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LYNM-PE1 Seismic Parameters from Borehole Log, Laboratory, and Tabletop Measurements

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ABSTRACT

The goal of this work is to provide a database of quality-checked seismic parameters that can be integrated with the Geologic Framework Model (GFM) for the LYNM-PE1 (Low Yield Nuclear Monitoring – Physical Experiment 1) testbed. We integrated data from geophysical borehole logs, tabletop measurements on collected core, and laboratory measurements. We reviewed for internal consistency among each measurement type, documented the caveats of measurement conditions, and integrated lithologic logs to check the validity of outlier values. The resulting consolidated parameter tables can be used as inputs for modeling and analysis codes and are designed to interface with the GFM, which is being actively developed.

ACKNOWLEDGEMENTS

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ACRONYMS AND TERMS

Acronym/Term	Definition
BH	Borehole
GFM	Geologic framework model
LYNM	Low yield nuclear monitoring
PE1	Physical Experiment 1
QC	Quality check
TT	Tabletop measurements
UZNT	Upper zeolitic nonwelded tuff
VNT	Vitric nonwelded tuff
V_P	P-wave velocity
V_S	S-wave velocity

1. MOTIVATION

The goal of this work is to provide a database of quality-checked seismic parameters that can be integrated with the Geologic Framework Model (GFM) for the LYNM-PE1 (Low Yield Nuclear Monitoring – Physical Experiment 1) testbed. Lithologies in the testbed are part of an interbedded sequence of nonwelded ash-fall, pumice-fall, and reworked tuffs from the Calico Hills Formation (Figure 1). Vitric content, alteration including zeolitization, argillization, and silicification; as well as relative amounts of pumice and matrix ash content vary both within and among these units (Myers et al., 2024; Bodmer et al., 2024; Wilson et al., 2024). These variations influence material properties that are used to differentiate among model layers in the GFM and in modeling and simulation codes. Among these properties, we compiled all available bulk densities and ultrasonic P- and S-wave velocities from geophysical borehole logs as well as tabletop measurements and laboratory measurements on core recovered from PE1 testbed lithologies. We reviewed the compiled data for internal consistency among each measurement type, documented the caveats of measurement conditions, and integrated lithologic logs to check the validity of outlier values. The resulting consolidated parameter tables can be used as inputs for modeling and analysis codes and are designed to interface with the GFM, which is being actively developed.

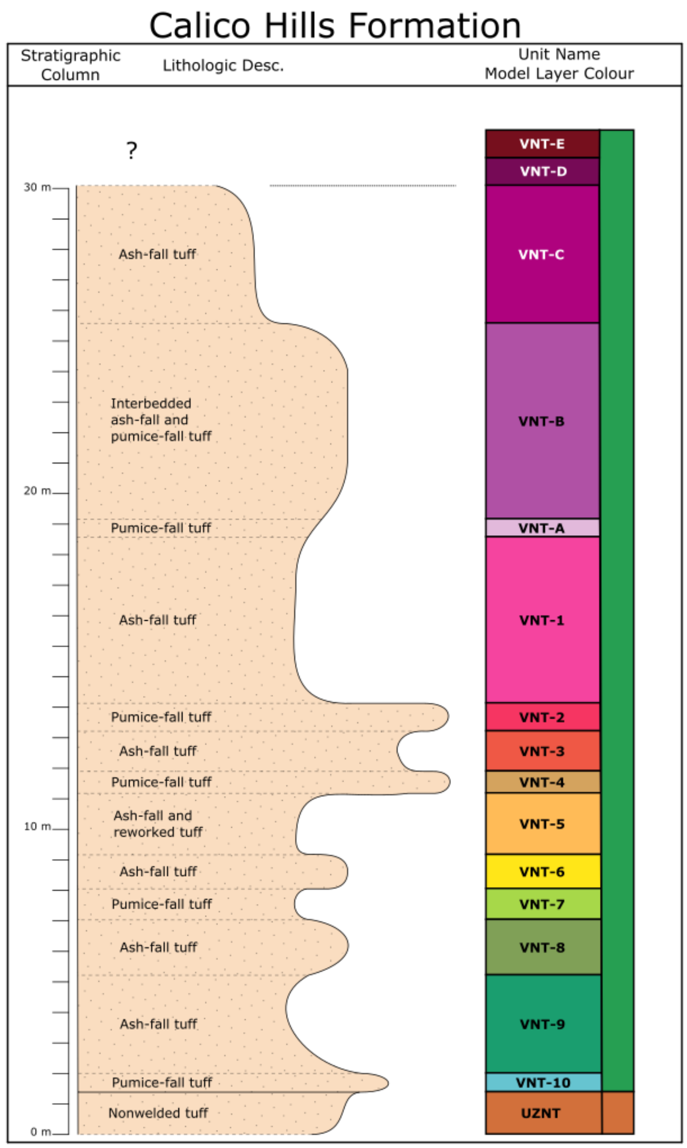


Figure 1. Schematic stratigraphic column representing nonwelded tuff units in the PE1 testbed and GFM.

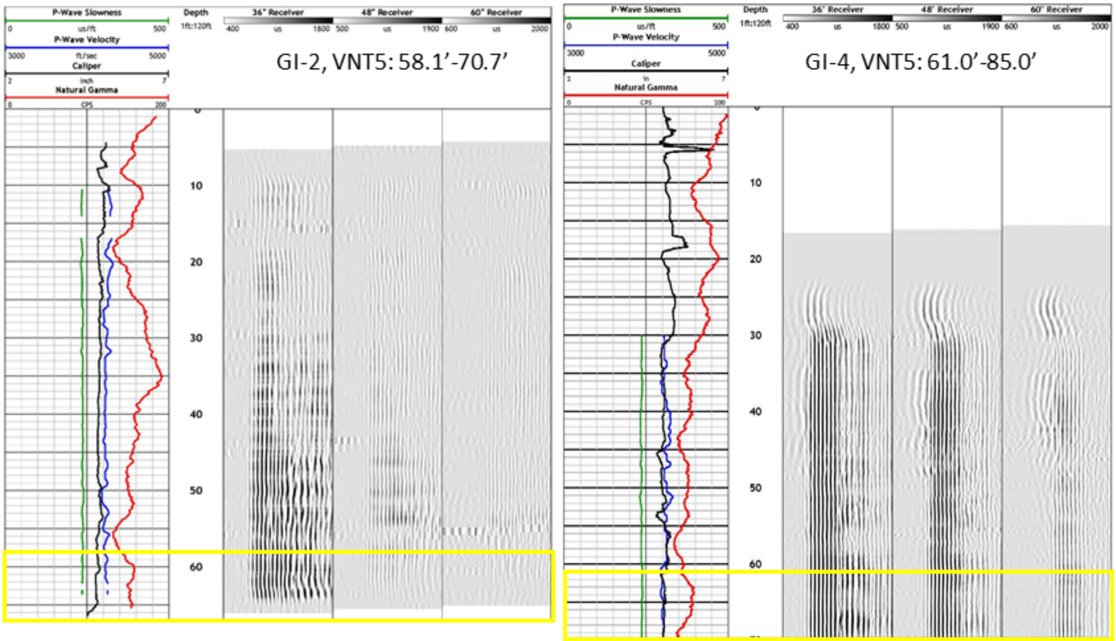
1.1. Data Types and Sources

Density and ultrasonic P- and S-wave velocity data from borehole logs, tabletop measurements, and lab measurements are compiled and quality-checked into a subset of reliable seismic parameters that reflect the available site characterization data. Density and sonic borehole logs run by Colog were reviewed and compiled with a measurement interval of ~0.1 ft. Ultrasonic velocities were measured on dry core in the USGS core library and are referred to as tabletop measurements. Measurement intervals were driven by lithologic variations with maximum spacing of ~5 ft. Density and ultrasonic velocities were measured on prepared right circular cylinder core samples with a mounted system in a controlled lab environment. These core samples were selected from boreholes GI-2, GI-3, GI-4, and AC-1 (Myers et al., 2024) to capture lithologic heterogeneity within UZNT and each VNT subunit. Measurements come from both dry and preserved (waxed) core and grab samples (intended to reflect in-situ saturation) and are noted as such in all tables and plots.

1.2. QC Steps

For each of 24 boreholes, a detailed review of density and sonic logs was performed to identify anomalous portions of the logs. Anomalies were common at the top of boreholes, where casing interfered with readings, and near the end of the boreholes. Seismic parameter values from these intervals are excluded in our compilation. Anomalous or outlier values in other intervals were checked against lithologic, permeability, and surface hardness logs for matching depth intervals to evaluate the inclusion of these values in our compilation. Erroneous data (flat intervals) existed in GI-2, GI-3, and GI-4 borehole sonic logs and are excluded. An example of a quality-check correlation performed on sonic borehole logs, where anomalously flat signal in GI-2 and GI-4 from VNT-5 depths are compared to data from VNT-5 in DA-7, is shown in Figure 2. All outlier values are noted with comments on their likely source (instrument-related, logging anomalies, lithologic variations, including fracture zones, lenses of material with high competency contrast, etc.) in Appendices A–C. Data excluded due to logging anomalies are listed in Table 1.

Data filtering was performed to remove borehole log data in which the logging tool likely sampled more than one lithologic unit (i.e., where the probe's depth of penetration exceeded the distance to a lithologic boundary). This distance is 0.3 feet for the sonic logging tool and 0.6 feet for the density logging tool. For subvertical holes intersecting bedding at roughly 8^{o} dip (Bodmer et al., 2024), data within 0.3 feet and 0.6 feet of a lithologic boundary were removed from the sonic and density datasets, respectively. For subhorizontal holes, the drilling depth that could be affected by overlying or underlying units for density logs expands. All sonic logs are from subvertical holes, so this expansion only affects a portion of the density dataset. Given the intersecting geometries of the boreholes and the shallowly dipping strata, density data within 4.3 feet of a lithologic boundary were excluded from subhorizontal borehole logs.



Unit & Data Source	# Data Points	Average	Std Dev	Min	Max
VNT5-BH-DA1	59	2.326	0.210	2.035	2.594
VNT5-BH-DA2	16	2.370	0.022	2.323	2.406
VNT5-BH-DA3	24	2.403	0.014	2.381	2.433
VNT5-BH-DA4	15	2.187	0.088	2.076	2.323
VNT5-BH-DA6	59	2.082	0.112	1.891	2.261
VNT5-BH-DA7	84	2.050	0.115	1.915	2.261
VNT5-BH-GI2	42	1.290	0.004	2.620	2.632
VNT5-BH-GI4	194	1.286	0.008	1.274	2.052

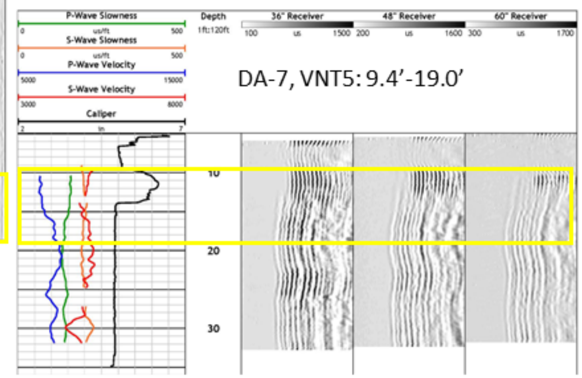


Figure 2. Example quality-check of sonic borehole logs, where anomalously flat signal (highlighted in yellow) in GI-2 and GI-4 from VNT-5 depths are compared to data from VNT-5 in DA-7.

Table 1. Catalog of Data Omissions from Seismic Parameter Compilation

Borehole	Depth Interval (ft)	Lithologic Unit(s)	Seismic Parameter	Reason for Omission
GI-2	<3.0	VNT-1	Density	Casing-related irregularities
GI-2	All	VNT-1 to VNT-5	V_P	Flat borehole log signal
GI-3	All	VNT-2 to VNT-5	V_P	Flat borehole log signal
GI-3	15.9	VNT-3	V_P, V_S	Dry Lab measurement anomaly
GI-4	All	VNT-2 to VNT-5	V_P	Flat borehole log signal
GI-6	41.7	VNT-5	V_P, V_S	Anomalous tabletop measurement
AC-1	146.8	UZNT	V_P, V_S	Part Sat Lab measurement anomaly
AC-2	<10.0	VNT-B	Density	Casing-related irregularities
AC-5	<10.0	VNT-1	Density	Casing-related irregularities
AC-5	>110.0	VNT-3 to VNT-4	Density	Log irregularities
HF-1	>80.0	VNT-5	Density	Log irregularities
DA-5	<7.2	VNT-3, VNT-5	Density	Casing-related irregularities
DA-6	<8	VNT-3	Density	Casing-related irregularities
DA-6	>29.8	VNT-8 to VNT-9	Density	Log irregularities
DA-7	<7.1	VNT-3	Density	Casing-related irregularities
GS-1	<5.0	VNT-1	Density	Casing-related irregularities
GS-1	>53.0	VNT-5	Density	Log irregularities
GS-2	<10.0	VNT-1	Density	Casing-related irregularities
GS-3	<7.1	VNT-1	Density	Casing-related irregularities
GS-3	>58.0	VNT-5 to VNT-6	Density	Log irregularities
GS-4	<11.0	VNT-A, VNT-1	Density	Casing-related irregularities in VNT-A, other irregularities in VNT-1
GS-6	all	VNT-A, VNT-B	Density	Casing-related irregularities
GS-8	all	VNT-A, VNT-B	Density	Casing-related irregularities

1.3. Compilation Details

All density and velocity data were compiled and imported into Excel files with lithology, sample type (borehole core or drift grab sample), locations (drilling depth or GPS), measurement types (borehole log, tabletop, dry lab, or partially saturated lab), parameter values, and units of parameter values. Units of velocity from borehole logs were in ft/s, tabletop measurements were in in/s, and lab measurements were in m/s; all velocity values were converted to km/s. Density values were reported in borehole logs and from lab measurements in g/cc, and no conversion was necessary. Data was originally sorted at high granularity with statistics and plots of values calling out lithologic units, borehole locations, and measurement types. Review of compiled data showed similar value ranges for the same measurement type across boreholes, which justified reducing grouping to just lithologic unit and measurement type.

2. DATA SOURCES AND ASSOCIATED CAVEATS

2.1. Borehole Logs

A total of 24 boreholes drilled during PE1 construction were characterized using a suite of downhole tools to produce geophysical logs (Bodmer et al., 2024). Full waveform sonic was run on down-going holes that could hold water (excluding GS holes) using a Mt. Sopris 2SAA (F)-1000 Multi-Frequency Full Waveform Sonic tool. Density was run using a Mt. Sopris Instruments HLP-4180. Of the 24 boreholes reviewed for density and velocity data, 19 contained reliable data (Table 2). The data from these borehole logs may be affected by in situ saturation conditions, which varies among boreholes, as detailed in Table 2. Sonic velocity logs require the borehole to hold water, typically in the form of added mine water, which was not possible for all holes and all depths, especially when considering the horizontal or upgoing nature of many of the holes. Natural saturation conditions in the boreholes vary as well though, depending on the time elapsed from drilling and if the hole holds or drains drilling fluids. While these field-scale measurements are made in a less controlled environment, which can cause variations in data values, they capture features with dense measurement spacing in a way not possible with core sample measurements in the lab or tabletop setting.

Table 2. Borehole Conditions Affecting Density and Sonic Logs

Borehole	Parameters Used	Orientation	In Situ Conditions Noted
GI-2	Density	Horizontal, -3° inclination	Standing water encountered at 69.5 ft
GI-3	Density	Horizontal, -1.5° inclination	None
GI-4	Density	Horizontal, drops in elevation toward TD	Standing water from drilling operations at TD
GI-5		Angled downward from horizontal	None
GI-6	Density	Horizontal, -1° inclination	Standing water visible in video at 64 ft
AC-1	Density	Steeply angled downward from horizontal	Water observed at 155.7 ft in Feb2022, tagged at 103 ft in June 2022
AC-2		Steeply angled upward from horizontal	None
AC-5	Density	Angled upward from horizontal	Mud and debris present
HF-1	Density	Horizontal, drops in elevation toward TD	None
DA-1	Density, V_P, V_S	Vertical	Water present at 36.2 ft; water added to facilitate logging
DA-2	Density, V_P, V_S	Vertical	Water added to dry hole
DA-3	Density, V_P, V_S	Vertical	Water added to dry hole
DA-4	Density, V_P, V_S	Vertical	Water added to dry hole
DA-5	Density, V_P, V_S	Vertical	Water added to dry hole

Borehole	Parameters Used	Orientation	In Situ Conditions Noted
DA-6	Density, V_P, V_S	Vertical	Water present at bottom of hole; water added to facilitate logging
DA-7	Density, V_P, V_S	Vertical	Water added to dry hole
GS-1	Density	Shallow dipping downward from horizontal	Small amount of standing water at 56 ft
GS-2	Density	Shallow dipping upward from horizontal	None
GS-3	Density	Shallow dipping downward from horizontal	Water at 60.5 ft
GS-4		Angled upward from horizontal	None
GS-5	Density	Angled downward from horizontal	Water at 54.2 ft
GS-6		Angled upward from horizontal	None
GS-7	Density	Angled downward from horizontal	None
GS-8		Steeply angled upward from horizontal	None

2.2. Tabletop Measurements

Velocity measurements were performed with a Proceq Pundit 200 UPV test instrument (Bodmer et al., 2024). This system serves as an all-in-one mobile velocity system capable of generating a pulse, amplifying and recording a signal, and storing waveforms for later analysis. The system consists of a tablet PC and a pair of exchangeable piezoelectric transducers. For this investigation, we utilized a set of 250 kHz compression wave transducers and a set of 250 kHz shear wave transducers. A transect of each was performed with each set of transducers to measure P- and S-wave velocities. Measurement depth intervals were driven by lithologic variations with maximum spacing of ~5 ft. Diameter of the core was measured at each location depth using a set of calipers. Measurements were made using handheld transducers, lacking the stability and accuracy of measurements made on a benchtop laboratory system. S-wave travel times were difficult to determine on core samples. The short travel distance across the diameter of the core was not sufficient to allow separation of P- and S-wave phases, resulting in an overlapping arrival. Additionally, it was not possible to measure S waves in the manufacturer-recommended method. Proceq recommends applying the shear wave transducers directly to the core with a sufficient coating of couplant to ensure proper contact. It was decided to use cellophane packaging in between the transducers and the core to prevent widespread contamination of the core from sticky, sugary gels used as couplants. It was not possible to pick the first arrival of the S wave in the recorded data, so velocities are calculated using the first identifiable peak of the S-wave phase. P waves were also picked using the first peak for consistency when comparing data, even though first arrival is more accurate.

2.3. Dry and Partially Saturated Lab Measurements

Selected cores from GI-2, GI-3, GI-4, and AC-1 were prepared into 2.5-inch diameter by 5-inch length right circular cylinder samples for geomechanical testing, including density and velocity lab measurements (Bodmer et al., 2024; Kibikas et al). Density values were also determined from grab samples (irregular roughly fish-sized samples) from the 1490, 1280, and 1190 drifts, as well as from a core segment from DA-1 (Wilson et al., 2024).

Density was calculated from mass and volume measurements. Ultrasonic velocities were measured both parallel (axial) and perpendicular (lateral) to the core axis using a pneumatically actuated measurement system. These measurements performed in a laboratory setting are expected to be more reliable than borehole logs and tabletop measurements since the testing conditions (sample geometry, saturation levels, instrument stability) are defined and controlled. On the other hand, as noted above, larger scale in-situ features captured by borehole logging are likely missed from tests that can only be done at a few locations. The small sample size may also introduce grain-scale variations that are less representative of a lithologic unit as a whole. Ultrasonic velocities combine both axial and lateral measurements, which introduces variation in these values.

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3. DATA COMPILATIONS

Box plots combining data types across boreholes for each VNT unit and UZNT are given in Figures 3 (density), 7 (P-wave velocity), and 12 (S-wave velocity). These plots allow us to compare the measurement types within a unit and reflects the averages and standard deviations in Tables 3 (density), 4 (P-wave velocity), and 5 (S-wave velocity). Trends for each measurement type within a given unit are explored in Figures 4‒6 (density), 8‒11 (P-wave velocity), and 13‒16 (S-wave velocity). Data from individual boreholes can be found in Appendices A‒C and are used to justify combining measurements from different boreholes of the same unit. For all plots, the lower bound of the box represents the value of the first quartile in the dataset, the upper bound represents the third quartile, the "x" in each box represents the mean of the dataset, the horizontal line is the median value in the dataset, and circles represent outlier data points.

3.1. Density

A combination of data from borehole logs and lab measurements are available for units VNT-3 through VNT-6, VNT-10, and UZNT (Figure 3). Density values for units VNT-A through VNT-D, VNT-1, VNT-2, and VNT-7 through VNT-9 are solely from borehole logs.

The largest variations within each individual unit are found in the borehole log data (Figure 3). The large ranges in borehole-derived datasets reflect both a high volume of data and lithologic heterogeneities that occur laterally and vertically within a given unit, as confirmed by quality checks of density logs and cross-examination with lithologic logs at drilling depths of interest. The range in values of borehole log densities from individual boreholes in each unit do tend to overlap to some degree, defining a range of densities that is distinct for each unit. This grouping is the basis for Figure 4. For a given unit, the standard deviation of densities combined across boreholes is greater than that for most individual boreholes, suggesting that the combined dataset captures the wide variations in these units. Exceptions where the variation within an individual borehole is greater than that of the data from all boreholes sampling a given unit include data from VNT-b (GS-6 and GS-8), VNT-1 (GS-1 and GS-2), VNT-3 (AC-1, GS-1, GS-3, and GS-5), VNT-5 (DA-1 and Da-6), VNT-8 (DA-5), VNT-9 (DA-3), and VNT-10 (AC-1). The significant variability in density for the listed units in the respective boreholes is attributed to lithologic heterogeneities.

Lab measurements on dry samples (VNT-3 through VNT-6, VNT-10, and UZNT) are consistently at the low end or below the data range of borehole-derived data and tend to have smaller ranges due to fewer data points (Figure 3). Lab measurements on partially saturated samples (VNT-3 through VNT-5 and UZNT) are expectedly higher than dry lab measurements and fall within the range of data derived from boreholes in which water or moisture was observed (Figure 2, Table 2). The presence of water in boreholes captured during logging and partially saturated sample collection accounts for these differences in densities. These combined datasets from lab measurements on dry samples (Figure 5) and partially saturated samples (Figure 6) show averages and standard deviations that fall within the ranges of those measurements from individual boreholes (compare Table 3 values with those in Figures A-7, A-8, A-9, and A-15), suggesting significant variability within these combined datasets. Even with this variation, the data ranges of dry lab measurements from individual boreholes overlap sufficiently within a given unit (Appendix A), justifying the grouping of those individual datasets that are represented in Figure 5. This relationship also exists for measurement on partially saturated samples (Appendix A and Figure 6).

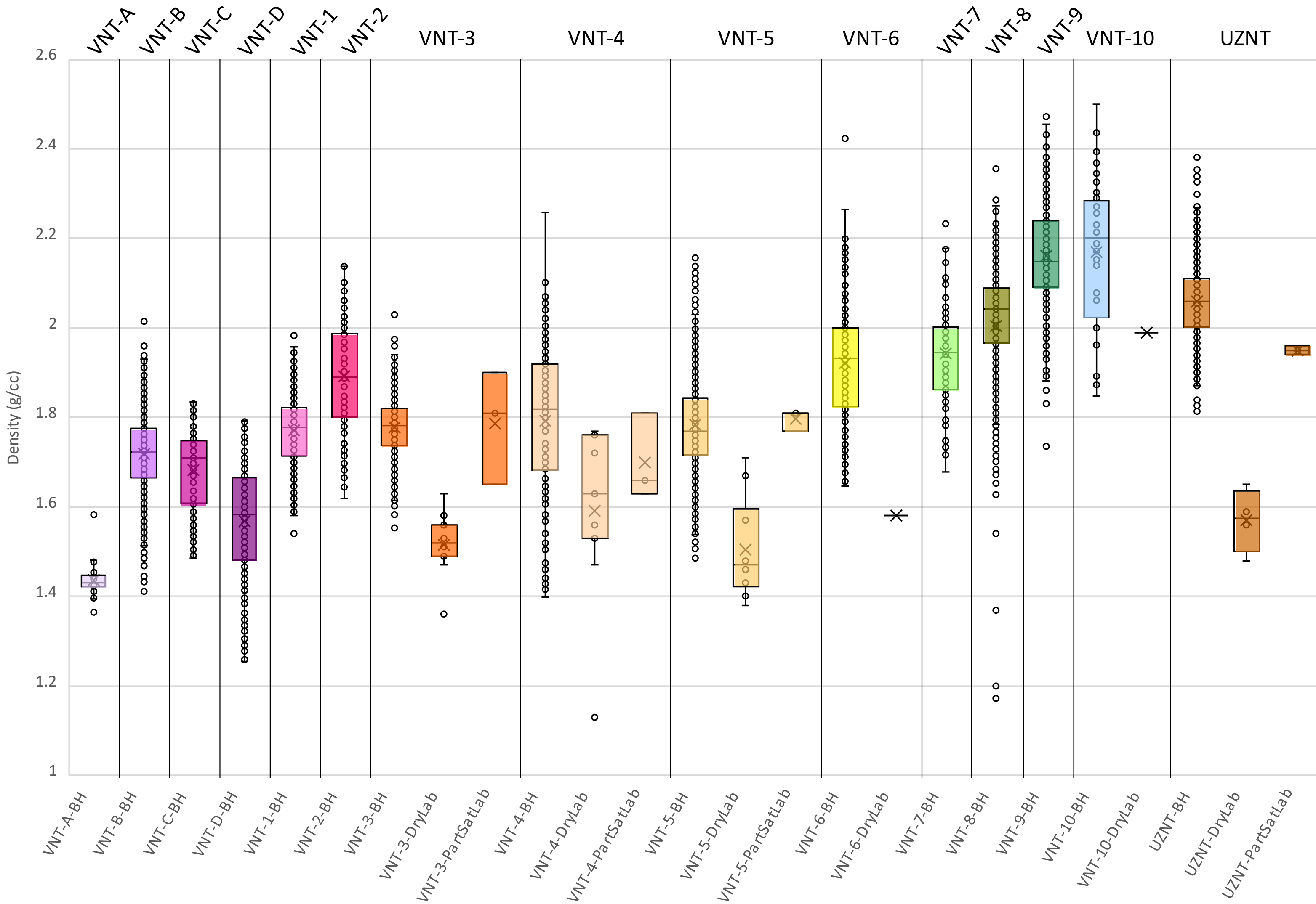

Figure 3. Plot of density values sorted by lithologic unit.

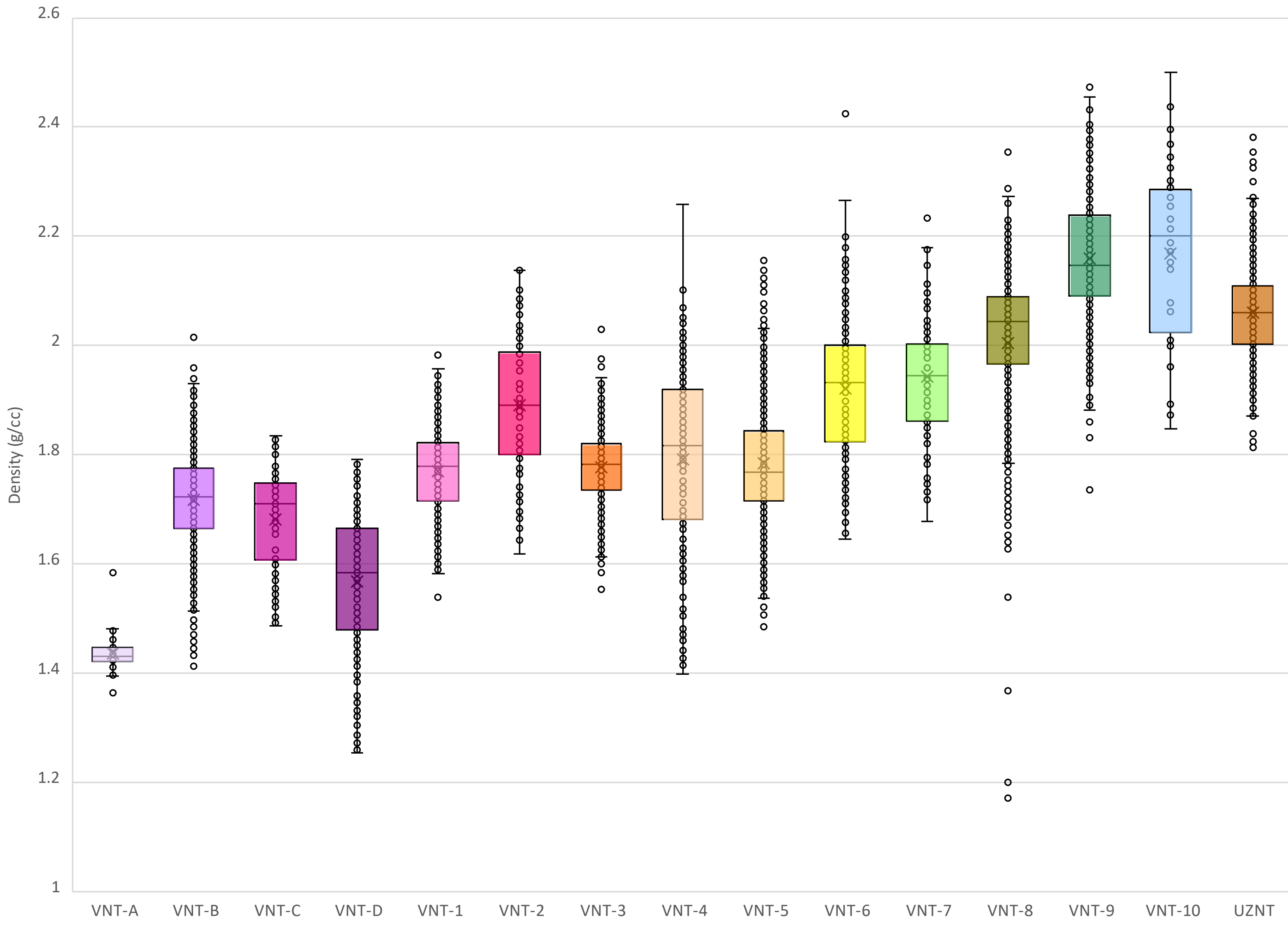

Figure 4. Plot of density values from merged borehole log data for a given lithologic unit.

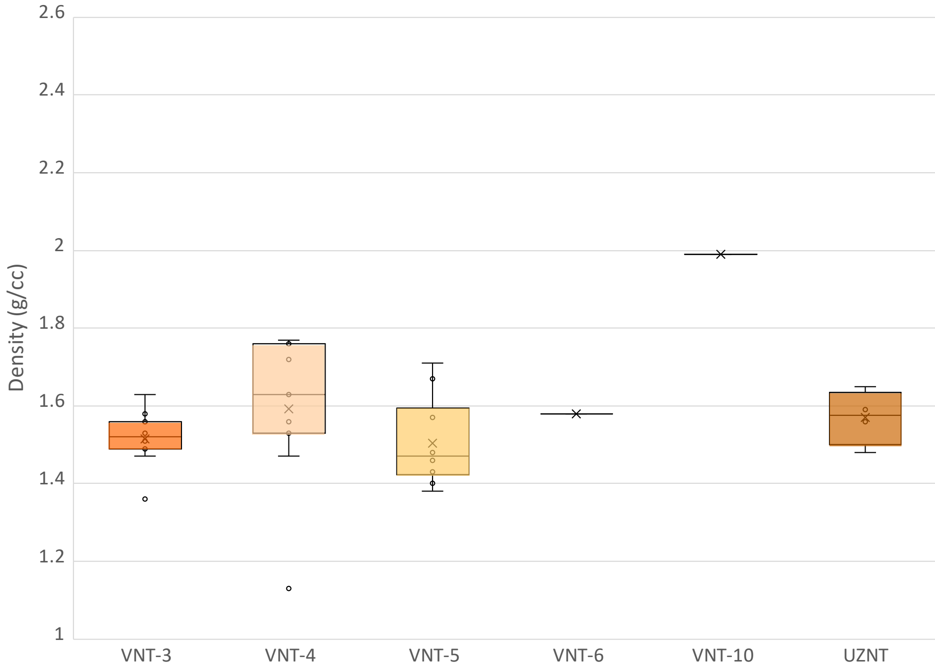

Figure 5. Plot of density values from dry lab measurements with corehole sources merged.

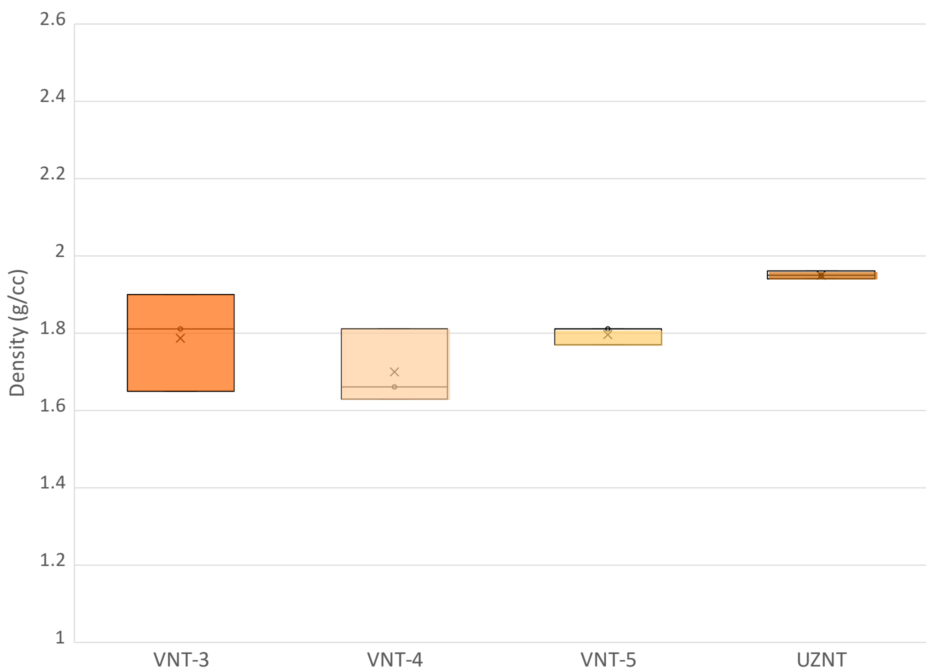

Figure 6. Plot of density values from partially saturated lab measurements with corehole sources merged.

Table 3. Density Values Grouped by Lithologic Unit and Data Source

Unit & Data Source*	# Data Points	Average (g/cc)	Std Dev (g/cc)	Min (g/cc)	Max (g/cc)
VNT-A-BH	34	1.436	0.035	1.364	1.584
VNT-B-BH	1506	1.718	0.083	1.412	2.019
VNT-C-BH	261	1.682	0.088	1.486	1.835
VNT-D-BH	335	1.568	0.128	1.254	1.791
VNT-1-BH	887	1.770	0.074	1.540	1.983
VNT-2-BH	107	1.891	0.121	1.619	2.138
VNT-3-BH	1366	1.778	0.061	1.553	2.029
VNT-3-DryLab	11	1.515	0.068	1.360	1.630
VNT-3-PartSatLab	3	1.787	0.127	1.650	1.900
VNT-4-BH	354	1.792	0.163	1.398	2.259
VNT-4-DryLab	11	1.592	0.187	1.130	1.770
VNT-4-PartSatLab	3	1.700	0.096	1.630	1.810
VNT-5-BH	1152	1.784	0.112	1.486	2.159
VNT-5-DryLab	10	1.504	0.111	1.380	1.710
VNT-5-PartSatLab	3	1.797	0.023	1.770	1.810
VNT-6-BH	260	1.922	0.127	1.646	2.424
VNT-6-DryLab	1	1.580	n/a	n/a	n/a
VNT-7-BH	129	1.942	0.106	1.679	2.234
VNT-8-BH	762	2.004	0.144	1.172	2.355
VNT-9-BH	506	2.160	0.108	1.735	2.483
VNT-10-BH	44	2.169	0.168	1.847	2.499
VNT-10-DryLab	1	1.990	n/a	n/a	n/a
UZNT-BH	1049	2.060	0.083	1.813	2.381
UZNT-DryLab	4	1.570	0.071	1.480	1.650
UZNT-PartSatLab	3	1.950	0.010	1.940	1.960

*BH = Sonic Borehole Log (in situ); DryLab, PartSatLab = SNL Geomechanics Lab Measurements on 2.5" diameter core; color coding tied to data source

3.2. P-wave Velocity

P-wave velocities are sourced from a combination of tabletop measurements, borehole logs, and measurements on dry and partially saturated samples for all units except VNT-1, VNT-2, and VNT-10, which are solely from tabletop measurements (Figure 7).

The largest variations within each individual unit are typically found in the tabletop measurements (Figure 7), with relatively tight distributions in VNT-1, VNT-7, VNT-8, and VNT-10 and with particularly wide distributions in VNT2 and UZNT. Borehole log data also have large ranges for VNT-7 through VNT-9, with outliers commonly contributing to the extended ranges. Lab measurements on samples from VNT-3 through VNT-5 have moderately large ranges of velocities, with UZNT having the tightest distribution for that measurement type (Figure 7).

Average velocities from tabletop measurements are lower than borehole and lab measurements in VNT-3 through VNT-6, VNT-9, and UZNT; their averages are higher than other measurement types in VNT-7 and VNT-8 (Figure 7). Average velocities from borehole logs are higher than dry lab measurements in VNT-5 and fall within the range velocities from lab measurements on partially saturated samples. P-wave velocities from lab measurements on partially saturated samples (VNT-3 through VNT-5, and UZNT) have variable ranges, but those ranges fall within the ranges of other measurement types (Figure 7).

Large ranges in velocities from borehole logs for VNT-5 through VNT-9 reflect both a high volume of data and lithologic heterogeneities that occur laterally and vertically within a given unit (Figure 8 and Appendix B). The standard deviation of velocities combined across boreholes for a given unit is generally larger than those from individual boreholes (compare Table 4 values with Appendix B figures). This grouping is the basis for Figure 8. Where this relationship exists, variations exhibited within individual boreholes are captured in the combined dataset. Combined standard deviations tend to be lower than individual standard deviations for VNT-5 and VNT-6 in borehole DA-1, suggesting that lithologic heterogeneities are not fully captured in the combined dataset.

Average velocities from partially saturated samples are lower than dry samples for VNT-3 but higher for VNT-4, VNT-5, and UZNT (Figures 9 and 10). The higher averages for these units are skewed by variably larger standard deviations for samples from individual boreholes compared to those of the combined dataset (Table 4, Appendix B). Even with this variation, the data ranges of dry samples from individual boreholes overlap sufficiently to justify combining those individual datasets that are represented in Figure 9. This relationship also exists for partially saturated samples (Appendix B and Figure 10).

Large ranges in velocities from tabletop measurements reflect both lithologic heterogeneities and instrument constraints. The standard deviation of velocities combined across boreholes for a given unit is generally larger than those from individual boreholes for a given unit, suggesting that variations exhibited within individual boreholes are captured in the combined dataset. Exceptions include VNT-1 (GI-2), VNT-3 (GI-2 and GI-4), VNT-5 (GI-2 and GI-3), VNT-6 (GI-6), and VNT-9 (GI-6). Although the standard deviations of combined borehole datasets are variably higher or lower than individual datasets for a given unit, the plotted ranges overlap sufficiently to justify combining those individual datasets. This justification is the basis for Figure 11. These variations can be further explored in Appendix B.

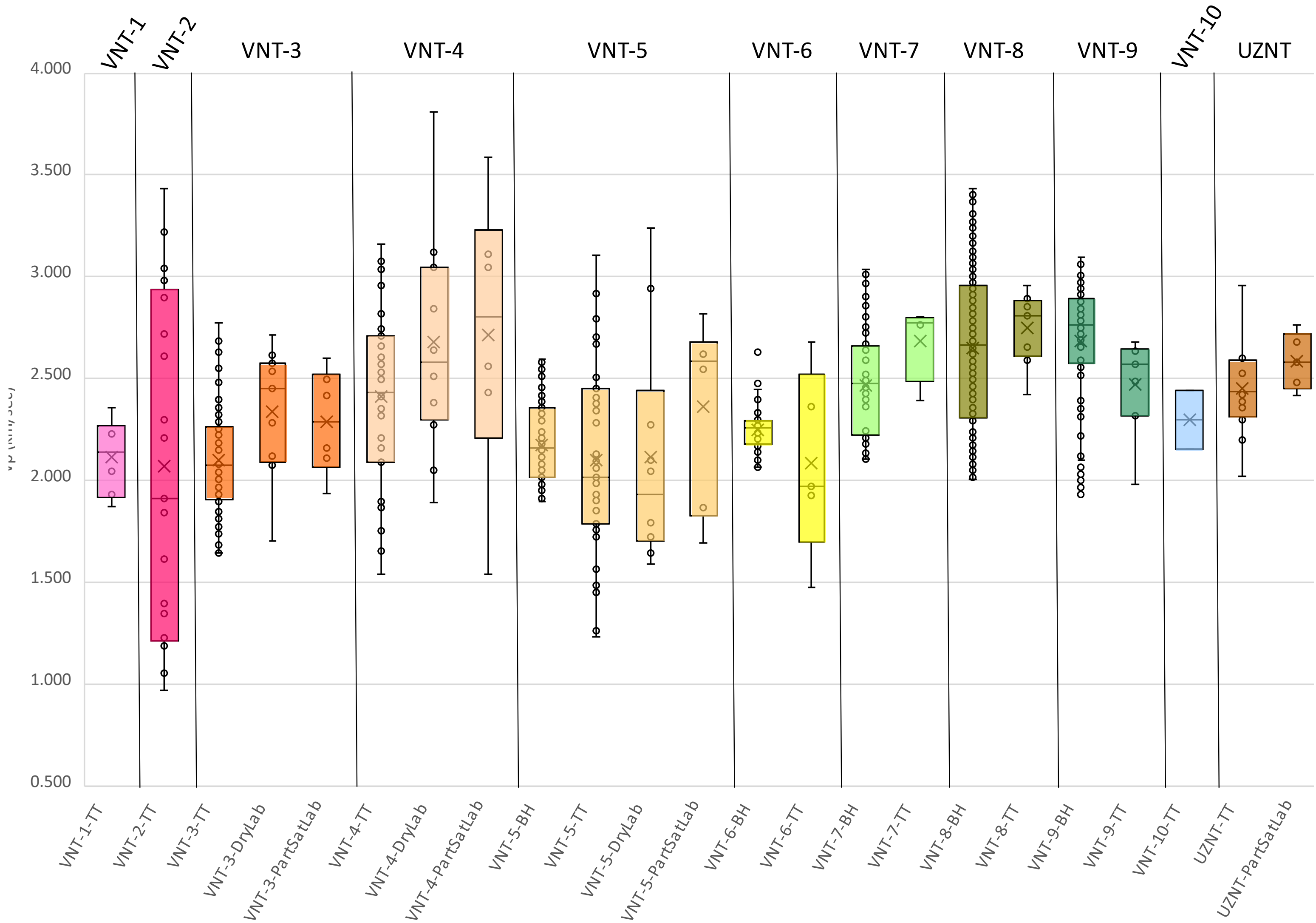

Figure 7. Plot of P-wave velocity values sorted by lithologic unit.

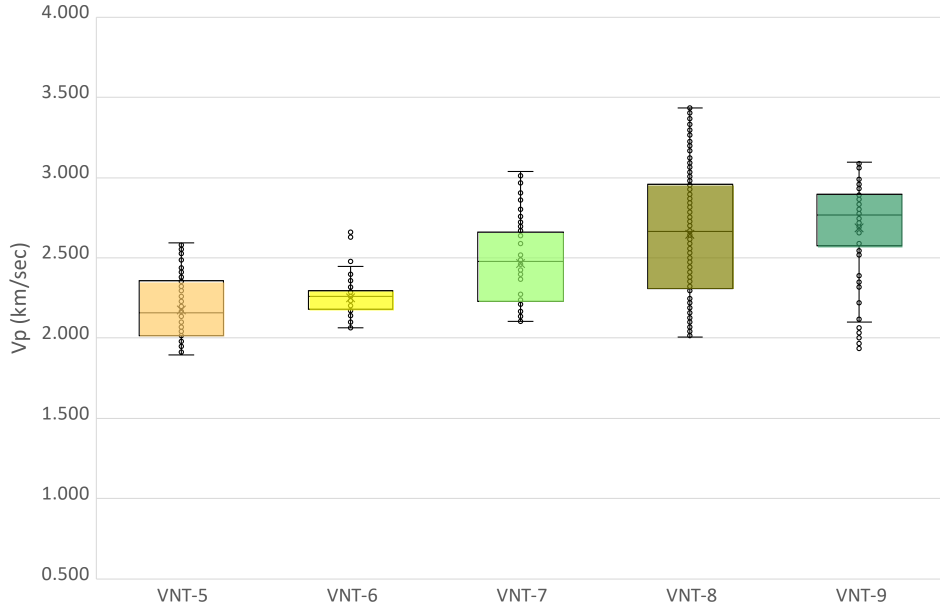

Figure 8. Plot of P-wave velocity values from merged borehole log data for a given lithologic unit.

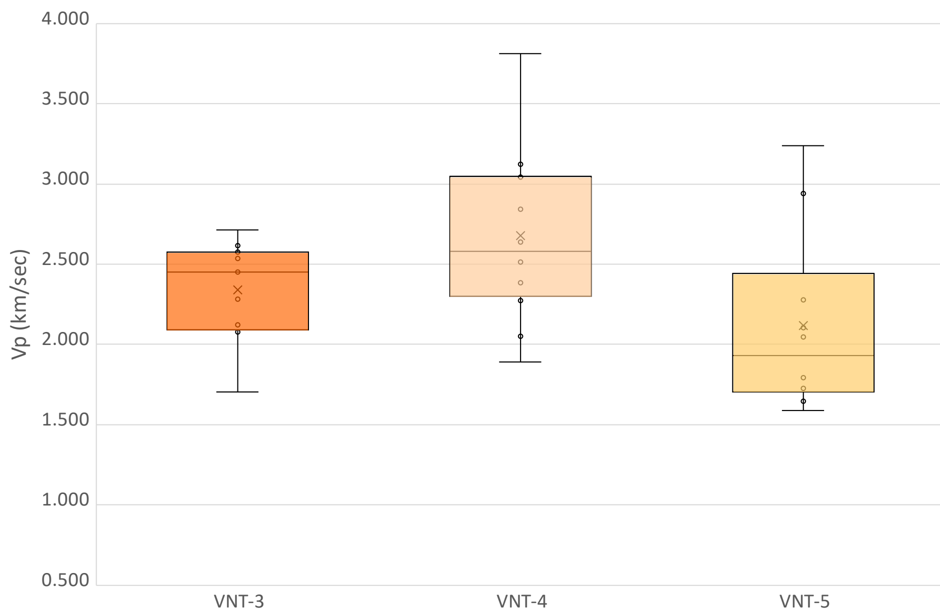

Figure 9. Plot of P-wave velocity values from dry lab measurements with corehole sources merged.

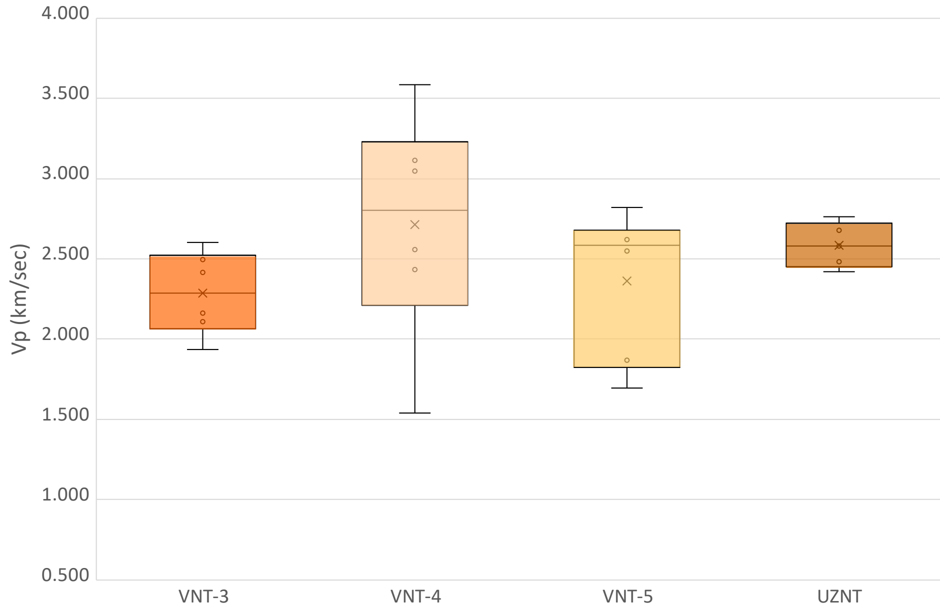

Figure 10. Plot of P-wave velocity values from partially saturated lab measurements with corehole sources merged.

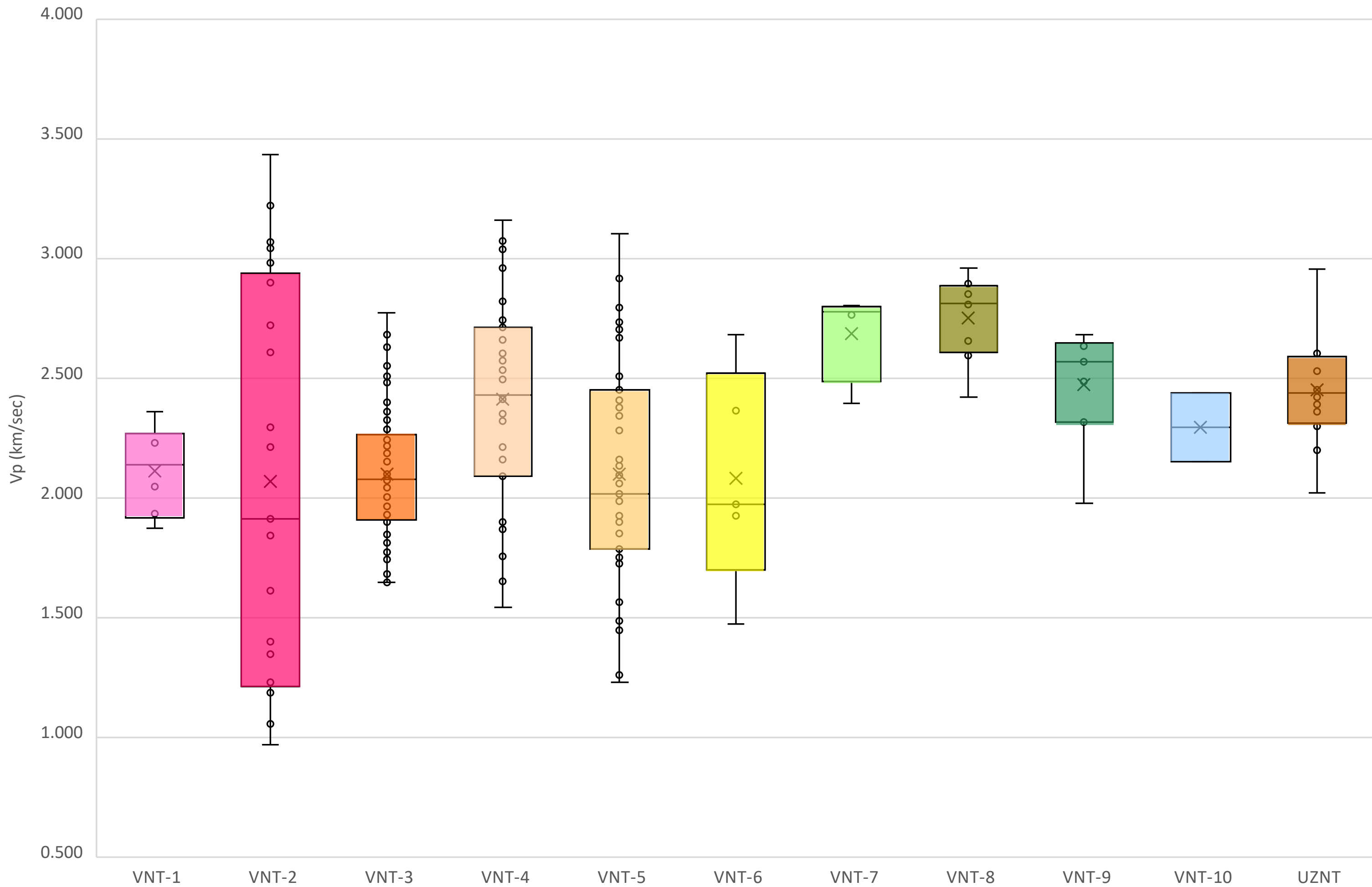

Figure 11. Plot of P-wave velocity values from tabletop measurements with corehole sources merged.

Table 4. P-wave Velocity Values Grouped by Lithologic Unit and Data Source

Unit & Data Source*	# Data Points	Average (km/sec)	Std Dev (km/sec)	Min (km/sec)	Max (km/sec)
VNT-1-TT	6	2.114	0.192	1.873	2.359
VNT-2-TT	21	2.068	0.835	0.969	3.435
VNT-3-TT	66	2.099	0.272	1.646	2.773
VNT-3-DryLab	11	2.338	0.308	1.706	2.715
VNT-3-PartSatLab	6	2.287	0.257	1.935	2.603
VNT-4-TT	35	2.410	0.434	1.542	3.160
VNT-4-DryLab	12	2.678	0.530	1.892	3.810
VNT-4-PartSatLab	6	2.713	0.708	1.541	3.584
VNT-5-BH	217	2.175	0.193	1.895	2.594
VNT-5-TT	51	2.100	0.440	1.231	3.104
VNT-5-DryLab	10	2.117	0.560	1.588	3.239
VNT-5-PartSatLab	6	2.364	0.463	1.695	2.819
VNT-6-BH	107	2.250	0.096	2.250	2.658
VNT-6-TT	5	2.083	0.459	1.475	2.682
VNT-7-BH	80	2.466	0.273	2.105	3.037
VNT-7-TT	4	2.686	0.196	2.393	2.802
VNT-8-BH	545	2.648	0.364	2.005	3.432
VNT-8-TT	8	2.750	0.179	2.422	2.959
VNT-9-BH	181	2.685	0.304	1.934	3.095
VNT-9-TT	7	2.473	0.251	1.979	2.681
VNT-10-TT	2	2.297	n/a	n/a	n/a
UZNT-TT	12	2.450	0.235	2.023	2.956
UZNT-PartSatLab	5	2.585	0.140	2.418	2.763

*TT = Tabletop Measurements using Proceq Pundit 2 on 2.5" Core; BH = Sonic Borehole Log (in situ); DryLab, PartSatLab = SNL Geomechanics Lab Measurements on 2.5" diameter core; color coding tied to data source

3.3. S-wave Velocity

Similar to the P-wave velocity dataset, S-wave velocities are sourced from a combination of tabletop measurements, borehole logs, and measurements on dry and partially saturated samples for all units except VNT-1, VNT-2, and VNT-10, which are solely from tabletop measurements (Figure 12).

The largest variations within each individual unit are typically found in the tabletop measurements (Figure 12). Borehole log data also have large ranges for VNT-5 through VNT-9, with outliers commonly contributing to the extended ranges. Lab measurements on samples from VNT-3 through VNT-5 also have large ranges of velocities, with partially saturated VNT-3 and UZNT having the tightest distribution for that measurement type.

Tabletop measurements are generally lower than borehole and lab measurements in VNT-3 through VNT-6, VNT-8, and VNT-9; their averages are higher than other measurement types in VNT-7 and UZNT (Figure 12). Borehole log velocities for VNT4 have little variation, fall within the range of velocities from tabletop measurements, and are lower than both dry and partially saturated lab measurements. Average borehole log velocities for VNT-5, VNT-6, VNT-8, VNT-9, and UZNT are higher compared to other measurement types. P-wave velocities from lab measurements on partially saturated samples (VNT-3 through VNT-5, and UZNT) average higher than tabletop measurements in all except UZNT, and average higher than borehole logs in VNT-3 and VNT-4 but not VNT-5 (Figure 12).

Ranges in velocities from borehole logs are widely distributed, with significant outliers for VNT-5 through VNT-9. This scatter reflects both a high volume of data and lithologic heterogeneities that occur laterally and vertically within these units (Figure 13). The standard deviations of velocities combined across boreholes are generally greater than those of individual boreholes for a given unit (Table 5, Appendix C). This relationship exists for all units except for VNT-5 in borehole DA-4, suggesting that variations exhibited within individual boreholes are largely captured in the combined dataset. This suggestion is the basis for Figure 13. These variations can be explored further in Appendix C.

Ranges in velocities from lab measurements on dry and partially saturated samples are similar for each unit tested (VNT-3 through VNT-5). Average velocities from dry samples are higher than partially saturated samples for VNT-3 and VNT-4, but slightly lower for VNT-5 (Figures 14 and 15). Combined standard deviations tend to be higher than individual standard deviations for most lab measurements from AC-1 and GI-4, although there are exceptions (Table 5, Appendix C). Where this relationship exists, variations exhibited within individual boreholes are captured in the combined dataset. Although the standard deviations of combined datasets for other boreholes are variably higher or lower than individual datasets, the plotted ranges overlap sufficiently to justify combining those individual datasets that are represented in Figures 14 and 15.

Tabletop measurements have variable ranges, with relatively tight distributions in VNT-8 and VNT-9, and particularly wide distributions for VNT-2, VNT-4, and VNT-5 (Figure 17). The outliers that widen these distributions have been quality-checked and compared to observations at similar drilling depths in lithologic logs, and all could be attributed to lithologic variations. Combined standard deviations tend to be higher than individual borehole standard deviations (Table 5, Appendix C). Where this relationship exists, variations exhibited within individual boreholes are captured in the combined dataset. Exceptions, where the combined standard deviation of tabletop measurements across all boreholes from a given unit are less than those from individual boreholes, include VNT-3 (GI-2), VNT-5 (GI-2 and GI-3), VNT-8 (GI-6), and VNT-9 (GI-6). Even with these exceptions, the plotted ranges overlap sufficiently to justify combining those individual datasets that are represented in Figure 16.

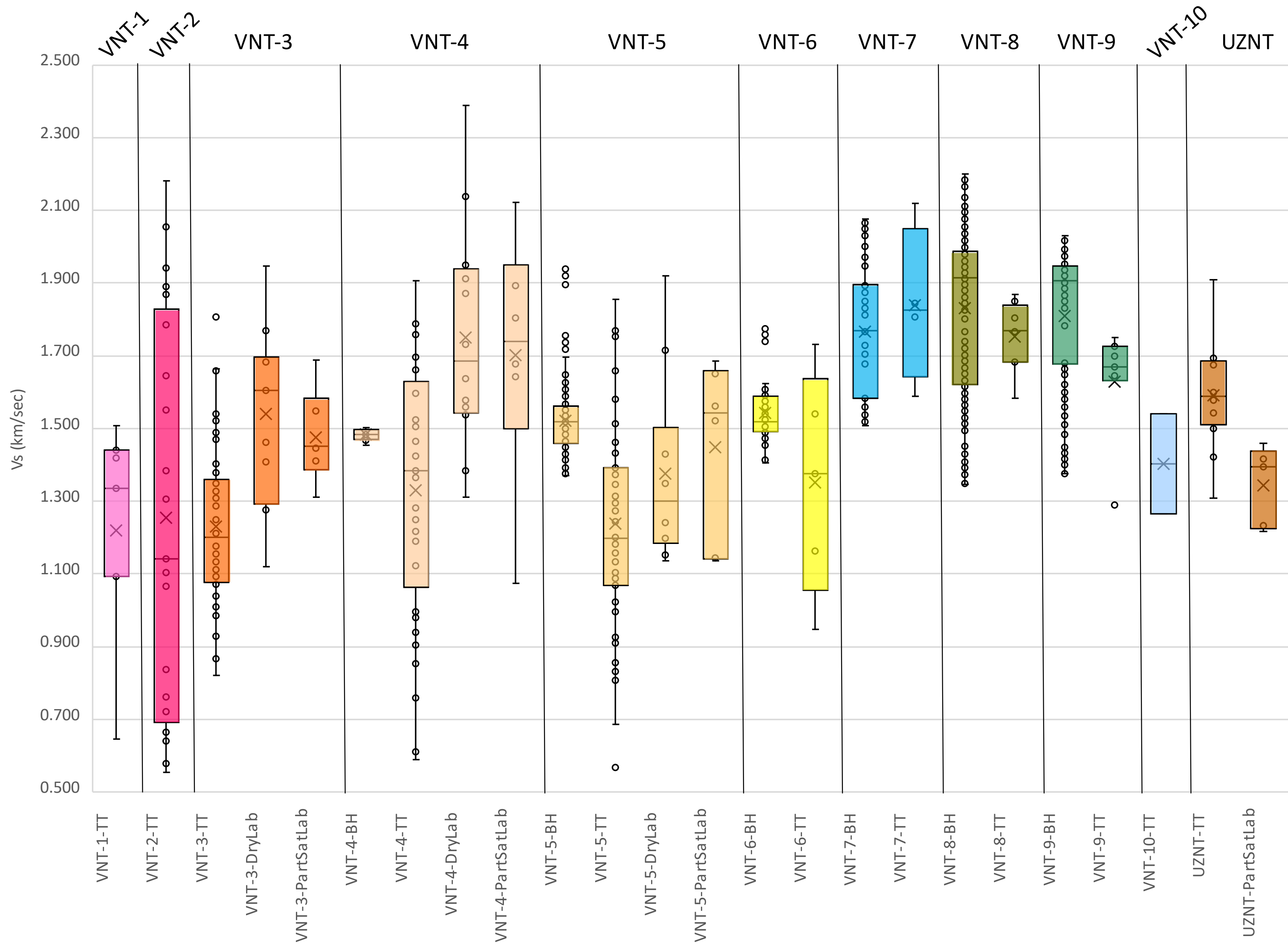

Figure 12. Plot of S-wave velocity values sorted by lithologic unit.

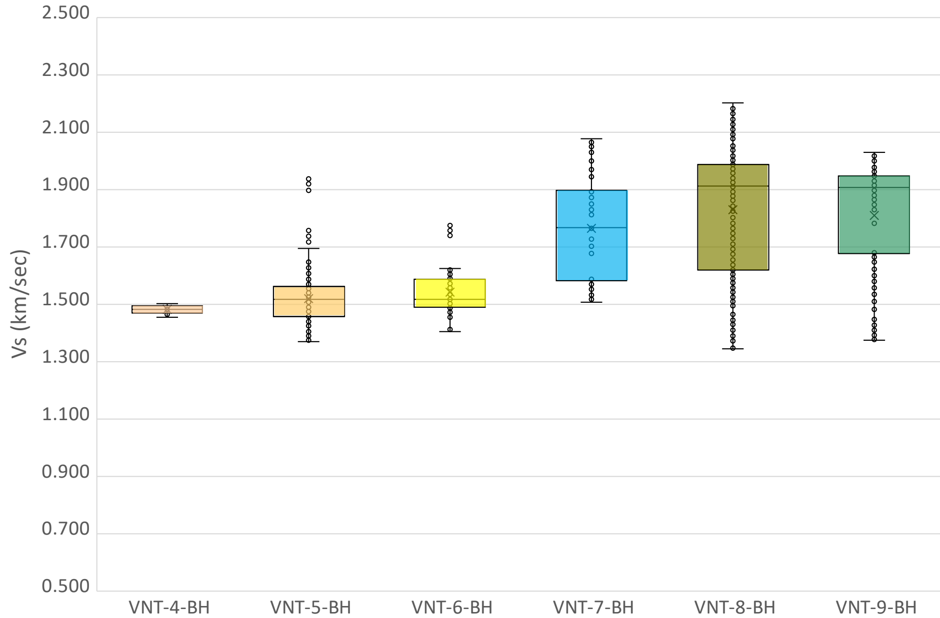

Figure 13. Plot of S-wave velocity values from merged borehole log data for a given lithologic unit.

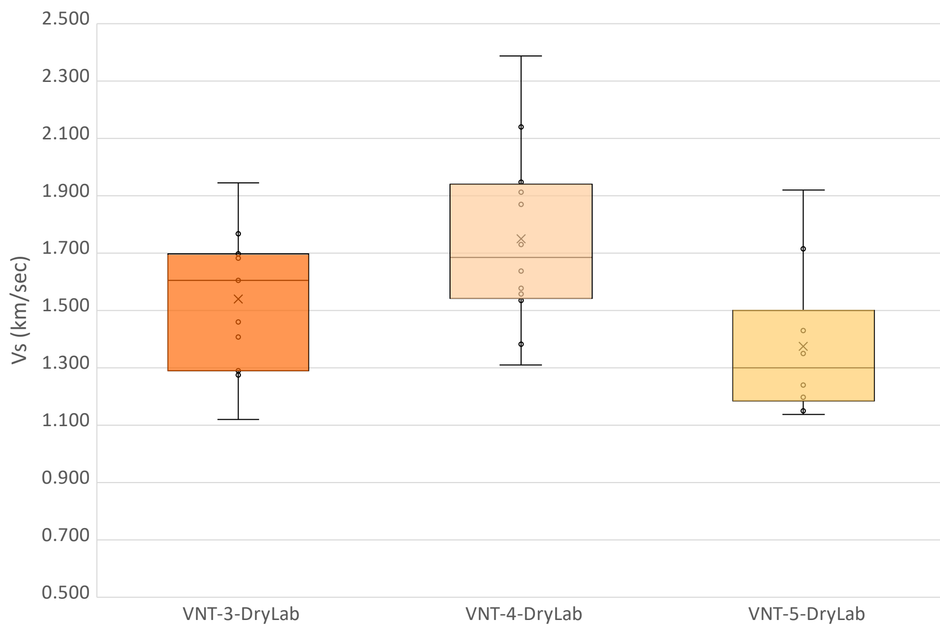

Figure 14. Plot of S-wave velocity values from dry lab measurements with corehole sources merged.

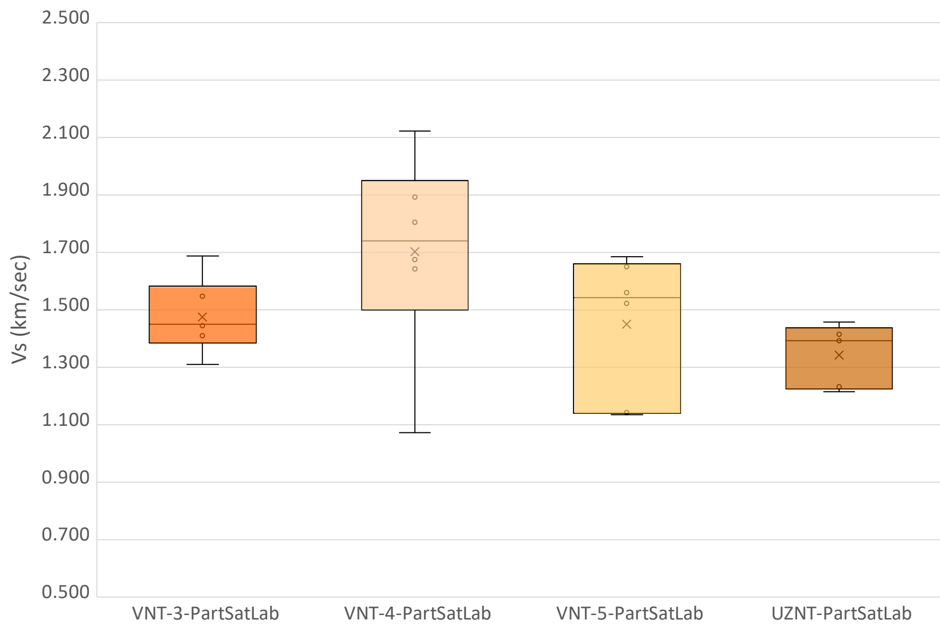

Figure 15. Plot of S-wave velocity values from partially saturated lab measurements with corehole sources merged.

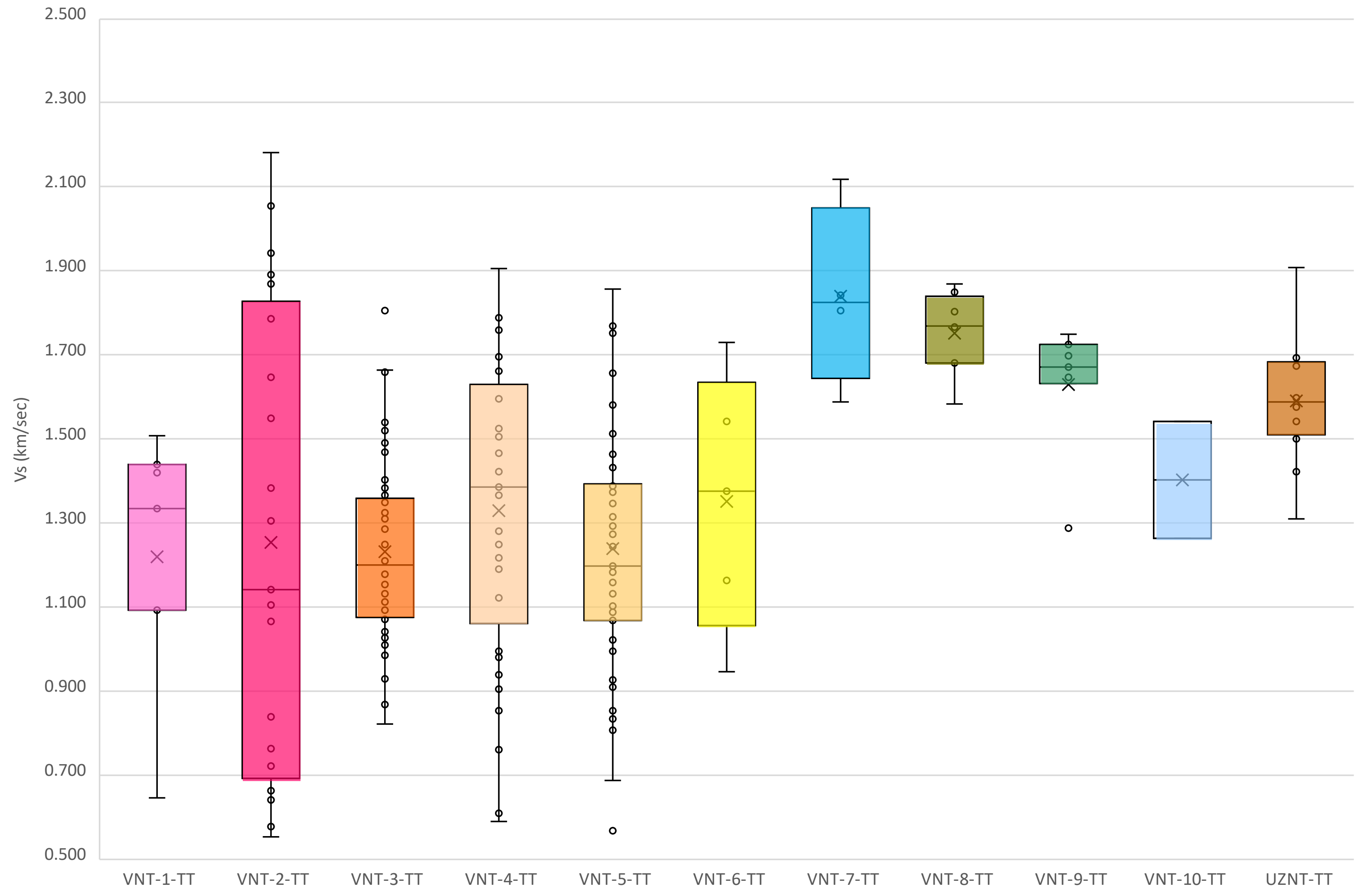

Figure 16. Plot of S-wave velocity values from tabletop measurements with corehole sources merged.

Table 5. S-wave Velocity Values Grouped by Lithologic Unit and Data Source

Unit & Data Source*	# Data Points	Average (km/sec)	Std Dev (km/sec)	Min (km/sec)	Max (km/sec)
VNT-1-TT	7	1.219	0.301	0.646	1.507
VNT-2-TT	21	1.254	0.552	0.554	2.181
VNT-3-TT	66	1.231	0.203	0.821	1.806
VNT-3-DryLab	11	1.541	0.249	1.121	1.946
VNT-3-PartSatLab	6	1.476	0.129	1.311	1.688
VNT-4-BH	9	1.482	0.016	1.454	1.503
VNT-4-TT	37	1.330	0.342	0.589	1.906
VNT-4-DryLab	12	1.749	0.315	1.310	2.388
VNT-4-PartSatLab	6	1.702	0.353	1.073	2.121
VNT-5-BH	192	1.521	0.106	1.371	1.938
VNT-5-TT	51	1.239	0.284	0.569	1.856
VNT-5-DryLab	10	1.374	0.256	1.137	1.920
VNT-5-PartSatLab	6	1.450	0.248	1.135	1.686
VNT-6-BH	117	1.541	0.073	1.405	1.774
VNT-6-TT	5	1.352	0.308	0.946	1.731
VNT-7-BH	53	1.766	0.178	1.508	2.077
VNT-7-TT	4	1.839	0.217	1.589	2.118
VNT-8-BH	429	1.831	0.213	1.346	2.201
VNT-8-TT	8	1.751	0.096	1.584	1.869
VNT-9-BH	153	1.809	0.207	1.376	2.030
VNT-9-TT	7	1.630	0.156	1.288	1.750
VNT-10-TT	2	1.403	0.195	1.264	1.541
UZNT-TT	12	1.591	0.150	1.309	1.908
UZNT-PartSatLab	5	1.343	0.111	1.216	1.458

*TT = Tabletop Measurements using Proceq Pundit 2 on 2.5" Core; BH = Sonic Borehole Log (in situ); DryLab, PartSatLab = SNL Geomechanics Lab Measurements on ~2.5" diameter core; color coding tied to data source

3.4. Comparison of Point Measurements Across Lab, Borehole Log, and Tabletop Determinations

For each density and velocity measurement obtained under controlled lab conditions, we compare values with those determined using borehole logs (density) and tabletop measurements (lateral V_P and V_S, Table 6). Density comparisons can only be made between lab and borehole log determinations since tabletop measurements did not include density. Velocity comparisons can only be made between lab and tabletop measurements since all sonic borehole logs at depths for which there are lab measurements in GI-2, GI-3, and GI-4 were anomalously flat and therefore not a reliable data source.

Densities determined in the lab under dry conditions are generally lower than those determined from borehole measurements, with one exception (GI-4-D-50.9-51.6), which may be due to variable lithic clast content. This general trend is expected for boreholes with varying saturation levels at the time of logging (Table 1). Densities determined in the lab under partially saturated conditions (preserved in situ moisture) are near equal or greater than borehole log determinations for most samples, confirming the preservation of moisture content for waxed samples.

Velocities determined in the lab are generally higher than those determined from tabletop measurements, although several sampling depths show the oppose trend. This variability exists in both dry and partially saturated sample comparisons. The source of the variability is likely from the tabletop measurements, which involve handheld instruments on unprepared and sometimes irregular core segments. Lab determinations may be more reliable since the velocity measurements are made on prepared right circular cylinders with a mounted instrument.

Table 6. Comparison of Lab, Borehole, and Tabletop Measurements for Specific Corehole Depths

Lab Sample ID	Lab Density (g/cc)	BH Density (g/cc)	Lab Lateral V_P (km/s)	TT Lateral V_P (km/s)	Lab Lateral V_S (km/s)	TT Lateral V_S (km/s)
GI-4-12.9-13.6 (D)	1.36	1.67	2.077	2.083	1.408	1.210
GI-3-20.6-21.2 (D)	1.52	1.80	2.617	2.160	1.697	1.331
GI-3-21.8-22.6 (D)	1.50	1.72	2.535	2.042	1.682	1.337
GI-4-48.8-49.3 (D)	1.63	2.00	2.512	2.610	1.638	1.365
GI-4-47.6-48.8-B (D)	1.53	1.90	2.272	2.590	1.558	1.365
GI-4-47.6-48.8-A (D)	1.56	1.90	2.639	2.590	1.578	1.365
GI-3-58.8-59.7 (D)	1.48	1.69	1.959	2.341	1.304	1.314
GI-2-71.9-73.6A (D)	1.48	nd	2.276	2.015	1.430	1.079
GI-2-71.9-73.6B (D)	1.46	nd	2.046	2.015	1.353	1.079
GI-3-21.2-21.8 (PS)	1.90	1.78	2.495	2.042	1.456	1.337
GI-4-14.5-15.0 (PS)	1.65	1.66	2.603	2.083	1.688	1.041
GI-2-30.5-31.5 (PS)	1.82	1.70	1.935	2.358	1.446	1.286
GI-4-50.3-50.9 (PS)	1.96	1.85	3.112	2.967	1.676	1.695
GI-4-37.5-38.1 (PS)	1.81	1.90	3.046	2.743	1.805	1.506
GI-3-44.6-45.3 (PS)	1.96	1.61	3.584	1.118	1.893	0.589
GI-2-66.1-66.6 (PS)	1.80	1.58	2.632	2.809	1.650	1.583
GI-4-69.5-70.0 (PS)	1.82	1.84	2.819	2.705	1.686	1.307
GI-4-62.0-62.7 (PS)	1.78	1.72	1.695	1.449	1.135	0.833
UZNT-AC-1-65.9-66.5 (PS)	1.94	1.96	2.484	2.529	1.416	1.577
UZNT-AC-1-95.4-96.0 (PS)	1.95	2.07	2.418	2.617	1.394	1.693
UZNT-AC-1-146.5-147.1 (PS)	1.96	2.10	2.680	2.200	1.458	1.587
GI-3-B-15.9-16.4 (D)	1.52	1.74	2.452	2.313	1.604	1.294
GI-2-40.3-41.3 (D)	1.58	1.64	2.121	1.684	1.291	0.868
GI-3-17.6-18.6B (D)	1.51	1.79	2.715	2.482	1.768	1.385
GI-4-50.9-51.6 (D)	1.72	1.58	3.044	2.967	1.871	1.695
GI-4-45.3-46.0 (D)	1.53	1.75	3.046	2.605	1.912	1.511
GI-4-42.0-43.2 (D)	1.77	1.87	3.810	3.036	2.388	1.662
GI-4-72.4-73.4 (D)	1.67	1.92	3.239	2.688	1.920	1.519
GI-2-71.9-73.6 (D)	1.46	nd	1.644	2.015	1.240	1.079
GI-4-68.1-69.2 (D)	1.43	1.81	2.102	1.854	1.251	1.087

BH= Borehole Log, TT = Tabletop Measurement, PS= Partially Saturated Lab Sample, D = Dry Lab Sample

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4. SUMMARY

The work provides a database of quality-checked seismic parameters to inform a high resolution GFM for the LYNM-PE1 testbed. Density and ultrasonic P- and S-wave velocity data from borehole logs, tabletop measurements, and laboratory measurements were compiled with a review for internal consistency among each measurement type, a review of the caveats of measurement conditions, and integration of lithologic logs to confirm lithologic units sampled and to check validity of outlier values. Review of the compiled data shows similar value ranges for the same measurement type across boreholes, which justified grouping data by lithologic units with representative values for each measurement type. These grouped datasets are presented as consolidated parameter tables that can be used as inputs for modeling and analysis codes and are designed to interface with the GFM. Box plots of parameter values from individual lithologic units as well as from those grouped by measurement type help visualize the variations within and among each lithologic unit.

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REFERENCES

Bodmer, M., Townsend, M., Roberts, B., Wilson, J., Reppart, J., Smith, D., Downs, N., Feldman, J., Choens, R.C., Heath, J., Holland, A., Barrow, P., Bartlett, T., Boukhalfa, H., Broome, S., Dietel, M., Downs, C., Ezzedine, S., Freimuth, C., Griego, J., Ingraham, M., Jaramillo, J., Jones, K., Kibikas, W., Kuhlman, K., Larotonda, J., Miller, A., Otto, S., Powell, M., Rodriguez, M., Tafoya, J., Valdez, N., Xu, G., 2024. LYNM PE1 Pre-Experiment A Site Characterization Report, SAND2024-07522.

Kibikas, W.M., Wilson, J.E., Jaramillo, J.L., Broome, S.T., Bodmer, M.A., Choens, R.C., Feldman, J. Geomechanical Properties of Vitric and Zeolitic Nonwelded Tuffs from the PE1 Testbed, Geomechanics for Energy and the Environment (submitted).

Myers, et al., 2024. A multi-Physics Experiment for Low-Yield Nuclear Explosion Monitoring. LLNL-TR-864107, 17p. DOI:https://doi.org/10.2172/2345984.

Wilson, J.E., Heath, J.E., Kuhlman, K.L., Xu, G., Bodmer, M.A., Broome, S.T., Jaramillo, J.L., Barrow, P., Rodriguez, M.A., Griego, J.J.M., Valdez, N.R., Reppart, J., Smith, D., Larotonda, J., Townsend, M., 2024. PE1 Site Characterization: Data Documentation on Geologic and Hydrologic Lab Testing. SAND2024-07526.

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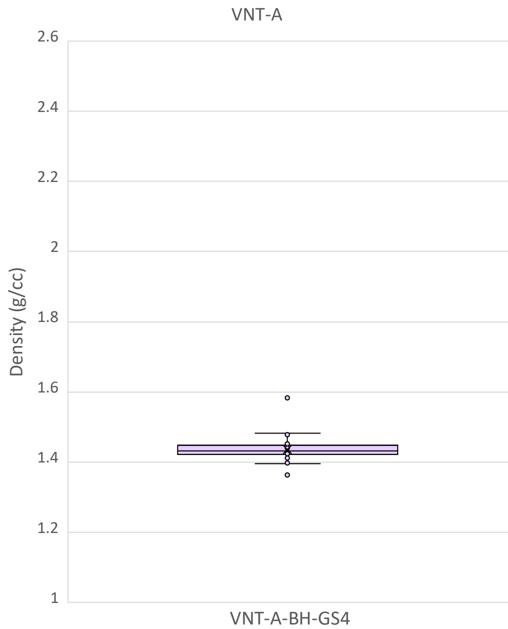
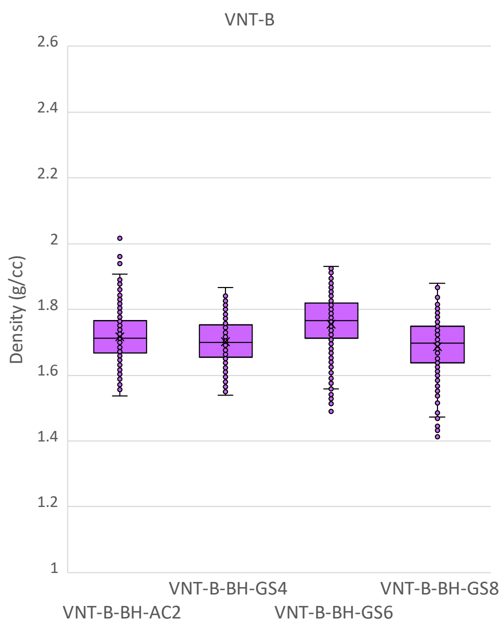
APPENDIX A. DENSITY



Unit & Data Source	# Data Points	Average (g/cc)	Std Dev (g/cc)	Min (g/cc)	Max (g/cc)
VNT-A-BH-GS4	34	1.436	0.035	1.364	1.584

- Anomalous values from <10.8’ in GS-4 and all data from GS-6 and GS-8 excluded due to borehole log irregularities
- Anomalously high values come from what appears to be a transition to different lithology at 22.4-23.0’; no irregularity in borehole log

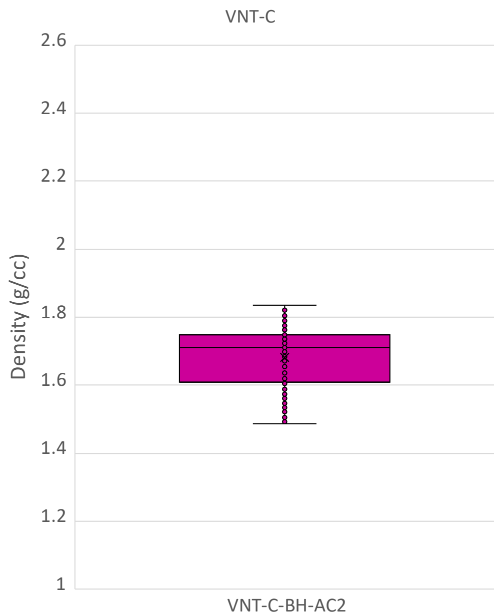
Figure A-1. Density values for VNT-A from borehole logs.



Unit & Data Source	# Data Points	Average (g/cc)	Std Dev (g/cc)	Min (g/cc)	Max (g/cc)
VNT-B-BH-AC2	436	1.716	0.075	1.536	2.019
VNT-B-BH-GS4	292	1.702	0.067	1.539	1.866
VNT-B-BH-GS6	442	1.755	0.085	1.491	1.930
VNT-B-BH-GS8	336	1.686	0.086	1.412	1.880

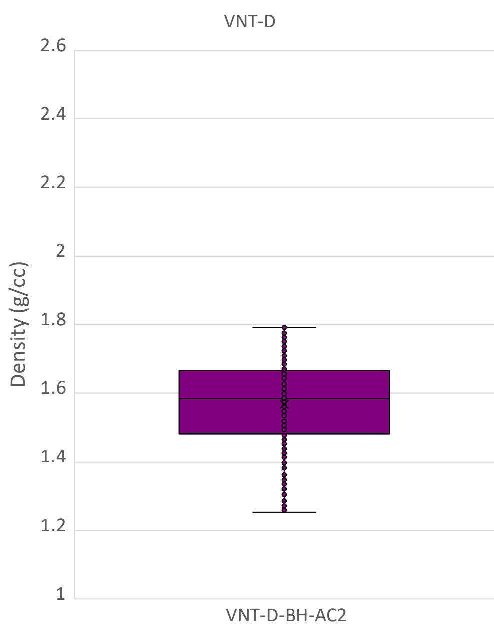
- Anomalous values from <10.0’ in AC-2, GS-6, and GS-8 excluded due to borehole log irregularities
- High values in AC-2 come from a zone at 10.6-11.7’, where there is a gradational increase then decrease with depth, no irregularities observed in borehole log
- Low values in GS-8 come from 31.1-33.6’, where there is a gradational decrease then increase with depth, appears to be lithologic variation

Figure A-2. Density values for VNT-B from borehole logs.



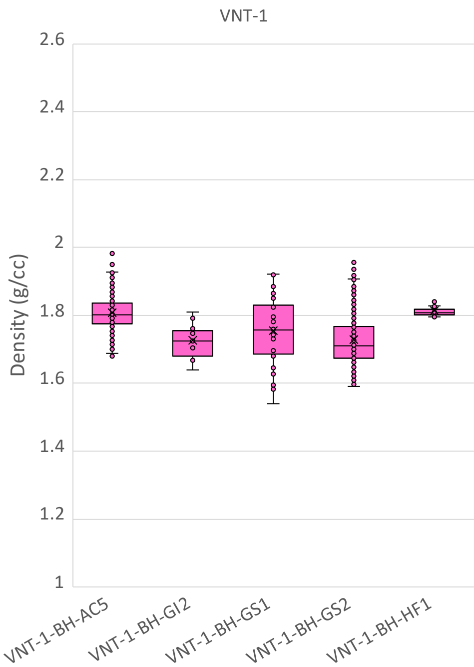
Unit & Data Source	# Data Points	Average (g/cc)	Std Dev (g/cc)	Min (g/cc)	Max (g/cc)
VNT-C-BH-AC2	261	1.682	0.088	1.486	1.835

Figure A-3. Density values for VNT-C from borehole logs.



Unit & Data Source	# Data Points	Average (g/cc)	Std Dev (g/cc)	Min (g/cc)	Max (g/cc)
VNT-D-BH-AC2	335	1.568	0.128	1.254	1.791

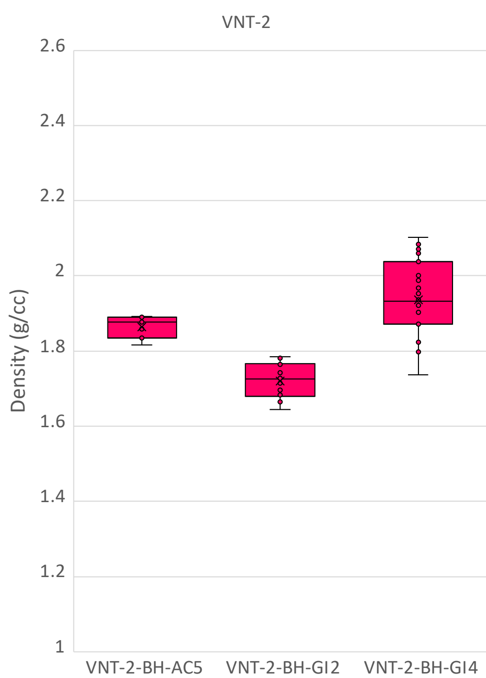
Figure A-4. Density values for VNT-D from borehole logs.



Unit & Data Source	# Data Points	Average (g/cc)	Std Dev (g/cc)	Min (g/cc)	Max (g/cc)
VNT-1-BH-AC5	416	1.808	0.048	1.680	1.983
VNT-1-BH-GI2	15	1.726	0.048	1.639	1.810
VNT-1-BH-GS1	40	1.755	0.093	1.540	1.921
VNT-1-BH-GS2	376	1.728	0.076	1.590	1.957
VNT-1-BH-HF1	40	1.813	0.015	1.796	1.848

- Anomalous values excluded: <10' in AC-5, <3' in GI-2, <5' in GS-1, and <10' in GS-2 due to borehole log irregularities
- Anomalously high values in AC-5 are from 56.7-60.5' with no borehole irregularities
- Anomalous high values in GS-1 are from 15.8-17.7' with no borehole irregularities

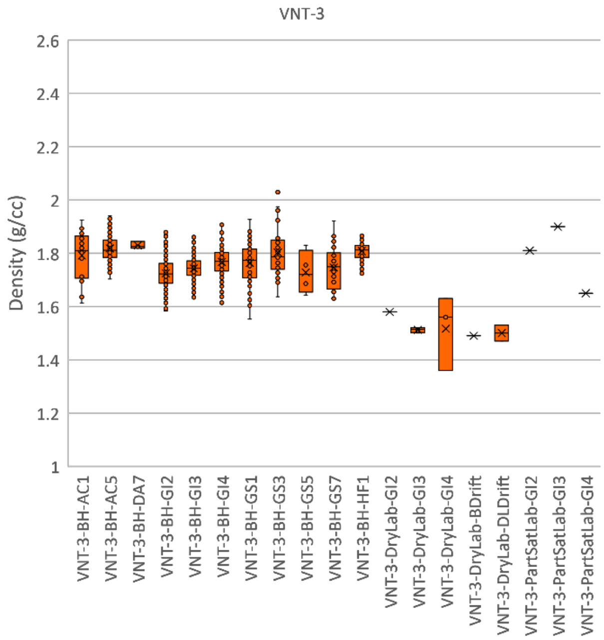
Figure A-5. Density values for VNT-1 from borehole logs.



Unit & Data Source	# Data Points	Average (g/cc)	Std Dev (g/cc)	Min (g/cc)	Max (g/cc)
VNT-2-BH-AC5	7	1.864	0.029	1.815	1.893
VNT-2-BH-GI2	14	1.721	0.045	1.644	1.785
VNT-2-BH-GI4	27	1.936	0.104	1.736	2.102

- Large ranges of values in GI-2 and GI-4 appear to represent natural lithologic variations, no data excluded

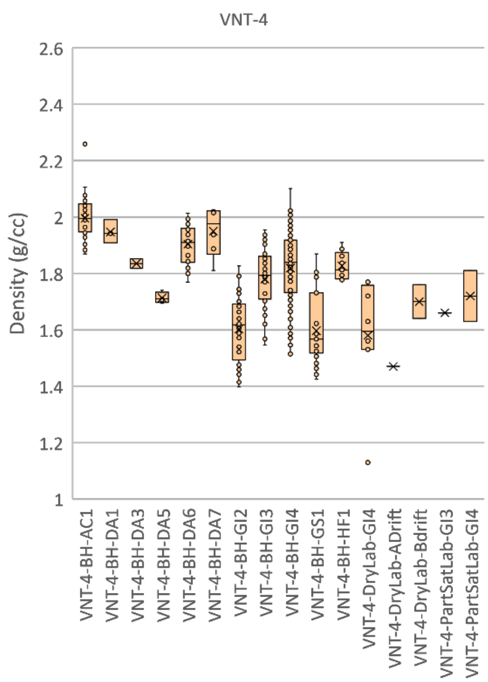
Figure A-6. Density values for VNT-2 from borehole logs.



Unit & Data Source	# Data Points	Average (g/cc)	Std Dev (g/cc)	Min (g/cc)	Max (g/cc)
VNT-3-BH-AC1	17	1.792	0.104	1.736	2.102
VNT-3-BH-AC5	331	1.818	0.044	1.703	1.941
VNT-3-BH-DA7	3	1.829	0.013	1.819	1.906
VNT-3-BH-GI2	162	1.725	0.058	1.584	1.879
VNT-3-BH-GI3	272	1.743	0.040	1.635	1.860
VNT-3-BH-GI4	172	1.768	0.054	1.614	1.908
VNT-3-BH-GS1	82	1.764	0.072	1.553	1.926
VNT-3-BH-GS3	39	1.803	0.084	1.637	2.029
VNT-3-BH-GS5	4	1.729	0.082	1.643	1.830
VNT-3-BH-HF1	249	1.808	0.032	1.721	1.870
VNT-3-DryLab-GI2	1	1.580	n/a	n/a	n/a
VNT-3-DryLab-GI3	4	1.513	0.010	1.500	1.520
VNT-3-DryLab-GI4	3	1.517	0.140	1.360	1.630
VNT-3-DryLab-Bdrift	1	1.490	n/a	n/a	n/a
VNT-3-DryLab-DLDrift	2	1.500	0.042	1.470	1.530
VNT-3-PartSatLab-GI2	1	1.810	n/a	n/a	n/a
VNT-3-PartSatLab-GI3	1	1.900	n/a	n/a	n/a
VNT-3-PartSatLab-GI4	1	1.650	n/a	n/a	n/a

- Anomalous values excluded: >110′ in AC-5, <7′ in DA-5 (all VNT-3 data), <8′ in DA-6 (all VNT-3 data), <7.1′ in DA-7 due to borehole log irregularities
- Lower values from Dry Lab reflect dry conditions compared to partially saturated conditions during borehole logging and preserved samples used for PartSat Lab tests

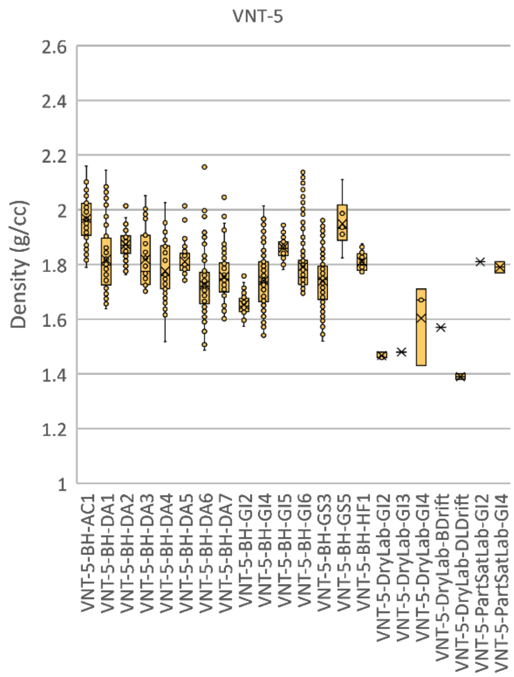
Figure A-7. Density values for VNT-3 from borehole logs and lab measurements on dry and partially saturated samples.



Unit & Data Source	# Data Points	Average (g/cc)	Std Dev (g/cc)	Min (g/cc)	Max (g/cc)
VNT-4-BH-AC1	32	1.995	0.078	1.869	2.259
VNT-4-BH-DA1	3	1.947	0.041	1.909	1.991
VNT-4-BH-DA3	2	1.835	0.025	1.817	1.852
VNT-4-BH-DA5	4	1.713	0.020	1.694	1.741
VNT-4-BH-DA6	30	1.904	0.067	1.770	2.013
VNT-4-BH-DA7	6	1.950	0.088	1.811	2.027
VNT-4-BH-GI2	52	1.603	0.110	1.398	1.827
VNT-4-BH-GI3	37	1.780	0.112	1.547	1.954
VNT-4-BH-GI4	152	1.819	0.132	1.509	2.101
VNT-4-BH-GS1	27	1.597	0.125	1.424	1.869
VNT-4-BH-HF1	9	1.826	0.050	1.774	1.909
VNT-4-DryLab-GI4	8	1.580	0.208	1.130	1.770
VNT-4-DryLab-Adrift	1	1.470	n/a	n/a	n/a
VNT-4-DryLab-Bdrift	2	1.700	0.085	1.640	1.760
VNT-4-PartSatLab-GI3	1	1.660	n/a	n/a	n/a
VNT-4-PartSatLab-GI4	2	1.720	0.127	1.630	1.810

- Anomalous values excluded: >110′ in AC-5 (all VNT-4 data) due to borehole log irregularities
- Anomalously high value in AC-1 @ 12.5′ appears to reflect heterogeneity; no borehole log anomalies
- Anomalous low value from DryLab in GI-4 is from 54.4′, which a lens of highly porous, friable, vitric, pumice-rich tuff; interpretation is that the value reflects heterogeneity in VNT-4

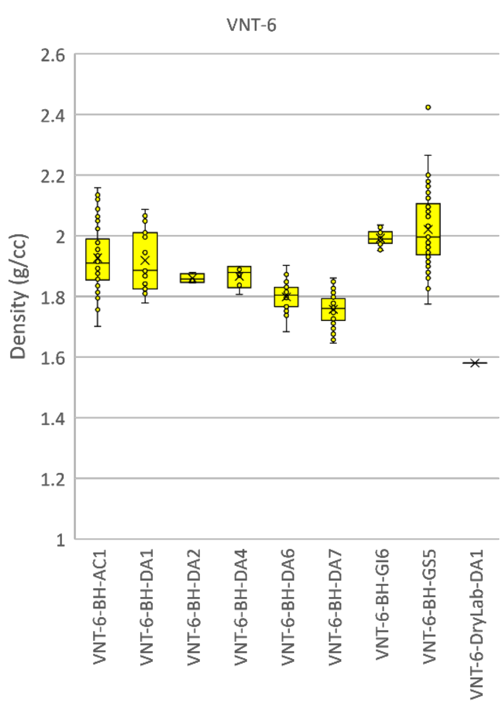
Figure A-8. Density values for VNT-4 from borehole logs and lab measurements on dry and partially saturated samples.



Unit & Data Source	# Data Points	Average (g/cc)	Std Dev (g/cc)	Min (g/cc)	Max (g/cc)
VNT-5-BH-AC1	57	1.968	0.080	1.790	2.159
VNT-5-BH-DA1	60	1.819	0.116	1.638	2.144
VNT-5-BH-DA2	38	1.873	0.052	1.763	2.015
VNT-5-BH-DA3	27	1.818	0.107	1.701	2.051
VNT-5-BH-DA4	42	1.776	0.103	1.518	2.025
VNT-5-BH-DA5	41	1.811	0.056	1.738	2.014
VNT-5-BH-DA6	60	1.724	0.120	1.486	2.156
VNT-5-BH-DA7	83	1.756	0.088	1.595	2.046
VNT-5-BH-GI2	34	1.653	0.042	1.574	1.758
VNT-5-BH-GI4	152	1.741	0.102	1.538	2.014
VNT-5-BH-GI5	36	1.862	0.039	1.781	1.948
VNT-5-BH-GI6	303	1.792	0.105	1.690	2.143
VNT-5-BH-GS3	171	1.739	0.090	1.521	1.963
VNT-5-BH-GS5	6	1.949	0.095	1.824	2.111
VNT-5-BH-HF1	42	1.810	0.032	1.772	1.876
VNT-5-DryLab-GI2	3	1.467	0.012	1.460	1.480
VNT-5-DryLab-GI3	1	1.480	n/a	n/a	n/a
VNT-5-DryLab-GI4	3	1.603	0.151	1.430	1.710
VNT-5-DryLab-Bdrift	1	1.570	n/a	n/a	n/a
VNT-5-DryLab-DLDrift	2	1.390	0.014	1.380	1.400
VNT-5-PartSatLab-GI2	1	1.810	n/a	n/a	n/a
VNT-5-PartSatLab-GI4	2	1.790	0.028	1.770	1.810

- Low value from Dry Lab DL Drift sample could represent heterogeneity in VNT-5
- Anomalous values excluded: <7.2' in DA-5, >58' in GS-3, >80' in HF-1 due to borehole log irregularities
- Anomalously high value in GS-5 is from 29.1' and occurs within a zone of increased densities; borehole log shows subtle changes in caliper and decrease in density-porosity with stable compensation

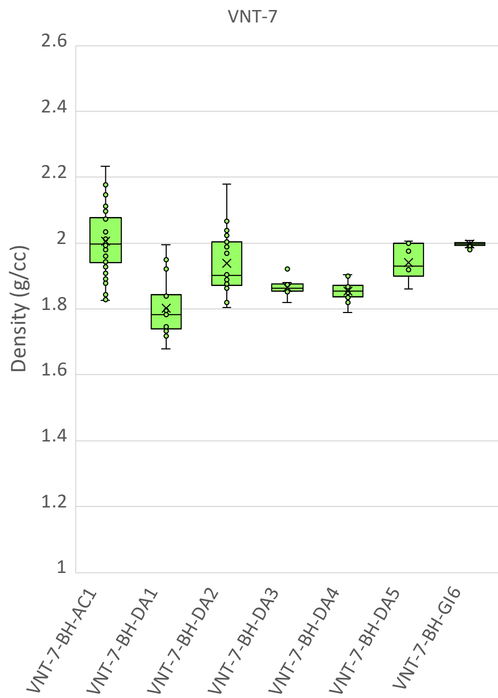
Figure A-9. Density values for VNT-5 from borehole logs and lab measurements on dry and partially saturated samples.



Unit & Data Source	# Data Points	Average (g/cc)	Std Dev (g/cc)	Min (g/cc)	Max (g/cc)
VNT-6-BH-AC1	58	1.927	0.106	1.702	2.158
VNT-6-BH-DA1	20	1.919	0.099	1.778	2.087
VNT-6-BH-DA2	4	1.859	0.015	1.844	1.879
VNT-6-BH-DA4	6	1.866	0.037	1.806	1.899
VNT-6-BH-DA6	24	1.799	0.048	1.684	1.903
VNT-6-BH-DA7	38	1.757	0.053	1.646	1.860
VNT-6-BH-GI6	47	1.992	0.025	1.950	2.036
VNT-6-BH-GS5	63	2.020	0.119	1.775	2.424
VNT-6-DryLab-DA1	1	1.580	n/a	n/a	n/a

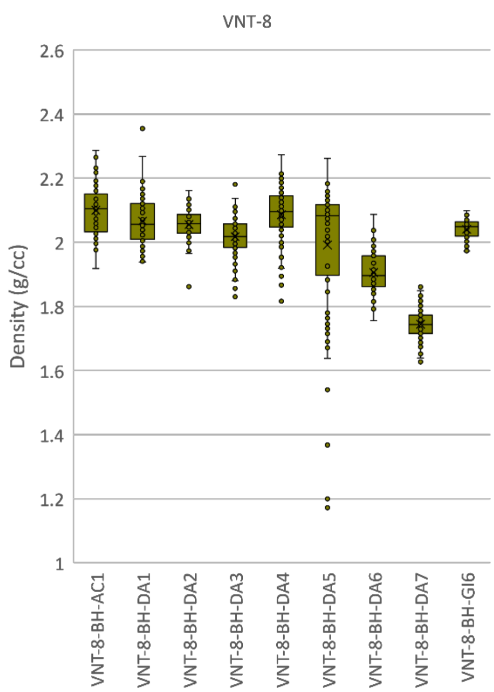
- Anomalous values excluded from drilling depths >58' in GS-3 due to borehole log irregularity (results in all values from GS-3 being excluded)
- Anomalously high value in GS-5 @ 37.2' appears to reflect peak density in a high-density zone, could represent lithologic variability

Figure A-10. Density values for VNT-6 from borehole logs and lab measurements on dry samples.



Unit & Data Source	# Data Points	Average (g/cc)	Std Dev (g/cc)	Min (g/cc)	Max (g/cc)
VNT-7-BH-AC1	48	2.006	0.096	1.825	2.234
VNT-7-BH-DA1	15	1.803	0.091	1.679	1.994
VNT-7-BH-DA2	23	1.940	0.092	1.805	2.178
VNT-7-BH-DA3	9	1.865	0.027	1.820	1.921
VNT-7-BH-DA4	12	1.855	0.032	1.790	1.905
VNT-7-BH-DA5	7	1.941	0.054	1.861	2.005
VNT-7-BH-GI6	15	1.997	0.007	1.980	2.007

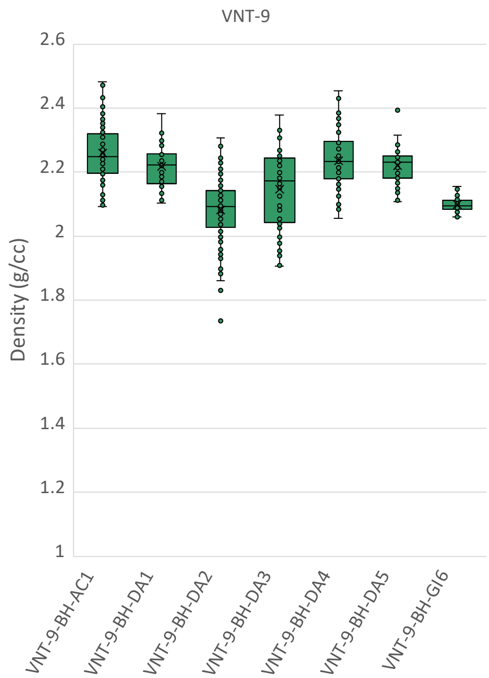
Figure A-11. Density values for VNT-7 from borehole logs.



Unit & Data Source	# Data Points	Average (g/cc)	Std Dev (g/cc)	Min (g/cc)	Max (g/cc)
VNT-8-BH-AC1	86	2.100	0.076	1.918	2.286
VNT-8-BH-DA1	72	2.066	0.082	1.939	2.355
VNT-8-BH-DA2	48	2.056	0.052	1.862	2.162
VNT-8-BH-DA3	85	2.018	0.061	1.831	2.181
VNT-8-BH-DA4	95	2.086	0.086	1.817	2.273
VNT-8-BH-DA5	96	1.992	0.215	1.172	2.261
VNT-8-BH-DA6	47	1.906	0.070	1.756	2.087
VNT-8-BH-DA7	92	1.745	0.044	1.627	1.861
VNT-8-BH-GI6	141	2.041	0.032	1.972	2.098

- Anomalous values excluded: >29.8’ in DA-6 due to borehole log irregularity
- Anomalously low values in DA-5 are from 20.0-20.4’ and appear to represent a natural low density zone

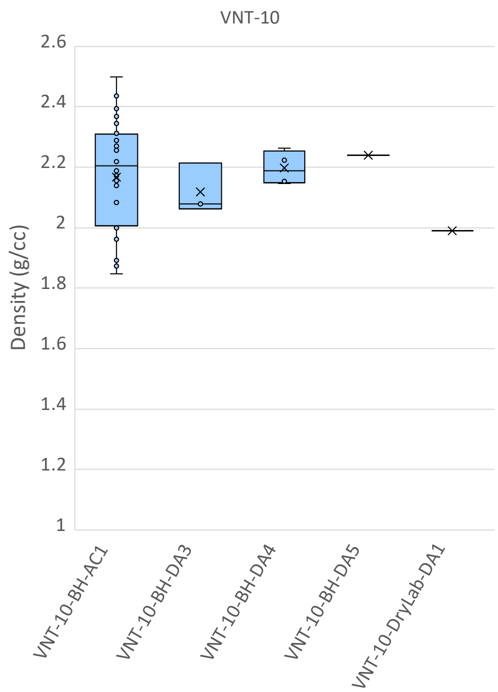
Figure A-12. Density values for VNT-8 from borehole logs.



Unit & Data Source	# Data Points	Average (g/cc)	Std Dev (g/cc)	Min (g/cc)	Max (g/cc)
VNT-9-BH-AC1	85	2.258	0.088	2.093	2.483
VNT-9-BH-DA1	40	2.217	0.061	2.103	2.382
VNT-9-BH-DA2	96	2.081	0.107	1.735	2.307
VNT-9-BH-DA3	70	2.148	0.119	1.906	2.379
VNT-9-BH-DA4	47	2.235	0.089	2.057	2.455
VNT-9-BH-DA5	35	2.221	0.059	2.109	2.393
VNT-9-BH-GI6	132	2.099	0.021	2.059	2.155

- Anomalous values excluded: >29.8’ in DA-6 (all VNT9 data from DA-6) due to borehole log irregularity
- Low value from DA-2 @ 32.7-32.8’ is from a slightly wider interval (32.6-32.9’) over lower densities

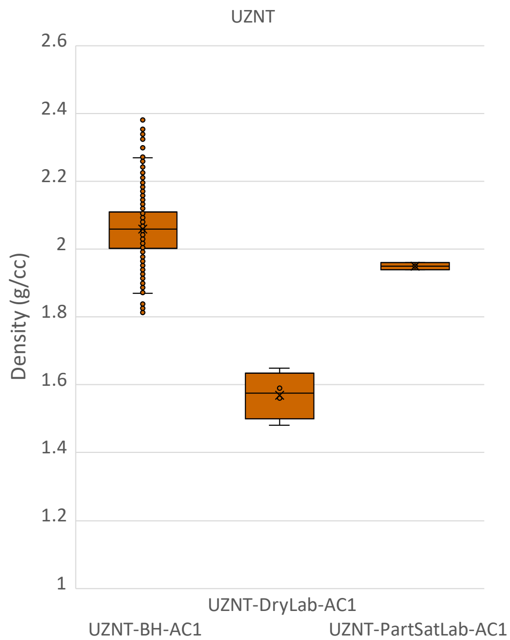
Figure A-13. Density values for VNT-9 from borehole logs.



Unit & Data Source	# Data Points	Average (g/cc)	Std Dev (g/cc)	Min (g/cc)	Max (g/cc)
VNT-10-BH-AC1	36	2.168	0.183	1.847	2.499
VNT-10-BH-DA3	3	2.118	0.084	2.061	2.214
VNT-10-BH-DA4	4	2.197	0.057	2.146	2.264
VNT-10-BH-DA5	1	2.240	n/a	n/a	n/a
VNT-10-DryLab-DA1	1	1.990	n/a	n/a	n/a

- Low value from Dry Lab measurement may represent difference in saturation conditions compared to in situ borehole logging

Figure A-14. Density values for VNT-10 from borehole logs and lab measurement on a dry sample.

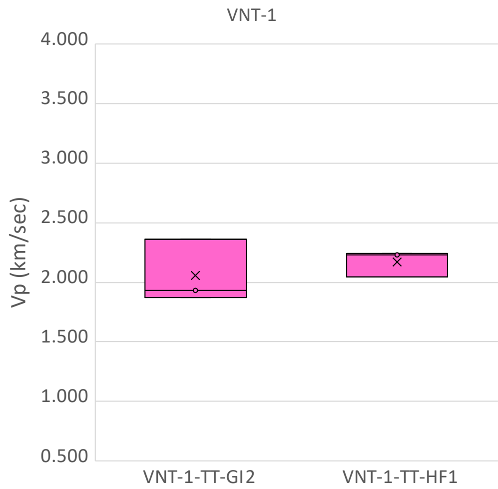


Unit & Data Source	# Data Points	Average (g/cc)	Std Dev (g/cc)	Min (g/cc)	Max (g/cc)
UZNT-BH-AC1	1049	2.060	0.083	1.813	2.381
UZNT-DryLab-AC1	4	1.570	0.071	1.480	1.650
UZNT-PartSatLab-AC1	3	1.950	0.010	1.940	1.960

- Large range of values from AC-1 borehole log likely reflects heterogeneity within UZNT with highs and lows occurring at all depths; no anomalous signal observed in borehole log

Figure A-15. Density values for UZNT from borehole logs and lab measurements on dry and partially saturated samples.

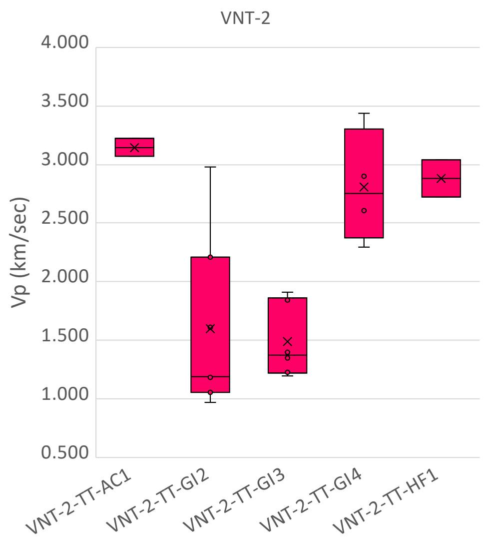
APPENDIX B. P-WAVE VELOCITY



Unit & Data Source	# Data Points	Average (km/sec)	Std Dev (km/sec)	Min (km/sec)	Max (km/sec)
VNT-1-TT-GI2	3	2.055	0.265	1.873	2.359
VNT-1-TT-HF1	3	2.172	0.109	2.047	2.240

- Anomalously low (1.3 km/sec) values in BH-GI2 excluded

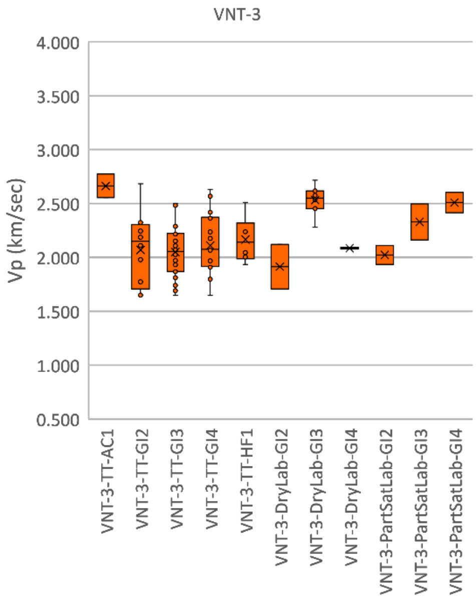
Figure B-16. P-wave velocities for VNT-1 from tabletop measurements.



Unit & Data Source	# Data Points	Average (km/sec)	Std Dev (km/sec)	Min (km/sec)	Max (km/sec)
VNT-2-TT-AC1	2	3.145	0.007	1.287	2.981
VNT-2-TT-GI2	7	1.601	0.108	3.069	3.221
VNT-2-TT-GI3	6	1.488	0.311	1.197	1.913
VNT-2-TT-GI4	4	2.810	0.484	2.296	3.435
VNT-2-TT-HF1	2	2.882	0.227	2.721	3.043

- Anomalously low (1.3 km/sec) values from GI2, GI3, and GI4 borehole logs excluded
- High and low values from GI-2 TT measurements represent lithologic variations

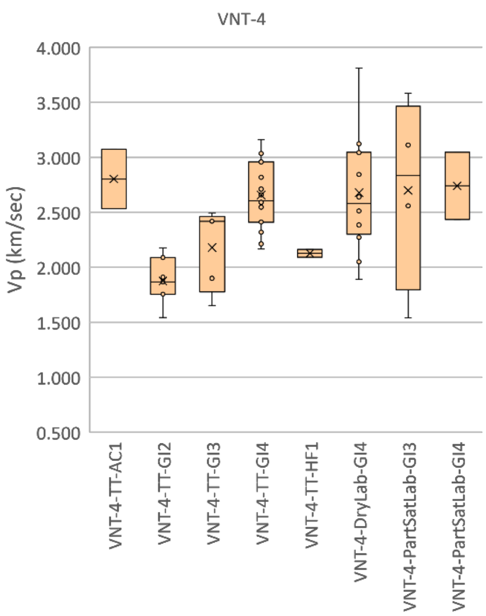
Figure B-2. P-wave velocities for VNT-2 from tabletop measurements.



Unit & Data Source	# Data Points	Average (km/sec)	Std Dev (km/sec)	Min (km/sec)	Max (km/sec)
VNT-3-TT-AC1	2	2.662	0.156	2.552	2.773
VNT-3-TT-GI2	12	2.069	0.328	1.646	2.683
VNT-3-TT-GI3	28	2.050	0.222	1.646	2.501
VNT-3-TT-GI4	18	2.110	0.276	1.648	2.631
VNT-3-TT-HF1	6	2.164	0.212	1.934	2.509
VNT-3-DryLab-GI2	2	1.914	0.293	1.706	2.121
VNT-3-DryLab-GI3	7	2.532	0.137	2.281	2.715
VNT-3-DryLab-GI4	2	2.085	0.011	2.077	2.092
VNT-3-PartSatLab-GI2	2	2.023	0.124	1.935	2.110
VNT-3-PartSatLab-GI3	2	2.329	0.235	2.162	2.495
VNT-3-PartSatLab-GI4	2	2.509	0.133	2.415	2.603

- Anomalously low (1.3 km/sec) values from GI2, GI3, and GI4 borehole logs excluded
- Anomalously low value from GI-3 Dry Lab test at 15.9’ excluded since there are no corresponding lithologic variations

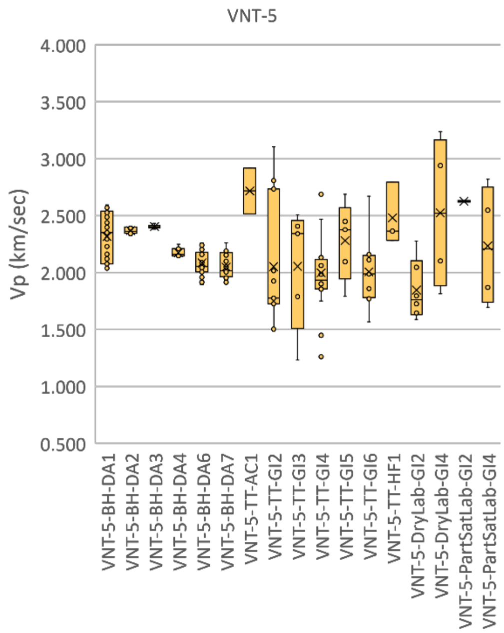
Figure B-3. P-wave velocities for VNT-3 from tabletop measurements and lab measurements on dry and partially saturated samples.



Unit & Data Source	# Data Points	Average (km/sec)	Std Dev (km/sec)	Min (km/sec)	Max (km/sec)
VNT-4-TT-AC1	2	2.803	0.383	2.532	3.074
VNT-4-TT-GI2	7	1.874	0.213	1.542	2.177
VNT-4-TT-GI3	5	2.179	0.379	1.653	2.495
VNT-4-TT-GI4	19	2.657	0.289	2.164	3.160
VNT-4-TT-HF1	2	2.126	0.050	2.091	2.162
VNT-4-DryLab-GI4	12	2.678	0.530	1.892	3.810
VNT-4-PartSatLab-GI3	4	2.699	0.878	1.541	3.584
VNT-4-PartSatLab-GI4	2	2.740	0.433	2.434	3.046

- Anomalously low (1.3 km/sec) values from GI2, GI3, and GI4 borehole logs excluded
- Anomalously low values from GI-4 tabletop measurements at 45.8’ (GI3) and 53.4’ (GI4) are included since they represent lithologic variations and have correspondingly anomalous Vp values

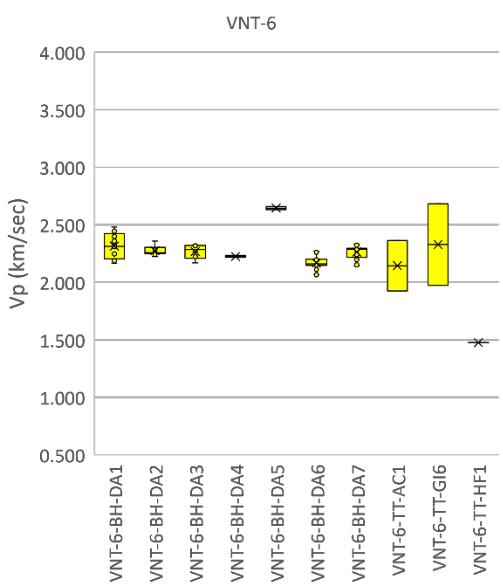
Figure B-4. P-wave velocities for VNT-4 from tabletop measurements and lab measurements on dry and partially saturated samples.



Unit & Data Source	# Data Points	Average (km/sec)	Std Dev (km/sec)	Min (km/sec)	Max (km/sec)
VNT-5-BH-DA1	51	2.316	0.216	2.035	2.594
VNT-5-BH-DA2	8	2.368	0.030	2.323	2.406
VNT-5-BH-DA3	24	2.403	0.014	2.381	2.433
VNT-5-BH-DA4	7	2.174	0.041	2.134	2.250
VNT-5-BH-DA6	51	2.085	0.104	1.895	2.261
VNT-5-BH-DA7	76	2.048	0.110	1.915	2.261
VNT-5-TT-AC1	2	2.716	0.285	2.514	2.918
VNT-5-TT-GI2	11	2.052	0.561	1.484	3.104
VNT-5-TT-GI3	5	2.055	0.538	1.231	2.507
VNT-5-TT-GI4	16	1.997	0.382	1.261	2.705
VNT-5-TT-GI5	5	2.280	0.345	1.790	2.687
VNT-5-TT-GI6	9	2.006	0.318	1.565	2.670
VNT-5-TT-HF1	3	2.480	0.276	2.281	2.795
VNT-5-DryLab-GI2	6	1.846	0.264	1.588	2.276
VNT-5-DryLab-GI4	4	2.524	0.675	1.813	3.239
VNT-5-PartSatLab-GI2	2	2.626	0.008	2.620	2.632
VNT-5-PartSatLab-GI4	4	2.233	0.537	1.695	2.819

- Anomalously low (1.3 km/sec) values from GI2, GI3, and GI4 borehole logs excluded
- Anomalous data from GI-4 (61.5', 62.9', and 73.7'), GI-5 (19.6'), and HF-1 (69.8') tabletop measurements included since they correspond to observed lithologic variations
- Anomalously high value from GI-6 tabletop measurement at 41.7' excluded since there are no corresponding lithologic variations

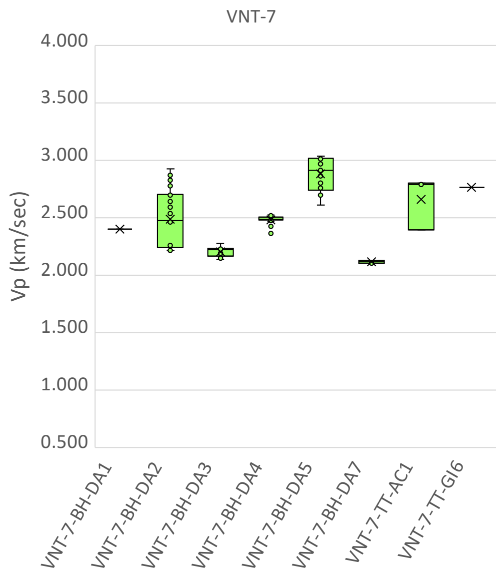
Figure B-5. P-wave velocities for VNT-5 from borehole logs, tabletop measurements, and lab measurements on dry and partially saturated samples.



Unit & Data Source	# Data Points	Average (km/sec)	Std Dev (km/sec)	Min (km/sec)	Max (km/sec)
VNT-6-BH-DA1	13	2.314	0.111	2.167	2.479
VNT-6-BH-DA2	10	2.273	0.039	2.223	2.358
VNT-6-BH-DA3	6	2.267	0.061	2.168	2.326
VNT-6-BH-DA4	2	2.224	0.011	2.216	2.232
VNT-6-BH-DA5	2	2.645	0.020	2.631	2.658
VNT-6-BH-DA6	30	2.166	0.056	2.065	2.269
VNT-6-BH-DA7	44	2.263	0.053	2.141	2.331
VNT-6-TT-AC1	2	2.144	0.310	1.924	2.363
VNT-6-TT-GI6	2	2.327	0.501	1.973	2.682
VNT-6-TT-HF1	1	1.475	n/a	n/a	n/a

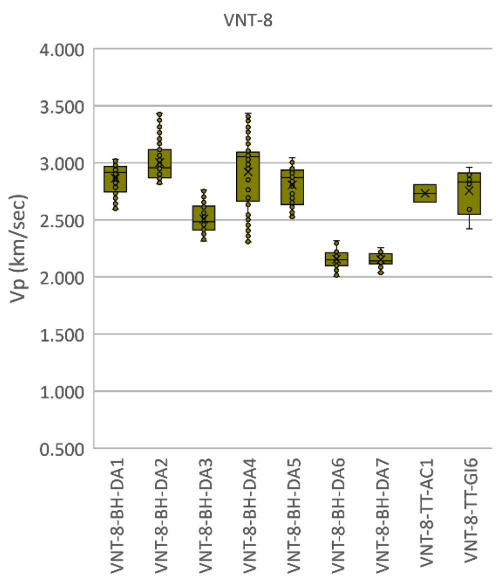
- Anomalous data from HF-1 (83.7') TT measurement included since it corresponds to observed lithologic variations (including hardness and permeability measurements)

Figure B-6. P-wave velocities for VNT-6 from borehole logs and tabletop measurements.



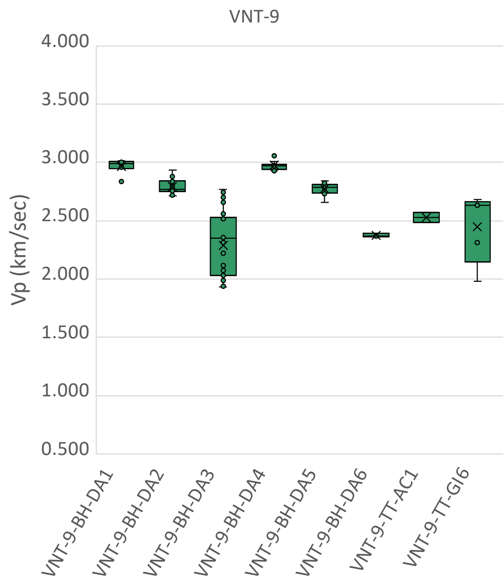
Unit & Data Source	# Data Points	Average (km/sec)	Std Dev (km/sec)	Min (km/sec)	Max (km/sec)
VNT-7-BH-DA1	2	2.399	0.004	2.396	2.402
VNT-7-BH-DA2	26	2.486	0.251	2.215	2.926
VNT-7-BH-DA3	15	2.204	0.038	2.137	2.273
VNT-7-BH-DA4	18	2.482	0.037	2.365	2.526
VNT-7-BH-DA5	13	2.878	0.147	2.612	3.037
VNT-7-BH-DA7	6	2.117	0.011	2.105	2.128
VNT-7-TT-AC1	3	2.660	0.232	2.393	2.802
VNT-7-TT-GI6	1	2.765	n/a	n/a	n/a

Figure B-7. P-wave velocities for VNT-7 from borehole logs and tabletop measurements.



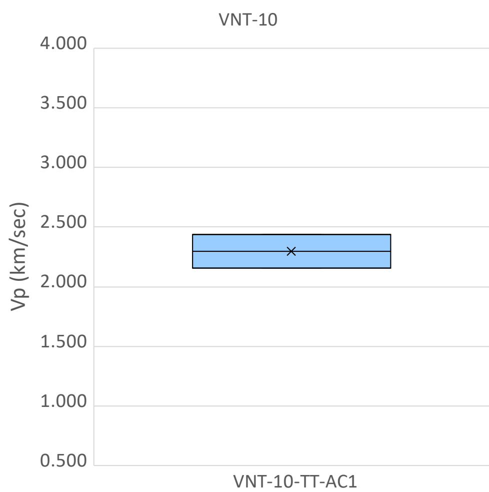
Unit & Data Source	# Data Points	Average (km/sec)	Std Dev (km/sec)	Min (km/sec)	Max (km/sec)
VNT-8-BH-DA1	78	2.865	0.134	2.593	3.032
VNT-8-BH-DA2	51	3.002	0.168	2.815	3.432
VNT-8-BH-DA4	85	2.509	0.117	2.315	2.764
VNT-8-BH-DA5	101	2.921	0.327	2.306	3.432
VNT-8-BH-DA6	96	2.807	0.159	2.524	3.043
VNT-8-BH-DA7	73	2.156	0.080	2.005	2.316
VNT-8-TT-AC1	61	2.152	0.060	2.037	2.254
VNT-8-TT-GI6	2	2.733	0.107	2.657	2.809

Figure B-8. P-wave velocities for VNT-8 from borehole logs and tabletop measurements.



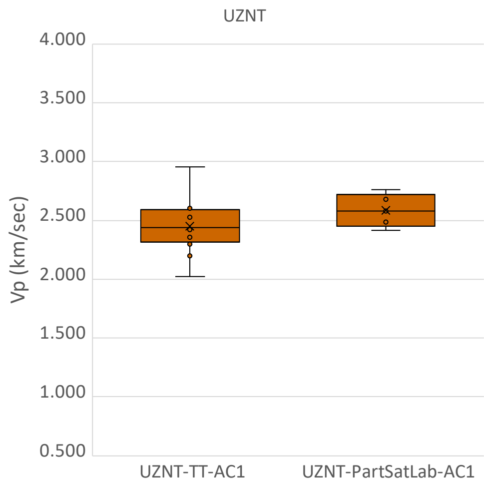
Unit & Data Source	# Data Points	Average (km/sec)	Std Dev (km/sec)	Min (km/sec)	Max (km/sec)
VNT-9-BH-DA1	7	2.965	0.062	2.836	3.015
VNT-9-BH-DA2	65	2.796	0.057	2.712	2.935
VNT-9-BH-DA3	51	2.289	0.268	1.934	2.771
VNT-9-BH-DA4	35	2.974	0.044	2.931	3.095
VNT-9-BH-DA5	20	2.774	0.047	2.658	2.840
VNT-9-BH-DA6	3	2.374	0.015	2.361	2.391
VNT-9-TT-AC1	2	2.527	0.060	2.485	2.570
VNT-9-TT-GI6	5	2.452	0.302	1.979	2.681

Figure B-9. P-wave velocities for VNT-9 from borehole logs and tabletop measurements.



Unit & Data Source	# Data Points	Average (km/sec)	Std Dev (km/sec)	Min (km/sec)	Max (km/sec)
VNT-10-TT-AC1	2	2.297	0.203	2.153	2.440

Figure B-10. P-wave velocities for VNT-10 from tabletop measurements.

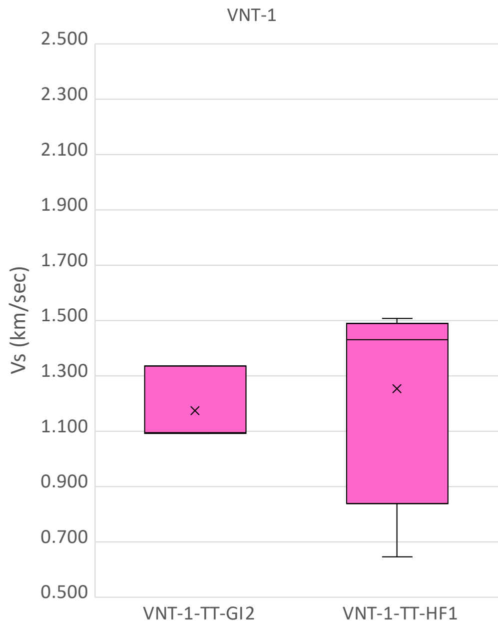


Unit & Data Source	# Data Points	Average (km/sec)	Std Dev (km/sec)	Min (km/sec)	Max (km/sec)
UZNT-TT-AC1	12	2.450	0.235	2.023	2.956
UZNT-PartSatLab-AC1	5	2.585	0.140	2.418	2.763

- Anomalously low value from AC-1 Part Sat Lab test at 146.8’ excluded since there are no corresponding lithologic variations

Figure B-11. P-wave velocities for UZNT from tabletop measurements and lab measurements on partially saturated samples.

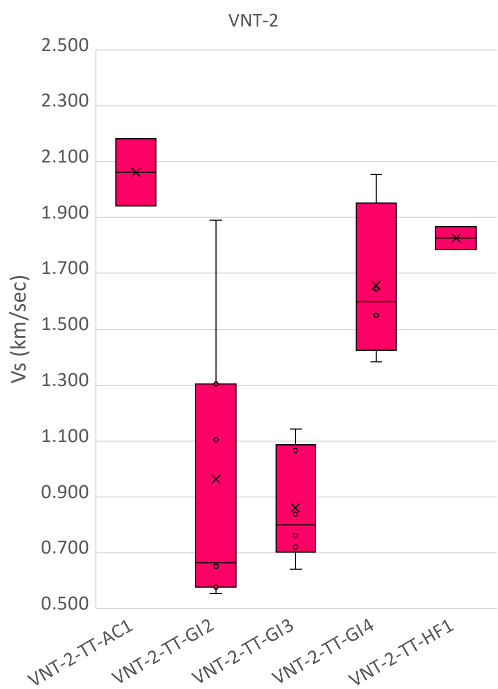
APPENDIX C. S-WAVE VELOCITY



Unit & Data Source	# Data Points	Average (km/sec)	Std Dev (km/sec)	Min (km/sec)	Max (km/sec)
VNT-1-TT-GI2	3	1.174	0.139	1.093	1.335
VNT-1-TT-HF1	4	1.253	0.406	0.646	1.507

- Anomalously low value from HF-1 (15.6') TT measurement included due to observed lithologic variations

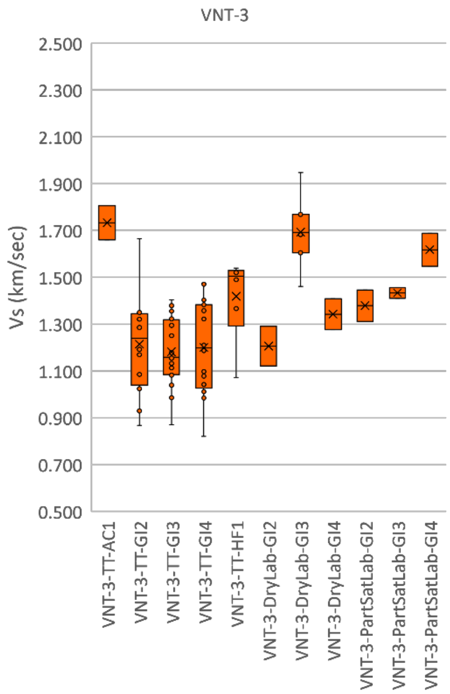
Figure C-1. S-wave velocities for VNT-1 from tabletop measurements.



Unit & Data Source	# Data Points	Average (km/sec)	Std Dev (km/sec)	Min (km/sec)	Max (km/sec)
VNT-2-TT-AC1	2	2.062	0.169	1.942	2.181
VNT-2-TT-GI2	7	0.964	0.500	0.554	1.891
VNT-2-TT-GI3	6	0.862	0.200	0.641	1.142
VNT-2-TT-GI4	4	1.658	0.286	1.383	2.054
VNT-2-TT-HF1	2	1.827	0.061	0.577	0.664

- Anomalously low values from GI-2 (13.3-17.0') and GI-3 (0.5'-5.3') TT measurements included due to observed lithologic variations

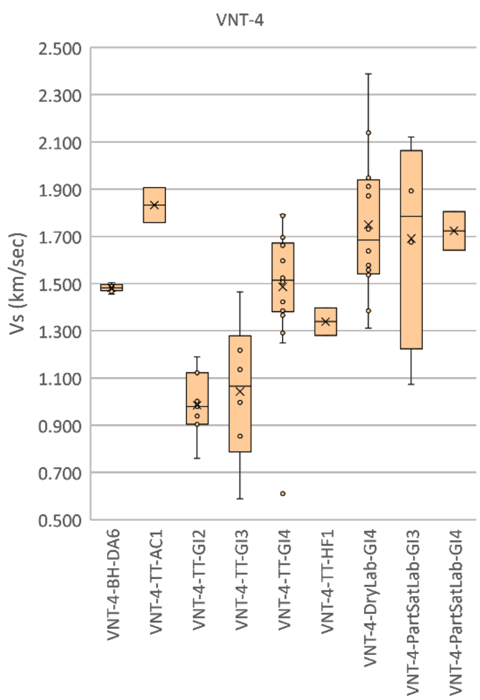
Figure C-2. S-wave velocities for VNT-2 from tabletop measurements.



Unit & Data Source	# Data Points	Average (km/sec)	Std Dev (km/sec)	Min (km/sec)	Max (km/sec)
VNT-3-TT-AC1	2	1.732	0.104	1.659	1.806
VNT-3-TT-GI2	12	1.214	0.219	0.868	1.665
VNT-3-TT-GI3	28	1.181	0.140	0.870	1.403
VNT-3-TT-GI4	18	1.200	0.195	0.821	1.475
VNT-3-TT-HF1	6	1.419	0.181	1.072	1.539
VNT-3-DryLab-GI2	2	1.206	0.120	1.121	1.291
VNT-3-DryLab-GI3	8	1.693	0.148	1.461	1.946
VNT-3-DryLab-GI4	2	1.342	0.093	1.276	1.408
VNT-3-PartSatLab-GI3	2	1.433	0.033	1.410	1.456
VNT-3-PartSatLab-GI2	2	1.379	0.095	1.311	1.446
VNT-3-PartSatLab-GI4	2	1.618	0.100	1.547	1.688

- Anomalously low value from GI-3 Dry Lab test at 15.9’ excluded since there are no corresponding lithologic variations
- Anomalously low values from GI-2 (41.5’), GI-3 (43.0’), and GI-4 (18.3’) TT measurements included due to observed lithologic variations

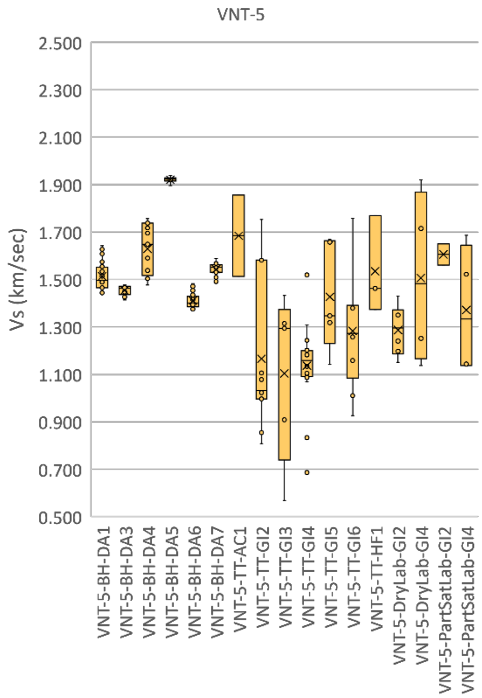
Figure C-3. S-wave velocities for VNT-3 from tabletop measurements and lab measurements on dry and partially saturated samples.



Unit & Data Source	# Data Points	Average (km/sec)	Std Dev (km/sec)	Min (km/sec)	Max (km/sec)
VNT-4-BH-DA6	9	1.482	0.016	1.454	1.503
VNT-4-TT-AC1	2	1.832	0.104	1.759	1.906
VNT-4-TT-GI2	7	0.985	0.142	0.760	1.189
VNT-4-TT-GI3	6	1.043	0.304	0.589	1.465
VNT-4-TT-GI4	20	1.486	0.261	0.610	1.792
VNT-4-TT-HF1	2	1.339	0.082	1.280	1.397
VNT-4-DryLab-GI4	12	1.749	0.315	1.310	2.388
VNT-4-PartSatLab-GI3	4	1.691	0.450	1.073	2.121
VNT-4-PartSatLab-GI4	2	1.724	0.115	1.642	1.805

- Anomalously low value from TT-GI4 is from 53.4’, which a zone of highly porous, friable, vitric, pumice-rich tuff
- Anomalously low values from GI-2 (46.8’) and GI-3 (45.8’) TT measurements included due to observed lithologic variations

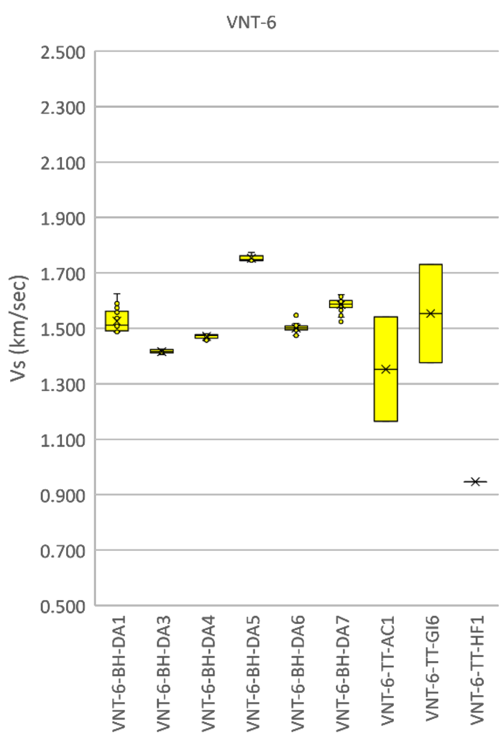
Figure C-4. S-wave velocities for VNT-4 from borehole logs, tabletop measurements, and lab measurements on dry and partially saturated samples.



Unit & Data Source	# Data Points	Average (km/sec)	Std Dev (km/sec)	Min (km/sec)	Max (km/sec)
VNT-5-BH-DA1	40	1.513	0.061	1.443	1.642
VNT-5-BH-DA3	15	1.454	0.020	1.413	1.642
VNT-5-BH-DA4	15	1.629	0.109	1.476	1.757
VNT-5-BH-DA5	6	1.921	0.014	1.896	1.938
VNT-5-BH-DA6	40	1.411	0.031	1.371	1.482
VNT-5-BH-DA7	76	1.544	0.027	1.479	1.588
VNT-5-TT-AC1	2	1.684	0.243	1.512	1.856
VNT-5-TT-GI2	11	1.166	0.319	0.808	1.432
VNT-5-TT-GI3	5	1.104	0.358	0.569	1.642
VNT-5-TT-GI4	16	1.137	0.184	0.686	1.519
VNT-5-TT-GI5	5	1.427	0.230	1.142	1.670
VNT-5-TT-GI6	10	1.283	0.244	0.926	1.757
VNT-5-TT-HF1	3	1.535	0.064	1.413	1.642
VNT-5-DryLab-GI2	6	1.287	0.107	1.151	1.430
VNT-5-DryLab-GI4	4	1.506	0.372	1.137	1.920
VNT-5-PartSatLab-GI2	2	1.606	0.063	1.561	1.650
VNT-5-PartSatLab-GI4	4	1.372	0.277	1.135	1.686

- Anomalously high value from GI-6 TT measurement at 41.7' excluded since there are no corresponding lithologic variations
- Anomalously low values from GI-2 (76.7'), GI-3 (57.1'), and GI-4 (61.1' and 62.9') TT measurements included due to observed lithologic variations

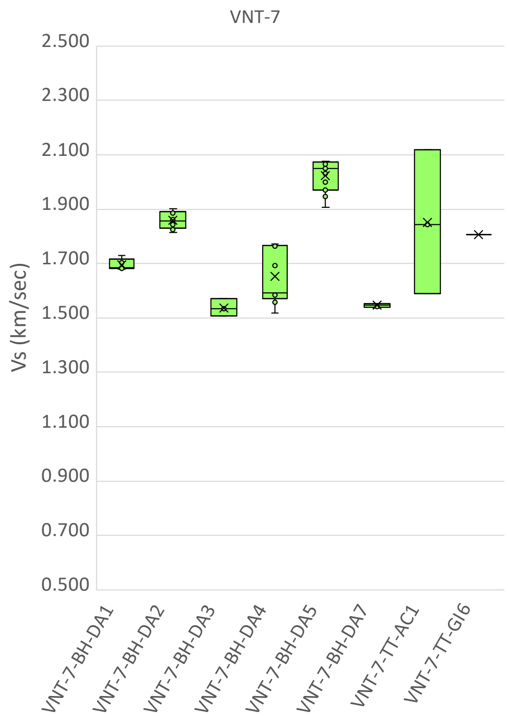
Figure C-5. S-wave velocities for VNT-5 from borehole logs, tabletop measurements, and lab measurements on dry and partially saturated samples.



Unit & Data Source	# Data Points	Average (km/sec)	Std Dev (km/sec)	Min (km/sec)	Max (km/sec)
VNT-6-BH-DA1	26	1.526	0.040	1.486	1.625
VNT-6-BH-DA3	6	1.416	0.009	1.454	1.481
VNT-6-BH-DA4	12	1.471	0.009	1.454	1.481
VNT-6-BH-DA5	6	1.753	0.012	1.740	1.774
VNT-6-BH-DA6	26	1.501	0.015	1.474	1.547
VNT-6-BH-DA7	41	1.585	0.021	1.524	1.621
VNT-6-TT-AC1	2	1.352	0.266	1.164	1.541
VNT-6-TT-GI6	2	1.553	0.251	1.376	1.731
VNT-6-TT-HF1	1	0.946	n/a	n/a	n/a

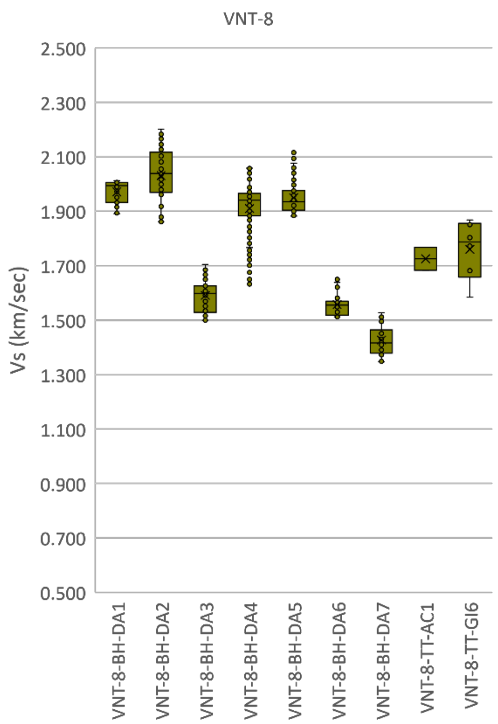
- Anomalously low value from HF-1 (83.7') TT measurement included due to observed lithologic variations (including hardness and permeability measurements)

Figure C-6. S-wave velocities for VNT-6 from borehole logs and tabletop measurements.



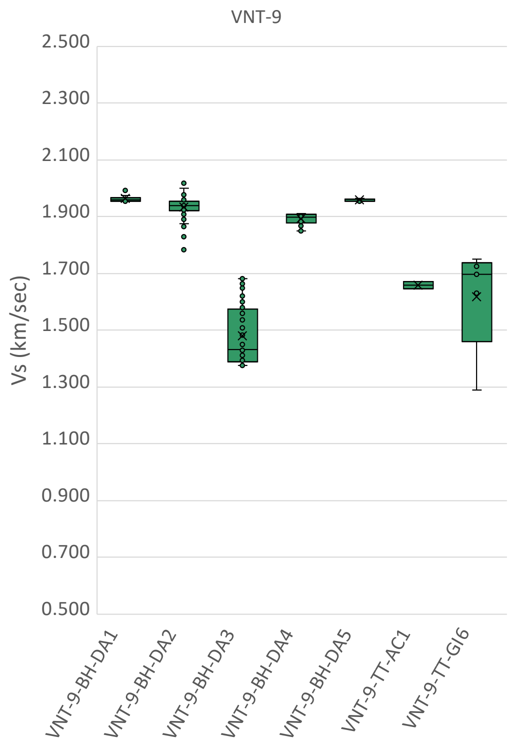
Unit & Data Source	# Data Points	Average (km/sec)	Std Dev (km/sec)	Min (km/sec)	Max (km/sec)
VNT-7-BH-DA1	5	1.696	0.020	1.678	1.728
VNT-7-BH-DA2	12	1.859	0.031	1.813	1.902
VNT-7-BH-DA3	3	1.537	0.031	1.508	1.570
VNT-7-BH-DA4	18	1.653	0.100	1.517	1.772
VNT-7-BH-DA5	11	2.023	0.059	1.906	2.077
VNT-7-BH-DA7	4	1.546	0.008	1.536	1.552
VNT-7-TT-AC1	3	1.850	0.264	1.589	2.118
VNT-7-TT-GI6	1	1.806	n/a	n/a	n/a

Figure C-7. S-wave velocities for VNT-7 from borehole logs and tabletop measurements.



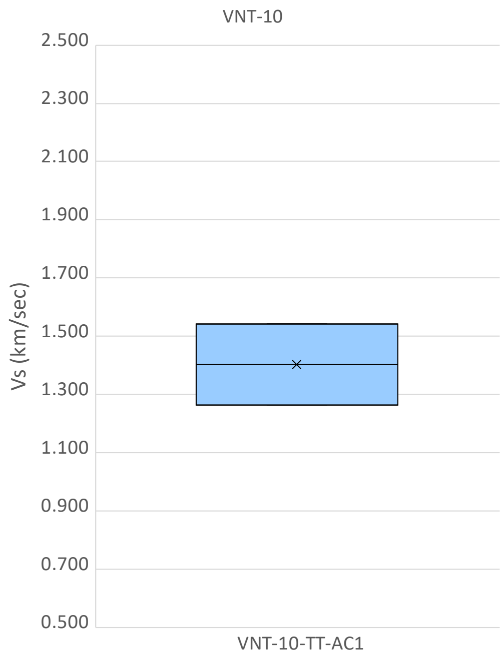
Unit & Data Source	# Data Points	Average (km/sec)	Std Dev (km/sec)	Min (km/sec)	Max (km/sec)
VNT-8-BH-DA1	68	1.972	0.042	1.892	2.012
VNT-8-BH-DA2	54	2.031	0.096	1.862	2.201
VNT-8-BH-DA3	56	1.591	0.061	1.499	1.705
VNT-8-BH-DA4	101	1.910	0.105	1.632	2.058
VNT-8-BH-DA5	78	1.949	0.060	1.882	2.115
VNT-8-BH-DA6	37	1.557	0.041	1.512	1.650
VNT-8-BH-DA7	35	1.427	0.060	1.346	1.527
VNT-8-TT-AC1	2	1.725	0.060	1.683	1.767
VNT-8-TT-GI6	6	1.760	0.109	1.584	1.869

Figure C-8. S-wave velocities for VNT-8 from borehole logs and tabletop measurements



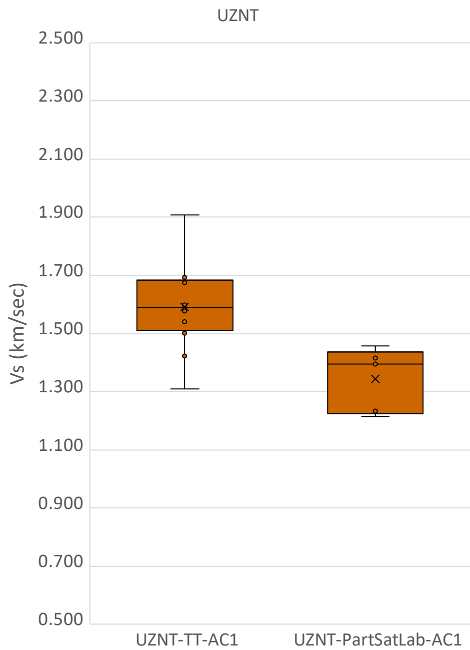
Unit & Data Source	# Data Points	Average (km/sec)	Std Dev (km/sec)	Min (km/sec)	Max (km/sec)
VNT-9-BH-DA1	10	1.963	0.012	1.954	1.992
VNT-9-BH-DA2	61	1.935	0.047	1.783	2.030
VNT-9-BH-DA3	40	1.480	0.108	1.376	1.682
VNT-9-BH-DA4	35	1.892	0.019	1.848	1.911
VNT-9-BH-DA5	7	1.959	0.004	1.954	1.963
VNT-9-TT-AC1	2	1.658	0.017	1.646	1.670
VNT-9-TT-GI6	5	1.619	0.190	1.288	1.750

Figure C-9. S-wave velocities for VNT-9 from borehole logs and tabletop measurements.



Unit & Data Source	# Data Points	Average (km/sec)	Std Dev (km/sec)	Min (km/sec)	Max (km/sec)
VNT-10-TT-AC1	2	1.403	0.195	1.264	1.541

Figure C-10. S-wave velocities for VNT-10 from tabletop measurements.



Unit & Data Source	# Data Points	Average (km/sec)	Std Dev (km/sec)	Min (km/sec)	Max (km/sec)
UZNT-TT-AC1	12	1.591	0.150	1.309	1.908
UZNT-PartSatLab-AC1	6	1.343	0.111	1.216	1.458

- Anomalously low value from AC-1 Part Sat Lab test at 146.8’ excluded since there are no corresponding lithologic variations

Figure C-11. S-wave velocities for UZNT from tabletop measurements and lab measurements on partially saturated samples.

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