```python
print("EARTHQUAKE MAGNITUDE DETECTION USING PRECURSOR SIGNALS")
print("DATASET - usa_earthquake_cleaned.csv")
```

```
EARTHQUAKE MAGNITUDE DETECTION USING PRECURSOR SIGNALS
DATASET - usa_earthquake_cleaned.csv
```

```python
import pandas as pd
import numpy as np
import matplotlib.pyplot as plt
import seaborn as sns
import sqlite3
from datetime import datetime
import warnings
warnings.filterwarnings('ignore')

plt.style.use('default')
sns.set_palette("husl")

pd.set_option('display.max_columns', None)
pd.set_option('display.width', 1000)

print("Libraries imported successfully!")
print(f"Analysis Date: {datetime.now().strftime('%Y-%m-%d %H:%M:
%S')}")
```

```
Libraries imported successfully!
Analysis Date: 2025-09-11 12:43:50
```

```python
raw_data = pd.read_csv('../data/raw/usa_earthquake_data.csv')
cleaned_data =
pd.read_csv('../data/processed/usa_earthquake_cleaned.csv')

print("DATASET COMPARISON: ")
print(f"Raw Data Shape: {raw_data.shape}")
print(f"Cleaned Data Shape: {cleaned_data.shape}")
print(f"Columns Removed: {set(raw_data.columns) -
set(cleaned_data.columns)}")
print(f"Columns Added: {set(cleaned_data.columns) -
set(raw_data.columns)}")

print("\nCLEANED DATA SAMPLE: ")
cleaned_data.head()
```

```
DATASET COMPARISON:
Raw Data Shape: (9451, 22)
Cleaned Data Shape: (9451, 19)
Columns Removed: {'time', 'dmin', 'id', 'magNst', 'nst'}
Columns Added: {'time_only', 'date'}

CLEANED DATA SAMPLE:
    latitude   longitude    depth  mag magType    gap   rms net
updated                                    place        type
horizontalError  depthError  magError     status locationSource
magSource       date time_only
0  31.604000 -104.213000   4.4198  1.7      ml  69.00  0.50  tx  2024-
01-26T05:08:27.774Z                 51 km NW of Toyah, Texas
earthquake             0.00    1.292059     0.100  automatic
tx        tx  1/26/2024   52:43.0
1  64.501000 -146.905800   4.2000  1.4      ml  89.91  0.75  ak  2024-
01-26T05:01:12.516Z                 2 km S of Salcha, Alaska
earthquake             0.46    0.200000     0.173  automatic
ak        ak  1/26/2024   42:50.7
2  63.529000 -147.554300  13.1000  1.6      ml  89.91  0.62  ak  2024-
01-26T04:34:54.160Z         71 km ESE of Denali Park, Alaska
earthquake             0.46    0.300000     0.173  automatic
ak        ak  1/26/2024   32:51.5
3  38.833168 -122.797165   1.7300  0.4      md  65.00  0.02  nc  2024-
01-26T04:46:12.828Z                       6 km W of Cobb, CA
earthquake             0.34    0.970000     0.310  automatic
nc        nc  1/26/2024   29:01.2
4  63.546200 -150.971900   0.0000  1.2      ml  89.91  0.80  ak  2024-
01-26T04:25:43.831Z  37 km E of Denali National Park, Alaska
earthquake             0.46    0.400000     0.173  automatic
ak        ak  1/26/2024   23:14.4
```

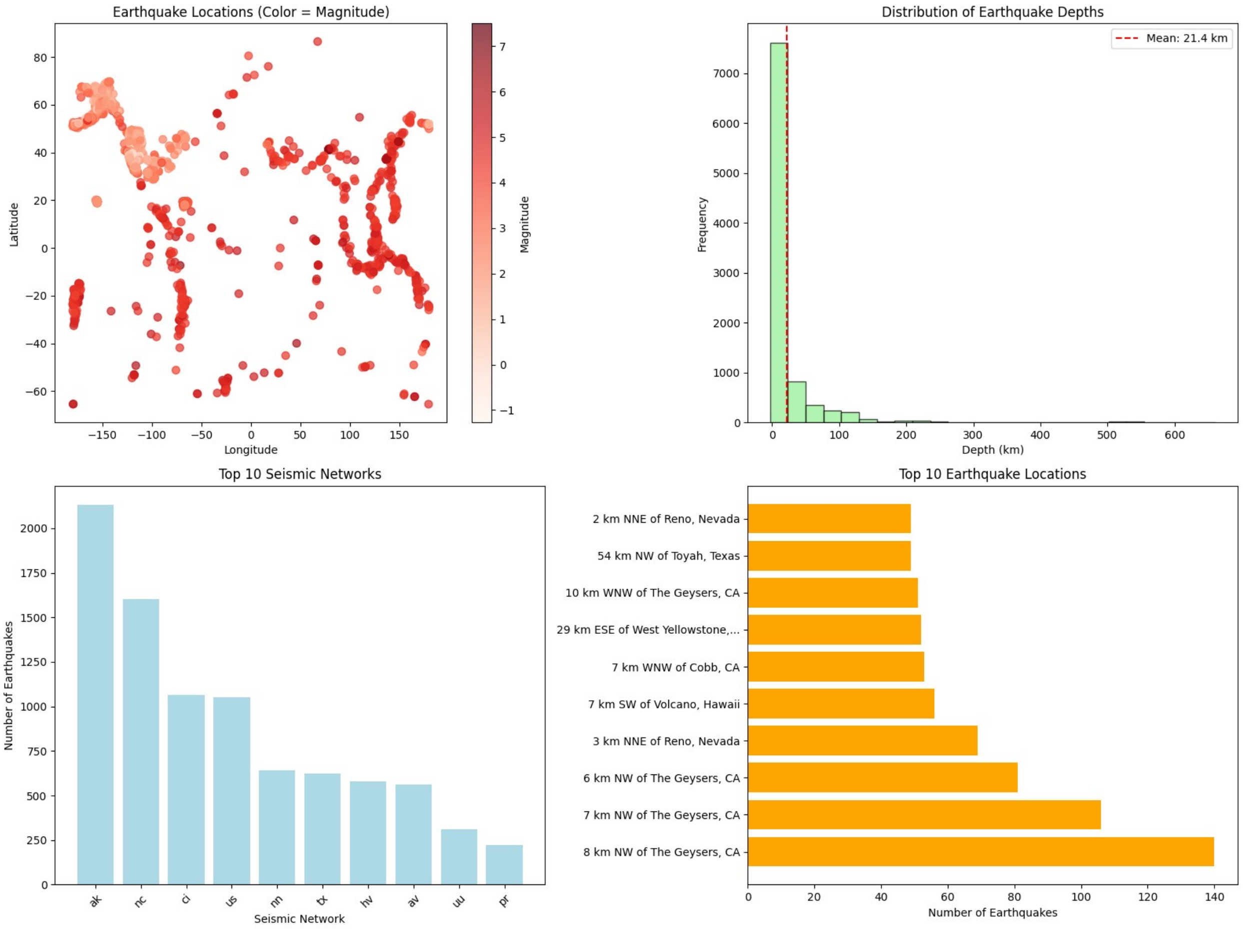
```
print("\nDATA TYPES: ")
print(cleaned_data.dtypes)

print("\nMISSING VALUES: ")
missing_values = cleaned_data.isnull().sum()
missing_percentage = (missing_values / len(cleaned_data)) * 100
missing_df = pd.DataFrame({
    'Missing Count': missing_values,
    'Percentage': missing_percentage
}).sort_values('Missing Count', ascending=False)
print(missing_df[missing_df['Missing Count'] > 0])

print("\nNUMERICAL STATISTICS: ")
cleaned_data.describe()
```

```
DATA TYPES:
latitude           float64
longitude          float64
depth              float64
mag                float64
magType             object
gap                float64
rms                float64
net                 object
```

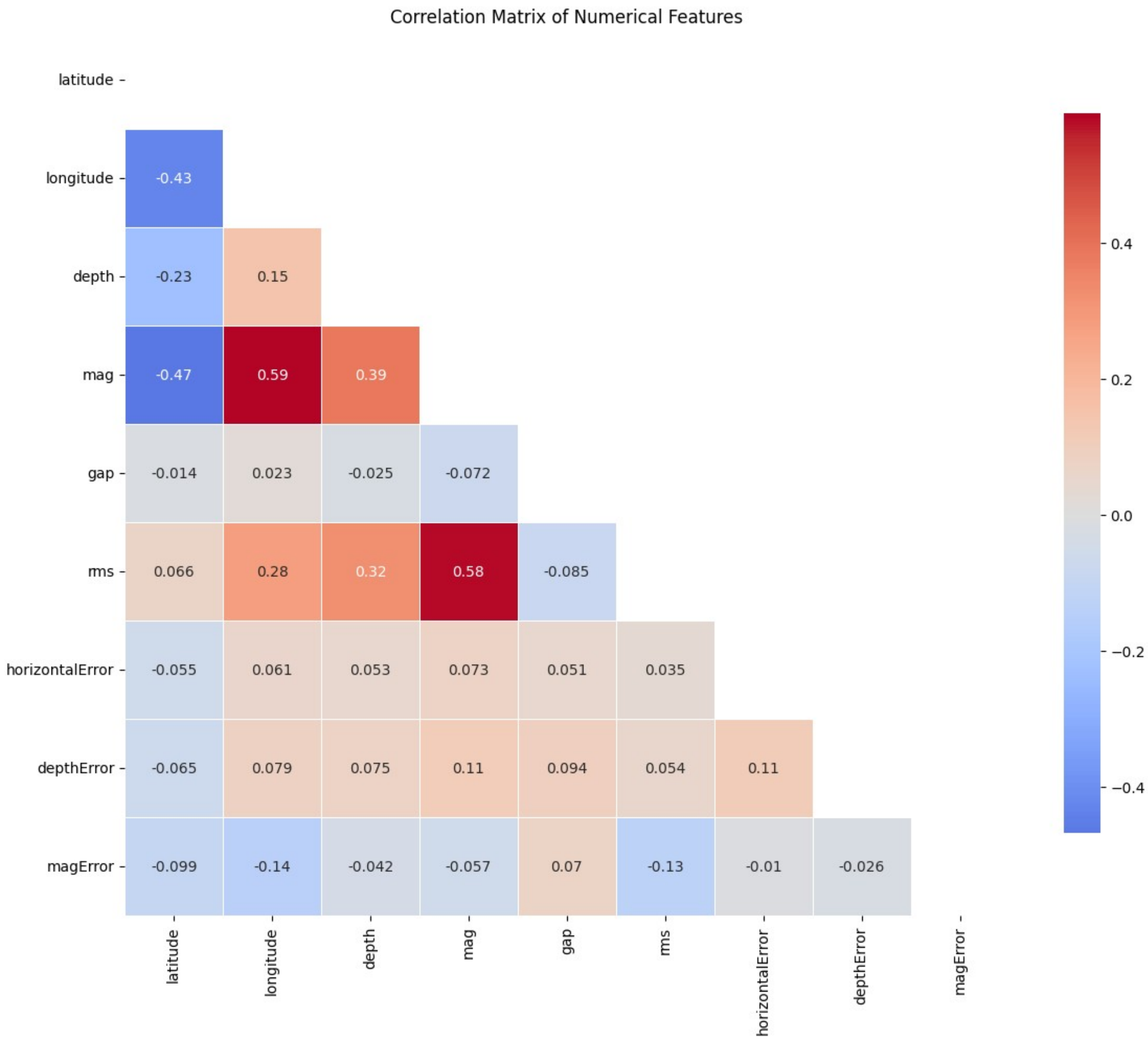
```
updated             object
place               object
type                object
horizontalError    float64
depthError         float64
magError           float64
status              object
locationSource      object
magSource           object
date                object
time_only           object
dtype: object

MISSING VALUES:
Empty DataFrame
Columns: [Missing Count, Percentage]
Index: []

NUMERICAL STATISTICS:

          latitude    longitude        depth          mag          gap
rms  horizontalError   depthError     magError
count  9451.000000  9451.000000  9451.000000  9451.000000  9451.000000
9451.000000      9451.000000  9451.000000  9451.000000
mean     39.946558  -110.580238    21.358118     1.631121   103.437011
0.290898         1.628428     2.113351     0.226302
std      18.996832    68.764250    50.809672     1.238299    54.598118
0.281351        27.223453     9.483877     0.326050
min     -65.436500  -179.968700    -3.170000    -1.270000    10.000000
0.000000         0.000000     0.000000     0.000000
25%      33.417833  -149.698400     2.816150     0.860000    70.000000
0.100000         0.330000     0.400000     0.130565
50%      38.817333  -122.447500     7.250000     1.400000    89.910000
0.177100         0.460000     0.720000     0.173000
75%      56.647900  -112.604333    14.300000     2.000000   119.000000
0.460000         0.660000     1.500000     0.211872
max      86.513000   179.996600   660.826000     7.500000   357.000000
2.930000      2626.244209   494.700000     5.160000
```

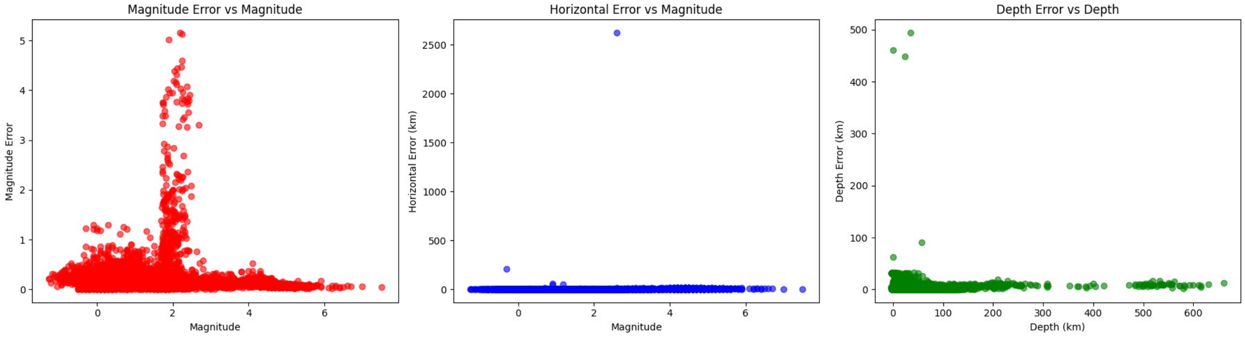
```
fig, axes = plt.subplots(2, 2, figsize=(16, 12))

scatter = axes[0,0].scatter(cleaned_data['longitude'],
cleaned_data['latitude'],
                           c=cleaned_data['mag'], cmap='Reds',
alpha=0.7, s=50)
axes[0,0].set_xlabel('Longitude')
axes[0,0].set_ylabel('Latitude')
axes[0,0].set_title('Earthquake Locations (Color = Magnitude)')
plt.colorbar(scatter, ax=axes[0,0], label='Magnitude')
```

```
axes[0,1].hist(cleaned_data['depth'], bins=25, alpha=0.7,
color='lightgreen', edgecolor='black')
axes[0,1].set_xlabel('Depth (km)')
axes[0,1].set_ylabel('Frequency')
axes[0,1].set_title('Distribution of Earthquake Depths')
axes[0,1].axvline(cleaned_data['depth'].mean(), color='red',
linestyle='--',
                  label=f'Mean: {cleaned_data["depth"].mean():.1f}
km')
axes[0,1].legend()

network_counts = cleaned_data['net'].value_counts().head(10)
axes[1,0].bar(network_counts.index, network_counts.values,
color='lightblue')
axes[1,0].set_xlabel('Seismic Network')
axes[1,0].set_ylabel('Number of Earthquakes')
axes[1,0].set_title('Top 10 Seismic Networks')
axes[1,0].tick_params(axis='x', rotation=45)

place_counts = cleaned_data['place'].value_counts().head(10)
axes[1,1].barh(range(len(place_counts)), place_counts.values,
color='orange')
axes[1,1].set_yticks(range(len(place_counts)))
axes[1,1].set_yticklabels([place[:30] + '...' if len(place) > 30 else
place for place in place_counts.index])
axes[1,1].set_xlabel('Number of Earthquakes')
axes[1,1].set_title('Top 10 Earthquake Locations')

plt.tight_layout()
plt.show()

print("GEOGRAPHIC STATISTICS: ")
print(f"Latitude Range: {cleaned_data['latitude'].min():.3f}° to
{cleaned_data['latitude'].max():.3f}°")
print(f"Longitude Range: {cleaned_data['longitude'].min():.3f}° to
{cleaned_data['longitude'].max():.3f}°")
print(f"Depth Range: {cleaned_data['depth'].min():.1f} -
{cleaned_data['depth'].max():.1f} km")
print(f"Average Depth: {cleaned_data['depth'].mean():.1f} km")

print(f"\nTop 5 Most Active Locations:")
print(cleaned_data['place'].value_counts().head())
```



```
GEOGRAPHIC STATISTICS:
Latitude Range: -65.436° to 86.513°
Longitude Range: -179.969° to 179.997°
Depth Range: -3.2 - 660.8 km
Average Depth: 21.4 km

Top 5 Most Active Locations:
place
8 km NW of The Geysers, CA    140
7 km NW of The Geysers, CA    106
6 km NW of The Geysers, CA     81
3 km NNE of Reno, Nevada       69
7 km SW of Volcano, Hawaii     56
Name: count, dtype: int64

numerical_cols = ['latitude', 'longitude', 'depth', 'mag', 'gap',
'rms', 'horizontalError', 'depthError', 'magError']
correlation_data = cleaned_data[numerical_cols].corr()

plt.figure(figsize=(12, 10))
mask = np.triu(np.ones_like(correlation_data, dtype=bool))
sns.heatmap(correlation_data, mask=mask, annot=True, cmap='coolwarm',
center=0,
            square=True, linewidths=0.5, cbar_kws={"shrink": 0.8})
plt.title('Correlation Matrix of Numerical Features')
plt.tight_layout()
plt.show()

fig, axes = plt.subplots(1, 3, figsize=(18, 5))

axes[0].scatter(cleaned_data['mag'], cleaned_data['magError'],
alpha=0.6, color='red')
axes[0].set_xlabel('Magnitude')
axes[0].set_ylabel('Magnitude Error')
axes[0].set_title('Magnitude Error vs Magnitude')

axes[1].scatter(cleaned_data['mag'], cleaned_data['horizontalError'],
alpha=0.6, color='blue')
axes[1].set_xlabel('Magnitude')
axes[1].set_ylabel('Horizontal Error (km)')
axes[1].set_title('Horizontal Error vs Magnitude')

axes[2].scatter(cleaned_data['depth'], cleaned_data['depthError'],
alpha=0.6, color='green')
axes[2].set_xlabel('Depth (km)')
axes[2].set_ylabel('Depth Error (km)')
axes[2].set_title('Depth Error vs Depth')

plt.tight_layout()
plt.show()

print("STRONG CORRELATIONS (|r| > 0.3): ")
correlation_pairs = []
for i in range(len(correlation_data.columns)):
    for j in range(i+1, len(correlation_data.columns)):
        corr_val = correlation_data.iloc[i, j]
        if abs(corr_val) > 0.3:
            correlation_pairs.append((correlation_data.columns[i],
correlation_data.columns[j], corr_val))

for col1, col2, corr in sorted(correlation_pairs, key=lambda x:
abs(x[2]), reverse=True):
    print(f"{col1} - {col2}: {corr:.3f}")
```





```
STRONG CORRELATIONS (|r| > 0.3):
longitude - mag: 0.591
mag - rms: 0.582
latitude - mag: -0.469
latitude - longitude: -0.430
```

```
depth - mag: 0.387
depth - rms: 0.323
```

```python
conn = sqlite3.connect('../data/earthquake_data.db')
cleaned_data.to_sql('earthquakes', conn, if_exists='replace',
index=False)
print("Data successfully loaded into SQLite database:
earthquake_data.db")

queries = {
    "Daily Summary": """
        SELECT date,
               COUNT(*) as earthquake_count,
               ROUND(AVG(mag), 2) as avg_magnitude,
               MAX(mag) as max_magnitude,
               ROUND(AVG(depth), 1) as avg_depth
        FROM earthquakes
        GROUP BY date
        ORDER BY date
    """,

    "Geographic Hotspots": """
        SELECT place,
               COUNT(*) as earthquake_count,
               ROUND(AVG(mag), 2) as avg_magnitude,
               MAX(mag) as max_magnitude
        FROM earthquakes
        GROUP BY place
        HAVING earthquake_count > 1
        ORDER BY earthquake_count DESC
        LIMIT 10
    """,

    "Network Performance": """
        SELECT net,
               COUNT(*) as earthquake_count,
               ROUND(AVG(mag), 2) as avg_magnitude,
               ROUND(AVG(magError), 3) as avg_mag_error
        FROM earthquakes
        GROUP BY net
        ORDER BY earthquake_count DESC
    """
}

for query_name, query in queries.items():
    print(f"\n{query_name.upper()}")
    result = pd.read_sql_query(query, conn)
    print(result)

conn.close()
```

```
Data successfully loaded into SQLite database: earthquake_data.db

DAILY SUMMARY
          date  earthquake_count  avg_magnitude  max_magnitude
avg_depth
0     1/1/2024               432           1.75            7.5
21.7
1    1/10/2024               243           1.47            5.0
19.1
2    1/11/2024               229           1.58            6.4
28.4
3    1/12/2024               222           1.74            5.9
22.0
4    1/13/2024               280           1.64            5.2
18.8
5    1/14/2024               242           1.50            5.2
28.0
6    1/15/2024               285           1.58            5.2
24.0
7    1/16/2024               267           1.45            5.0
20.0
8    1/17/2024               262           1.56            5.6
19.5
9    1/18/2024               316           1.45            6.4
18.1
10   1/19/2024               343           1.55            5.6
16.9
11    1/2/2024               313           1.66            5.4
19.0
12   1/20/2024               442           1.56            6.6
16.4
13   1/21/2024               309           1.52            5.4
17.9
14   1/22/2024               297           1.77            7.0
16.7
15   1/23/2024               284           1.77            6.3
19.1
16   1/24/2024               348           1.55            5.4
15.7
17   1/25/2024               323           1.38            5.6
15.0
18   1/26/2024                49           1.87            5.1
20.0
19    1/3/2024               280           1.87            5.5
22.6
20    1/4/2024               353           1.65            5.6
28.6
21    1/5/2024               302           1.71            5.2
17.1
```

```
22    1/6/2024               279          1.52            5.6
18.6
23    1/7/2024               216          1.92            5.6
17.9
24    1/8/2024               257          1.66            6.7
17.4
25    1/9/2024               265          1.52            5.9
23.0
26  12/27/2023               262          1.90            5.8
24.8
27  12/28/2023               397          1.73            6.5
31.7
28  12/29/2023               427          1.59            5.7
26.0
29  12/30/2023               512          1.72            6.3
23.4
30  12/31/2023               415          1.64            5.3
28.4

GEOGRAPHIC HOTSPOTS
                                    place  earthquake_count
avg_magnitude  max_magnitude
0              8 km NW of The Geysers, CA               140
0.84           2.83
1              7 km NW of The Geysers, CA               106
0.94           2.23
2              6 km NW of The Geysers, CA                81
0.94           3.41
3                3 km NNE of Reno, Nevada                69
0.51           1.40
4              7 km SW of Volcano, Hawaii                56
1.81           2.55
5                    7 km WNW of Cobb, CA                53
0.77           1.74
6  29 km ESE of West Yellowstone, Montana                52
1.18           3.29
7            10 km WNW of The Geysers, CA                51
0.77           1.53
8                54 km NW of Toyah, Texas                49
1.95           3.00
9                2 km NNE of Reno, Nevada                49
0.91           1.90

NETWORK PERFORMANCE
   net  earthquake_count  avg_magnitude  avg_mag_error
0   ak              2132           1.66          0.173
1   nc              1602           0.98          0.203
2   ci              1063           1.18          0.148
3   us              1053           4.31          0.111
4   nn               642           0.67          0.287
```

```
5   tx                623           1.91          0.167
6   hv                581           1.94          0.867
7   av                563           0.14          0.250
8   uu                312           0.74          0.296
9   pr                223           2.72          0.107
10  ok                220           1.41          0.211
11  mb                214           1.23          0.203
12  uw                193           1.12          0.150
13  nm                 24           1.94          0.097
14  se                  6           2.07          0.075
```

```python
print("EARTHQUAKE DATA ANALYSIS SUMMARY")

print(f"DATASET OVERVIEW:")
print(f"   • Time Period: {cleaned_data['date'].min()} to {cleaned_data['date'].max()}")
print(f"   • Total Earthquakes: {len(cleaned_data):,}")
print(f"   • Geographic Coverage: USA (Lat: {cleaned_data['latitude'].min():.1f}° to {cleaned_data['latitude'].max():.1f}°)")
print(f"   • Monitoring Networks: {cleaned_data['net'].nunique()} networks")

print(f"\nMAGNITUDE INSIGHTS:")
print(f"   • Magnitude Range: {cleaned_data['mag'].min():.1f} - {cleaned_data['mag'].max():.1f}")
print(f"   • Average Magnitude: {cleaned_data['mag'].mean():.2f}")
print(f"   • Most Common Mag Type: {cleaned_data['magType'].mode()[0]} ({(cleaned_data['magType'] == cleaned_data['magType'].mode()[0]).sum()} earthquakes)")
print(f"   • High Magnitude (>4.0): {(cleaned_data['mag'] > 4.0).sum()} earthquakes")

most_active_place = cleaned_data['place'].value_counts().index[0]
most_active_count = cleaned_data['place'].value_counts().iloc[0]
print(f"\nGEOGRAPHIC INSIGHTS:")
print(f"   • Most Active Location: {most_active_place} ({most_active_count} earthquakes)")
print(f"   • Average Depth: {cleaned_data['depth'].mean():.1f} km")
print(f"   • Deepest Earthquake: {cleaned_data['depth'].max():.1f} km")
print(f"   • Shallowest Earthquake: {cleaned_data['depth'].min():.1f} km")

print(f"\nDATA QUALITY:")
print(f"   • Completeness: {((1 - cleaned_data.isnull().sum().sum() / (len(cleaned_data) * len(cleaned_data.columns))) * 100):.1f}%")
print(f"   • Average Magnitude Error: {cleaned_data['magError'].mean():.3f}")
print(f"    • Average Horizontal Error:
{cleaned_data['horizontalError'].mean():.2f} km")
```

```
EARTHQUAKE DATA ANALYSIS SUMMARY
DATASET OVERVIEW:
   • Time Period: 1/1/2024 to 12/31/2023
   • Total Earthquakes: 9,451
   • Geographic Coverage: USA (Lat: -65.4° to 86.5°)
   • Monitoring Networks: 15 networks

MAGNITUDE INSIGHTS:
   • Magnitude Range: -1.3 - 7.5
   • Average Magnitude: 1.63
   • Most Common Mag Type: ml (6092 earthquakes)
   • High Magnitude (>4.0): 880 earthquakes

GEOGRAPHIC INSIGHTS:
   • Most Active Location: 8 km NW of The Geysers, CA (140
earthquakes)
   • Average Depth: 21.4 km
   • Deepest Earthquake: 660.8 km
   • Shallowest Earthquake: -3.2 km

DATA QUALITY:
   • Completeness: 100.0%
   • Average Magnitude Error: 0.226
   • Average Horizontal Error: 1.63 km
```