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PRESIDENCY UNIVERSITY BENGALURU

SCHOOL OF ENGINEERING

MAKE-UP EXAMINATION - JULY 2024

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| **Semester :** V | **Date :** 9-July-2024 |
| **Course Code :** PET3001 | **Time :** 01:30 PM to 04:30 PM |
| **Course Name :** Geomechanics forWellbore Stability Analysis | **Max Marks :** 100 |
| **Program :** B.Tech. (Petroleum Engineering) | **Weightage :** 50% |

**Instructions:**

1. *Read all questions carefully and answer accordingly.*
2. *Question paper consists of 3 parts.*
3. *Scientific and non-programmable calculator are permitted.*
4. *Do not write any information on the question paper other than Roll Number.*

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| **PART A** | | | |
| **ANSWER ANY 5 QUESTIONS 5Q X 2M=10M** | | | |
| 1 | Define “Borehole Breakout”. | (CO 1) | [Knowledge] |
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| 2 | Recall any two chief physical factors that control the type of deformation of rocks at depth. | (CO 1) | [Knowledge] |
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| 3 | Fill in the blanks with the appropriate answer: During drilling, if (a) \_\_\_\_\_ is found to be increasing or (b) \_\_\_\_\_ is found to be decreasing, then that indicates the presence of an overpressure zone beneath the surface. | (CO 2) | [Knowledge] |
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| 4 | List at least two causes of pore pressure formation. | (CO 2) | [Knowledge] |
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| 5 | Select the correct answer: As we begin to axially compress a cylindrical sample of rock, small cracks inside the rock begin to close and the stress-strain relation is \_\_\_\_\_.  (A) Linear and irreversible  (B) Linear and reversible  (C) Non-linear and irreversible  (D) Non-linear and reversible | (CO 3) | [Knowledge] |
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| 6 | Select the correct answer: Assuming a coefficient of sliding friction of 0.6, an overburden stress of 11000 psi, a minimum horizontal stress of 8000 psi, which of the following stress states is possible?  (A) Reverse faulting only  (B) Normal faulting only  (C) Strike-slip faulting only  (D) Normal and/or strike-slip faulting  (E) Any faulting regime is possible | (CO 4) | [Knowledge] |
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| 7 | Fill in the blank with an appropriate word: Correctly interpreted Instantaneous Shut In Pressure (ISIP) is a reasonable estimate of the \_\_\_\_\_ principal stress magnitude. | (CO 5) | [Knowledge] |
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| **PART B** | | | |
| **ANSWER ANY 5 QUESTIONS 5Q X 10M=50M** | | | |
| 8 | Field photos of different geological faults are displayed in Figures A through C. Identify the faults and classify all with the block diagrams as per E. M. Anderson’s Stress Classification Scheme. | (CO 1) | [Comprehension] |
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| 9 | Figure XY display the variation of pore pressure with depth from observations in the Monte Cristo field along the Texas Gulf coast (after Engelder and Leftwich 1997). The way in which pore pressure varies with depth in this field is similar to what is seen throughout the Gulf of Mexico oil and gas province and many active sedimentary basins where overpressure is encountered at depth. Summarise the information that can be extracted from Figure XY. | (CO 2) | [Comprehension] |
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| 10 | The observation that a given reservoir can sometimes be compartmentalized and hydraulically isolated from surrounding formations has received a lot of attention over the past decades. The economic reason for this interest is obvious as production from distinct compartments has a major impact on the drilling program required to achieve reservoir drainage. Ortoleva (1994) presents a compilation of papers related to the subject of reservoir compartmentalization. The easiest way to think about separate reservoir compartments is in the context of a series of permeable sands separated by impermeable shales (Figure AB) assuming, for the moment, that the lateral extent of each sand is limited. The case shown in the Figure is from a well in Egypt (Nashaat 1998). Illustrate the importance of the Figure being a reservoir geomechanical engineer from the oil and gas industry. | (CO 2) | [Comprehension] |
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| 11 | The pressure in a liquid at a given depth is called the hydrostatic pressure and pore pressure is the pressure of the fluid in the pore space of the rock. When pore pressure exceeds the hydrostatic pressure, an overpressure situation occurs. Explain the significance of Figure 01 in line with the above statement.  C:\Users\Admin\OneDrive - presidencyuniversity.in\Desktop\Figure 11.jpg  **Figure 01** | (CO 3) | [Comprehension] |
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| 12 | In vertical wells, the occurrence of tensile fractures in a wall usually implies that (i) Shmin is the minimum principal stress, and (ii) there are large differences between the two horizontal principal stresses, SHmax and Shmin. The occurrence of tensile fractures is also influenced by high mud weight and cooling of the wellbore wall. The processes that control the initiation of tensile wall fractures are important for understanding the initiation of hydraulic fractures. However, hydrofracs are distinguished from tensile wall fractures in that they propagate from the wellbore into the far field, away from the wellbore stress concentration. The importance of drilling-induced tensile fractures as a means of obtaining important information about stress orientation and magnitude as well as how hydraulic fractures yield extremely important information about the magnitude of the least principal stress. The stress concentration around a vertical well drilled parallel to the vertical principal stress, Sv, in an isotropic, elastic medium is described by the Kirsch equations. Explain the causes for the bending of stress trajectories due to the creation of a cylindrical opening (like a wellbore) with the help of Figure A.  C:\Users\Admin\OneDrive - presidencyuniversity.in\Desktop\Figure A.jpg  **Figure A** | (CO 4) | [Comprehension] |
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| 13 | Figure AA summarises the data derived from uncomputed dipmeter logs that shows the azimuth of the well, deviation of the well from vertical, the azimuth of a reference arm as determined from a magnetometer in the tool (pad 1 azimuth) and the diameters of the well as determined from the 1–3 and 2–4 caliper pairs. Explain the difference between breakout, washout, and keyseat as shown in Figure AA. Illustrate the reasons for the occurrence of breakout, washout, and keyseat.  C:\Users\Admin\OneDrive - presidencyuniversity.in\Desktop\Figure AA.jpg  **Figure AA** | (CO 4) | [Comprehension] |
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| 14 | Natural fracture data interpreted from an FMI image log in a vertical well from the Barnett Shale has been presented in Table 1. This image log has been processed using the software GMI Imager, in which fractures were picked as abrupt contrasts in the electrical resistivity image of the borehole wall. Analyze the data presented in Table 1 and answer the following:  (a) Which of the following strike intervals contains the highest number of fractures?  (i) 0° to 90°  (ii) 90° to 180°  (iii) 180° to 270°  (iv) 270° to 360°  (b) Which of the following dip direction intervals contains the highest number of fractures?  (i) 0° to 90°  (ii) 90° to 180°  (iii) 180° to 270°  (iv) 270° to 360°  (c) Which of the following aperture intervals contains the highest number of gently dipping fractures of which the dip is less than 45°?  (i) 0 mm to 4 mm  (ii) 4 mm to 8 mm  (iii) Greater than 8 mm  (d) Which of the following aperture intervals contains the highest number of nearly north-south striking fractures of which the strike is either between 0° and 15°, or between 75° and 105°, or between 345° and 360°?  (i) 0 mm to 4 mm  (ii) 4 mm to 8 mm  (iii) Greater than 8 mm    **Table 1:**   |  |  |  |  |  | | --- | --- | --- | --- | --- | | **Depth (ft)** | **Strike (degree)** | **Dip (degree)** | **Dip Direction (degree)** | **Aperture (millimeter)** | | 5200.82 | 228.25 | 76.41 | 318.25 | 4.31 | | 5200.97 | 207.80 | 86.11 | 297.80 | 5.87 | | 5205.07 | 233.97 | 84.07 | 323.97 | 7.22 | | 5208.82 | 206.68 | 82.67 | 296.68 | 5.52 | | 5221.97 | 214.65 | 77.20 | 304.65 | 5.44 | | 5232.42 | 211.99 | 79.37 | 301.99 | 9.95 | | 5248.54 | 214.61 | 79.88 | 304.61 | 12.24 | | 5252.68 | 226.41 | 84.78 | 316.41 | 10.21 | | 5269.20 | 245.50 | 80.63 | 335.50 | 8.22 | | 5280.63 | 238.08 | 81.70 | 328.08 | 2.67 | | 5290.00 | 226.76 | 83.85 | 316.76 | 5.28 | | 5298.56 | 212.76 | 82.34 | 302.76 | 2.28 | | 5422.93 | 220.49 | 75.45 | 310.49 | 2.21 | | 5480.59 | 235.58 | 78.23 | 325.58 | 2.79 | | 5486.79 | 203.03 | 80.78 | 293.03 | 1.92 | | 5541.47 | 228.51 | 78.70 | 318.51 | 0.25 | | 5629.33 | 190.00 | 82.13 | 280.00 | 0.79 | | 5654.14 | 162.75 | 18.04 | 252.75 | 9.69 | | 5691.06 | 7.48 | 15.89 | 97.48 | 9.44 | | 5715.48 | 162.80 | 7.92 | 252.80 | 2.69 | | 5857.44 | 224.46 | 85.04 | 314.46 | 1.15 | | 5878.72 | 219.11 | 86.63 | 309.11 | 3.08 | | 6000.14 | 5.74 | 11.19 | 95.74 | 11.29 | | 6020.27 | 0.37 | 40.44 | 90.37 | 11.04 | | 6114.42 | 201.54 | 56.87 | 291.54 | 5.53 | | 6142.56 | 208.40 | 59.07 | 298.40 | 4.22 | | 6154.56 | 200.38 | 56.88 | 290.38 | 0.25 | | 6164.20 | 351.60 | 5.34 | 81.60 | 16.72 | | (CO 5) | [Comprehension] |
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| **PART C** | | | |
| **ANSWER ANY 2 QUESTIONS 2Q X 20M=40M** | | | |
| 14 | Understanding of reservoir stress state has multifaceted applications in hydrocarbon exploration and development. Reservoir geomechanical characterization is crucial in achieving stable wellbore, optimum drilling, ideal horizontal well trajectories, perforation direction, stimulation, and completion schemes, which greatly impacts the reservoir production. This is also critical for the later stages of field development where the primary challenges are faced due to the reservoir depletion and necessary repressurization by water injection to maintain production targets as well as caprock integrity. The Density Log data presented in Table A is recorded in an onshore well located in Assam-Arakan Basin. Determine (a) Vertical Stress, (b) Vertical Stress Gradient, and (c) Porosity based on the available log data.  It is mandatory to write all equations which are applicable. Do not write the answers directly as it is mandatory to write the important steps used for computation. Use the following units in your calculation: ‘ft’ for depth, ‘g/cc’ for density, ‘psi’ for overburden stress, and ‘psi/ft’ for overburden stress gradient and pore pressure gradient. Use 9.8 m/s2 to approximate g, the acceleration due to gravity. Use the formula ρb = (1 - Ø) ρmatrix + Ø ρfluid to compute porosity assuming full saturation of 1.0 g/cm3 water in the pores. Here Ø is the porosity. For ρmatrix, assume 2.7 g/cm3, which is a reasonable value for a mixture of quartz, feldspar, mica and clay.  **Table A:**   |  |  | | --- | --- | | **Depth (ft)** | **Density (g/cc)** | | 3891.50 | 2.6594 | | 3892.00 | 2.6426 | | (CO 1) | [Application] |
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| 15 | Unconfined Compressive Strength (UCS) is one of the most important mechanical properties of rocks widely used in different engineering-related projects to evaluate the stability of structures against loads. Information related to UCS also plays an important role in the oil and gas industry. Rock samples can be tested in the laboratory to find out UCS directly. To get the UCS at the in-situ condition, well log data is used in the oil and gas industry. Refer to the well log data shared in Table 1 and answer the following:  (a) Name the geophysical log data required for the calculation of UCS,  (b) Estimate the UCS of the formation encountered at 4256.50 ft using sonic travel time (Δt) data directly, and  (c) Predict the UCS of the formation encountered at 4259.50 ft using density-porosity data directly, if possible.  Table 2.1 through Table 2.3 may be referred to for finding out the most suitable equation to calculate USC.  **Table 1:**   |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | | **Depth (ft)** | **Density (g/cc)** | **Δt\_comp. (μs/ft)** | **Δt\_shear (μs/ft)** | **Formation Name** | **Formation Type** | | 4250.00 | 2.6363 | 70.3154 | 126.5105 | P | Sandstone | | 4250.50 | 2.6322 | 68.2713 | 125.3421 | | 4251.00 | 2.5969 | 73.9180 | 134.3668 | | 4251.50 | 2.7472 | 72.9881 | 134.6025 | | 4252.00 | 2.6879 | 70.6541 | 131.0170 | | 4252.50 | 2.6090 | 64.2715 | 118.7308 | | 4253.00 | 2.7408 | 57.9452 | 112.7404 | | 4253.50 | 2.5913 | 54.2315 | 106.4179 | | 4254.00 | 2.7339 | 49.3006 | 101.1393 | | 4254.50 | 2.7363 | 48.6093 | 98.2395 | | 4255.00 | 2.7862 | 46.7769 | 98.5376 | | 4255.50 | 2.7409 | 47.6919 | 95.0032 | | 4256.00 | 2.7210 | 47.0965 | 92.3078 | | 4256.50 | 2.7204 | 47.2167 | 95.9393 | | 4257.00 | 2.7264 | 46.8250 | 96.0021 | | 4257.50 | 2.7395 | 48.9384 | 93.4016 | Q | Limestone | | 4258.00 | 2.7233 | 47.4132 | 94.2504 | | 4258.50 | 2.7221 | 48.2833 | 94.1394 | | 4259.00 | 2.7153 | 47.7699 | 95.3368 | | 4259.50 | 2.7152 | 48.2850 | 95.4636 | | 4260.00 | 2.7017 | 47.7034 | 95.4235 | | ***Additional Information:***  *- Assume full saturation of 1.10 g/cc water in the pores.*  *- Use matrix density of 2.85 g/cc, which is a reasonable value for a matrix of quartz, feldspar, mica and clay.*  *- Assume hydrostatic pore pressure of 0.44 psi/ft*  *- Use 9.8 m/s2 to approximate g, the acceleration due to gravity.* | | | | | |   **Table 2.1: Equations for estimating UCS of Sandstone.**  C:\Users\Admin\OneDrive - presidencyuniversity.in\Desktop\Table 1.jpg  **Table 2.2: Equations for estimating UCS of Shale.**  C:\Users\Admin\OneDrive - presidencyuniversity.in\Desktop\Table 2.jpg  **Table 2.3: Equations for estimating UCS of Carbonate.**  C:\Users\Admin\OneDrive - presidencyuniversity.in\Desktop\Table 3.jpg | (CO 3) | [Application] |
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| 16 | The energy demand is continually increasing and with the decline of conventional reservoirs, the importance of understanding unconventional reservoirs is even greater. Within the last decade, the exploration and production of shale reservoirs has increased significantly, due to coupled horizontal drilling and hydraulic fracturing applications, along with other advancements in completion technologies. Estimation of the lower bound of the minimum horizontal stress, the upper bound of the maximum horizontal stress, and the range of possible magnitudes of the maximum horizontal stress given a magnitude of the minimum horizontal stress. Answer the following based on knowledge of the vertical stress, the pore pressure, and the coefficient of sliding friction.  (a) Assuming a coefficient of sliding friction of 0.6, an overburden stress of 42.52 psi, and a pore pressure of 18.96 psi at 5500 ft depth, (i) identify the faulting regime with explanation, and (ii) compute the upper bound of the maximum horizontal stress.  (b) Assuming a coefficient of sliding friction of 0.6, an overburden stress of 42.52 psi, and a pore pressure of 18.96 psi at 5500 ft depth, (i) identify the faulting regime with explanation, and (ii) identify the faulting regime and determine the lower bound of the maximum horizontal stress. | (CO 4) | [Application] |
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