

**Characterizing the geomechanical properties beneath the seafloor in the  
Terrebonne Basin, Gulf of Mexico outer continental shelf**

A thesis submitted by

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## **I. Abstract**

This study characterizes the compressive behavior of sediment near the seafloor in the Terrebonne Basin, Gulf of Mexico, based on cores collected during the UT-GOM2-2 Expedition (Walker Ridge 313, Site H). The sampled section of the sediment consists of mud and carbonate ooze extending to a depth of 832 mbsf. The primary focus is on the upper 150 mbsf, a zone often overlooked during offshore drilling. Index testing included measurements of moisture content, bulk and grain density, Atterberg limits, and particle size distribution. The sediment is classed as a high plasticity silty clay. Samples from both lithologies were tested to assess compression and permeability with depth. Constant rate of strain tests were used to define primary compression and permeability behavior, while incremental oedometer tests were performed to evaluate secondary compression rates. Porosity measurements were compared to logging-while-drilling data, with significant offsets in the porosity profile with depth attributed to lithological differences. The ooze layers are found to be much more compressible than the mud layers. A unique aspect of this study is the comparison between intact and resedimented specimens during constant rate of strain testing.

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### III. Contents

|                                                        |    |
|--------------------------------------------------------|----|
| Chapter 1 - Introduction.....                          | 24 |
| 1.1    Problem Statement .....                         | 24 |
| 1.2    Scope and Objectives .....                      | 25 |
| 1.3    Organization .....                              | 25 |
| Chapter 2 - Background .....                           | 27 |
| 2.1    Introduction .....                              | 27 |
| 2.2    Drilling Expedition.....                        | 28 |
| 2.3    Calcareous Sediments .....                      | 28 |
| 2.4    Logging Data.....                               | 29 |
| 2.5    Resedimented Gulf of Mexico, Eugene Island..... | 30 |
| Chapter 3 - Materials and Specimen Preparation .....   | 35 |
| 3.1    Introduction .....                              | 35 |
| 3.2    Drilling Equipment.....                         | 35 |
| 3.3    Material Processing on ship .....               | 36 |
| 3.4    Material Processing Salt Lake City .....        | 37 |
| 3.4.1    Cylindrical Plugs.....                        | 37 |
| 3.4.2    Whole Round Sections.....                     | 38 |
| 3.5    Material Processing Tufts University .....      | 38 |
| 3.5.1    Whole Round Processing Protocol .....         | 39 |
| 3.6    Resedimentation .....                           | 41 |
| 3.6.1    Mixing and Deposition .....                   | 42 |

|                                        |                                             |    |
|----------------------------------------|---------------------------------------------|----|
| 3.6.2                                  | Consolidation .....                         | 43 |
| 3.6.3                                  | Extrusion .....                             | 44 |
| 3.6.4                                  | Resedimented vs intact specimen. ....       | 44 |
| Chapter 4 - Laboratory Equipment ..... |                                             | 75 |
| 4.1                                    | Introduction .....                          | 75 |
| 4.2                                    | Index Testing.....                          | 75 |
| 4.2.1                                  | Grain Density Testing Equipment .....       | 75 |
| 4.2.2                                  | Particle Size Analysis Equipment.....       | 76 |
| 4.2.3                                  | Atterberg Limits Equipment .....            | 76 |
| 4.3                                    | Constant Rate of Strain Test Equipment..... | 76 |
| 4.3.1                                  | Transducers .....                           | 77 |
| 4.3.2                                  | Pressure Volume Actuators.....              | 78 |
| 4.3.3                                  | DC Motor Controllers .....                  | 78 |
| 4.3.4                                  | Data Acquisition System.....                | 79 |
| 4.3.5                                  | Data Analysis .....                         | 79 |
| 4.4                                    | Oedometer Testing Equipment.....            | 79 |
| Chapter 5 - Research Methodology ..... |                                             | 86 |
| 5.1                                    | Introduction .....                          | 86 |
| 5.2                                    | Particle Size Analysis.....                 | 86 |
| 5.2.1                                  | Testing Procedure .....                     | 89 |
| 5.2.2                                  | Hydrometer Calibration Procedure .....      | 90 |

|                                                      |                                                      |     |
|------------------------------------------------------|------------------------------------------------------|-----|
| 5.3                                                  | Grain Density – Water Submersion Method .....        | 91  |
| 5.3.1                                                | Testing Procedure .....                              | 92  |
| 5.3.2                                                | Volumetric Flask Calibration Procedure .....         | 93  |
| 5.4                                                  | Grain Density – Gas Pycnometer .....                 | 94  |
| 5.4.1                                                | Testing Procedure .....                              | 94  |
| 5.4.2                                                | Gas Pycnometer Calibration Procedure .....           | 95  |
| 5.5                                                  | Atterberg Limits .....                               | 95  |
| 5.5.1                                                | Liquid Limit Testing Procedure – Casagrande .....    | 96  |
| 5.5.2                                                | Plastic Limit Testing Procedure.....                 | 96  |
| 5.6                                                  | CRS Testing .....                                    | 97  |
| 5.6.1                                                | Preconsolidation Pressure .....                      | 97  |
| 5.6.2                                                | Permeability .....                                   | 99  |
| 5.6.3                                                | Apparatus Compressibility.....                       | 100 |
| 5.6.4                                                | CRS Testing Procedure.....                           | 100 |
| 5.7                                                  | Oedometer Testing .....                              | 102 |
| 5.7.1                                                | Oedometer Testing Procedure.....                     | 103 |
| Chapter 6 - Experimental Results and Discussion..... |                                                      | 109 |
| 6.1                                                  | Overview of Experiments.....                         | 109 |
| 6.2                                                  | Moisture and Density (MAD) and porosity Results..... | 109 |
| 6.3                                                  | Particle size analysis.....                          | 110 |

|                                                   |                                   |     |
|---------------------------------------------------|-----------------------------------|-----|
| 6.4                                               | Grain Density .....               | 111 |
| 6.4.1                                             | Water Submersion Method .....     | 111 |
| 6.4.2                                             | Gas Pycnometer Method.....        | 112 |
| 6.4.3                                             | Comparison of both methods .....  | 112 |
| 6.5                                               | Atterberg Limits .....            | 112 |
| 6.6                                               | X-Ray Diffraction Analysis .....  | 113 |
| 6.7                                               | CRS Testing .....                 | 114 |
| 6.7.1                                             | Intact Vs Resedimented .....      | 114 |
| 6.7.2                                             | Compression Curves .....          | 116 |
| 6.7.3                                             | Preconsolidation Pressure .....   | 118 |
| 6.7.4                                             | Stress Profiles.....              | 119 |
| 6.7.5                                             | Porosity .....                    | 120 |
| 6.7.6                                             | Permeability .....                | 121 |
| 6.7.7                                             | Influence of fossils.....         | 122 |
| 6.8                                               | Oedometer Testing .....           | 123 |
| 6.9                                               | Strength Correlation .....        | 123 |
| 6.10                                              | Compressibility Correlation ..... | 124 |
| Chapter 7 - Conclusions and Recommendations ..... |                                   | 167 |
| 7.1                                               | Summary of Conducted Work.....    | 167 |
| 7.2                                               | Summary of Results .....          | 168 |

|     |                              |     |
|-----|------------------------------|-----|
| 7.3 | Future Work .....            | 169 |
|     | Appendix A – References..... | 172 |
|     | Appendix B – Tables.....     | 177 |

## IV. List of Tables

|                                                                                            |     |
|--------------------------------------------------------------------------------------------|-----|
| Table 3-1 Resedimentation Log.....                                                         | 46  |
| Table 3-2 Whole round core section log of samples sent to Tufts.....                       | 47  |
| Table 5-1 Constant rate of strain testing log.....                                         | 104 |
| Table 6-1 - Summary of Layers .....                                                        | 125 |
| Table 6-2 Average compression curve fitting parameters .....                               | 125 |
| Table 6-3 - Strength correlation by Casey & Germaine from Atterberg limits .....           | 126 |
| Table 6-4 - Compression correlation by Terzaghi, Peck & Skempton from Atterberg limits.... | 126 |
| Table 7-1 - Density, water content, and porosity of SC Plugs.....                          | 177 |
| Table 7-2 Density, Water Content and Porosity of MAD Sections.....                         | 185 |
| Table 7-3 Particle Size Results on Blended Material Using Hydrometer Method .....          | 188 |
| Table 7-4 Grain Density by Water Submersion on Blended Material.....                       | 190 |
| Table 7-5 Grain Density by Gas Pycnometer on WC Plugs.....                                 | 192 |
| Table 7-6 Grain Density for SC Plugs using Gas Pycnometer .....                            | 194 |
| Table 7-7 – Summary of consolidation results for sample H003-7H-3B1 – OED223.....          | 202 |
| Table 7-8 – CRS test summary with specific test information .....                          | 203 |

## V. List of Figures

|                                                                                                                                                                                                                |    |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----|
| Figure 2-1 Drilling location - Terrebonne Basin, Gulf of Mexico - Located 265 miles southeast of Galveston, Texas, 193 miles southwest of Port Fourchon, Louisiana. Eugene Island Block 330 is also shown..... | 31 |
| Figure 2-2 Hydrate Coring Expedition (UT-GOM2-2) in the summer of 2023 (courtesy of P Flemings) . ....                                                                                                         | 31 |
| Figure 2-3 Drilling log information, lithofacies, and cored intervals. ....                                                                                                                                    | 32 |
| Figure 2-4 Grain size distribution of RGoM-EI by (Betts, 2014) – Classed as fine-grained material. ....                                                                                                        | 33 |
| Figure 2-5 Plasticity chart of RGoM-EI and Boston Blue Clay (BBC) by (Hanley, 2017) .....                                                                                                                      | 33 |
| Figure 2-6 Average Uniaxial Compression Curve of RGoM-EI courtesy of Emre Uyeturk shown by (Doran 2023). ....                                                                                                  | 34 |
| Figure 3-1 G-APC Piston Sampler – Used when drilling to depths of 300 mbsf in very soft to moderately firm sediments. ....                                                                                     | 48 |
| Figure 3-2 G-XCB Rotary Sampler – Used when drilling deeper than 300 mbsf in soft to moderately hard sediments. ....                                                                                           | 48 |
| Figure 3-3 G-APC sampler being deployed at the beginning of the expedition during the summer of 2023 .....                                                                                                     | 49 |
| Figure 3-4 Initial stage of material processing during the expedition. ....                                                                                                                                    | 49 |
| Figure 3-5 Summary of samples sent to Tufts Laboratory and the engineering test intended/ parameter to be tested. ....                                                                                         | 50 |

|                                                                                                                                                                                                                                                                |    |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----|
| Figure 3-6 - Processing of whole round sections into pieces for individual moisture and density measurements. Sample is split into half 1 and 2. Half 1 is used to extract UNH section C. Half 2 is used to extract MAD plug G and water content slice F. .... | 50 |
| Figure 3-7 Sample during processing .....                                                                                                                                                                                                                      | 51 |
| Figure 3-8 Blended material generated from sample processing. Stored at 4°C for future testing. ....                                                                                                                                                           | 51 |
| Figure 3-9 De-Airing the slurry mixture to remove any entrapped air before deposition. ....                                                                                                                                                                    | 52 |
| Figure 3-10 Deposition suction gun used to tremie the slurry into the consolidometer. ....                                                                                                                                                                     | 52 |
| Figure 3-11 Incremental sample loading – Includes consolidometer and axial loading being applied. ....                                                                                                                                                         | 53 |
| Figure 3-12 CRS sample being extruded from consolidometer before the trimming process. ....                                                                                                                                                                    | 53 |
| Figure 3-15 CT-H003-1H-3B .....                                                                                                                                                                                                                                | 54 |
| Figure 3-14 CT-H003-1H-2B .....                                                                                                                                                                                                                                | 54 |
| Figure 3-13 CT - H003-1H-1B .....                                                                                                                                                                                                                              | 54 |
| Figure 3-17 CT-H003-1H-5B .....                                                                                                                                                                                                                                | 54 |
| Figure 3-16 CT-H003-1H-4B .....                                                                                                                                                                                                                                | 54 |
| Figure 3-18 CT-H003-2H-1B .....                                                                                                                                                                                                                                | 54 |
| Figure 3-20 CT-H003-2H-3B .....                                                                                                                                                                                                                                | 55 |
| Figure 3-21 CT-H003-2H-2B .....                                                                                                                                                                                                                                | 55 |
| Figure 3-19 CT-H003-2H-4B .....                                                                                                                                                                                                                                | 55 |
| Figure 3-24 CT-H003-2H-5B .....                                                                                                                                                                                                                                | 55 |
| Figure 3-23 CT-H003-2H-6B .....                                                                                                                                                                                                                                | 55 |
| Figure 3-22 CT-H003-3H-1B .....                                                                                                                                                                                                                                | 55 |

|                                   |    |
|-----------------------------------|----|
| Figure 3-27 CT-H003-3H-4B .....   | 56 |
| Figure 3-26 CT-H003-3H-3B .....   | 56 |
| Figure 3-25 CT-H003-3H-2B .....   | 56 |
| Figure 3-28 CT-H003-3H-5B .....   | 56 |
| Figure 3-29 CT-H003-3H-6B .....   | 56 |
| Figure 3-30 CT-H003-6H-2B .....   | 56 |
| Figure 3-31 CT-H003-7H-3B1 .....  | 57 |
| Figure 3-33 CT-H003-6H-3B .....   | 57 |
| Figure 3-32 CT-H003-6H-6B .....   | 57 |
| Figure 3-35 CT-H003-8CS-3C .....  | 57 |
| Figure 3-36 CT-H003-7H-5B1 .....  | 57 |
| Figure 3-34 CT-H003-9H-2B1 .....  | 57 |
| Figure 3-37 CT-H003-10H-5B1 ..... | 58 |
| Figure 3-38 CT-H003-9H-5B .....   | 58 |
| Figure 3-39 CT-H003-10H-3B1 ..... | 58 |
| Figure 3-41 CT-H003-11H-1B .....  | 58 |
| Figure 3-42 CT-H003-11H-4B .....  | 58 |
| Figure 3-40 CT-H003-12H-2B .....  | 58 |
| Figure 3-45 CT-H003-12H-5B .....  | 59 |
| Figure 3-43 CT-H003-14H-6B1 ..... | 59 |
| Figure 3-44 CT-H003-14H-2B .....  | 59 |
| Figure 3-48 CT-H003-18H-2B .....  | 59 |
| Figure 3-47 CT-H003-16H-1B .....  | 59 |

|                                         |    |
|-----------------------------------------|----|
| Figure 3-46 CT-H003-16H-4B .....        | 59 |
| Figure 3-49 CT-H003-20H-2B .....        | 60 |
| Figure 3-51 CT-H003-18H-5B .....        | 60 |
| Figure 3-50 CT-H003-19CS-5C .....       | 60 |
| Figure 3-52 CT-H003-21H-6B .....        | 60 |
| Figure 3-54 CT-H003-21H-3B .....        | 60 |
| Figure 3-53 CT-H003-20H-5B .....        | 60 |
| Figure 3-55 CT-H003-22H-4B .....        | 61 |
| Figure 3-56 CT-H003-23H-2B .....        | 61 |
| Figure 3-57 CT-H003-22H-2B .....        | 61 |
| Figure 3-60 CT-H003-24CS-5C .....       | 61 |
| Figure 3-59 CT-H003-23H-4B .....        | 61 |
| Figure 3-58 CT-H003-25H-7B .....        | 61 |
| Figure 3-61 CT-H003-27CS-4B .....       | 62 |
| Figure 3-62 CT-H003-26X-6B .....        | 62 |
| Figure 3-63 CT-H003-26X-4B .....        | 62 |
| Figure 3-64 - Sample - H003-1H-4B ..... | 63 |
| Figure 3-65 - Sample - H003-1H-5B ..... | 63 |
| Figure 3-66 - Sample - H003-2H-1B ..... | 63 |
| Figure 3-67 - Sample - H003-2H-3B ..... | 63 |
| Figure 3-68 - Sample - H003-2H-4B ..... | 64 |
| Figure 3-69 - Sample - H003-2H-5B ..... | 64 |
| Figure 3-70 - Sample - H003-3H-1B ..... | 64 |

|                                           |    |
|-------------------------------------------|----|
| Figure 3-71 - Sample - H003-2H-6B .....   | 64 |
| Figure 3-72 - Sample - H003-3H-3B .....   | 65 |
| Figure 3-73 - Sample - H003-3H-2B .....   | 65 |
| Figure 3-74 - Sample - H003-3H-4B .....   | 65 |
| Figure 3-75 - Sample - H003-3H-5B .....   | 65 |
| Figure 3-76 - Sample - H003-7H-3B1 .....  | 66 |
| Figure 3-77 - Sample - H003-6H-2B .....   | 66 |
| Figure 3-78 - Sample - H003-3H-6B .....   | 66 |
| Figure 3-79 - Sample - H003-6H-6B .....   | 66 |
| Figure 3-80 - Sample - H003-8CS-3C .....  | 67 |
| Figure 3-81 - Sample - H003-7H-5B1 .....  | 67 |
| Figure 3-82 - Sample - H003-9H-5B .....   | 67 |
| Figure 3-83 - Sample - H003-9H-2B1 .....  | 67 |
| Figure 3-84 - Sample - H003-10H-5B1 ..... | 68 |
| Figure 3-85 - Sample - H003-10H-3B1 ..... | 68 |
| Figure 3-86 - Sample - H003-11H-4B .....  | 68 |
| Figure 3-87 - Sample - H003-11H-1B .....  | 68 |
| Figure 3-88 - Sample - H003-12H-2B .....  | 69 |
| Figure 3-89 - Sample - H003-12H-5B .....  | 69 |
| Figure 3-90 - Sample - H003-14H-6B1 ..... | 69 |
| Figure 3-91 - Sample - H003-14H-2B .....  | 69 |
| Figure 3-92 Sample - H003-16H-4B .....    | 70 |
| Figure 3-93 - Sample - H003-16H-1B .....  | 70 |

|                                                                          |    |
|--------------------------------------------------------------------------|----|
| Figure 3-94 Sample - H003-17H-2B1 .....                                  | 70 |
| Figure 3-95 - Sample - H003-18H-2B1 .....                                | 70 |
| Figure 3-96 - Sample - H003-19CS-4C .....                                | 71 |
| Figure 3-97 - Sample - H003-18H-5B .....                                 | 71 |
| Figure 3-98 - Sample - H003-20H-5B .....                                 | 71 |
| Figure 3-99 - Sample - H003-20H-2B .....                                 | 71 |
| Figure 3-100 - Sample - H003-21H-3B .....                                | 72 |
| Figure 3-101 - Sample - H003-21H-6B .....                                | 72 |
| Figure 3-102 - Sample - H003-22H-2B .....                                | 72 |
| Figure 3-103 - Sample - H003-22H-4B .....                                | 72 |
| Figure 3-104 - Sample - H003-23H-4B .....                                | 73 |
| Figure 3-105 - Sample - H003-23H-2B .....                                | 73 |
| Figure 3-106 - Sample - H003-26X-6B .....                                | 73 |
| Figure 3-107 - Sample - H003-26X-4B .....                                | 73 |
| Figure 3-108 - Sample - H003-25H-7B .....                                | 74 |
| Figure 3-109 - Sample - H003-24CS-5C .....                               | 74 |
| Figure 3-110 - Sample - H003-27CS-4B .....                               | 74 |
| Figure 4-1 AccuPyc 3 Gas Pycnometer .....                                | 80 |
| Figure 4-2 Volumetric flasks .....                                       | 81 |
| Figure 4-3 Volumetric flasks in temperature-controlled environment ..... | 81 |
| Figure 4-4 Six sedimentation flasks.....                                 | 82 |
| Figure 4-5 H151 Specific Gravity Hydrometer .....                        | 82 |
| Figure 4-6 Casagrande cup .....                                          | 83 |

|                                                                                                                                                                                                     |     |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----|
| Figure 4-7 CRS Cell schematic.....                                                                                                                                                                  | 83  |
| Figure 4-8 CRS testing apparatus .....                                                                                                                                                              | 84  |
| Figure 4-9 Wall mounted PVA's controlling load and cell pressure.....                                                                                                                               | 84  |
| Figure 4-10 D-C Motor Control Box .....                                                                                                                                                             | 85  |
| Figure 4-11 MIT Load frame and CRS cell used for oedometer testing .....                                                                                                                            | 85  |
| Figure 5-1 Hydrometer - Critical dimensions. Credit: (Germaine, 2009) .....                                                                                                                         | 105 |
| Figure 5-2 - Apparatus compressibility CRS STA08. Fitting function and parameters were added to the computer program before testing. ....                                                           | 106 |
| Figure 5-3 - Apparatus compressibility CRS STA09 Fitting function and parameters were added to the computer program before testing. ....                                                            | 107 |
| Figure 5-4 - Apparatus compressibility CRS STA02 Fitting function and parameters were added to the computer program before testing. ....                                                            | 107 |
| Figure 5-5 Apparatus compressibility investigation of the effects of sanding the porous stones with sand paper. ....                                                                                | 108 |
| Figure 6-1 283 SC plugs water content measurement plotted with depth. (0-900 mbsf) .....                                                                                                            | 127 |
| Figure 6-2 WC samples water content measurement. Measurements for the plug, wedge & blended included. (0-300 mbsf).....                                                                             | 127 |
| Figure 6-3 Wet density measurement of the 283 SC plugs plotted with depth. (0-900 mbsf) ...                                                                                                         | 128 |
| Figure 6-4 Wet density measurement of the 53 WC samples. Measurement of the plug and full section include. (0-300 mbsf) .....                                                                       | 129 |
| Figure 6-5 Porosity calculated from 283 SC plugs plotted with depth. A grain density of 2.72 g/cm <sup>3</sup> is assumed for the calculation. (0-900 mbsf). LWD data included for comparison. .... | 130 |

|                                                                                                                                                                    |     |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----|
| Figure 6-6 53 WC samples porosity calculation assuming a grain density of 2.72 g/cm <sup>3</sup> . LWD data plug and full section included. (0-300 mbsf) .....     | 130 |
| Figure 6-7 Ternary plot of data from 50 hydrometer tests. The majority of samples plot in the silty clay region. RGOM EI is also included. ....                    | 131 |
| Figure 6-8 Grain size distribution graph of all the samples located in the ooze layers. Higher percentage sand content noticed in the ooze layers. ....            | 132 |
| Figure 6-9 Grain size distribution graph of all the samples located in the mud layers.....                                                                         | 133 |
| Figure 6-10 Ooze sample under a microscope. Fossils and shells are visible. Many shells are greater than 75 microns.....                                           | 134 |
| Figure 6-11 Ooze sample under a microscope. Fossils and shells are visible. Many shells are greater than 75 microns.....                                           | 134 |
| Figure 6-12 +200 fraction with fossils and shells evident. Ooze sample. ....                                                                                       | 135 |
| Figure 6-13 +200 fraction with quartz evident. Mud sample. ....                                                                                                    | 135 |
| Figure 6-14 Grain density comparison. Measurement by gas pycnometer on WR plugs and water submersion method on blended material. ....                              | 136 |
| Figure 6-15 Plasticity chart. 5 Samples tested. H003-6H-6B, H003-12H-2B, H003-21H-6B, H003-22H-4B & H003-9H2B1. Sediment classed as high-plasticity clay (CH)..... | 136 |
| Figure 6-16 - X-ray Diffraction results on Mud sample. Whole sample analysis. ....                                                                                 | 137 |
| Figure 6-17- X-ray Diffraction results on Ooze sample. Whole sample analysis. ....                                                                                 | 137 |
| Figure 6-18 - Comparison of Intact vs. Resedimented Mud Samples. ....                                                                                              | 138 |
| Figure 6-19 - Comparison of Intact vs. Resedimented Mud Samples. ....                                                                                              | 138 |
| Figure 6-20 – Comparison of Intact vs. Resedimented Ooze Samples.....                                                                                              | 139 |
| Figure 6-21 - Average compression curve for mud and ooze layers. 24 tests in total averaged.                                                                       | 140 |

|                                                                                                                                                                                                                                              |     |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----|
| Figure 6-22 – Layer 1 compression curves. Average curve included. (4-23 mbsf). Ooze .....                                                                                                                                                    | 140 |
| Figure 6-23– Layer 2 compression curves. Average curve included. (23-64 mbsf).Mud .....                                                                                                                                                      | 141 |
| Figure 6-24– Layer 3 compression curves. Average curve included. 64-78 mbsf). Ooze .....                                                                                                                                                     | 141 |
| Figure 6-25– Layer 4 compression curves. Average curve included. (78-103 mbsf). Mud .....                                                                                                                                                    | 142 |
| Figure 6-26– Layer 5 compression curves. Average curve included. (103-114 mbsf). Ooze ....                                                                                                                                                   | 142 |
| Figure 6-27– Layer 6 compression curves. Average curve included. (114-138 mbsf). Mud .....                                                                                                                                                   | 143 |
| Figure 6-28– Layer 7 compression curve. (138-154 mbsf). Ooze .....                                                                                                                                                                           | 143 |
| Figure 6-29– Layer 8 compression curves. Average curve included. (154-900 mbsf). Mud .....                                                                                                                                                   | 144 |
| Figure 6-30 - Pressure/ Stress profile. Hydrostatic pressure, effective pressure, total pressure, and<br>preconsolidation pressure of each CRS test. Upper and lower preconsolidation pressure reported<br>for each test. (0-300 mbsf) ..... | 145 |
| Figure 6-31 - Pressure/ Stress profile. Hydrostatic pressure, effective pressure, total pressure, and<br>preconsolidation pressure of each CRS test. Upper and lower preconsolidation pressure reported<br>for each test. (0-900 mbsf) ..... | 146 |
| Figure 6-32 - Preconsolidation pressure construction by strain energy method. CRS 1791 - Sample<br>H003-2H-2B. The effective preconsolidation pressure is estimated to be between 0.065 MPa and<br>0.105 MPa. ....                           | 147 |
| Figure 6-33- Preconsolidation pressure construction by strain energy method. CRS 1787 - Sample<br>H003-2H-6B. The effective preconsolidation pressure is estimated to be between 0.08 MPa and<br>0.12 MPa. ....                              | 147 |
| Figure 6-34 - Preconsolidation pressure construction by strain energy method. CRS 1788 - Sample<br>H003-2H-6B. The effective preconsolidation pressure is estimated to be between 0.09 MPa and<br>0.125 MPa. ....                            | 148 |

|                                                                                                                                                                                                             |     |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----|
| Figure 6-35 - Preconsolidation pressure construction by strain energy method. CRS 1792 - Sample H003-3H-3B. The effective preconsolidation pressure is estimated to be between 0.14 MPa and 0.185 MPa. .... | 148 |
| Figure 6-36 - Preconsolidation pressure construction by strain energy method. CRS 1801 - Sample H003-3H-5B. The effective preconsolidation pressure is estimated to be between 0.16 MPa and 0.19 MPa. ....  | 149 |
| Figure 6-37 - Preconsolidation pressure construction by strain energy method. CRS 1785 - Sample H003-6H-2B. The effective preconsolidation pressure is estimated to be between 0.205 MPa and 0.24 MPa. .... | 149 |
| Figure 6-38 - Preconsolidation pressure construction by strain energy method. CRS 1786 - Sample H003-6H-2B. The effective preconsolidation pressure is estimated to be between 0.205 MPa and 0.24 MPa. .... | 150 |
| Figure 6-39 - Preconsolidation pressure construction by strain energy method. CRS 1793 - Sample H003-7H-3B1. The effective preconsolidation pressure is estimated to be between 0.3 MPa and 0.36 MPa. ....  | 150 |
| Figure 6-40 - Preconsolidation pressure construction by strain energy method. CRS 1781 - Sample H003-9H-2B1. The effective preconsolidation pressure is estimated to be between 0.3 MPa and 0.4 MPa. ....   | 151 |
| Figure 6-41 - Preconsolidation pressure construction by strain energy method. CRS 1780 - Sample H003-9H-2B1. The effective preconsolidation pressure is estimated to be between 0.3 MPa and 0.38 MPa. ....  | 151 |

|                                                                                                                                                                                                              |     |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----|
| Figure 6-42 - Preconsolidation pressure construction by strain energy method. CRS 1795 - Sample H003-10H-5B1. The effective preconsolidation pressure is estimated to be between 0.4 MPa and 0.5 MPa. ....   | 152 |
| Figure 6-43 - Preconsolidation pressure construction by strain energy method. CRS 1777 - Sample H003-12H-2B. The effective preconsolidation pressure is estimated to be between 0.53 MPa and 0.61 MPa. ....  | 152 |
| Figure 6-44 - Preconsolidation pressure construction by strain energy method. CRS 1779 - Sample H003-12H-2B. The effective preconsolidation pressure is estimated to be between 0.6 MPa and 0.66 MPa. ....   | 153 |
| Figure 6-45 - Preconsolidation pressure construction by strain energy method. CRS 1802 - Sample H003-14H-2B. The effective preconsolidation pressure is estimated to be between 0.54 MPa and 0.7 MPa. ....   | 153 |
| Figure 6-46 - Preconsolidation pressure construction by strain energy method. CRS 1796 - Sample H003-16H-1B. The effective preconsolidation pressure is estimated to be between 0.6 MPa and 0.75 MPa. ....   | 154 |
| Figure 6-47 - Preconsolidation pressure construction by strain energy method. CRS 1803 - Sample H003-17H-2B1. The effective preconsolidation pressure is estimated to be between 0.65 MPa and 0.85 MPa. .... | 154 |
| Figure 6-48 - Preconsolidation pressure construction by strain energy method. CRS 1782 - Sample H003-18H-2B1. The effective preconsolidation pressure is estimated to be between 0.75 MPa and 0.9 MPa. ....  | 155 |

|                                                                                                                                                                                                              |     |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----|
| Figure 6-49 - Preconsolidation pressure construction by strain energy method. CRS 1783 - Sample H003-18H-2B1. The effective preconsolidation pressure is estimated to be between 0.75 MPa and 0.95 MPa. .... | 155 |
| Figure 6-50 - Preconsolidation pressure construction by strain energy method. CRS 1797 - Sample H003-20H-2B. The effective preconsolidation pressure is estimated to be between 0.85 MPa and 1 MPa. ....     | 156 |
| Figure 6-51 - Preconsolidation pressure construction by strain energy method. CRS 1775 - Sample H003-22H-4B. The effective preconsolidation pressure is estimated to be between 0.8 MPa and 0.9 MPa. ....    | 156 |
| Figure 6-52 - Preconsolidation pressure construction by strain energy method. CRS 1776 - Sample H003-22H-4B. The effective preconsolidation pressure is estimated to be between 0.8 MPa and 0.9 MPa. ....    | 157 |
| Figure 6-53 - Preconsolidation pressure construction by strain energy method. CRS 1807 - Sample H003-23H-4B. The effective preconsolidation pressure is estimated to be between 0.65 MPa and 1 MPa. ....     | 157 |
| Figure 6-54 - Preconsolidation pressure construction by strain energy method. CRS 1798 - Sample H003-26X-4B. The effective preconsolidation pressure is estimated to be between 2.1 MPa and 2.7 MPa. ....    | 158 |
| Figure 6-55 - Preconsolidation pressure construction by strain energy method. CRS 1826 - Sample H002-14cs-3a2. The effective preconsolidation pressure is estimated to be between 8.5 MPa and 10 MPa. ....   | 158 |
| Figure 6-56 – Porosity profile including in-situ sample porosity CRS porosity model & LWD porosity data (0-300 mbsf).....                                                                                    | 159 |

|                                                                                                                                               |     |
|-----------------------------------------------------------------------------------------------------------------------------------------------|-----|
| Figure 6-57 - Porosity profile including in-situ sample porosity CRS porosity model & LWD porosity data (0-900 mbsf).....                     | 160 |
| Figure 6-58 – Layer specific permeability curves. Layer 1 to 8.....                                                                           | 161 |
| Figure 6-59 – Permeability profile. (0-900 mbsf).....                                                                                         | 162 |
| Figure 6-60 - Cc Vs % Sand Content of mud and ooze samples.....                                                                               | 163 |
| Figure 6-61 – Compression results for OED223 – H003-7H-3B1 .....                                                                              | 164 |
| Figure 6-62 - Load Increment 9 OED 223 - 64 kg/cm2 – Log of time method.....                                                                  | 164 |
| Figure 6-63 - Undrained shear strength is derived from the correlation by Casey 2013 from Atterberg limits, with lab vane data included. .... | 165 |
| Figure 6-64 - Compression index comparison – CRS test, Terzaghi & Peck correlation and Skempton. ....                                         | 166 |

## VI. Symbols

|                |                                                |
|----------------|------------------------------------------------|
| ADC            | Analog-to-Digital Converter                    |
| BBC            | Boston Blue Clay                               |
| CRS            | Constant Rate of Strain                        |
| KSC            | Kgf/cm <sup>2</sup>                            |
| LVDT           | Linear Voltage Displacement Transducer         |
| MPa            | Megapascals                                    |
| OED            | Oedometer                                      |
| PC             | Personal Computer                              |
| PVA            | Pressure Volume Actuator                       |
| RBBC           | Resedimented Boston Blue Clay                  |
| RGoM-EI        | Resedimented Gulf of Mexico Eugene Island Clay |
| UNH            | University of New Hampshire                    |
| SLC            | Salt Lake City                                 |
| WR             | Whole Round                                    |
| SC             | Split Core                                     |
| RBBC           | Resedimented Boston Blue Clay                  |
| MAD            | Moisture and Density                           |
| MBSF           | Meters below sea level                         |
| TX             | Triaxial                                       |
| C <sub>c</sub> | Compression Index                              |
| e              | Void Ratio                                     |
| K <sub>0</sub> | Coefficient of Lateral Earth Pressure at Rest  |
| n              | Porosity                                       |
| NC             | Normally Consolidated                          |
| OC             | Overconsolidated                               |
| OCR            | Overconsolidation Ratio                        |
| S <sub>u</sub> | Undrained Shear Strength                       |
| t              | Time                                           |
| u              | Pore Pressure                                  |
| w <sub>n</sub> | Natural Water Content                          |

|              |                                     |
|--------------|-------------------------------------|
| $\epsilon_a$ | Axial Strain                        |
| $\gamma_t$   | Total Unit Weight                   |
| $\gamma_w$   | Unit Weight of Water                |
| $\sigma'_p$  | Effective Preconsolidation Pressure |

# **Chapter 1 - Introduction**

## **1.1 Problem Statement**

The Terrebonne Basin, located on the outer continental shelf of the Gulf of Mexico, presents a unique and complex geomechanical environment beneath the seafloor. Accurate characterization of the geomechanical properties in this region is crucial for understanding subsurface behavior, particularly in the context of offshore drilling and offshore platform operations. The seafloor and subsurface sediments in the Terrebonne Basin are composed of a diverse range of materials, including unconsolidated clays, sands, and silts, with significant variations in composition, porosity, permeability, and strength. Additionally, the presence of complex geological features such as faults, salt domes, and fluid reservoirs further complicates the geomechanical behavior of the region. Despite the increasing interest in exploring and exploiting hydrocarbon resources in this basin, there remains a significant knowledge gap regarding the geotechnical properties of the seafloor sediments and underlying strata directly below the mudline. The primary challenge lies in the difficulty of accurately measuring the mechanical properties of deepwater sediments. Without a detailed understanding of the geomechanical characteristics, (including shear strength), compaction, pore pressure, and sediment deformation behavior, there is an elevated risk of infrastructure failure, ineffective resource extraction, and environmental hazards. This study seeks to contribute to filling the existing gap by focusing on the comprehensive characterization of geomechanical properties beneath the seafloor in the Terrebonne Basin. The findings will inform the design and management of offshore exploration and production activities, contributing to safer, more efficient, and environmentally responsible practices for offshore drilling expeditions.

## **1.2 Scope and Objectives**

This study focuses on characterizing the geomechanical properties beneath the seafloor in the Terrebonne Basin, located on the outer continental shelf of the Gulf of Mexico. The research aims to provide a detailed understanding of the mechanical behavior of seafloor sediments and underlying strata through laboratory testing. The scope of the study includes:

- 1) Analyzing the composition and structure of subsurface materials.
- 2) Identifying variations in sediment properties with depth.
- 3) Conducting index tests, including Atterberg limits, grain size analysis, and grain density, to establish baseline material properties.
- 4) Measuring key mechanical properties, including compressibility, permeability, and porosity.
- 5) Analyzing resedimented samples to assess changes in mechanical properties compared with intact samples.

## **1.3 Organization**

This thesis is organized into nine chapters:

Chapter two details the background information about the wider research project. It also reviews previous studies and similar materials to establish a foundation for the research.

Chapter three describes the drilling equipment and material processing methods used to collect and prepare samples. It details the initial measurements and accurately explains the resedimentation process to replicate in-situ conditions.

Chapter four details the laboratory equipment used for testing, including the setup of computer controls and data acquisition systems.

Chapter five outlines the testing procedures conducted during the research, including index testing, constant rate of strain (CRS) testing, and oedometer testing (OED). It provides a step-by-step explanation of each method.

Chapter six presents all the testing results. The following index testing results are detailed: moisture and density (MAD), particle size analysis, grain density, Atterberg limits, and X-ray diffraction analysis. CRS testing results include intact vs. resedimented analysis, compression curves, maximum past pressure constructions, porosity profiles, and permeability profiles. The oedometer testing details the secondary compression portion of the compression behavior.

Chapter seven consists of a summary of the work conducted and a summary of the results. Details of the areas for future potential work are also detailed.

Appendix A contains all references used in this document.

Appendix B consists of tables detailing all testing results.

## **Chapter 2 - Background**

### **2.1 Introduction**

The research forms part of The University of Texas at Austin (UT) Gulf of Mexico Deepwater Hydrate Coring Expedition (UT-GOM2-2) in the summer and fall of 2023. The team drilled, cored, made downhole measurements, and analyzed samples from the seafloor to the base of the gas hydrate stability zone at Site H in Walker Ridge Block 313 (Site H, WR313) in the Terrebonne basin, deepwater Gulf of Mexico. This was the primary expedition of the Deepwater Methane Hydrate Characterization & Scientific Assessment project (DE-FE0023919). This project is funded by the United States Department of Energy (DOE), National Energy Technology Laboratory (NETL), and advised by the United States Geological Survey (USGS) and the Bureau of Ocean Energy Management (BOEM). The team successfully sampled and analyzed hydrate-bearing reservoirs' physical, chemical, and biological properties, their bounding strata, and the overlying sedimentary section. Completed and ongoing analyses of data and samples from the expedition will inform biological, geochemical, and geomechanical models to constrain the role of gas hydrates in the carbon cycle and the potential for gas hydrates as an energy resource. Much research has been conducted on sediments in the Gulf of Mexico, with few taking large continuous core intervals into the seafloor. This makes the work conducted as part of this project very interesting. Many industry and academic institutions contributed to various elements of this expedition, each having a specific area to research. Tufts University was tasked with analyzing the sediment's geomechanical, moisture and density (MAD), and physical properties. Full details of the project are detailed in (Flemings et al., 2024).

## **2.2 Drilling Expedition**

The expedition was 265 miles southeast of Galveston, Texas, 193 miles southwest of Port Fourchon, Louisiana, which is shown in Figure 2-1. Figure 2-2 captures the drilling vessel during the expedition in the summer of 2023. The drilling expedition consisted of two boreholes, H002 and H003. H003 was drilled to a depth of approximately 300 mbsf. Samples were collected continuously to a depth of 150 mbsf and at intervals thereafter. H002 was drilled to approximately 850 mbsf, and samples were recovered at targeted intervals. Figure 2-3 is an extract from (Flemings et al., 2024) which illustrates drilling log information and the cored intervals of the expedition. The gamma ray, resistivity, and bulk density measurements were measured in H001, which is in the immediate vicinity of H002 and H003. From the seafloor to 150 mbsf, interbedded mud and carbonate ooze were encountered through the sediment column. The ooze has abundant Calcareous Nannofossils, a high porosity, a low density, and a low clay content. The mud is a silty clay dominated by quartz and feldspar. Ooze is thought to record sedimentation out of the water column, whereas mud is believed to record shelf-derived sediment. The sediment obtained from the ooze layers is grey, whereas the sediment in the mud layers is much darker. This difference in lithology became very interesting as distinct differences in the mechanical behavior of the sediment became obvious. These differences are analyzed in detail in the results chapter.

## **2.3 Calcareous Sediments**

Calcareous sediments have been known to be problematic during drilling operations. They are often composed of the skeletal remains of marine organisms and tend to have high porosity and low compressive strength. If not anticipated or managed correctly, they can lead to significant problems during drilling, as they can be categorized as weak sediments. High-porosity sediment leads to high permeability, increasing the risk of fluid loss into the formation. This increases the

risk of collapse due to the drop in hydrostatic pressure in the well. (Aregbe, 2017) presents a study detailing the causes of wellbore instability. Higher porosities or sudden porosity increases in sediments are sometimes overlooked during the well-planning stage. This was the case in the BP Deepwater Horizon Oil Spill in 2010. The explosion and subsequent oil spill resulted in one of the largest environmental disasters in history, leading to significant loss of life, environmental damage, and economic impact in the Gulf of Mexico. (Skogdalen and Vinnem, 2012) present a study detailing major shortcomings in the design and construction of this well. This is an extreme outcome of drilling in challenging sediments but highlights the need for caution. (Pritchard and Lacy, 2011) conclude that in some categories of complex wells, wellbore instability events are as high as 10 % of the total deepwater well time and well control incidents over four times those of “normal” wells. This indicates that serious risk mitigation is a significant issue in drilling complex wells. Consequently, the industry needs to assess risks better and monitor well operations. It is imperative that the industry adopt standards that ensure process safety around design and execution to ensure safe and reliable deepwater operations.

## **2.4 Logging Data.**

Before the drilling expedition, a previous well, H001, was drilled in 2009 in the immediate vicinity of H002 and H003. The purpose of this well was to collect a comprehensive suite of logging-while-drilling (LWD) data within gas-hydrate-bearing sand reservoirs to make accurate estimates of the concentration of gas hydrates under various geologic conditions and to understand the geologic controls on the occurrence of gas hydrate. The downhole logging program implemented during the 2009 expedition was developed under the guidance of the Borehole Research Group from the Lamont-Doherty Earth Observatory of Columbia University. Six tools were used in this hole to obtain various measurements. The tools were as follows: the MP3 (multipole acoustic –

subsequently commercialized under the name SonicScope), geoVISION (electrical imaging), EcoScope (propagation resistivity, density, and neutron porosity), TeleScope, PeriScope (directional propagation resistivity), and sonicVISION (monopole acoustic). Full details of the tools can be found in (Collett et al., 2012). The bulk density measurement obtained from the EcoScope tool was converted to a porosity, assuming a grain density, for comparison purposes in this research. This information is also plotted in Figures 2-3.

## **2.5 Resedimented Gulf of Mexico, Eugene Island**

Comparisons will be made to The Gulf of Mexico, Eugene Island (RGoM-EI) clay as it is a well-researched clay deposited relatively close to the sediment researched as part of this project. The location is also represented in Figure 2-1. It is a smectite-rich high plasticity clay. The material referenced is from 10.2 cm drill cores from wells A-12 and A-20ST2 from 2300 m to 2500 m below the mudline and was obtained as part of the Integrated Ocean Drilling Program (Betts, 2014). A grain size analysis was conducted by (Betts, 2014) and was classed as a fine-grained material. The grain size distribution curve is shown in Figure 2-4. (Hanley, 2017) concludes that the material is a high-plasticity clay (CH). This is represented on the plasticity chart shown in Figure 2-5. The water submersion method determined the specific gravity ( $G_s$ ) of RGoM-EI to be 2.775 (Fahy, 2014). (Anderson et al., 1995) determined the in-situ pore fluid salinities for the Eugene block 330 field ranges between 74 to 80 g/L. The compressive behavior of the sediment is shown in Figure 2-6. This is an average uniaxial compression curve calculated from multiple CRS tests. The change in void ratio versus axial effective stress is shown in this figure by (Doran, 2023). The sediment properties listed in this section are fundamental engineering properties that can vary significantly. It is interesting to compare both materials, given that they are located relatively close

in the Gulf of Mexico. It must be noted that the depth of the referenced RGoM-EI material is between 2300 mbsf and 2500 mbsf compared to the UT-GOM2-2, being zero mbsf to 850 mbsf.

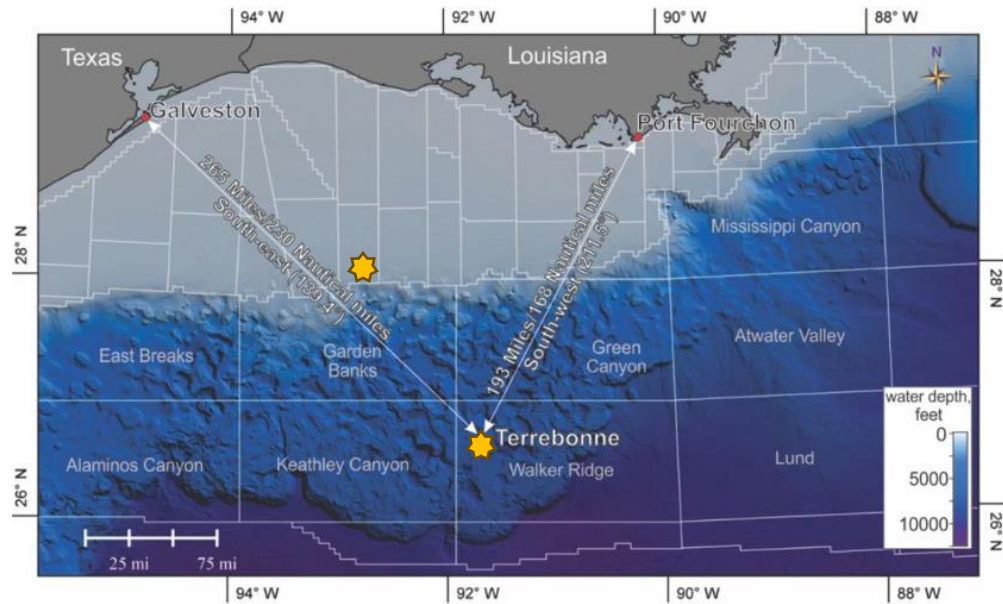


Figure 2-1 Drilling location - Terrebonne Basin, Gulf of Mexico - Located 265 miles southeast of Galveston, Texas, 193 miles southwest of Port Fourchon, Louisiana. Eugene Island Block 330 is also shown.



Figure 2-2 Hydrate Coring Expedition (UT-GOM2-2) in the summer of 2023 (courtesy of P Flemings) .

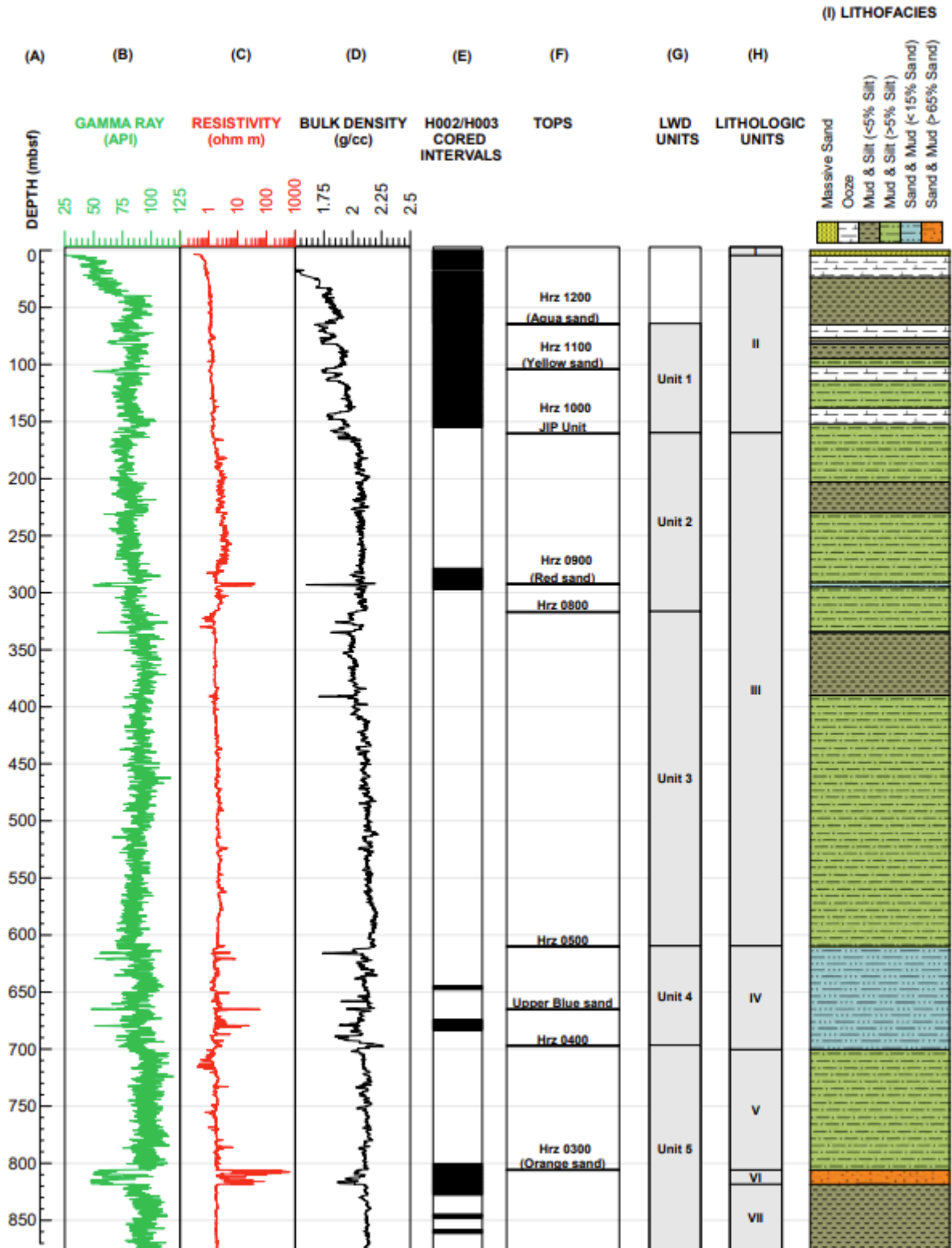


Figure 2-3 Drilling log information, lithofacies, and cored intervals.

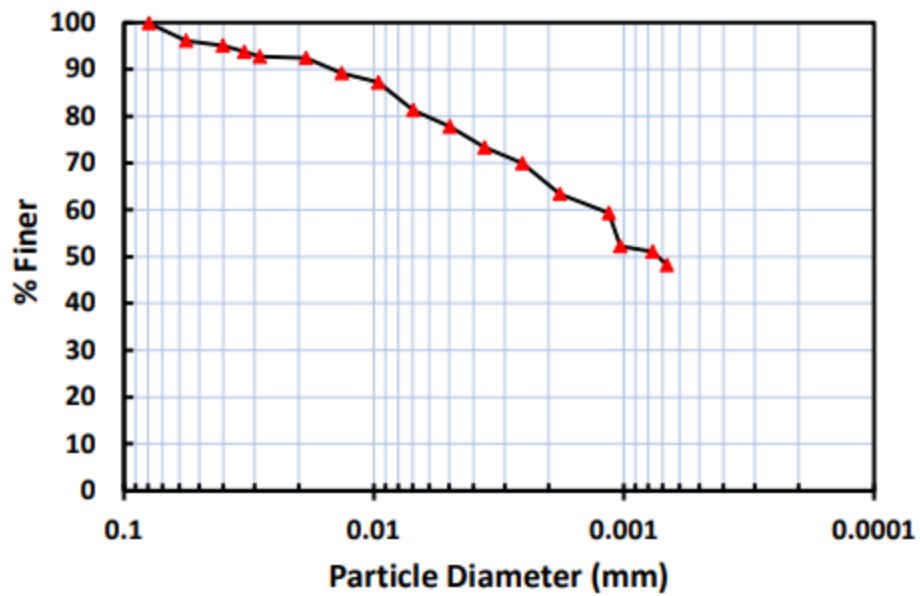


Figure 2-4 Grain size distribution of RGoM-EI by (Betts, 2014) – Classed as fine-grained material.

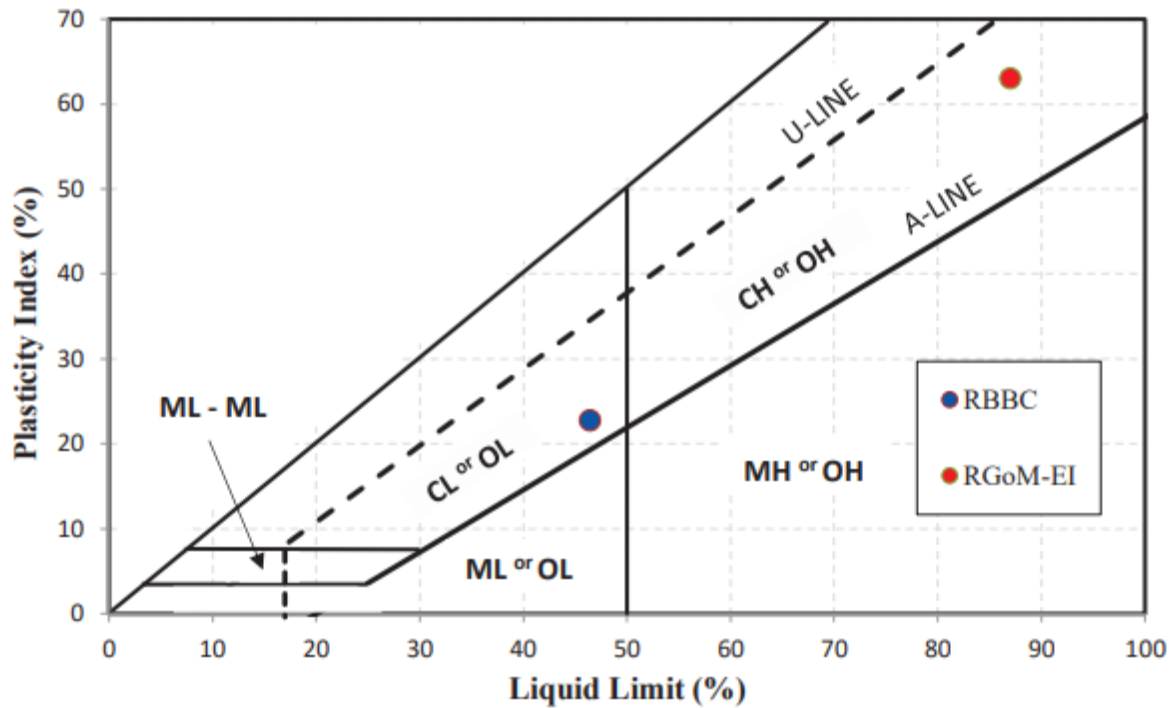


Figure 2-5 Plasticity chart of RGoM-EI and Boston Blue Clay (BBC) by (Hanley, 2017)

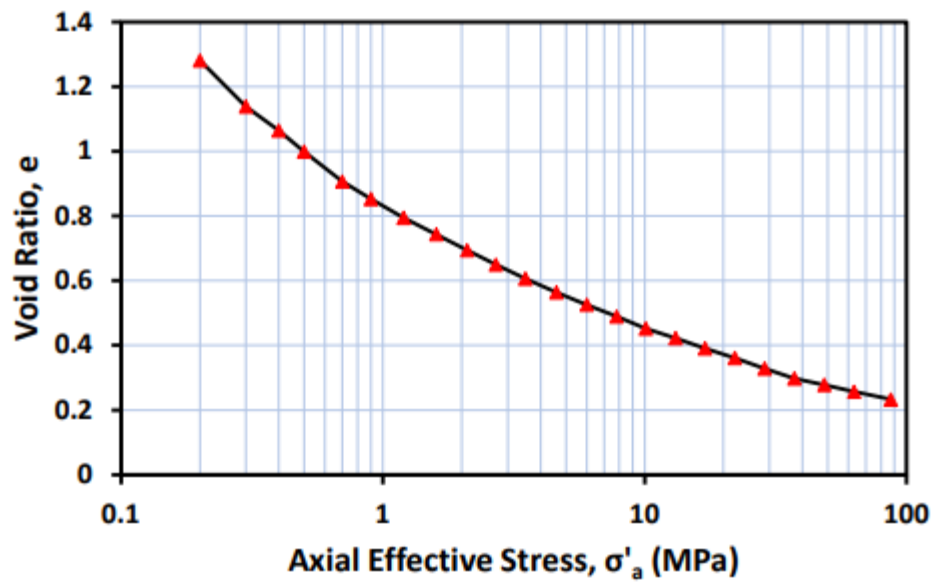


Figure 2-6 Average Uniaxial Compression Curve of RGoM-EI courtesy of Emre Uyeturk shown by (Doran 2023).

## **Chapter 3 - Materials and Specimen Preparation**

### **3.1 Introduction**

This chapter provides the reader with information on how the test material was obtained and how it was processed thereafter. The deep-sea drilling equipment used as part of the expedition is described. The materials were initially processed on the drilling ship into 1-meter length sections and short sections for chemical, biological, and mechanical analysis. The samples were further processed at a Salt Lake City (SLC) facility, and finally at Tufts University. The procedures and protocols followed at each location are described in detail in this chapter. The cores obtained from the expedition are broken down into whole round (WR) cores and split core (SC) plugs as part of these procedures. The WR cores and SC plugs are central to this research. A log of WR samples is presented in Table 3-2. Resedimented samples are also created as part of this project, with the procedures and potential issues detailed in this chapter.

### **3.2 Drilling Equipment**

Geotek Coring Tools provided two different types of samplers for the coring expedition. The G-APC coring tool shown in Figure 3-1 was used to recover samples in the first 300 mbsf. The tool was designed for high-resolution sampling under the sea floor. It is a wireline retrievable hydraulically actuated piston core designed to recover relatively undisturbed continuous 6.7cm length 9.5m long oriented core samples from very soft to moderately firm sediments. Using the coring wireline, the G-APC coring tool runs to the bottom of the drill string. Pump pressure is applied to the drill pipe, which severs the shear pins and hydraulically fires the inner core barrel 9.5 m into the sediment. The core barrel is lined with a plastic liner to assist in removal and prevent damage to the core. A full-closing core catcher is located at the bottom of the inner core barrel to assist in retaining the core when the core barrel is retrieved to the drill floor using the wireline.

The G-XCB shown in Figure 3-2 is a wireline retrievable rotary coring system designed to recover 6.7cm diameter x 9.5m long cores in soft to moderately hard sediments. It is typically deployed when the sediment becomes too hard for core recovery using the G-APC. The G-XCB uses an integral cutting shoe to trim the core. The shoe is positioned ahead of the main core bit, which reduces core “washing” (i.e., core damage caused by water jets from the main drill bit nozzles). This improves core recovery and reduces core disturbance in soft to moderately hard formations. A unique retraction device allows the extended cutting shoe on the G-XCB to retract inside the bottom hole assembly to reduce failures when hard formations are encountered. A core barrel swivel allows the core to remain stationary relative to the formation as the bit rotates, thereby reducing the transfer of rotary torque to weakly laminated formations. This reduces “biscuiting” (artificial layering). Figure 3-3 shows the G-APC being deployed at the beginning of the drilling expedition.

### **3.3 Material Processing on ship**

Initial sample processing occurred on the ship. This involved scanning, labeling, and keeping samples in a temperature-controlled environment. One of the main goals of this expedition was to obtain pressure cores in the hydrate-bearing layers. These cores are not of significance to the work conducted in this thesis. This was a very complex part of the expedition, and more details can be found in (Flemings et al., 2024). Some initial testing occurred on board the ship, which is documented in the preliminary report. Figures 3-4 show sample processing on board the ship. The conventional samples were recovered in 9.5 m long sections and cut into roughly 1 m sections for processing and transport. WR sections were also selected and cut on the ship.

### **3.4 Material Processing Salt Lake City**

Some of the samples were shipped to the SLC, Utah facility for further processing after the expedition. The samples were initially CT scanned to assess the integrity of the core. These scans were analyzed before further processing began. The scans highlight the presence of sand, stones, layering, and internal voids or cracks. Pebbles and stones appear as round clear zones, while voids are patches of darkness. Differences in density or layering are displayed as changes in color shade. The CT scans of the cores sent to Tufts University and were central to this research are shown in Figures 3-16 to 3-66.

The 9.5m length samples were cut into 1m shorter sections on the ship and assigned to different institutions for testing. SC samples were retained from the 9.5m sections in SLC. For testing, 53 WR sections and 283 SC plugs were assigned to Tufts University. The procedures for obtaining the SC plugs are detailed in the following section.

#### **3.4.1 Cylindrical Plugs**

Local MAD measurements were made at specific locations (depths) after characterizing the core with the CT scan and splitting it in half at SLC. The cylindrical plugs were acquired by pushing a brass cork cutter through the  $\frac{1}{2}$  section. The plug was cut to a specific length and measured to 0.01 mm using a digital caliper. The diameter was set by the ID of the cutter, which was also measured to 0.01 mm with a digital caliper. The plug was extruded into a marked container of known mass to 0.001 g. The mass of the wet plug and container was recorded to 0.001 g. Plugs acquired during SLC operations were placed in glass containers, massed on-site, and then shipped to Tufts for processing.

### **3.4.2 Whole Round Sections**

After CT scanning at the SLC site, WR sections were cut from the core sections. Each section was up to 20 cm in length. The sections were capped and sealed with electrical tape. The mass of the sealed section was measured to 0.01 g. The section was then sealed in a plastic bag and returned to 4 deg C storage. Sections were shipped to Tufts laboratory in coolers with thermal packs to reduce temperature variations.

### **3.5 Material Processing Tufts University**

MAD plugs were taken at SLC from the section processed at SLC and the WR sections processed at Tufts University. Plugs acquired from the MAD whole rounds at Tufts were placed in aluminum containers, massed, and processed immediately. They were dried at 110 degrees Celsius to constant mass in a forced draft oven, cooled in a desiccator, and massed. Plugs were stored in a 4-degree Celsius refrigerator while waiting for further analysis.

Figure 3-5 illustrates the testing process for WR samples sent to Tufts University, the engineering value measured, and the samples retained for future CRS testing. The 283 SC plugs were stored in a temperature-controlled environment at Tufts University until testing. MAD measurements were made on three types of specimens, cylindrical plugs removed from SC sections, cylindrical WR sections, and trimmed mechanical test specimens. Moisture (water content) and wet density determinations require measurements of the wet mass, the wet volume, and the oven-dry mass. Mass measurements are straightforward, but volume determination can be challenging depending on the material's stiffness. This leads to the use of several methods for volume determination. The first method is to measure the physical dimensions of the specimen Method (A), which only applies to regular shaped specimens. The second method (B) is to additionally measure the grain density

and the salt content of the pore fluid. The volume is calculated based on the assumption of 100% saturation. Method B is more applicable for soft and swelling materials.

The WR sections were assessed at Tufts to evaluate integrity, confirm lithology, and identify the potential value for mechanical testing. Before processing the WR section, a 5 cm in-length sample was retained from each 20 cm sample. The 5 cm sample was used for CRS testing. The processing procedure is detailed in the following section. Figures 3-67 to 3-113 show the samples being processed in Tufts Laboratory. Many of the samples have interesting features such as the burrow holes seen in Figure 3-74. Figure 3-70 also has some very unusual features.

### **3.5.1 Whole Round Processing Protocol**

- Verification of pre-shipping mass.
  - Remove the plastic bag
  - Measure the mass of the sample with caps
- If applicable, cut section for CRS compression sample and label tube section, seal, and store in refrigerator at 4 degrees C for future testing.
- The average density of the sediment ( $\rho_t$ )
  - Remove caps and square ends
  - Measure the mass of the section tube and sediment (nearest 0.01 g)
  - Measure the length of sediment in the tube (nearest 0.01 mm)
  - Measure the length of the tube (nearest 0.01)
- Extrude sample keeping track of the direction of x-ray and orientation (top)
- Split in half lengthwise using a wire saw or knife depending on sediment stiffness
- Use one-half of the section to obtain the University New Hampshire (UNH) subsample
  - See the illustration (Figure 3-6) to obtain section C from the middle of the tube

- Place half #1 core with flat side down
  - Make two vertical cuts to obtain a center slice (B & C) that is about 1 cm thick
  - Using the center slice, make one cut to obtain a 1 cm slice (C) from the center edge, which is the length of the section
  - Transfer this rectangular section to the plastic U channel with the incoming X-ray direction on top
  - Label the shallow end (top) on the U channel
  - Wrap in plastic, seal in zip-lock bag, label, and refrigerate
- Use the half #2 to obtain a MAD plug
- Place the core with the flat side down
  - Pick a clay-rich section of the sample
  - Use the cork corer to cut a plug (G) through the section
  - Extrude about 2 cm and cut with a wire saw
  - Measure the plug length to 0.01 mm
  - Transfer to an aluminum container of known mass to 0.001 g.
  - Measure the wet mass and oven dry to get water content
- Use a slice of the half #2 to obtain the average water content
- Cut a pie-shaped slice (F) about 15 degrees the length of the section
  - Transfer to an aluminum container of known mass to the nearest 0.01 g
  - Use this material to measure the average water content of the section
- Combine all the remaining material (A, B, D, and E) and blend this on a glass plate
- Acquire a representative sample of about 50 g and measure the water content

- Transfer all the unused blended material from the section to a storage container and label
- Store in 4 degree C refrigerator

Figure 3-7 shows a sample undergoing the processing procedure in the lab. The blended material is then stored in a temperature-controlled environment, as shown in Figure 3-8.

### **3.6 Resedimentation**

This section explains the process of resedimentation as it relates to this research. This is the first time the same local material has been resedimented, and the results are compared to the intact behavior. All resedimented test specimens used in this research were produced through this process. Resedimentation refers to the one-dimensional consolidation of a dilute slurry of clay material in a rigid-walled cylindrical container, also known as a consolidometer. Early techniques of resedimentation were developed and performed on Boston Blue Clay (BBC) at Massachusetts Institute of Technology (MIT) by (Ladd and Varallvay, 1965). (Abdulhadi, 2009) made significant changes to the resedimentation process by preparing individual resedimented samples for each separate test specimen. This approach reduced the cross-sectional area of the consolidometer, substantially reducing the load that must be applied to consolidate the specimen to a particular pre-consolidation stress. Resedimentation enables one to produce samples of identical composition from a given source material, free from the blemishes found in individual intact samples. It is advantageous, as samples can be formed with any desired preconsolidation stress, porosity, or pore fluid salt concentration. This enables an individual to separate out each of these important variables and subject a given material to systematic laboratory investigations. This process would not be possible with the use of intact samples. More importantly, resedimenting soil samples for laboratory testing overcomes the practical problems of sampling disturbance and, more

economically, reduces the cost associated with intact samples. The resedimentation process has evolved and improved over time, and the steps followed for this research are similar to those of (Hanley, 2017) who divides the process into four main steps: powdering, deposition, consolidation, followed by sample extrusion, and preparation.

In this research, the powdering step is eliminated. The material is fine-grained, uniform, and has a known water content. More water is added to mix the water content to 110%. The air is removed from the slurry, deposited into the tube, and consolidated to 0.2 MPa. When the material has been consolidated, it is extruded and trimmed to the dimensions of a test specimen. Researchers have recently altered the resedimentation process for specific project requirements. Details of these variations can be found in (Jones, 2010), (Grennan, 2010), (Kontopoulos, 2012), (Casey, 2014) and (Hanley, 2017).

Table 3-1 details the resedimented samples created for this research. The samples with the intended use of CRS testing are created from the trimmings of the 5 cm engineering sample. The triaxial samples are created from the blended material.

### **3.6.1 Mixing and Deposition**

An Excel spreadsheet is used to quantify the additional water and salt that must be added to make the desired sample. The samples are batched at 35 g/l water as per the in-situ conditions. The final volume, final void ratio, batching water content, and salt concentration must be considered when creating samples. Sea salt is used in the mixture to increase concentration. The spreadsheet also has a factor of safety parameter that accounts for slurry lost throughout the mixing process. The samples are thoroughly mixed after the water has been added to the mixture. This process produces a homogenous slurry of a required pore fluid salt concentration without lumps. The mixing water content is generally taken to be approximately equal to twice the liquid limit of the soil. This

usually results in a workable yet stable slurry without free surface water. After mixing, the slurry is left to hydrate over a period of at least 24 hours. Following hydration, the slurry is remixed, placed in a sealed container, and exposed to negative pressure (under  $> 25$  inches Hg) using a vacuum. This process removes any entrapped air that may be present in the mixture, as seen in Figure 3-9.

(Hanley, 2017) eliminated the tremie funnel method of transferring the de-aired slurry into the consolidometer used by previous researchers. His method involved placing the de-aired material into a funnel with the suction gun securely sealed to the spout, which was very efficient, as seen in Figure 3-10. The material is then drawn into the gun under negative pressure and is forced out under pressure into the consolidometer. This method was much more successful, as it produced samples with no entrapped air that had a lower water content and hence would take less time to consolidate, and it also had a lower loss factor of slurry.

### **3.6.2 Consolidation**

The material is deposited into the 35 mm diameter consolidometer, as described in the previous section. A porous stone and nylon filter is placed at the base of the consolidometer. The same is replicated at the top after slurry deposition. The nylon filter fabric is a barrier that prevents small clay particles from entering and clogging the pores in the porous stones. The sample can drain at the top and bottom as a floating tube configuration allows two-way drainage. The sample is loaded incrementally until the desired stress is achieved, as Figure 3-11 shows. It is standard practice to double the load at each increment. The resedimented sample is given additional time for at least one cycle of secondary compression before being rebounded to  $OCR = 4$ , using a single unload increment. At  $OCR = 4$ , the clay is assumed to be close to isotropic effective stress conditions. This minimizes the shear strains associated with sample extrusion from the consolidometer.

### **3.6.3 Extrusion**

After the consolidation stage, the sample is extruded from the consolidometer and prepared for either CRS or triaxial testing, as seen in Figure 3-12. Samples resedimented to below approximately 1 MPa (low stress) can be extruded manually from the consolidometer with moderate effort, as was the case for this research. These samples are subsequently trimmed to the required diameter for testing using the combination of a soil sample trimmer stand, a wire saw, a confining ring, and a specimen mold. A recess tool is also used to extrude the sample further. The last trimming portion is performed with a razor blade to achieve high-quality samples of identical volume. The razor blade is moved across the top and bottom of the confining ring, removing any excess material from the top and bottom of the sample.

Samples resedimented to higher stresses typically require a hydraulic jack for extrusion. It is also normal practice to resediment samples to the desired diameter for testing to eliminate the trimming phase. This is advantageous as it can be difficult to trim consolidated samples to very high stresses. This method is often used when resedimenting samples for triaxial testing. (Germaine, 2009) describes sample preparation in detail, which is also detailed in Section 5.6.4.

### **3.6.4 Resedimented vs intact specimen.**

This project posed a unique opportunity to compare the compressive behavior of intact samples versus samples resedimented from the trimmings of those exact intact samples. This offered an opportunity to directly evaluate the concept of resedimentation. The 5cm WR sample was used for this process. The sample was initially used to conduct 2 separate CRS tests. The trimmings were retained and resedimented to create 2 resedimented samples. Some researchers have expressed concerns about the results obtained from resedimented samples. These concerns arise as resedimentation removes the in situ fabric created during the initial deposition. (Skempton and

Jones, 1944) first highlighted this as a potential concern. When the sediment is experimentally compressed it may not accurately reflect the fabric of the original sediment column.

Another concern arises from the fact that loading and strain occur over a relatively short period (Days to weeks) in the lab. This is unlike what happens in the field, as the same strain and loading may occur over millions of years. (Betts, 2014) proposes two effects of strain rate. The first is that the inter-particle bonding imparts strength to an open fabric of clay that resists low strain rates but is overcome by high strain rates. This hypothesis was derived from the work of (Skempton and Jones, 1944) and (Burland, 1990). The second strain rate effect is that very low strain rates allow secondary compression to occur along with primary compression, which may result in lower porosities and greater strains at a given effective stress, which was derived from the work of (Karig and Ask, 2003). The results of previous research differ greatly (Burland, 1990) found that field sediments tended to support about five times as much effective stress as reconstituted specimens at the same porosity, with the curves starting to converge above 10 MPa. (Karig and Ask, 2003) found that resedimented sediments produced a compression curve with the same slope as the intact material but about 6 porosity units higher.

(Betts, 2014) concluded that the compression curves obtained from intact core samples resemble that of the resedimented material in both local slope ( $C_c$ ) and absolute value, suggesting that compression behavior for RGoM-EI is like that occurring in the field

Table 3-1 Resedimentation Log

| Resedimentation Log |              |                       |     |             |                    |              |
|---------------------|--------------|-----------------------|-----|-------------|--------------------|--------------|
| Number              |              | Section Location (cm) |     | Comp. Depth | Source             | Intended Use |
| Resed               | Core Section | Top                   | Bot | (MBSF)      |                    |              |
| RS811               | H003-02H-6b  | 115                   | 120 | 14.74       | Engineering Sample | CRS          |
| RS809               | H003-06H-2b  | 90                    | 95  | 33.55       | Engineering Sample | CRS          |
| RS808               | H003-09H-2b1 | 31                    | 36  | 51.27       | Engineering Sample | CRS          |
| RS812               | H003-12H-2b  | 105                   | 110 | 72.41       | Engineering Sample | CRS          |
| RS813               | H003-02H-6b  | 100                   | 115 | 14.74       | Blended Material   | Triaxial     |
| RS805               | H003-06H-2b  | 95                    | 110 | 33.55       | Blended Material   | Triaxial     |
| RS804               | H003-09H-2b1 | 36                    | 51  | 51.27       | Blended Material   | Triaxial     |
| RS806               | H003-12H-2b  | 90                    | 105 | 72.41       | Blended Material   | Triaxial     |
| RS807               | H003-18H-2b1 | 70                    | 85  | 106.44      | Blended Material   | Triaxial     |
| RS810               | H003-22H-4b  | 90                    | 105 | 135.06      | Blended Material   | Triaxial     |

Table 3-2 Whole round core section log of samples sent to Tufts

| <b>Whole Round Cores Section Log</b> |                 |                    |                       |              |                 |                    |                       |
|--------------------------------------|-----------------|--------------------|-----------------------|--------------|-----------------|--------------------|-----------------------|
| Location                             |                 |                    | Mid<br>Comp.<br>Depth | Location     |                 |                    | Mid<br>Comp.<br>Depth |
| Core Section                         | Top<br>Location | Bottom<br>Location |                       | Core Section | Top<br>Location | Bottom<br>Location |                       |
|                                      | (cm)            | (cm)               | (MBSF)                |              | (cm)            | (cm)               | (MBSF)                |
|                                      |                 |                    |                       |              |                 |                    |                       |
| H003-01H-1b                          | 95              | 115                | 1.05                  | H003-11H-1b  | 123             | 143                | 64.71                 |
| H003-01H-2b                          | 95              | 115                | 2.55                  | H003-11H-4b  | 90              | 110                | 68.11                 |
| H003-01H-3b                          | 95              | 115                | 4.05                  | H003-12H-2b  | 90              | 110                | 72.61                 |
| H003-01H-4b                          | 95              | 115                | 5.55                  | H003-12H-5b  | 122             | 142                | 76.28                 |
| H003-01H-5b                          | 81              | 101                | 6.91                  | H003-14H-2b  | 71              | 91                 | 82.68                 |
| H003-02H-1b                          | 100             | 120                | 9.16                  | H003-14H-6b1 | 52              | 72                 | 86.83                 |
| H003-02H-2b                          | 100             | 120                | 10.44                 | H003-16H-1b  | 85              | 110                | 92.20                 |
| H003-02H-3b                          | 100             | 120                | 11.71                 | H003-16H-4b  | 127             | 147                | 96.23                 |
| H003-02H-4b                          | 100             | 120                | 12.98                 | H003-17H-2b1 | 76              | 94                 | 98.98                 |
| H003-02H-5b                          | 100             | 120                | 14.26                 | H003-17H-4b  | 133             | 154                | 101.76                |
| H003-02H-6b                          | 100             | 120                | 15.53                 | H003-18H-2b1 | 70              | 90                 | 106.25                |
| H003-03H-1b                          | 66              | 86                 | 19.23                 | H003-18H-5b  | 90              | 110                | 109.37                |
| H003-03H-2b                          | 90              | 110                | 20.64                 | H003-19CS-5c | 40              | 60                 | 113.50                |
| H003-03H-3b                          | 90              | 110                | 21.89                 | H003-20H-2b  | 117             | 137                | 116.00                |
| H003-03H-4b                          | 90              | 110                | 23.14                 | H003-20H-5b  | 90              | 110                | 119.38                |
| H003-03H-5b                          | 90              | 110                | 24.52                 | H003-21H-3b  | 85              | 107                | 125.11                |
| H003-03H-6b                          | 90              | 110                | 25.77                 | H003-21H-6b  | 74              | 94                 | 128.27                |
| H003-06H-2b                          | 90              | 110                | 33.99                 | H003-22H-2b  | 90              | 110                | 131.74                |
| H003-06H-3b                          | 80              | 100                | 34.93                 | H003-22H-4b  | 90              | 110                | 134.72                |
| H003-06H-6b                          | 90              | 110                | 38.03                 | H003-23H-2b  | 99              | 120                | 139.23                |
| H003-07H-3b1                         | 38              | 58                 | 42.33                 | H003-23H-4b  | 79              | 100                | 141.63                |
| H003-07H-5b1                         | 41              | 61                 | 44.94                 | H003-24CS-5c | 43              | 63                 | 147.06                |
| H003-08CS-3c                         | 58              | 78                 | 48.61                 | H003-25H-7b  | 55              | 75                 | 152.29                |
| H003-09H-2b1                         | 31              | 51                 | 51.18                 | H003-26X-4b  | 77              | 97                 | 282.87                |
| H003-09H-5b                          | 50              | 70                 | 54.60                 | H003-26X-6b  | 57              | 81                 | 285.52                |
| H003-10H-3b1                         | 25              | 45                 | 59.52                 | H003-27CS-4b | 19              | 37                 | 288.86                |
| H003-10H-5b1                         | 48              | 68                 | 61.80                 |              |                 |                    |                       |



Figure 3-1 G-APC Piston Sampler – Used when drilling to depths of 300 mbsf in very soft to moderately firm sediments.

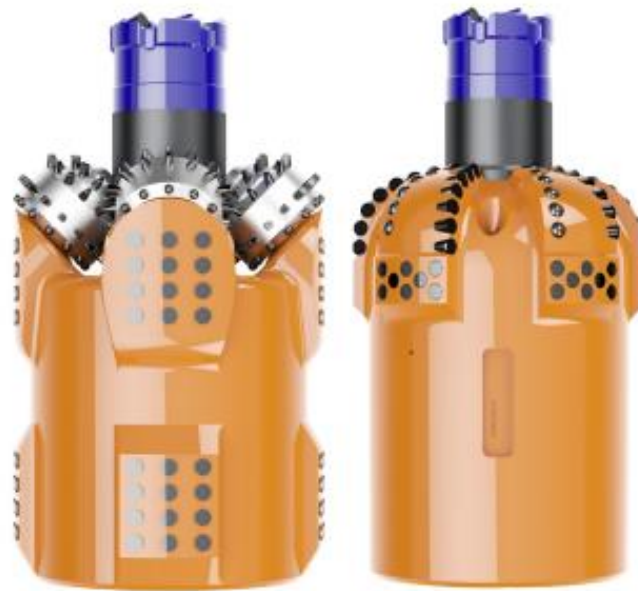


Figure 3-2 G-XCB Rotary Sampler – Used when drilling deeper than 300 mbsf in soft to moderately hard sediments.

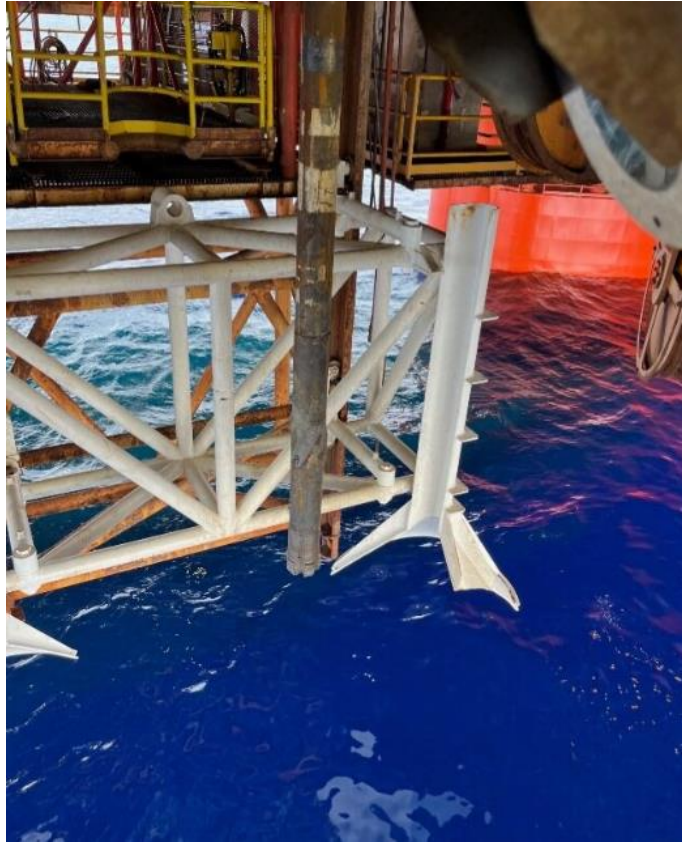


Figure 3-3 G-APC sampler being deployed at the beginning of the expedition during the summer of 2023



Figure 3-4 Initial stage of material processing during the expedition.

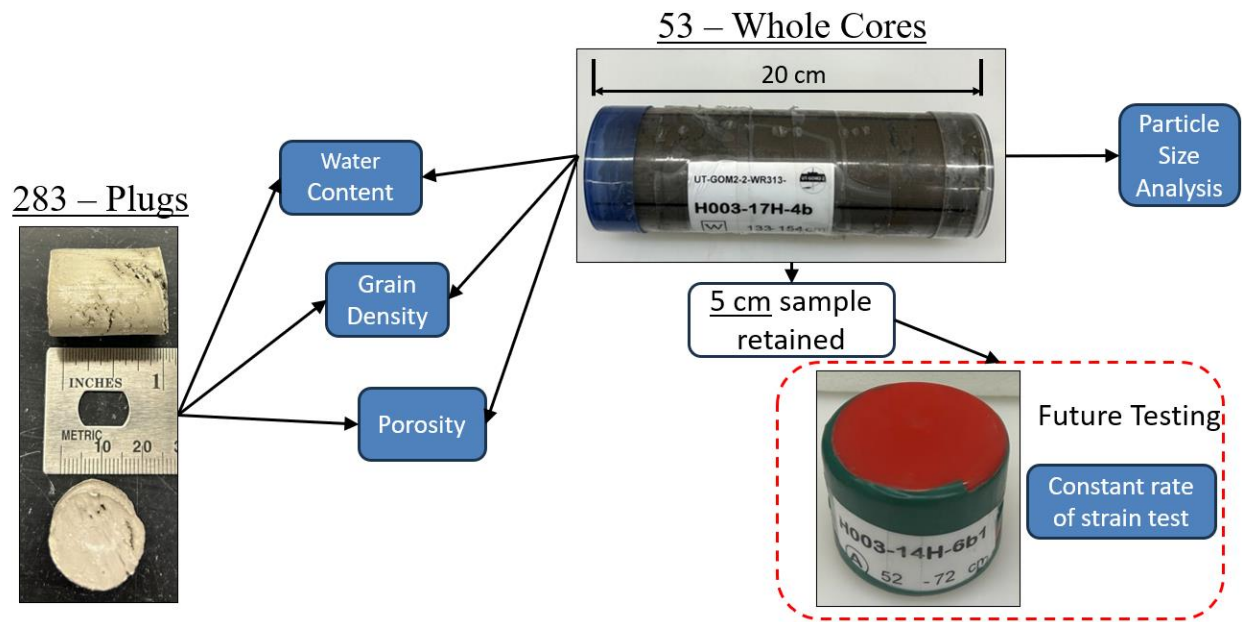


Figure 3-5 Summary of samples sent to Tufts Laboratory and the engineering test intended/parameter to be tested.

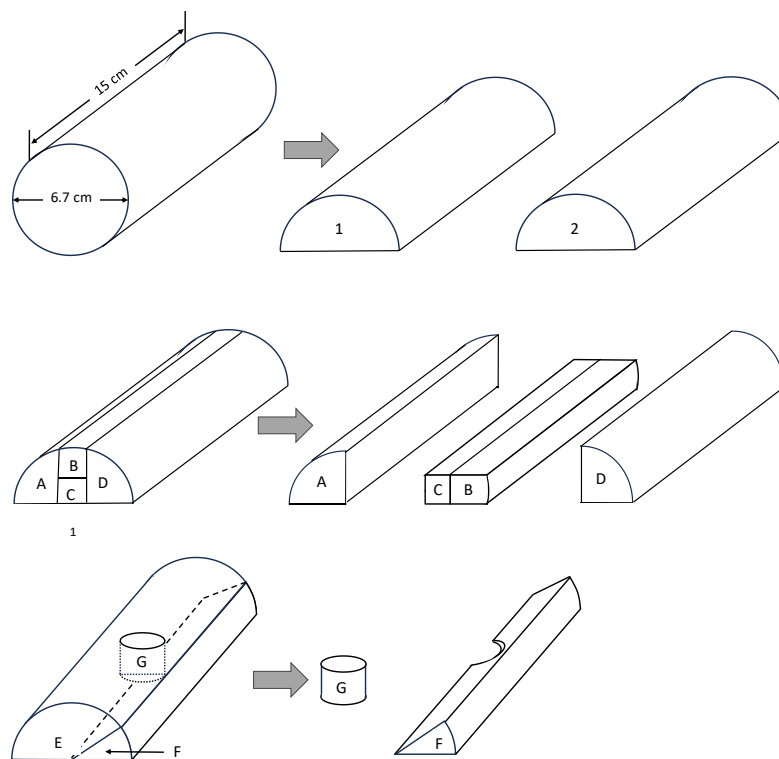


Figure 3-6 - Processing of whole round sections into pieces for individual moisture and density measurements. Sample is split into half 1 and 2. Half 1 is used to extract UNH section C. Half 2 is used to extract MAD plug G and water content slice F.



Figure 3-7 Sample during processing

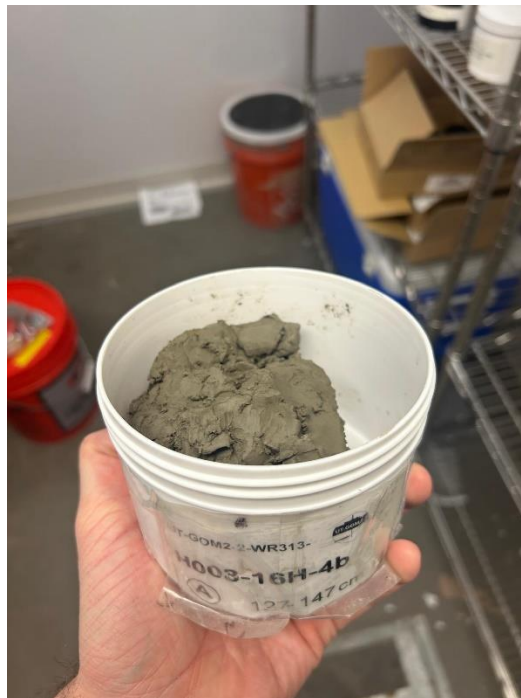


Figure 3-8 Blended material generated from sample processing. Stored at 4°C for future testing.

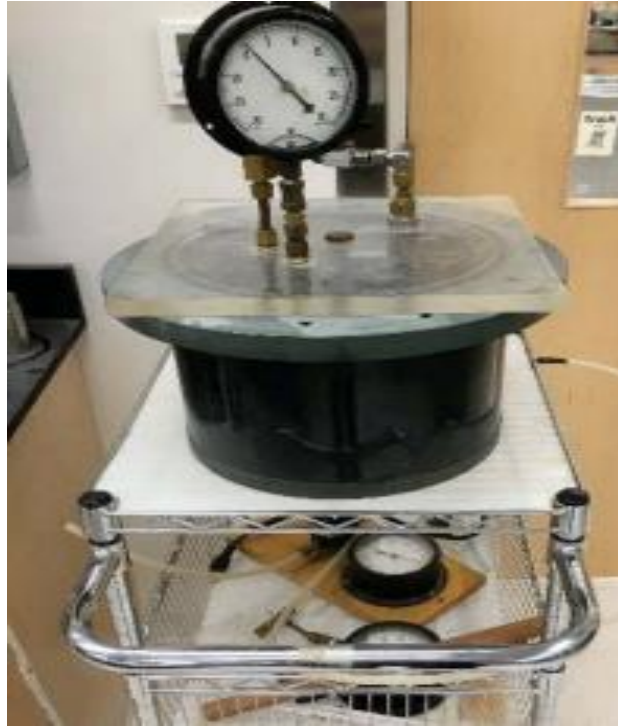


Figure 3-9 De-Airing the slurry mixture to remove any entrapped air before deposition.



Figure 3-10 Deposition suction gun used to tremie the slurry into the consolidometer.



Figure 3-11 Incremental sample loading – Includes consolidometer and axial loading being applied.



Figure 3-12 CRS sample being extruded from consolidometer before the trimming process.

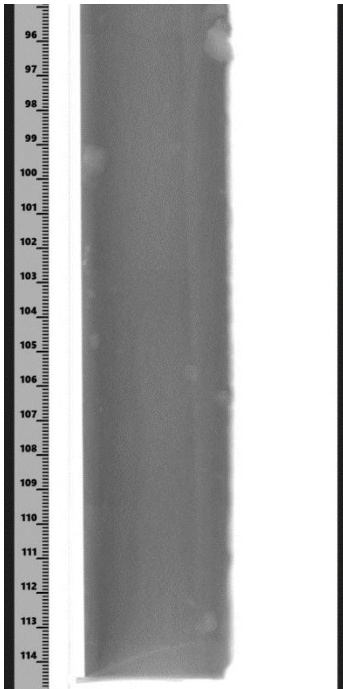


Figure 3-15 CT - H003-1H-1B

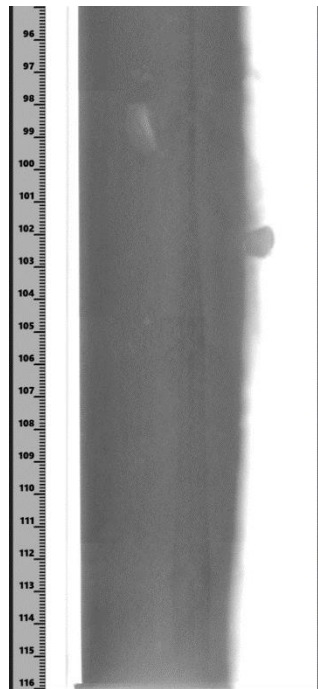


Figure 3-14 CT-H003-1H-2B

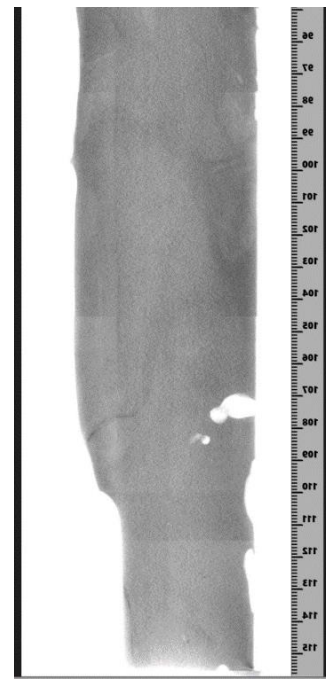


Figure 3-13 CT-H003-1H-3B

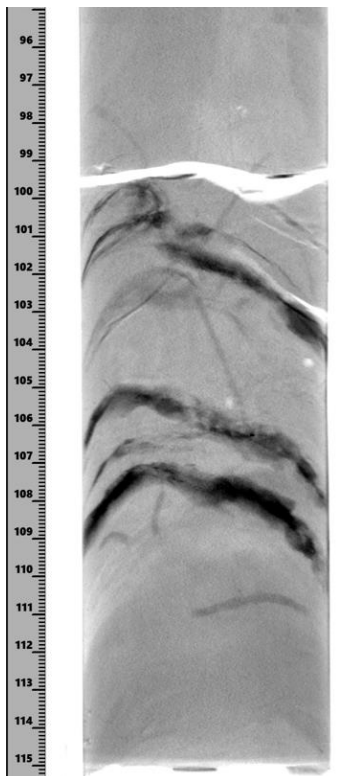


Figure 3-17 CT-H003-1H-4B

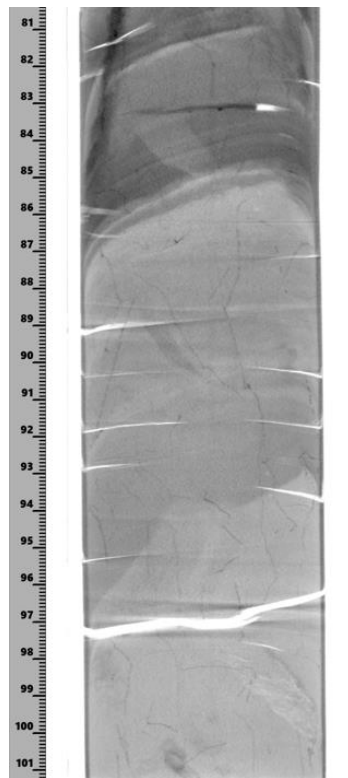


Figure 3-16 CT-H003-1H-5B

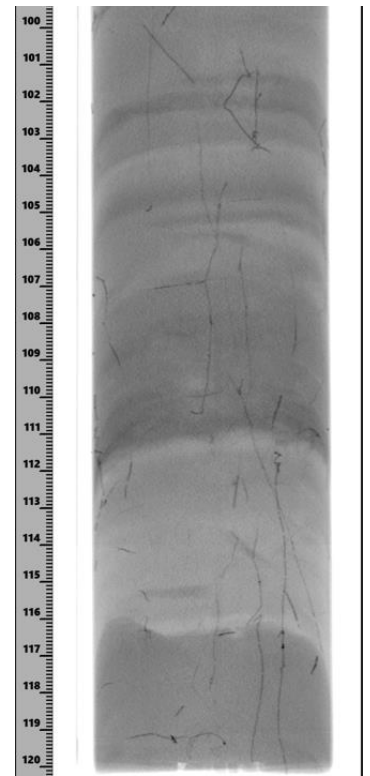


Figure 3-18 CT-H003-2H-1B

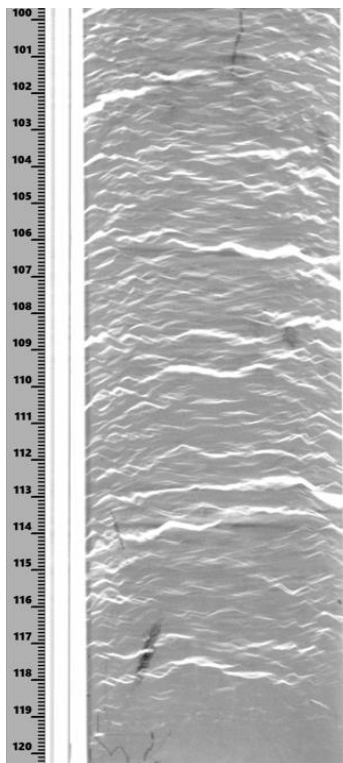


Figure 3-21 CT-H003-2H-4B

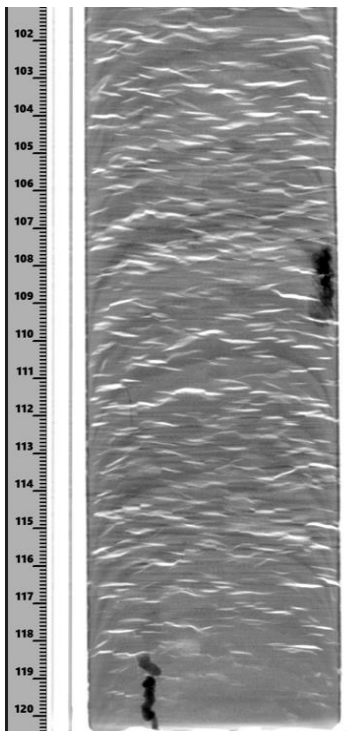


Figure 3-19 CT-H003-2H-3B

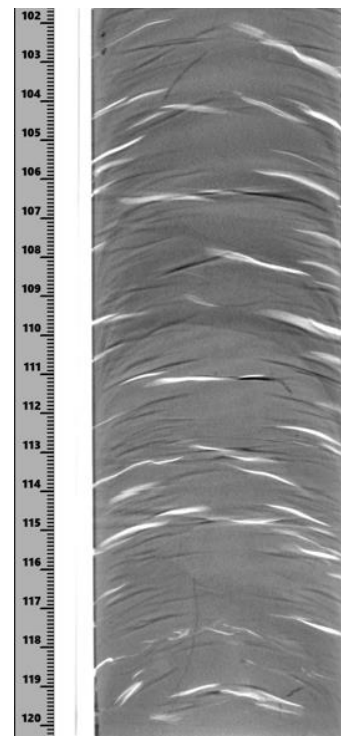


Figure 3-20 CT-H003-2H-2B

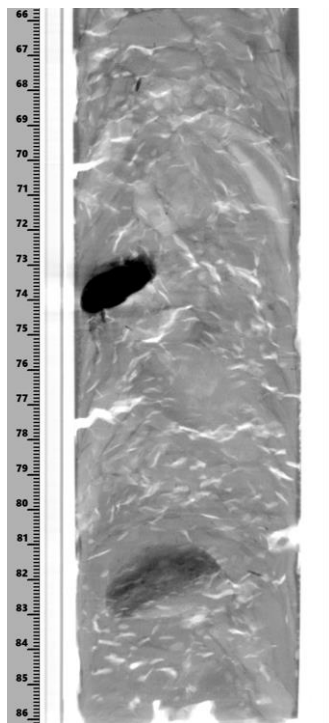


Figure 3-24 CT-H003-3H-1B

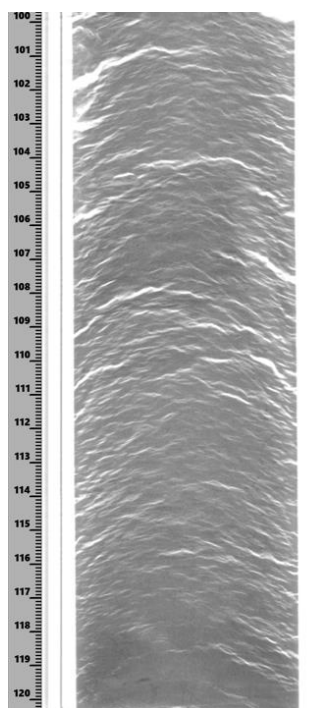


Figure 3-23 CT-H003-2H-6B

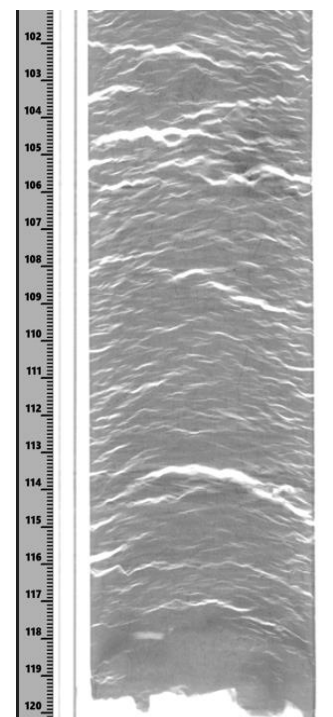


Figure 3-22 CT-H003-2H-5B

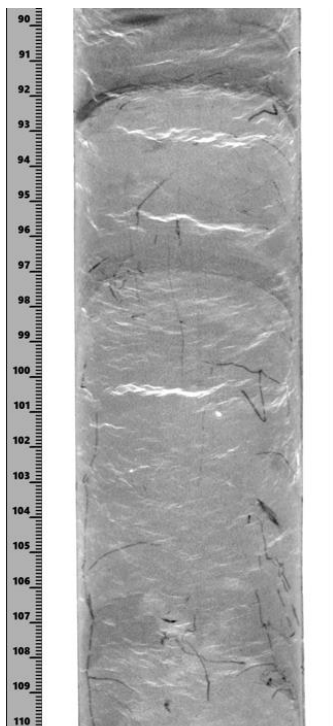


Figure 3-27 CT-H003-3H-2B

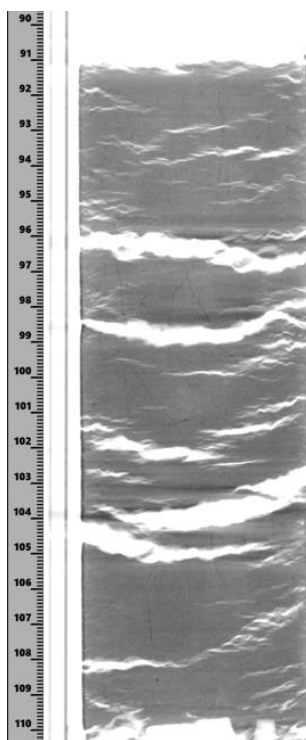


Figure 3-26 CT-H003-3H-3B

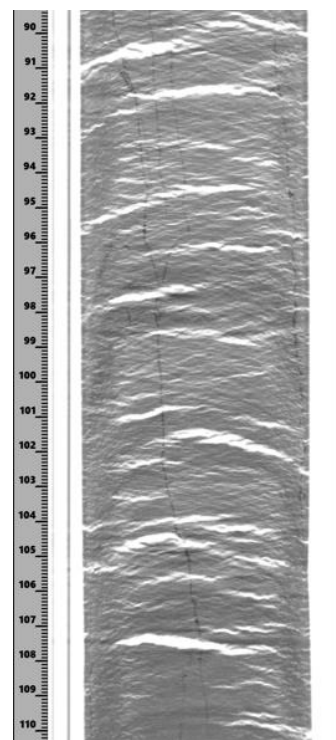


Figure 3-25 CT-H003-3H-4B

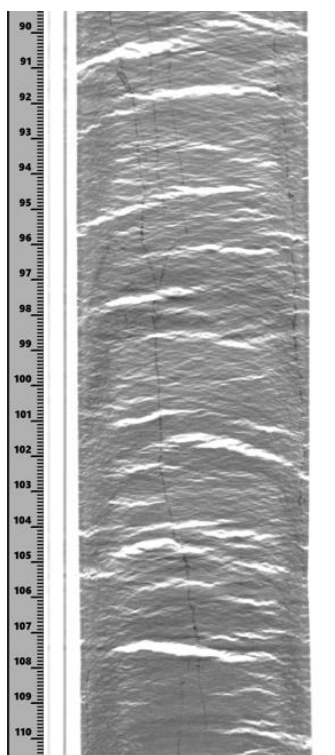


Figure 3-28 CT-H003-3H-5B

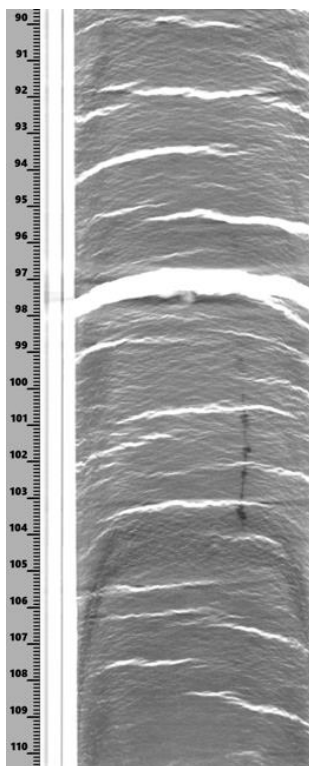


Figure 3-29 CT-H003-3H-6B

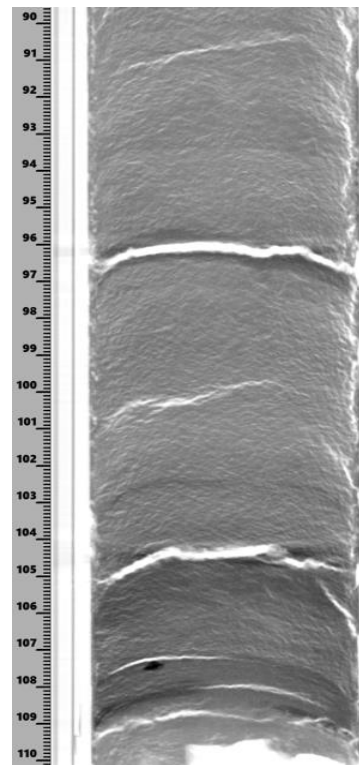


Figure 3-30 CT-H003-6H-2B

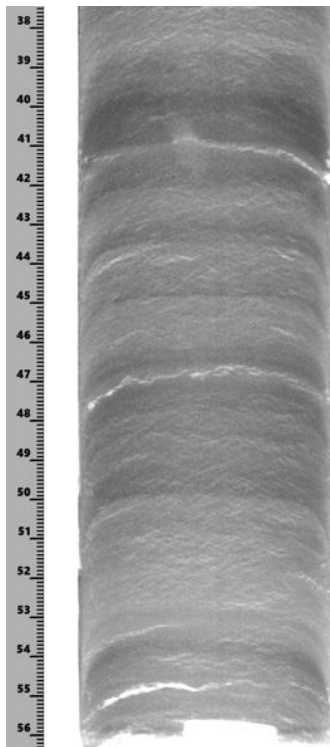


Figure 3-31 CT-H003-7H-3B1

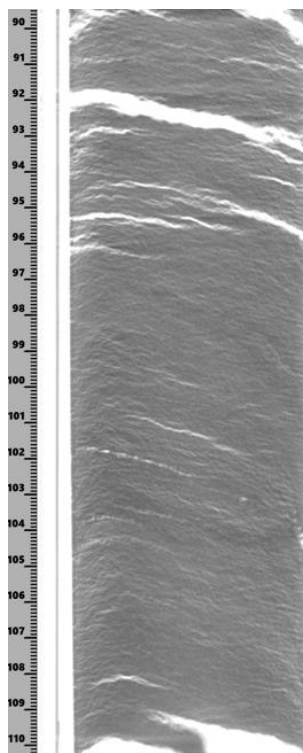


Figure 3-33 CT-H003-6H-6B

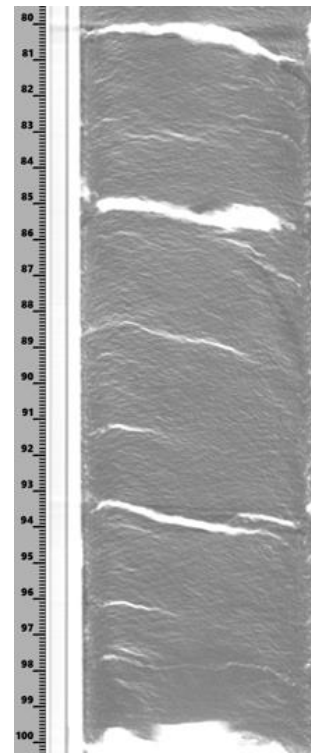


Figure 3-32 CT-H003-6H-3B

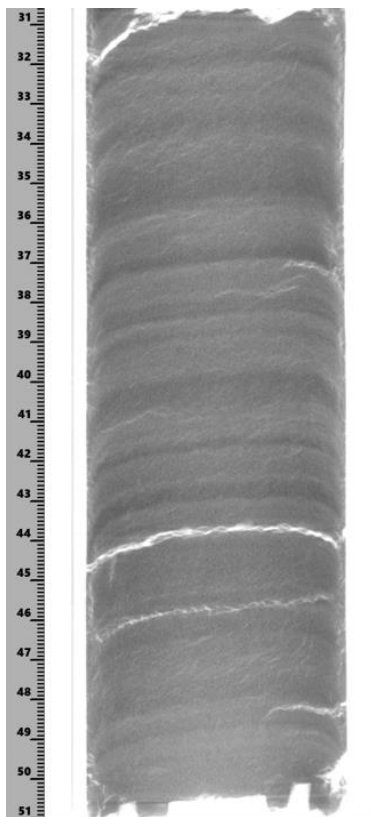


Figure 3-36 CT-H003-9H-2B1

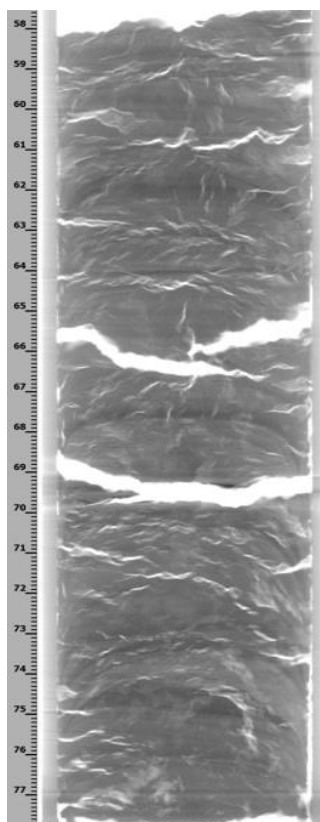


Figure 3-34 CT-H003-8CS-3C

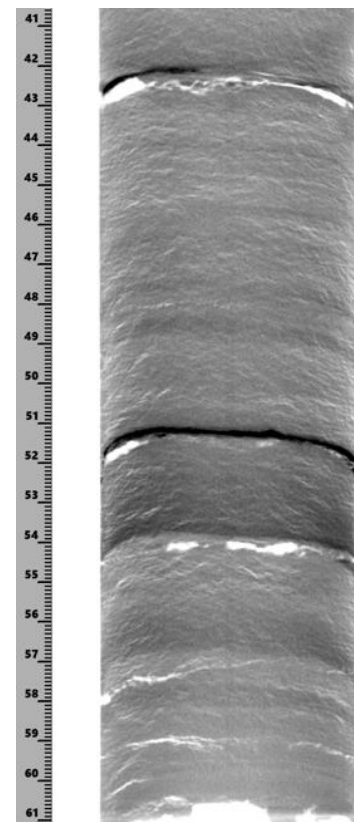


Figure 3-35 CT-H003-7H-5B1

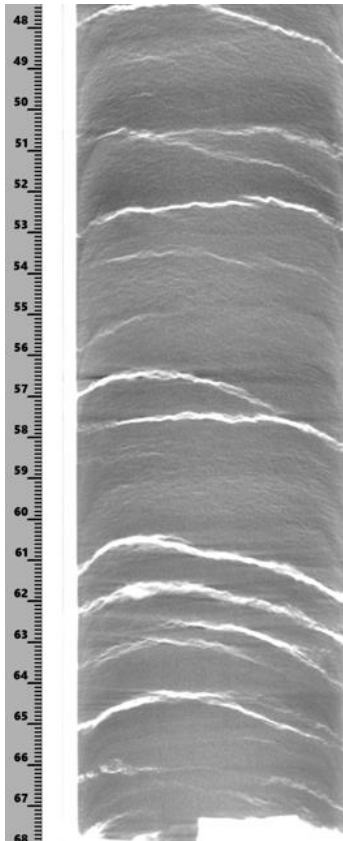


Figure 3-37 CT-H003-10H-5B1

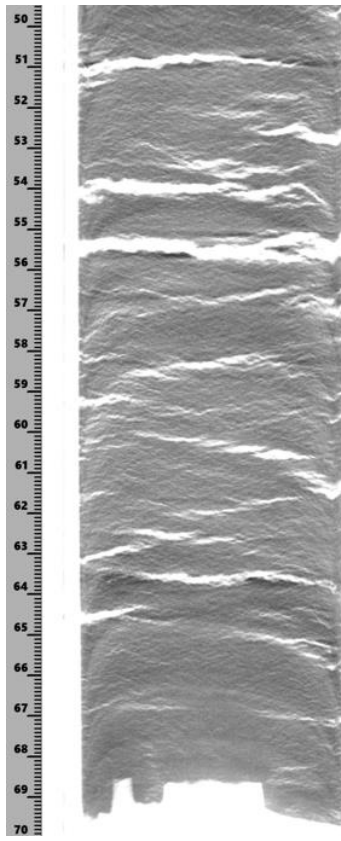


Figure 3-38 CT-H003-9H-5B

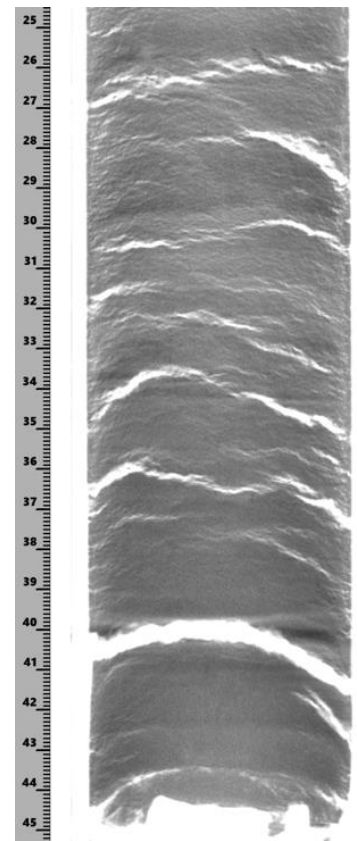


Figure 3-39 CT-H003-10H-3B1

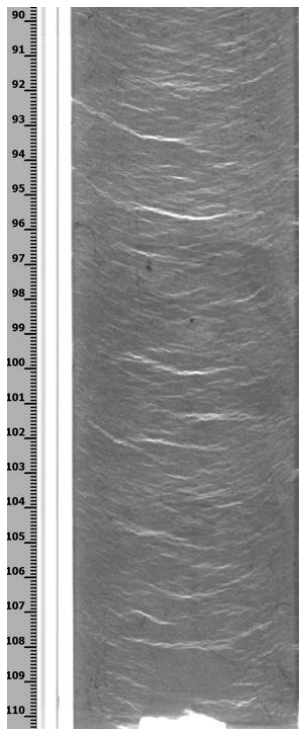


Figure 3-42 CT-H003-12H-2B

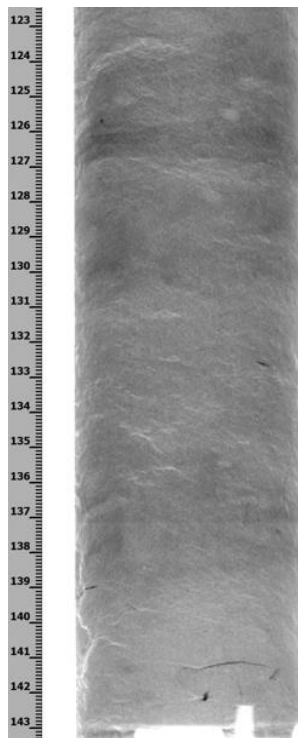


Figure 3-40 CT-H003-11H-1B

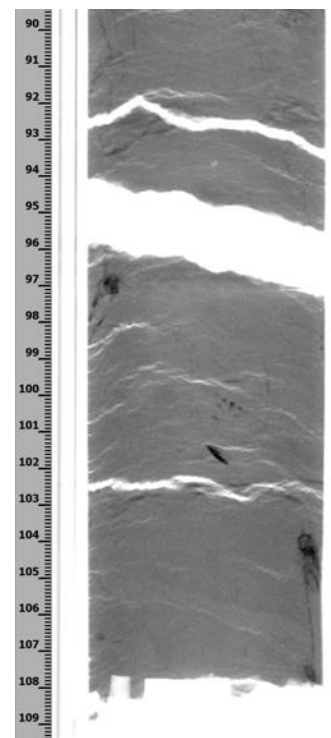


Figure 3-41 CT-H003-11H-4B

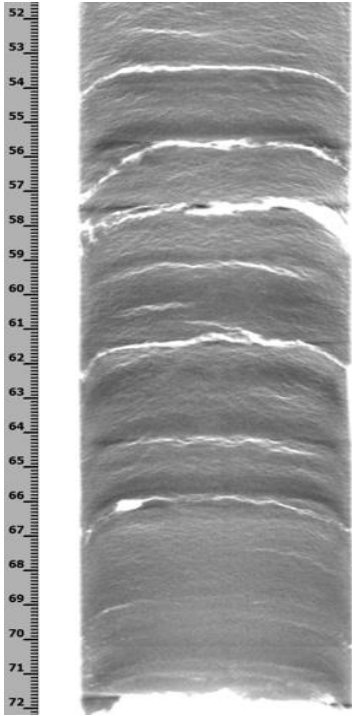


Figure 3-44 CT-H003-14H-6B1

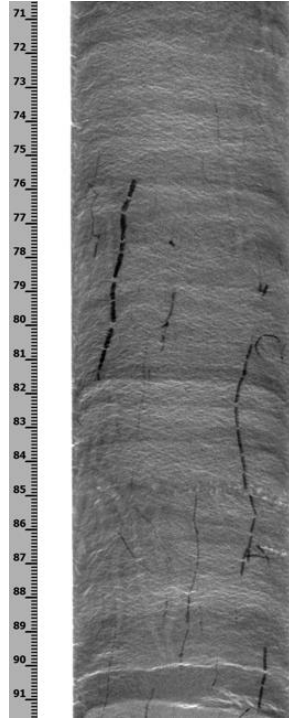


Figure 3-45 CT-H003-14H-2B

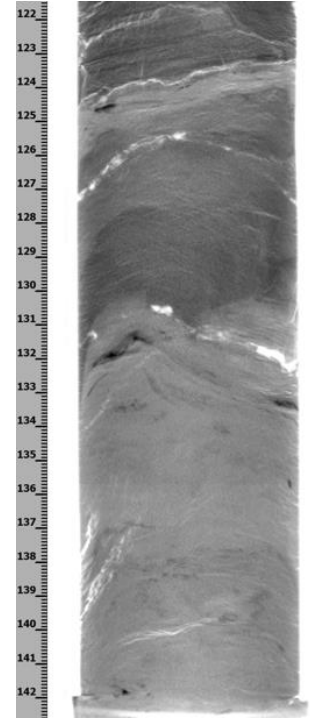


Figure 3-43 CT-H003-12H-5B

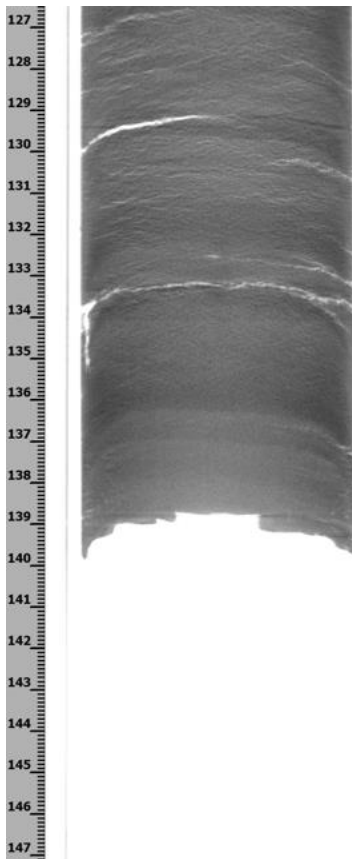


Figure 3-48 CT-H003-16H-4B

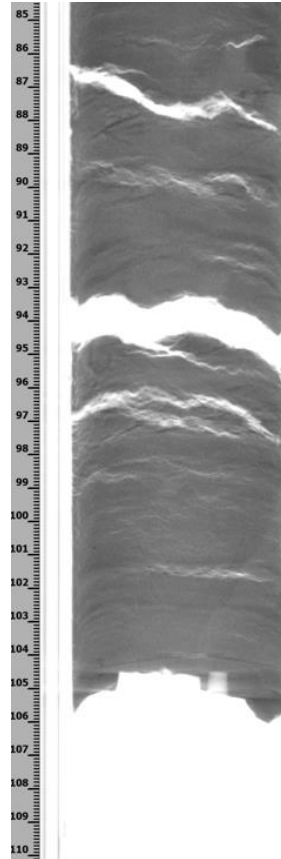


Figure 3-47 CT-H003-16H-1B

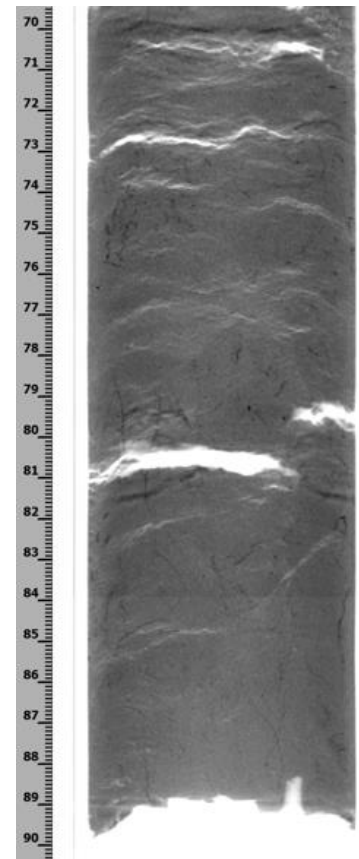


Figure 3-46 CT-H003-18H-2B

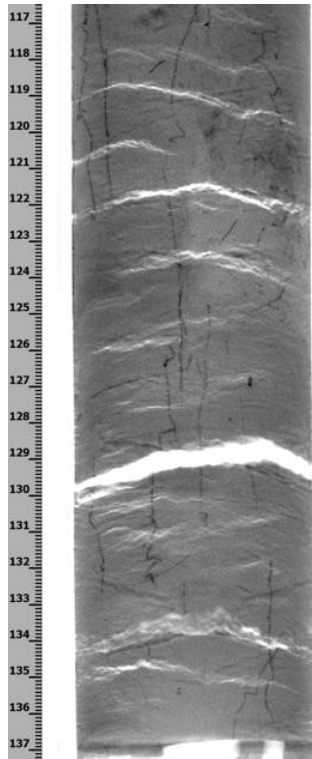


Figure 3-49 CT-H003-20H-2B

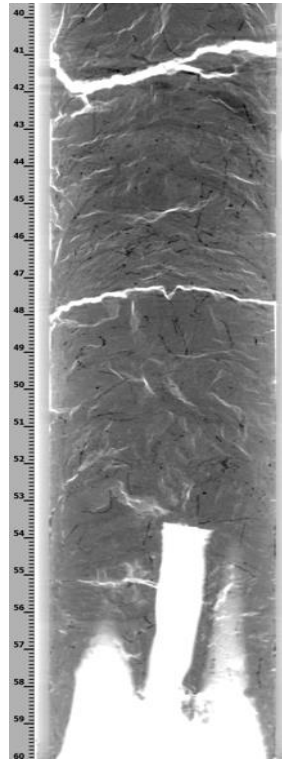


Figure 3-51 CT-H003-19CS-5C

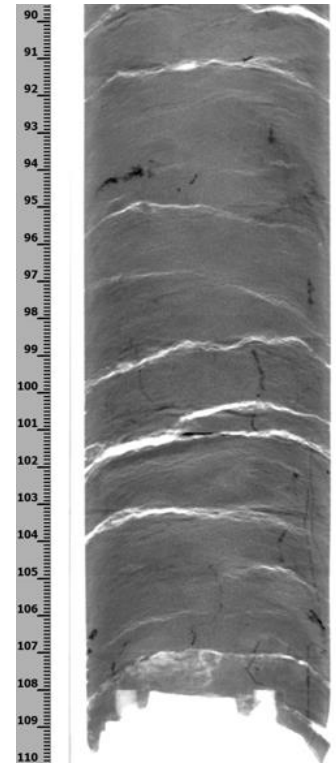


Figure 3-50 CT-H003-18H-5B

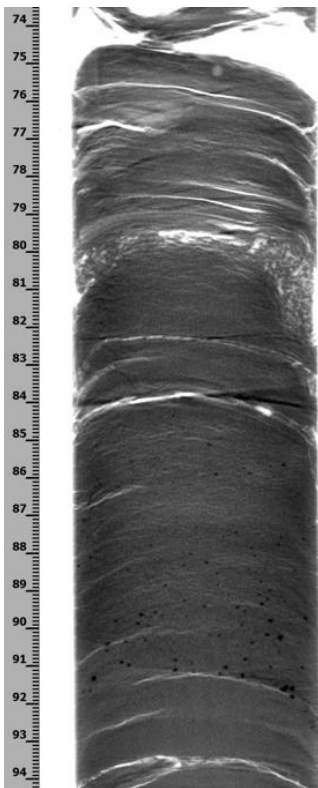


Figure 3-52 CT-H003-21H-6B

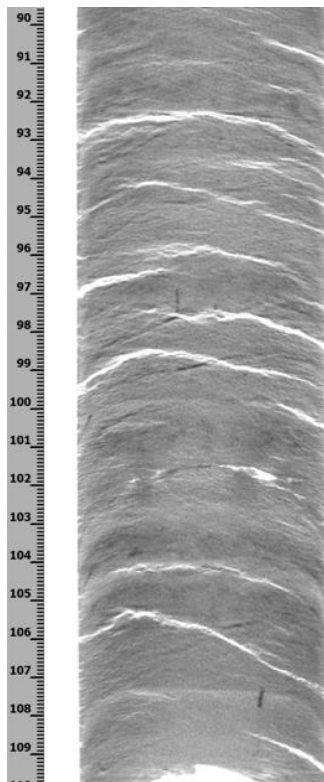


Figure 3-54 CT-H003-20H-5B

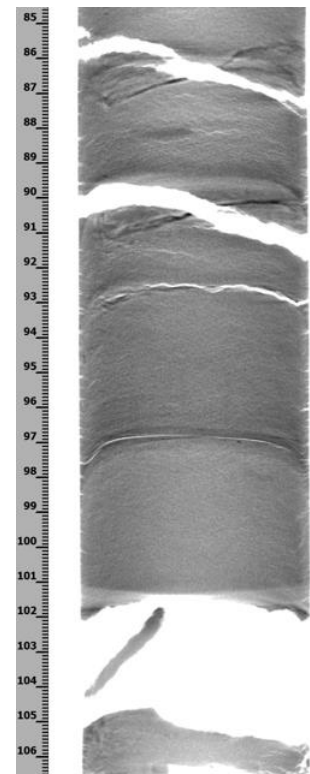


Figure 3-53 CT-H003-21H-3B

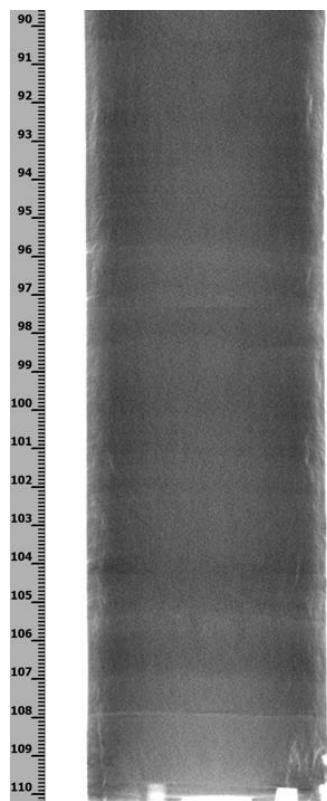


Figure 3-55 CT-H003-22H-4B

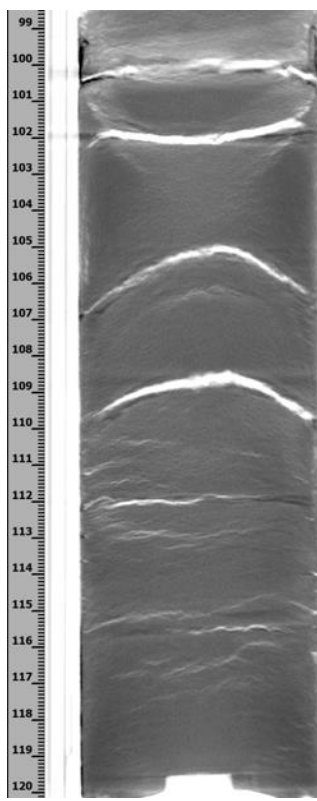


Figure 3-56 CT-H003-23H-2B

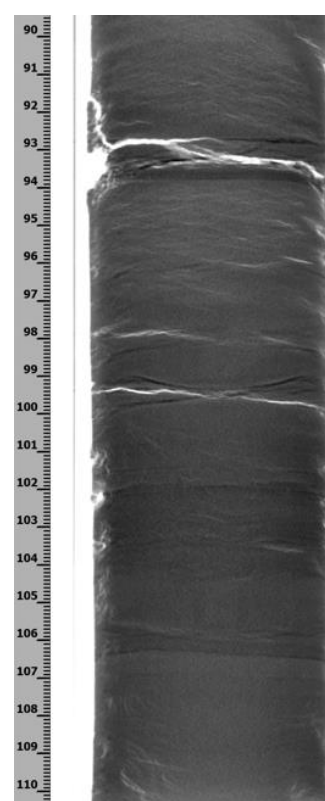


Figure 3-57 CT-H003-22H-2B

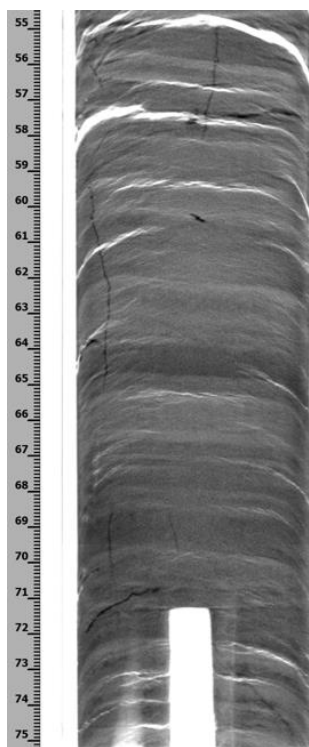


Figure 3-60 CT-H003-25H-7B

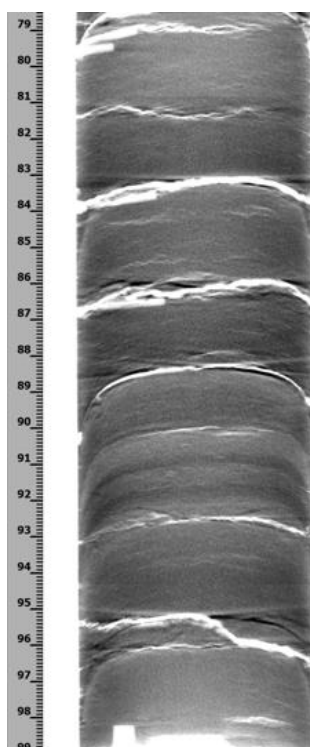


Figure 3-59 CT-H003-23H-4B

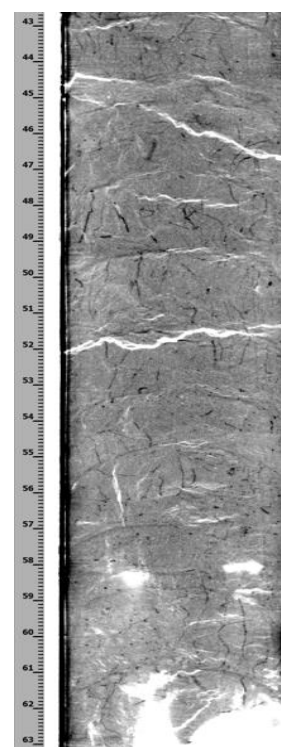


Figure 3-58 CT-H003-24CS-5C

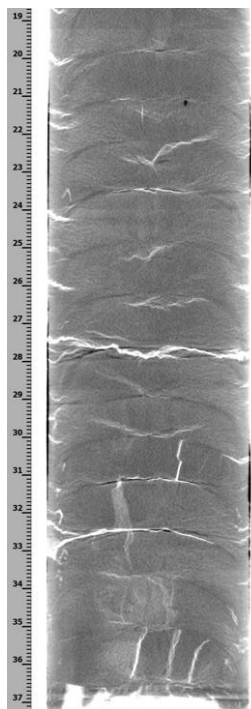


Figure 3-61 CT-H003-27CS-4B

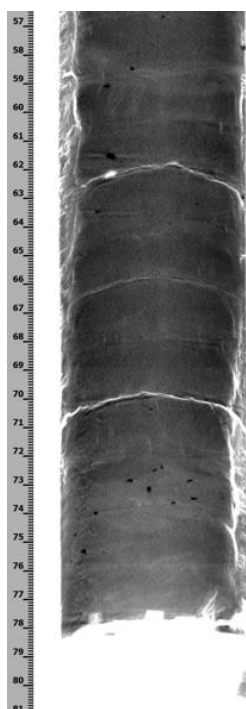


Figure 3-62 CT-H003-26X-6B

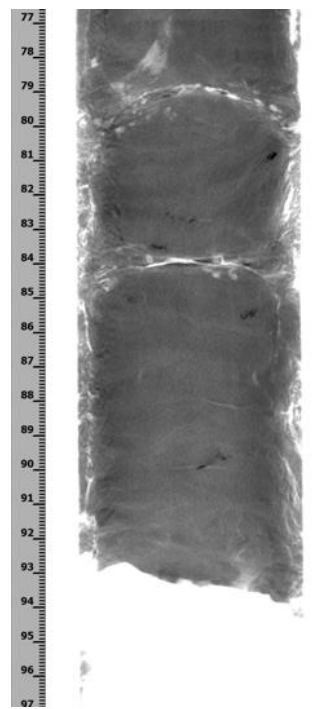


Figure 3-63 CT-H003-26X-4B

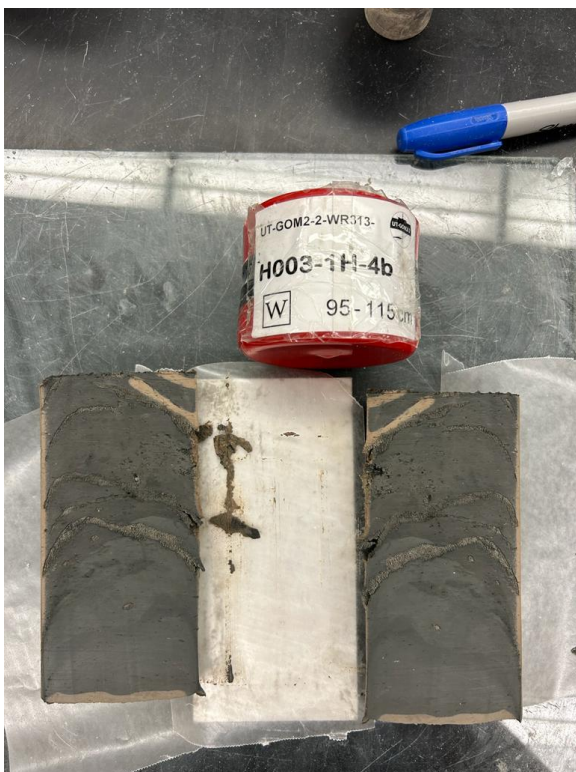


Figure 3-64 - Sample - H003-1H-4B



Figure 3-65 - Sample - H003-1H-5B

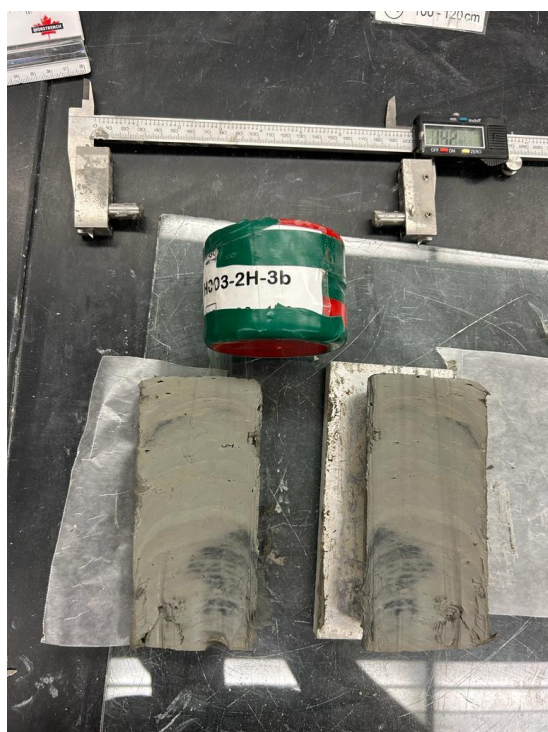


Figure 3-67 - Sample - H003-2H-3B



Figure 3-66 - Sample - H003-2H-1B

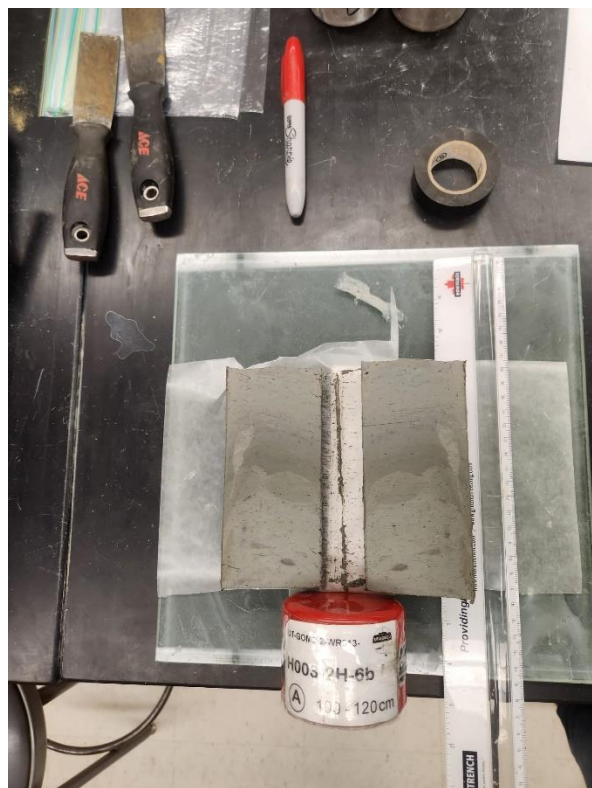


Figure 3-71 - Sample - H003-2H-6B



Figure 3-70 - Sample - H003-3H-1B



Figure 3-68 - Sample - H003-2H-4B



Figure 3-69 - Sample - H003-2H-5B



Figure 3-73 - Sample - H003-3H-2B

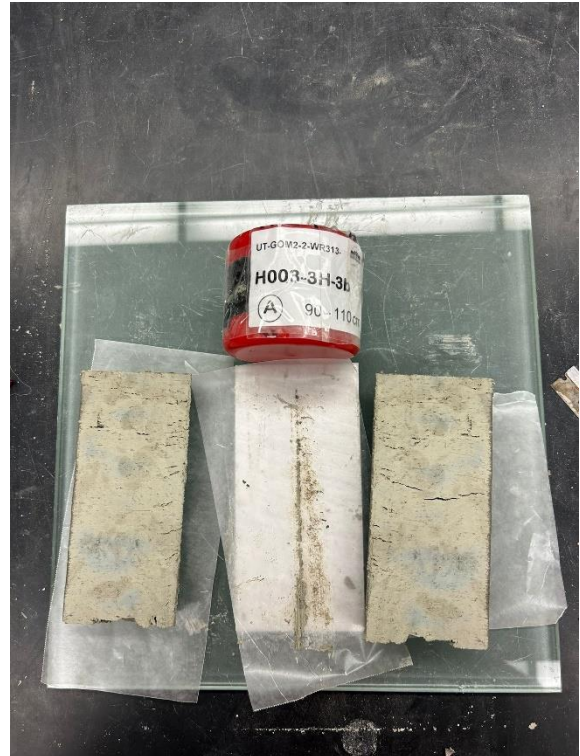


Figure 3-72 - Sample - H003-3H-3B



Figure 3-75 - Sample - H003-3H-5B



Figure 3-74 - Sample - H003-3H-4B

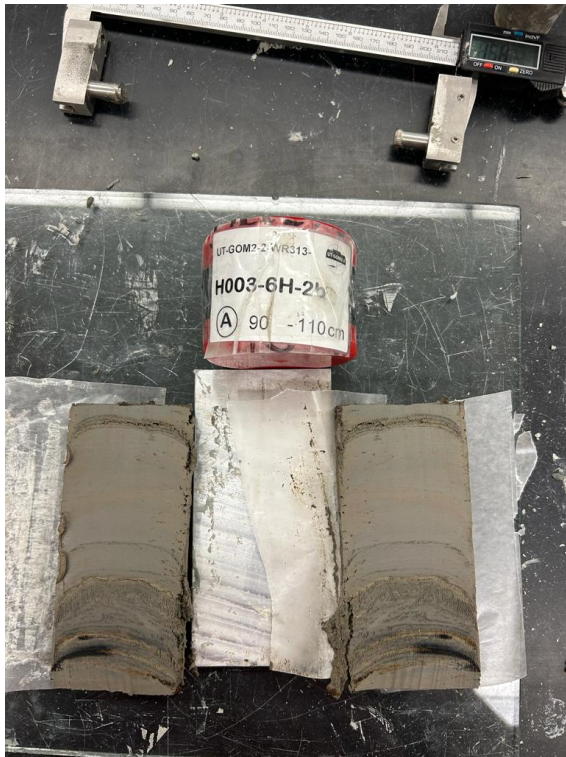


Figure 3-77 - Sample - H003-6H-2B

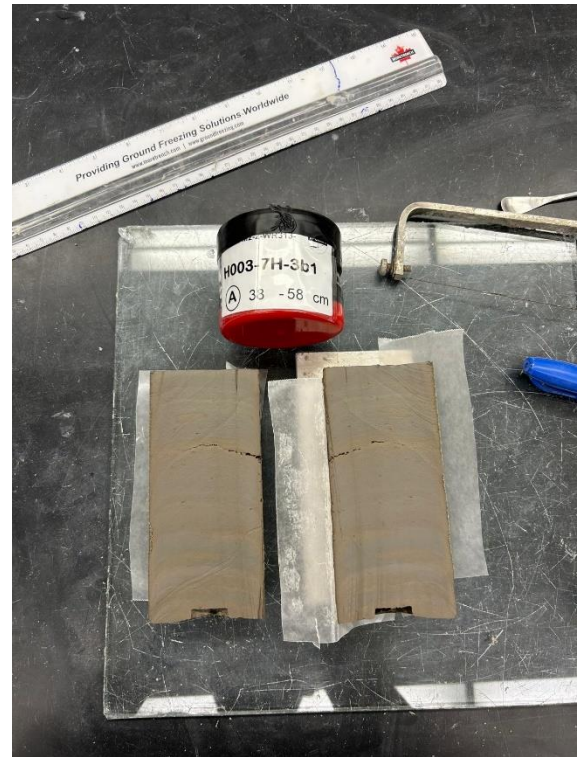


Figure 3-76 - Sample - H003-7H-3B1



Figure 3-79 - Sample - H003-6H-6B



Figure 3-78 - Sample - H003-3H-6B



Figure 3-81 - Sample - H003-7H-5B1



Figure 3-80 - Sample - H003-8CS-3C



Figure 3-83 - Sample - H003-9H-2B1

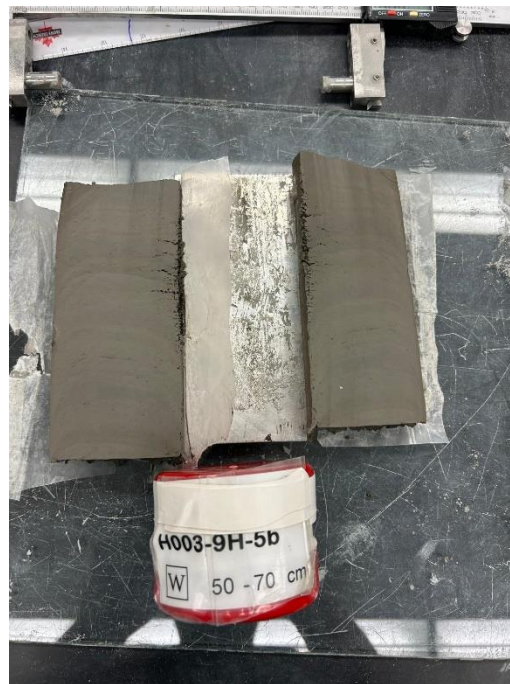


Figure 3-82 - Sample - H003-9H-5B

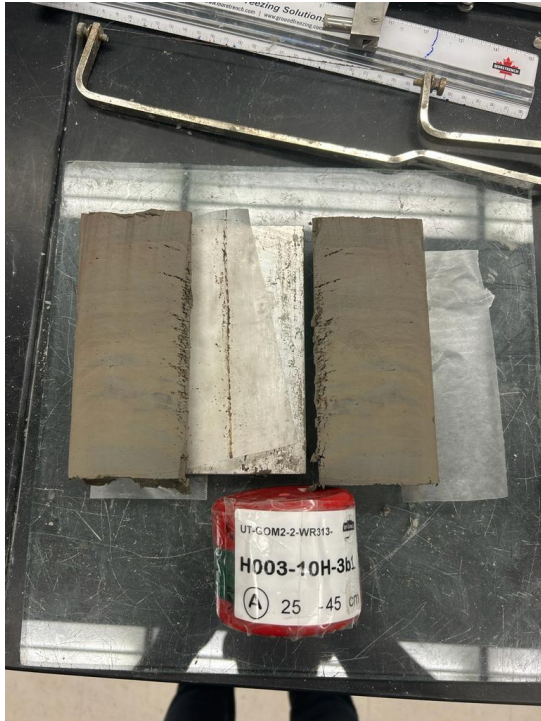


Figure 3-85 - Sample - H003-10H-3B1



Figure 3-84 - Sample - H003-10H-5B1



Figure 3-87 - Sample - H003-11H-1B



Figure 3-86 - Sample - H003-11H-4B



Figure 3-89 - Sample - H003-12H-5B

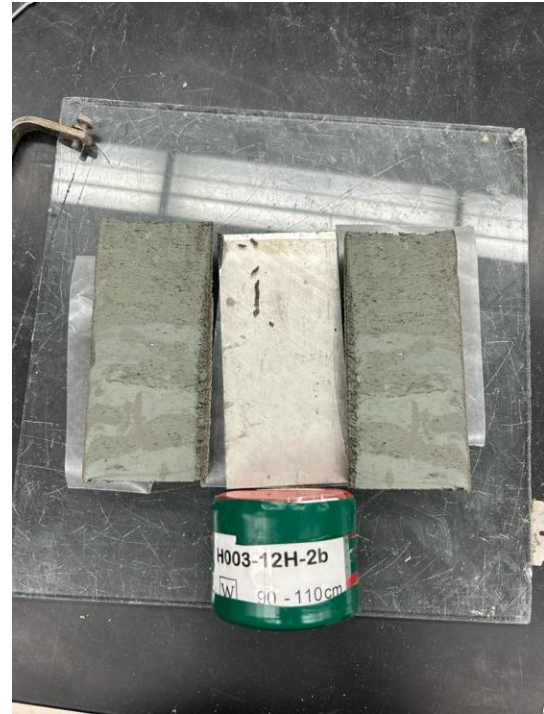


Figure 3-88 - Sample - H003-12H-2B

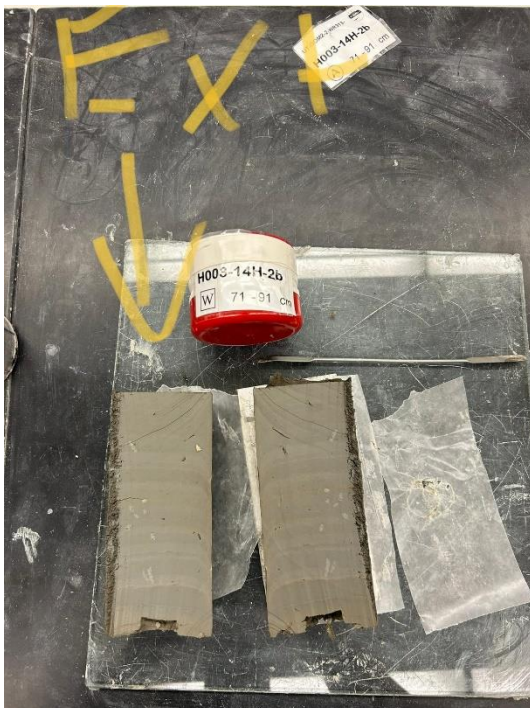


Figure 3-91 - Sample - H003-14H-2B



Figure 3-90 - Sample - H003-14H-6B1

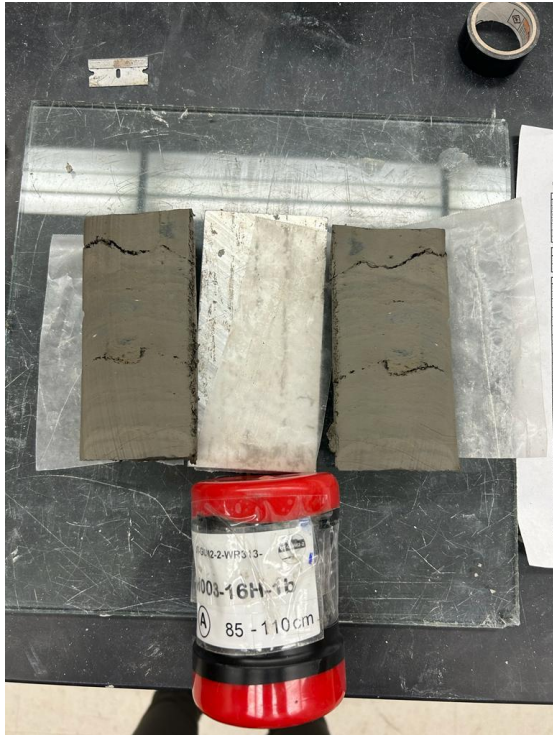


Figure 3-93 - Sample - H003-16H-1B

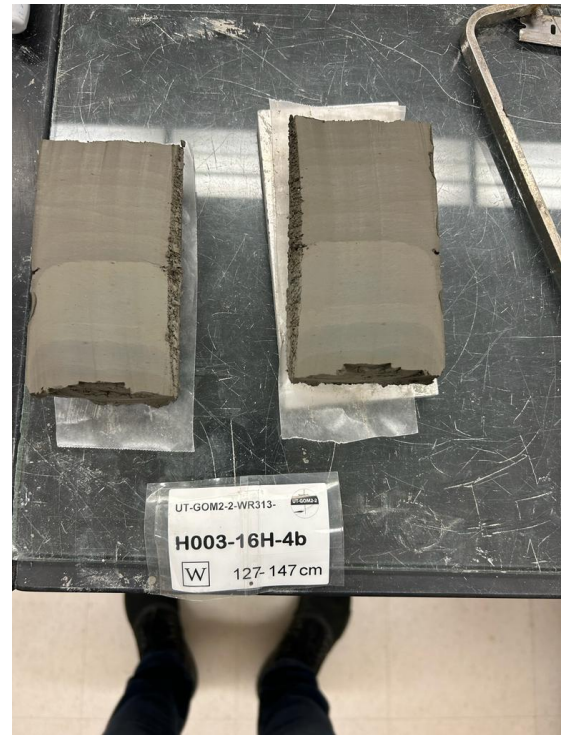


Figure 3-92 Sample - H003-16H-4B



Figure 3-94 Sample - H003-17H-2B1

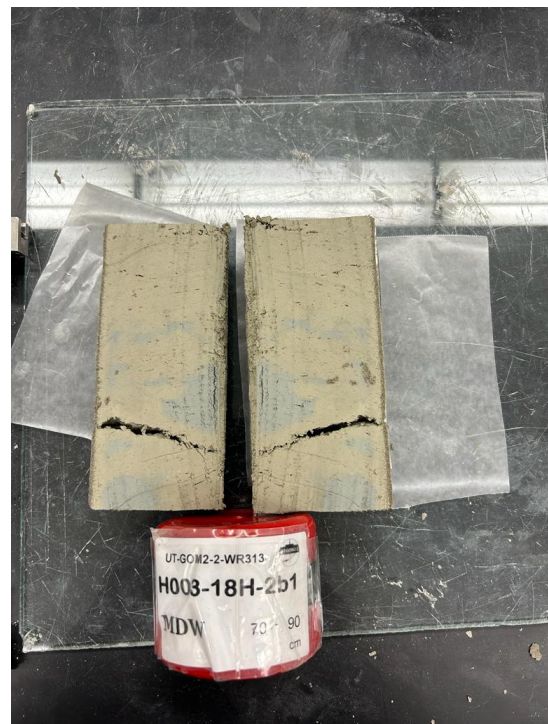


Figure 3-95 - Sample - H003-18H-2B1

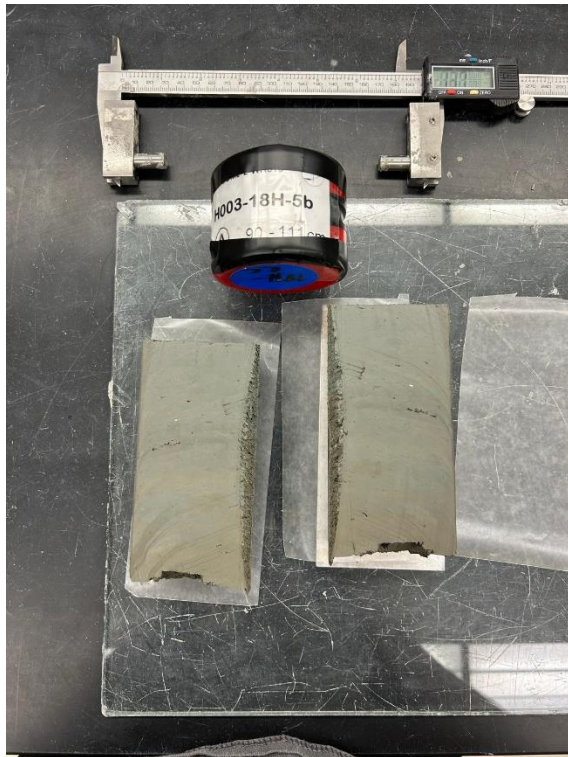


Figure 3-97 - Sample - H003-18H-5B

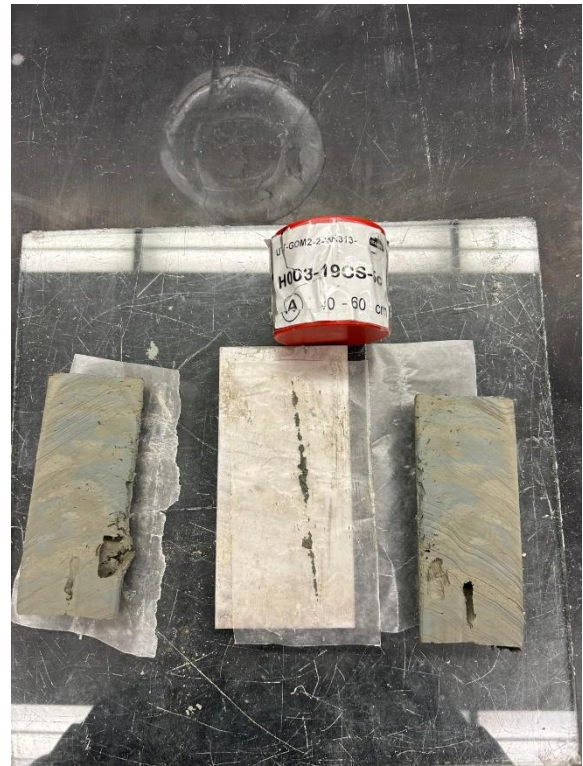


Figure 3-96 - Sample - H003-19CS-4C

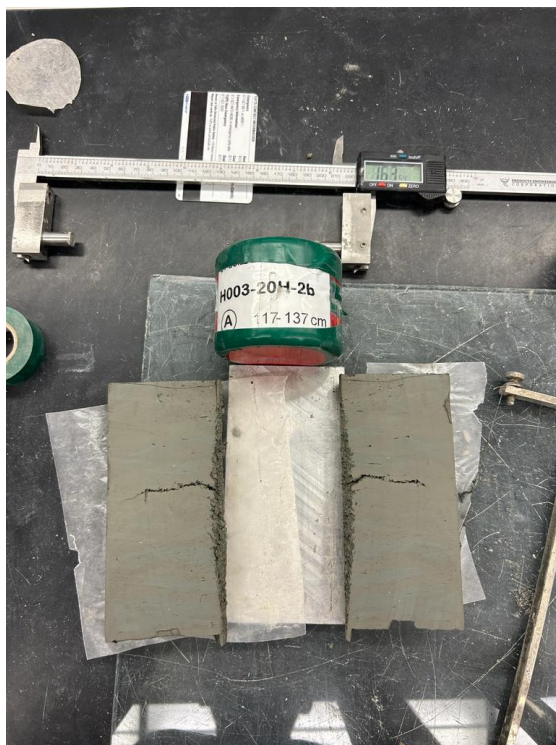


Figure 3-99 - Sample - H003-20H-2B



Figure 3-98 - Sample - H003-20H-5B



Figure 3-101 - Sample - H003-21H-6B

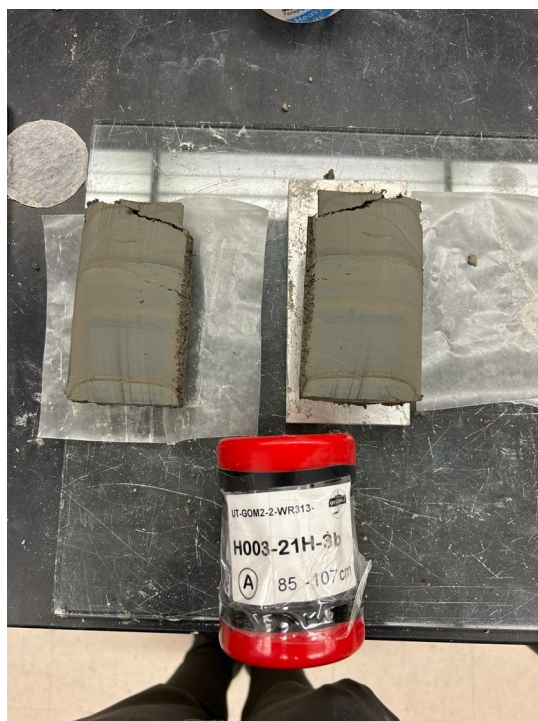


Figure 3-100 - Sample - H003-21H-3B



Figure 3-103 - Sample - H003-22H-4B



Figure 3-102 - Sample - H003-22H-2B



Figure 3-105 - Sample - H003-23H-2B



Figure 3-104 - Sample - H003-23H-4B



Figure 3-107 - Sample - H003-26X-4B



Figure 3-106 - Sample - H003-26X-6B

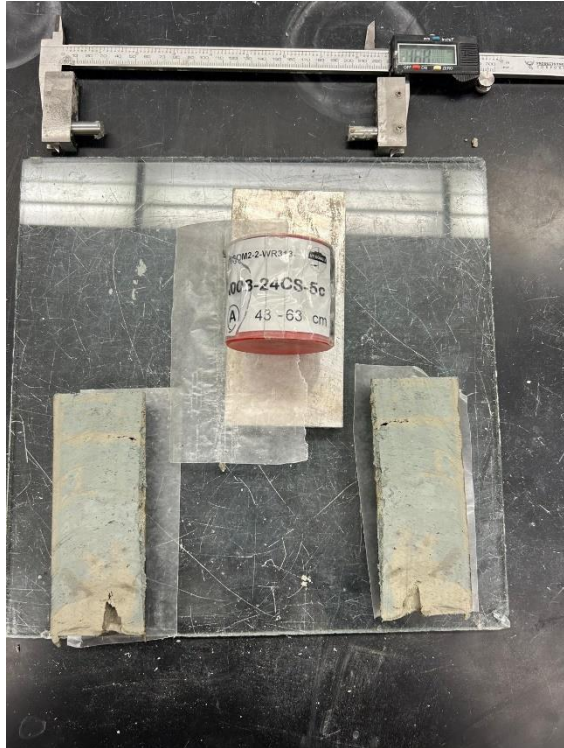


Figure 3-109 - Sample - H003-24CS-5C



Figure 3-108 - Sample - H003-25H-7B



Figure 3-110 - Sample - H003-27CS-4B

## **Chapter 4 - Laboratory Equipment**

### **4.1 Introduction**

This chapter describes the laboratory equipment used during this research. The equipment used to conduct the particle size analysis of fine-grained sediments is described. The grain density is measured using the water submersion method and by gas pycnometer technology which is detailed. The compressive behavior of the sediment is tested using a highly sophisticated CRS testing apparatus. Components of the apparatus include LDVTs, pressure transducers, and a load frame. The cell pressure and the axial load are generated using a pressure-volume actuator (PVA). The system controls and the data acquisition system are detailed. Lastly, the equipment used to conduct oedometer tests is detailed.

### **4.2 Index Testing**

#### **4.2.1 Grain Density Testing Equipment**

The grain density of sediment was measured using two separate methods, the gas pycnometer method and the water submersion method. An AccuPyc III gas pycnometer was used, as shown in Figure 4-1. The AccuPyc III pycnometer is a fast, fully automatic pycnometer that provides high-speed, high-precision volume measurements and true density calculations on various powders, solids, and slurries. After analyses start with a few touches, data are collected, calculations are performed, and results are displayed. A 10cc capacity insert is used, and a minimal amount of the operator's attention is required.

The water submersion method (ASTM D854) was used in a conventional iodine flask, as shown in Figures 4-2 and 4-3. To improve efficiency, samples were tested in batches of 6. The procedures are detailed in Sections 5.3.1 & 5.4.1.

#### **4.2.2 Particle Size Analysis Equipment**

The particle size of the sediment was analyzed using the hydrometer method (ASTM D7829). The sedimentation volumetrics used are shown in Figure 4-4, and the hydrometer used is shown in Figure 4-5. The hydrometer is a buoyancy-based device that balances the weight (mass times gravity) of the device with the weight of displaced fluid. A hydrometer is placed in the sedimentation to determine the specific gravity of the fluid at a series of times. The fraction of suspended particles is calculated using the particles' specific gravity. The procedures are detailed in Section 5.2.1.

#### **4.2.3 Atterberg Limits Equipment**

The liquid limit is quantified using a Casagrandes cup, shown in Figure 4-6. The plastic limit is conducted using the rolling method (ASTM D4318) only one hand and a glass plate. The concept of Atterberg limits and procedures followed are detailed in Section 5.5.

### **4.3 Constant Rate of Strain Test Equipment**

A modified Trautwein CRS cell offered more flexibility than traditional incremental oedometer tests. The Trautwein CRS cell consists of a clear plexiglass chamber mounted on a metal base with a recess designed to accommodate a porous stone. This stone connects to a base drainage line to measure excess pore pressures during consolidation. The specimen is held in place by a confining ring above the porous stone, and consolidation stress is applied from above using a piston. A schematic diagram of the CRS cell is shown in Figures 4-7 & 4-8. The specimen is constrained

axially between two rigid parallel platens and radially by a rigid ring to ensure a constant cross-sectional area. The specimen is then loaded at a constant strain rate with no lateral deformations, while the top boundary provides drainage and the bottom boundary measures pore pressure. Axial deformation is applied constantly, while time, axial deformation, load, and excess pore pressure are continuously recorded. A 10,000 lb. load frame is used in this configuration. The engineering parameters are measured using transducers detailed in the following sections. The CRS test is advantageous as it is fully computer-controlled and does not need much attention as it runs. Testing procedures are detailed in Section 5.6.4.

#### **4.3.1 Transducers**

There are three types of transducers used during triaxial testing. These are Linear Voltage Displacement Transducers (LVDTs), pressure transducers, and load cells. This section will cover information regarding each model used for CRS testing. Two Transtek Inc. LVDTs are used to measure axial displacement throughout the test. An average reading is used for analysis. LVDTs consist of a ferromagnetic core that moves inside a tube composed of three solenoidal coils. As the core moves, the voltage produced by the device changes based on the relative displacement from the device's zero position. LVDTs measure displacements on the order of microns, are low hysteresis, are frictionless, and have a high linear range. The LVDTs used in this research have a 5 V DC linear range (-2.5 to +2.5 V). LVDTs are calibrated using a micrometer.

The load cell used is a Data Instruments JP-1000—a 10000 lb (~4540 kg) capacity load cell.

Omega™ PX-102 flush diaphragm pressure transducers are used to measure the cell and pore/back pressure. These pressure transducers have a 200 PSI capacity, an input voltage range of 5 – 6 V with a 100-mV output, and only deviate 0.25% from the best-fit straight line (BSFL). They can

withstand over 160 million load cycles, making them extremely robust measurement devices. This is reflected in the nearly constant calibration factor recorded by multiple students over the years.

#### **4.3.2 Pressure Volume Actuators**

PVAs control axial load and cell pressure. These wall-mounted PVAs have a pressure capacity of 14 MPa and a volume capacity of 47 cm<sup>3</sup>. A 0.5 tone Duff-Norton inverted ball-screw jack is driven by a Maxon Motors continuous output servomotor (with 80 mNm of torque geared at 100:1). This screw jack pushes a 2.85 cm<sup>2</sup> constant cross-sectional area piston upwards into the hydraulic chamber of the PVA. PVAs are shown in Figure 4-9.

For the axial PVA, the hydraulic pressure generated in the PVA pushes a jack, which in turn drives the base pedestal upwards against a stationary crossbar. The stationary crossbar has a 10-ton capacity. The pressure is transmitted to the specimen through the hardened steel piston. The cell pressure PVA maintains the required cell pressure in the sample controlled by a pressure transducer. The salinity of the cell fluid PVA is adjusted for each test to match that of the specimen.

#### **4.3.3 DC Motor Controllers**

Dr. Germaine designed and manufactured the custom-made motor control box. The box houses three Maxon Motor ESCON 50/5 servo controllers, an AC to DC power supply, a control card, and a fan shown in Figure 4-10. The servo controllers use a pulse-width modulated signal to control the motors. Tachometers measure the speed of the motor, and by changing the gain and output on the servo controllers using a USB interface and the ESCON software can make the motor run faster for the same control voltage coming from the PC. This can be especially useful, as the gear ratio is hard to manually change as significant disassembly of the PVA motor housing is required. Another way to change the gain of the motors is to add a voltage divider to the tachometer and

ground, which can be done next to the motor or inside the box itself. The box also houses electronics to control the limit switches and manual switches on the outside.

#### **4.3.4 Data Acquisition System**

In addition to the local data from the PC controlling the test, high-precision data from the pressure transducers, LVDTs, and load cells are necessary for data analysis. A Hewlett Packard HP3497-based central data acquisition system (DAQ) is used for this process. The central DAQ is an auto-ranging, low-noise dual slope integrating A/D converter. The expansion unit has 200 channels, meaning that 200 transducers can be monitored in the lab simultaneously. A custom-built software program called Windap allows one to use a Windows PC to set up data recording tasks with the channels of choice, desired reading interval, and total number of readings. It also allows one to save data, take manual readings, and retire tasks as necessary.

#### **4.3.5 Data Analysis**

After a test and collecting the .dat file from the central DAQ, the information can be analyzed using innumerable methods. The simplest is to set up an Excel file with the calibration factors of each transducer and functions in place to calculate each engineering parameter of interest. The lab has an Excel template that generates all possible engineering parameters from a CRS test dependent on material properties.

### **4.4 Oedometer Testing Equipment**

Oedometer testing was conducted using the MIT load frame combined with a CRS cell. The MIT load frame is a lever arm system with a 100:1 load ratio. It is a very simple yet effective device. This option was chosen due to the sample size. The resedimented samples have a diameter of approximately 35mm and are too small for the conventional oedometer ring. Two LDVTs are used to measure strain and are averaged the same way as CRS testing. The pressure transducers on the

CRS cell are unused for the oedometer test. The specimen has top and bottom drainage to an external water reservoir. The apparatus is shown in Figure 4-11 below. The procedures are detailed in Section 5.7.1



Figure 4-1 AccuPyc 3 Gas Pycnometer



Figure 4-2 Volumetric flasks



Figure 4-3 Volumetric flasks in temperature-controlled environment



Figure 4-4 Six sedimentation flasks

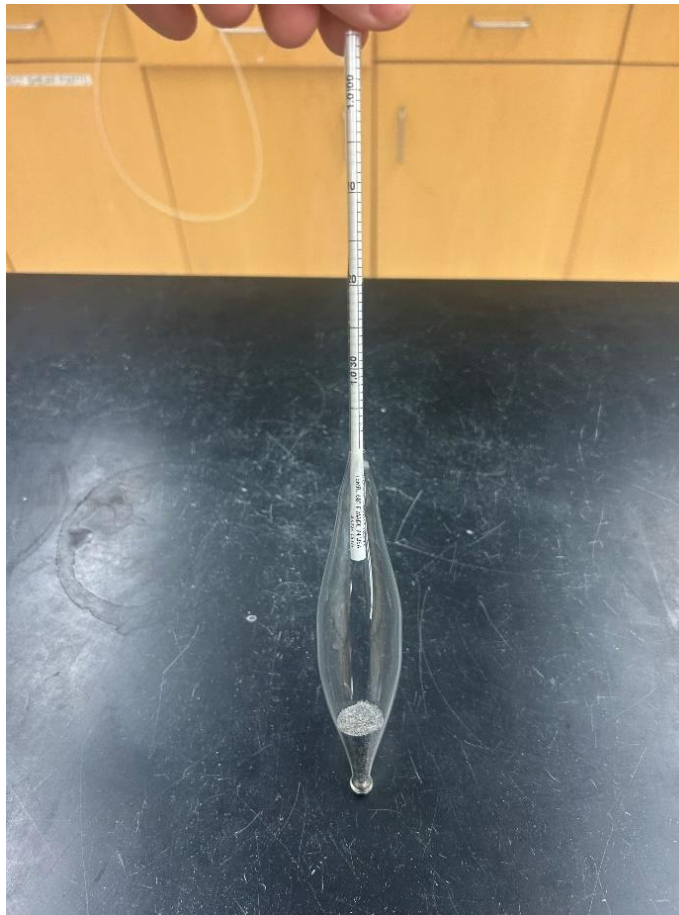


Figure 4-5 H151 Specific Gravity Hydrometer



Figure 4-6 Casagrande cup

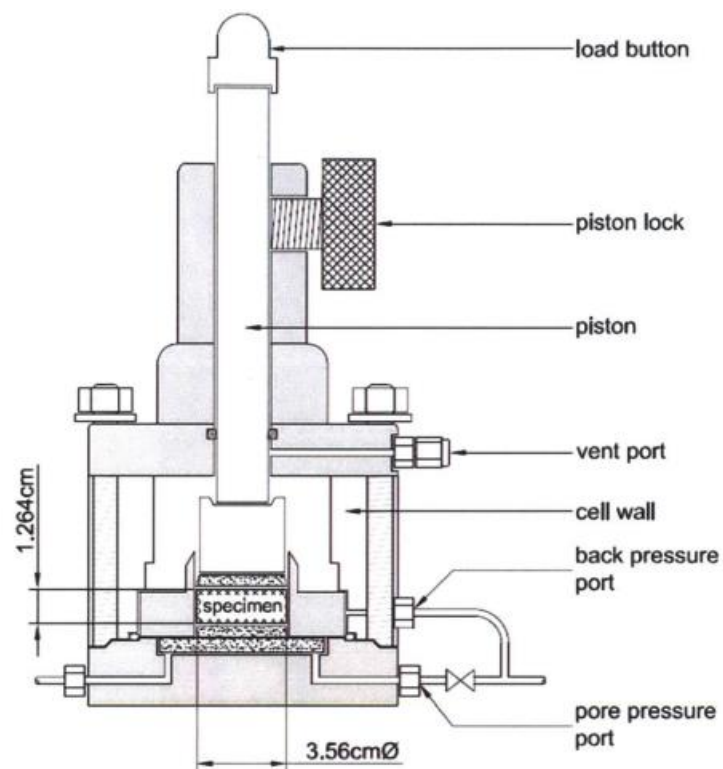


Figure 4-7 CRS Cell schematic

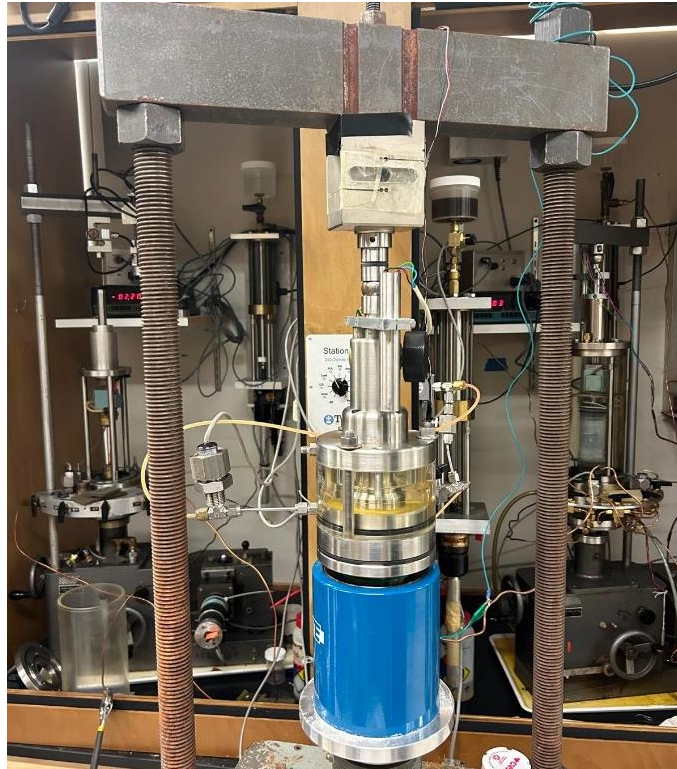


Figure 4-8 CRS testing apparatus



Figure 4-9 Wall mounted PVA's controlling load and cell pressure

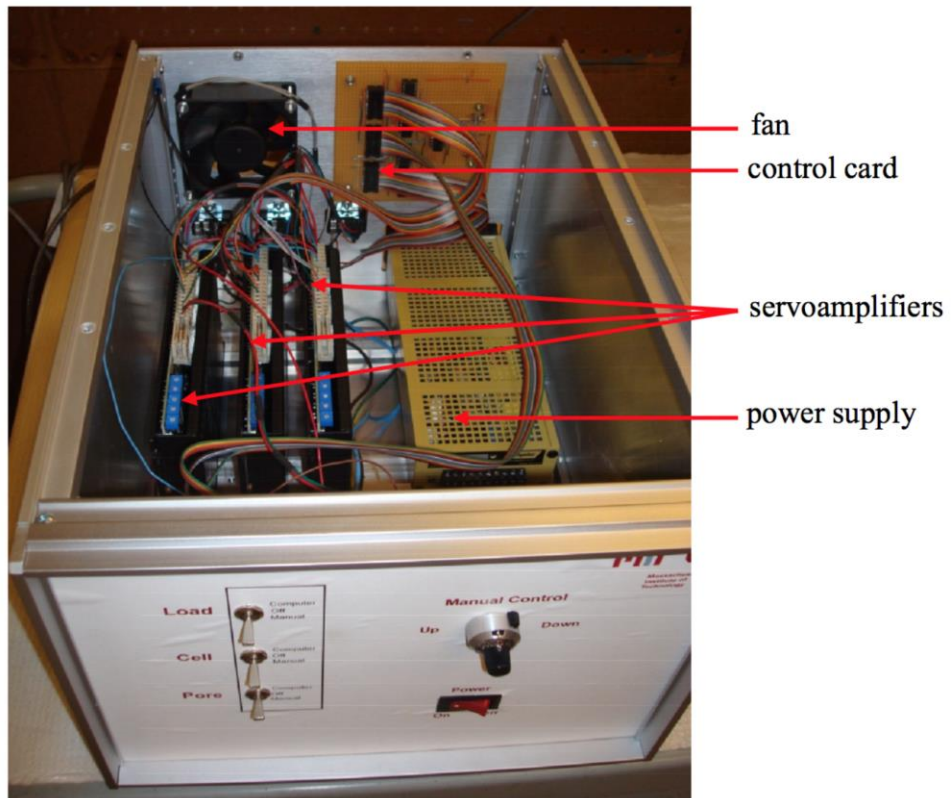


Figure 4-10 D-C Motor Control Box



Figure 4-11 MIT Load frame and CRS cell used for oedometer testing

## **Chapter 5 - Research Methodology**

### **5.1 Introduction**

This chapter describes the methodology for all the experiments conducted as part of this research. The detailed experiments include sedimentation using the hydrometer method, grain density using the water submersion method and gas pycnometer method, Atterberg limits testing, CRS testing and finally oedometer testing. Step-by-step procedures are detailed for each experiment, and all experiments are conducted in accordance with ASTM standards. The CRS test and the oedometer test can often be very useful due to the information provided by a single test. All engineering parameters provided by these tests are detailed in this chapter. In total, 50 hydrometer tests were completed, 50-grain density measurements by water submersion method, 5 Atterberg limits, 333-grain density measurements by gas pycnometer (50 plugs from MAD sections & 283 SC plugs), 32 CRS tests, and 1 oedometer test.

### **5.2 Particle Size Analysis**

The particle size analysis is completed in accordance with (ASTM-D7928, 2021). Sedimentation methods determine grain size distributions of fine-grained soils, describing particles falling through a fluid. This theory separates the particles by size in space and time. The concept is that the smaller particles take longer to drop out of the solution. Stokes's law is then used to determine particle size during sedimentation. The law provides a governing equation based on the hydrodynamics of a single spherical particle falling through a stationary fluid. The particle is driven downward by gravitational forces and retarded by drag forces. A particle will accelerate

downward in the fluid until the drag forces equal the gravitational force. Once these forces are in equilibrium, the particle will achieve terminal velocity, defined as (v).

$$v = \frac{(p_s - p_f)gD^2}{18\mu} \quad (5.1)$$

Where:

v = terminal velocity (cm/s)

p<sub>s</sub> = mass density of solids (g/cm<sup>3</sup>)

p<sub>f</sub> = mass density of fluid (g/cm<sup>3</sup>)

g = acceleration due to gravity (cm/s<sup>2</sup>)

D = diameter of the particle (mm)

μ = viscosity of fluid (mPa-s)

The terminal velocity of a particle can be expressed as a function of the density difference between the particle and fluid, the particle diameter, and the fluid viscosity. The terminal velocity is proportional to the diameter of the squared particle, and this principle is used to separate particles by size in both time and position within the sedimentation flask. Take the velocity as the distance of travel divided by the travel time, assume that the fluid is water, and the temperature remains constant during the entire experiment; we can then rearrange Equation 5.1. Essentially at any given time, if the fluid properties and the distance of fall are known, the diameter of the largest particle in suspension at that location can be found using:

$$D = \sqrt{\frac{18\mu}{p_w g (G_s - 1)} \frac{H}{t}} \quad (5.2)$$

Where:

H = distance particle falls (cm)

$\rho_w$  = mass density of water (g/cm<sup>3</sup>)

$G_s$  = specific gravity (dimensionless)

$t$  = time for fall (s)

A H151 hydrometer is used to measure the specific gravity of the solution at certain time intervals and is then used to calculate the particle size distribution. The percentage of particles remaining in suspension is calculated using the particles' specific gravity. The hydrometer is inserted into the solution and integrates the fluid density where it is submerged. The critical dimensions of the hydrometer are shown in Figure 5-1. The center of buoyancy (cb) is the reading location equal to the distance  $H$  from the free surface. The expanded bulb section makes the hydrometer most sensitive to depth range  $h$ . The center of buoyancy (cb) of this section is taken as the reading location that is equal to the distance  $H$  from the free surface. As soil particles settle below the hydrometer and the specific gravity of the suspension decreases, the hydrometer moves into the suspension. This creates a dependence between the reading,  $r$ , and the depth,  $H$ , from the free surface to the center of buoyancy. The scale on the hydrometer is calibrated to provide values of the specific gravity of the suspension referenced to distilled water at 20°C.

The mass of material contained within the average measurement depth zone,  $h$ , which is the percent finer material at a given time, is expressed in (Equation 5.3) This is normalized to the dry mass of the soil in the cylinder.

$$N_m = \frac{G_s}{G_s - 1} \left( \frac{V}{M_D} \right) p_c (r_m - r_{w,m}) \times 100 \quad (5.3)$$

Where:

$N_m$  = percent finer material at reading  $m$  (%)

$V$  = volume of suspension (cm<sup>3</sup>)

$M_d$  = dry soil mass of hydrometer specimen (g)

$p_c$  = mass density of water at the calibration temperature (g/cm<sup>3</sup>)

$r_m$  = hydrometer reading in suspension at time,  $t$ , and temperature,  $T$  (dimensionless)

$r_{w,m}$  = hydrometer reading in water with dispersant at the same temperature as for  $r_m$  (dimensionless)

$m$  = reading number

### 5.2.1 Testing Procedure

1. Obtain the equivalent of about 35 gm of dry soil from the blended material.
2. Mix the soil with 5.00 grams of sodium hexametaphosphate and distilled water as necessary to form a thick slurry (milkshake consistency). Use a shaker bottle and 4 ceramic balls.
3. Allow the solution to temper for at least 16 hr.
4. Transfer the slurry into a blender cup and blend at low speed for 60 seconds. Rinse all the soil from the tempering container into the blender and remove the balls.
5. Transfer the dilute slurry to a 1000 cc cylinder and fill it with distilled water. Transfer all the soil from the blender to the cylinder and fill it to the indicated mark on the cylinder.
6. Allow the temperature to equilibrate for a few hours.
7. Mix thoroughly using the hand mixing method and begin the sedimentation experiment.
8. Obtain two sets of specific gravity readings ( $r_h$ ) for the first two minutes of sedimentation with the hydrometer remaining in the suspension. Obtain readings at 15, 30, 60, 90, 120 seconds.
9. Read the hydrometer at the top of the meniscus.
10. Record the temperature of the slurry to 0.01 C for each reading every 30 minutes.

11. Record the hydrometer reading to 0.2 of a division by estimating five increments between divisions. This resolution is necessary for the calculations.
12. Remix the slurry and obtain readings at 2, 4, 8, 16 minutes, etc. Take readings for at least two days or until the suspension is clear, whichever comes first.
13. For each reading, place the hydrometer in the slurry about 10 seconds before the reading time, allow the hydrometer to stabilize, take a reading, and return to the wash water.
14. Between readings, cover the cylinder with a rubber stopper to prevent evaporation. Properly filling the cylinder is extremely important.
15. At the end of the experiment, mix the suspension, pour the slurry through a #200 sieve and into an evaporating dish, and obtain the final dry mass of soil and sodium hexametaphosphate. The +200 fraction is retained on the sieve and classed as the sand portion.

### **5.2.2 Hydrometer Calibration Procedure**

The hydrometer readings must be corrected for temperature, the dispersing agent, and the meniscus. This is done by subtracting the specific gravity reading ( $r_w$ ) of a liquid at the same temperature as the slurry, which is composed of distilled water and dispersing agent in the same proportion as in the sedimentation test. Equation 2 from (ASTM-D7928, 2021) is used to do this correction.

The effective depth ( $H$ ) of the hydrometer versus the hydrometer reading must also be calculated by the following steps:

1. Determine the center of volume as the midpoint of the bulb.
2. Calculate the reading depth ( $H_r$ ) as the distance from a particular reading and the center of volume.

3. During the first 2 minutes of a test, the effective depth is the reading depth plus the meniscus correction (cm = top to bottom of meniscus).
4. Calculate the cylinder area ( $A_j$ ) from the volume and distance between calibration marks.
5. Measure the volume of the hydrometer ( $V_b$ ) by water displacement.
6. For reading after 2 minutes, the effective depth is:

$$H = Hr - \left( \frac{Vb}{2A_j} \right) + cm \quad (5.4)$$

### 5.3 Grain Density – Water Submersion Method

The grain density and specific gravity of the sediment are measured in general accordance with (ASTM-D854, 2023). The water submersion technique applies to measuring the specific gravity of heavy (relative to water), nonreactive particles. The submersion method can be used for particles with low specific gravity values or particles that react with water by replacing water with kerosene or other liquids (Germaine, 2009). The specific gravity at the test temperature ( $G_{sr}$ ) can be calculated using the following equation:

$$G_{sr} = \frac{M_s}{(M_{B+Wt} + M_s) - M_{B+W+St}} \quad (5.5)$$

Where:

$M_{B+W+St}$  = mass of the volumetric flask, water, and soil at temperature T, determined experimentally (g)

$M_s$  = mass of dry soil (g)

$M_{B+W+St}$  and  $M_{B+Wt}$  are at identical volumes and temperatures.

The measured specific gravity is then corrected to 20 degrees Celsius by accounting for the change in water density. This calculation is valid, assuming the particle density remains unchanged.

Equation 5.6 is used for this correction:

$$G_s = G_{sr} \frac{pwt}{pw_{20}} \quad (5.6)$$

### 5.3.1 Testing Procedure

1. Obtain 40 gm of fine-grained soil from the blender material.
2. Mix soil in a shaker bottle with distilled water.
3. Transfer the slurry into the volumetric flask. Do not fill more than 1/3 of the flask.
4. Deair slurry with a vacuum for about 10 minutes.
5. Fill the volumetric with distilled water (do this slowly so there is clear water at the top of the volumetric).
6. Place the volumetric with the plug (cover) in the resting position in a Styrofoam cooler for 12 hours to equilibrate the temperature.
7. Cap off the volumetric, dry the rim, and determine the mass to 0.01 gm. This is the mass of the bottle, water, and soil. Do this quickly and handle the volumetric with gloves to prevent temperature changes.
8. Use an electronic thermometer to measure the temperature (T) in volumetric to 0.1°C. To equilibrate the thermometer, it is best to store it in a small container of water in the cooler.
9. Add water to the top of the flask and return the plug to the resting position.
10. Repeat 7 to 9 at least three more times waiting at least 15 minutes between readings.
11. After four sets of measurements, obtain the dry mass of the soil. Pour off some of the clear water. Cap the volumetric with a rubber stopper and shake vigorously to break up the soil,

which sticks to the bottom. Pour the slurry into an evaporating dish, dry in the oven, and determine the dry mass of soil.

### 5.3.2 Volumetric Flask Calibration Procedure

1. Determine the mass of clean, dry volumetric ( $M_B$ ).
2. Fill with distilled water.
3. Place in cooler for at least 3 hrs. to equilibrate the temperature.
4. Cap off, dry, determine mass ( $(M_B + M_W)_T$ ), and record temperature as described above.
5. Repeat steps 3 and 4 at least three times.
6. The theoretical equation which describes the change in mass with temperature is:

$$(M_B + M_W)_T = M_B + V_{BTc}(1 + (T - T_c)\epsilon)(\gamma_w T - \gamma_a T) \quad (5.7)$$

Where:

$\epsilon$  = cubic expansion of glass ( $0.1 \times 10^{-4} / ^\circ\text{C}$ )

$\gamma_{wT}$  = unit weight of water at T

$\gamma_{aT}$  = unit weight of air (0.00129/cc)

$V_{BTc}$  = volume of volumetric at  $T_c$

$M_B$  = weight of the bottle

7. Obtain the volume of the bottle using the following:

$$V_B = ((M_B + M_W)_T - M_B) / \gamma_{wT} \quad (5.8)$$

8. Evaluate the quality of the data (and your testing procedure) by computing the bottle volume for each calibration point and report the mean and standard deviation. The standard deviation should be less than 0.04 cc.

## **5.4 Grain Density – Gas Pycnometer**

A gas pycnometer measures the grain density in accordance with (ASTM-D5550, 2023). This test method can be used instead of or in conjunction with (ASTM-D854, 2023). This method requires highly sophisticated commercial technology instead of the water submersion method, which can be conducted using readily available laboratory equipment. The gas pycnometer measures the volume ( $\pm 0.2\%$ ) of a test specimen with a known mass. The density is calculated from these measurements. The mass must be measured to ( $\pm 0.1\%$ ) of the test specimen and in accordance with (ASTM-D4753, 2024). The gas pycnometer is recognized as one of the most reliable techniques for obtaining true, absolute, skeletal, and apparent volume and density. This technique is non-destructive, as it uses the gas displacement method to measure volume. Inert gases, helium in this case, are used as the displacement medium. Density calculations using the gas displacement method are thought to be much more accurate and reproducible than the traditional Archimedes water displacement method.

### **5.4.1 Testing Procedure**

1. Crush the test specimen using a mortar and pestle ensuring no contamination.
2. Record the mass of the gas pycnometer tare.
3. Fill the tare  $\frac{2}{3}$  full of the crushed material (about 5-7 g).
4. Place the filled tare in a conventional oven tare and then into the oven at 110 degrees Celsius for 12 hours to remove moisture. Ensure the pycnometer tare is stable by placing a steel nut around the smaller tare.
5. Remove the oven tare from the oven after 12 hours and place a cover on the tare for 10 minutes, allowing the material to cool down and not absorb moisture.
6. Record the mass of the dry material and tare.

7. Place the tare and dry specimen in the gas pycnometer and start the analysis. The analysis cycle included three purge cycles and three measurement cycles. The average volume and standard deviation are recorded.
8. Record the volume obtained from the gas pycnometer and the conclusion of the analysis.

#### **5.4.2 Gas Pycnometer Calibration Procedure**

The gas pycnometer should be calibrated on a regular basis to ensure the accuracy of the results obtained. The gas pycnometer in Tufts TAG Laboratory is verified by inserting two steel balls of known volume into the chamber. A calibration process embedded in the system's settings is then run to verify the volume of the chamber. The manufacturer states to calibrate the machine every 90 days, or when major changes are made to normal operating conditions (such as temperature differences, switching gases, or if a change to the internal chamber is suspected).

#### **5.5 Atterberg Limits**

The boundaries of Atterberg Limits first defined by (Casagrande, 1932) are used in this research. Casagrande developed relatively simple index tests to quantify the boundaries of when the soil behaves like a plastic or liquid material governed by the amount of water bound in the soil. As the amount of water increases in the soil, the particle spacing increases, and the interaction between adjacent particles decreases, altering mechanical behavior. The assemblage of particles changes from a densely packed solid to a very loosely packed liquid (Germaine, 2009). The plastic limit defines the boundary between semi-solid and plastic mechanical behavior. The liquid limit indicates the boundary between plastic and fluid-like behavior. The testing in the research is conducted in accordance with (ASTM-D4318, 2017).

### **5.5.1 Liquid Limit Testing Procedure – Casagrande**

1. Mix about 100 gm of the blended soil to about 15 drop consistency and place the covered bowl in a humid room for 24 hours to temper.
2. Place soil in a clean, calibrated Casagrande cup to a maximum depth of 1/2 inch. The soil should form a flat horizontal surface with the bottom lip of the cup. This volume can be checked by filling the cup with water while it is in the strike position. Remove the entrapped air and smooth the surface.
3. Groove soil with an ASTM-type tool, keeping the tool perpendicular to the cup at the point of contact.
4. Turn the crank at 2 blows/second until the groove closes for 1/2 inch and record the number of blows.
5. Remove soil from the cup and return it to the dish.
6. Mix soil in the dish and repeat steps 2, 3, 4, and 5 until two consistent blow counts ( $\pm 1$ ) are measured.
7. Obtain soil water content by removing about 10 gm of paste perpendicular and across closed groove.
8. Obtain four separate water content determinations between 15 and 35 blows by drying the soil slightly and repeating steps 2 through 7.
9. Plot the water content against the log of blows, draw the flow curve, and select the liquid limit as the intersection of this curve and the 25-blow line.

### **5.5.2 Plastic Limit Testing Procedure**

1. Separate about 20 gm of the tempered soil before starting the liquid limit experiment and set aside to dry. It works well to set this on a paper towel.

2. Roll 1/3 of the soil into 1/8" strand on a glass plate.
3. Repeat step 2 until the strand shows signs of crumbling when it reaches 1/8" in diameter.  
This is the plastic limit.
4. Obtain water content of crumbled material.
5. Repeat steps 2 through 4 for each of the remaining two-thirds.

## **5.6 CRS Testing**

The CRS testing was carried out in accordance with (ASTM-D4186/D4186M, 2020). The specimen was incrementally back-pressured using the Pressure Volume Actuator. Cell and pore pressure were measured using the pressure transducers, axial deformations were measured using the LDVTs, and the load was monitored with a load cell, as previously mentioned. Adjustments are made to account for the compressibility of the apparatus, which are detailed in section 5.6.3. (FORCE, 1998), (Gonzalez, 2000) & (HORAN, 2012) present detailed accounts of CRS testing with similar procedures followed during this research.

Samples were chosen from different elevations in the borehole to gain a comprehensive understanding of material behavior in the deposit. Table 5-1 records 32 successful CRS tests conducted as part of this research. These include 2 tests on 6 samples to assess the repeatability of the results and 5 tests on 3 resedimented samples.

### **5.6.1 Preconsolidation Pressure**

Many empirical methods can be used to locate the preconsolidation pressure. (Casagrande, 1936), (Schmertmann, 1955), (Janbu, 1969), (Butterfield, 1979), and (Becker et al., 1987) have all presented various methods over the years. The most commonly used methods are (Casagrande, 1936) & (Becker et al., 1987). The latter was used in this research. (Becker et al., 1987) presented a work-based procedure to determine the pre-consolidation stress. This method plots work against

consolidation stress where work is the specimen's strain energy per unit volume. This method can be used to approximate an upper and lower bound for the pre-consolidation stress, which is advantageous as there is often much debate about this topic.

The quantity of work is calculated for each increment as the sum of the average force for each increment multiplied by the increment in deformation and divided by the current volume. A natural scale plots the work versus the axial effective stress. The curve is geometrically like the strain versus log stress plot. A line is drawn through the high-stress linear portion of the data. The low-stress range should also approximate a straight line. This is often subjective to the individual conducting the construction. The stress at the intersection of these two lines represents pre-consolidation stress. The strain energy method has the advantage of plotting stress on a natural scale. This reduces the variation in the pre-consolidation pressure due to subjective decisions about the slope of the initial straight-line (Germaine, 2009).

The strain energy is given by:

$$W_j = \sum_{m=1}^j \left( \frac{\sigma'_{v,m} + \sigma'_{v,m-1}}{2} \right) \left( \ln \frac{1 - \varepsilon_{a,m-1}}{1 - \varepsilon_{a,m}} \right) \quad (5.9)$$

Where:

$W_j$  = work per unit volume of the specimen up to increment  $j$  (kN-m/m<sup>3</sup>)

$j$  = index value for stress increment (integer)

$\sigma'_{v,m}$  = vertical effective stress at current increment (MPa)

$\sigma'_{v,m-1}$  = vertical effective stress at previous increment (MPa)

$\varepsilon_{a,m}$  = axial strain at current increment (decimal)

$\varepsilon_{a,m-1}$  = axial strain at the previous increment (decimal)

$m$  = index used in summation (integer)

### 5.6.2 Permeability

The permeability of the sample is measured as the CRS test is running. The hydraulic conductivity is first calculated using methods first adopted by (Wissa et al., 1971) which uses the relationship between the pore pressure and cell pressure change. This is outlined in equation 5.10.

$$u_h = \frac{\epsilon(H_0 H_n) \gamma_w}{2k} \quad (5.10)$$

Where:

$u_h$  = Excess pore pressure at the midpoint of the specimen (stress)

$\epsilon$  = Average strain rate during consolidation (0.5%/hour)

$H_0$  = Half the starting specimen height (length)

$H_n$  = Half the specimen height at evaluation point n (length)

$\gamma_w$  = Specific weight of the pore water (force by volume)

$k$  = Hydraulic conductivity (length by time)

The term hydraulic conductivity cannot be mistaken for the term permeability. Permeability includes the intrinsic properties of the porous fluid. The permeability is calculated using the following expression:

$$K = \frac{k\mu}{p_f g} \quad (5.11)$$

Where:

$K$  = intrinsic permeability ( $m^2$ )

$g$  = acceleration due to gravity ( $m/s^2$ )

$\mu$  = viscosity of fluid (Pa-s)

$\rho_f$  = mass density of fluid ( $Mg/m^3$ )

$k$  = hydraulic conductivity (m/s)

### **5.6.3 Apparatus Compressibility**

The apparatus's compressibility must be considered during testing, as samples are subjected to relatively high stress (40 MPa). An incompressible stainless steel specimen is loaded into the apparatus prior to testing. The recorded strain is then separated from the axial strain data obtained during the test. Two assessments of the apparatus's compressibility were conducted for the stress range up to 40 MPa for each testing apparatus. Three different testing stations were employed during this research to enhance productivity. The results of each compressibility test are presented in Figures 5-2 to 5-4. The compressibility function is incorporated into the testing software, with the respective function values shown in each figure.

The impact of sanding the porous stone on the compressibility of the apparatus was also investigated. It was believed that sanding the porous stone would decrease the apparatus's compressibility. Figure 5-5 clearly shows that the effects are minimal.

### **5.6.4 CRS Testing Procedure**

1. Clean the cutter ring, filter screen, and recess tool to remove dirt or residue. Weigh the cutter ring and filter screen, then clean and weigh the recess tool. Apply grease to the inside of the cutter ring to assist with trimming after weighing.
2. Extract the soil sample from the confining tube and square the ends using a squaring block.
3. Position the soil sample beneath the cutter-ring, ensuring it fully occupies the area. Carefully trim the soil using the trimming tool, keeping the cutter ring orthogonal to the turntable. Continue trimming until the target height of 1.5 cm is reached. Remove the cutter ring, push the soil through with a recess tool, trim any excess soil with a wire saw, and use a straight edge to eliminate residual soil. Clean the trimmed surface, cover it with filter paper, insert a slightly deeper recess tool, and trim the final surface with the blade.

4. Weigh the soil, cutter ring, and recess tool together as one unit. Subtract the initial masses measured in step 1 to determine the soil's mass. The sample is now prepared for testing.
5. Assemble the testing cell. Gently lower the piston onto the soil to apply light pressure, ensuring the specimen is seated without excessive stress. Lock the piston, then position the cell into the load frame. Attach the LVDTs to the load button and monitor the voltage to confirm contact with the load cell. Zero the force and displacement transducers.
6. Fill the cell with 35 g/l salt water using a siphon, ensuring all test lines are saturated. The pore pressure transducer should not be connected until the housing overflows with fluid. Once the cell is filled, connect the PVA and allow it to drip under slight pressure to ensure proper line saturation. Zero transducers with reservoir open to the atmosphere.
7. Back pressure saturate the specimen in accordance with (ASTM-D4186/D4186M, 2020), progressively increasing the pressure to 0.035, 0.070, 0.150, 0.300, and ultimately 0.396 MPa with 10-minute intervals between steps. Leave the system to equilibrate overnight before starting the test.
8. After back pressure saturation, unlock the piston and close the valve on the cell pressure line to allow excess pore pressures to develop. The specimen is now ready for loading at the desired strain rate (0.5%/hr). The maximum testing stress for this research was 40 MPa, corresponding to approximately 4,000 kg of axial force. The test concludes once this maximum stress is reached.
9. Following the test, gradually reduce the cell pressure over 30 seconds. Remove the CRS cell and extrude the soil from the cutter ring, noting any extrusion inside the ring. If extrusion occurs, collect and determine the mass of it separately. Weigh the final wet mass of the specimen, then place it in an oven at 110°C until it reaches a constant mass.

## 5.7 Oedometer Testing

The oedometer is a commonly run test to assess soil samples' compressive behavior. The oedometer test differs from the CRS test as the secondary compression element of soil behavior is captured. Secondary compression can be problematic in many engineering problems and must be measured accurately. A typical test might extend over several weeks and require more than a dozen stress increments. The methods for determining the preconsolidation pressure, which are detailed in Section 5.6.1, are also valid for the oedometer test. The oedometer test applies a series of constant stress levels to the specimen. The deformation is measured versus time during each constant stress increment. Consolidation theory is used to interpret each stress increment. The deformation results can be presented in terms of settlement, strain, or void ratio. All three values are linear variations of the same deformation measurement. The main purpose of the oedometer test was to assess the secondary compression behavior of the sediment in this research. The following information can be obtained from an incremental oedometer test:

- 1) Plots of strain,  $\epsilon_a$ , versus time for each stress increment.
- 2) Interpretation of the time curves to get the end of primary strain associated with each stress level
- 3) Interpretation of the time curve to get the coefficient of consolidation,  $c_v$
- 4) Interpretation of the time curves to get a rate of secondary compression,  $C_{\alpha \epsilon}$
- 5) Plot of strain versus axial effective stress,  $\sigma'_a$
- 6) Pre-consolidation stress,  $\sigma'_p$
- 7) Compression ratio (CR), recompression ratio (RR), and swelling ratio (SR)
- 8) Hydraulic conductivity,  $k_v$ , for each stress increment

### 5.7.1 Oedometer Testing Procedure

A CRS cell is used to complete the incremental oedometer test. This means that sample preparation steps 1 to 5 of section 5.4.1 are the same here. The process used for this research continues as follows;

1. Where do you set the tare load and what seating load??
2. Fill the cell with water of the appropriate salinity and apply the first load increment. If the specimen begins to swell, immediately apply the next increment. Generally, increasing the stress level to about 1/4 of the overburden stress will be sufficient to prevent swelling.
3. Record the displacement reading versus time using the central data acquisition system for each increment. Start the task using a one-second interval. Apply the load to the specimen and quickly change the reading rate to 'c' for consolidation and a zero for the delay. This will result in about 50 readings per day.
4. Adjust balance arm as necessary during the increment to keep lever mechanism in place.
5. Plot both root t and log t curves during each increment.
6. The load increment was doubled at each loading. The sample was loaded into the normally consolidated range, and enough time was allowed to capture the secondary compression behavior.
7. At the end of the test, unload the specimen to zero and allow time for swelling.
8. Remove the apparatus from the frame and disassemble it.
9. Dry the surface of the specimen and determine its wet mass, including the top filter screen and ring. Extrude the soil and obtain its water content and dry mass by oven drying.

Table 5-1 Constant rate of strain testing log

| Constant Rate of Strain Test Log |          |         |         |               |                          |     |        |
|----------------------------------|----------|---------|---------|---------------|--------------------------|-----|--------|
| Test                             |          |         |         | Core Section  | Section Location<br>(cm) |     | Depth  |
| Intact 1                         | Intact 2 | Resed 1 | Resed 2 |               | Top                      | Bot | (MBSF) |
| CRS1799                          | (-)      | (-)     | (-)     | H003-01H-5b   | 96                       | 101 | 6.07   |
| CRS1791                          | (-)      | (-)     | (-)     | H003-02H-2b   | 115                      | 120 | 9.60   |
| CRS1800                          | (-)      | (-)     | (-)     | H003-02H-4b   | 115                      | 120 | 12.17  |
| CRS1787                          | CRS1788  | (-)     | (-)     | H003-02H-6b   | 115                      | 120 | 14.74  |
| CRS1792                          | (-)      | (-)     | (-)     | H003-03H-3b   | 90                       | 95  | 21.24  |
| CRS1801                          | (-)      | (-)     | (-)     | H003-03H-5b   | 105                      | 110 | 23.90  |
| CRS1785                          | CRS1786  | CRS1812 | CRS1811 | H003-06H-2b   | 90                       | 95  | 33.55  |
| CRS1793                          | (-)      | (-)     | (-)     | H003-07H-3b1  | 38                       | 43  | 42.28  |
| CRS1780                          | CRS1781  | CRS1814 | CRS1813 | H003-09H-2b1  | 31                       | 36  | 51.27  |
| CRS1795                          | (-)      | (-)     | (-)     | H003-10H-5b1  | 48                       | 53  | 61.84  |
| CRS1777                          | CRS1779  | CRS1825 | (-)     | H003-12H-2b   | 105                      | 110 | 72.41  |
| CRS1802                          | (-)      | (-)     | (-)     | H003-14H-2b1  | 67                       | 72  | 82.70  |
| CRS1796                          | (-)      | (-)     | (-)     | H003-16H-1b   | 100                      | 110 | 92.16  |
| CRS1803                          | (-)      | (-)     | (-)     | H003-17H-2b1  | 76                       | 81  | 99.09  |
| CRS1782                          | CRS1783  | (-)     | (-)     | H003-18H-2b1  | 85                       | 90  | 106.44 |
| CRS1797                          | (-)      | (-)     | (-)     | H003-20H-2b1  | 117                      | 122 | 115.91 |
| CRS1806                          | (-)      | (-)     | (-)     | H003-21H-3b   | 97                       | 107 | 125.37 |
| CRS1775                          | CRS1776  | (-)     | (-)     | H003-22H-4b   | 105                      | 110 | 135.06 |
| CRS1807                          | (-)      | (-)     | (-)     | H003-23H-4b   | 79                       | 84  | 142.08 |
| CRS1798                          | (-)      | (-)     | (-)     | H003-26X-4b   | 89                       | 97  | 284.83 |
| CRS1826                          | (-)      | (-)     | (-)     | H002-14CS-3A2 | 13                       | 21  | 827.00 |

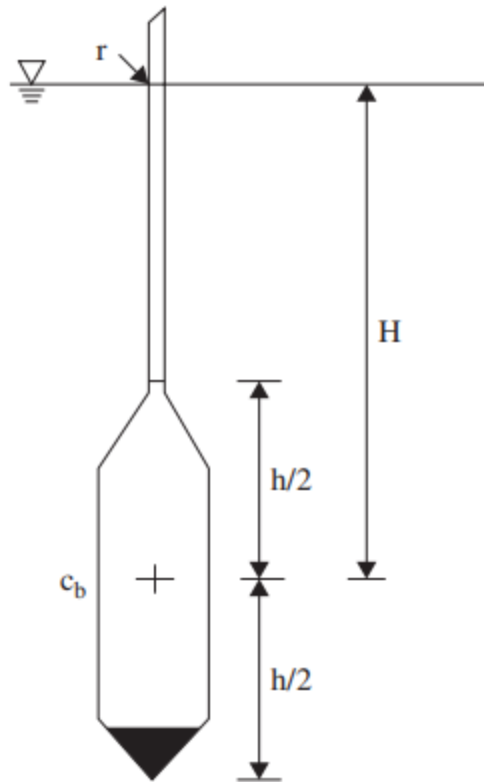


Figure 5-1 Hydrometer - Critical dimensions. Credit: (Germaine, 2009)

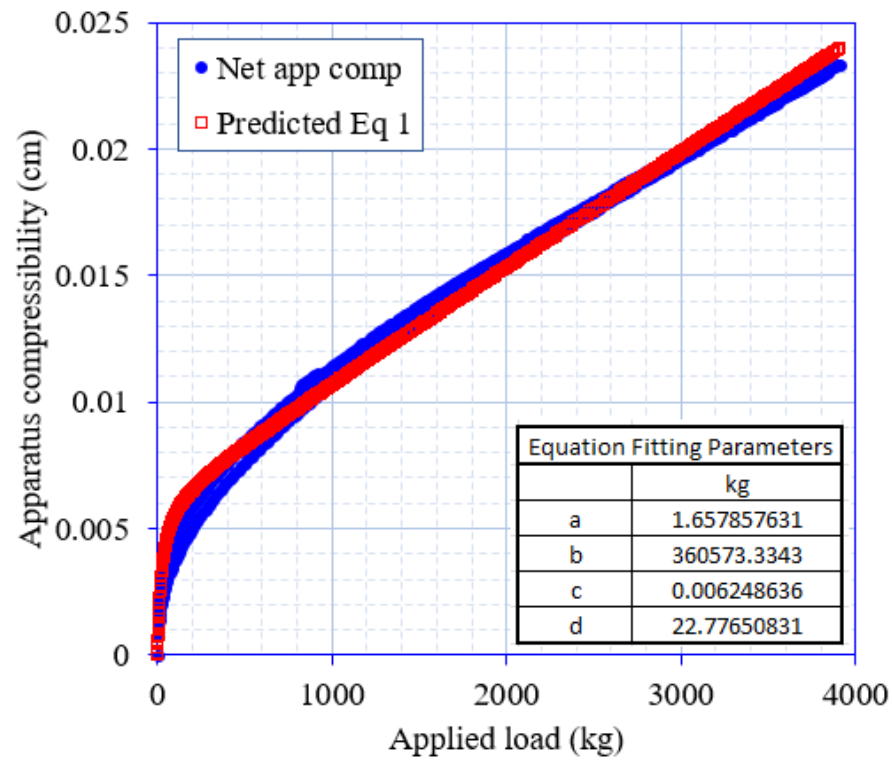


Figure 5-2 - Apparatus compressibility CRS STA08. Fitting function and parameters were added to the computer program before testing.

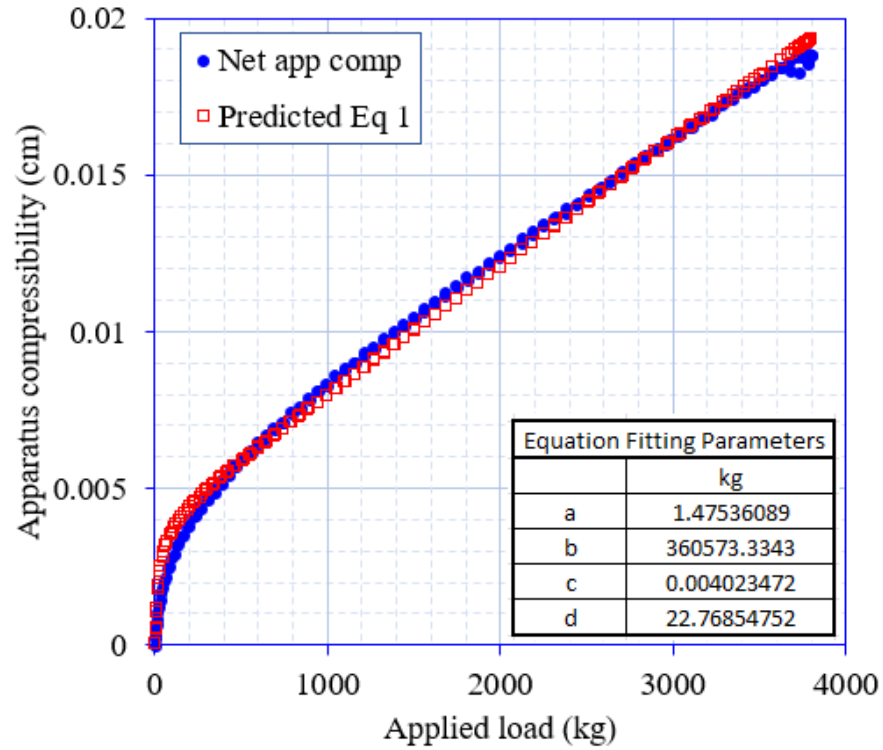


Figure 5-3 - Apparatus compressibility CRS STA09 Fitting function and parameters were added to the computer program before testing.

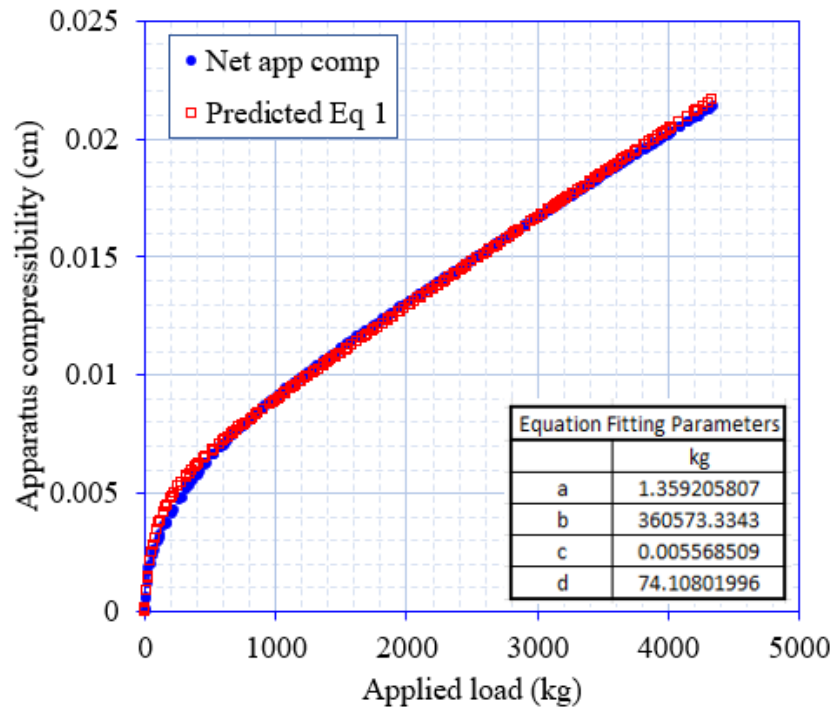


Figure 5-4 - Apparatus compressibility CRS STA02 Fitting function and parameters were added to the computer program before testing.

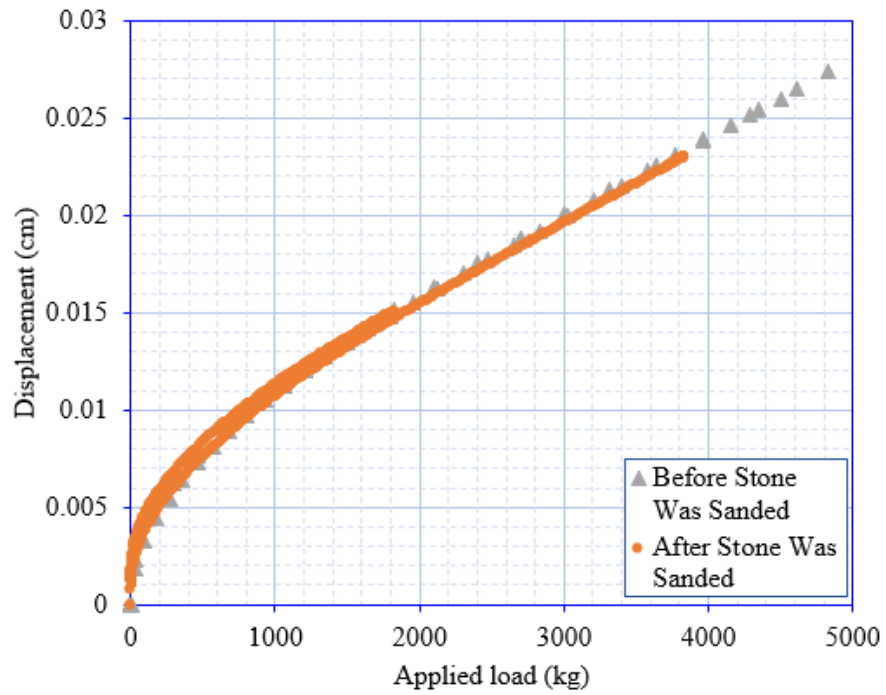


Figure 5-5 Apparatus compressibility investigation of the effects of sanding the porous stones with sand paper.

## **Chapter 6 - Experimental Results and Discussion**

### **6.1 Overview of Experiments**

This section presents the results of MAD measurements, particle size analysis, grain density, Atterberg limits, and mineralogical composition. Additionally, it includes a comparison of the compressive behavior between intact and resedimented samples. The results of CRS testing are utilized to generate stress profiles and analyze the stress history of the sediment column. Finally, OED testing is conducted to quantify the secondary compression behavior of the sediment.

### **6.2 Moisture and Density (MAD) and porosity Results**

The MAD results have been systematically analyzed by categorizing them into two groups: the 283 SC plugs and the 53 WR samples. The data obtained from the SC plugs include measurements of water content, wet density, and porosity, with the corresponding profiles illustrated in Figures 6-1 through 6-6.

Figures 6-1 and 6-2 show the water content measurements of the 283 SC plugs and 53 WR samples, respectively. Trends are observed at various depth intervals. It is presumed that these trends correlate with the ooze and mud layers. The water content increases within the ooze layers and trends downward overall.

Figures 6-3 and 6-4 illustrate the computed wet density values derived from direct measurement techniques and the assumption of 100% saturation. Given the strong agreement between the saturation-based estimates and measured data, the assumption of full saturation is deemed a valid and reliable approach.

Figures 6-5 and 6-6 illustrate the porosity measurements for both the 283 SC plugs and the 53 WR samples. The porosity is calculated using an assumed saturation of 100% and a grain density of 2.72 g/cm<sup>3</sup>. One of the most apparent trends observed in these results is within the ooze layers, where a decrease in wet density accompanies an increase in porosity. These variations are likely attributed to the relatively unconsolidated nature of the ooze, which retains a higher volume of pore water and exhibits lower compaction. Also plotted is the LWD data.

One notable trend across both datasets is that the porosity values derived from the laboratory-measured samples generally plot to the right of the LWD data. This discrepancy is expected and can be attributed to the fact that the recovered samples are in an unloaded state during testing. Unlike in situ conditions, where the sediment is subjected to overburden pressure, the extracted samples are no longer compressed by the surrounding geological formations. As a result, they tend to exhibit higher porosity values than those recorded by downhole logging tools, which measure properties in their natural subsurface state

For reference, the complete set of measured values can be found in Appendix A Tables 9-1 and 9-2.

### **6.3 Particle size analysis**

Most of the collected samples fall within the silty clay region of the ternary diagram, as shown in Figure 6-7. Particles less than 2 microns are classed as clay and particles between 75 and 2 microns are classed as silt. To facilitate analysis, the samples have been categorized into two groups: mud and ooze. Despite this distinction, all samples contain a similar clay content, averaging 58%, indicating a predominantly fine-grained composition. Differences become apparent when comparing the silt and sand fractions between the two groups. The mud samples have an average silt content of 41% and a minimal sand content of 1%, while the ooze samples have a slightly

lower average silt content of 36% but a higher sand content of 6%. This indicates that the ooze samples contain a greater proportion of coarser material. These differences are clearly illustrated in Figures 6-8 and 6-9. The overall similarity in clay content across all samples suggests a uniform fine-grained nature, with variations in silt and sand fractions distinguishing the two groups. A complete set of measured values for each sample can be found in Table 7-3.

The results obtained align with expectations for Gulf of Mexico sediments. Specifically, the RGoM-EI sediment samples plot within the ternary diagram's silty clay region as seen in Figure 6-7. This consistency underscores the characteristic fine-grained nature of sediments in the Gulf.

Microscopic analysis of the ooze samples reveals a significant presence of spherical-like microfossils embedded within the sediment. As shown in Figures 6-10 and 6-11, these microfossils appear to be abundant and well-preserved, contributing to the distinct composition of the ooze samples. It is estimated that many of these shells exceed 75 microns in size, leading to their classification as sand-sized particles in the grain size analysis. The sediment is further analyzed in Figures 6-12 and 6-13. The +200 fraction is analyzed under a microscope, and the high porosity ooze sample clearly has shells evident, with an abundance of quartz in the mud samples. To further understand their impact, the effects of these microfossils are specifically analyzed in the CRS testing results.

## **6.4 Grain Density**

### **6.4.1 Water Submersion Method**

A total of 50 WR samples were tested using the water submersion method to determine their grain density. The source of the material was the blended material of the MAD sections. The average grain density for this data set was found to be 2.795 g/cm<sup>3</sup>, with a standard deviation of 0.041, indicating a relatively small variation in the measurements. This number is consistent with

sediments from the Gulf of Mexico. The full set of results can be found in Table 7-4, providing detailed data for each sample tested.

#### **6.4.2 Gas Pycnometer Method**

A total of 333 grain density measurements were conducted using the gas pycnometer. 283 on SC plugs and 50 on plugs from the WR sections. The average value for the SC plugs is 2.727 g/cm<sup>3</sup> with a standard deviation of 0.023. The average value for the WR plugs is 2.734 g/cm<sup>3</sup> with a standard deviation of 0.027. The low standard deviations in both data sets indicate high measurement consistency and reliability. The complete data sets are in Tables 9-5 & 9-6.

#### **6.4.3 Comparison of both methods**

The grain density results clearly indicate that the gas pycnometer yields lower densities compared to the water submersion method. A direct comparison of both methods was conducted on WR plugs and blended material, with the results shown in Figure 6-14, highlighting the noticeable difference. One possible explanation for this difference is that the water submersion method may account for bound water within the sample, leading to higher density values compared to the gas pycnometer, which does not capture this additional volume.

### **6.5 Atterberg Limits**

The plasticity index (PI) of the tested soil samples was determined from the measured liquid limit (LL) and plastic limit (PL) values of five samples. The PI values range from 32% to 49%, with an average of 38%, while the LL values range from 59% to 75%, averaging 65%. These results are presented in Figure 6-15 on a plasticity chart. Based on the Unified Soil Classification System (USCS), the PI values classify the soil as high-plasticity clay (CH). The data points are clustered in two distinct locations within the CH zone. An analysis of the relationship between clay content and PI reveals no clear trend, suggesting that factors beyond clay content, such as mineral

composition and soil structure, may influence plasticity behavior. The results were also analyzed for a trend between mud and ooze layers, but no clear trend is evident. The results align with expectations for sediment with a high clay content, which is consistent with the soil's known composition.

The results are also compared to the RGoM-EI findings reported by (Hanley,2017), who estimated a PI of 64% and an LL of 87% (see Figure 2-5). While both materials are classified as CH under the USCS, the RGoM-EI material exhibits significantly higher plasticity than the soil analyzed in this study.

In contrast, the tested material can also be compared to Boston Blue Clay (BBC), as Hanley (2017) presented in Figure 2-5. Unlike the CH classification of the studied soil, BBC is categorized as a low-plasticity clay (CL) under the USCS. Hanley (2017) estimated the PI of BBC to be 24% and the LL to be 47%, both of which are significantly lower than the values obtained in this study. This distinction highlights the researched soil's greater plasticity and moisture sensitivity compared to BBC.

## **6.6 X-Ray Diffraction Analysis**

Samples were sent to the James Hutton Institute in Scotland for X-ray diffraction analysis. The results for two samples, one mud and one ooze, are shown in Figures 6-16 and 6-17. The mud sample is dominated by Illite/Illite-Smectite (35%), followed by Quartz (19%), Plagioclase (15%), Calcite (13%), and smaller amounts of K-feldspar (9%) and Dolomite (9%). The ooze sample is primarily composed of Illite/Illite-Smectite (38%) and Calcite (34%), followed by Quartz (14%), with smaller amounts of Dolomite (6%), Plagioclase (5%), and K-feldspar (3%). The most significant observation is that the ooze sample contains a higher percentage of calcite.

## **6.7 CRS Testing**

### **6.7.1 Intact Vs Resedimented**

An analysis of the compressive behavior during CRS testing was conducted on both intact and resedimented samples from three different specimens: H003-6H-2B, H003-9H-2B1, and H003-12H-2B. The results are presented in Figures 6-18 to 6-20, providing a comparative view of how the different samples respond to compression under increasing stress.

H003-6H-2B, located at 33.5 mbsf, is a mud sample on which two tests were conducted using intact specimens and two using resedimented specimens. The average behavior of each category is plotted for comparison to evaluate variations in compressive response. The intact sample is plotted for comparison to evaluate variations in compressive response. The intact sample exhibits slightly greater resistance to compression, sustaining higher stresses at a given void ratio compared to the resedimented sample. However, as the void ratio decreases, the differences between the two samples diminish, leading their behaviors to converge gradually. This implies that, under high stress, the structural differences between intact and resedimented samples become less distinct.  $C_c$ , calculated as the average slope of the compression curve between 1 and 40 MPa, is 0.373 for the intact sample and 0.357 for the resedimented sample, suggesting only a slight reduction in compressibility in the resedimented material.

H003-9H-2B1, located at 55 mbsf, is also a mud sample, tested under identical conditions, with two intact and two resedimented specimens analyzed. The average behavior of each category is again plotted for comparison, revealing a different trend than that observed in H003-6H-2B. Unlike the shallower sample, this specimen exhibits lower resistance to compression in the intact state, with the intact sample sustaining lower stresses at a given void ratio than the resedimented sample. The compression curve for the intact sample is consistently shifted to the left throughout its entire length, with minimal convergence at higher stress levels. This suggests a fundamental difference

in the natural state of this sample.  $C_c$  for the resedimented sample is 0.337, while for the intact sample, it is 0.323.

H003-12H-2B, located at 72 mbsf, is an ooze sample, with two tests conducted on intact specimens and one on a resedimented specimen. The average behavior of the intact behavior is plotted against the resedimented test, showing a trend more consistent with that of H003-6H-2B. The intact sample exhibits greater resistance to compression, sustaining higher stresses at a given void ratio compared to the resedimented sample. The overall behavior closely resembles that of H003-6H-2B. The difference in behavior between the intact and resedimented samples decreases at higher stresses, aligning with the general observation that microstructural differences are less significant under extreme loading conditions.  $C_c$  for the intact samples is 0.454, while the resedimented specimen has a  $C_c$  value of 0.410, demonstrating a moderate reduction in compressibility due to resedimentation.

Overall, the results indicate that intact samples generally exhibit higher resistance to compression compared to their resedimented trimmings, with the notable exception of sample H003-9H-2B1. This observation is supported by one-to-one comparisons, revealing excellent overall agreement between intact and resedimented samples. The differences in void ratio are minimal, and the compression behavior of both sample types tends to converge as the applied stress increases. This convergence suggests that the initial discrepancies are primarily attributable to differences in depositional fabric and structure, which are gradually overridden under higher stress conditions. To the best of the authors' knowledge, this study represents the first direct, sample-by-sample comparison of intact and resedimented specimens of the same local material.

### 6.7.2 Compression Curves

The compression curves were analyzed for specific depth-identified layers and separately for ooze and mud samples to investigate differences in mechanical behavior. The specific test locations are displayed in Table 5-1. Table 7-8 also details test information. The comparison between ooze and mud is illustrated in Figure 6-21, while the layer-specific compression curves are detailed in Figures 6-22 to 6-29. The sediment column is divided into eight distinct layers, which are summarized in Table 6-1.

A clear distinction in mechanical behavior is evident between ooze and mud samples in Figure 6-21. The ooze layers exhibit significantly higher initial void ratios and greater compressibility than the mud layers. In contrast, the mud samples begin with a lower void ratio and are notably less compressible, suggesting a fundamental difference in their composition. These trends indicate that ooze layers are more susceptible to volume reduction.

Nine ooze samples were averaged to generate an overall compression curve, with the one standard deviation limits of the behavior also plotted to illustrate variability within the ooze dataset. Similarly, fifteen mud samples were averaged, with their respective standard deviation included. This approach ensures that the trends observed in the data are representative of the broader sediment characteristics rather than anomalies from individual samples. The  $C_c$  values further support these findings, with the ooze layers averaging a  $C_c$  value of 0.443, indicating higher compressibility, while the mud layers have a lower average  $C_c$  of 0.324, confirming their reduced compressibility. Some variability in ooze results is attributed to the fact that layers are classified by depth.

Overall, these findings emphasize the fundamental differences between ooze and mud regarding their compressive response, with ooze layers showing a more pronounced volume reduction under stress. The data indicate that lithology plays a crucial role in determining the sediment's mechanical behavior.

Figure 6-22 illustrates the compression data for Layer 1, which is 19 m thick. This ooze layer consists of five tested samples, from which the average curve was generated. It is a very soft, uncompacted layer, and the samples were particularly sensitive during processing. While variability exists in the initial void ratios, all tested samples converge at a void ratio of approximately 0.34 at 40 MPa.

Figure 6-23 illustrates the compression data for Layer 2, a mud layer 41 m thick. The behavior of seven CRS tests characterizes this layer. Compared to the previous layer, there is less variability in the initial void ratios, with most samples converging at a void ratio of 0.28 at 40 MPa. Each curve's behavior is relatively consistent, exhibiting a slight concavity downward in the compression curve.

Layer 3 is represented by only two CRS tests, as illustrated in Figure 6-24. This layer also consists of ooze and converges at a void ratio of 0.36 under a pressure of 40 MPa. The layer has an approximate thickness of 12 meters, and the concavity downward is evident.

Layer 4 is averaged using three CRS tests and is represented in Figure 6-25. This is a 25 m thick mud layer. The variability in the initial void ratio is minimal, and all curves converge at a pressure of 5 MPa. Behavior at high stress is very consistent between all tests in this layer.

Figure 6-26 shows the compression data for Layer 5, which is 11 m thick and classified as an ooze layer. Only two tests were conducted in this layer. No concavity is observed at higher stresses, and both tests converge at a void ratio of 0.36 at a stress of 40 MPa.

Figure 6-27 presents the compression data for Layer 6, which is a mud layer that is 24 m thick. Only three tests were performed in this layer. The variability in the initial void ratio is minimal, with all tests converging at a void ratio of 0.3 at 40 MPa. Some slight concavity downward is observed at higher stresses.

The compressive behavior of Layer 7 is described by just one CRS test in Figure 6-28. This ooze layer is 16 m thick with minimal concavity noticed in the curve. A void ratio of 0.26 is reached at 40 MPa.

Figure 6-29 presents the data for Layer 8, which is classified as a mud layer. This layer has a thickness of 746 m for the purpose of this research. Descriptions of the layer stem from two tests: one at 285 mbsf and another at 832 mbsf. While more data would improve the representation of the layer, this was not feasible for several reasons. Both tests start at a relatively low void ratio in comparison to the complete data set and possess similar compressive characteristics at higher stresses.

### **6.7.3 Preconsolidation Pressure**

The interpretation of the preconsolidation pressure for all the compression tests are displayed in Figures 6-32 to 6-55, with 24 samples reported using the strain energy method. Each graph indicates both upper and lower values of preconsolidation pressures. A consistent challenge across all graphs was determining the transition from the elastic to the virgin compression portions of the graph. This transition is a crucial point in determining the preconsolidation pressure, yet its precise

location was often ambiguous due to variations in sample behavior. The primary reason for this uncertainty is believed to be sampling disturbance, which affects the soil structure and compressibility characteristics. Further evidence of sample disturbance is provided by the CT scan images, which clearly reveal shear deformation within the specimens. This shear deformation suggests that the natural structure of the soil was altered during sampling, leading to changes in stress-strain behavior. Disturbed samples tend to exhibit a more gradual transition between the elastic and virgin compression regions, making it challenging to pinpoint the exact preconsolidation pressure.

While the strain energy method offered valuable insights into the preconsolidation pressures of the tested samples, the presence of sample disturbance and shear deformation introduces uncertainties that must be considered when interpreting the results. The work of (Santagata and Germaine, 2002) lends credibility to the findings. They presented results from a comprehensive parametric study on the effects of simulated sampling disturbance on low to medium-sensitivity normally consolidated clays (NC). Their research provided a useful framework for quantifying the effects of tube penetration and stress release, assessing the sensitivity of NC soils to disturbance, and determining which engineering parameters are most affected by disturbance. The tests conducted indicate that disturbance influences the preconsolidation pressure to a lesser degree.

#### **6.7.4 Stress Profiles**

The stress profiles for the sediment column are presented in Figures 6-30 and 6-31, which differ only in depth scale to highlight the data concentration within the upper 150 meters below seafloor (mbsf). The construction of the effective stress profile begins at 4 mbsf, following an assumed effective stress value beneath the surface sand layer (0–4 mbsf). From this point downward, the

profile is developed in 1-meter increments using an Excel-based method. For each increment, the total density is computed using a curve-fitting equation derived from the average compression behavior of the corresponding layer. The parameters are shown in Table 6-2. The total vertical stress is then calculated by integrating the density over depth. Hydrostatic pore pressure is estimated at each depth increment and subtracted from the total stress to obtain the effective stress. This iterative approach continues layer by layer, generating the complete effective stress profile for the sediment column

For clarity, the 2000 m depth of seawater above the deposit is excluded from the calculations. The stress profiles encompass hydrostatic pressure, effective pressure, total pressure, and preconsolidation pressure of each CRS test, with upper and lower maximum past pressure reported for each test.

The maximum past pressure results appear to track the hydrostatic water pressure line up to 115 mbsf, indicating an absence of overpressure as expected. Beyond this point, there is a slight shift to the right up to 285 mbsf, suggesting some overpressure. The deep sample collected at 832 mbsf does not exhibit significant signs of overpressure. Instead, the results suggest that the deeper sediments have had sufficient time or permeability to allow fluid escape, and the pore water has not accumulated significant pressure during burial.

#### **6.7.5 Porosity**

The porosity profiles are illustrated in Figures 6-56 and 6-57, with the only difference between the two plots being the depth scale. The LWD data was utilized to derive a porosity profile of the sediment column. In contrast, the porosity profile from the CRS tests was constructed based on the effective stress profile assuming hydrostatic pore pressures detailed in the preceding sections. To develop the CRS porosity profile, layer-specific average compression curves are used, enabling

a more refined representation of porosity variations with depth. Both methods reveal increases in porosity within the ooze layers, demonstrating consistent trends between the two approaches. However, the LWD data highlights a notable increase in porosity at approximately 350 mbsf, a feature that the CRS model does not capture. However, there is an absence of tested samples in that depth range. Additionally, the LWD data tends to predict slightly higher porosity values at greater depths compared to the CRS-based estimations. The in-situ porosity for each CRS test is also plotted using the compression curve for each test in Figures 6-56 and 6-57. The in situ effective stress and individual compression curve are used to determine the porosity at the location of each individual test.

The overall porosity trend shows a steady decrease with depth, as anticipated. There are also clear differences between lithologies and slight differences between measurement types. This may indicate tool-specific bias or resolution effects. In the drilling industry, sudden variations in porosity at shallow depths are often overlooked during the planning phase because they are assumed to be negligible or non-existent. However, ignoring these fluctuations could have serious implications for future well stability and performance. The porosity profile clearly illustrates that significant shifts in porosity occur due to changes in lithology. These variations emphasize the need for careful consideration of porosity trends during well planning to ensure accurate assessments of formation properties and to mitigate potential drilling risks.

#### **6.7.6 Permeability**

The porosity-permeability relationship is used to construct the permeability profile shown in Figure 6-59. This profile is developed using layer-specific permeability curves, as illustrated in Figure 6-58, to represent permeability variations with depth accurately. In Figure 6-58, the red curves correspond to the ooze layers, while the black curves represent the mud layers. A

permeability porosity relationship is generated during the CRS test which is detailed in the methodology section. This relationship is then averaged for each layer as presented in Figure 6-58. The permeability profile which is computed based on the porosity depth profile and the individual layer average curves reveals a distinct increase in permeability within the ooze layers, reflecting their relatively higher porosity and lower resistance to fluid flow compared to the surrounding mud layers. This contrast highlights the significant influence of lithology on permeability distribution. The overall mud permeability trend exhibits a decline with increasing depth, driven by compaction and the progressive reduction of pore space, which restricts fluid movement through the sediment. It is also interesting to see that the trend in the ooze is opposite to what is expected. Permeability increases with depth, showing that the composition is more important than the stress effect.

It is important to recognize that permeability likely shows greater variability in the deeper sections. However, the lack of samples from this depth range limits the ability to capture these fluctuations, potentially resulting in an underestimation of permeability variations in the lower part of the profile.

#### **6.7.7 Influence of fossils**

Figure 6-60 presents a plot of  $C_c$  versus percentage sand content for both ooze and mud samples. The plot reveals that most ooze samples exhibit high compressibility alongside a high sand content percentage. This trend is likely due to the presence of fossils within the ooze samples, many of which exceed 75 microns in size and are classified as sand in hydrometer testing. However, this pattern is not consistent across all ooze samples. Notably, the sample retrieved from 142 meters below the seafloor (mbsf) demonstrates the lowest compressibility and sand content. This could indicate that shell fragments have undergone crushing during burial, reducing their contribution to

the sand fraction. Additionally, it is possible that some shells are smaller than 75 microns, classifying them as silt, which may contribute to a greater void space compared to mud samples.

## **6.8 Oedometer Testing**

One OED test was conducted on sample H003-7H-3B1, which is a mud layer (#2) located at 42 mbsf. The test involved nine increments, reaching a stress of 64 MPa. The compression curve is depicted in Figure 6-61, with a summary of results provided in Table 7-7. Sample disturbance is again evident, as the determination of the elastic and virgin compression portions of the graph is unclear. It is clear from the plot that the sample experienced some swelling effects in the early portion of the graph. The preconsolidation pressure was omitted, as extensive determinations were made in the CRS testing results section of this report. The primary purpose of the OED testing was to measure secondary compression. Figure 6-62 illustrates the log time versus strain curve for load increment nine, where the value of secondary compression for this increment is 0.277 %/log time. The ratio of secondary to primary is approximately 1.5%. The average secondary compression value across all increments is 0.3002 %/log time with a standard deviation of 0.0317. For context the secondary compression value for RBBC is reported to be 0.28 %/log time +/- 0.05, reported by (Cauble, 1993) and (Sheahan, 1991). (Uyeturk, 2024) reports the ratio for BBC and RBBC range between 2.3-3%.

## **6.9 Strength Correlation**

The liquid limit was used to estimate the undrained shear strength of the sediment. An equation correlating Liquid Limit and vertical effective stress is derived by (Casey and Germaine, 2013). The results of five samples are presented in Figure 6-63. The actual data is shown in Table 6-3 for reference. Also included in the plot is the undrained shear strength derived from lab vane measurements. The values are significantly lower, which seems unreasonable. One possible

reason is that the sediment has been unloaded when the lab vane measurements are taken. The equations used are 6.1, 6.2 & 6.3.

$$\frac{Su}{\sigma'v_0} = S1(1000\sigma'p(mpa))^T \quad (6.1)$$

$$S1 = 0.86LOG(WL) - 1.04 \quad (6.2)$$

$$T = -0.46LOG(WL) + 0.73 \quad (6.3)$$

### 6.10 Compressibility Correlation

The compressibility of the sediment was correlated to the liquid limit using (Terzaghi et al., 1996) and also (Skempton and Jones, 1944). The equations utilized are 6.2 and 6.3, respectively. The results are presented in Figure 6-64, and the actual values are shown in Table 6-4. Skempton's approach aligns best with the compression index ( $C_c$ ) derived from actual CRS testing data of the sediment.

$$C_c = 0.009(w_l - 10\%) \quad (6.4)$$

$$C_c = 0.007(w_l - 10\%) \quad (6.5)$$

Table 6-1 - Summary of Layers

| Layer | Depth ( mbsf ) | Ooze/Mud |
|-------|----------------|----------|
| 1     | 4-23           | Ooze     |
| 2     | 23-64          | Mud      |
| 3     | 64-78          | Ooze     |
| 4     | 78-103         | Mud      |
| 5     | 103-114        | Ooze     |
| 6     | 114-138        | Mud      |
| 7     | 138-154        | Ooze     |
| 8     | 154-900        | Mud      |

Table 6-2 Average compression curve fitting parameters

| Layer | top Depth | Curve Fitting Parameters |          |          |          |          |
|-------|-----------|--------------------------|----------|----------|----------|----------|
| 1     | 4         | 5.98623                  | 1.02859  | 0.16681  | 2.09535  | 0.31426  |
| 2     | 23        | 4.298057                 | 55.37279 | 6.649475 | 0.007454 | 2.670708 |
| 3     | 64        | 1.755954                 | 0.734102 | 0.551733 | 0.742345 | 0.033028 |
| 4     | 78        | 1.640115                 | 0.812805 | 0.403542 | 0.774985 | 0.181371 |
| 5     | 103       | 1.489205                 | 0.075172 | 0.575461 | 1.414628 | -0.03182 |
| 6     | 114       | 1.055665                 | 1.563135 | 1.03372  | 0.253855 | 0.044538 |
| 7     | 138       | 1.543674                 | 2.249956 | 0.434742 | 0.58614  | 0.185258 |
| 8     | 154       | 2.86693                  | 0.13121  | 0.32848  | 0.2718   | 1.90363  |

Table 6-3 - Strength correlation by Casey & Germaine from Atterberg limits

| Sample      | Depth  | PL  | LL  | PI  | $\sigma'_{vo}$ | Casey & Germaine 2013 |        |                    |          |
|-------------|--------|-----|-----|-----|----------------|-----------------------|--------|--------------------|----------|
|             |        |     |     |     |                | S1                    | T      | Su/ $\sigma'_{vo}$ | Su (MPa) |
| (-)         | (mbsf) | (%) | (%) | (%) | (MPa)          | (-)                   | (-)    | (-)                | (MPa)    |
| H003-6H-6B  | 37.63  | 30  | 74  | 44  | 0.280          | 0.568                 | -0.130 | 0.273              | 0.076    |
| H003-9H-2B1 | 51.18  | 30  | 61  | 33  | 0.397          | 0.495                 | -0.091 | 0.287              | 0.114    |
| H003-12H-2B | 72.41  | 26  | 75  | 49  | 0.568          | 0.573                 | -0.133 | 0.247              | 0.140    |
| H003-21H-6B | 128.66 | 23  | 57  | 34  | 1.059          | 0.470                 | -0.078 | 0.274              | 0.290    |
| H003-22H-4B | 135.06 | 27  | 59  | 32  | 1.126          | 0.483                 | -0.085 | 0.267              | 0.300    |

Table 6-4 - Compression correlation by Terzaghi, Peck & Skempton from Atterberg limits

|             |        |     |     |     | CRS   | Terzaghi & Peck | Skempton |
|-------------|--------|-----|-----|-----|-------|-----------------|----------|
| Sample      | Depth  | PL  | LL  | PI  | Cc    | Cc              | Cc       |
| (-)         | (mbsf) | (%) | (%) | (%) | (-)   | (-)             | (-)      |
| H003-9H-2B1 | 51.18  | 30  | 61  | 33  | 0.323 | 0.459           | 0.357    |
| H003-12H-2B | 72.41  | 26  | 75  | 49  | 0.453 | 0.585           | 0.455    |
| H003-22H-4B | 135.06 | 27  | 59  | 32  | 0.295 | 0.441           | 0.343    |

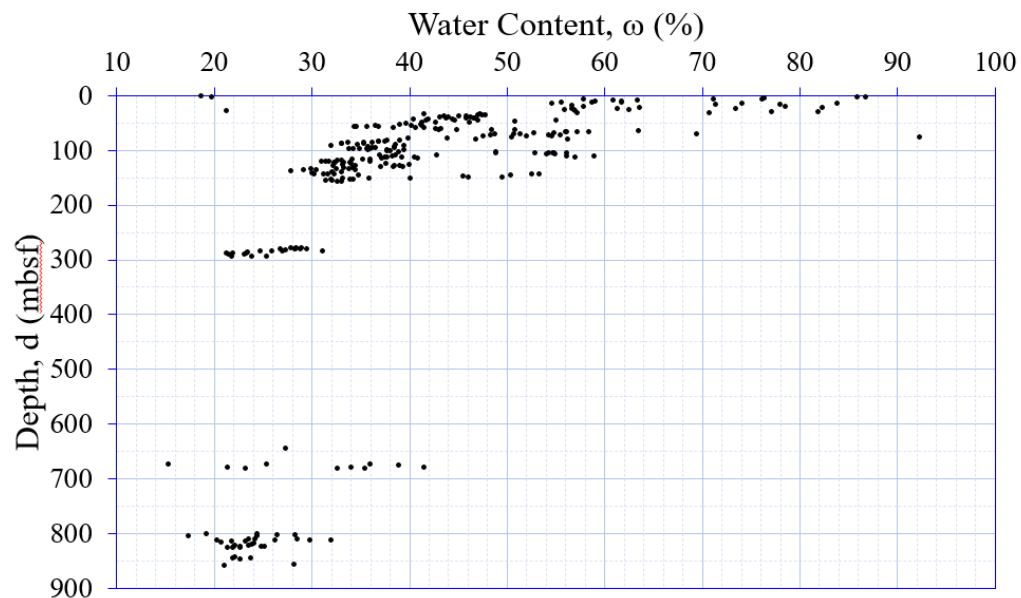


Figure 6-1 283 SC plugs water content measurement plotted with depth. (0-900 mbsf)

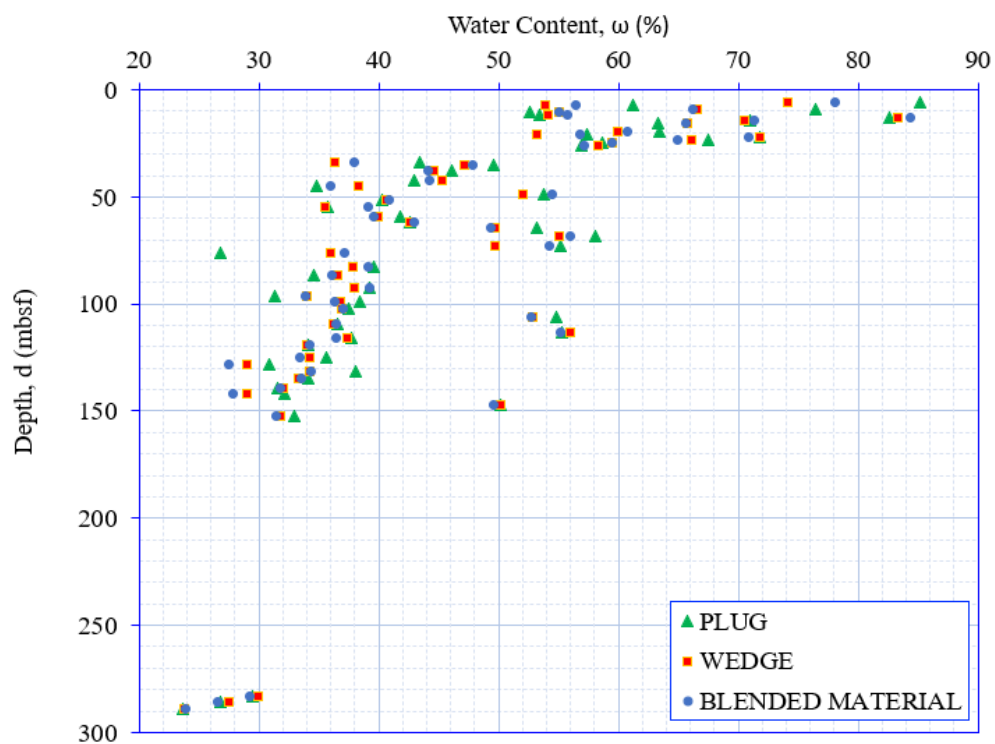


Figure 6-2 WC samples water content measurement. Measurements for the plug, wedge & blended included. (0-300 mbsf)

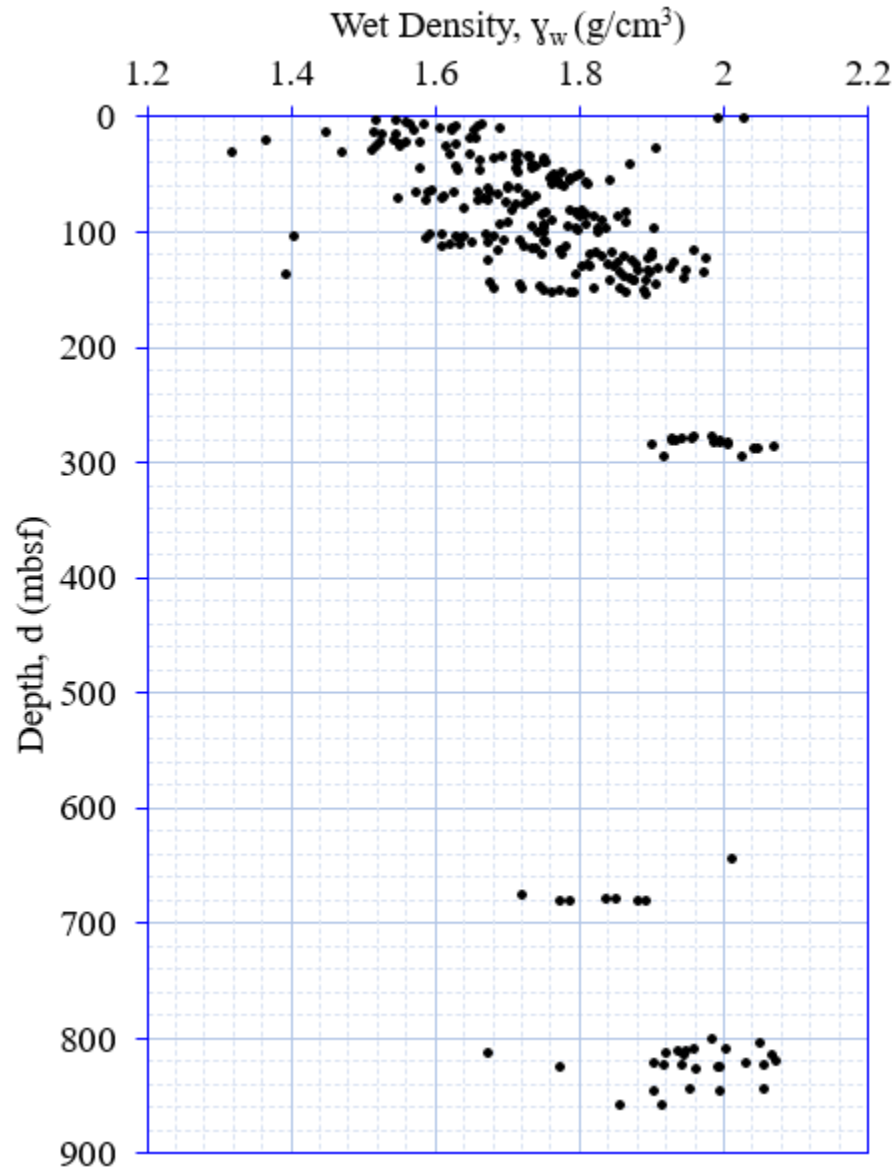


Figure 6-3 Wet density measurement of the 283 SC plugs plotted with depth. (0-900 mbsf)

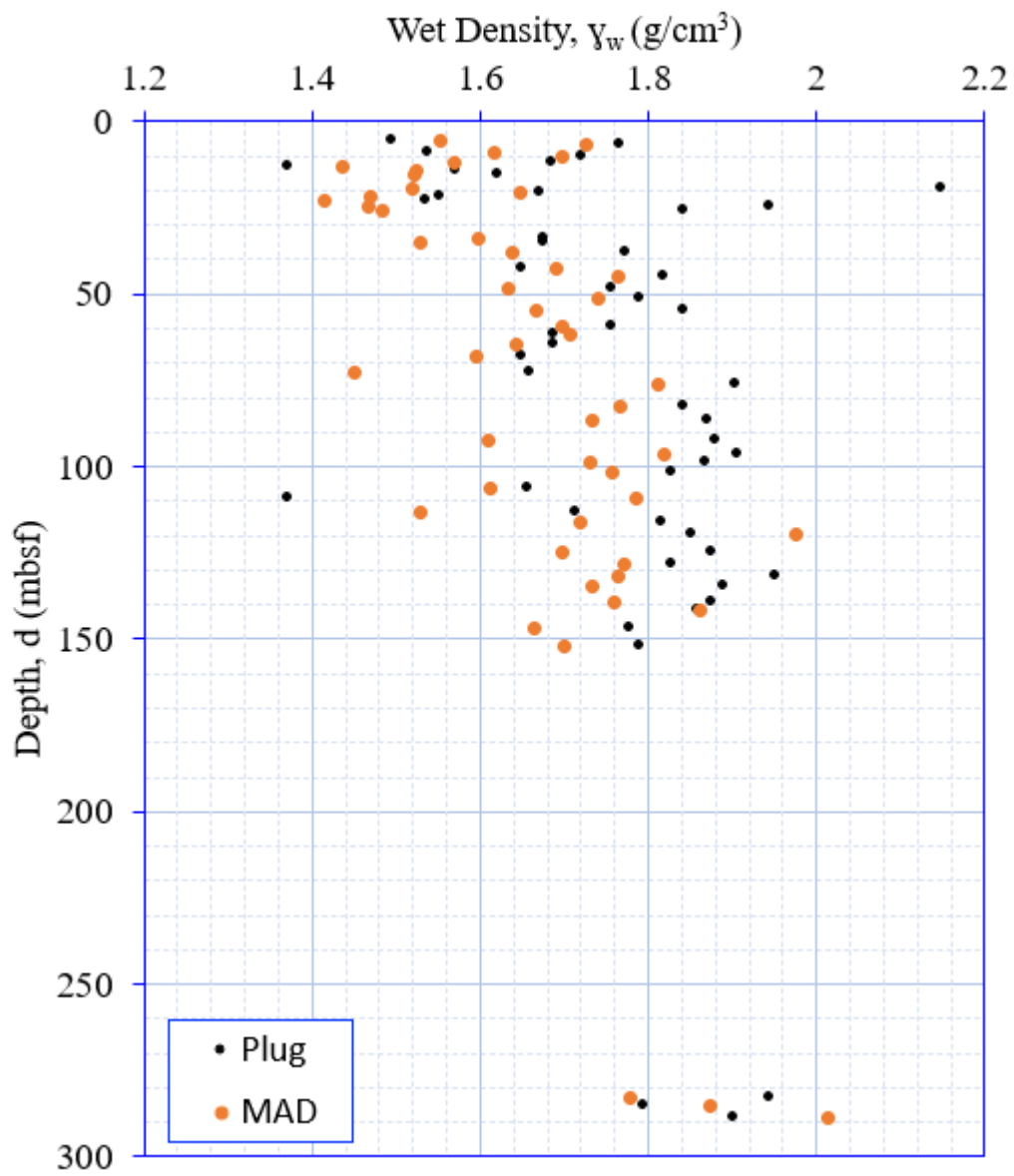


Figure 6-4 Wet density measurement of the 53 WC samples. Measurement of the plug and full section include. (0-300 mbsf)

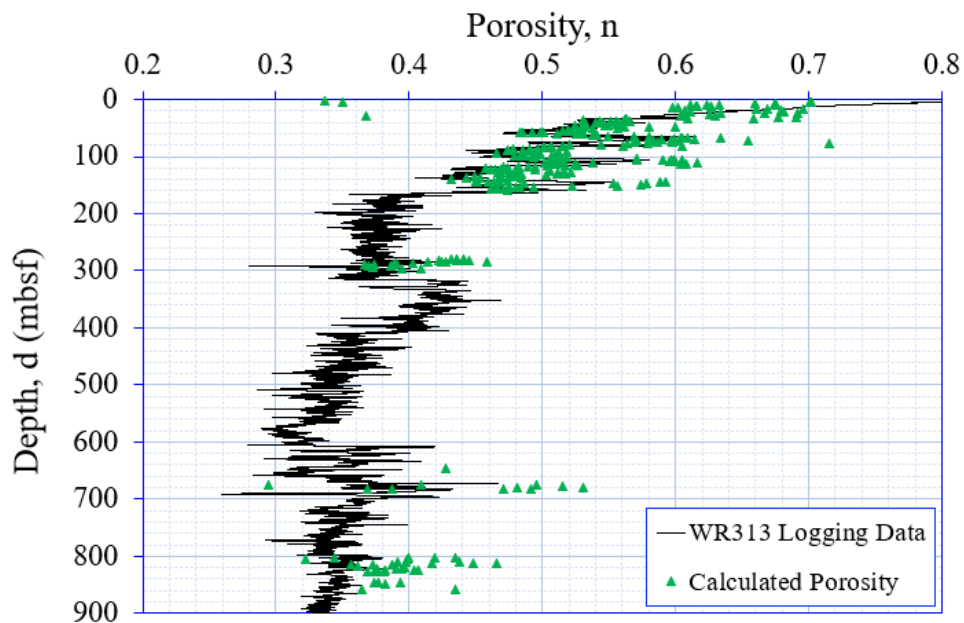


Figure 6-5 Porosity calculated from 283 SC plugs plotted with depth. A grain density of 2.72 g/cm<sup>3</sup> is assumed for the calculation. (0-900 mbsf). LWD data included for comparison.

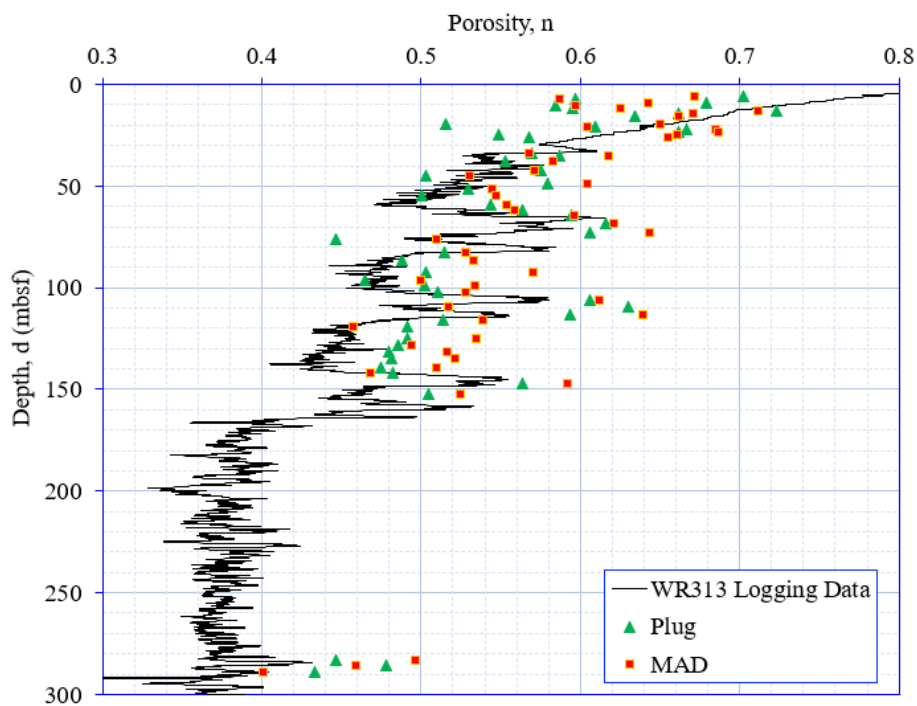


Figure 6-6 53 WC samples porosity calculation assuming a grain density of 2.72 g/cm<sup>3</sup>. LWD data plug and full section included. (0-300 mbsf)

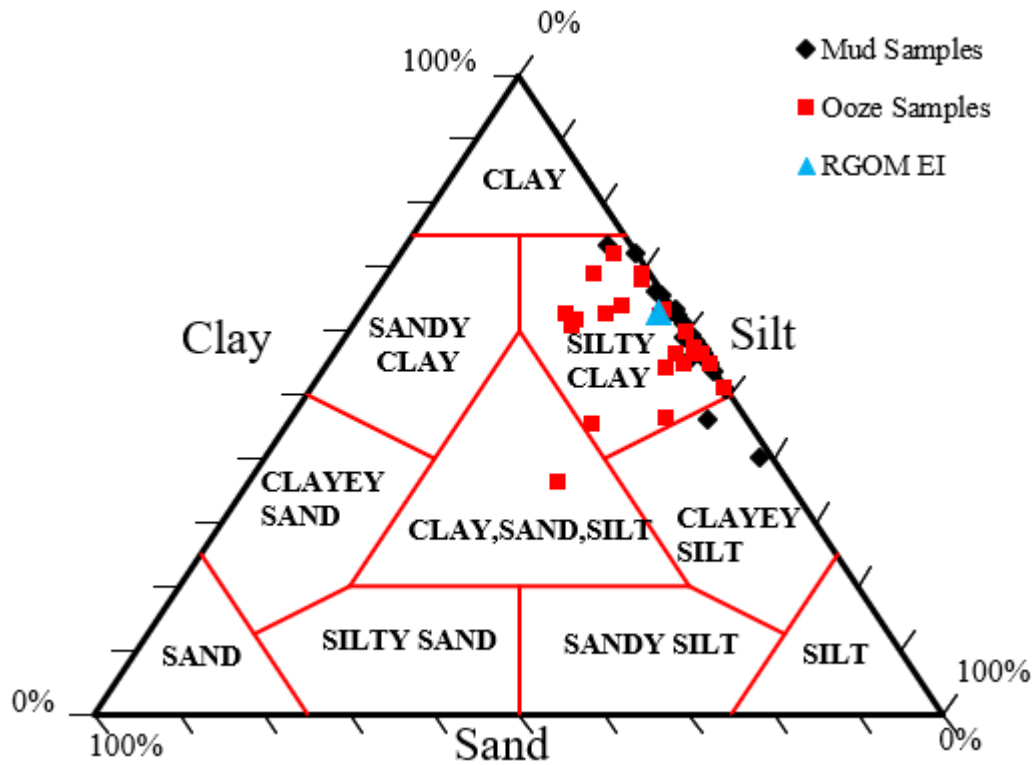


Figure 6-7 Ternary plot of data from 50 hydrometer tests. The majority of samples plot in the silty clay region. RGOM EI is also included.

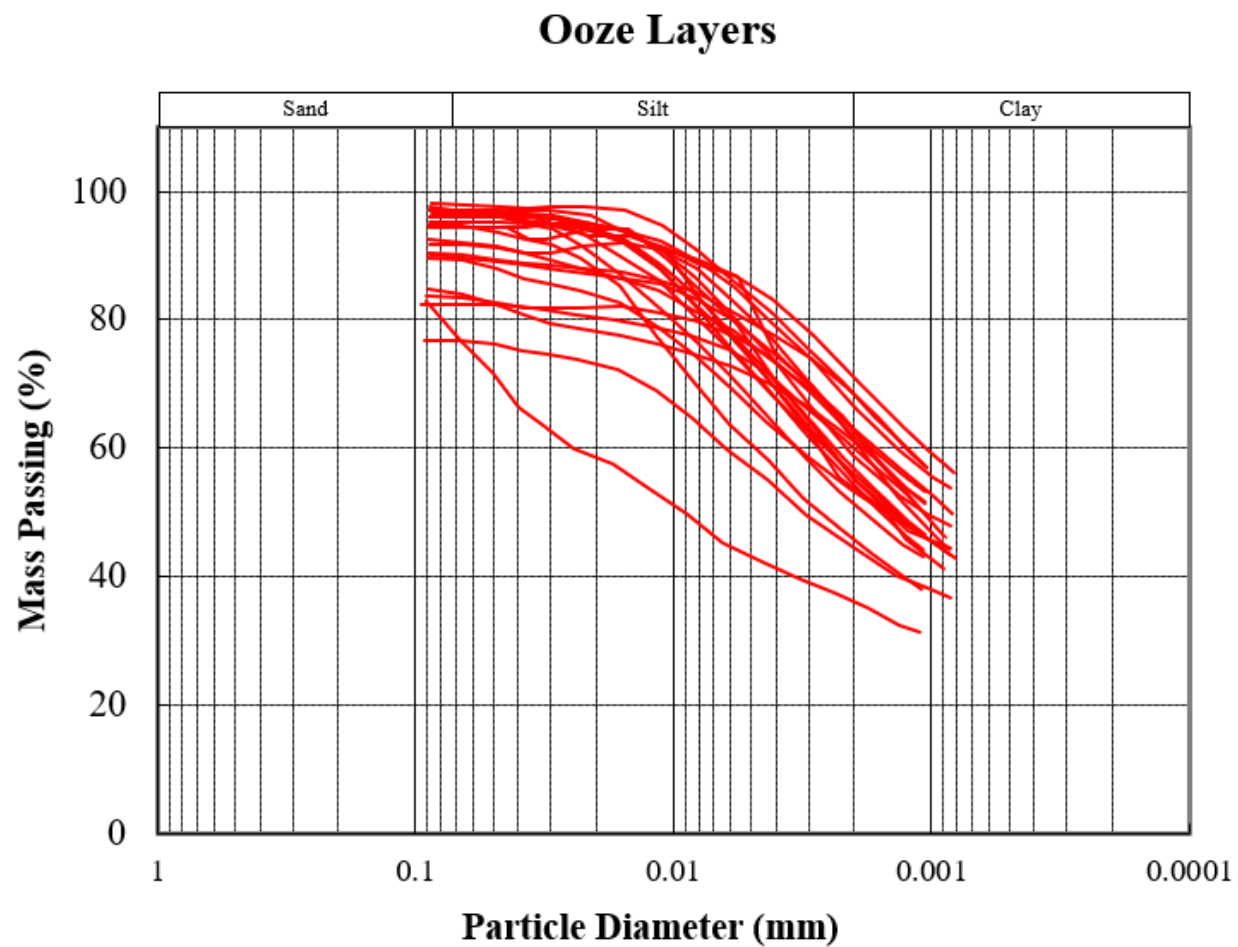


Figure 6-8 Grain size distribution graph of all the samples located in the ooze layers. Higher percentage sand content noticed in the ooze layers.

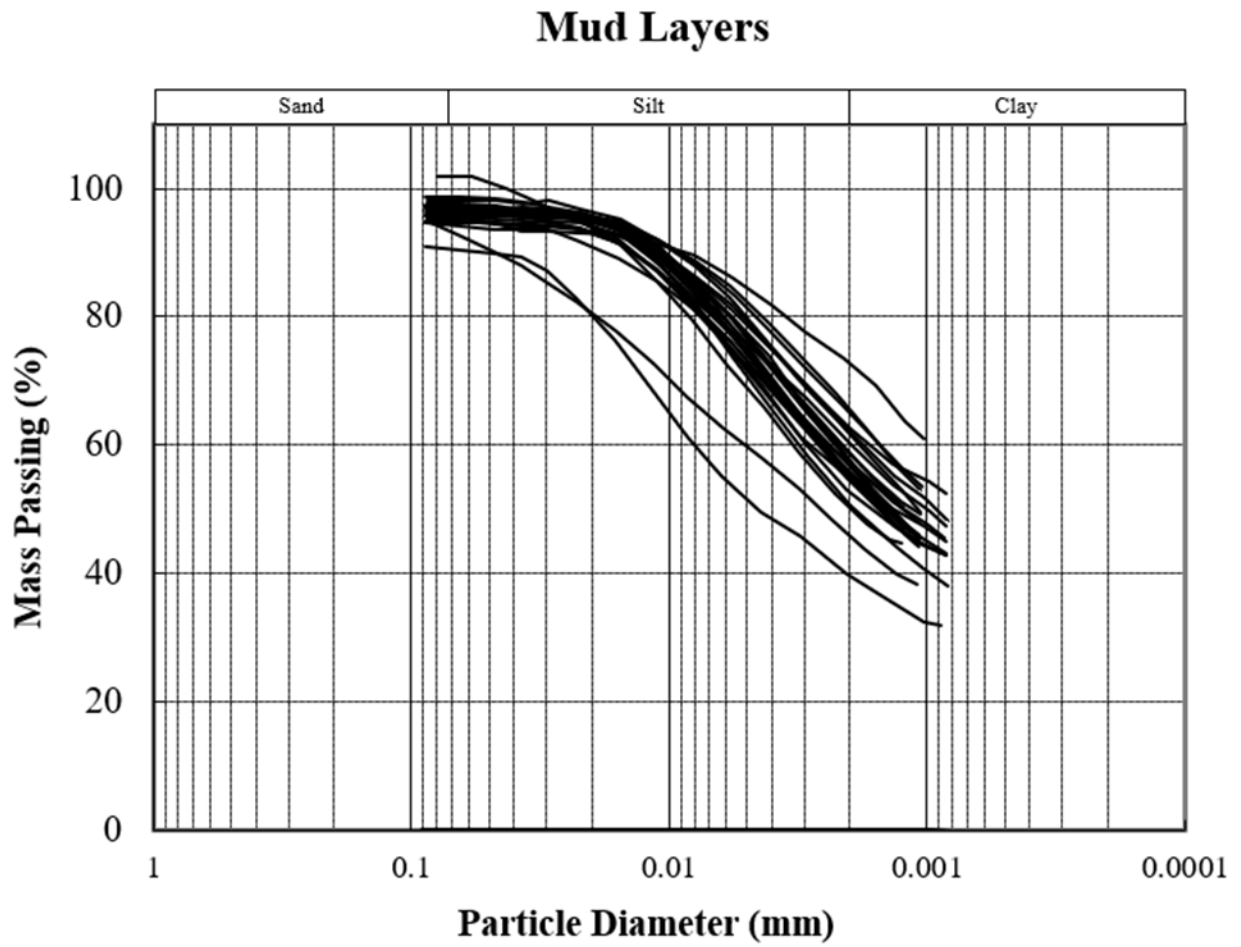


Figure 6-9 Grain size distribution graph of all the samples located in the mud layers.

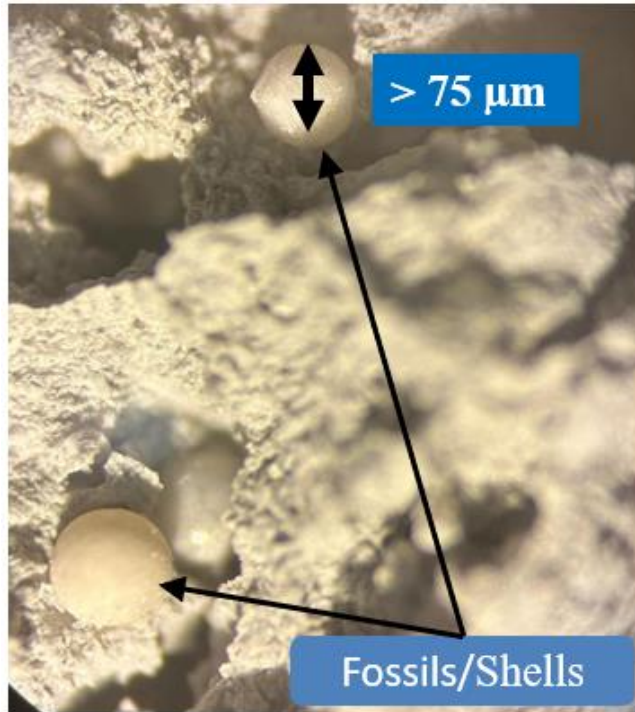


Figure 6-10 Ooze sample under a microscope. Fossils and shells are visible. Many shells are greater than 75 microns.

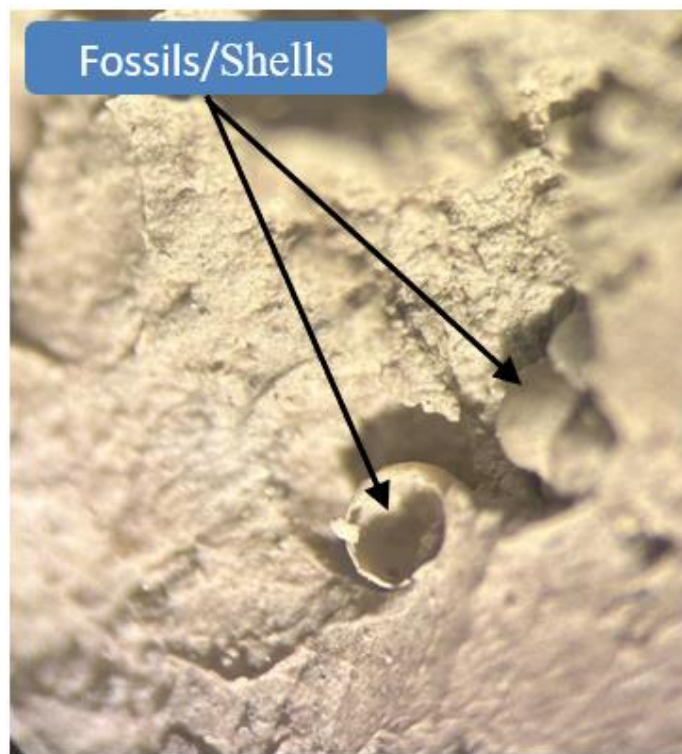


Figure 6-11 Ooze sample under a microscope. Fossils and shells are visible. Many shells are greater than 75 microns.

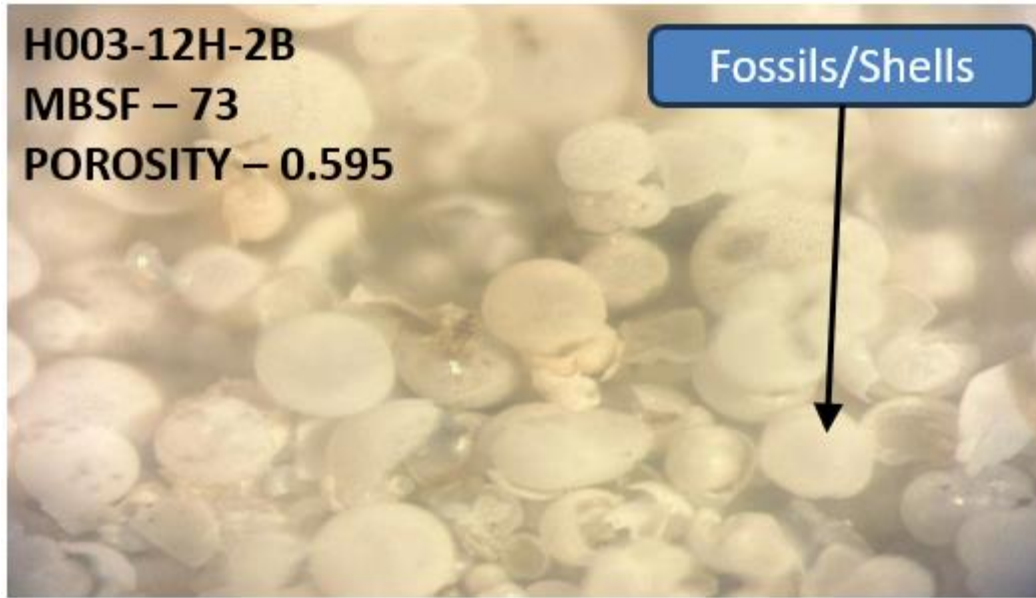


Figure 6-12 +200 fraction with fossils and shells evident. Ooze sample.

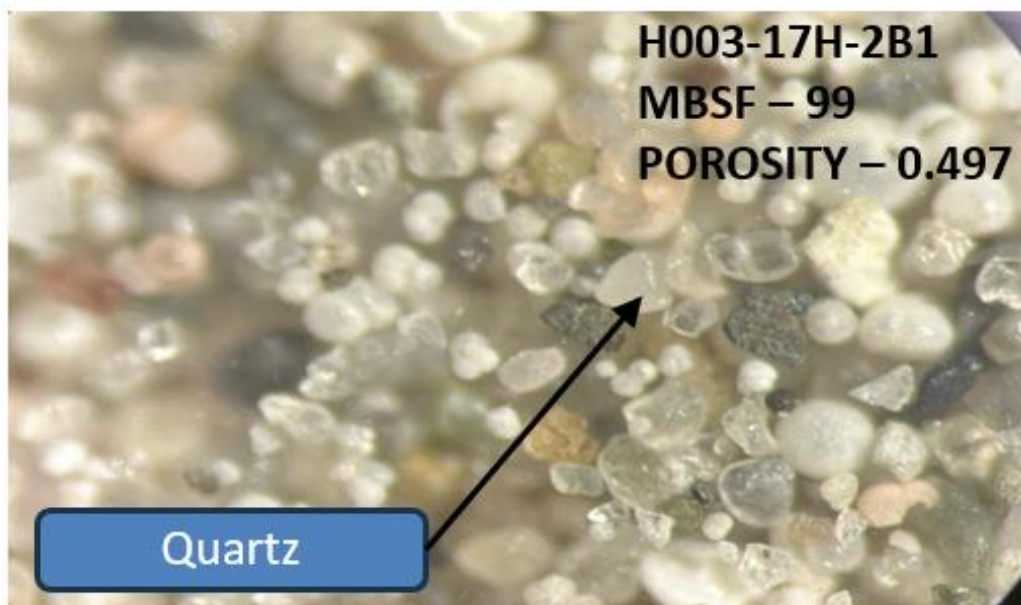


Figure 6-13 +200 fraction with quartz evident. Mud sample.

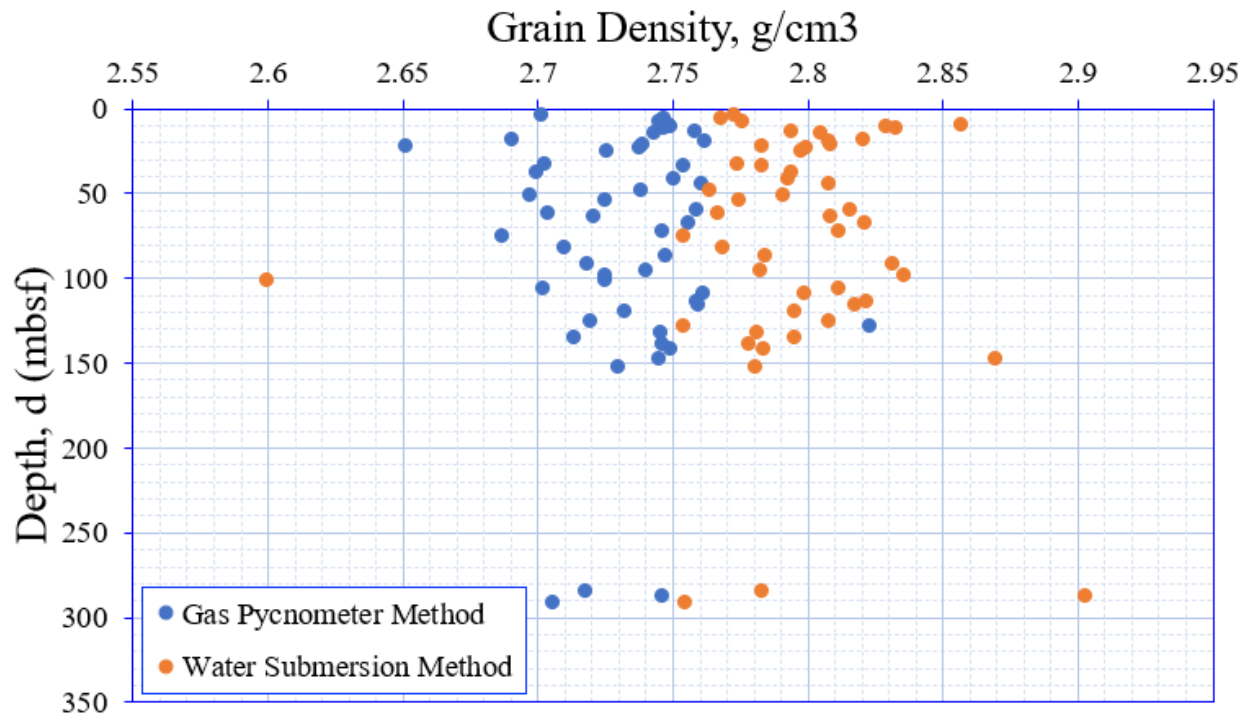


Figure 6-14 Grain density comparison. Measurement by gas pycnometer on WR plugs and water submersion method on blended material.

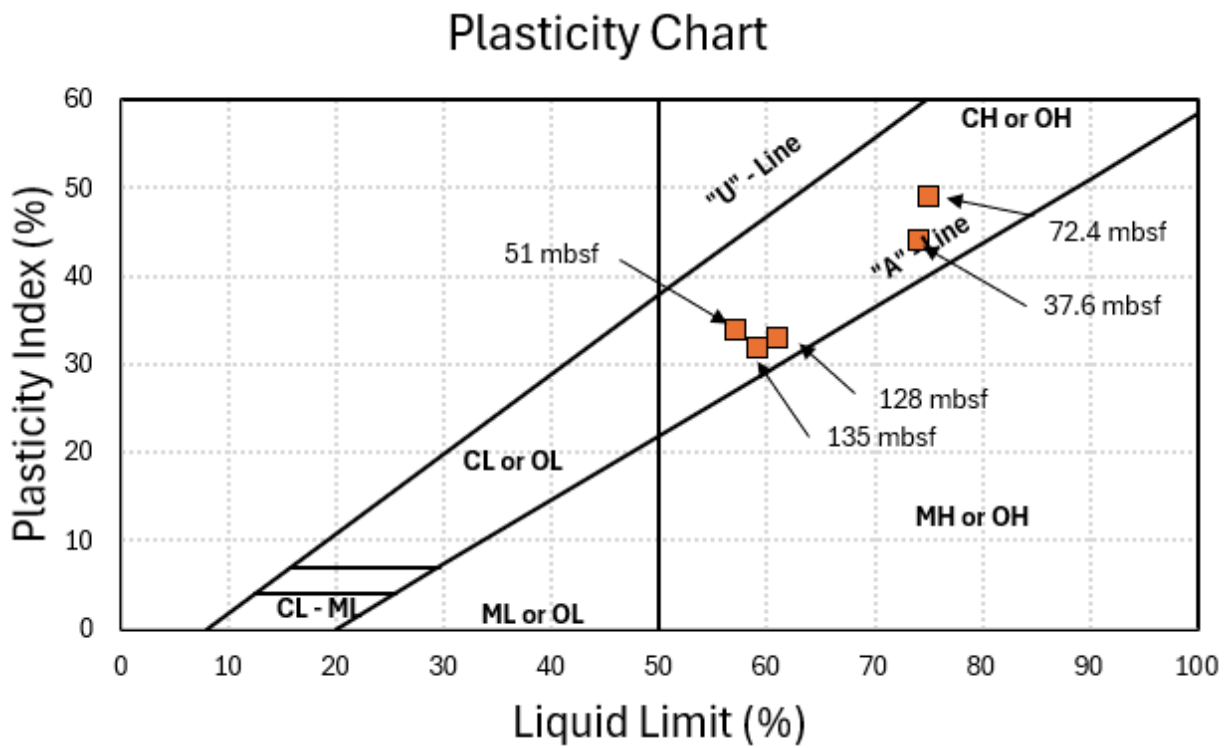


Figure 6-15 Plasticity chart. 5 Samples tested. H003-6H-6B, H003-12H-2B, H003-21H-6B, H003-22H-4B & H003-9H2B1. Sediment classed as high-plasticity clay (CH).

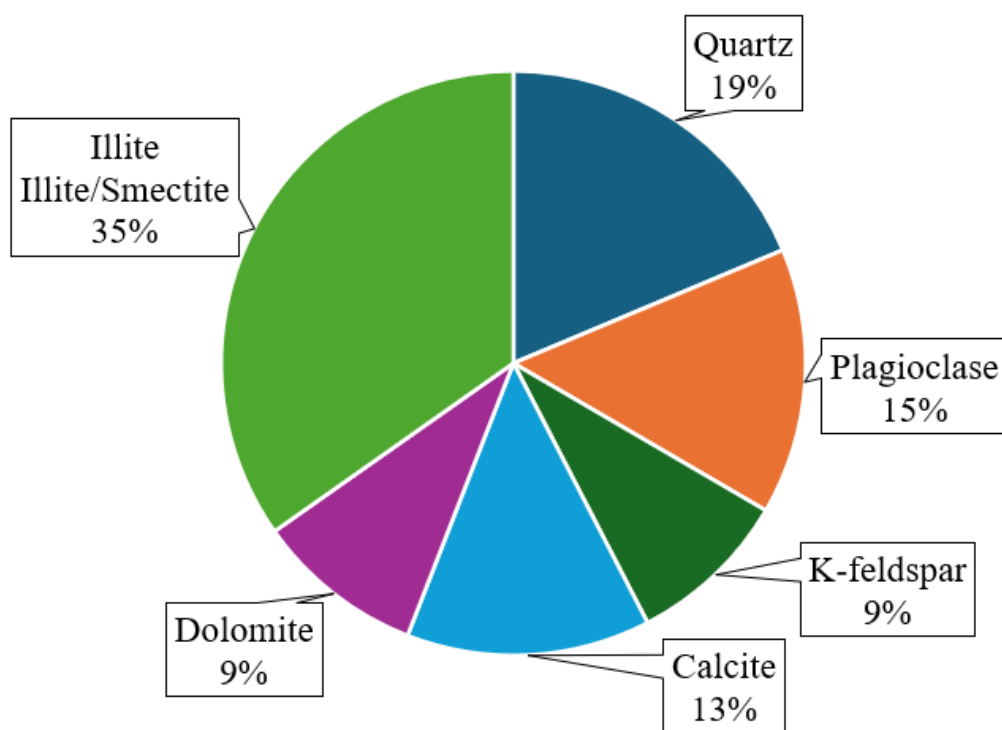


Figure 6-16 - X-ray Diffraction results on Mud sample. Whole sample analysis.

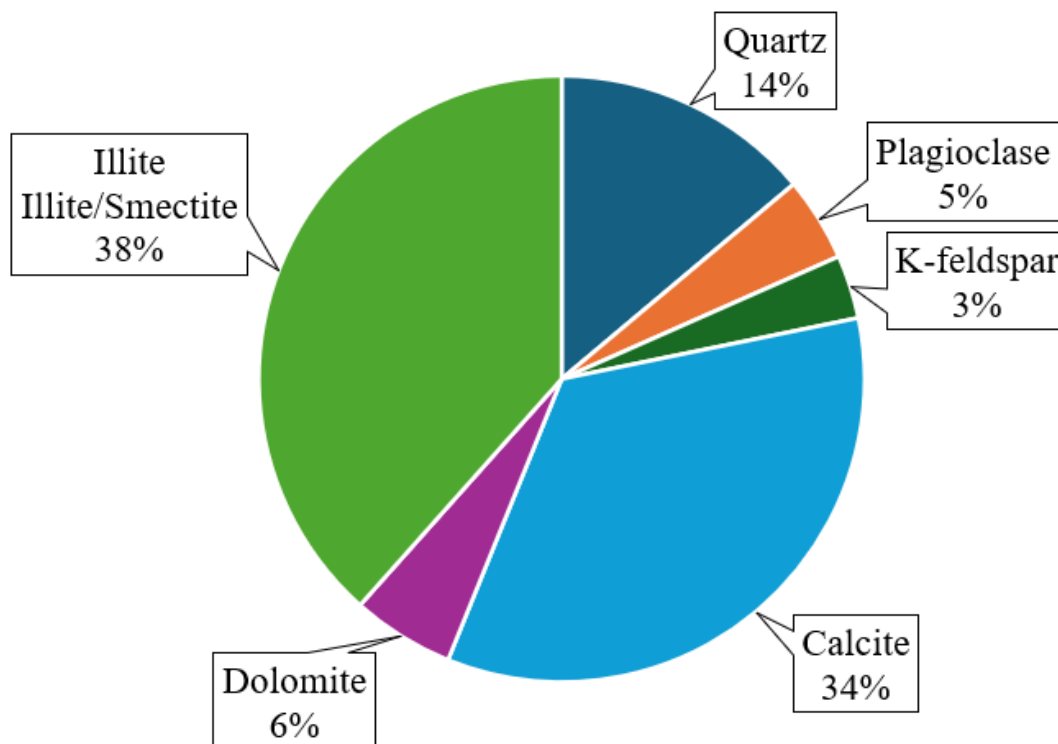


Figure 6-17- X-ray Diffraction results on Ooze sample. Whole sample analysis.

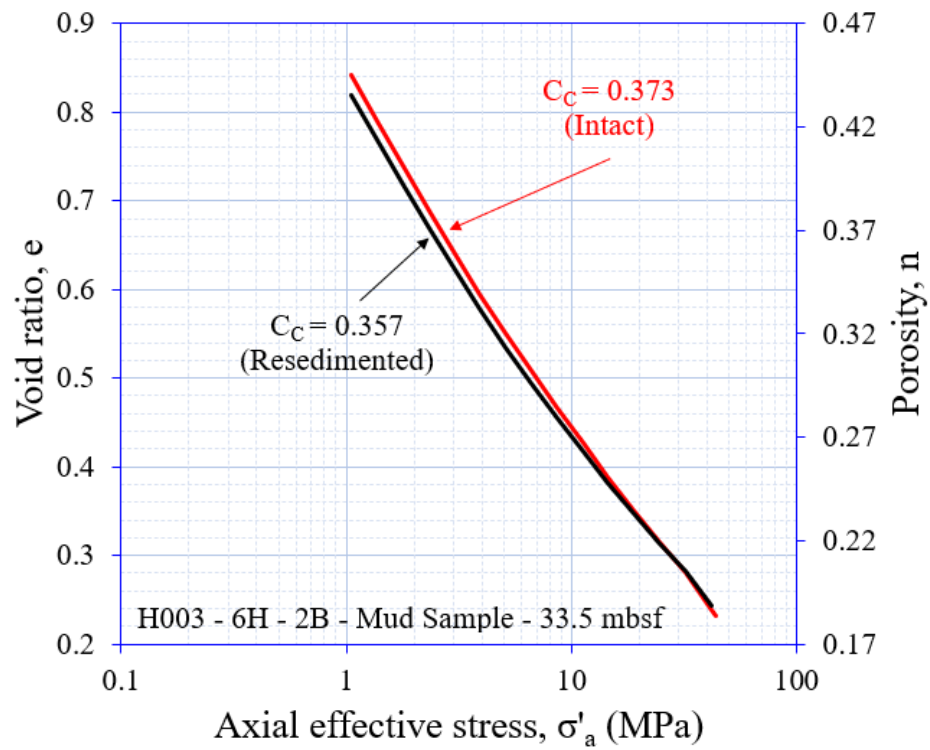


Figure 6-18 - Comparison of Intact vs. Resedimented Mud Samples.

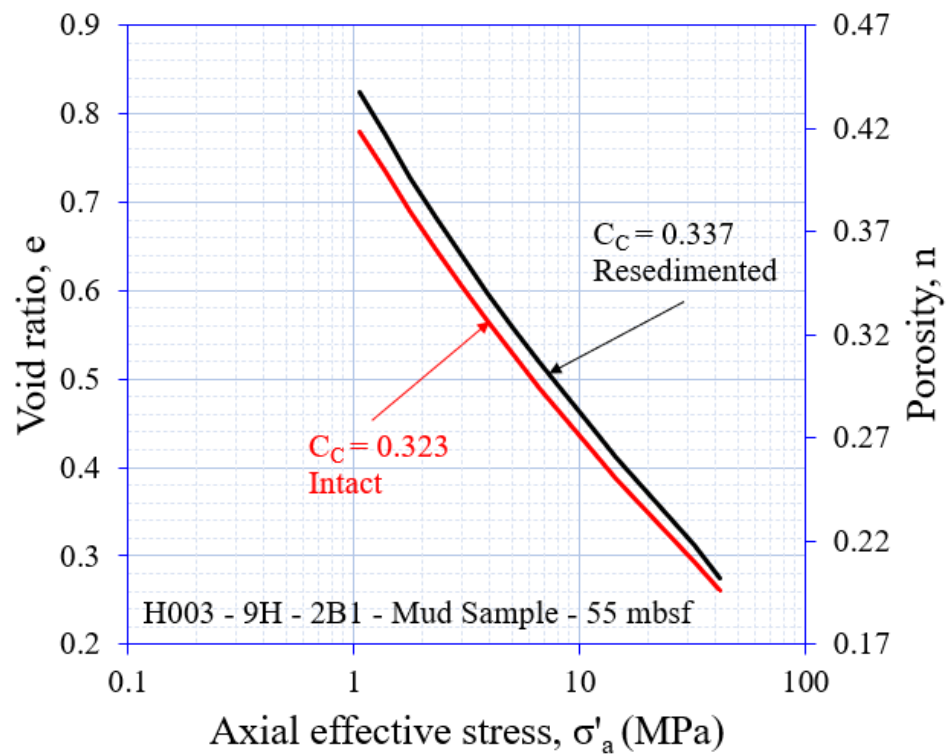


Figure 6-19 - Comparison of Intact vs. Resedimented Mud Samples.

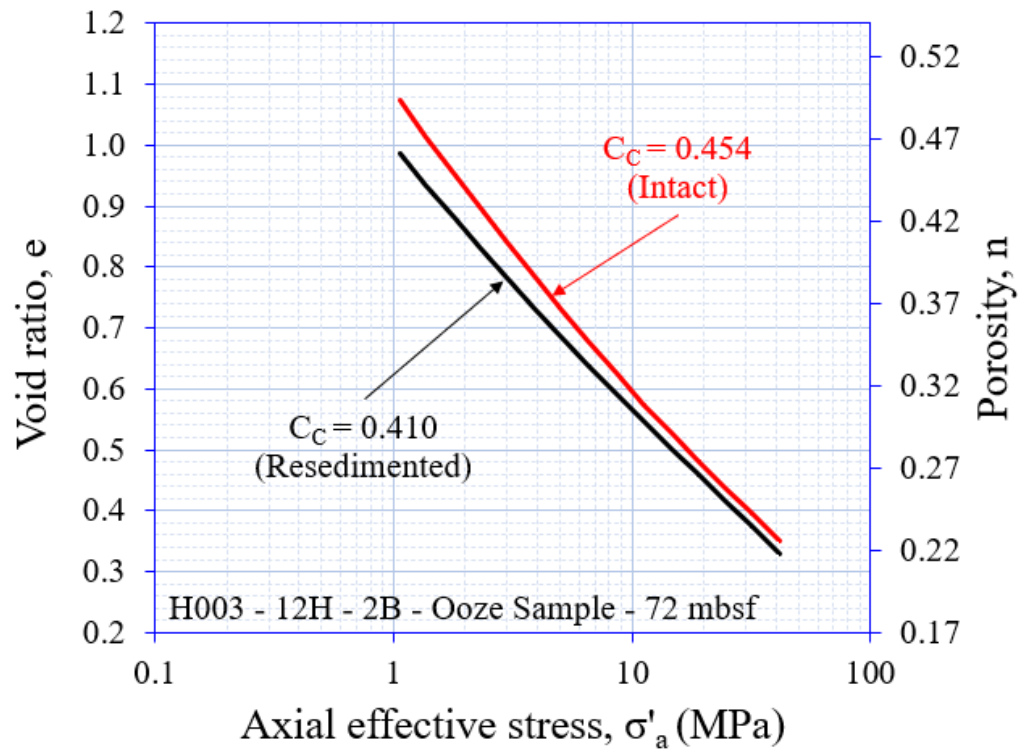


Figure 6-20 – Comparison of Intact vs. Resedimented Ooze Samples.

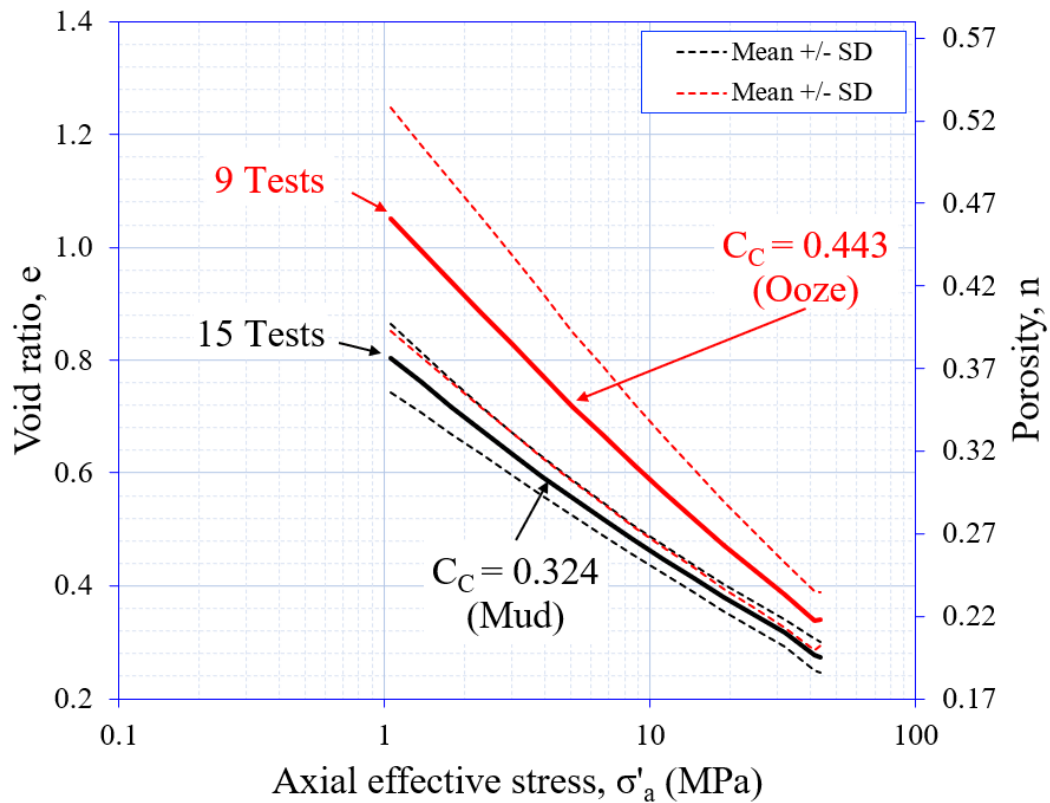


Figure 6-21 - Average compression curve for mud and ooze layers. 24 tests in total averaged.

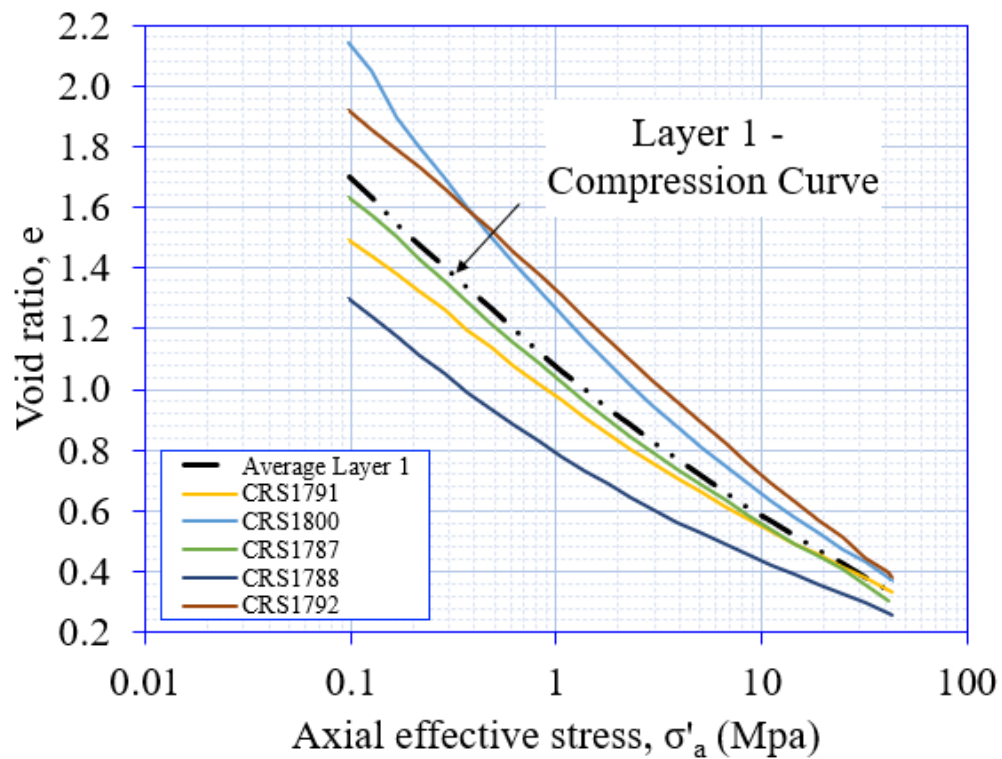


Figure 6-22 – Layer 1 compression curves. Average curve included. (4-23 mbsf). Ooze

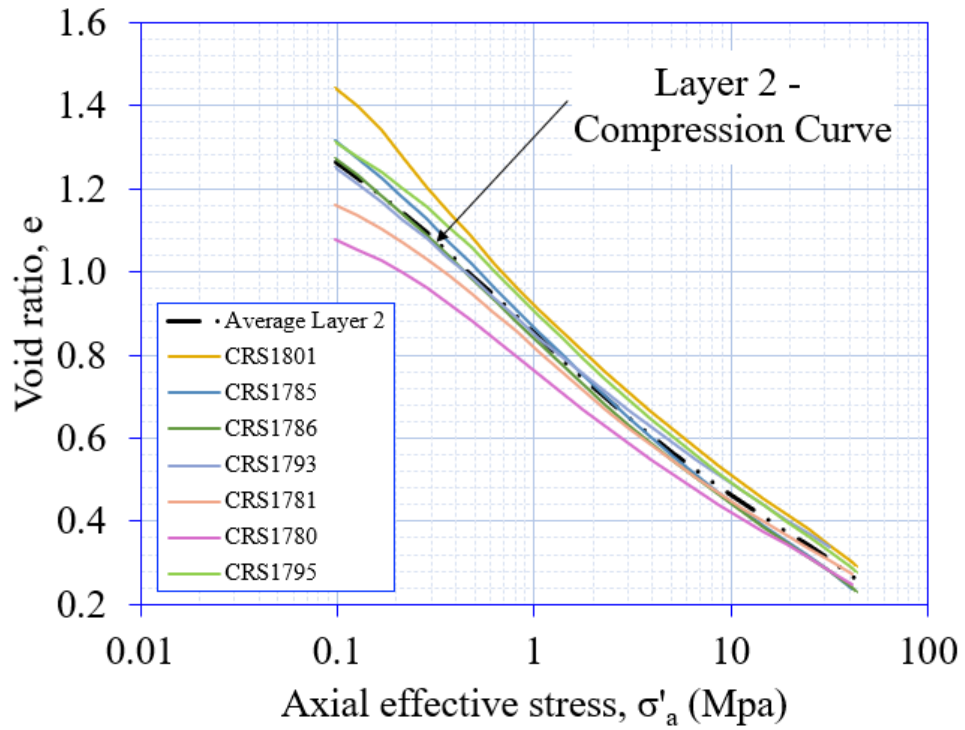


Figure 6-23– Layer 2 compression curves. Average curve included. (23-64 mbsf).Mud

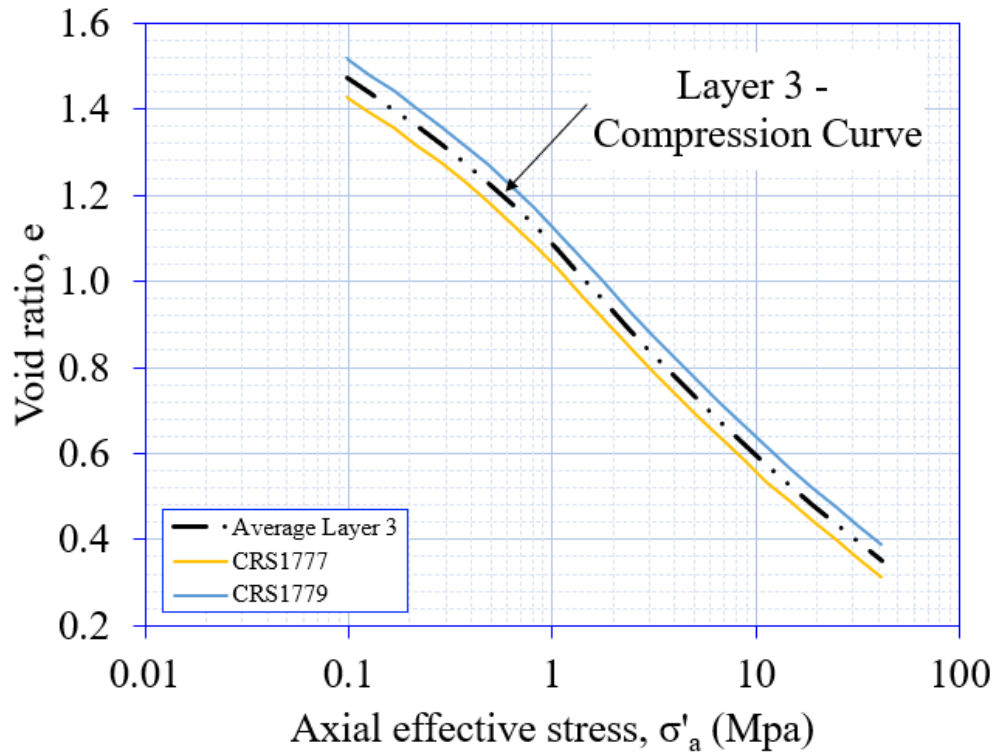


Figure 6-24– Layer 3 compression curves. Average curve included. 64-78 mbsf). Ooze

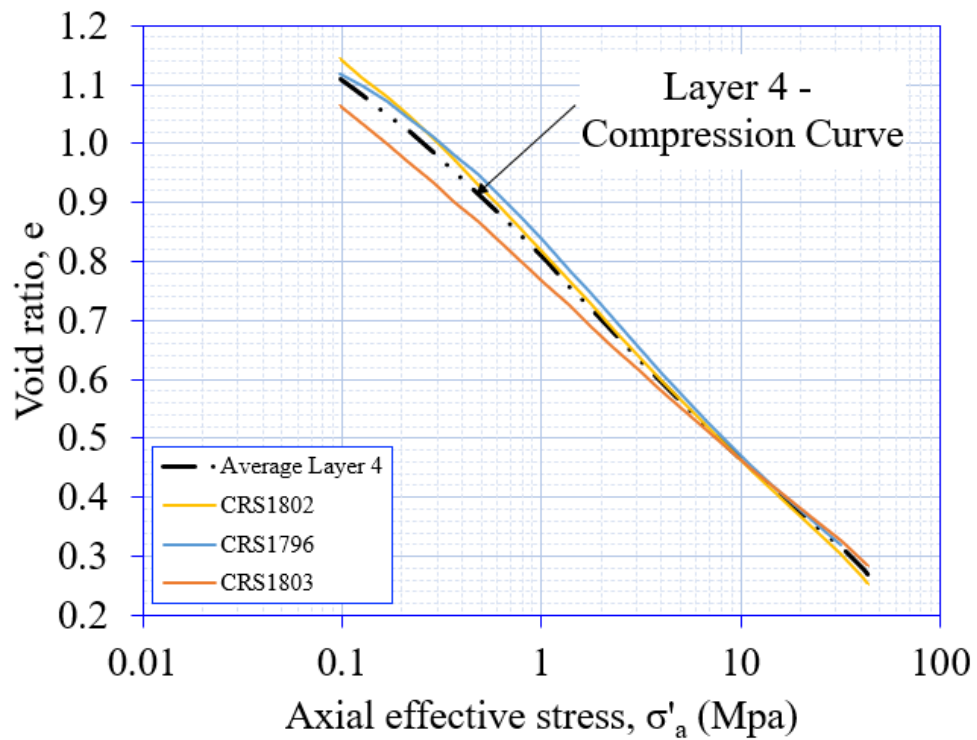


Figure 6-25– Layer 4 compression curves. Average curve included. (78-103 mbsf). Mud

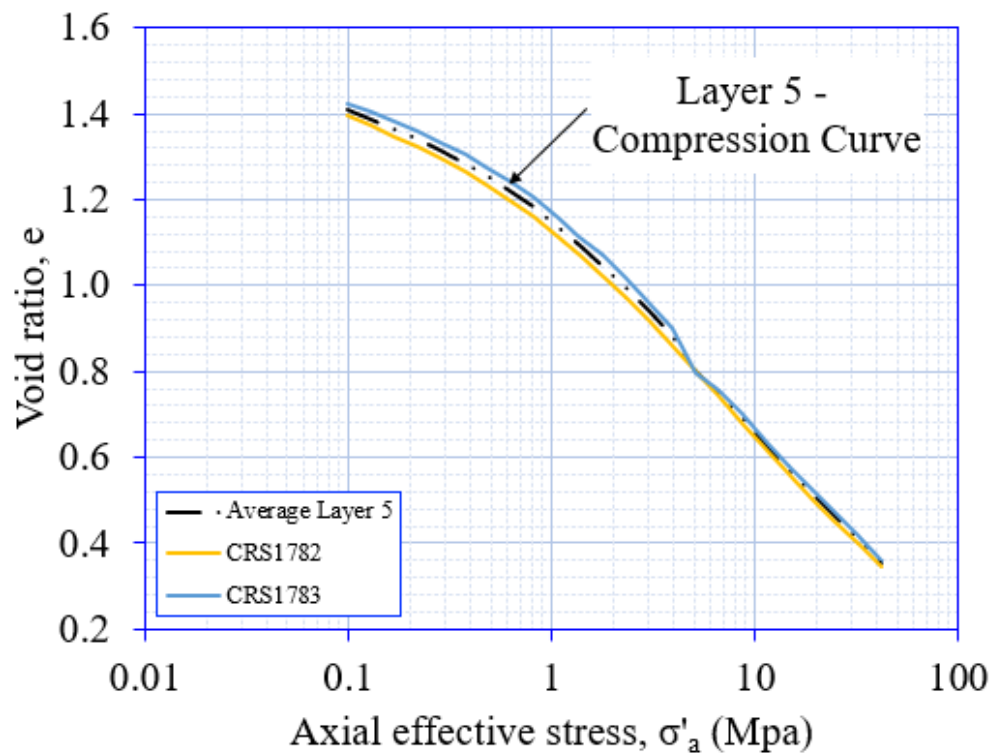


Figure 6-26– Layer 5 compression curves. Average curve included. (103-114 mbsf). Ooze

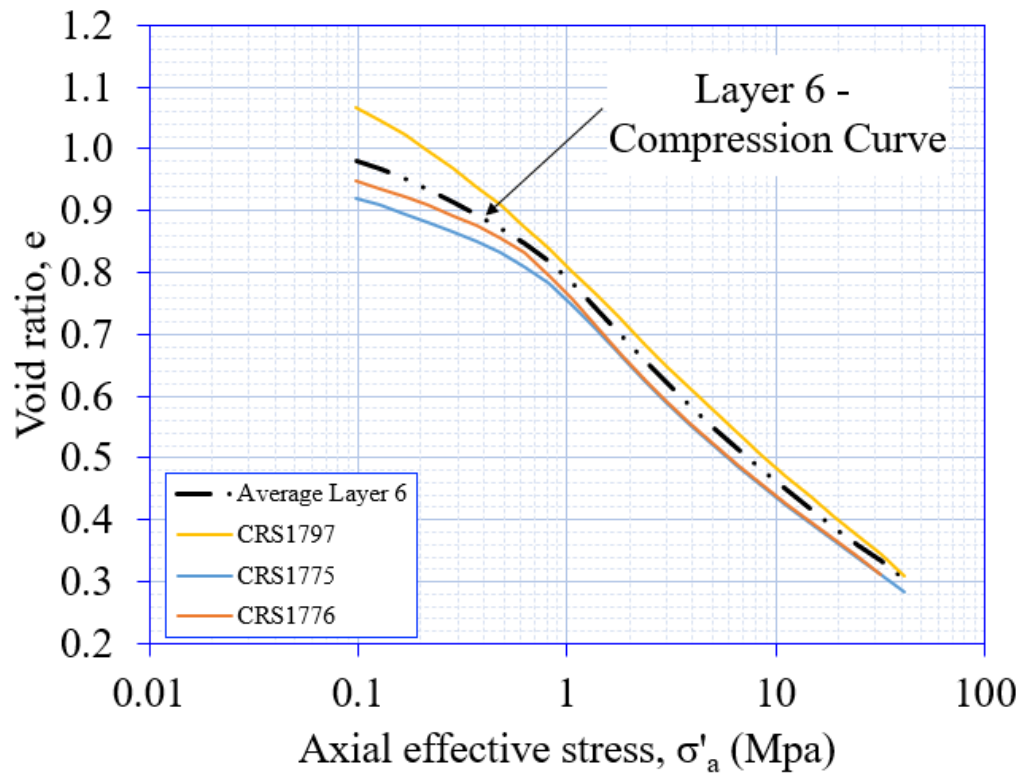


Figure 6-27– Layer 6 compression curves. Average curve included. (114-138 mbsf). Mud

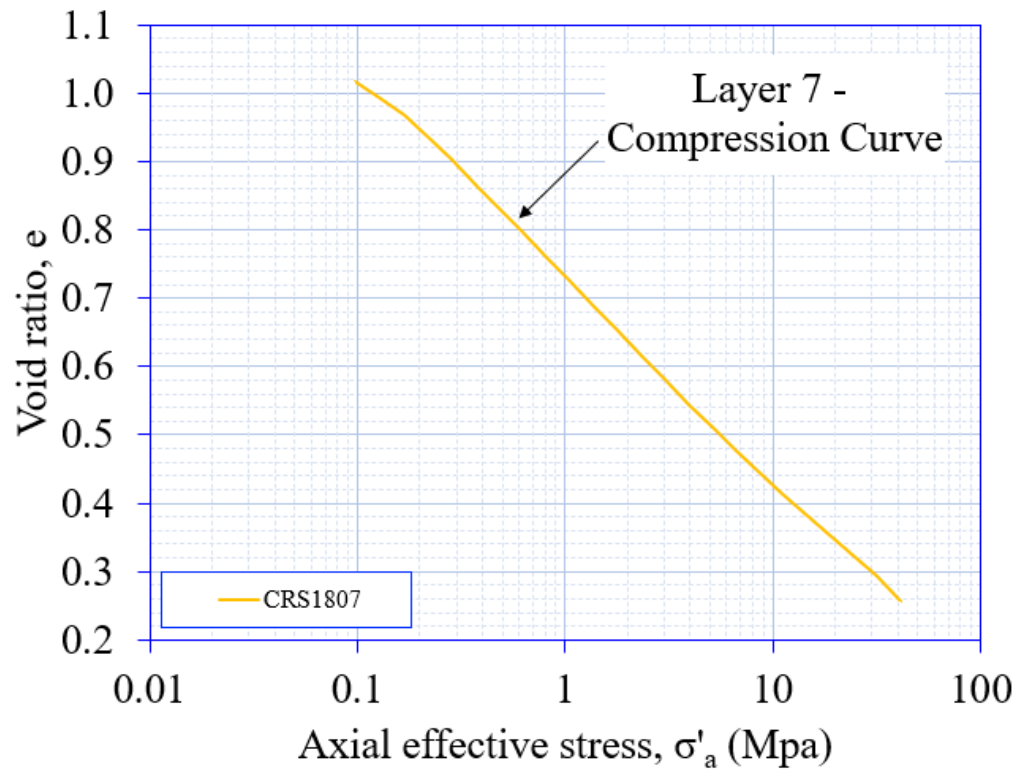


Figure 6-28– Layer 7 compression curve. (138-154 mbsf). Ooze

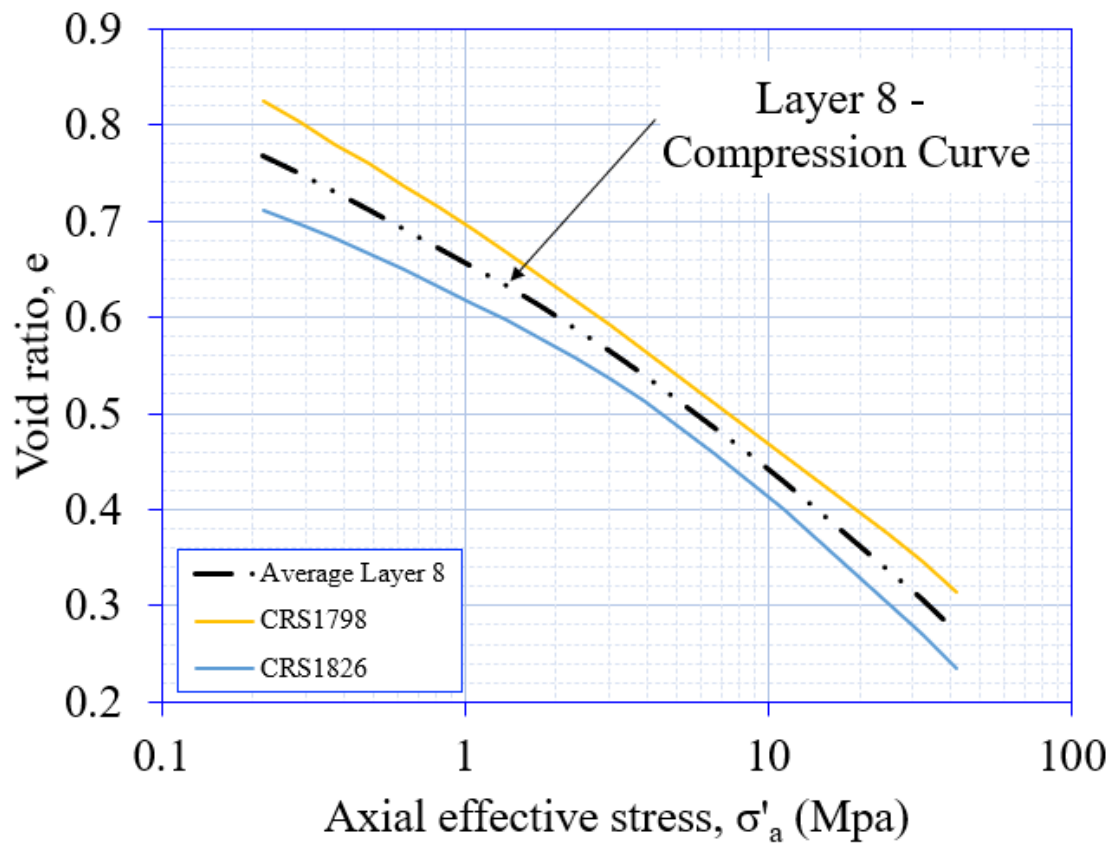


Figure 6-29– Layer 8 compression curves. Average curve included. (154-900 mbsf). Mud

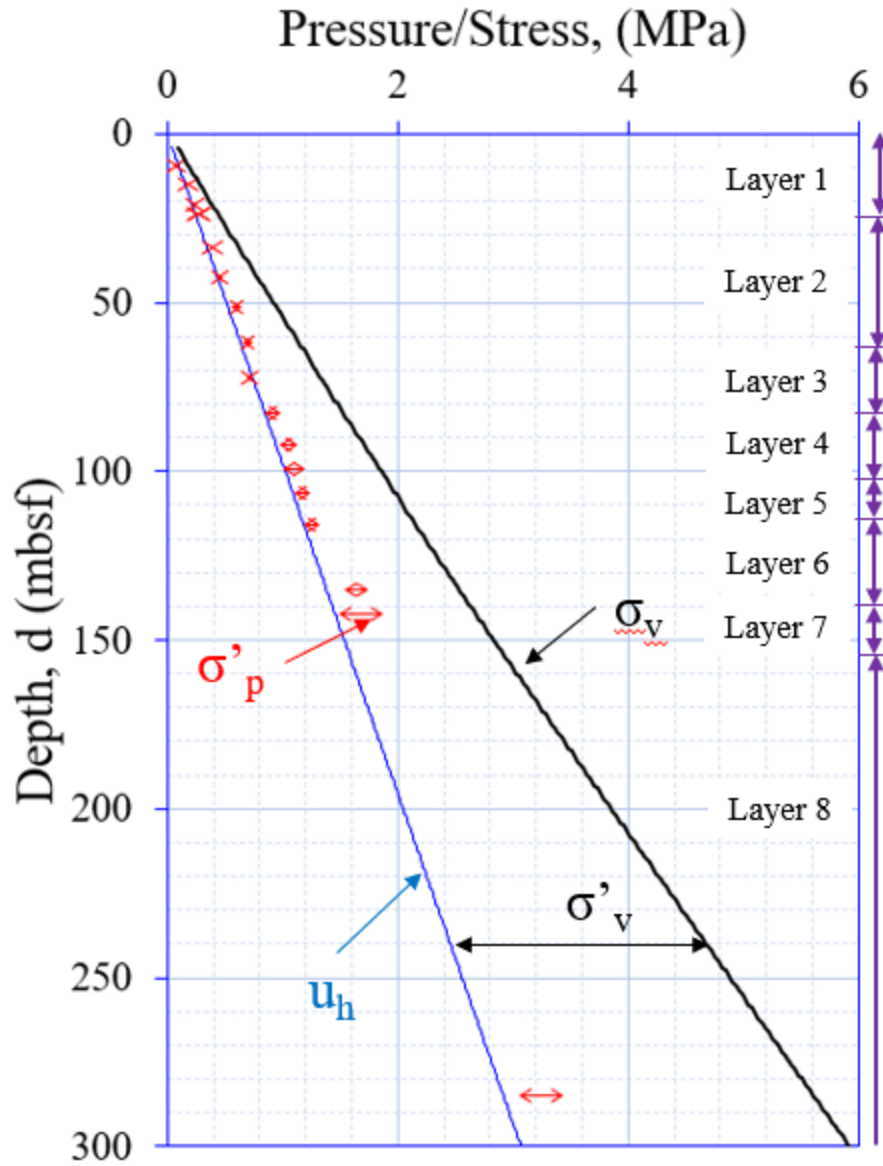


Figure 6-30 - Pressure/ Stress profile. Hydrostatic pressure, effective pressure, total pressure, and preconsolidation pressure of each CRS test. Upper and lower preconsolidation pressure reported for each test. (0-300 mbsf)

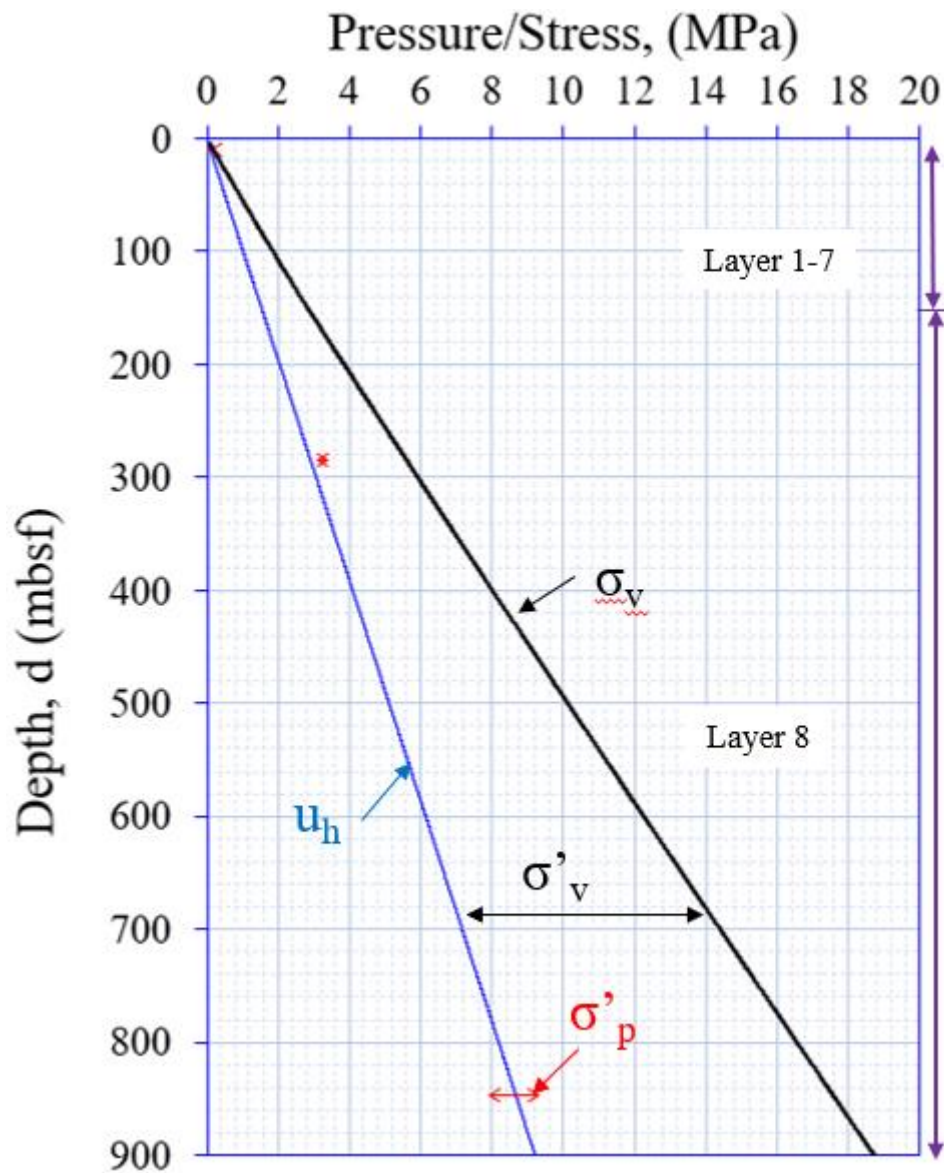


Figure 6-31 - Pressure/ Stress profile. Hydrostatic pressure, effective pressure, total pressure, and preconsolidation pressure of each CRS test. Upper and lower preconsolidation pressure reported for each test. (0-900 mbsf)

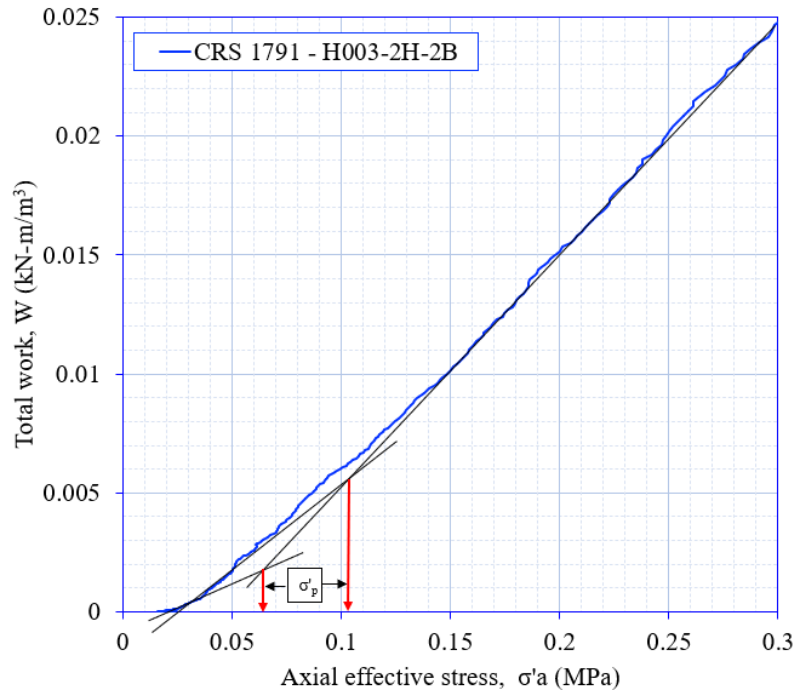


Figure 6-32 - Preconsolidation pressure construction by strain energy method. CRS 1791 - Sample H003-2H-2B. The effective preconsolidation pressure is estimated to be between 0.065 MPa and 0.105 MPa.

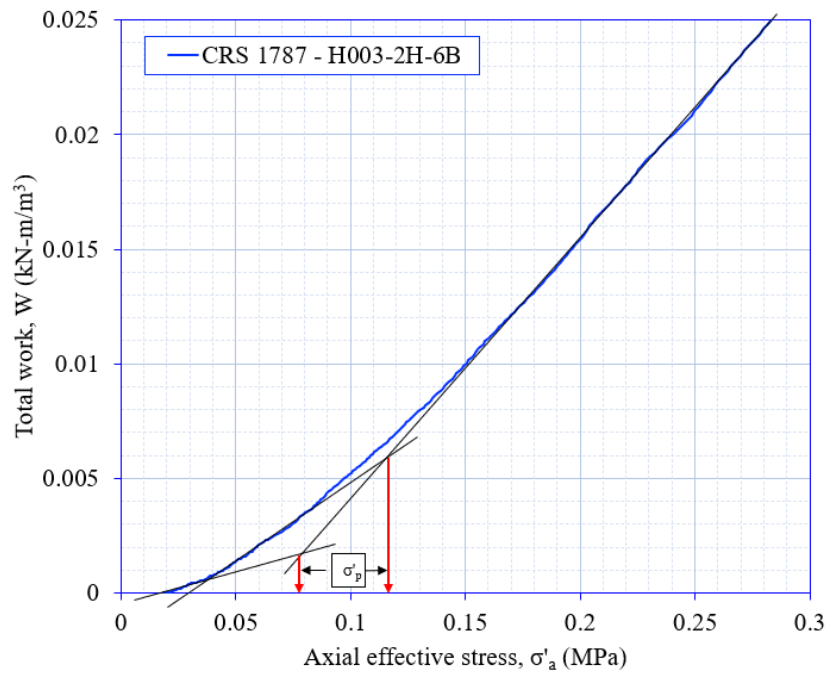


Figure 6-33- Preconsolidation pressure construction by strain energy method. CRS 1787 - Sample H003-2H-6B. The effective preconsolidation pressure is estimated to be between 0.08 MPa and 0.12 MPa.

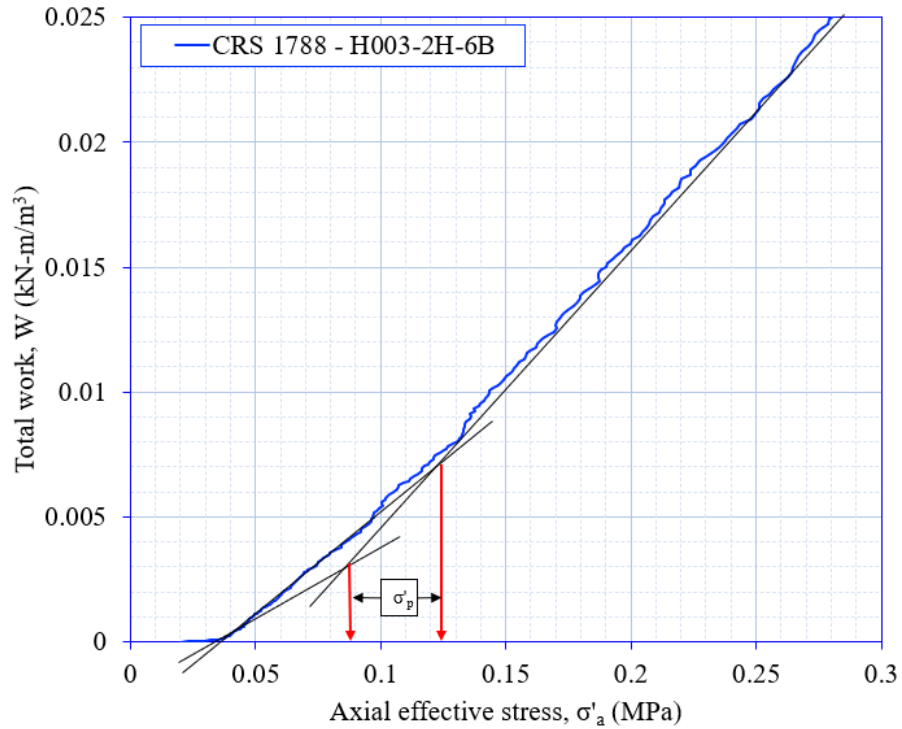


Figure 6-34 - Preconsolidation pressure construction by strain energy method. CRS 1788 - Sample H003-2H-6B. The effective preconsolidation pressure is estimated to be between 0.09 MPa and 0.125 MPa.

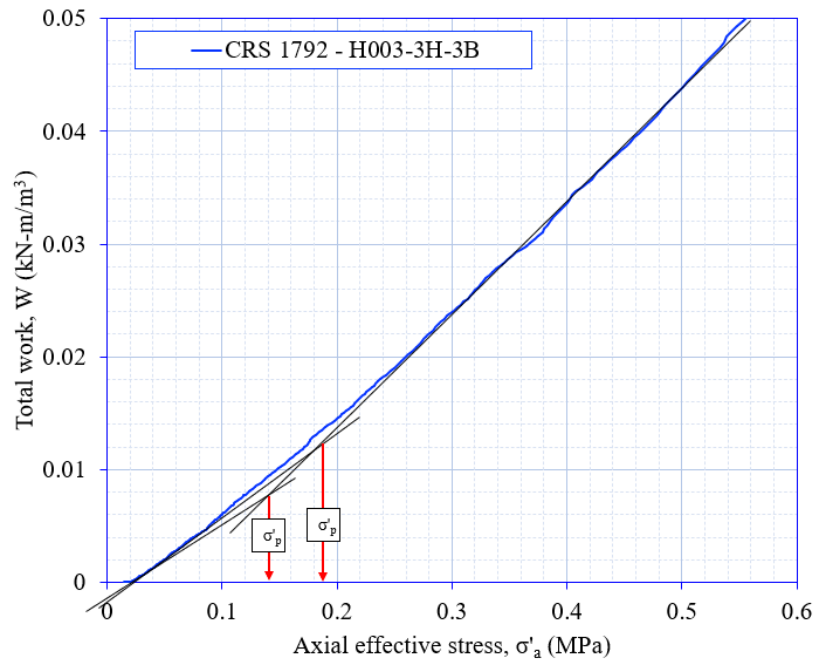


Figure 6-35 - Preconsolidation pressure construction by strain energy method. CRS 1792 - Sample H003-3H-3B. The effective preconsolidation pressure is estimated to be between 0.14 MPa and 0.185 MPa.

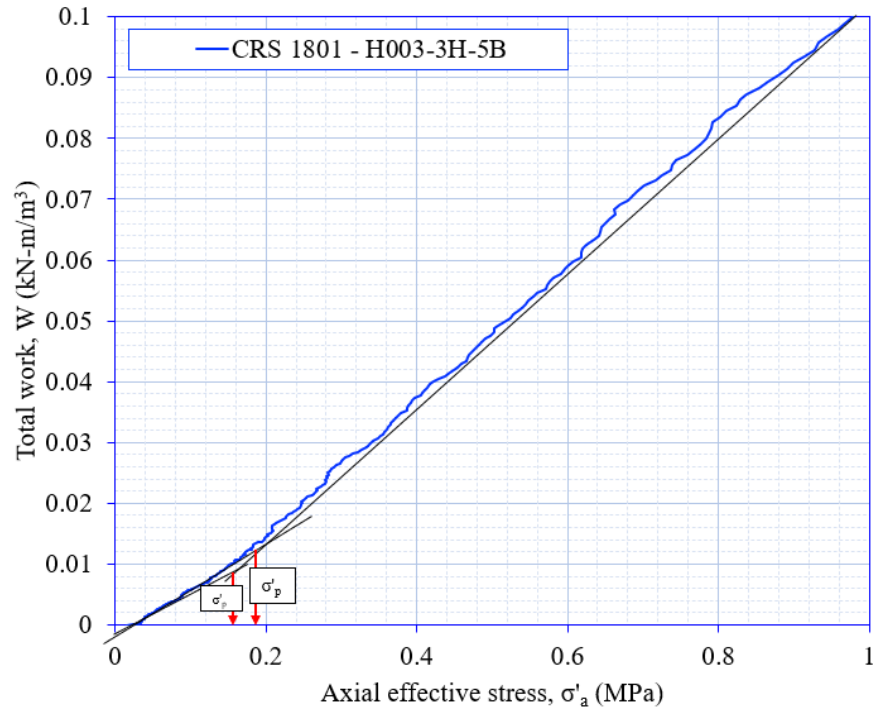


Figure 6-36 - Preconsolidation pressure construction by strain energy method. CRS 1801 - Sample H003-3H-5B. The effective preconsolidation pressure is estimated to be between 0.16 MPa and 0.19 MPa.

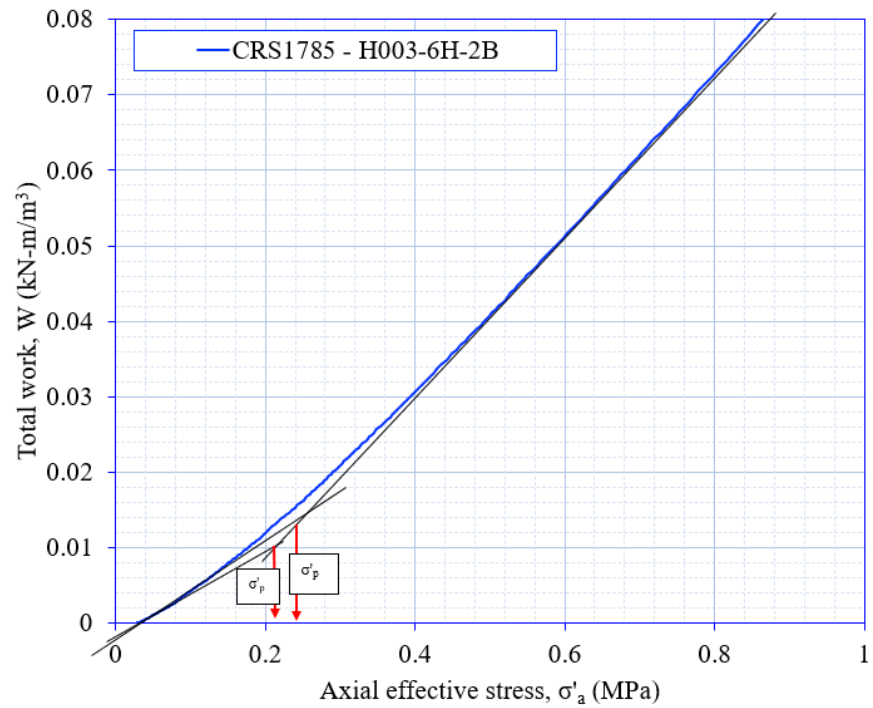


Figure 6-37 - Preconsolidation pressure construction by strain energy method. CRS 1785 - Sample H003-6H-2B. The effective preconsolidation pressure is estimated to be between 0.205 MPa and 0.24 MPa.

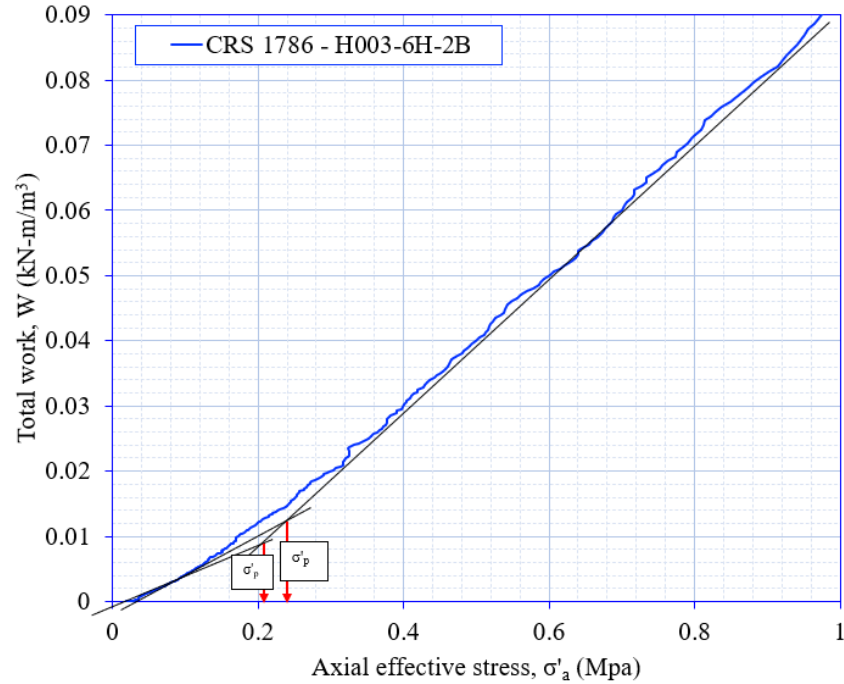


Figure 6-38 - Preconsolidation pressure construction by strain energy method. CRS 1786 - Sample H003-6H-2B. The effective preconsolidation pressure is estimated to be between 0.205 MPa and 0.24 MPa.

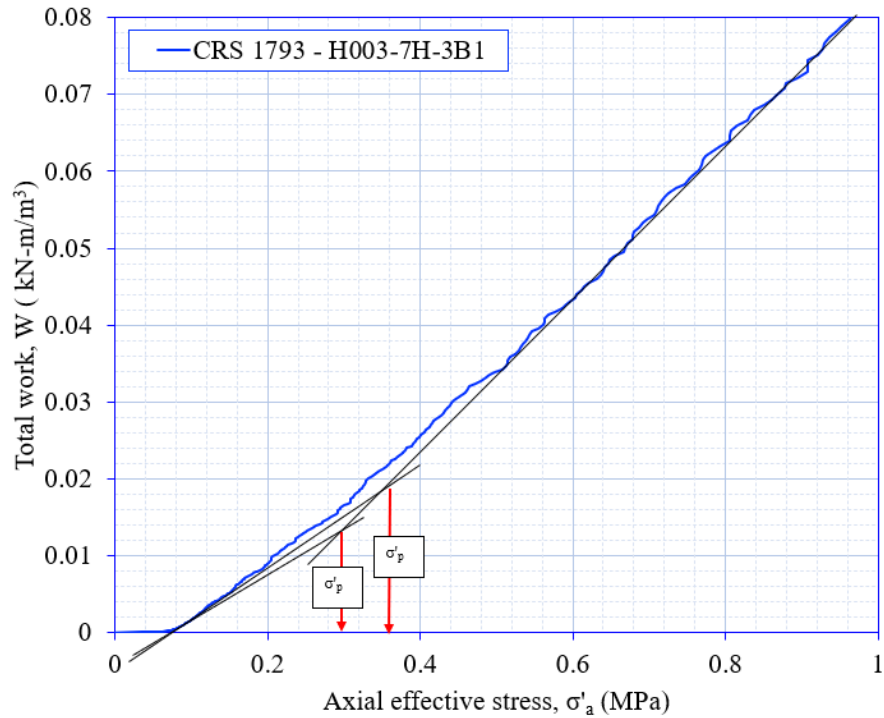


Figure 6-39 - Preconsolidation pressure construction by strain energy method. CRS 1793 - Sample H003-7H-3B1. The effective preconsolidation pressure is estimated to be between 0.3 MPa and 0.36 MPa.

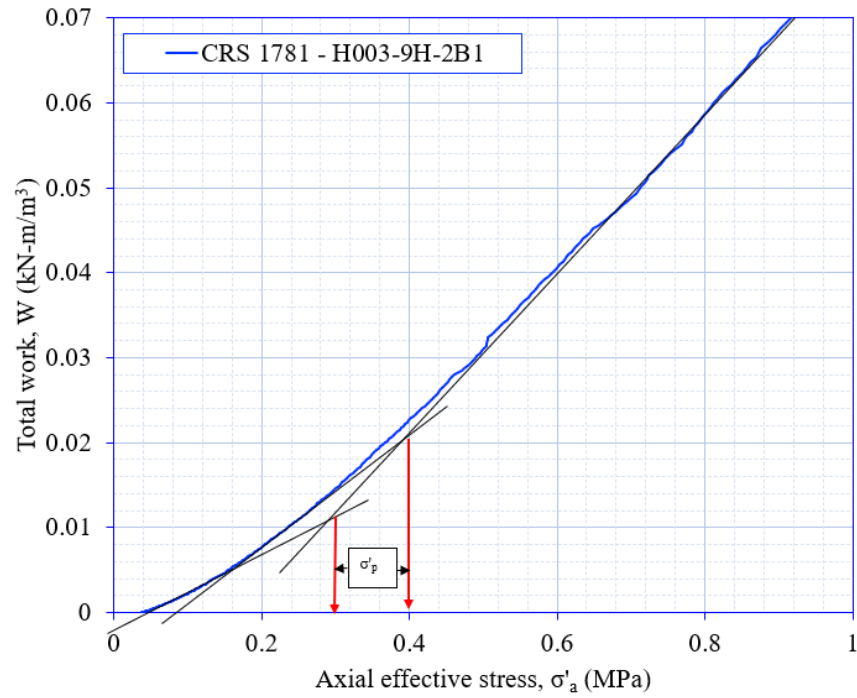


Figure 6-40 - Preconsolidation pressure construction by strain energy method. CRS 1781 - Sample H003-9H-2B1. The effective preconsolidation pressure is estimated to be between 0.3 MPa and 0.4 MPa.

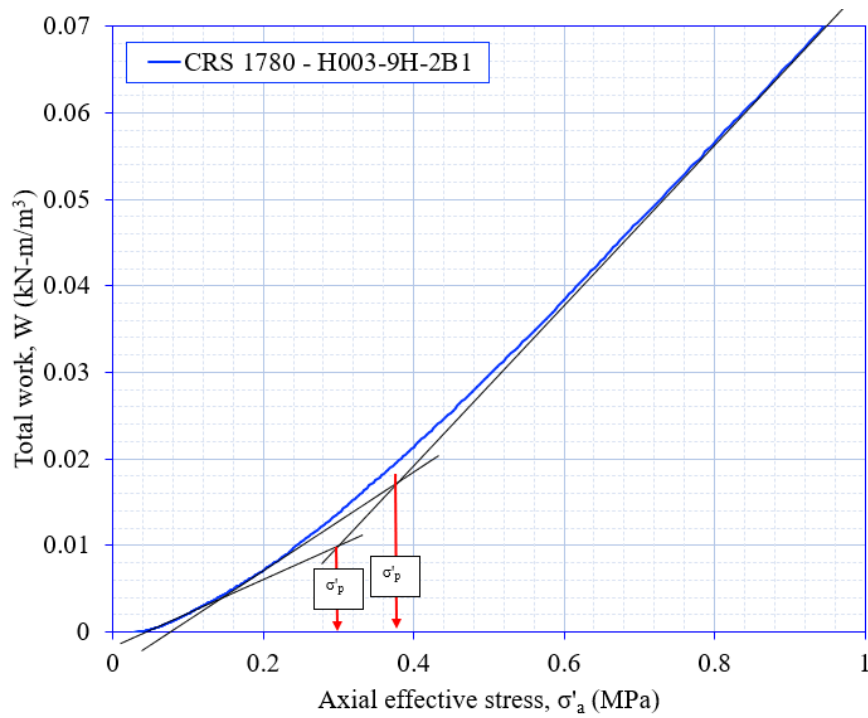


Figure 6-41 - Preconsolidation pressure construction by strain energy method. CRS 1780 - Sample H003-9H-2B1. The effective preconsolidation pressure is estimated to be between 0.3 MPa and 0.38 MPa.

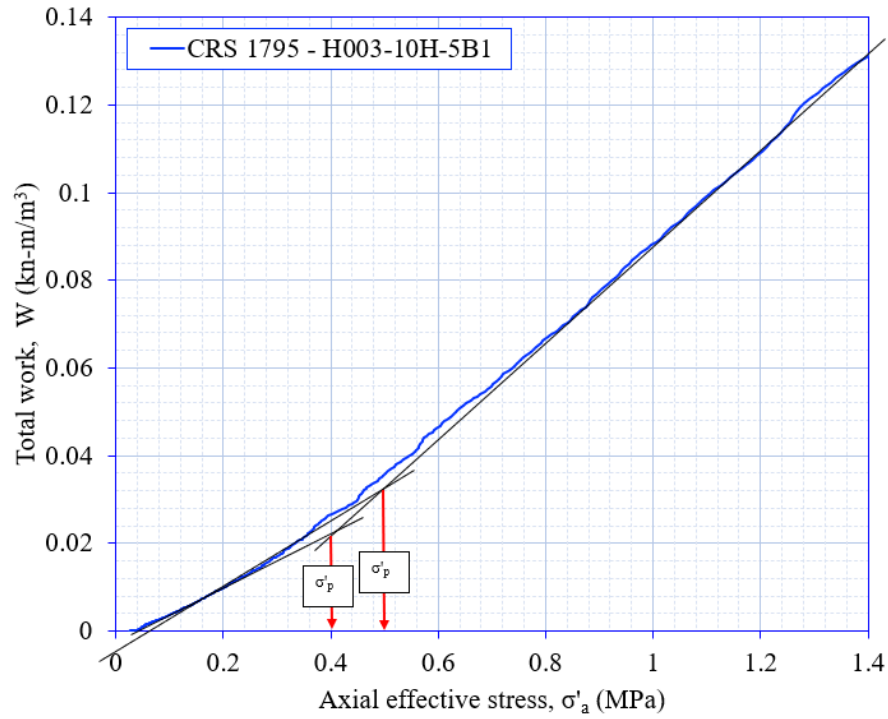


Figure 6-42 - Preconsolidation pressure construction by strain energy method. CRS 1795 - Sample H003-10H-5B1. The effective preconsolidation pressure is estimated to be between 0.4 MPa and 0.5 MPa.

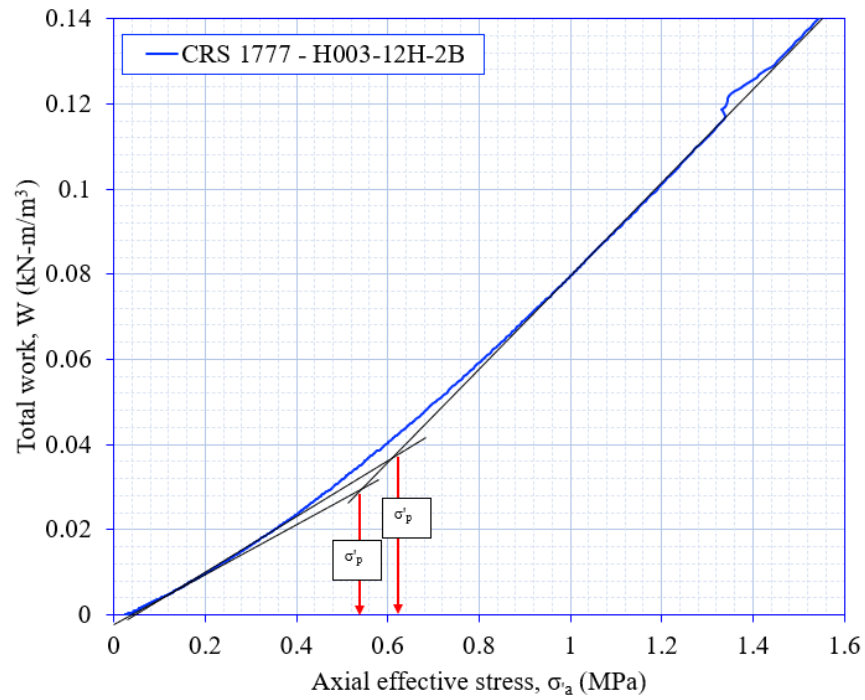


Figure 6-43 - Preconsolidation pressure construction by strain energy method. CRS 1777 - Sample H003-12H-2B. The effective preconsolidation pressure is estimated to be between 0.53 MPa and 0.61 MPa.

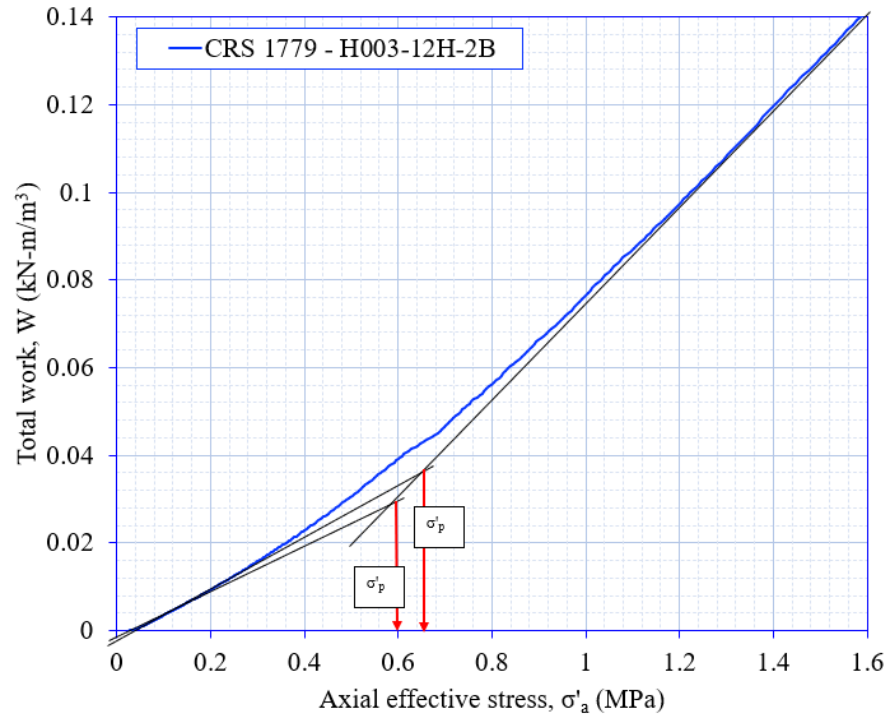


Figure 6-44 - Preconsolidation pressure construction by strain energy method. CRS 1779 - Sample H003-12H-2B. The effective preconsolidation pressure is estimated to be between 0.6 MPa and 0.66 MPa.

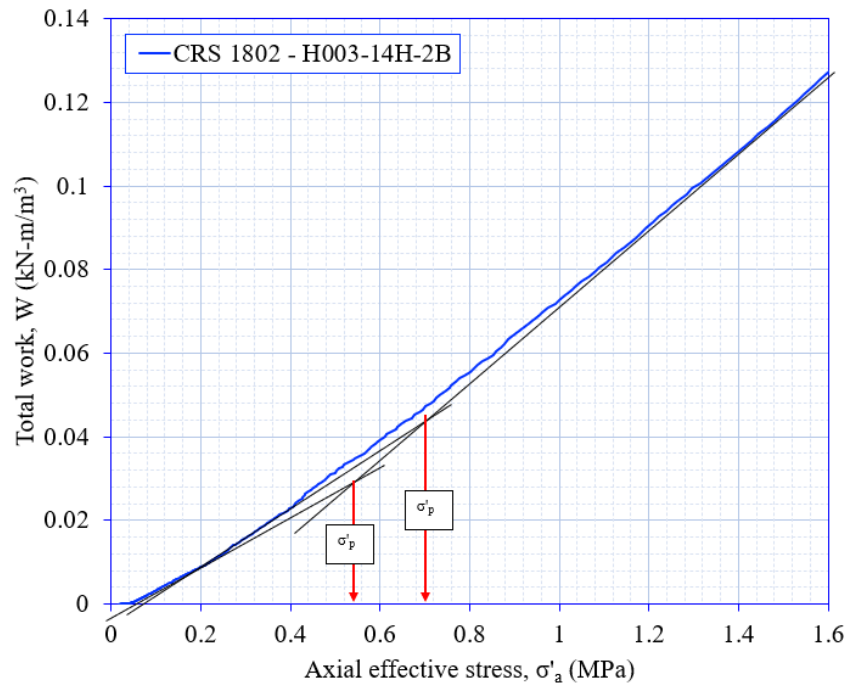


Figure 6-45 - Preconsolidation pressure construction by strain energy method. CRS 1802 - Sample H003-14H-2B. The effective preconsolidation pressure is estimated to be between 0.54 MPa and 0.7 MPa.

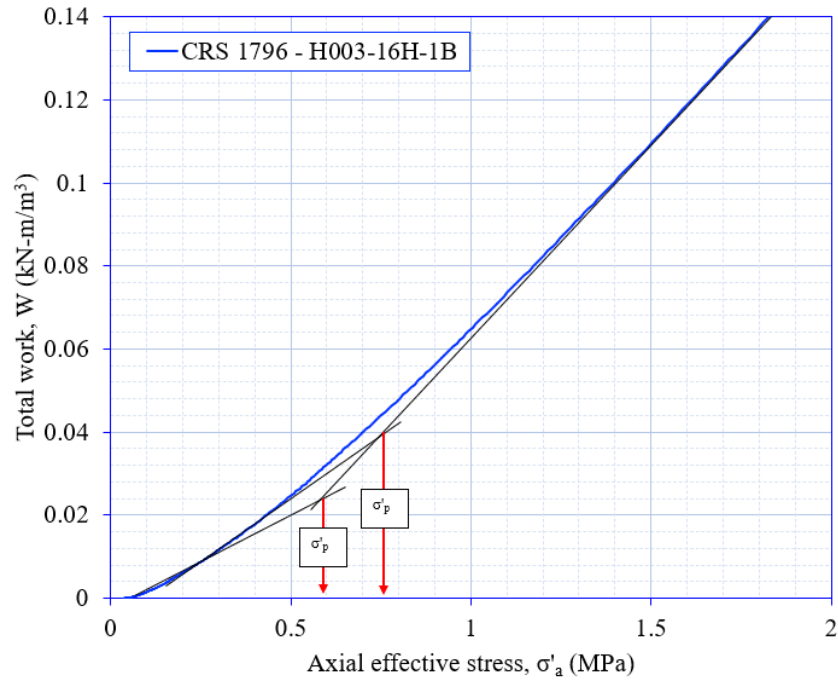


Figure 6-46 - Preconsolidation pressure construction by strain energy method. CRS 1796 - Sample H003-16H-1B. The effective preconsolidation pressure is estimated to be between 0.6 MPa and 0.75 MPa.

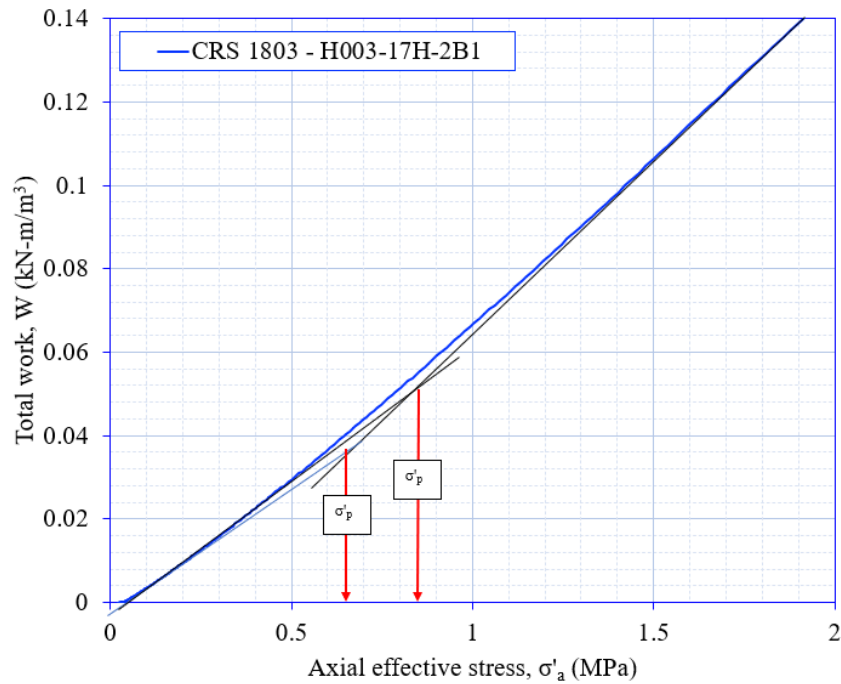


Figure 6-47 - Preconsolidation pressure construction by strain energy method. CRS 1803 - Sample H003-17H-2B1. The effective preconsolidation pressure is estimated to be between 0.65 MPa and 0.85 MPa.

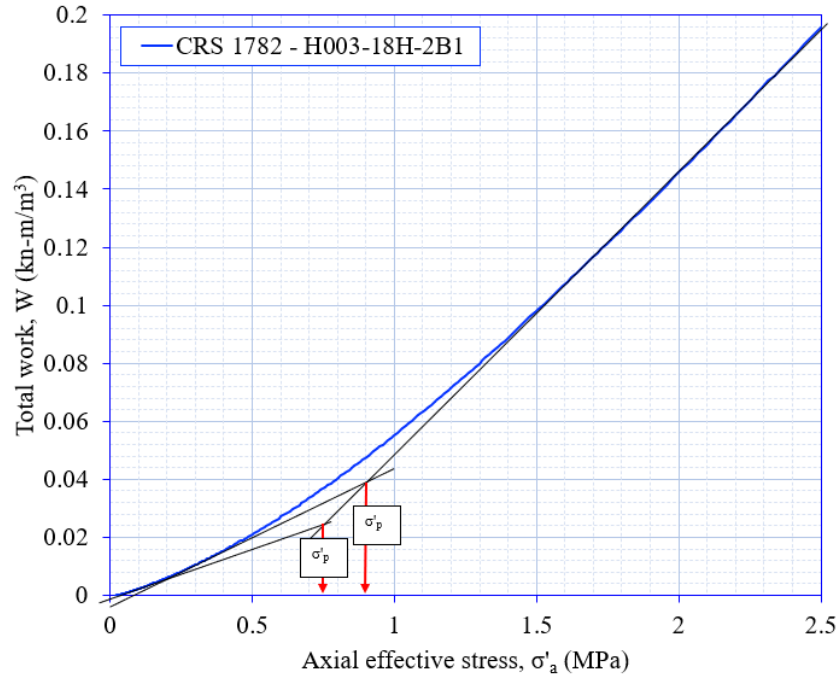


Figure 6-48 - Preconsolidation pressure construction by strain energy method. CRS 1782 - Sample H003-18H-2B1. The effective preconsolidation pressure is estimated to be between 0.75 MPa and 0.9 MPa.

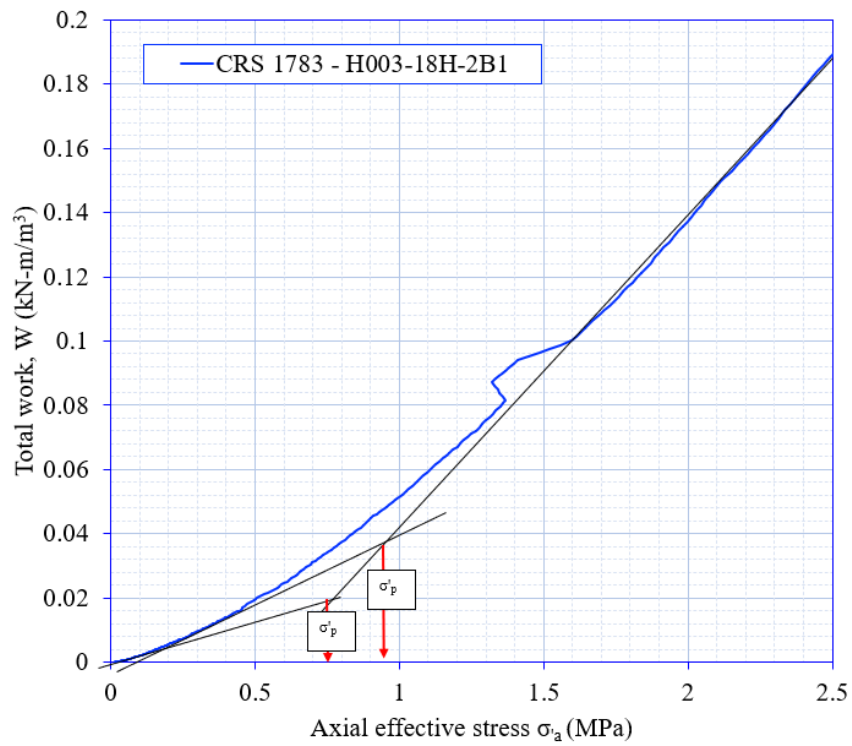


Figure 6-49 - Preconsolidation pressure construction by strain energy method. CRS 1783 - Sample H003-18H-2B1. The effective preconsolidation pressure is estimated to be between 0.75 MPa and 0.95 MPa.

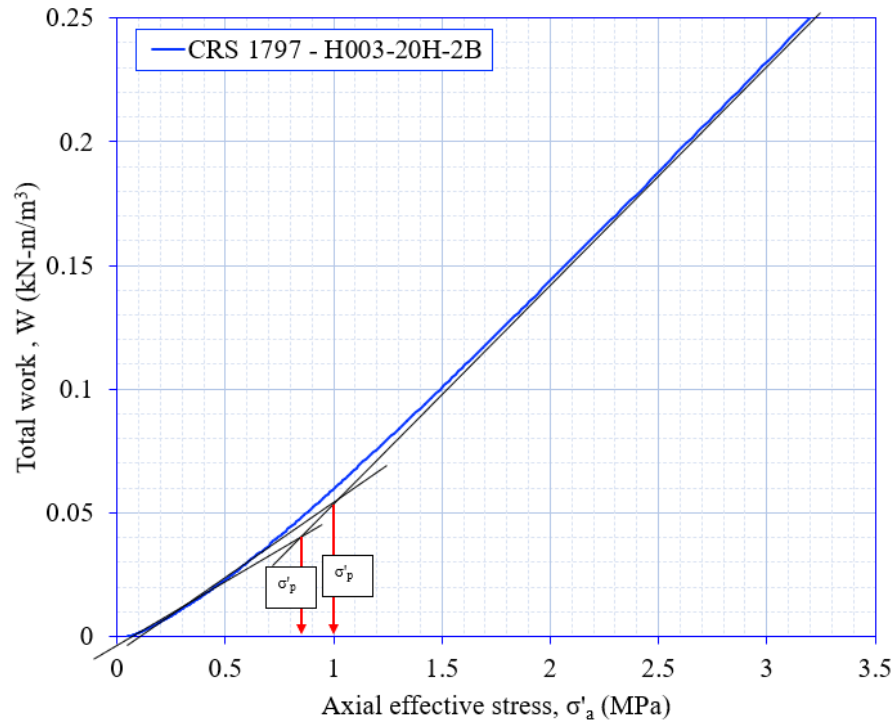


Figure 6-50 - Preconsolidation pressure construction by strain energy method. CRS 1797 - Sample H003-20H-2B. The effective preconsolidation pressure is estimated to be between 0.85 MPa and 1 MPa.

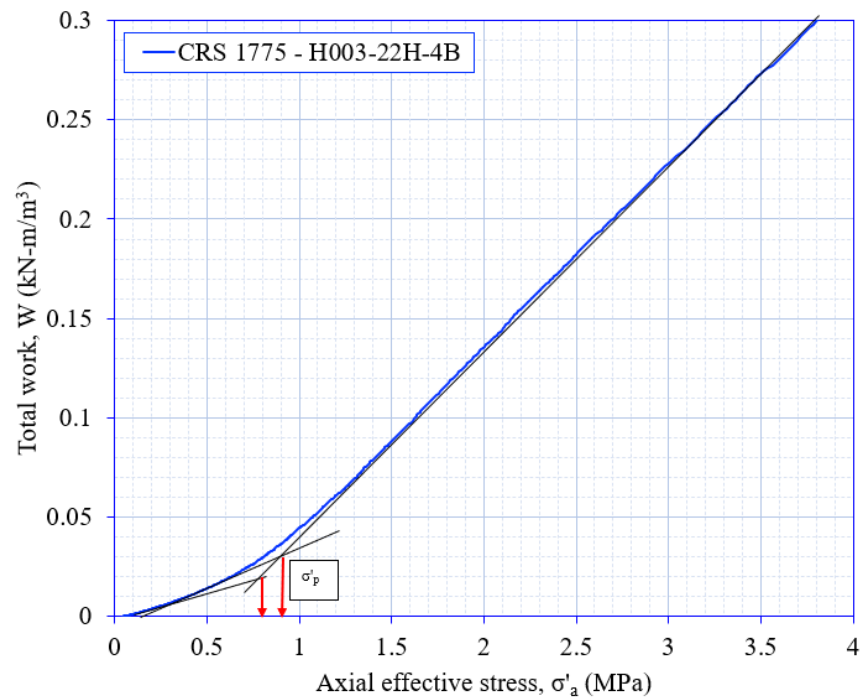


Figure 6-51 - Preconsolidation pressure construction by strain energy method. CRS 1775 - Sample H003-22H-4B. The effective preconsolidation pressure is estimated to be between 0.8 MPa and 0.9 MPa.

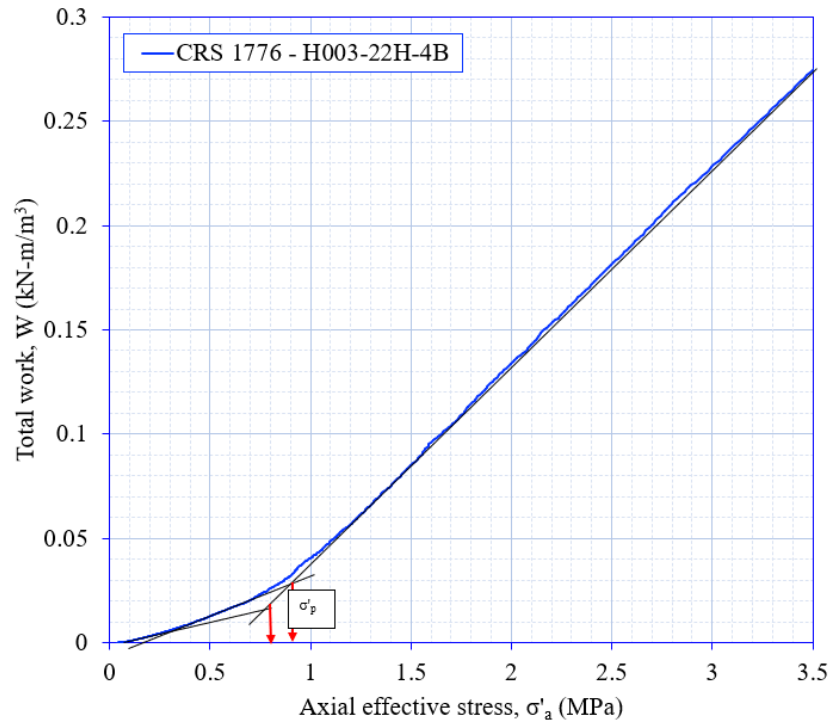


Figure 6-52 - Preconsolidation pressure construction by strain energy method. CRS 1776 - Sample H003-22H-4B. The effective preconsolidation pressure is estimated to be between 0.8 MPa and 0.9 MPa.

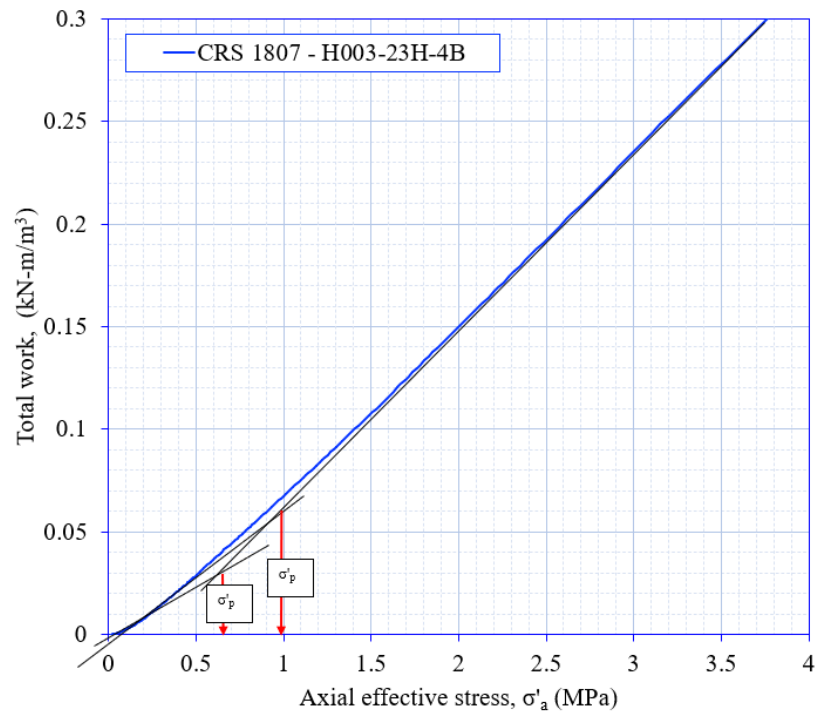


Figure 6-53 - Preconsolidation pressure construction by strain energy method. CRS 1807 - Sample H003-23H-4B. The effective preconsolidation pressure is estimated to be between 0.65 MPa and 1 MPa.

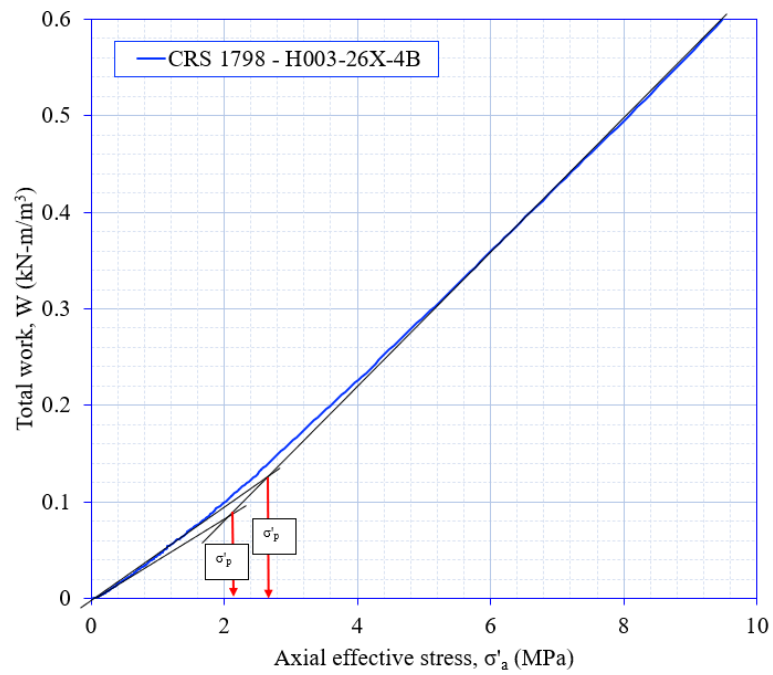


Figure 6-54 - Preconsolidation pressure construction by strain energy method. CRS 1798 - Sample H003-26X-4B. The effective preconsolidation pressure is estimated to be between 2.1 MPa and 2.7 MPa.

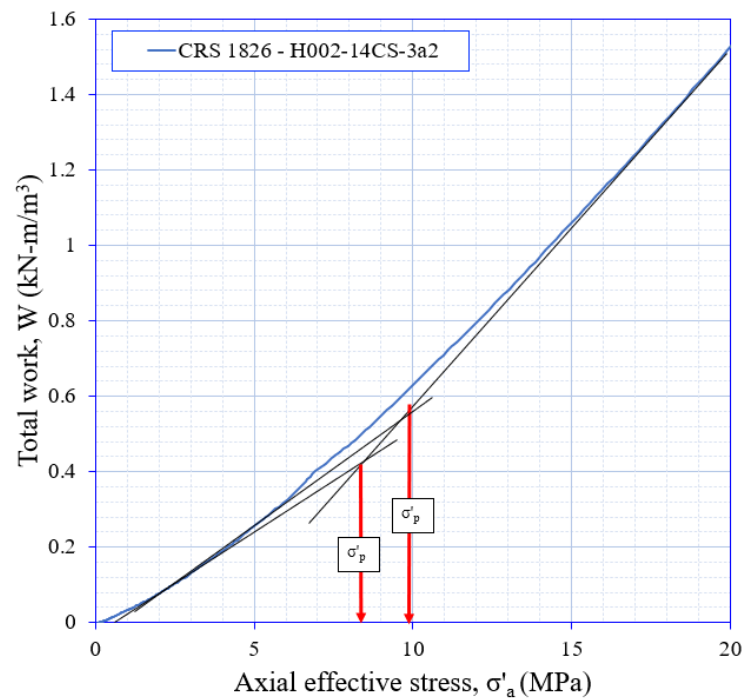


Figure 6-55 - Preconsolidation pressure construction by strain energy method. CRS 1826 - Sample H002-14cs-3a2. The effective preconsolidation pressure is estimated to be between 8.5 MPa and 10 MPa.

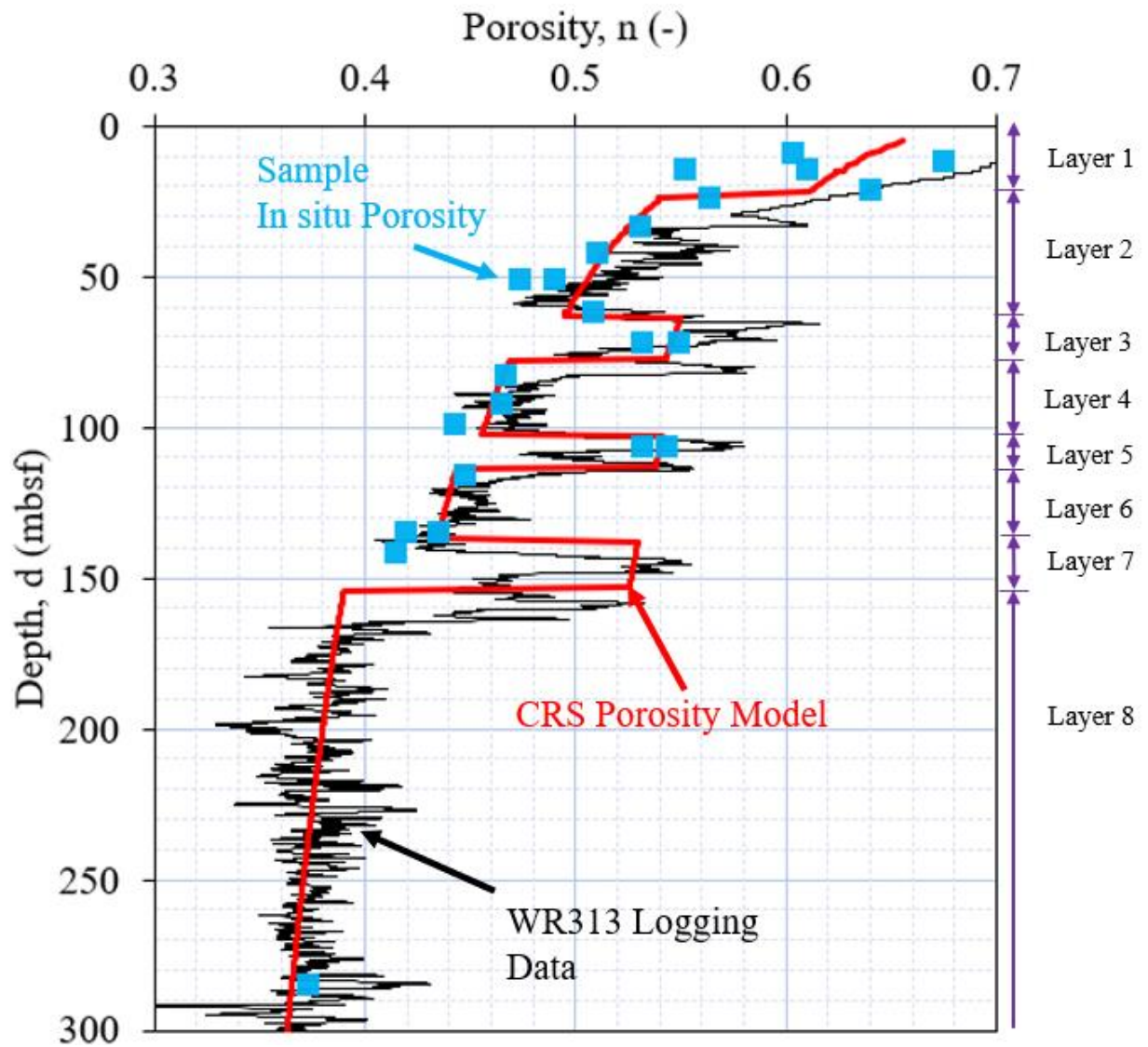


Figure 6-56 – Porosity profile including in-situ sample porosity CRS porosity model & LWD porosity data (0-300 mbsf)

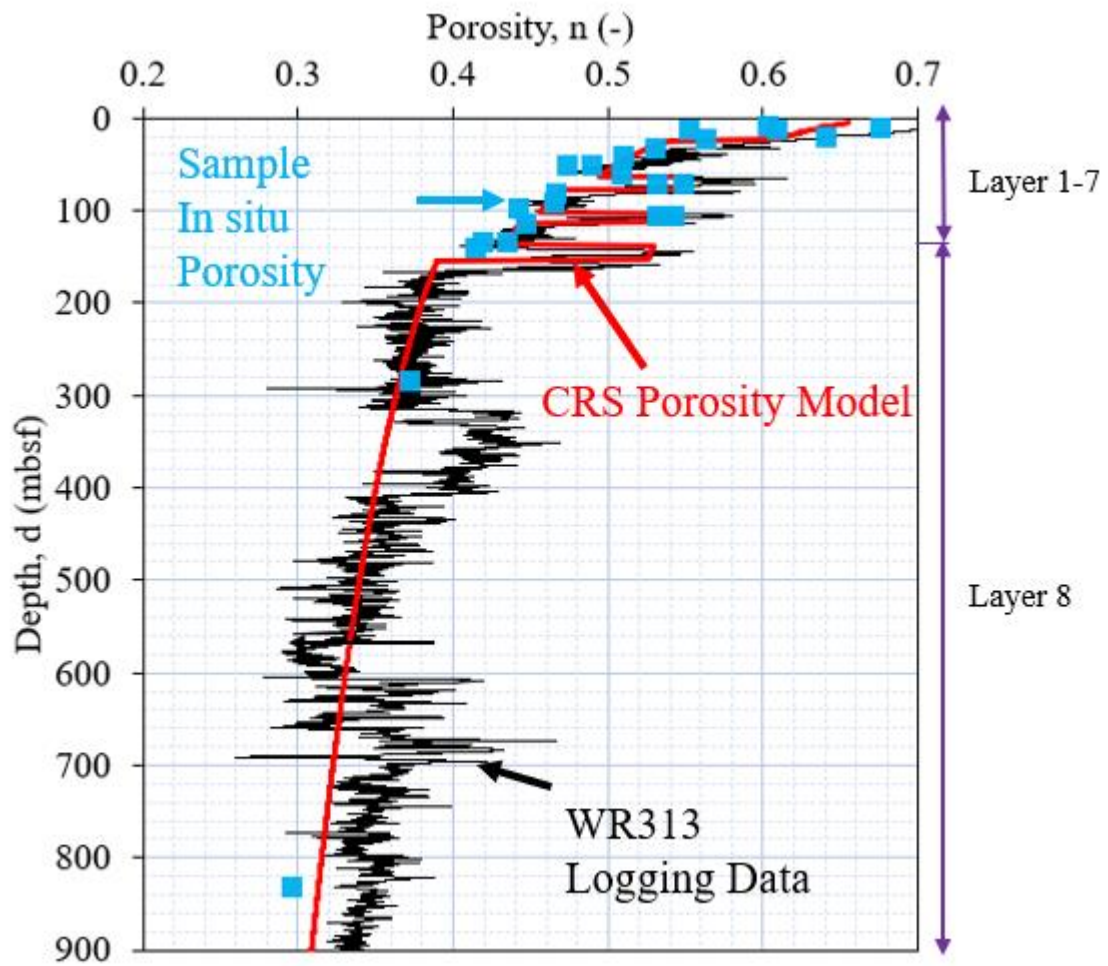


Figure 6-57 - Porosity profile including in-situ sample porosity CRS porosity model & LWD porosity data (0-900 mbsf)

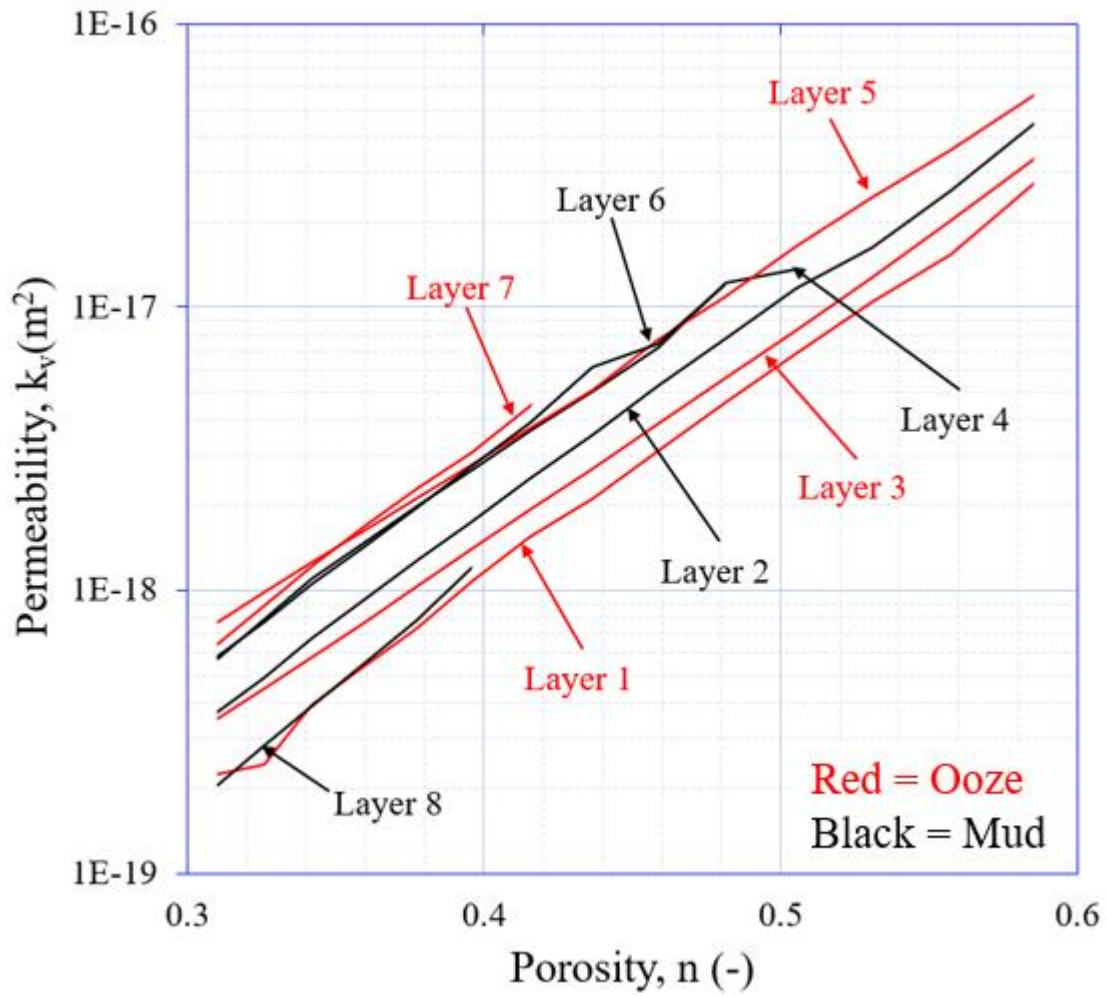


Figure 6-58 – Layer specific permeability curves. Layer 1 to 8.

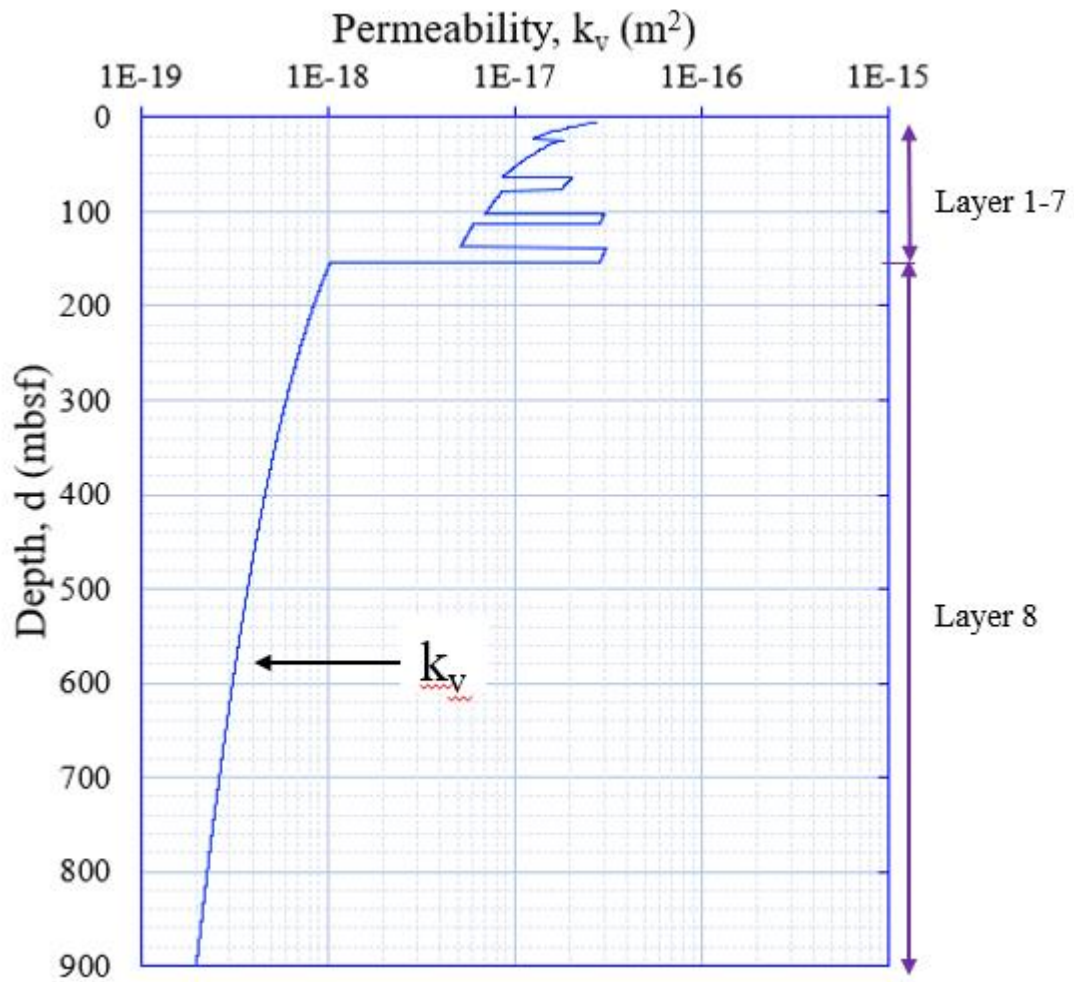


Figure 6-59 – Permeability profile. (0-900 mbsf).

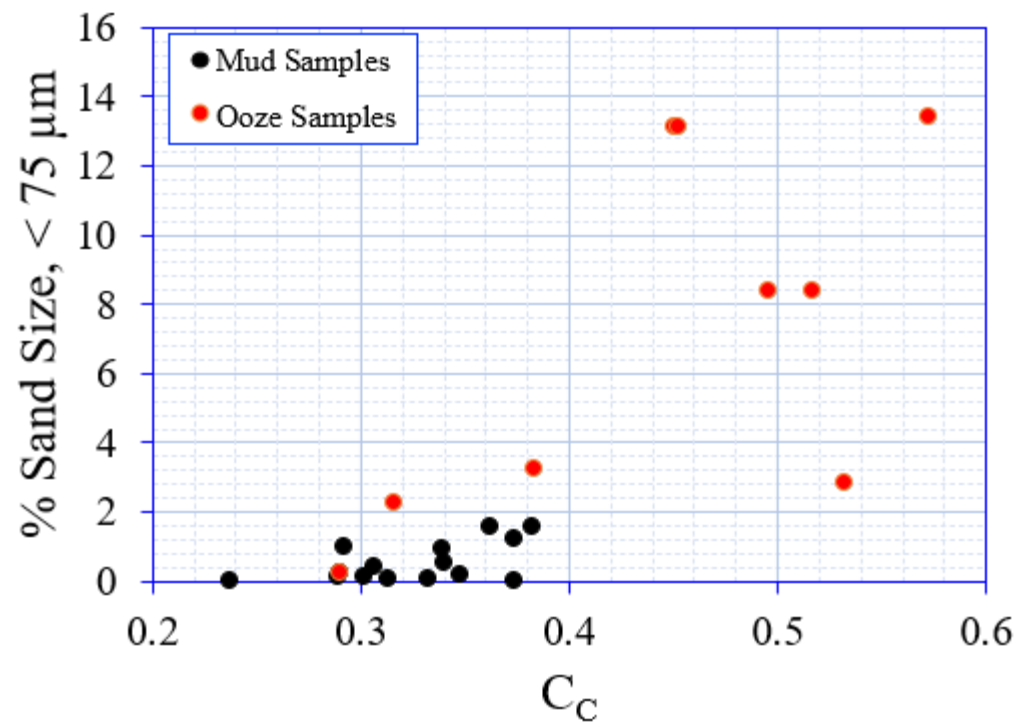


Figure 6-60 -  $C_c$  Vs % Sand Content of mud and ooze samples

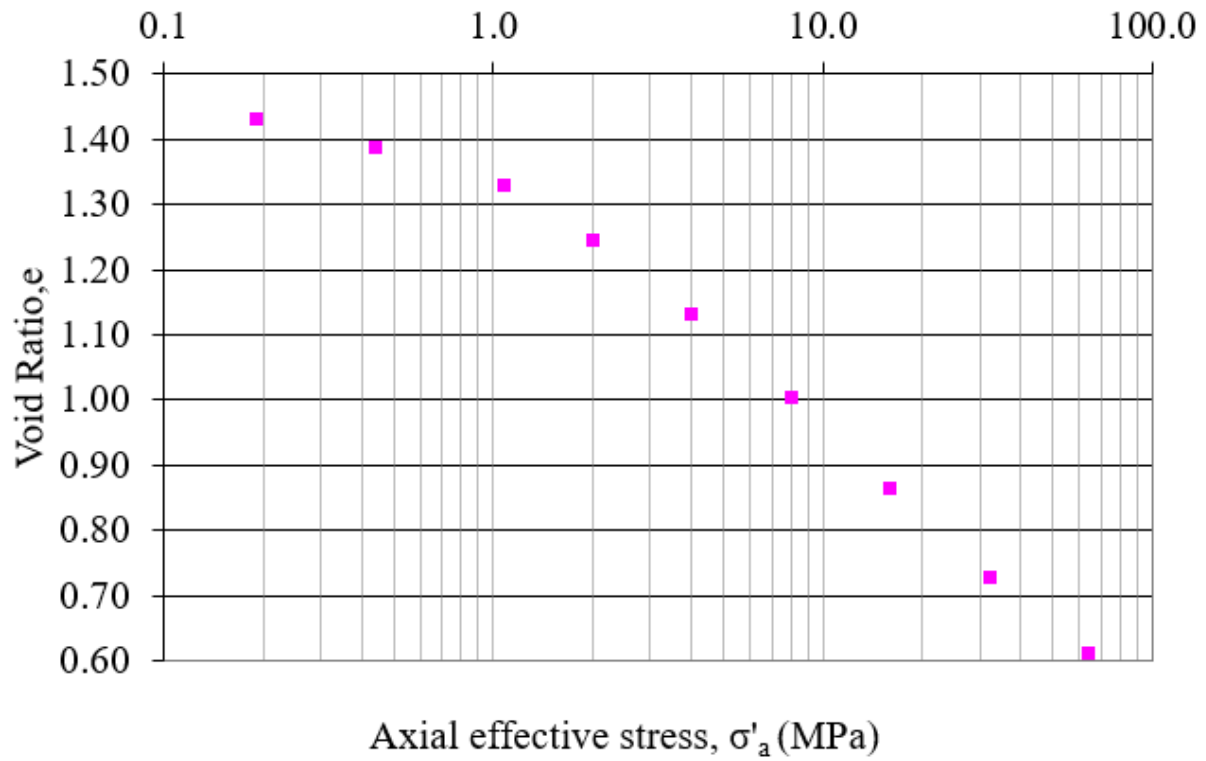


Figure 6-61 – Compression results for OED223 – H003-7H-3B1

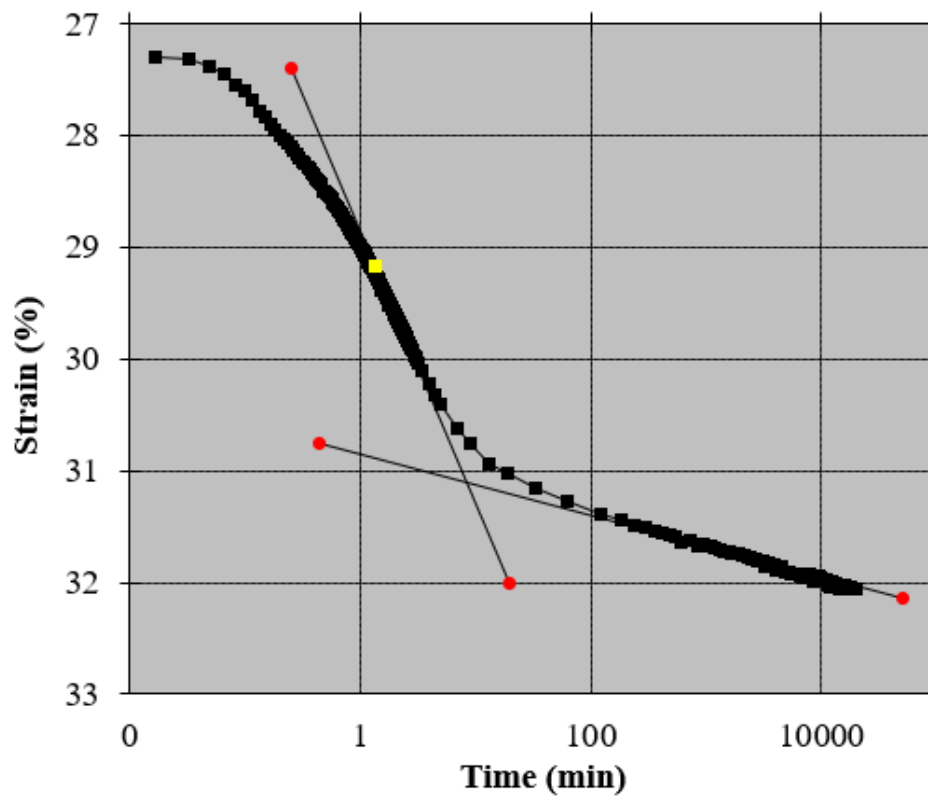


Figure 6-62 - Load Increment 9 OED 223 - 64 kg/cm<sup>2</sup> – Log of time method

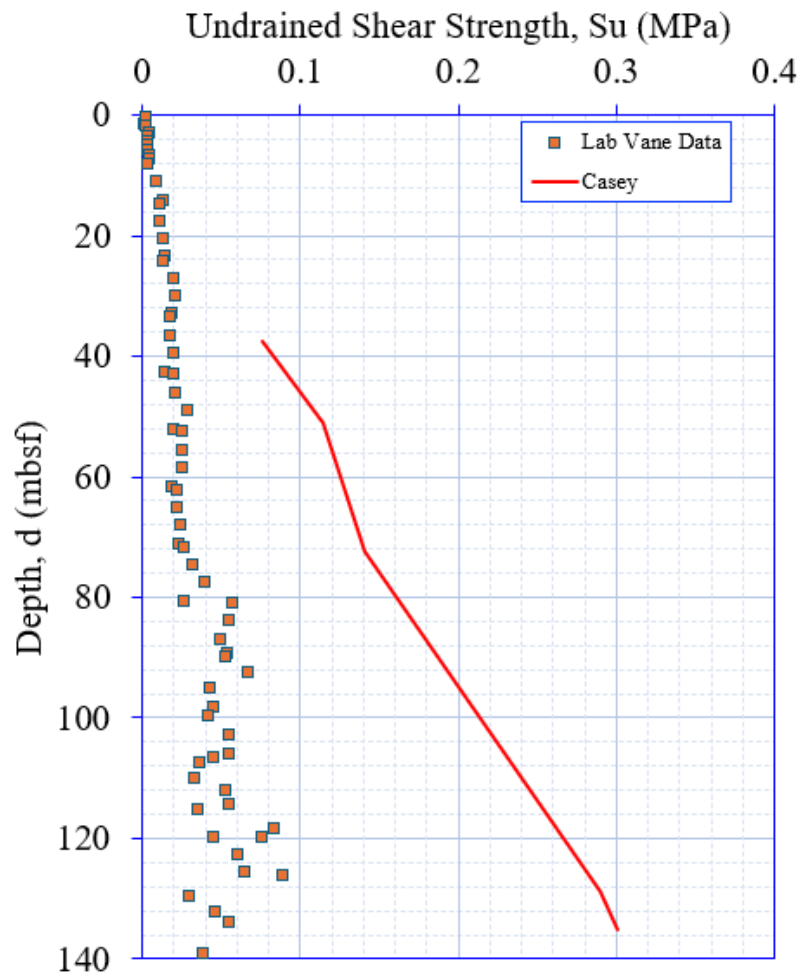


Figure 6-63 - Undrained shear strength is derived from the correlation by Casey 2013 from Atterberg limits, with lab vane data included.

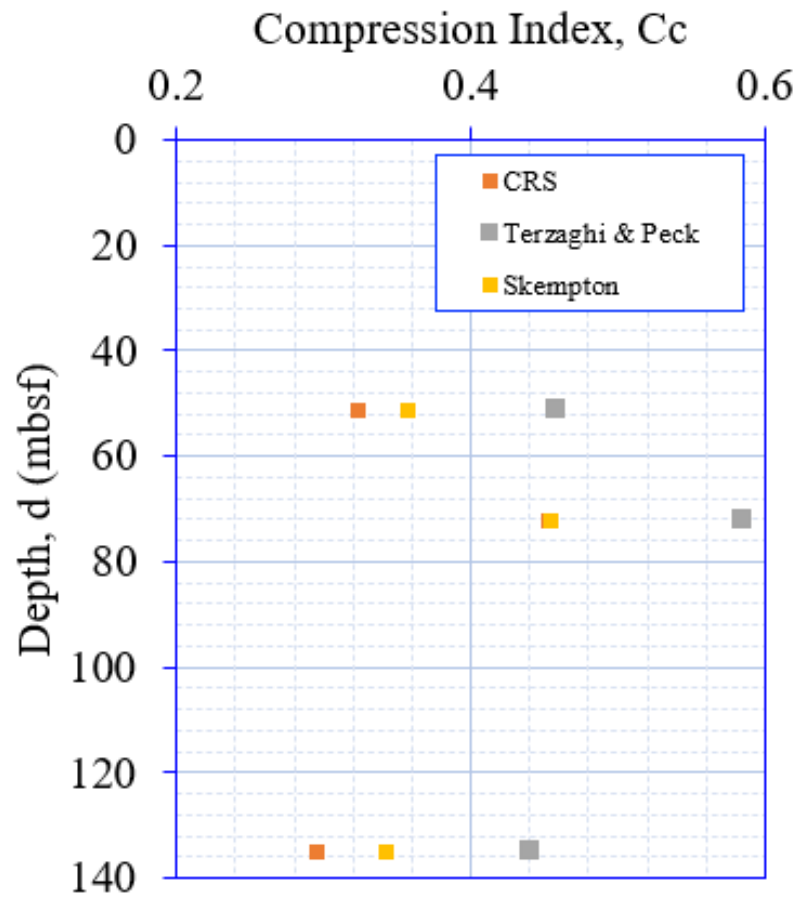


Figure 6-64 - Compression index comparison – CRS test, Terzaghi & Peck correlation and Skempton.

## **Chapter 7 - Conclusions and Recommendations**

### **7.1 Summary of Conducted Work**

This study examines 53 whole-round samples, and 283 split-core plugs collected from Walker Ridge Block 313 (Site H, WR313) in the Terrebonne Basin, located in the deepwater Gulf of Mexico. The samples, retrieved from depths ranging from 0 to 832 meters below the seafloor (mbsf), were initially processed aboard the research vessel and later at a facility in Salt Lake City. The author's involvement in the research began when the samples arrived at Tufts University.

At Tufts, the author played a central role in preparing the samples for geomechanical testing. A critical first step involved reviewing CT scans to identify samples suitable for engineering analysis. The study included comprehensive physical property measurements on the 283 split-core plugs, including water content, wet density, porosity, and degree of saturation. These measurements required precise volume and mass assessments, as well as oven-drying procedures. Additionally, grain density was determined using a gas pycnometer.

Similarly, the 53 whole-round samples underwent the same fundamental measurements as the split-core plugs. However, their grain density was also assessed using the water submersion method, and they also underwent grain size distribution analysis using the hydrometer method.

A portion of the whole-round samples was tested using the CRS apparatus. The CRS test results were instrumental in developing stress, porosity, and permeability profiles, which were then compared against pre-existing LWD data from a well drilled beside the wells used for this research. To further investigate sediment behavior, resedimented samples were produced from the trimmings of the CRS-tested specimens, enabling a direct comparison between intact and resedimented material. To the author's knowledge, this direct comparison is the first of its kind.

The final phase of the testing program involved OED testing, which provided insight into the secondary compression behavior of the sediment.

Essentially, the work involved a comprehensive laboratory-based geomechanical testing program.

#### Summary of testing

- **333** - grain density measurements using the gas pycnometer
- **333** - moisture and density measurements
- **53** - WR samples processed
- **50** - specific gravity measurements using the water submersion method
- **50** - grain size analysis by the hydrometer method
- **33** - CRS tests (Intact & Resedimented with 4 failed tests)
- **1** - Oedometer test

## **7.2 Summary of Results**

The MAD measurements reveal notable variations within the sediment column, with decreases in wet density and increases in porosity observed at specific intervals. These changes are attributed to variations in lithology, likely consisting of interbedded layers of mud and ooze. While smear slide testing was not conducted as part of this study, additional analyses by other researchers in the overall project identify the presence of these layers.

Particle size analysis classifies the sediment as silty clay, a uniformly fine-grained material. Some ooze samples show higher percentages of sand-sized particles. Microscopic examination reveals spherical features, presumed to be fossils, within the ooze samples.

Grain density measurements yield an average value of 2.795 g/cm<sup>3</sup> (standard deviation: 0.041) using the water submersion method, while the gas pycnometer method produces an average of 2.734 g/cm<sup>3</sup> (standard deviation: 0.027). According to Atterberg limits testing, the sediment is classified as high-plasticity clay with 58% clay content.

X-ray diffraction analysis shows higher calcite content in the ooze samples with both dominated by illite and illite smectite.

The comparison of intact and resedimented samples under CRS testing conditions shows similar overall behavior. Among the three samples tested, two exhibit greater resistance to compression at a specific void ratio, while the third demonstrates the opposite trend, indicating reduced resistance.

Multiple CRS tests indicate that ooze layers are significantly more compressible than mud layers, with an average  $C_c$  of 0.443 for ooze and 0.324 for mud. Stress profiles, including preconsolidation pressure values, confirm that the sediment column is normally consolidated, showing no significant evidence of overpressure. It is also noted that sample disturbance may have had somewhat of an impact on the results. Shear deformation is clear in many CT scans. Porosity and permeability profiles show increases within the ooze layers, aligning with the trends in LWD data.

OED testing results indicate that the average secondary compression rate across all increments for one test is 0.30% per log cycle of time, with a standard deviation of 0.032.

### **7.3 Future Work**

The work primarily focused on index testing the compressive behavior of the sediment. Although a significant study was conducted on the compressive behavior in the upper half of the sediment column, further compression testing is needed on deeper samples. This would add robustness to

the study and further explore the possibility of overpressure in the deeper sediments. Pore pressure prediction and the behavior of deep sediments are of huge importance to the offshore drilling industry. This reinforces the need for further exploration.

Understanding the shear behavior of sediment is crucial. While this study detailed pocket vane testing and liquid limit correlations, it still presents a significant opportunity to further examine shear behavior through triaxial testing, which is also essential for understanding the material's overall mechanical response. It should be noted that the pocket vane values obtained are extremely low and unrealistic. By expanding research into shear strength, a more comprehensive mechanical characterization of the sediment can be achieved, thus enhancing its applicability to the offshore drilling industry.

## Appendix A – References

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## **Appendix B - Tables**

Table 7-1 - Density, water content, and porosity of SC Plugs

| Density, Water Content, and Porosity of Split Core Plugs |              |          |        |             |             |               |          |          |            |
|----------------------------------------------------------|--------------|----------|--------|-------------|-------------|---------------|----------|----------|------------|
| Jar No.                                                  | Location     |          | Depth  | Comp. Depth | Wet Density | Water Content | Porosity |          | Saturation |
|                                                          | Core Section | Location |        |             |             |               | S=100    | Measured |            |
|                                                          |              | (cm)     | (MBSF) | (MBSF)      | (g/cc)      | (%)           | (-)      | (-)      | (%)        |
| A1                                                       | H003-01H-2a  | 88.5     | 2.39   | 2.39        | 2.030       | 18.67         | 0.337    | 0.370    | 86.5       |
| A2                                                       | H003-01H-3a  | 59.5     | 3.60   | 3.60        | 1.995       | 19.81         | 0.350    | 0.387    | 85.5       |
| A4                                                       | H003-01H-4a  | 44.5     | 4.95   | 4.95        | 1.519       | 86.79         | 0.702    | 0.700    | 101.0      |
| A3                                                       | H003-01H-4a  | 57.0     | 5.07   | 5.07        | 1.548       | 86.01         | 0.701    | 0.693    | 103.4      |
| A5                                                       | H003-01H-5a  | 69.0     | 6.69   | 6.69        | 1.563       | 76.46         | 0.675    | 0.674    | 100.7      |
| A6                                                       | H003-01H-cc  | 15.5     | 7.52   | 7.52        | 1.588       | 71.18         | 0.659    | 0.658    | 100.5      |
| A7                                                       | H003-02H-1a  | 13.0     | 8.36   | 8.34        | 1.667       | 57.88         | 0.612    | 0.611    | 100.2      |
| A8                                                       | H003-02H-1a  | 65.0     | 8.88   | 8.78        | 1.567       | 76.17         | 0.674    | 0.672    | 101.0      |
| A9                                                       | H003-02H-2a  | 13.0     | 9.86   | 9.61        | 1.631       | 63.41         | 0.633    | 0.632    | 100.3      |
| A10                                                      | H003-02H-2a  | 50.5     | 10.23  | 9.93        | 1.663       | 60.93         | 0.624    | 0.620    | 101.8      |
| A11                                                      | H003-02H-3a  | 13.0     | 11.36  | 10.89       | 1.693       | 59.09         | 0.616    | 0.608    | 103.6      |
| A12                                                      | H003-02H-3a  | 63.0     | 11.86  | 11.31       | 1.609       | 61.79         | 0.627    | 0.634    | 97.1       |
| A13                                                      | H003-02H-4a  | 13.0     | 12.86  | 12.16       | 1.625       | 58.82         | 0.615    | 0.623    | 96.8       |
| A14                                                      | H003-02H-4a  | 63.0     | 13.36  | 12.58       | 1.625       | 55.60         | 0.602    | 0.615    | 94.5       |
| A15                                                      | H003-02H-5a  | 12.0     | 14.35  | 13.43       | 1.574       | 61.78         | 0.627    | 0.642    | 93.9       |
| A16                                                      | H003-02H-5a  | 63.0     | 14.86  | 13.86       | 1.657       | 54.69         | 0.598    | 0.605    | 96.9       |
| A17                                                      | H003-02H-6a  | 12.0     | 15.85  | 14.70       | 1.451       | 83.90         | 0.695    | 0.709    | 93.5       |
| A18                                                      | H003-02H-6a  | 69.5     | 16.42  | 15.19       | 1.518       | 74.19         | 0.669    | 0.679    | 95.4       |
| A19                                                      | H003-02H-7a  | 17.5     | 17.40  | 16.02       | 1.530       | 71.44         | 0.660    | 0.671    | 95.1       |
| A20                                                      | H003-02H-cc  | 13.0     | 18.02  | 16.54       | 1.547       | 78.04         | 0.680    | 0.680    | 99.9       |
| A21                                                      | H003-03H-2a  | 21.5     | 20.26  | 19.98       | 1.659       | 56.68         | 0.607    | 0.610    | 98.5       |
| A22                                                      | H003-03H-2a  | 73.0     | 20.77  | 20.41       | 1.650       | 57.90         | 0.612    | 0.615    | 98.6       |
| A23                                                      | H003-03H-3a2 | 60.0     | 22.14  | 21.56       | 1.545       | 78.64         | 0.681    | 0.681    | 100.0      |
| A24                                                      | H003-03H-4a  | 11.5     | 23.16  | 22.40       | 1.368       | 82.40         | 0.691    | 0.724    | 85.5       |
| A25                                                      | H003-03H-4a  | 72.0     | 23.76  | 22.91       | 1.582       | 63.67         | 0.634    | 0.644    | 95.7       |
| A26                                                      | H003-03H-5a  | 11.5     | 24.81  | 23.78       | 1.526       | 73.54         | 0.667    | 0.676    | 95.8       |
| A27                                                      | H003-03H-5a  | 78.5     | 25.48  | 24.34       | 1.561       | 56.77         | 0.607    | 0.633    | 89.4       |
| A28                                                      | H003-03H-6a  | 12.5     | 26.32  | 25.04       | 1.555       | 61.37         | 0.625    | 0.645    | 91.8       |
| A29                                                      | H003-03H-6a  | 74.0     | 26.93  | 25.56       | 1.630       | 56.89         | 0.607    | 0.617    | 95.9       |
| A30                                                      | H003-03H-7a  | 14.0     | 27.83  | 26.31       | 1.521       | 62.52         | 0.630    | 0.655    | 89.4       |
| A31                                                      | H003-03H-7a  | 43.0     | 28.12  | 26.55       | 1.554       | 55.97         | 0.604    | 0.633    | 88.3       |
| A32                                                      | H003-03H-cc  | 43.0     | 28.87  | 27.18       | 1.617       | 57.00         | 0.608    | 0.621    | 94.8       |
| A33                                                      | H003-04CS-3a | 22.5     | 29.35  | 29.21       | 1.907       | 21.35         | 0.367    | 0.421    | 79.8       |

| Density, Water Content, and Porosity of Split Core Plugs |                |          |        |        |        |       |          |          |            |
|----------------------------------------------------------|----------------|----------|--------|--------|--------|-------|----------|----------|------------|
| Jar                                                      | Location       |          | Depth  | Comp.  | Wet    | Water | Porosity |          | Saturation |
| No.                                                      | Core Section   | Location |        |        |        |       | S=100    | Measured |            |
|                                                          |                | (cm)     | (MBSF) | (MBSF) | (g/cc) | (%)   | (-)      | (-)      | (%)        |
| A34                                                      | H003-05CS-1    | 29.0     | 30.47  | 30.45  | 1.514  | 77.23 | 0.677    | 0.685    | 96.5       |
| A35                                                      | H003-05CS-2cde | 47.0     | 31.75  | 31.64  | 1.321  | 81.99 | 0.690    | 0.733    | 81.4       |
| A36                                                      | H003-06H-1     | 122.5    | 33.53  | 33.13  | 1.472  | 70.79 | 0.658    | 0.683    | 89.6       |
| A37                                                      | H003-06H-2a    | 16.0     | 33.97  | 33.43  | 1.623  | 57.23 | 0.609    | 0.620    | 95.4       |
| A38                                                      | H003-06H-2a    | 68.0     | 34.49  | 33.78  | 1.718  | 47.27 | 0.562    | 0.570    | 96.8       |
| A39                                                      | H003-06H-3a    | 14.0     | 35.45  | 34.42  | 1.714  | 41.56 | 0.531    | 0.554    | 91.0       |
| A40                                                      | H003-06H-3a    | 68.0     | 35.99  | 34.79  | 1.651  | 47.10 | 0.562    | 0.587    | 90.2       |
| A41                                                      | H003-06H-4a    | 14.0     | 36.95  | 35.43  | 1.731  | 47.53 | 0.564    | 0.568    | 98.4       |
| A42                                                      | H003-06H-4c    | 108.0    | 37.89  | 36.06  | 1.696  | 47.85 | 0.566    | 0.578    | 95.2       |
| A43                                                      | H003-06H-5a    | 14.0     | 38.45  | 36.44  | 1.733  | 43.63 | 0.543    | 0.556    | 94.9       |
| A44                                                      | H003-06H-5a    | 92.0     | 39.23  | 36.97  | 1.684  | 45.13 | 0.551    | 0.573    | 91.6       |
| A45                                                      | H003-06H-6a1   | 35.0     | 40.16  | 37.59  | 1.753  | 44.09 | 0.545    | 0.552    | 97.3       |
| A46                                                      | H003-06H-7     | 46.0     | 41.77  | 38.68  | 1.715  | 43.89 | 0.544    | 0.561    | 93.4       |
| A47                                                      | H003-06H-cc    | 36.0     | 42.48  | 39.15  | 1.666  | 46.80 | 0.560    | 0.582    | 91.4       |
| A48                                                      | H003-07H-1     | 23.0     | 39.55  | 39.52  | 1.754  | 45.86 | 0.555    | 0.557    | 99.2       |
| A49                                                      | H003-07H-1     | 106.0    | 40.38  | 40.24  | 1.756  | 43.21 | 0.540    | 0.548    | 96.8       |
| A50                                                      | H003-07H-2     | 53.0     | 41.35  | 41.07  | 1.716  | 46.30 | 0.557    | 0.568    | 95.8       |
| A51                                                      | H003-07H-2     | 135.0    | 42.17  | 41.78  | 1.754  | 45.92 | 0.555    | 0.557    | 99.2       |
| A52                                                      | H003-07H-3a    | 14.0     | 42.46  | 42.03  | 1.737  | 46.69 | 0.559    | 0.564    | 98.2       |
| A53                                                      | H003-07H-4a    | 16.0     | 43.98  | 43.35  | 1.873  | 41.96 | 0.533    | 0.514    | 107.9      |
| A54                                                      | H003-07H-4a    | 101.0    | 44.83  | 44.08  | 1.632  | 44.50 | 0.548    | 0.584    | 86.2       |
| A55                                                      | H003-07H-5a    | 9.5      | 45.41  | 44.59  | 1.741  | 40.50 | 0.524    | 0.544    | 92.5       |
| A56                                                      | H003-07H-6     | 19.0     | 46.79  | 45.77  | 1.713  | 44.75 | 0.549    | 0.564    | 94.1       |
| A57                                                      | H003-07H-6     | 43.0     | 47.03  | 45.98  | 1.582  | 47.05 | 0.561    | 0.604    | 83.9       |
| A58                                                      | H003-07H-cc    | 21.0     | 47.47  | 46.36  | 1.735  | 41.81 | 0.532    | 0.549    | 93.3       |
| C7                                                       | H003-08CS-2    | 56.0     | 47.29  | 47.29  | 1.633  | 55.05 | 0.600    | 0.612    | 94.9       |
| C8                                                       | H003-08CS-3a   | 26.0     | 48.19  | 48.19  | 1.665  | 50.86 | 0.580    | 0.594    | 94.7       |
| A59                                                      | H003-09H-1a    | 27.0     | 49.95  | 49.89  | 1.717  | 46.22 | 0.557    | 0.567    | 95.8       |
| A60                                                      | H003-09H-1a    | 83.0     | 50.51  | 50.33  | 1.778  | 41.35 | 0.529    | 0.537    | 97.0       |
| A61                                                      | H003-09H-2a    | 15.5     | 51.34  | 50.98  | 1.767  | 42.76 | 0.538    | 0.544    | 97.4       |
| A62                                                      | H003-09H-3a    | 16.0     | 52.50  | 51.90  | 1.804  | 39.77 | 0.520    | 0.525    | 98.0       |
| A63                                                      | H003-09H-3a    | 98.0     | 53.32  | 52.54  | 1.765  | 41.23 | 0.529    | 0.540    | 95.7       |
| A64                                                      | H003-09H-4a1   | 73.0     | 54.57  | 53.53  | 1.798  | 39.10 | 0.515    | 0.524    | 96.6       |
| A65                                                      | H003-09H-5a    | 13.0     | 55.47  | 54.23  | 1.789  | 40.23 | 0.522    | 0.530    | 97.0       |
| A66                                                      | H003-09H-6a    | 26.0     | 56.71  | 55.21  | 1.770  | 36.55 | 0.499    | 0.523    | 90.8       |
| A67                                                      | H003-09H-6a    | 84.0     | 57.29  | 55.66  | 1.762  | 34.41 | 0.483    | 0.517    | 87.4       |

| Density, Water Content, and Porosity of Split Core Plugs |              |          |        |        |        |       |          |          |            |
|----------------------------------------------------------|--------------|----------|--------|--------|--------|-------|----------|----------|------------|
| Jar                                                      | Location     |          | Depth  | Comp.  | Wet    | Water | Porosity |          | Saturation |
| No.                                                      | Core Section | Location |        |        |        |       | S=100    | Measured |            |
|                                                          |              | (cm)     | (MBSF) | (MBSF) | (g/cc) | (%)   | (-)      | (-)      | (%)        |
| A68                                                      | H003-09H-cc  | 26.0     | 58.12  | 56.32  | 1.790  | 36.86 | 0.501    | 0.518    | 93.2       |
| A69                                                      | H003-10H-1a1 | 17.0     | 56.86  | 56.84  | 1.771  | 41.36 | 0.529    | 0.539    | 96.4       |
| A70                                                      | H003-10H-1a1 | 96.0     | 57.65  | 57.50  | 1.845  | 34.67 | 0.485    | 0.495    | 96.1       |
| A71                                                      | H003-10H-2   | 17.0     | 58.36  | 58.10  | 1.813  | 35.67 | 0.492    | 0.508    | 94.0       |
| A72                                                      | H003-10H-2   | 118.0    | 59.37  | 58.96  | 1.773  | 40.65 | 0.525    | 0.536    | 95.8       |
| A73                                                      | H003-10H-3a  | 14.0     | 59.83  | 59.35  | 1.776  | 41.53 | 0.530    | 0.538    | 97.1       |
| A74                                                      | H003-10H-4   | 11.0     | 60.78  | 60.15  | 1.814  | 38.44 | 0.511    | 0.517    | 97.5       |
| A75                                                      | H003-10H-4   | 100.0    | 61.67  | 60.90  | 1.765  | 43.28 | 0.541    | 0.546    | 97.8       |
| A76                                                      | H003-10H-5a  | 11.0     | 62.26  | 61.40  | 1.703  | 42.78 | 0.538    | 0.561    | 91.2       |
| A77                                                      | H003-10H-6   | 12.0     | 63.64  | 62.57  | 1.781  | 43.05 | 0.539    | 0.541    | 99.2       |
| A78                                                      | H003-10H-cc  | 36.0     | 64.72  | 63.48  | 1.677  | 50.84 | 0.580    | 0.591    | 95.9       |
| A79                                                      | H003-11H-1a1 | 25.0     | 63.95  | 63.89  | 1.717  | 48.53 | 0.569    | 0.574    | 97.9       |
| A80                                                      | H003-11H-1a1 | 85.0     | 64.55  | 64.35  | 1.704  | 44.87 | 0.550    | 0.567    | 93.3       |
| A81                                                      | H003-11H-2a  | 15.0     | 66.33  | 65.70  | 1.598  | 63.52 | 0.633    | 0.640    | 97.2       |
| A82                                                      | H003-11H-2a  | 84.5     | 67.03  | 66.23  | 1.679  | 57.29 | 0.609    | 0.607    | 100.9      |
| A83                                                      | H003-11H-3a  | 16.0     | 67.84  | 66.85  | 1.591  | 56.04 | 0.604    | 0.624    | 91.7       |
| A84                                                      | H003-11H-3a  | 63.0     | 68.31  | 67.20  | 1.630  | 56.23 | 0.605    | 0.616    | 95.4       |
| A85                                                      | H003-11H-4a  | 16.0     | 68.67  | 67.48  | 1.576  | 58.48 | 0.614    | 0.634    | 91.9       |
| A86                                                      | H003-11H-4a  | 70.0     | 69.21  | 67.89  | 1.663  | 54.84 | 0.599    | 0.605    | 97.6       |
| A87                                                      | H003-11H-5a  | 15.5     | 70.22  | 68.65  | 1.690  | 52.79 | 0.589    | 0.593    | 98.7       |
| A88                                                      | H003-11H-5a  | 70.0     | 70.76  | 69.06  | 1.727  | 50.78 | 0.580    | 0.578    | 100.8      |
| A89                                                      | H003-11H-6a  | 30.0     | 71.81  | 69.86  | 1.743  | 48.86 | 0.571    | 0.569    | 100.8      |
| A90                                                      | H003-11H-cca | 30.0     | 72.54  | 70.41  | 1.614  | 51.37 | 0.583    | 0.607    | 90.4       |
| A91                                                      | H003-12H-1   | 139.5    | 72.11  | 71.77  | 1.549  | 69.54 | 0.654    | 0.663    | 96.0       |
| A92                                                      | H003-12H-2a  | 38.0     | 72.59  | 72.14  | 1.671  | 54.31 | 0.596    | 0.601    | 98.0       |
| A93                                                      | H003-12H-2a  | 75.0     | 72.96  | 72.42  | 1.613  | 55.55 | 0.602    | 0.618    | 93.4       |
| A94                                                      | H003-12H-3   | 50.0     | 74.21  | 73.37  | 1.676  | 48.41 | 0.568    | 0.584    | 93.8       |
| A95                                                      | H003-12H-3   | 130.0    | 75.01  | 73.98  | 1.662  | 52.02 | 0.586    | 0.597    | 95.4       |
| A96                                                      | H003-12H-4a  | 27.5     | 75.49  | 74.34  | 1.589  | 54.62 | 0.598    | 0.622    | 90.4       |
| A97                                                      | H003-12H-4a  | 78.0     | 75.99  | 74.73  | 1.733  | 47.59 | 0.564    | 0.568    | 98.6       |
| A98                                                      | H003-12H-5a  | 5.0      | 76.76  | 75.31  | 1.700  | 50.50 | 0.579    | 0.584    | 97.9       |
| A99                                                      | H003-12H-6a  | 49.0     | 79.02  | 77.03  | 1.724  | 43.94 | 0.544    | 0.559    | 94.4       |
| A100                                                     | H003-12H-cc  | 24.5     | 79.46  | 77.36  | 1.714  | 39.90 | 0.520    | 0.549    | 89.2       |
| C9                                                       | H003-13CS-1  | 32.5     | 78.05  | 78.05  | 1.998  | 92.38 | 0.715    |          |            |
| B1                                                       | H003-14H-1a  | 33.5     | 81.11  | 81.04  | 1.643  | 56.26 | 0.605    | 0.613    | 96.7       |
| B2                                                       | H003-14H-1a  | 132.5    | 82.10  | 81.84  | 1.708  | 46.89 | 0.561    | 0.572    | 95.5       |

| Density, Water Content, and Porosity of Split Core Plugs |              |          |        |        |        |       |          |          |            |
|----------------------------------------------------------|--------------|----------|--------|--------|--------|-------|----------|----------|------------|
| Jar                                                      | Location     |          | Depth  | Comp.  | Wet    | Water | Porosity |          | Saturation |
| No.                                                      | Core Section | Location |        |        |        |       | S=100    | Measured |            |
|                                                          |              | (cm)     | (MBSF) | (MBSF) | (g/cc) | (%)   | (-)      | (-)      | (%)        |
| B3                                                       | H003-14H-2a  | 12.5     | 82.45  | 82.13  | 1.790  | 39.07 | 0.515    | 0.526    | 95.8       |
| B4                                                       | H003-14H-2a  | 60.0     | 82.92  | 82.51  | 1.805  | 37.76 | 0.507    | 0.517    | 95.8       |
| B5                                                       | H003-14H-3a2 | 50.5     | 84.24  | 83.58  | 1.799  | 36.92 | 0.501    | 0.516    | 94.1       |
| B6                                                       | H003-14H-3a2 | 122.0    | 84.95  | 84.15  | 1.757  | 36.96 | 0.501    | 0.528    | 90.0       |
| B7                                                       | H003-14H-4a  | 18.0     | 85.42  | 84.53  | 1.867  | 37.59 | 0.506    | 0.500    | 102.2      |
| B8                                                       | H003-14H-4a  | 120.0    | 86.44  | 85.36  | 1.809  | 35.37 | 0.490    | 0.508    | 93.3       |
| B9                                                       | H003-14H-5a  | 15.5     | 86.90  | 85.73  | 1.750  | 36.24 | 0.496    | 0.527    | 88.5       |
| B10                                                      | H003-14H-5a  | 68.0     | 87.42  | 86.15  | 1.811  | 33.73 | 0.478    | 0.501    | 91.3       |
| B11                                                      | H003-14H-6a  | 41.0     | 88.05  | 86.66  | 1.801  | 35.37 | 0.490    | 0.510    | 92.4       |
| B12                                                      | H003-14H-7   | 14.0     | 89.13  | 87.54  | 1.856  | 33.08 | 0.474    | 0.486    | 95.0       |
| B13                                                      | H003-14H-cc  | 15.0     | 89.52  | 87.85  | 1.804  | 33.15 | 0.474    | 0.501    | 89.8       |
| B14                                                      | H003-14H-cc  | 67.0     | 90.04  | 88.27  | 1.824  | 34.71 | 0.486    | 0.501    | 93.9       |
| B15                                                      | H003-16H-1a  | 33.0     | 91.77  | 91.70  | 1.834  | 38.59 | 0.512    | 0.513    | 99.8       |
| B16                                                      | H003-16H-1a  | 73.0     | 92.17  | 92.01  | 1.764  | 39.53 | 0.518    | 0.534    | 93.6       |
| B17                                                      | H003-16H-2   | 33.0     | 93.53  | 93.07  | 1.866  | 32.00 | 0.465    | 0.479    | 94.6       |
| B18                                                      | H003-16H-2   | 132.0    | 94.52  | 93.85  | 1.702  | 35.83 | 0.494    | 0.538    | 83.6       |
| B19                                                      | H003-16H-3a  | 39.5     | 95.10  | 94.29  | 1.693  | 38.56 | 0.512    | 0.550    | 85.9       |
| B20                                                      | H003-16H-3c  | 139.5    | 96.10  | 95.08  | 1.813  | 38.57 | 0.512    | 0.518    | 97.5       |
| B21                                                      | H003-16H-4a  | 19.5     | 96.40  | 95.31  | 1.753  | 36.58 | 0.499    | 0.527    | 89.2       |
| B22                                                      | H003-16H-4a  | 97.5     | 97.18  | 95.92  | 1.754  | 36.22 | 0.496    | 0.526    | 88.9       |
| B23                                                      | H003-16H-5   | 16.0     | 98.29  | 96.79  | 1.787  | 34.97 | 0.487    | 0.512    | 90.5       |
| B24                                                      | H003-16H-5   | 60.0     | 98.73  | 97.13  | 1.753  | 36.02 | 0.495    | 0.525    | 88.5       |
| B25                                                      | H003-16H-cca | 15.0     | 99.09  | 97.41  | 1.737  | 35.71 | 0.493    | 0.528    | 86.7       |
| B26                                                      | H003-16H-ccc | 62.0     | 99.56  | 97.78  | 1.828  | 37.77 | 0.507    | 0.511    | 98.2       |
| B27                                                      | H003-17H-1a  | 42.5     | 98.27  | 98.16  | 1.798  | 35.78 | 0.493    | 0.512    | 92.7       |
| B28                                                      | H003-17H-2a  | 18.0     | 98.71  | 98.49  | 1.838  | 34.36 | 0.483    | 0.496    | 94.9       |
| B29                                                      | H003-17H-2a  | 38.0     | 98.91  | 98.63  | 1.906  | 33.84 | 0.479    | 0.475    | 101.6      |
| B30                                                      | H003-17H-3b1 | 14.0     | 100.33 | 99.69  | 1.799  | 35.87 | 0.494    | 0.512    | 92.9       |
| B31                                                      | H003-17H-3b1 | 76.0     | 100.95 | 100.15 | 1.749  | 39.52 | 0.518    | 0.538    | 92.2       |
| B32                                                      | H003-17H-4a  | 34.0     | 102.03 | 100.95 | 1.753  | 38.06 | 0.509    | 0.532    | 91.0       |
| B33                                                      | H003-17H-4a  | 84.5     | 102.54 | 101.32 | 1.746  | 37.76 | 0.507    | 0.533    | 89.9       |
| B34                                                      | H003-17H-5   | 38.0     | 104.07 | 102.46 | 1.829  | 38.92 | 0.514    | 0.515    | 99.6       |
| B35                                                      | H003-17H-5   | 98.0     | 104.67 | 102.91 | 1.672  | 48.96 | 0.571    | 0.587    | 93.8       |
| B36                                                      | H003-17H-6a  | 23.5     | 105.43 | 103.47 | 1.611  | 48.94 | 0.571    | 0.602    | 88.2       |
| B37                                                      | H003-17H-cc  | 7.5      | 105.84 | 103.77 | 1.596  | 56.20 | 0.605    | 0.624    | 92.3       |
| B38                                                      | H003-18H-1a1 | 115.0    | 105.39 | 105.05 | 1.630  | 54.89 | 0.599    | 0.612    | 94.5       |

| Density, Water Content, and Porosity of Split Core Plugs |              |          |        |        |        |       |          |          |            |
|----------------------------------------------------------|--------------|----------|--------|--------|--------|-------|----------|----------|------------|
| Jar                                                      | Location     |          | Depth  | Comp.  | Wet    | Water | Porosity |          | Saturation |
| No.                                                      | Core Section | Location |        |        |        |       | S=100    | Measured |            |
|                                                          |              | (cm)     | (MBSF) | (MBSF) | (g/cc) | (%)   | (-)      | (-)      | (%)        |
| B39                                                      | H003-18H-1a1 | 183.0    | 106.07 | 105.52 | 1.683  | 54.78 | 0.598    | 0.600    | 99.5       |
| B40                                                      | H003-18H-2a  | 9.5      | 106.41 | 105.76 | 1.407  | 54.30 | 0.596    | 0.664    | 74.7       |
| B41                                                      | H003-18H-2a  | 44.0     | 106.75 | 106.00 | 1.642  | 52.92 | 0.590    | 0.605    | 94.2       |
| B42                                                      | H003-18H-3a  | 11.5     | 107.94 | 106.83 | 1.637  | 54.09 | 0.595    | 0.609    | 94.6       |
| B43                                                      | H003-18H-3a  | 100.0    | 108.82 | 107.45 | 1.588  | 55.00 | 0.599    | 0.623    | 90.7       |
| B44                                                      | H003-18H-4   | 33.0     | 109.65 | 108.03 | 1.698  | 38.68 | 0.513    | 0.549    | 86.5       |
| B45                                                      | H003-18H-4   | 111.0    | 110.43 | 108.57 | 1.721  | 42.83 | 0.538    | 0.556    | 92.9       |
| B46                                                      | H003-18H-5a  | 36.0     | 110.93 | 108.92 | 1.752  | 37.02 | 0.502    | 0.529    | 89.6       |
| B47                                                      | H003-18H-6   | 60.0     | 112.79 | 110.23 | 1.654  | 38.33 | 0.510    | 0.560    | 82.1       |
| B48                                                      | H003-18H-cc  | 47.0     | 113.39 | 110.65 | 1.674  | 37.78 | 0.507    | 0.552    | 83.3       |
| B49                                                      | H003-18H-cc  | 72.0     | 113.64 | 110.82 | 1.755  | 37.53 | 0.505    | 0.530    | 90.5       |
| C10                                                      | H003-19CS-3c | 74.0     | 111.76 | 111.66 | 1.990  | 59.05 | 0.616    | 0.621    | 97.9       |
| C11                                                      | H003-19CS-4  | 33.0     | 112.48 | 112.30 | 2.009  | 56.17 | 0.604    | 0.617    | 94.9       |
| C12                                                      | H003-19CS-5a | 12.5     | 113.47 | 113.17 | 1.998  | 57.02 | 0.608    | 0.622    | 94.2       |
| B51                                                      | H003-20H-1a  | 37.0     | 114.37 | 114.31 | 1.785  | 40.61 | 0.525    | 0.533    | 97.0       |
| B50                                                      | H003-20H-1a  | 77.0     | 114.77 | 114.65 | 1.726  | 39.34 | 0.517    | 0.544    | 89.7       |
| B52                                                      | H003-20H-2a  | 18.5     | 115.28 | 115.08 | 1.736  | 40.87 | 0.526    | 0.546    | 92.4       |
| B53                                                      | H003-20H-2a  | 82.5     | 115.92 | 115.62 | 1.743  | 37.29 | 0.504    | 0.532    | 89.1       |
| B55                                                      | H003-20H-3   | 20.0     | 117.15 | 116.65 | 1.961  | 36.02 | 0.495    | 0.469    | 111.0      |
| B54                                                      | H003-20H-3   | 86.0     | 117.81 | 117.21 | 1.689  | 35.25 | 0.489    | 0.540    | 81.7       |
| B56                                                      | H003-20H-4   | 19.0     | 118.64 | 117.91 | 1.774  | 34.26 | 0.482    | 0.513    | 88.4       |
| B57                                                      | H003-20H-4   | 75.0     | 119.20 | 118.38 | 1.826  | 32.69 | 0.471    | 0.493    | 91.4       |
| B58                                                      | H003-20H-5a1 | 28.0     | 119.66 | 118.77 | 1.847  | 33.07 | 0.474    | 0.489    | 94.1       |
| B59                                                      | H003-20H-6   | 9.0      | 120.97 | 119.88 | 1.903  | 31.05 | 0.458    | 0.465    | 97.1       |
| B60                                                      | H003-20H-6   | 82.0     | 121.70 | 120.49 | 1.817  | 31.86 | 0.464    | 0.492    | 89.3       |
| B61                                                      | H003-20H-6   | 127.0    | 122.15 | 120.87 | 1.777  | 31.50 | 0.461    | 0.502    | 84.9       |
| B62                                                      | H003-20H-cc  | 41.0     | 122.79 | 121.41 | 1.750  | 32.42 | 0.469    | 0.513    | 83.6       |
| B63                                                      | H003-21H-1a1 | 44.0     | 122.06 | 122.00 | 1.833  | 36.00 | 0.495    | 0.504    | 96.5       |
| B64                                                      | H003-21H-1a3 | 114.0    | 122.76 | 122.62 | 1.903  | 33.31 | 0.475    | 0.474    | 100.5      |
| B65                                                      | H003-21H-2a  | 23.0     | 123.35 | 123.14 | 1.864  | 33.95 | 0.480    | 0.488    | 97.1       |
| B66                                                      | H003-21H-2a  | 121.0    | 124.33 | 124.01 | 1.896  | 32.32 | 0.468    | 0.472    | 98.3       |
| B67                                                      | H003-21H-3a  | 14.0     | 124.76 | 124.38 | 1.978  | 37.62 | 0.506    | 0.471    | 115.1      |
| B68                                                      | H003-21H-4   | 13.0     | 126.25 | 125.70 | 1.874  | 34.10 | 0.481    | 0.485    | 98.4       |
| B69                                                      | H003-21H-4   | 129.0    | 127.41 | 126.72 | 1.676  | 40.02 | 0.521    | 0.559    | 85.9       |
| B70                                                      | H003-21H-5   | 62.0     | 128.24 | 127.45 | 1.855  | 33.24 | 0.475    | 0.487    | 95.2       |
| B71                                                      | H003-21H-6a  | 33.0     | 128.65 | 127.82 | 1.934  | 32.21 | 0.467    | 0.461    | 102.4      |

| Density, Water Content, and Porosity of Split Core Plugs |              |          |        |        |        |       |          |          |            |
|----------------------------------------------------------|--------------|----------|--------|--------|--------|-------|----------|----------|------------|
| Jar                                                      | Location     |          | Depth  | Comp.  | Wet    | Water | Porosity |          | Saturation |
| No.                                                      | Core Section | Location |        |        |        |       | S=100    | Measured |            |
|                                                          |              | (cm)     | (MBSF) | (MBSF) | (g/cc) | (%)   | (-)      | (-)      | (%)        |
| B72                                                      | H003-21H-7   | 9.0      | 129.75 | 128.79 | 1.881  | 34.54 | 0.484    | 0.485    | 99.7       |
| B73                                                      | H003-21H-cc  | 9.0      | 130.09 | 129.09 | 1.813  | 38.55 | 0.512    | 0.518    | 97.5       |
| B74                                                      | H003-22H-1   | 20.0     | 129.44 | 129.44 | 1.841  | 39.09 | 0.515    | 0.513    | 101.1      |
| B75                                                      | H003-22H-1   | 128.0    | 130.52 | 130.52 | 1.817  | 38.40 | 0.511    | 0.517    | 97.8       |
| B76                                                      | H003-22H-2a1 | 10.5     | 130.84 | 130.84 | 1.807  | 39.41 | 0.517    | 0.523    | 97.9       |
| B77                                                      | H003-22H-2a2 | 68.5     | 131.42 | 131.42 | 1.851  | 37.16 | 0.503    | 0.503    | 99.9       |
| B78                                                      | H003-22H-3   | 19.0     | 132.43 | 132.43 | 1.910  | 34.28 | 0.482    | 0.476    | 102.6      |
| B79                                                      | H003-22H-3   | 133.0    | 133.57 | 133.57 | 1.929  | 33.34 | 0.476    | 0.467    | 103.4      |
| B80                                                      | H003-22H-4a2 | 38.0     | 134.10 | 134.10 | 1.883  | 34.28 | 0.483    | 0.483    | 99.6       |
| B81                                                      | H003-22H-4a2 | 83.0     | 134.55 | 134.55 | 1.951  | 29.99 | 0.449    | 0.447    | 100.8      |
| B82                                                      | H003-22H-5   | 22.5     | 135.44 | 135.44 | 1.898  | 33.83 | 0.479    | 0.478    | 100.6      |
| B83                                                      | H003-22H-5   | 89.5     | 136.11 | 136.11 | 1.859  | 32.59 | 0.470    | 0.484    | 94.7       |
| B84                                                      | H003-22H-cc  | 11.0     | 136.40 | 136.40 | 1.900  | 30.51 | 0.454    | 0.464    | 95.9       |
| B85                                                      | H003-23H-1a  | 26.0     | 137.12 | 137.08 | 1.974  | 29.23 | 0.443    | 0.437    | 102.3      |
| B86                                                      | H003-23H-1a  | 69.0     | 137.55 | 137.45 | 1.394  | 34.58 | 0.485    | 0.618    | 58.0       |
| B87                                                      | H003-23H-2a  | 20.0     | 138.72 | 138.46 | 1.796  | 27.96 | 0.432    | 0.483    | 81.4       |
| B71A                                                     | H003-23H-3a  | 33.0     | 140.90 | 140.34 | 1.865  | 32.12 | 0.466    | 0.480    | 94.6       |
| B72A                                                     | H003-23H-4a  | 26.0     | 141.76 | 141.08 | 1.873  | 33.07 | 0.474    | 0.481    | 96.9       |
| B73A                                                     | H003-23H-5   | 10.0     | 143.20 | 142.32 | 1.947  | 30.13 | 0.450    | 0.449    | 100.6      |
| B74A                                                     | H003-23H-5   | 82.0     | 143.92 | 142.94 | 1.895  | 31.77 | 0.464    | 0.470    | 97.3       |
| B75A                                                     | H003-23H-6   | 11.0     | 144.66 | 143.58 | 1.879  | 30.26 | 0.452    | 0.469    | 93.3       |
| B76A                                                     | H003-23H-6   | 45.0     | 145.00 | 143.87 | 1.877  | 31.27 | 0.460    | 0.473    | 94.6       |
| B77A                                                     | H003-23H-cc  | 19.0     | 145.38 | 144.20 | 1.843  | 32.33 | 0.468    | 0.487    | 92.7       |
| C13                                                      | H003-24CS-2  | 55.5     | 145.09 | 145.02 | 1.904  | 52.56 | 0.588    | 0.595    | 97.3       |
| C67                                                      | H003-24cs-3  | 8.0      | 145.56 | 145.43 | 1.996  | 53.41 | 0.592    | 0.631    | 85.1       |
| C14                                                      | H003-24CS-5a | 25.0     | 147.13 | 146.81 | 2.009  | 50.46 | 0.578    | 0.579    | 99.9       |
| B88                                                      | H003-25H-10  | 13.0     | 147.65 | 147.62 | 1.908  | 34.83 | 0.487    | 0.479    | 103.2      |
| B89                                                      | H003-25H-10  | 50.0     | 148.02 | 147.89 | 1.747  | 45.54 | 0.553    | 0.558    | 98.1       |
| B78A                                                     | H003-25H-3   | 21.5     | 150.49 | 149.68 | 1.685  | 49.57 | 0.574    | 0.585    | 95.6       |
| B79A                                                     | H003-25H-4   | 32.5     | 151.09 | 150.12 | 1.722  | 46.14 | 0.557    | 0.566    | 96.2       |
| B80A                                                     | H003-25H-5a  | 60.0     | 152.01 | 150.79 | 1.822  | 40.17 | 0.522    | 0.521    | 100.3      |
| B81A                                                     | H003-25H-6a  | 15.0     | 152.52 | 151.16 | 1.859  | 33.22 | 0.475    | 0.486    | 95.5       |
| B82A                                                     | H003-25H-6c  | 77.5     | 153.15 | 151.62 | 1.752  | 35.90 | 0.494    | 0.525    | 88.3       |
| B83A                                                     | H003-25H-7a  | 27.0     | 153.69 | 152.01 | 1.774  | 33.96 | 0.480    | 0.512    | 88.0       |
| B85A                                                     | H003-25H-8b  | 27.0     | 154.71 | 152.76 | 1.892  | 34.35 | 0.483    | 0.481    | 100.7      |
| B84A                                                     | H003-25H-8b  | 84.5     | 155.29 | 153.18 | 1.866  | 32.08 | 0.466    | 0.480    | 94.7       |

| Density, Water Content, and Porosity of Split Core Plugs |              |          |        |        |        |       |          |          |            |
|----------------------------------------------------------|--------------|----------|--------|--------|--------|-------|----------|----------|------------|
| Jar                                                      | Location     |          | Depth  | Comp.  | Wet    | Water | Porosity |          | Saturation |
| No.                                                      | Core Section | Location |        |        |        |       | S=100    | Measured |            |
|                                                          |              | (cm)     | (MBSF) | (MBSF) | (g/cc) | (%)   | (-)      | (-)      | (%)        |
| B86A                                                     | H003-25H-9a  | 9.0      | 155.73 | 153.50 | 1.794  | 32.15 | 0.466    | 0.500    | 87.4       |
| B87A                                                     | H003-25H-9b  | 60.0     | 156.24 | 153.87 | 1.766  | 31.52 | 0.462    | 0.506    | 83.8       |
| B90                                                      | H003-25H-cc  | 19.0     | 157.49 | 154.78 | 1.789  | 32.64 | 0.470    | 0.503    | 87.6       |
| B91                                                      | H003-25H-cc  | 51.5     | 157.82 | 155.02 | 1.895  | 33.13 | 0.474    | 0.476    | 99.3       |
| B92                                                      | H003-26X-1a  | 62.0     | 279.21 | 279.21 | 1.961  | 28.45 | 0.436    | 0.438    | 99.4       |
| B93                                                      | H003-26X-1a  | 121.0    | 279.80 | 279.80 | 1.985  | 28.98 | 0.441    | 0.433    | 103.2      |
| B94                                                      | H003-26X-2   | 37.0     | 280.28 | 280.28 | 1.932  | 27.97 | 0.432    | 0.444    | 95.3       |
| B95                                                      | H003-26X-2   | 106.0    | 280.97 | 280.97 | 1.959  | 28.38 | 0.436    | 0.438    | 99.0       |
| B96                                                      | H003-26X-3a  | 34.0     | 281.59 | 281.59 | 1.945  | 28.95 | 0.441    | 0.444    | 98.4       |
| B97                                                      | H003-26X-3a  | 49.0     | 281.74 | 281.74 | 1.936  | 29.50 | 0.445    | 0.449    | 98.3       |
| B98                                                      | H003-26X-4a  | 19.0     | 282.19 | 282.19 | 1.930  | 28.40 | 0.436    | 0.446    | 95.8       |
| B99                                                      | H003-26X-4a  | 47.0     | 282.47 | 282.47 | 1.998  | 26.82 | 0.422    | 0.420    | 100.9      |
| C1                                                       | H003-26X-5a  | 58.5     | 283.95 | 283.95 | 1.990  | 27.42 | 0.427    | 0.425    | 101.0      |
| C2                                                       | H003-26X-5a  | 118.0    | 284.55 | 284.55 | 2.009  | 27.10 | 0.424    | 0.418    | 102.7      |
| C3                                                       | H003-26X-6a  | 14.0     | 284.97 | 284.97 | 1.998  | 26.03 | 0.415    | 0.416    | 99.3       |
| C4                                                       | H003-26X-6a  | 44.0     | 285.27 | 285.27 | 1.904  | 31.18 | 0.459    | 0.466    | 97.4       |
| C5                                                       | H003-26X-7c  | 44.0     | 286.42 | 286.42 | 2.009  | 24.76 | 0.402    | 0.407    | 98.2       |
| C6                                                       | H003-26X-cc  | 31.0     | 286.83 | 286.83 | 2.073  | 23.53 | 0.390    | 0.382    | 103.5      |
| C60                                                      | H003-27cs-3  | 8.0      | 288.46 | 288.46 | 1.788  | 21.27 | 0.366    | 0.537    | 49.9       |
| C15                                                      | H003-27CS-4a | 11.0     | 288.69 | 288.69 | 2.073  | 23.36 | 0.389    | 0.388    | 100.3      |
| C16                                                      | H003-27CS-5a | 33.0     | 289.75 | 289.75 | 1.939  | 21.97 | 0.374    | 0.383    | 96.2       |
| C56                                                      | H003-28cs-1a | 10.0     | 290.88 | 290.88 | 1.996  | 23.16 | 0.386    | 0.394    | 96.9       |
| C57                                                      | H003-28cs-1c | 56.0     | 291.34 | 291.34 | 1.853  | 21.57 | 0.370    | 0.389    | 92.0       |
| C61                                                      | H003-29cs-4  | 10.5     | 294.88 | 294.88 | 1.894  | 21.86 | 0.373    | 0.466    | 68.2       |
| C17                                                      | H003-29CS-3c | 57.0     | 295.55 | 295.55 | 2.073  | 25.44 | 0.409    | 0.436    | 89.4       |
| C18                                                      | H003-29CS-5a | 13.5     | 295.76 | 295.76 | 1.775  | 23.96 | 0.395    | 0.398    | 98.7       |
| C19                                                      | H002-01FB-1b | 41.0     | 645.06 | 645.06 | 1.634  | 27.42 | 0.427    | 0.418    | 103.7      |
| C62                                                      | H002-02fb-2  | 6.5      | 674.43 | 674.43 | 1.774  | 36.08 | 0.495    | 0.547    | 81.4       |
| C55                                                      | H002-02fb-4  | 15.0     | 675.28 | 675.28 | 1.996  | 25.46 | 0.409    | 0.488    | 72.7       |
| C63                                                      | H002-02fb-5  | 10.0     | 675.43 | 675.43 | 1.987  | 15.38 | 0.295    | 0.401    | 62.4       |
| C20                                                      | H002-03FB-2a | 2.0      | 677.39 | 677.39 | 1.960  | 39.01 | 0.515    | 0.543    | 89.2       |
| C21                                                      | H0020-4FB-1a | 7.0      | 680.38 | 680.38 | 1.923  | 41.60 | 0.531    | 0.518    | 105.3      |
| C22                                                      | H002-04FB-2a | 9.0      | 681.06 | 681.06 | 2.073  | 34.08 | 0.481    | 0.495    | 94.6       |
| C23                                                      | H002-04FB-2a | 32.0     | 681.29 | 681.29 | 1.524  | 21.47 | 0.369    | 0.429    | 77.8       |
| C24                                                      | H002-04FB-3a | 3.0      | 681.70 | 681.70 | 1.945  | 35.48 | 0.491    | 0.514    | 91.3       |
| C25                                                      | H002-04FB-4a | 22.0     | 682.47 | 682.47 | 1.676  | 32.73 | 0.471    | 0.474    | 98.6       |

| Density, Water Content, and Porosity of Split Core Plugs |               |          |        |        |        |       |          |          |            |
|----------------------------------------------------------|---------------|----------|--------|--------|--------|-------|----------|----------|------------|
| Jar                                                      | Location      |          | Depth  | Comp.  | Wet    | Water | Porosity |          | Saturation |
| No.                                                      | Core Section  | Location |        |        |        |       | S=100    | Measured |            |
|                                                          |               | (cm)     | (MBSF) | (MBSF) | (g/cc) | (%)   | (-)      | (-)      | (%)        |
| C26                                                      | H002-04FB-4a  | 44.5     | 682.70 | 682.70 | 1.972  | 23.24 | 0.387    | 0.470    | 71.3       |
| C27                                                      | H002-05CS-3c  | 46.5     | 802.47 | 802.47 | 2.070  | 24.44 | 0.399    | 0.412    | 94.9       |
| C58                                                      | H002-05cs-4   | 14.5     | 802.67 | 802.67 | 1.838  | 19.24 | 0.344    | 0.400    | 78.3       |
| C53                                                      | H002-06cs-2a  | 7.0      | 803.62 | 803.62 | 2.033  | 28.31 | 0.435    | 0.427    | 103.3      |
| C54                                                      | H002-06cs-2c  | 27.0     | 803.82 | 803.82 | 1.724  | 26.52 | 0.419    | 0.438    | 92.5       |
| C28                                                      | H002-06CS-5a  | 3.5      | 805.64 | 805.64 | 1.918  | 24.42 | 0.399    | 0.393    | 102.8      |
| C59                                                      | H002-06cs-6   | 8.5      | 806.04 | 806.04 | 1.884  | 17.46 | 0.322    | 0.382    | 76.9       |
| C64                                                      | H002-08cs-2   | 9.0      | 810.64 | 810.64 | 1.941  | 23.61 | 0.391    | 0.513    | 60.9       |
| C29                                                      | H002-08CS-3a1 | 20.0     | 810.95 | 810.95 | 1.965  | 24.23 | 0.397    | 0.419    | 91.4       |
| C30                                                      | H002-08CS-3a1 | 29.0     | 811.04 | 811.04 | 2.051  | 28.61 | 0.438    | 0.426    | 105.0      |
| C31                                                      | H002-09CS-1a  | 8.0      | 812.68 | 812.67 | 2.043  | 29.91 | 0.449    | 0.447    | 100.6      |
| C32                                                      | H002-09CS-1a  | 60.0     | 813.20 | 813.13 | 2.027  | 32.03 | 0.466    | 0.459    | 102.7      |
| C33                                                      | H002-09CS-2a  | 7.5      | 813.67 | 813.55 | 1.955  | 26.35 | 0.417    | 0.439    | 91.5       |
| C34                                                      | H002-09CS-3a1 | 13.5     | 814.31 | 814.12 | 2.057  | 20.39 | 0.357    | 0.487    | 58.3       |
| C35                                                      | H002-09CS-4b  | 15.0     | 815.26 | 814.97 | 2.057  | 23.25 | 0.387    | 0.381    | 102.6      |
| C36                                                      | H002-09CS-4b  | 66.5     | 815.77 | 815.43 | 2.005  | 21.89 | 0.373    | 0.411    | 85.2       |
| C65                                                      | H002-10cs-2   | 15.5     | 816.84 | 816.71 | 1.905  | 20.77 | 0.361    | 0.388    | 89.1       |
| C66                                                      | H002-11cs-1   | 8.0      | 818.77 | 818.76 | 1.858  | 24.12 | 0.396    | 0.447    | 81.1       |
| C37                                                      | H002-12CS-1a  | 6.0      | 821.80 | 821.79 | 1.930  | 23.96 | 0.395    | 0.383    | 104.8      |
| C38                                                      | H002-12CS-1a  | 61.0     | 822.35 | 822.28 | 2.052  | 22.16 | 0.376    | 0.426    | 81.3       |
| C39                                                      | H002-12CS-2a  | 7.5      | 823.13 | 822.96 | 2.015  | 23.57 | 0.391    | 0.394    | 98.6       |
| C40                                                      | H002-12CS-3a1 | 16.5     | 824.35 | 824.03 | 1.950  | 22.78 | 0.383    | 0.383    | 99.9       |
| C41                                                      | H002-12CS-3a1 | 54.5     | 824.73 | 824.36 | 1.949  | 22.13 | 0.376    | 0.414    | 85.4       |
| C42                                                      | H002-13CS-1a3 | 31.0     | 825.10 | 825.06 | 1.768  | 24.86 | 0.403    | 0.434    | 88.1       |
| C43                                                      | H002-13CS-1c  | 73.5     | 825.52 | 825.44 | 1.920  | 25.26 | 0.407    | 0.413    | 97.7       |
| C44                                                      | H002-13CS-2a  | 15.0     | 826.73 | 826.51 | 2.027  | 21.94 | 0.374    | 0.397    | 90.6       |
| C45                                                      | H002-13CS-2a  | 65.0     | 827.23 | 826.95 | 2.013  | 22.68 | 0.382    | 0.467    | 70.3       |
| C46                                                      | H002-13CS-3a  | 14.5     | 827.78 | 827.44 | 1.675  | 21.46 | 0.369    | 0.404    | 86.1       |
| C47                                                      | H002-14CS-1c  | 50.0     | 845.10 | 845.04 | 1.745  | 22.23 | 0.377    | 0.411    | 86.7       |
| C48                                                      | H002-14CS-2a  | 33.0     | 845.77 | 845.64 | 1.875  | 23.85 | 0.393    | 0.388    | 102.2      |
| C49                                                      | H002-14CS-3a3 | 34.0     | 847.08 | 846.80 | 1.997  | 21.94 | 0.374    | 0.397    | 90.6       |
| C50                                                      | H002-14CS-3a3 | 86.5     | 847.61 | 847.26 | 2.007  | 22.76 | 0.382    | 0.428    | 82.6       |
| C51                                                      | H002-15CS-1a  | 14.5     | 858.46 | 858.45 | 1.863  | 28.30 | 0.435    | 0.467    | 87.9       |
| C52                                                      | H002-15CS-2a1 | 6.5      | 859.15 | 859.06 | 1.904  | 21.12 | 0.365    | 0.418    | 80.1       |

Table 7-2 Density, Water Content and Porosity of MAD Sections

| Density, Water Content, and Porosity of MAD Sections |       |         |              |       |            |       |             |         |               |       |         |              |       |             |       |            |       |
|------------------------------------------------------|-------|---------|--------------|-------|------------|-------|-------------|---------|---------------|-------|---------|--------------|-------|-------------|-------|------------|-------|
| Location                                             |       |         | Depth (MBSF) |       |            |       | Wet Density |         | Water Content |       |         | Porosity     |       |             |       | Saturation |       |
| Core Section                                         | Plug  | MAD Mid |              |       | Compressed |       | MAD         | Plug    | Wedge         | Plug  | Blended | Plug (S=100) | Plug  | MAD (S=100) | MAD   | Plug       | MAD   |
|                                                      | (cm)  | (cm)    | Plug         | MAD   | Plug       | MAD   | (g/cm3)     | (g/cm3) | (%)           | (%)   | (%)     | (-)          | (-)   | (-)         | (-)   | (%)        | (%)   |
| H003-01H-4b                                          | 107.5 | 107.5   | 5.58         | 5.58  | 5.58       | 5.58  | 1.553       | 1.496   | 74.10         | 85.17 | 78.07   | 0.698        | 0.702 | 0.680       | 0.671 | 98.1       | 98.6  |
| H003-01H-5b                                          | 88.0  | 88.5    | 6.88         | 6.89  | 6.88       | 6.89  | 1.726       | 1.767   | 53.91         | 61.25 | 56.42   | 0.625        | 0.596 | 0.605       | 0.587 | 112.7      | 103.2 |
| H003-02H-1b                                          | 112.5 | 112.5   | 9.35         | 9.35  | 9.18       | 9.18  | 1.617       | 1.538   | 66.54         | 76.41 | 66.15   | 0.675        | 0.679 | 0.643       | 0.642 | 98.3       | 100.7 |
| H003-02H-2b                                          | 107.2 | 107.5   | 10.80        | 10.80 | 10.41      | 10.42 | 1.697       | 1.721   | 55.09         | 52.63 | 55.05   | 0.589        | 0.585 | 0.600       | 0.597 | 101.7      | 101.2 |
| H003-02H-3b                                          | 112.5 | 112.5   | 12.35        | 12.35 | 11.73      | 11.73 | 1.570       | 1.687   | 54.15         | 53.47 | 55.71   | 0.593        | 0.595 | 0.602       | 0.625 | 98.9       | 88.5  |
| H003-02H-4b                                          | 107.0 | 107.5   | 13.80        | 13.80 | 12.96      | 12.96 | 1.436       | 1.372   | 83.31         | 82.65 | 84.36   | 0.692        | 0.723 | 0.696       | 0.712 | 86.0       | 91.9  |
| H003-02H-5b                                          | 112.5 | 112.5   | 15.35        | 15.35 | 14.28      | 14.28 | 1.525       | 1.572   | 70.48         | 70.97 | 71.29   | 0.659        | 0.661 | 0.660       | 0.671 | 98.9       | 94.2  |
| H003-02H-6b                                          | 107.5 | 107.5   | 16.80        | 16.80 | 15.51      | 15.51 | 1.522       | 1.621   | 65.71         | 63.30 | 65.59   | 0.633        | 0.634 | 0.641       | 0.662 | 99.2       | 91.4  |
| H003-03H-3b                                          | 76.0  | 78.5    | 19.35        | 19.38 | 19.23      | 19.25 | 1.519       | 2.149   | 59.94         | 63.44 | 60.76   | 0.633        | 0.516 | 0.623       | 0.650 | 162.0      | 87.7  |
| H003-03H-2b                                          | 97.0  | 97.5    | 21.01        | 21.02 | 20.61      | 20.62 | 1.647       | 1.671   | 53.18         | 57.38 | 56.77   | 0.609        | 0.609 | 0.607       | 0.604 | 100.3      | 94.8  |
| H003-03H-3b                                          | 97.5  | 102.5   | 22.52        | 22.57 | 21.87      | 21.91 | 1.471       | 1.554   | 71.78         | 71.81 | 70.81   | 0.661        | 0.667 | 0.658       | 0.685 | 97.6       | 89.9  |
| H003-03H-4b                                          | 97.5  | 97.5    | 24.02        | 24.02 | 23.12      | 23.12 | 1.415       | 1.537   | 66.13         | 67.50 | 64.96   | 0.647        | 0.662 | 0.639       | 0.686 | 93.8       | 82.2  |
| H003-03H-5b                                          | 97.5  | 97.5    | 25.67        | 25.67 | 24.50      | 24.50 | 1.468       | 1.945   | 59.51         | 58.69 | 59.49   | 0.615        | 0.549 | 0.618       | 0.661 | 131.3      | 83.0  |
| H003-03H-6b                                          | 97.0  | 97.5    | 27.16        | 27.17 | 25.75      | 25.75 | 1.483       | 1.842   | 58.33         | 56.90 | 57.15   | 0.607        | 0.568 | 0.609       | 0.655 | 117.9      | 83.5  |
| H003-06H-2b                                          | 102.5 | 102.5   | 34.83        | 34.83 | 34.01      | 34.01 | 1.599       | 1.676   | 36.31         | 43.45 | 38.01   | 0.542        | 0.570 | 0.508       | 0.568 | 89.3       | 75.1  |
| H003-06H-3b                                          | 88.0  | 87.5    | 36.19        | 36.18 | 34.92      | 34.92 | 1.530       | 1.677   | 47.18         | 49.54 | 47.81   | 0.574        | 0.587 | 0.565       | 0.617 | 94.8       | 79.6  |
| H003-06H-6b                                          | 97.0  | 97.5    | 40.78        | 40.78 | 38.01      | 38.01 | 1.639       | 1.774   | 44.60         | 46.08 | 44.07   | 0.556        | 0.553 | 0.545       | 0.582 | 101.4      | 87.0  |
| H003-07H-3b1                                         | 51.0  | 50.5    | 42.83        | 42.82 | 42.35      | 42.35 | 1.690       | 1.649   | 45.24         | 42.96 | 44.25   | 0.539        | 0.575 | 0.546       | 0.571 | 86.3       | 92.3  |
| H003-07H-5b1                                         | 48.5  | 53.5    | 45.80        | 45.85 | 44.92      | 44.97 | 1.763       | 1.819   | 38.31         | 34.79 | 35.96   | 0.486        | 0.503 | 0.494       | 0.530 | 93.5       | 92.3  |
| H003-08CS-3c                                         | 65.0  | 65.5    | 48.58        | 48.59 | 48.58      | 48.59 | 1.633       | 1.756   | 52.08         | 53.78 | 54.49   | 0.594        | 0.579 | 0.597       | 0.604 | 106.2      | 92.7  |

| Density, Water Content, and Porosity of MAD Sections |       |         |              |        |            |        |             |         |               |       |         |              |       |             |       |            |       |
|------------------------------------------------------|-------|---------|--------------|--------|------------|--------|-------------|---------|---------------|-------|---------|--------------|-------|-------------|-------|------------|-------|
| Location                                             |       |         | Depth (MBSF) |        |            |        | Wet Density |         | Water Content |       |         | Porosity     |       |             |       | Saturation |       |
| Core Section                                         | Plug  | MAD Mid |              |        | Compressed |        | MAD         | Plug    | Wedge         | Plug  | Blended | Plug (S=100) | Plug  | MAD (S=100) | MAD   | Plug       | MAD   |
|                                                      | (cm)  | (cm)    | Plug         | MAD    | Plug       | MAD    | (g/cm3)     | (g/cm3) | (%)           | (%)   | (%)     | (-)          | (-)   | (-)         | (-)   | (%)        | (%)   |
| H003-09H-2b1                                         | 43.5  | 43.5    | 51.62        | 51.62  | 51.20      | 51.20  | 1.740       | 1.791   | 40.66         | 40.26 | 40.88   | 0.523        | 0.530 | 0.526       | 0.544 | 97.2       | 92.6  |
| H003-09H-5b                                          | 57.0  | 57.5    | 55.91        | 55.92  | 54.58      | 54.58  | 1.667       | 1.842   | 35.46         | 35.77 | 39.14   | 0.493        | 0.500 | 0.516       | 0.547 | 97.1       | 80.0  |
| H003-10H-3b1                                         | 32.0  | 32.5    | 60.01        | 60.02  | 59.50      | 59.50  | 1.697       | 1.757   | 39.93         | 41.83 | 39.62   | 0.532        | 0.544 | 0.519       | 0.553 | 95.5       | 87.7  |
| H003-10H-5b1                                         | 59.0  | 60.5    | 62.74        | 62.76  | 61.81      | 61.82  | 1.707       | 1.688   | 42.57         | 42.55 | 42.94   | 0.536        | 0.564 | 0.539       | 0.559 | 89.5       | 91.3  |
| H003-11H-1b                                          | 130.5 | 130.5   | 65.01        | 65.01  | 64.69      | 64.69  | 1.642       | 1.687   | 49.68         | 53.13 | 49.36   | 0.591        | 0.594 | 0.573       | 0.596 | 98.7       | 91.6  |
| H003-11H-4b                                          | 97.0  | 96.5    | 69.48        | 69.48  | 68.09      | 68.09  | 1.597       | 1.649   | 55.03         | 58.04 | 56.02   | 0.612        | 0.616 | 0.604       | 0.621 | 98.6       | 91.5  |
| H003-12H-2b                                          | 97.0  | 97.5    | 73.18        | 73.19  | 72.59      | 72.59  | 1.451       | 1.659   | 49.72         | 55.12 | 54.19   | 0.600        | 0.606 | 0.596       | 0.643 | 97.4       | 75.1  |
| H003-12H-5b                                          | 129.5 | 129.5   | 78.01        | 78.01  | 76.26      | 76.26  | 1.811       | 1.905   | 35.96         | 26.74 | 37.20   | 0.421        | 0.446 | 0.503       | 0.509 | 90.2       | 94.2  |
| H003-14H-2b                                          | 83.0  | 83.5    | 83.15        | 83.16  | 82.70      | 82.70  | 1.766       | 1.842   | 37.88         | 39.63 | 39.10   | 0.519        | 0.514 | 0.515       | 0.528 | 101.8      | 92.0  |
| H003-14H-6b1                                         | 59.5  | 59.5    | 88.24        | 88.24  | 86.81      | 86.81  | 1.733       | 1.872   | 36.60         | 34.64 | 36.11   | 0.485        | 0.488 | 0.496       | 0.533 | 98.9       | 87.3  |
| H003-16H-1b                                          | 92.5  | 92.5    | 92.37        | 92.37  | 92.16      | 92.16  | 1.610       | 1.880   | 37.99         | 39.26 | 39.20   | 0.516        | 0.503 | 0.516       | 0.570 | 105.6      | 77.9  |
| H003-16H-4b                                          | 134.5 | 133.5   | 97.55        | 97.54  | 96.21      | 96.20  | 1.819       | 1.908   | 33.99         | 31.37 | 33.85   | 0.460        | 0.465 | 0.479       | 0.500 | 98.1       | 92.5  |
| H003-17H-2b1                                         | 88.0  | 87.5    | 99.41        | 99.41  | 99.01      | 99.00  | 1.732       | 1.869   | 36.83         | 38.38 | 36.38   | 0.511        | 0.503 | 0.497       | 0.534 | 103.3      | 87.5  |
| H003-17H-4b                                          | 155.5 | 154.0   | 103.25       | 103.23 | 101.85     | 101.84 | 1.756       | 1.829   | 36.92         | 37.49 | 37.02   | 0.505        | 0.510 | 0.502       | 0.528 | 97.9       | 89.9  |
| H003-18H-2b1                                         | 77.5  | 77.5    | 107.09       | 107.09 | 106.23     | 106.23 | 1.613       | 1.658   | 52.86         | 54.86 | 52.70   | 0.599        | 0.606 | 0.589       | 0.611 | 97.1       | 91.4  |
| H003-18H-5b                                          | 102.0 | 103.0   | 111.59       | 111.60 | 109.39     | 109.39 | 1.785       | 1.372   | 36.25         | 36.54 | 36.40   | 0.498        | 0.630 | 0.497       | 0.517 | 58.4       | 91.9  |
| H003-19CS-5c                                         | 52.0  | 52.5    | 113.87       | 113.87 | 113.52     | 113.52 | 1.528       | 1.714   | 55.98         | 55.23 | 55.18   | 0.600        | 0.593 | 0.600       | 0.639 | 102.9      | 86.0  |
| H003-20H-2b1                                         | 129.0 | 129.5   | 116.39       | 116.39 | 116.01     | 116.02 | 1.719       | 1.817   | 37.33         | 37.74 | 36.44   | 0.507        | 0.514 | 0.498       | 0.539 | 97.0       | 86.9  |
| H003-20H-5b                                          | 97.0  | 97.5    | 120.35       | 120.35 | 119.35     | 119.36 | 1.975       | 1.851   | 34.00         | 34.07 | 34.21   | 0.481        | 0.491 | 0.482       | 0.457 | 95.9       | 109.8 |
| H003-21H-3b                                          | 92.0  | 91.0    | 125.54       | 125.53 | 125.07     | 125.06 | 1.697       | 1.875   | 34.24         | 35.69 | 33.43   | 0.493        | 0.491 | 0.476       | 0.534 | 100.6      | 81.2  |
| H003-21H-6b                                          | 86.0  | 81.5    | 129.18       | 129.13 | 128.28     | 128.24 | 1.772       | 1.829   | 29.02         | 30.89 | 27.46   | 0.457        | 0.485 | 0.428       | 0.494 | 89.1       | 80.8  |

| Density, Water Content, and Porosity of MAD Sections |       |         |              |        |            |        |             |         |               |       |         |              |       |             |       |            |      |
|------------------------------------------------------|-------|---------|--------------|--------|------------|--------|-------------|---------|---------------|-------|---------|--------------|-------|-------------|-------|------------|------|
| Location                                             |       |         | Depth (MBSF) |        |            |        | Wet Density |         | Water Content |       |         | Porosity     |       |             |       | Saturation |      |
| Core Section                                         | Plug  | MAD Mid |              |        | Compressed |        | MAD         | Plug    | Wedge         | Plug  | Blended | Plug (S=100) | Plug  | MAD (S=100) | MAD   | Plug       | MAD  |
|                                                      | (cm)  | (cm)    | Plug         | MAD    | Plug       | MAD    | (g/cm3)     | (g/cm3) | (%)           | (%)   | (%)     | (-)          | (-)   | (-)         | (-)   | (%)        | (%)  |
| H003-22H-2b                                          | 97.0  | 97.5    | 131.71       | 131.71 | 131.71     | 131.71 | 1.764       | 1.951   | 34.25         | 38.08 | 34.30   | 0.509        | 0.480 | 0.483       | 0.516 | 112.4      | 87.4 |
| H003-22H-4b                                          | 97.0  | 97.5    | 134.69       | 134.69 | 134.69     | 134.69 | 1.734       | 1.890   | 33.26         | 34.17 | 33.54   | 0.482        | 0.481 | 0.477       | 0.521 | 100.2      | 83.2 |
| H003-23H-2b                                          | 106.0 | 107.0   | 139.58       | 139.59 | 139.20     | 139.21 | 1.759       | 1.876   | 32.07         | 31.59 | 31.78   | 0.462        | 0.475 | 0.464       | 0.509 | 95.0       | 84.0 |
| H003-23H-4b                                          | 91.0  | 92.0    | 142.41       | 142.42 | 141.64     | 141.65 | 1.862       | 1.859   | 28.99         | 32.19 | 27.83   | 0.467        | 0.482 | 0.431       | 0.468 | 94.0       | 89.5 |
| H003-24CS-5c                                         | 55.0  | 55.5    | 147.43       | 147.43 | 147.07     | 147.08 | 1.663       | 1.778   | 50.19         | 50.13 | 49.58   | 0.577        | 0.564 | 0.574       | 0.592 | 105.5      | 94.1 |
| H003-25H-7b                                          | 62.0  | 67.5    | 154.04       | 154.10 | 152.27     | 152.31 | 1.701       | 1.789   | 31.82         | 32.94 | 31.45   | 0.473        | 0.504 | 0.461       | 0.525 | 88.1       | 78.4 |
| H003-26X-4b                                          | 84.5  | 83.0    | 282.84       | 282.83 | 282.84     | 282.83 | 1.778       | 1.945   | 29.96         | 29.50 | 29.27   | 0.445        | 0.447 | 0.443       | 0.496 | 99.4       | 82.8 |
| H003-26X-6b                                          | 64.0  | 65.0    | 285.47       | 285.48 | 285.47     | 285.48 | 1.874       | 1.796   | 27.50         | 26.78 | 26.59   | 0.421        | 0.478 | 0.420       | 0.459 | 79.4       | 88.2 |
| H003-27CS-4b                                         | 31.0  | 30.5    | 288.89       | 288.89 | 288.89     | 288.89 | 2.014       | 1.903   | 23.72         | 23.67 | 23.88   | 0.392        | 0.433 | 0.394       | 0.400 | 84.2       | 96.6 |

Table 7-3 Particle Size Results on Blended Material Using Hydrometer Method

| Particle Size Results on Blended Material Using Hydrometer |       |      |          |        |             |        |            |        |
|------------------------------------------------------------|-------|------|----------|--------|-------------|--------|------------|--------|
| Entry                                                      | TEST  | Hole | Core-Sec | Depth  | Comp. Depth | % Clay | % Silt     | % Sand |
| No.                                                        | No.   |      |          | (MBSF) | (MBSF)      | <2 um  | 2 to 75 um | >75 um |
| 1                                                          | HY195 | H003 | 1H-4B    | 5.58   | 4.56        | 61.60  | 26.05      | 12.35  |
| 2                                                          | HY217 | H003 | 1H-5B    | 6.89   | 6.07        | 46.14  | 44.36      | 9.49   |
| 3                                                          | HY185 | H003 | 2H-1B    | 9.35   | 8.31        | 56.40  | 42.59      | 1.02   |
| 4                                                          | HY175 | H003 | 2H-2B    | 10.80  | 9.6         | 54.64  | 42.16      | 3.20   |
| 5                                                          | HY206 | H003 | 2H-3B    | 12.35  | 10.88       | 56.14  | 40.37      | 3.49   |
| 6                                                          | HY213 | H003 | 2H-4B    | 13.80  | 12.17       | 71.99  | 25.20      | 2.80   |
| 7                                                          | HY186 | H003 | 2H-5B    | 15.35  | 13.45       | 67.78  | 30.62      | 1.61   |
| 8                                                          | HY176 | H003 | 2H-6B    | 16.80  | 14.74       | 62.36  | 35.41      | 2.23   |
| 9                                                          | HY205 | H003 | 3H-1B    | 19.38  | 18.75       | 45.24  | 36.05      | 18.71  |
| 10                                                         | HY211 | H003 | 3H-2B    | 21.02  | 19.98       | 53.95  | 40.31      | 5.73   |
| 11                                                         | HY177 | H003 | 3H-3B    | 22.57  | 21.24       | 60.74  | 25.86      | 13.40  |
| 12                                                         | HY180 | H003 | 3H-4B    | 24.02  | 22.51       | 63.18  | 35.51      | 1.31   |
| 13                                                         | HY204 | H003 | 3H-5B    | 25.67  | 23.9        | 58.87  | 39.94      | 1.19   |
| 14                                                         | HY216 | H003 | 3H-6B    | 27.17  | 25.17       | 53.78  | 46.02      | 0.20   |
| 15                                                         | HY187 | H003 | 6H-2B    | 34.83  | 33.55       | 40.25  | 58.20      | 1.55   |
| 16                                                         | HY179 | H003 | 6H-3B    | 36.18  | 34.57       | 55.61  | 42.16      | 2.23   |
| 17                                                         | HY207 | H003 | 6H-6B    | 40.78  | 37.63       | 55.65  | 44.20      | 0.15   |
| 18                                                         | HY218 | H003 | 7H-3B1   | 42.82  | 42.28       | 58.25  | 40.87      | 0.88   |
| 19                                                         | HY174 | H003 | 7H-5B1   | 45.75  | 44.9        | 50.68  | 49.00      | 0.32   |
| 20                                                         | HY222 | H003 | 8CS-3C   | 48.59  | 48.42       | 55.82  | 44.04      | 0.14   |
| 21                                                         | HY198 | H003 | 9H-2B1   | 51.62  | 51.27       | 55.34  | 44.61      | 0.06   |
| 22                                                         | HY214 | H003 | 9H-5B    | 55.92  | 54.57       | 51.80  | 48.13      | 0.07   |
| 23                                                         | HY199 | H003 | 10H-3B1  | 60.02  | 59.73       | 59.32  | 40.56      | 0.12   |
| 24                                                         | HY191 | H003 | 10H-5B1  | 62.76  | 61.84       | 63.35  | 36.65      | 0.00   |
| 25                                                         | HY184 | H003 | 11H-1B   | 65.01  | 64.2        | 68.90  | 30.11      | 0.99   |
| 26                                                         | HY208 | H003 | 11H-4B   | 69.48  | 67.88       | 63.74  | 30.30      | 5.96   |
| 27                                                         | HY203 | H003 | 12H-2B   | 73.19  | 72.41       | 62.54  | 24.37      | 13.09  |
| 28                                                         | HY182 | H003 | 12H-5B   | 78.01  | 75.87       | 36.24  | 36.48      | 27.28  |
| 29                                                         | HY212 | H003 | 14H-2B   | 83.16  | 82.7        | 56.33  | 43.15      | 0.52   |
| 30                                                         | HY201 | H003 | 14H-6B1  | 88.24  | 86.83       | 57.36  | 42.55      | 0.09   |
| 31                                                         | HY190 | H003 | 16H-1B   | 92.37  | 92.16       | 58.20  | 41.62      | 0.17   |
| 32                                                         | HY193 | H003 | 16H-4B   | 97.54  | 95.92       | 55.03  | 44.92      | 0.06   |
| 33                                                         | HY196 | H003 | 17H-2B1  | 99.41  | 99.09       | 66.18  | 32.86      | 0.97   |
| 34                                                         | HY224 | H003 | 17H-4B   | 103.10 | 101.46      | 72.10  | 27.54      | 0.36   |
| 35                                                         | HY188 | H003 | 18H-2B1  | 107.09 | 106.44      | 62.52  | 29.14      | 8.34   |

| Particle Size Results on Blended Material Using Hydrometer |       |      |          |        |             |        |            |        |
|------------------------------------------------------------|-------|------|----------|--------|-------------|--------|------------|--------|
| Entry                                                      | TEST  | Hole | Core-Sec | Depth  | Comp. Depth | % Clay | % Silt     | % Sand |
| No.                                                        | No.   |      |          | (MBSF) | (MBSF)      | <2 um  | 2 to 75 um | >75 um |
| 35                                                         | HY188 | H003 | 18H-2B1  | 107.09 | 106.44      | 62.52  | 29.14      | 8.34   |
| 36                                                         | HY215 | H003 | 18H-5B   | 111.60 | 109.45      | 59.87  | 39.76      | 0.38   |
| 37                                                         | HY221 | H003 | 19CS-5C  | 113.87 | 114.06      | 73.23  | 23.68      | 3.10   |
| 38                                                         | HY202 | H003 | 20H-2B1  | 116.39 | 115.91      | 65.58  | 34.04      | 0.39   |
| 39                                                         | HY210 | H003 | 20H-5B   | 120.35 | 119.55      | 63.12  | 36.45      | 0.44   |
| 40                                                         | HY189 | H003 | 21H-3B   | 125.53 | 125.37      | 61.09  | 38.82      | 0.09   |
| 41                                                         | HY181 | H003 | 21H-6B   | 129.13 | 128.66      | 46.15  | 49.14      | 4.71   |
| 42                                                         | HY209 | H003 | 22H-2B   | 131.71 | 132.05      | 56.96  | 42.89      | 0.15   |
| 43                                                         | HY197 | H003 | 22H-4B   | 134.69 | 135.06      | 57.46  | 42.46      | 0.09   |
| 44                                                         | HY200 | H003 | 23H-2B   | 139.59 | 139.49      | 54.71  | 45.27      | 0.03   |
| 45                                                         | HY183 | H003 | 23H-4B   | 142.42 | 142.08      | 51.09  | 48.67      | 0.23   |
| 46                                                         | HY220 | H003 | 24CS-5C  | 147.43 | 147.41      | 68.99  | 24.49      | 6.52   |
| 47                                                         | HY178 | H003 | 25H-7B   | 154.10 | 152.94      | 57.29  | 41.97      | 0.74   |
| 48                                                         | HY194 | H003 | 26X-4B   | 282.83 | 284.83      | 56.39  | 43.61      | 0.00   |
| 49                                                         | HY219 | H003 | 26X-6B   | 285.48 | 287.682     | 62.56  | 37.26      | 0.17   |
| 50                                                         | HY223 | H003 | 27CS-4B  | 288.89 | 291.47      | 56.37  | 43.51      | 0.12   |

Table 7-4 Grain Density by Water Submersion on Blended Material

| Grain Density by Water Submersion on Blended Material |         |              |                          |     |       |             |                                       |         |         |
|-------------------------------------------------------|---------|--------------|--------------------------|-----|-------|-------------|---------------------------------------|---------|---------|
| Entry                                                 | Test    |              | Section Location<br>(cm) |     |       | Comp. Depth | Grain Density<br>(g/cm <sup>3</sup> ) |         | Source  |
| No.                                                   | No.     | Core Section | Top                      | Bot | Mid   | (MBSF)      | Average                               | Std Dev |         |
| 1                                                     | SG206   | H003-01H-4b  | 100                      | 115 | 107.5 | 4.56        | 2.773                                 | 0.002   | Blended |
| 2                                                     | SG213-2 | H003-01H-5b  | 81                       | 101 | 91.0  | 6.07        | 2.768                                 | 0.003   | Blended |
| 3                                                     | SG230   | H003-02H-1b  | 100                      | 120 | 110.0 | 8.31        | 2.776                                 | 0.005   | Blended |
| 4                                                     | SG231   | H003-02H-2b  | 100                      | 120 | 110.0 | 9.60        | 2.857                                 | 0.010   | Blended |
| 5                                                     | SG202   | H003-02H-3b  | 105                      | 120 | 112.5 | 10.88       | 2.829                                 | 0.004   | Blended |
| 6                                                     | SG211   | H003-02H-4b  | 100                      | 120 | 110.0 | 12.17       | 2.833                                 | 0.006   | Blended |
| 7                                                     | SG219   | H003-02H-5b  | 100                      | 120 | 110.0 | 13.45       | 2.794                                 | 0.006   | Blended |
| 8                                                     | SG232   | H003-02H-6b  | 100                      | 120 | 110.0 | 14.74       | 2.805                                 | 0.002   | Blended |
| 9                                                     | SG200   | H003-03H-1b  | 71                       | 86  | 78.5  | 18.75       | 2.821                                 | 0.004   | Blended |
| 10                                                    | SG209   | H003-03H-2b  | 90                       | 110 | 100.0 | 19.98       | 2.808                                 | 0.003   | Blended |
| 11                                                    | SG228   | H003-03H-3b  | 90                       | 110 | 100.0 | 21.24       | 2.809                                 | 0.001   | Blended |
| 12                                                    | SG234   | H003-03H-4b  | 90                       | 110 | 100.0 | 22.51       | 2.783                                 | 0.006   | Blended |
| 13                                                    | SG191   | H003-03H-5b  | 90                       | 105 | 97.5  | 23.90       | 2.800                                 | 0.005   | Blended |
| 14                                                    | SG214-1 | H003-03H-6b  | 90                       | 110 | 100.0 | 25.17       | 2.798                                 | 0.004   | Blended |
| 15                                                    | SG220   | H003-06H-2b  | 90                       | 110 | 100.0 | 33.55       | 2.774                                 | 0.007   | Blended |
| 16                                                    | SG233   | H003-06H-3b  | 80                       | 100 | 90.0  | 34.57       | 2.783                                 | 0.008   | Blended |
| 17                                                    | SG201   | H003-06H-6b  | 90                       | 105 | 97.5  | 37.63       | 2.794                                 | 0.004   | Blended |
| 18                                                    | SG214-2 | H003-07H-3b1 | 38                       | 58  | 48.0  | 42.28       | 2.793                                 | 0.005   | Blended |
| 19                                                    | SG229   | H003-07H-5b1 | 41                       | 61  | 51.0  | 44.90       | 2.808                                 | 0.005   | Blended |
| 20                                                    | SG218   | H003-8CS-3c  | 58                       | 78  | 68.0  | 48.42       | 2.764                                 | 0.004   | Blended |
| 21                                                    | SG203   | H003-09H-2b1 | 36                       | 51  | 43.5  | 51.27       | 2.791                                 | 0.005   | Blended |
| 22                                                    | SG212   | H003-09H-5b  | 50                       | 70  | 60.0  | 54.57       | 2.775                                 | 0.005   | Blended |
| 23                                                    | SG196   | H003-10H-3b1 | 25                       | 40  | 32.5  | 59.73       | 2.816                                 | 0.010   | Blended |
| 24                                                    | SG224   | H003-10H-5b1 | 48                       | 68  | 58.0  | 61.84       | 2.767                                 | 0.005   | Blended |
| 25                                                    | SG227   | H003-11H-1b  | 123                      | 143 | 133.0 | 64.20       | 2.809                                 | 0.004   | Blended |
| 26                                                    | SG199   | H003-11H-4b  | 90                       | 103 | 96.5  | 67.88       | 2.821                                 | 0.002   | Blended |
| 27                                                    | SG192   | H003-12H-2b  | 90                       | 105 | 97.5  | 72.41       | 2.812                                 | 0.011   | Blended |
| 28                                                    | SG238   | H003-12H-5B  | 122                      | 142 | 132.0 | 75.87       | 2.754                                 | 0.003   | Blended |
| 29                                                    | SG194   | H003-14H-6b1 | 52                       | 67  | 59.5  | 86.83       | 2.784                                 | 0.002   | Blended |

| Grain Density by Water Submersion on Blended Material |         |              |                          |     |       |             |                                       |         |         |
|-------------------------------------------------------|---------|--------------|--------------------------|-----|-------|-------------|---------------------------------------|---------|---------|
| Entry                                                 | Test    |              | Section Location<br>(cm) |     |       | Comp. Depth | Grain Density<br>(g/cm <sup>3</sup> ) |         | Source  |
| No.                                                   | No.     | Core Section | Top                      | Bot | Mid   | (MBSF)      | Average                               | Std Dev |         |
| 30                                                    | SG210   | H003-14H-2b  | 71                       | 91  | 81.0  | 82.70       | 2.769                                 | 0.003   | Blended |
| 31                                                    | SG223   | H003-16H-1b  | 85                       | 110 | 97.5  | 92.16       | 2.832                                 | 0.009   | Blended |
| 32                                                    | SG208   | H003-16H-4b  | 127                      | 140 | 133.5 | 95.92       | 2.783                                 | 0.005   | Blended |
| 33                                                    | SG205   | H003-17H-2b1 | 81                       | 94  | 87.5  | 99.09       | 2.836                                 | 0.008   | Blended |
| 34                                                    | SG237   | H003-17H-4B  | 133                      | 154 | 143.5 | 101.46      | 2.600                                 | 0.004   | Blended |
| 35                                                    | SG221   | H003-18H-2b1 | 70                       | 90  | 80.0  | 106.44      | 2.812                                 | 0.007   | Blended |
| 36                                                    | SG213-1 | H003-18H-5b  | 90                       | 110 | 100.0 | 109.45      | 2.799                                 | 0.008   | Blended |
| 37                                                    | SG217   | H003-19CS-5c | 40                       | 60  | 50.0  | 114.06      | 2.822                                 | 0.006   | Blended |
| 38                                                    | SG193   | H003-20H-2b1 | 122                      | 137 | 129.5 | 115.91      | 2.818                                 | 0.011   | Blended |
| 39                                                    | SG197   | H003-20H-5b  | 90                       | 105 | 97.5  | 119.55      | 2.795                                 | 0.005   | Blended |
| 40                                                    | SG222   | H003-21H-3b  | 85                       | 107 | 96.0  | 125.37      | 2.808                                 | 0.009   | Blended |
| 41                                                    | SG235   | H003-21H-6b  | 74                       | 94  | 84.0  | 128.66      | 2.754                                 | 0.003   | Blended |
| 42                                                    | SG198   | H003-22H-2b  | 90                       | 105 | 97.5  | 132.05      | 2.781                                 | 0.005   | Blended |
| 43                                                    | SG204   | H003-22H-4b  | 90                       | 105 | 97.5  | 135.06      | 2.796                                 | 0.007   | Blended |
| 44                                                    | SG195   | H003-23H-2b  | 99                       | 115 | 107.0 | 139.49      | 2.778                                 | 0.004   | Blended |
| 45                                                    | SG225   | H003-23H-4b  | 79                       | 100 | 89.5  | 142.08      | 2.784                                 | 0.003   | Blended |
| 46                                                    | SG216   | H003-24CS-5c | 43                       | 63  | 53.0  | 147.89      | 2.870                                 | 0.009   | Blended |
| 47                                                    | SG226   | H003-25H-7b  | 55                       | 75  | 65.0  | 152.94      | 2.781                                 | 0.003   | Blended |
| 48                                                    | SG207   | H003-26X-4b  | 77                       | 89  | 83.0  | 284.83      | 2.783                                 | 0.003   | Blended |
| 49                                                    | SG215   | H003-26X-6b  | 57                       | 81  | 69.0  | 287.68      | 2.903                                 | 0.007   | Blended |
| 50                                                    | SG236   | H003-27CS-4B | 19                       | 37  | 28.0  | 291.47      | 2.755                                 | 0.004   | Blended |

Table 7-5 Grain Density by Gas Pycnometer on WC Plugs

| Grain Density by Gas Pycnometer on WC Plugs |       |              |                          |     |       |             |                                       |         |        |
|---------------------------------------------|-------|--------------|--------------------------|-----|-------|-------------|---------------------------------------|---------|--------|
| Entry                                       | Test  |              | Section Location<br>(cm) |     |       | Comp. Depth | Grain Density<br>(g/cm <sup>3</sup> ) |         | Source |
| No.                                         | No.   | Core Section | Top                      | Bot | Mid   | (MBSF)      | Average                               | Std Dev |        |
| 1                                           | PY306 | H003-01H-4b  | 100                      | 115 | 107.5 | 4.56        | 2.702                                 | 0.0076  | Plug   |
| 2                                           | PY307 | H003-01H-5b  | 81                       | 101 | 91    | 6.07        | 2.747                                 | 0.0185  | Plug   |
| 3                                           | PY308 | H003-02H-1b  | 100                      | 120 | 110   | 8.31        | 2.745                                 | 0.0224  | Plug   |
| 4                                           | PY309 | H003-02H-2b  | 100                      | 120 | 110   | 9.60        | 2.749                                 | 0.0155  | Plug   |
| 5                                           | PY310 | H003-02H-3b  | 105                      | 120 | 112.5 | 10.88       | 2.750                                 | 0.0158  | Plug   |
| 6                                           | PY311 | H003-02H-4b  | 100                      | 120 | 110   | 12.17       | 2.747                                 | 0.0228  | Plug   |
| 7                                           | PY312 | H003-02H-5b  | 100                      | 120 | 110   | 13.45       | 2.758                                 | 0.0205  | Plug   |
| 8                                           | PY313 | H003-02H-6b  | 100                      | 120 | 110   | 14.74       | 2.743                                 | 0.0169  | Plug   |
| 9                                           | PY314 | H003-03H-1b  | 71                       | 86  | 78.5  | 18.75       | 2.691                                 | 0.0003  | Plug   |
| 10                                          | PY315 | H003-03H-2b  | 90                       | 110 | 100   | 19.98       | 2.762                                 | 0.0232  | Plug   |
| 11                                          | PY316 | H003-03H-3b  | 90                       | 110 | 100   | 21.24       | 2.739                                 | 0.0207  | Plug   |
| 12                                          | PY317 | H003-03H-4b  | 90                       | 110 | 100   | 22.51       | 2.651                                 | 0.0003  | Plug   |
| 13                                          | PY318 | H003-03H-5b  | 90                       | 105 | 97.5  | 23.90       | 2.738                                 | 0.0199  | Plug   |
| 14                                          | PY319 | H003-03H-6b  | 90                       | 110 | 100   | 25.17       | 2.726                                 | 0.02    | Plug   |
| 15                                          | PY320 | H003-06H-2b  | 90                       | 110 | 100   | 33.55       | 2.703                                 | 0.0003  | Plug   |
| 16                                          | PY321 | H003-06H-3b  | 80                       | 100 | 90    | 34.57       | 2.754                                 | 0.0186  | Plug   |
| 17                                          | PY322 | H003-06H-6b  | 90                       | 105 | 97.5  | 37.63       | 2.700                                 | 0.0006  | Plug   |
| 18                                          | PY323 | H003-07H-3b1 | 38                       | 58  | 48    | 42.28       | 2.751                                 | 0.0166  | Plug   |
| 19                                          | PY324 | H003-07H-5b1 | 41                       | 61  | 51    | 44.90       | 2.761                                 | 0.0141  | Plug   |
| 20                                          | PY325 | H003-8CS-3c  | 58                       | 78  | 68    | 48.42       | 2.739                                 | 0.0184  | Plug   |
| 21                                          | PY326 | H003-09H-2b1 | 36                       | 51  | 43.5  | 51.27       | 2.697                                 | 0.0072  | Plug   |
| 22                                          | PY327 | H003-09H-5b  | 50                       | 70  | 60    | 54.57       | 2.725                                 | 0.0058  | Plug   |
| 23                                          | PY328 | H003-10H-3b1 | 25                       | 40  | 32.5  | 59.73       | 2.759                                 | 0.0168  | Plug   |
| 24                                          | PY329 | H003-10H-5b1 | 48                       | 68  | 58    | 61.84       | 2.704                                 | 0.0086  | Plug   |
| 25                                          | PY330 | H003-11H-1b  | 123                      | 143 | 133   | 64.20       | 2.721                                 | 0.0064  | Plug   |
| 26                                          | PY331 | H003-11H-4b  | 90                       | 103 | 96.5  | 67.88       | 2.756                                 | 0.0223  | Plug   |
| 27                                          | PY332 | H003-12H-2b  | 90                       | 105 | 97.5  | 72.41       | 2.746                                 | 0.0187  | Plug   |
| 28                                          | PY333 | H003-12H-5B  | 122                      | 142 | 132   | 75.87       | 2.687                                 | 0.0003  | Plug   |
| 29                                          | PY334 | H003-14H-2b1 | 52                       | 67  | 59.5  | 82.70       | 2.748                                 | 0.0157  | Plug   |
| 30                                          | PY335 | H003-14H-2b  | 71                       | 91  | 81    | 82.70       | 2.710                                 | 0.0004  | Plug   |

| Grain Density by Gas Pycnometer on WC Plugs |       |              |                          |     |       |             |                                       |         |        |
|---------------------------------------------|-------|--------------|--------------------------|-----|-------|-------------|---------------------------------------|---------|--------|
| Entry                                       | Test  |              | Section Location<br>(cm) |     |       | Comp. Depth | Grain Density<br>(g/cm <sup>3</sup> ) |         | Source |
| No.                                         | No.   | Core Section | Top                      | Bot | Mid   | (MBSF)      | Average                               | Std Dev |        |
| 31                                          | PY336 | H003-16H-1b  | 85                       | 110 | 97.5  | 92.16       | 2.719                                 | 0.0061  | Plug   |
| 32                                          | PY337 | H003-16H-4b  | 127                      | 140 | 133.5 | 95.92       | 2.740                                 | 0.0042  | Plug   |
| 33                                          | PY338 | H003-17H-2b1 | 81                       | 94  | 87.5  | 99.09       | 2.725                                 | 0.0077  | Plug   |
| 34                                          | PY339 | H003-17H-4B  | 133                      | 154 | 143.5 | 101.46      | 2.725                                 | 0.0079  | Plug   |
| 35                                          | PY340 | H003-18H-2b1 | 70                       | 90  | 80    | 106.44      | 2.703                                 | 0.0065  | Plug   |
| 36                                          | PY341 | H003-18H-5b  | 90                       | 110 | 100   | 109.45      | 2.761                                 | 0.0183  | Plug   |
| 37                                          | PY342 | H003-19CS-5c | 40                       | 60  | 50    | 114.06      | 2.759                                 | 0.0217  | Plug   |
| 38                                          | PY343 | H003-20H-2b1 | 122                      | 137 | 129.5 | 115.91      | 2.760                                 | 0.0176  | Plug   |
| 39                                          | PY344 | H003-20H-5b  | 90                       | 105 | 97.5  | 119.55      | 2.733                                 | 0.0149  | Plug   |
| 40                                          | PY345 | H003-21H-3b  | 85                       | 107 | 96    | 125.37      | 2.720                                 | 0.0024  | Plug   |
| 41                                          | PY346 | H003-21H-6b  | 74                       | 94  | 84    | 128.66      | 2.823                                 | 0.0205  | Plug   |
| 42                                          | PY347 | H003-22H-2b  | 90                       | 105 | 97.5  | 132.05      | 2.746                                 | 0.016   | Plug   |
| 43                                          | PY348 | H003-22H-4b  | 90                       | 105 | 97.5  | 135.06      | 2.714                                 | 0.0059  | Plug   |
| 44                                          | PY349 | H003-23H-2b  | 99                       | 115 | 107   | 139.49      | 2.746                                 | 0.0148  | Plug   |
| 45                                          | PY350 | H003-23H-4b  | 79                       | 100 | 89.5  | 142.08      | 2.749                                 | 0.0152  | Plug   |
| 46                                          | PY351 | H003-24CS-5c | 43                       | 63  | 53    | 147.89      | 2.745                                 | 0.0212  | Plug   |
| 47                                          | PY352 | H003-25H-7b  | 55                       | 75  | 65    | 152.94      | 2.730                                 | 0.0173  | Plug   |
| 48                                          | PY353 | H003-26X-4b  | 77                       | 89  | 83    | 284.83      | 2.718                                 | 0.0059  | Plug   |
| 49                                          | PY354 | H003-26X-6b  | 57                       | 81  | 69    | 287.68      | 2.746                                 | 0.0134  | Plug   |
| 50                                          | PY355 | H003-27CS-4B | 19                       | 37  | 28    | 291.47      | 2.706                                 |         | Plug   |

Table 7-6 Grain Density for SC Plugs using Gas Pycnometer

| Grain Density for SC Plugs using Gas Pycnometer |       |               |          |        |             |                      |                      |        |
|-------------------------------------------------|-------|---------------|----------|--------|-------------|----------------------|----------------------|--------|
| Entry                                           | Test  | Core Section  | Location | Depth  | Comp. Depth | Density              | Std. Dev.            | Source |
| No.                                             | No.   |               | (cm)     | (MBSF) | (MBSF)      | (g/cm <sup>3</sup> ) | (g/cm <sup>3</sup> ) |        |
| 1                                               | PY016 | H003-20H-4    | 19.0     | 118.64 | 117.91      | 2.725                | 0.006                | plug   |
| 2                                               | PY018 | H002-12CS-1a  | 61.0     | 822.35 | 822.28      | 2.727                | 0.006                | plug   |
| 3                                               | PY020 | H002-04FB-4a  | 22.0     | 682.47 | 682.47      | 2.748                | 0.009                | plug   |
| 4                                               | PY022 | H003-14H-1a   | 132.5    | 82.10  | 81.84       | 2.711                | 0.006                | plug   |
| 5                                               | PY024 | H003-14H-1a   | 33.5     | 81.11  | 81.04       | 2.709                | 0.005                | plug   |
| 6                                               | PY026 | H003-26X-1a   | 62.0     | 279.21 | 279.21      | 2.731                | 0.006                | plug   |
| 7                                               | PY028 | H002-08CS-3a1 | 29.0     | 811.04 | 811.04      | 2.722                | 0.007                | plug   |
| 8                                               | PY030 | H003-01H-2a   | 88.5     | 2.39   | 2.39        | 2.659                | 0.000                | plug   |
| 9                                               | PY031 | H003-01H-3a   | 59.5     | 3.60   | 3.60        | 2.654                | 0.000                | plug   |
| 10                                              | PY032 | H003-01H-4a   | 57.0     | 5.07   | 5.07        | 2.692                | 0.003                | plug   |
| 11                                              | PY033 | H003-01H-4a   | 44.5     | 4.95   | 4.95        | 2.683                | 0.008                | plug   |
| 12                                              | PY034 | H003-01H-5a   | 69.0     | 6.69   | 6.69        | 2.701                | 0.011                | plug   |
| 13                                              | PY035 | H003-01H-cc   | 15.5     | 7.52   | 7.52        | 2.683                | 0.012                | plug   |
| 14                                              | PY036 | H003-02H-1a   | 13.0     | 8.36   | 8.34        | 2.706                | 0.007                | plug   |
| 15                                              | PY037 | H003-02H-1a   | 65.0     | 8.88   | 8.78        | 2.702                | 0.011                | plug   |
| 16                                              | PY038 | H003-02H-2a   | 13.0     | 9.86   | 9.61        | 2.716                | 0.009                | plug   |
| 17                                              | PY039 | H003-02H-2a   | 50.5     | 10.23  | 9.93        | 2.718                | 0.007                | plug   |
| 18                                              | PY040 | H003-02H-3a   | 13.0     | 11.36  | 10.89       | 2.712                | 0.006                | plug   |
| 19                                              | PY041 | H003-02H-3a   | 63.0     | 11.86  | 11.31       | 2.694                | 0.009                | plug   |
| 20                                              | PY042 | H003-02H-4a   | 13.0     | 12.86  | 12.16       | 2.713                | 0.006                | plug   |
| 21                                              | PY043 | H003-02H-4a   | 63.0     | 13.36  | 12.58       | 2.714                | 0.004                | plug   |
| 22                                              | PY044 | H003-02H-5a   | 12.0     | 14.35  | 13.43       | 2.717                | 0.006                | plug   |
| 23                                              | PY045 | H003-02H-5a   | 63.0     | 14.86  | 13.86       | 2.712                | 0.006                | plug   |
| 24                                              | PY046 | H003-02H-6a   | 12.0     | 15.85  | 14.70       | 2.712                | 0.011                | plug   |
| 25                                              | PY047 | H003-02H-6a   | 69.5     | 16.42  | 15.19       | 2.716                | 0.008                | plug   |
| 26                                              | PY048 | H003-02H-7a   | 17.5     | 17.40  | 16.02       | 2.708                | 0.008                | plug   |
| 27                                              | PY049 | H003-02H-cc   | 13.0     | 18.02  | 16.54       | 2.721                | 0.012                | plug   |
| 28                                              | PY050 | H003-03H-2a   | 21.5     | 20.26  | 19.98       | 2.732                | 0.012                | plug   |
| 29                                              | PY051 | H003-03H-2a   | 73.0     | 20.77  | 20.41       | 2.734                | 0.011                | plug   |
| 30                                              | PY052 | H003-03H-3a2  | 60.0     | 22.14  | 21.56       | 2.697                | 0.009                | plug   |
| 31                                              | PY053 | H003-03H-4a   | 11.5     | 23.16  | 22.40       | 2.701                | 0.010                | plug   |
| 32                                              | PY054 | H003-03H-4a   | 72.0     | 23.76  | 22.91       | 2.688                | 0.010                | plug   |
| 33                                              | PY055 | H003-03H-5a   | 11.5     | 24.81  | 23.78       | 2.706                | 0.012                | plug   |
| 34                                              | PY056 | H003-03H-5a   | 78.5     | 25.48  | 24.34       | 2.701                | 0.008                | plug   |
| 35                                              | PY057 | H003-03H-6a   | 12.5     | 26.32  | 25.04       | 2.704                | 0.010                | plug   |

| Grain Density for SC Plugs using Gas Pycnometer |       |                |          |        |             |         |           |        |
|-------------------------------------------------|-------|----------------|----------|--------|-------------|---------|-----------|--------|
| Entry                                           | Test  | Core Section   | Location | Depth  | Comp. Depth | Density | Std. Dev. | Source |
| No.                                             | No.   |                | (cm)     | (MBSF) | (MBSF)      | (g/cm3) | (g/cm3)   |        |
| 36                                              | PY058 | H003-03H-6a    | 74.0     | 26.93  | 25.56       | 2.715   | 0.010     | plug   |
| 37                                              | PY059 | H003-03H-7a    | 43.0     | 28.12  | 26.55       | 2.704   | 0.011     | plug   |
| 38                                              | PY060 | H003-03H-7a    | 14.0     | 27.83  | 26.31       | 2.693   | 0.009     | plug   |
| 39                                              | PY061 | H003-03H-cc    | 43.0     | 28.87  | 27.18       | 2.703   | 0.009     | plug   |
| 40                                              | PY062 | H003-04CS-3a   | 22.5     | 29.35  | 29.21       | 2.646   | 0.000     | plug   |
| 41                                              | PY063 | H003-05CS-1    | 29.0     | 30.47  | 30.45       | 2.714   | 0.007     | plug   |
| 42                                              | PY064 | H003-05CS-2cde | 47.0     | 31.75  | 31.64       | 2.709   | 0.008     | plug   |
| 43                                              | PY065 | H003-06H-1     | 122.5    | 33.53  | 33.13       | 2.713   | 0.009     | plug   |
| 44                                              | PY066 | H003-06H-2a    | 16.0     | 33.97  | 33.43       | 2.716   | 0.010     | plug   |
| 45                                              | PY067 | H003-06H-2a    | 68.0     | 34.49  | 33.78       | 2.729   | 0.008     | plug   |
| 46                                              | PY068 | H003-06H-3a    | 14.0     | 35.45  | 34.42       | 2.727   | 0.005     | plug   |
| 47                                              | PY069 | H003-06H-3a    | 68.0     | 35.99  | 34.79       | 2.716   | 0.008     | plug   |
| 48                                              | PY070 | H003-06H-4a    | 14.0     | 36.95  | 35.43       | 2.699   | 0.008     | plug   |
| 49                                              | PY071 | H003-06H-4c    | 108.0    | 37.89  | 36.06       | 2.708   | 0.007     | plug   |
| 50                                              | PY072 | H003-06H-5a    | 14.0     | 38.45  | 36.44       | 2.721   | 0.009     | plug   |
| 51                                              | PY073 | H003-06H-5a    | 92.0     | 39.23  | 36.97       | 2.720   | 0.008     | plug   |
| 52                                              | PY074 | H003-06H-6a1   | 35.0     | 40.16  | 37.59       | 2.722   | 0.008     | plug   |
| 53                                              | PY075 | H003-06H-7     | 46.0     | 41.77  | 38.68       | 2.723   | 0.008     | plug   |
| 54                                              | PY076 | H003-06H-cc    | 36.0     | 42.48  | 39.15       | 2.716   | 0.007     | plug   |
| 55                                              | PY078 | H003-07H-1     | 23.0     | 39.55  | 39.52       | 2.717   | 0.007     | plug   |
| 56                                              | PY077 | H003-07H-1     | 106.0    | 40.38  | 40.24       | 2.717   | 0.006     | plug   |
| 57                                              | PY080 | H003-07H-2     | 53.0     | 41.35  | 41.07       | 2.709   | 0.007     | plug   |
| 58                                              | PY079 | H003-07H-2     | 135.0    | 42.17  | 41.78       | 2.722   | 0.007     | plug   |
| 59                                              | PY081 | H003-07H-3a    | 14.0     | 42.46  | 42.03       | 2.723   | 0.006     | plug   |
| 60                                              | PY082 | H003-07H-4a    | 16.0     | 43.98  | 43.35       | 2.731   | 0.009     | plug   |
| 61                                              | PY083 | H003-07H-4a    | 101.0    | 44.83  | 44.08       | 2.725   | 0.007     | plug   |
| 62                                              | PY084 | H003-07H-5a    | 9.5      | 45.41  | 44.59       | 2.719   | 0.007     | plug   |
| 63                                              | PY086 | H003-07H-6     | 19.0     | 46.79  | 45.77       | 2.719   | 0.007     | plug   |
| 64                                              | PY085 | H003-07H-6     | 43.0     | 47.03  | 45.98       | 2.693   | 0.007     | plug   |
| 65                                              | PY087 | H003-07H-cc    | 21.0     | 47.47  | 46.36       | 2.701   | 0.005     | plug   |
| 66                                              | PY090 | H003-09H-1a    | 27.0     | 49.95  | 49.89       | 2.704   | 0.007     | plug   |
| 67                                              | PY091 | H003-09H-1a    | 83.0     | 50.51  | 50.33       | 2.700   | 0.006     | plug   |
| 68                                              | PY092 | H003-09H-2a    | 15.5     | 51.34  | 50.98       | 2.710   | 0.009     | plug   |
| 69                                              | PY094 | H003-09H-3a    | 16.0     | 52.50  | 51.90       | 2.734   | 0.006     | plug   |
| 70                                              | PY093 | H003-09H-3a    | 98.0     | 53.32  | 52.54       | 2.719   | 0.007     | plug   |

| Grain Density for SC Plugs using Gas Pycnometer |       |              |          |        |             |         |           |        |
|-------------------------------------------------|-------|--------------|----------|--------|-------------|---------|-----------|--------|
| Entry                                           | Test  | Core Section | Location | Depth  | Comp. Depth | Density | Std. Dev. | Source |
| No.                                             | No.   |              | (cm)     | (MBSF) | (MBSF)      | (g/cm3) | (g/cm3)   |        |
| 71                                              | PY095 | H003-09H-4a1 | 73.0     | 54.57  | 53.53       | 2.718   | 0.006     | plug   |
| 72                                              | PY096 | H003-09H-5a  | 13.0     | 55.47  | 54.23       | 2.721   | 0.006     | plug   |
| 73                                              | PY098 | H003-09H-6a  | 26.0     | 56.71  | 55.21       | 2.747   | 0.005     | plug   |
| 74                                              | PY097 | H003-09H-6a  | 84.0     | 57.29  | 55.66       | 2.726   | 0.005     | plug   |
| 75                                              | PY099 | H003-09H-cc  | 26.0     | 58.12  | 56.32       | 2.748   | 0.006     | plug   |
| 76                                              | PY100 | H003-10H-1a1 | 17.0     | 56.86  | 56.84       | 2.731   | 0.004     | plug   |
| 77                                              | PY101 | H003-10H-1a1 | 96.0     | 57.65  | 57.50       | 2.749   | 0.004     | plug   |
| 78                                              | PY102 | H003-10H-2   | 17.0     | 58.36  | 58.10       | 2.746   | 0.006     | plug   |
| 79                                              | PY103 | H003-10H-2   | 118.0    | 59.37  | 58.96       | 2.716   | 0.005     | plug   |
| 80                                              | PY104 | H003-10H-3a  | 14.0     | 59.83  | 59.35       | 2.736   | 0.005     | plug   |
| 81                                              | PY106 | H003-10H-4   | 11.0     | 60.78  | 60.15       | 2.744   | 0.006     | plug   |
| 82                                              | PY105 | H003-10H-4   | 100.0    | 61.67  | 60.90       | 2.727   | 0.008     | plug   |
| 83                                              | PY107 | H003-10H-5a  | 11.0     | 62.26  | 61.40       | 2.706   | 0.009     | plug   |
| 84                                              | PY108 | H003-10H-6   | 12.0     | 63.64  | 62.57       | 2.709   | 0.008     | plug   |
| 85                                              | PY109 | H003-10H-cc  | 36.0     | 64.72  | 63.48       | 2.741   | 0.010     | plug   |
| 86                                              | PY110 | H003-11H-1a1 | 25.0     | 63.95  | 63.89       | 2.726   | 0.006     | plug   |
| 87                                              | PY111 | H003-11H-1a1 | 85.0     | 64.55  | 64.35       | 2.728   | 0.007     | plug   |
| 88                                              | PY112 | H003-11H-2a  | 15.0     | 66.33  | 65.70       | 2.698   | 0.009     | plug   |
| 89                                              | PY113 | H003-11H-2a  | 84.5     | 67.03  | 66.23       | 2.715   | 0.108     | plug   |
| 90                                              | PY114 | H003-11H-3a  | 16.0     | 67.84  | 66.85       | 2.723   | 0.010     | plug   |
| 91                                              | PY115 | H003-11H-3a  | 63.0     | 68.31  | 67.20       | 2.731   | 0.013     | plug   |
| 92                                              | PY116 | H003-11H-4a  | 16.0     | 68.67  | 67.48       | 2.723   | 0.013     | plug   |
| 93                                              | PY117 | H003-11H-4a  | 70.0     | 69.21  | 67.89       | 2.732   | 0.013     | plug   |
| 94                                              | PY118 | H003-11H-5a  | 15.5     | 70.22  | 68.65       | 2.739   | 0.011     | plug   |
| 95                                              | PY119 | H003-11H-5a  | 70.0     | 70.76  | 69.06       | 2.724   | 0.012     | plug   |
| 96                                              | PY120 | H003-11H-6a  | 30.0     | 71.81  | 69.86       | 2.717   | 0.009     | plug   |
| 97                                              | PY121 | H003-11H-cca | 30.0     | 72.54  | 70.41       | 2.727   | 0.009     | plug   |
| 98                                              | PY122 | H003-12H-1   | 139.5    | 72.11  | 71.77       | 2.731   | 0.011     | plug   |
| 99                                              | PY124 | H003-12H-2a  | 38.0     | 72.59  | 72.14       | 2.747   | 0.008     | plug   |
| 100                                             | PY123 | H003-12H-2a  | 75.0     | 72.96  | 72.42       | 2.717   | 0.008     | plug   |
| 101                                             | PY126 | H003-12H-3   | 50.0     | 74.21  | 73.37       | 2.758   | 0.012     | plug   |
| 102                                             | PY125 | H003-12H-3   | 130.0    | 75.01  | 73.98       | 2.694   | 0.005     | plug   |
| 103                                             | PY128 | H003-12H-4a  | 27.5     | 75.49  | 74.34       | 2.734   | 0.013     | plug   |
| 104                                             | PY127 | H003-12H-4a  | 78.0     | 75.99  | 74.73       | 2.756   | 0.022     | plug   |
| 105                                             | PY129 | H003-12H-5a  | 5.0      | 76.76  | 75.31       | 2.749   | 0.022     | plug   |

| Grain Density for SC Plugs using Gas Pycnometer |       |              |          |        |             |         |           |        |
|-------------------------------------------------|-------|--------------|----------|--------|-------------|---------|-----------|--------|
| Entry                                           | Test  | Core Section | Location | Depth  | Comp. Depth | Density | Std. Dev. | Source |
| No.                                             | No.   |              | (cm)     | (MBSF) | (MBSF)      | (g/cm3) | (g/cm3)   |        |
| 106                                             | PY130 | H003-12H-6a  | 49.0     | 79.02  | 77.03       | 2.747   | 0.023     | plug   |
| 107                                             | PY131 | H003-12H-cc  | 24.5     | 79.46  | 77.36       | 2.731   | 0.019     | plug   |
| 108                                             | PY132 | H003-14H-2a  | 12.5     | 82.45  | 82.13       | 2.729   | 0.020     | plug   |
| 109                                             | PY133 | H003-14H-2a  | 60.0     | 82.92  | 82.51       | 2.742   | 0.014     | plug   |
| 110                                             | PY134 | H003-14H-3a2 | 50.5     | 84.24  | 83.58       | 2.729   | 0.013     | plug   |
| 111                                             | PY135 | H003-14H-3a2 | 122.0    | 84.95  | 84.15       | 2.744   | 0.014     | plug   |
| 112                                             | PY136 | H003-14H-4a  | 18.0     | 85.42  | 84.53       | 2.718   | 0.022     | plug   |
| 113                                             | PY137 | H003-14H-4a  | 120.0    | 86.44  | 85.36       | 2.737   | 0.012     | plug   |
| 114                                             | PY138 | H003-14H-5a  | 15.5     | 86.90  | 85.73       | 2.732   | 0.015     | plug   |
| 115                                             | PY139 | H003-14H-5a  | 68.0     | 87.42  | 86.15       | 2.736   | 0.015     | plug   |
| 116                                             | PY140 | H003-14H-6a  | 41.0     | 88.05  | 86.66       | 2.741   | 0.015     | plug   |
| 117                                             | PY141 | H003-14H-7   | 14.0     | 89.13  | 87.54       | 2.737   | 0.010     | plug   |
| 118                                             | PY142 | H003-14H-cc  | 15.0     | 89.52  | 87.85       | 2.743   | 0.013     | plug   |
| 119                                             | PY143 | H003-14H-cc  | 67.0     | 90.04  | 88.27       | 2.739   | 0.014     | plug   |
| 120                                             | PY144 | H003-16H-1a  | 33.0     | 91.77  | 91.70       | 2.761   | 0.014     | plug   |
| 121                                             | PY145 | H003-16H-1a  | 73.0     | 92.17  | 92.01       | 2.736   | 0.016     | plug   |
| 122                                             | PY146 | H003-16H-2   | 33.0     | 93.53  | 93.07       | 2.736   | 0.011     | plug   |
| 123                                             | PY147 | H003-16H-2   | 132.0    | 94.52  | 93.85       | 2.722   | 0.016     | plug   |
| 124                                             | PY148 | H003-16H-3a  | 39.5     | 95.10  | 94.29       | 2.739   | 0.018     | plug   |
| 125                                             | PY149 | H003-16H-3c  | 139.5    | 96.10  | 95.08       | 2.725   | 0.014     | plug   |
| 126                                             | PY150 | H003-16H-4a  | 19.5     | 96.40  | 95.31       | 2.731   | 0.015     | plug   |
| 127                                             | PY151 | H003-16H-4a  | 97.5     | 97.18  | 95.92       | 2.746   | 0.013     | plug   |
| 128                                             | PY152 | H003-16H-5   | 16.0     | 98.29  | 96.79       | 2.741   | 0.013     | plug   |
| 129                                             | PY153 | H003-16H-5   | 60.0     | 98.73  | 97.13       | 2.723   | 0.017     | plug   |
| 130                                             | PY154 | H003-16H-cca | 15.0     | 99.09  | 97.41       | 2.720   | 0.006     | plug   |
| 131                                             | PY155 | H003-16H-ccc | 62.0     | 99.56  | 97.78       | 2.745   | 0.014     | plug   |
| 132                                             | PY156 | H003-17H-1a  | 42.5     | 98.27  | 98.16       | 2.750   | 0.013     | plug   |
| 133                                             | PY157 | H003-17H-2a  | 18.0     | 98.71  | 98.49       | 2.750   | 0.013     | plug   |
| 134                                             | PY158 | H003-17H-2a  | 38.0     | 98.91  | 98.63       | 2.709   | 0.000     | plug   |
| 135                                             | PY159 | H003-17H-3b1 | 14.0     | 100.33 | 99.69       | 2.755   | 0.014     | plug   |
| 136                                             | PY160 | H003-17H-3b1 | 76.0     | 100.95 | 100.15      | 2.763   | 0.017     | plug   |
| 137                                             | PY161 | H003-17H-4a  | 34.0     | 102.03 | 100.95      | 2.746   | 0.017     | plug   |
| 138                                             | PY162 | H003-17H-4a  | 84.5     | 102.54 | 101.32      | 2.722   | 0.008     | plug   |
| 139                                             | PY163 | H003-17H-5   | 38.0     | 104.07 | 102.46      | 2.746   | 0.018     | plug   |
| 140                                             | PY164 | H003-17H-5   | 98.0     | 104.67 | 102.91      | 2.751   | 0.023     | plug   |

| Grain Density for SC Plugs using Gas Pycnometer |       |              |          |        |             |                      |                      |        |
|-------------------------------------------------|-------|--------------|----------|--------|-------------|----------------------|----------------------|--------|
| Entry                                           | Test  | Core Section | Location | Depth  | Comp. Depth | Density              | Std. Dev.            | Source |
| No.                                             | No.   |              | (cm)     | (MBSF) | (MBSF)      | (g/cm <sup>3</sup> ) | (g/cm <sup>3</sup> ) |        |
| 141                                             | PY165 | H003-17H-6a  | 23.5     | 105.43 | 103.47      | 2.755                | 0.024                | plug   |
| 142                                             | PY166 | H003-17H-cc  | 7.5      | 105.84 | 103.77      | 2.700                | 0.003                | plug   |
| 143                                             | PY167 | H003-18H-1a1 | 115.0    | 105.39 | 105.05      | 2.687                | 0.001                | plug   |
| 144                                             | PY168 | H003-18H-1a1 | 183.0    | 106.07 | 105.52      | 2.726                | 0.020                | plug   |
| 145                                             | PY169 | H003-18H-2a  | 9.5      | 106.41 | 105.76      | 2.704                | 0.012                | plug   |
| 146                                             | PY170 | H003-18H-2a  | 44.0     | 106.75 | 106.00      | 2.737                | 0.016                | plug   |
| 147                                             | PY171 | H003-18H-3a  | 11.5     | 107.94 | 106.83      | 2.736                | 0.021                | plug   |
| 148                                             | PY172 | H003-18H-3a  | 100.0    | 108.82 | 107.45      | 2.760                | 0.023                | plug   |
| 149                                             | PY173 | H003-18H-4   | 33.0     | 109.65 | 108.03      | 2.738                | 0.019                | plug   |
| 150                                             | PY174 | H003-18H-4   | 111.0    | 110.43 | 108.57      | 2.754                | 0.020                | plug   |
| 151                                             | PY175 | H003-18H-5a  | 36.0     | 110.93 | 108.92      | 2.763                | 0.018                | plug   |
| 152                                             | PY176 | H003-18H-6   | 60.0     | 112.79 | 110.23      | 2.744                | 0.016                | plug   |
| 153                                             | PY177 | H003-18H-cc  | 47.0     | 113.39 | 110.65      | 2.756                | 0.016                | plug   |
| 154                                             | PY178 | H003-18H-cc  | 72.0     | 113.64 | 110.82      | 2.757                | 0.017                | plug   |
| 155                                             | PY179 | H003-20H-1a  | 77.0     | 114.77 | 114.65      | 2.740                | 0.015                | plug   |
| 156                                             | PY180 | H003-20H-1a  | 37.0     | 114.37 | 114.31      | 2.753                | 0.016                | plug   |
| 157                                             | PY181 | H003-20H-2a  | 18.5     | 115.28 | 115.08      | 2.718                | 0.001                | plug   |
| 158                                             | PY182 | H003-20H-2a  | 82.5     | 115.92 | 115.62      | 2.735                | 0.011                | plug   |
| 159                                             | PY183 | H003-20H-3   | 86.0     | 117.81 | 117.21      | 2.728                | 0.014                | plug   |
| 160                                             | PY184 | H003-20H-3   | 20.0     | 117.15 | 116.65      | 2.722                | 0.013                | plug   |
| 161                                             | PY185 | H003-20H-4   | 75.0     | 119.20 | 118.38      | 2.734                | 0.014                | plug   |
| 162                                             | PY186 | H003-20H-5a1 | 28.0     | 119.66 | 118.77      | 2.739                | 0.012                | plug   |
| 163                                             | PY187 | H003-20H-6   | 9.0      | 120.97 | 119.88      | 2.737                | 0.013                | plug   |
| 164                                             | PY188 | H003-20H-6   | 82.0     | 121.70 | 120.49      | 2.731                | 0.012                | plug   |
| 165                                             | PY189 | H003-20H-6   | 127.0    | 122.15 | 120.87      | 2.705                | 0.001                | plug   |
| 166                                             | PY190 | H003-20H-cc  | 41.0     | 122.79 | 121.41      | 2.730                | 0.010                | plug   |
| 167                                             | PY191 | H003-21H-1a1 | 44.0     | 122.06 | 122.00      | 2.745                | 0.016                | plug   |
| 168                                             | PY192 | H003-21H-1a3 | 114.0    | 122.76 | 122.62      | 2.721                | 0.010                | plug   |
| 169                                             | PY193 | H003-21H-2a  | 23.0     | 123.35 | 123.14      | 2.732                | 0.013                | plug   |
| 170                                             | PY194 | H003-21H-2a  | 121.0    | 124.33 | 124.01      | 2.693                | 0.000                | plug   |
| 171                                             | PY195 | H003-21H-3a  | 14.0     | 124.76 | 124.38      | 2.721                | 0.015                | plug   |
| 172                                             | PY196 | H003-21H-4   | 13.0     | 126.25 | 125.70      | 2.737                | 0.014                | plug   |
| 173                                             | PY197 | H003-21H-4   | 129.0    | 127.41 | 126.72      | 2.725                | 0.014                | plug   |
| 174                                             | PY198 | H003-21H-5   | 62.0     | 128.24 | 127.45      | 2.739                | 0.014                | plug   |
| 175                                             | PY199 | H003-21H-6a  | 33.0     | 128.65 | 127.82      | 2.743                | 0.014                | plug   |

| Grain Density for SC Plugs using Gas Pycnometer |       |              |          |        |             |         |           |        |
|-------------------------------------------------|-------|--------------|----------|--------|-------------|---------|-----------|--------|
| Entry                                           | Test  | Core Section | Location | Depth  | Comp. Depth | Density | Std. Dev. | Source |
| No.                                             | No.   |              | (cm)     | (MBSF) | (MBSF)      | (g/cm3) | (g/cm3)   |        |
| 176                                             | PY200 | H003-21H-7   | 9.0      | 129.75 | 128.79      | 2.740   | 0.014     | plug   |
| 177                                             | PY201 | H003-21H-cc  | 9.0      | 130.09 | 129.09      | 2.736   | 0.013     | plug   |
| 178                                             | PY202 | H003-22H-1   | 20.0     | 129.44 | 129.44      | 2.745   | 0.014     | plug   |
| 179                                             | PY203 | H003-22H-1   | 128.0    | 130.52 | 130.52      | 2.731   | 0.014     | plug   |
| 180                                             | PY204 | H003-22H-2a1 | 10.5     | 130.84 | 130.84      | 2.726   | 0.013     | plug   |
| 181                                             | PY205 | H003-22H-2a2 | 68.5     | 131.42 | 131.42      | 2.737   | 0.013     | plug   |
| 182                                             | PY206 | H003-22H-3   | 19.0     | 132.43 | 132.43      | 2.705   | 0.004     | plug   |
| 183                                             | PY207 | H003-22H-3   | 133.0    | 133.57 | 133.57      | 2.734   | 0.014     | plug   |
| 184                                             | PY208 | H003-22H-4a2 | 38.0     | 134.10 | 134.10      | 2.732   | 0.015     | plug   |
| 185                                             | PY209 | H003-22H-4a2 | 83.0     | 134.55 | 134.55      | 2.728   | 0.010     | plug   |
| 186                                             | PY210 | H003-22H-5   | 22.5     | 135.44 | 135.44      | 2.740   | 0.017     | plug   |
| 187                                             | PY211 | H003-22H-5   | 89.5     | 136.11 | 136.11      | 2.741   | 0.014     | plug   |
| 188                                             | PY212 | H003-22H-cc  | 11.0     | 136.40 | 136.40      | 2.724   | 0.013     | plug   |
| 189                                             | PY213 | H003-23H-1a  | 26.0     | 137.12 | 137.08      | 2.684   | 0.000     | plug   |
| 190                                             | PY214 | H003-23H-1a  | 69.0     | 137.55 | 137.45      | 2.735   | 0.014     | plug   |
| 191                                             | PY215 | H003-23H-2a  | 20.0     | 138.72 | 138.46      | 2.716   | 0.022     | plug   |
| 192                                             | PY216 | H003-23H-3a  | 33.0     | 140.90 | 140.34      | 2.730   | 0.014     | plug   |
| 193                                             | PY217 | H003-23H-4a  | 26.0     | 141.76 | 141.08      | 2.737   | 0.016     | plug   |
| 194                                             | PY218 | H003-23H-5   | 10.0     | 143.20 | 142.32      | 2.734   | 0.014     | plug   |
| 195                                             | PY219 | H003-23H-5   | 82.0     | 143.92 | 142.94      | 2.738   | 0.014     | plug   |
| 196                                             | PY220 | H003-23H-6   | 11.0     | 144.66 | 143.58      | 2.740   | 0.014     | plug   |
| 197                                             | PY221 | H003-23H-6   | 45.0     | 145.00 | 143.87      | 2.738   | 0.014     | plug   |
| 198                                             | PY222 | H003-23H-cc  | 19.0     | 145.38 | 144.20      | 2.729   | 0.011     | plug   |
| 199                                             | PY223 | H003-25H-3   | 21.5     | 150.49 | 149.68      | 2.692   | 0.000     | plug   |
| 200                                             | PY224 | H003-25H-4   | 32.5     | 151.09 | 150.12      | 2.766   | 0.024     | plug   |
| 201                                             | PY225 | H003-25H-5a  | 60.0     | 152.01 | 150.79      | 2.747   | 0.018     | plug   |
| 202                                             | PY226 | H003-25H-6a  | 15.0     | 152.52 | 151.16      | 2.734   | 0.018     | plug   |
| 203                                             | PY227 | H003-25H-6c  | 77.5     | 153.15 | 151.62      | 2.713   | 0.018     | plug   |
| 204                                             | PY228 | H003-25H-7a  | 27.0     | 153.69 | 152.01      | 2.715   | 0.018     | plug   |
| 205                                             | PY229 | H003-25H-8b  | 84.5     | 155.29 | 153.18      | 2.748   | 0.015     | plug   |
| 206                                             | PY230 | H003-25H-8b  | 27.0     | 154.71 | 152.76      | 2.736   | 0.016     | plug   |
| 207                                             | PY231 | H003-25H-9a  | 9.0      | 155.73 | 153.50      | 2.708   | 0.018     | plug   |
| 208                                             | PY232 | H003-25H-9b  | 60.0     | 156.24 | 153.87      | 2.722   | 0.017     | plug   |
| 209                                             | PY233 | H003-25H-10  | 13.0     | 147.65 | 147.62      | 2.741   | 0.017     | plug   |
| 210                                             | PY234 | H003-25H-10  | 50.0     | 148.02 | 147.89      | 2.759   | 0.023     | plug   |

| Grain Density for SC Plugs using Gas Pycnometer |       |               |          |        |             |                      |                      |        |
|-------------------------------------------------|-------|---------------|----------|--------|-------------|----------------------|----------------------|--------|
| Entry                                           | Test  | Core Section  | Location | Depth  | Comp. Depth | Density              | Std. Dev.            | Source |
| No.                                             | No.   |               | (cm)     | (MBSF) | (MBSF)      | (g/cm <sup>3</sup> ) | (g/cm <sup>3</sup> ) |        |
| 211                                             | PY235 | H003-25H-cc   | 19.0     | 157.49 | 154.78      | 2.746                | 0.017                | plug   |
| 212                                             | PY236 | H003-25H-cc   | 51.5     | 157.82 | 155.02      | 2.748                | 0.017                | plug   |
| 213                                             | PY237 | H003-26X-1a   | 121.0    | 279.80 | 279.80      | 2.703                | 0.000                | plug   |
| 214                                             | PY238 | H003-26X-2    | 37.0     | 280.28 | 280.28      | 2.745                | 0.016                | plug   |
| 215                                             | PY239 | H003-26X-2    | 106.0    | 280.97 | 280.97      | 2.744                | 0.016                | plug   |
| 216                                             | PY240 | H003-26X-3a   | 34.0     | 281.59 | 281.59      | 2.743                | 0.016                | plug   |
| 217                                             | PY241 | H003-26X-3a   | 49.0     | 281.74 | 281.74      | 2.727                | 0.008                | plug   |
| 218                                             | PY242 | H003-26X-4a   | 19.0     | 282.19 | 282.19      | 2.748                | 0.015                | plug   |
| 219                                             | PY243 | H003-26X-4a   | 47.0     | 282.47 | 282.47      | 2.738                | 0.015                | plug   |
| 220                                             | PY244 | H003-26X-5a   | 58.5     | 283.95 | 283.95      | 2.745                | 0.017                | plug   |
| 221                                             | PY245 | H003-26X-5a   | 118.0    | 284.55 | 284.55      | 2.750                | 0.015                | plug   |
| 222                                             | PY246 | H003-26X-6a   | 14.0     | 284.97 | 284.97      | 2.719                | 0.001                | plug   |
| 223                                             | PY247 | H003-26X-6a   | 44.0     | 285.27 | 285.27      | 2.732                | 0.002                | plug   |
| 224                                             | PY248 | H003-26X-7c   | 44.0     | 286.42 | 286.42      | 2.747                | 0.015                | plug   |
| 225                                             | PY249 | H003-26X-cc   | 31.0     | 286.83 | 286.83      | 2.735                | 0.013                | plug   |
| 226                                             | PY088 | H003-08CS-2   | 56.0     | 47.29  | 47.29       | 2.734                | 0.018                | plug   |
| 227                                             | PY089 | H003-08CS-3a  | 26.0     | 48.19  | 48.19       | 2.726                | 0.016                | plug   |
| 228                                             | PY250 | H003-13CS-1   | 32.5     | 78.05  | 78.05       | 2.721                | 0.018                | plug   |
| 229                                             | PY251 | H003-19CS-3c  | 74.0     | 111.76 | 111.66      | 2.754                | 0.024                | plug   |
| 230                                             | PY252 | H003-19CS-4   | 33.0     | 112.48 | 112.30      | 2.696                | 0.001                | plug   |
| 231                                             | PY253 | H003-19CS-5a  | 12.5     | 113.47 | 113.17      | 2.722                | 0.019                | plug   |
| 232                                             | PY254 | H003-24CS-2   | 55.5     | 145.09 | 145.02      | 2.761                | 0.025                | plug   |
| 233                                             | PY255 | H003-24CS-5a  | 25.0     | 147.13 | 146.81      | 2.762                | 0.024                | plug   |
| 234                                             | PY256 | H003-27CS-4a  | 11.0     | 288.69 | 288.69      | 2.751                | 0.014                | plug   |
| 235                                             | PY257 | H003-27CS-5a  | 33.0     | 289.75 | 289.75      | 2.742                | 0.015                | plug   |
| 236                                             | PY258 | H003-29CS-3c  | 57.0     | 295.55 | 295.55      | 2.750                | 0.017                | plug   |
| 237                                             | PY259 | H003-29CS-5a  | 13.5     | 295.76 | 295.76      | 2.712                | 0.001                | plug   |
| 238                                             | PY260 | H002-01FB-1b  | 41.0     | 645.06 | 645.06      | 2.782                | 0.026                | plug   |
| 239                                             | PY261 | H002-03FB-2a  | 2.0      | 677.39 | 677.39      | 2.767                | 0.025                | plug   |
| 240                                             | PY262 | H002-04FB-1a  | 7.0      | 680.38 | 680.38      | 2.738                | 0.022                | plug   |
| 241                                             | PY263 | H002-04FB-2a  | 9.0      | 681.06 | 681.06      | 2.731                | 0.012                | plug   |
| 242                                             | PY264 | H002-04FB-2a  | 32.0     | 681.29 | 681.29      | 2.691                | 0.006                | plug   |
| 243                                             | PY265 | H002-04FB-3a  | 3.0      | 681.70 | 681.70      | 2.765                | 0.023                | plug   |
| 244                                             | PY266 | H002-04FB-4a  | 44.5     | 682.70 | 682.70      | 2.685                | 0.007                | plug   |
| 245                                             | PY267 | H002-05CS-3c  | 46.5     | 802.47 | 802.47      | 2.768                | 0.006                | plug   |
| 246                                             | PY268 | H002-06CS-5a  | 3.5      | 805.64 | 805.64      | 2.774                | 0.001                | plug   |
| 247                                             | PY269 | H002-08CS-3a1 | 20.0     | 810.95 | 810.95      | 2.742                | 0.015                | plug   |

| Grain Density for SC Plugs using Gas Pycnometer |       |               |          |        |             |         |           |        |
|-------------------------------------------------|-------|---------------|----------|--------|-------------|---------|-----------|--------|
| Entry                                           | Test  | Core Section  | Location | Depth  | Comp. Depth | Density | Std. Dev. | Source |
| No.                                             | No.   |               | (cm)     | (MBSF) | (MBSF)      | (g/cm3) | (g/cm3)   |        |
| 248                                             | PY270 | H002-09CS-1a  | 8.0      | 812.68 | 812.67      | 2.707   | 0.001     | plug   |
| 249                                             | PY271 | H002-09CS-1a  | 60.0     | 813.20 | 813.13      | 2.749   | 0.016     | plug   |
| 250                                             | PY272 | H002-09CS-2a  | 7.5      | 813.67 | 813.55      | 2.719   | 0.001     | plug   |
| 251                                             | PY273 | H002-09CS-3a1 | 13.5     | 814.31 | 814.12      | 2.681   | 0.000     | plug   |
| 252                                             | PY274 | H002-09CS-4b  | 15.0     | 815.26 | 814.97      | 2.734   | 0.012     | plug   |
| 253                                             | PY275 | H002-09CS-4b  | 66.5     | 815.77 | 815.43      | 2.687   | 0.007     | plug   |
| 254                                             | PY276 | H002-12CS-1a  | 6.0      | 821.80 | 821.79      | 2.750   | 0.014     | plug   |
| 255                                             | PY277 | H002-12CS-2a  | 7.5      | 823.13 | 822.96      | 2.750   | 0.016     | plug   |
| 256                                             | PY278 | H002-12CS-3a1 | 16.5     | 824.35 | 824.03      | 2.747   | 0.016     | plug   |
| 257                                             | PY279 | H002-12CS-3a1 | 54.5     | 824.73 | 824.36      | 2.739   | 0.016     | plug   |
| 258                                             | PY280 | H002-13CS-1a3 | 31.0     | 825.10 | 825.06      | 2.755   | 0.016     | plug   |
| 259                                             | PY281 | H002-13CS-1c  | 73.5     | 825.52 | 825.44      | 2.709   | 0.002     | plug   |
| 260                                             | PY282 | H002-13CS-2a  | 15.0     | 826.73 | 826.51      | 2.756   | 0.014     | plug   |
| 261                                             | PY283 | H002-13CS-2a  | 65.0     | 827.23 | 826.95      | 2.718   | 0.001     | plug   |
| 262                                             | PY284 | H002-13CS-3a  | 14.5     | 827.78 | 827.44      | 2.723   | 0.001     | plug   |
| 263                                             | PY285 | H002-14CS-1c  | 50.0     | 845.10 | 845.04      | 2.774   | 0.016     | plug   |
| 264                                             | PY286 | H002-14CS-2a  | 33.0     | 845.77 | 845.64      | 2.784   | 0.017     | plug   |
| 265                                             | PY287 | H002-14CS-3a3 | 34.0     | 847.08 | 846.80      | 2.745   | 0.001     | plug   |
| 266                                             | PY288 | H002-14CS-3a3 | 86.5     | 847.61 | 847.26      | 2.773   | 0.017     | plug   |
| 267                                             | PY289 | H002-15CS-1a  | 14.5     | 858.46 | 858.45      | 2.776   | 0.002     | plug   |
| 268                                             | PY290 | H002-15CS-2a1 | 6.5      | 859.15 | 859.06      | 2.792   | 0.018     | plug   |
| 269                                             | PY291 | H002-06cs-2a  | 7.0      | 803.62 | 803.62      | 2.785   | 0.023     | plug   |
| 270                                             | PY292 | H002-06cs-2c  | 27.0     | 803.82 | 803.82      | 2.776   | 0.021     | plug   |
| 271                                             | PY293 | H002-02fb-4   | 15.0     | 675.28 | 675.28      | 2.678   | 0.007     | plug   |
| 272                                             | PY294 | H003-28cs-1a  | 10.0     | 290.88 | 290.88      | 2.721   | 0.007     | plug   |
| 273                                             | PY295 | H003-28cs-1c  | 56.0     | 291.34 | 291.34      | 2.730   | 0.007     | plug   |
| 274                                             | PY296 | H002-05cs-4   | 14.5     | 802.67 | 802.67      | 2.744   | 0.011     | plug   |
| 275                                             | PY297 | H002-06cs-6   | 8.5      | 806.04 | 806.04      | 2.701   | 0.008     | plug   |
| 276                                             | PY298 | H003-27cs-3   | 8.0      | 288.46 | 288.46      | 2.725   | 0.008     | plug   |
| 277                                             | PY299 | H003-29cs-4   | 10.5     | 294.88 | 294.88      | 2.710   | 0.000     | plug   |
| 278                                             | PY300 | H002-02fb-2   | 6.5      | 674.43 | 674.43      | 2.670   | 0.000     | plug   |
| 279                                             | PY301 | H002-02fb-5   | 10.0     | 675.43 | 675.43      | 2.708   | 0.000     | plug   |
| 280                                             | PY302 | H002-08cs-2   | 9.0      | 810.64 | 810.64      | 2.701   | 0.006     | plug   |
| 281                                             | PY303 | H002-10cs-2   | 15.5     | 816.84 | 816.71      | 2.645   | 0.001     | plug   |
| 282                                             | PY304 | H002-11cs-1   | 8.0      | 818.77 | 818.76      | 2.649   | 0.000     | plug   |
| 283                                             | PY305 | H003-24cs-3   | 8.0      | 145.56 | 145.43      | 2.716   | 0.010     | plug   |

Table 7-7 – Summary of consolidation results for sample H003-7H-3B1 – OED223

| SUMMARY OF CONSOLIDATION TEST RESULTS |                                            |            |            |              |            |            |              |                                |                                  |                                   |                       |                                      |         |         |                          |
|---------------------------------------|--------------------------------------------|------------|------------|--------------|------------|------------|--------------|--------------------------------|----------------------------------|-----------------------------------|-----------------------|--------------------------------------|---------|---------|--------------------------|
| Oedometer No. 223                     |                                            |            |            |              |            |            |              |                                |                                  |                                   |                       |                                      |         |         |                          |
| Sample H003-7H-3B1                    |                                            |            |            |              |            |            |              |                                |                                  |                                   |                       |                                      |         |         |                          |
| Inc. No.                              | Consolidation Stress (kg/cm <sup>2</sup> ) | Primary    |            |              | Increment  |            |              | Rate of Secondary (%/log time) | Compression Ratio (%/log stress) | Coef. of Compressibility (-Δe/Δσ) | Strain @ 50% cons (%) | Coeff of Consol (cm <sup>2</sup> /s) |         |         | Hydraulic Conduct (cm/s) |
|                                       |                                            | Time (min) | Strain (%) | Void Ratio e | Time (min) | Strain (%) | Void Ratio e |                                |                                  |                                   |                       | Root T                               | Log T   | Avg     |                          |
| S                                     |                                            |            |            | 1.371        |            | 0          | 1.371        |                                |                                  |                                   |                       |                                      |         |         |                          |
| 1                                     | 0.191                                      | 0          | -2.599     | 1.407        | 10         | -2.53      | 1.431        | 0.0416                         |                                  |                                   |                       |                                      |         |         |                          |
| 2                                     | 0.441                                      | 1          | -1.025     | 1.385        | 1562       | -0.72      | 1.388        | 0.0989                         | 4.3340                           | 0.086445994                       | -2.7497               | 0.0159                               | 0.01062 | 0.01327 | 6.6978E-07               |
| 3                                     | 1.083                                      | 19         | 1.382      | 1.352        | 962        | 1.76       | 1.329        | 0.2217                         | 6.1649                           | 0.051401049                       | -1.7874               | 0.0008                               | 0.00068 | 0.00074 | 7.9441E-11               |
| 4                                     | 2.006                                      | 15         | 4.601      | 1.308        | 5283       | 5.31       | 1.245        | 0.2839                         | 12.0128                          | 0.047772918                       | 0.2910                | 0.0009                               | 0.00061 | 0.00078 | 1.4039E-11               |
| 5                                     | 4.015                                      | 16         | 9.421      | 1.242        | 1802       | 10.12      | 1.131        | 0.3552                         | 15.9958                          | 0.032892902                       | 3.2503                | 0.0012                               | 0.00057 | 0.00089 | 3.2274E-11               |
| 6                                     | 8.010                                      | 14         | 14.929     | 1.166        | 842        | 15.45      | 1.005        | 0.3149                         | 18.3653                          | 0.018903629                       | 7.4103                | 0.0008                               | 0.00054 | 0.00068 | 3.0263E-11               |
| 7                                     | 16.000                                     | 11         | 20.727     | 1.087        | 1322       | 21.34      | 0.865        | 0.3010                         | 19.2955                          | 0.009948707                       | 12.4645               | 0.0010                               | 0.00060 | 0.00079 | 1.1905E-11               |
| 8                                     | 32.003                                     | 10         | 26.342     | 1.010        | 8642       | 27.17      | 0.727        | 0.2689                         | 18.6495                          | 0.004810283                       | 18.1884               | 0.0010                               | 0.00069 | 0.00085 | 9.4169E-13               |
| 9                                     | 64.032                                     | 9          | 31.105     | 0.945        | 19683      | 32.06      | 0.611        | 0.2773                         | 15.8149                          | 0.002039046                       | 23.8708               | 0.00077                              | 0.00047 | 0.00062 | 1.2919E-13               |
|                                       |                                            |            |            |              |            |            |              |                                |                                  |                                   |                       |                                      |         |         |                          |

Table 7-8 – CRS test summary with specific test information

| Test Name | Soil Type | Sample        | Samle Type   | Strain Rate | Notes       |
|-----------|-----------|---------------|--------------|-------------|-------------|
| CRS1799   | GOM2-2    | H003-01H-5b   | Intact       | 0.5%/ hour  | Failed Test |
| CRS1791   | GOM2-2    | H003-02H-2b   | Intact       | 0.5%/ hour  |             |
| CRS1800   | GOM2-2    | H003-02H-4b   | Intact       | 0.5%/ hour  |             |
| CRS1787   | GOM2-2    | H003-02H-6b   | Intact       | 0.5%/ hour  | Failed Test |
| CRS1788   | GOM2-2    | H003-02H-6b   | Intact       | 0.5%/ hour  |             |
| CRS1792   | GOM2-2    | H003-03H-3b   | Intact       | 0.5%/ hour  |             |
| CRS1801   | GOM2-2    | H003-03H-5b   | Intact       | 0.5%/ hour  |             |
| CRS1785   | GOM2-2    | H003-06H-2b   | Intact       | 0.5%/ hour  |             |
| CRS1786   | GOM2-2    | H003-06H-2b   | Intact       | 0.5%/ hour  |             |
| CRS1793   | GOM2-2    | H003-07H-3b1  | Intact       | 0.5%/ hour  |             |
| CRS1780   | GOM2-2    | H003-09H-2b1  | Intact       | 0.5%/ hour  |             |
| CRS1781   | GOM2-2    | H003-09H-2b1  | Intact       | 0.5%/ hour  |             |
| CRS1795   | GOM2-2    | H003-10H-5b1  | Intact       | 0.5%/ hour  |             |
| CRS1777   | GOM2-2    | H003-12H-2b   | Intact       | 0.5%/ hour  |             |
| CRS1779   | GOM2-2    | H003-12H-2b   | Intact       | 0.5%/ hour  |             |
| CRS1802   | GOM2-2    | H003-14H-2b1  | Intact       | 0.5%/ hour  |             |
| CRS1796   | GOM2-2    | H003-16H-1b   | Intact       | 0.5%/ hour  |             |
| CRS1803   | GOM2-2    | H003-17H-2b1  | Intact       | 0.5%/ hour  |             |
| CRS1782   | GOM2-2    | H003-18H-2b1  | Intact       | 0.5%/ hour  |             |
| CRS1783   | GOM2-2    | H003-18H-2b1  | Intact       | 0.5%/ hour  |             |
| CRS1797   | GOM2-2    | H003-20H-2b1  | Intact       | 0.5%/ hour  |             |
| CRS1806   | GOM2-2    | H003-21H-3b   | Intact       | 0.5%/ hour  | Failed Test |
| CRS1775   | GOM2-2    | H003-22H-4b   | Intact       | 0.5%/ hour  |             |
| CRS1776   | GOM2-2    | H003-22H-4b   | Intact       | 0.5%/ hour  |             |
| CRS1807   | GOM2-2    | H003-23H-4b   | Intact       | 0.5%/ hour  |             |
| CRS1798   | GOM2-2    | H003-26X-4b   | Intact       | 0.5%/ hour  |             |
| CRS1826   | GOM2-2    | H002-14CS-3A2 | Intact       | 0.5%/ hour  |             |
| CRS1812   | GOM2-2    | H003-06H-2b   | Resedimented | 0.5%/ hour  |             |
| CRS1811   | GOM2-2    | H003-06H-2b   | Resedimented | 0.5%/ hour  | Failed Test |
| CRS1814   | GOM2-2    | H003-09H-2b1  | Resedimented | 0.5%/ hour  |             |
| CRS1813   | GOM2-2    | H003-09H-2b1  | Resedimented | 0.5%/ hour  |             |
| CRS1825   | GOM2-2    | H003-12H-2b   | Resedimented | 0.5%/ hour  |             |