Mechanical Earth Modeling
(PETE 4241)
Homework#3

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1. The given homework data contains bulk density data, as well as sonic log data (compressional and shear velocities expressed as travel times). The formation top depths for several lithologies are given, and the appropriate correlations to use in these lithologies are provided. From the given data, calculate the following for all of the given depths:

(a) Hydrostatic pore pressure in MPa. The pore pressure can be calculated (assuming $\overline{\rho}_w$ =1000 kg/m^3) as follows:

$$p_p = \rho_w g z \tag{1.1}$$

	Depth_Barnett(km)	PorePressure(MPa)
0	1.524000	14.935200
1	1.560576	15.293645
2	1.597152	15.652090
3	1.633728	16.010534
4	1.670304	16.368979
5	1.706880	16.727424
6	1.743456	17.085869
7	1.780032	17.444314
8	1.816608	17.802758
9	1.853184	18.161203

(b) Porosity. The porosity can be based on density log as follows:

$$\phi = \frac{\rho_m - \rho_b}{\rho_m - \rho_w} \tag{1.2}$$

Assuming $\rho_w = 1000\ kg/m^3$, $\overline{\rho}_{rock} = 2700\ kg/m^3$.

	Depth_Barnett(km)	Porosity_Barnett(-)
0	1.524000	0.172882
1	1.560576	0.132412
2	1.597152	0.056882
3	1.633728	0.019765
4	1.670304	0.031824
5	1.706880	0.034588
6	1.743456	-0.031353
7	1.780032	0.139235
8	1.816608	-0.009294
9	1.853184	-0.010588

(c) Compressional and shear velocities (V_p and V_s) in m/s, which is simply inverse of transit times.

	Depth_Barnett(km)	V_p (m/s)	V_s (m/s)
0	1.524000	3944.073861	2654.090504
1	1.560576	3988.338559	1645.679040
2	1.597152	4540.491261	2797.801046
3	1.633728	5932.742784	3385.124554
4	1.670304	4865.496479	2707.475404
5	1.706880	4286.823363	2570.655062
6	1.743456	3919.173476	2431.799124
7	1.780032	3635.890823	2270.994968
8	1.816608	6315.135191	3288.891574
9	1.853184	6379.491859	3303.749886

(d) Shear modulus (G,MPa), Possion ratio and Youngs Modulus (E, GPa), which can be calculated as follows:

$$\begin{gathered} G = \rho_m V_s^2 \\ \nu = \frac{V_p^2 - 2V_s^2}{2(V_p^2 - V_s^2)} \\ E = 2G(1+\nu) \end{gathered} \tag{1.3}$$

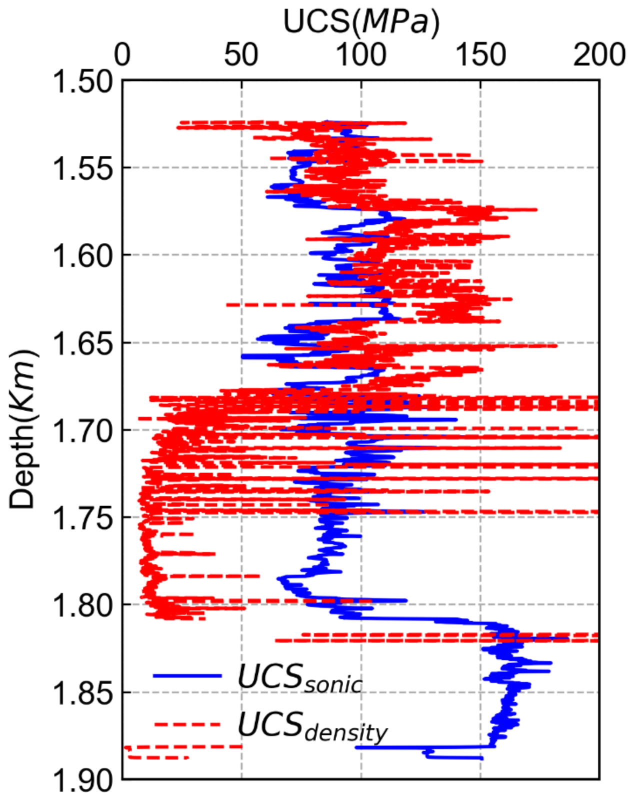
	Depth_Barnett(km)	G(MPa)	υ	E(MPa)
0	1.524000	16949.040964	0.086196	36819.975886
1	1.560576	6702.671441	0.397403	18732.671914
2	1.597152	20377.827179	0.193953	48660.326189
3	1.633728	30554.459578	0.258638	76914.023287
4	1.670304	19395.566377	0.275727	49486.894899
5	1.706880	17453.755978	0.219241	42560.678747
6	1.743456	16282.044235	0.186985	38653.091062
7	1.780032	12704.268121	0.180152	29985.923257
8	1.816608	29376.286593	0.313915	77195.874561
9	1.853184	29666.326678	0.316763	78127.030606

(e) UCS from the sonic logs (interval transit time data) and also from the bulk density log. The Equations for different formation are shown as follows:

Formation	Depth	Type	Sonic log Eqn	Density Log Eqn
Marble Falls	5000-5167	Limestone	$0.4067E^{0.51}$	$135.9e^{-4.8\phi}$
Duffer	5167-5514	Limestone	$2.4E^{0.34}$	$135.9e^{-4.8\phi}$
Barnett	5514-6195	Shale	$0.0528E^{0.712}$	$1.001\phi^{-1.143}$

	Depth_Barnett(km)	UCS_Sonic(MPa)	UCS_Density(MPa)
0	1.524000	85.640586	59.268859
1	1.560576	68.060502	71.976728
2	1.597152	94.156596	103.428859
3	1.633728	110.015309	123.599776
4	1.670304	94.697369	116.648645
5	1.706880	104.348932	46.820809
6	1.743456	97.433677	NaN
7	1.780032	81.320329	9.530783
8	1.816608	159.441333	NaN
9	1.853184	160.808300	NaN

(f) Plot the UCS (from both density and sonic logs) vs depth. Put the UCS on the x-axis and depth on the y-axis.



2. (a,b,c) What is absolute difference of two UCS models @ 5,100 , 5300 and 5800 ft?
(d) What is the value of the UCS estimated from the sonic logs for the Marble Falls Formation at a depth of 5,100, 5300, 5800 ft?

The values are shown as follows:

	Value
$\|UCS_s$-$UCS_d\|$ (MPa) @ 5100ft	15.582132
$\|UCS_s$-$UCS_d\|$ (MPa) @ 5300ft	14.490010
$\|UCS_s$-$UCS_d\|$ (MPa) @ 5800ft	74.798200
UCS_{sonic} (MPa) @ 5100ft	71.802490
UCS_{sonic} (MPa) @ 5300ft	91.063016
UCS_{sonic} (MPa) @ 5800ft	87.790432

3. Perform all calculation above on Volve field and make reasonable assumptions.

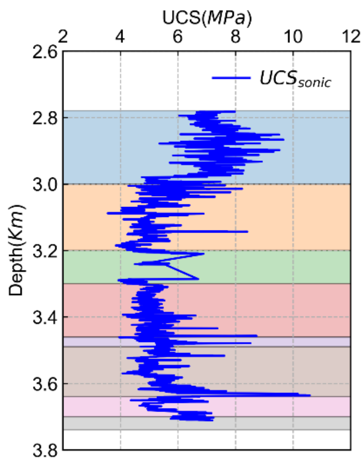
Using the Schlumberger Log Data Toolbox to convert LIS to DLIS and convert DLIS to LIS. The DTCO, DTSM and RHOB is the keywords for Compressional wave delay time, Shear wave delay time and bulk density.

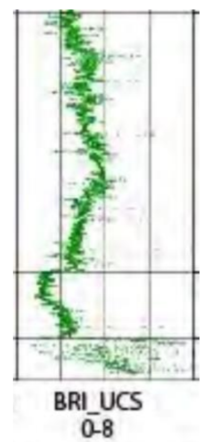
As mentioned in HW1, Volve produced oil from sandstone of Jurassic age in the Hugin Formation (Byberg, 2016). Kalani (2018) used an empirical correlation to evaluate the rock brittleness of the Egersund Basin where the oil is also produced form the same Middle Jurassic reservoir sands. The empirical correlation from sonic log is shown as follows:

$$UCS = \exp\left(-6.36 + 2.45 \log\left(0.86 V_p - 1172\right)\right) \tag{1.4}$$

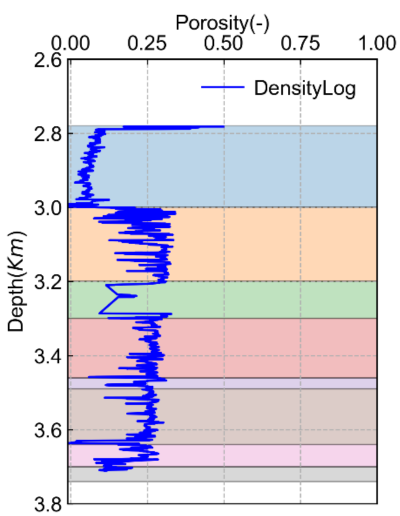
where the unit of UCS is MPa and the unit of V_p is m/s. The UCS can be calculated as follows:

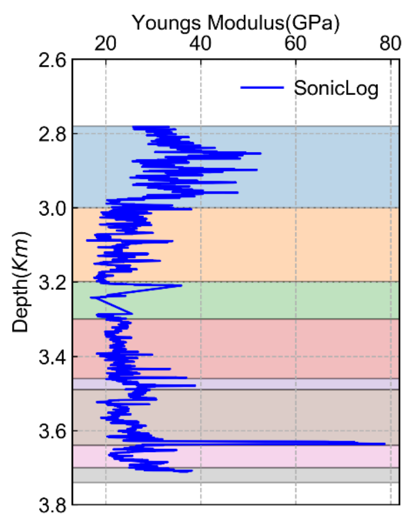
	Depth_Barnett(km)	UCS_Sonic(MPa)
0	2.782367	7.637170
1	2.866492	8.245833
2	2.950616	7.196401
3	3.042514	4.714544
4	3.126638	5.638136
5	3.235604	4.777263
6	3.365449	5.033325
7	3.449574	5.125461
8	3.533699	5.002137
9	3.617824	4.667461





As shown in figure above, calculated UCS is matched well with the reference data (Kalani, 2018). As a reference, the calculated porosity and Young's modulus are also shown as follows:





Reference

[1] Byberg, I., 2016. Reservoir Characterization of the Skagerrak Formation (Master's thesis, University of Stavanger, Norway).

[2] Kalani, M., 2018. Multiscale seal characterization in the North Sea Implications from clay sedimentology, well logs interpretation and seismic analyses.