Mechanical Earth Modeling
(PETE 4241)
Homework#2

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01/23, 2019

1. Estimate porosity assuming an exponential reduction in porosity as the effective stress increases (exponential compaction trend). Use the Athy's equation where the initial porosity, ϕ_0 is given as 0.386 and the coefficient of compaction is 0.0313 MPa^{-1}

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

$$\phi = \phi_0 \exp(-\beta \sigma_v') \tag{1}$$

The effective vertical stress can be calculated as follows:

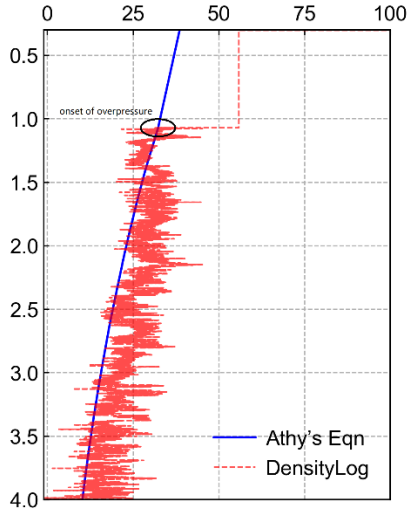
$$\sigma_v' = \sigma_v - p_p \tag{2}$$

	Depth_GOM(km)	Effective Vertical Stress (MPa)
0	0.000000	0.000000
1	1.362761	9.059376
2	1.655369	12.416045
3	1.947977	15.797511
4	2.240585	19.210016
5	2.533193	22.859070
6	2.825801	26.487320
7	3.118409	30.305806
8	3.411017	34.177761
9	3.703625	38.194008

	Depth_GOM(km)	Porosity
0	0.000000	0.386000
1	1.362761	0.290696
2	1.655369	0.261704
3	1.947977	0.235421
4	2.240585	0.211572
5	2.533193	0.188736
6	2.825801	0.168474
7	3.118409	0.149495
8	3.411017	0.132433
9	3.703625	0.116789

Plot this theoretical compaction trend on the same plot as the porosity computed in Problem 2 (iv) of homework 1.

(ii) The figure is shown as follows:



By comparing the theoretical and calculated porosities, estimate the depth at which the onset of overpressure causes a deviation from the theoretical compaction trend.

(iii) As shown in figure above, the onset of pressure can be clearly founded at a depth of 1.2 km.

2. Rearrange the Athy's equation to obtain pore pressure as a function of porosity and total vertical stress. Show all steps.

(i) The Athy's equation can be expressed as follows:

$$\phi = \phi_0 e^{-\beta(\sigma_v - p_p)} \tag{3}$$

Rearrange the above equation arrives:

$$-\frac{1}{\beta}\ln(\frac{\phi}{\phi_0}) = \sigma_v - p_p$$
$$p_p = \sigma_v + \frac{1}{\beta}\ln(\frac{\phi}{\phi_0}) \tag{4}$$

Calculate pore pressure using the porosity calculated from the density log in Problem 2(iv) of homework 1.

(ii) Using Eq. 4, the calculated pore pressure is shown as follows:

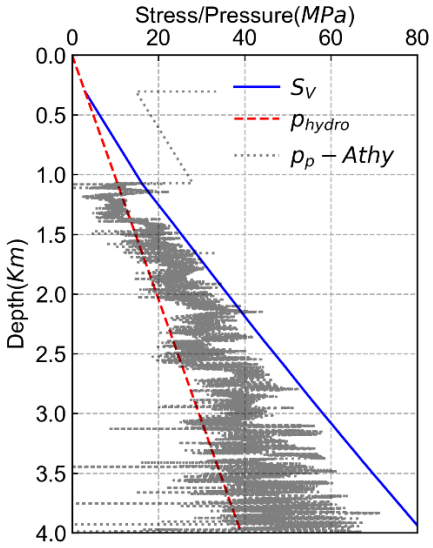
	Depth_GOM(km)	Porosity_GOM(-)		Depth_GOM(km)	Pore Pressure
0	0.000000	1.000000	0	0.000000	33.399753
1	1.362761	0.260000	1	1.362761	10.223413
2	1.655369	0.291765	2	1.655369	22.474032
3	1.947977	0.316471	3	1.947977	28.545397
4	2.240585	0.276471	4	2.240585	31.313817
5	2.533193	0.302353	5	2.533193	33.884590
6	2.825801	0.210588	6	2.825801	35.530366
7	3.118409	0.158235	7	3.118409	31.044725
8	3.411017	0.154118	8	3.411017	36.132438
9	3.703625	0.224118	9	3.703625	54.044376

Plot this calculated pore pressure together with the hydrostatic pressure and total vertical stress (versus depth).

(iii) The plot is shown as follows:

Use the plot from iii above to estimate the magnitude of the overpressure (in MPa) at 10,000 ft (3048 m) in the GOM data set

(iv) The magnitude of the over pressure is 11.82 MPa



3. Can you estimate the pore pressure versus depth for your assigned well in the Volve field. It is okay to use the internet to find representative parameters or make reasonable assumptions for unavailable data. It is okay for you all to collaborate on any homework involving the Volve field, since you all work on different wells.

(i) 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). The paramters for Athy's equation can be found on the same Hugin formation, where surface porosity is 0.37 and compaction parameter is 0.0266 MPa^{-1} (Karstens, 2015)

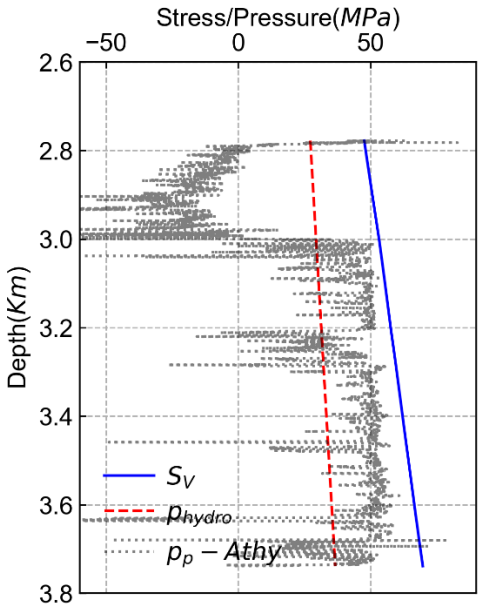
Porosity Φ	37%	Arts et al., 2008
Compaction parameter k	0.0266 MPa^{-1}	Hantschel and Kauerauf, 2009

	Depth_Volve(km)	Porosity_Volve(-)
0	0.000000	0.555635
1	2.873807	0.056464
2	2.969971	0.059900
3	3.066136	0.151025
4	3.162300	0.306434
5	3.258464	0.259154
6	3.354629	0.289134
7	3.450793	0.261879
8	3.546958	0.275447
9	3.643122	0.234921

	Depth_Volve(km)	Pore Pressure
0	0.000000	62.927802
1	2.873807	-16.880739
2	2.969971	-18.456706
3	3.066136	19.257988
4	3.162300	49.562924
5	3.258464	46.188682
6	3.354629	51.425321
7	3.450793	50.790396
8	3.546958	53.290500
9	3.643122	51.323159

Plot this calculated pore pressure together with the hydrostatic pressure and total vertical stress (versus depth).

(ii) The plot is shown as follows:



Reference

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

[2] Karstens, J., 2015. Focused fluid conduits in the Southern Viking Graben and their implications for the Sleipner CO2 storage project (Doctoral dissertation, Christian-Albrechts-Universität).