C01_FinalProject

April 12, 2023

1 Largest Earthquakes Data Analysis

1.0.1 About Dataset

CONTENT Earthquakes are caused by movements within the Earth's crust and uppermost mantle. They range from events too weak to be detectable except by sensitive instrumentation, to sudden and violent events lasting many minutes which have caused some of the greatest disasters in human history. Below, earthquakes are listed by period, region or country, year, magnitude, cost, fatalities and number of scientific studies.

1.0.2 Context

The Modified Mercalli intensity scale (MM, MMI, or MCS), developed from Giuseppe Mercalli's Mercalli intensity scale of 1902, is a seismic intensity scale used for measuring the intensity of shaking produced by an earthquake. It measures the effects of an earthquake at a given location, distinguished from the earthquake's inherent force or strength as measured by seismic magnitude scales (such as the "Mw" magnitude usually reported for an earthquake). While shaking is caused by the seismic energy released by an earthquake, earthquakes differ in how much of their energy is radiated as seismic waves. Deeper earthquakes also have less interaction with the surface, and their energy is spread out across a larger volume. Shaking intensity is localized, generally diminishing with distance from the earthquake's epicenter, but can be amplified in sedimentary basins and certain kinds of unconsolidated soils.

The data was imported from Kaggle:

https://www.kaggle.com/datasets/rajkumarpandey02/lists-of-earthquakes-deadliest-and-largest?select=Largest+earthquakes+by+year.csv

1.1 Imports

[61]:
```
import pandas as pd
import matplotlib.pyplot as plt
import zipfile
import os
from geopy.geocoders import Nominatim
import numpy as np
import roman
import datetime
```

1.2 Data Loading

[2]:
```
cwd = os.getcwd()
```

[3]:
```
with zipfile.ZipFile("archive.zip", mode="r") as archive:
    filenames = archive.infolist()
    for file in filenames:
        archive.extract(file, path=cwd)
```

[4]:
```
df = pd.read_csv('Largest earthquakes by year.csv', index_col=0)
```

1.3 First Look at Data and Cleaning

[5]:
```
df.head()
```

[5]:

	Year	Magnitude	Location	Depth (km)	MMI	Notes	Deaths	Injuries	Event	Date
0	1937	7.8	Republic of China, Qinghai	15.0	VIII	-	0	0	[8]	January 7
1	1938	8.5-8.6	Dutch East Indies, Maluku offshore	60.0	VII	A damaging tsunami up to 1.5 meters high was r…	0	0	1938 Banda Sea earthquake	February 1
2	1939	8.1	Dutch East Indies, Central Sulawesi offshore	150.0	VII	-	0	0	[9]	December 21
3	1940	8.2	Peru, Lima	45.0	VIII	A tsunami up to 2 meters high was generated wi…	179-300	3500	1940 Lima earthquake	May 24
4	1941	8.0	Japan, Miyazaki offshore	35.0	VII	A tsunami up to 1.2 meters high was observed i…	2	0	1941 Hyūga-nada earthquake	November 18

[6]:
```
df.shape
```

[6]:
```
(91, 10)
```

There are several columns that need to be 'fixed'. Let's seee what data types we are dealing with:

[7]:
```
df.dtypes
```

[7]:
```
Year            int64
Magnitude      object
Location       object
Depth (km)    float64
```

```
MMI            object
Notes          object
Deaths         object
Injuries       object
Event          object
Date           object
dtype: object
```

1.3.1 Notes and Event

We are going to delete these two columns

[8]:
```
df.drop(['Notes', 'Event'], inplace=True, axis=1)
```

1.3.2 Magnitude

The Magnitude column is an object, because of these three values :

[9]:
```
df[df.Magnitude.str.len()>3]
```

[9]:
```
    Year Magnitude                          Location  Depth (km)   MMI  \
1   1938   8.5-8.6  Dutch East Indies, Maluku offshore        60.0   VII
6   1943   7.9-8.2                      Chile, Coquimbo        35.0  VIII
70  2004   9.1-9.3                  Indonesia, Sumatra        10.0    IX

    Deaths Injuries         Date
1        0        0   February 1
6       11        0      April 6
70  227898   125000  December 26
```

According to Wikipedia (https://en.wikipedia.org/wiki/Lists_of_earthquakes) we can replace these values with:

- 8.5
- 8.1
- 9.1

[10]:
```
df.Magnitude.replace()
```

[10]:
```
0         7.8
1     8.5-8.6
2         8.1
3         8.2
4         8.0
       ...
86        7.8
87        8.2
88        7.6
89        7.6
```

```
90        7.8
Name: Magnitude, Length: 91, dtype: object
```

[11]:
```
df.replace({'Magnitude' : { '8.5-8.6' : '8.5', '7.9-8.2' : '8.1', '9.1-9.3' :␣
 ↪'9.1' }}, inplace=True)
```

Let's convert the column to numbers:

[12]:
```
df['Magnitude'] = df['Magnitude'].astype(float)
```

1.3.3 Date

[13]:
```
# df['Courses'].astype(str) +"-"+ df["Duration"]
df["Date"] = pd.to_datetime(df['Year'].astype(str) +" "+ df["Date"])
```

We can now remove the column 'Year'

[29]:
```
df.drop('Year', axis=1, inplace=True)
```

[30]:
```
df.head()
```

[30]:

	Magnitude	Location	Depth (km)	MMI	\
0	7.8	Republic of China, Qinghai	15.0	8	
1	8.5	Dutch East Indies, Maluku offshore	60.0	7	
2	8.1	Dutch East Indies, Central Sulawesi offshore	150.0	7	
3	8.2	Peru, Lima	45.0	8	
4	8.0	Japan, Miyazaki offshore	35.0	7	

	Deaths	Injuries	Date	Offshore	Country
0	0	0	1937-01-07	0	Republic of China
1	0	0	1938-02-01	1	Dutch East Indies
2	0	0	1939-12-21	1	Dutch East Indies
3	179	3500	1940-05-24	0	Peru
4	2	0	1941-11-18	1	Japan

1.3.4 Location

[15]:
```
# instantiate a new Nominatim client
app = Nominatim(user_agent="tutorial")
# get location raw data
location = app.geocode("China, Qinghai").raw
# print raw data
print(location)
```

```
{'place_id': 307784541, 'licence': 'Data © OpenStreetMap contributors, ODbL 1.0.
https://osm.org/copyright', 'osm_type': 'relation', 'osm_id': 153269,
'boundingbox': ['31.6018045', '39.2142318', '89.4022166', '103.0694065'], 'lat':
'35.40709525', 'lon': '95.95211573241954', 'display_name': '  ,  ', 'class':
'boundary', 'type': 'administrative', 'importance': 0.610517291768724, 'icon': '
```

```
https://nominatim.openstreetmap.org/ui/mapicons/poi_boundary_administrative.p.20
.png'}
```

We can create a column 'Offshore':

[16]:
```
# df[df['A'].str.contains("hello")]
df['Offshore'] = np.where(df['Location'].str.contains("offshore"), 1, 0)
```

And a column 'Country':

[17]:
```
df['Country'] = df['Location'].str.split(',').str[0]
```

1.3.5 Depth

Let's rename the column as 'Depth':

[38]:
```
df.rename(columns={"Depth (km)": "Depth"}, inplace=True)
```

1.3.6 MMI

[18]:
```
df.MMI.value_counts()
```

[18]:
```
VIII      23
IX        22
VII       16
VI        10
X          4
XI         4
V          3
IV         3
I          2
XII        2
IX[14]     1
VI[18]     1
Name: MMI, dtype: int64
```

We need to correct IX[14] and VI[18]

[19]:
```
df.replace({'MMI' : { 'IX[14]' : 'IX', 'VI[18]' : 'VI' }}, inplace=True)
```

[20]:
```
df.MMI = [roman.fromRoman(str(n)) for n in df.MMI]
```

1.3.7 Deaths

[21]:
```
df.Deaths.value_counts()
```

[21]:
```
0          35
2           5
1           3
189         2
```

```
3           2
21          2
98          1
2444        1
10000       1
938         1
1621        1
127         1
2500        1
12          1
166         1
145         1
1[27]       1
227898      1
1313        1
23          1
87587       1
550         1
19747       1
10          1
6           1
43          1
28          1
600         1
85          1
30          1
11          1
1223        1
4000        1
173         1
2233        1
50          1
4800        1
2336        1
179-300     1
56          1
6000        1
131         1
125         1
86          1
52          1
78          1
8000        1
57,350+     1
Name: Deaths, dtype: int64
```

[22]:
```
df[df.Deaths.isin(['1[27]', '179-300', '57,350+'])]
```

[22]:
```
     Year  Magnitude                       Location  Depth (km)  MMI   Deaths  \
3    1940        8.2                     Peru, Lima        45.0    8  179-300
47   1981        7.7                    Samoa, Apia        25.0    6    1[27]
90   2023        7.8  Turkey, Southeastern Anatolia        17.9   12  57,350+

    Injuries       Date  Offshore Country
3        3500 1940-05-24         0    Peru
47          0 1981-09-01         0   Samoa
90   130,000+ 2023-02-06         0  Turkey
```

We replace these values with:

- 179
- 1
- 57658

And convert the column to integers:

[23]:
```
df.replace({'Deaths' : { '1[27]': '1', '179-300': '179', '57,350+': '57658' }},␣
 ↪inplace=True)
df['Deaths'] = df['Deaths'].astype(int)
```

1.3.8 Injuries

[24]:
```
df.Injuries.value_counts()
```

[24]:
```
0           49
1            2
3000         2
7            1
423          1
11305        1
2713         1
849          1
125000       1
300          1
374177       1
12000        1
1742         1
6000         1
12           1
9            1
34           1
250          1
42           1
35           1
59           1
71           1
3500         1
```

```
4            1
25           1
2135         1
1200         1
51           1
13           1
11000        1
330          1
5            1
759          1
27           1
2400         1
10000        1
1100         1
1325         1
30000        1
7700         1
130,000+     1
Name: Injuries, dtype: int64
```

[25]:
```
df[df.Injuries == '130,000+']
```

[25]:
```
    Year  Magnitude                      Location  Depth (km)  MMI  Deaths  \
90  2023        7.8  Turkey, Southeastern Anatolia        17.9   12   57658

    Injuries       Date  Offshore Country
90  130,000+ 2023-02-06         0  Turkey
```

[26]:
```
df.replace({'Injuries': {'130,000+': '12170'}}, inplace=True)
df['Injuries'] = df['Injuries'].astype(int)
```

1.3.9 Final Dataframe

[31]:
```
df.head()
```

[31]:
```
   Magnitude                                   Location  Depth (km)  MMI  \
0        7.8                  Republic of China, Qinghai        15.0    8
1        8.5           Dutch East Indies, Maluku offshore        60.0    7
2        8.1  Dutch East Indies, Central Sulawesi offshore       150.0    7
3        8.2                                 Peru, Lima        45.0    8
4        8.0                    Japan, Miyazaki offshore        35.0    7

   Deaths  Injuries       Date  Offshore            Country
0       0         0 1937-01-07         0  Republic of China
1       0         0 1938-02-01         1  Dutch East Indies
2       0         0 1939-12-21         1  Dutch East Indies
3     179      3500 1940-05-24         0               Peru
```

```
4       2         0 1941-11-18         1              Japan
```

[32]:
```
df.describe()
```

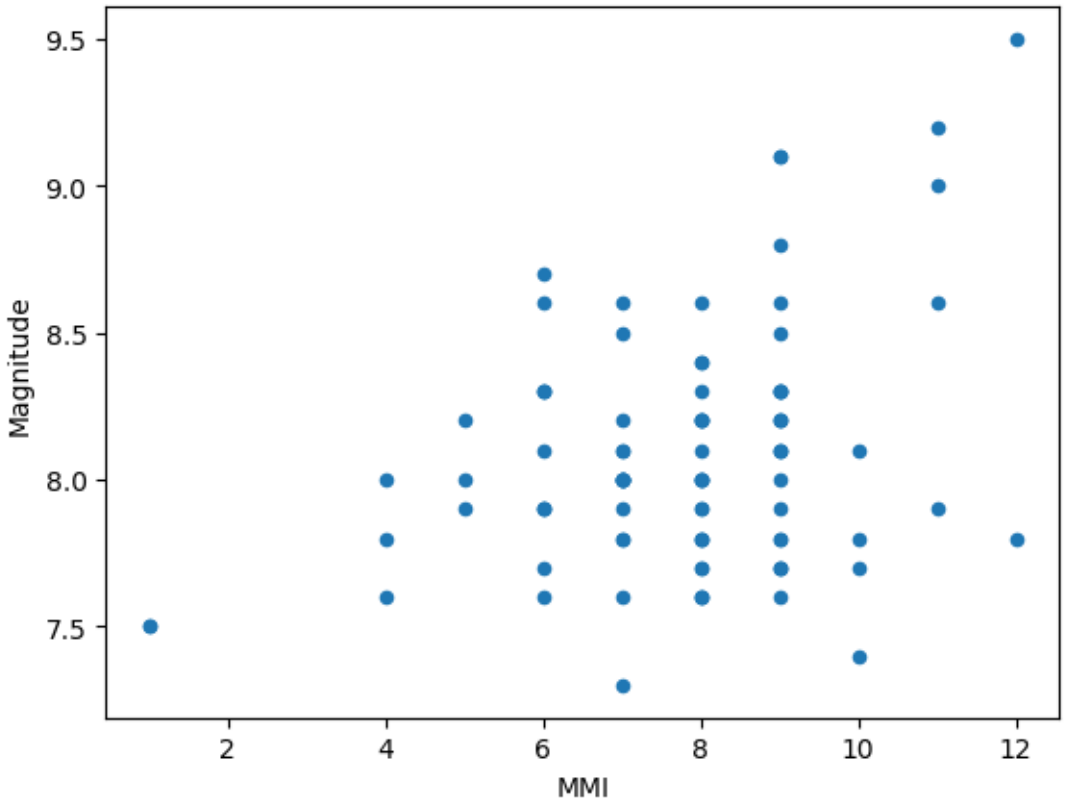
[32]:
```
       Magnitude  Depth (km)        MMI         Deaths       Injuries  \
count  91.000000   91.000000  91.000000      91.000000      91.000000
mean    8.078022   67.140659   7.758242    4874.747253    6865.648352
std     0.409010  140.280440   1.928388   26125.826571   41236.078294
min     7.300000    3.000000   1.000000       0.000000       0.000000
25%     7.800000   18.050000   7.000000       0.000000       0.000000
50%     8.000000   25.500000   8.000000       3.000000       0.000000
75%     8.300000   36.000000   9.000000     169.500000     376.500000
max     9.500000  644.800000  12.000000  227898.000000  374177.000000

       Offshore
count  91.000000
mean    0.131868
std     0.340222
min     0.000000
25%     0.000000
50%     0.000000
75%     0.000000
max     1.000000
```

1.4 Data Visualization

1.4.1 Relationship between Magnitude and MMI

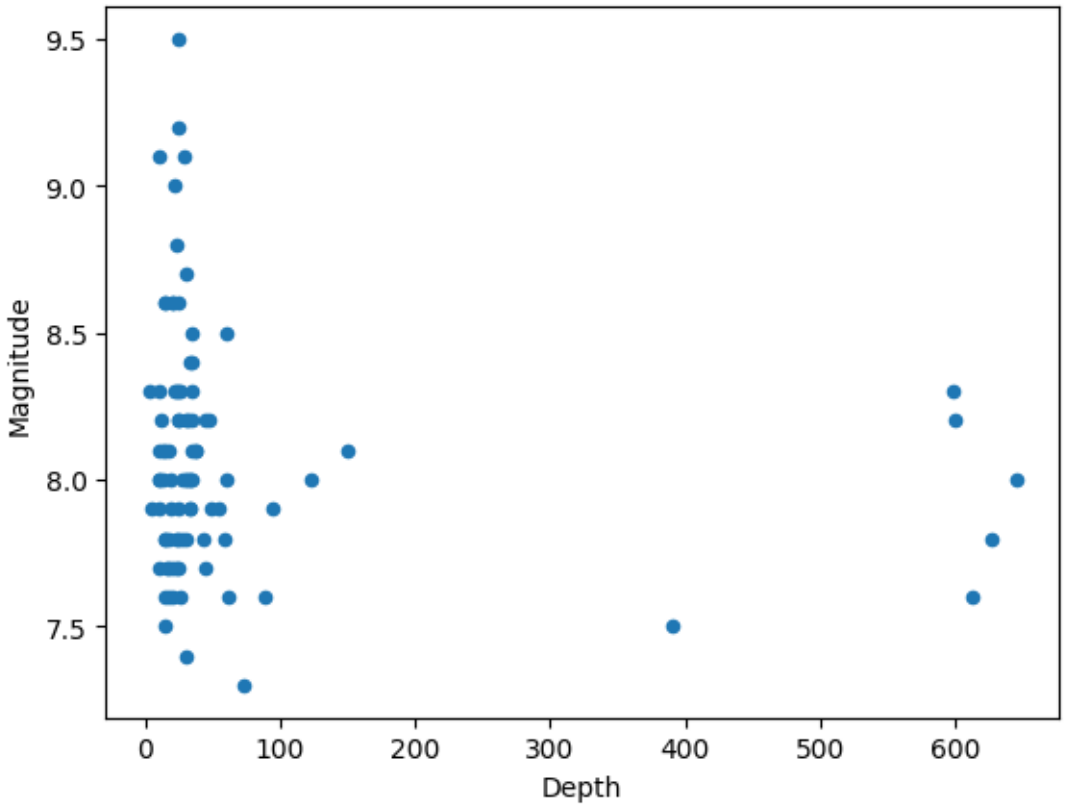
[34]:
```
df.plot.scatter(x='MMI', y='Magnitude')
plt.show()
```



There is a general positive correlation. However it is not uncommon to have earthquakes with similar magnitudes but very different MMI's. This is because the MMI measures the effects of an earthquake at a given location, distinguished from the earthquake's inherent force or strength as measured by seismic magnitude scales (link)

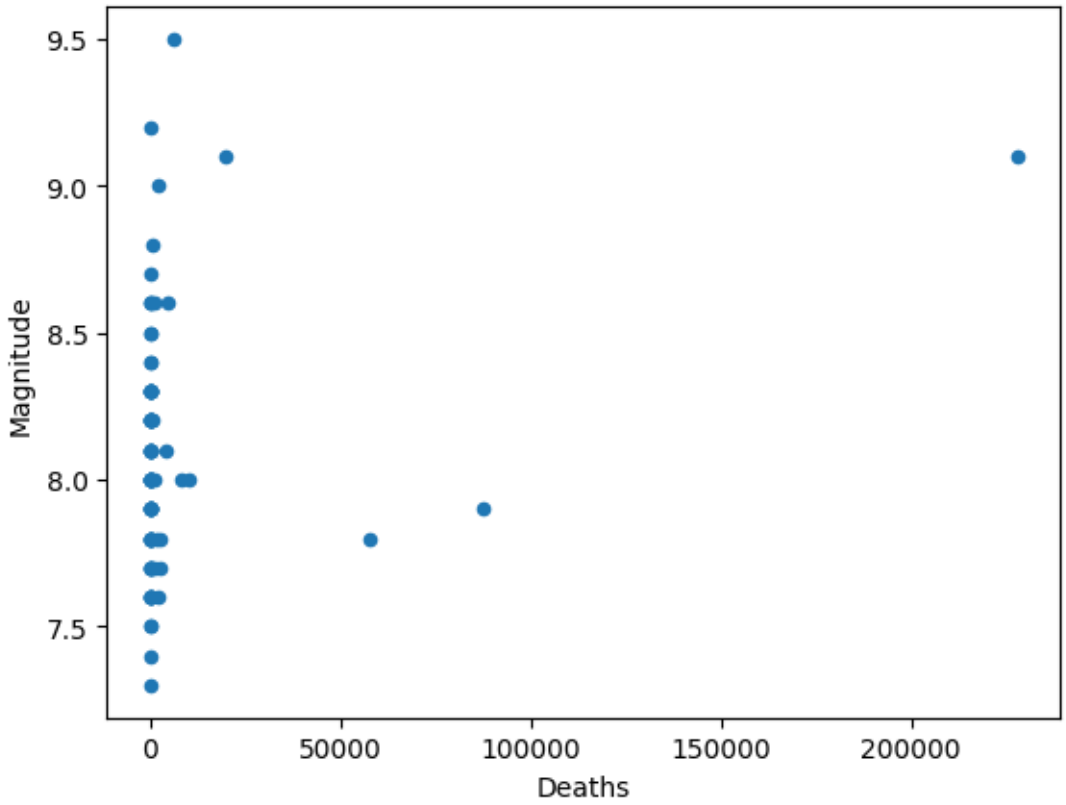
1.4.2 Relationship between Magnitude and Depth

[40]:
```
df.plot.scatter(x='Depth', y='Magnitude')
plt.show()
```



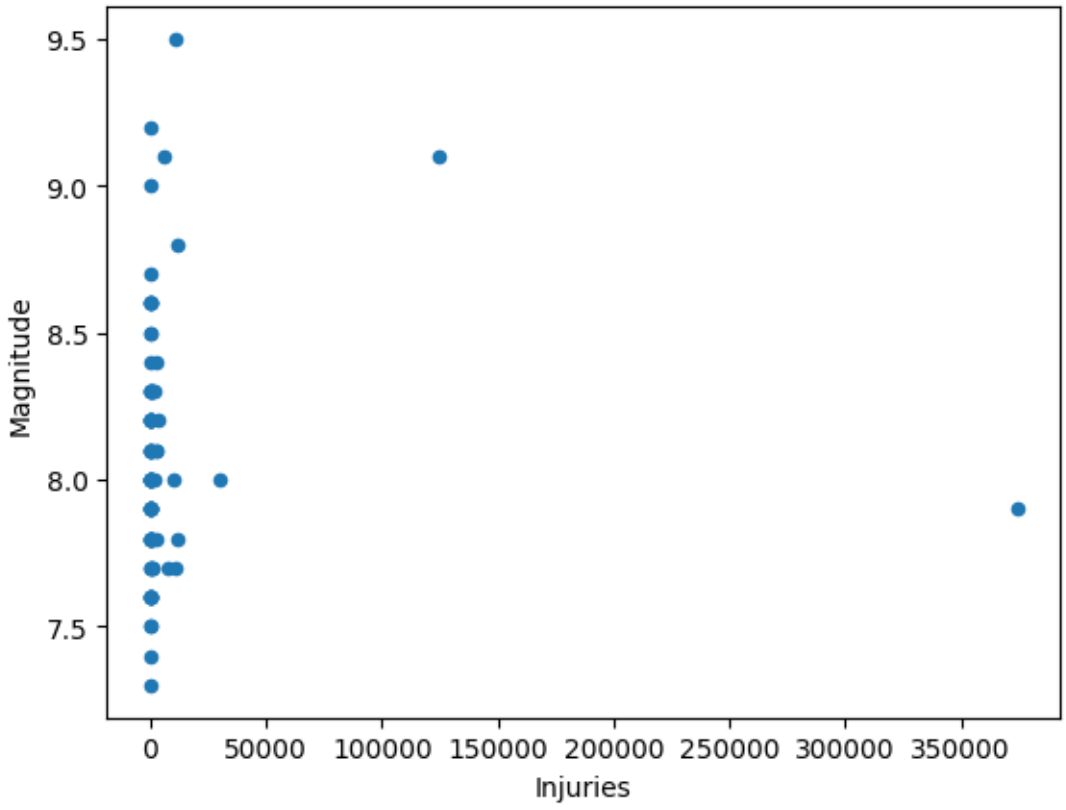
1.4.3 Relationship between Magnitude and Deaths

[41]:
```
df.plot.scatter(x='Deaths', y='Magnitude')
plt.show()
```



1.4.4 Relationship between Magnitude and Injuries

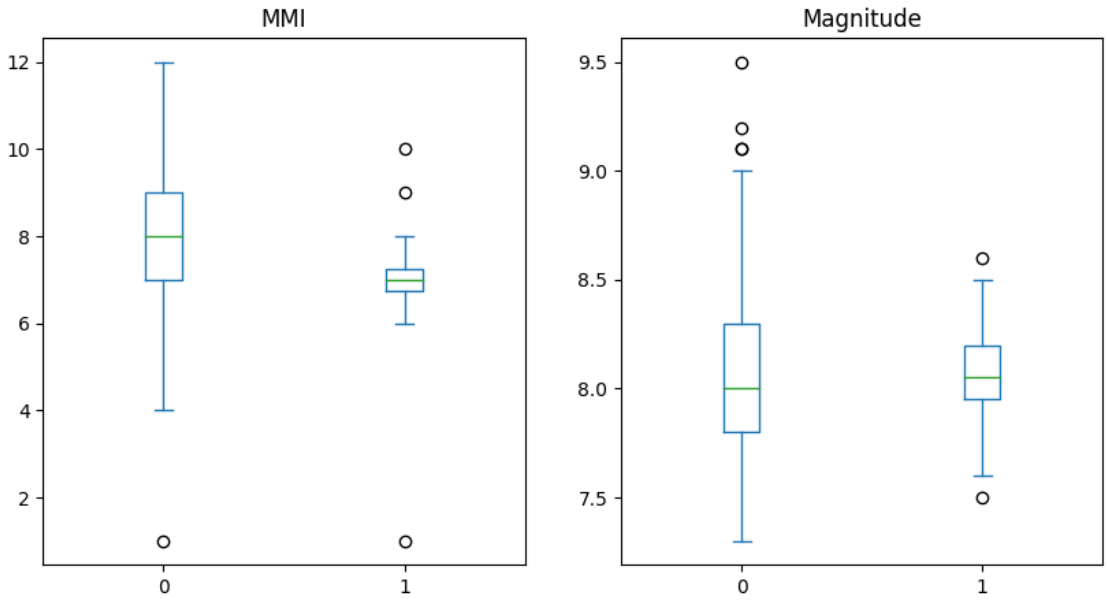
[42]:
```
df.plot.scatter(x='Injuries', y='Magnitude')
plt.show()
```



1.4.5 Difference between Offshore and Land

[58]:
```
df.plot.box(column = ['Magnitude', 'MMI'],
            by='Offshore', figsize=(10,5))

plt.show()
```



1.4.6 Deaths and Injuries over the Years

[77]:
```
df_group_by_year = df.groupby(df['Date'].dt.year)[['Deaths', 'Injuries']].sum()


df_group_by_year.index.names = ['Year']
```

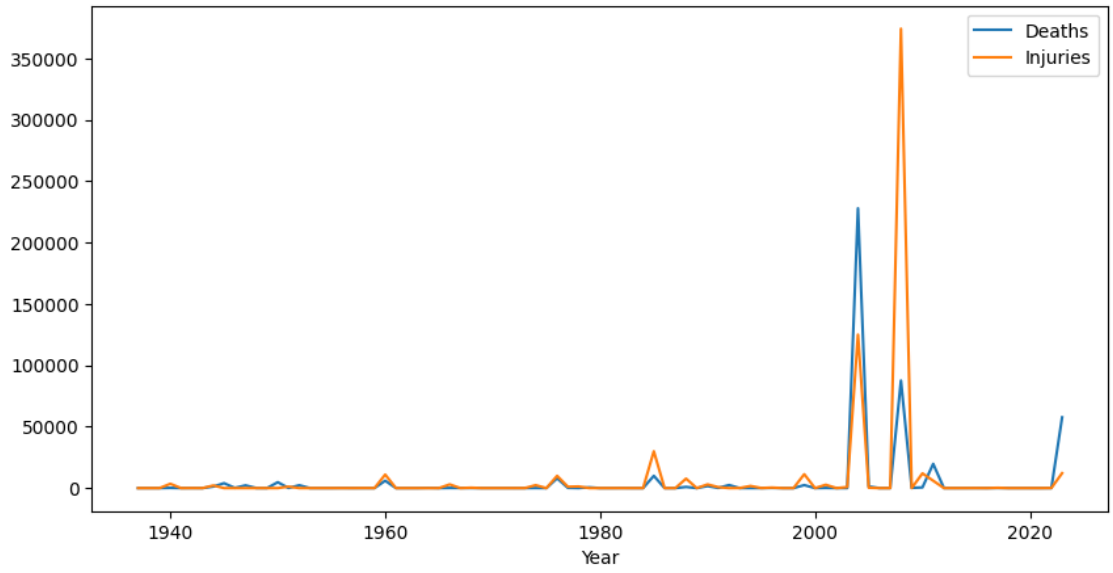
[78]:
```
df_group_by_year
```

[78]:
```
      Deaths  Injuries
Year
1937       0         0
1938       0         0
1939       0         0
1940     179      3500
1941       2         0
…        …         …
2019       2         0
2020       0         0
2021       0         0
2022      23        77
2023   57658     12170

[87 rows x 2 columns]
```

[84]:
```
df_group_by_year.plot.line( y=['Deaths', 'Injuries'],
                           figsize=(10,5))
```

```
plt.show()
```



1.4.7 Deaths and Injuries by Country

[95]:
```
df_group_by_country = df.groupby('Country')[['Deaths', 'Injuries']].sum()
df_group_by_country.sort_values(by='Deaths', ascending=True, inplace=True)

df_group_by_country
```

[95]:

Country	Deaths	Injuries
north Atlantic Ocean	0	0
Republic of China	0	0
Guam	0	71
Fiji offshore	0	0
Fiji	0	0
Dutch East Indies	0	0
Spain	0	0
Canada	0	0
Australia	0	0
Antarctica	0	0
Solomon Islands	0	0
New Zealand	0	0
Russia	12	1743
Papua New Guinea	26	47
El Salvador	43	0
Greece	56	0

Costa Rica	127	759
Alaska	131	0
United States	175	1
Samoa	190	7
Colombia	601	4
Myanmar-China border region	938	7700
Soviet Union	2337	64
Taiwan	2529	12505
Peru	2792	11638
India	4000	0
India-China	4800	0
Chile	6591	23102
Philippines	9671	13000
Mexico	10100	30285
Japan	21053	10666
Turkey	57744	12170
China	87587	374177
Indonesia	232099	126835

[ ]:

[101]:
```
df_group_by_country[df_group_by_country.Deaths>100].plot.barh(figsize=(8,6),)

plt.show()
```