Mechanical Earth Modeling
(PETE 4241)
Homework#1

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1. Using the given density log data for the Barnett shale well and Gulf of Mexico (GOM) offshore well, compute the following quantities for each given depth:

(i) The vertical stress can be calculated in onshore and offshore as follows:

$$S_v = \bar{\rho}_{bulk} g z_0 + \int_{z_0}^{z} \rho_{bulk}(z) g dz \quad \text{Onshore}$$

$$S_v = \rho_w g z_w + \bar{\rho}_{bulk} g (z_0 - z_w) + \int_{z_0 - z_w}^{z} \rho_{bulk}(z) g dz \quad \text{Offshore} \tag{1}$$

	Depth_Barnett(km)	Stress_Barnett(MPa)		Depth_GOM(km)	Stress_GOM(MPa)
0	0.028956	0.539161	0	0.304800	2.987040
1	0.214884	3.993620	1	1.362761	22.410683
2	0.400812	8.800325	2	1.654759	28.621874
3	0.586740	13.572935	3	1.946758	34.858354
4	0.772668	18.389257	4	2.238756	41.124196
5	0.958596	23.217325	5	2.530754	47.627678
6	1.144524	28.029166	6	2.822753	54.106854
7	1.330452	32.850742	7	3.114751	60.775627
8	1.516380	37.619146	8	3.406750	67.499105
9	1.702308	42.374368	9	3.698748	74.375632
10	1.888236	50.819649	10	3.990746	81.293008

(ii) The pore pressure can be calculated as follows:

$$S_v = \bar{\rho}_w g z \tag{2}$$

	Depth_Barnett(km)	PorePressure_Barnett(MPa)		Depth_GOM(km)	PorePressure_GOM(MPa)
0	0.028956	0.283769	0	0.304800	2.987040
1	0.214884	2.105863	1	1.362761	13.355056
2	0.400964	3.929451	2	1.655064	16.219627
3	0.587045	5.753039	3	1.947367	19.084199
4	0.773125	7.576627	4	2.239670	21.948770
5	0.959206	9.400215	5	2.531974	24.813341
6	1.145286	11.223803	6	2.824277	27.677913
7	1.331366	13.047391	7	3.116580	30.542484
8	1.517447	14.870979	8	3.408883	33.407055
9	1.703527	16.694567	9	3.701186	36.271627

(iii) The gradient is computed using second order accurate central differences in the interior points and either first or second order accurate one-sides (forward or backwards) differences at the boundaries. Here the *np.gradient* function in *numpy* library is used.

	Depth_Barnett(km)	Sv_Barnett_grad(MPa/km)		Depth_GOM(km)	Sv_GOM_grad(MPa/km)
0	0.028956	18.511219	0	0.304800	13.47500
1	0.214884	24.530625	1	1.362761	22.16270
2	0.400812	25.628470	2	1.654759	21.77560
3	0.586740	25.826430	3	1.946758	20.66820
4	0.772668	25.917080	4	2.238756	21.54285
5	0.958596	26.119695	5	2.530754	21.56000
6	1.144524	26.007485	6	2.822753	22.27050
7	1.330452	25.846275	7	3.114751	22.37830
8	1.516380	25.170565	8	3.406750	24.34810
9	1.702308	25.252150	9	3.698748	22.65760
10	1.888236	9792.650000	10	3.990746	22.55470

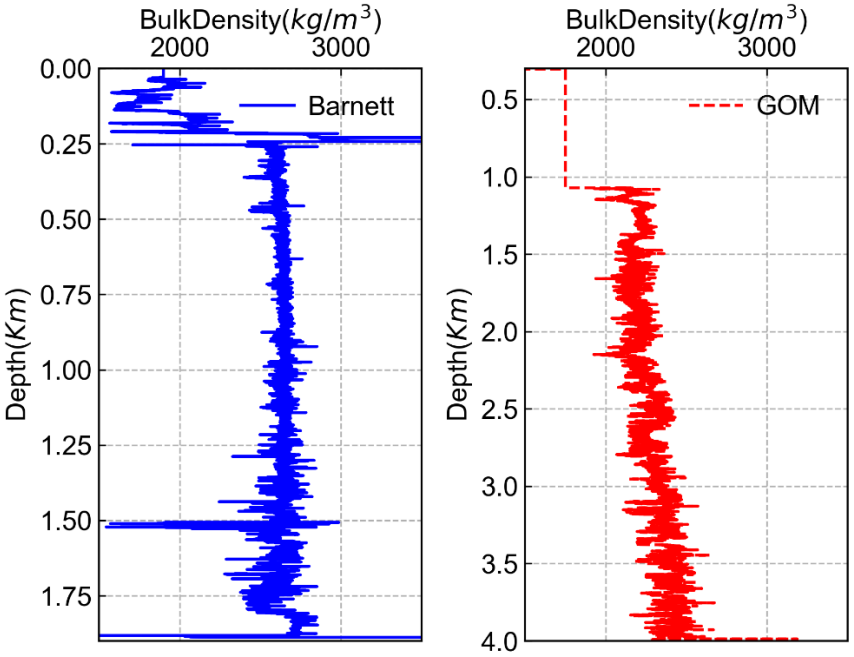
(iv) The porosity can be easily calculated from the bulk density as follows:

$$\phi = \frac{\rho_m - \rho_b}{\rho_m - \rho_f} \tag{3}$$

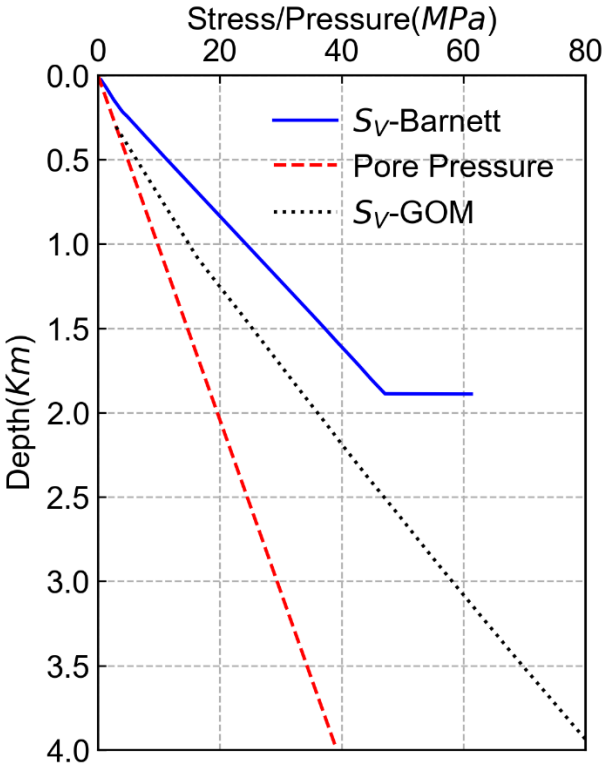
	Depth_Barnett(km)	Porosity_Barnett(-)		Depth_GOM(km)	Porosity_GOM(-)
0	0.028956	0.470588	0	0.304800	1.000000
1	0.214884	0.115647	1	1.362761	0.260000
2	0.400964	0.051765	2	1.655064	0.278824
3	0.587045	0.024353	3	1.947367	0.314118
4	0.773125	0.027000	4	2.239670	0.272941
5	0.959206	0.022706	5	2.531974	0.243529
6	1.145286	0.027000	6	2.824277	0.202353
7	1.331366	0.021529	7	3.116580	0.144118
8	1.517447	0.038824	8	3.408883	0.136471
9	1.703527	0.098765	9	3.701186	0.247647

2. Create the following plots for the Barnett and GOM wells (with the x-axis above and have depth increase downwards on the y-axis)

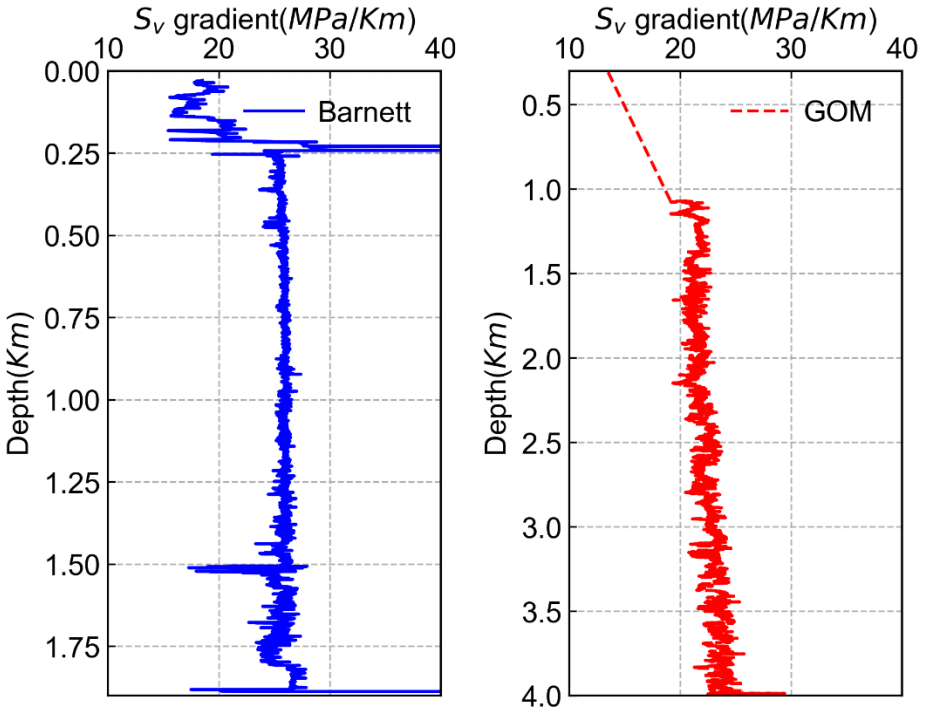
(i) depth vs density



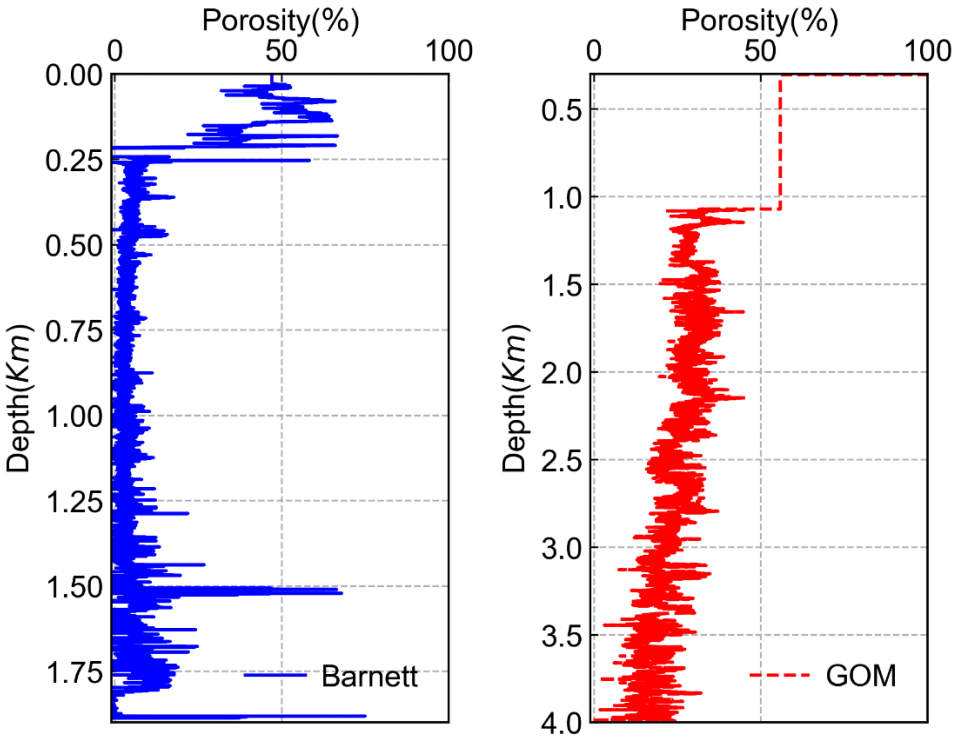
(ii) Vertical stress and hydrostatic pressure vs depth



(iii) depth versus gradient of vertical stress



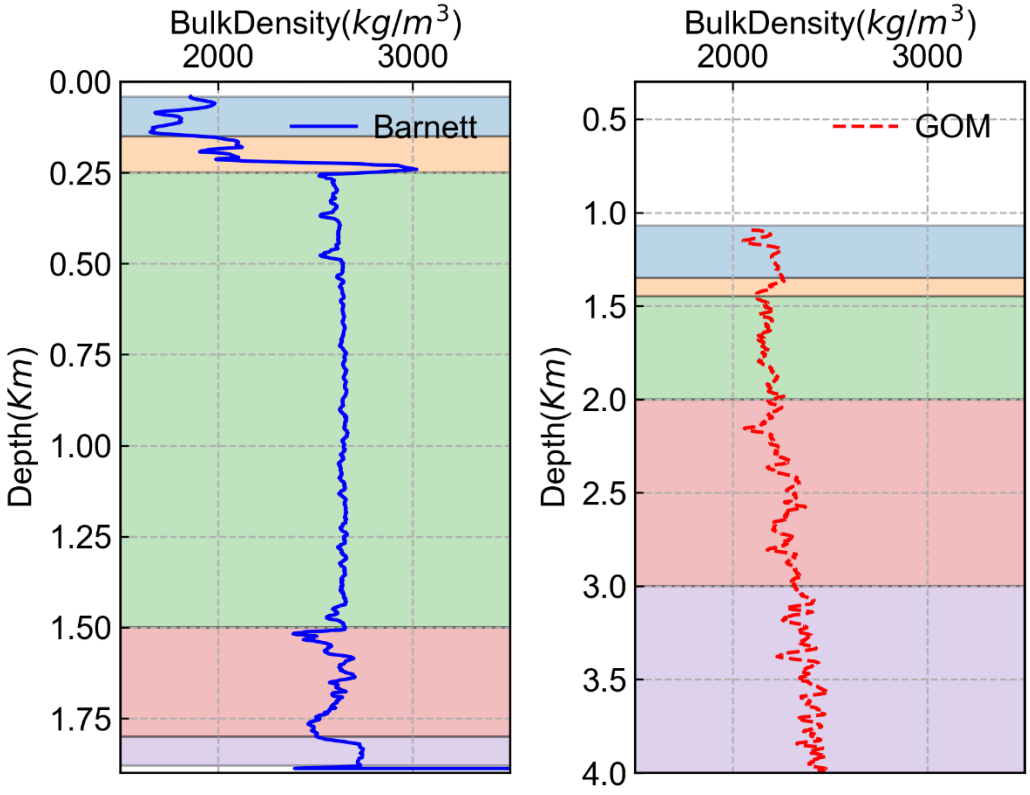
(iv) depth versus porosity



3. Post-processing the data with blocks

(i) Based on the smoothed density log by moving average in *Pandas* library, the block can be expressed as follows:

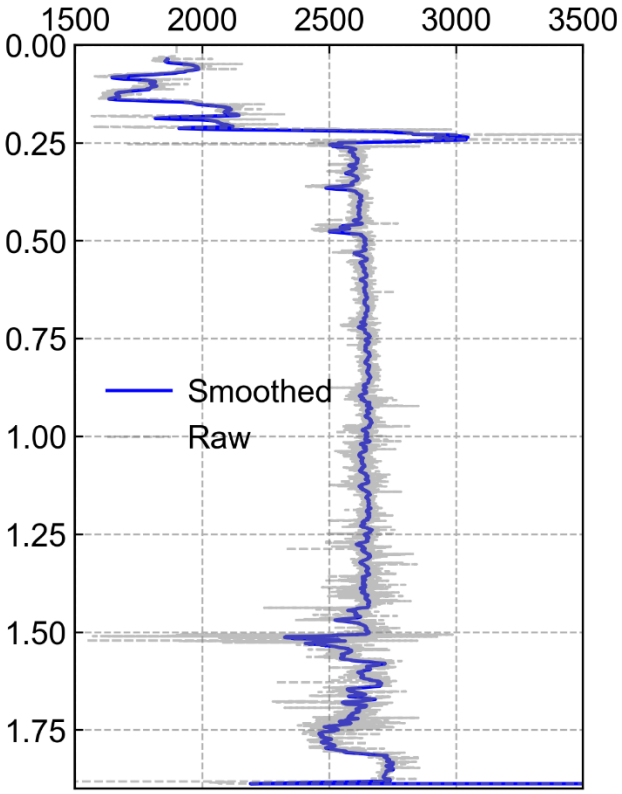
	Block_Barnett(km)	Block_GOM(km)
0	(0.041, 0.15)	(1.07, 1.35)
1	(0.15, 0.25)	(1.35, 1.45)
2	(0.25, 1.5)	(1.45, 2.0)
3	(1.5, 1.8)	(2.0, 3.0)
4	(1.8, 1.88)	(3.0, 4.0)



(ii) The average density for the blocks can be expressed as follows:

	Block_Barnett(km)	Average Density(kg/m^3)		Block_GOM(km)	Average Density(kg/m^3)
0	(0.041, 0.15)	1809.017063	0	(1.07, 1.35)	2194.688865
1	(0.15, 0.25)	2325.148933	1	(1.35, 1.45)	2175.615854
2	(0.25, 1.5)	2633.100719	2	(1.45, 2.0)	2181.517184
3	(1.5, 1.8)	2573.398680	3	(2.0, 3.0)	2256.200549
4	(1.8, 1.88)	2714.509542	4	(3.0, 4.0)	2385.530387

(iii) As shown in 3 (i), I used moving average algorithm in Pandas library to find the 'True' trend line for density log which allows us to easily interoperate and analyze the log by removing the spikes and noise in the data:



4. The estimated quantities are shown as follows:

	Value
S_v **(MPa) @ 5000ft Barnett**	37.807537
p_p **(MPa) @ 5000ft Barnett**	14.935200
S_v **(MPa) @ 5000ft GOM**	25.839252
p_p **(MPa) @ 5000ft GOM**	14.935200
$grad(S_v)$ **(MPa/km) @ 5000ft Barnett**	22.852620
$grad(S_v)$ **(MPa/km) @ 5000ft GOM**	21.285600
$Porosity$ **@ 2500ft Barnett**	0.029235
$Porosity$ **@ 10000ft GOM**	0.197647
$\rho_b\ (g/cc)$ **@ 5000ft Barnett**	2.406100
$\rho_b\ (g/cc)$ **@ 5000ft GOM**	2.164000

5. Perform all calculation in Q1,2,3 on Volve field and make reasonable assumptions.

Volve is a field in the central part of the North Sea, 5 km north of the Sleipner Øst field. Volve produced oil from sandstone of Jurassic age in the Hugin Formation (Byberg, 2016). For the well 15_9-F-14, the DLIS file is converted to LAS using LAS Viewer (toftkaer.net).

The density log data is available from 2777-3738 m. Assuming water density is 1.02 g/cc, matrix density is 2.6878 g/cc. The sediments above the 2777 m with an average bulk density of 1.75 g/cc

5.1 Thus, the results for Q1 are shown as follows:

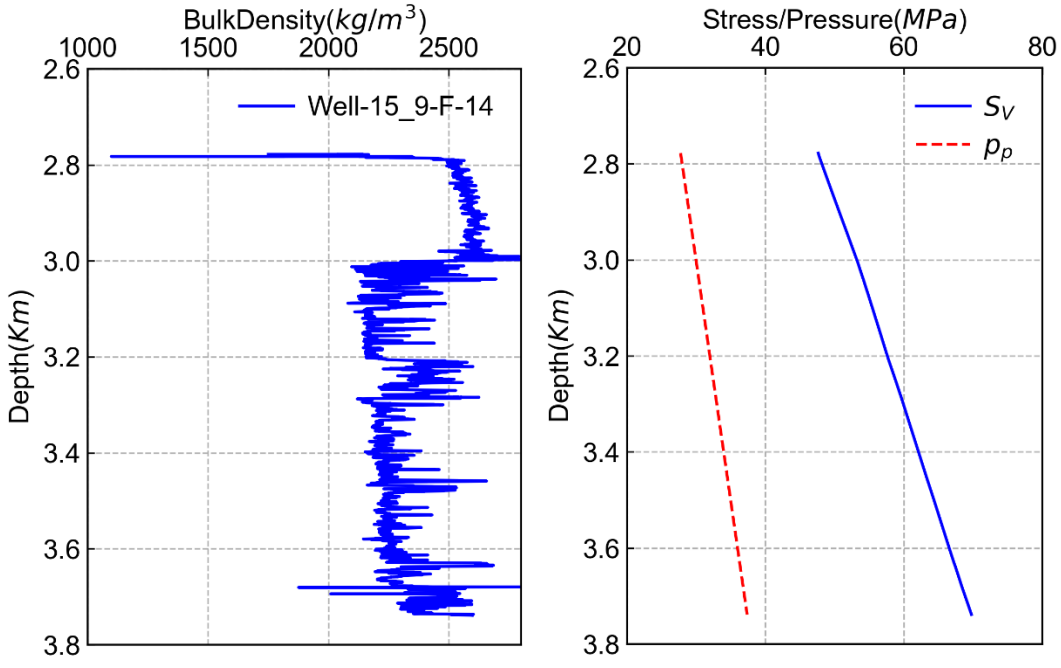
	Depth(km)	Vertical Stress(MPa)
0	2.777947	47.641794
1	2.873959	50.005211
2	2.970124	52.453629
3	3.066288	54.710798
4	3.162452	56.802317
5	3.258617	58.978301
6	3.354781	61.114823
7	3.450946	63.226384
8	3.547110	65.376154
9	3.643274	67.538006

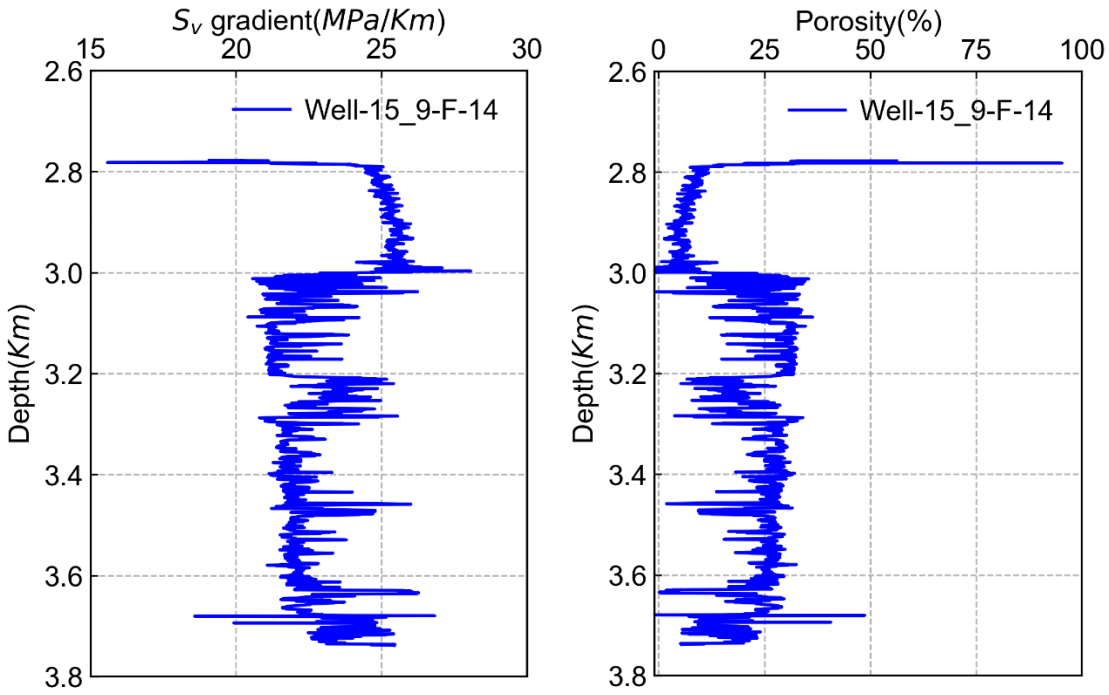
	Depth(km)	PorePressure(MPa)
0	2.777947	27.768360
1	2.873959	28.728096
2	2.970124	29.689356
3	3.066288	30.650615
4	3.162452	31.611874
5	3.258617	32.573134
6	3.354781	33.534393
7	3.450946	34.495652
8	3.547110	35.456912
9	3.643274	36.418171

	Depth(km)	Sv_grad(MPa/km)
0	2.777947	19.082563
1	2.873959	25.311685
2	2.970124	25.407235
3	3.066288	23.928905
4	3.162452	21.279475
5	3.258617	21.972825
6	3.354781	21.613900
7	3.450946	21.948815
8	3.547110	21.883645
9	3.643274	22.350370

	Depth(km)	Porosity(-)
0	2.777947	0.562298
1	2.873959	0.063197
2	2.970124	0.056781
3	3.066288	0.145821
4	3.162452	0.308850
5	3.258617	0.266459
6	3.354781	0.289363
7	3.450946	0.268977
8	3.547110	0.271495
9	3.643274	0.243255

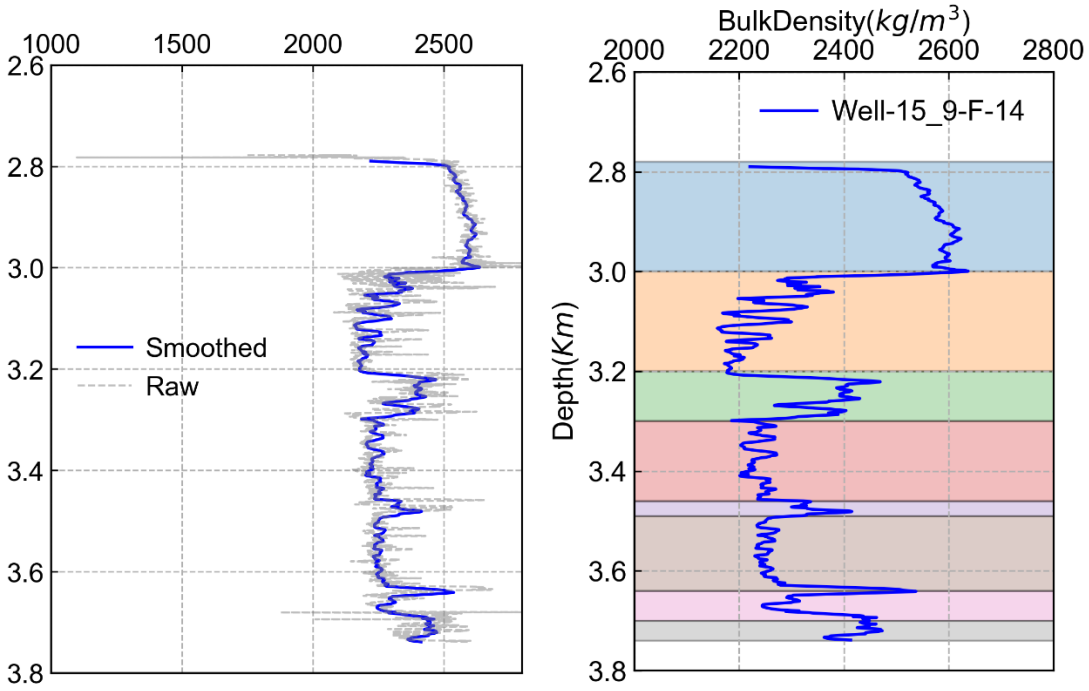
5.2 The plot for Q2 are shown as follows:





5.3 The block and average density for Q3 are shown as follows:

	Block_Barnett(km)	Average Density(kg/m^3)
0	(2.78, 3.0)	2565.705194
1	(3.0, 3.2)	2240.725991
2	(3.2, 3.3)	2355.387043
3	(3.3, 3.46)	2244.391524
4	(3.46, 3.49)	2317.567005
5	(3.49, 3.64)	2276.087805
6	(3.64, 3.7)	2339.470558
7	(3.7, 3.74)	2426.927953



Reference

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