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Research Article

Pit Slope Configuration for Open Pit Mining – A Case Study

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Abstract

To achieve stable pit wall slopes, it is imperative to obtain a fair knowledge of the rock mass characterisation before designing the pit. Insufficient knowledge of the competency of the country rock could lead to using unsupported slope configuration in the design process which can consequently lead to slope failure. In this study, the geomechnical properties of the Bremen-Nkosuo concession are analysed using Bieniawski's classification scheme to determine the Rock Mass Rating (RMR) for defining safe pit slope configuration of the Nkosuo pit. The findings show that the rockmass are best described as 'fair' for the two main lithologies existing at the concession. Subsequently, localised adjustment factors are applied to the calculated RMR to arrive at Mining Rock Mass Ratings (MRMR). These MRMR values are correlated with 50 m fixed stack height and 1.2 safety factor to determine optimum Bench Slack Angle (BSA) of 54 °and 57 °for host sedimentary and granitic rocks respectively. For individual benches, optimum slope design configurations were 10 m, 800, and 6.6 m respectively for bench height, bench face angle and catch berm for metasedimentary rocks. Likewise, that for granitic formation were 10 m bench height, 800 face angle and 6.0 m catch berm width. These configurations are in conformance with mineral and mining regulations of Ghana. Slope stability assessment was performed which included Slope Mass Rating (SMR), Kinematic and Limit equilibrium analysis. From the analysis, multi-bench scale slope instability occurrence was found to be rare but single-double scale could be possible at the western wall of the planned pit with probability of failure of about 0.4. Presplit and trim shots perimeter blasting techniques are recommended to maintain the integrity of the final pit walls at certain areas.

Keywords

Pit Slope Stability, Bench, Berm, Rock Mass Characterisation

1. Introduction

Since slopes in open pits are considered as geotechnical structures, their design and construction should always take into account technical, economic, environmental, and safety concerns [1]. The optimal slope design for open pit mining typically maximises overall slope angles while minimising waste stripping, efficiently managing the danger of overall slope instability, and allowing for the safe movement of equipment, materials and employees, during mining operations [2].

Conducting a good structural analysis of any formation requires that geotechnical investigations be sufficiently performed. Geotechnical core logging begins the gathering of useful data required to quantify the engineering properties of the rock mass. Engineering properties of the rock mass is useful in determining the behaviour and response of the rock

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mass when pit slopes, tunnels, haulages, and stopes are excavated in them. It is thus important to restate that logging for rock mass data is crucial for gathering data on all the geotechnical factors that may affect the stability and effectiveness of the rock mass. These geotechnical factors include: material strength and anisotropy valuation, quantity of discontinuity, quality of defect and orientation of defect.

The following parameters are known to influence the stability of each defined zone or interval and their effect could cause identified zones to respond uniformly when exposed within pit walls:

i. Thickness of geotechnical zone
ii. Rock Quality Designation (RQD)
iii. Length of Solid Core Recovered (SCR)
iv. Intact Rock Strength or hardness (IRS)
v. Total number or density or Fracture Frequency of structures (FF)
vi. Discontinuity Spacing. Between the apparent sets of structures and true spacing
vii. Types of structural defects
viii. Weathering grade and intensity
ix. Relative orientation of structures to the core axis

Perseus Mining Ghana Limited (PMGL) intends expanding its open pit operations and extensive exploration indicates that the Bremen deposit is economically mineable. Though pit slope configurations have been obtained and applied for exploiting ore using open pit technology by PGML, due to the heterogeneity of earth material both laterally and longitudinally across the concession, it is necessary to determine slope configurations which could be used to mine the Nkosuo Pit of the Bremen deposit. This study thus seeks to:

i. Perform slope stability assessment on the Nkosuo pit walls; and
ii. Determines the optimal open pit slope parameters for various geotechnically defined domains of the potential pit.

2. Resources and Methods Used

2.1. Resources

In this study, secondary geotechnical data from the Geological Department of PGML was used. The data was adequately logged and laboratory testing for different geotechnically defined domains were obtained. In addition, some significant hydrogeological data was also used for the analysis. About 95% of Uniaxial Compressive Strength (UCS) results from the laboratory analysis passed the statistical test performed. This is an indication that both the laboratory and sampling procedures are of higher standard as presented in Appendix I. Averages from the statistical analysis of the data are summarised in Table 1.

Slide v6 Software was utilised to determine the Shear Strength properties of Oxide-Transition and fresh rock components of the slope. Corresponding UCS values were determined from the Lab and Point Load as summarised in Appendix I.

Table 1. *Laboratory Testing Data.*

Domain	Average UCS, MPa	Density, g/cm^3
Oxide - Transition	15.00	1.80
Metasedimentary Rocks	170.89	2.78
Intrusives	162.08	2.69

2.2. Methods

Rock Mass Classification and Characterisation

To obtain the abstract descriptions of rock mass from intrinsic and structural factors, rock mass classification was employed. Rock Mass Classification give quantitative data and guidelines for engineering objectives by simple mathematical computations [3]. The primary benefit of rock mass

classifications is that they provide a straightforward and efficient means of expressing the quality of rock masses and summarising previous practice [4]. In this study, attention is paid both the engineering attributes of the rock material and the defects in determining the overall behaviour of the rock mass. The variables mostly used in classifying rocks include:

i. Strength and deformability of intact rock:
ii. Rock Quality Designation (RQD) which measures the degree of fracturing in a drill core;
iii. Discontinuity condition (infill material, spacing, orientation, width, roughness, weathering, etc.);
iv. Groundwater pressure and flow;
v. In-situ stress; and
vi. Major rock defect such as faults and fold.

The commonly used classification methods in rock mechanics to assist designing in infrastructure are as follows:

Rock load Classification

The technique, which Terzaghi first used in 1946, uses a descriptive classification of rock classes to assess the effect of rock load on steel-supported tunnels.

Rock Tunneling Index or Q-system

The Q-System is a classification method for determining rock mass properties and tunnel support requirements [5]. Derived from 212 case histories, it consists of six parameters: joint roughness number (Jr), joint water reduction factor (Jw), joint set number (Jn), joint alteration number (Ja), stress reduction factor (SRF), and rock quality designation (RQD). These parameters are grouped into three quotients and used to calculate the Q value. The system accounts for rock mass geometry, inter-block shear strength, and active stress, taking into consideration various factors such as shear zones, water pressure, and rock competency.

Geological Strength Index (GSI)

GSI was the first concept used in in-situ observations of the rock mass conditions and correlations created by the RMR-system to infer the attributes of the rock mass [6]. The two primary parameters used by GSI are the discontinuity surface quality and the rock mass structure.

Rock Mass Rating (RMR) System

RMR method was subsequently proposed to determine the necessary support measures for tunnels [7]. The system's usage of a few fundamental parameters makes it practicable. Many case studies have been used to test and refine it ever since it was created. In 1988, this system was improved with various ratings given to various factors [8]. The classification of a rockmass is based on the following six criteria, with respective ratings summarised in Appendix II.

a) Uniaxial Compressive Strength Rating (UCS)
b) Rock Quality Designation Rating (RQD)
c) Discontinuities Spacing rating (JS)
d) Discontinuities Condition rating (JC)
e) Groundwater condition rating (GW)
f) Discontinuities Orientation rating (JD).

In this study, the RMR is calculated based on classification scheme using Equation (1).

$$\text{RMR} = \text{UCS} + \text{RQD} + \text{JS} + \text{JC} + \text{GW} \qquad (1)$$

Mining (Modified) Rock Mass Rating (MRMR)

A modified rock mass rating, MRMR, was imperitive [9]. The MRMR modifies RMR values to reflect dynamism in various mining environments. As a result, the MRMR system uses Bieniawski's fundamental RMR value and modifies it to take into consideration *in-situ* and mining-induced stresses (I), joint orientation (J), the impact of blasting (B), and weathering (W) [10] as shown in Equation (2).

$$MRMR = RMR \times Effect\ (\mathrm{I} \times \mathrm{J} \times \mathrm{B} \times \mathrm{W}) \qquad (2)$$

The following is considered when choosing adjustment factors taking into consideration life of excavation, type of exaction and behaviour of the rocks with time [9].

Mining Induced Stresses: The geometry and orientation of the excavation cause regional stresses to be redistributed, which leads to mining-induced stresses. Maximum, lowest, and differential redistributed stresses are of interest, and the rating could range from 60% from stress difference to 120% from maximum stress consequences [10]. The factors to take into account when assessing mining-induced stresses for slope stability include:

i. Alterations in geometry brought on by an expansion of the mining area;
ii. Wall failures such as immense wedges; and
iii. Dykes and sills with the potential to release tension into nearby, more capable rocks or hold back high stress.

Joint plane Orientation: The behaviour of the rock mass depends on the size, shape, and orientation of the excavation. The stability of the excavation is significantly influenced by the attitude of the discontinuity and if the bases of the blocks are exposed, thus the ratings must be changed accordingly. The position of the discontinuity in relation to the block's vertical axes determines the size of the adjustment. The number of joints that dip away from the vertical axis determines how unstable the block is because gravity is a very important force to take into account. Discontinuity orientation adjusytment for number of faces is presented in Table 2 [9].

Table 2. *Discontinuity Orientation Adjustment.*

Quantity of Discontinuity Shaping the Block	**No. of Faces Dipping From Vertical**				
	70.0%	**75.0%**	**80.0%**	**85.0%**	**790.0%**
3	3		2		
4	4	3		2	
5	5	4	3	2	1
6	6	5	4	3	2,1

Table 3. *Blasting Adjustment.*

Blasting Method	**Percentage Adjustment**
Boring	100.0
Perimeter blasting	97.0
Production blasting	94.0
Poor blasting	80.0

Blasting: Rock mass displacement from blasting causes new fractures and loosens the rock mass [9]. Hence, adjustments are recommended as presented in Table 3.

Weathering: While choosing the dimension of the entrance and the support design, it is important to keep in mind that some types of rocks weather easily. Three rating parameters that are undermined by weathering are IRS, RQD or FF/m, and joint condition. The percentage RQD can be decreased by increasing in fractures and the IRS can decrease significantly as chemical decomposition occurs. The joint condition is affected by alteration of the wall rocks and joint infilling [9] (see Table 4).

Slope Mass Rating (SMR)

Some of the geomechanics rock classification listed above are modifications of the original ones but SMR is commonly used [11]. SMR is calculated from basic RMR [12] which was initially intended for tunnelling but also included an adjustment factor for slopes to consider the influence of discontinuities orientation on the rock slope stability geometry. SMR is computed by applying four adjustments to RMR [12]. These variables are reliant on the method used for slope excavation as well as the current state of the slope-rock mass relationship [13]:

$$SMR = RMR + (F1 \times F2 \times F3) + F4 \quad (3)$$

where:

RMR is the fundamental RMR from Bieniawski's classification of rock masses;

F1 affected by the parallelism calculated as *A* in Table 5 between dip direction of the discontinuity α_j, and slope dip, α_s;

F2 is a function in relation to probability of discontinuity shear strength. In the case of planar failure, it depends on the discontinuity dip, B=j. For toppling failure, this parameter is equal to 1.0.

F3 depends on the slope, s, and discontinuity, *j*, dips connection, *C* as shown in Table 5. The original Bieniawski correction factor reflects the likelihood that the discontinuity will emerge on the slope face in the event of a planar failure.

F4 depends on the blasting technique to be used as shown in Table 6 [14].

Romana outlined five stability classifications based on SMR results as presented on Table 7 [13].

Bench Height Design Consideration

The commonly used bench heigh of 10 –18 m is recommended for large open pit and/or cut mineral exploitation. The ultimate choice is typically made by balancing the height with the excavation equipment's capability. Where regulations and rock mass strength allow, stacking of benching aiming at steepening the inter-ramp gradient is common. Double- and triple-benching, which make way for broader, and reliable benches on the steepened inter-ramp slope are being employed as a way to improve safety, despite the fact that the idea was probably first used to increase productivity. Also, from Ghana Mining and Minerals Regulation, LI 2182, subsection 88b, bench height of 20 m, and least bench width of 5 m are recommended [15]. However, experimental relationship between bench height and berm width was established as given in Equation 4 [16].

$$\text{Bench width (m) } b = (0.2 \text{ x bench height} + 4.5) \text{ m} \quad (4)$$

The radius of failed material in the form of a cone and a pyramid on catch berm can be calculated using Equations 5 and 6 [17].

$$R = \sqrt[3]{\frac{6kv}{\Pi} + \frac{\tan\alpha - \tan\emptyset}{\tan\alpha \cdot \tan\emptyset}} \quad (5)$$

$$R = \sqrt{\frac{6KV}{L} \times \frac{\tan\alpha - \tan\emptyset}{\tan\emptyset \cdot \tan\alpha}} \quad (6)$$

where:

K = 1.5 swelling factor;

R = radius of failed material;

V = volume of failed rock (cubic metres);

L = Length of wedge;

α = bench face angle (degrees); and

ø = repose angle, which is usually 380^0.

Table 4. *Rock Weathering Adjustments.*

Degree of Weathering	Potential Weathering and Adjustments (%)				
	Half Year	One Year	Two Year	Three Year	Four or more Year
Fresh	100.0	100.0	100.0	100.0	100.0
Slight	88.0	90.0	92.0	94.0	96.0
Moderate	82.0	84.0	86.0	88.0	90.0
High	70.0	72.0	74.0	76.0	78.0
Complete	54.0	56.0	58.0	60.0	62.0
Residual	30.0	32.0	34.0	36.0	38.0

(Source: Laubscher, 1990)

Table 5. *Correction Parameters for SMR.*

Failure mode		Very favourable	Favourable	Normal	Unfavourable	Very unfavourable
P						
T	A =| αj -αs| |αj -αs+180|	>30 º	30-20 º	20-10 º	10-5 º	<5 º
P/T	F1	0.15	0.40	0.70	0.85	1.00
P	B = βj	<20 º	20-30 º	30-35 º	35-45 º	>45 º
P	F2	0.15	0.40	0.70	0.85	1.00
T		1.00				
P	βj - βs	>10 º	10-0 º	0 º	0-(-10 º)	<(-10 º)
T	C =βj +βs	<110 º	110-120 º	>120 º	-	-
P/T	F3	0	-6	-25	-50	-60
FAILURE: P is planar; T is toppling. DIP DIRECTION: j is discontinuity; s is slope. DIP: j discontinuity; s: slope						

(Source: Romana, 1985)

Table 6. *Values Corresponding to Factor F4.*

Excavation method (F4)			
Presplitting	+10		
Smooth blasting	+8	Blasting or Mechanical	0
Natural slope	+15	Natural	+15

(Source: Romana, 1985)

Table 7. *Romana Description of Rockmass.*

Class No	V	IV	III	II	I
SMR	0 - 20	21 - 40	41 - 60	61 - 80	81 - 100
Rockmass description	Very Bad	Bad	Normal	Good	Very Good
Stability	Fully Instable	Instable	Partially Stable	Stable	Fully Stable
Failures	Big Planer or soil-like or circular	Planer or big wedges	Planer along some joint and many wedges	Some block failure	No Failure
Probability of failure	0.9	0.6	0.4	0.2	0

(Source: Bieniawski, 1982)

3. Results and Discussions

3.1. Diamond Drill Core Logging Results

Sixty-six (66) intact samples comprising of 36 and 30 each of Granite and Metagraywacke respectively were observed. Results of the Uniaxial Compressive Strength and Shear Strength properties of Oxide component of the slope are shown in Table 8.

Results of detailed geotechnical logging conducted (see Appendix VI) for five (5) oriented diamond drilled cores with varying hole designs are summarily presented in Table 9.

Table 8. *Bremen-Nkosuo Laboratory Outcome.*

Domain	UCS	Density
Oxide - Transition	15.00	1.80
Metasedimentary Rocks	170.89	2.78
Intrusives	162.08	2.69

Table 9. *Drilled Holes Design.*

Hole ID	Collar_Y	Collar_Y	Collar_Y	DIP (degrees)	AZIMUTH (degrees)	FINAL DEPTH (m)
NKS0145RD	20117.71	10975.28	1188.10	55	90	130.0
NKS0146RD	20117.48	10806.21	1174.62	55	90	165.2
NKS0148DD	19918.92	11030.30	1191.26	55	270	115.0
NKS0149DD	20056.20	10947.00	1190.48	49	225	145.2
NKS0168DD	19917.39	11133.00	1206.82	55	90	110.2

3.2. Geological Structural Data Interpretation

The geological structure of the Nkosuo pit formation was analysed to give the dip directions of each discontinuity in Dips V5 Software as graphically illustrated in Figures 1 and 2. The structural outcome of data analysis is summarised in Table 10.

3.2.1. Rock Mass Classification and Characterisation

By applying the Bieniawski and Laubscher classifications schemes to the Nkosuo deposit, both the fresh hosted rocks and the intrusives have ‘Good’ rock mass ratings. For the oxide to transition horizons within 40 m depth, a ‘Poor’ rock mass rating was observed. From the analysis the results of the RMR of the Nkosuo pit formation for each defined domain are summarised on Table 11.

The corresponding Mining Rock Mass Rating (MRMR) was computed using Equation 2 and the results presented in Table 12.

3.2.2. Bench Stack Angle (BSA) Design Consideration

For cuts involving design slopes and curves up to 100 m height, the slope performance curves for Rock Mass Rating with an assumption factor of safety of one is applied [7], making no adjustments for orientation. In contrast to Bieniawski's slope performance curves, Robertson's and Douglas's curves are applicable to lesser strength rock mass group, as shown in Figure 3 [18].

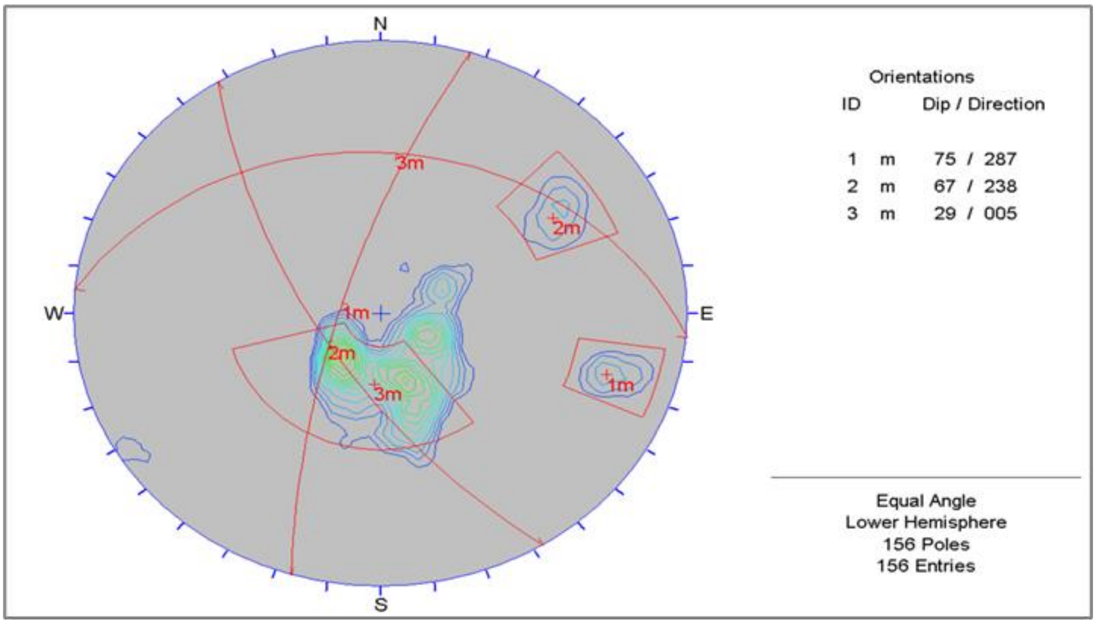


Figure 1. *Structural Configuration within Intrusives (Granites).*

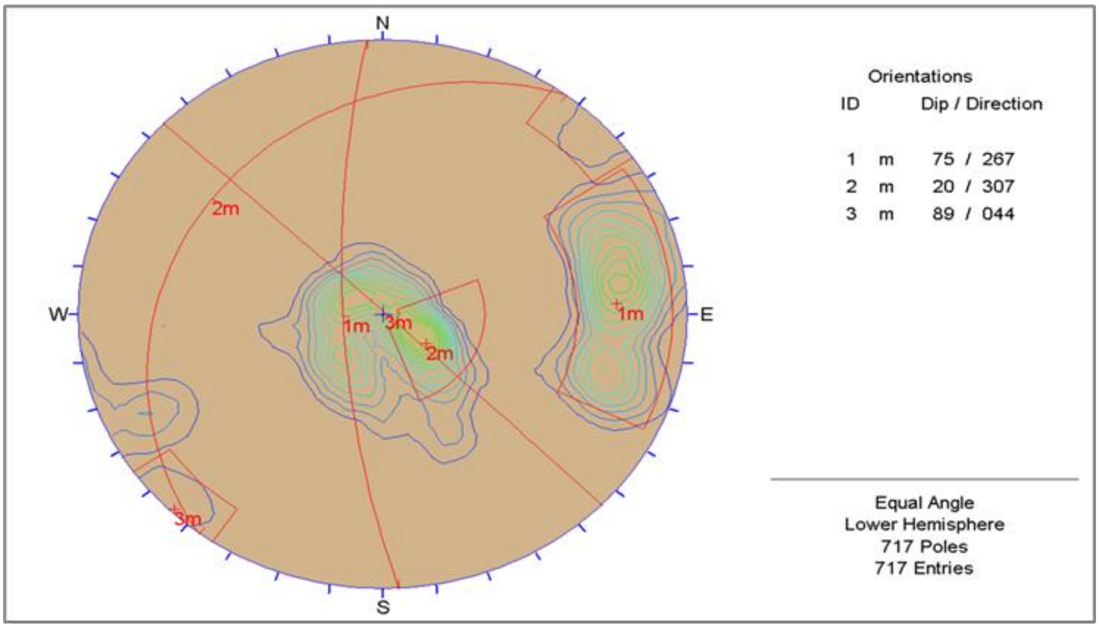


Figure 2. *Structural Configuration within Host (Metagraywacke) Rocks.*

Table 10. *Summary of Structural Information.*

Lithology	Dip	Dip Direction	Joint Set
Intrusive (Granite and Porphyry	75	287	3
	67	238	
	29	005	
Metasedimentary rocks	75	267	3
	20	307	
	89	044	

Table 11. *Rockmass Rating at Bremen – Nkosuo.*

Rock Type	Geotechnical Domain	UCS	RQD	Joint Spacing	Joint Con-dition	Ground-water	RMR		
		Rating	Rating	Rating	Rating	Rating	Rating	Class	Description
Weathered	Oxide - Transition	2	3	10	4	7	26	IV	Poor Rock
Fresh	Metasedimentary Rocks	12	13	10	19	10	64	II	Good Rock
	Intrusive Rocks	12	20	15	20	10	77	II	Good Rock

Table 12. *Mining Rock Mass Rating.*

Geotechnical Domain	MRMR	Slack Angle (BSA)	
		FoS=1.5	FoS=1.2
Oxide – Transition	13.78	34	39
Metasedimentary Rocks	49.66	49	54
Intrusive Rocks	52.28	51	57

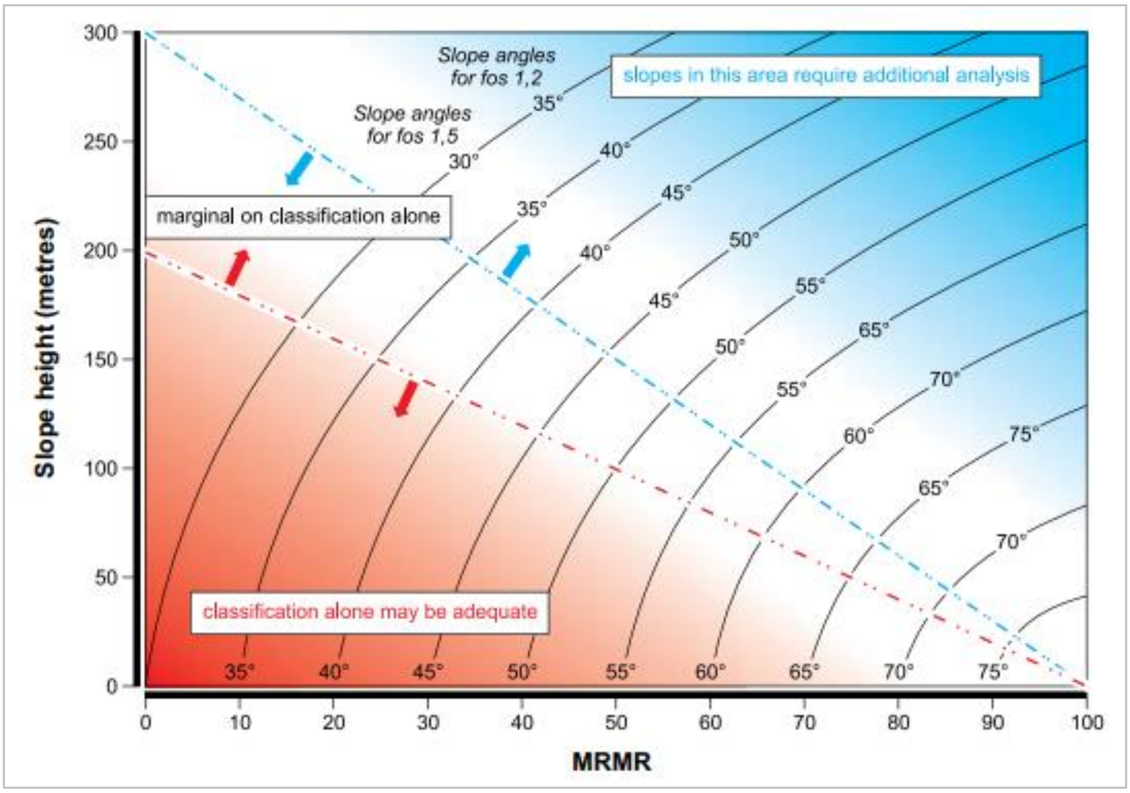


Figure 3. *Slope Height vs. Slope Angle Graph for MRMR [17] (Haines and Terbrugge, 1991).*

The height of each bench stack was set at 50 m. Indicative Bench Slope Ange (IBSA) was selected at a FoS of 1.2 and 1.5 from Figure 3. The slope height versus Slope Angle graph based on the MRMR chart [19] is used to correlate slope angles from computed MRMR values, and a summary of the outcome is presented in Table 13.

Table 13. *Indicative Bench Stack Design.*

Geotechnical Domain	MRMR	Slack Angle (BSA)	
		FoS=1.5	FoS=1.2
Oxide – Transition	13.78	34	39
Metasedimentary Rocks	49.66	49	54
Intrusive Rocks	52.28	51	57

3.2.3. Bench Scale Design

Bench Height (H) Design and Bench Face Angle (A)

From the logging and weathering profile interpretation, an average Oxide-Transition thickness of 50 m was obtained. Similarly, the bench height obtained from the analysis was 10 m to18 m. Therefore, for the purpose of this work, a 10 m bench height is considered for preliminary assessment. With most structures logged dipping around 65 to 750, the choice of 800 as an initial assessment is considered. Thus, using Equation 4, the berm configuration for the Nkosuo pit is obtained as 6.6 m.

The estimated maximum volume from potential wedges is 100 m^3. This yields a berm (R) value of approximately 6.5 m. However, the correlation between MRMR and Selected Bench Stack height falls under the section of Figure 4, where rockmass classification alone is adjudged to be adequate. This means the berm width could be adjusted to achieve the Indicative Inter-bench Stack Angle (IBSA). Results are presented in Table 14.

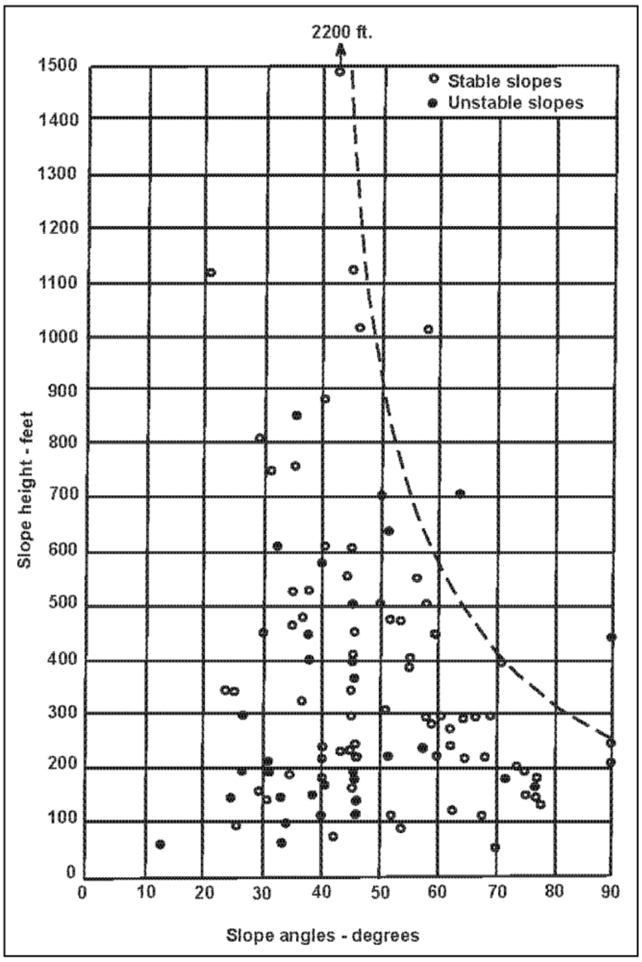


Figure 4. *Slope Height vs Slope Angle Created [19].*

Table 14. Summary of Bench Face Design Parameters.

Geotechnical Domain	Bench Height (m)	Bench Face angle (degree)	Berm width (m)
Oxide – Transition	5	80	5.0
Metasedimentary Rocks	10	80	6.5
Intrusive Rocks	10	80	6.0

3.2.4. Kinematic Analysis

Planer, toppling and wedge stability assessments are conducted for four sectors of the pit based on lithological configuration. Results from the assessment are presented in Appendix II. Various conditions and criteria considered for each mode of failure are based on the following assumptions:

i. The longest axis of the pit will follow the general strike of the orebody.

ii. The north and south walls are made completely of metasedimentary units, whiles the east and west walls are only made up of intrusives.

Limit equilibrium analysis

The stability of rockmass at inter ramp and overall slope stability were established by employing the Limit equilibrium technique based on indicative bench stack angles from Table 14 and a Factor of safety of 1.2 (see Figures 5 and 6).

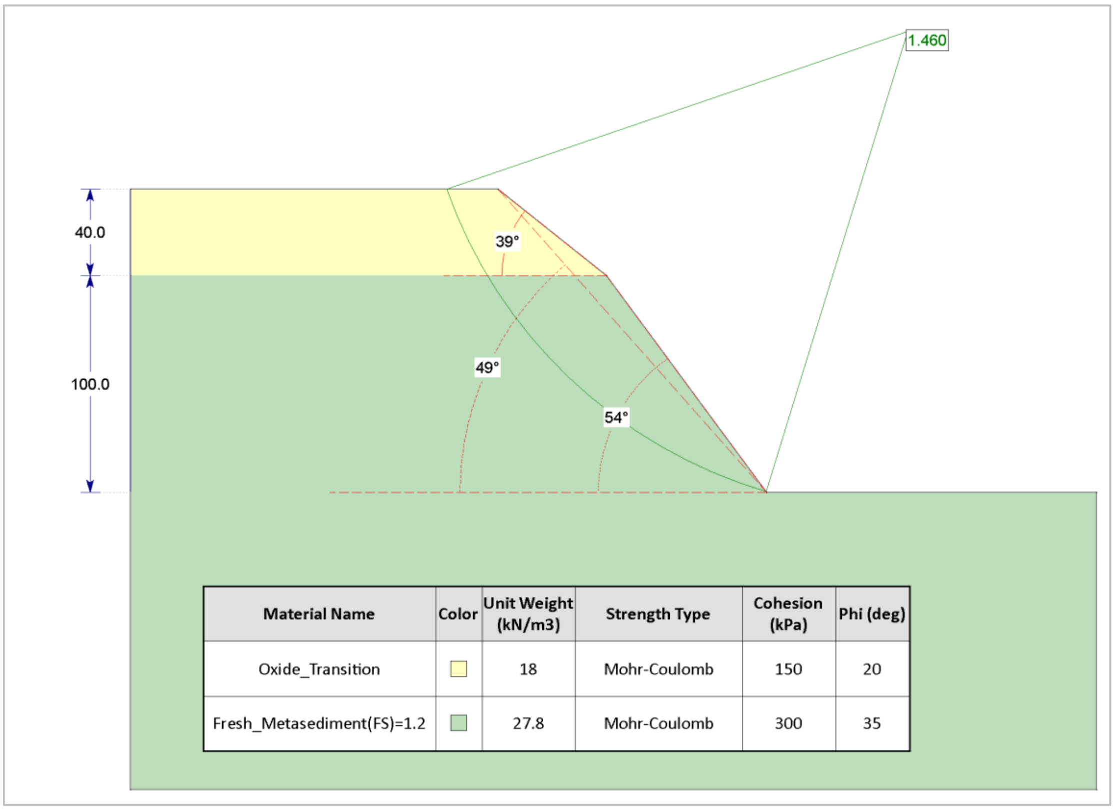
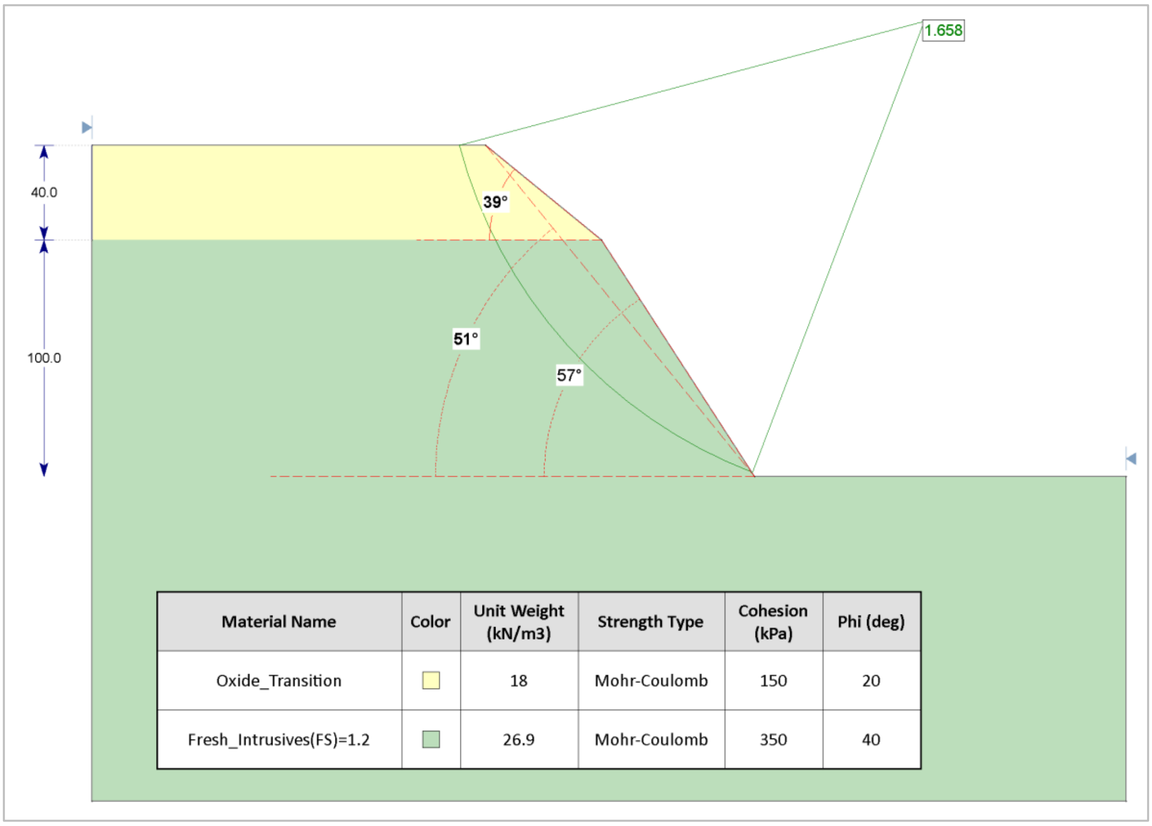
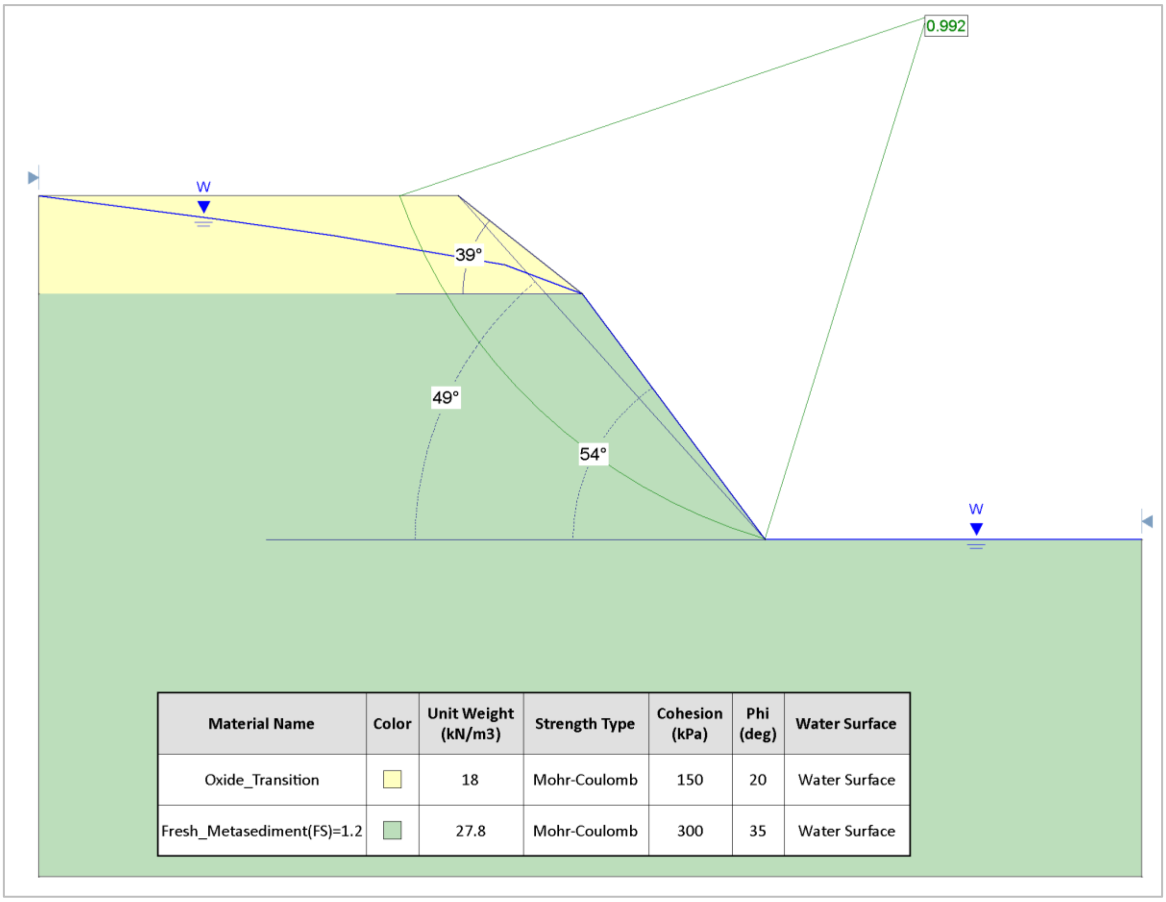


Figure 5. Limit Equilibrium Analysis for Slope in Metasedimentary Rocks.



Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)
Oxide_Transition		18	Mohr-Coulomb	150	20
Fresh_Intrusives(FS)=1.2		26.9	Mohr-Coulomb	350	40

Figure 6. *Kinematic Analysis for Slope in Intrusive Rocks.*



Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Water Surface
Oxide_Transition		18	Mohr-Coulomb	150	20	Water Surface
Fresh_Metasediment(FS)=1.2		27.8	Mohr-Coulomb	300	35	Water Surface

Figure 7. *Effect of Groundwater on Potential Slope.*

The general geological structural trend at the concession is steeply dipping foliations with some lower angled trusts discontinuities within the intrusives. This is seen to be consistent within the oxide to transition sectors of the horizon.

Slope Stability Assessment Results

Limit equilibrium assessment of the above slope configuration shows that larger scale (multi-benched) instability will be rare for most sectors of the planned pit in both the oxide and fresh components of the slope. This analysis assumed a completely dry slope. However, toppling with a 40% chance could occur at the west wall, whiles wedges and planer failures could occur at the other sectors of the pit at the bench scales. The factor of Safety at Overall and Bench Stack (Inter Ramp) scales drop significantly with a rise in groundwater regime, as shown in Figure 7. This is an indication that groundwater could impact negatively on the stability of the slopes.

4. Conclusions and Recommendations

Generally, rockmass classification and characterisation in both the metasedimentary and Granitic rock were found to be within the ‘Good rockmass’ class with respective RMRs of 64 and 77 with corresponding MRMRs of 49.7 and 52.3 for the Nkosuo pit area. The indicative Bench Stack Angle (IBSA) for Metasedimentary formation was 540 and that of the Granitic intrusion is 570 at 1.2 factor of safety. For metasedimentary formations, optimum bench scale slope design configurations were 10 m bench height, 800 face angle and 6.5 m catch berm width. In the case of granitic rock formations, 10 m bench height, 800 face angle and 6.0 m catch berm width were obtained.

Presplit and/or trim perimeter blasting techniques will be required during slope design implementation to achieve a slope of higher integrity throughout the life of the pit. From slope stability analysis, toppling failure mode has a 40% chance of occurring at a multi-bench scale for the west wall of the pit. The remaining walls could experience some single bench scale of planer and wedge, but highly unlikely. Attempt to lower potential water table is expected to improve stability. The minimum width of the double lane ramp (Geotechnical berm) is 21.0 m and that of a single lane is 14.0 m for trucks of 6.0 m maximum width. This is consistent with Minerals and Mining law and mining equipment specifications to be used. It is recommended that a spiral pit design option could be considered since no major slope instabilities is anticipated at any sectors of the pit walls. This option will ensure slopes have the same height before Geotechnical berms or ramps to reduce potential rockfall risk.

Abbreviations

RQD	Rock Quality Designation
SCR	Solid Core Recovered
IRS	Intact Rock Strength or Hardness
FF	Fracture Frequency of Structures
UCS	Uniaxial Compressive Strength Rating
PMGL	Perseus Mining Ghana Limited
RQD	Rock Quality Designation Rating
JS	Discontinuities Spacing Rating
JC	Discontinuities Condition Rating
GW	Groundwater Condition Rating
JD	Discontinuities Orientation Rating
JR	Joint Roughness Number
JW	Joint Water Reduction Factor
JN	Joint Set Number
JA	Joint Alteration Number
SRF	Stress Reduction Factor
GSI	Geological Strength Index
RMR	Rock Mass Rating
MRMR	Mining (Modified) Rock Mass Rating
FF	Free Face
I	Mining-Induced Stresses
J	Joint Orientation
B	Impact of Blasting
W	Weathering
SMR	Slope Mass Rating
BSA	Bench Stack Angle

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Author Contributions

Richard Gyebuni: Conceptualization, Resources, Data curation, Software, Formal Analysis, Supervision, Investigation, Visualization, Methodology, Writing – original draft, Project administration, Writing – review & editing

Festus Kunkyin-Saadaari: Conceptualization, Resources, Data curation, Software, Formal Analysis, Supervision, Funding acquisition, Validation, Visualization, Methodology, Writing – original draft, Project administration, Writing – review & editing

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Ethical Statement

The authors state that the research was conducted according to ethical standards.

Conflicts of Interest

The authors declare no conflicts of interest.

Appendix

Appendix I. Statistical Analysis of Laboratory UCS Testing

Table A1. Statistical Analysis of Laboratory UCS Testing for Metagreywacke.

Metagreywacke					
Sample ID	**Rock Type**	**Density, g/cm^3**	**UCS, MPa**	**z-score (UCS)**	**p-value (UCS)**
UCM-05A	Greywacke	2.76	45.0	-1.711	0.0436
UCM-05B	Greywacke	2.75	50.4	-1.636	0.0505
UCM-05C	Greywacke	2.75	72.5	-1.326	0.0918
UCM-06A	Greywacke	2.75	80.4	-1.214	0.1131
UCM-06B	Greywacke	2.73	85.9	-1.136	0.1271
UCM-06C	Greywacke	2.76	96.0	-0.994	0.1611
UCM-11A	Greywacke	2.78	106.7	-0.845	0.2005
UCM-11B	Greywacke	2.79	113.2	-0.753	0.2266
UCM-11C	Greywacke	2.84	119.7	-0.661	0.2546
UCM-12A	Greywacke	2.90	126.8	-0.561	0.2877
UCM-12B	Greywacke	2.93	132.5	-0.481	0.3156
UCM-12C	Greywacke	2.93	134.9	-0.447	0.3264
UCM-13A	Greywacke	2.77	143.1	-0.332	0.3707
UCM-13B	Greywacke	2.79	145.4	-0.299	0.3821
UCM-13C	Greywacke	2.79	166.1	-0.008	0.4960
UCM-14A	Greywacke	2.78	170.2	0.049	0.5199
UCM-14B	Greywacke	2.78	177.1	0.147	0.5596
UCM-14C	Greywacke	2.76	178.4	0.164	0.5636
UCM-19A	Greywacke	2.74	181.0	0.201	0.5793
UCM-19B	Greywacke	2.74	190.2	0.330	0.6293
UCM-19C	Greywacke	2.74	213.3	0.655	0.7454
UCM-20A	Greywacke	2.78	214.6	0.673	0.7486
UCM-20B	Greywacke	2.78	218.9	0.734	0.7673
UCM-20C	Greywacke	2.78	219.7	0.745	0.7734
UCM-21A	Greywacke	2.75	237.8	1.000	0.8413
UCM-21B	Greywacke	2.74	252.7	1.209	0.8869
UCM-21C	Greywacke	2.74	272.0	1.481	0.9306
UCM-22A	Greywacke	2.66	279.7	1.590	0.9441
UCM-22B	Greywacke	2.78	285.8	1.675	0.9525
UCM-22C	Greywacke	2.74	291.0	1.748	0.9599
Mean Density		2.78			

Metagreywacke					
Sample ID	**Rock Type**	**Density, g/cm^3**	**UCS, MPa**	**z-score (UCS)**	**p-value (UCS)**
Population Mean UCS			166.70		
Standard Deviation			71.10		
Sample Mean UCS			170.89		

Table A2. *Statistical Analysis of Laboratory UCS Testing for Granite.*

Granite **Rocklab**	**Rock Type**	**Density, g/cm^3**	**UCS, MPa**	**z-score (UCS)**	**p-value (UCS)**
UCM-01C	Granite	2.68	71.4	-3.30	0.00
UCM-16C	Granite	2.68	104.0	-2.06	0.02
UCM-07C	Granite	2.70	115.4	-1.62	0.05
UCM-16B	Granite	2.69	118.6	-1.50	0.07
UCM-02A	Granite	2.68	127.7	-1.15	0.13
UCM-02C	Granite	2.68	135.4	-0.86	0.19
UCM-09B	Granite	2.68	139.2	-0.71	0.24
UCM-03A	Granite	2.76	141.9	-0.61	0.27
UCM-07B	Granite	2.71	142.9	-0.57	0.28
UCM-17A	Granite	2.70	143.6	-0.55	0.29
UCM-09A	Granite	2.68	151.5	-0.25	0.40
UCM-09C	Granite	2.68	153.6	-0.16	0.44
UCM-10B	Granite	2.69	155.5	-0.10	0.46
UCM-16A	Granite	2.68	159.6	0.06	0.52
UCM-07A	Granite	2.70	159.9	0.08	0.53
UCM-10A	Granite	2.70	162.2	0.16	0.56
UCM-08C	Granite	2.68	163.5	0.21	0.58
UCM-04B	Granite	2.70	163.6	0.22	0.59
UCM-18A	Granite	2.70	165.0	0.27	0.61
UCM-08A	Granite	2.69	166.4	0.32	0.63
UCM-03B	Granite	2.72	168.0	0.38	0.65
UCM-18B	Granite	2.70	168.4	0.40	0.66
UCM-08B	Granite	2.70	169.1	0.42	0.66
UCM-10C	Granite	2.70	169.1	0.43	0.67
UCM-02B	Granite	2.68	172.5	0.56	0.71
UCM-04C	Granite	2.72	173.8	0.60	0.73
UCM-18C	Granite	2.70	175.2	0.66	0.75
UCM-17B	Granite	2.70	175.4	0.67	0.75

Granite Rocklab	Rock Type	Density, g/cm^3	UCS, MPa	z-score (UCS)	p-value (UCS)
UCM-15B	Granite	2.68	177.8	0.76	0.78
UCM-01A	Granite	2.69	177.9	0.76	0.78
UCM-17C	Granite	2.70	178.1	0.77	0.78
UCM-03C	Granite	2.69	178.5	0.78	0.78
UCM-15C	Granite	2.68	179.7	0.83	0.80
UCM-01B	Granite	2.67	186.3	1.08	0.86
UCM-15A	Granite	2.70	197.1	1.49	0.93
UCM-04A	Granite	2.71	198.3	1.54	0.94
Mean Density			2.69		
Population Mean			157.95		
Standard Deviation			26.21		
Sample Mean			162.08		

Appendix II. Rockmass Rating

Table A3. Rockmass Rating.

	Parameters		Range of values				
A. Classification Parameters and Their Ratings							
1	Strength of intact rock material	Point load strength index	>10MPa	4-10 MPa	2 – 4 MPa	1 – 2 MPa	For this low range uniaxial compressive test is preferred
		Uniaxial comp. strength	>250MPa	100-250 MPa	50-100MPa	25-50 MPa	5-25 MPa · 1-5 MPa · <1 MPa
	Ratings		15	12	7	4	2 · 1 · 0
2	Drill core Quality RQD		90%-100%	75%-90%	50%-75%	25%-50%	<25%
	Rating		20	17	13	8	3
3	Spacing of discontinuities		>2 m	0.6-2.0 m	200-600 mm	60-200 mm	< 60 mm
	Rating		20	15	10	8	5
4	Condition of discontinuity (See E)		Very rough surfaces Not continuous No separation Unweathered wall rock	Slightly rough surfaces Separation < 1mm Slightly weathered walls	Slightly rough surfaces Separation <1mm Highly weathered walls	Slickensided surfaces or Gouge <5 mm thick or Separation 1-5mm continuous	Soft gouge >5mm thick or Separation > 5mm Continuous
	Rating		30	25	20	10	0
5	Groundwater	Inflow per 10 m tunnel length (l/m)	None	< 10	10-25	25-125	>125
		(Joint press)/ (major princi-	0	<0.1	0.1-0.2	0.2-0.5	>0.5

Parameters		**Range of values**				
	pal σ					
	General condition	Completely dry	Damp	Wet	Dripping	Flowing
Rating		15	10	7	4	0
B. Rating Adustment for Discontinuity Orientation						
Strike and dip orientation		Very favourable	Favourable	Fair	Unfavourable	Very Unfavourable
	Tunnels & mines	0	-2	-5	-10	-12
Ratings	Foundations	0	-2	-7	-15	-25
	Slopes	0	-5	-25	-50	-60
C. Rock Mass Classes Determined from Total Ratings						
Rating		100 ← 81	80 ← 61	60 ← 41	40 ← 21	< 21
Class Number		I	II	III	IV	V
Description		Very good rock	Good rock	Fair rock	Poor rock	Very poor rock
D. Meaning of Rock Classes						
Class number		I	II	III	IV	V
Average stand-up time		20yrs for 15 m span	1 year for 10 m span	1 week for 5 m span	10 hrs for 2.5 m span	30 min for 1 m span
Cohesion of rock mass (kPa)		> 400	300 - 400	200 - 300	100 - 200	< 100
Friction angle of rock mass (deg)		< 45	35 - 45	25 - 35	15 - 25	< 15
E. Guidelines for Classification of Discontinuity Condition						
Discontinuity length (persistence)		< 1m	1 – 3 m	3 – 10 m	10 – 20 m	>20 m
Rating		6	4	2	1	0
Separation (aperture)		None	< 0.1 mm	0.1– 1.0 m	1 – 5 mm	>5 mm
Rating		6	5	4	1	0
Roughness		Very rough	Rough	Slightly rough	Smooth	Slickensided
Rating		6	5	3	1	0
Infilling (gouge)		None	Hard filing <5 mm	Hard filling > 5 mm	Soft filling < 5 mm	Soft filling >5 mm
Rating		6	4	2	2	0
Weathering		Unweathered	Slightly weathered	Moderately weathered	Highly weathered	Decomposed
Rating		6	5	3	1	0

F. Effect of Discontinuity Strike and Dip Orientation in Tunnneling**

Strike perpendicular to tunnel axis		Strike parallel to tunnel axis	
Drive with dip. Dip 45 – 90°	Drive with dip. Dip 20 – 45°	Dip 45 – 90°	Dip 20 – 45°
Very favourable	Favourable	Very favourable	Fair
Drive against dip. Dip 45 – 90°	Drive against dip. Dip 20 – 45°	Dip 0 – 20 Irrespective of strike	
Fair	Unfavourable	Fair	

(*Source:* 1989); *Some conditions are mutually exclusive. For example, if infilling is present, the roughness of the surface will be over-shadowed by the influence of the gouge. In such case use A.4 directly. **Modified after Wickham et all. (1972)

Appendix III. Slope Mass Rating (SMR) Results

Table A4. Slope Mass Rating (SMR) Results.

	St1	St2	Wedge		RMR	Slope Face		F1		F2		F3		F4		SMR	Stability	Failures	Support
								Value A	Factor	Value B	Factor	Value C	Factor						
Intrusive	75/287	67/238	47	133	77	80	0	133	0.15	47	1	-33	-60	Smooth Blasting	8	76.0	Stable	Some blocks	Occasional/Spot
			47	133	77	80	180	47	0.15	47	1	-33	-60	Smooth Blasting	8	76.0	Stable	Some blocks	Occasional/Spot
	75/287	29/005	88	92	77	80	0	92	0.15	88	1	8	-6	Smooth Blasting	8	84.1	Fully stable	None	None
			88	92	77	80	180	88	0.15	88	1	8	-6	Smooth Blasting	8	84.1	Fully stable	None	None
	29/005	67/238	84	96	77	80	0	96	0.15	84	1	4	-6	Smooth Blasting	8	84.1	Fully stable	None	None
			84	96	77	80	180	84	0.15	84	1	4	-6	Smooth Blasting	8	84.1	Fully stable	None	None
Metasediment	75/267	20/307	60	120	64	80	90	30	0.4	60	1	-20	-60	Presplitting	10	50.0	Partially Stable	Many wedges/Some Joint	Systematic
			60	120	64	80	270	150	0.15	60	1	-20	-60	Smooth Blasting	8	63.0	Stable	Some blocks	Occasional/Spot
	75/267	89/044	45	133	64	80	90	43	0.15	45	1	-35	-60	Smooth Blasting	8	63.0	Stable	Some blocks	Occasional/Spot
			45	133	64	80	270	137	0.15	45	1	-35	-60	Smooth Blasting	8	63.0	Stable	Some blocks	Occasional/Spot
	20/307	89/044	88	91	64	80	90	1	1	88	1	8	-6	Smooth Blasting	8	66.0	Stable	Some blocks	Occasional/Spot
			88	91	64	80	270	179	0.15	88	1	8	-6	Smooth Blasting	8	71.1	Stable	Some blocks	Occasional/Spot

Appendix IIII. Logged Data: Oxide – Transition

Table A5. Logged Data: Oxide – Transition.

DHID	From (m)	To (m)	TCR (m)	TCR (%)	SCR (cm)	SCR (%)	RQD (cm)	RQD (%)	Spacing	Joint Sets	FF	FF/m	Rock type	Weathering	Micro roughness	Alteration	Infil	Groundwater
NKS0145RD	83.1	84.6	1.5	100%	1.25	83%	0.36	24%	104	1	14.4	9.6	Metagreywacke	4	2	1	5	Moist
NKS0145RD	102.6	104.1	1.5	100%	0.92	61%	0.41	27%	184	1	8.2	5.4	Metagrey-wacke	4	2	1	5	Moist
NKS0146RD	55	55.7	0.5	71%	0.5	71%	0	0%	71	1	9.8	14.0	Metagrey-wacke	4	2	1	4	Moist
NKS014	55.7	56.	0.9	98	0.9	90	0	0%	75	1	13.	13.	Metagrey-	4	2	1	4	Moist

DHID	From (m)	To (m)	TCR (m)	TCR (%)	SCR (cm)	SCR (%)	RQD (cm)	RQD (%)	Spacing	Joint Sets	FF	FF/m	Rock type	Weathe-ring	Micro rough-ness	Al-teration	Infil	Groundwa-ter
6RD		7	8	%		%					3	3	wacke					
NKS0146RD	56.7	57.2	0.45	90%	0.33	66%	0	0%	83	1	6.1	12.1	Metagrey-wacke	4	2	1	4	Moist
NKS0146RD	57.2	58.2	1.5	150%	1.28	128%	0.21	21%	85	1	11.7	11.7	Metagrey-wacke	4	2	1	4	Moist
NKS0146RD	58.2	60.4	1.68	76%	1.45	66%	1.31	60%	207	1	10.6	4.8	Metagrey-wacke	4	2	1	4	Moist
NKS0146RD	60.4	61.7	1.3	100%	1.3	100%	1.07	82%	279	2	4.7	3.6	Metagrey-wacke	4	2	1	4	Moist
NKS0146RD	61.7	63.2	1.5	100%	1.5	100%	1.19	79%	214	1	7.0	4.7	Metagrey-wacke	4	2	1	4	Moist
NKS0146RD	63.2	64.7	1.45	97%	1.45	97%	1.25	83%	311	2	4.8	3.2	Metagrey-wacke	4	3	2	9	Moist
NKS0146RD	64.7	66.2	1.5	100%	1.5	100%	1.27	85%	375	1	4.0	2.7	Metagrey-wacke	4	2	0	1	Moist
NKS0146RD	66.2	67.7	1.46	97%	1.46	97%	1.46	97%	292	1	5.1	3.4	Metagrey-wacke	4	2	1	4	Moist
NKS0148RD	14.8	15.8	1	100%	1	100%	0.92	92%	1,000	1	1.0	1.0	Sap rock	3	6	0	5	
NKS0148RD	15.8	16.8	1	100%	1	100%	0.7	70%	500	1	2.0	2.0	Sap rock	4	6	0	5	
NKS0148RD	16.8	17.8	0.98	98%	0.98	98%	0.98	98%	490	1	2.0	2.0	Sap rock	4	6	0	5	
NKS0148RD	19.8	20.8	1	100%	1	100%	1	100%	1,000	1	1.0	1.0	Sap rock	4	4	1	7	
NKS0149DD	33.9	35.4	1.4	93%	1.08	72%		0%	1,080	1	1.4	0.9	Granite	3	6	1	7	
NKS0149DD	35.4	36.9	1.26	84%	1.26	84%	0.85	57%	756	3	2.0	1.3	Granite	3	6	1	5	
NKS0149DD	36.9	38.4	1.45	97%	0.9	60%	0.83	55%	675	2	2.2	1.5	Granite	3	3	1	4	
NKS0149DD	38.4	39.9	1.4	93%	1.1	73%	0	0%	550	2	2.7	1.8	Metagrey-wacke	3	3	1	4	
NKS0149DD	39.9	41.4	1.43	95%	1.43	95%	1.23	82%	358	6	4.2	2.8	Metagrey-wacke	4	2	1	4	
NKS0149DD	42.9	44.4	1.5	100%	1.3	87%	0.72	48%	325	4	4.6	3.1	Metagrey-wacke	4	2	1	4	
NKS0149DD	45.9	46.3	1.5	375%	0.35	88%	0.19	48%	175	2	2.3	5.7	Metagrey-wacke	4	3	1	4	
NKS0149DD	50	52.2	2	91%	0.6	27%	0.53	24%	200	3	11.0	5.0	Metagrey-wacke	4	2	1	4	Moist
NKS0149DD	52.2	53.7	1.5	100%	1.4	93%	0.64	43%	210	10	7.1	4.8	Metagrey-wacke	4	2	1	4	Moist
NKS0149DD	53.7	55.2	1.45	97%	1.45	97%	0.85	57%	326	8	4.6	3.1	Metagrey-wacke	4	2	1	4	Moist

DHID	From (m)	To (m)	TCR (m)	TCR (%)	SCR (cm)	SCR (%)	RQD (cm)	RQD (%)	Spacing	Joint Sets	FF	FF/m	Rock type	Weathering	Microroughness	Alteration	Infil	Groundwater
NKS0168DD	71.8	73.3	1.35	90%	1.27	85%	0.66	44%	318	2	4.7	3.1	Sap rock	2	2	1	4	Moist
NKS0168DD	73.3	74.8	1.5	100%	1.24	83%	0.97	65%	372	2	4.0	2.7	Sap rock	2	2	1	4	Moist
NKS0168DD	74.8	76.3	1.44	96%	1.44	96%	1.34	89%	240	1	6.3	4.2	Sap rock	2	2	1	4	Moist
NKS0168DD	76.3	77.8	1.5	100%	1.38	92%	1.1	73%	259	2	5.8	3.9	Sap rock	2	2	1	4	Moist
NKS0168DD	77.8	79.3	1.44	96%	1.38	92%	1.3	87%	276	1	5.4	3.6	Metagrey-wacke	3	2	1	4	Moist
NKS0168DD	79.3	80.8	1.4	93%	1.4	93%	0.57	38%	630	3	2.4	1.6	Metagrey-wacke	3	2	1	4	Moist
NKS0168DD	80.8	82.3	1.44	96%	1.44	96%	0.73	49%	240	2	6.3	4.2	Metagrey-wacke	3	2	1	5	Moist
NKS0168DD	82.3	83.8	1.32	88%	1.12	75%	0	0%	144	3	10.4	6.9	Metagrey-wacke	4	2	0	4	Moist
NKS0168DD	83.8	85.7	1.9	100%	1.79	94%	0.57	30%	179	2	10.6	5.6	Metagrey-wacke	4	2	1	4	Moist
NKS0168DD	85.7	86.2	0.5	100%	0.5	100%	0.5	100%	250	1	2.0	4.0	Metagrey-wacke	4	3	1	5	Moist
NKS0168DD	86.2	87.7	1.5	100%	1.5	100%	1.1	73%	205	2	7.3	4.9	Metagrey-wacke	4	2	1	7	Moist
NKS0168DD	88.7	90.2	1.5	100%	1.3	87%	1.2	80%	260	3	5.8	3.8	Metagrey-wacke	4	2	0	5	Moist
NKS0168DD	90.2	91.7	1.45	97%	1.45	97%	1.35	90%	1,088	2	1.4	0.9	Metagrey-wacke	4	2	1	5	Moist
NKS0168DD	91.7	93.2	1.5	100%	1.5	100%	1.28	85%	300	3	5.0	3.3	Metagrey-wacke	4	2	1	7	Moist
NKS0220DD	71.8	73.3	1.35	90%	1.27	85%	0.66	44%	318	2	4.7	3.1	Sap rock	2	2	1	4	Moist
NKS0220DD	73.3	74.8	1.5	100%	1.24	83%	0.97	65%	372	2	4.0	2.7	Sap rock	2	2	1	4	Moist
NKS0220DD	74.8	76.3	1.44	96%	1.44	96%	1.34	89%	240	1	6.3	4.2	Sap rock	2	2	1	4	Moist
NKS0220DD	76.3	77.8	1.5	100%	1.38	92%	1.1	73%	259	2	5.8	3.9	Sap rock	2	2	1	4	Moist
NKS0220DD	77.8	79.3	1.44	96%	1.38	92%	1.3	87%	276	1	5.4	3.6	Metagrey-wacke	3	2	1	4	Moist
NKS0220DD	79.3	80.8	1.4	93%	1.4	93%	0.57	38%	630	3	2.4	1.6	Metagrey-wacke	3	2	1	4	Moist
NKS0220DD	80.8	82.3	1.44	96%	1.44	96%	0.73	49%	240	2	6.3	4.2	Metagrey-wacke	3	2	1	5	Moist
NKS0220DD	82.3	83.8	1.32	88%	1.12	75%	0	0%	144	3	10.4	6.9	Metagrey-wacke	4	2	0	4	Moist
NKS022	83.8	85.	1.9	100	1.79	94	0.57	30%	179	2	10.	5.6	Metagrey-	4	2	1	4	Moist

DHID	From (m)	To (m)	TCR (m)	TCR (%)	SCR (cm)	SCR (%)	RQD (cm)	RQD (%)	Spacing	Joint Sets	FF	FF/m	Rock type	Weathe-ring	Micro rough-ness	Al-teration	Infil	Groundwa-ter
0DD		7		%		%					6		wacke					
NKS0220DD	85.7	86.2	0.5	100%	0.5	100%	0.5	100%	250	1	2.0	4.0	Metagrey-wacke	4	3	1	5	Moist
NKS0220DD	86.2	87.7	1.5	100%	1.5	100%	1.1	73%	205	2	7.3	4.9	Metagrey-wacke	4	2	1	7	Moist
NKS0220DD	88.7	90.2	1.5	100%	1.3	87%	1.2	80%	260	3	5.8	3.8	Metagrey-wacke	4	2	0	5	Moist
NKS0220DD	90.2	91.7	1.45	97%	1.45	97%	1.35	90%	1088	2	1.4	0.9	Metagrey-wacke	4	2	1	5	Moist
NKS0220DD	91.7	93.2	1.5	100%	1.5	100%	1.28	85%	300	3	5.0	3.3	Metagrey-wacke	4	2	1	7	Moist

Table A6. *Logged Data: Fresh Metasediment.*

DHID	From (m)	To (m)	TCR (m)	TCR (%)	SCR (cm)	SCR (%)	RQD (cm)	RQD (%)	Spacing	Joint Sets	FF	FF/m	Rock type	Weathering	Micro rough-ness	Altera-tion	In-fil	Ground water
NKS0145RD	78.6	80.1	1.48	99%	1.48	99%	1.28	85%	247	2	6.1	4.1	Metagrey wacke	5	2	1	5	Moist
NKS0145RD	80.1	81.6	1.5	100%	1.5	100%	1.3	87%	188	1	8.0	5.3	Meta-grey-wacke	5	2	2	9	Moist
NKS0145RD	81.6	83.1	1.5	100%	1.3	87%	0.31	21%	76	1	19.6	13.1	Meta-grey-wacke	5	2	1	5	Moist
NKS0145RD	86.1	87.6	1.5	100%	1.5	100%	0.61	41%	161	2	9.3	6.2	Meta-grey-wacke	5	3	2	9	Moist
NKS0145RD	87.6	89.1	1.5	100%	1.5	100%	1.04	69%	205	2	7.3	4.9	Meta-grey-wacke	5	2	1	5	Moist
NKS0145RD	89.1	90.6	1.4	93%	1.4	93%	1.35	90%	263	2	5.7	3.8	Meta-grey-wacke	6	1	1	5	Moist
NKS0145RD	90.6	92.1	1.5	100%	1.5	100%	1.27	85%	300	1	5.0	3.3	Meta-grey-wacke	6	3	1	5	Moist
NKS0145RD	92.1	93.6	1.5	100%	1.5	100%	1.4	93%	386	3	3.9	2.6	Meta-grey-wacke	6	2	1	5	Moist
NKS0145RD	93.6	95.1	1.5	100%	1.5	100%	1.16	77%	193	3	7.8	5.2	Meta-grey-wacke	6	1	1	5	Moist
NKS0145RD	95.1	96.6	1.5	100%	1.5	100%	1.42	95%	375	2	4.0	2.7	Meta-grey-wacke	6	2	1	5	Moist

DHID	From (m)	To (m)	TCR (m)	TCR (%)	SCR (cm)	SCR (%)	RQD (cm)	RQD (%)	Spacing	Joint Sets	FF	FF/m	Rock type	Weathering	Micro rough-ness	Altera-tion	In-fil	Ground water
NKS0145RD	96.6	98.1	1.5	100%	1.5	100%	1.39	93%	450	2	3.3	2.2	Meta-grey-wacke	6	1	1	5	Moist
NKS0145RD	98.1	99.6	1.46	97%	1.46	97%	1.05	70%	243	2	6.2	4.1	Meta-grey-wacke	6	3	2	9	Moist
NKS0145RD	99.6	101.2	1.4	87%	1.4	87%	1.02	64%	191	2	8.4	5.2	Meta-grey-wacke	6	3	0	7	Moist
NKS0145RD	101.2	102.6	1.5	107%	1.22	87%	1	71%	111	1	12.6	9.0	Meta-grey-wacke	5	2	1	5	Moist
NKS0145RD	104.1	105.6	1.5	100%	1.5	100%	1.26	84%	321	2	4.7	3.1	Meta-grey-wacke	5	5	1	5	Moist
NKS0145RD	105.6	107.1	1.5	100%	1.5	100%	1.5	100%	563	2	2.7	1.8	Meta-grey-wacke	5	3	0	7	Moist
NKS0145RD	107.1	108.6	1.5	100%	1.5	100%	1.34	89%	250	1	6.0	4.0	Meta-grey-wacke	6	3	0	1	Moist
NKS0145RD	108.6	110.1	1.5	100%	1.5	100%	1.42	95%	375	1	4.0	2.7	Meta-grey-wacke	6	3	0	7	Moist
NKS0145RD	110.1	111.6	1.5	100%	1.5	100%	1.43	95%	500	1	3.0	2.0	Meta-grey-wacke	6	3	0	1	Moist
NKS0145RD	111.6	113.1	1.5	100%	1.5	100%	1.5	100%	750	1	2.0	1.3	Meta-grey-wacke	6	3	2	9	Moist
NKS0145RD	113.1	114.6	1.5	100%	1.5	100%	1.5	100%	750	1	2.0	1.3	Meta-grey-wacke	6	3	0	7	Moist
NKS0145RD	114.6	116.1	1.46	97%	1.46	97%	1.46	97%	1,460	1	1.0	0.7	Meta-grey-wacke	6	2	1	5	Moist
NKS0145RD	116.1	117.6	1.5	100%	1.5	100%	1.5	100%	1,500	1	1.0	0.7	Meta-grey-wacke	6	2	1	5	Moist
NKS0145RD	117.6	119.1	1.42	95%	1.42	95%	1.42	95%	473	1	3.2	2.1	Meta-grey-wacke	6	3	0	7	Moist
NKS0145RD	119.1	120.6	1.5	100%	1.5	100%	1.5	100%	500	1	3.0	2.0	Meta-grey-wacke	6	3	0	9	Moist
NKS0145RD	120.6	122.1	1.45	97%	1.45	97%	1.45	97%	1,450	1	1.0	0.7	Meta-grey-wacke	6	3	0	9	Moist

DHID	From (m)	To (m)	TCR (m)	TCR (%)	SCR (cm)	SCR (%)	RQD (cm)	RQD (%)	Spacing	Joint Sets	FF	FF/m	Rock type	Weathering	Micro roughness	Altera-tion	In-fil	Ground water
NKS0145RD	122.1	123.6	1.5	100%	1.5	100%	1.43	95%	750	1	2.0	1.3	Meta-greywacke	6	2	0	1	Moist
NKS0145RD	123.6	125.1	1.5	100%	1.5	100%	1.44	96%	375	1	4.0	2.7	Meta-greywacke	6	1	1	5	Moist
NKS0145RD	125.1	126.6	1.5	100%	1.1	73%	0.66	44%	183	2	8.2	5.5	Meta-greywacke	6	2	1	5	Moist
NKS0145RD	126.6	128.1	1.5	100%	1.5	100%	1.37	91%	300	1	5.0	3.3	Meta-greywacke	6	1	1	5	Moist
NKS0145RD	128.1	129.6	1.44	96%	1.44	96%	1.23	82%	206	1	7.3	4.9	Meta-greywacke	6	2	0	7	Moist
NKS0145RD	129.6	130	0.4	100%	0.4	100%	0.4	100%	400	1	1.0	2.5	Meta-greywacke	6	3	0	1	Moist
NKS0146RD	67.7	69.2	1.5	100%	1.5	100%	1.38	92%	214	1	7.0	4.7	Meta-greywacke	5	2	1	5	Moist
NKS0146RD	69.2	70.7	1.4	93%	1.4	93%	1.4	93%	467	1	3.2	2.1	Meta-greywacke	5	2	0	1	Moist
NKS0146RD	70.7	72.2	1.5	100%	1.5	100%	1.28	85%	150	1	10.0	6.7	Meta-greywacke	5	2	1	4	Moist
NKS0146RD	72.2	73.7	1.35	90%	1.35	90%	1.35	90%	450	1	3.3	2.2	Meta-greywacke	5	2	1	7	Moist
NKS0146RD	73.7	75.2	1.5	100%	1.4	93%	1.24	83%	233	1	6.4	4.3	Meta-greywacke	5	2	0	1	Moist
NKS0146RD	75.2	76.7	1.5	100%	1.5	100%	1.42	95%	375	2	4.0	2.7	Meta-greywacke	5	2	1	4	Moist
NKS0146RD	76.7	78.2	1.5	100%	1.5	100%	1.45	97%	540	3	2.8	1.9	Meta-greywacke	5	2	1	4	Moist
NKS0146RD	78.2	79.7	1.5	100%	1.5	100%	1.44	96%	1,125	2	1.3	0.9	Meta-greywacke	5	5	1	4	Moist
NKS0146RD	79.7	81.2	1.5	100%	1.5	100%	1.37	91%	338	3	4.4	3.0	Meta-greywacke	5	2	1	4	Moist
NKS0146RD	81.2	82.7	1.44	96%	1.44	96%	1.42	95%	360	2	4.2	2.8	Meta-greywacke	5	2	1	4	Moist

DHID	From (m)	To (m)	TCR (m)	TCR (%)	SCR (cm)	SCR (%)	RQD (cm)	RQD (%)	Spacing	Joint Sets	FF	FF/m	Rock type	Weathering	Micro roughness	Alteration	In-fil	Ground water
NKS0146RD	82.7	84.2	1.5	100%	1.5	100%	1.5	100%	214	1	7.0	4.7	Meta-greywacke	6	2	1	9	Moist
NKS0146RD	84.2	85.7	1.41	94%	1.41	94%	1.41	94%	423	2	3.5	2.4	Meta-greywacke	6	3	2	9	Moist
NKS0146RD	85.7	87.2	1.5	100%	1.5	100%	1.5	100%	375	1	4.0	2.7	Meta-greywacke	6	2	1	4	Moist
NKS0146RD	87.2	88.7	1.5	100%	1.5	100%	1.5	100%	300	1	5.0	3.3	Meta-greywacke	6	3	1	7	Moist
NKS0146RD	88.7	90.2	1.5	100%	1.5	100%	1.21	81%	375	2	4.0	2.7	Meta-greywacke	6	2	1	4	Moist
NKS0146RD	90.2	91.7	1.26	84%	1.26	84%	1.26	84%	630	1	2.4	1.6	Meta-greywacke	6	3	0	1	Moist
NKS0146RD	91.7	93.2	1.5	100%	1.5	100%	1.43	95%	500	1	3.0	2.0	Meta-greywacke	6	3	1	4	Moist
NKS0146RD	93.2	94.7	1.45	97%	1.45	97%	1.45	97%	725	1	2.1	1.4	Meta-greywacke	6	3	2	9	Moist
NKS0149DD	46.3	47.8	1.5	100%	1.36	91%	1.36	91%	453	3	3.3	2.2	Meta-greywacke	5	2	1	4	Moist
NKS0149DD	47.8	49.3	1.5	100%	1.5	100%	1.43	95%	500	3	3.0	2.0	Meta-greywacke	5	2	1	5	Moist
NKS0149DD	49.3	50	0.7	100%	0.7	100%	0.49	70%	350	3	2.0	2.9	Meta-greywacke	5	2	1	4	Moist
NKS0149DD	55.2	56.7	1.5	100%	1.5	100%	1	67%	450	5	3.3	2.2	Metagreywacke	5	2	1	4	Moist
NKS0149DD	56.7	58.2	1.2	80%	0.86	57%	0.43	29%	215	4	7.0	4.7	Metagrey-wacke	5	2	1	4	Moist
NKS0149DD	58.2	59.7	1.45	97%	1.25	83%	1.25	83%	208	9	7.2	4.8	Metagrey-wacke	5	2	1	5	Moist
NKS0149DD	59.7	61.2	1.5	100%	1.5	100%	1.4	93%	450	5	3.3	2.2	Metagrey-wacke	5	2	1	4	Moist
NKS0149DD	61.2	62.7	1.47	98%	1.47	98%	0.76	51%	245	9	6.1	4.1	Metagrey-wacke	5	3	1	4	Moist
NKS0149DD	62.7	64.2	1.5	100%	1.5	100%	1	67%	375	6	4.0	2.7	Metagrey-wacke	5	2	1	7	Moist
NKS0149D	68.7	70.2	1.5	100	1.5	100	1.0	72%	338	8	4.4	3.0	Metagrey-	5	2	1	4	Moist

D				%		%	8						wacke					
NKS0149DD	70.2	71.7	1.43	95%	1.43	95%	1.2	80%	358	6	4.2	2.8	Metagreywacke	6	2	1	5	Moist
NKS0149DD	71.7	73.2	1.47	98%	1.47	98%	0.83	55%	170	13	8.8	5.9	Metagreywacke	6	6	1	4	Moist
NKS0149DD	73.2	74.7	1.5	100%	1.5	100%	0.54	36%	141	16	10.7	7.1	Metagreywacke	6	6	1	5	Moist
NKS0149DD	74.7	76.2	1.45	97%	1.45	97%	0.64	43%	186	14	8.0	5.4	Metagreywacke	6	2	1	4	Moist
NKS0149DD	76.2	77.7	1.5	100%	1.5	100%	1.21	81%	107	14	14.0	9.3	Metagreywacke	6	2	1	5	Moist
NKS0149DD	77.7	79.2	1.1	73%	1.1	73%	0.67	45%	165	10	9.1	6.1	Metagreywacke	6	2	1	5	Moist
NKS0149DD	79.2	80.7	1.5	100%	1.5	100%	1.47	98%	450	6	3.3	2.2	Metagreywacke	6	2	1	4	Moist
NKS0149DD	80.7	82.2	1.5	100%	1.5	100%	1.02	68%	300	9	5.0	3.3	Metagreywacke	6	2	1	5	Moist
NKS0149DD	82.2	83.7	1.5	100%	1.5	100%	1.36	91%	563	4	2.7	1.8	Metagreywacke	6	2	1	5	Moist
NKS0149DD	83.7	85.2	1.5	100%	1.5	100%	1.19	79%	338	8	4.4	3.0	Metagreywacke	6	2	1	4	Moist
NKS0149DD	85.2	86.7	1.5	100%	1.5	100%	1.12	75%	173	13	8.7	5.8	Metagreywacke	6	2	1	5	Moist
NKS0149DD	89.7	91.2	1.5	100%	1.5	100%	1.26	84%	375	6	4.0	2.7	Metagreywacke	6	2	0	1	Moist
NKS0149DD	91.2	92.7	1.5	100%	1.5	100%	1.35	90%	563	4	2.7	1.8	Metagreywacke	6	3	0	1	Moist
NKS0149DD	92.7	94.2	1.42	95%	1.4	93%	1.35	90%	420	5	3.6	2.4	Metagreywacke	6	2	1	7	Moist
NKS0149DD	94.2	95.7	1.48	99%	1.48	99%	1.28	85%	296	5	5.1	3.4	Metagreywacke	6	2	1	7	Moist
NKS0149DD	95.7	97.2	1.46	97%	1.46	97%	1.46	97%	657	4	2.3	1.5	Metagreywacke	6	3	0	1	Moist
NKS0149DD	97.2	98.7	1.5	100%	1.5	100%	1.45	97%	750	3	2.0	1.3	Metagreywacke	6	3	1	7	Moist
NKS0149DD	98.7	100.2	1.43	95%	1.43	95%	1.43	95%	715	3	2.1	1.4	Metagreywacke	6	2	1	7	Moist
NKS0149DD	100.2	101.7	1.5	100%	1.5	100%	1.5	100%	750	2	2.0	1.3	Metagreywacke	6	2	0	1	Moist
NKS0149DD	101.7	103.2	1.5	100%	1.5	100%	1.5	100%	750	2	2.0	1.3	Metagreywacke	6	2	1	7	Moist
NKS0149DD	103.2	104.7	1.5	100%	1.5	100%	1.5	100%	750	2	2.0	1.3	Metagreywacke	6	2	0	1	Moist
NKS0149DD	104.7	106.2	1.5	100%	1.5	100%	1.5	100%	500	3	3.0	2.0	Metagreywacke	6	3	1	7	Moist
NKS0149DD	106.2	107.7	1.44	96%	1.44	96%	1.44	96%	720	2	2.1	1.4	Metagreywacke	6	3	0	1	Moist
NKS0149D	107.	109.	1.5	100	1.5	100	1.5	100	450	5	3.3	2.2	Metagrey-	6	3	0	1	Moist

D	7	2		%		%		%					wacke					
NKS0149DD	109.2	110.7	1.5	100%	1.5	100%	1.5	100%	375	4	4.0	2.7	Metagreywacke	6	3	2	9	Moist
NKS0149DD	110.7	112.2	1.5	100%	1.5	100%	1.41	94%	450	5	3.3	2.2	Metagreywacke	6	6	0	1	Moist
NKS0149DD	112.2	113.7	1.5	100%	1.5	100%	1.48	99%	500	3	3.0	2.0	Metagreywacke	6	3	2	9	Moist
NKS0149DD	113.7	115.2	1.3	87%	1.3	87%	1.3	87%	1300	1	1.2	0.8	Metagreywacke	6	3	2	9	Moist
NKS0149DD	115.2	116.7	1.5	100%	1.5	100%	0.95	63%	205	11	7.3	4.9	Metagreywacke	6	3	1	7	Moist
NKS0149DD	116.7	118.2	1.5	100%	1.5	100%	1.31	87%	375	6	4.0	2.7	Metagreywacke	6	3	1	7	Moist
NKS0149DD	118.2	119.7	1.43	95%	1.43	95%	1.1	73%	268	8	5.6	3.7	Metagreywacke	6	3	1	8	Moist
NKS0149DD	119.7	121.2	1.5	100%	1.5	100%	1.02	68%	300	5	5.0	3.3	Metagreywacke	6	3	0	1	Moist
NKS0149DD	121.2	122.7	1.5	100%	1.5	100%	1.12	75%	136	11	11.0	7.3	Metagreywacke	6	3	2	9	Moist
NKS0149DD	122.7	124.2	1.5	100%	1.5	100%	1.06	71%	125	12	12.0	8.0	Metagreywacke	6	3	0	1	Moist
NKS0149DD	124.2	125.7	1.4	93%	1.4	93%	0.77	51%	175	12	8.6	5.7	Metagreywacke	6	3	0	1	Moist
NKS0149DD	125.7	127.2	1.44	96%	1.44	96%	1.35	90%	206	7	7.3	4.9	Metagreywacke	6	3	0	1	Moist
NKS0149DD	127.2	128.7	1.46	97%	1.46	97%	0.87	58%	375	7	4.0	2.7	Metagreywacke	6	3	0	1	Moist
NKS0149DD	128.7	130.2	1.45	97%	1.45	97%	1.2	80%	272	8	5.5	3.7	Metagreywacke	6	3	1	8	Moist
NKS0149DD	130.2	131.7	1.45	97%	1.45	97%	1	67%	435	6	3.4	2.3	Metagreywacke	6	2	1	7	Moist
NKS0149DD	131.7	133.2	1.5	100%	1.5	100%	1.45	97%	225	10	6.7	4.4	Metagreywacke	6	3	0	9	Moist
NKS0149DD	133.2	134.7	1.46	97%	1.46	97%	1.17	78%	548	4	2.7	1.8	Metagreywacke	6	3	0	1	Moist
NKS0149DD	134.7	136.2	1.43	95%	1.43	95%	1.24	83%	322	8	4.7	3.1	Metagreywacke	6	2	1	7	Moist
NKS0149DD	136.2	137.7	1.5	100%	1.5	100%	1.1	73%	281	8	5.3	3.6	Metagreywacke	6	3	0	1	Moist
NKS0149DD	137.7	139.2	1.5	100%	1.5	100%	1.39	93%	321	7	4.7	3.1	Metagreywacke	6	3	1	7	Moist
NKS0149DD	139.2	140.7	1.5	100%	1.29	86%	0.76	51%	176	11	8.5	5.7	Metagreywacke	6	2	1	8	Moist
NKS0149DD	140.7	142.2	1.42	95%	1.42	95%	0.62	41%	197	13	7.6	5.1	Metagreywacke	6	2	1	9	Moist
NKS0149DD	142.2	143.7	1.5	100%	1.5	100%	1.3	87%	225	10	6.7	4.4	Metagreywacke	6	2	1	7	Moist
NKS0149D	143.	145.	1.5	100	1.3	91%	0.6	41%	204	10	7.4	4.9	Metagrey-	6	3	1	7	Moist

D	7	2		%	6		1						wacke					
NKS0168DD	87.7	88.7	1	100%	1	100%	0.89	89%	300	3	3.3	3.3	Metagreywacke	5	2	0	4	Moist
NKS0168DD	93.2	94.7	1.35	90%	1.35	90%	1.24	83%	450	1	3.3	2.2	Meta-greywacke	5	2	0	1	Moist
NKS0168DD	94.7	96.2	1.36	91%	1.11	74%	0.72	48%	833	2	1.8	1.2	Meta-greywacke	5	2	1	7	Moist
NKS0168DD	96.2	97.7	1.5	100%	1.26	84%	0.97	65%	454	3	3.3	2.2	Meta-greywacke	5	1	1	5	Moist
NKS0168DD	97.7	98.8	1.1	100%	0.48	44%	0.2	18%	480	1	2.3	2.1	Meta-greywacke	5	1	1	5	Moist
NKS0168DD	98.8	100.7	1.83	96%		0%	0	0%	1	0	0.0	0.0	Meta-greywacke	5				Moist
NKS0168DD	100.7	102.2	1	67%		0%	0	0%	1	0	0.0	0.0	Meta-greywacke	5				Moist
NKS0168DD	102.2	103.7	1.3	87%	1.07	71%	0.47	31%	97	1	15.4	10.3	Meta-greywacke	5	2	1	5	Moist
NKS0168DD	103.7	105.2	1.5	100%	1.5	100%	0.98	65%	125	1	12.0	8.0	Meta-greywacke	5	2	1	7	Moist
NKS0168DD	105.2	106.7	1.5	100%	1.5	100%	1.42	95%	375	2	4.0	2.7	Meta-greywacke	6	2	0	7	Moist
NKS0168DD	106.7	108.2	1.45	97%	1.45	97%	1.23	82%	725	2	2.1	1.4	Meta-greywacke	6	5	0	7	Moist
NKS0168DD	108.2	110.2	2	100%	2	100%	1.59	80%	400	3	5.0	2.5	Meta-greywacke	6	2	1	4	Moist
NKS0220DD	87.7	88.7	1	100%	1	100%	0.89	89%	300	3	3.3	3.3	Meta-greywacke	5	2	0	4	Moist
NKS0220DD	93.2	94.7	1.35	90%	1.35	90%	1.24	83%	450	1	3.3	2.2	Meta-greywacke	5	2	0	1	Moist
NKS0220DD	94.7	96.2	1.36	91%	1.11	74%	0.72	48%	833	2	1.8	1.2	Meta-greywacke	5	2	1	7	Moist
NKS0220DD	96.2	97.7	1.5	100%	1.26	84%	0.97	65%	454	3	3.3	2.2	Meta-greywacke	5	1	1	5	Moist
NKS0220DD	97.7	98.8	1.1	100%	0.48	44%	0.2	18%	480	1	2.3	2.1	Meta-greywacke	5	1	1	5	Moist
NKS02	102.	103.	1.3	87%	1.07	71%	0.47	31%	97	1	15.4	10.3	Meta-	5	2	1	5	Moist

20DD	2	7											greywacke					
NKS0220DD	103.7	105.2	1.5	100%	1.5	100%	0.98	65%	125	1	12.0	8.0	Meta-greywacke	5	2	1	7	Moist
NKS0220DD	105.2	106.7	1.5	100%	1.5	100%	1.42	95%	375	2	4.0	2.7	Meta-greywacke	6	2	0	7	Moist
NKS0220DD	106.7	108.2	1.45	97%	1.45	97%	1.23	82%	725	2	2.1	1.4	Meta-greywacke	6	5	0	7	Moist
NKS0220DD	108.2	110.2	2	100%	2	100%	1.59	80%	400	3	5.0	2.5	Meta-greywacke	6	2	1	4	Moist

Table A7. *Logged Data: Fresh Intrusive.*

DHID	From (m)	To (m)	TCR (m)	TCR (%)	SCR (cm)	SCR (%)	RQD (cm)	RQD (%)	Spacing (m)	Joint Sets	FF	FF/m	Rock type	Weathering	Microroughness	Alteration	Infil	Groundwater
NKS0145RD	60	62.1	2.04	97%	2.04	97%	2.04	97%	1530	2	1.4	0.7	Granite	6	3	1	7	Moist
NKS0145RD	62.1	63.6	1.5	100%	1.5	100%	1.5	100%	1000	0	0.0	0.0	Granite	6				Moist
NKS0145RD	63.6	65.1	1.47	98%	1.47	98%	1.47	98%	735	2	2.0	1.4	Granite	6	6	1	5	Moist
NKS0145RD	65.1	66.6	1.5	100%	1.5	100%	1.46	97%	1500	1	1.0	0.7	Granite	6	3	0	1	Moist
NKS0145RD	66.6	68.1	1.48	99%	1.48	99%	1.48	99%	370	1	4.1	2.7	Granite	6	3	2	9	Moist
NKS0145RD	68.1	69.6	1.5	100%	1.5	100%	1.5	100%	1500	1	1.0	0.7	Granite	6	6	0	9	Moist
NKS0145RD	69.6	71.1	1.47	98%	1.47	98%	1.47	98%	490	1	3.1	2.0	Granite	6	3	1	5	Moist
NKS0145RD	71.1	72.6	1.26	84%	1.26	84%	1.26	84%	1000	0	0.0	0.0	Granite	6				Moist
NKS0145RD	72.6	74.1	1.5	100%	1.5	100%	1.45	97%	900	3	1.7	1.1	Granite	6	2	1	5	Moist
NKS0145RD	74.1	75.6	1.5	100%	1.5	100%	1.5	100%	1500	1	1.0	0.7	Granite	5	5	1	5	Moist
NKS0145RD	75.6	77.1	1.45	97%	1.45	97%	1.35	90%	1450	1	1.0	0.7	Granite	5	2	1	2	Moist
NKS0146RD	94.7	96.2	1.5	100%	1.5	100%	1.5	100%	1000	0	0.0	0.0	Granite	6				Moist
NKS0146RD	96.2	97.7	1.5	100%	1.5	100%	1.5	100%	1000	0	0.0	0.0	Granite	6				Moist
NKS0146RD	97.7	99.2	1.5	100%	1.33	89%	1.31	87%	1000	0	0.0	0.0	Granite	6				Moist
NKS0146RD	99.2	100.7	1.2	80%	1.2	80%	1.2	80%	900	2	1.7	1.1	Granite	6	5	1	5	Moist

DHID	From (m)	To (m)	TCR (m)	TCR (%)	SCR (cm)	SCR (%)	RQD (cm)	RQD (%)	Spacing (m)	Joint Sets	FF	FF/m	Rock type	Weathering	Micro roughness	Alteration	Infil	Groundwater
NKS0146RD	100.7	102.2	1.5	100%	1.5	100%	1.42	95%	1500	1	1.0	0.7	Granite	6	5	1	5	Moist
NKS0146RD	102.2	103.7	0.8	53%	0.72	48%	0.53	35%	180	2	8.3	5.6	Granite	6	3	1	7	Moist
NKS0146RD	103.7	105.2	1.4	93%	1.4	93%	1.3	87%	1400	1	1.1	0.7	Granite	6	5	2	9	Moist
NKS0146RD	105.2	106.7	1.14	76%	1.14	76%	1.14	76%	1000	0	0.0	0.0	Granite	6				Moist
NKS0146RD	106.7	108.2	1.5	100%	1.5	100%	1.41	94%	500	1	3.0	2.0	Granite	6	5	1	7	Moist
NKS0146RD	108.2	109.7	1.45	97%	1.45	97%	1.45	97%	1450	1	1.0	0.7	Granite	6	5	1	4	Moist
NKS0146RD	109.7	111.2	1.5	100%	1.5	100%	1.5	100%	1000	0	0.0	0.0	Granite	6				Moist
NKS0146RD	111.2	112.7	1.42	95%	1.42	95%	1.42	95%	1420	1	1.1	0.7	Granite	6	3	2	9	Moist
NKS0146RD	112.7	114.2	1.5	100%	1.5	100%	1.5	100%	1125	2	1.3	0.9	Granite	6	3	2	9	Moist
NKS0146RD	114.2	115.7	1.5	100%	1.5	100%	1.5	100%	1000	0	0.0	0.0	Granite	6				Moist
NKS0146RD	115.7	117.2	1.48	99%	1.48	99%	1.48	99%	1000	0	0.0	0.0	Granite	6				Moist
NKS0146RD	117.2	118.7	1.37	91%	1.37	91%	1.37	91%	1370	1	1.1	0.7	Granite	6	3	2	9	Moist
NKS0146RD	118.7	120.2	1.5	100%	1.5	100%	1.5	100%	1125	2	1.3	0.9	Granite	6	5	1	5	Moist
NKS0146RD	120.2	121.7	1.5	100%	1.5	100%	1.5	100%	1500	1	1.0	0.7	Granite	6	3	2	9	Moist
NKS0146RD	121.7	123.2	1.5	100%	1.5	100%	1.5	100%	500	1	3.0	2.0	Granite	6	3	2	9	Moist
NKS0146RD	123.2	124.7	1.5	100%	1.5	100%	1.5	100%	1500	1	1.0	0.7	Granite	6	3	2	9	Moist
NKS0146RD	124.7	126.2	1.5	100%	1.5	100%	1.5	100%	1500	1	1.0	0.7	Granite	6	3	2	9	Moist
NKS0146RD	126.2	127.7	1.46	97%	1.46	97%	1.46	97%	1000	0	0.0	0.0	Granite	6				Moist
NKS0146RD	127.7	129.2	1.5	100%	1.5	100%	1.5	100%	1000	0	0.0	0.0	Granite	6				Moist
NKS0146RD	129.2	130.7	1.44	96%	1.44	96%	1.44	96%	1000	0	0.0	0.0	Granite	6				Moist
NKS0146RD	130.7	132.2	1.5	100%	1.5	100%	1.5	100%	1000	0	0.0	0.0	Granite	6				Moist
NKS0146RD	132.2	133.7	1.48	99%	1.48	99%	1.42	95%	740	1	2.0	1.4	Granite	6	3	1	4	Moist
NKS014	133	135	1.5	100	1.5	100	1.5	100%	1500	1	1.0	0.7	Granite	6	3	2	9	Moist

DHID	From (m)	To (m)	TCR (m)	TCR (%)	SCR (cm)	SCR (%)	RQD (cm)	RQD (%)	Spacing (m)	Joint Sets	FF	FF/m	Rock type	Weathering	Micro roughness	Alteration	Infil	Groundwater
6RD	.7	.2		%		%												
NKS0146RD	135.2	136.7	1.42	95%	1.42	95%	1.42	95%	1420	1	1.1	0.7	Granite	6	3	2	9	Moist
NKS0146RD	136.7	138.2	1.45	97%	1.45	97%	1.45	97%	725	1	2.1	1.4	Granite	6	3	2	9	Moist
NKS0146RD	138.2	139.7	1.5	100%	1.5	100%	1.5	100%	1500	1	1.0	0.7	Granite	6	3	1	5	Moist
NKS0146RD	139.7	141.2	1.5	100%	1.5	100%	1.5	100%	500	1	3.0	2.0	Granite	6	2	1	5	Moist
NKS0146RD	141.2	142.7	1.33	89%	1.33	89%	1.33	89%	1000	0	0.0	0.0	Granite	6				Moist
NKS0146RD	142.7	144.2	1.5	100%	1.5	100%	1.4	93%	500	1	3.0	2.0	Granite	6	3	0	1	Moist
NKS0146RD	144.2	145.7	1.42	95%	1.42	95%	1.42	95%	1065	2	1.4	0.9	Granite	6	3	1	5	Moist
NKS0146RD	145.7	147.2	1.5	100%	1.5	100%	1.5	100%	1500	1	1.0	0.7	Granite	6	2	1	7	Moist
NKS0146RD	147.2	148.7	1.5	100%	1.5	100%	1.5	100%	450	3	3.3	2.2	Granite	6	2	1	4	Moist
NKS0146RD	148.7	150.2	1.33	89%	1.33	89%	1.33	89%	665	1	2.3	1.5	Granite	6	2	1	4	Moist
NKS0146RD	150.2	151.7	1.48	99%	1.48	99%	1.48	99%	370	2	4.1	2.7	Granite	6	2	1	4	Moist
NKS0146RD	151.7	153.2	1.5	100%	1.5	100%	1.5	100%	300	1	5.0	3.3	Granite	6	2	1	5	Moist
NKS0146RD	153.2	154.7	1.39	93%	1.39	93%	1.39	93%	695	1	2.2	1.4	Granite	6	2	0	1	Moist
NKS0146RD	154.7	156.2	1.5	100%	1.5	100%	1.4	93%	900	3	1.7	1.1	Granite	6	2	1	5	Moist
NKS0146RD	156.2	157.7	1.45	97%	1.45	97%	1.45	97%	483	1	3.1	2.1	Granite	6	2	1	5	Moist
NKS0146RD	157.7	159.2	1.5	100%	1.5	100%	1.5	100%	1125	2	1.3	0.9	Granite	6	2	1	5	Moist
NKS0146RD	159.2	160.7	1.44	96%	1.44	96%	1.44	96%	1440	1	1.0	0.7	Granite	6	5	0	1	Moist
NKS0146RD	160.7	162.2	1.5	100%	1.5	100%	1.5	100%	450	2	3.3	2.2	Granite	6	3	1	5	Moist
NKS0146RD	162.2	163.7	1.5	100%	1.5	100%	1.5	100%	750	2	2.0	1.3	Granite	6	2	1	5	Moist
NKS0146RD	163.7	165.2	1.5	100%	1.5	100%	1.5	100%	1500	1	1.0	0.7	Granite	6	3	2	9	Moist
NKS0148RD	21.8	22.8	0.88	88%	0.88	88%	0.88	88%	1000	0	0.0	0.0	Granite	5				Moist
NKS0148RD	22.8	24.3	1.5	100%	1.5	100	1.5	100%	1500	1	1.0	0.7	Granite	5	6	1	5	Moist

						%												
NKS0148RD	24.3	25.8	1.46	97%	1.46	97%	1.46	97%	1000	0	0.0	0.0	Granite	5				Moist
NKS0148RD	25.8	27.3	1.5	100%	1.5	100 %	1.5	100%	1500	1	1.0	0.7	Granite	5	6	1	7	Moist
NKS0148RD	27.3	28.8	1.42	95%	1.42	95%	1.42	95%	1000	0	0.0	0.0	Granite	5				Moist
NKS0148RD	28.8	30.3	1.5	100%	1.5	100 %	1.5	100%	1500	1	1.0	0.7	Granite	5	6	0	9	Moist
NKS0148RD	30.3	31.8	1.48	99%	1.48	99%	1.48	99%	1000	0	0.0	0.0	Granite	5				Moist
NKS0148RD	31.8	33.3	1.5	100%	1.5	100 %	1.5	100%	1000	0	0.0	0.0	Granite	5				Moist
NKS0148RD	33.3	34.8	1.5	100%	1.5	100 %	1.5	100%	1500	1	1.0	0.7	Granite	5	6	0	1	Moist
NKS0148RD	34.8	36.3	1.5	100%	1.5	100 %	1.5	100%	1000	0	0.0	0.0	Granite	5				Moist
NKS0148RD	36.3	37.8	1.5	100%	1.5	100 %	1.48	99%	1000	0	0.0	0.0	Granite	5				Moist
NKS0148RD	37.8	39.3	1.37	91%	1.37	91%	1.37	91%	1028	2	1.5	1.0	Granite	5	3	0	5	Moist
NKS0148RD	39.3	40.8	1.5	100%	1.5	100 %	1.44	96%	750	1	2.0	1.3	Granite	5	3	0	9	Moist
NKS0148RD	40.8	42.3	1.5	100%	1.4	93%	1.28	85%	420	2	3.6	2.4	Granite	5	6	0	5	Moist
NKS0148RD	42.3	43.8	1.5	100%	1.5	100 %	1.5	100%	1500	1	1.0	0.7	Granite	5	6	0	9	Moist
NKS0148RD	43.8	45.3	1.5	100%	1.5	100 %	1.42	95%	1125	2	1.3	0.9	Granite	5	6	1	7	Moist
NKS0148RD	45.3	46.8	1.5	100%	1.5	100 %	1.5	100%	1500	1	1.0	0.7	Granite	5	6	0	9	Moist
NKS0148RD	46.8	48.3	1.5	100%	1.5	100 %	1.5	100%	1000	0	0.0	0.0	Granite	5				Moist
NKS0148RD	48.3	49.8	1.5	100%	1.5	100 %	1.5	100%	1000	0	0.0	0.0	Granite	5				Moist
NKS0148RD	49.8	51.3	1.44	96%	1.44	96%	1.44	96%	1000	0	0.0	0.0	Granite	5				Moist
NKS0148RD	51.3	52.8	1.49	99%	1.49	99%	1.49	99%	1000	0	0.0	0.0	Granite	5				Moist
NKS0148RD	52.8	54.3	1.5	100%	1.5	100 %	1.4	93%	1500	1	1.0	0.7	Granite	5	3	0	9	Moist
NKS0148RD	54.3	55.8	1.5	100%	1.5	100 %	1.5	100%	1000	0	0.0	0.0	Granite	6				Moist
NKS0148RD	55.8	57.3	1.5	100%	1.5	100 %	1.5	100%	1000	0	0.0	0.0	Granite	6				Moist
NKS0148RD	57.3	58.8	1.47	98%	1.47	98%	1.47	98%	735	1	2.0	1.4	Granite	6	3	0	9	Moist
NKS0148RD	58.8	60.3	1.39	93%	1.39	93%	1.39	93%	1000	0	0.0	0.0	Granite	6				Moist
NKS0148RD	60.3	61.8	1.46	97%	1.46	97%	1.46	97%	1460	1	1.0	0.7	Granite	6	2	1	7	Moist
NKS0148RD	61.8	63.3	1.5	100%	1.5	100 %	1.5	100%	1000	0	0.0	0.0	Granite	6				Moist
NKS0148RD	63.3	64.8	1.5	100%	1.5	100 %	1.5	100%	1000	0	0.0	0.0	Granite	6				Moist
NKS0148RD	64.8	66.3	1.47	98%	1.47	98%	1.47	98%	1000	0	0.0	0.0	Granite	6				Moist

NKS0148RD	66.3	67.8	1.5	100%	1.5	100%	1.4	93%	750	1	2.0	1.3	Granite	6	2	1	7	Moist
NKS0148RD	67.8	69.3	1.49	99%	1.49	99%	1.49	99%	1490	1	1.0	0.7	Granite	6	2	1	7	Moist
NKS0148RD	69.3	70.8	1.45	97%	1.45	97%	1.45	97%	1450	1	1.0	0.7	Granite	6	3	0	9	Moist
NKS0148RD	70.8	72.3	1.5	100%	1.5	100%	1.5	100%	750	1	2.0	1.3	Granite	6	3	1	5	Moist
NKS0148RD	72.3	73.8	1.47	98%	1.47	98%	1.47	98%	1470	1	1.0	0.7	Granite	6	2	1	7	Moist
NKS0148RD	73.8	75.3	1.5	100%	1.5	100%	1.5	100%	1500	1	1.0	0.7	Granite	6	3	0	9	Moist
NKS0148RD	75.3	76.8	1.5	100%	1.5	100%	1.5	100%	1500	1	1.0	0.7	Granite	6	3	0	9	Moist
NKS0148RD	76.8	78.3	1.49	99%	1.49	99%	1.49	99%	1000	0	0.0	0.0	Granite	6				Moist
NKS0148RD	78.3	79.8	1.5	100%	1.5	100%	1.5	100%	750	1	2.0	1.3	Granite	6	3	0	9	Moist
NKS0148RD	79.8	81.3	1.5	100%	1.5	100%	1.5	100%	1000	0	0.0	0.0	Granite	6				Moist
NKS0148RD	81.3	82.8	1.35	90%	1.35	90%	1.35	90%	1350	1	1.1	0.7	Granite	6	3	0	9	Moist
NKS0148RD	82.8	84.3	1.46	97%	1.46	97%	1.46	97%	1095	2	1.4	0.9	Granite	6	3	0	9	Moist
NKS0148RD	84.3	85.8	1.5	100%	1.5	100%	1.5	100%	500	1	3.0	2.0	Granite	6	3	0	5	Moist
NKS0148RD	85.8	87.3	1.48	99%	1.48	99%	1.48	99%	1110	2	1.4	0.9	Granite	6	3	0	9	Moist
NKS0148RD	87.3	88.8	1.4	93%	1.4	93%	1.35	90%	467	1	3.2	2.1	Granite	6	3	0	9	Moist
NKS0148RD	88.8	90.3	1.5	100%	1.5	100%	1.5	100%	750	2	2.0	1.3	Granite	6	3	1	5	Moist
NKS0148RD	90.3	91.8	1.5	100%	1.5	100%	1.5	100%	1000	0	0.0	0.0	Granite	6				Moist
NKS0148RD	91.8	93.3	1.28	85%	1.08	72%	1.08	72%	324	2	4.6	3.1	Granite	6	3	0	9	Moist
NKS0148RD	93.3	94.8	1.5	100%	1.5	100%	1.43	95%	540	3	2.8	1.9	Granite	6	3	1	4	Moist
NKS0148RD	94.8	96.3	1.5	100%	1.11	74%	0.98	65%	222	1	6.8	4.5	Granite	6	6	1	7	Moist
NKS0148RD	96.3	97.8	1.5	100%	1.35	90%	1	67%	450	1	3.3	2.2	Granite	6	2	2	9	Moist
NKS0148RD	97.8	99.3	1.46	97%	1.46	97%	1.14	76%	313	2	4.8	3.2	Granite	6	3	2	9	Moist
NKS0148RD	99.3	100.8	1.38	92%	1.38	92%	1.18	79%	1035	2	1.4	1.0	Granite	6	3	2	9	Moist
NKS0148RD	100.8	102.3	1.5	100%	1.5	100%	1.5	100%	563	2	2.7	1.8	Granite	6	2	2	9	Moist
NKS0148RD	102.3	103.8	1.48	99%	1.48	99%	1.42	95%	1480	1	1.0	0.7	Granite	6	6	0	9	Moist
NKS0148RD	103.8	105.3	1.46	97%	1.46	97%	1.46	97%	487	1	3.1	2.1	Granite	6	2	1	7	Moist
NKS0148RD	105.3	106.8	1.5	100%	1.45	97%	1.41	94%	311	2	4.8	3.2	Granite	6	2	1	7	Moist
NKS0148RD	106.8	108.3	1.5	100%	1.5	100%	1.5	100%	321	2	4.7	3.1	Granite	6	3	1	4	Moist
NKS0148RD	108.	109.	1.5	100	1.32	88%	1.22	81%	990	2	1.5	1.0	Granite	6	3	1	4	Moist

	3	8		%														
NKS0148RD	109.8	111.3	1.46	97%	1.46	97%	1.46	97%	1095	2	1.4	0.9	Granite	6	3	0	9	Moist
NKS0148RD	111.3	112.8	1.46	97%	1.46	97%	1.46	97%	1460	1	1.0	0.7	Granite	6	3	1	7	Moist
NKS0148RD	112.8	114.3	1.5	100%	1.47	98%	1.47	98%	315	2	4.8	3.2	porphry	6	3	0	9	Moist
NKS0148RD	114.3	115	0.7	100%	0.7	100%	0.7	100%	1000	0			porphry	6				Moist
NKS0149DD	64.2	65.7	1.5	100%	1.5	100%	0.97	65%	750	3	2.0	1.3	Granite	5	3	1	7	Moist
NKS0149DD	65.7	67.2	1.5	100%	1.5	100%	1.17	78%	338	2	4.4	3.0	Porphry	5	2	1	4	Moist
NKS0149DD	67.2	68.7	1.45	97%	1.45	97%	1.06	71%	181	2	8.3	5.5	Granite	5	2	1	5	Moist
NKS0149DD	86.7	88.2	1.42	95%	1.42	95%	1	67%	426	1	3.5	2.3	Granite	6	2	1	4	Moist
NKS0149DD	88.2	89.7	1.5	100%	1.5	100%	0.97	65%	450	1	3.3	2.2	Granite	6	2	1	7	Moist

Appendix IV. Laboratory Results

Table A8. Laboratory Results.

SPECIMEN PARTICULARS					SPECIMEN DIMENSIONS				SPECIMEN TEST RESULTS								
Rock lab No	Sample ID	Depth		Sample Lithology	Diameter	Height	Ratio	Mass	Density	Failure	Strength	Tangent Modulus	Secant Modulus	Poisson's Tangent	Poisson's Secant	Linear Strain at	Failure Code
UCM-01A				Granite	60.92	161.73	2.7	1266.84	2.69	518.5	177.9	60.0	56.9	0.26	0.17	0.003266	YA
UCM-01B	NKS0145RD_1	62.14	62.84	Granite	60.91	161.65	2.7	1259.52	2.67	542.8	186.3	59.8	53.3	0.35	0.20	0.003538	YA
UCM-01C				Granite	60.96	161.86	2.7	1265.31	2.68	208.5	71.4	59.5	56.8	0.26	0.19	0.001247	YA
UCM-02A				Granite	60.98	151.62	2.5	1186.74	2.68	373.0	127.7	56.9	56.1	0.28	0.20	0.002301	3B
UCM-02B	NKS0145RD_2	63.75	64.4	Granite	60.97	154.06	2.5	1205.81	2.68	503.7	172.5	60.1	59.4	0.32	0.22	0.003106	YA
UCM-02C				Granite	60.99	129.91	2.1	1016.98	2.68	395.6	135.4	60.5	58.5	0.29	0.21	0.002362	3B
UCM-03A				Granite	41.73	69.78	1.7	263.75	2.76	194.1	141.9	69.4	74.3	0.26	0.22	0.002014	4B
UCM-03B	NKS0145RD_3	65.85	66	Granite	42.51	66.78	1.6	257.91	2.72	238.4	168.0	59.8	62.5	0.35	0.25	0.002883	YA
UCM-03C				Granite	42.60	74.13	1.7	283.95	2.69	254.4	178.5	56.0	57.3	0.32	0.21	0.003464	YA

SPECIMEN PARTICULARS					SPECIMEN DIMENSIONS				SPECIMEN TEST RESULTS								
Rock lab No	Sample ID	Depth		Sample Lithology	Diameter	Height	Ratio	Mass	Density	Failure	Strength	Tangent Modulus	Secant Modulus	Poisson's Tangent	Poisson's Secant	Linear Strain at	Failure Code
UCM-04A				Granite	35.46	68.58	1.9	183.27	2.71	195.8	198.3	62.1	62.9	0.36	0.26	0.003378	YA
UCM-04B	NKS0145RD_4	68.85	69.18	Granite	35.45	62.98	1.8	167.53	2.70	161.5	163.6	52.9	50.7	0.30	0.19	0.003262	YA
UCM-04C				Granite	35.48	64.22	1.8	172.95	2.72	171.8	173.8	65.3	62.5	0.32	0.26	0.002720	YA
UCM-05A				Greywacke	60.96	160.45	2.6	1293.52	2.76	280.3	96.0	65.6	66.8	0.35	0.29	0.001646	4B
UCM-05B	NKS0145RD_5	113.39	114.01	Greywacke	60.98	161.07	2.6	1293.70	2.75	394.0	134.9	56.4	63.9	0.27	0.24	0.002247	3B
UCM-05C				Greywacke	61.01	163.45	2.7	1315.78	2.75	387.4	132.5	58.1	65.7	0.26	0.24	0.002231	4B
UCM-06A				Greywacke	60.95	160.04	2.6	1285.68	2.75	211.4	72.5	44.6	52.8	0.23	0.21	0.001613	5B
UCM-06B	NKS0145RD_6	121.4	122.05	Greywacke	60.95	158.80	2.6	1266.23	2.73	250.7	85.9	52.3	58.5	0.35	0.29	0.001672	5B
UCM-06C				Greywacke	60.97	163.27	2.7	1314.07	2.76	234.7	80.4	37.3	47.0	0.22	0.20	0.002177	5B
UCM-07A				Granite	60.61	160.72	2.7	1253.56	2.70	461.4	159.9	64.9	61.5	0.31	0.23	0.002825	YA
UCM-07B	NKS0148DD_1	28.85	29.55	Granite	60.70	162.44	2.7	1271.92	2.71	413.6	142.9	59.8	57.6	0.35	0.24	0.002591	YA
UCM-07C				Granite	60.73	153.68	2.5	1202.05	2.70	334.4	115.4	55.0	53.5	0.29	0.21	0.002233	2B
UCM-08A				Granite	60.96	159.73	2.6	1253.46	2.69	485.7	166.4	62.0	60.5	0.32	0.22	0.002839	YA
UCM-08B	NKS0148DD_2	46.81	47.5	Granite	60.96	146.62	2.4	1156.44	2.70	493.5	169.1	61.1	59.2	0.30	0.24	0.003258	YA
UCM-08C				Granite	61.08	161.00	2.6	1263.12	2.68	479.1	163.5	61.3	60.4	0.28	0.21	0.002835	YA
UCM-09A				Granite	60.92	163.14	2.7	1273.25	2.68	441.6	151.5	60.4	59.9	0.26	0.19	0.002802	YA
UCM-09B	NKS0148DD_3	63.74	64.44	Granite	60.93	163.74	2.7	1277.89	2.68	405.9	139.2	58.8	58.7	0.28	0.21	0.002382	2B
UCM-09C				Granite	60.95	155.29	2.5	1212.31	2.68	448.3	153.6	61.0	59.9	0.36	0.26	0.002837	YA
UCM-10A				Granite	60.97	161.00	2.6	1267.32	2.70	473.6	162.2	60.2	58.6	0.24	0.17	0.002993	YA
UCM-10B	NKS0148DD_4	74.07	74.77	Granite	60.98	166.65	2.7	1310.02	2.69	454.0	155.5	64.5	61.0	0.28	0.20	0.002551	YA
UCM-10C				Granite	60.94	162.26	2.7	1276.78	2.70	493.3	169.1	78.1	71.7	0.37	0.24	0.002279	YA

SPECIMEN PARTICULARS					SPECIMEN DIMENSIONS					SPECIMEN TEST RESULTS							
Rock lab No	**Sample ID**	**Depth**		**Sample Lithology**	**Diameter**	**Height**	**Ratio to**	**Mass**	**Density**	**Failure**	**Strength**	**Tangent Modulus**	**Secant Modulus**	**Poisson's Tangent**	**Poisson's Secant**	**Linear Strain at**	**Failure Code**
UCM-11A				Greywacke	41.75	75.45	1.8	287.51	2.78	372.4	272.0	80.7	84.0	0.30	0.25	0.003528	0B
UCM-11B	NKS0168DD_1	107.3	107.56	Greywacke	41.83	74.23	1.8	284.47	2.79	155.5	113.2	80.0	79.3	0.24	0.21	0.001395	5B
UCM-11C				Greywacke	41.72	75.48	1.8	292.83	2.84	382.4	279.7	73.2	76.5	0.38	0.29	0.003911	YA
UCM-12A				Greywacke	34.52	75.27	2.2	204.41	2.90	159.3	170.2	54.1	61.8	0.24	0.21	0.003201	3B
UCM-12B	NKS0168DD_2	109.7	110.07	Greywacke	34.39	64.47	1.9	175.41	2.93	165.7	178.4	53.3	59.1	0.29	0.23	0.003325	YA
UCM-12C				Greywacke	34.28	57.86	1.7	156.61	2.93	202.0	218.9	54.7	64.5	0.23	0.20	0.004270	YA
UCM-13A				Greywacke	60.64	159.94	2.6	1280.55	2.77	345.7	119.7	32.3	32.2	0.43	0.26	0.003795	YA
UCM-13B	NKS0146RD_1	72.68	73.18	Greywacke	60.58	163.14	2.7	1310.68	2.79	129.8	45.0	32.3	36.5	0.13	0.13	0.001320	5B
UCM-13C				Greywacke	60.61	154.27	2.5	1239.97	2.79	145.4	50.4	32.5	36.9	0.27	0.22	0.001495	4B
UCM-14A				Greywacke	60.50	158.16	2.6	1262.52	2.78	509.2	177.1	64.8	67.2	0.23	0.20	0.002820	YA
UCM-14B	NKS0146RD_2	89.49	89.99	Greywacke	60.52	160.37	2.6	1284.11	2.78	411.6	143.1	63.0	66.1	0.26	0.22	0.002320	4B
UCM-14C				Greywacke	60.53	155.62	2.6	1238.00	2.76	306.9	106.7	54.1	54.0	0.23	0.18	0.001984	5B
UCM-15A				Granite	60.65	159.65	2.6	1245.67	2.70	569.3	197.1	68.0	67.1	0.35	0.26	0.003135	YA
UCM-15B	NKS0146RD_3	114.58	115.28	Granite	60.64	160.93	2.7	1247.04	2.68	513.4	177.8	63.6	63.5	0.28	0.21	0.002917	YA
UCM-15C				Granite	60.67	162.00	2.7	1253.59	2.68	519.4	179.7	64.5	62.9	0.29	0.21	0.003173	YA
UCM-16A				Granite	60.75	161.96	2.7	1258.16	2.68	462.7	159.6	67.2	65.9	0.32	0.24	0.002609	YA
UCM-16B	NKS0146RD_4	143.01	143.71	Granite	60.74	156.10	2.6	1216.23	2.69	343.7	118.6	59.5	57.5	0.28	0.22	0.002146	3B
UCM-16C				Granite	60.74	162.45	2.7	1263.62	2.68	301.4	104.0	67.4	68.1	0.24	0.22	0.001585	2B
UCM-17A				Granite	60.83	162.26	2.7	1271.10	2.70	417.4	143.6	65.5	62.6	0.41	0.25	0.002248	5B
UCM-17B	NKS0146RD_5	159.25	159.95	Granite	60.84	164.15	2.7	1287.25	2.70	510.0	175.4	69.9	64.6	0.29	0.18	0.002804	YA
UCM-17C				Granite	60.83	163.98	2.7	1285.31	2.70	517.5	178.1	68.6	62.2	0.37	0.23	0.002930	YA

SPECIMEN PARTICULARS					SPECIMEN DIMENSIONS				SPECIMEN TEST RESULTS								
Rock lab No	Sample ID	Depth		Sample Lithology	Diameter	Height	Ratio to	Mass	Density	Failure	Strength	Tangent Modulus	Secant Modulus	Poisson's Tangent	Poisson's Secant	Linear Strain at	Failure Code
UCM-18A				Granite	60.82	161.51	2.7	1265.56	2.70	479.4	165.0	66.6	56.8	0.27	0.16	0.002787	YA
UCM-18B	NKS0146RD_6	163.8	164.45	Granite	60.82	164.26	2.7	1286.91	2.70	489.1	168.4	73.8	61.8	0.39	0.23	0.002470	YA
UCM-18C				Granite	60.84	162.03	2.7	1269.80	2.70	509.2	175.2	64.3	57.5	0.26	0.17	0.003322	YA
UCM-19A				Greywacke	60.89	163.18	2.7	1300.54	2.74	369.3	126.8	71.5	76.4	0.23	0.21	0.001755	2B
UCM-19B	NKS0149DD_1	100.67	101.27	Greywacke	60.88	155.80	2.6	1242.43	2.74	423.3	145.4	69.7	75.9	0.23	0.22	0.002045	3B
UCM-19C				Greywacke	60.90	161.57	2.7	1287.64	2.74	639.9	219.7	64.5	71.4	0.28	0.24	0.003480	YA
UCM-20A				Greywacke	60.83	154.46	2.5	1248.64	2.78	552.7	190.2	69.8	77.3	0.26	0.24	0.002775	1B
UCM-20B	NKS0149DD_2	106.47	107.07	Greywacke	60.82	152.35	2.5	1230.65	2.78	525.9	181.0	72.6	79.3	0.29	0.26	0.002523	1B
UCM-20C				Greywacke	60.83	152.94	2.5	1235.66	2.78	482.8	166.1	70.9	77.7	0.27	0.25	0.002316	1B
UCM-21A				Greywacke	60.66	161.52	2.7	1281.71	2.75	616.4	213.3	78.0	81.8	0.27	0.25	0.002751	2B
UCM-21B	NKS0149DD_3	113.76	114.37	Greywacke	60.73	157.22	2.6	1248.72	2.74	621.5	214.6	75.5	79.9	0.23	0.20	0.002768	YA
UCM-21C				Greywacke	60.74	160.97	2.7	1279.94	2.74	828.0	285.8	73.9	79.2	0.30	0.26	0.004045	YA
UCM-22A				Greywacke	42.75	71.59	1.7	273.81	2.66	417.7	291.0	78.9	82.9	0.24	0.22	0.003679	YA
UCM-22B	NKS0149DD_4	117.7	118.04	Greywacke	42.84	70.51	1.6	282.65	2.78	364.2	252.7	80.6	83.8	0.30	0.26	0.003164	YA
UCM-22C				Greywacke	42.75	75.87	1.8	298.33	2.74	341.3	237.8	79.7	81.0	0.32	0.27	0.002989	YA

UCM-15A				Granite	60.65	159.65	2.6	1245.67	2.70	569.3	197.1	68.0	67.1	0.35	0.26	0.003135	YA
UCM-15B	NKS0146RD_3	114.58	115.28	Granite	60.64	160.93	2.7	1247.04	2.68	513.4	177.8	63.6	63.5	0.28	0.21	0.002917	YA
UCM-15C				Granite	60.67	162.00	2.7	1253.59	2.68	519.4	179.7	64.5	62.9	0.29	0.21	0.003173	YA
UCM-16A				Granite	60.75	161.96	2.7	1258.16	2.68	462.7	159.6	67.2	65.9	0.32	0.24	0.002609	YA
UCM-16B	NKS0146RD_4	143.01	143.71	Granite	60.74	156.10	2.6	1216.23	2.69	343.7	118.6	59.5	57.5	0.28	0.22	0.002146	3B
UCM-1				Gran-	60.74	162.4	2.7	1263	2.68	301.	104.	67.4	68.1	0.24	0.2	0.0015	2B

6C				ite		5		.62		4	0				2	85	
UCM-17A				Granite	60.83	162.26	2.7	1271.10	2.70	417.4	143.6	65.5	62.6	0.41	0.25	0.002248	5B
UCM-17B	NKS0146RD_5	159.25	159.95	Granite	60.84	164.15	2.7	1287.25	2.70	510.0	175.4	69.9	64.6	0.29	0.18	0.002804	YA
UCM-17C				Granite	60.83	163.98	2.7	1285.31	2.70	517.5	178.1	68.6	62.2	0.37	0.23	0.002930	YA
UCM-18A				Granite	60.82	161.51	2.7	1265.56	2.70	479.4	165.0	66.6	56.8	0.27	0.16	0.002787	YA
UCM-18B	NKS0146RD_6	163.8	164.45	Granite	60.82	164.26	2.7	1286.91	2.70	489.1	168.4	73.8	61.8	0.39	0.23	0.002470	YA
UCM-18C				Granite	60.84	162.03	2.7	1269.80	2.70	509.2	175.2	64.3	57.5	0.26	0.17	0.003322	YA
UCM-19A				Greywacke	60.89	163.18	2.7	1300.54	2.74	369.3	126.8	71.5	76.4	0.23	0.21	0.001755	2B
UCM-19B	NKS0149DD_1	100.67	101.27	Greywacke	60.88	155.80	2.6	1242.43	2.74	423.3	145.4	69.7	75.9	0.23	0.22	0.002045	3B
UCM-19C				Greywacke	60.90	161.57	2.7	1287.64	2.74	639.9	219.7	64.5	71.4	0.28	0.24	0.003480	YA
UCM-20A				Greywacke	60.83	154.46	2.5	1248.64	2.78	552.7	190.2	69.8	77.3	0.26	0.24	0.002775	1B
UCM-20B	NKS0149DD_2	106.47	107.07	Greywacke	60.82	152.35	2.5	1230.65	2.78	525.9	181.0	72.6	79.3	0.29	0.26	0.002523	1B
UCM-20C				Greywacke	60.83	152.94	2.5	1235.66	2.78	482.8	166.1	70.9	77.7	0.27	0.25	0.002316	1B
UCM-21A				Greywacke	60.66	161.52	2.7	1281.71	2.75	616.4	213.3	78.0	81.8	0.27	0.25	0.002751	2B
UCM-21B	NKS0149DD_3	113.76	114.37	Greywacke	60.73	157.22	2.6	1248.72	2.74	621.5	214.6	75.5	79.9	0.23	0.20	0.002768	YA
UCM-21C				Greywacke	60.74	160.97	2.7	1279.94	2.74	828.0	285.8	73.9	79.2	0.30	0.26	0.004045	YA
UCM-22A				Greywacke	42.75	71.59	1.7	273.81	2.66	417.7	291.0	78.9	82.9	0.24	0.22	0.003679	YA
UCM-22B	NKS0149DD_4	117.7	118.04	Greywacke	42.84	70.51	1.6	282.65	2.78	364.2	252.7	80.6	83.8	0.30	0.26	0.003164	YA
UCM-22C				Greywacke	42.75	75.87	1.8	298.33	2.74	341.3	237.8	79.7	81.0	0.32	0.27	0.002989	YA

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