data[column].str.contains(value, na=False, case=False)]
```

In [ ]:

```
# plotly heatmap
def heatmap(pdata, hov_name, hov_data, sensitivity, title):
  geo_df = gpd.read_file(gpd.datasets.get_path('naturalearth_cities'))
  return px.density_mapbox(
      pdata,
      lat=pdata.lat,
      lon=pdata.lng,
      radius=sensitivity,
      hover_name=hov_name,
      hover_data=hov_data,
      mapbox_style="stamen-terrain",
      title = title
  )
```

Data Analysis

Introduction to the data and important terms

In [ ]:

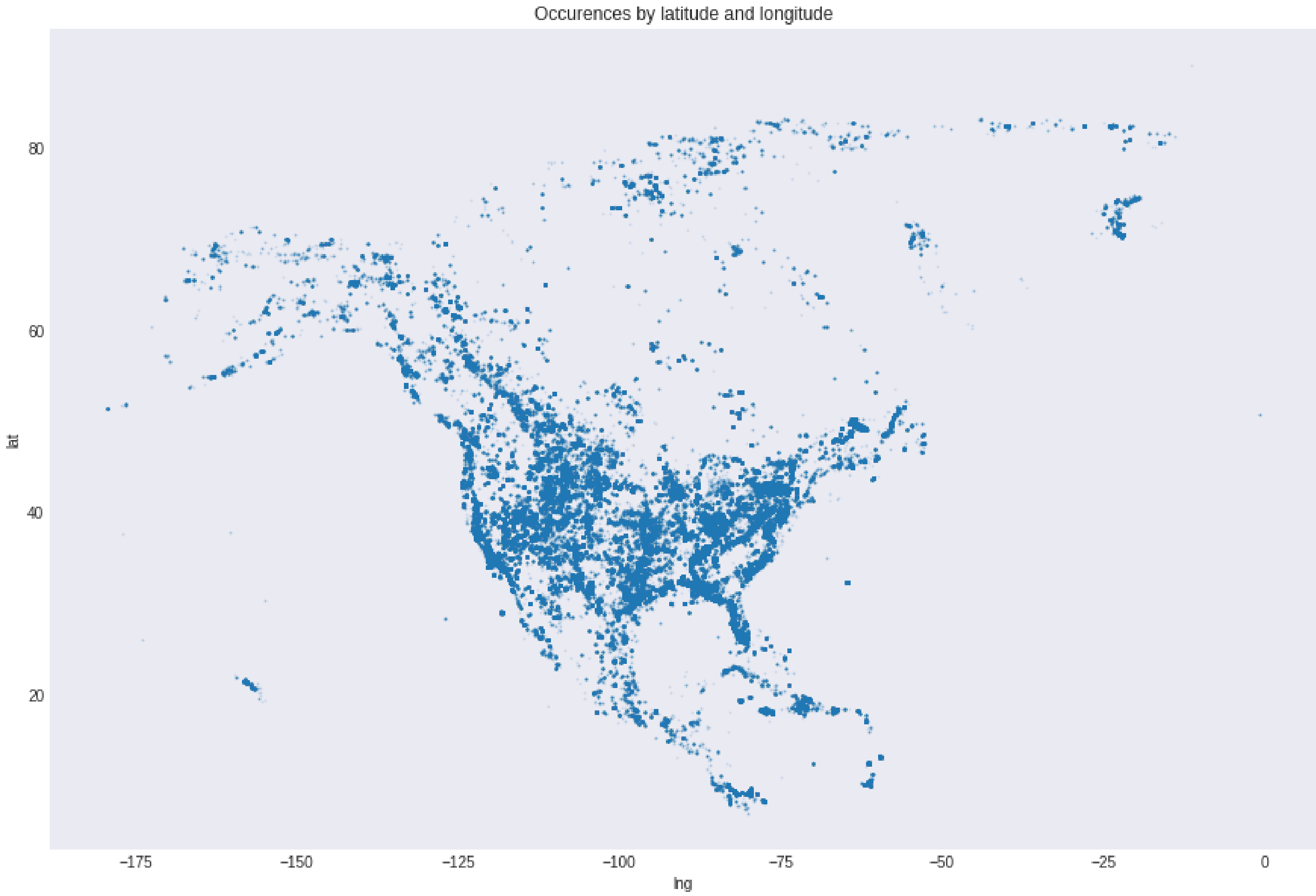
```
print('-'*160)
print("This program allows users to learn more about the geology surrounding their locati
on by exploring paleotological findings from the area.")
print()
print("Paleotontology involves the study of fossils, which are mineralized remains of liv
ing things. Fossils are found everywhere.")
print()
print("Here is a scatterplot plotting the latitude and longitude of various fossils found
in North America.")
print('-'*160)
plt.style.use('seaborn-dark')
```

```
occs.loc[occs['lat']>0].loc[occs['lng']<0].plot(kind='scatter', x='lng', y='lat', title=
'Occurences by latitude and longitude', figsize=(15, 10), s=1, alpha=0.1)
```

```
--------------------------------------------------------------------------------------------------------------------------------------------------------------
This program allows users to learn more about the geology surrounding their location by e
xploring paleotological findings from the area.

Paleotontology involves the study of fossils, which are mineralized remains of living thi
ngs. Fossils are found everywhere.

Here is a scatterplot plotting the latitude and longitude of various fossils found in Nor
th America.
--------------------------------------------------------------------------------------------------------------------------------------------------------------
```

Out[ ]:

```
<matplotlib.axes._subplots.AxesSubplot at 0x7faad9c87160>
```



In [ ]:

```
print('-'*160)
print("The program makes use of the Paleobiology Database, a database tracking millions o
f \"occurences\" of fossils referenced in research papers studying paleontology.", end='\
n\n')
print("When a fossil is found as part of a study, information is collected about the foss
il and the surrounding geological conditions. This information is represented" + '\n' +
"as columns within a dataframe containing data imported from the Paleobiology Database, o
r PBDB.\n")
print("Each occurence represents a single species found at a site, and can contain multip
le specimens.")
print('-'*160)
occs.sample(5)
```

```
--------------------------------------------------------------------------------------------------------------------------------------------------------------
The program makes use of the Paleobiology Database, a database tracking millions of "occu
rences" of fossils referenced in research papers studying paleontology.
```

When a fossil is found as part of a study, information is collected about the fossil and the surrounding geological conditions. This information is represented as columns within a dataframe containing data imported from the Paleobiology Database, or PBDB.

Each occurence represents a single species found at a site, and can contain multiple specimens.

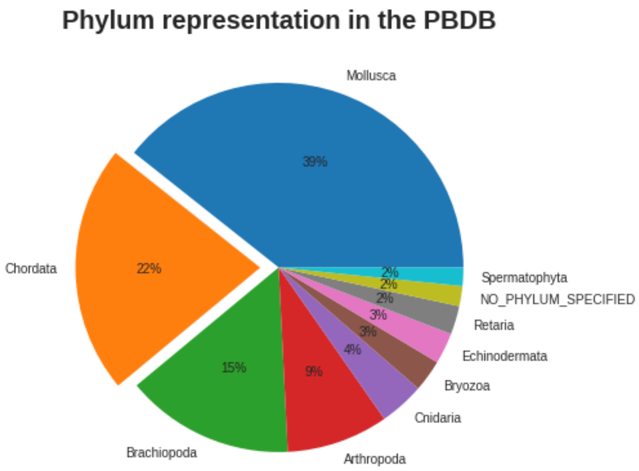
Out[ ]:

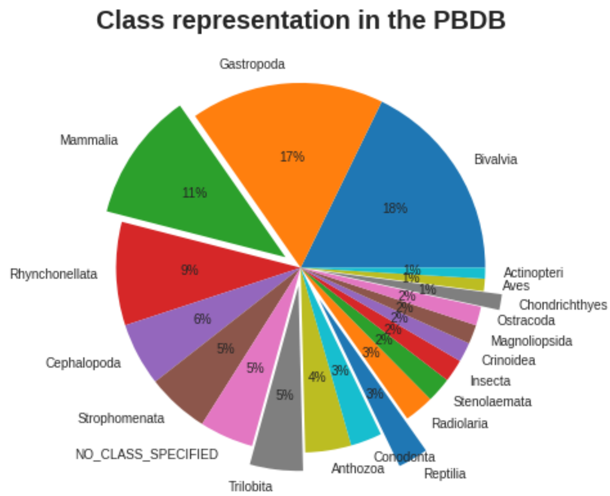
	occurrence_no	collection_no	identified_name	identified_rank	identified_no	difference	accepted_name	accepted_ra
205612	445943	43886	Fenestrellina sp.	genus	25556	NaN	Fenestrellina	gen
140337	237815	23713	Taeniocrada sp.	genus	263721	NaN	Taeniocrada	gen
88289	143151	12386	Rhipidomella sp.	genus	26974	NaN	Rhipidomella	gen
485520	1330180	179083	Phytosauridae indet.	unranked clade	38293	replaced by	Mystriosuchinae	subfam
268010	619001	66703	Macoma balthica	species	107606	NaN	Macoma balthica	speci

In [ ]:

```
print('-'*160)
print("This particular dataset includes data on " + str(len(occs)) + " occurences located in North America. The PBDB contains data on over 1.4 million occurences in total. This may " + '\n' + "seem like a lot, but the fossils you see here are not exactly the kind of fossil you may see in a museum.", end = '\n\n')
print("A quick analysis of the different phylum (a classification rank) shows that Chordata, the phylum that mostly consists of vertebrates such as sharks and " + '\n' + "dinosaurs, makes up only 22% of all occurences.", end = '\n\n')
print("A closer analysis of the different classes (a subset of phylums) shows that Reptilia, the class that dinosaurs fall under, make up just 3% of all occurences." + '\n' + "Although shark teeth are some of the most commonly owned fossils, they make up less than 1% of occurences under Chondrichthyes.  A majority of occurences" + '\n' + "are classified as what most of us recognize as just \"shells\".")
print('-'*160 + '\n')
occs_pie = occs['class'].value_counts()[:20].rename_axis('class').to_frame('count')
fig, ax = plt.subplots(1,2)
fig.set_figheight(10)
fig.set_figwidth(18)
fig.subplots_adjust(wspace=0.8)
explode1 = (0, 0.1, 0, 0, 0, 0, 0, 0, 0, 0)
explode2 = (0, 0, 0.1, 0, 0, 0, 0, 0.1, 0, 0, 0.2, 0, 0, 0, 0, 0, 0, 0.1, 0, 0)
ax[0].pie(occs['phylum'].value_counts()[:10].rename_axis('phylum').to_frame('count')['count'],labels=occs['phylum'].value_counts()[:10].rename_axis('phylum').to_frame('count').index, explode=explode1, autopct='%1.f%%')
ax[0].set_title('Phylum representation in the PBDB',size=20, fontweight = 'bold')
ax[1].pie(occs['class'].value_counts()[:20].rename_axis('class').to_frame('count')['count'],labels=occs['class'].value_counts()[:20].rename_axis('class').to_frame('count').index, explode=explode2, autopct='%1.f%%')
ax[1].set_title('Class representation in the PBDB',size=20, fontweight = 'bold')
fig.show()
```

```
-------------------------------------------------------------------------
This particular dataset includes data on 546979 occurences located in North America. The
PBDB contains data on over 1.4 million occurences in total. This may
seem like a lot, but the fossils you see here are not exactly the kind of fossil you may
see in a museum.

A quick analysis of the different phylum (a classification rank) shows that Chordata, the
phylum that mostly consists of vertebrates such as sharks and
dinosaurs, makes up only 22% of all occurences.

A closer analysis of the different classes (a subset of phylums) shows that Reptilia, the
class that dinosaurs fall under, make up just 3% of all occurences.
Although shark teeth are some of the most commonly owned fossils, they make up less than
1% of occurences under Chondrichthyes.  A majority of occurences
are classified as what most of us recognize as just "shells".
---------------------------------------------------------------------------------------
-------------------------------------------------------------------------
```





In [ ]:

```
print('-'*160)
print("Additionally, even fossils that would be recognizeable by name may not be recogniz
eable as an occurence. This map of T-rex occurences shows",len(filter(occs, 'accepted_nam
e', 'tyrannosaurus')), "total occurences. \nAre T-rexes that common?", end = '\n\n')
print("This is because a vast majority of vertebrate fossils are found incomplete. Just a
single tooth or chunk of bone would still count as anoccurence as long as it" + '\n' + "i
s identifiable as T-rex with reasonable confidence. Considering T-rexes existed for 2 mil
lion years and regularly regenerated teeth, it makes sense that T-rex" + '\n' + "fossils
are found relatively often.\n")
print("On the other hand, only a small percentage of fossils found end up in a paper and
in the PBDB. Finds made by amateur collectors make up a majority of total \nfinds for man
y species, but almost never get recognized as an occurence in the PBDB.")
print('-'*160)
heatmap(filter(occs, 'accepted_name', 'tyrannosaurus'), 'accepted_name', ['occurrence_no
', 'formation.1', 'min_ma'], 6, 'Tyrannosaurus Rex Occurences').show()
```

```
---------------------------------------------------------------------------------------
-------------------------------------------------------------------------
Additionally, even fossils that would be recognizeable by name may not be recognizeable a
s an occurence. This map of T-rex occurences shows 79 total occurences.
Are T-rexes that common?

This is because a vast majority of vertebrate fossils are found incomplete. Just a single
tooth or chunk of bone would still count as anoccurence as long as it
is identifiable as T-rex with reasonable confidence. Considering T-rexes existed for 2 mi
llion years and regularly regenerated teeth, it makes sense that T-rex
fossils are found relatively often.

On the other hand, only a small percentage of fossils found end up in a paper and in the
PBDB. Finds made by amateur collectors make up a majority of total
finds for many species, but almost never get recognized as an occurence in the PBDB.
---------------------------------------------------------------------------------------
-------------------------------------------------------------------------
```

Location-Specific Analysis

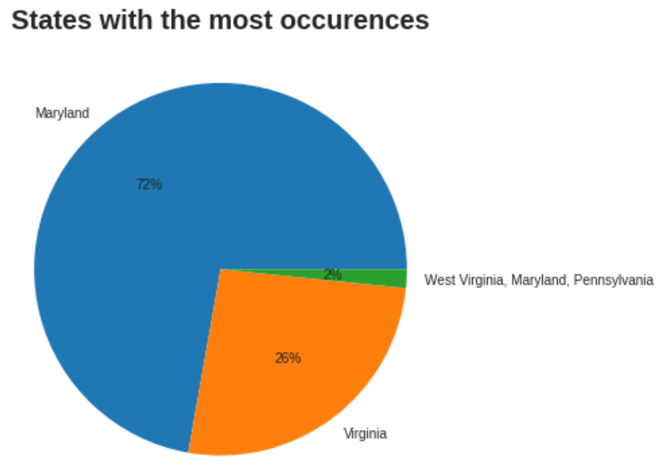
In [ ]:

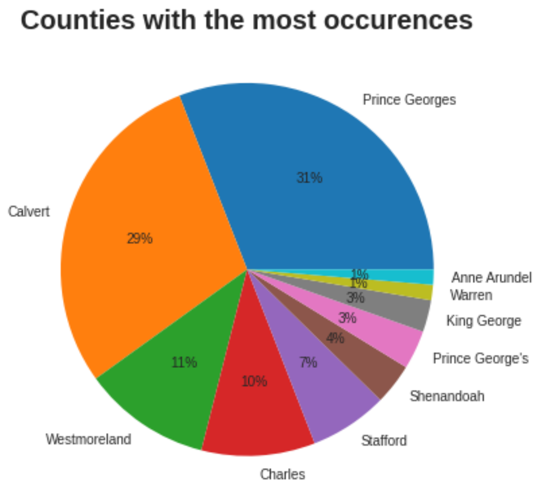
```
# tell user about what you can find around your area

local = {
    'lat': float(input("Enter Latitude: ")),
    'prx': float(input("Enter Search Radius (km): "))
}

if local['lat'] == 0:
  local['lat'], local['lng'] = 38.954503, -77.247611
elif local['lat'] == 1:
  local['lat'], local['lng'] = 40.729009, -73.995959
elif local['lat'] == 2:
  local['lat'], local['lng']= 43.058888, -76.031289
else:
  local['lng'] = float(input("Enter Longitude: "))

proximity = distances(occs, local['lat'], local['lng'], local['prx'])

print('-'*120)
print('Search Report Summary')
print('The search returned ' + str(len(proximity)) + ' occurences within ' + str(local['
prx']) + ' kilometers of ' + str(local['lat']) + ', ' + str(local['lng']) + '.')
usa_occ_score, y_occ_score = round(100*409217/3797000,2), round(100*len(proximity)/spher
ical_sector_area(local['prx']),2)
print('Your search radius contains ' + str(y_occ_score) + ' occurences per square km, wh
ich is ' + str(abs(round(100*y_occ_score / usa_occ_score) - 100)) + "% " + ('higher' if
100*y_occ_score / usa_occ_score > 100 else 'lower') + ' than the national average of ' +
str(usa_occ_score) + '.')
print('The average age of occurences within your search is',round(proximity['avg_ma'].mea
n(),2), 'million years.')
print('-'*120)
heatmap(proximity, 'accepted_name', ['occurrence_no', 'formation.1', 'min_ma'], 6, 'Near
by Fossil Occurences').show()
```

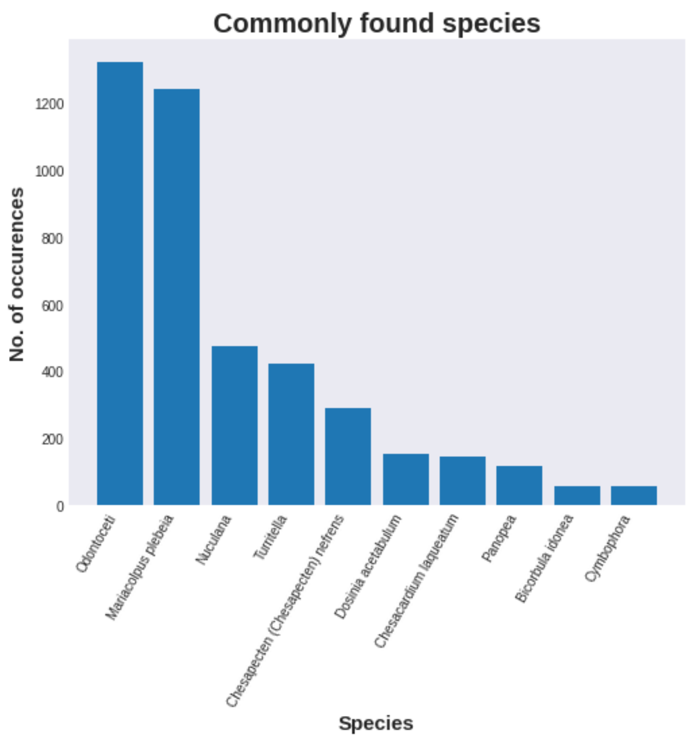
```
Enter Latitude: 0
Enter Search Radius (km): 100
-----------------------------------------------------------------------------------------
---------------------------------
Search Report Summary
The search returned 5084 occurences within 100.0 kilometers of 38.954503, -77.247611.
Your search radius contains 16.18 occurences per square km, which is 50% higher than the
national average of 10.78.
The average age of occurences within your search is 89.09 million years.
-----------------------------------------------------------------------------------------
---------------------------------
```

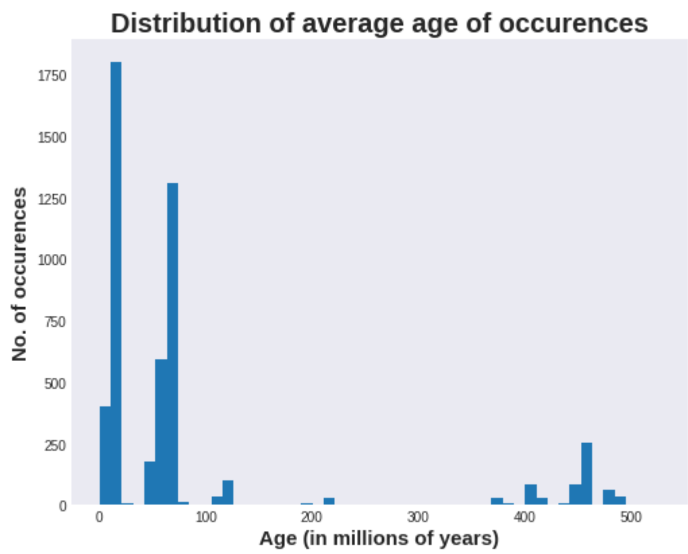
In [ ]:

```
fig, ax = plt.subplots(2,2)
fig.set_figheight(14)
fig.set_figwidth(18)
fig.subplots_adjust(wspace=0.2)
ax[0,0].pie(proximity['state'].value_counts()[:3].rename_axis('state').to_frame('count')['count'],labels=proximity['state'].value_counts()[:3].rename_axis('state').to_frame('count').index, autopct='%1.f%%')
ax[0,0].set_title('States with the most occurences',size=20, fontweight = 'bold')
ax[0,1].pie(proximity['county'].value_counts()[:10].rename_axis('county').to_frame('count')['count'],labels=proximity['county'].value_counts()[:10].rename_axis('county').to_frame('count').index, autopct='%1.f%%')
ax[0,1].set_title('Counties with the most occurences',size=20, fontweight = 'bold')
ax[1,0].bar(proximity['accepted_name'].value_counts()[:10].rename_axis('accepted_name').to_frame('count').index, height=proximity['county'].value_counts()[:10].rename_axis('accepted_name').to_frame('count')['count'],)
ax[1,0].set_title('Commonly found species',size=20, fontweight = 'bold')
ax[1,0].set_xticklabels(proximity['accepted_name'].value_counts()[:10].rename_axis('accepted_name').to_frame('count').index, Rotation='60', ha="right")
ax[1,0].set_xlabel("Species",size=15, fontweight = 'bold')
ax[1,0].set_ylabel("No. of occurences",size=15, fontweight = 'bold')
ax[1,1].hist(proximity['avg_ma'],bins=50)
ax[1,1].set_title('Distribution of average age of occurences',size=20, fontweight = 'bold')
ax[1,1].set_xlabel("Age (in millions of years)",size=15, fontweight = 'bold')
ax[1,1].set_ylabel("No. of occurences",size=15, fontweight = 'bold')
fig.show()
```









In [ ]:

```
# group, formation, member
group_age = proximity.groupby('stratgroup.1')['avg_ma'].mean().sort_values()
formation_age = proximity.groupby('formation.1')['avg_ma'].mean().sort_values()
member_age = proximity.groupby('member.1')['avg_ma'].mean().sort_values()
gmf = proximity.groupby(['stratgroup.1', 'formation.1','member.1','avg_ma']).mean()
gmf.drop(gmf.columns.difference(['lng','lat']), 1, inplace=True)
gmf_r = gmf.reset_index()
heatmap(gmf_r, 'member.1',['avg_ma','formation.1','stratgroup.1'],10,'Estimated Location
of Members, Formations, and Groups').show()
gmf
```

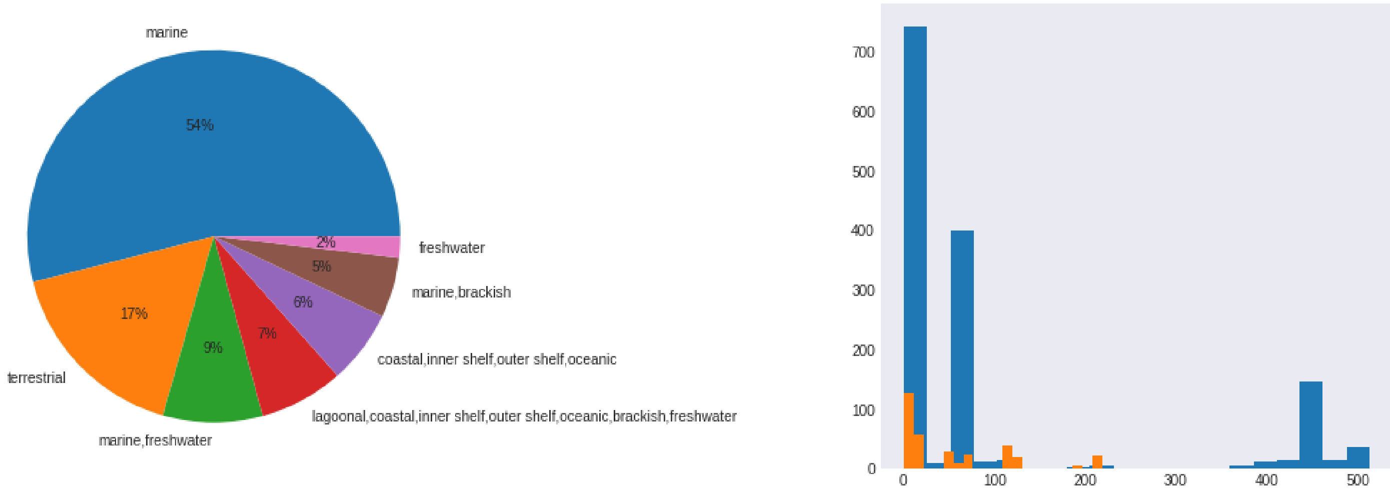
Out[ ]:

stratgroup.1	formation.1	member.1	avg_ma	lng	lat
Chatham	Bull Run	Balls Bluff	218.2500	-77.481913	38.883427
		Groveton	216.7500	-77.915054	38.439735
	Manassas Sandstone	Poolesville	218.2500	-77.455517	38.778140
Chesapeake	Calvert	Boston Cliffs	12.7200	-76.461945	38.450279
		Calvert Beach	12.7200	-76.513611	38.517502
			13.7890	-76.966942	38.180279
			14.8950	-76.710510	38.473481
		Conoy	12.7200	-76.461945	38.450279
		Drumcliff	12.7200	-76.471466	38.461135
		Fairhaven	18.2050	-76.782070	38.633863
		Little Cove Point	9.4330	-76.461945	38.450279
		Plum Point	12.7200	-76.500000	38.400002
			13.7890	-76.522408	38.638704
			14.8950	-76.686371	38.373145
			18.2050	-76.522915	38.627697
		Plum Point Marl	13.7890	-76.525722	38.645944
		Popes Creek Sand	18.2050	-76.726461	38.700186
	Choptank	Boston Cliffs	12.7200	-76.551573	38.411286
			13.7890	-76.505445	38.508456
		Conoy	12.7200	-76.478615	38.357224
		Drumcliff	12.7200	-76.508268	38.435260
			13.7890	-76.491818	38.396405
		St. Leonard	12.7200	-76.482498	38.471668
	Eastover	Claremont Manor	6.2895	-76.831112	38.163496
	St Mary's	Little Cove Point	8.4705	-76.387497	38.361389
	St Marys	Little Cove Point	9.4330	-76.387497	38.362778
Pamunkey	Aquia	Paspotansa	57.2500	-77.272084	38.318055
		Piscataway	57.2500	-77.299446	38.372780
			57.6000	-77.010399	38.743500
	Nanjemoy	Potapaco	52.2000	-77.265160	38.242618
		Woodstock	44.5500	-76.991669	38.407223

stratgroup_1	formation_1	member_1	avg_ma	lng	lat
			51.9000	-77.015278	38.382534
Wilcox	Tuscahoma	Bells Landing Marl	57.6000	-76.548889	38.953056

In [ ]:

```
fig, ax = plt.subplots(1,2)
fig.set_figheight(6)
fig.set_figwidth(18)
fig.subplots_adjust(wspace=0.8)
taxon_ages = proximity[['taxon_environment', 'avg_ma']].dropna()
ax[0].pie(proximity['taxon_environment'].value_counts()[:7].rename_axis('taxon_environme
nt').to_frame('count')['count'],labels=proximity['taxon_environment'].value_counts()[:7]
.rename_axis('taxon_environment').to_frame('count').index, autopct='%1.f%%')
ax[1].hist(taxon_ages.loc[taxon_ages['taxon_environment'].str.contains('marine', na=False
)]['avg_ma'], bins=20)
ax[1].hist(taxon_ages.loc[taxon_ages['taxon_environment'].str.contains('terr', na=False)
]['avg_ma'], bins=20)
fig.show()
```



In [ ]:

```
# track paleological location over time
paleoprx = distances(occs, local['lat'], local['lng'], local['prx'] if input("Scale up s
earch radius to increase accuracy? (Y/N) ") == 'N' else 300)
paleoloc = paleoprx[['avg_ma','paleolat','paleolng']]
paleoloc['avg_ma'] = paleoloc['avg_ma'].round(0)
empty = pd.DataFrame(index=np.arange(528), columns=np.arange(0))
empty.reset_index(inplace=True)
empty.rename(columns={'index': "avg_ma"}, inplace=True)
locs = pd.merge(paleoloc.groupby('avg_ma')['paleolat'].mean().sort_values(), paleoloc.gro
upby('avg_ma')['paleolng'].mean().sort_values(), how='inner', on='avg_ma')
paleoloc_ = pd.merge(empty, locs, how='left', on='avg_ma')
paleoloc_.sort_values('avg_ma',inplace=True)
paleoloc_['paleolat'] = paleoloc_['paleolat'].interpolate(method='spline', order=2)
paleoloc_['paleolng'] = paleoloc_['paleolng'].interpolate(method='spline', order=2)
heatmap(paleoloc_.rename(columns={'paleolat': "lat", 'paleolng': "lng"}), 'avg_ma', ['la
t', 'lng'], 10, 'Track Your Geology Over Time').show()
```

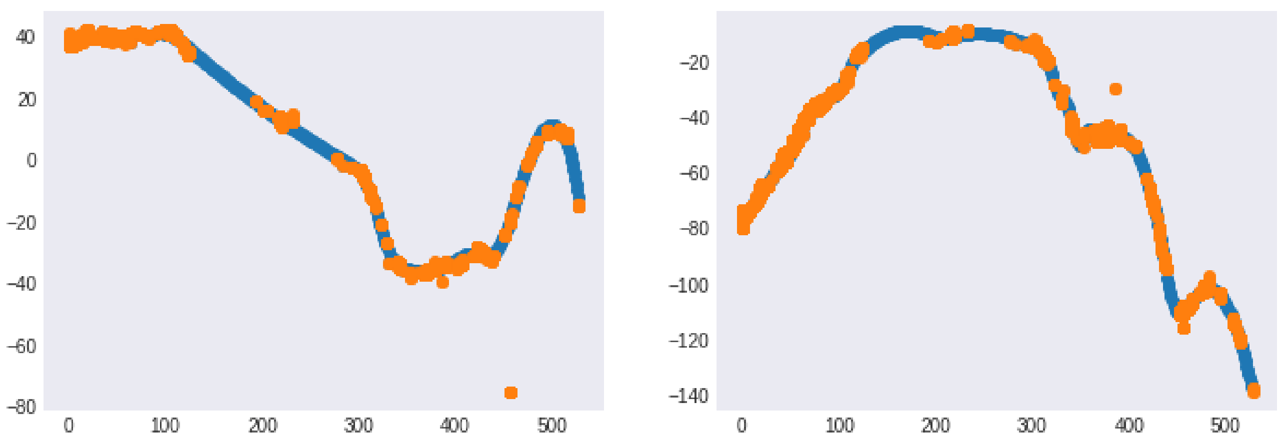
```
Scale up search radius to increase accuracy? (Y/N) Y
```

Tests

In [ ]:

```
# Tests
print("Actual interpolation")
fig, ax = plt.subplots(1,2)
fig.set_figheight(4)
fig.set_figwidth(12)
ax[0].scatter(paleoloc_['avg_ma'], paleoloc_['paleolat'])
ax[0].scatter(paleoloc['avg_ma'], paleoloc['paleolat'])
ax[1].scatter(paleoloc_['avg_ma'], paleoloc_['paleolng'])
ax[1].scatter(paleoloc['avg_ma'], paleoloc['paleolng'])
fig.show()
```

```
Actual interpolation
```



In [ ]:

```
# Heatmap using data before interpolation
heatmap(paleoloc.rename(columns={'paleolat': "lat", 'paleolng': "lng"}), 'avg_ma', ['lat
', 'lng'], 10, 'Track Your Geology Over Time').show()
```

Occurence Search Tools

Search by species

In [ ]:

```
heatmap(filter(occs, 'accepted_name', input('Enter specimen name: ')), 'accepted_name',
['occurrence_no', 'formation.1', 'min_ma'], 6, 'Specimens Map').show()
```

```
Enter specimen name: trilobit
```

Search by state

In [ ]:

```
heatmap(filter(occs, 'state', input('Enter state: ')), 'state', ['occurrence_no', 'formation.1', 'min_ma'], 6, 'Specimens Map').show()
```

```
Enter state: New York
```

Search by county

Visualizations

In [ ]:

```
import requests
import io
import seaborn as sns
import matplotlib
import matplotlib.pyplot as plt
from math import radians, cos, sin, asin, sqrt
pd.options.mode.chained_assignment = None
```

In [ ]:

```
states = occs.loc[occs['cc'] == 'US']
states = states.groupby(['state'])['max_ma'].mean()
#We would like to see what states the oldest fossils would be located and where the youngest are
#This could give us insights into the previous environments of the current states
states = pd.DataFrame(states)
states = states.sort_values(by='max_ma',ascending=False)
states = states.reset_index()
states = states[states.state != ('Califormia','Flrida','Sussex','Michiagn','florida','Unknown','')]
states = states.sort_values(by = 'max_ma',ascending = False)
states = states.set_index('state')
```

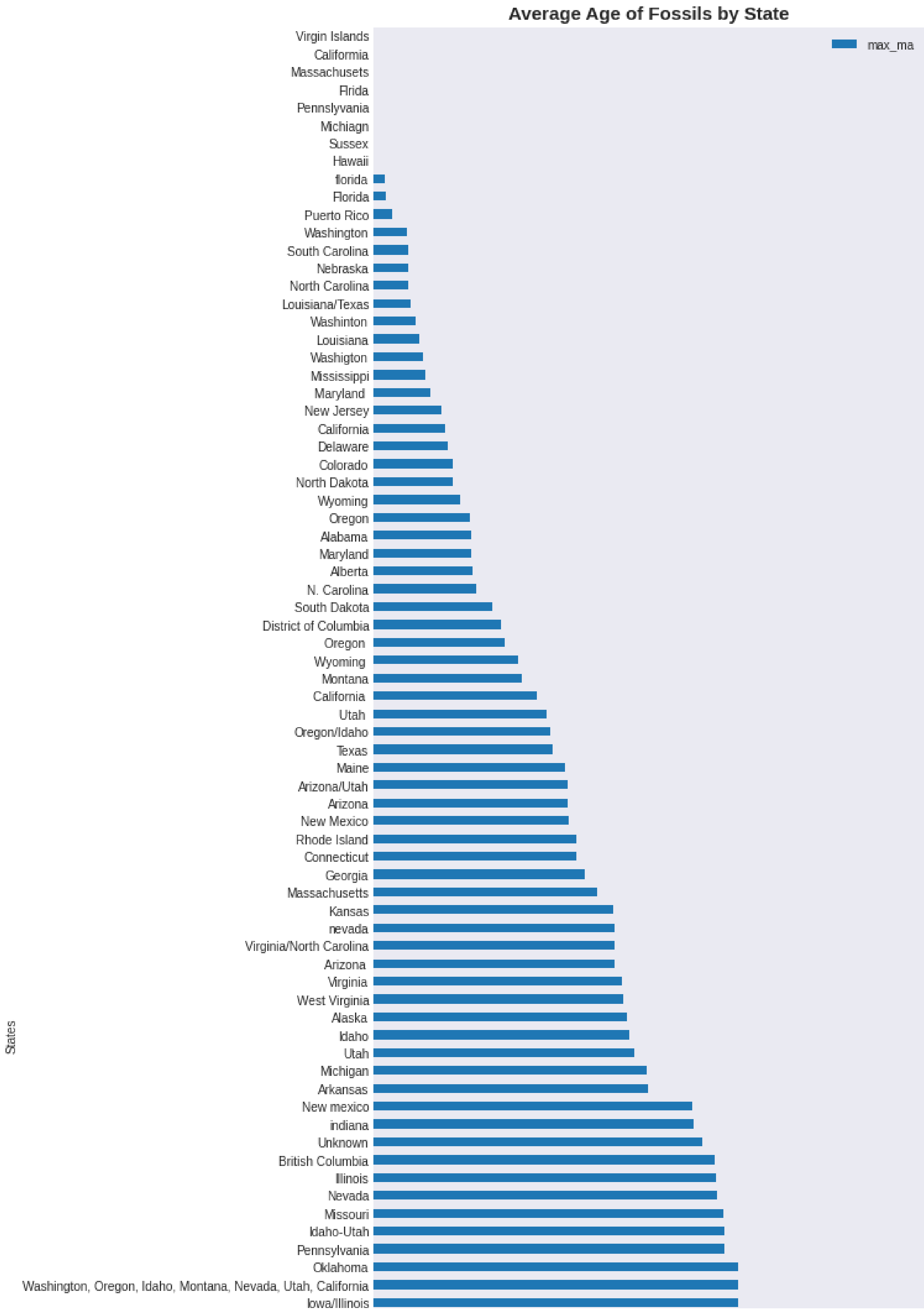
In [ ]:

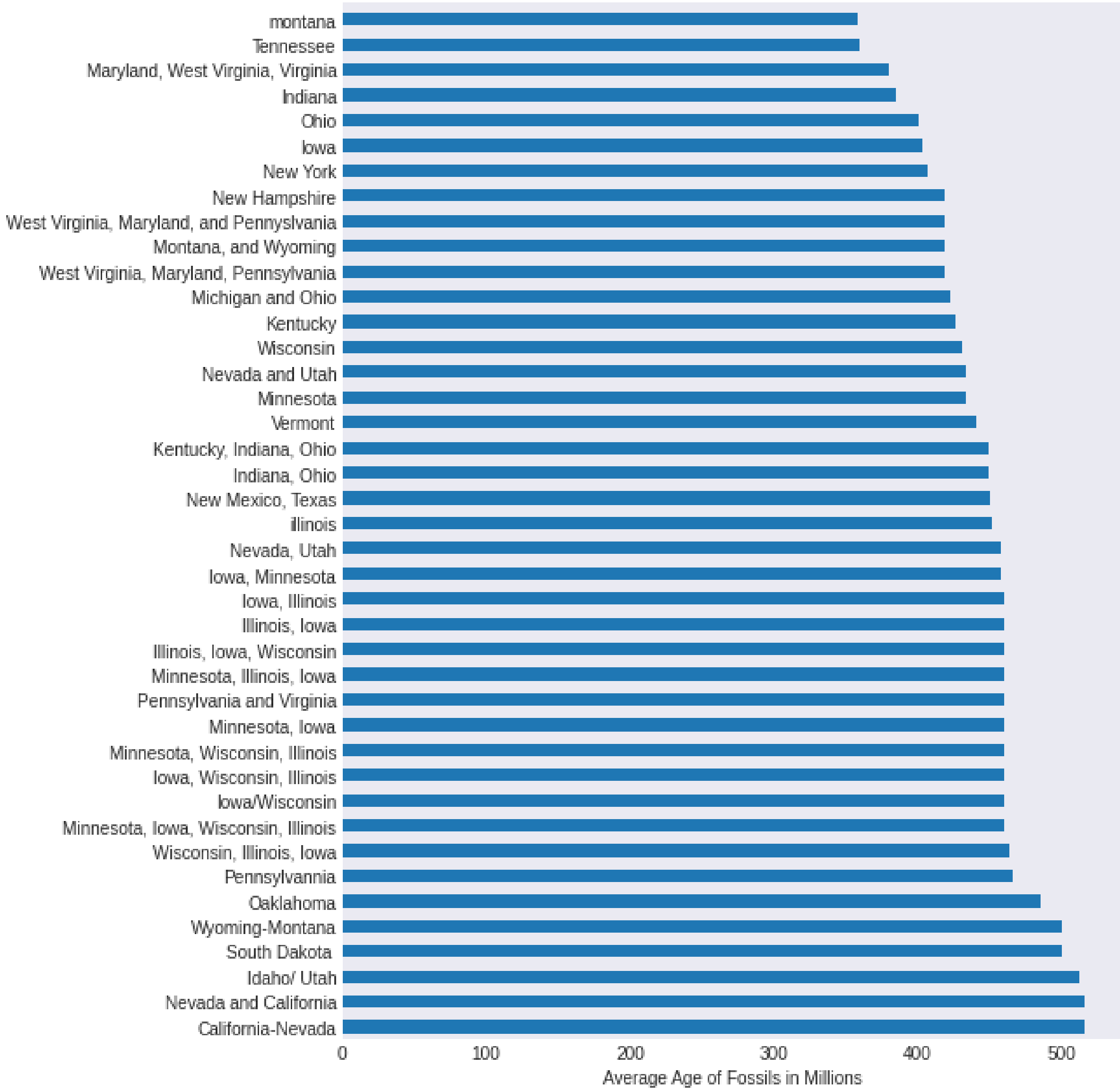
```
fig, ax = plt.subplots()
```

```
states.plot.barh(figsize = (8,30), ax=ax)
ax.set_title('Average Age of Fossils by State',size=15, fontweight = 'bold')
ax.set_ylabel('States')
ax.set_xlabel('Average Age of Fossils in Millions')
```

Out[ ]:

```
Text(0.5, 0, 'Average Age of Fossils in Millions')
```





In [ ]:

```
rank = occs.groupby('identified_rank')['max_ma'].mean()
rank = pd.DataFrame(rank)
rank = rank.reset_index()
rank = rank.loc[(rank['identified_rank']).isin(['kingdom','phylum','class','order','fami
ly','genus','species'])]
rank = rank.reindex([6,8,0,7,1,2,9])
rank
```

Out[ ]:

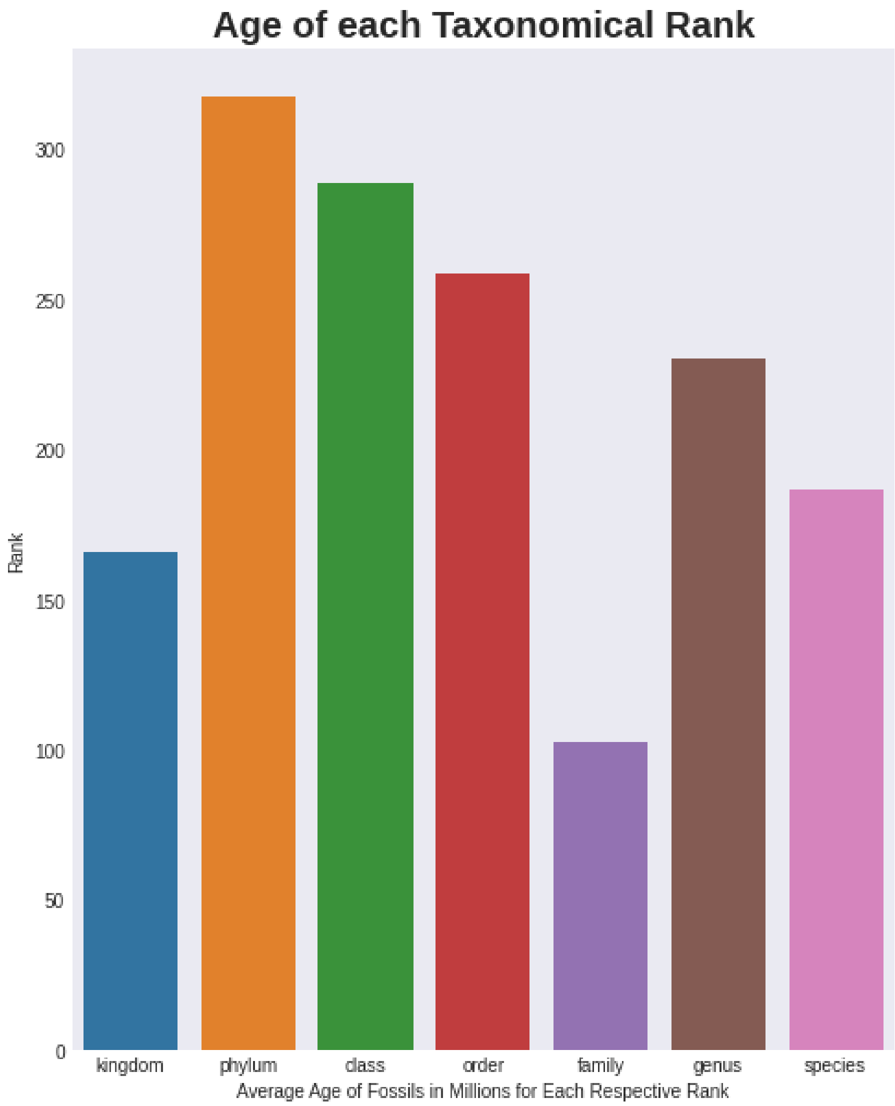
	identified_rank	max_ma
6	kingdom	166.153996
8	phylum	318.027774
0	class	288.973864
7	order	258.718479
1	family	102.719258
2	genus	230.715823
9	species	187.043246

In [ ]:

```
fig = plt.figure(figsize=(8,10))
sns.barplot(x='identified_rank', y= 'max_ma', data=rank)
plt.title('Age of each Taxonomical Rank',fontsize=20,fontweight= 'bold')
plt.ylabel('Rank')
plt.xlabel('Average Age of Fossils in Millions for Each Respective Rank')
```

Out[ ]:

```
Text(0.5, 0, 'Average Age of Fossils in Millions for Each Respective Rank')
```



In [ ]: