Homework 1 Solutions

Problem 1

Compute the vertical stress gradient resulting from a carbonate rock made of 70% dolomite and 30% calcite, porosity 10% and filled with brine ~1,060 kg/m3. Provide answer in psi/ft, MPa/km, and ppg.

Solving for density of carbonate rock matrix

$$\rho_{matrix} = 0.7 \times 2.87 + 0.3 \times 2.71 = 2.822 gm/cc$$

Solving for bulk mass density of carbonate rock

$$\rho_{bulk} = 0.9 \times 2.822 + 0.1 \times 1.06 = 2.646 gm/cc$$

Density of water is $\rho_{water} = 1 gm/cc = 8.33 ppg$

This corresponds to pressure gradients of $0.433 psi/ft = 9.792 MPa/km$

Computing the vertical stress gradient

$$\frac{dS_v}{dh} = \frac{2.646 gm/cc}{1 gm/cc} \times 0.433 psi/ft = 1.146 psi/ft$$

$$\frac{dS_v}{dh} = \frac{2.646 gm/cc}{1 gm/cc} \times 8.33 ppg = 22.04 ppg$$

$$\frac{dS_v}{dh} = \frac{2.646 gm/cc}{1 gm/cc} \times 9.792 MPa/km = 25.90 MPa/km$$

Problem 2

Calculate (without the help of a computer) the total vertical stress in an offshore location at 10,000 ft of total depth (from surface) for which: water depth is 1,000m, bulk mass density of rock at the seabed is 1,800 kg/m3 increasing linearly until a depth of 500 m below sea-floor to 2,350 kg/m3 and relatively constant after it. Why would rock bulk mass density increase with depth?

From 0 to 1000m, the vertical stress is

$$1000 kg/m^3 \times 9.81 m/s^2 \times 1000 m = 9.81 MPa$$

From 1000 to 1500m, the vertical stress is

$$\frac{1800 kg/m^3 + 2350 kg/m^3}{2} \times 9.81 m/s^2 \times 500 m = 10.18 MPa$$

From 1500 to 3048m (10000ft), the vertical stress is

$$2350 kg/m^3 \times 9.81 m/s^2 \times 1548 m = 36.378 MPa$$

The total vertical stress at 10000 ft is thus

$$9.81 MPa + 10.18 MPa + 36.378 MPa = 56.36 MPa = 8174 psi$$

Problem 3

The following table contains the estimated bulk mass densities as a function of depth for an offshore location in Brazil. Water depth is 500m. Measurements indicate that porosity of shale layers estimated through resistivity measurements.

a) Plot the profiles of Sv vs. depth (MPa vs. m and ft vs psi)

b) Plot the profile of hydrostatic water pressure. Assume the density of brine is 1031 kg/m3 in the rock pore space (MPa vs. m and ft vs. psi).

c) Plot hypothetical vertical effective stress vs. depth assuming hydrostatic pore pressure gradient (MPa vs. m and ft vs. psi).

d) Additional compaction lab measurements on shale cores indicate a good fitting of the porosity-effective vertical stress relation through the equation $\phi = \phi_0 exp(-\beta\sigma_v)$, with parameters $\phi_0 = 0.38$ and $\beta = 0.03MPa^{-1}$. Estimate the actual pore pressure in the shale. Is there overpressure? At what depth does it start?

Actual pore pressure starts to deviate from hydrostatic pressure trend at 1200m (3937ft) depth, but the deviation is significant from 1500m (4921ft) depth

f) Plot actual vertical effective stress vs. depth (MPa vs. m and ft vs. psi).

f) Plot actual vertical effective stress vs. depth (MPa vs. m and ft vs. psi).

In [1]:
```
import pandas as pd
excel_file = 'HW1.xlsx'
DataTable = pd.read_excel(excel_file, sheet_name=0)
DataTable.head(21)
```

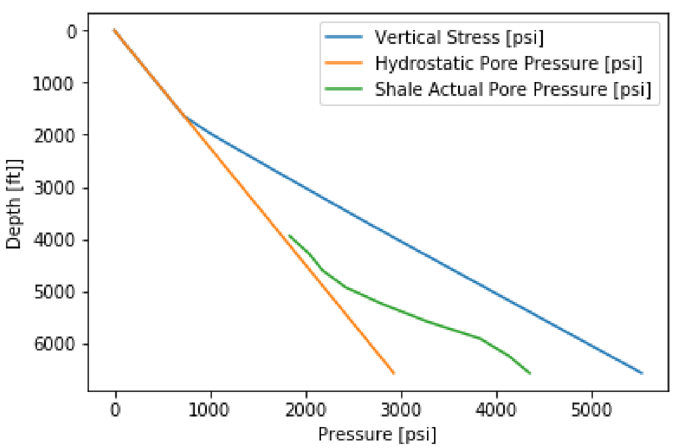
Out[1]:

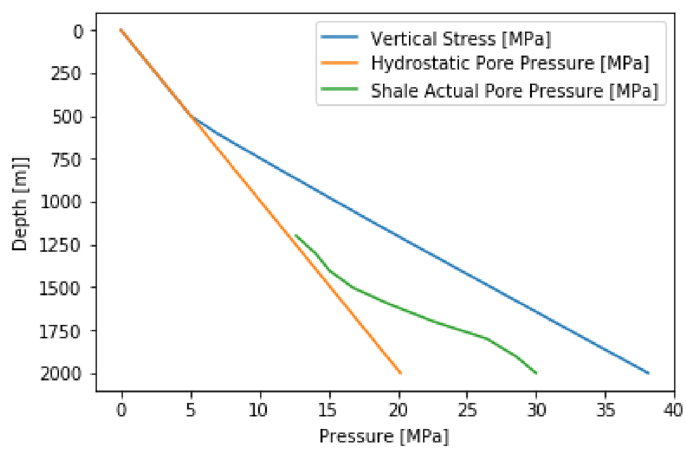
	Depth [ft]	Depth [m]	Bulk Mass Density [kg/m3]	Shale Porosity []	Vertical Stress [MPa]	Vertical Stress [psi]	Hydrostatic Pore Pressure [MPa]	Hydrostatic Pore Pressure [psi]	Predicted Effective Vertical Stress [MPa]	Predicted Effective Vertical Stress [psi]	Actual Effective Vertical Stress [MPa]	Actual Effective Vertical Stress [psi]	Shale Actual Pore Pressure [MPa]	Actu P
0	0.000000	0	1025	NaN	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	NaN	NaN	NaN	
1	328.083990	100	1026	NaN	1.004938	145.753937	1.004938	145.753937	0.000000	0.000000	NaN	NaN	NaN	
2	656.167979	200	1026	NaN	2.009877	291.507874	2.009877	291.507874	0.000000	0.000000	NaN	NaN	NaN	
3	984.251969	300	1030	NaN	3.018733	437.830052	3.026569	438.966535	-0.007836	-1.136483	NaN	NaN	NaN	
4	1312.335958	400	1030	NaN	4.027589	584.152231	4.035425	585.288714	-0.007836	-1.136483	NaN	NaN	NaN	
5	1640.419948	500	1031	NaN	5.037425	730.616470	5.049179	732.321194	-0.011754	-1.704724	NaN	NaN	NaN	
6	1968.503937	600	1900	NaN	6.898422	1000.531168	6.059015	878.785433	0.839408	121.745735	NaN	NaN	NaN	
7	2296.587927	700	2190	NaN	9.043466	1311.643373	7.068850	1025.249672	1.974616	286.393701	NaN	NaN	NaN	
8	2624.671916	800	2200	NaN	11.198305	1624.176181	8.078686	1171.713911	3.119619	452.462270	NaN	NaN	NaN	
9	2952.755906	900	2230	NaN	13.382528	1940.970801	9.088522	1318.178150	4.294006	622.792651	NaN	NaN	NaN	
10	3280.839895	1000	2235	NaN	15.571648	2258.475722	10.098358	1464.642388	5.473290	793.833333	NaN	NaN	NaN	
11	3608.923885	1100	2240	NaN	17.765666	2576.690945	11.108194	1611.106627	6.657472	965.584318	NaN	NaN	NaN	
12	3937.007874	1200	2275	0.305	19.993965	2899.878281	12.118029	1757.570866	7.875935	1142.307415	7.328649	1062.930284	12.665316	1836
13	4265.091864	1300	2305	0.297	22.251648	3227.327428	13.127865	1904.035105	9.123783	1323.292323	8.214637	1191.431918	14.037011	2035
14	4593.175853	1400	2310	0.286	24.514229	3555.486877	14.137701	2050.499344	10.376528	1504.987533	9.472648	1373.890906	15.041581	2181
15	4921.259843	1500	2308	0.281	26.774850	3883.362205	15.147537	2196.963583	11.627314	1686.398622	10.060553	1459.159243	16.714298	2424
16	5249.343832	1600	2310	0.285	29.037431	4211.521654	16.157372	2343.427822	12.880059	1868.093832	9.589402	1390.824686	19.448029	2820
17	5577.427822	1700	2305	0.293	31.295114	4538.970801	17.167208	2489.892060	14.127906	2049.078740	8.666621	1256.986676	22.628493	3281
18	5905.511811	1800	2310	0.307	33.557695	4867.130249	18.177044	2636.356299	15.380651	2230.773950	7.110784	1031.331548	26.446911	3835
19	6233.595801	1900	2324	0.305	35.833988	5197.278543	19.186880	2782.820538	16.647108	2414.458005	7.328649	1062.930284	28.505339	4134
20	6561.679790	2000	2319	0.298	38.105384	5526.716535	20.196716	2929.284777	17.908669	2597.431759	8.102592	1175.181182	30.002792	4351

In [3]:
```python
import matplotlib.pyplot as plt
import numpy as np

plt.gca().invert_yaxis()
y = DataTable['Depth [ft]']
x1 = DataTable['Vertical Stress [psi]']
x2 = DataTable['Hydrostatic Pore Pressure [psi]']
#x3 = DataTable['Predicted Effective Vertical Stress [psi]']
#x4 = DataTable['Actual Effective Vertical Stress [psi]']
x5 = DataTable['Shale Actual Pore Pressure [psi]']
plt.plot(x1,y,label='Vertical Stress [psi]')
plt.plot(x2,y,label='Hydrostatic Pore Pressure [psi]')
#plt.plot(x3,y,label='Predicted Effective Vertical Stress [psi]')
#plt.plot(x4,y,label='Actual Effective Vertical Stress [psi]')
plt.plot(x5,y,label='Shale Actual Pore Pressure [psi]')
plt.xlabel('Pressure [psi]')
plt.ylabel('Depth [ft]]')
plt.legend()
plt.show()

plt.gca().invert_yaxis()
y = DataTable['Depth [m]']
x6 = DataTable['Vertical Stress [MPa]']
x7 = DataTable['Hydrostatic Pore Pressure [MPa]']
#x8 = DataTable['Predicted Effective Vertical Stress [MPa]']
#x9 = DataTable['Actual Effective Vertical Stress [MPa]']
x10 = DataTable['Shale Actual Pore Pressure [MPa]']
plt.plot(x6,y,label='Vertical Stress [MPa]')
plt.plot(x7,y,label='Hydrostatic Pore Pressure [MPa]')
#plt.plot(x8,y,label='Predicted Effective Vertical Stress [MPa]')
#plt.plot(x9,y,label='Actual Effective Vertical Stress [MPa]')
plt.plot(x10,y,label='Shale Actual Pore Pressure [MPa]')
plt.xlabel('Pressure [MPa]')
plt.ylabel('Depth [m]]')
plt.legend()
plt.show()
```

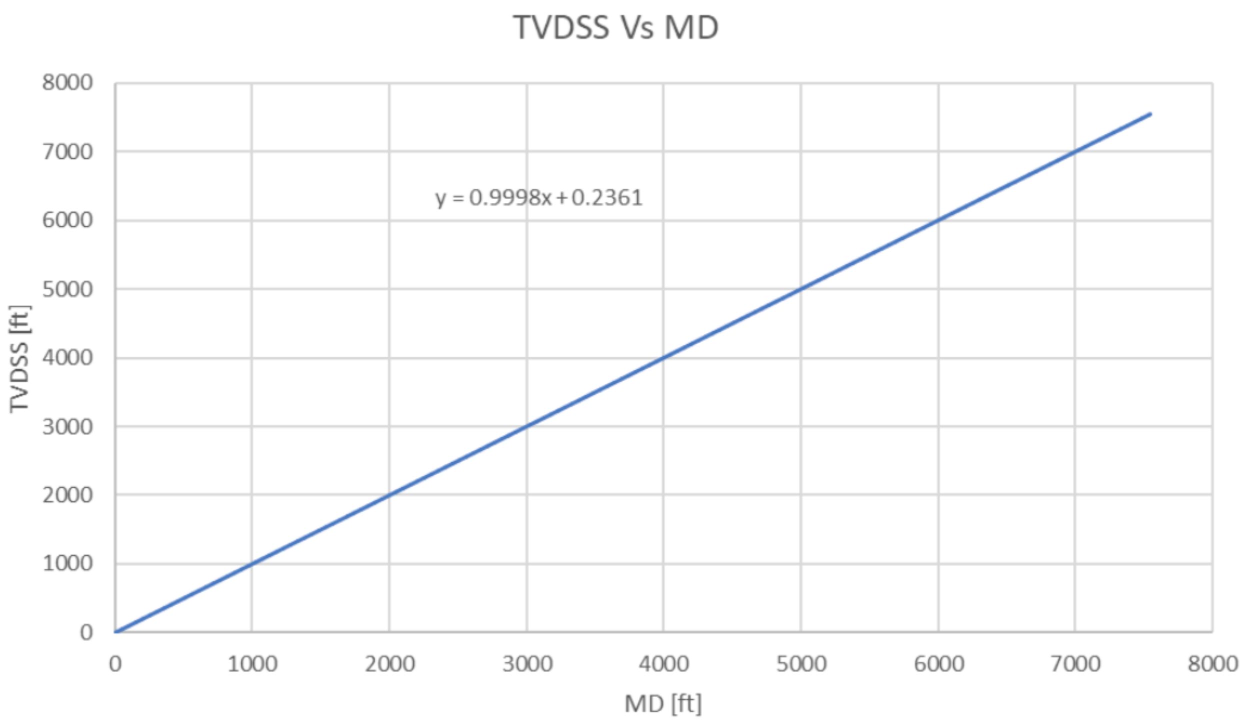




Problem 4

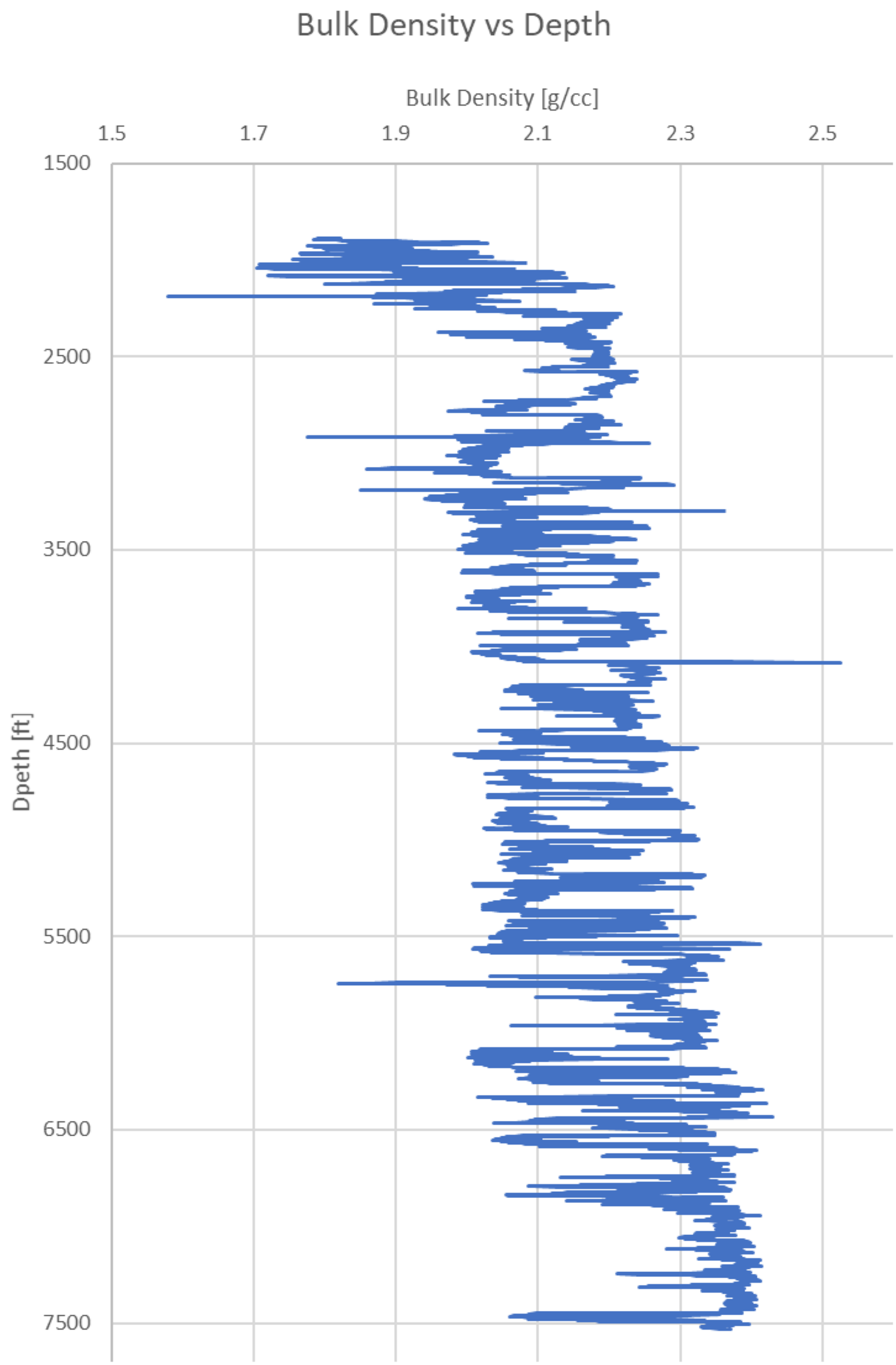
Go to https://github.com/dnicolasespinoza/GeomechanicsJupyter and download the files "HCLonghorn.las" and "HCdeviationsurvey.dev". The files include the well logging data and the well trajectory of a well for the Longhorn Field near Plaquemines Parish, Louisiana. The oilfield is an onshore oilfield. The first one is a well logging file (.las). You will find here measured depth (DEPTH [ft] - Track 1) and bulk mass density (ZDNC [g/cc] - Track 27). The second file has the deviation survey of the well. Column 3 is measured depth (MD), column 4 is TVDSS, column 5 is the E-W offset from the surface location, and column 6 is the N-S offset from the surface location. The water depth at this well location is 38 ft. You may assume an average bulk mass density of 2 g/cc between the surface and the beginning of the bulk density data.

1. **Plot TVDSS [ft] as a function of MD [ft]. For this simple trajectory you may use a linear fit to relate TVDSS and MD.**



2. **Plot bulk density (x-axis) verse TVDSS (ft) (y-axis).**

Use the correlation between TVDSS and MD from part one, to plot TVDSS versus bulk density.



3. Compute and plot the total vertical stress (psi) (x-axis) versus TVDSS (ft) (y-axis). Compute and plot also the expected hydrostatic pore pressure.