REPORT

TIGER ZONE PROJECT
YUKON TERRITORY, CANADA

REPORT ON
SCOPING LEVEL PIT SLOPE EVALUATION

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1.0 INTRODUCTION

Golder Associates Inc. (Golder) is pleased to provide this Scoping level review with pit slope design recommendations for ATAC Resources Limited's (ATAC) Tiger Zone gold project. The Tiger Zone is one of several mineralized areas within ATAC's Rau Property. The project site is located approximately 75 kilometers northeast of Mayo, Yukon Territory, Canada.

1.1 Scope of Work

The Scope of Work for this Scoping level study was defined in Golder's Proposal of October 30, 2013, "Scoping Level Pit Slope Design Study, Tiger Zone, Rau Property, Yukon Territory, Canada," as providing Scoping level geotechnical input and pit slope design recommendations based on a review of available information.

1.2 Method of Work

The method of work was outlined in Golder's Proposal, and included:

- Collection and review of available data, including geologic model, core logs, and core photographs
- A site visit to review site conditions and exploration core
- Development of scoping-level pit slope design recommendations based on available data
- Recommendations for a geotechnical program to support a pre-feasibility level slope design
- Documentation of the study in an engineering report

The work was initiated by a kickoff meeting in ATAC's Vancouver office on November 14, 2013 that was attended by Rob Carne, President of ATAC; Graham Downs, Chief Executive Officer, ATAC; and George Lightwood, Senior Geotechnical Engineer with Golder's Reno office. Others at the meeting included Andrew Carne, Project Engineer, and Heather Friday, Geologist, both with Archer Cathro, and Associates, Limited (Archer Cathro), and Sabrey Hafez, Senior Mining Engineer, with Tetra Tech of Vancouver, British Columbia. Archer Cathro provides geological consulting services for ATAC, and their geologists logged the Tiger Zone core. Tetra Tech provides mining engineering services, including pit design, for ATAC.

George Lightwood visited the project site with Heather Friday and Sabrey Hafez on November 15 and 16, 2013. The purpose of this site visit was to primarily review exploration core and surface features of the pit area. The project site cannot be accessed by permanent roads, so we flew to the site in a helicopter. Since daylight hours are limited during the late fall, we only spent about a total of 12 hours at the site over the two days. There was about one-half to one meter of snow at the project site, so it was not possible to observe rock outcrops in the pit area; however, it was possible to observe the physiographic features of the project area.

1.3 Available Data

Information available for ATAC to support this pit slope evaluation includes:

- NI43-101 report (Stroshein, et. al., 2011)
- An Assessment report (Dumala, 2011)
- Core Photographs
- A database containing geology, assay data, and geotechnical data from the 132 coreholes drilled by ATAC Resources in the Tiger Zone.
- Geologic logs and photographs of auger cuttings from the mineralized (Oxide) materials
- Preliminary pit design

1.4 Planned Pit Development

A preliminary pit shell for Tiger Zone was provided to Golder and is shown in Figure 1.1. The pit is approximately 850 m long, 200 to 300 m wide and is about 100 m deep. The highest slope will be about 300 m high on the north side of the pit. The long axis of the pit follows the trend of the mineralization, which is to the northwest. The mineralized material, designated Oxide in Figure 1.1, will be mined from the pit and placed on heap leach pads to recover gold.

2.0 SITE CONDITIONS

2.1 Topography and Vegetation

The Tiger Zone project is located in the Nadalen Range of the Selwyn Mountains and is drained by creeks that flow into rivers that are part of the Yukon River watershed. The pit is located on the south and west facing slopes of Rackla Ridge and the elevation of the ground surface ranges from about 1200 to 1600 m in the pit area. Existing slopes in the pit area range from about 25 to 40 degrees. Photographs of the project site and pit area are shown in Figure 2.1.

The slopes in the pit area are typically covered with vegetation consisting of moss, low shrubs, and mature black spruce. The tree-line is at approximately 1500 m (Dumala, 2011). Except where drill roads have been cut into the slopes, there are few outcrops of bedrock in the pit area.

2.2 Climate

The area that includes the Tiger Zone property has a subarctic climate. Weather data obtained from Environment, Canada (2014) indicates that in Mayo, the nearest town with published weather data, the average daily temperatures range from 23 degrees Celsius in summer to -21 degrees in winter. Extreme temperatures can range from -52 degrees C to 36 degrees Celsius. Winters are long and cold and below freezing temperatures occur about 230 days each year. The project area is typically snow free from June to September.

Mayo receives about 200 mm of rain and 150 cm of snow annually. Most of the rain falls between May and September with most snowfall from October to April. At the time of the site visit to the Tiger Zone, there was about one-quarter to one-half meter of snow on the ground.

Permafrost is reported to exist at lower elevations in the project area. Permafrost has not been identified in the pit area except possibly at a few locations on north facing slopes at low elevations (Andrew Carne, 2014).

2.3 Regional Geology

The regional geology is described in the reports by Dumala (2011) and Stroshein, et. al.(2011). The following discussion of the regional and site geology is based on these reports.

The Rau Property, which includes the Tiger Zone, occurs within a band of regional-scale thrust and high angle reverse faults that imbricate the rocks of the Selwyn Basin and the Mackenzie Platform. The stratigraphic sequence of the Selwyn Basin consists of regionally metamorphosed, basinal sediments of Neoproterozoic to Paleozoic age. The stratigraphic sequence of the Makenzie Platform consists dominantly of shallow water carbonate and clastic sediments that were deposited between the Mid-Proterozoic Eon through the Paleozoic Era.

The project area underwent compressional orogenesis and thrusting during the Jurassic to Cretaceous Periods. During the late Cretaceous Period, felsic plutons intruded the sedimentary sequence; however, the thrusting pre-dates the intrusions. A second compressional orogenic event accompanied by emplacement of felsic intrusions occurred during the Neogene period about 65 Ma.

The Rau Property lies within a northwest trending thrust package bounded by the west-northwest trending Dawson Thrust to the south and the similarly trending Kathleen Lakes Fault to the north. The stratigraphic units within this package of sediments form open folds that are aligned parallel to the thrusts and plunge gently to the southeast. Several high angle faults are inferred on the property.

2.4 Site Geology

ATAC developed a geologic model of the pit area using GEMS, a computerized geologic modelling and mine program developed by Gemcom, Software International, Inc. The Tiger Zone mineralization projected into the pit slopes is shown in Figure 1.1. ATAC provided Golder with a set of sections that show the location of the mineralization, major rock units, and faults in the pit area. Typical sections are provided in Figures 2.2 through 2.5.

2.4.1 Lithology

The mineralization at the Tiger Zone is hosted in carbonate rocks of the Paleozoic Bouvette Formation. The Bouvette Formation was deposited between the Cambrian and Devonian Periods and consists of limestones and dolostones with minor quartzite. The Bouvette Formation contains thin interbedded horizons of volcanic and volcaniclastic rock of the Marmot Formation that range in thickness from a few to about 20 meters thick.

Stroshein et. al. (2011) indicates that the carbonate units typically consist of crinoid wackestone and lime mudstone and some units lack layering and sedimentary structures. The volcanic units consist of green-grey amygdaloidal flows, and the volcaniclastic units consist of sericitized silt- to mud-grade material presumed to be of volcanic origin. No volcanic units appear to be located in the pit area; however, the volcaniclastic units will be exposed in the east side of the pit shown in Figure 2.2 through 2.5.

The geologic logs of the coreholes indicate that the rocks units in the pit area consist primarily of:

- Limestone
- Dolomite
- Marble
- Volcaniclastic Rock
- Oxide (mineralized rock)

The position of the Oxide and Volcaniclastic Rock in the pit and the pit slopes are shown in Figures 2.2 through 2.5. The unlabeled rock units shown in these figures consist either of Limestone, Dolomite, or Marble.

The mineralized material is included in the rock unit designated Oxide in the geologic model and on the geologic logs of the coreholes. Stroshein et. al. describes the oxide as a “very competent, weakly porous limonitic mud to rubbly porous limonitic grit.” It contains a high proportion of limonite, goethite, and siderite giving the rock a color that ranges from a deep red to orange rust color to dark brown (Stroshein, et al., 2011). Our review of the core on site indicated that much of the Oxide is poorly indurated and friable, though it is sufficiently competent to hold together when cored.

2.4.2 Structure

2.4.2.1 Major Structures

Major structures that can affect pit slope stability consist of faults and contacts between geologic units. Faults have been interpreted from coreholes and are shown in Figures 2.2 through 2.3. The faults in the pit area typically strike approximately to the northwest, similar to the trend of the mineralization and dip steeply to the east and west.

A significant fault, referred to as the “Footwall” fault truncates the mineralized material (Oxide) pit area to the southwest. This faults strikes approximately north-northwest and dips to the northeast at approximately 80 degrees. The amount of displacement on this fault is not known, but the Limestone to in the footwall of Footwall fault may be considerably older than the Limestone in the hanging wall of the Footwall fault (Rob Carne, 2013).

Based on the sections shown in Figures 2.2 through 2.3, the Volcaniclastic rock forms a layer 10 to 40 meters thick with open folds. The overall dip of this layer ranges from 50 to 80 degrees to the northeast. It only occurs on the east side of the pit and dips into the pit slope.

2.4.2.2 Minor Structure

Minor structures noted in the geologic logs include joints, bedding planes, foliation, and veins. These structures were observed in the core, and the geologic logs indicate the relative orientation (angle to core axis) of these structures. Joints, bedding planes, and foliation can form discontinuities that are planes of weakness in the rock mass. Veins can form planes of weakness when there is a significant difference between the strength of the vein material and the wall rock. At the Tiger Zone, veins are unlikely to form planes of weakness based on our review of the core.

2.4.3 Alteration

Alteration changes the chemical or mineralogical composition of rock and can thus either reduce or increase the strength of intact rock. Alteration is not described in the reports by Stroshein et. al. (2011) and Dumala (2011); however, alteration minerals noted in the geologic logs include Dolomite, Sericite, Calcite (Calcification), and Oxide (Oxidation).

Dolomitization and calcification can change the fabric of the rock and can results in the destruction or cementation of primary structures, particularly bedding planes, so as to create a stronger rock mass. Intense seritization can weaken the rock or reduce the strength of rock discontinuities, particularly if the sericite is localized along joint and bedding plane surfaces.

In the Tiger Zone, oxidation of consists primarily of weathering of sulfide mineralization to iron hydroxides and oxides. The effect of oxidation of sulfides is typically to reduce the strength of the intact rock.

While not a form of alteration, marbleization can also affect the rock mass properties. During Marbleization, the recrystallization of calcite can destroy primary structures such as bedding planes that may form planes of weakness.

2.4.4 Mineralization

Stroshein et. al. (2011) indicates that mineralization at the Tiger Zone consists of sediment-hosted gold mineralization. The gold occurs in both oxide and sulfide mineralization; however, only oxide mineralization will be mined.

2.4.5 Weathering

Both mechanical and chemical weathering of the rock mass has affected the properties of the rock mass in the pit area. The frequent freeze-thaw cycles typical of sub-arctic climates has resulted in fracturing of the rock mass near the ground surface due to frost wedging. The oxidation of the sulfides in the mineralized rock (Oxide) has significantly weakened the intact rock to the extent that much of the Oxide appears to have a soil-like character.

2.5 Geotechnical Investigations

There are no prior, or existing, geotechnical investigations for pit slopes at the Tiger Zone.

2.5.1 Surface Mapping

Geologic mapping of the pit area has not been performed. Low shrubs and moss and a layer of broken rock and soil occur at the surface, so there are few suitable exposures from which to observe the characteristics of the rock mass and measure structure orientations.

2.5.2 Geotechnical Logging of Coreholes

ATAC has drilled 132 coreholes within the project area as part of their mineral exploration program. The core drilling was performed for mineral resource studies and the geologic logs include rock type descriptions, alteration minerals, and descriptions of minor structures intersecting the core.

As shown in Figures 2.2 through 2.5, most of the coreholes plunge to the southeast so they intersect the mineralized zone. A few coreholes were drilled at an angle to the northeast. Based on the location and number of the coreholes in the pit slopes, the geology of the pit slopes is well defined for a Scoping level project.

We combined the geologic logs into a database containing all coreholes. The percent of each rock type in the database by drilled length and the average core recovery for the major rock units are as follows:

Table 2.1: Major Rock Units Encountered in Exploration Coreholes

Rock Type	Rock Code	Drilled Length (meters)	Average Core Recovery[1] (percent)	Percent of Total Length Core[2]
Limestone	LST	14347	89.9	60
Dolomite	DOL	3131	90.8	13
Oxide	OX	2765	66.8	12
Volcaniclastic	VOL	2365	90.3	10
Marble	MBL	1161	91.4	5

Notes: 1. Weighted by Length
2. Major rock units only.

Ninety-three percent of the core in the 132 coreholes was classified as one of the rock units listed in Table 2.1, and these units will be exposed in the pit slopes. Other rock units encountered during coring include the Leopard Zone (LEP), Overburden (OVB), and other units. The Leopard Zone occurs below the bottom of the pit shell shown in Figure 1.1. Other units represent only a very small proportion of the rock mass, typically less than one percent of the total core drilled, and we did not consider them in our data analysis.

No core drilling for pit slope geotechnical studies has been performed; however, ATAC geologists collected the following geotechnical data from each of the exploration coreholes:

- Core Recovery
- Rock Quality Designation
- Rock Strength
- Weathering

During the site visit, we reviewed core from coreholes 09-41, 10-72, and 10-132. The purpose of this review was to observe the geotechnical properties of the core and particularly the condition of rock discontinuities formed by minor structures in the core. We also collected representative samples of core for laboratory tests. These core samples are stored in ATAC's warehouse in Whitehorse, YT to provide rock core samples for laboratory testing in future pit slope studies.

2.5.3 Auger Holes

Four auger holes were drilled by ATAC in 2013 to collect bulk samples of the Oxide for metallurgical testing. According to Heather Friday, Geologist for Archer Cathro, each auger hole was drilled with a five inch diameter continuous flight auger to a depth of 48 feet. The holes were advanced in stages by advancing the auger five feet and then tripping the string of five-foot long auger sections out of the hole to obtain samples. The samples were sealed in five gallon buckets and shipped to Kappes, Cassiday & Associates, Inc. (KCA) in Reno, Nevada for metallurgical tests. KCA measured the moisture content of each sample. A list of auger holes, sample depths and moisture content for each sample is provided in Appendix A.

ATAC provided Golder with geologic logs of the auger holes. They also provided photographs of the auger sections containing the cuttings as each section was lifted out of the hole. We reviewed the geologic logs, photographs, and also the samples stored at KCA's laboratory. We selected representative samples of Oxide from the auger holes for the soil index and direct shear tests performed as part of this study. The results of these tests are presented in Section 3.

2.6 Hydrogeology

There are no observation wells or piezometers in the pit area. Drillers reported that groundwater was not encountered in the coreholes and groundwater is not expected to be encountered in the pit.

The geologic logs of the auger holes do not indicate that these holes encountered groundwater; however, auger cuttings from RAU-13-A01 appear to be wet based on the photographs taken during drilling. This hole was drilled in a small drainage that crosses the pit area. The wet auger cuttings indicate groundwater may be encountered in the Oxide at shallow depths near the drainage.

3.0 LABORATORY TESTING

Soil index tests were performed on representative samples of the Oxide obtained from the auger holes. The tests were performed at Golder's laboratory in Lakewood, Colorado, and the test results are provided in Appendix B – Results of Laboratory Testing.

3.1 Soil Index Tests

The results of the soil index tests (particle size, Atterberg Limits, and specific gravity of soil particles) on the Oxide are summarized in Table 3.1.

Table 3.1: Soil Index Test Results for Oxide

Auger Hole	Sample Number	Sample Depth (feet)	USCS Symbol[1]	Soil Description	Atterberg Limits[2]			Specific Gravity of Soil Particles (g/cc)
					LL	PL	PI	
RAU-13-A01	2	13 - 18	SM	Silty sand with gravel	NP	NP	NP	-
RAU-13-A01	4	23 - 28	ML	Sandy silt	NP	NP	NP	-
RAU-13-A02	5	28 - 33	SM	Sandy silt	34	33	1	-
RAU-13-A03	3	23 - 28	SM	Silty sand	NP	NP	NP	3.28
RAU-13-A04	3	18 - 23	SM	Silty sand with gravel	28	24	4	-
RAU-13-A04	5	28 – 33	ML	Sandy silt	28	25	3	

Notes: 1. USCS = Unified Soil Classification System
2. LL = Liquid Limit, PL = Plastic Limit, PI = Plastic Index, NP = Non-plastic

These test results indicate that when the Oxide is disaggregated, it consists of silty sand (SM) and silt (ML). The fines in the silty sand are either non-plastic or consist of low plasticity silt (ML).

The specific gravity of the soil particles is 3.28 and indicates that the Oxide contains a higher proportion of iron oxides and hydroxides (Magnetite, Hematite, Limonite, Goethite) compared to soils composed of primarily quartz, calcite and dolomite.

3.2 Direct Shear Tests

Consolidated drained direct shear tests were performed on re-compacted samples of Oxide. A separate specimen was prepared for each normal load increment (500, 1000, and 1500 kPa). Each specimen was consolidated and sheared at a rate sufficiently slow to provide drainage so effective strength properties could be obtained. The resulting Mohr-Coulomb shear strength parameters are provided in Table 3.2.

Table 3.2: Mohr Coulomb Shear Strength Parameters from Direct Shear Tests

Auger Hole	Sample Number	Sample Depth (feet)	Average Dry Density[1] (kN/m^3)	Average Water Content[1] (percent)	Effective Mohr-Coulomb Shear Strength Parameters			
					Peak		Residual	
					Friction Angle (degrees)	Cohesion (kPa)	Friction Angle (degrees)	Cohesion (kPa)
RAU-13-A03	3	23 - 28	21.2	15.7	32	256	37	31

Notes: 1. Average Dry Density and Water Content of the three test specimens

The residual and peak friction angles are within a range (30 to 40 degrees) typical of dense to very dense silty sand and silt (Navfac, 1986). The value for cohesion in Table 3.2 results from performing a linear regression through pairs of peak normal and shear stress. The actual shear strength envelope for the re-compacted Oxide is probably non-linear at low stresses (Terzaghi, et al., 1996) which is typical for a very dense granular soil.

The results of the direct shear tests indicate a residual friction angle greater than the peak friction angle. Typically, the residual friction angle will be equal to or less than the peak friction angle. The plot of shear strength versus displacement for the specimens indicates a well-defined peak strength for the specimen sheared at an applied normal stress of 500 kPa, and less well defined peaks for the specimens tested with applied normal loads of 1000 and 1500 kPa. The difference in the shape of the stress-displacement curves may due to differences in specimen preparation, particularly compaction of the soil in the shear ring.

Our experience indicates that shear strength properties obtained from direct shear tests on disturbed samples of highly weathered rock such as the Oxide are typically lower than shear strength properties obtained from direct shear and consolidated undrained triaxial tests on “undisturbed” core samples. The shear strength parameters listed in Table 3.2 are preliminary, and appropriate only for Scoping level slope stability analyses.

4.0 GEOTECHNICAL CHARACTERIZATION

The data sources described previously were used to characterize the geotechnical properties of the rock units. These characteristics are used in empirical estimates of the rock mass shear strength properties used in slope stability analyses. They also allow us to obtain an understanding of the controls on pit slope stability based on rock mass strength, degree of fracturing, and structure orientations; and they allow us to select the appropriate mining methods, particularly blasting techniques, to maximize pit slope angles and produce stable bench faces.

4.1 Rock Strength

The rock strength for each core interval was recorded by ATAC geologists. ATAC uses the term “hardness” during geotechnical logging to describe the resistance of the rock to break under an applied load; however, for this report we will use the term “strength” in accordance with typical geotechnical engineering practice. The field classification and identification used by ATAC to estimate rock strength is approximately equivalent to the International Society for Rock Mechanics Classification (ISRM). The ISRM Strength Classification is correlated with approximate ranges of the Unconfined Compressive Strength (UCS) as shown in Table 4.1.

Table 4.1: ATAC and ISRM Rock Strength Classifications

ATAC Strength Classification		ISRM Strength Classification and UCS		
Classification and Code[1]	**Field Identification[1]**	**ISRM Strength (R)**	**Field Identification**	**UCS (MPa)**
Extremely Weak (EW)	Can be readily indented, grooved or gouged with fingernail, or carved with a knife. Breaks with light pressure.	R0	Indented with thumbnail	0.25-1
Very Weak (VW)	Can be grooved or gouged easily by knife or sharp pick with light pressure, can be scratched with fingernail. Breaks with light to moderate manual pressure	R1	Crumbles under firm blow with point of geological hammer, can be peeled with a pocket knife	1-5
Weak (W)	Can be grooved or gouged easily by knife or sharp pick with moderate or heavy pressure. Core or fragment breaks with light hammer blow to heavy manual pressure.	R2	Can be peeled with a pocket knife with difficulty, shallow indentations made by a firm blow of geologic hammer	5-25
Medium Strong (MS)	Can be scratched with knife or sharp pick with light or moderate pressure. Core or fragment breaks with moderate hammer blow.	R3	Cannot be scraped or peeled with a pocket knife, specimen can be fractured with a single firm blow of geological hammer	25-50
Strong (S)	Can be scratched with knife or sharp pick with difficulty (heavy pressure). Heavy hammer blow required to break specimen.	R4	Specimen requires more than one blow of geologic hammer to fracture it	50-100
Very Strong (VS)	Cannot be scratched with knife or sharp pick. Core or fragment breaks with repeated heavy hammer blows.	R5	Specimen requires many blows of geological hammer to fracture it	100-250
Extremely Strong (ES)	Core or fragment cannot be scratched with knife or sharp pick; can only be chipped with repeated heavy hammer blows	R6	Specimen can only be chipped with geological hammer	>250

Notes: 1. From ATAC Manual for Core Handling

The rock strength data collected by ATAC indicates that all rock types can range in strength from Extremely Weak to Very Strong; however, the typical ISRM rock strength classification for each of the major units is provided in Table 4.2.

Table 4.2: Typical Rock Strength of Major Rock Units

Rock Type	Rock Code	Typical Rock Strength[1]	ISRM Rock Strength Classification
Limestone	LST	R3	Medium Strong
Dolomite	DOL	R3	Medium Strong
Oxide	OX	R0	Extremely Weak
Volcaniclastic	VOL	R3	Medium Strong
Marble	MBL	R3	Medium Strong

Notes: 1. Greater than 50 percent of the core was assigned this strength

Table 4.2 indicate that the Limestone, Dolomite, Volcaniclastic, and Marble were typically classified as Medium Strong (R3, 25 < UCS < 50 MPa) rock. Based on our review of the rock core while on site, some of the Limestone, Dolomite, and Marble may consist of Strong (R4, 50 < UCS < 100 MPa) rock; however, no laboratory tests were performed to confirm our observations. Carbonate rocks can be difficult to classify by the field identification methods listed in Table 4.1 because rocks composed primarily of calcite and dolomite can be scratched with a steel knife point or scribe, and foliated rocks will often break with one blow of hammer along the foliation although this is not an indication of the intact strength of the rock material between foliation planes. Stacey and Read (2009) indicate that the strength of limestone, dolomite, and marble can range from Medium Strong (R3, 25 < UCS <50 MPa) to Very Strong (R5, 100 < UCS <250 MPa).

The Oxide is classified as an Extremely Weak (R0, 0.25 < UCS < 1.0 MPa) rock and is consistent with our review of the core.

4.2 Weathering

ATAC records the degree of weathering of each core run based on the following classification:

Table 4.3: ATAC Weathering Classification[1]

Classification	Code	Field Identification
Fresh	FR	No weathering effect visible to naked eye
Slightly weathered	SW	Visible change in appearance but not significant change in strength
Moderately weathered	MW	Visible change in appearance and with significant loss in strength
Highly weathered	HW	Shows considerable change in appearance and loss in strength. Material is still a rock but normally very weak
Extremely weathered	EW	Has soil properties and often shows complete change in appearance

Notes: 1. ATAC Manual for Core Handling

For this project the weathering is related to the strength of the rock and can be used to identify those portions of the rock core that are soil-like. The typical degree of weathering for each rock unit is as follows:

Table 4.4: Typical Degree of Weathering of Major Rock Units

Rock Type	Rock Code	Degree of Weathering[1]	Weathering Classification
Limestone	LST	FR to SW	Fresh to Slightly Weathered
Dolomite	DOL	FR to SW	Fresh to Slightly Weathered
Oxide	OX	EW	Extremely Weathered
Volcaniclastic	VOL	FR to SW	Fresh to Slightly Weathered
Marble	MBL	FR to SW	Fresh to Slightly Weathered

Notes: 1. Greater than 50 percent of the core was assigned these weathering classifications

Table 4.4 indicates that the Limestone, Dolomite, Marble, and Volcaniclastic rocks are typically Fresh to Slightly Weathered. The Oxide is typically Extremely Weathered, indicating it has soil-like characteristics.

4.3 Rock Fracturing

ATAC measures the Rock Quality Designation (RQD) for each core run and this data can be used to assess the degree of rock fracturing. RQD is the percentage of sound core recovered in lengths of 10 cm or greater (Deere, 1964) and can be correlated to discontinuity spacing as shown in Table 4.5.

Table 4.5: Rock Quality Designation (RQD) System

RQD (percent)	Rock Quality Classification	Approximate Discontinuity Spacing (mm)[1]
0-25	Very Poor	< 70
25-50	Poor	70 to 100
50-75	Fair	100 to 150
75-90	Good	150 to 300
90-100	Excellent	> 300

Notes: 1. Based on correlation between RQD and mean discontinuity spacing by Bieniawski (1989).

Typical and average values for RQD for each of the major rock units are shown in Table 4.4

Table 4.6: Typical and Average RQD of Major Rock Units

Rock Type	Rock Code	Typical Range of RQD	Average RQD[2]	Rock Quality Classification[3]
Limestone	LST	36 to 89	61	Fair
Dolomite	DOL	59 to 92	71	Fair
Oxide	OX	0	6	Very Poor
Volcaniclastic	VOL	34 to 86	59	Fair
Marble	MBL	52 to 95	71	Fair

Notes: 1. 50 percent of the core is within this range
2. Weighted average based on core length
3. Rock Quality Classification from Table 4.5 based on Average RQD

Based on the RQD values listed in Table 4.6, the Limestone, Dolomite, Volcaniclastic, and Marble are all classified as having Fair (50 < RQD < 75 percent) Rock Quality. The average value of RQD for the Dolomite and Marble are somewhat greater than the average RQD for the Limestone and indicate that the Dolomite and Marble are less fractured than the Limestone. The Rock Quality of the Oxide is Very Poor (0 <RQD < 25 percent) indicating its soil-like nature.

4.4 Structure

Structures that form planes of weakness in the rock upon which sliding may occur are of interest in pit slope stability studies. Wide fault zones containing highly fractured rock also limit the ability to form steep stable benches.

Minor structures that form discontinuities in the rock mass consist predominantly of joints, foliation, and bedding planes. The Limestone contains structures described in the geologic logs as bedding planes, foliation and joints. Based on our review of the core and geologic logs, the Marble and Dolomite typically contain joints, but are not foliated. The dominant structure of the Volcaniclastic is foliation which may be closely spaced.

In the core we reviewed on site, joints in the Limestone are typically planar and smooth to very rough with either no surface coating or a coating of iron oxide on the joint surface. Joints in Marble and Dolomite are very rough and typically contain no infilling. Where the Limestone and Volcaniclastic Rocks are foliated, the discontinuities may be planar, smooth, and typically have a coating of sericite on the joint surface. Joints with thick infillings of low strength clay were not observed in the core during the site visit.

No structure orientation data is available from either structure mapping or oriented core. The foliation is thought to have approximately the same orientation as the Footwall Fault that truncates the Oxide mineralization to the southwest; that is, the foliation likely dips steeply to the northeast.

4.5 Rock Mass Rating

Bieniawski's (1976) Rock Mass Rating (RMR_{76}) classification system was used to provide a quantitative measure of rock mass quality. This system incorporates unconfined compressive strength (UCS), Rock Quality Designation (RQD), joint spacing, joint condition (as defined by Joint Condition Rating), and groundwater condition to characterize rock masses. Each of these parameters is assigned a numerical rating, and the sum of the rating values yields an RMR_{76} rating from 0 (very poor quality rock mass) to 100 (very good quality rock mass). For this study, we used RMR_{76} to estimate the rock mass strength of the Limestone, Dolomite, Volcaniclastic Rock and Marble for use in slope stability studies. A Groundwater Rating of 10 (dry) is assigned to the rock mass as groundwater is not a property of the rock mass. The RMR_{76} classification system is summarized in Table 4.7.

Table 4.7: Summary of Rock Mass Rating (RMR_{76}) System[1]

Parameter	**Range of Values[2]**						
UCS (MPa) Rating	>200Mpa **(15)**	100-200 MPa **(12)**	50-100 MPa **(7)**	25-50Mpa **(4)**	10-25 **(2)**	<3-10 **(1)**	1-3 **(0)**
RQD Rating	90-100% **(20)**	75-90% **(17)**	50-75% **(13)**	25-50% **(8)**	< 25% **(3)**		
Joint Spacing Rating	>3m **(30)**	1-3m **(25)**	0.3-1m **(20)**	50-300mm **(10)**	< 50mm **(5)**		
Joint Condition Rating	Very rough No separation Hard wall rock **(25)**	Slightly rough Separation < 1mm Hard wall rock **(20)**	Slightly rough Separation < 1mm Soft wall rock **(12)**	Slickensides, Separation or gouge < 5mm **(6)**	Soft gouge or Separation > 5mm **(0)**		
Groundwater Rating	Completely Dry **(10)**		Moist **(7)**	Mod. Pressure **(4)**	Severe **(0)**		
Total RMR_{76} Value (Sum of Ratings for 5 Items) =							
Rating	**100 – 81**	**80 – 61**	**60 – 41**	**40 – 21**	**20 – 0**		
Description	I – Very Good	II – Good	III – Fair	IV – Poor	V – Very Poor		

Notes: 1. Rating system from Bieniawski, 1976.
2. Rating values are shown in parentheses.

For determination of the typical RMR_{76} for each rock unit, we assumed the typical Rock Strength (Table 4.2), Weathering Index (Table 4.4) and RQD (Table 4.6) assigned to each rock type is representative of the rock type throughout the project area. The Joint Condition Rating (JCR) assigned to each rock type was based on the joint characteristics we observed in the exploration core during the site visit, We assume that this JCR is representative for each rock unit regardless of location. These are appropriate assumptions for this Scoping level study. However, for Pre-feasibility and Feasibility level studies, we would assign the ratings for each parameter in Table 4.7 to each core interval and then calculate RMR_{76} for each core interval.

Based on the results of our data analysis of the RQD, rock strength, and weathering data, the Limestone, Dolomite, and Marble are similar, so we combined them into one unit referred to as Carbonate Rocks.

Table 4.8: Typical RMR_{76} for Major Rock Types

Geotechnical Unit		UCS[1]	RQD[2]	Joint Spacing[2]	Joint Condition	Ground-water	RMR_{76}	Rock Mass Quality
Carbonate Rocks (Limestone, Dolomite, and Marble)	Value or Condition	25 to 50 MPa	50 to 75 %	100 to 150 mm	Very to Slightly Rough with hard rock contacts	dry	59	Fair
	Rating	4	13	10	22	10		
Volcani-clastic	Value or Condition	25 to 50 MPa	50 to 75 %	100 to 150 mm	Slightly rough with hard rock contacts	dry	57	Fair
	Rating	4	13	10	20	10		
Oxide	Value or Condition	< 1 MPa	<25 %	<50 mm	Decomposed Rock Mass with rock blocks > 5 mm separation	10	16	Very Poor
	Rating	0	3	3	0	10		

Notes: 1. typical value from Table 4.2; 2. Typical value from Table 4.5

The Rock Mass Rating values shown in Table 4.7 indicate that the Rock Mass Quality of the Carbonate Rocks (Limestone, Dolomite, and Marble) and Volcaniclastic is typically Fair ($40 < RMR_{76} < 60$) Quality rock mass. The Rock Mass Quality of the Oxide is typically Very Poor ($0 < RMR_{76} < 20$).

The manner in which we performed our data analysis assumes that each rock type has a characteristic Rock Mass Quality that applies to each rock type throughout the project area. In actuality, the Rock Mass Quality will vary from place to place. The spatial variation of the Rock Mass Quality, RQD, and rock strength is typically evaluated during Pre-Feasibility Level pit slope studies.

4.6 Geotechnical Units

We divided the soil and rock masses into geotechnical units. Slopes of similar orientation and height developed within the same geotechnical unit should generally perform similarly. Geotechnical units may be subdivisions of rock types if there are significant variations in their mechanical and structural characteristics. Alternatively, geotechnical units may combine several geologic or lithologic units if mechanical and structural characteristics of the units are similar.

Based on the RQD, rock strength, and weathering data collected by ATAC for the exploration core and summarized in Table 4.1, 4.3 and 4.5, and our observation of the exploration core, we divided the rock masses into the following geotechnical units for this scoping level study.

- Carbonate Rocks
- Volcaniclastic
- Oxide

The Carbonate Rock includes Limestone, Dolomite, and Marble. The Dolomite and Marble have not been modelled as separate geologic units in the existing geologic model, so their location in the pit slopes is not defined. They have similar properties based on the strength and weathering data collected by ATAC; however, they may be slightly less fractured and are less likely to be foliated based on our review of the core and core photographs.

4.6.1 Carbonate Rock

The Carbonate Rock is typically a Medium Strong (R3, 25 < UCS < 50 MPa) rock with a variable degree of rock fracturing that will form a blocky rock mass. The RQD measurements (Table 4.6) indicate that its Rock Quality ranges from Poor (25 < RQD < 50) to Good (75 < RQD < 90), but is typically Fair (50 < RQD < 75). Where the limestone is dolomitized or marbleized, the rock strength will likely be higher strength and less fractured. Fair Quality Rock Masses consisting of Medium Strong Rock are characterized as typically having high shear strength relative to the slope height, so strength-controlled instability of inter-ramp and overall slopes is not anticipated. Given that the Rock Quality is greater than “Fair Quality” (RQD = 50 to 75) it may be difficult to pre-split the rock, which is essential for safely maximizing slope angles. It should be possible to form bench faces in this rock by trim blasting. Examples of typical core consisting of Carbonate rock are shown in Figure 4.1

4.6.2 Volcaniclastic Rock

The Volcaniclastic Rock is a Medium Strong (R3, 25 < UCS < 50 MPa) rock with a variable degree of rock fracturing that will produce a blocky or seamy rock mass. Similar to the Carbonate Rock, the RQD measurements (Table 4.6) indicate that most of the rock consists of Poor (25 < RQD < 50) to Good (75 < RQD < 90) Quality rock, but it is typically Fair (50 < RQD < 75) Quality rock. The Volcaniclastic Rock appears as 10 to 20 meter thick layers in the cross sections shown in Figures 2.2 through 2.5, it and dips to the northeast. Based on geologic interpretations, the foliation in the Volcaniclastic Rock also dips to the northeast and into the bench faces, a favorable orientation for bench slope stability. The rock mass shear strength is high relative to the slope height, and the ability to form steep slopes will be dependent upon the steepness of stable bench faces that can be developed in this unit. Typical core from the Volcaniclastic Rock showing the foliation is shown in Figure 4.2

4.6.3 Oxide

The Oxide is classified as an Extremely Weak Rock (R0, 0.25 < UCS < 1 MPa). The mineralization and weathering processes in this unit have destroyed the primary structures in the rock and it is highly fractured. To estimate its engineering behavior in pit slopes, the Oxide should be considered to consist of a very dense silty sand or very hard silt with low plasticity. It strength in pit slopes is dependent primarily on the frictional strength it develops under load rather than its intact strength. Its ability to form steep pit slopes of significant height will be dependent upon its shear strength. Our experience with similar materials is that this material can be mechanically excavated without blasting. These materials will readily erode where exposed in the pit slopes.

Where the water content of the Oxide is greater than about 20 percent, the Oxide is likely nearly saturated. That is, the voids in the soil mass are almost completely filled with water. The depth of seasonal frost penetration could range from about 1 to 2 meters on exposed surfaces. Silty sands and silts are susceptible to significant strength loss upon thawing in the summer months, particularly when they are nearly saturated. Degradation and erosion of benches excavated in Oxide should be anticipated during the summer thaw. Figure 4.2 shows typical core obtained in the Oxide.

5.0 STABILITY EVALUATION

5.1 Potential Stability Controls

Pit slope stability in competent rock is generally controlled by structural conditions and operating practices. Pervasive structures such as joints commonly control bench-scale stability, while individual faults, shears, contacts, and other continuous structures that can develop along bedding or foliation can control large-scale stability, and bench-scale stability locally.

Rock mass failures are generally limited to very high slopes in competent rock masses or smaller slopes in weak rock masses. Our preliminary stability evaluation consists of evaluating the potential control of pervasive and large-scale structures on bench and inter-ramp slope stability. We also assessed the risk of rock mass instability for overall slopes qualitatively based on rock mass characteristics, and on slope stability analyses and slope performance in similar materials at other open pit mines.

Where there are no structural controls on pit slope stability, and the rock mass strength precludes rock mass failure, stability and safely achievable slope designs are controlled by operating practices. We evaluated operating practices, particularly blasting methods, based on the characteristics of the geotechnical units defined by their RQD, RMR_{76}, and ISRM Rock Strength Classification.

5.2 Structurally Controlled Stability

The stability of slopes in competent rock can be controlled by structures, or combinations of structures that define kinematic failure modes. These involve movement of intact blocks along one or more discontinuities, typically in planar, wedge, toppling, or combination modes. Stability with respect to these failure modes is a function of slope orientation, discontinuity orientation, discontinuity shear strength, groundwater conditions, and external forces. Structures that could potentially control stability at the Tiger Zone include bedding, joints, foliation, faults, and contacts.

Kinematic failure modes can affect bench-scale, inter-ramp, or overall slopes, depending on the continuity of the structures. As such, persistence is an important consideration in evaluating the significance of any potential failure modes that are indicated. Bedding, foliation, fault, and contact structures may be continuous on an overall slope scale. Joints generally have more limited continuity, but until exposure during mining allows persistence to be evaluated directly, prominent structures such as the foliation that may form a control on bench stability should be considered continuous on an inter-ramp scale.

There is currently little quantitative data on the distribution of structures and their orientations in the Tiger Zone. However, the geological model enables a preliminary assessment of potential structural controls on slope stability. This assessment is based on assumed geological conditions and will need to be confirmed by additional studies, particularly by oriented core measurements.

5.2.1 Large-Scale Structurally Controlled Stability

Faults strike to the northwest and dip steeply to the east and west (Figures 2.2 through 2.5). Faults in these orientations could not control large-scale slope stability because they dip more steeply than the design slope angles. Any instability related to these faults would be expected to be bench-scale or multi-bench instability limited to the immediate vicinity of the fault zones due to locally low rock mass strength. Where such conditions exist, it is sometimes possible to excavate the pit slope such that if falls in the footwall of the fault zone, for example, stability is improved if the pit wall is excavated into the footwall of the Footwall fault as shown in Figure 2.5

5.2.2 Bench-Scale Stability

Bench-scale stability will be controlled by structures with limited continuity, such as joints, and also by continuous structures such as foliation and faults where they are present. Foliation is expected to be the primary structural control of bench stability. As described previously, foliation is thought to dip steeply to the northeast in the Volcaniclastic Rock; it will dip into the pit slopes, an orientation favorable for stability.

The orientations of the joint and bedding planes in the Limestone are not defined. Widely spaced and rough joints are unlikely to form a control on bench slope stability over extensive areas of the pit. The high RQD values in the Carbonate Rocks, particularly those composed of Marble and Dolomite, suggest that jointing may not be so ubiquitous and wide spread in these rock units to form a control on the steepness of bench faces.

Bench-scale stability will also be controlled by both rock quality in terms of fracture intensity, and operating procedures of blasting and scaling. Rock quality and operating practices will limit stable bench face angles where structural conditions are favorable.

5.3 Stability of Benches and Inter-ramp Slopes in Oxide

Figure 1.1 indicates that slopes in Oxide could be up to 50 to 60 m high in the northern portion of the pit. While the Oxide is not actually a sanded dolomite, it has similar engineering properties and we expect it to behave similarly in pit slopes. Our experience indicates that these materials can be benched and the benches are stable slopes as long as they remain dry. Over time the benches are susceptible to erosion. At an open pit mine in Nevada, we have observed stable pit slopes excavated at 55 degrees and up to 50 m high in sanded dolomite.

These materials are friable and prone to erosion. As the material erodes from bench faces and crests, it accumulates and fills catch benches so they no longer provide good rockfall catchment. Eventually, the material forms talus slopes at the angle of repose at the base of the pit slope.

In areas such as Nevada with cold, semi-arid climates, erosion of bench faces may occur slowly so as to not fill benches during mining in small pits with short lives. Due to the subarctic climate with its increased frost penetration, rapid snowmelt, and decreased evaporation rates, the erosion of benches may be more rapid and severe in the Tiger Zone pit.

The depth of seasonal frost at the project site could be up to several meters. Upon thawing, the Oxide may lose strength, particularly if it is near saturation either due to groundwater or surface water infiltration. The thawed material would be easily eroded by surface water flowing onto benches from snowmelt or precipitation. The unanticipated loss of benches in the Oxide due to erosion and thaw weakening may require step-outs be left in the pit. Consideration should be given to scheduling and equipment selection during Pre-feasibility and Feasibility level studies to select appropriate mining methods to lessen the impact of bench erosion in the Oxide.

In the subarctic, where ground water is trapped behind frozen rock and soil, high pore pressures can develop that result in bench and inter-ramp slope instability. Surface drainage controls at the pit perimeter and on benches can reduce the amount of infiltration into benches and improve bench face stability. These controls should be evaluated and developed further during Pre-feasibility level studies.

5.4 Rock Mass Stability

Where there is no simple structural control of stability, estimates of rock mass strength are used to evaluate the stability of slopes in rock masses. The slope of greatest concern is the high slope on the north side of the proposed pit (Section A-A’ in Figure 5.1). We evaluated the stability of this slope by performing a limiting equilibrium slope stability analysis using the program Slide 6.0 (Rocscience, 2012).

The weight of the soil and rock in pit slopes creates shear stresses within those slopes. Pore pressure in the slope reduces the available effective shear strength of the rock mass. If the shear stresses are greater than the available effective shear strength over large zones within the slope, the pit slope will become unstable. The likelihood for pit slope instability due to shear through the soil and rock mass comprising the pit slopes was evaluated by performing limiting equilibrium slope stability analyses using Spencer’s Method of Slices (Spencer, 1967) as implemented in the computer program Slide 6.0 (Rocscience, 2012). Spencer’s method is an “accurate” method that satisfies both horizontal and vertical force and moment equilibrium. It provides calculated factors-of-safety (FOS) that are comparable to values calculated by other “accurate” methods.

In evaluating slope stability by limiting equilibrium methods, a FOS that represents the ratio of the resistance along the slip surface (mobilized through soil or rock mass strength) over the driving forces destabilizing the slide mass is computed for trial surfaces through the soil or rock mass. The FOS for each trial surface is calculated and the minimum FOS provides an indication of the level of stability of the slope. Algorithms programmed within Slide generate trial slope surfaces and identify the surface with the lowest FOS (critical surface). Typical minimum acceptable FOS for open pit mine slopes are on the order 1.2 to 1.3 for overall slopes where the consequences of failure are low, and are up to 1.5 for slopes containing critical facilities and access ramps (Read and Stacey, 2009).

5.4.1 Generalized Hoek-Brown Failure Criterion

The results of soil shear strength tests, such as were performed on the Oxide, can be used directly in slope stability analyses. It is inappropriate however to use the results of small-scale laboratory tests on intact rock to directly estimate the shear strength of rock masses containing fractures. Defects in the rock mass reduce the shear strength to a value less than the shear strength of the intact rock obtained by UCS and triaxial tests of samples of rock core. The most reliable estimates of the rock mass shear strength are obtained from the back analysis of failed slopes, and reliable lower bound estimates can be obtained from back analyses of stable slopes. In-situ tests can sometimes be conducted on representative volumes of rock mass, but high quality in-situ tests are expensive and are usually not justified unless the impacts of slope failure are great. If there are no comparable slope failures in similar rock masses, the rock mass shear strength can be estimated through the use of empirical rock mass shear strength criteria. For this study, we estimated the rock mass shear strength based on the method initially developed by Hoek and Brown (1980) and subsequently modified based on experience (Hoek and Brown, 1988; Hoek et. al., 2002).

The Hoek-Brown rock mass strength criterion is the most widely accepted method of estimating rock mass shear strength in rock masses comprised of brittle, fractured rock such as the Carbonate and Volcaniclastic Rock at the Tiger Zone project. Hoek and Brown’s rock mass strength criterion is based on empirical results and utilizes the RMR classification system developed by Bieniawski (1976).

The generalized Hoek-Brown criterion (Hoek, et al., 2002) defines the relationship between major principal stress and minor principal stress at failure based on the following equation:

$$\sigma'_1 = \sigma'_3 + \sigma_{ci}\left(m_b \frac{\sigma'_3}{\sigma_{ci}} + s\right)^a$$

where:

σ'_1 = the major effective principal stress at failure

σ'_3 = the minor effective principal stress (confining stress)

m_b, s, a = Hoek-Brown material constants for jointed rock mass

σ_{ci} = the uniaxial compressive strength of intact rock

Values for m and s vary with rock mass quality and rock type, with the upper limits of the value ranges defined by m and s for intact rock (i.e., intact core samples). Triaxial compressive strength testing data can be used to determine m for intact rock (termed m_i); alternatively, published data can be used if triaxial test data is unavailable. The value of s for intact rock is 1.

Given the values of m_i and s for intact rock, the parameters m and s for the broken rock mass are calculated based on the following equations (Hoek et al., 2002); in effect, these equations reduce m and s from the values for intact rock based on the rock mass quality, as indicated by the measured RMR_{76}. A disturbance factor which relates to the effects of blasting/excavation and stress relief on rock mass integrity is also applied:

$$m_b = m_i \, exp\left(\frac{RMR_{76} - 100}{28 - 14D}\right)$$

$$s = exp\left(\frac{RMR_{76} - 100}{9 - 3D}\right)$$

where D is a factor that depends on the degree of disturbance that the rock mass has been subjected to by blast damage and stress relaxation. D varies from 0 for undisturbed rock to 1 for very disturbed rock.

Hoek et al. (2002) provide the following expression for determining a value for constant a that is a function of RMR_{76}:

$$a = \frac{1}{2} + \frac{1}{6}\left[exp\left(\frac{-RMR_{76}}{15}\right) - exp\left(\frac{-20}{3}\right)\right]$$

Given the uncertainty in the results of slope stability analyses based on rock mass shear strength estimates, the appropriate use of such analyses is not necessarily as a design tool to select an appropriate slope height and slope angle based on safety factors, but rather as a basis for semi-quantitative estimates of the likelihood that rock mass shear strength is a controlling factor in slope design. If stability analyses using conservative assumptions indicate reasonable safety factors, our experience suggests that rock mass failure is unlikely to be a controlling factor. If unacceptable safety factors are calculated, additional evaluation of the potential for, and the impacts from, a rock mass failure would be required. These evaluations might include evaluation of the impact of unstable slopes on mine plans and incorporation of design elements and operating practices to reduce the impact of potential rock mass failure mechanisms. They may also include additional engineering studies and laboratory testing depending on the failure mechanism.

5.4.2 Design Material Properties

5.4.2.1 Rock Mass

The Hoek-Brown shear strength criteria requires the estimation of the UCS and material constant, m_i, of the intact rock; the rock mass quality (RMR_{76}); and an estimate of the degree of disturbance of the rock mass as defined by a disturbance parameter, *D*. We developed Hoek-Brown shear strength parameters for the Carbonate Rock based on the typical geotechnical parameters presented in Section 4. We did not develop parameters for the Volcaniclastic Rock because it does not occur in Section A-A’ shown in Figure 5.1

Since no laboratory UCS tests or field point load tests are available, we assumed that the UCS of the Carbonate rock is the average value of Medium Strength (R3, 25 < UCS < 50 MPa); that is the UCS is equal to 37 MPa.

A material constant, m_i, can be determined from triaxial tests on intact rock; however, these are often not available for Scoping level studies. Hoek and Karzulovic (2000) indicate that the value of m_i for limestone and dolomite can range from 6 to 15; we used an average m_i of 10 for our analyses.

We assumed a value of RMR_{76} of 59 for the Carbonate Rock corresponding to the typical value of RMR_{76} in Table 4.8.

A disturbance factor, D, of 0 was selected for use in our analysis. This is an appropriate value to use for shear surfaces extending deep into the rock mass where stress relaxation or damage due to blasting is unlikely to occur (Hoek, 2012).

A summary of the values of UCS, RMR_{76}, m_i, and D used in the Hoek-Brown Failure Criterion formulas to obtain the Hoek-Brown rock mass shear strength parameters m_b, s, and a used in our analyses are provided in Table 5.1.

Table 5.1: Design Rock Mass Properties

Geotechnical Unit	Unit Weight (kN/m^3)	UCS (MPa)	RMR_{76}	Hoek-Brown Failure Criterion Parameters				
				m_i	D	m_b	s	a
Carbonate Rocks	28	37	59	10	0	1.0326	0.00022	0.5099

5.4.2.2 Oxide

Design shear strength parameters for our slope stability analysis were estimated from the direct shear tests presented in Section 3. The following properties were used in the analysis:

- Friction angle = 32 degrees
- Cohesion = 250 kPa
- Unit Weight = 24 kN/m^3

5.5 Stability Analyses

Figures 5.2 and 5.3 show the configuration of the slope corresponding to the Section A-A’ in Figure 5.1. In the sections used in the analyses, the portion of the slope consisting of Oxide is somewhat larger than is indicated in Section A-A' to simplify that analysis. This adds an additional degree of conservatism into the analyses.

Important assumptions of the analyses include:

- The rock mass is accurately characterized by the average value of rock strength and RQD assigned to the core by ATAC geologists and the value of RMR_{76} assigned to the rock mass in Table 4.8.
- The strength of the Oxide can be represented by the results of direct shear tests on remolded material.
- A disturbance factor, *D*, of 0 applied to rock mass strength estimates implies that good quality, controlled blasting will be used near the pit walls to minimize disturbance of the rock mass due to blasting
- The shear surface in the rock mass does not follow unfavorably oriented major structures.

For the stability analyses, we considered three slope geometries to evaluate the stability of the current design and also the potential for steepening the pit slopes. Case 1 (Inter-ramp Slope Angle (IRA) in Carbonate Rock = 45 degrees, IRA in Oxide = 30 degrees). In Cases 2 and 3 we steepened the IRA in the Carbonate Rock in 5 degree increments and by 10 degree increments in the Oxide to evaluate if steeper pit slopes would be stable. The slope configurations we evaluated are shown in Figure 5.2 and 5.3. These slope configurations assume that if the inter-ramp slope angles in the Carbonate Rock and Oxide were steeper the amount of stripping would be reduced so the slopes shown in Figure 5.2 and 5.3 are not as high as the slope shown in Figure 5.1.

The regional groundwater table is thought to be located below the pit; however, there are no groundwater measurements to verify this. Perched water is frequently encountered in rock masses, and joints and open fractures may be great enough to allow the water contained in the rock mass to drain freely; however, the degree of drainage will not be known until the pit is excavated. We performed one set of analyses assuming the slope is fully depressurized (most favorable conditions), which corresponds to the groundwater condition thought to most likely exist.

To evaluate the effects of less favorable groundwater conditions we also modelled partial saturation by assuming a range of pore pressure coefficients. The pore pressure coefficient is a convenient way to express the pore pressure in a slope. This pore pressure is expressed as a function of depth below the slope. The pore pressure coefficient (r_u) defines pore water pressure as:

$$u = r_u * \gamma(t) * z$$

Where:

u= pore pressure
r_u=pore pressure coefficient
γ(t) = total unit weight of material
z=depth of soil above point where pore pressure is defined

A pore pressure coefficient of 0.1 might exist if there is locally perched groundwater. A pore pressure coefficient of 0.2 might be representative of a condition where the pit intersects a regional groundwater table that located at a depth equal to about one-half of the slope height.

The results of all of the analyses are summarized in Table 5.3.

Table 5.3: Summary of Scoping Level Slope Stability Analyses for Section A-A'

Case	Inter-ramp Slope Angle (degrees)		Factor-of-Safety for Indicated Groundwater Condition[1]		
	Carbonate Rock	Oxide	Fully-Drained	r_u=0.1	r_u=0.2
1 (Current design in Figure 1.1)	45	30	1.68	1.46	1.24
2	50	40	1.53	1.33	1.12
3	55	50	1.36	1.16	0.96

Note: 1. r_u = pore pressure coefficient

Acceptable factors-of-safety (Factor of Safety $\geq$ 1.3) for overall slopes in open pit mines (Read and Stacey, 2009) were obtained for all cases for the fully drained slopes over a range of inter-ramp slope angles. These stability analyses also indicate we would not anticipate slope instability due to overstressing of the rock mass even if Oxide material occurs at the toe for the pit as shown in Figure 1.1 for fully drained conditions. Unacceptable factors-of-safety (FOS < 1.3) were obtained where high pore pressure conditions exist (r_u = 0.2) for all slope angles and for moderate pore pressures (r_u = 0.1) for the slope angles assumed for Case 3. These results suggest that there is potential for increasing the design slope angles provided groundwater and structural conditions are favorable

6.0 SLOPE DESIGN

Our preliminary geotechnical characterization and stability analyses indicate that neither rock mass shear strength nor major structures form a control on the stability of pit slopes in Carbonate and Volcaniclastic Rock. Even where Oxide occurs at the toe of the slope, the shear strength of the Oxide and Carbonate and Volcaniclastic Rock is sufficiently high so as to not form a control on the stability of the pit providing pore pressures are low or the rock mass is fully drained. In this case, the inter-ramp slope angles are limited by achievable bench configurations.

Based on our preliminary investigations and understanding of the geology of the Tiger Zone, the orientation and persistence of the rock fabric, in this case the joints, foliation and bedding planes does not place a control on the stability of the bench faces. Where structure does not control bench stability, the bench face angle is controlled by operating practice, particularly blasting, and excavation methods and bench face scaling.

Given a stable bench configuration, the inter-ramp slope angle can be obtained by:

$$IRA = \arctan (H / (W + H \cot (B)))$$

Where IRA is the inter-ramp slope angle, W is the catch bench width, H is the bench height, and B is the bench face angle. The relationship between bench face angle, catch bench width, bench height and inter-ramp slope angle is shown in Figure 6.1.

Effective catch benches should be developed to retain rocks falling from the scaled bench faces. The width of catch benches is selected based on empirical guidelines and experience. A commonly used empirical criterion for catch bench width is the Modified Ritchie Criterion (Ryan and Pryor, 2000) as follows:

$$W = 4.5 + 0.2H$$

Where W is the minimum width of the catch bench a bench of height, H, both in meters.

The Modified Ritchie Criterion was developed based on empirical studies that correlated rockfall travel distance with the height of steep rock slopes (Ritchie, 1963). It is suitable for estimating catch bench width for steep bench faces in hard rock where fall of rock from the bench face is the primary mode of rockfall. Site-specific experience, where this is available, can also be used to select the design catch bench width. A typical minimum catch bench width that is effective for retaining rockfalls from steep bench faces is on the order of 8 meters.

In some provinces in Canada, the design width of catch benches is prescribed in safety regulations. For example, in British Columbia (2008), the minimum width of catch benches is specified to be 8 m. Based on a review of regulations, we did not identify similar regulations specifying minimum catch bench width for Yukon Territory (2010).

If strong structural control at flatter angles is lacking, the following BFA ranges are typically achievable, depending on rock quality and blasting methods:

- Standard production blasting (including Buffer blasting) – 55-65 degrees
- Effective controlled blasting (Trim Blasting) – 65-70 degrees
- Best-case controlled blasting (Pre-splitting) – 70-80 degrees

Design bench height is dependent on the reach of excavating equipment and the ore control requirements. Production benches can be stacked where feasible to optimize inter-ramp slope angles. Assuming the mining will be accomplished in 5 m high production benches, effective scaling of bench faces, and the benches are stacked to leave catch benches at 10, 15, and 20 meter vertical intervals, the maximum achievable inter-ramp slope angles are then as follows:

Table 6.1: Inter-ramp Slope Angle based on Bench Configuration

Vertical Separation between Stacked 5–m high Benches (m)	Catch Bench Width (m)	Blasting Method	Bench Face Angle (degrees)	Inter-ramp Slope Angle (degrees)
10 (double benching)	6.5	Standard Production Blasting	65	42
15 (triple benching)	7.5		65	46
20 (quad benching)	8.5		65	48
10 (double benching)	6.5	Trim Blasting	70	45
15 (triple benching)	7.5		70	50
20 (quad benching)	8.5		70	52
10 (double benching)	6.5	Pre-splitting	75	47
15 (triple benching)	7.5		75	52
20 (quad benching)	8.5		75	55

For this project, a conservative design assumption is that bench face angles of 70 degrees can be achieved by double benching (10 m high benches), trim blasting and effective bench face scaling in Carbonate and Volcaniclastic Rock. For this case, the corresponding inter-ramp slope is 45 degrees if 6.5 m catch benches are left in the pit slope.

If the rock conditions are better than anticipated, it may be possible to form steeper bench face angles by pre-splitting the Carbonate and Volcaniclastic Rock. Alternatively, if triple benching can be accomplished so that a 7.5 m wide catch bench is left every 15 vertical m or an 8.5 m wide catch bench every 20 m, then it may be possible to achieve inter-ramp slope angles of 50 degree or steeper in the Carbonate Rock.

The stability analyses indicate that the inter-ramp slope angle in the Oxide is not a control on overall pit slope stability providing the slope is fully drained. The steepness of inter-ramp slope angles in the Oxide then depend on the ability to maintain catch benches in the slope. Triple benching is likely to be difficult in the Oxide; however, it should be possible to double bench so as to leave a 6.5 meter wide catch bench in the slope every 10 meters. Assuming benches in Oxide formed by machine excavation and trimmed with a dozer to form bench faces at 0.5H:1V (about 63 degrees), the corresponding inter-ramp slope angle is 40 degrees.

Over time, the benches in the Oxide will erode and debris will accumulate on and fill the catch benches. As the benches erode, the inter-ramp slopes in the Oxide will approach the angle of repose of the material. For the Oxide, this is approximately 37 degrees based on the direct shear tests presented in Section 3. The rate at which the benches will fill with debris from erosion will depend on site specific conditions, and may not be known until the pit is developed. To add an additional degree of conservatism to the design, we recommend that in areas of the pit where inter-ramp slopes are greater than 30 m high, the inter-ramp slope angle in the Oxide be limited to 35 degrees for the Scoping level study.

7.0 CONCLUSIONS

7.1 General

Based on the geotechnical data available, rock quality and structural conditions generally appear favorable for the development of moderate to steep inter-ramp slopes within the competent Carbonate and the Volcaniclastic Rocks providing future studies do not indicate unfavorable joint and foliation orientations. The steepness of the inter-ramp slopes will likely be dependent on the ability to form steep, stable bench faces and on the bench configuration during mining.

Specific conclusions supported by our characterization and stability evaluation include:

- Faults are not expected to form large plane shear and wedge failures so they do not form a control on overall pit slope stability
- Rock mass shear strength of the Carbonate and Volcaniclastic Rock is sufficiently high that the potential for overall slope failure due to overstressing the rock mass is indicated to be low.
- Where Oxide occurs in the toe of the slope, the limiting equilibrium analyses indicates the potential for rock mass shear failure is within acceptable limits for the expected groundwater conditions (fully drained) and likely range of inter-ramp slope angles achievable in the Carbonate and Volcaniclastic Rocks.
- Steep bench face angles should be generally achievable with careful blasting, excavation and scaling where structure orientations are favorable for bench stability.
- The benches in Oxide will be stable if developed by careful excavation method (no blasting to form bench faces) and trimmed, but will likely deteriorate to the extent that catch benches are lost due to erosion.

Engineering geologic conditions that may require significantly different slope angles are:

- Unfavorable structural orientations that result in bench face instability
- Zones of intense fracturing along faults that could result in bench face instability or generate rockfall from steep bench faces
- Local perched groundwater trapped behind frozen bench faces, particularly in the Oxide
- Severe and rapid erosion and loss of catch benches in the Oxide

7.2 Risks

Risks of rock mass failure appear to be low in the competent rock units (Carbonate and Volcaniclastic Rock) even where the Oxide occurs at the toe of the slope. Risk to rock slope stability therefore pertain primarily to geological risks related to the undocumented orientation of joints and foliation or presence of large, unfavorably oriented structures and the potential for encountering highly fractured rock adjacent to faults. For slope composed of Oxide, the risk to slope stability pertains to the loss of catch benches due to erosion and thaw weakening of the benches.

There are risks associated with mining at high latitudes that do not occur in more temperate climates. Besides thaw instability of the Oxide, seasonal freezing of bench faces can result in trapped water behind bench faces that in turn result in localized instability. Control of surface water for an open pit operating in the subarctic can be critical to achieving bench face stability.

7.3 Opportunities

Based on the geotechnical data and providing the orientation of jointing and foliation in the competent rock units is favorable, the Carbonate and Volcaniclastic rocks are generally favorable for development of steep slopes. Where there is no evident structural control, stability will be controlled by mining practice and there is the potential to maximize slope angles by implementing best operating practices in blasting, excavation, and scaling. Such practices will typically increase perimeter blasting costs. However, they should result in more stable and safer pit slopes, maximize safely achievable inter-ramp slope angles, and decrease scaling costs.

Realizing these opportunities at the Pre-feasibility level would require that ATAC:

- Determine the orientation of minor structures in the Carbonate and Volcaniclastic Rocks by structural measurements on oriented core
- Include the geotechnical data in the corehole database in the GEMS database, locations of weak and highly fractured Carbonate and Volcaniclastic Rock can be projected into the pit slopes

8.0 RECOMMENDATIONS

8.1 Scoping-Level Slope Design Recommendations

For bedrock slopes where the Oxide does not occur in the toe of slope, there is indicated to be little potential for either rock mass or structural control of overall or inter-ramp slope angles. Achievable pit slope angles in the bedrock (Carbonate and Volcaniclastic Rocks) will be determined by the bench configurations that can be developed and maintained safely. Bench configurations are defined by production bench height, achievable bench face angle (BFA), and catch bench width, all of which combine to define the inter-ramp slope angle (IRA) as shown in Figure 6.1. Since catch bench width for a given bench height is constant according to our design criteria, maximizing the IRA will be contingent on excavating the BFA as steep as possible.

The block model has been developed assuming blocks are 5 m high; this is the typical bench height required for grade control in small open pit gold mines. Stacking benches will be required to achieve moderate to steep inter-ramp slope angles. While it is premature to determine the most suitable bench configuration for optimized slope design, available data indicate that moderate to steep inter-ramp slope angles should be feasible in strong rock units (Carbonate and Volcaniclastic Rocks) and moderate slope angels should be feasible in the Oxide.

The scoping-level slope design recommendations in Table 8.1 are based on our current understanding of geotechnical conditions at the site, and assumptions regarding operating practices as noted.

Table 8.1: Scoping Level Pit Slope Design Recommendations

Geotechnical Unit	Inter-ramp Slope Angle (degrees)	Assumptions[1]
Carbonate Rock (Limestone, Dolomite and Marble) **Volcaniclastic Rock**	45	Trim Blasting Bench Height = 10 m (double benching) Bench Face Angle = 70 degrees Minimum Catch Bench Width = 6.5 m
Oxide (< 30 m high)	40	Buffer blasting (if required to loosen the Oxide)[2] Trim bench face by machine Bench Height = 10 m Bench Face Angle = 63 degrees Minimum Catch Bench Width = 6.5 m
Oxide (> 30 m high)	35	Buffer blasting (if required to loosen the Oxide)[2] Bench faces trimmed by dozer or excavator Bench Height = 10 m Bench Face Angle = 63 degrees Minimum Catch Bench Width = 10 m

Notes: 1. See Figure 6.1 for definition of bench height, catch bench width, bench face angle, and inter-ramp slope angle
2. No blasting in soil-like Oxide

If additional geologic modelling and geotechnical studies indicate that waste rock (Carbonate Rock and Volcaniclastic) has a low degree of fracturing in the pit slopes, consists of Medium Strong (R3, 25 < UCS <50 MPa) rock with Good to Excellent (75 < RQD < 100) Rock Quality with no adversely oriented systematic structure, it may be possible to excavate inter-ramp slopes as steep as 50 to 55 degrees. This condition may exist in the Dolomite and Marble on the west side of the pit.

Details of benching configurations should be resolved during Pre-feasibility and Feasibility-level studies. Details of surface water control and scheduling should also be resolved during the Pre-feasibility and feasibility level studies.

Flatter slope designs may be required if unexpected highly fractured zones or unfavorably oriented structures are encountered in the Fair Quality, Medium Strong Carbonate and Volcaniclastic Rock; if high pore pressure conditions are encountered in the Oxide; or if erosion and thaw instability of the benches in the Oxide is severe.

8.2 Recommended Geotechnical Program to Support Pre-Feasibility Pit Slope Designs

Pre-Feasibility and Feasibility level pit slope designs should be based on factual data that documents geotechnical conditions in the vicinity of the pit slopes with a level of reliability that is consistent with ore reserve estimates. This should be achieved by a program of core drilling and testing to support feasibility-level pit slope design analyses.

The Occupational Health and Safety Act for Yukon Territory also requires that a design report be prepared and maintained for operating mines (Yukon Territory, 2010). The information required in this design report can most efficiently be collected during Pre-Feasibility and Feasibility Level pit slope design studies.

The following sections describe a program that should be completed to support Pre-Feasibility level pit slope designs. The geotechnical drilling program outlined will be sufficient for a Feasibility-level study if it documents favorable subsurface geotechnical conditions to a degree that enables reliable interpretation and projection of geotechnical conditions to all important slope sectors. However, if the geotechnical drilling program identifies unfavorable conditions, or does not document conditions sufficiently to enable reliable extrapolation of conditions to all important pit slopes using the geotechnical and geologic models, additional geotechnical core drilling would be required to fill the geotechnical data gaps in order to support Feasibility-level pit slope designs.

8.2.1 Geologic Modelling

The data already collected by ATAC provides a good basis for developing a computerized geologic model. We recommend that the RQD, Weathering, and Rock Strength data be included in this model. Projection of this data into the pit slopes should enable us to identify locations where steep bench faces can be obtained.

Wire frame models of the major faults shown in the cross sections should be prepared and projected into the pit slopes. These projections can be used to identify large structurally controlled failures and combined with the RQD data indicate where fractured rock zones are likely to occur in the pit slopes or near bench faces.

The geologic model containing RQD, Weathering, Rock Strength and models of major faults in addition to the lithologic models should be completed prior to finalizing the location of any future geotechnical coreholes.

8.2.2 Exploration Core Drilling

Basic geotechnical data of RQD, degree of weathering, and a field strength estimate should be logged for all exploration cores to support further development of a geotechnical model of rock mass quality and structure.

8.2.3 Geotechnical Drilling

8.2.3.1 Geotechnical Core Logging

Geotechnical coreholes should be drilled in the areas of the proposed pit walls to allow characterization of the rock mass and to help identify any pervasive structures or major faults that may influence bench slope performance. These coreholes should be logged to obtain detailed geotechnical information used to calculate Rock Mass Rating (RMR – Table 6.2). Additionally, the core should be oriented to identify structural sets that may control stability.

Targets for drilling should include:

- The Limestone in the highest (north) pit slope.
- The Limestone and Volcaniclastic in the east wall of the pit
- The Limestone, Dolomite, and Marble in the west wall of the pit
- The fault that truncates the Oxide on the southwest
- The Oxide where it will be exposed in the west and north walls of the pit.

The geotechnical coreholes should be inclined at about 60°, drilled into the pit walls, and pierce the walls around 1/3 of the height from the pit bottom, and should extend to the depth of the pit bottom. We estimate five or six geotechnical coreholes will be required for the Pre-Feasibility Study.

The final locations of the geotechnical coreholes should be determined based on the geologic model and discussions with site personnel to ensure that the locations are representative and accessible. To the extent practical, geotechnical coreholes can be located to provide additional information for resources estimates, condemnation purposes, or waste rock characterization.

Geotechnical coreholes should be logged to collect data including RQD, lithology, total core recovery, fracture frequency, ISRM strength index, joint condition (JCR), and weathering/alteration index. Fracture characteristics should also be documented by collecting detailed information on the individual fractures within each run, such as depth, type, shape, roughness, infilling type, and infilling thickness. Triple tube (HQ-3) coring is the preferred method of drilling for geotechnical purposes to maximize core recovery and minimize disturbance in sensitive material. The triple tube system enables the core to be viewed and logged in as close to its in situ condition as possible, and minimizes disturbance during transfer of core from the split tubes to the core box or sample tray. The drilling company should provide extra split tubes to temporarily store the core until it has been logged. Many companies have old split tubes available; if these are not available the drillers should supply suitable materials for temporarily storing core, such as split PVC tubing of an appropriate diameter, or angle iron core trays.

Drilling quality, and driller knowledge and experience, are important considerations in implementing a successful geotechnical core drilling program. We recommend contracting a drilling company that will staff the project with drillers experienced in geotechnical core drilling and that will provide all necessary equipment and supplies.

8.2.3.2 Core Orientation

Design of pit slopes in rock generally requires oriented coring to provide joint, bedding, foliation and discontinuity data to support design. Obtaining orientations for discontinuities in drill core can be accomplished by several mechanical methods or by using televiewer surveys. Several methods can produce acceptable results in good quality rock.

We understand that ATAC Resources uses the the Reflex Ace Core Tool (ACT) for core orientation at other properties and their geologists are experienced in its use. Golder experience is that of the currently available mechanical methods, the ACT core orientation system, when used properly, can provide good results over a wide range of conditions. ACT system is an appropriate core orientation system for use at ATAC's Tiger Zone project. Where mechanical core orientation systems are used, it is critical that quality control checks, including comparing the orientation reference line from one run to the next, be conducted during drilling operations and structural orientation data be plotted on stereonets as it is collected. Minor variations in procedures and lack of care by drilling company personnel can reduce the reliability of structural orientations collected by these methods to the extent that the data is useless. When mechanical methods of core orientation are used, we recommend that the drilling operation be staffed with a geologist familiar in the correct use of these tools to make sure that drilling company personnel are using the appropriate techniques for core orientation and marking the core.

In poor rock quality rock, fracturing of the core commonly limits the ability to achieve reliable orientations using mechanical methods, and televiewer surveys generally enable more reliable orientation. Structures that intersect the borehole walls are clearly identifiable in televiewer images, but televiewer images by themselves often do not allow positive identification of structure type, or whether structures are “open” or “healed”. Televiewer images also do not allow evaluation of discontinuity properties (roughness, infilling type, etc.). Positive evaluation of these details requires correlation of the televiewer image logs with drill core. Televiewer surveys are performed after drilling is completed, so there is a risk of hole collapse and the loss of data due to inaccessibility; this is not a risk with mechanical methods. Compared to mechanical core orientation methods, there is less risk of obtaining unreliable data from televiewer surveys as it does not depend on the experience and care of the drilling company personnel to correctly use the orientation equipment and mark the core.

8.2.3.3 Drillhole Surveys

We recommend that the geotechnical coreholes be surveyed using a gyroscopic system. The survey data will be used to correct the ‘apparent’ measured structural orientations to ‘true’ orientations. It is our experience that this method produces more consistently accurate surveys.

8.2.3.4 Field Strength Testing

Point load testing should be implemented to measure strength of selected representative core samples to support the field strength classification system.

8.2.3.5 Laboratory Testing

Laboratory testing should include:

- compressive strength (UCS) testing on representative core samples from different geotechnical and alteration units for calibration of field point load tests
- soil index tests on gouge from fault zones and Oxide
- direct shear tests on gouge from fault zones
- direct shear tests on discontinuities, particularly foliation, in rock
- consolidated undrained triaxial tests with pore pressure measurements (CU/pp triaxial tests) on undisturbed samples of Oxide
- direct shear tests on intact samples of Oxide

The triaxial tests on the Oxide provide the most reliable estimates of shear strength of these materials; however, such samples can be difficult to obtain. The direct shear tests on intact samples is less reliable but easier to perform, and the results of these tests provide a check on the results of the triaxial tests. We recommend that both triaxial and direct shear tests be performed.

8.2.4 Surface Mapping

The vegetation and cover of soil and fractured rock at the surface make obtaining structure orientation measurements difficult; however, to the extent this can be accomplished such data is useful for providing a check on structure orientation measurements obtained from oriented core.

8.2.5 Pre-Feasibility Level Analysis and Pit Slope Design

The geologic model and the geotechnical investigation program should be used to develop a geotechnical model that characterizes the important mechanical and structural characteristics of the geotechnical units and supports the slope design process. Important elements of the engineering evaluation and feasibility level design should include:

- Evaluate and document structural characteristics and domains
- Characterize rock strength from field and laboratory testing
- Develop geotechnical model based on latest geologic model and geotechnical investigation
- Consider all surface and subsurface structural data spatially relative to pit slope locations to assess significance of any systematic variability
- Confirm overall slope stability using rock mass characterization and engineering analyses
- Evaluate large-scale and bench-scale structural controls of stability
- Develop bench configurations based on production bench heights, structural controls, and predicted blast performance and operating practices
- Develop standards for catch bench development and bench scaling consistent with slope design recommendations
- Develop preliminary perimeter blast designs to be used as a basis for estimating drilling equipment capital costs, and drilling and blasting operating costs
- Assess risks and opportunities for recommended slope designs
- Define ongoing geotechnical program appropriate to support risk management and pit slope optimization
- Document investigation, testing, model development, analyses, slope design recommendations, operating practices required, and recommended monitoring program in an engineering report

9.0 CLOSING

It has been a pleasure to work with ATAC personnel on this project. This report has been prepared for the exclusive use of ATAC and their consultants in preparation of a PEA for the Tiger Zone. If a substantial period of time elapses between the date of this report and the time design and development of the final pit occurs, we recommend that we review our conclusions and recommendations to account for new data that may be been developed in the time elapsed.

Respectfully,

GOLDER ASSOCIATES INC.

George Lightwood
Senior Engineer

GL/ap

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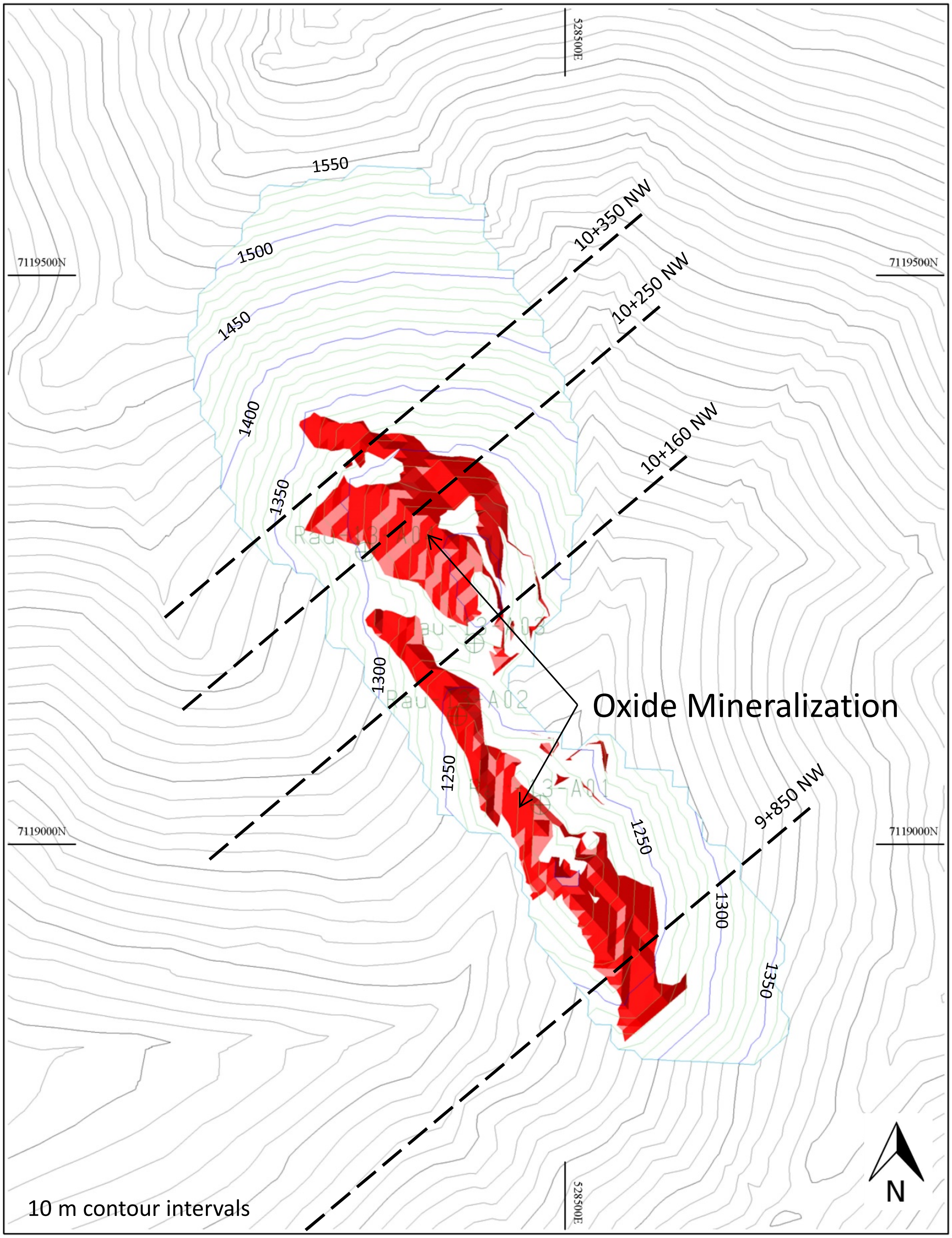
FIGURES



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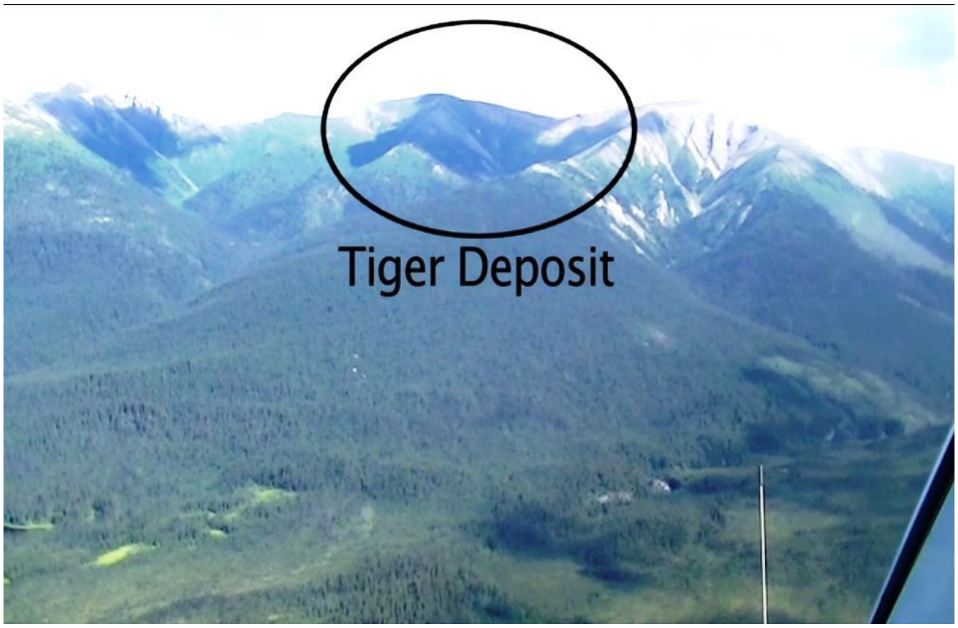
TIGER ZONE,
RAU PROPERTY
YT, CANADA

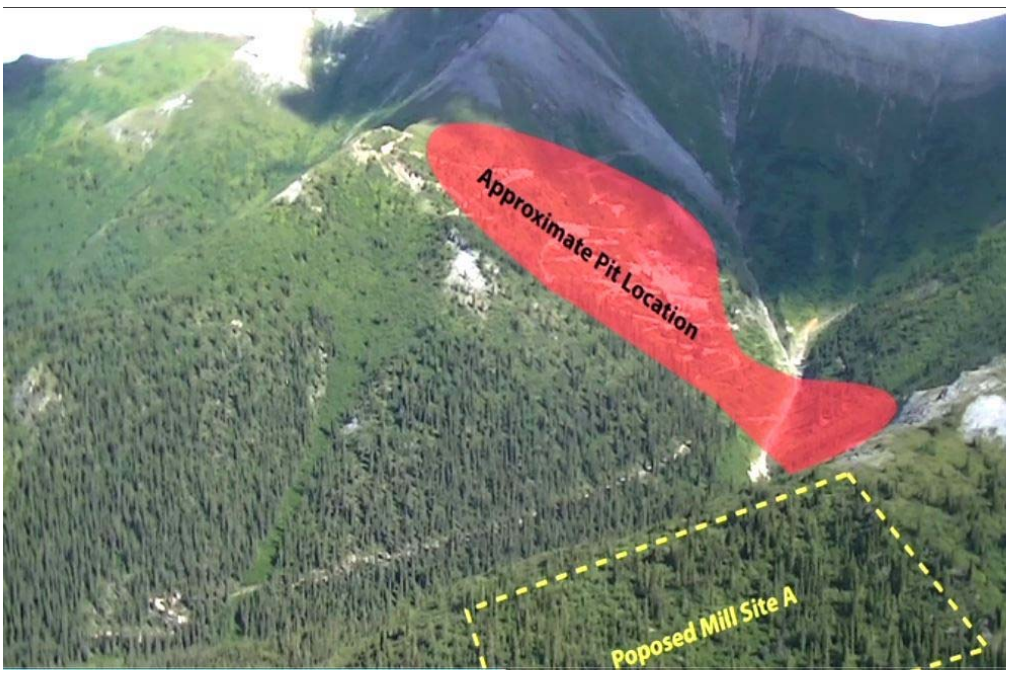
Drawn	Date	Project Number
GL	27 Jan 2014	1302357

Title

Figure 1.1
Pit Shell and Oxide Mineralization



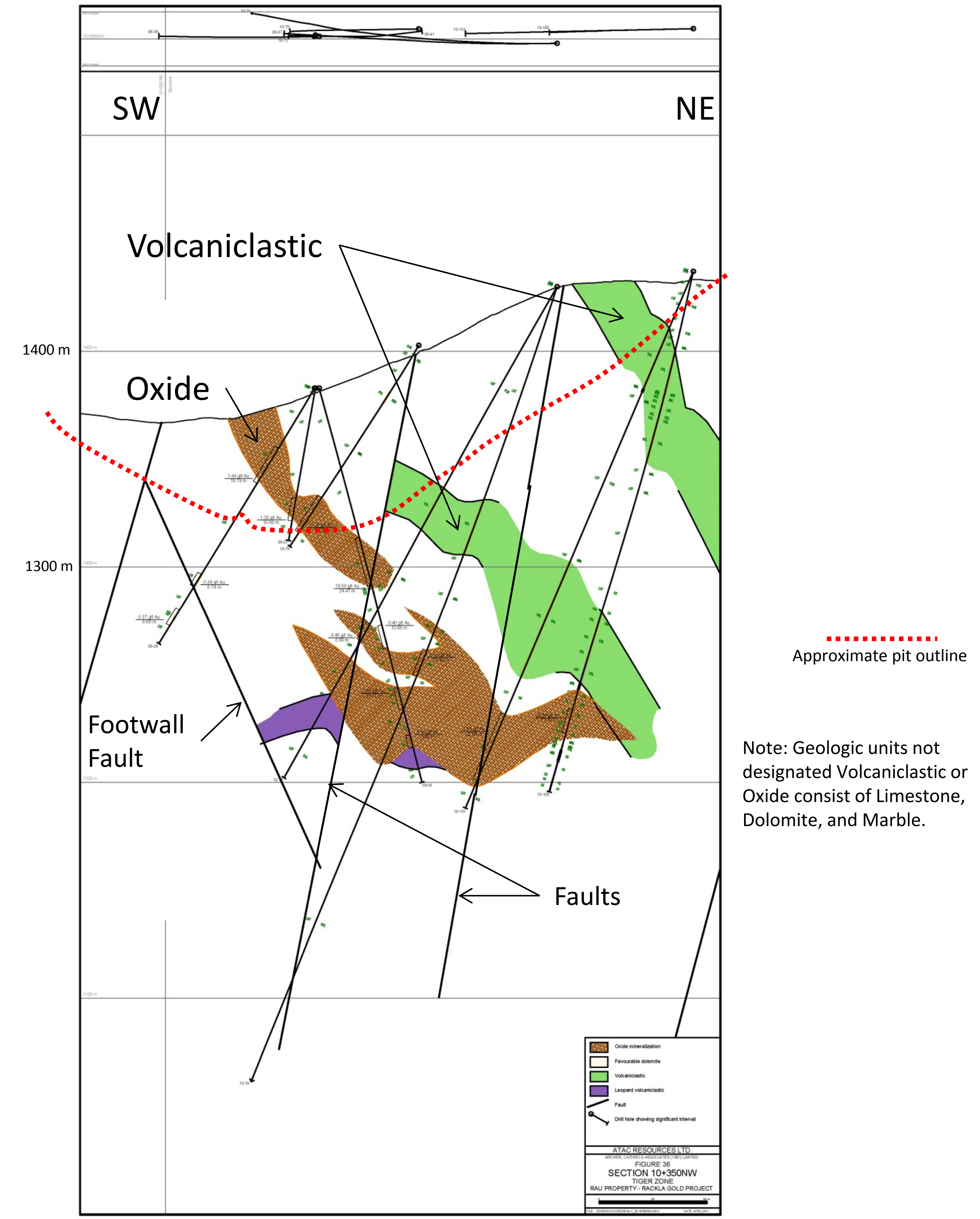
Tiger Zone Deposit



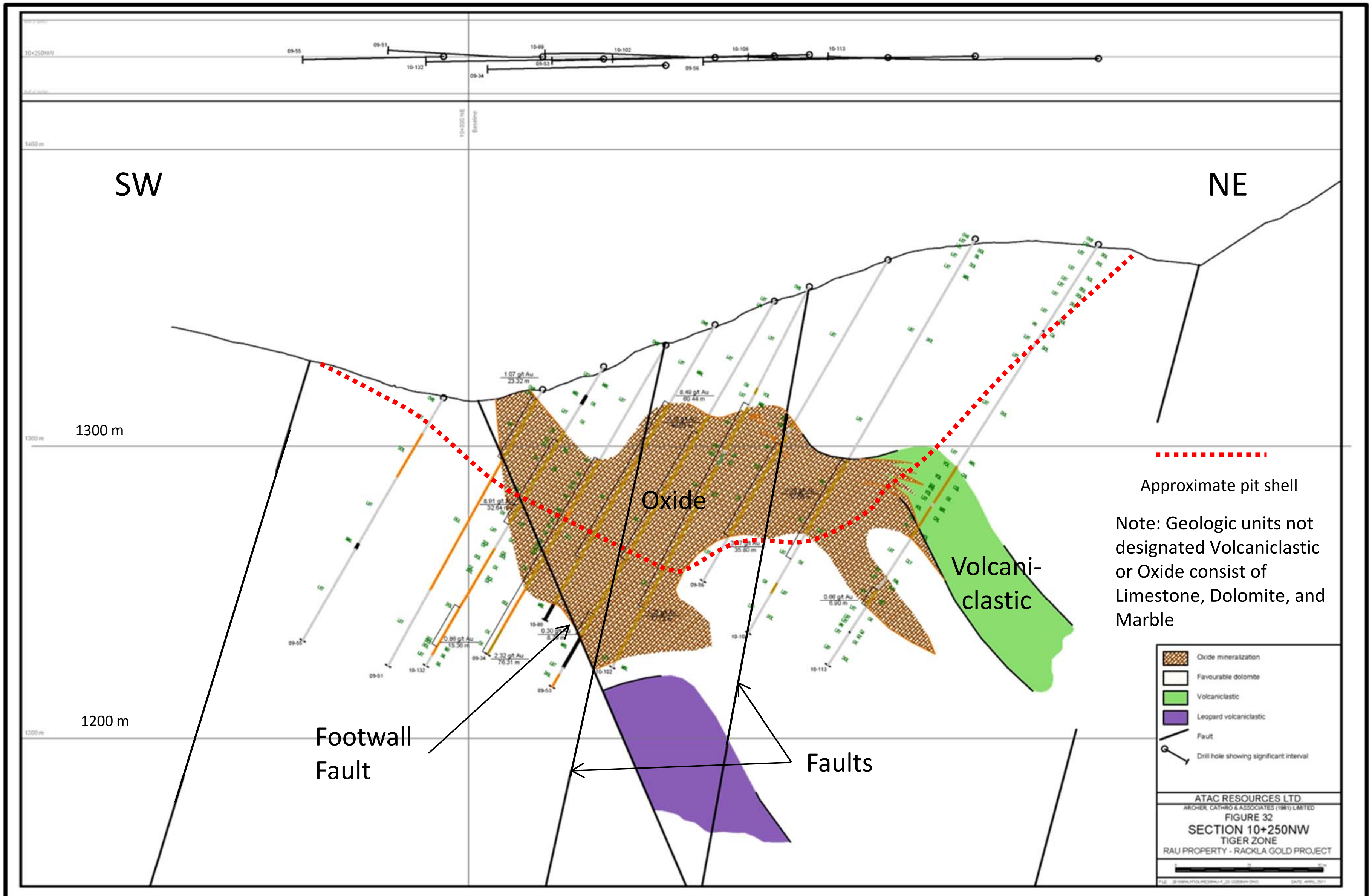
Pit Location

Note: Photographs provided by ATAC Flyover on July 19, 2013

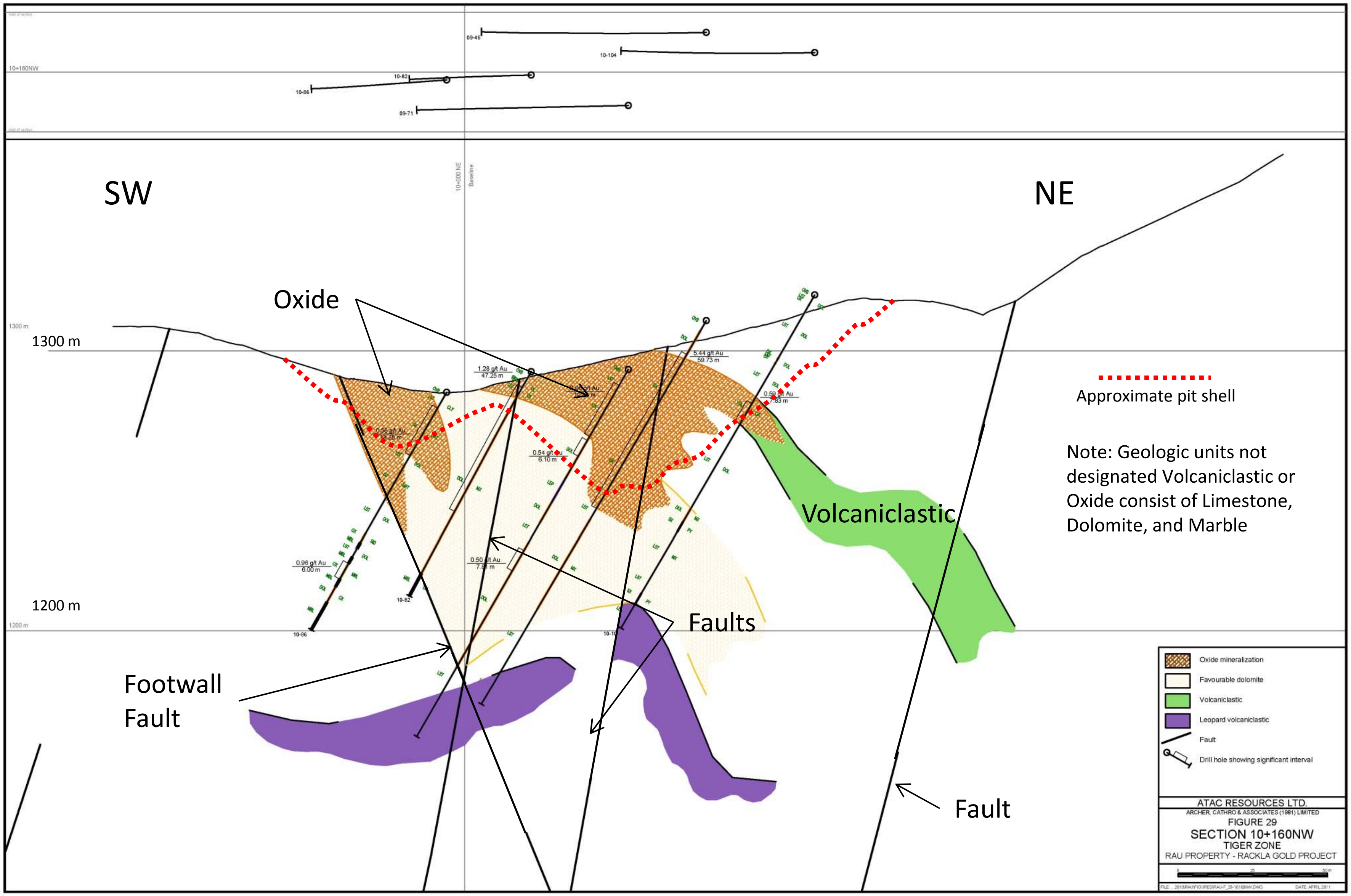
ATAC Resources Ltd. / Golder Associates	ATAC RESOURCES LTD. TIGER ZONE, RAU PROPERTY YT, CANADA	Drawn GL	Date 27 Jan 2014	Project Number 1302357
		Title	**Figure 2.1** **Site Photographs**	



ATAC RESOURCES LTD. TIGER ZONE, RAU PROPERTY YT, CANADA	Drawn GL	Date 27 Jan 2014	Project Number 1302357
	Title	**Figure 2.2** **Section 10+350NW**	



Golder Associates / ATAC Resources Ltd. — ATAC RESOURCES LTD. TIGER ZONE, RAU PROPERTY YT, CANADA	Drawn	GL	Date	27 Jan 2014	Project Number 1302357
	Title	**Figure 2.3 Section 10+250NW**			



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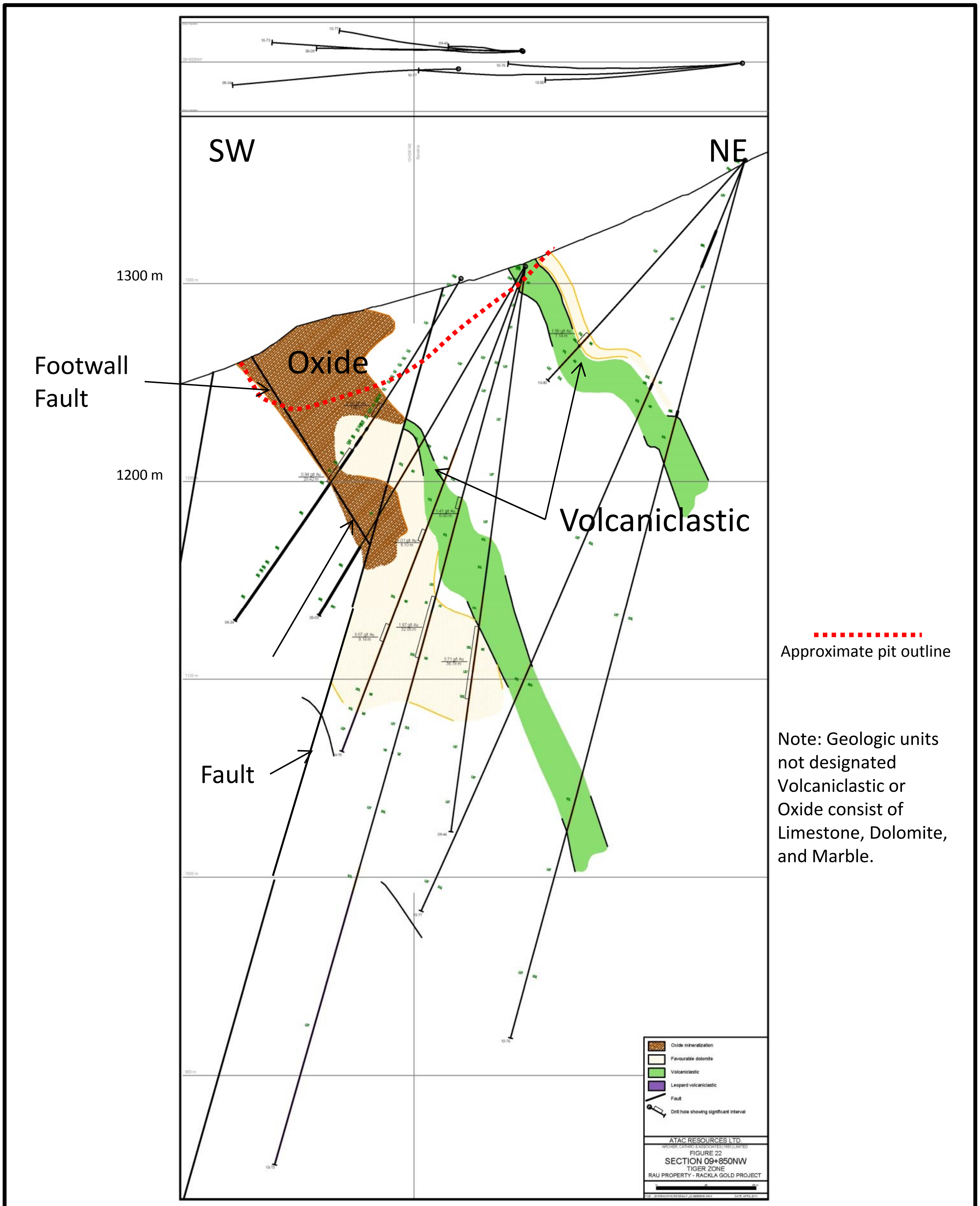
Drawn	GL	Date	27 Jan 2014	Project Number	1302357
Title	**Figure 2.4 Section 10+160NW**				



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Title

Figure 2.5
Section 09+850 NW

Limestone

Dolomite

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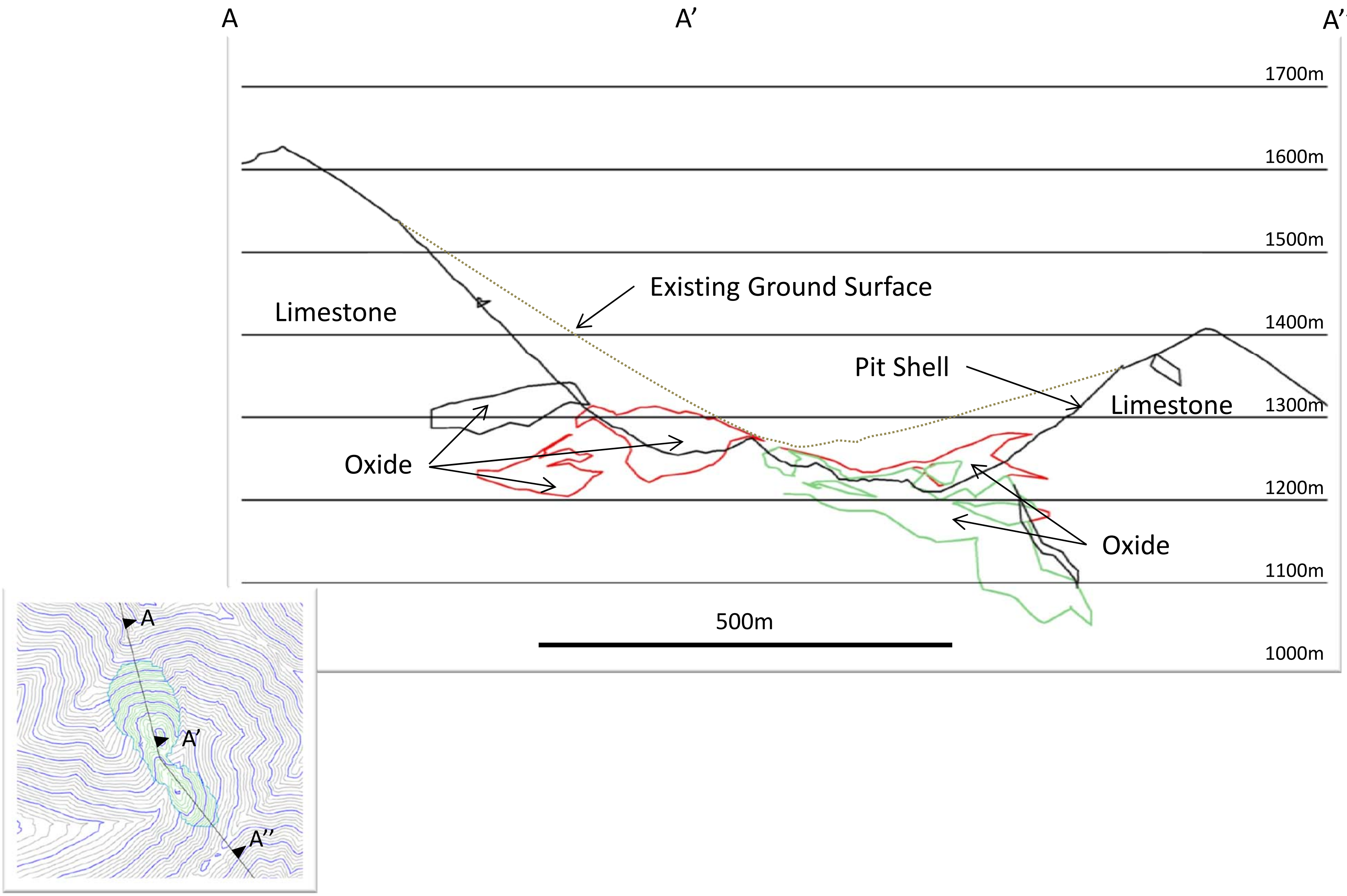
Title: **Figure 4.1**
Core Photographs of Carbonate Rock

Volcaniclastic

Oxide

ATAC RESOURCES LTD. TIGER ZONE, RAU PROPERTY YT, CANADA Golder Associates	Drawn GL	Date 27 Jan 2014	Project Number 1302357
	Title	**Figure 4.2** **Core Photographs of Volcaniclastic Rock and Oxide**	



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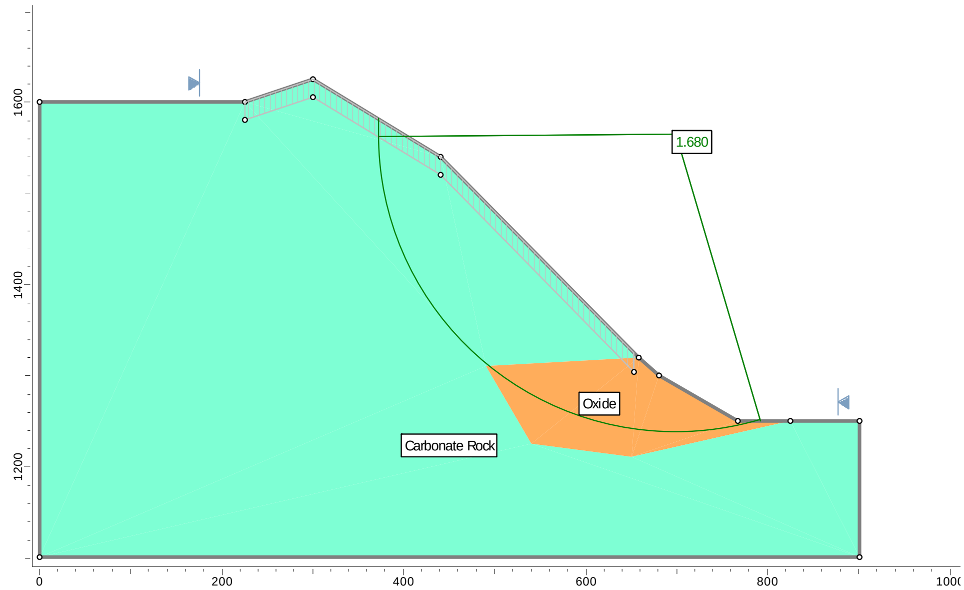
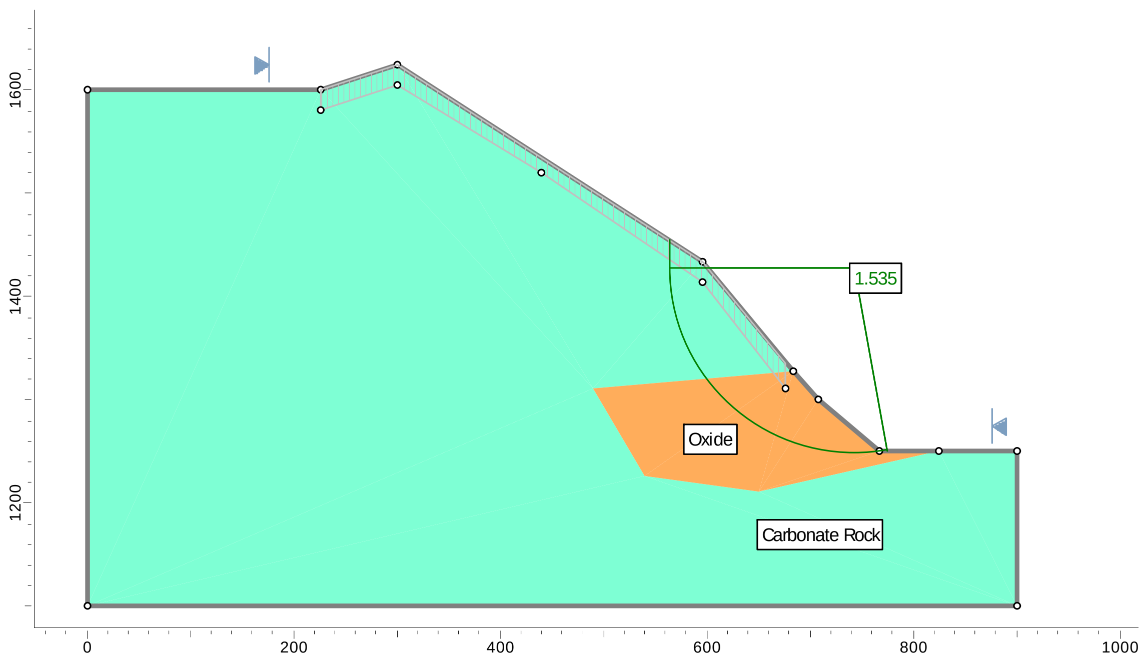
Drawn	GL	Date	27 Jan 2014	Project Number	1302357

Title

Figure 5.1
Section A-A''



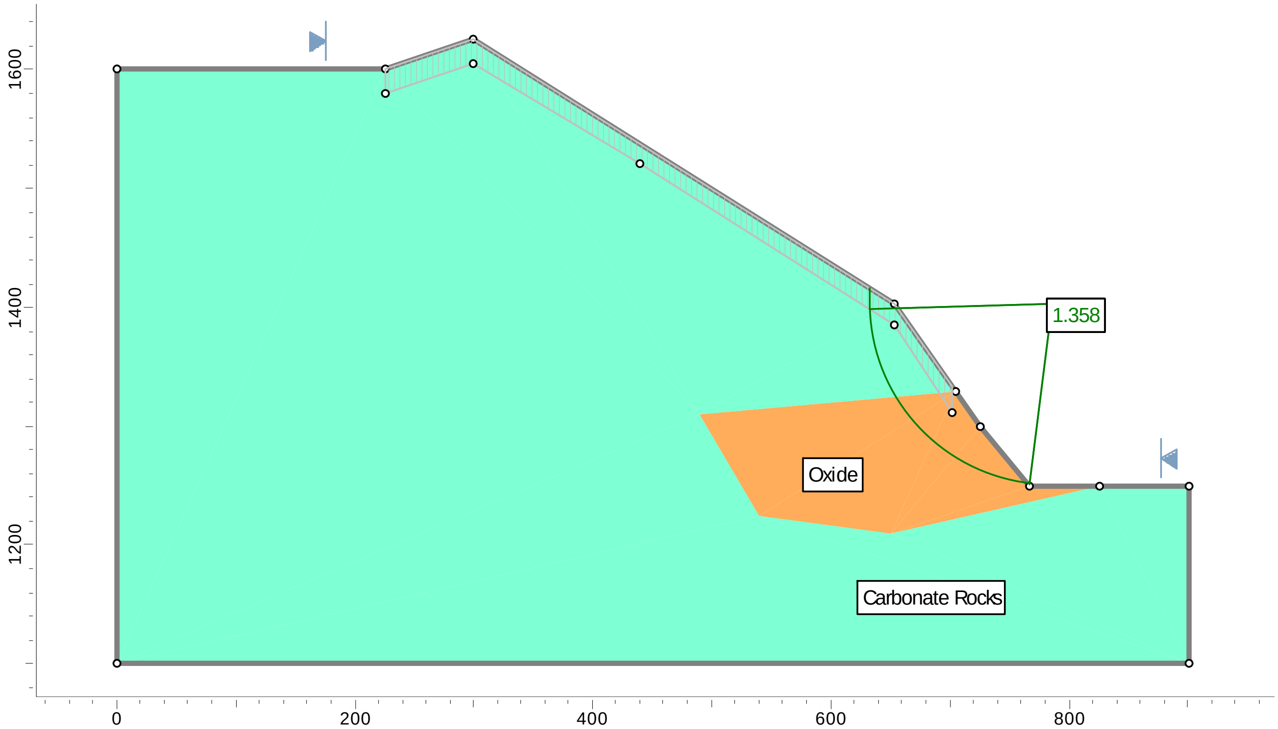
Case 1 – Fully Drained
IRA: 45 deg. in Carbonate Rock, 30 deg. in Oxide



Case 2 – Fully Drained
IRA: 50 deg. in Carbonate Rock, 40 deg. in Oxide

Notes: All distances in meters
See Table 5.2 for other groundwater conditions

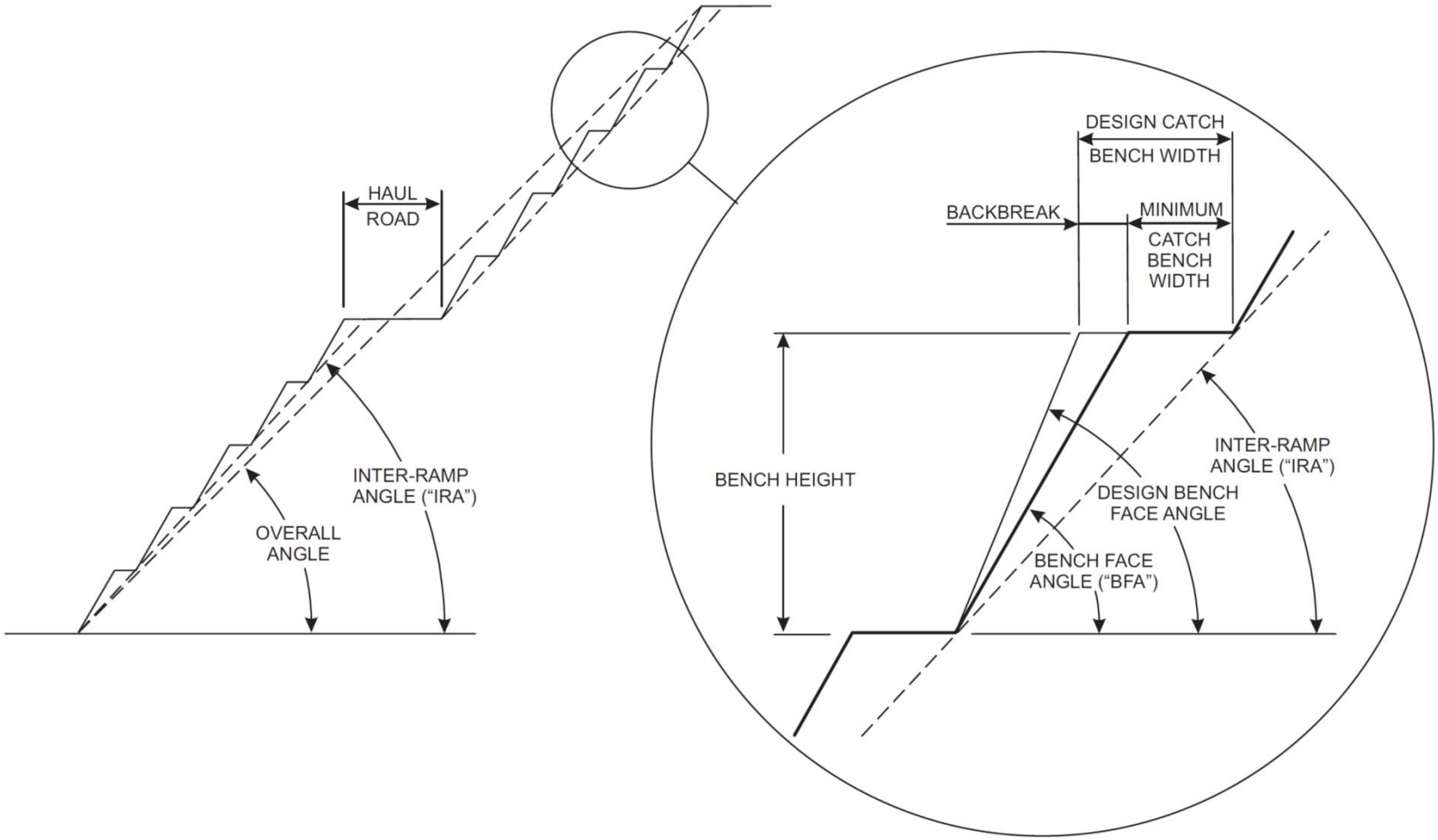
ATAC RESOURCES LTD. TIGER ZONE, RAU PROPERTY YT, CANADA	Drawn GL	Date 27 Jan 2014	Project Number 1302357
	Title	**Figure 5.2 Results of Slope Stability Analyses (1 of 2)**	



Case 3 – Fully Drained
IRA: 55 deg. in Carbonate Rock, 50 deg. in Oxide

Notes: All distances in meters
See Table 5.2 for other groundwater conditions

ATAC RESOURCES LTD. TIGER ZONE, RAU PROPERTY YT, CANADA	Drawn GL	Date 27 Jan 2014	Project Number 130-0709
	Title	**Figure 5.3** **Results of Slope Stability Analyses (2 of 2)**	



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Drawn	GL	Date	27 Jan 2014	Project Number	1302357
Title	**Figure 6.1 Slope Terminology**				

APPENDIX A
SOIL DESCRIPTIONS AND MOISTURE CONTENTS FOR AUGER HOLE SAMPLES

Hole: Rau-13-A01

Elevation 1221 m
Depth 48 feet
Easting 528478
Northing 7119035

From (ft)	To (ft)	Soil type	Sample Number	Laboratory Test (Yes/No)	Gravel %	Sand %	Fines%	Soil Classification and Description (group name, color, moisture content, plasticity of fines)	USCS Group Symbol	Comments	Moisture Content
7.5	13.0	OXI	Rau-13-A01-1	No				SILTY GRAVEL with sand, orange brown, moist-wet, NP fines	GM	Recent transport with FeOx, 1.5" max clast size	11.0%
13.0	18.0	OXI	Rau-13-A01-2	Yes	39	39	22	SILTY SAND with gravel, dark orange brown, wet, NP fines	SM	2" max clast size	26.4%
18.0	23.0	OXI	Rau-13-A01-3	No				SILTY SAND with gravel, dark orange brown, moist-wet, NP fines	SM	1" max clast size, heavy FeOx	24.2%
23.0	28.0	OXI	Rau-13-A01-4	Yes	6	43	51	SANDY SILT, dark reddish-brown, wet, NP fines	ML	gravel clasts consist of into FeOx clumps of fine sand and silt	25.5%
28.0	33.0	OXI	Rau-13-A01-5	No				SANDY SILT with gravel, dark reddish-brown, moist-wet, NP fines	ML	weathered clasts, many remain competent	16.6%
33.0	38.0	OXI	Rau-13-A01-6	No				SANDY SILT, dark red, wet, NP fines, fine sand	ML	clumps of FeOx appear to be weathered clasts of gravel	26.0%
38.0	43.0	OXI	Rau-13-A01-7	No				SANDY SILT, dark reddish-brown, wet, NP fines, fine sand	ML	clumps of FeOx appear to be weathered clasts of gravel	34.2%
43.0	48.0	OXI	Rau-13-A01-8	No				SANDY SILT with gravel, dark reddish-brown, wet, NP fines	ML	clumps of FeOx appear to be weathered clasts of gravel	26.0%

Hole: Rau-13-A02

Elevation 1260 m
Depth 48 feet
Easting 528405 mE
Northing 7119113 mN

From (ft)	To (ft)	Soil type	Sample Number	Laboratory Test (Yes/No)	Gravel %	Sand %	Fines%	Soil Classification and Description (group name, color, moisture content, plasticity of fines)	USCS Group Symbol	Comments	Moisture Content
8.00	14.00	OVB	Rau-13-A02-1	No				SILTY SAND with gravel, grey-brown, moist, NP fines	SM	Includes recent transported soils	8.8%
14.00	18.00	OXI	Rau-13-A02-2	No				SILTY SAND with gravel, brown-orange-brown, moist, NP fines	SM	Includes recent transported soils	8.1%
18.00	23.00	OXI	Rau-13-A02-3	No				SILTY SAND, reddish brown, moist, NP fines	SM		14.7%
23.00	28.00	OXI	Rau-13-A02-4	No				SILTY SAND, dark-brown-reddish-black, moist, NP fines	SM		19.4%
28.00	33.00	OXI	Rau-13-A02-5	Yes	8	46	46	SILTY SAND, dark-reddish-brown, moist, NP fines	SM		20.9%
33.00	38.00	OXI	Rau-13-A02-6	No				SILTY SAND, dark-reddish-brown, moist, NP fines	SM	trace organics	20.2%
38.00	43.00	OXI	Rau-13-A02-7	No				SILTY SAND, dark-reddish-brown, moist, NP fines	SM	near optimum water content	18.0%
43.00	48.00	OXI	Rau-13-A02-8	No				dark-reddish-brown, moist-wet, NP fines	SM	water saturated soil	22.0%

Hole: Rau-13-A03

Elevation 1267 m
Depth 48 feet
Easting 528420 mE
Northing 7119177 mN

From (ft)	To (ft)	Soil type	Sample Number	Laboratory Test (Yes/No)	Gravel %	Sand %	Fines%	Soil Classification and Description (group name, color, moisture content, plasticity of fines)	USCS Group Symbol	Comments	Moisture Content
10.00	18.00	OXI	Rau-13-A03-1	No				SILTY SAND, reddish-brown, moist, NP fines	SM	very fine grained sand or silt	14.8%
18.00	23.00	OXI	Rau-13-A03-2	No				SILTY SAND, reddish-brown, moist, NP fines	SM	very fine grained sand or silt	15.4%
23.00	28.00	OXI	Rau-13-A03-3	Yes	13	53	34	SILTY SAND, reddish-brown, moist, NP fines, fine-medium sand	SM	very fine grained sand or silt	12.6%
28.00	33.00	OXI	Rau-13-A03-4	No				SILTY SAND, reddish-brown, moist, NP fines	SM	very fine grained sand or silt	11.5%
33.00	38.00	OXI	Rau-13-A03-5	No				SILTY SAND, reddish-brown, moist, NP fines	SM	washed soil over #200 seive, approx 35% fines by visual estimate	11.9%
38.00	43.00	OXI	Rau-13-A03-6	No				SILTY SAND, reddish-brown, moist, NP fines	SM		14.3%
43.00	48.00	OXI	Rau-13-A03-7	No				SILTY SAND, reddish-brown, moist, NP fines	SM		10.7%

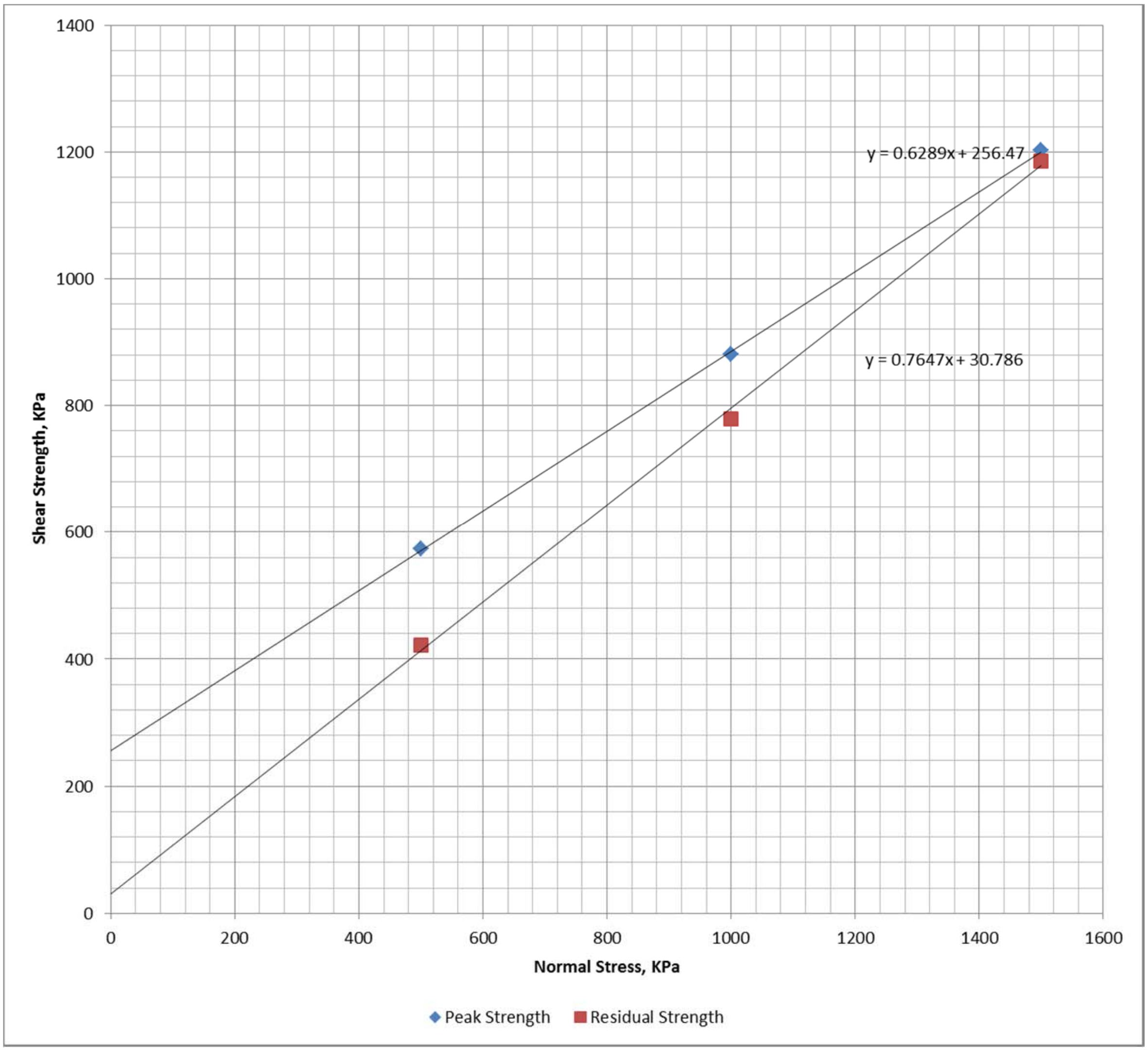
Hole: Rau-13-A04

Elevation 1307 m
Depth 48 feet
Easting 528324 mE
Northing 7119257 mN

From (ft)	To (ft)	Soil type	Sample Number	Laboratory Test (Yes/No)	Gravel %	Sand %	Fines%	Soil Classification and Description (group name, color, moisture content, plasticity of fines)	USCS Group Symbol	Comments	Moisture Content
3.00	13.00	OXI	Rau-13-A03-1	No				SILTY SAND with gravel, very loose, orange-reddish-brown, moist, NP fines	SM		13.1%
13.00	18.00	OXI	Rau-13-A03-2	No				SILTY SAND, very loose, reddish-brown, moist, NP fines	SM		19.6%
18.00	23.00	OXI	Rau-13-A03-3	Yes	18	37	45	SILTY SAND with gravel, very loose, reddish-brown, moist, NP fines	SM	trace organics	16.1%
23.00	28.00	OXI	Rau-13-A03-4	No				SILTY SAND, very loose, reddish, moist, NP fines	SM		16.2%
28.00	33.00	OXI	Rau-13-A03-5	Yes	4	31	65	SILT, medium dense, reddish-brown, wet, NP fines	ML		19.0%
33.00	38.00	OXI	Rau-13-A03-6	No				SILT, medium dense, reddish-brown, wet, NP fines	ML		20.5%
38.00	43.00	OXI	Rau-13-A03-7	No				SILT, medium dense, reddish-brown, wet, NP fines	ML		19.1%
43.00	48.00	OXI	Rau-13-A03-8	No				SILT, medium dense, reddish-brown, wet, NP fines	ML		20.8

Notes: Soil Descriptions and USCS Classification by Visual Manual Methods for Samples without Laboratory Testing
NP = Non-Plastic
Moisture Contents Provided by Kappes, Cassiday & Assoc., Reno, NV

APPENDIX B
LABORATORY TESTING RESULTS



Effective Mohr- Coulomb Shear
Strength Properties:

Peak: Friction Angle = 32deg.
Cohesion = 256 kPa

Residual: Friction Angle = 37 deg.
Cohesion = 31 kPa

ATAC RESOURCES LTD. TIGER ZONE, RAU PROPERTY YT, CANADA	Drawn GL	Date 01/27/14	Project Number 1302357
	Title	**Figure B-1** **Results of Direct Shear Test on Oxide**	

Boring or Test Pit:	A03-3		Boring or Test Pit:	A03-3		Boring or Test Pit:	A03-3	
Sample:	--		Sample:	--		Sample:	--	
Depth:	23-28	ft	Depth:	23-28	ft	Depth:	23-28	ft
Point No.:	1		Point No.:	2		Point No.:	3	

	Initial			**Initial**			**Initial**	
Thickness =	2.990	cm	Thickness =	2.987	cm	Thickness =	2.992	cm
Diameter =	6.337	cm	Diameter =	6.337	cm	Diameter =	6.337	cm
Wet Mass =	224.75	g	Wet Mass =	224.90	g	Wet Mass =	221.19	g
Area =	31.54	cm^2	Area =	31.54	cm^2	Area =	31.54	cm^2
Volume =	94.30	cm^3	Volume =	94.22	cm^3	Volume =	94.38	cm^3
Specific Gravity =	3.28	(ASTM D854)	Specific Gravity =	3.28	(ASTM D854)	Specific Gravity =	3.28	(ASTM D854)
Dry Mass of Solids =	198.54	g	Dry Mass of Solids =	199.73	g	Dry Mass of Solids =	195.92	g
Moisture Content =	13.2%		Moisture Content =	12.6%		Moisture Content =	12.9%	
Wet Unit Weight =	23.37	kN/m^3	Wet Unit Weight =	23.41	kN/m^3	Wet Unit Weight =	22.98	kN/m^3
Dry Unit Weight =	20.65	kN/m^3	Dry Unit Weight =	20.79	kN/m^3	Dry Unit Weight =	20.36	kN/m^3
Void Ratio =	0.56		Void Ratio =	0.54		Void Ratio =	0.58	
Percent Saturation =	78%		Percent Saturation =	76%		Percent Saturation =	73%	

	Pre-Shear			**Pre-Shear**			**Pre-Shear**	
Thickness =	2.911	cm	Thickness =	2.910	cm	Thickness =	2.905	cm
Diameter =	6.337	cm	Diameter =	6.337	cm	Diameter =	6.337	cm
Area =	31.54	cm^2	Area =	31.54	cm^2	Area =	31.54	cm^2
Volume =	91.81	cm^3	Volume =	91.78	cm^3	Volume =	91.64	cm^3
Moisture Content =	15.6%		Moisture Content =	15.4%		Moisture Content =	16.2%	
Wet Unit Weight =	24.5	kN/m^3	Wet Unit Weight =	24.6	kN/m^3	Wet Unit Weight =	24.4	kN/m^3
Dry Unit Weight =	21.2	kN/m^3	Dry Unit Weight =	21.3	kN/m^3	Dry Unit Weight =	21.0	kN/m^3
Void Ratio =	0.51		Void Ratio =	0.50		Void Ratio =	0.53	
Percent Saturation =	100%		Percent Saturation =	100%		Percent Saturation =	100%	

Shear Rate =	0.0838	mm/min	Shear Rate =	0.0838	mm/min	Shear Rate =	0.0838	mm/min
Normal Stress =	500	kPa	Normal Stress =	1,000	kPa	Normal Stress =	1,500	kPa

Notes:

Sample description: Silty sand, dark reddish brown, moist

Atterberg limits: LL = NP PL = NP PI = NP (ASTM D4318)

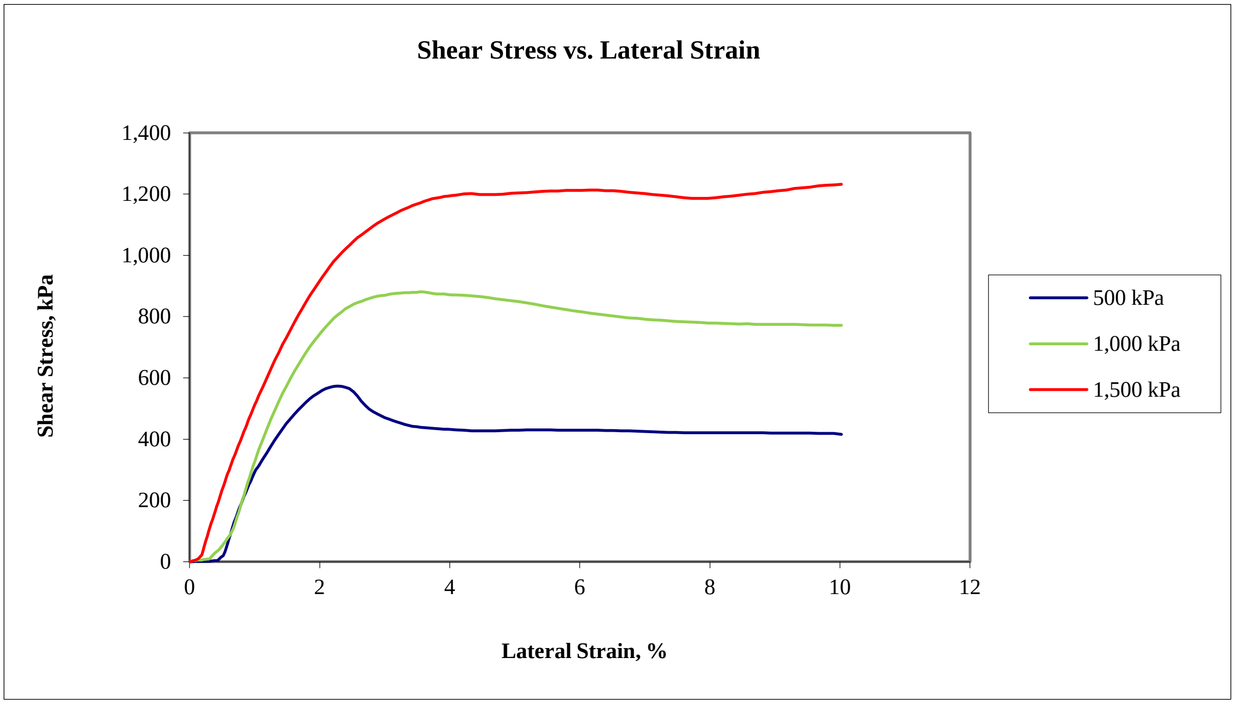
Percent finer: 1.91 cm = 99% No. 4 = 87% No. 200 = 34% (ASTM D422, refer to separate report)

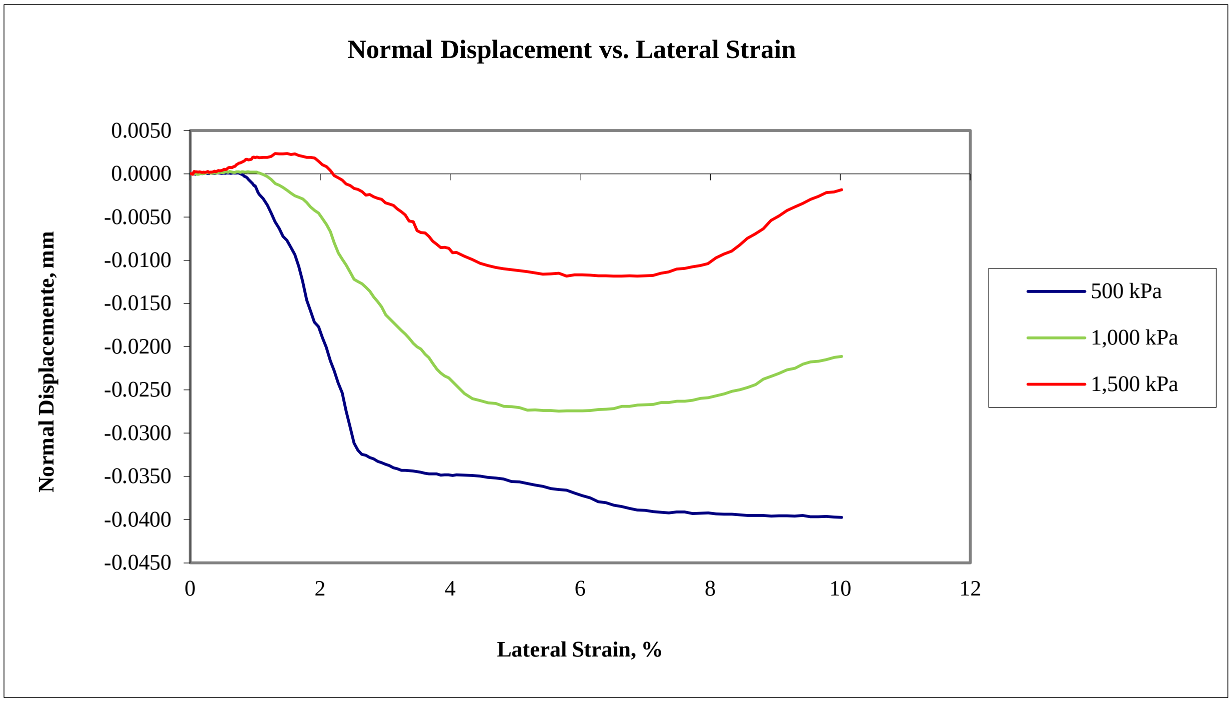
Specimen type: [ ] Intact [X] Reconstituted Remold targets: 20.50 kN/m3 (dry) at 14.0% moisture

Inundation: Yes

Apparatus: 6.35 -mm nominal diameter box, GeoTac automated test system, GeoJac loading system

Golder Associates Inc. Golder Associates	**Title:** ASTM D3080 CONSOLIDATED DRAINED DIRECT SHEAR TEST REPORT SAMPLE AND TEST DATA				
Job Short Title: ATAC/Pit Slope Study/BC					
Sample: A03-3 @ 23 - 28 ft.	**Technician:** PRH	**Reviewed:** CCS	**Date:** 12/23/2013	**Job Number:** 1302357.2	**Figure:** 1





Golder Associates Inc. Golder Associates	**Title:** ASTM D3080 CONSOLIDATED DRAINED DIRECT SHEAR TEST REPORT SHEAR STRESS AND NORMAL DISPLACEMENT PLOTS				
Job Short Title: ATAC/Pit Slope Study/BC					
Sample: A03-3 @ 23 - 28 ft.	**Technician:** PRH	**Reviewed:** CCS	**Date:** 12/23/2013	**Job Number:** 1302357.2	**Figure:** 2

Consolidation Data Used to Determine Shear Rate

The shear rate for Point No. 1 was based on ASTM D3080 guidance for:

-USCS classification of SW-SM, SP-SM, or SM

-Minimum time to failure = 60 min

-Soil other than normally consolidated fine-grained soil

-Displacement at failure = 5.1 mm

The shear rate for Point No. 2 was based on ASTM D3080 guidance for:

-USCS classification of SW-SM, SP-SM, or SM

-Minimum time to failure = 60 min

-Soil other than normally consolidated fine-grained soil

-Displacement at failure = 5.1 mm

The shear rate for Point No. 3 was based on ASTM D3080 guidance for:

-USCS classification of SW-SM, SP-SM, or SM

-Minimum time to failure = 60 min

-Soil other than normally consolidated fine-grained soil

-Displacement at failure = 5.1 mm

Normal Stress, kPa	Normal Displacement, mm	Load Duration, min
Point No. 1		
5	0.0072	60
500	0.0718	795
Point No. 2		
5	-0.0005	60
1,000	0.0777	795
Point No. 3		
5	-0.0017	60
1,500	0.0887	795

Golder Associates Inc.

Title: ASTM D3080 CONSOLIDATED DRAINED DIRECT SHEAR TEST REPORT CONSOLIDATION DATA

Job Short Title: ATAC/Pit Slope Study/BC

Sample:	Technician:	Reviewed:	Date:	Job Number:	Figure:
A03-3 @ 23 - 28 ft.	PRH	CCS	12/23/2013	1302357.2	3

Point No.:	1		Point No.:	2		Point No.:	3	
Normal Stress =	500	kPa	Normal Stress =	1,000	kPa	Normal Stress =	1,500	kPa
Shear Rate =	0.0838	mm/min	Shear Rate =	0.0838	mm/min	Shear Rate =	0.0838	mm/min

Shear Stress kPa	Lateral Strain %	Normal Displacement mm	Shear Stress kPa	Lateral Strain %	Normal Displacement mm	Shear Stress kPa	Lateral Strain %	Normal Displacement mm
1	0.1	-0.0001	4	0.1	0.0000	5	0.1	0.0002
1	0.2	0.0000	6	0.2	0.0000	22	0.2	0.0002
1	0.3	0.0000	9	0.3	0.0001	98	0.3	0.0002
3	0.4	0.0000	29	0.4	0.0001	166	0.4	0.0002
17	0.5	0.0000	47	0.5	0.0001	220	0.5	0.0004
58	0.6	0.0001	76	0.6	0.0001	286	0.6	0.0007
129	0.7	0.0001	120	0.7	0.0002	345	0.7	0.0009
189	0.8	-0.0001	189	0.8	0.0002	402	0.8	0.0013
244	0.9	-0.0006	260	0.9	0.0002	458	0.9	0.0016
283	1.0	-0.0014	316	1.0	0.0002	502	1.0	0.0019
451	1.5	-0.0077	575	1.5	-0.0019	733	1.5	0.0023
551	2.0	-0.0177	736	2.0	-0.0046	909	2.0	0.0014
565	2.5	-0.0292	833	2.5	-0.0114	1,033	2.5	-0.0014
476	2.9	-0.0334	869	2.9	-0.0154	1,112	2.9	-0.0030
440	3.5	-0.0345	879	3.5	-0.0200	1,168	3.5	-0.0066
432	4.0	-0.0348	871	4.0	-0.0236	1,193	4.0	-0.0086
427	4.5	-0.0350	866	4.5	-0.0262	1,199	4.5	-0.0104
429	4.9	-0.0356	852	4.9	-0.0270	1,203	4.9	-0.0111
430	5.4	-0.0362	836	5.4	-0.0274	1,209	5.4	-0.0116
430	5.9	-0.0369	819	5.9	-0.0274	1,212	5.9	-0.0117
429	6.4	-0.0381	805	6.4	-0.0272	1,212	6.4	-0.0118
426	6.9	-0.0389	794	6.9	-0.0267	1,204	6.9	-0.0118
422	7.5	-0.0391	784	7.5	-0.0263	1,191	7.5	-0.0110
421	8.0	-0.0392	779	8.0	-0.0259	1,186	8.0	-0.0104
421	8.5	-0.0394	776	8.5	-0.0250	1,197	8.5	-0.0082
420	8.9	-0.0396	775	8.9	-0.0234	1,208	8.9	-0.0054
420	9.4	-0.0395	774	9.4	-0.0220	1,221	9.4	-0.0034
419	9.9	-0.0397	771	9.9	-0.0212	1,230	9.9	-0.0021

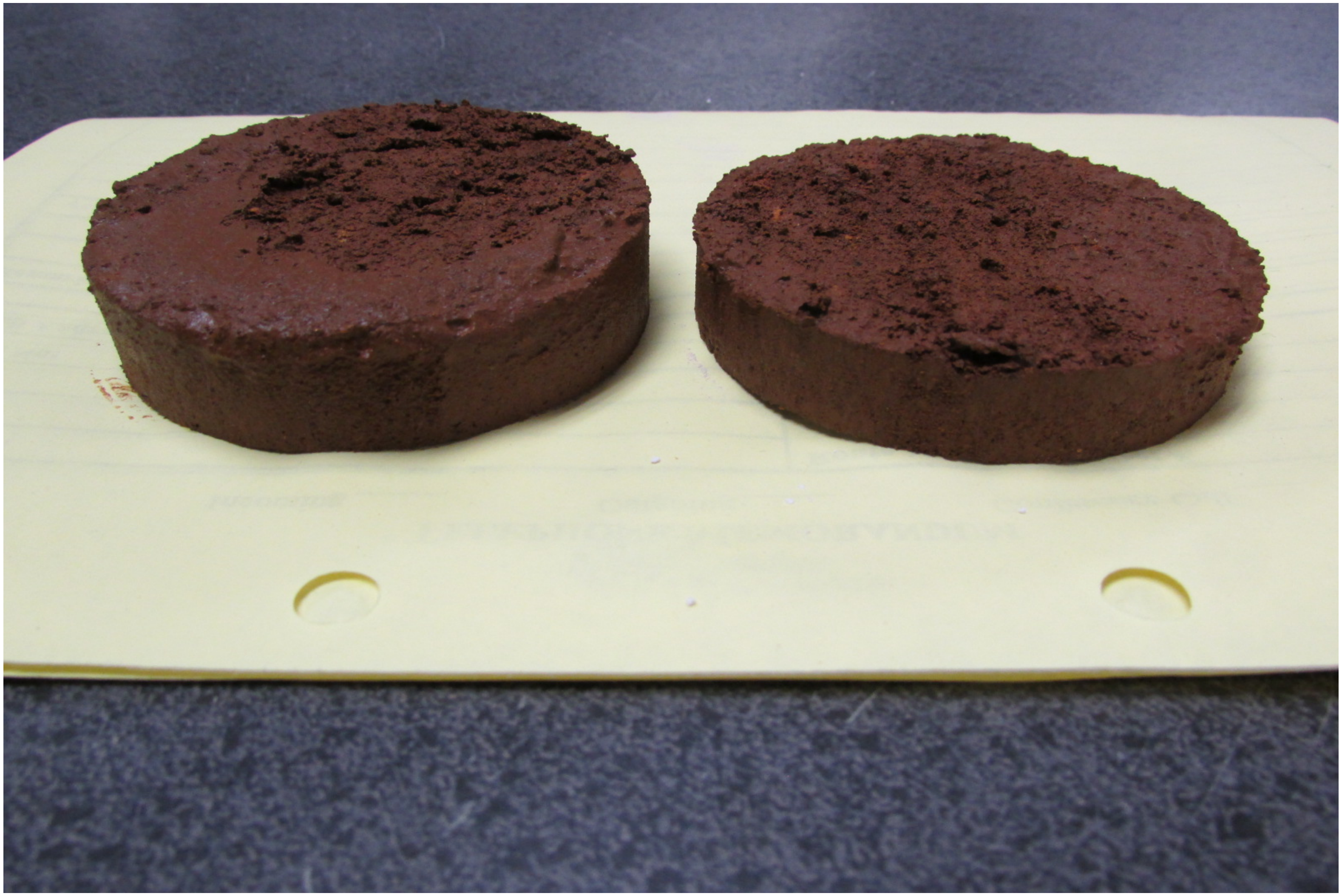
Golder Associates Inc.

Title:
ASTM D3080
CONSOLIDATED DRAINED DIRECT SHEAR TEST REPORT
SHEAR DATA

Job Short Title: ATAC/Pit Slope Study/BC

Sample: A03-3 @ 23 - 28 ft.

Technician:	Reviewed:	Date:	Job Number:	Figure:
PRH	CCS	12/23/2013	1302357.2	4



Golder Associates Inc.	Title: ASTM D3080 CONSOLIDATED DRAINED DIRECT SHEAR TEST REPORT SPECIMEN PHOTOGRAPH - 500.0 kPa			
Job Short Title: ATAC/Pit Slope Study/BC				
Sample: A03-3 @ 23 - 28 ft.	Technician: PRH	Reviewed: CCS	Date: 12/23/2013	Job Number: 1302357.2	Figure: 5

Golder Associates Inc.	Title: ASTM D3080 CONSOLIDATED DRAINED DIRECT SHEAR TEST REPORT SPECIMEN PHOTOGRAPH - 1,000.0 kPa			
Job Short Title: ATAC/Pit Slope Study/BC				
Sample: A03-3 @ 23 - 28 ft.	Technician: PRH	Reviewed: CCS	Date: 12/23/2013	Job Number: 1302357.2	Figure: 6

Golder Associates Inc.	Title: ASTM D3080 CONSOLIDATED DRAINED DIRECT SHEAR TEST REPORT SPECIMEN PHOTOGRAPH - 1,500.0 kPa
Job Short Title: ATAC/Pit Slope Study/BC	

Sample:	Technician:	Reviewed:	Date:	Job Number:	Figure:
A03-3 @ 23 - 28 ft.	PRH	CCS	12/23/2013	1302357.2	7

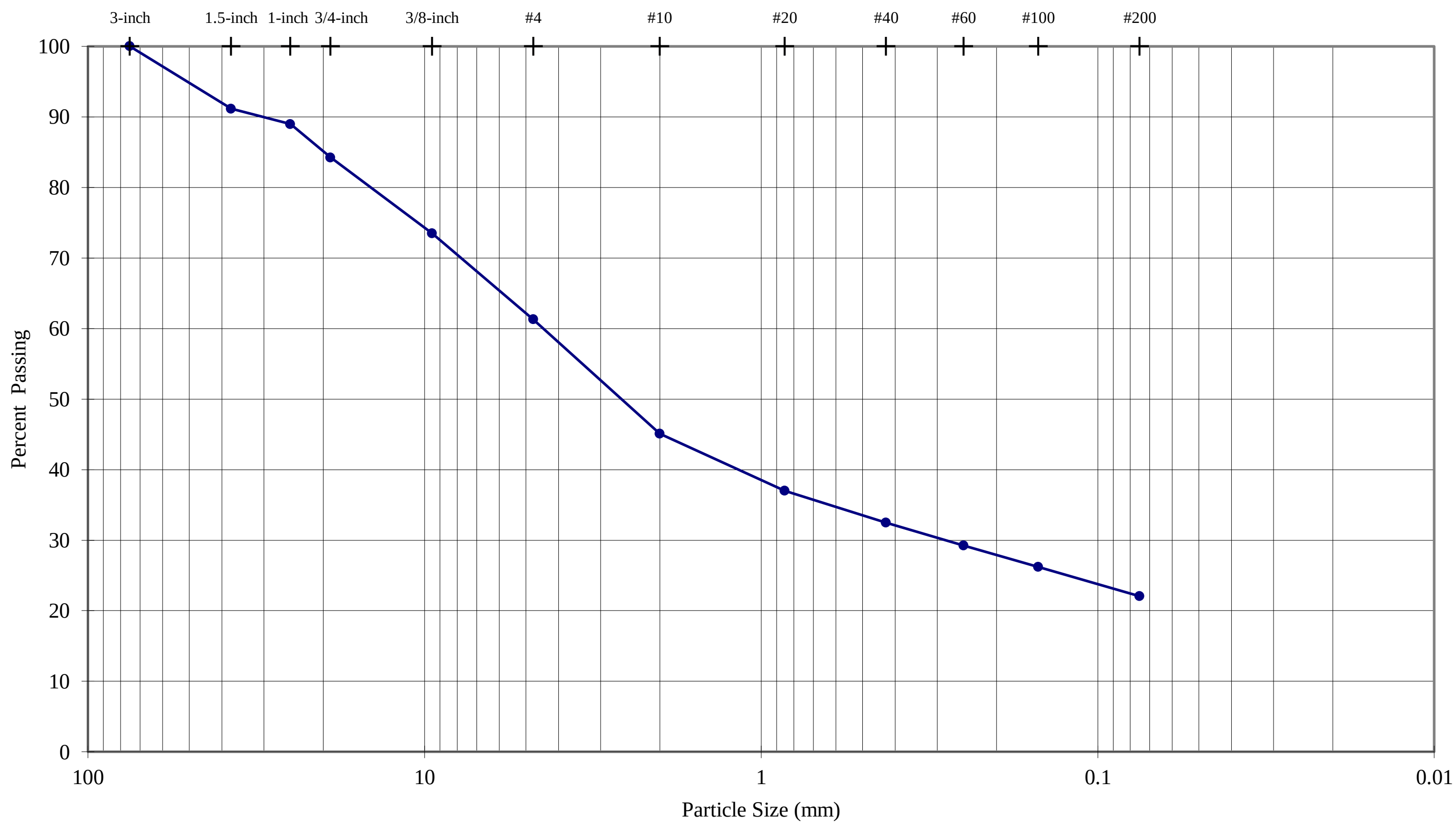
Golder Associates

December-13 **1302357.200**

PARTICLE SIZE DISTRIBUTION & ATTERBERG LIMITS

ASTM D421, D422, D4318

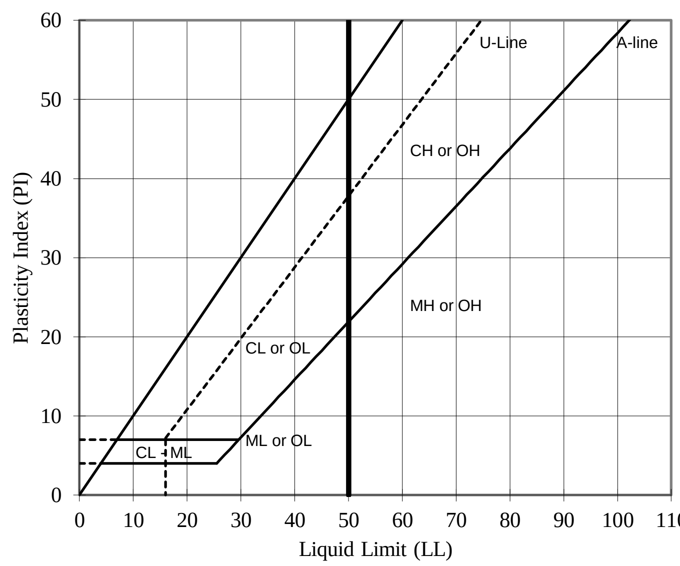
PROJECT NAME: **ATAC/Pit Slope Study/BC**
SAMPLE ID: **A01-2** DEPTH (ft): **13-18**
TYPE: **Bag**



Sieve Analysis (Initial Separation on No. 4 Sieve)

Sieve	Particle Size (mm)	% Passing
3-inch	75.0	**100.0**
1.5-inch	37.5	**91.2**
1-inch	25.0	**89.0**
3/4-inch	19.0	**84.2**
3/8-inch	9.5	**73.5**
#4	4.8	**61.3**
#10	2.00	**45.1**
#20	0.85	**37.0**
#40	0.43	**32.5**
#60	0.25	**29.2**
#100	0.15	**26.2**
#200	0.075	**22.0**

Description	Percentage
Coarse Gravel	**15.78**
Fine Gravel	**22.95**
Coarse Sand	**16.21**
Medium Sand	**12.59**
Fine Sand	**10.43**
Silt or Clay Fines	**22.04**



USCS Description (ASTM D 2487):

Silty sand with gravel, dark brown, moist

LL	PL	PI
NP	**NP**	**NP**

As-Received Moisture Content (%): --

USCS Group Symbol: SM

Notes: 0g of particles up to 75.0mm maximum size were removed from particle size analysis sample prior to testing
Particle size analysis sample was not mechanically dispersed; hydrometer test was not performed
Sample prepared for Atterberg Limits testing by the dry method
Material retained on No. 40 sieve removed from Atterberg Limits sample by sieving
Plastic Limit test performed by hand rolling. Method A Liquid Limit test performed using mechanical device

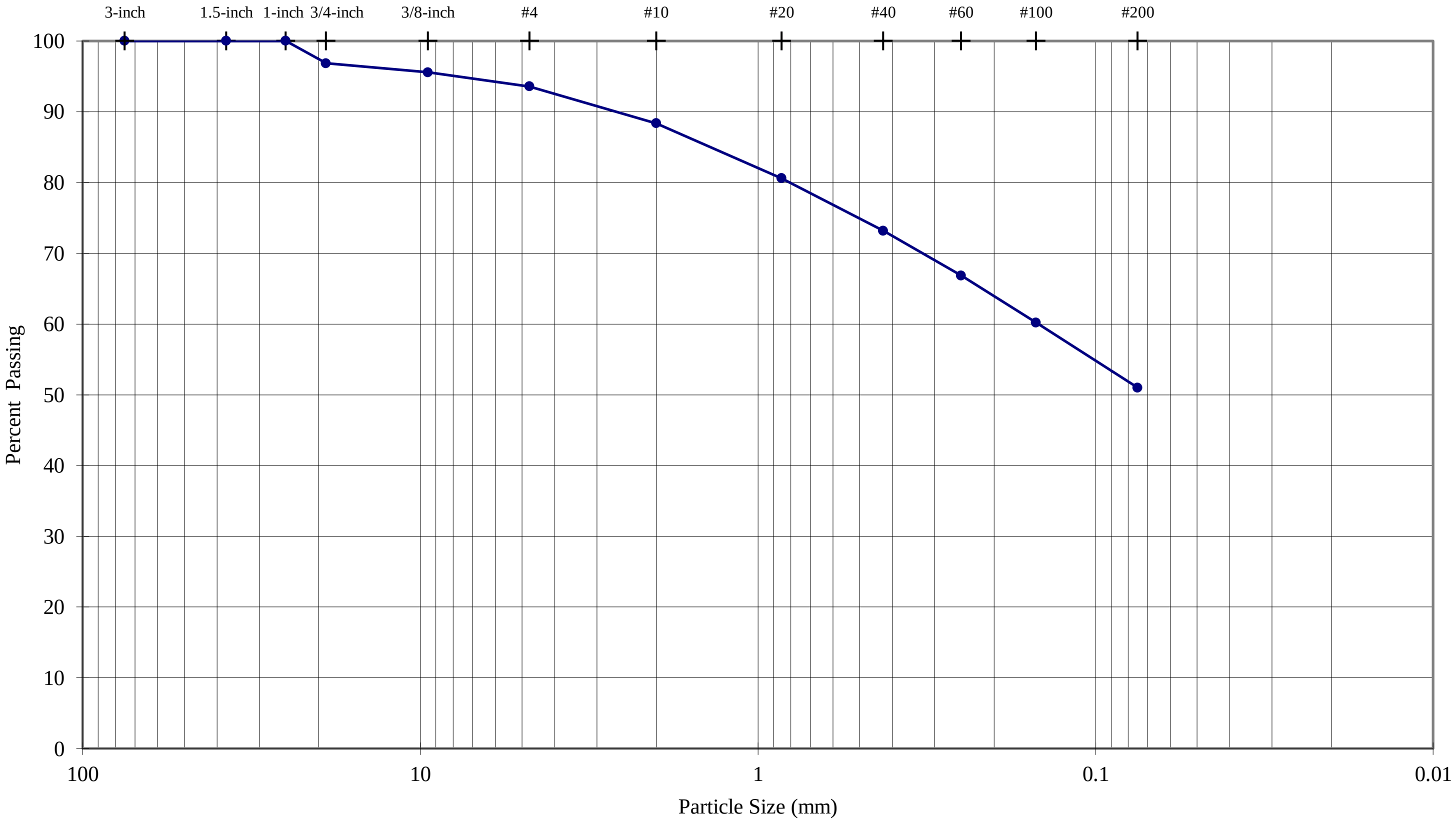
TECH	LR
DATE	12/12/2013
REVIEW	MB

December-13 1302357.200

PARTICLE SIZE DISTRIBUTION & ATTERBERG LIMITS

ASTM D421, D422, D4318

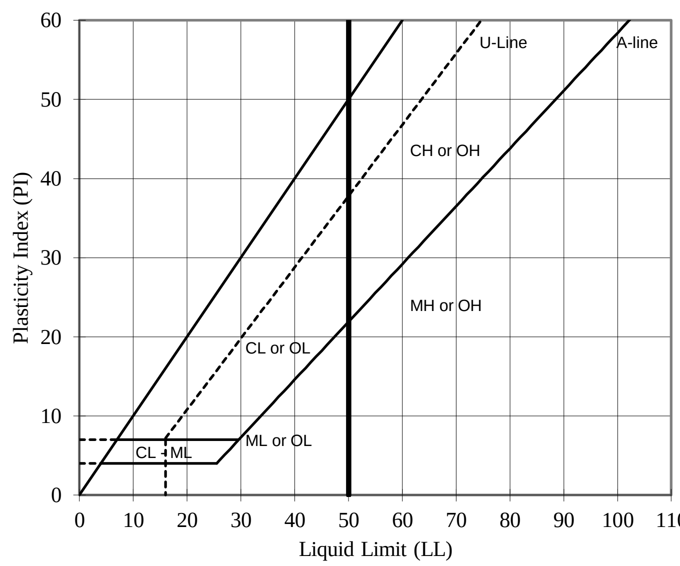
PROJECT NAME: **ATAC/Pit Slope Study/BC**
SAMPLE ID: **A01-4** DEPTH (ft): **23-28**
TYPE: **Bag**



Sieve Analysis (Initial Separation on No. 4 Sieve)

Sieve	Particle Size (mm)	% Passing
3-inch	75.0	**100.0**
1.5-inch	37.5	**100.0**
1-inch	25.0	**100.0**
3/4-inch	19.0	**96.8**
3/8-inch	9.5	**95.6**
#4	4.8	**93.6**
#10	2.00	**88.4**
#20	0.85	**80.6**
#40	0.43	**73.2**
#60	0.25	**66.8**
#100	0.15	**60.2**
#200	0.075	**51.0**

Description	Percentage
Coarse Gravel	**3.17**
Fine Gravel	**3.26**
Coarse Sand	**5.21**
Medium Sand	**15.19**
Fine Sand	**22.21**
Silt or Clay Fines	**50.97**



LL	PL	PI
NP	**NP**	**NP**

USCS Description (ASTM D 2487):

Sandy silt, dark reddish brown, moist

As-Received Moisture Content (%): --

USCS Group Symbol: ML

Notes: 0g of particles up to 25.0mm maximum size were removed from particle size analysis sample prior to testing
Particle size analysis sample was not mechanically dispersed; hydrometer test was not performed
Sample prepared for Atterberg Limits testing by the dry method
Material retained on No. 40 sieve removed from Atterberg Limits sample by sieving
Plastic Limit test performed by hand rolling. Method A Liquid Limit test performed using mechanical device

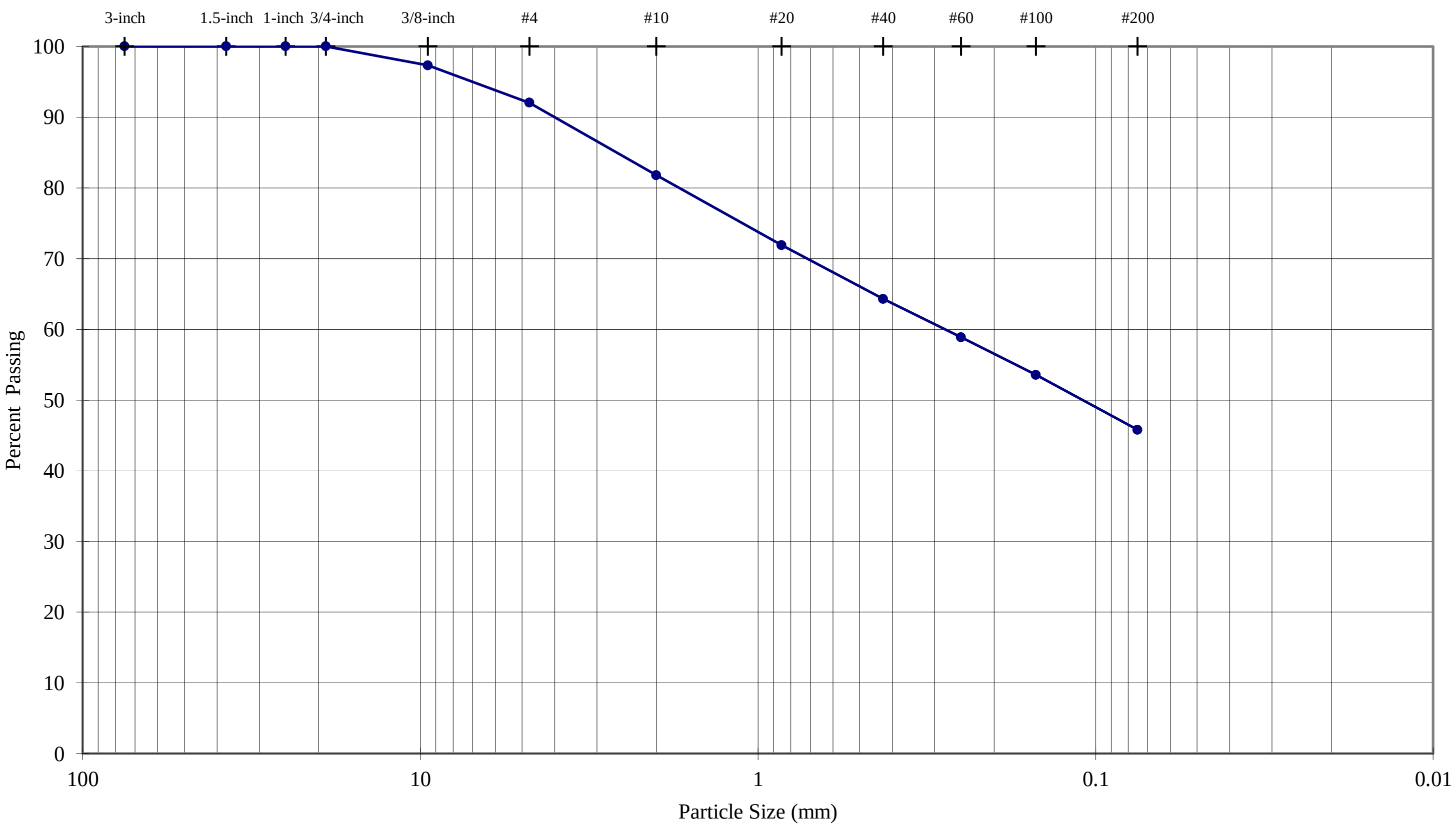
TECH	LR
DATE	12/12/2013
REVIEW	MB

December-13 1302357.200

PARTICLE SIZE DISTRIBUTION & ATTERBERG LIMITS

ASTM D421, D422, D4318

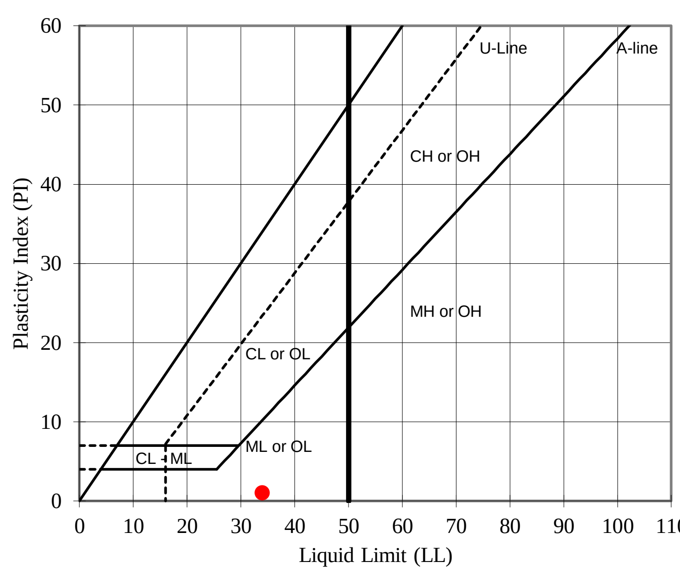
PROJECT NAME: **ATAC/Pit Slope Study/BC**
SAMPLE ID: **A02-5** DEPTH (ft): **28-33**
TYPE: **Bag**



Sieve Analysis (Initial Separation on No. 4 Sieve)

Sieve	Particle Size (mm)	% Passing
3-inch	75.0	**100.0**
1.5-inch	37.5	**100.0**
1-inch	25.0	**100.0**
3/4-inch	19.0	**100.0**
3/8-inch	9.5	**97.3**
#4	4.8	**92.0**
#10	2.00	**81.8**
#20	0.85	**71.9**
#40	0.43	**64.3**
#60	0.25	**58.8**
#100	0.15	**53.6**
#200	0.075	**45.8**

Description	Percentage
Coarse Gravel	**0.00**
Fine Gravel	**7.98**
Coarse Sand	**10.25**
Medium Sand	**17.50**
Fine Sand	**18.49**
Silt or Clay Fines	**45.77**



LL	PL	PI
34	**33**	**1**

USCS Description (ASTM D 2487):
Silty sand, dark reddish brown, moist

As-Received Moisture Content (%): --

USCS Group Symbol: SM

Notes: 0g of particles up to 19.0mm maximum size were removed from particle size analysis sample prior to testing
Particle size analysis sample was not mechanically dispersed; hydrometer test was not performed
Sample prepared for Atterberg Limits testing by the dry method
Material retained on No. 40 sieve removed from Atterberg Limits sample by sieving
Plastic Limit test performed by hand rolling. Method A Liquid Limit test performed using mechanical device

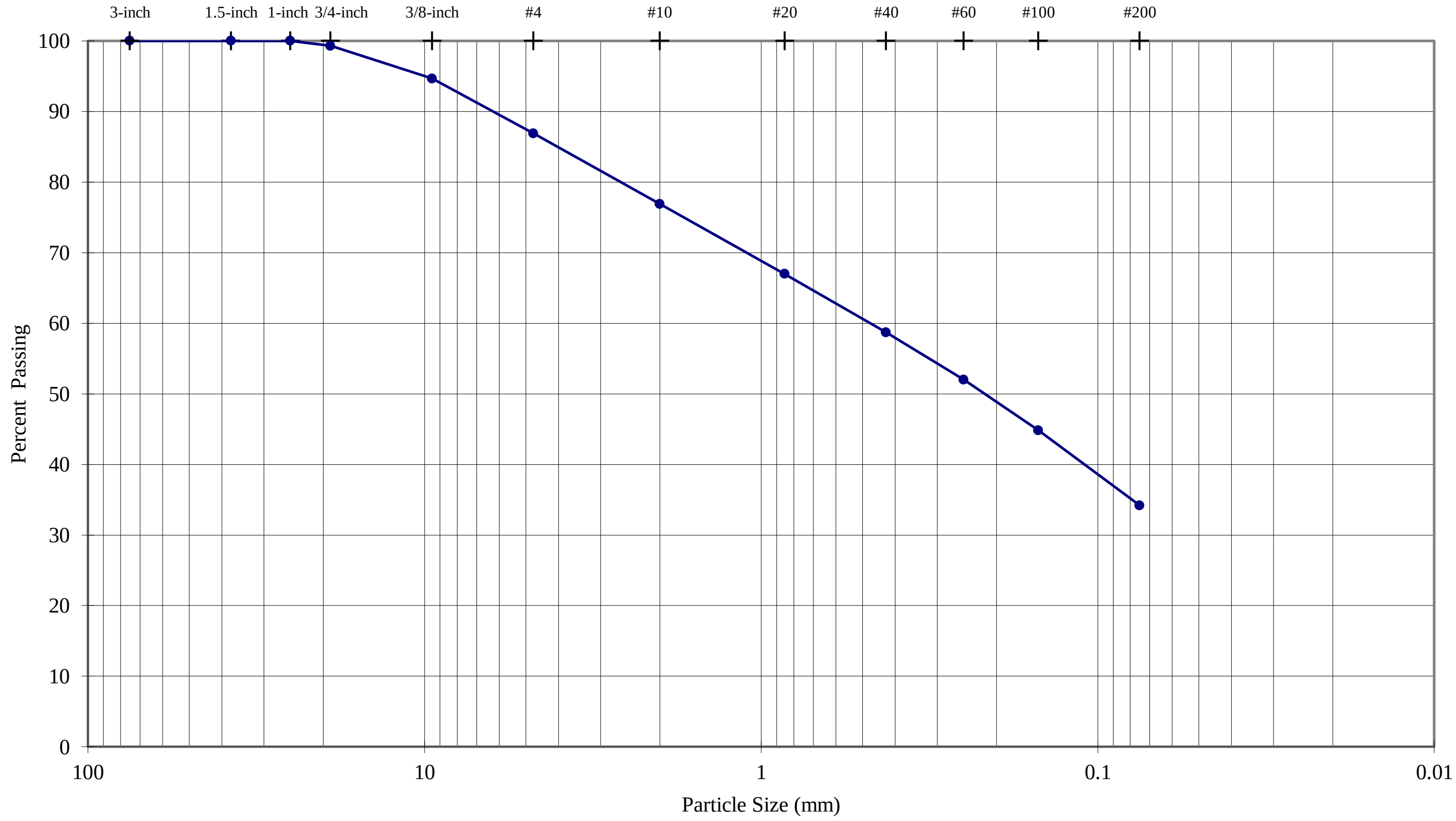
TECH	LR
DATE	12/12/2013
REVIEW	MB

December-13 1302357.200

PARTICLE SIZE DISTRIBUTION & ATTERBERG LIMITS

ASTM D421, D422, D4318

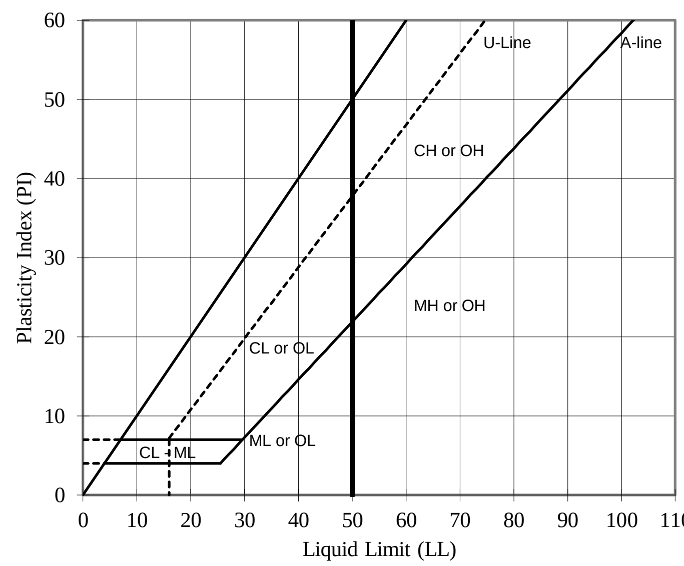
PROJECT NAME: **ATAC/Pit Slope Study/BC**
SAMPLE ID: **A03-3** DEPTH (ft): **23-28**
TYPE: **Bag**



Sieve Analysis (Initial Separation on No. 4 Sieve)

Sieve	Particle Size (mm)	% Passing
3-inch	75.0	**100.0**
1.5-inch	37.5	**100.0**
1-inch	25.0	**100.0**
3/4-inch	19.0	**99.3**
3/8-inch	9.5	**94.7**
#4	4.8	**86.9**
#10	2.00	**76.9**
#20	0.85	**67.0**
#40	0.43	**58.7**
#60	0.25	**52.0**
#100	0.15	**44.8**
#200	0.075	**34.2**

Description	Percentage
Coarse Gravel	**0.72**
Fine Gravel	**12.39**
Coarse Sand	**10.00**
Medium Sand	**18.20**
Fine Sand	**24.50**
Silt or Clay Fines	**34.19**



USCS Description (ASTM D 2487):

Silty sand, dark reddish brown, moist

LL	PL	PI
NP	**NP**	**NP**

As-Received Moisture Content (%): --

USCS Group Symbol: SM

Notes: 0g of particles up to 25.0mm maximum size were removed from particle size analysis sample prior to testing
Particle size analysis sample was not mechanically dispersed; hydrometer test was not performed
Sample prepared for Atterberg Limits testing by the dry method
Material retained on No. 40 sieve removed from Atterberg Limits sample by sieving
Plastic Limit test performed by hand rolling. Method A Liquid Limit test performed using mechanical device

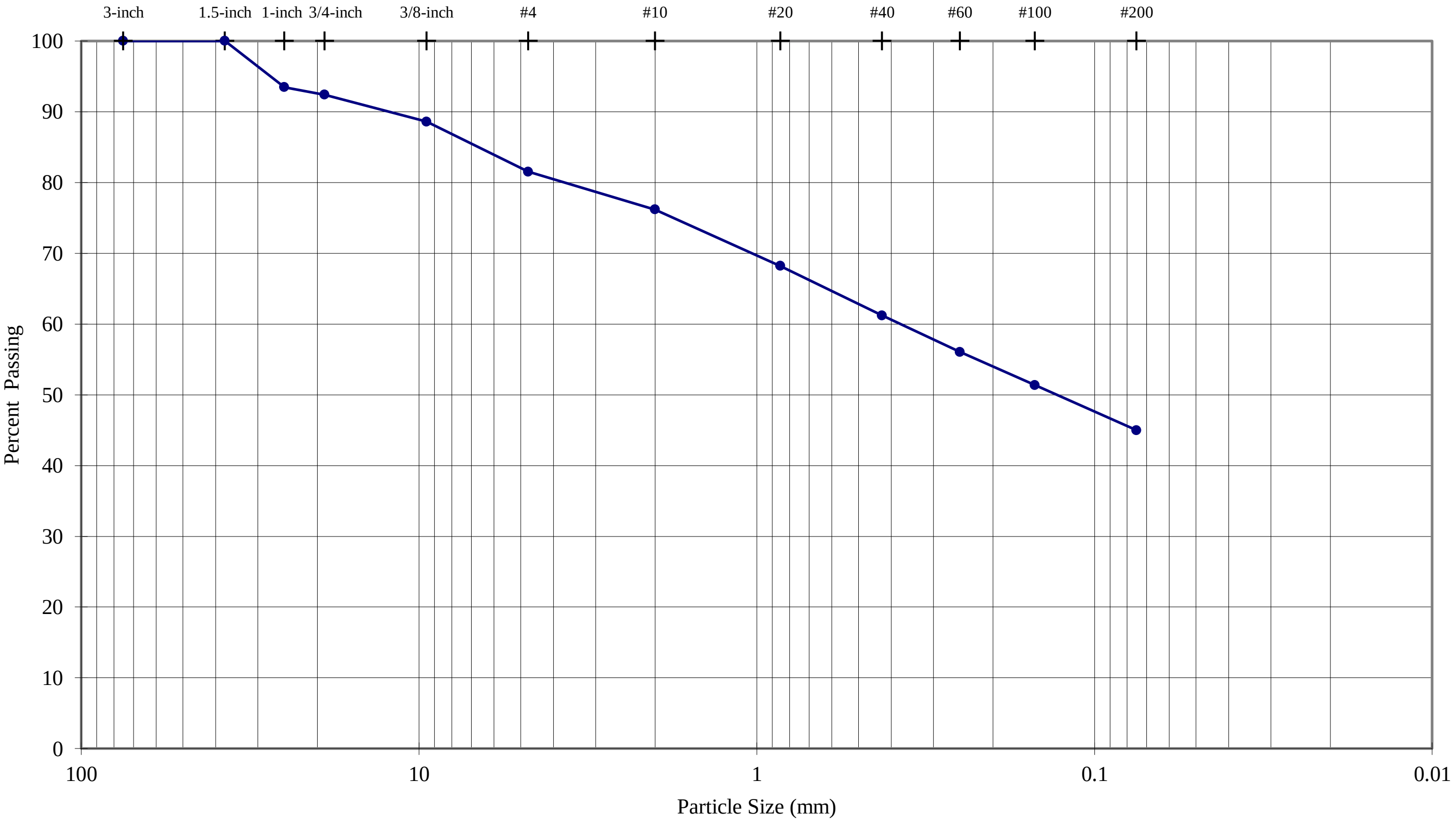
TECH	PRH
DATE	12/13/2013
REVIEW	MB

December-13 | 1301357.2

PARTICLE SIZE DISTRIBUTION & ATTERBERG LIMITS

ASTM D421, D422, D4318

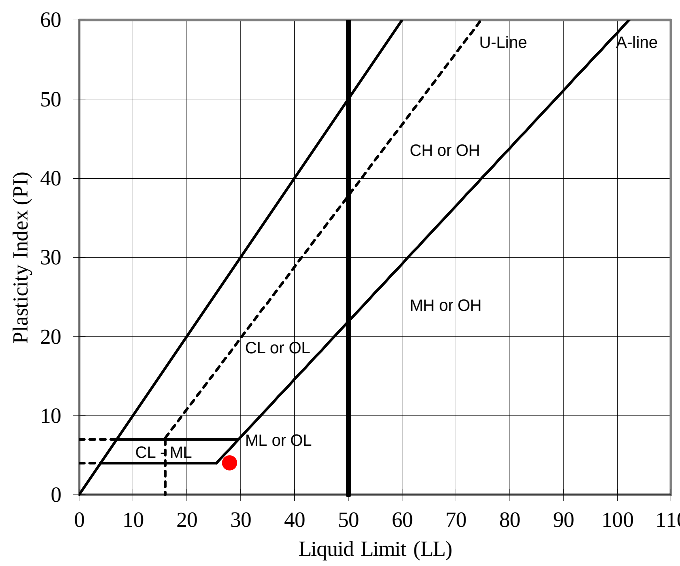
PROJECT NAME: **ATAC/Pit Slope Study/BC**
SAMPLE ID: **A04-3** DEPTH (ft): **18-23**
TYPE: **Bag**



Sieve Analysis (Initial Separation on No. 4 Sieve)

Sieve	Particle Size (mm)	% Passing
3-inch	75.0	**100.0**
1.5-inch	37.5	**100.0**
1-inch	25.0	**93.5**
3/4-inch	19.0	**92.4**
3/8-inch	9.5	**88.6**
#4	4.8	**81.5**
#10	2.00	**76.2**
#20	0.85	**68.2**
#40	0.43	**61.2**
#60	0.25	**56.0**
#100	0.15	**51.4**
#200	0.075	**45.0**

Description	Percentage
Coarse Gravel	**7.60**
Fine Gravel	**10.88**
Coarse Sand	**5.34**
Medium Sand	**14.97**
Fine Sand	**16.25**
Silt or Clay Fines	**44.96**



LL	PL	PI
28	**24**	**4**

USCS Description (ASTM D 2487):
Silty sand with gravel, dark reddish brown, moist

As-Received Moisture Content (%): --

USCS Group Symbol: SM

Notes: 0g of particles up to 37.5mm maximum size were removed from particle size analysis sample prior to testing
Particle size analysis sample was not mechanically dispersed; hydrometer test was not performed
Sample prepared for Atterberg Limits testing by the dry method
Material retained on No. 40 sieve removed from Atterberg Limits sample by sieving
Plastic Limit test performed by hand rolling. Method A Liquid Limit test performed using mechanical device

TECH	LR
DATE	12/12/2013
REVIEW	MB

December-13 1302357.200

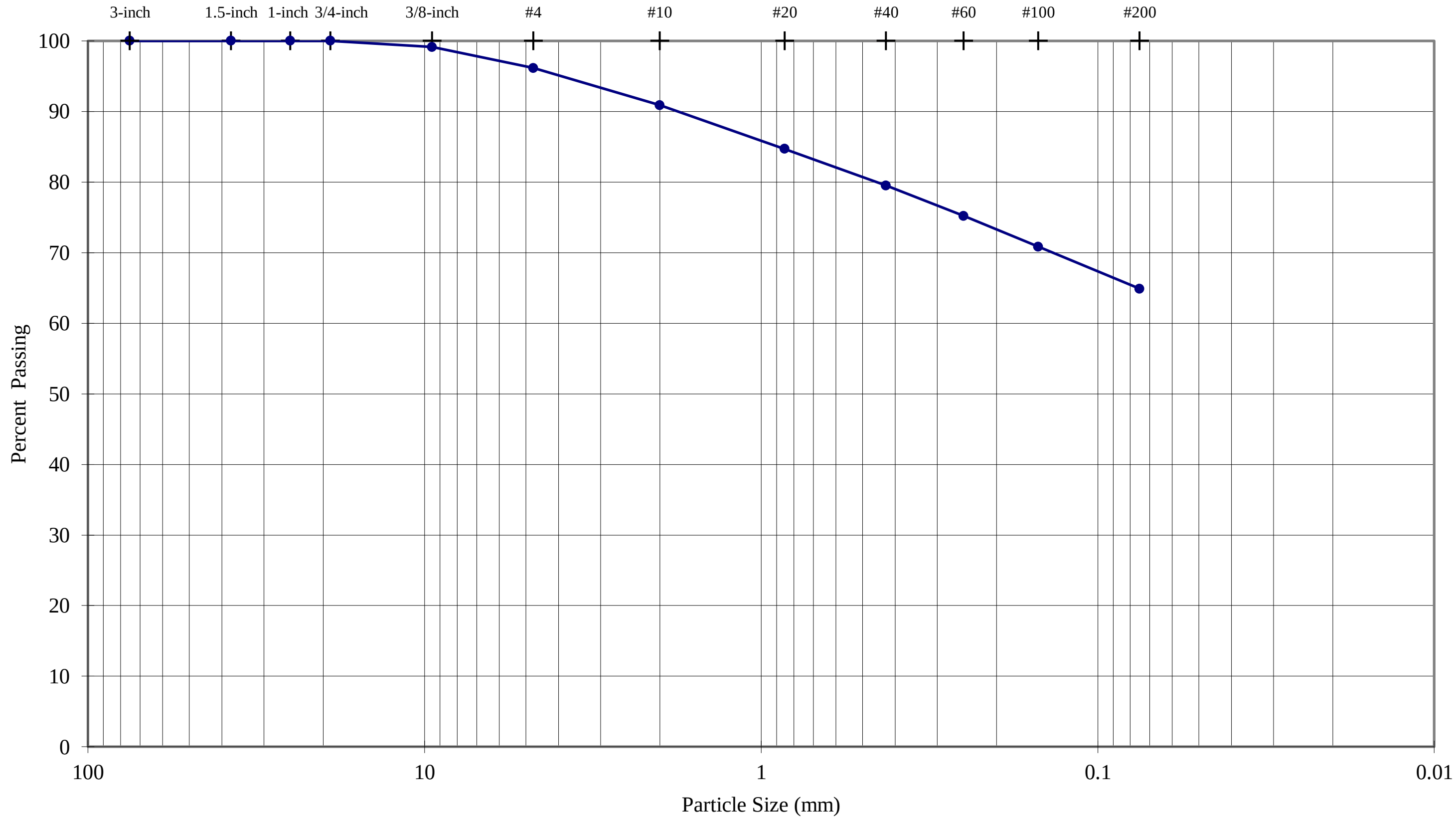
PARTICLE SIZE DISTRIBUTION & ATTERBERG LIMITS

ASTM D421, D422, D4318

PROJECT NAME: **ATAC/Pit Slope Study/BC**

SAMPLE ID: **A04-5** DEPTH (ft): **28-33**

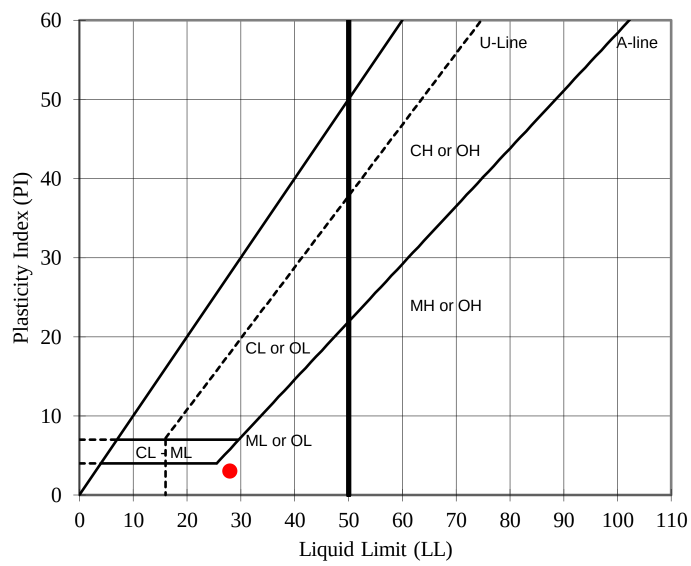
TYPE: **Bag**



Sieve Analysis (Initial Separation on No. 4 Sieve)

Sieve	Particle Size (mm)	% Passing
3-inch	75.0	**100.0**
1.5-inch	37.5	**100.0**
1-inch	25.0	**100.0**
3/4-inch	19.0	**100.0**
3/8-inch	9.5	**99.1**
#4	4.8	**96.1**
#10	2.00	**90.9**
#20	0.85	**84.7**
#40	0.43	**79.5**
#60	0.25	**75.2**
#100	0.15	**70.8**
#200	0.075	**64.9**

Description	Percentage
Coarse Gravel	**0.00**
Fine Gravel	**3.86**
Coarse Sand	**5.28**
Medium Sand	**11.39**
Fine Sand	**14.60**
Silt or Clay Fines	**64.87**



LL	PL	PI
28	**25**	**3**

USCS Description (ASTM D 2487):

Sandy silt, dark reddish brown, moist

As-Received Moisture Content (%): --

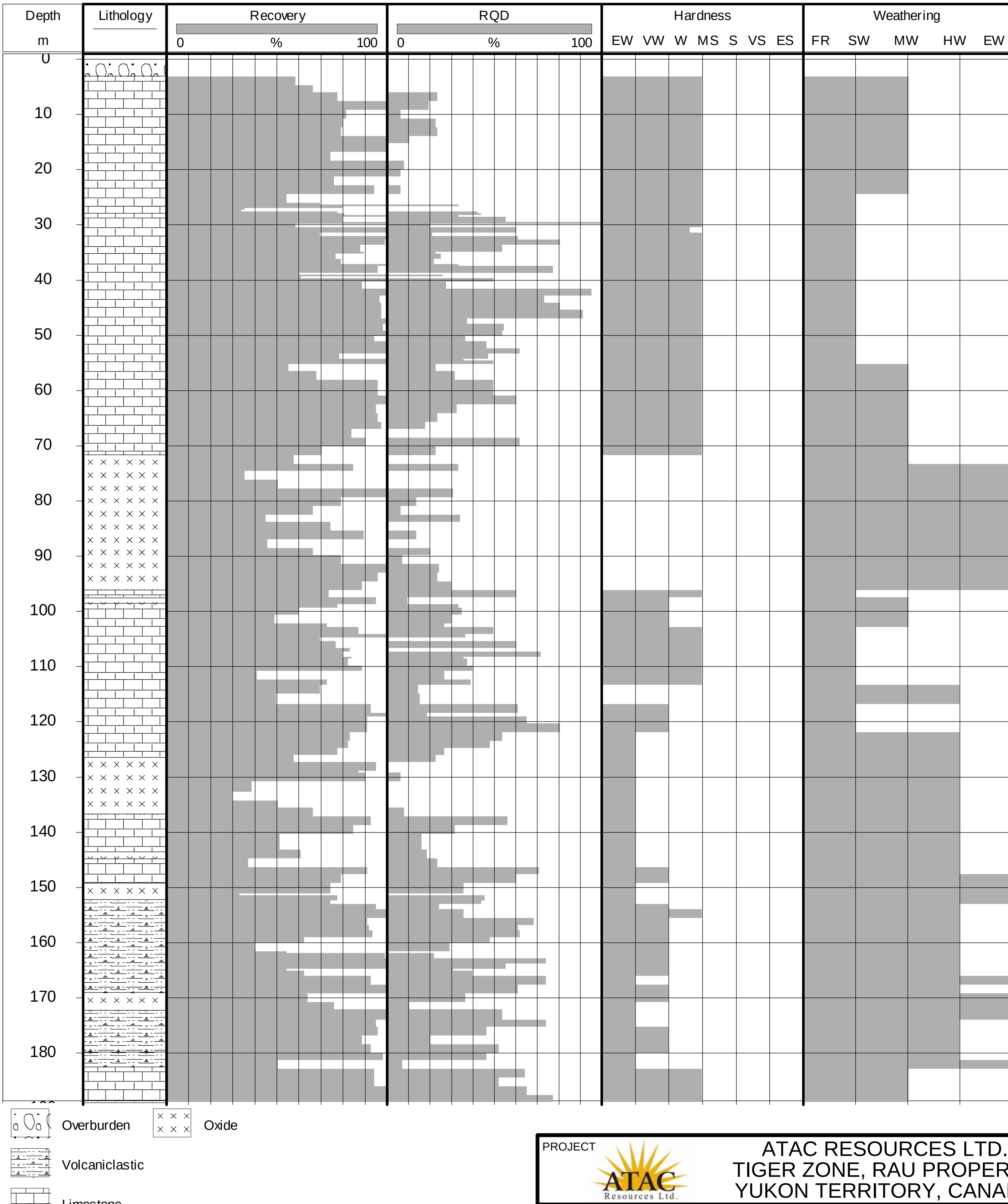
USCS Group Symbol: ML

Notes: 0g of particles up to 19.0mm maximum size were removed from particle size analysis sample prior to testing
Particle size analysis sample was not mechanically dispersed; hydrometer test was not performed
Sample prepared for Atterberg Limits testing by the dry method
Material retained on No. 40 sieve removed from Atterberg Limits sample by sieving
Plastic Limit test performed by hand rolling. Method A Liquid Limit test performed using mechanical device

TECH	LR
DATE	12/12/2013
REVIEW	MB

APPENDIX C
DOWNHOLE PLOTS OF GEOTECHNICAL DATA

RAU-09-041



HARDNESS

ES	Extremely Strong
VS	Very Strong
S	Strong
MS	Moderately Strong
W	Weak
VW	Very Weak
EW	Extremely Weak

Weathering

FR	Fresh
SW	Slightly Weathered
MW	Moderately Weathered
HW	Highly Weathered
EW	Extremely Weathered

PROJECT

ATAC Resources Ltd.

ATAC RESOURCES LTD.
TIGER ZONE, RAU PROPERTY
YUKON TERRITORY, CANADA

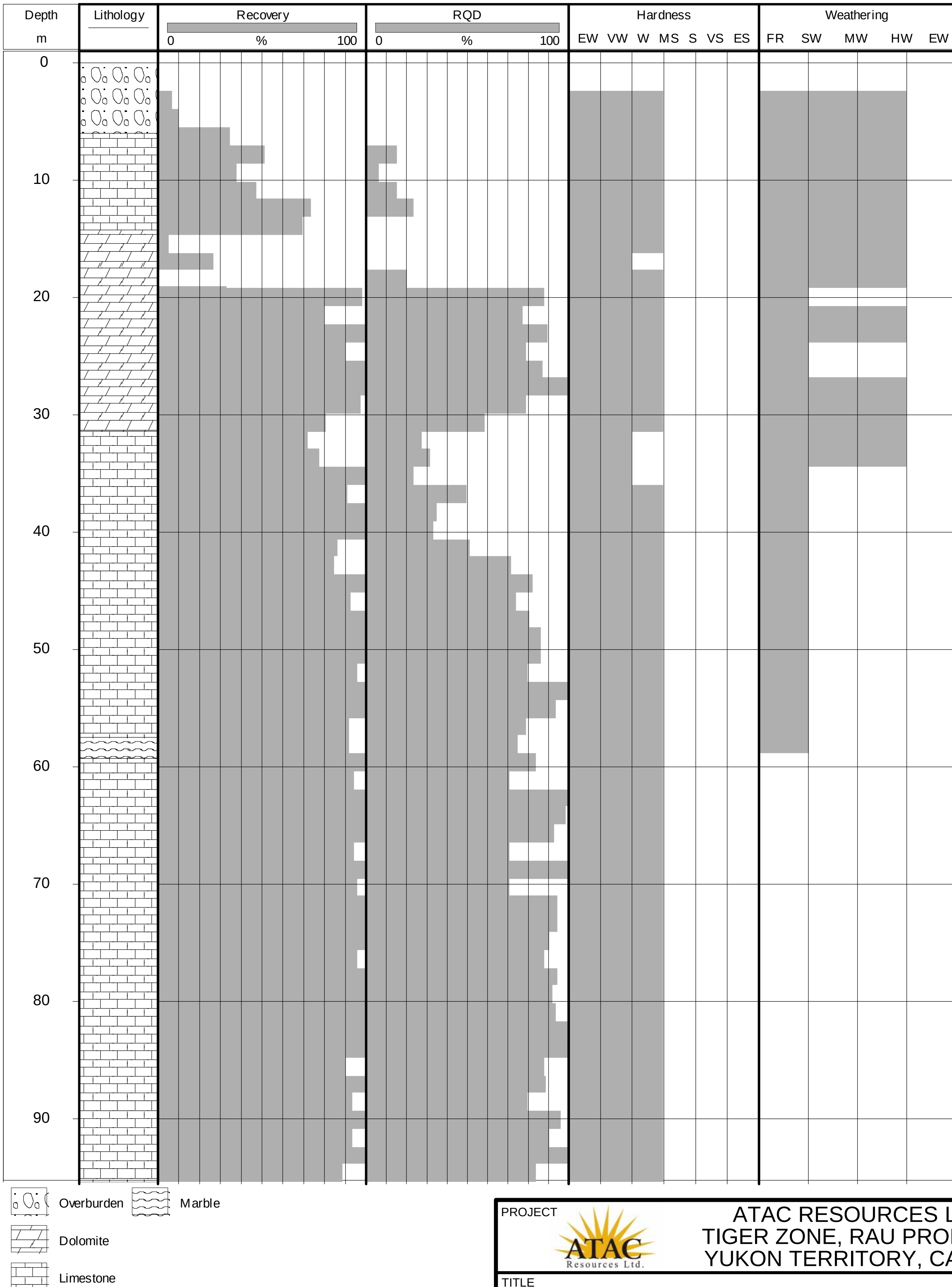
TITLE

Downhole plot of Recovery, RQD, Hardness, and Weathering for RAU-09-041

Golder Associates

PROJECT No.		1302357	FILE No.	
DESIGN	GTL	11/12/2013	SCALE	NOT TO SCALE
CADD	BJE	11/12/2013	FIGURE	
-	-	-		C-1
-	-	-		

RAU-09-055



HARDNESS

ES	Extremely Strong
VS	Very Strong
S	Strong
MS	Moderately Strong
W	Weak
VW	Very Weak
EW	Extremely Weak

Weathering

FR	Fresh
SW	Slightly Weathered
MW	Moderately Weathered
HW	Highly Weathered
EW	Extremely Weathered

PROJECT

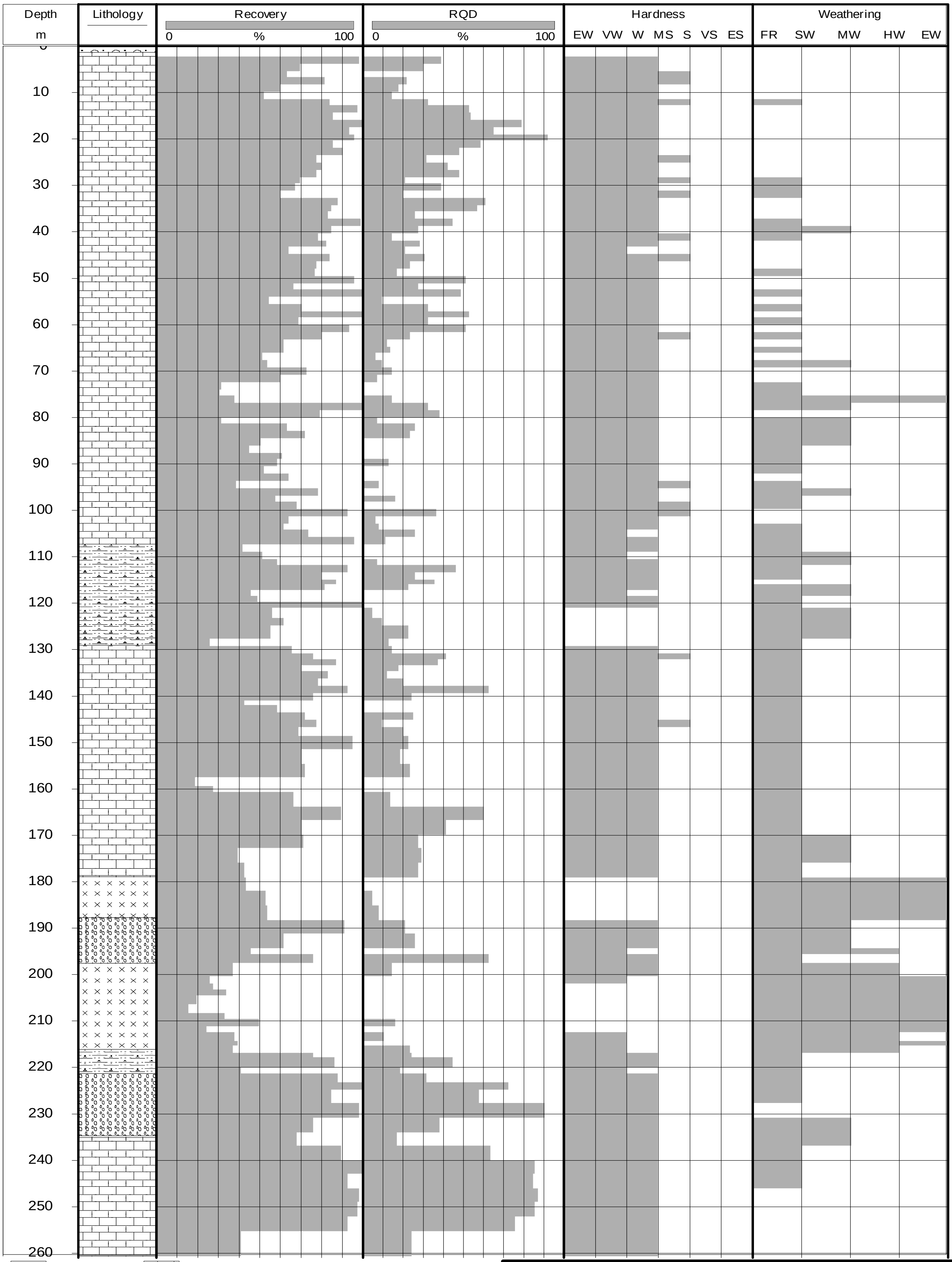
ATAC RESOURCES LTD.
TIGER ZONE, RAU PROPERTY
YUKON TERRITORY, CANADA

TITLE

Downhole plot of Recovery, RQD, Hardness, and Weathering for RAU-09-055

PROJECT No.		1302357	FILE No.	
DESIGN	GTL	11/12/2013	SCALE	NOT TO SCALE
CADD	BJE	11/12/2013	FIGURE	
-	-	-		C-2
-	-	-		

RAU-10-072



Overburden | Limestone
Gravel | Shale
Volcaniclastic | Oxide

HARDNESS

ES	Extremely Strong
VS	Very Strong
S	Strong
MS	Moderately Strong
W	Weak
VW	Very Weak
EW	Extremely Weak

Weathering

FR	Fresh
SW	Slightly Weathered
MW	Moderately Weathered
HW	Highly Weathered
EW	Extremely Weathered

PROJECT

ATAC Resources Ltd.

ATAC RESOURCES LTD.
TIGER ZONE, RAU PROPERTY
YUKON TERRITORY, CANADA

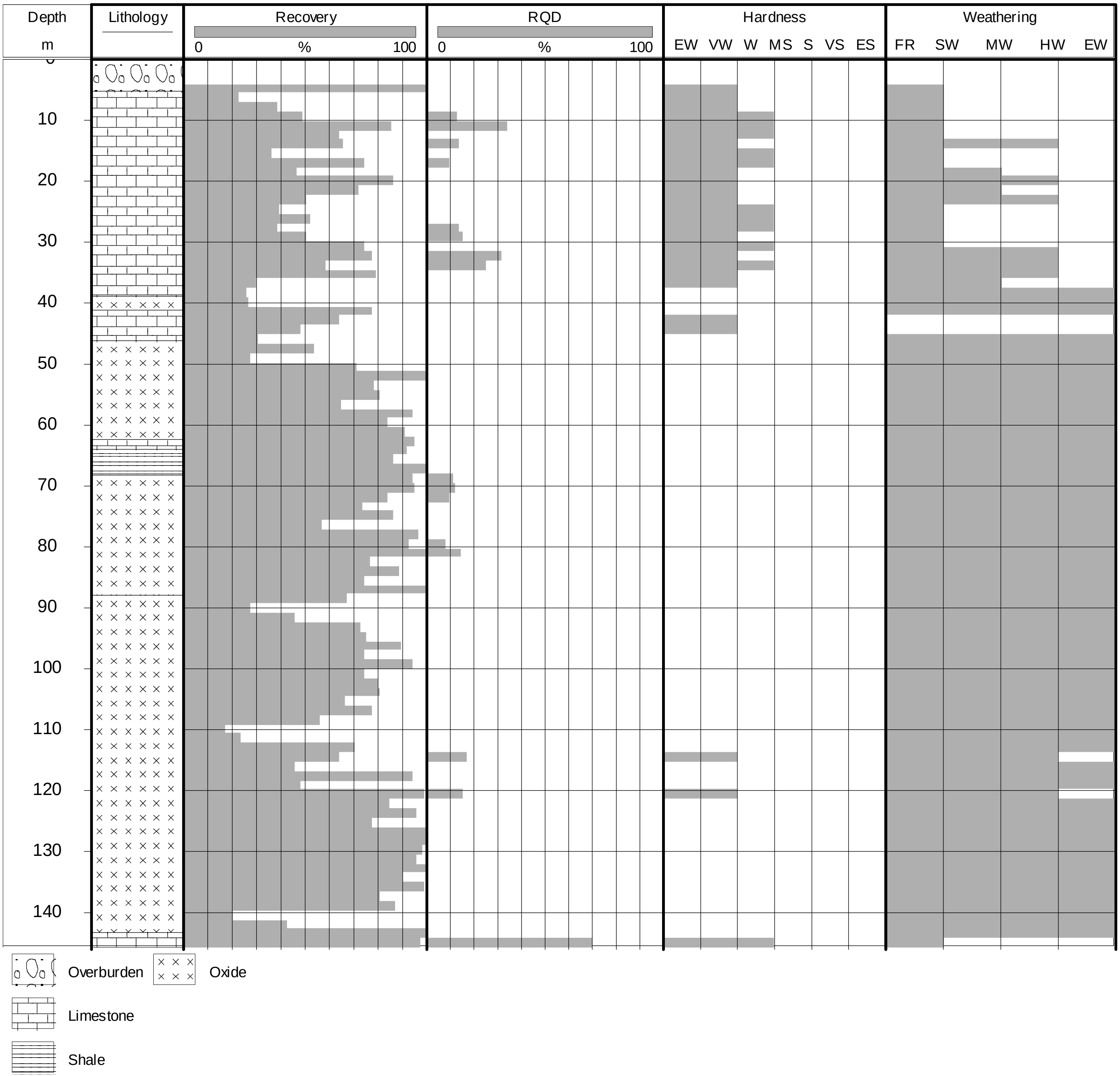
TITLE

Downhole plot of Recovery, RQD, Hardness, and Weathering for RAU-10-072

Golder Associates

PROJECT No.		1302357	FILE No.
DESIGN	GTL	11/12/2013	SCALE NOT TO SCALE
CADD	BJE	11/12/2013	FIGURE
-	-	-	**C-3**
-	-	-	

RAU-10-102



HARDNESS

ES	Extremely Strong
VS	Very Strong
S	Strong
MS	Moderately Strong
W	Weak
VW	Very Weak
EW	Extremely Weak

Weathering

FR	Fresh
SW	Slightly Weathered
MW	Moderately Weathered
HW	Highly Weathered
EW	Extremely Weathered

PROJECT

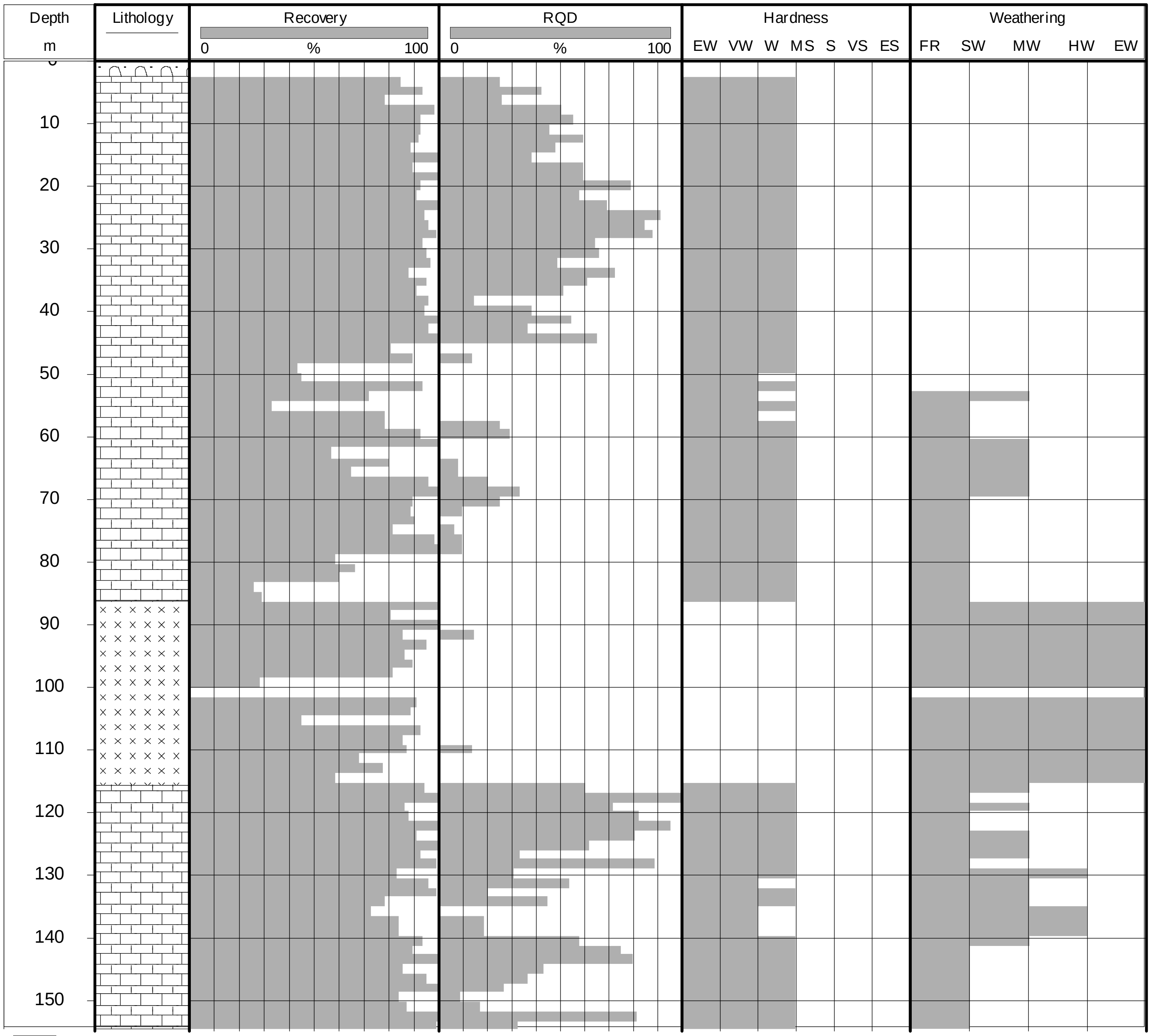
ATAC RESOURCES LTD.
TIGER ZONE, RAU PROPERTY
YUKON TERRITORY, CANADA

TITLE

Downhole plot of Recovery, RQD, Hardness, and Weathering for RAU-10-102

PROJECT No.		1302357	FILE No.	
DESIGN	GTL	11/12/2013	SCALE	NOT TO SCALE
CADD	BJE	11/12/2013	FIGURE	C-4
-	-	-		
-	-	-		

RAU-10-108



Overburden

Limestone

Oxide

HARDNESS

ES	Extremely Strong
VS	Very Strong
S	Strong
MS	Moderately Strong
W	Weak
VW	Very Weak
EW	Extremely Weak

Weathering

FR	Fresh
SW	Slightly Weathered
MW	Moderately Weathered
HW	Highly Weathered
EW	Extremely Weathered

PROJECT

ATAC Resources Ltd.

ATAC RESOURCES LTD.
TIGER ZONE, RAU PROPERTY
YUKON TERRITORY, CANADA

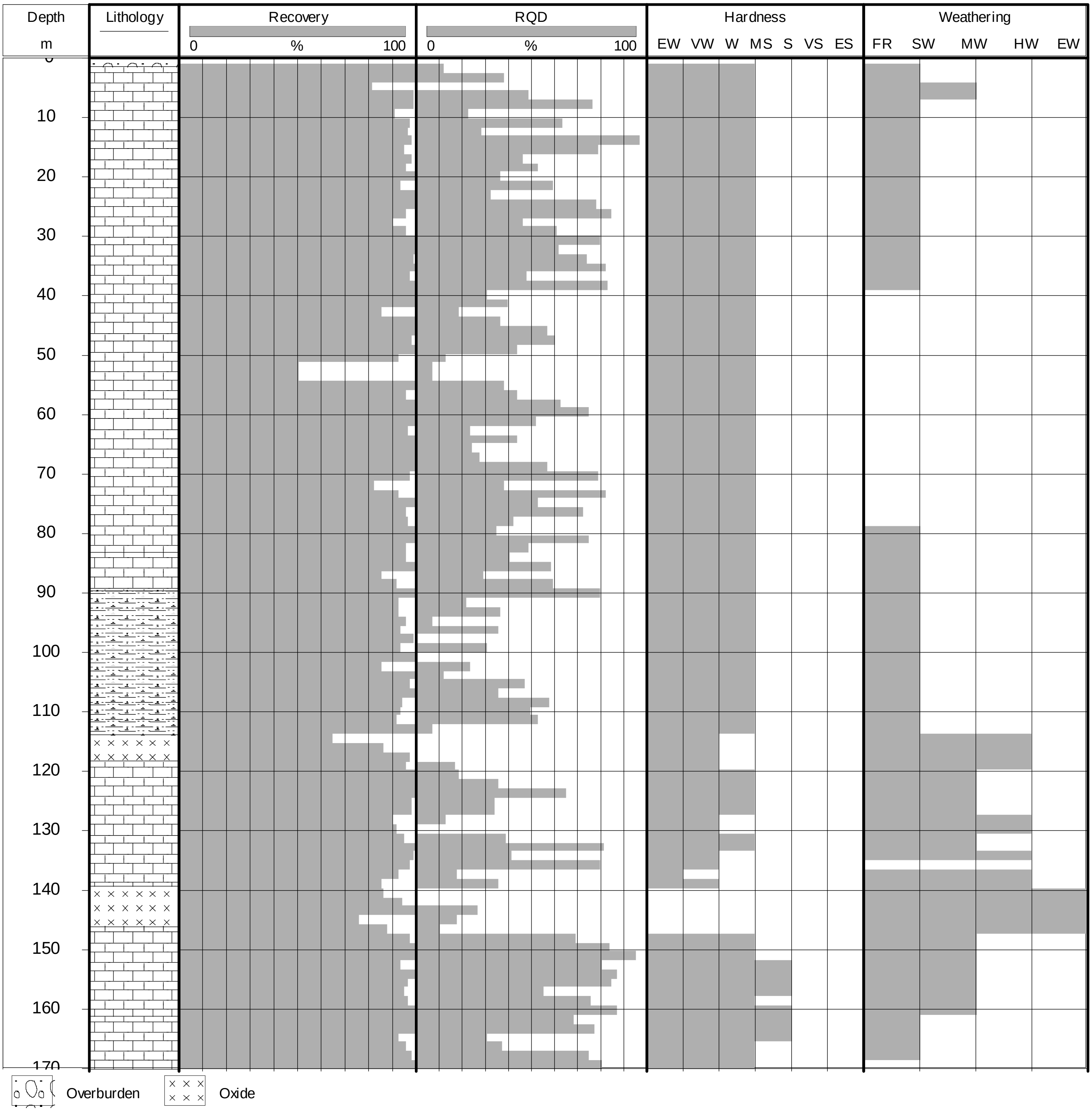
TITLE

Downhole plot of Recovery, RQD, Hardness, and Weathering for RAU-10-108

Golder Associates

PROJECT No.		1302357	FILE No.
DESIGN	GTL	11/12/2013	SCALE NOT TO SCALE
CADD	BJE	11/12/2013	FIGURE
-	-	-	**C-5**
-	-	-	

RAU-10-113



HARDNESS	
ES	Extremely Strong
VS	Very Strong
S	Strong
MS	Moderately Strong
W	Weak
VW	Very Weak
EW	Extremely Weak

Weathering	
FR	Fresh
SW	Slightly Weathered
MW	Moderately Weathered
HW	Highly Weathered
EW	Extremely Weathered

PROJECT

ATAC Resources Ltd.

ATAC RESOURCES LTD.
TIGER ZONE, RAU PROPERTY
YUKON TERRITORY, CANADA

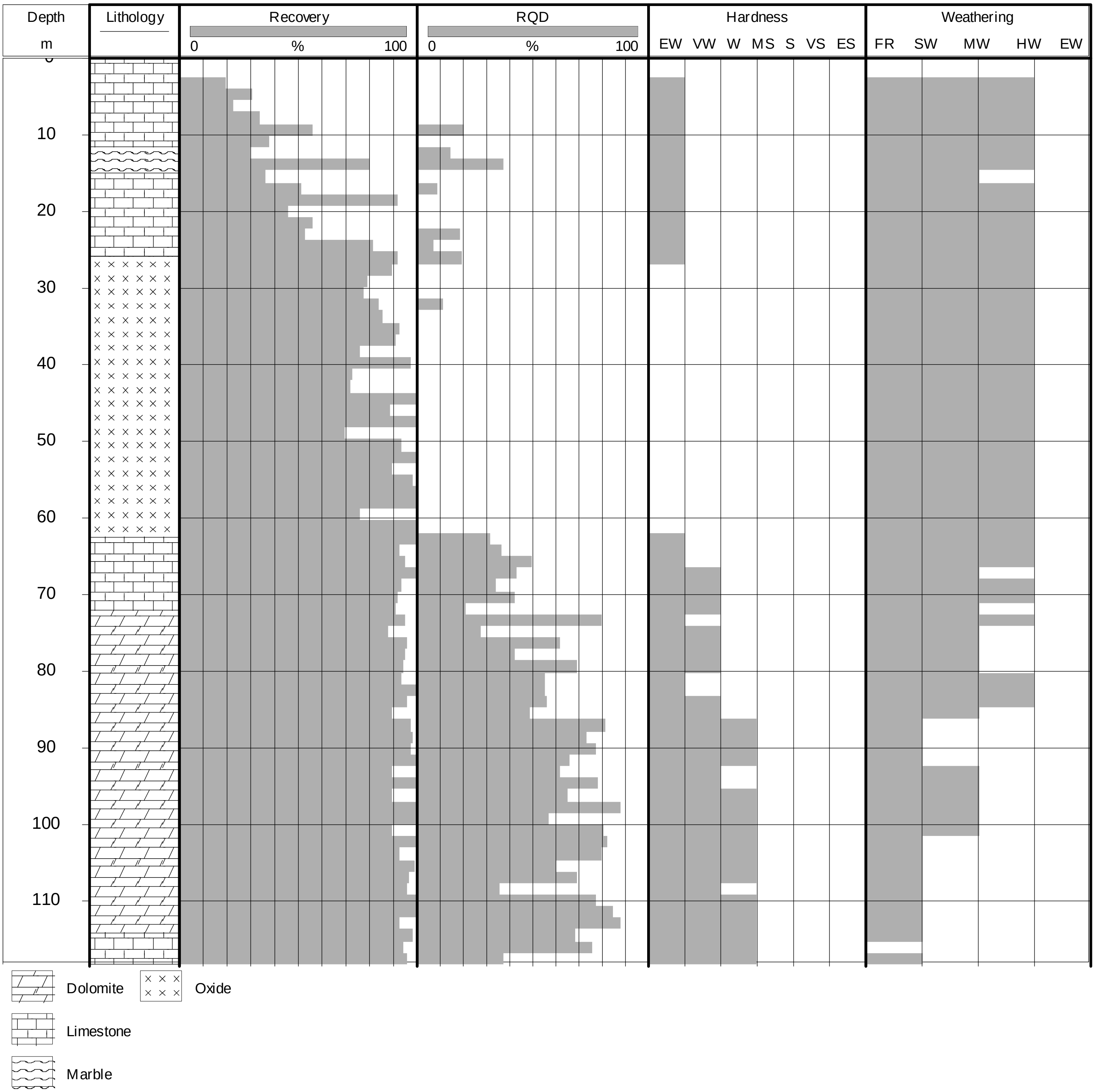
TITLE

Downhole plot of Recovery, RQD, Hardness, and Weathering for RAU-10-113

Golder Associates

PROJECT No.		1302357	FILE No.
DESIGN	GTL	11/12/2013	SCALE NOT TO SCALE
CADD	BJE	11/12/2013	FIGURE
-	-	-	**C-6**
-	-	-	

RAU-10-132



HARDNESS

ES	Extremely Strong
VS	Very Strong
S	Strong
MS	Moderately Strong
W	Weak
VW	Very Weak
EW	Extremely Weak

Weathering

FR	Fresh
SW	Slightly Weathered
MW	Moderately Weathered
HW	Highly Weathered
EW	Extremely Weathered

PROJECT

ATAC Resources Ltd.

ATAC RESOURCES LTD.
TIGER ZONE, RAU PROPERTY
YUKON TERRITORY, CANADA

TITLE

Downhole plot of Recovery, RQD, Hardness, and Weathering for RAU-10-132

Golder Associates

PROJECT No.		1302357	FILE No.	
DESIGN	GTL	11/12/2013	SCALE	NOT TO SCALE
CADD	BJE	11/12/2013	FIGURE	C-7
-	-	-		
-	-	-		

APPENDIX D
DISTRIBUTION OF RQD, HARDNESS AND WEATHERING IN COREHOLES

RQD Classification

RQD (percent)	Rock Quality Classification	Approximate Discontinuity Spacing (mm)[1]
0-25	Very Poor	< 70
25-50	Poor	70 to 100
50-75	Fair	100 to 150
75-90	Good	150 to 300
90-100	Excellent	> 300

Notes: 1. Bieniawski (1989).

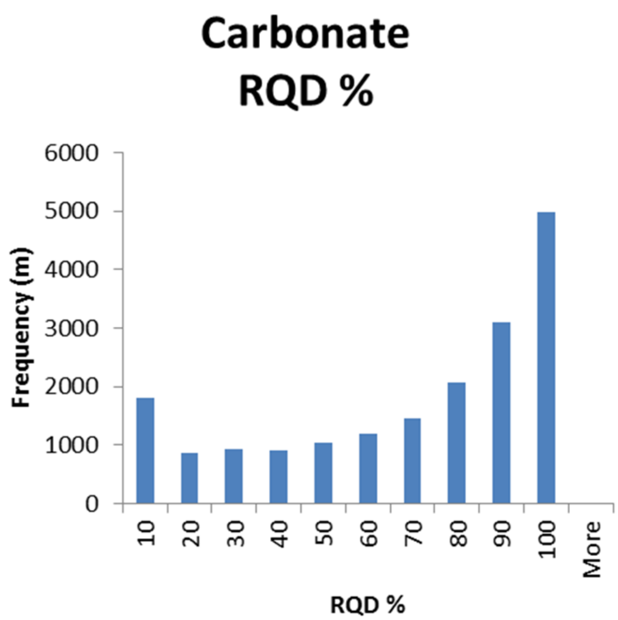
Hardness Categories

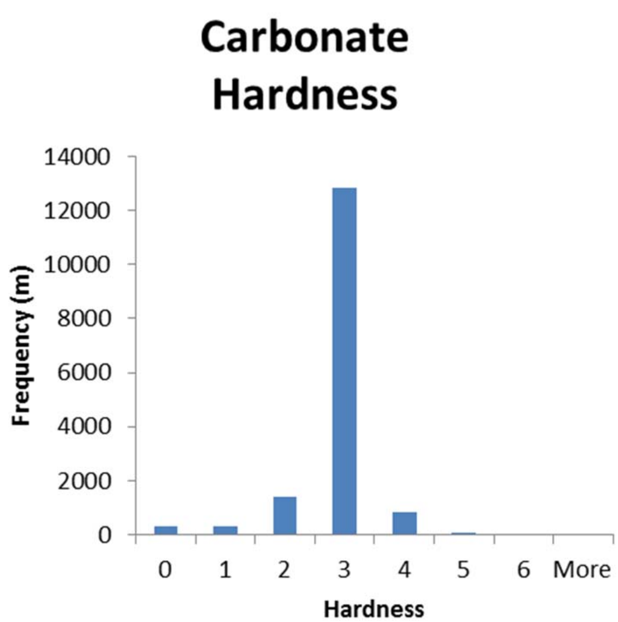
Category	ATAC Code	Description
0	EW	Extremely Weak
1	VW	Very Weak
2	W	Weak
3	MS	Medium Strong
4	S	Strong
5	VS	Very Strong
6	ES	Extremely

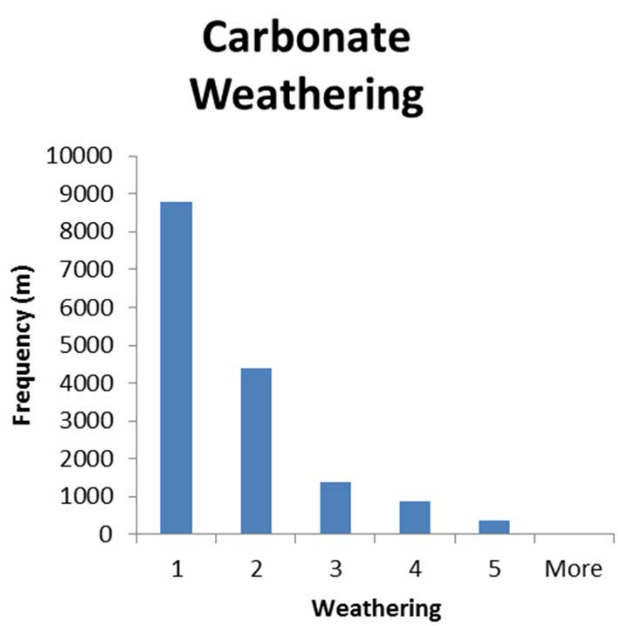
Weathering Categories

Category	ATAC Code	Description
1	FR	Fresh
2	SW	Slightly weathered
3	MW	Moderately weathered
4	HW	Highly weathered
5	EW	Extremely weathered

ATAC Resources Ltd. / Golder Associates	ATAC RESOURCES LTD. TIGER ZONE, RAU PROPERTY YT, CANADA	Drawn GL	Date 01/27/14	Project Number 1302357
		Title	**Figure D-1** **Geotechnical Data Categories**	

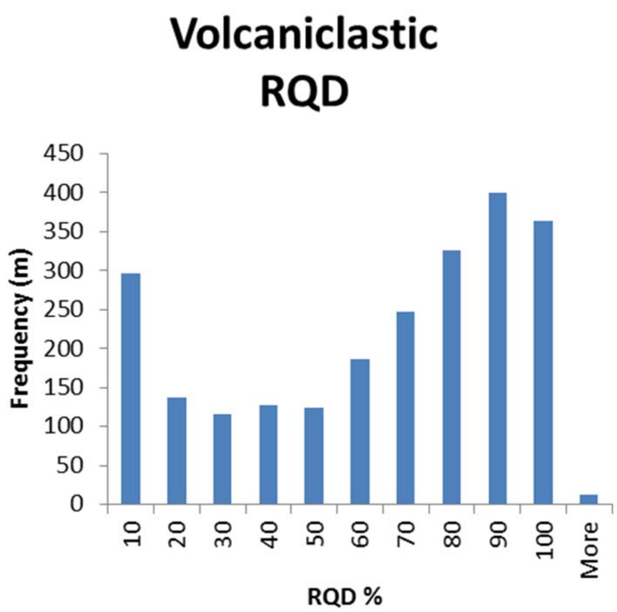


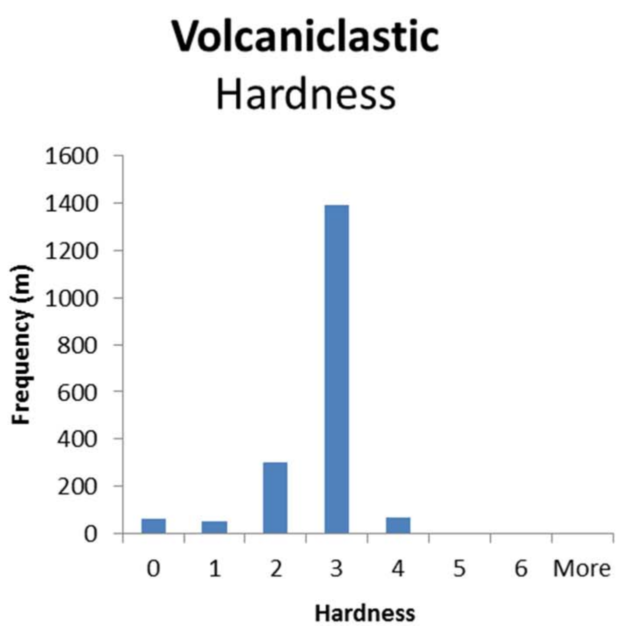


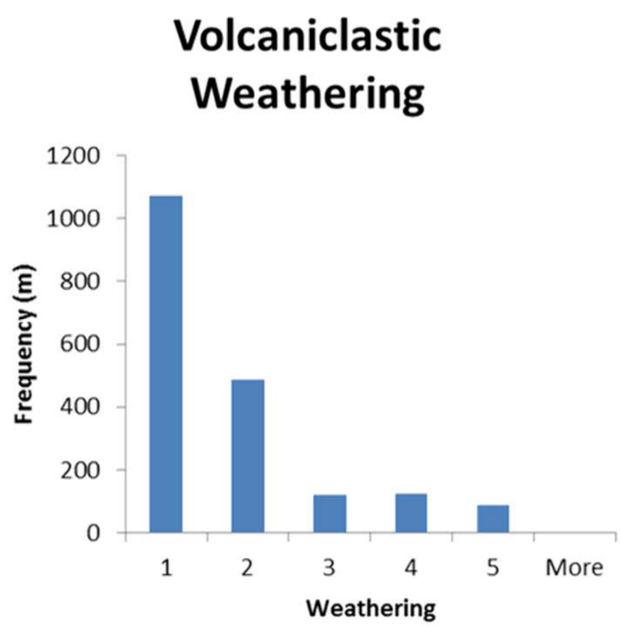


Notes: 1. See Figure D-1 for Explanation of Categories
2. Frequency = length drilled in meters

	Drawn	Date	Project Number
ATAC RESOURCES LTD. TIGER ZONE, RAU PROPERTY YT, CANADA	JB	01/27/14	1302357
	Title	**Figure D-1 Geotechnical Data for Carbonate Rocks**	

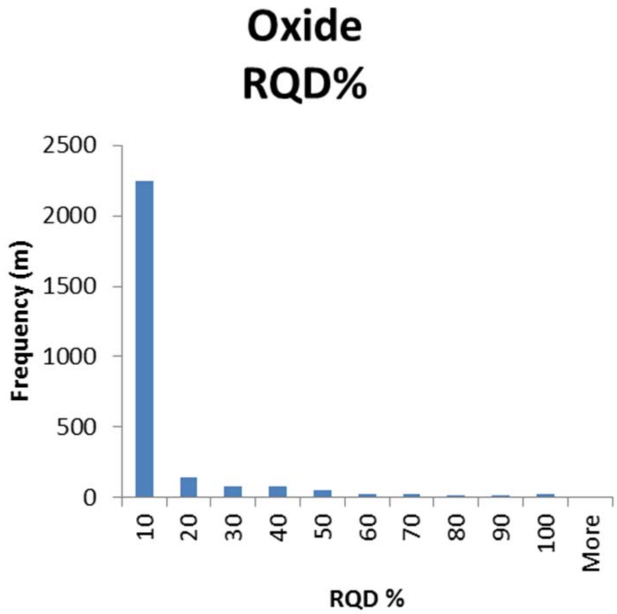


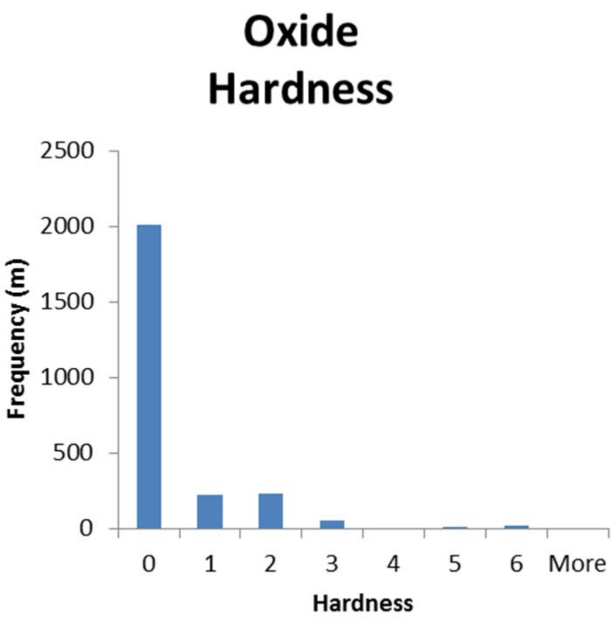


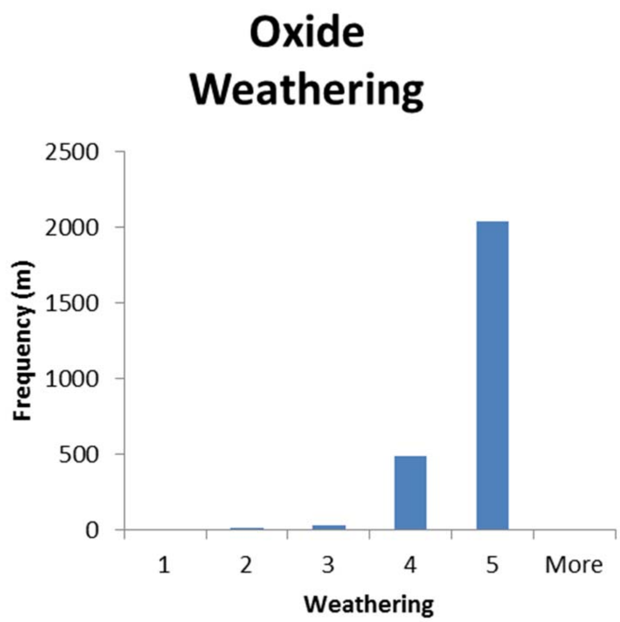


Notes: 1. See Figure D-1 for Explanation of Categories
2. Frequency = length drilled in meters

ATAC RESOURCES LTD. TIGER ZONE, RAU PROPERTY YT, CANADA	Drawn JB	Date 01/27/14	Project Number 1302357
	Title	**Figure D-3 Geotechnical Data for Volcaniclastic**	







Notes: 1. See Figure D-1 for Explanation of Categories
2. Frequency = length drilled in meters

ATAC RESOURCES LTD. TIGER ZONE, RAU PROPERTY YT, CANADA	Drawn JB	Date 01/27/14	Project Number 1302357
	Title	**Figure D-4** **Geotechnical Data for Oxide**	

Established in 1960, Golder Associates is a global, employee-owned organization that helps clients find sustainable solutions to the challenges of finite resources, energy and water supply and management, waste management, urbanization, and climate change. We provide a wide range of independent consulting, design, and construction services in our specialist areas of earth, environment, and energy. By building strong relationships and meeting the needs of clients, our people have created one of the most trusted professional services organizations in the world.

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North America	+ 1 800 275 3281
South America	+ 56 2 2616 2000

solutions@golder.com
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GolderAddress2
Tel: Phone Number
Fax: Fax Number

Golder Associates

Engineering Earth's Development, Preserving Earth's Integrity