# Final Report: Material Site Investigations, Dunbar Siding to Livengood Railroad Extension Route, Interior Alaska

**For:**

**Procurement and Contract Purchase Order FP03864**
**University of Alaska- Fairbanks Contract No. 10-0088:**
**2010 Livengood Railroad Extension**
**Institute of Northern Engineering**
**Duckering Building, Room 525**
**P.O. Box 757920**
**Fairbanks, Alaska USA 99775**

By:

**Pacific Rim Geological Consulting, Inc.**
P.O. Box 81906
Fairbanks, Alaska USA 99708
Phone (907) 458-8951
Fax (907) 458-8511
Email: Bundtzen@mosquitonet.com

**June 6, 2011**

**Cover Photos:**

Left: Pollux Aviation R-44 helicopter picks up PRGCI contractor Larry Nichols west of station #205346, central portion of the proposed Dunbar to Livengood rail corridor, August 17, 2010.

Right: PRGCI geologist Greg Laird inspects an outcrop of dark gray, crackled Globe quartzite in a burned area near station #10GL121.

# Material Site Investigations, Dunbar Siding to Livengood Railroad Extension Route, Interior Alaska

By:

Thomas K. Bundtzen, Paul A. Metz, Greg Laird, Cristina Laird, Peppi Bolz, Kyle Obermiller, and Matthew Billings

# Table of Contents

# Figures

# Tables

# Executive Summary

This project is part of the Alaska-Canada Rail Link (ACRL) investigations undertaken by the University of Alaska, Fairbanks (UAF) and funded by the U.S. Department of Transportation (USDOT) and the Alaska Department of Transportation and Public Facilities (ADOT&PF). Initial funding from USDOT was received in 2005, and the Phase I ARCL Pre-feasibility Study was released in July 2007. Phase II ACRL investigations, funded by ADOT&PF, began in late 2006, and include investigations of potential railroad extensions in Alaska, as well as refinements of the Phase I mineral freight forecast and capital and operating cost estimates for the railroad extensions into Canada. The stated objective of the ACRL projects is to examine the feasibility of extending the Alaska Railroad System to connect with the North American railroad grid, and to examine the impact these extensions would have on the development of the energy resources on the North Slope of Alaska, and the mineral resources along the connecting transportation corridors. The proposed railroad extension from Dunbar to Livengood is an integral part of the proposed railroad grid. The Principal Investigator for the ACRL investigations is Paul A. Metz, Professor of Geological Engineering, Department of Mining and Geological Engineering, University of Alaska, Fairbanks.

Pacific Rim Geological Consulting, Inc. (PRGCI), as a contractor, completed the following: 1) investigated the various rock types, both within, and adjacent to, the Dunbar Siding to Livengood rail corridor, for their suitability to produce Alaska Railroad Corporation (ARRC) riprap, ARRC mainline class 4 railroad ballast, and other engineered construction materials; 2) compiled a strip map depicting the geologic units sampled; and 3) wrote a report that describes and interprets the riprap, ballast and general aggregate potential of the rail route.

Field work in the ARRC Dunbar-Livengood rail corridor commenced on July 31, 2010, and ended on August 19, 2010. The principle method of field transportation was a Robinson R-44 helicopter contracted from Pollux Aviation of Wasilla, Alaska and flown by pilot Chris Jordan.

During the field investigations, ten rock units were investigated and sampled. From south-to-north, they include: 1) the Fairbanks schist, 2) the Wickersham grit and associated units, 3) the Tolovana limestone, 4) the Globe quartzite, 5) Mesozoic gabbro sills, 6) the Wilbur Creek flysch and associated hornfels; 7) the Cascaden Formation; 8) the Livengood ophiolite; 9) the Livengood Dome chert; and 10) Mesozoic-Tertiary intrusions.

PRGCI chose to use the work of Weber and others (1992), which was compiled by Wilson and others (1998), as the principle rock unit control for the Livengood quadrangle, where about 90 percent of the Dunbar-Livengood rail corridor is located. Other, more detailed, sources within the Livengood quadrangle include Robinson and Metz (1979), Bundtzen (1983), Robinson (1983), Smith (1983) and Metz (1991). For the southern-most part of the route, in the Fairbanks quadrangle, PRGCI used the geological information provided by Robinson and others (1990), Newberry and others (1996) and Wilson and others (1998). Plate I is the principle map base for this project, and depicts station locations collected during this investigation.

At field stations, geologists collected hand specimens for both petrographic and trace element analyses, and much larger samples capable of being investigated for material properties. PRGCI acquired thin sections from almost all field stations, in order to provide information for generalized rock classification schemes. Where it was judged to be necessary, trace element data provided more specific rock classification criteria, and was also useful for oxidation estimates. PRGCI selected large bulk samples (generally >50 pounds) from twenty six (26) stations to be tested at the Mappa Test Laboratory in North Pole, Alaska, for bulk specific gravity (SSD), apparent bulk specific gravity, water absorption in percent, T-13 (Alaska Test Method) degradation in percent, Los Angeles abrasion loss in percent, and soundness freeze-thaw in percent.

The Department of Transportation and Public Facilities (DOTPF), as well as predecessor agencies, have conducted material site studies along the Elliott and George Parks Highways, which are underlain by the same rock units found in the Dunbar to Livengood rail corridor. When relevant, that information has been used in this investigation.

In general, rock outcrops were sparse, subdued, and covered with vegetation or loess; accurate characterization of surface rock quality was limited by exposure throughout much of the corridor. The additional effects of a recent wildfire burn in the central part of the rail corridor hampered traverses, but did provide rock exposures that had previously been buried beneath vegetation. Wherever possible, PRGCI geologists collected structural data, including scan-line measurements of joint sets, in order to estimate riprap potential.

PRGCI did not test all engineering specifications needed for both ARRC railroad ballast and riprap. PRGCI did select material tests judged to be the most important to assess the potential for both construction applications. To test the potential for ARRC mainline class 4 railroad ballast, several important physical tests were completed, including Los Angeles (LA) abrasion loss (in percent); water absorption (in percent), and bulk specific gravity (BSG). For riprap, physical measurements (joint and fracture distribution) collected on the surface, T-13 degradation (in percent), soundness loss (in percent), and bulk specific gravity were all considered. For clarification, individual test values were averaged, although individual results were sometimes noted.

## Potential ARRC Mainline Class 4 Ballast Sources

The LA abrasion loss test results from seven geologic units were higher than the maximum value allowed (20 percent) for ARRC mainline class 4 railroad ballast specifications. These include the Fairbanks schist, the grit unit; the Tolovana limestone, the Cascaden Formation, the Livengood Dome chert, the Wilbur Creek flysch, and the Mesozoic intrusions. In contrast, the Globe quartzite, the Mesozoic gabbro sills, the Wilbur hornfels, and the diabase sills within the Livengood ophiolite, all resulted in LA abrasion loss values at or below 20.6 percent, with the best results being from the diabase sills in the Livengood ophiolite.

All but two of rock units tested resulted in water absorption values exceeding the maximum accepted value of 0.50 percent. The Tolovana limestone contained an average water absorption value below 0.50

percent (0.33 percent), and the average value of the five Globe quartzite samples was barely over (0.58 percent), with three out of five quartzite samples registering values less than 0.50 percent. The Fairbanks schist and Wilbur Creek flysch also had individual samples that tested below 0.50 percent, but the average value of all the samples collected from these two units exceeded 0.50 percent (0.85 percent and 1.21 percent, respectively).

All the rock units tested passed the ARRC's ballast specifications for soundness, that is, at or below 1.00 percent. The Livengood Dome chert tested right at that limit.

All of the rock units tested had bulk specific gravities within the value range required to produce ballast. Two of the units, the Mesozoic gabbro sills and the diabase sills of the Livengood ophiolite, contained especially high bulk specific gravity measurements (exceeding 2.90), which is a desired physical property for this application.

The unit that came the closest to passing all of the ARRC's mainline class 4 ballast specifications is the Globe quartzite. Despite elevated water absorption values, the diabase sills in the Livengood ophiolite and the Mesozoic gabbro sills also performed well during material testing. The high specific gravity obtained from the latter two rock units would also give these units an advantage over units that exhibit lower specific gravity measurements.

## Potential ARRC Riprap Sources

ARRC riprap engineering specifications are not as rigorous as the ballast specifications previously described. Many of the rock units examined during this study performed very well during T-13 degradation testing. All but one rock unit, the Tolovana limestone, yielded T-13 degradation values that exceeded the minimum allowable value of 50 (less than 50 percent loss), and five units, the Globe quartzite, the Wilbur Creek hornfels, the Mesozoic gabbro sills, the Livengood Dome chert and the Mesozoic-Tertiary intrusions, contained T-13 values at or exceeding 80 percent, which would be considered an excellent degradation value for any construction application.

Water absorption and soundness specifications place more limits on potential riprap sources for the rail corridor. However, the Grit unit, the Globe quartzite, and the Wilbur Creek hornfels all pass these specifications for riprap.

The biggest uncertainty for determining the availability of riprap in the rail corridor is class size and yield. The general lack of outcrop exposure prevented the PRGCI team from collecting many of the measurements of joints and fractures needed to evaluate coarse riprap potential, i.e., classes 2, 3, and 4. However, the PRGCI team judges that four rock types exhibit coarse riprap potential: 1) the Fairbanks schist, 2) the Tolovana limestone, 3) the Globe quartzite, and 4) the diabase sills in the Livengood ophiolite. All four of these units contained evidence of large blocks of in-situ materials. However, without more detailed joint spacing (Block Size Indices) or, importantly, drill data, there is no way to estimate important parameters, such as yield.

The senior writer has observed coarse riprap developed at the North Nenana Quarry, located about three miles north of Nenana, and eleven miles south-southwest of the Dunbar siding. This quarry, which is owned by Doyon Limited, contains laminated quartzite zones of the Fairbanks schist, and has yielded class 3, and some class 4, riprap, although specific yields (percent of waste) are not known. North Nenana Quarry supplied road base material and riprap for the construction of the access road used to explore for oil and gas in the Nenana Basin during 2009. T-13 values on the order of 45-50 percent have been obtained from the North Nenana rock material. This quarry could conceivably be a source for riprap for the southern portion of the rail corridor. More importantly, it confirms that, despite generally negative test results obtained from previous DOTPF studies, the Fairbanks schist might be able to supply the rail corridor with riprap if the right quarry site is located.

## Recommendations

The PRGCI team located material that meets the specifications for the ARRC's mainline class 4 railroad ballast. In particular, the Globe quartzite came the closest to meeting all the specifications for which it was tested. If further confirmatory work is desired, PRGCI recommends more sampling and work on the Globe quartzite, the diabase sills in the Livengood ophiolite, and the Mesozoic gabbro sills. Gradation testing (ASTM D75, ASTM E11, ASTM C136, and ASTM C117), as well as *Clay Lumps and Friable Particles* (ASTM C142) and *Flat and Elongated Particles* (USACE CRD-119) could help confirm the desirability of these units for ARRC ballast applications.

Riprap assessment is limited by the poor outcrop exposure in the area. The units described above, which contain favorable physical properties for ballast, should also be tested with a diamond drill, and the core evaluated for riprap potential. PRGCI does not consider the Grit unit, the Wilbur Creek flysch and associated hornfels, the Livengood Dome chert, and the Cascaden Formation, to be potential source materials for the proposed ARRC Dunbar-Livengood rail project. However, other units, especially the Tolovana limestone, might yield coarse riprap if further laboratory testing on diamond drill core confirmed such a potential.

Other factors also affect the PRGCI team's recommendations. Although hornfels seemed to test well for riprap quality, the exposures near Shorty Creek, where most of the tested hornfels was collected, are erratic in shape and limited in tonnage. In addition, they comprise a portion of a metallic mineral zone that could be developed for metals in the future. The intrusions themselves could be sources of riprap. One problem common to most intrusions in interior Alaska, where Pleistocene glaciations has been generally absent, has been grussification processes. In these cases, core drilling must confirm the nature of the underlying intrusive rocks.

In summary, several rock units have tested positively for desired future construction uses should the decision be made to develop railroad access to Livengood. Units such as the Globe quartzite, the Livengood ophiolite, the Mesoszoic gabbro sills, and the Tolovana limestone hold promise to meet the ARRC's construction specifications. Future work should include more detailed surface sampling and mapping, selected mechanical excavation, and shallow core drilling to test key rock prospect locations in the Globe quartzite, the diabase sills in the Livengood ophiolite, and in the Mesozoic gabbro sills.

# Introduction, Scope, and Purpose

This investigation is a part of the Alaska Canada Rail Link (ACRL) Project that was initiated by Principal Investigator Paul Metz, Professor of Geological Engineering, Department of Mining and Geological Engineering, University of Alaska, Fairbanks (UAF), and funded by the U.S. Department of Transportation (USDOT) and the Alaska Department of Transportation and Public Facilities (ADOT&PF). The Phase I work funded by USDOT commenced in 2005, and the Phase I pre-feasibility study for the extension of the Alaska Railroad from Delta Junction to three alternative locations in northwestern British Columbia was released in July 2007. Previously, from 2003 to 2005, UAF conducted a pre-feasibility study for the U.S. Department of Defense (USDOD) for the extension of the Alaska Railroad from Eielson AFB to Delta Junction, Alaska. Phase II work, funded by ADOT&PF, commenced in late 2006, and examined the potential railroad extensions in Alaska, as well the potential to increase the mineral freight forecasts made in Phase I. The primary goal of the ACRL Project, as stated in the initial UAF proposal, is to examine the impact that an extension of the Alaska Railroad System to the North American Railroad Grid would have on the development of the oil and natural gas resources of the North Slope of Alaska, and on the mineral resources along the corridors for the various railroad extensions. These natural resource developments would be the primary providers of the railroad freight required to generate the revenue necessary for the large capital investment needed for the railroad extensions.

One such route, known as the Dunbar Siding to Livengood Railroad Extension, would link the historic Livengood mining district with the mainline Alaska Railroad at Dunbar Station, about 50 miles (80 km) west of Fairbanks and 10 miles (15 km) north-northeast of Nenana (Figure 1). The total length of the rail line from Dunbar to Livengood is about 45 miles (72 km). The route traverses the Dunbar-Brooks-Terminal Trail (DBTT), a well-known, established, RS-2477 right-of-way.

Field work took place from July 31 to August 17, 2010. Transportation consisted of a helicopter chartered from Pollux Aviation (Wasilla, Alaska), augmented by surface access along the Elliott Highway and Murphy Dome Road. Participating in the effort were Thomas K. Bundtzen, project manager for Pacific Rim Geological Consulting, Inc (PRGCI), PRGCI geological contractor Greg Laird, PRGCI geologist Cristina Laird, PRGCI contractor Larry Nichols, Dr. Paul Metz from the Department of Mining and Geological Engineering at UAF , and Peppi Bolz, Mark Taylor, Matthew Billings, and Kyle Obermiller, all students from the Department of Mining and Geological Engineering at UAF.

The purpose of this investigation was to: 1) investigate the various rock types both within, and adjacent to, the proposed Dunbar Siding to Livengood rail corridor for their suitability to produce ARRC riprap, ARRC mainline class 4 railroad ballast, and other engineered construction materials, 2) compile a strip map depicting the geologic units and engineering geological units, and 3) write a report that describes and interprets the riprap, ballast and general aggregate potential of the rail route.

# Geography of Dunbar-Livengood Corridor

The Dunbar-Livengood rail corridor traverses a heavily vegetated part of the Yukon-Tanana upland, an area of rounded ridges and broad, sediment-filled lowlands. The western edge of the route occupies Minto Lakes, Lower Goldstream Creek, and the Tatalina River and Tolovana River wetlands complex (Figure 1). Elevations range from 363 feet at Dunbar Station in the southern-most portion of the tract, to 2231 feet at the head of Shorty Creek near the northern-most part of the tract. The region has never been glaciated.

The entire project area is below timberline. Eolian silt covers virtually all of the landscape, but appears to thin along the route in a northerly direction (Figure 2). Bedrock control can be found on ridge tops and along steep bluffs where rivers cut into the topography (Figure 3). However, lower slopes are covered by an anastamosing network of alluvial-colluvial fan complexes.

Climax forests consisting of mature birch, white spruce, and black spruce cover about 65 percent of the route mapped. However, large burn areas occur in the Washington Creek and Tatalina River areas. The downed trees in both areas made for slow and tedious traversing. Lowlands are covered by upland sphagnum peat deposits, dwarf birch, and stunted black spruce forests. The upper slopes, especially along their south faces, are covered by mature paper birch stands.

The route follows an RS-2477 right-of-way known as the Dunbar-Brooks-Terminal Trail (DBTT) (Figure 1). From south to north, the route traverses north-northeast across a series of second order, west-flowing streams opposite Minto Lakes, until it intersects the Chatanika River, a major upper tributary of the Tanana River basin. From the Chatanika River, the route then strikes north to the intersection of Washington Creek and the Tatalina River, where the route takes a sharp turn to the northwest. The DBTT then returns to a more northerly direction, and cuts through the low area between VABM Minto, and the pronounced north-south ridgeline at the head of Wilbur and Slate Creeks. The DBTT then skirts the eastern edge of the Tolovana lowland, until it intersects the Elliot and Dalton Highways.

The rail route follows two, very distinct, north-south lineaments, that juxtapose the uplands of the Tatalina River and Washington Creek on the east, against Tolovana Hot Springs Dome and Dugan Hills on the west. It is generally recognized that these distinctive linear features are part of a north-south, high angle fault system that controls the distribution of sediments in the Minto Flats trough. Seismic evidence suggests that unconsolidated sediments in this depo-center locally exceed 10,000 feet in thickness. The Minto Flats trough has been the focus of recent exploration for gas, and, to a lesser extent, oil, by Doyon Limited and other partners.

The entire rail route lies within a zone of discontinuous permafrost. Although not drill-tested, the amount of permafrost present can be estimated from landforms. North-facing slopes and low-lying areas are all underlain by a frozen substrate. However, south-facing slopes and most of the ridge tops appear to be thawed.

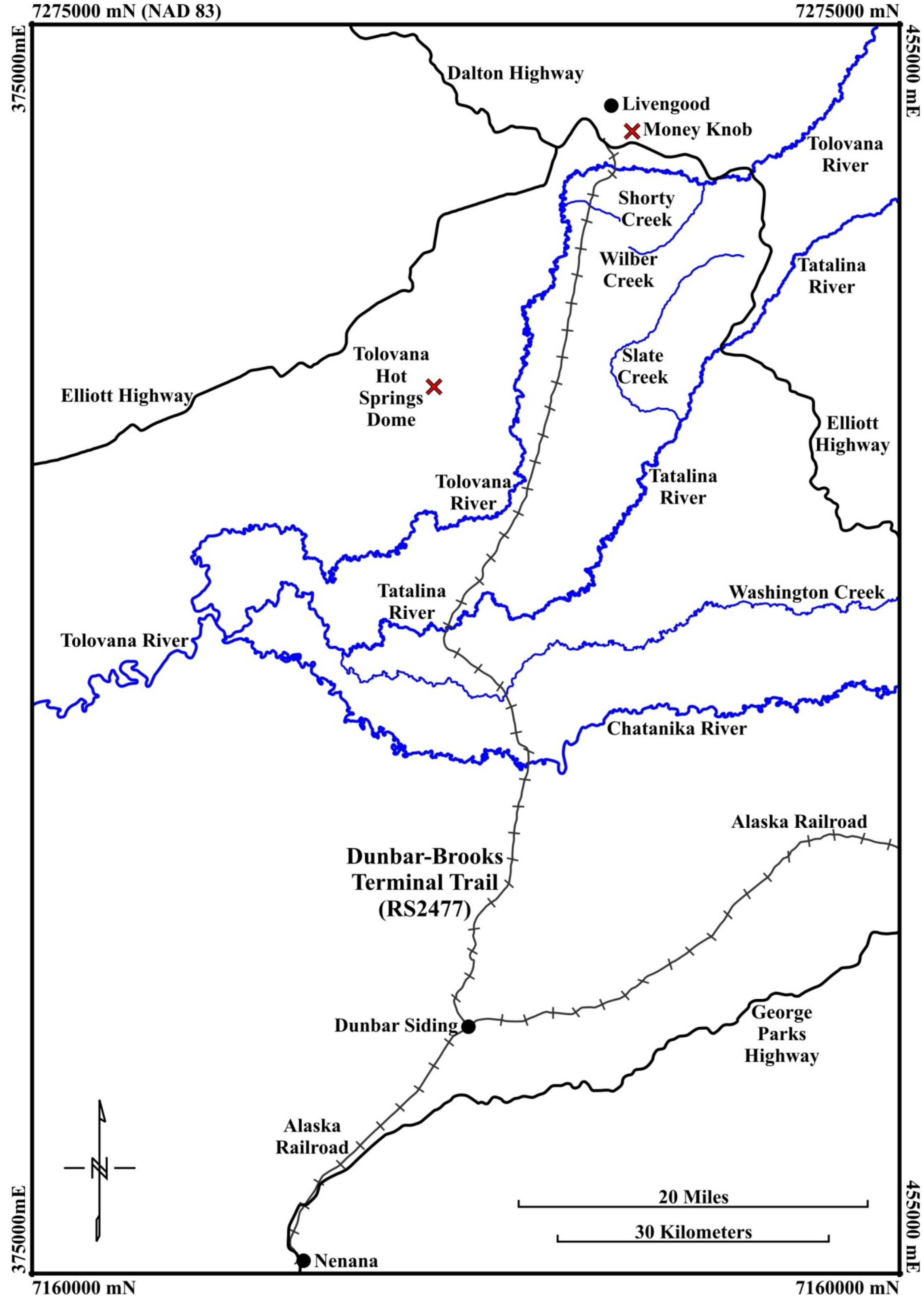


Figure 1 Location map showing the Dunbar-Brooks-Terminal Trail (DBTT) and geographic features

**Figure 2  Peppi Bolz examines a thick loess deposit in the Standard Creek logging road complex, about six miles north-northeast of Dunbar; photo illustrates the thick deposits of eolian materials and vegetation that overlie much of the Dunbar-Livengood rail corridor**

**Figure 3  Outcrops of the Tolovana limestone unit (Dtr) at VABM Minto, illustrating some of the better exposed bedrock within the Dunbar-Livengood rail corridor**

# Methodology

On June 16, 2010, Bundtzen, Metz, and the UAF students met with Bruce Carr and others of the Alaska Railroad Corporation (ARRC) to discuss the objectives of the project from the perspective of the ARRC's needs. The need to locate sites suitable for the production of mainline class 4 railroad ballast and riprap was emphasized by ARRC personnel, as well as the need for a better understanding of the ground conditions that a potential rail transport might encounter.

From July 17-19, 2010, the senior author (Bundtzen) reviewed and edited an air-photo interpretation of the route, that had been compiled by UAF engineering students Elliott Thorum, Matt Billings, Charlie Bohart, and Kyle Obermiller. After conducting an air photo examination of the route, the writer suggested the addition of lineaments and alluvial-colluvial units.

On July 20 and 22, 2010, the field crews drove the Elliot Highway from Fairbanks to Livengood and examined in detail the artificially produced outcrops in road cuts. The rock units in the Livengood quadrangle strike southwest-to-northeast, and regional mapping completed by Weber and others (1992) show that the same rock units exposed along the Elliott Highway would be encountered within most of the Dunbar-Livengood railroad corridor itself.

On July 26, 2010, PRGCI personnel overflew the proposed rail route, using a Cessna 206 fixed wing aircraft piloted by Ken Joupe of KenAir in Fairbanks. The flight gave the Livengood team a better understanding of the obstacles and challenges that would be faced during the investigation. It allowed the team to identify areas where surface access (vehicles) could be used, thus saving helicopter flight hours. The flight also helped the team pinpoint the locations of potential landing zones, bedrock outcrops, and limitations caused by vegetation and burned areas.

Field work in the Dunbar-Livengood rail corridor commenced on July 31, 2010 and ended on August 19, 2010. The principle mode of field transportation was a Robinson R-44 helicopter chartered from Pollux Aviation in Wasilla, Alaska, and piloted by Chris Jordan. The PRGCI team decided to work from south to north along the proposed route. PRGCI personnel arranged to drive participants to a site near the U.S. Department of Defense Murphy Dome station to await transport into the field. Helicopter fuel was also transported to the site in 55 gallon drums in the back of a pickup truck, to avoid flights back to Fairbanks. From Murphy Dome, the team was able to use the helicopter to access sites on both sides of the Chatanika River, Washington Creek, and the lower Tatalina River near VABM Minto.

As work progressed to the central and northern portions of the rail route, PRGCI personnel transported crews and helicopter fuel to an Alaska Department of Transportation and Public Facilities (DOTPF) barrow pit-materials site situated north of the Tolovana limestone unit, at approximately Mile 45 of the Elliott Highway (near the head of the Tatalina River). From there, the helicopter was used to move geologists into the field to access sites on Tolovana Hot Springs Dome, Slate Creek, Shorty Creek, Wilbur Creek, and other priority target areas south of Livengood.

During the field investigations, ten (10) major rock units were investigated and sampled. The PRGCI team chose to use the work of Weber and others (1992), which was compiled in color by Wilson and others (1998), as the principle rock unit control for the Livengood quadrangle, where about 90 percent of the Dunbar-Livengood rail route is located. Other, more detailed, sources within the Livengood quadrangle include Robinson and Metz (1979), Bundtzen (1983), Robinson (1983), Smith (1983) and Metz (1991). For the southern-most part of the route, in the Fairbanks quadrangle, the geological information provided by Robinson and others (1990), Newberry and others (1996) and Wilson and others (1998) was used. Plate I is the principle map base for this report, and shows where the field crews' stations are located.

During the 2010 investigation, 205 field stations were located (see Appendix I and Plate I). Team geologists collected hand specimens for both petrographic and trace element analyses, and much larger samples capable of being investigated for material properties. Petrographic thin sections were made by Jim Deininger Labs in Fairbanks. Hand specimens for thin section were collected from almost all of the field stations in order to provide information for generalized rock classification schemes. Where judged to be necessary, trace element data provided more specific rock classification criteria, and was also used for oxidation estimates. Finally, large bulk samples (generally >50 pounds) were collected from twenty six (26) stations, and were tested at the Mappa Test Laboratory in North Pole, Alaska for bulk specific gravity (SSD), apparent bulk specific gravity, water absorption in percent, T-13 (Alaska Test Method) degradation in percent, Los Angeles abrasion (loss) in percent, and soundness (freeze/thaw) in percent. A total of 194 samples underwent laboratory investigations (see Table 1).

The Department of Transportation and Public Facilities (DOTPF) and predecessor agencies have conducted material site studies along the Elliott and George Parks Highways, which are underlain by the same rock units as is the proposed Dunbar-Livengood rail corridor. When relevant, that information has been included in this investigation.

In general, rock outcrops were sparse and subdued, and covered with vegetation or loess, limiting accurate characterization of rock quality at the surface throughout much of the corridor. The additional effects of a recent burn in the central part of the rail corridor slowed down traverses. However, whenever possible, the Livengood rail team collected structural data, including scan-line measurements of joint sets, in order to estimate riprap potential.

**Table 1 Summary of laboratory sample protocol during the Dunbar-Livengood rail corridor project**

| Sample Type | Analytical or Laboratory Method Used | Number of Samples |
|---|---|---|
| Bulk Sample (>30 pounds) | MAPPA, Inc. material tests, including bulk specific gravity, apparent specific gravity, Los Angeles abrasion (loss), water absorption, sodium sulfate soundness | 26 |
| Rock Grab | Standard 25x40 mm thin section | 139 |
| Rock Grab | ME-ICP06 Whole Rock Package; ME-MS81 38 element fusion ICP-MS; OA-GRA05 Loss on Ignition | 29 |
| **Total** | **NA** | **194** |

# Geological Summary

The proposed Dunbar to Livengood rail corridor transects one of the most diverse geologic sections in Alaska. Weber and others (1985) provides for a useful geological framework from which to view the bedrock geology of the Dunbar-Livengood rail corridor. Geologic units range from Proterozoic to Quaternary, and nearly every geologic period is represented within the rail corridor. PRGCI adopted the work of Weber and others (1992) and Wilson and others (1998) as the geological map base for this investigation, making minor modifications where appropriate (see Plate I).

Recently, the Alaska Division of Geological and Geophysical Surveys has studied portions of the area, including geologic hazards throughout the Livengood quadrangle (Reger and others, 2003), and the economic geology of the Tolovana mining district (Athey and others, 2004 a, b; Greisel and others, 2010). These investigations also provided useful new geologic and geochemical data for portions of the rail corridor.

From south to north, ten (10) geologic packages are briefly described below, based on summaries provided by Bundtzen (1983), Weber and others (1985, 1992), Albanese (1983), Robinson (1983), Smith (1983), Wilson and others (1998), Hall and others (1984) and Metz (1991). Distribution of the generalized rock units described below appears on Figure 2 and on Plate I.

**The Fairbanks schist unit (PzZyqs)** mainly consists of micaceous quartzite, garnet muscovite schist, and quartz muscovite schist. In the southeastern corner of Plate I, eclogitic rocks are structurally juxtaposed over the Fairbanks schist. Most of the Fairbanks schist exhibits low angles of compositional banding and foliation. The Fairbanks schist underlies nearly 40 percent of the rail corridor from Dunbar station to Washington Creek. Age control is uncertain, and the Fairbanks schist probably includes rocks of both Proterozoic and Paleozoic ages.

**The Grit unit (CZwl, CZwa, CZw)** includes meta-conglomerate, coarse grained arenaceous sandstone, quartzite, siltstone, peculiar maroon and green phyllite, and carbonate rocks. Chapman and others (1971) first refers to this sequence of rocks as Grit of the Yukon-Tanana Terrane, and tentatively links this unit with the Windermere Group of Southern Canada. The age is based on two fossil localities, found northeast of the Elliott Highway, that contain Oldhamia, a Cambrian trace fossil. The contact with the Fairbanks schist has been regarded by others as a major tectonic boundary, but locally thought to be depositional - implying linkage with the Yukon-Tanana Terrane. The Grit unit underlies as much as 15 percent of the rail corridor, but is largely covered by the colluvium and vegetation of the Tatalina River flats (Figure 1, Plate I). A thin sliver of the Grit unit occurs north of the Tolovana limestone, which suggests a complicated structural juxtaposition of rock units in this area.

**The Tolovana limestone and Ordovician Fossil Creek volcanics units (Dtr, Ofc)** comprise a thin, but distinctive, Lower to Middle Paleozoic, limestone and volcanic tuff section, that core the VABM Minto area midway through the rail corridor. As originally defined by Mertie (1937), the Tolovana limestone is a belt of thin-bedded to massive carbonate of mainly Middle Devonian age, but includes Silurian members in the White Mountains. Outcrops of unit Dtr can be mapped from Willow Creek north of

Cache Mountain in the White Mountains to Minto Flats, a distance of about 75 miles (120 km). Bundtzen (1983), who mapped three members in the Globe Creek area, mapped the Tolovana limestone as a structural klippen over younger units. The Fossil Creek volcanics occur on both sides of both the Tolovana limestone and Globe quartzite-gabbro complex described below - sometimes appearing structurally underneath or structurally adjacent to the carbonates on its northern contact. Poor exposures prevent a more complete understanding of what is obviously a complicated contact relationship between rock units.

**Mesozoic sill complex and Globe quartzite units (Trn, Msq)** consist of light gray, massive to thinly laminated, quartzite, cherty argillite (locally chert), and claystone of Mississippian age juxtaposed by porphyro-aphanitic, pyroxene greenstone-gabbro sills thought to be of Triassic age. Wilson and others (1998) and Weber and others (1992) loosely correlate the greenstone-gabbro sills with the Nikolai greenstone and related rocks that form important, aerially extensive units in South-central Alaska. The Globe quartzite, named after exposures on Globe Creek in the eastern part of the Livengood quadrangle, was originally assigned an early Paleozoic age (Chapman and others [1971] and Bundtzen [1983]). Later, Weber and others (1992) believed it to be correlative with the Mississippian Keno Hill quartzite, in north-central Yukon Territory, Canada, on the north side of the Tintina Fault. As such, the Globe quartzite may provide an important link to the continental margin of North America - now offset 450 km by the Tintina strike-slip fault. Exposures of units Mgq and Trn underlie only a small portion of the proposed rail corridor. However, more of this section could conceivably underlie the vegetated Tatalina River flats.

**Mesozoic flysch (the Wilbur Creek flysch) unit (Kwcf)** underlies about 35 percent of the proposed rail corridor. It underlies most of the prominent north-south ridgeline that begins at Twin Creek to the south, and end at the juncture of Livengood Creek and the Tolovana River to the north. Previous workers, including Bundtzen (1983) and Weber and others (1992), have subdivided the Wilbur Creek flysch into a coarser grained, graded, sandstone-conglomerate dominated section, versus a finer grained, graded, mudstone-fine siltstone dominated section. Both are part of a turbidite sequence. Wilson and others (1998) lumped both sedimentary facies into a single unit, Kwcf. Provenance is of local derivation, and samples include clasts from the Cambrian mafic/ultramafic ophiolites, the Cascadan Formation, the Amy Creek dolomite, and the Grit section. Age is based on the presence of *Paragastrolites flexicostatus* of Albian (upper Lower Cretaceous) age. The Wilbur Creek flysch near Shorty Creek is cut by small, mineralized plutons that contain copper, gold and silver. This area is currently under an exploration lease by Select Resources, Inc.

**The Cascaden Formation unit (Dcb)** underlies much of Cascaden Ridge, and the world class Money Knob gold deposit currently being developed by International Tower Hill Mines, Inc. It consists of a siliciclastic section composed of gray/olive gray shale, siltstone, and sub-lithic sandstone. Conglomerates contain mafic/ultramafic rocks derived from the underlying Livengood ophiolite belt. Thin carbonate and calcareous sandstone units contain abundant Middle Devonian fossils assemblages. Weber and others (1985) believe that the Cascaden Formation is equivalent to the Nastion River Formation that outcrops on the north side of the Tintina Fault zone near Eagle, implying a similar right lateral offset of 450 km, as has been suggested for the Globe quartzite-Keno Hill quartzite comparison. The Cascaden Formation occupies about 5 percent of the proposed rail corridor, at its northern end.

**The Livengood ophiolite unit (MzZum)** consists of variable amounts of chert, diabase sills, gabbro, basalt, and serpetenized ultramafic rocks that have been interpreted to be a structurally complex, dismembered ophiolite. The MzZum unit forms a distinctive belt of rocks that appear to be intercalated with, or in structural juxtaposition with, the Cascaden Formation (Dcb) north of the Tolovana River and on both sides of Livengood Creek. Clasts of ultramafics are found in the Devonian Cascaden Formation, and preliminary isotopic ages suggest a Cambrian age for gabbroic rocks (F. Weber, pers commun., with Bundtzen, 1993). Mafic igneous units at the Money Knob gold deposit also host significant gold mineralization as does the overlying Cascaden Ridge Formation.

**The Amy Creek Unit (SZa)** consists mainly of light gray-yellow, dolomitic mudstone packestone and locally massive dolomite. It forms a three mile wide belt at the extreme northern edge of the rail corridor. The age of the Amy Creek unit is somewhat controversial, with some suggesting an age slightly older than the Middle Devonian Cascaden Ridge formation which it underlies. Others suggest a Late Proterozoic age, citing analogs to the Late Proterozoic Kataktoruk Dolomite in the Southern Brooks Range (R.B. Blodgett, oral commun., 2000). No fossils have been found. The Amy Creek unit mostly underlies a zone outside the rail corridor, but is proximal enough to be considered as a possible material source.

**The Livengood Dome Chert Unit (Oc)** consists of dark gray-black and variegated banded chert and interbedded limestone and dolostone that has yielded graptolites of Upper Ordovician age. Like the Amy Creek unit, it lies outside the rail corridor, but was investigated and sampled for possible application as a material source for railroad infrastructure, due to its proximity to the corridor.

**Mesozoic Intrusions Units (TKgd, Tpgr)** are felsic and intermediate plutonic rocks that generally range from 50-75 Ma. They are broadly considered to be a northeastern extension of the Kuskokwim Mineral Belt, but may also includ older, Mid- Cretaceous Fort Knox age plutons. The largest body of unit, TKgd, forms the core of Tolovana Hot Springs Dome. Smaller bodies of the unit, Tpgr, outcrop at the head of Shorty Creek, where prominent zones of hornfels and metasomatic alteration are developed within the Wilber Creek flysch.

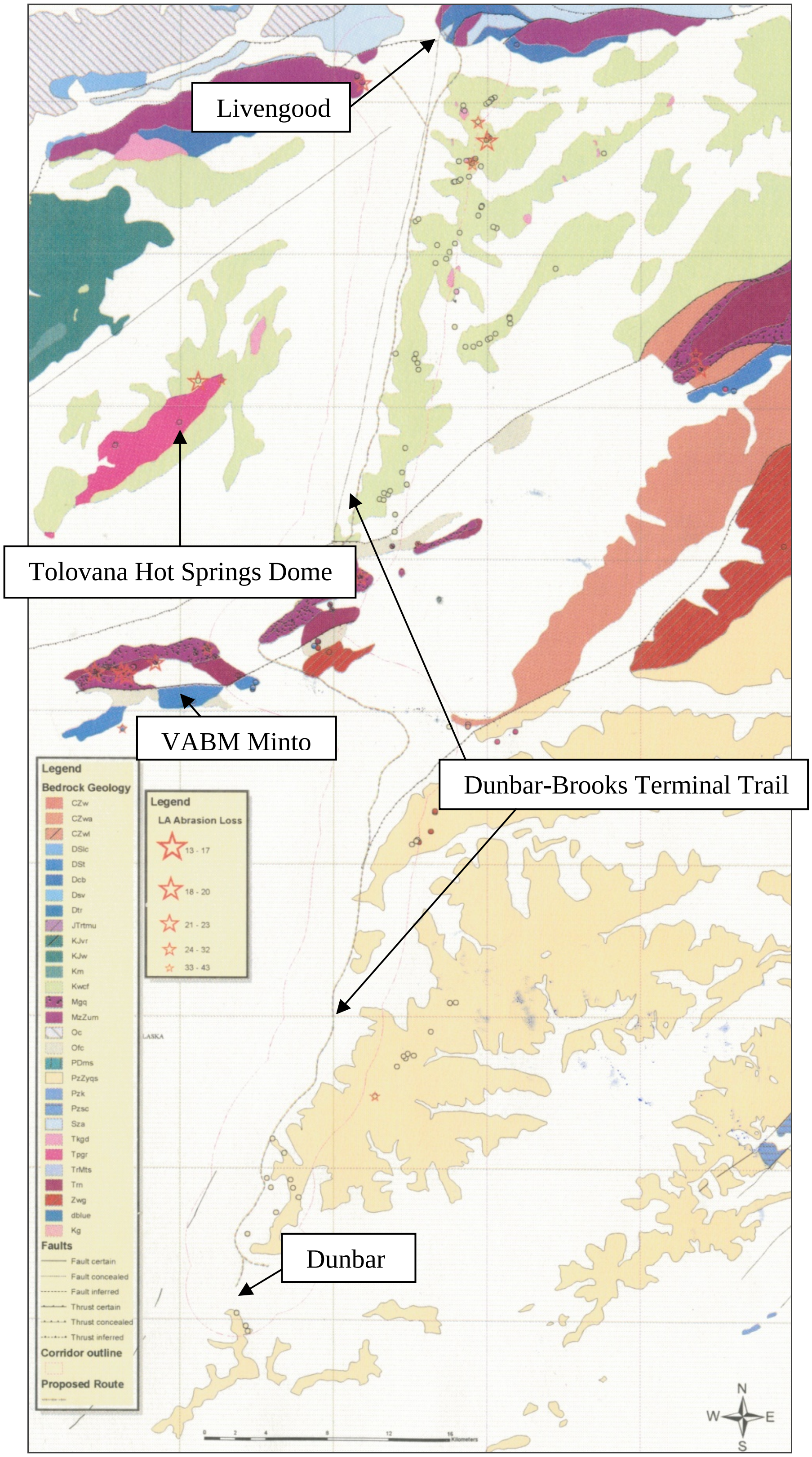


**Figure 4 Regional geologic sketch of the Dunbar-Livengood rail corridor; map base compiled by Peppi Bolz**

# Characterization of Rock Units and Results of Material Site Investigations

## Fairbanks schist unit (PzZyqs, Plate I)

### Field Observations

The PRGCI-UAF team established thirty five (35) stations in the Fairbanks schist unit between Dunbar Station and the Chatanika River (Plate I; Appendix I). The stations were located on ridge crests west of Murphy Dome, and along road cuts of the Standard Creek logging road system. Bedrock control is largely confined to these two modes, since almost all of the area underlain by the Fairbanks schist is below timberline. Sixteen (16) thin sections were cut from samples of the unit, and a sample from one site underwent material analyses. Outcrops were generally composed of flattened, equant exposures that form tors along summits and ridge lines. More than 80 percent of bedrock control is rubble and float.

### Petrographic and Geochemical Summary

A majority of the sites contained fine-to-medium grained, light gray, locally tan weathered, biotite-bearing, feldspathic, quartz-rich porphyro-clastic meta-sandstone (Figure 5). Interlocking, rounded, strained, quartz anhedra up to 0.3 mm form the dominant textural style (Figures 7, 8). Grains are sometimes marked by a fine dust of hematite(?). Isolated grains of both biotite and muscovite can be found throughout each thin section sampled, but they constitute only a small percentage of the total groundmass. Point count work from six (6) thin sections (sample numbers 204685, 205411, 205412, 204413, 205414, 205415) show the following compositions in percent: quartz: 88.0; biotite 5.0; muscovite 3.0; feldspar 1.0; amphibole 1.0; opaques (hematite) 1.5; and chlorite 0.5. The results from two major oxide analyses of the Fairbanks schist are shown in Table 2. The geochemical data shows that the samples are mostly composed of silica, with virtually nothing else, except 1.38% iron oxide, in sample #205242. Both rock samples can be classified as impure quartzite.

### Structural Data

Structural data is limited to only a few outcrop areas. Individual localities will be summarized here. Foliation, which approximates compositional banding in most areas, is nearly horizontal in most outcrops but can dip either southeast or northwest a few degrees, depending on which limb of the fold axis the rock exposures occur. At stations #205410 and #205411 on VABM Luck, the two principle joint directions are north $55^o$ east, dipping $70^o$ southeast, and north $42^o$ west, dipping $80^o$ southwest. These high angle joint spaces maintain a wide average of about 24 inches for about 100 feet of the ridge top and 70 feet in a vertical direction, and then decrease in average widths to about 12 inches. Based on the wider zones, the VABM Luck area could conceivably produce class 3 and class 4 Riprap (Figure 5). While resource estimates cannot be calculated from the available data, the data do suggest riprap potential in the more massive, quartzite-rich sections of the Fairbanks schist, like the one found at VABM Luck.

Figure 5  A rare exposure of Fairbanks schist at station #205100

Figure 6  An outcrop of siliceous Fairbanks schist at station #205411, near VABM Luck, illustrating riprap potential

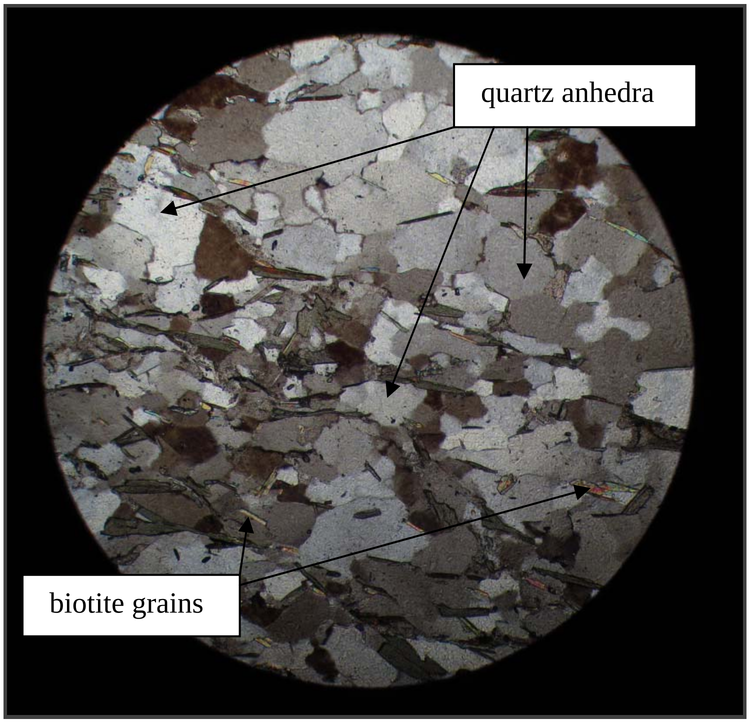


**Figure 7 Photomicrograph of Fairbanks schist-quartzite from station #204685, crossed nicols, 100X, showing interlocking, strained quartz anhedra and minor, isolated grains of biotite**

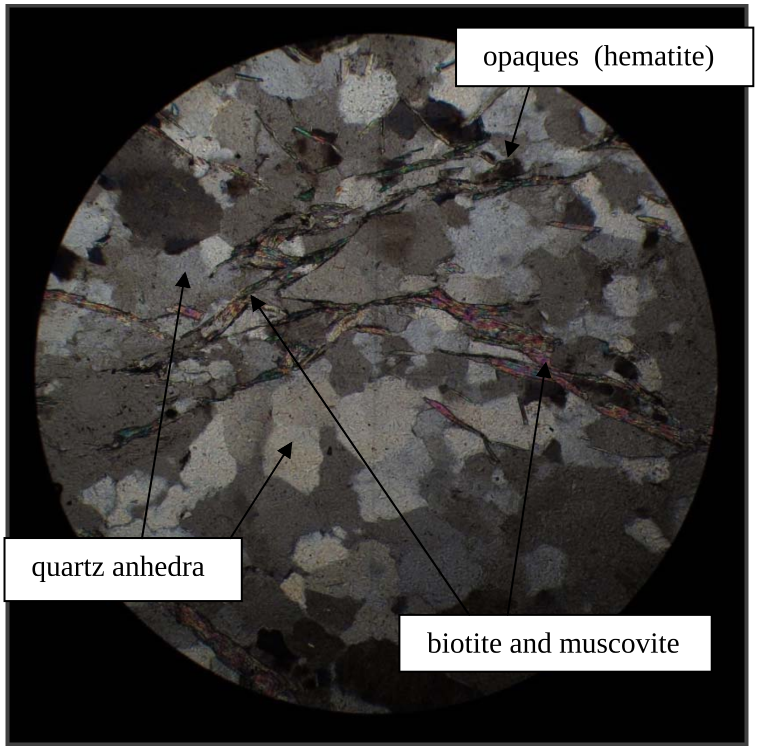


**Figure 8 Photomicrograph of Fairbanks schist-quartzite from station #205242, crossed nicols, 100X, showing interlocking, strained quartz anhedra with biotite and muscovite following structural zones, i.e., late cleavage**

**Table 2 Results of major oxide analyses, Fairbanks schist, Dunbar to Livengood rail corridor project(1)**

| Sample/ Station Location | #204685 | #205242 |
|---|---|---|
| **Field Rock Type** | **Muscovite quartzose schist** | **Micaceous quartzite** |
| **$SiO_2$ (%)** | 93.60 | 93.50 |
| **$Al_2O_3$ (%)** | 0.13 | 4.09 |
| **$Fe_2O_3$ (%)** | 0.97 | 1.38 |
| **CaO (%)** | 0.01 | 0.02 |
| **MgO (%)** | 0.01 | 0.10 |
| **$Na_2O$ (%)** | 0.01 | 0.02 |
| **$K_2O$ (%)** | 0.02 | 0.63 |
| **$Cr_2O_3$ (%)** | <0.01 | <0.01 |
| **$TiO_2$ (%)** | <0.01 | 0.11 |
| **MnO (%)** | 0.01 | 0.01 |
| **$P_2O_5$ (%)** | <0.01 | 0.02 |
| **SrO (%)** | <0.01 | <0.01 |
| **BaO (%)** | <0.01 | 0.02 |
| **LOI (%)** | 0.70 | 1.20 |
| **TOTAL (%)** | 95.50 | 101.00 |

(1)From ALS Minerals (see Appendix II)

**Table 3 Results of material analyses, Fairbanks schist, Dunbar to Livengood rail corridor project(1)**

| Sample No | Lab No. | Weight (kg) | Bulk Specific Gravity (SSD) | Bulk Specific Gravity (Dry) | Apparent Specific Gravity | Water Absorption (%) | Degradation Alaska Test Method T-13 (%) | Los Angeles Abrasion Loss (%) | Soundness Loss (%) |
|---|---|---|---|---|---|---|---|---|---|
| **204685** | **1603** | 16.5 | 2.657 | 2.646 | 2.675 | 0.40 | 91 | 28 | 0.19 |
| **205242** | **1368** | 18.0 | 2.588 | 2.555 | 2.644 | 1.30 | 44 | 32 | 0.89 |

(1) Analyses from MappaTest Labs, Inc., North Pole, Alaska

### Material Test Summary

Table 3 summarizes material test results from two samples. Sample #204685 had a high T-13 degradation value of 91 percent, a moderate Los Angeles abrasion loss value of 28 percent, and low sodium sulfate and water absorption values. In contrast were values from location #205242, which produced a T-13 degradation value of 44 percent, a Los Angeles abrasion loss value of 32 percent, and high water absorption and freeze/thaw soundness values. The former sample was from a nearly massive quartzite layer, and the latter sample was from a more micaceous, quartzose schist zone.

Past material investigations have been conducted in the Fairbanks schist by the Alaska Department of Transportation and Public Facilities (DOTPF), as well as by private concerns, for example, Doyon Limited. Chatwood and Shumway (1966) conducted material site investigations along the Elliott Highway from Olnes to Snowshoe Ridge, which is near the contact between the Fairbanks schist and the Grit units. From eight (8) pit sites, they obtained LA abrasions loss values ranging from 37 to 59, and averaging 48. Bulk specific gravity estimates from these pit sites ranged from 2.57 to 2.78, and averaged

2.67. No T-13 degradation or water absorption data was collected from these samples. Vournas and Chatwood (1967) investigated nine (9) material pits in Fairbanks schist lithologies in the Murphy Dome area. T-13 degradation values ranged from 20 to 88 percent, and averaged 46 percent, LA abrasion loss values ranged from 23 to 92 percent, and averaged 50 percent, bulk specific gravity values ranged from 2.39 to 2.94, and averaged 2.61.

## Grit Unit (CZwl, CZwa, CZw, Plate I)

### Field Observations

The PRGCI-UAF team established eleven (11) stations in the composited Grit unit (Plate I, Appendix I). Geological control of the Grit section is poor in both the rail corridor and in adjacent areas. Outcrop control improves toward the Elliott Highway, where the Grit unit was first described by Chapman and others (1971). Outcrops of the Grit units are nearly absent. Control was float encountered during traverses.

### Petrographic and Geochemical Summary

Samples from the Grit units are decidedly quartz-rich, and superficially similar to the quartz-rich units in the Fairbanks schist (Figures 9-12). The primary differences are that the Grit section contains variable amounts of green-to-maroon phyllite interbeds, which constitute up to 60 percent of outcrops where observed. Station #205418 exhibits features typical of the Grit section, where distinctly green, fissile, laminated, micaceous layers are interbedded with thin layers of meta-sandstone that have distinct feldspar clasts. Point count work from six thin sections (sample numbers 205415, 10GL103, 205430, 205439, 204692, 204691) yields the following compositions in percent: quartz: 82.0; feldspar 7.5; biotite 4.5; muscovite 2.0; amphibole 1.0; opaques (hematite) 1.5; and chlorite and epidote 1.5. The chief difference between the coarse, clastic sections of the Grit units versus those in the Fairbanks schist, is an appreciable increase in detrital feldspar grains, and a decrease in regional metamorphism in the former rock unit (Figures 11-12). The results from two major oxide analyses are shown in Table 4. Sample #204941 is very similar to the impure quartzite units observed in the Fairbanks schist. However, sample #204938 exhibits a more alumina-alkali chemistry, resulting from the addition of the feldspathic and alumina components observed in the Grit units in thin section during this investigation and elsewhere, (Chapman and others, 1971; Weber and others 1992).

### Structural Data

Very little structural data was collected from the Grit units during this study due to poor outcrop control. At sample site #205418, a parallel system of joints, striking north 70$^o$ east and dipping 70$^o$ northwest, cut the outcrops at a spacing of 4 inches or less. No riprap potential was observed at that station, or at any station in the Grit units during the 2010 field work.

**Figure 9 Massive sandstone Grit unit (float) at station #204938 in a burn area north of the Tatalina River**

**Figure 10 Wickersham Grit section at station #205418; note the friable maroon and green phylitic rocks**

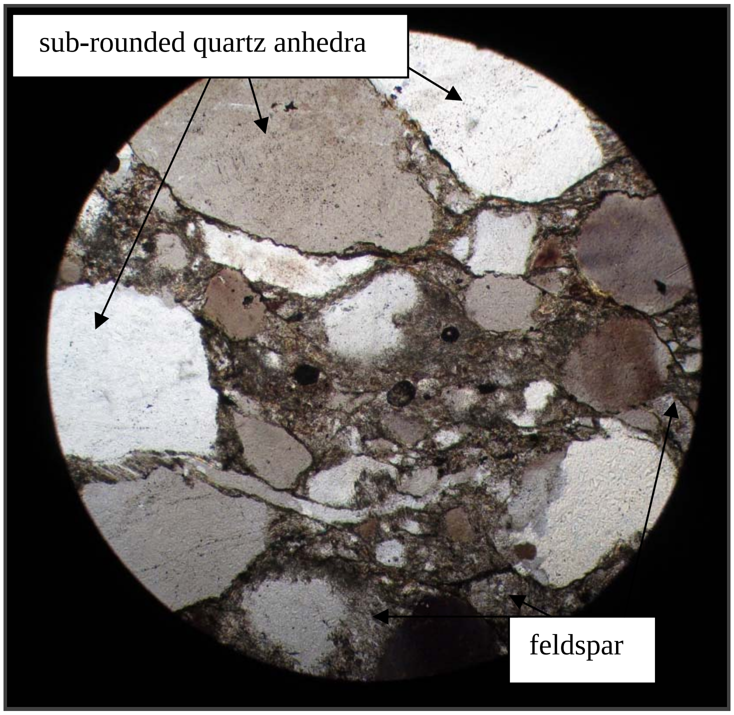


**Figure 11 Photomicrograph of the Grit unit from station #204941, crossed nicols, 100X, showing interlocking, strained quartz anhedra, feldspar grains, and fine grained meta-clasts**

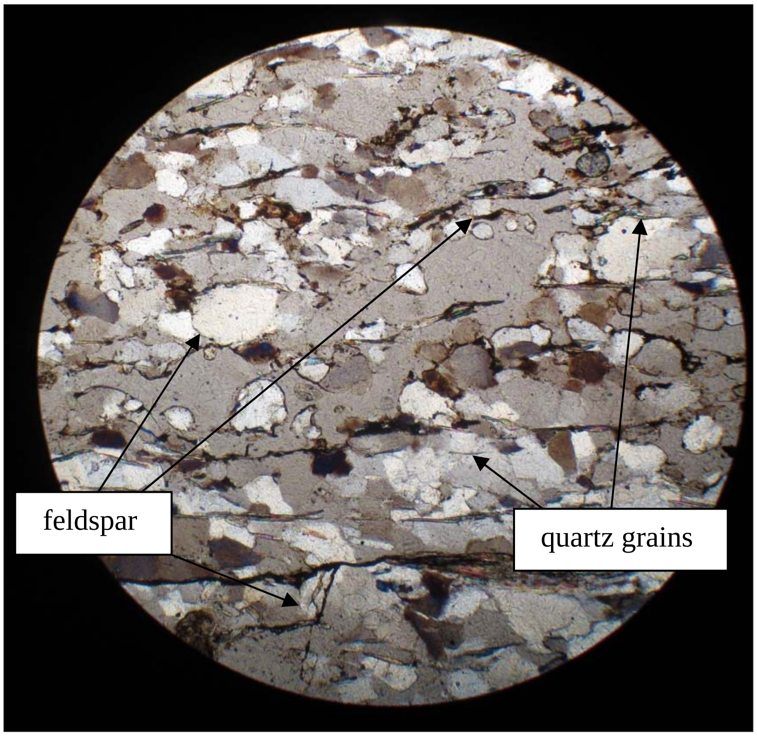


**Figure 12 Photomicrograph of the Grit unit from station #204938, crossed nicols, 100X, showing interlocking, strained quartz anhedra, small feldspar grains, and fine grained quartz meta-clasts; the overall texture is similar to that observed in the Fairbanks schist; note the sub-parallel fractures in the groundmass with accompanying alteration**

**Table 4 Results of major oxide analyses, Grit unit(s), Dunbar to Livengood rail corridor project**(1)

| Sample/ Station Location | #204941 | #204938 |
|---|---|---|
| **Field Rock Type** | **Meta-Sandstone** | **Phyllitic meta-sandstone** |
| **$SiO_2$ (%)** | 94.70 | 80.70 |
| **$Al_2O_3$ (%)** | 1.08 | 6.74 |
| **$Fe_2O_3$ (%)** | 0.97 | 4.19 |
| **CaO (%)** | 0.02 | 0.09 |
| **MgO (%)** | 0.02 | 0.71 |
| **$Na_2O$ (%)** | 0.01 | 0.67 |
| **$K_2O$ (%)** | 0.08 | 0.81 |
| **$Cr_2O_3$ (%)** | <0.01 | 0.01 |
| **$TiO_2$ (%)** | 0.14 | 0.32 |
| **MnO (%)** | 0.01 | 0.03 |
| **$P_2O_5$ (%)** | <0.01 | 0.02 |
| **SrO (%)** | <0.01 | <0.01 |
| **BaO (%)** | 0.01 | 0.04 |
| **LOI (%)** | 0.70 | 1.69 |
| **TOTAL (%)** | 97.70 | 96.00 |

**(1)** From ALS Minerals see Appendix II

**Table 5 Results of material analyses, Grit unit(s), Dunbar to Livengood rail corridor project**(1)

| Sample No. | Lab No. | Weight (kg) | Bulk Specific Gravity (SSD) | Bulk Specific Gravity (Dry) | Apparent Specific Gravity | Water Absorption (%) | Degradation Alaska Test Method T-13 (%) | Los Angeles Abrasion Loss (%) | Soundness Loss (%) |
|---|---|---|---|---|---|---|---|---|---|
| **204941** | **1605** | 20.5 | 2.592 | 2.565 | 2.635 | 1.04 | 65 | 35 | 0.42 |

(1)Analyses from Mappa Test Labs, Inc., North Pole, Alaska

### Material Test Summary

Table 5 summarizes the results of the material tests completed for a single sample from the Grit unit. Results are similar to those that were obtained with samples from the Fairbanks schist unit. Most localities of Grit examined were rejected as potential material site candidates, because of the incompetent nature of the sampled material. The single sample site from which collected rock was material tested might be capable of producing useable construction material. T-13 degradation values and Los Angeles abrasion values are both within acceptable limits, although a water absorption value of 1.04 percent is considered unacceptable. The material could not make ARRC mainline class 4 railroad ballast, but selected siliceous layers could produce aggregate for some use along the rail route.

DOTPF conducted material testing in the Grit unit along the Elliott Highway north of Wickersham Dome (Chatwood and Shumway, 1966). At one site near the Headwaters of Globe Creek (Mile 25.0), a sample of coarse sandstone in the Wickersham Grit unit yielded a Los Angeles abrasion loss value of 57 percent. A bulk specific gravity value from the same sample was 2.82.

## Tolovana Limestone Unit (Dtr)

### Field Observations

The Tolovana limestone is one of the most conspicuous and best exposed rock units in the proposed Dunbar to Livengood rail corridor. It forms locally rugged outcrops, sometimes barren of vegetation, on the south facing slopes of VABM Minto about midway along the rail route. However, there is a general lack of bedrock control of the Tolovana Limestone to the east of the corridor in the Tatalina River lowlands, as was observed by Bundtzen (1983) west of the Elliot Highway. Fourteen (14) stations were occupied over a strike length of approximately five miles.

### Petrographic and Geochemical Summary

Exposures of the Tolovana Limestone examined during this study consist of two recognizable facies that appear as the single unit Dtr.

- A fine grained, molted, laminated, light gray, recrystallized limestone that underlies the summit of VABM Minto exhibits a mostly aphanitic texture (Figure 13). It appears to be locally in fault contact with an underlying, more massive micritic limestone. This fine grained, laminated facies contains numerous crosscutting carbonate veins. In this facies, a distinctive orange lichen covers slopes and colluviums, and might serve as a mappable marker during more detailed work. This unit is estimated to be about 400 feet thick.

- Stratigraphically below the laminated limestone is a more massive, medium gray, micritic, recrystallized limestone, which makes up much of the lower slopes of VABM Minto (Figures 14-16. This more massive limestone variety contains fewer crosscutting carbonate veins, and is expressed in larger, more massive outcrops. The more massive micritic limestone unit is estimated to be about 550 feet thick.

Ten (10) thin sections of the Tolovana Limestone were examined (sample numbers 205433, 204951, 204950, 10GL105, 205346, 205345, 205443, 204959, 205370, 205369). Effectively, the two facies identified above were confirmed (Figures 17-18). The laminated, fine-grained lime-mud contains larger carbonate grains of clastic origin. The massive micritic facies is composed of entirely of calcite without other mineral grains.

Major oxide analyses of two Tolovana limestone samples are summarized in Table 6. Although sample numbers 204959 and 204951 represent the massive micritic and laminated faces respectively, both are very similar geochemically. They are composed of nearly pure calcium carbonate, virtually devoid of impurities. Calcium carbonate equivalent values of 101.66 and 100.89 (in percent) after Barksdale (2001) were obtained for samples 204959 and 204951, respectively. The senior writer (Bundtzen) is unaware of the existence of more pure limestone compositions elsewhere in Alaskan limestone terranes.

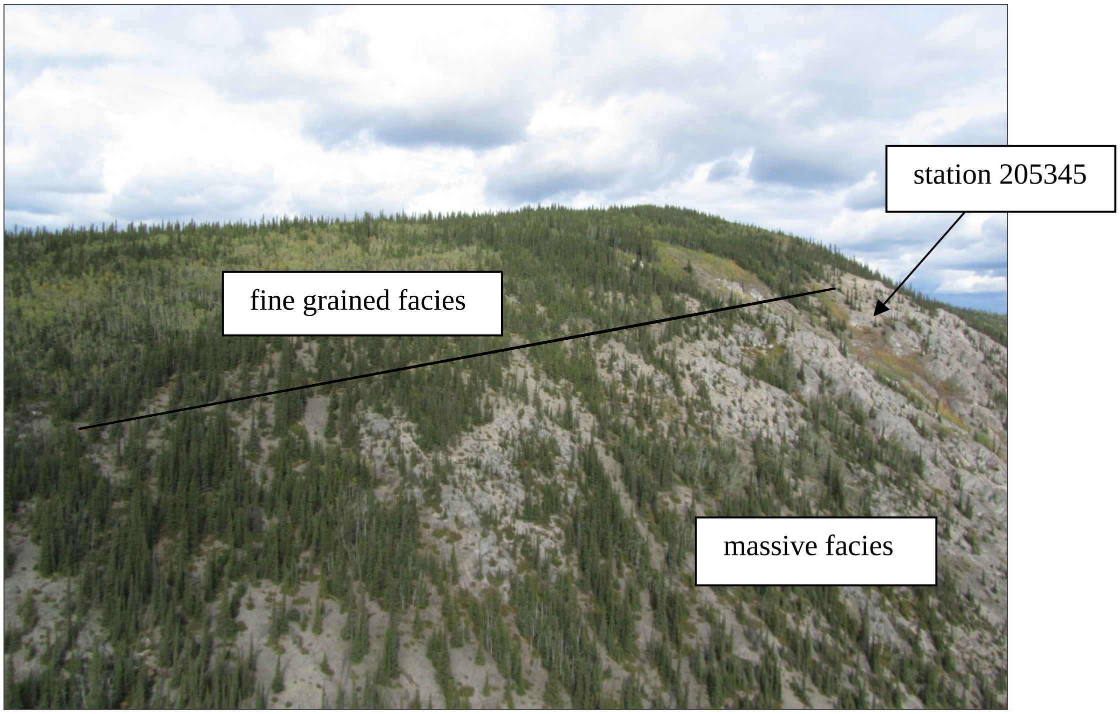


**Figure 13 The lower slopes of VABM Minto, illustrating the more massive facies of the Tolovana limestone**

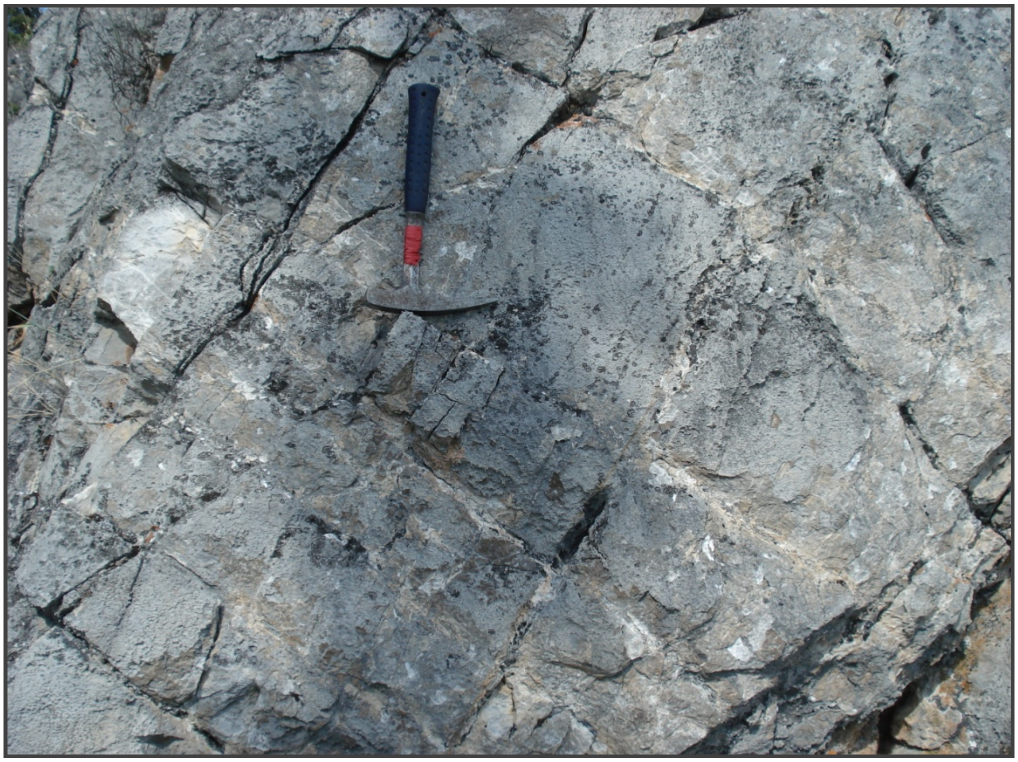


**Figure 14 The massive facies of the Tolovana limestone at station #204933 in the rail corridor**

**Figure 15 Peppi Bolz examines Tolovana limestone near the contact between the massive and fine grained facies at station #205929, south of VABM Minto**

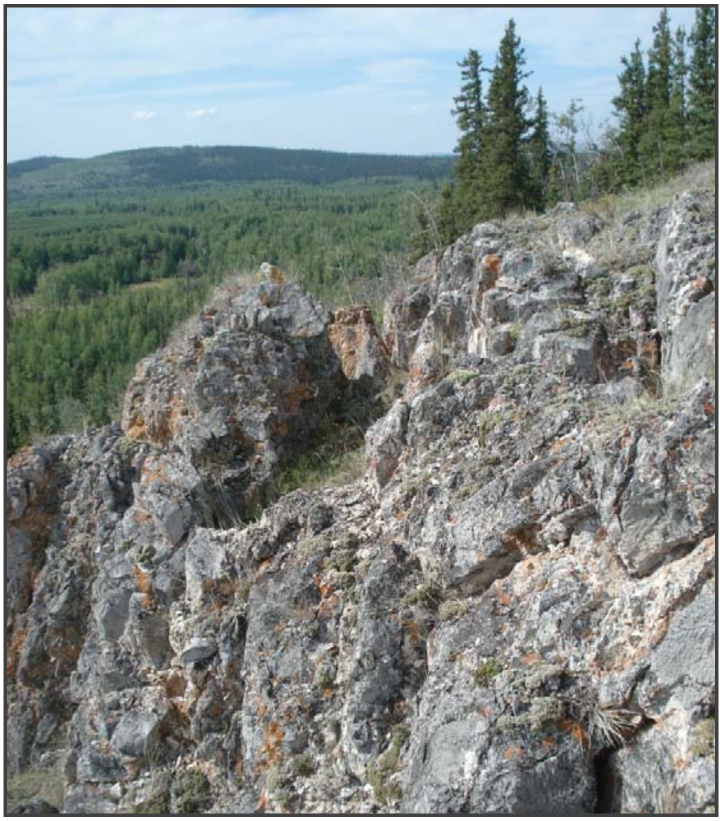


**Figure 16 Massive facies Tolovana limestone at station #205931**

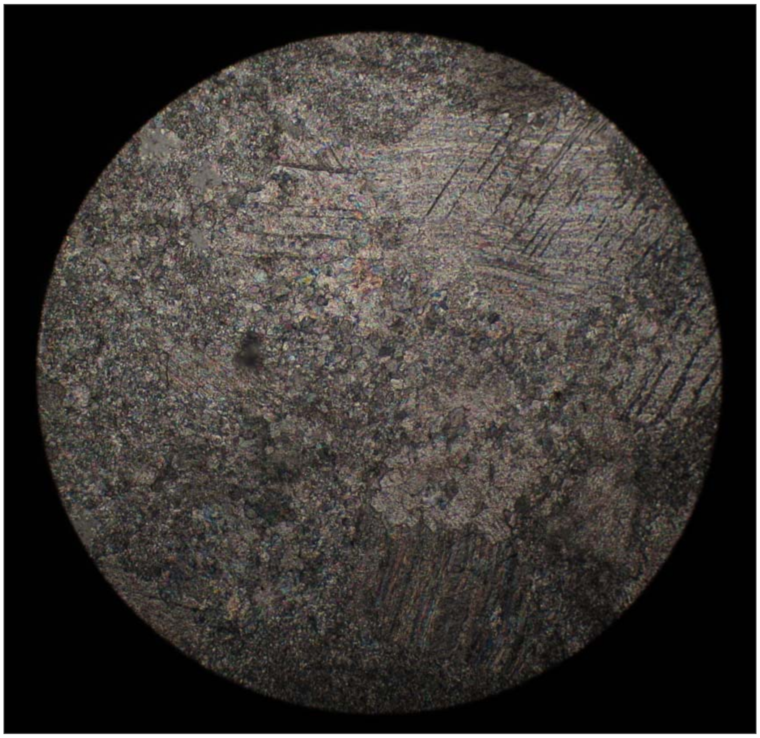


**Figure 17 Photomicrograph of Tolovana limestone from station #204959, south of VABM Minto , crossed nicols, 100X; shows massive micrite - essentially large, pure, carbonate grains, without any other mineral grains**

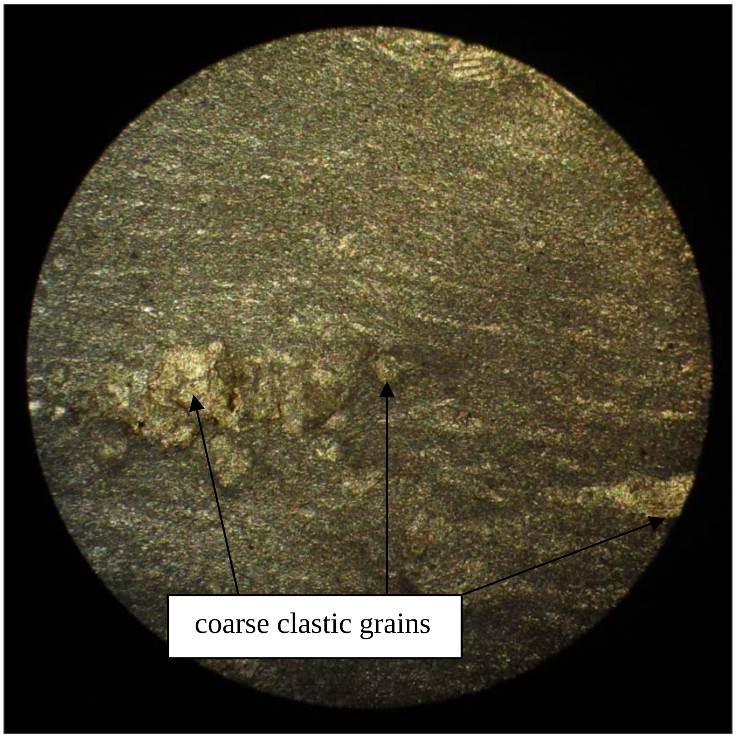


**Figure 18 Photomicrograph of the Tolovana limestone from station #204951, southwest of VABM Minto , crossed nicols, 100X; shows laminated, fine grained facies; note some of the coarse grains are of clastic origin**

**Table 6 Results of major oxide analyses, Tolovana limestone, Dunbar to Livengood rail corridor project(1)**

| Sample/ Station Location | #204959 | #204951 |
|---|---|---|
| **Field Rock Type** | **Massive micritic limestone** | **Fine grained laminated limestone** |
| **$SiO_2$ (%)** | <0.01 | <0.01 |
| **$Al_2O_3$ (%)** | 0.10 | 0.12 |
| **$Fe_2O_3$ (%)** | 0.07 | 0.09 |
| **CaO (%)** | 56.70 | 56.10 |
| **MgO (%)** | 0.30 | 0.42 |
| **$Na_2O$ (%)** | 0.02 | 0.02 |
| **$K_2O$ (%)** | 0.02 | 0.05 |
| **$Cr_2O_3$ (%)** | <0.01 | <0.01 |
| **$TiO_2$ (%)** | 0.01 | 0.01 |
| **MnO (%)** | <0.01 | <0.01 |
| **$P_2O_5$ (%)** | 0.06 | <0.01 |
| **SrO (%)** | 0.01 | 0.02 |
| **BaO (%)** | 0.01 | <0.01 |
| **LOI (%)** | 43.10 | 43.40 |
| **TOTAL (%)** | 100.00 | 100.50 |
| **Calcium Carbonate Equivalence (in percent)** | 101.66 | 100.89 |

(1)From ALS Minerals (see Appendix II)

**Table 7 Results of material analyses, Tolovana limestone, Dunbar to Livengood rail corridor project(1)**

| Sample No. | Lab No. | Weight (kg) | Bulk Specific Gravity (SSD) | Bulk Specific Gravity (Dry) | Apparent Specific Gravity | Water Absorption (%) | Degradation Alaska Test Method T-13 (%) | Los Angeles Abrasion Loss (%) | Soundness Loss (%) |
|---|---|---|---|---|---|---|---|---|---|
| **204959** | **1366** | 16.5 | 2.697 | 2.687 | 2.712 | 0.35 | 30 | 29 | 0.40 |
| **205268** | **1373** | 21.5 | 2.705 | 2.697 | 2.720 | 0.31 | 42 | 27 | 1.20 |

(1)Analyses from Mappa Test Labs, Inc., North Pole, Alaska

### Structural Data

Structural data was collected at several stations on VABM Minto. The fine grained laminated facies was too fractured to collect meaningful joint information. At station #205345, in the massive facies, two prominent joints that strike north 45° west dipping 80° southwest and north 55° east dipping 80° southeast define a conjugate stress field in a roughly 150 feet by 200 feet area. Joint spacing within this area varies from 10.0 inches to 18.0 inches, and averages about 12.0 inches. Although detailed mapping was not completed, PRGCI estimates that class 1 to 2 riprap potential does exist in the massive facies south of VABM Minto at station #205345, and probably at other localities as well.

### Material Test Summary

Table 7 summarizes material test results from two stations: massive micritic limestone, and laminated, fine-grained limestone, respectively. T-13 degradation values from both samples indicate that the limestone is marginal for base applications in road construction. Los Angeles abrasion loss values ranging from 27-29 percent suggest that neither sample would be suitable for class 4 railroad ballast. The fine grained lime mudstone has a high sodium sulfate soundness value. As previously suggested, the chief value of the Tolovana limestone is in its remarkably pure geochemical properties. In addition, some of the more massive micritic zones could conceivably yield class 1 and 2 riprap.

## Globe Quartzite Unit (Mgq)

### Field Observations

The Globe quartzite is one of the most interesting units that the PRGCI team examined during this study. It occurs as subtle exposures in low, hilly areas extending from the Elliot Highway southwestward through the Dunbar-Livengood Rail route and beyond. Bedrock control is subdued, vegetated, and found within a recently burned area (Figures 19-22). Fifteen (15) stations were occupied in the Globe quartzite unit during the 2010 field work.

### Petrographic and Geochemical Summary

Most of the exposures of the Globe quartzite were sufficiently fine grained that they could be mistaken for chert. However, upon inspection of thin sections (sample numbers 205367, 205371, 205433, 205432, and 205310), the Globe unit exhibits a granular, clastic sedimentary texture composed largely of tight, interlocking quartz anhedra, with very minor other mineralogical constituents (Figures 23-26). Quartzites are characterized by having no pore space (due to recrystallization), and instead have interlocking grain boundaries with triple junctions. No feldspars were recognized. Several grains of zircon were identified as detrital grains. One conspicuous feature seen in thin section is iron-oxide infilling fractures within the quartzite, which give outcrops an iron staining locally. The origin of the darker gray color in some quartzite exposures remains unknown.

Table 8 illustrates the very high silica content of the Globe quartzite. $SiO_2$ values range from 91.10 to 95.80 percent, and average 93.70 percent. Three samples approximate the minimum 95 percent $SiO_2$ needed for metallurgical grade silica. Additionally, the Loss on Ignition (LOI) values are low, and the Total values are low, suggesting that the $SiO_2$ content may be understated. Except for small amounts of iron and alumina, there are no impurities. Elevated zirconium, ranging from 240 to 348 ppm, and averaging about 300 ppm, occurs in the samples, and likely reflects the detrital zircon grains recognized in thin section.

### Structural Data

Very little structural data is available from any exposures of the Globe quartzite. Most exposures exhibit densely spaced, multi-directional fracture patterns, perhaps due to the brittle nature of the rock type reacting to failures caused by freeze and thaw cycles.

Figure 19  Greg Laird examines a subdued outcrop of Globe quartzite at station #205366, north of VABM Minto

Figure 20  Greg Laird examines a subdued, fractured outcrop of Globe quartzite at station #205367

Figure 21  Globe quartzite boulder at station #205432, northwest of the Tatalina River

Figure 22  Rubble crop of Globe quartzite at station #205433, about eight miles northeast of station #205432

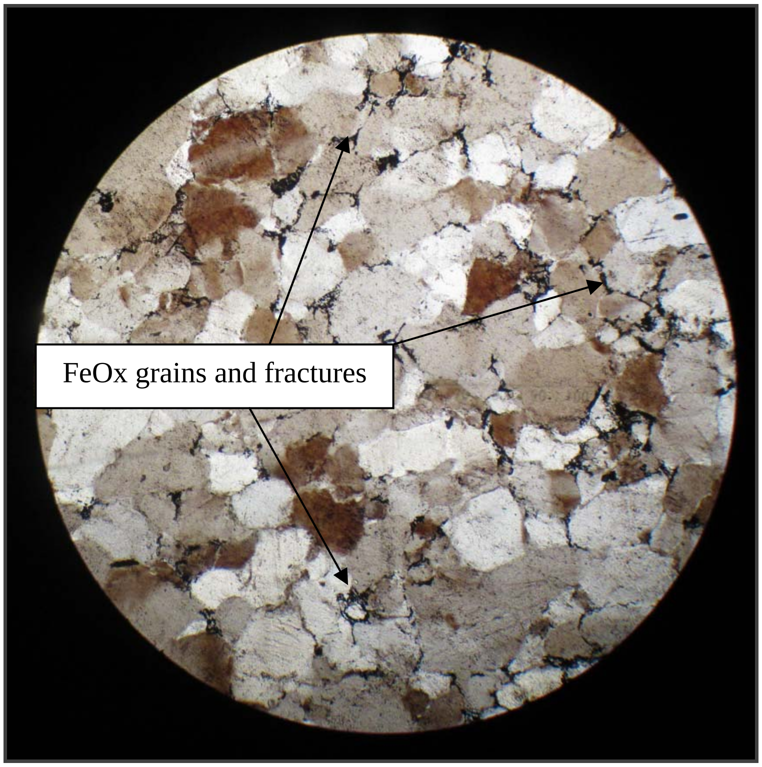


**Figure 23 Photomicrograph of Globe quartzite from station #205367, crossed nicols, 100X; shows interlocking quartz anhedra and minor FeOx along fracture boundaries**

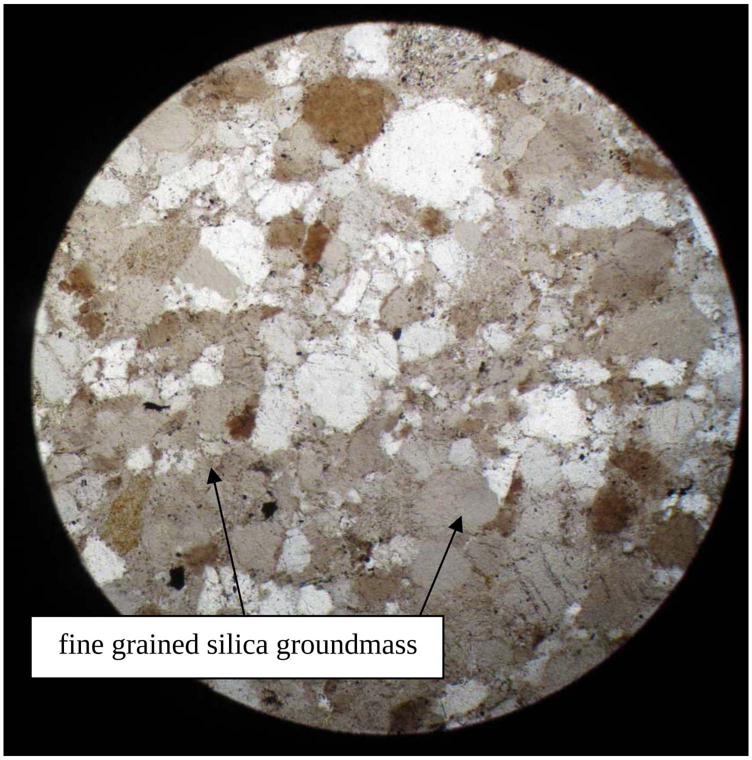


**Figure 24 Photomicrograph of Globe quartzite from station #205371, crossed nicols, 100X; shows interlocking quartz anhedra with a finer grained, siliceous groundmass**

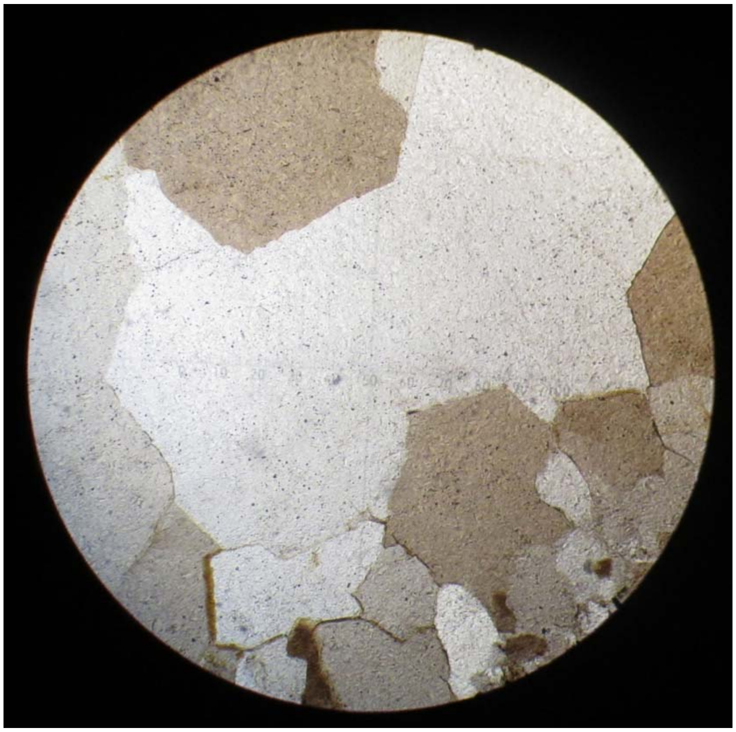


**Figure 25 Photomicrograph of Globe quartzite from station #205432, crossed nicols, 100X; shows unusually coarse-grained, interlocking quartz anhedra**

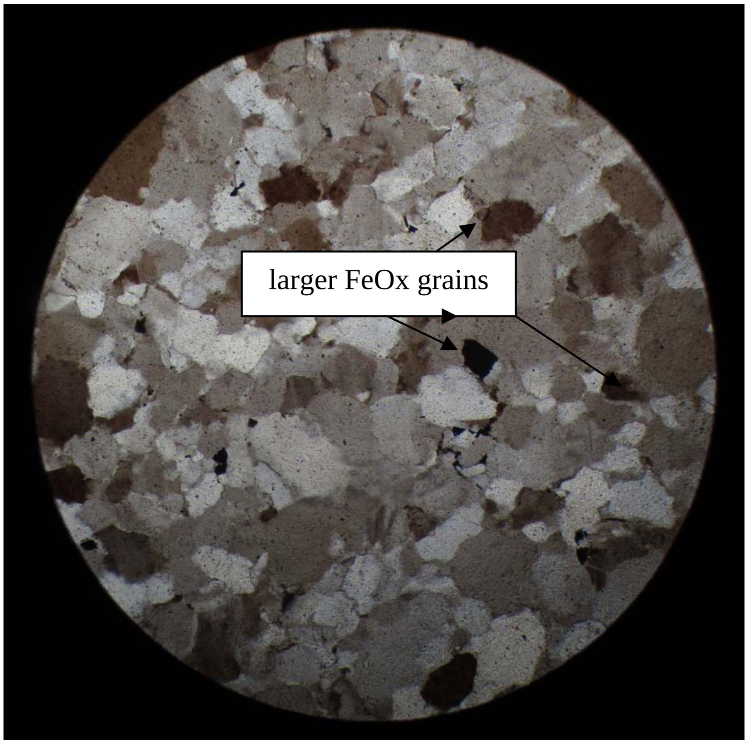


**Figure 26 Photomicrograph of Globe quartzite from station #205433, crossed nicols, 100X; shows interlocking quartz anhedra and large, isolated, opaque iron oxide grains**

**Table 8 Results of major oxide analyses, Globe quartzite, Dunbar to Livengood rail corridor project**(1)

| Sample/ Station Location | #205367 | #205371 | #205433 | #205432 | #205310 |
|---|---|---|---|---|---|
| **Field Rock Type** | **Quartzite conglomerate** | **Light gray quartzite** | **Light gray quartzite** | **Light gray quartzite** | **Fe-Stained quartzite** |
| **$SiO_2$ (%)** | 94.50 | 92.60 | 94.80 | 95.30 | 93.90 |
| **$Al_2O_3$ (%)** | 0.37 | 1.14 | 0.65 | 0.84 | 1.08 |
| **$Fe_2O_3$ (%)** | 2.12 | 0.81 | 0.77 | 0.99 | 1.58 |
| **CaO (%)** | 0.01 | 0.03 | <0.01 | 0.03 | 0.07 |
| **MgO (%)** | 0.01 | 0.03 | 0.02 | 0.03 | 0.03 |
| **$Na_2O$ (%)** | 0.01 | 0.03 | <0.01 | 0.02 | <0.01 |
| **$K_2O$ (%)** | 0.08 | 0.18 | 0.06 | 0.15 | 0.01 |
| **$Cr_2O_3$ (%)** | <0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| **$TiO_2$ (%)** | 0.08 | 0.16 | 0.18 | 0.17 | 0.17 |
| **MnO (%)** | 0.01 | 0.01 | 0.01 | 0.01 | 0.02 |
| **$P_2O_5$ (%)** | 0.10 | <0.01 | <0.01 | <0.01 | 0.07 |
| **SrO (%)** | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| **BaO (%)** | <0.01 | 0.02 | 0.01 | 0.01 | <0.01 |
| **LOI (%)** | 0.30 | 0.00 | 0.00 | 0.40 | 0.40 |
| **TOTAL (%)** | 97.60 | 95.00 | 96.50 | 98.00 | 97.30 |

(1)From ALS Minerals (see Appendix II)

**Table 9 Results of material analyses, Globe quartzite, Dunbar to Livengood rail corridor project**(1)

| Sample No. | Lab No. | Weight (kg) | Bulk Specific Gravity (SSD) | Bulk Specific Gravity (Dry) | Apparent Specific Gravity | Water Absorption (%) | Degradation Alaska Test Method T-13 (%) | Los Angeles Abrasion Loss (%) | Soundness Loss (%) |
|---|---|---|---|---|---|---|---|---|---|
| **204934** | **1604** | 17.5 | 2.604 | 2.585 | 2.634 | 0.72 | 90 | 23 | 0.12 |
| **205367** | **1382** | 21.0 | 2.629 | 2.619 | 2.646 | 0.38 | 95 | 23 | 0.17 |
| **205371** | **1608** | 24.5 | 2.560 | 2.534 | 2.603 | 1.05 | 82 | 20 | 0.65 |
| **205432** | **1376** | 23.0 | 2.634 | 2.623 | 2.651 | 0.40 | 95 | 18 | 0.29 |
| **205433** | **1375** | 18.0 | 2.637 | 2.528 | 2.651 | 0.33 | 95 | 19 | 0.27 |

(1)Analyses from Mappa Test Labs, Inc., North Pole, Alaska

### Material Test Summary

Table 9 summarizes the results of materials tests from five sample locations. The Globe quartzite yields very high T-13 degradation values (ranging from 82-95 percent, and averaging 91.4 percent), suggesting a wide variety of aggregate applications. More importantly, three out of five Los Angeles abrasion loss (in percent) values are 20 or less - sufficient to qualify for class 4 railroad ballast. In summary, the Globe quartzite could provide ARRC mainline class 4 railroad ballast, and could also be used to for other aggregate applications, but riprap potential is largely unknown. Sample stations #205432 and #205433 should be drill-tested or mechanically excavated.

## Mesozoic Gabbro Sills Unit (Trn)

### Field Observations

A narrow belt of gabbro sills intrudes the Globe quartzite section and the older units north of VABM Minto. By analogy with the Keno Hill quartzite, host rocks which were intruded by the sills are mostly the Mississippian Globe quartzite. But contact relationships with other units in the proposed Dunbar-Livengood rail corridor are poorly understood and subject to interpretation. This belt of sills strikes northeast to the Elliott Highway north of the Tolovana limestone. Most exposures of unit Trn were found in a recently burned area (Figure 27). The sills are ubiquitously marked by brownish-tan exposures in outcrop, rubble, and float. Twelve (12) stations were occupied in the gabbro sill unit (Trn).

### Petrographic and Geochemical Summary

Several textural variants of gabbro were identified during thin section examination, including: 1) poikilophitic gabbro; 2) labradorite-diallage (bronze clinopyroxene) gabbro; and 3) medium grained olivine gabbro (Figures 28-31). In most cases, clinopyroxene, namely augite is the dominant mafic mineral, but hornblende was identified in two thin sections, and olivine, largely altered to iddingsite, was also identified in two thin sections. All thin sections show fairly well developed alteration of original melt minerals, and original calcic plagioclase has been albitized.

Table 10 summarizes the results of major oxide and selected trace element analyses from four samples of the Trn unit. All samples are geochemically gabbro, and show significant iron enrichment, a moderate magnesia content, high titanium, and moderate alumina, all characteristic of tholeiites. All samples are enriched in sodium, and one sample, #205372 with 4.76 percent $Na_2O$, appears to be spilitized. The samples are also somewhat enriched in chromium, nickel, cobalt, and, locally, copper. The iron content is exceptionally high, averaging 12.84 percent, and probably relates back to the rocks' distinctive, tannish oxidation surfaces observed in outcrop.

### Structural Data

Structural data was obtained from a few outcrops, where high angle joints cut up the rock into tightly spaced orthogonal shapes. No large riprap potential was identified, but potential for classes 1 and 2 riprap exists.

### Material Test Summary

Table 11 summarizes the results of material tests conducted on samples from four stations. Despite obvious hydrothermal and deuteric alteration, the gabbro suite from unit Trn performed well during the Mappa material testing. Three samples are from within the proposed rail corridor, but one sample, #205372, is from the Elliott Highway. The three samples from the proposed rail corridor have an average apparent specific gravity of 3.040, water absorption values averaging about 1.00 percent, T-13 degradation values averaging 69 percent, and, most importantly, Los Angeles abrasion loss values averaging 14.6 percent, the lowest average abrasion loss values of any rock type tested during this study. All three samples from the proposed corridor meet or exceed most of the class 4 railroad ballast specifications, but exceed the maximum allowed water absorption limit.

**Figure 27 An outcrop of pyroxene gabbro at station #204960, illustrating joint and fracture arrangement, northwest of VABM Minto**

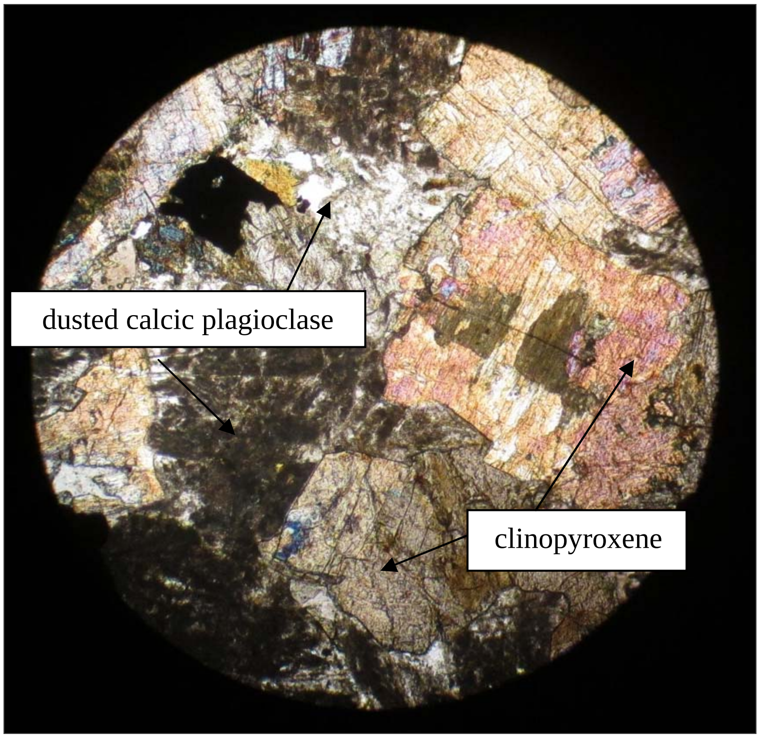


**Figure 28 Photomicrograph of a gabbro sill complex (unit Trn) at station #204960, crossed nicols, 100X; shows large clinopyroxene grains altering to leucoxene, calcic-plagioclase, and opaques in hypidiomorphic texture**

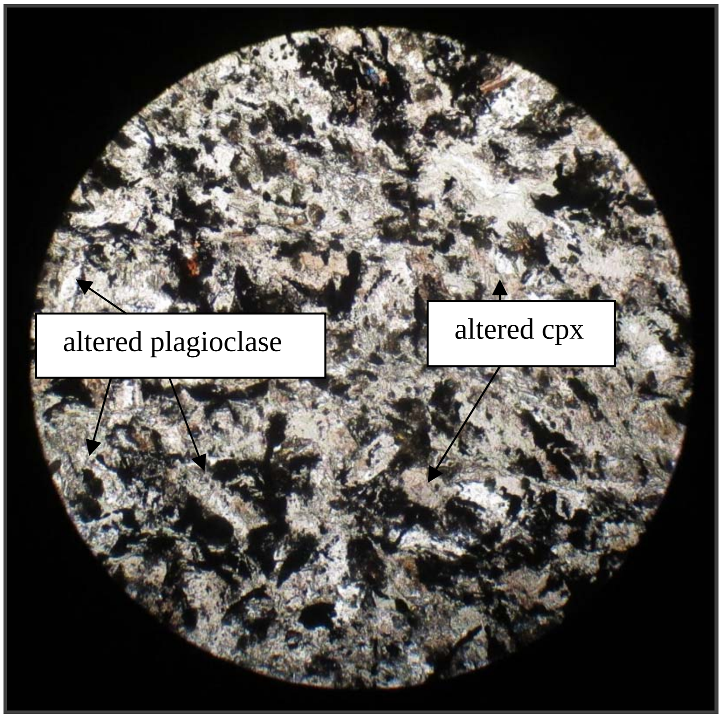


**Figure 29  Photomicrograph of a gabbro sill complex (unit Trn) at station #205372, crossed nicols, 100X; near the Elliott Highway; shows clinopyroxene grains largely altered to antigorite, calcic-plagioclase altered to albite, chlorite, and carbonate, and abundant opaques after amphibole?**

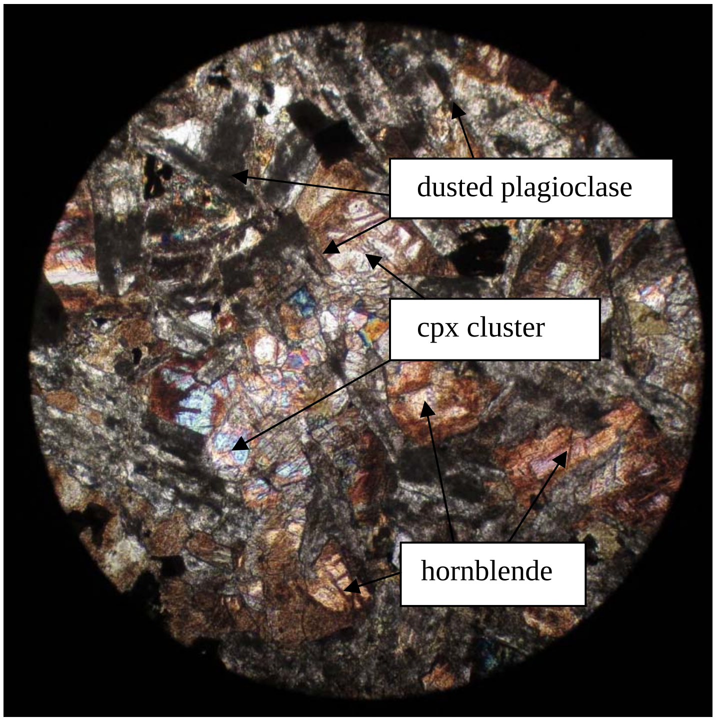


**Figure 30  Photomicrograph of a gabbro sill complex (unit Trn) at station #205308, crossed nicols, 100X; shows both clinopyroxene and hornblende grains largely altered to antigorite, calcic-plagioclase (An57) altered to albite, chlorite, and carbonate, and opaque minerals now mainly iron oxides and leucoxene**

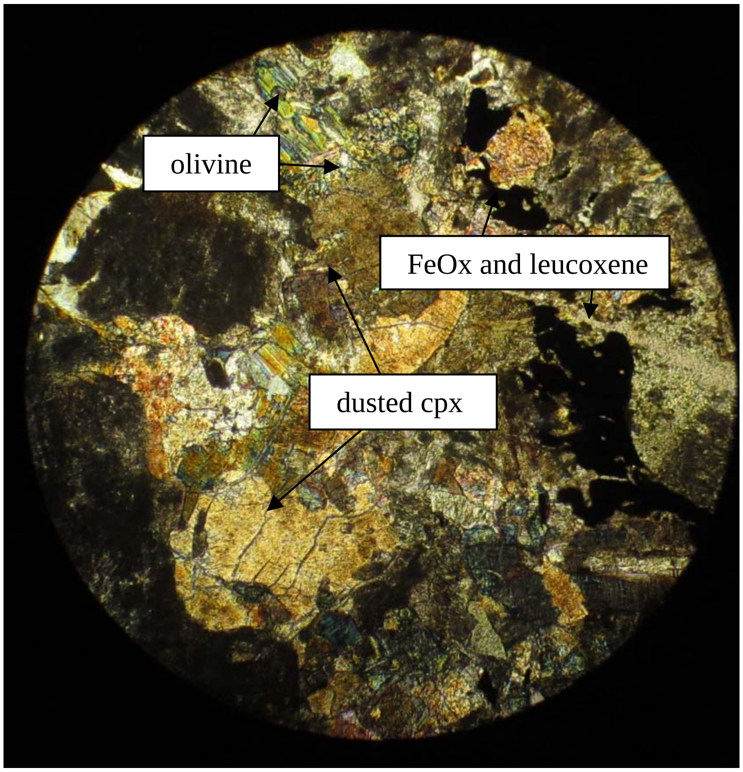


**Figure 31 Photomicrograph of a gabbro sill complex (unit Trn) at station #205311, crossed nicols, 100X; shows both clinopyroxene grains largely altered to antigorite, small olivine grains altered to iddingsite, calcic-plagioclase altered to albite and chlorite and carbonate, and opaque minerals now mainly iron oxides and leucoxene**

**Table 10 Results of major oxide analyses, gabbro sill complex unit (Trn), Dunbar to Livengood rail corridor project(1)**

| Sample/ Station Location | #205372 | #205311 | #204960 | #205308 |
|---|---|---|---|---|
| **Field Rock Type** | **Pyroxene Gabbro** | **Pyroxene Gabbro** | **Pyroxene Gabbro** | **Hornblende pyroxene gabbro** |
| **$SiO_2$ (%)** | 48.50 | 47.10 | 48.00 | 46.30 |
| **$Al_2O_3$ (%)** | 13.95 | 15.55 | 13.25 | 13.50 |
| **$Fe_2O_3$ (%)** | 12.05 | 12.45 | 14.40 | 12.45 |
| **CaO (%)** | 5.88 | 10.95 | 9.96 | 9.63 |
| **MgO (%)** | 5.82 | 5.81 | 5.38 | 6.06 |
| **$Na_2O$ (%)** | 4.76 | 2.62 | 2.29 | 2.61 |
| **$K_2O$ (%)** | 0.65 | 0.30 | 0.45 | 0.26 |
| **$Cr_2O_3$ (%)** | 0.05 | 0.02 | <0.01 | 0.03 |
| **$TiO_2$ (%)** | 2.35 | 1.64 | 2.42 | 1.95 |
| **MnO (%)** | 0.13 | 0.19 | 0.21 | 0.20 |
| **$P_2O_5$ (%)** | 0.25 | 0.14 | 0.18 | 0.17 |
| **SrO (%)** | 0.08 | 0.03 | 0.05 | 0.03 |
| **BaO (%)** | 0.08 | 0.02 | 0.16 | 0.15 |
| **LOI (%)** | 3.53 | 2.10 | 1.39 | 3.37 |
| **TOTAL (%)** | 98.10 | 98.90 | 98.10 | 96.70 |
| **Cr (ppm)** | 350 | 160 | 30 | 230 |
| **Ni (ppm)** | 274 | 83 | 51 | 82 |
| **Co (ppm)** | 55.0 | 46.0 | 47.8 | 44.8 |
| **Cu (ppm)** | 41 | 190 | 225 | 163 |
| **V (ppm)** | 164 | 369 | 427 | 392 |

(1)From ALS Minerals (see Appendix II)

**Table 11 Results of material analyses, gabbro-diorite sill complex unit (Trn), Dunbar to Livengood rail corridor project(1)**

| Sample No. | Lab No. | Weight (kg) | Bulk Specific Gravity (SSD) | Bulk Specific Gravity (Dry) | Apparent Specific Gravity | Water Absorption (%) | Degradation Alaska Test Method T-13 (%) | Los Angeles Abrasion Loss (%) | Soundness Loss (%) |
|---|---|---|---|---|---|---|---|---|---|
| **204960** | **1367** | 19.0 | 2.970 | 2.923 | 3.069 | 1.63 | 77 | 16 | 0.18 |
| **205308** | **1606** | 22.0 | 2.981 | 2.960 | 3.024 | 0.72 | 61 | 15 | 1.00 |
| **205311** | **1377** | 19.5 | 2.998 | 2.978 | 3.038 | 0.67 | 70 | 13 | 0.65 |
| **205372** | **1609** | 25.0 | 2.871 | 2,856 | 2.899 | 0.51 | 20 | 22 | 0.94 |

(1)Analyses from Mappa Test Labs, Inc., North Pole, Alaska

## Wilbur Creek Flysch Unit (Kwcf) and Thermally Altered Flysch (Hornfels)

### Field Observations

Sixty one (61), or more than 32 percent, of the stations occupied during this investigation were in the Wilbur Creek flysch unit. The Wilbur Creek flysch underlies approximately 35 percent of the proposed Dunbar to Livengood rail corridor. Most of the unit is covered in vegetation, and control was achieved through digging shallow pits on the tops of bluffs. Some exposures were found in mineral exploration trenches near Shorty Creek, along the Alyeska Pipeline corridor, and in road cuts (Figures 32-34).

### Petrographic and Geochemical Summary

Thin section examination focused mainly on coarse sandstones, conglomerates (Figures 35-36), and hornfels (Figure 37), because it was from these units that materials sites have previously been selected, and clast size was large enough to determine mineralogical provenance. Coarse, clastic lithologies show the immature nature of the sandstones (Figures 35, 36). Strong volcaniclastic provenance is apparent in most of the sandstones. As has been reported by previous work, Weber and others (1992), clasts of ultramafic rocks suggests that local units, such as the Livengood ophiolite, were contributing material to the Wilbur Creek flysch. Thermally altered Wilbur Creek flysch (hornfels) has mineralogical compositions indistinguishable from unaltered units. However, a distinctive re-crystallization has taken place, thus providing a more durable petro-fabric.

Table 12 summarizes the chemical components of two flysch samples and two hornfels samples. All of the rocks contain moderate iron content, high alumina content, and a mix of alkalis and magnesium - all typical of turbidite settings. In addition, some slight enrichment in chromium, nickel, and cobalt suggest the ultramafic clast component previously described. Sample #205319 tested the hornfels found at Tolovana Hot Springs Dome. The other hornfels samples are from the Shorty Creek area. Hornfels sample #205315, from a locality near the Trans Alaska Pipeline, contained 156 ppm tungsten , 87 ppm lead, 28 ppm tin, 8 ppm molybdenum, and 5 ppm silver, indicating the effects of hydrothermal alteration.

### Structural Data

Exposures of the Wilbur Creek flysch are very poor, and the only structural information was derived from hornfels caps and road cuts east of the proposed corridor. At stations #205419 and #205420, several high angle joint sets were identified, including: 1) north 45° east strike, dipping vertically; 2) N-S strike, dipping 80° west; and 3) north 22° west strike, dipping 70° southwest. Spacing ranged from 8 inches to 4 feet, and some large riprap potential was recognized.

In contrast are the structural complexities observed in road cuts along the Elliott Highway. There, the Wilbur Creek flysch is complexly isoclinally folded, with inter-beds of siltstone and argillite largely sheared and penciled out. No potential for riprap of any size was recognized at these locations.

**Figure 32  The massive facies of the Wilbur Creek flysch at station #205419; the flysch shows the effects of hornfels - note the joints**

**Figure 33  The thin bedded facies of the Wilbur Creek flysch at station #205418 - note the fold deformation**

**Figure 34  Peppi Bolz digging for bedrock control for the Wilbur Creek flysch unit (Kwsf) at station #205328 - a typical exposure for this unit**

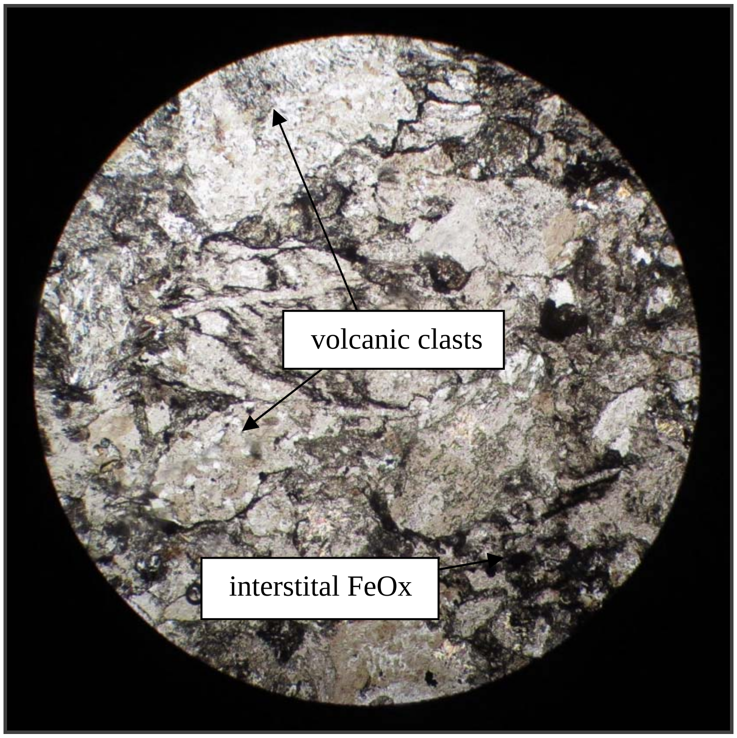


**Figure 35  Photomicrograph of coarse grained Wilbur Creek flysch unit (Kwcf) from station #205324, plane light, 100X; shows the immature groundmass typical of the lithic sandstones of this unit; note the volcanic clasts**

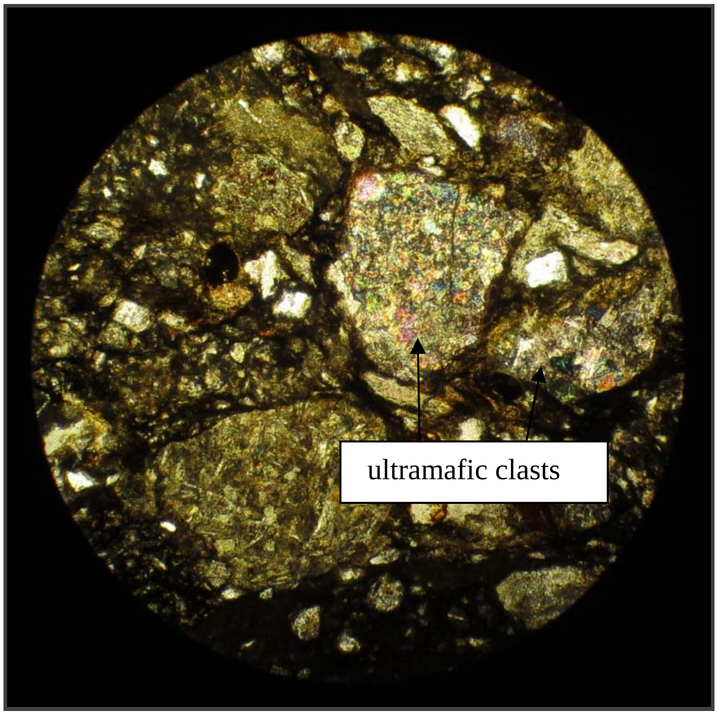


**Figure 36 Photomicrograph of coarse grained Wilbur Creek flysch unit (Kwcf) from station #205421, crossed nicols, 100X; shows the immature groundmass typical of the lithic sandstones of this unit; note the clasts of ultramafic rock - probably derived from the Cambrian ophiolite unit; this sight also shows the effects of thermal metamorphism (hornfels)**

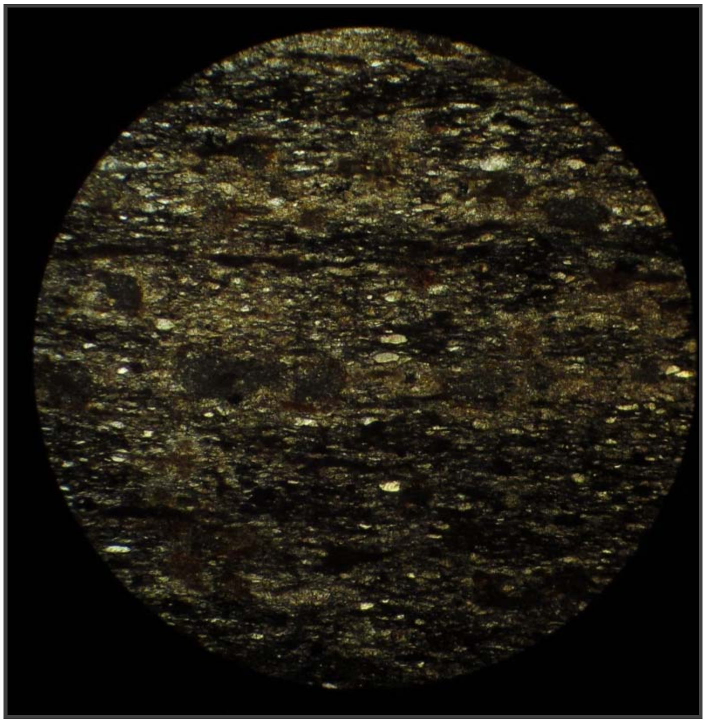


**Figure 37 Photomicrograph of hornfels from the Wilbur Creek flysch unit (Kwcf) from station #205319, crossed nicols, 100X; shows the fine grained, 'welded' groundmass typical of this unit**

**Table 12 Results of major oxide analyses, Wilbur Creek flysch unit (Kwcf) and hornfels, Dunbar to Livengood rail corridor project[(1)]**

| Sample/Station Location | #205324 | #205421 | #205315 | #205319 |
|---|---|---|---|---|
| **Field Rock Type** | **Conglomerate** | **Conglomerate** | **Hornfels Pipeline** | **Hornfels Tolovana H.S.** |
| **$SiO_2$ (%)** | 60.70 | 57.60 | 63.40 | 55.30 |
| **$Al_2O_3$ (%)** | 14.35 | 15.45 | 11.90 | 19.00 |
| **$Fe_2O_3$ (%)** | 7.39 | 8.55 | 3.17 | 8.85 |
| **CaO (%)** | 4.12 | 2.61 | 0.09 | 1.92 |
| **MgO (%)** | 3.12 | 3.52 | 1.56 | 3.86 |
| **$Na_2O$ (%)** | 3.92 | 3.98 | 0.33 | 2.38 |
| **$K_2O$ (%)** | 1.01 | 1.34 | 2.50 | 3.95 |
| **$Cr_2O_3$ (%)** | 0.02 | 0.02 | 0.02 | 0.03 |
| **$TiO_2$ (%)** | 0.82 | 0.94 | 0.64 | 1.09 |
| **MnO (%)** | 0.18 | 0.20 | 0.01 | 0.16 |
| **$P_2O_5$ (%)** | 0.19 | 0.24 | 0.17 | 0.34 |
| **SrO (%)** | 0.03 | 0.02 | 0.01 | 0.03 |
| **BaO (%)** | 0.05 | 0.10 | 0.02 | 0.15 |
| **LOI (%)** | 2.57 | 3.78 | 2.87 | 0.00 |
| **TOTAL (%)** | 98.50 | 98.40 | 86.70 | 97.00 |

**(1)**From ALS Minerals (see Appendix II)

**Table 13 Results of material analyses, Wilbur Creek flysch unit (Kwcf) and hornfels, Dunbar to Livengood rail corridor project[(1)]**

| Sample No. | Lab No. | Weight (kg) | Bulk Specific Gravity (SSD) | Bulk Specific Gravity (Dry) | Apparent Specific Gravity | Water Absorption (%) | Degradation Alaska Test Method T-13 (%) | Los Angeles Abrasion Loss (%) | Soundness Loss (%) |
|---|---|---|---|---|---|---|---|---|---|
| **205421** | **1610** | 21.0 | 2.705 | 2.672 | 2.763 | 1.24 | 48 | 22 | 0.25 |
| **205420** | **1374** | 23.0 | 2.702 | 2.657 | 2.781 | 1.59 | 95 | 17 | 0.37 |
| **205324** | **1607** | 18.0 | 2.769 | 2.757 | 2.790 | 0.43 | 74 | 14 | 0.40 |
| **205315** | **1378** | 18.0 | 2.614 | 2.576 | 2.677 | 1.47 | 91 | 22 | 0.10 |
| **205319** | **1379** | 19.0 | 2.704 | 2.687 | 2.733 | 0.62 | 90 | 15 | 0.62 |

(1)Analyses from Mappa Test Labs, Inc., North Pole, Alaska

### Material Test Summary

The results of materials testing upon two sandstone samples and three hornfels samples from the Wilbur Creek flysch are shown in Table 13. The samples averaged 2.705 specific gravity, 1.07 percent water absorption, 79 percent T-13 degradation, and 18 percent Los Angeles abrasion loss, with the hornfels samples performing the best. The vast majority of the Wilbur Creek flysch exposures were found to be unsuitable for material studies, and were not submitted for laboratory testing. Laboratory tests from sample #205421 best typifies the reality of the Wilbur Creek flysch unit's physical characteristics, that sample being a selected coarse grained variant. Flysch without thermal effects has excessive water absorption values averaging 1.37 percent. The hornfels aureoles sampled are part of a mineralized prospect area currently under exploration by the private sector.

Weaver and Vournas (1968) tested the Wilbur Creek flysch at two sites near the Tolovana River Bridge on the Elliott Highway.  They reported T-13 degradation values averaging 33 percent, LA abrasion loss values ranging from 22 to 32, and water absorption values of 1.10 and 2.06 percent respectively.  Bulk specific gravity averaged 2.69.

## Cascaden Formation Unit (Dcb)

### Field Observations

Outcrops of the Cascaden Formation occur along the Elliott Highway near Livengood for a distance of about 4 miles. Intertwined with the sedimentary stratigraphy are intrusive components of the Livengood ophiolite unit. The Cascaden Formation is chiefly rhythmically interbedded, gray to olive gray, shale, gray siltstone, and sub-lithic sandstone. Less abundant components observed in the road cut exposures are gray limestone and polymictic pebble conglomerate (Figure 38). Three stations were occupied in the Cascaden Formation during the 2010 field program.

### Petrographic and Geochemical Summary

Through completion of field point-count data at stations #205373, #205351 and #205352, conglomeratic clasts in the Cascaden Formation include intra-formational shale and sandstone (50%), mafic-ultramafic rocks (25%), chert (10%), dolomite (10-15%), and limestone (10%). Limestone lenses are frequently fossilferous, and contain Middle Devonian pelecypods, gastropods, bryzoans, tantaculids, trilobites, algae, corals, conodonts, brachiopods and plant fragments (Figure 39). Most of the fossils are found in calcareous debris flows. Weber and others (1985) believe that the Cascaden Formation represents the onset of a turbidite depositional environment, and is similar to the possibly correlative Nation River Formation near Eagle. No major oxide or trace element geochemical analyses were obtained from the Cascaden Formation during this investigation.

### Structural Data

Isolated knobs of calcareous sandstone at stations #205351, #205352 and #205373, exhibit wide joint spacing averaging 25 inches, suggesting riprap potential. The chief limitation in assessing potential riprap possibilities is the size of the rock exposures. The maximum outcrop area from which a riprap potential could be ascertained is 40 feet by 30 feet.

### Material Test Summary

The PRGCI team did not submit a sample of Cascaden Formation for material testing. Slater and Misterek (1978) tested rock from one site in the Cascaden Ridge Formation (at Mile 57.8 of the Elliott Highway) during a DOTPF materials study. The DOTPF study reported the following values from the Cascaden Ridge Formation: 24.0 percent Los Angeles abrasion loss with a specific gravity of 2.74. T-13 degradation, water absorption, and sodium sulfate values were not obtained from the Cascaden Formation during the State study. The LA abrasion loss value exceeds the maximum allowed for the development of class 4 railroad ballast. According to Slater and Misterek (1978), *“this site will not provide suitable materials for road construction purposes”*.

**Figure 38 A boulder of coarse grained sandstone-conglomerate from the Cascaden Ridge Formation at Cascaden Ridge, near Mile 57.9 of the Elliott Highway**

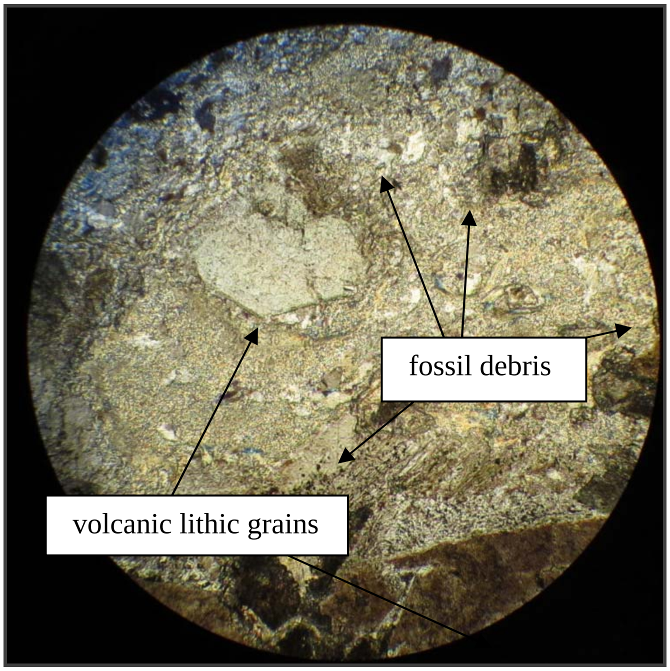


**Figure 39 Photomicrograph of tuffaceous sandstone from the Cascaden Formation (Dcb) at station #205373, crossed nicols, 100X; shows large volcanic grains and fossil fragments (shell debris)**

## Livengood Ophiolite Unit (MzZum)

### Field Observations

A structurally complex rock package that contains: 1) altered ultramafic rocks - chiefly serpentenite after harzburgite; 2) diabase sills; 3) black chert; and 4) basaltic flows. Many past workers, including PRGCI geologists, believe this assemblage of rocks represents a dismembered ophiolite. According to Bundtzen (1983) *"the diorite, gabbro, and greenstone appear to represent a hypabyssal suite characterized by initial multiple intrusion and subsequent tectonic dismemberment"*. Studies by Reifenstuhl and others (1992) in the adjacent Tanana quadrangle yielded Ar/Ar ages ranging from 465-536 Ma for the Livengood ophiolite. Most of the contacts with adjacent rock units (the Cascaden Formation, the Livengood Dome chert, and the Amy Creek unit) appear to be fault zones. Even the contacts between different members of the Livengood ophiolite appear to be structural in nature. The exposures in the proposed rail corridor are but a small part of a 150 mile long belt extending from Serpentine Ridge in the Tanana quadrangle, northeast to the edge of the Yukon Flats. Exposures range from rubble in saddles to outcrops along ridge tops and in road cuts. Four (4) stations were occupied in the Livengood ophiolite unit during the 2010 field investigations.

### Petrographic and Geochemical Summary

Rocks studied in the proposed rail corridor were dominantly serpentenized harzburgite, and gabbro-diorite intrusions: variety diabase sills (Figure 40). Gabbros consist of clinopyroxene-bearing, plagioclase-dominant igneous rocks. Micro-fractures in the groundmass are common. Small grains of olivine are present in the calcic-dominant groundmass (Figures 41, 42). Despite their age, the original igneous fabric is completely preserved, although all of the original mineralogy has been transformed into alteration products.

At station #205442, serpentenized harzburgite(?) was sampled, and found to contain 39.20 percent $SiO_2$, more than 35 percent MgO, 2,540 ppm chromium, and 2,150 ppm nickel, attesting to its ultamafic parentage (Table 14). Sample #206262 is more typical of gabbroic melts, with moderate magnesia, iron, and calcium content. With 4.70 percent $Na_2O$, sample #205262 appears to have undergone spilitic alteration.

### Structural Data

Structural data collection was confined to a few localities. At station #205421 and #205442, both located just west of an Alyeska Pipeline camp, joints cut a diabase sill complex at strikes of north $55^o$ east and north $45^o$ west, with dips for both being essentially vertical. There, large blocks up to 10 feet in equi-dimension seem to indicate the potential for large riprap (classes 3 and 4).

In contrast, no outcrop exposures were found in areas underlain by serpentenite, chert and basalt. Instead, only rubble crop and float were visible for these latter lithologies. In general, the best rock size seems to be associated with diabase or gabbroic sills.

**Figure 40 An iron stained diabase sill at station #205442 in the Livengood ophiolite section, illustrating the relative freshness of these exposures in a serpentenite-dominant unit**

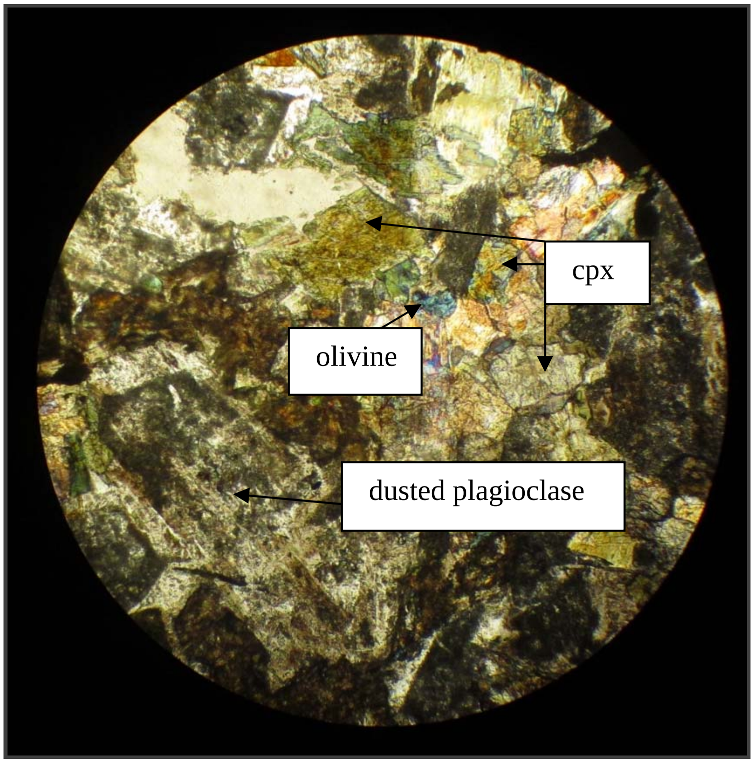


**Figure 41 Photomicrograph of diabase/gabbro Livengood ophiolite unit (MzZum) from station #205262, crossed nicols, 100X; shows clinopyroxene grains, dusted calcic plagioclase, and olivine**

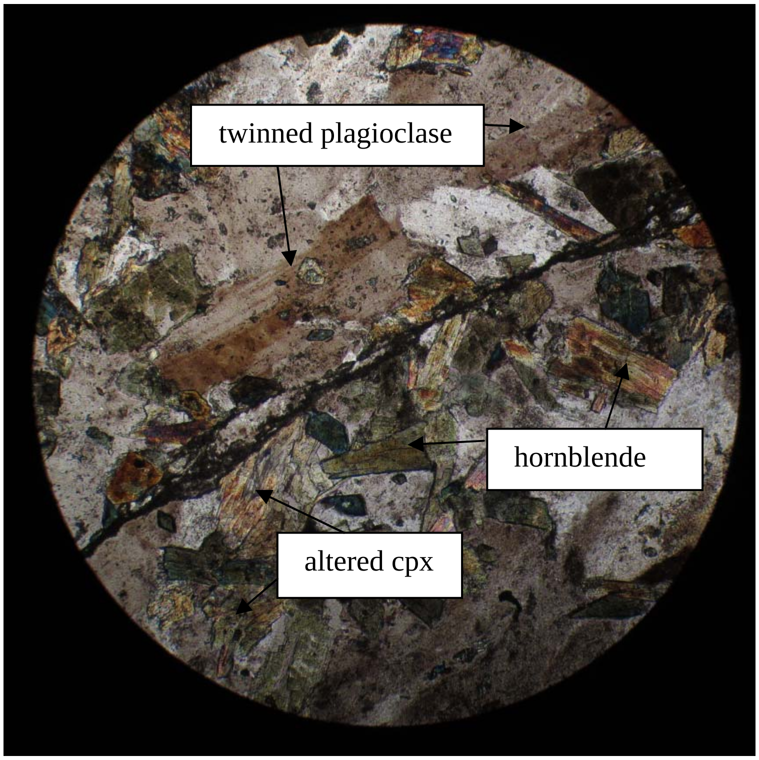


**Figure 42 Photomicrograph of diabase/gabbro Livengood ophiolite unit (MzZum) from station #205442, crossed nicols, 100X; shows twinned calcic plagioclase (An=65); primary amphibole and clinopyroxene**

**Table 14 Results of major oxide analyses, Livengood ophiolite unit (MzZum), Dunbar to Livengood rail corridor project(1)**

| Sample/Station Location | #205441 | #205262 |
|---|---|---|
| **Field Rock Type** | **Serpentenite after Harzburgite** | **Pyroxene diabase** |
| **$SiO_2$ (%)** | 39.60 | 51.50 |
| **$Al_2O_3$ (%)** | 0.64 | 15.30 |
| **$Fe_2O_3$ (%)** | 7.53 | 9.04 |
| **CaO (%)** | 0.13 | 9.07 |
| **MgO (%)** | 35.40 | 5.50 |
| **$Na_2O$ (%)** | 0.01 | 4.70 |
| **$K_2O$ (%)** | <0.01 | 0.46 |
| **$Cr_2O_3$ (%)** | 0.37 | 0.02 |
| **$TiO_2$ (%)** | 0.01 | 0.70 |
| **MnO (%)** | 0.08 | 0.14 |
| **$P_2O_5$ (%)** | <0.01 | 0.08 |
| **SrO (%)** | <0.01 | 0.04 |
| **BaO (%)** | <0.01 | 0.05 |
| **LOI (%)** | 13.30 | 2.18 |
| **TOTAL (%)** | 97.10 | 98.80 |
| **Cr (ppm)** | 2,540 | 140 |
| **Ni (ppm)** | 2,150 | 55 |
| **Co (ppm)** | 104.0 | 30.4 |
| **Cu (ppm)** | 9 | 132 |
| **V (ppm)** | ND | 369 |

(1)From ALS Minerals see Appendix II

**Table 15 Results of material analyses, Livengood ophiolite unit (MzZum), Dunbar to Livengood rail corridor project(1)**

| Sample No. | Lab No. | Weight (kg) | Bulk Specific Gravity (SSD) | Bulk Specific Gravity (Dry) | Apparent Specific Gravity | Water Absorption (%) | Degradation Alaska Test Method T-13 (%) | Los Angeles Abrasion Loss (%) | Soundness Loss (%) |
|---|---|---|---|---|---|---|---|---|---|
| **205442** | **1611** | 23.0 | 2.807 | 2.780 | 2.857 | 0.97 | 77 | 18 | 0.71 |
| **205262** | **1371** | 16.6 | 2.920 | 2.904 | 2.950 | 0.54 | 82 | 13 | 0.47 |

(1)Analyses from Mappa Test Labs, Inc., North Pole, Alaska

## Material Test Summary

Table 15 summarizes the materials test results from two samples in the Livengood ophiolite unit. Both are from diabase to gabbro sill exposures west of Livengood. Specific gravity averages 2.90, T-13 degradation values average about 80 percent, and Los Angeles abrasion loss values average about 15 percent. The chief weakness in these otherwise positive test results is water absorption values. Class 4 railroad ballast requires a water absorption value of 0.50 percent or less. The average water absorption value for the two samples from the Livengood ophiolite unit is 0.76 percent. Slater and Misterek (1978) sampled the gabbroic rocks of the MzZum unit at several different locations, including on Money Knob, near Livengood. Their samples had specific gravity values ranging from 2.78-2.84, Los Angles abrasion loss values from 15-19 percent, and an average degradation value of 57 percent, but they were not tested for water absorption properties. Slater and Misterek (1978) believed that this rock unit might be suitable for riprap applications.

## Livengood Dome Chert Unit (Oc)

### Field Observations

The Livengood Dome chert consists of nearly 1500 feet of variegated chert (about 70 percent) with beds of graptolitic shale and tuffs (about 30 percent). The age has been firmly established as Upper Ordovician on the basis of graptolites discovered in 1971 by Dr. Don Triplehorn of the University of Alaska, Fairbanks. The lead author of this report identified those graptolites during a 1972 undergraduate special course credit supervised by Dick Allison. Identifications were later confirmed by U.S. Geological Survey graptolite expert Mike Churkin. The exposure shown in Figure 42 (PRGCI station #205259), located near Lost Creek, has been largely reclaimed by DOTPF, and thus cannot be viewed today. The Livengood Dome chert strikes east-west, and is crosscut by numerous faults and folds. Five (5) stations were occupied in the Livengood Dome chert unit during the 2010 field study.

### Petrographic and Geochemical Summary

The Livengood Dome chert ranges from light gray to grayish black, with uncommon yellowish, reddish, and greenish bands. Besides the graptolitic shale horizons, some tuffaceous beds with orange lithic tuffs have been recognized. A basal comglomerate, composed of rounded pebbles of chert, occurs near the base of the unit, and presumably above the Cambrian ophiolite section.

Several morphological types of Livengood Dome chert are recognized: 1) massive to banded amorphous silica with tiny FeOx grains (station #205260, Figure 44); 2) amorphous silica with many small FeOx grains and 5-15 percent remobilization of silica in quartz veins (station #205259, Figure 43); and 3) amorphous chert substantially transformed into crosscutting quartz vein stockwork, usually in fold axes and along shear zones (station #205261, Figure 45).

The results of geochemical analyses of two samples, one un-deformed and the other substantially veined, are shown in Table 16. There is very little geochemical difference between the two samples, although there is some iron introduction into the latter, deformed sample. Both samples average 93.80 percent $SiO_2$ content.

### Structural Data

Complex deformation, including folding and fracturing, is encountered in nearly in every exposure. This is probably due to the brittle nature of the chert, and its inability to yield to compressive forces during deformation. The intense fracturing caused by deformation is well illustrated in Figure 45. Both high angle and low angle shear zones are normally encountered in outcrop.

**Figure 43 An exposure of Livengood Dome chert near Lost Creek, at Mile 72.7 of the Elliott Highway; from Weber and others (1985); near PRGCI sample station #205259**

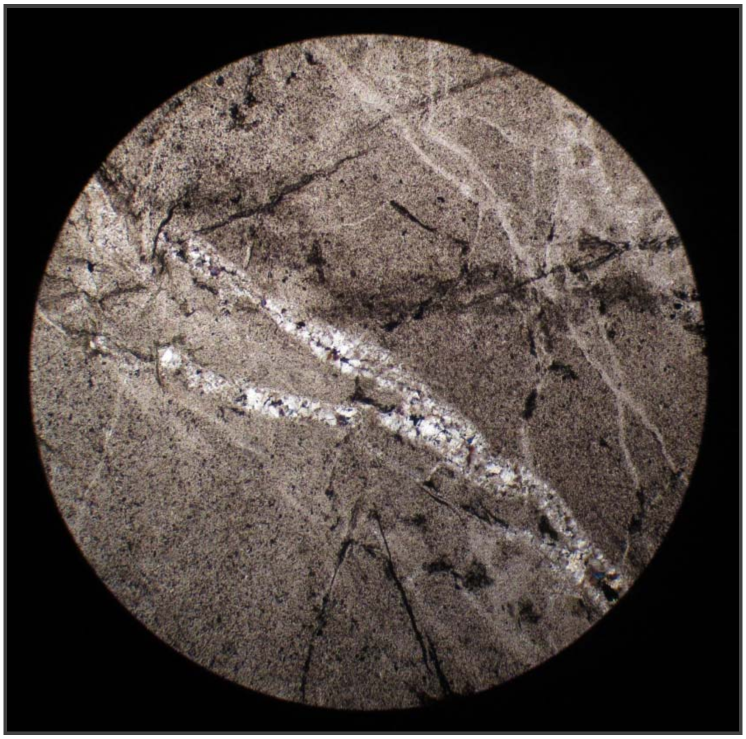


**Figure 44 Photomicrograph of the Livengood Dome chert (Oc) from station #205259, crossed nicols, 100X; shows a very fine grained silica matrix that has been cut by remobilized quartz veins and veinlets; note the FeOx veinlets**

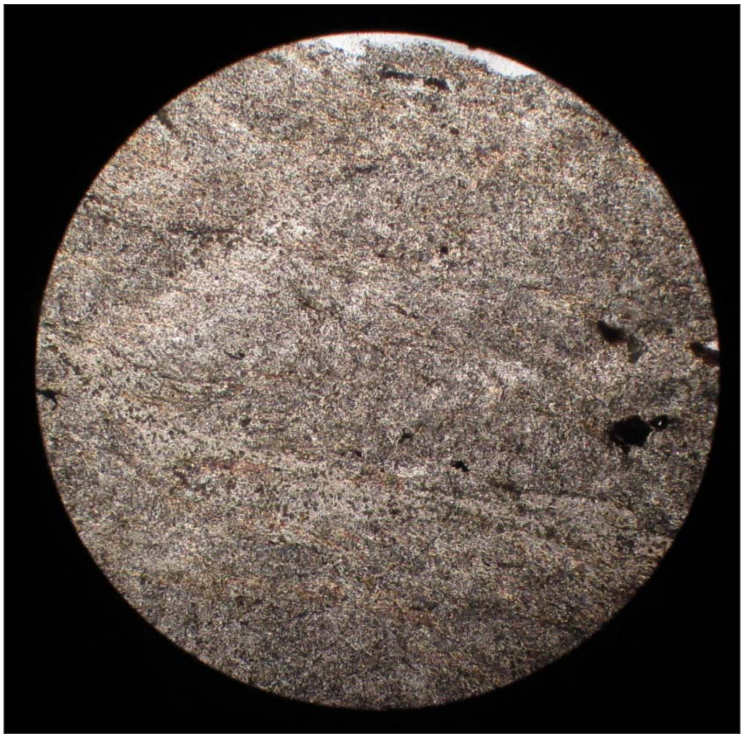


**Figure 45 Photomicrograph of Livengood Dome chert (Oc) from station #205260, crossed nicols, 100X; shows the very fine grained silica matrix without remobilized quartz; note the FeOx veinlets and grains throughout the groundmass**

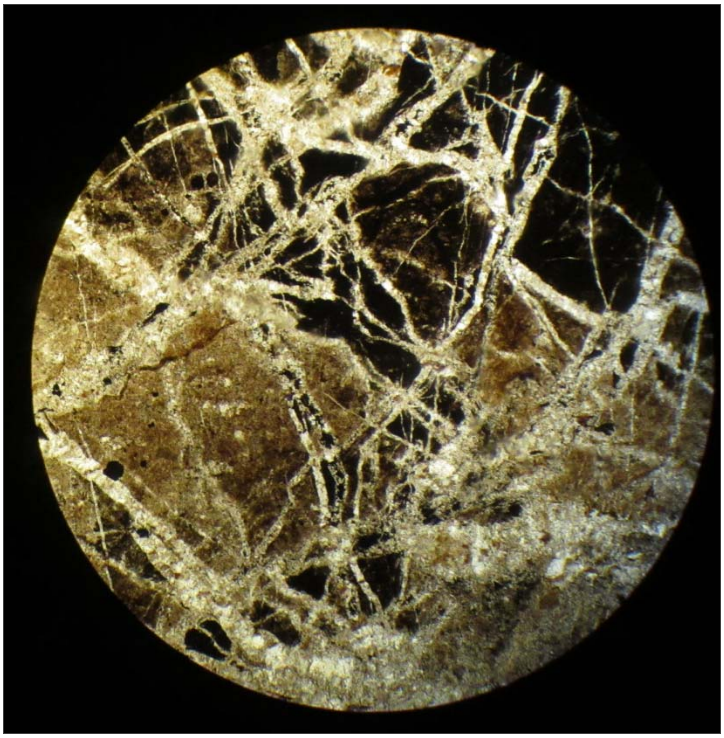


**Figure 46 Photomicrograph of Livengood Dome chert (Oc) from station #205261, crossed nicols, 100X; shows the Livengood chert substantially replaced by secondary quartz veinlet zones**

**Table 16 Results of major oxide analyses, Livengood Dome chert (Oc), Dunbar to Livengood rail corridor project(1)**

| Sample/Station Location | #205260 | #205261 |
|---|---|---|
| **Field Rock Type** | **Massive chert** | **Veined chert** |
| **$SiO_2$ (%)** | 94.60 | 92.80 |
| **$Al_2O_3$ (%)** | 0.51 | 0.90 |
| **$Fe_2O_3$ (%)** | 1.32 | 1.59 |
| **CaO (%)** | 0.05 | 0.03 |
| **MgO (%)** | 0.04 | 0.22 |
| **$Na_2O$ (%)** | 0.05 | 0.02 |
| **$K_2O$ (%)** | 0.08 | 0.17 |
| **$Cr_2O_3$ (%)** | <0.01 | 0.01 |
| **$TiO_2$ (%)** | 0.02 | 0.04 |
| **MnO (%)** | 0.01 | 0.01 |
| **$P_2O_5$ (%)** | <0.01 | <0.01 |
| **SrO (%)** | <0.01 | <0.01 |
| **BaO (%)** | 0.05 | 0.02 |
| **LOI (%)** | 0.00 | 0.10 |
| **TOTAL (%)** | 96.60 | 95.90 |

(1)From ALS Minerals (see Appendix II)

**Table 17 Results of material analyses, Livengood Dome chert (Oc), Dunbar to Livengood rail corridor project(1)**

| Sample No | Lab No. | Weight (kg) | Bulk Specific Gravity (SSD) | Bulk Specific Gravity (Dry) | Apparent Specific Gravity | Water Absorption (%) | Degradation Alaska Test Method T-13 (%) | Los Angeles Abrasion Loss (%) | Soundness Loss (%) |
|---|---|---|---|---|---|---|---|---|---|
| **205259** | **1369** | 24.0 | 2.611 | 2.593 | 2.640 | 0.69 | 84 | 23 | 1.34 |
| **205260** | **1370** | 12.0 | 2.579 | 2.537 | 2.648 | 1.66 | 96 | 26 | 0.66 |

(1)Analyses from Mappa Test Labs, Inc., North Pole, Alaska

### Material Test Summary

Table 17 summarizes the results of materials tests conducted on two samples from the Livengood Dome chert unit. They have an average specific gravity of 2.644, a fairly high water absorption value averaging 1.17 percent, a T-13 degradation value averaging 90 percent; and a Los Angeles abrasion loss value of 24.5 percent. The chert does not pass specifications for the ARRC's mainline class 4 railroad ballast due to excessive LA abrasion loss and water absorption values.

Slater and Misterek (1978) conducted material tests from several sites in the Livengood Dome chert unit, near Money Knob. They reported some similar values to those that were obtained by the PRGCI team, while results of other tests differed. Their samples resulted in: specific gravity values ranging from 2.61-2.64 (similar to the 2010 results); an average T-13 degradation values of only 35 percent (poor); a range of LA abrasion loss values from 23-29 percent (similar to the 2010 data set), and some very high water absorption values (up to 7.00 percent).

Slater and Misterek (1978) reported that large potential volumes of chert exist near the Elliott Highway. However, they believed the Livengood Dome chert to be *“too weathered and altered; hence the Livengood Dome Chert is of marginal value for construction purposes”*.

## Mesozoic-Tertiary Intrusion Units (TKgd, Tprg)

### Field Observations

Mesozoic-Tertiary intrusions of two distinctive suites intrude the layered rocks of the proposed Dunbar to Livengood rail corridor. The oldest, the Tolovana Hot Springs Dome pluton unit (TKgd), is an elongate, late Cretaceous intrusion covering about 15 square miles on the Tolovana Hot Springs Dome west of the Tolovana-Minto Flats area. The pluton cuts the Wilbur Creek flysch unit of Early Late Cretaceous age. A pronounced hornfels aureole about half a mile wide rims the plutonic contact zone.

The younger suite (Tprg) constitutes a series of ten (10) small bodies, each less than one square mile in size, that intrude a thirty square mile area of the Wilbur Creek flysch unit south of the Elliott Highway and east of the Tolovana-Minto Flats area. This region of small igneous bodies has been refered to as the Shorty Creek intrusive swarm. Some pronounced zones of hard hornfels have been identified surrounding the small igneous bodies. Because of their ubiquitous association, previous materials site investigations have grouped the hornfels with the Wilbur Creek flysch unit. Four (4) stations were occupied in these intrusive rocks during the 2010 field studies.

### Petrographic and Geochemical Summary

Texturally and mineralogically, the Tolovana Hot Springs Dome pluton is a tight, unaltered, medium grained, equigranular, biotite, pyroxene granodiorite to monzonite. Fresh, twinned plagioclase (An30) makes up most of the groundmass (Figure 46). Quartz grains are uncommon to rare. The ‘I Type’ granitic rock at station #205320 contains 8.43 percent total $K_2O$ + $Na_2O$, and is clearly alkaline geochemically. Reaction rim relationships between clinopyrozene and biotite suggest a differentiation process during crystallization. The Tolovana Hot Springs Dome pluton is enriched in REE elements such as cerium and neodymium and also contains elevated niobium, thorium, and uranium (Table 18).
The Shorty Creek intrusions all contain porphyro-aphanitic textures with large biotite grains in an inclusion-charged, feldspar-quartz matrix. Most of the thin sections exhibit evidence of hydrothermal metasomatism, particularly argillic and potassic alteration. In several thin sections, numerous micro-fractures contain blebs of FeOx and trace sulfides (Figure 47). The Shorty Creek intrusive swarm exhibits more of a calc-alkaline magnetite series chemistry typical of base metal-precious metal porphyry systems. Despite being selected as a fresh rock, sample #205263 contains slightly elevated copper, lead, and molybdenum (Appendix IV).

### Structural Data

No structural measurements were taken from any intrusive exposures in the proposed rail corridor, and all samples collected were described as either rubble crop or float. At station #205320 (Tolovana Hot Springs Dome), boulders as large as thirty inches in diameter were observed, but potential yield (percentage of large versus small rock sizes) is not known. Clast sizes in rubble crop and float in the small intrusions in the Shorty Creek area are smaller than at Tolovana Hot Springs Dome, and average four to six inches in diameter.

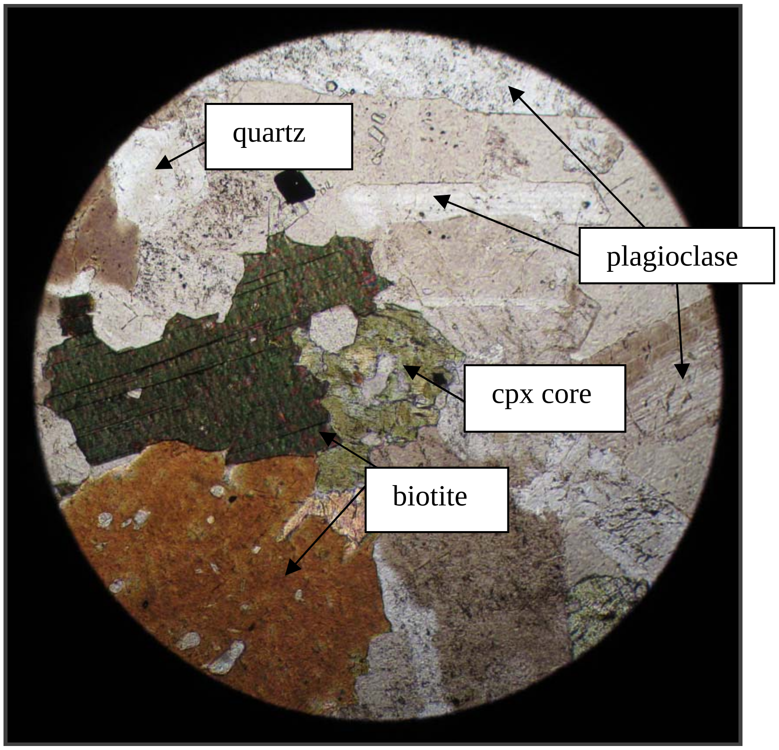


**Figure 47 Photomicrograph of Tolovana Hot Springs pluton unit (TKgd) from station #205320, crossed nicols, 100X; shows coarse, fresh, interlocking biotite grains attached to a pyroxene grain in a general groundmass of twinned plagioclase (An25) and quartz; note the freshness of the sample**

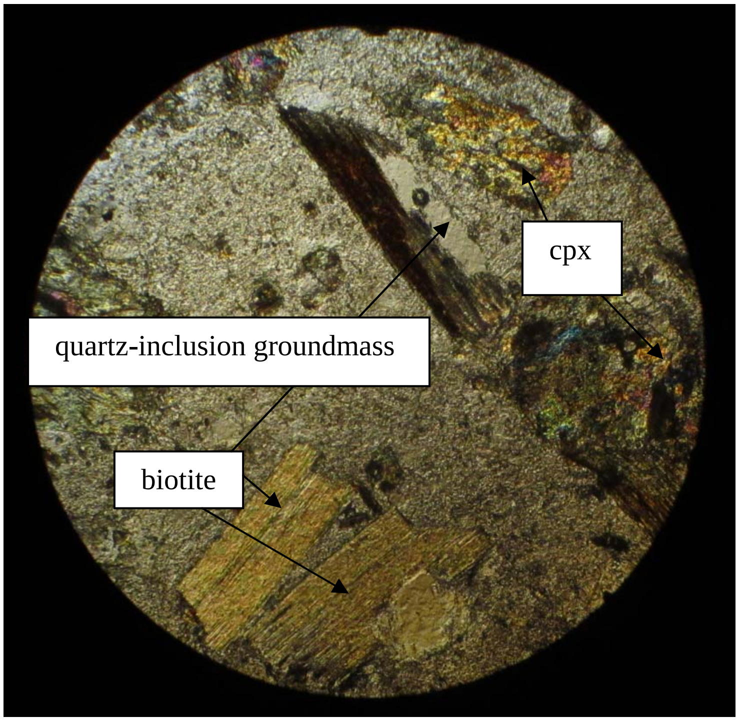


**Figure 48 Photomicrograph of the intermediate porphyry near Shorty Creek (unit Tprg) at station #205263, crossed nicols, 100X; shows large biotite grains in inclusion-charged, quartz-rich groundmass, and minor cpx grains**

**Table 18 Results of major oxide and selected trace element analyses, Mesozoic-Tertiary intrusion units (TKgr, Tpgr), Dunbar to Livengood rail corridor project(1)**

| Sample/Station Location | #205320 | #205263 |
|---|---|---|
| **Field Rock Type** | **Biotite monzonite** | **Intermediate porphyry** |
| **$SiO_2$ (%)** | 57.40 | 62.40 |
| **$Al_2O_3$ (%)** | 16.50 | 15.50 |
| **$Fe_2O_3$ (%)** | 6.44 | 5.25 |
| **CaO (%)** | 4.32 | 3.30 |
| **MgO (%)** | 2.41 | 1.79 |
| **$Na_2O$ (%)** | 3.58 | 2.70 |
| **$K_2O$ (%)** | 4.85 | 2.82 |
| **$Cr_2O_3$ (%)** | <0.01 | <0.01 |
| **$TiO_2$ (%)** | 0.99 | 0.56 |
| **MnO (%)** | 0.12 | 0.12 |
| **$P_2O_5$ (%)** | 0.64 | 0.21 |
| **SrO (%)** | 0.11 | 0.08 |
| **BaO (%)** | 0.25 | 0.16 |
| **LOI** | 0.59 | 1.79 |
| **TOTAL (%)** | 98.20 | 96.70 |
| **Ba (ppm)** | 2,110 | 1,385 |
| **Ce (ppm)** | 169.0 | 97.3 |
| **La (ppm)** | 88.8 | 55.8 |
| **Nb (ppm)** | 52.1 | 15.1 |
| **Nd (ppm)** | 66.4 | 35.8 |
| **Th (ppm)** | 33.0 | 15.5 |
| **U (ppm)** | 8.39 | 3.58 |

(1)From ALS Minerals (see Appendix II)

**Table 19 Results of material analyses, Mesozoic-Tertiary intrusion units (TKgr, Tpgr), Dunbar to Livengood rail corridor project(1)**

| Sample No. | Lab No. | Weight (kg) | Bulk Specific Gravity (SSD) | Bulk Specific Gravity (Dry) | Apparent Specific Gravity | Water Absorption (%) | Degradation Alaska Test Method T-13 (%) | Los Angeles Abrasion Loss (%) | Soundness Loss (%) |
|---|---|---|---|---|---|---|---|---|---|
| **205320** | **1380** | 14.0 | 2.724 | 2.706 | 2.756 | 0.68 | 84 | 28 | 1.20 |
| **205263** | **1372** | 16.0 | 2.691 | 2.675 | 2.718 | 0.59 | 82 | 14 | 0.10 |

(1)Analyses from MAPPA Test Labs, Inc., North Pole, Alaska

## Material Test Summary

One sample of intrusive from the Tolovana Hot Springs Dome and one sample of intrusive from the Shorty Creek area were submitted to MAPPA Test Labs for material testing. The samples yielded similar results in apparent specific gravity, averaging 2.737, water absorption, averaging 0.635 percent, and T-13 degradation values, averaging 83 percent. The Tolovana Hot Springs pluton contained a decidedly higher LA abrasion loss value (28 percent, versus 14 percent for the Shorty Creek intrusion), as well as a much higher sodium sulfate soundness result (1.20 percent loss versus 0.10 percent loss for the Shorty Creek intrusion).

The more altered intrusion (Tprg) yielded better materials testing results.  Caution is recommended in interpreting these results, since most intrusive rocks in Interior Alaska exhibit grussification to significant depths.

# Conclusions

Interpretations made from the data collected during this study were affected by the lack of good bedrock exposures, which limited the field crews' ability to estimate properties such as riprap potential. When physical characteristics were ambiguous due to exposures within the proposed rail corridor, the PRGCI team examined the results of material testing previously conducted by the Alaska Department of Transportation and Public Facilities (DOTPF), and even some accessible private reports. As seen in Appendix II, the PRGCI team did not test for all engineering specifications needed for both railroad ballast and riprap. The selected material tests were judged to be the most important to assess the potential for both construction applications. To test the potential for mainline class 4 railroad ballast, several important physical tests were completed, including Los Angeles abrasion loss (in percent); water absorption (in percent), and bulk specific gravity or BSG. To assess riprap potential, physical measurements made on the surface, T-13 degradation (in percent), soundness (in percent), and bulk specific gravity were all considered. Table 20 presents some selected areas of interest for further work. Table 21 presents a matrix of physical characteristics from the material testing done, and compares them with engineering specifications for the ARRC's mainline class 4 railroad ballast, and riprap. Figures 49-51 compare various measured values in material samples. The reader is referred to this summary during the following discussions.

## ARRC Mainline Class 4 Ballast Sources

Eight of the geologic units tested failed to meet the important Los Angeles abrasion loss requirement (maximum value of 20 percent) for mainline class 4 railroad ballast. (For clarification, in this report, the average of several values was considered for each rock unit.) The units that failed the LA abrasion requirement include the Fairbanks schist, the Grit unit, the Tolovana limestone, the Cascaden Formation, the Livengood Dome chert, the Wilbur Creek flysch, the Mesozoic intrusions (but just barely), and the Globe quartzite (though only by 0.6 percent). In contrast, the Mesozoic gabbro sills, the Wilbur hornfels, and the dolerite sills within the Livengood ophiolite all resulted in LA abrasion loss values at or below 20 percent, with the best result from the diabase sills in the Livengood ophiolite.

All but one of the rock units contained water absorption values exceeding the maximum allowable (0.50 percent). The Tolovana limestone contained an average water absorption value of 0.33 percent. The Globe quartzite just barely failed to meet the specification, with an average water absorption value of 0.58 percent, with three of the five samples resulting in values below 0.50%. The Fairbanks schist and the Wilbur Creek flysch also had individual samples that tested below 0.50 percent, but their overall average values were considerable higher, 0.85 percent and 1.21 percent, respectively.

All the rock units tested passed the ARRC's ballast specifications for soundness: at or below 1.00 percent, though the Livengood Dome chert was right at the test limit.

All of the rock units tested contained the minimum bulk specific gravity measurements. Two units, the Mesozoic gabbro sills and the diabase sills of the Livengood ophiolite, contained high bulk specific gravity measurements (exceeding 2.90), which would be a desired physical property for ballast application.

The rock unit that came the closest to passing all of the ARRC's mainline class 4 ballast specifications was the Globe quartzite. Despite slightly excess water absorption values, intrusions in the Livengood ophiolite and the Mesozoic gabbro sills also performed well overall during material testing for ARRC ballast applications. As previously mentioned, the high specific gravity obtained from the latter two rock units would give them an advantage over units that exhibit lower specific gravity measurements.

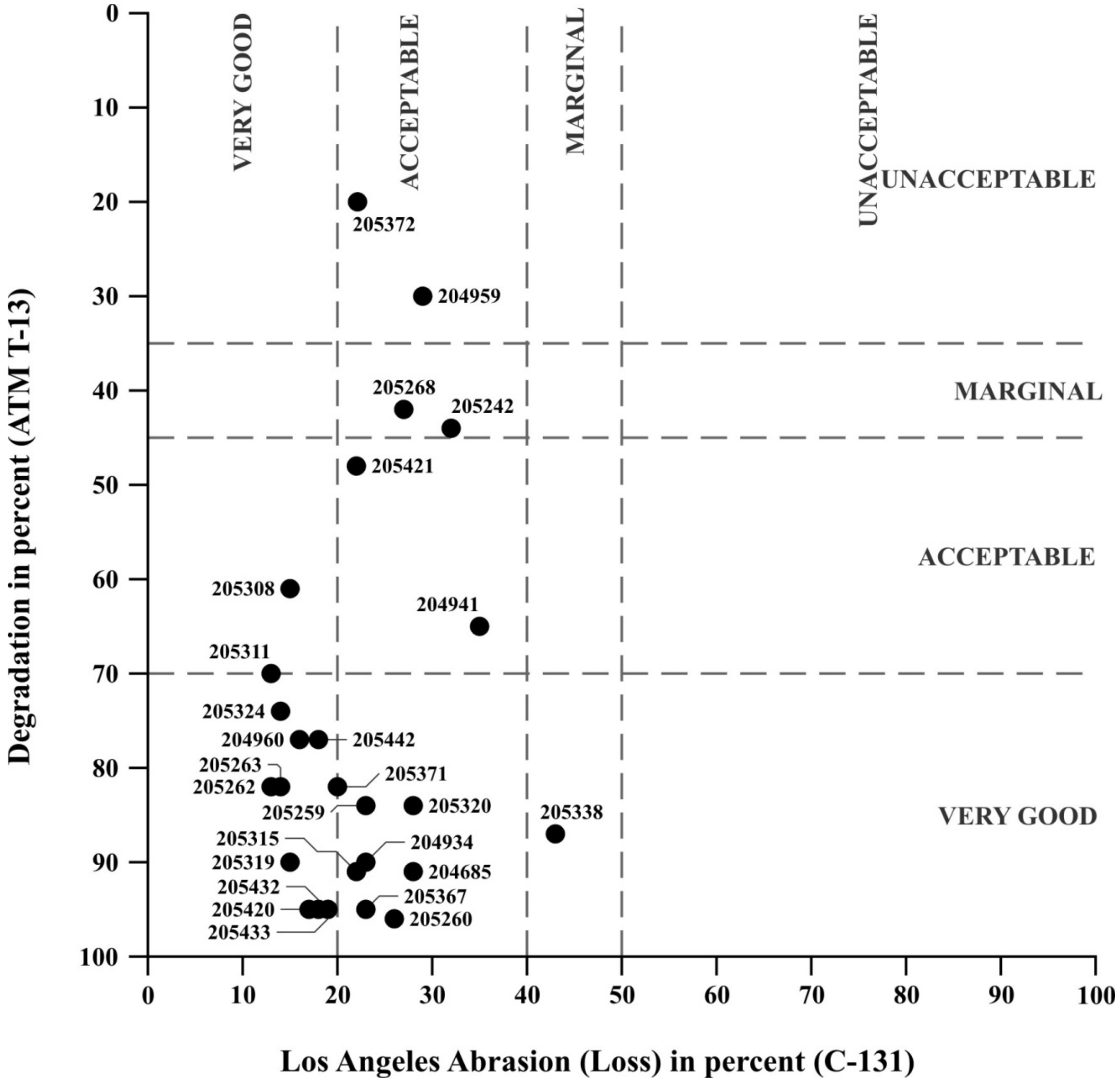


**Figure 49 Plot of Los Angeles abrasion (loss) values versus T-13 degradation values, constructed from data from the results of material analyses, Dunbar to Livengood rail corridor project**

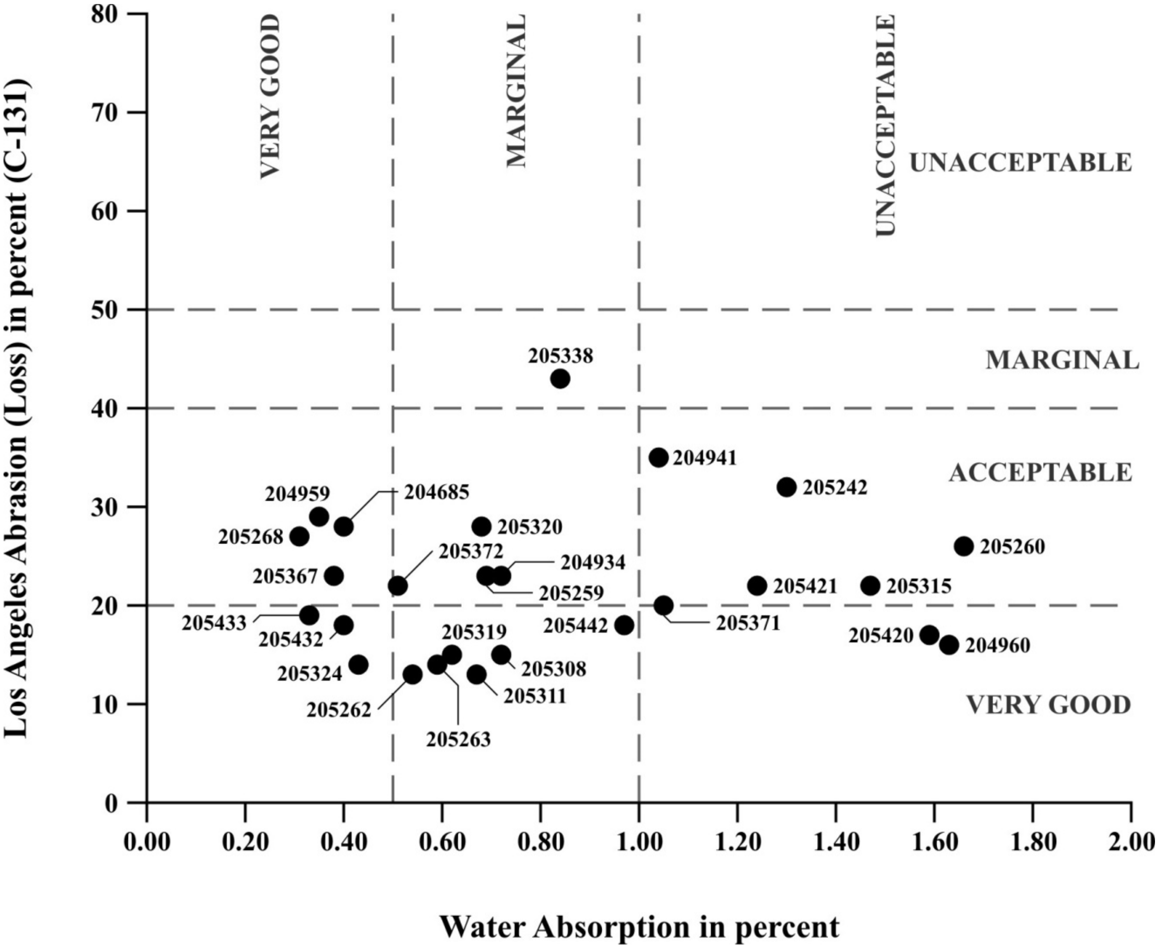


Figure 50  Plot of Los Angeles abrasion (loss) values versus water absorption values, constructed from data from the results of material analyses, Dunbar to Livengood rail corridor project

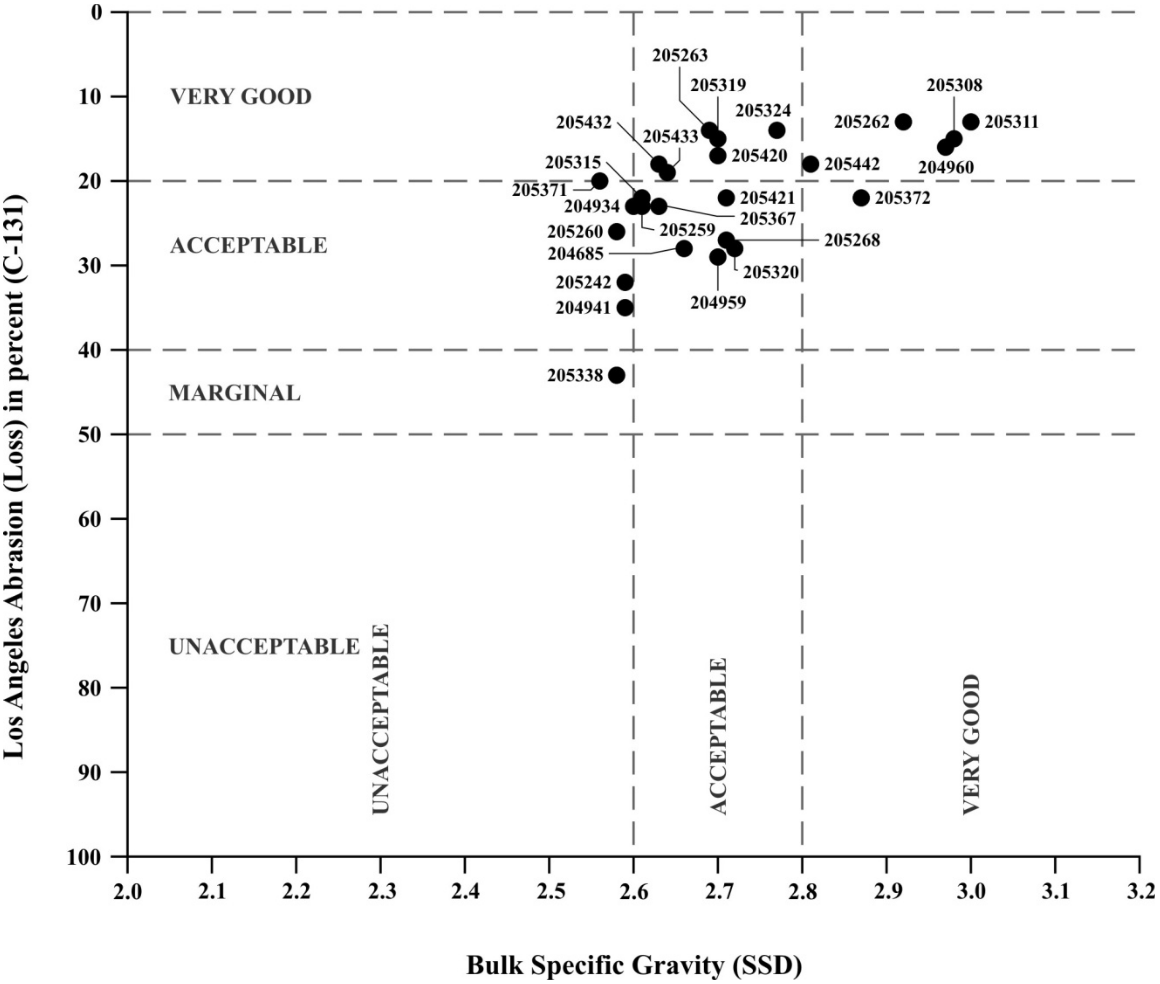


Figure 51 Plot of Los Angeles abrasion (loss) values versus bulk specific gravity (SSD) values, constructed from data from the results of material analyses, Dunbar to Livengood rail corridor project

## Potential Riprap Sources

The ARRC's riprap specifications are not as rigorous as their ballast specifications, and are similar to specifications for DOTPF applications. Many of the rock units examined during this study performed very well during T-13 degradation testing. All but one rock unit, the Tolovana limestone, yielded T-13 degradation values that exceeded 50 (<50 percent loss), and five units, the Globe quartzite, the Wilbur Creek hornfels, the Mesozoic gabbro sills, the Livengood Dome chert and the Mesozoic-Tertiary intrusions resulted in T-13 values at or exceeding 80 percent, which is considered an excellent degradation value for any construction application.

Water absorption and soundness specifications place more limits on potential riprap sources for the proposed rail corridor. However, the Grit unit, the Globe quartzite, and the Wilbur Creek hornfels all pass these specifications for riprap.

The biggest uncertainty for determining the availability of riprap in the rail corridor is lack of knowledge concerning class size and yield. Poor rock exposure prevented the PRGCI team from collecting accurate measurements of joints and fractures to determine coarse riprap potential, such as required for classes 2, 3, and 4 riprap. However, from the data collected, the PRGCI team judges that three rock types have the potential to provide coarse riprap: 1) the Fairbanks schist; 2) the Tolovana limestone; and 3) the dolerite sills in the Livengood ophiolite. All contained evidence of large blocks of in-situ materials that would conform to riprap 2, 3, and even 4 sizes. However, without collecting more detailed joint spacing (Block Size Indices) or, importantly, drill data, there would be no way to estimate important parameters such as yield.

The senior writer has observed the coarse riprap developed at the North Nenana Quarry, about 3 miles north of Nenana and 11 miles south-southwest of the Dunbar siding. This quarry, which is owned by Doyon Limited, contains zones of laminated quartzite in the Fairbanks schist unit, and has yielded class 3 and some class 4 riprap, although yield (percent of waste rock versus usable rock) is not known. The North Nenana Quarry supplied road base and riprap material for the construction of an access road that was used to explore for oil and gas, a project conducted by Doyon and others in 2009. T-13 degradation values on the order of 45-50 percent have been obtained from the North Nenana rock material. This quarry could conceivably be a source for riprap for the southern portion of the rail corridor. More importantly, it indicates that despite generally negative test results obtained from previous DOTPF studies, the Fairbanks schist unit might be able to supply the proposed rail corridor with riprap, if the right sites were located.

## Recommendations

The PRGCI/UAF team located material that meets the specifications for mainline class 4 railroad ballast. In particular, the Globe quartzite passed all criteria tested for the ARRC's ballast application. If further confirmatory work is desired, the PRGCI team recommends more sampling work on the Globe quartzite, the dolerite sill localities in the Livengood ophiolite, and the Mesozoic gabbro sills. Gradation testing (ASTM D75, ASTM E11, ASTM C136, and ASTM C117), as well as *Clay Lumps and Friable Particles* (ASTM C142) and *Flat and Elongated Particles* (USACE CRD-119) could further help confirm the desirability of these units for railroad ballast applications.

Riprap assessment is hampered by the limited outcrops in the area. The same units described in the above paragraph, which contain favorable physical properties for ballast, should also be tested with a diamond drill to collect sufficient data for the accurate assessment of riprap potential. The PRGCI team does not believe that the Grit unit, the Wilbur Creek flysch and associated hornfels unit, the Livengood Dome chert unit, and the Cascaden Formation unit, to be potential source materials for the proposed ARRC Dunbar to Livengood rail project. However, other rock units, especially the Tolovana limestone unit, might yield coarse riprap, and drill testing and further laboratory testing could confirm such a potential.

Other factors affect the materials potential of some of the rock units, as well. Although the hornfels seemed to test well for riprap quality, the exposures near Shorty Creek, where most of the hornfels samples were collected, are erratic in shape and limited in tonnage. In addition, they comprise a portion of a metallic mineral zone that could be developed for metals in the future. The intrusions themselves could be sources of riprap, though one problem common to most intrusions in interior Alaska, where Pleistocene glaciations have been generally absent, has been ubiquitous grussification processes.

In summary, several of the rock units tested have the potential to be used for construction applications should the decision be made to develop railroad access to Livengood. Units such as the Globe quartzite, the Livengood ophiolite, the Mesoszoic gabbro sills, and the Tolovana limestone hold the most promise to meet the ARRC's construction specifications.

Future work should include more detailed surface sampling and mapping, mechanical excavation, and shallow core drilling to test key rock prospect locations in the Globe quartzite, the diabase sills in the Livengood ophiolite, the Mesozoic gabbro sills, and the non-metamorphosed intrusions. Core drilling must confirm the extent of grussification of the intrusive rocks at depth.

**Table 20 Selected stations recommended for further site and laboratory investigations for ballast and riprap potential, Dunbar to Livengood rail corridor project(1)**

| Geologic Unit | Station | Easting | Northing | Suggested Work |
|---|---|---|---|---|
| Fairbanks schist | 205411 | 425230 | 7197394 | Additional joint set study for riprap assessment |
| Fairbanks schist | 205251 | 423822 | 7193684 | Additional joint set study, drill(?) for block size estimates |
| Tolovana limestone | 204933 | 409434 | 7220201 | Additional joint set study, drill(?) for block size estimates |
| Globe quartzite | 205432 | 408382 | 7223179 | More sampling and possible trenching; drill? |
| Globe quartzite | 205433 | 421717 | 7228861 | More sampling and possible trenching; drill? |
| Globe quartzite | 205367 | 411784 | 7224070 | More sampling and possible trenching; drill? |
| Gabbro sills | 205960 | 406512 | 7222404 | More sampling and joint study; drill? |
| Gabbro sills | 205308 | 406158 | 7222534 | More sampling and joint study; drill? |
| Livengood ophiolite | 205442 | 421861 | 7261252 | More sampling and joint study; drill? |
| Livengood ophiolite | 205262 | 421593 | 7261563 | More sampling and joint study; drill? |
| Livengood ophiolite | 205424 | 421524 | 7261664 | More sampling and joint study; drill? |

(1)Coordinates are in NAD83; Zone 06W

**Table 21 Matrix summarizing the material testing results and the physical measurements by geologic unit, as they relate to engineering specifications for the Alaska Railroad Corporation's mainline class 4 railroad ballast and riprap, Dunbar to Livengood rail corridor project**

| Rock Unit | Bulk Specific Gravity 2.60 Minimum(1) | Water Absorption < 0.50% (ballast) < 2.50% (riprap) | T-13 Degradation in percent 50 Minimum | Los Angeles Abrasion Loss (in percent) 20 maximum | Soundness 1.00% maximum ballast; 0.50% riprap | Comments (physical characteristics) |
|---|---|---|---|---|---|---|
| **Fairbanks schist** | 2.555-2.675 (2)<br>Average = 2.615 | 0.40-1.30 (2)<br>Average = 0.85 | 44-91 (2)<br>Average = 68 | 28-32 (2)<br>Average = 30 | 0.19-0.89 (2)<br>Average = 0.54 | Massive quartzite has riprap potential |
| **Grit unit** | 2.592 (1) | 1.04 (1) | 65 (1) | 35 (1) | 0.42 (1) | In general, an incompetent unit with some resistant sandstone |
| **Tolovana limestone** | 2.687-2.697 (2)<br>Average = 2.692 | 0.31-0.35 (2)<br>Average = 0.33 | 30-42 (2)<br>Average = 36 | 27-29 (2)<br>Average = 28 | 0.40-1.20 (2)<br>Average = 0.80 | Good riprap potential in massive facies; poor otherwise |
| **Globe quartzite** | 2.560-2.637 (5)<br>Average = 2.613 | 0.33-1.05 (5)<br>Average = 0.58 | 82-95 (5)<br>Average = 91.4 | 18-23 (5)<br>Average = 20.6 | 0.12-0.65 (5)<br>0.30 | Very hard, exposures with some riprap potential; a metallurgical silica resource |
| **Mesozoic gabbro sills** | 2.856-2.978 (4)<br>Average = 2.929 | 0.51-1.63 (4)<br>Average = 0.88 | 20-77 (4)<br>Average = 57 | 13-22 (4)<br>Average = 16.5 | 0.18-1.00 (4)<br>Average = 0.69 | Some outcrop areas exhibit riprap potential; all samples are uniformly altered |
| **Wilbur Creek flysch(2)** | 2.657-2.760 (4)<br>Average = 2.722 | 0.43-2.06 (4)<br>Average = 1.21 | 48-74 (2)<br>Average = 61 | 14-75 (4)<br>Average = 34 | 0.25-0.40 (2)<br>Average = 0.33 | Two samples are resistant - conglomerate layers |
| **Wilbur Creek hornfels** | 2.576-2.687 (3)<br>Average = 2.640 | 0.62-1.59 (3)<br>Average = 1.23 | 90-95 (3)<br>Average = 92 | 15-22 (3)<br>Average = 18 | 0.10-0.62 (3)<br>Average = 0.36 | Hornfels is very hard due to recrystallization; locally large blocks at Shorty Creek |
| **Cascaden Formation(3)** | 2.74 (1) | NA | NA | 24 (1) | NA | In general material is < 4 inches; some conglomerates exhibit larger sizes - most are poor |
| **Livengood ophiolite** | 2.780-2.904 (2)<br>Average = 2.842 | 0.54-0.97 (2)<br>Average = 0.76 | 77-82 (2)<br>Average = 80 | 13-18 (2)<br>Average = 15.5 | 0.47-0.71 (2)<br>Average = 0.59 | Some diabase sills exhibit massive surface boulders with coarse riprap potential; the other are lithologies incompetent |
| **Livengood Dome chert** | 2.537-2.593 (2)<br>Average = 2.565 | 0.69-1.66 (2)<br>Average = 1.18 | 84-96 (2)<br>Average = 90 | 23-26 (2)<br>Average = 24.5 | 0.66-1.34 (2)<br>Average = 1.00 | Most exposures affected by complex deformation |
| **Mesozoic Tertiary intrusions** | 2.691-2.724 (2)<br>Average = 2.708 | 0.59-0.68 (2)<br>Average = 0.64 | 82-84 (2)<br>Average = 83 | 14-28 (2)<br>Average = 21 | 0.10-1.20 (2)<br>Average = 0.65 | No exposures studied; rock chips are partially grussified |

(1)(x) = number of measurements

(2)Includes selected data from Weaver and Vournas (1968**)**

(3)includes data from Slater and Misterek (1978)

# References Cited

Albanese, M.D., 1983a, Bedrock geologic map of the Livengood B-4 quadrangle, Alaska:  Alaska Division of Geological and Geophysical Surveys Report of Investigations 83-3, one sheet at scale 1:40,000

Albanese, M.D., 1983b, Geochemical reconnaissance of the Livengood B-3, B-4, C-3, and C-4 quadrangles, Alaska:  Alaska Division of Geological and Geophysical Surveys Report of Investigations 83-1, 55 pages, 4 sheets at scale 1:63,360.

Athey, J.E., Szumigala, D.J., Newberry, R.J., Werdon, M.B., and Hicks, S.A., 2004b, Bedrock geologic map of the Livengood  SW C-3 and SE C-4 quadrangles, Tolovana Mining District, Alaska:  Alaska Division of Geological and Geophysical Surveys Preliminary Interpretive report 2004-3B, one sheet at 1:50,000 scale.

Athey, J.E., Werdon, M.B., Szumigala, D.J., Newberry, R.J., Hicks, S.A., and Erickson, R., 2004a, Major oxide, minor oxide, and trace element geochemistry data from rocks collected in the Livengood quadrangle,  Tolovana Mining District, Alaska:  Alaska Division of Geological and Geophysical Surveys Raw Data File 2004-2  13 pages, scale: 1:63,360.

Barksdale, R.D., 2001, editor, *The Aggregate Handbook*:  National Stone, Sand, and Gravel Association, 4th Printing, Arlington, Virginia, 1,005 pages

Bundtzen, T.K., 1983, Bedrock geologic outcrop map of the Livengood  B-3  quadrangle, Alaska:  Alaska Division of Geological and Geophysical Surveys Report of Investigations 83-6, one sheet @ scale 1:40,000.

Chapman, R.M., Weber, F.R., and Taber, Bond, 1971, Preliminary geologic map of the Livengood quadrangle, Alaska:  U.S. Geological Survey Open File report 71-66 (483), 2 sheets, scale 1:250,000

Chatwood, G., and Shumway, R.D., 1966, Material site investigations, Olnes to Snow Pass project S-0680-(10), Unpublished material testing report by Alaska Department of Highways, 126 pages.

Dover, J.H., 1994, Geology of Part of East-Central Alaska; in, Plafker, G., and Berg, H.C., editors, The Geology of Alaska, The Geology of North America, Geological Society of America Decade of North American Geology (DNAG), pages 153-204.

Foster, H.L., Keith, T.E.C., and Menzies, W.D., 1994, Geology of the Yukon-Tanana Upland area of east-central Alaska, in, Plafker, G., and Berg, H.C., editors, The Geology of Alaska, The Geology of North America, Geological Society of America Decade of North American Geology (DNAG), pages 153-204

Griesel, G.A., Szumigala, D.J., Freeman, L.K., Newberry, R.J., Elliott, B.A., and Werdon, M.B., 2010, Major oxide, minor oxide, and trace element geochemistry from rocks collected in the Livengood quadrangle during 2010:  Alaska Division of Geological and Geophysical Surveys Raw Data File 2010-3, 31 pages.

Hall, M.H., Smith, T.E., and Weber, F.R., 1984, Geologic guide to the Fairbanks-Livengood  area, East-Central Alaska:  Alaska Division of Geological and Geophysical Surveys field guide, 12 pages.

Mertie, J.B.  Jr., 1937, The Yukon-Tanana Region, Alaska:  U.S. Geological survey Bulletin 872, 276 pages.

Metz, P.A., 1991, Metallogeny of the Fairbanks Mining district Alaska, and adjacent areas:  Mineral Industry Research Laboratory (MIRL) Report 90, School of Mineral Engineering, University of Alaska, Fairbanks, 369 pages.

Reger, R.D., Stevens, D.S.P., and Smith, R.L., 2003, Survey of geology, geologic materials, and geologic hazards in proposed access corridors in the Livengood quadrangle, Alaska:   Alaska Division of Geological and Geophysical Surveys Miscellaneous Publication 86, 5 sheets, scale:  1:250,000

Reifenstuhl, R.R., Dover, J.H., Newberry, R.J., Clautice, K.H., Liss, S., Blodgett, R.B., and Weber, F.R., 1998, Geologic map of the Tanana A-1 and A-2 quadrangles, Alaska:  Alaska Division of Geological and Geophysical Surveys Public Data File 98-37a, scale 1:63,360

Robinson, M.S., 1983, Bedrock geologic map of the Livengood C-4 quadrangle, Alaska:  Alaska Division of Geological and Geophysical Surveys Report of Investigations 83-4, one sheet @ scale 1:40,000

Robinson, M.S., and Metz, P.A., 1979, Evaluation of the mineral resources of the Trans-Alaska Pipeline Corridor Phases I and II: University of Alaska Fairbanks Final Contract Report to the U.S. Bureau of Mines, Grant No. G0166180, 263 p., geologic maps, 48 sheets, scale 63:360.

Slater, W.H., and Misterek, P.W., 1978, Engineering geology, Tolovana River to Livengood project S-0680-(17), Alaska Department of transportation and Public facilities unpublished report.

Smith, T.E., 1983, Bedrock geologic map of the Livengood C-3 quadrangle, Alaska:  Alaska Division of Geological and Geophysical Surveys Report of Investigations 83-5, one sheet @ scale 1:40,000

Vournas, G., and Chatwood, G., 1967, Degradation testing of schist pits, Nenana-25 miles west; Project F-037-1 (8) Unpublished Alaska Department of Highways unpublished report, 10 pages.

Vournas, G., and Sherman, R.G., 1963, Materials report, Defense Access Road, Murphy Dome Air Force Base, Project R-AD-3 (1), Fairbanks District, Alaska Department of Highways report, 99 pages.

Weaver, M.K., and Vournas, G., 1968a, Materials investigation, Washington Creek, Mile 18, Elliott Highway: Project S-0680 (15), Alaska Department of Highways unpublished report, 43 pages.

Weaver, M.K., and Vournas, G., 1968b, Material site report, riprap 645-012-2 Project S-0645 (5): Alaska Department of Highways unpublished report.

Weaver, M.K., and Vournas, G., 1968c, Materials site Report Goldstream Road Mile5-11, Project Number S-0647 (2), Alaska Department of Highways unpublished report.

Weber, F.R., Smith, T.E., Hall, M.H., and Forbes, R.B., 1985, Geologic guide to the Fairbanks-Livengood area: Anchorage, Alaska Geological Society, 44 pages.

Wilson, F.H., Dover, J.H., Bradley, D.C., Weber, F.R., Bundtzen, T.K., and Haeussler, P.J., 1998, United States Geological Survey Open File Report 98-133, 63 pages; three sheets at 1:500,000 scale.

# Appendix I  Excel Spreadsheet of Field Data Collected During the 2010 Dunbar to Livengood Rail Corridor Investigations

| Count | Station # | Geologist | Date | Easting | Northing | Datum | Zone | Elevation | Elevation Units | Type (exposure) |
|---|---|---|---|---|---|---|---|---|---|---|
| **1** | **204683** | GML/CRL | 8/1/2010 | 416266 | 7187018 | NAD83 | 06W | 203 | meters | rubble crop |
| **2** | **204684** | GML/CRL | 8/1/2010 | 414403 | 7185603 | NAD83 | 06W | 151 | meters | surface rubble |
| **3** | **204685** | GML/CRL | 8/2/2010 | 422694 | 7194733 | NAD83 | 06W | 666 | meters | outcrop |
| **4** | **204686** | GML/CRL | 8/2/2010 | 424832 | 7197509 | NAD83 | 06W | 758 | meters | outcrop |
| **5** | **204687** | GML/CRL | 8/2/2010 | 424564 | 7197356 | NAD83 | 06W | 755 | meters | outcrop |
| **6** | **204688** | GML/CRL | 8/2/2010 | 424119 | 7196672 | NAD83 | 06W | 701 | meters | outcrop |
| **7** | **204689** | GML/LN | 8/3/2010 | 430864 | 7214499 | NAD83 | 06W | 252 | meters | float |
| **8** | **204691** | GML/LN | 8/3/2010 | 431822 | 7218685 | NAD83 | 06W | 156 | meters | outcrop |
| **9** | **204692** | GML/LN | 8/3/2010 | 430652 | 7218022 | NAD83 | 06W | 153 | meters | outcrop |
| **10** | **204925** | CRL/Bolz | 8/3/2010 | 423213 | 7204884 | NAD83 | 06W | 351 | meters | float from a bulldozer cut trail |
| **11** | **204926** | CRL/Bolz | 8/3/2010 | 422670 | 7204647 | NAD83 | 06W | 399 | meters | float/rubble crop - from a bulldozer cut at the summit of a dome |
| **12** | **204927** | CRL/Bolz | 8/3/2010 | 422603 | 7204593 | NAD83 | 06W | 398 | meters | float from a bulldozer cut trail |
| **13** | **204928** | CRL/Bolz | 8/3/2010 | 435368 | 7223747 | NAD83 | 06W | 642 | meters | rubble crop |
| **14** | **204929** | CRL/Bolz | 8/4/2010 | 408981 | 7219981 | NAD83 | 06W | 121 | meters | outcrop |
| **15** | **204930** | CRL/Bolz | 8/4/2010 | 409043 | 7219955 | NAD83 | 06W | 133 | meters | outcrop |
| **16** | **204931** | CRL/Bolz | 8/4/2010 | 409087 | 7219978 | NAD83 | 06W | 143 | meters | outcrop |
| **17** | **204932** | CRL/Bolz | 8/4/2010 | 409205 | 7219971 | NAD83 | 06W | 163 | meters | outcrop |
| **18** | **204933** | CRL/Bolz | 8/4/2010 | 409434 | 7220201 | NAD83 | 06W | 212 | meters | outcrop |
| **19** | **204934** | CRL/Bolz | 8/5/2010 | 408569 | 7222459 | NAD83 | 06W | 187 | meters | float gathered from the root balls of overturned trees |

| Count | Station # | Geologist | Date | Easting | Northing | Datum | Zone | Elevation | Elevation Units | Type (exposure) |
|---|---|---|---|---|---|---|---|---|---|---|
| **20** | **204935** | CRL/Bolz | 8/7/2010 | 418878 | 7224171 | NAD83 | 06W | 155 | meters | float in drainage |
| **21** | **204936** | CRL/Bolz | 8/7/2010 | 419337 | 7224063 | NAD83 | 06W | 169 | meters | float - small cobbles collected from the root ball of an overturned tree |
| **22** | **204937** | CRL/Bolz | 8/7/2010 | 419610 | 7223909 | NAD83 | 06W | 153 | meters | float chips dug from a drainage - not in place, but some of the only rock found in this area of very poor exposure |
| **23** | **204938** | CRL/Bolz | 8/7/2010 | 419731 | 7223812 | NAD83 | 06W | 167 | meters | float boulder in forest |
| **24** | **204939** | CRL/Bolz | 8/7/2010 | 419956 | 7223651 | NAD83 | 06W | 198 | meters | regolith from a 30cm deep hole in orange, clay-rich soil - no exposure in this area |
| **25** | **204940** | CRL/Bolz | 8/7/2010 | 420360 | 7223415 | NAD83 | 06W | 222 | meters | regolith from a 30cm deep hole in orange, clay-rich soil - no exposure in this area |
| **26** | **204941** | CRL/Bolz | 8/9/2010 | 421568 | 7223115 | NAD83 | 06W | 194 | meters | float - dug from the top of a shallow drainage/game trail |
| **27** | **204942** | CRL/Bolz | 8/9/2010 | 422450 | 7223377 | NAD83 | 06W | 200 | meters | float - chips from beneath a fallen tree in a burn |
| **28** | **204950** | GML/LN | 8/4/2010 | 414713 | 7221407 | NAD83 | 06W | 125 | meters | rubble crop |
| **29** | **204951** | GML/LN | 8/4/2010 | 414891 | 7221848 | NAD83 | 06W | 254 | meters | outcrop |
| **30** | **204952** | GML/LN | 8/4/2010 | 412226 | 7223539 | NAD83 | 06W | 308 | meters | dug rubble |
| **31** | **204953** | GML/LN | 8/6/2010 | 428570 | 7243928 | NAD83 | 06W | 190 | meters | rubble crop |
| **32** | **204954** | GML/LN | 8/6/2010 | 427862 | 7245233 | NAD83 | 06W | 231 | meters | dug rubble |
| **33** | **204955** | GML/LN | 8/6/2010 | 427985 | 7247547 | NAD83 | 06W | 453 | meters | rubble crop |
| **34** | **204956** | GML/LN | 8/6/2010 | 425324 | 7252155 | NAD83 | 06W | 196 | meters | rubble crop |

| Count | Station # | Geologist | Date | Easting | Northing | Datum | Zone | Elevation | Elevation Units | Type (exposure) |
|---|---|---|---|---|---|---|---|---|---|---|
| **35** | **204957** | GML/LN | 8/7/2010 | 429406 | 7252544 | NAD83 | 06W | 652 | meters | rubble crop |
| **36** | **204958** | GML/LN | 8/7/2010 | 429654 | 7253190 | NAD83 | 06W | 637 | meters | outcrop |
| **37** | **204959** | GML/LN | 8/9/2010 | 406234 | 7218821 | NAD83 | 06W | 103 | meters | outcrop |
| **38** | **204960** | GML/LN | 8/9/2010 | 406512 | 7222404 | NAD83 | 06W | 249 | meters | outcrop |
| **39** | **204961** | GML/LN | 8/9/2010 | 406968 | 7222857 | NAD83 | 06W | 281 | meters | dug rubble |
| **40** | **204962** | GML/LN | 8/9/2010 | 406909 | 7222829 | NAD83 | 06W | 282 | meters | dug rubble |
| **41** | **204963** | GML/LN | 8/9/2010 | 406723 | 7222696 | NAD83 | 06W | 288 | meters | rubble crop |
| **42** | **204964** | GML/LN | 8/10/2010 | 427810 | 7254749 | NAD83 | 06W | 502 | meters | dug rubble |
| **43** | **204965** | GML/LN | 8/10/2010 | 427893 | 7254775 | NAD83 | 06W | 503 | meters | dug rubble |
| **44** | **204974** | CRL/Bolz | 8/9/2010 | 423853 | 7224234 | NAD83 | 06W | 172 | meters | float - sub-rounded, water-lain gravel beneath 25cm of loess in a shallow drainage at the base of an overturned tree; no exposure in this area |
| **45** | **205100** | Bundtzen | 8/7/2010 | 424699 | 7197215 | NAD83 | 06W | 2471 | feet | outcrop |
| **46** | **205221** | Bundtzen/Bolz | 8/1/2010 | 417735 | 7188036 | NAD83 | 06W | 1018 | feet | rubble |
| **47** | **205242** | Metz | 8/1/2011 | 432388 | 7203727 | NAD83 | 06W | 2577 | feet | outcrop |
| **48** | **205243** | Metz | 8/1/2011 | 436952 | 7203542 | NAD83 | 06W | 2466 | feet | outcrop |
| **49** | **205244** | Metz | 8/2/2011 | 427449 | 7201022 | NAD83 | 06W | 2729 | feet | outcrop |
| **50** | **205245** | Metz | 8/2/2011 | 428227 | 7201180 | NAD83 | 06W | 2801 | feet | outcrop |
| **51** | **205246** | Metz | 8/2/2011 | 428242 | 7202197 | NAD83 | 06W | 2568 | feet | float |
| **52** | **205247** | Metz | 8/4/2011 | 410713 | 7220607 | NAD83 | 06W | 1076 | feet | outcrop |
| **53** | **205248** | Metz | 8/4/2011 | 410711 | 7221010 | NAD83 | 06W | 1396 | feet | outcrop |
| **54** | **205249** | Metz | 8/5/2011 | 411644 | 7221192 | NAD83 | 06W | 1075 | feet | outcrop |

| Count | Station # | Geologist | Date | Easting | Northing | Datum | Zone | Elevation | Elevation Units | Type (exposure) |
|---|---|---|---|---|---|---|---|---|---|---|
| **55** | **205250** | Metz | 8/5/2011 | 411854 | 7221096 | NAD83 | 06W | 948 | feet | outcrop |
| **56** | **205251** | Metz | 8/6/2011 | 423822 | 7193684 | NAD83 | 06W | 2366 | feet | outcrop |
| **57** | **205252** | Metz | 8/6/2011 | 424021 | 7193886 | NAD83 | 06W | 2398 | feet | outcrop |
| **58** | **205253** | Metz | 8/6/2011 | 424051 | 7194201 | NAD83 | 06W | 2258 | feet | outcrop |
| **59** | **205254** | Metz | 8/6/2011 | 423844 | 7194557 | NAD83 | 06W | 2273 | feet | outcrop |
| **60** | **205255** | Metz | 8/6/2011 | 423811 | 7195247 | NAD83 | 06W | 2320 | feet | outcrop |
| **61** | **205256** | Metz | 8/6/2011 | 424018 | 7195386 | NAD83 | 06W | 2314 | feet | outcrop |
| **62** | **205257** | Metz | 8/9/2011 | 411624 | 7220248 | NAD83 | 06W | 397 | feet | float |
| **63** | **205258** | Metz | 8/11/2011 | 425317 | 7265878 | NAD83 | 06W | 645 | feet | outcrop |
| **64** | **205259** | Metz | 8/11/2011 | 423265 | 7263752 | NAD83 | 06W | 641 | feet | outcrop |
| **65** | **205261** | Metz | 8/13/2011 | 430361 | 7273823 | NAD83 | 06W | 2107 | feet | float |
| **66** | **205262** | Metz | 8/16/2011 | 421593 | 7261563 | NAD83 | 06W | 840 | feet | outcrop |
| **67** | **205263** | Metz | 8/16/2011 | 428716 | 7261888 | NAD83 | 06W | 571 | feet | float |
| **68** | **205264** | Metz | 8/17/2011 | 424104 | 7193831 | NAD83 | 06W | 2358 | feet | outcrop |
| **69** | **205265** | Metz | 8/17/2011 | 424489 | 7193677 | NAD83 | 06W | 2253 | feet | outcrop |
| **70** | **205266** | Metz | 8/17/2011 | 423771 | 7193472 | NAD83 | 06W | 2258 | feet | outcrop |
| **71** | **205306** | GML/LN | 8/10/2010 | 428188 | 7251425 | NAD83 | 06W | 523 | meters | rubble crop |
| **72** | **205307** | GML/LN | 8/10/2010 | 428429 | 7259756 | NAD83 | 06W | 523 | meters | rubble crop |
| **73** | **205308** | GML/LN | 8/11/2010 | 406158 | 7222534 | NAD83 | 06W | 221 | meters | surface rubble |
| **74** | **205309** | GML/LN | 8/11/2010 | 405381 | 7222801 | NAD83 | 06W | 218 | meters | surface rubble |
| **75** | **205310** | GML/LN | 8/11/2010 | 404537 | 7222361 | NAD83 | 06W | 183 | meters | surface rubble |
| **76** | **205311** | GML/LN | 8/11/2010 | 404423 | 7222539 | NAD83 | 06W | 197 | meters | outcrop |
| **77** | **205312** | GML/LN | 8/12/2010 | 430473 | 7260291 | NAD83 | 06W | 557 | meters | dug rubble |

| Count | Station # | Geologist | Date | Easting | Northing | Datum | Zone | Elevation | Elevation Units | Type (exposure) |
|---|---|---|---|---|---|---|---|---|---|---|
| **78** | **205313** | GML/LN | 8/12/2010 | 430008 | 7259905 | NAD83 | 06W | 531 | meters | surface rubble |
| **79** | **205314** | GML/LN | 8/12/2010 | 429935 | 7259869 | NAD83 | 06W | 529 | meters | dug rubble |
| **80** | **205315** | GML/LN | 8/12/2010 | 428999 | 7255956 | NAD83 | 06W | 518 | meters | rubble crop |
| **81** | **205316** | GML/LN | 8/12/2010 | 429578 | 7255766 | NAD83 | 06W | 529 | meters | rubble crop |
| **82** | **205317** | GML/LN | 8/13/2010 | 427884 | 7250711 | NAD83 | 06W | 482 | meters | surface rubble |
| **83** | **205318** | GML/LN | 8/14/2010 | 430607 | 7251719 | NAD83 | 06W | 483 | meters | surface rubble |
| **84** | **205319** | GML/LN | 8/14/2010 | 411155 | 7241640 | NAD83 | 06W | 656 | meters | outcrop |
| **85** | **205320** | GML/LN | 8/14/2010 | 412683 | 7241687 | NAD83 | 06W | 693 | meters | rubble crop |
| **86** | **205321** | GML/LN | 8/14/2010 | 409942 | 7238886 | NAD83 | 06W | 636 | meters | rubble crop |
| **87** | **205322** | GML/LN | 8/14/2010 | 405781 | 7237407 | NAD83 | 06W | 323 | meters | outcrop |
| **88** | **205323** | GML/LN | 8/14/2010 | 405752 | 7237354 | NAD83 | 06W | 322 | meters | rubble crop |
| **89** | **205324** | GML/LN | 8/14/2010 | 434443 | 7249074 | NAD83 | 06W | 360 | meters | outcrop |
| **90** | **205325** | GML/LN | 8/16/2010 | 431428 | 7245887 | NAD83 | 06W | 275 | meters | dug rubble |
| **91** | **205326** | Bundtzen/Bolz | 8/12/2010 | 425233 | 7243121 | NAD83 | 06W | 1495 | feet | rubble |
| **92** | **205327** | Bundtzen/Bolz | 8/12/2010 | 425441 | 7242855 | NAD83 | 06W | 1512 | feet | rubble |
| **93** | **205328** | Bundtzen/Bolz | 8/12/2010 | 425515 | 7242422 | NAD83 | 06W | 1693 | feet | rubble |
| **94** | **205329** | Bundtzen/Bolz | 8/12/2010 | 425350 | 7243450 | NAD83 | 06W | 1660 | feet | rubble |
| **95** | **205330** | Bundtzen/Bolz | 8/13/2010 | 422974 | 7233896 | NAD83 | 06W | 1167 | feet | rubble |
| **96** | **205331** | Bundtzen/Bolz | 8/13/2010 | 423242 | 7233851 | NAD83 | 06W | 1343 | feet | rubble |
| **97** | **205332** | Bundtzen/Bolz | 8/13/2010 | 423525 | 7234201 | NAD83 | 06W | 1352 | feet | rubble |
| **98** | **205333** | Bundtzen/Bolz | 8/13/2010 | 423653 | 7234444 | NAD83 | 06W | 1360 | feet | rubble |
| **99** | **205334** | Bundtzen/Bolz | 8/13/2010 | 423253 | 7234303 | NAD83 | 06W | 1201 | feet | outcrop |
| **100** | **205335** | Bundtzen/Bolz | 8/14/2010 | 423975 | 7232887 | NAD83 | 06W | 1183 | feet | rubble |

| Count | Station # | Geologist | Date | Easting | Northing | Datum | Zone | Elevation | Elevation Units | Type (exposure) |
|---|---|---|---|---|---|---|---|---|---|---|
| **101** | **205336** | Bundtzen/Bolz | 8/14/2010 | 423950 | 7231753 | NAD83 | 06W | 930 | feet | rubble |
| **102** | **205337** | Bundtzen/Bolz | 8/14/2010 | 423790 | 7230814 | NAD83 | 06W | 1005 | feet | rubble |
| **103** | **205338** | Bundtzen/Bolz | 8/14/2010 | 425471 | 7230978 | NAD83 | 06W | 1139 | feet | rubble crop |
| **104** | **205339** | Bundtzen/Bolz | 8/16/2010 | 424739 | 7234865 | NAD83 | 06W | 1341 | feet | rubble |
| **105** | **205340** | Bundtzen/Bolz | 8/16/2010 | 424429 | 7235663 | NAD83 | 06W | 1545 | feet | rubble |
| **106** | **205341** | Bundtzen/Bolz | 8/16/2010 | 424641 | 7237261 | NAD83 | 06W | 1923 | feet | outcrop |
| **107** | **205342** | Bundtzen/Bolz | 8/17/2010 | 421716 | 7228854 | NAD83 | 06W | 1366 | feet | outcrop |
| **108** | **205343** | Bundtzen/Bolz | 8/17/2010 | 419752 | 7226979 | NAD83 | 06W | 841 | feet | rubble |
| **109** | **205344** | Bundtzen/Bolz | 8/17/2010 | 419874 | 7226637 | NAD83 | 06W | 880 | feet | rubble |
| **110** | **205345** | Bundtzen/Bolz | 8/17/2010 | 410701 | 7220607 | NAD83 | 06W | 1087 | feet | outcrop |
| **111** | **205346** | Bundtzen/Bolz | 8/17/2010 | 410630 | 7220608 | NAD83 | 06W | 1099 | feet | outcrop |
| **112** | **205365** | GML/LN | 8/16/2010 | 429227 | 7256278 | NAD83 | 06W | 520 | meters | outcrop |
| **113** | **205366** | GML/LN | 8/17/2010 | 410989 | 7223749 | NAD83 | 06W | 288 | meters | dug rubble |
| **114** | **205367** | GML/LN | 8/17/2010 | 411784 | 7224070 | NAD83 | 06W | 320 | meters | surface rubble |
| **115** | **205368** | GML/LN | 8/25/2010 | 449295 | 7230847 | NAD83 | 06W | 586 | meters | rubble crop |
| **116** | **205369** | GML/LN | 8/25/2010 | 446044 | 7241076 | NAD83 | 06W | 270 | meters | rubble crop |
| **117** | **205370** | GML/LN | 8/25/2010 | 445491 | 7241188 | NAD83 | 06W | 304 | meters | rubble crop |
| **118** | **205371** | GML/LN | 8/25/2010 | 443894 | 7242553 | NAD83 | 06W | 399 | meters | rubble crop |
| **119** | **205372** | GML/LN | 8/25/2010 | 443577 | 7243472 | NAD83 | 06W | 366 | meters | surface rubble |
| **120** | **205373** | GML/LN | 8/25/2010 | 431913 | 7263746 | NAD83 | 06W | 254 | meters | outcrop |
| **121** | **205410** | Bundtzen/Bolz | 8/12/2010 | 424009 | 7243460 | NAD83 | 06W | 567 | feet | rubble |
| **122** | **205411** | Bundtzen | 8/7/2010 | 425230 | 7197394 | NAD83 | 06W | 2450 | feet | outcrop |
| **123** | **205412** | Bundtzen | 8/7/2010 | 426335 | 7198969 | NAD83 | 06W | 1921 | feet | rubble |

| Count | Station # | Geologist | Date | Easting | Northing | Datum | Zone | Elevation | Elevation Units | Type (exposure) |
|---|---|---|---|---|---|---|---|---|---|---|
| **124** | **205413** | Bundtzen | 8/7/2010 | 427578 | 7200851 | NAD83 | 06W | 2756 | feet | rubble |
| **125** | **205414** | Bundtzen | 8/7/2010 | 427956 | 7200883 | NAD83 | 06W | 2814 | feet | outcrop |
| **126** | **205415** | Bundtzen | 8/9/2010 | 425551 | 7211425 | NAD83 | 06W | 1604 | feet | rubble |
| **127** | **205416** | Bundtzen | 8/9/2010 | 426325 | 7212115 | NAD83 | 06W | 1627 | feet | rubble |
| **128** | **205417** | Bundtzen | 8/9/2010 | 426594 | 7213372 | NAD83 | 06W | 1050 | feet | rubble |
| **129** | **205418** | Bundtzen | 8/9/2010 | 426593 | 7213457 | NAD83 | 06W | 1020 | feet | outcrop |
| **130** | **205419** | Bundtzen/Bolz | 8/10/2010 | 430146 | 7257631 | NAD83 | 06W | 1870 | feet | outcrop |
| **131** | **205420** | Bundtzen/Bolz | 8/10/2010 | 429950 | 7257489 | NAD83 | 06W | 1813 | feet | outcrop |
| **132** | **205421** | Bundtzen/Bolz | 8/10/2010 | 429380 | 7258700 | NAD83 | 06W | 1940 | feet | outcrop |
| **133** | **205422** | Bundtzen/Bolz | 8/11/2010 | 428423 | 7259496 | NAD83 | 06W | 1568 | feet | rubble |
| **134** | **205423** | Bundtzen/Bolz | 8/11/2010 | 421515 | 7261627 | NAD83 | 06W | 932 | feet | rubble |
| **135** | **205424** | Bundtzen/Bolz | 8/11/2010 | 421524 | 7261664 | NAD83 | 06W | 880 | feet | rubble |
| **136** | **205425** | Bundtzen/Bolz | 8/11/2010 | 437592 | 7256640 | NAD83 | 06W | 1629 | feet | outcrop |
| **137** | **205426** | Bolz/Nichols | 8/2/2010 | 417374 | 7188652 | NAD83 | 06W | 286 | meters | rubblecrop |
| **138** | **205427** | Bolz/Nichols | 8/2/2010 | 417212 | 7189197 | NAD83 | 06W | n/a |  | rubblecrop |
| **139** | **205428** | Bolz/Nichols | 8/2/2010 | 415928 | 7188676 | NAD83 | 06W | n/a |  | outcrop |
| **140** | **205429** | Bolz/Nichols | 8/2/2010 | 415664 | 7189294 | NAD83 | 06W | 125 | meters | rubblecrop |
| **141** | **205430** | Bolz/Laird | 8/3/2010 | 428740 | 7219149 | NAD83 | 06W | 215 | meters | rubblecrop |
| **142** | **205431** | Bolz/Laird | 8/3/2010 | 428726 | 7218996 | NAD83 | 06W | 196 | meters | rubblecrop |
| **143** | **205432** | Bolz/Laird | 8/5/2010 | 408382 | 7223179 | NAD83 | 06W | 263 | meters | float |
| **144** | **205433** | Bolz/Laird | 8/6/2010 | 421717 | 7228861 | NAD83 | 06W | 428 | meters | outcrop |
| **145** | **205434** | Bolz/Laird | 8/6/2010 | 418749 | 7224274 | NAD83 | 06W | 161 | meters | float |
| **146** | **205435** | Bolz/Laird | 8/6/2010 | 418701 | 7224255 | NAD83 | 06W | 148 | meters | outcrop |

| Count | Station # | Geologist | Date | Easting | Northing | Datum | Zone | Elevation | Elevation Units | Type (exposure) |
|---|---|---|---|---|---|---|---|---|---|---|
| **147** | **205436** | Bolz/Laird | 8/6/2010 | 418981 | 7224541 | NAD83 | 06W | 171 | meters | outcrop |
| **148** | **205437** | Bolz/Laird | 8/6/2010 | 418944 | 7224561 | NAD83 | 06W | 163 | meters | float |
| **149** | **205438** | Bolz/Laird | 8/7/2010 | 418959 | 7224125 | NAD83 | 06W | 157 | meters | outcrop regolith |
| **150** | **205438** | Bolz/Laird | 8/7/2010 | 418960 | 7224136 | NAD83 | 06W | 157 | meters | float |
| **151** | **205439** | Bolz/Laird | 8/7/2010 | 419675 | 7223840 | NAD83 | 06W | n/a | | float |
| **152** | **205440** | Bolz/Bundtzen | 8/10/2010 | 430005 | 7257761 | NAD83 | 06W | 570 | meters | outcrop |
| **153** | **205441** | Bolz/Bundtzen | 8/11/2010 | 428531 | 7259417 | NAD83 | 06W | 465 | meters | float |
| **154** | **205442** | Bolz/Bundtzen | 8/11/2010 | 421861 | 7261252 | NAD83 | 06W | n/a | | rubblecrop |
| **155** | **205443** | Bolz/Bundtzen | 8/17/2010 | 410802 | 7220604 | NAD83 | 06W | 301 | meters | outcrop |
| **156** | **205461** | GML/LN | 8/5/2010 | 413765 | 7222303 | NAD83 | 06W | 240 | meters | outcrop |
| **157** | **205462** | GML/LN | 8/5/2010 | 411814 | 7224168 | NAD83 | 06W | 314 | meters | surface rubble |
| **158** | **205463** | GML/LN | 8/5/2010 | 411842 | 7224054 | NAD83 | 06W | 322 | meters | surface rubble |
| **159** | **205487** | Matt B & Kyle O | 8/17/10 | 416029 | 7191911 | NAD83 | 06W | 135 | meters | outcrop |
| **160** | **205488** | Matt B & Kyle O | 8/16/10 | 428140 | 7256097 | NAD83 | 06W | n/a | | outcrop |
| **161** | **205489** | Matt B & Kyle O | 8/17/10 | 414423 | 7179191 | NAD83 | 06W | 1038 | feet | outcrop |
| **162** | **205490** | Matt B & Kyle O | 8/17/10 | 414300 | 7179538 | NAD83 | 06W | 1051 | feet | outcrop |
| **163** | **205491** | Matt B & Kyle O | 8/17/10 | 413688 | 7180387 | NAD83 | 06W | 965 | feet | outcrop |
| **164** | **205492** | Matt Billings | 8/11/2010 | 424038 | 7243561 | NAD83 | 06W | n/a | | grab |
| **165** | **205494** | Matt Billings | 8/12/2010 | 425507 | 7252304 | NAD83 | 06W | n/a | | |
| **166** | **205495** | Matt Billings | 8/16/2010 | 428839 | 7256165 | NAD83 | 06W | n/a | | channel |
| **167** | **205496** | Matt Billings | 8/16/2010 | 428625 | 7256147 | NAD83 | 06W | n/a | | float |
| **168** | **209260** | Metz | 8/13/2011 | 431772 | 7274753 | NAD83 | 06W | 2590 | feet | float |
| **169** | **10GL100** | GML/LN | 8/2/2010 | 416793 | 7190961 | NAD83 | 06W | n/a | | dirt |

| Count | Station # | Geologist | Date | Easting | Northing | Datum | Zone | Elevation | Elevation Units | Type (exposure) |
|---|---|---|---|---|---|---|---|---|---|---|
| **170** | **10GL101** | GML/LN | 8/2/2010 | | | NAD83 | 06W | n/a | | dirt |
| **171** | **10GL102** | GML/LN | 8/3/2010 | 425442 | 7211578 | NAD83 | 06W | n/a | | dug rubble |
| **172** | **10GL103** | GML/LN | 8/3/2010 | 425373 | 7211490 | NAD83 | 06W | n/a | | dug rubble |
| **173** | **10GL104** | GML/LN | 8/3/2010 | 425085 | 7211274 | NAD83 | 06W | n/a | | dug rubble |
| **174** | **10GL105** | GML/LN | 8/4/2010 | 414727 | 7221510 | NAD83 | 06W | n/a | | outcrop |
| **175** | **10GL106** | GML/LN | 8/4/2010 | 427521 | 7219002 | NAD83 | 06W | n/a | | dirt |
| **176** | **10GL109** | GML/LN | 8/4/2010 | 426722 | 7250604 | NAD83 | 06W | n/a | | dug rubble |
| **177** | **10GL110** | GML/LN | 8/4/2010 | 429593 | 7253089 | NAD83 | 06W | n/a | | dug rubble |
| **178** | **10GL111** | GML/LN | 8/4/2010 | 429615 | 7253127 | NAD83 | 06W | n/a | | outcrop |
| **179** | **10GL112** | GML/LN | 8/10/2010 | 428142 | 7254811 | NAD83 | 06W | n/a | | dug rubble |
| **180** | **10GL113** | GML/LN | 8/10/2010 | 428243 | 7254913 | NAD83 | 06W | n/a | | dug rubble |
| **181** | **10GL114** | GML/LN | 8/10/2010 | 428803 | 7255091 | NAD83 | 06W | n/a | | dug rubble |
| **182** | **10GL115** | GML/LN | 8/11/2010 | 405822 | 7222663 | NAD83 | 06W | n/a | | outcrop |
| **183** | **10GL116** | GML/LN | 8/11/2010 | 405704 | 7222626 | NAD83 | 06W | n/a | | outcrop |
| **184** | **10GL117** | GML/LN | 8/11/2010 | 405490 | 7222789 | NAD83 | 06W | n/a | | outcrop |
| **185** | **10GL119** | GML/LN | 8/11/2010 | 405289 | 7222824 | NAD83 | 06W | n/a | | dug rubble |
| **186** | **10GL120** | GML/LN | 8/11/2010 | 405158 | 7222838 | NAD83 | 06W | n/a | | dug rubble |
| **187** | **10GL121** | GML/LN | 8/11/2010 | 405053 | 7222797 | NAD83 | 06W | n/a | | dug rubble |
| **188** | **10GL122** | GML/LN | 8/11/2010 | 404720 | 7222340 | NAD83 | 06W | n/a | | dug rubble |
| **189** | **10GL123** | GML/LN | 8/11/2010 | 404367 | 7222531 | NAD83 | 06W | n/a | | outcrop |
| **190** | **10GL124** | GML/LN | 8/11/2010 | 404258 | 7222522 | NAD83 | 06W | n/a | | outcrop |
| **191** | **10GL125** | GML/LN | 8/12/2010 | 430301 | 7260187 | NAD83 | 06W | n/a | | dug rubble |
| **192** | **10GL126** | GML/LN | 8/12/2010 | 430246 | 7260167 | NAD83 | 06W | n/a | | dug rubble |

| Count | Station # | Geologist | Date | Easting | Northing | Datum | Zone | Elevation | Elevation Units | Type (exposure) |
|---|---|---|---|---|---|---|---|---|---|---|
| **193** | **10GL127** | GML/LN | 8/12/2010 | 430152 | 7260018 | NAD83 | 06W | n/a | | dug rubble |
| **194** | **10GL128** | GML/LN | 8/12/2010 | 430083 | 7259962 | NAD83 | 06W | n/a | | dug rubble |
| **195** | **10GL129** | GML/LN | 8/12/2010 | 427529 | 7250147 | NAD83 | 06W | n/a | | dug rubble |
| **196** | **10GL130** | GML/LN | 8/12/2010 | 427314 | 7249698 | NAD83 | 06W | n/a | | dug rubble |
| **197** | **10GL131** | GML/LN | 8/12/2010 | 426623 | 7249418 | NAD83 | 06W | n/a | | dug rubble |
| **198** | **10GL132** | GML/LN | 8/14/2010 | 430390 | 7251800 | NAD83 | 06W | n/a | | dug rubble |
| **199** | **10GL133** | GML/LN | 8/16/2010 | 429085 | 7243931 | NAD83 | 06W | n/a | | dug rubble |
| **200** | **10GL134** | GML/LN | 8/16/2010 | 429484 | 7244132 | NAD83 | 06W | n/a | | dug rubble |
| **201** | **10GL135** | GML/LN | 8/16/2010 | 430028 | 7244407 | NAD83 | 06W | n/a | | dug rubble |
| **202** | **10GL136** | GML/LN | 8/16/2010 | 430197 | 7244495 | NAD83 | 06W | n/a | | dug rubble |
| **203** | **10GL137** | GML/LN | 8/16/2010 | 430523 | 7244793 | NAD83 | 06W | n/a | | dug rubble |
| **204** | **10GL138** | GML/LN | 8/16/2010 | 431486 | 7245443 | NAD83 | 06W | n/a | | dug rubble |
| **205** | **10GL139** | GML/LN | 8/16/2010 | 431445 | 7245806 | NAD83 | 06W | n/a | | dug rubble |

| Count | Station # | Rock Type | Geologic Unit |
|---|---|---|---|
| **1** | **204683** | schist | Fairbanks schist (Robinson and others, 1990) |
| **2** | **204684** | schist | Fairbanks schist (Robinson and others, 1990) |
| **3** | **204685** | schist | Fairbanks schist (Robinson and others, 1990) |
| **4** | **204686** | schist | Fairbanks schist (Robinson and others, 1990) |
| **5** | **204687** | schist | Fairbanks schist (Robinson and others, 1990) |
| **6** | **204688** | schist | Fairbanks schist (Robinson and others, 1990) |
| **7** | **204689** | schist | Fairbanks schist (Robinson and others, 1990) |
| **8** | **204691** | meta-sediments | (Weber and others, 1992) |
| **9** | **204692** | schist | (Weber and others, 1990) |
| **10** | **204925** | muscovite-quartz schist | Fairbanks schist |
| **11** | **204926** | mica-quartz schist | Fairbanks schist |
| **12** | **204927** | muscovite-biotite-quartz schist | Fairbanks schist |
| **13** | **204928** | phyllite | Fairbanks schist |
| **14** | **204929** | limestone breccia | Tolovana limestone |
| **15** | **204930** | limestone | Tolovana limestone |
| **16** | **204931** | limestone | Tolovana limestone |
| **17** | **204932** | limestone | Tolovana limestone |
| **18** | **204933** | limestone | Tolovana limestone |
| **19** | **204934** | quartzite | Globe quartzite |
| **20** | **204935** | grit(?) | grit |
| **21** | **204936** | chert | radiolarian chert |
| **22** | **204937** | chert | radiolarian chert |

| Count | Station # | Rock Type | Geologic Unit |
|---|---|---|---|
| 23 | 204938 | grit | grit |
| 24 | 204939 | grit | grit |
| 25 | 204940 | grit | grit |
| 26 | 204941 | grit | grit |
| 27 | 204942 | grit | grit |
| 28 | 204950 | limestone | Tolovana limestone (DStb, Bundtzen, 1983) |
| 29 | 204951 | limestone | Tolovana limestone (DStl, Bundtzen, 1983) |
| 30 | 204952 | meta-chert/quartzite | OCc or Ocq (Bundtzen, 1983) |
| 31 | 204953 | feldspar schist | KJcg(?) (Bundtzen, 1983) |
| 32 | 204954 | phyllite | KJcg |
| 33 | 204955 | rhyolite | TKfd (Bundtzen, 1983) |
| 34 | 204956 | shale | KJcg |
| 35 | 204957 | sandstone | KJst (Bundtzen, 1983) |
| 36 | 204958 | conglomerate | KJcg |
| 37 | 204959 | limestone | Tolovana limestone (DStb, Bundtzen, 1983) |
| 38 | 204960 | gabbro/diorite | OCg (Bundtzen, 1983) |
| 39 | 204961 | meta-quartzite | OCq (Bundtzen, 1983) |
| 40 | 204962 | border phase | OCg (Bundtzen, 1983) |
| 41 | 204963 | gabbro/diorite | OCg (Bundtzen, 1983) |
| 42 | 204964 | sandstone | KJst (Bundtzen, 1983) |
| 43 | 204965 | phyllite | KJst (Bundtzen, 1983) |
| 44 | 204974 | grit | grit |
| 45 | 205100 | schist | Fairbanks schist (Robinson and others, 1990) |

| Count | Station # | Rock Type | Geologic Unit |
|---|---|---|---|
| **46** | **205221** | phyllitic schist | Fairbanks schist (Robinson and others, 1990) |
| **47** | **205242** | feldspathic quartzite | Fairbanks schist (Robinson and others, 1990) |
| **48** | **205243** | massive quartzite | Fairbanks schist (Robinson and others, 1990) |
| **49** | **205244** | massive quartzite | Fairbanks schist (Robinson and others, 1990) |
| **50** | **205245** | muscovite-chlorite-garnet schist | Fairbanks schist (Robinson and others, 1990) |
| **51** | **205246** | feldspathic quartzite | Fairbanks schist (Robinson and others, 1990) |
| **52** | **205247** | fine grained limestone | Tolovana limestone (Weber and others, 1992) |
| **53** | **205248** | fine grained limestone | Tolovana limestone (Weber and others, 1992) |
| **54** | **205249** | fine grained limestone | Tolovana limestone (Weber and others, 1992) |
| **55** | **205250** | fine grained limestone | Tolovana limestone (Weber and others, 1992) |
| **56** | **205251** | micaceous quartzite | Fairbanks schist (Robinson and others, 1990) |
| **57** | **205252** | micaceous quartzite | Fairbanks schist (Robinson and others, 1990) |
| **58** | **205253** | quartz | Fairbanks schist (Robinson and others, 1990) |
| **59** | **205254** | micaceous quartzite | Fairbanks schist (Robinson and others, 1990) |
| **60** | **205255** | micaceous quartzite | Fairbanks schist (Robinson and others, 1990) |
| **61** | **205256** | micaceous quartzite | Fairbanks schist (Robinson and others, 1990) |
| **62** | **205257** | black phyllite | Livengood Dome chert (Weber and others, 1992) |
| **63** | **205258** | chert | Livengood Dome chert (Weber and others, 1992) |
| **64** | **205259** | chert | Livengood Dome chert (Weber and others, 1992) |
| **65** | **205261** | chert | Livengood Dome chert (Weber and others, 1992) |
| **66** | **205262** | pyroxene diorite | Livengood ophiolite (Weber and others, 1992) |
| **67** | **205263** | biotite-quartz-feldspar porphyry | TK intrusion, Shorty Creek suite |
| **68** | **205264** | micaceous quartzite | Fairbanks schist (Robinson and others, 1990) |

| Count | Station # | Rock Type | Geologic Unit |
|---|---|---|---|
| **69** | **205265** | biotite-muscovite-quartz schist | Fairbanks schist (Robinson and others, 1990) |
| **70** | **205266** | muscovite schist | Fairbanks schist (Robinson and others, 1990) |
| **71** | **205306** | sandstone | KJst (Bundtzen, 1983) |
| **72** | **205307** | phyllite | KJst (Bundtzen, 1983) |
| **73** | **205308** | gabbro/diorite | OCg (Bundtzen, 1983) |
| **74** | **205309** | meta-quartzite | OCq (Bundtzen, 1983) |
| **75** | **205310** | meta-quartzite | OCq (Bundtzen, 1983) |
| **76** | **205311** | gabbro/diorite | OCg (Bundtzen, 1983) |
| **77** | **205312** | phyllite | KJst (Bundtzen, 1983) |
| **78** | **205313** | conglomerate | KJst (Bundtzen, 1983) |
| **79** | **205314** | phyllite | KJst (Bundtzen, 1983) |
| **80** | **205315** | meta-quartzite | hornfels |
| **81** | **205316** | phyllite | KJst (Bundtzen, 1983) |
| **82** | **205317** | sandstone | KJst (Bundtzen, 1983) |
| **83** | **205318** | sandstone | KJst (Bundtzen, 1983) |
| **84** | **205319** | hornfels | mst (Albanese, 1983) |
| **85** | **205320** | granite | TKqm (Albanese, 1983) |
| **86** | **205321** | granite | TKqm (Albanese, 1983) |
| **87** | **205322** | granite | TKqm (Albanese, 1983) |
| **88** | **205323** | tourmaline | TKqm (Albanese, 1983) |
| **89** | **205324** | conglomerate | KJcg (Bundtzen, 1983) |
| **90** | **205325** | schist | KJcg(?) (Bundtzen, 1983) |
| **91** | **205326** | siltstone | Wilbur Creek flysch (Weber and others, 1992) |

| Count | Station # | Rock Type | Geologic Unit |
|---|---|---|---|
| **92** | **205327** | sandstone | Wilbur Creek flysch (Weber and others, 1992) |
| **93** | **205328** | siltstone | Wilbur Creek flysch (Weber and others, 1992) |
| **94** | **205329** | sandstone | Wilbur Creek flysch (Weber and others, 1992) |
| **95** | **205330** | siltstone | Wilbur Creek flysch (Weber and others, 1992) |
| **96** | **205331** | sandstone | Wilbur Creek flysch (Weber and others, 1992) |
| **97** | **205332** | sandstone | Wilbur Creek flysch (Weber and others, 1992) |
| **98** | **205333** | mudstone | Wilbur Creek flysch (Weber and others, 1992) |
| **99** | **205334** | mudstone | Wilbur Creek flysch (Weber and others, 1992) |
| **100** | **205335** | mudstone | Wilbur Creek flysch (Weber and others, 1992) |
| **101** | **205336** | mudstone | Wilbur Creek flysch (Weber and others, 1992) |
| **102** | **205337** | quartzite | Globe quartzite (Weber and others, 1992) |
| **103** | **205338** | banded chert | Globe quartzite (Weber and others, 1992) |
| **104** | **205339** | siltstone | Wilbur Creek flysch (Weber and others, 1992) |
| **105** | **205340** | sandstone | Wilbur Creek flysch (Weber and others, 1992) |
| **106** | **205341** | sandstone | Wilbur Creek flysch (Weber and others, 1992) |
| **107** | **205342** | quartzite | Globe quartzite (Weber and others, 1992) |
| **108** | **205343** | quartzite | Globe quartzite (Weber and others, 1992) |
| **109** | **205344** | quartzite | Globe quartzite (Weber and others, 1992) |
| **110** | **205345** | limestone | Tolovana limestone (Bundtzen, 1983) |
| **111** | **205346** | limestone | Tolovana limestone (Bundtzen, 1983) |
| **112** | **205365** | hornfels | KJcg(?) (Bundtzen, 1983) |
| **113** | **205366** | quartzite | Globe quartzite (Weber and others, 1992) |
| **114** | **205367** | quartzite | Globe quartzite (Weber and others, 1992) |

| Count | Station # | Rock Type | Geologic Unit |
|---|---|---|---|
| **115** | **205368** | grit | Wickersham grit (Weber and others, 1992) |
| **116** | **205369** | limestone | Tolovana limestone (DStb, Bundtzen, 1983) |
| **117** | **205370** | gabbro/diorite | OCg (Bundtzen, 1983) |
| **118** | **205371** | quartzite | OCq (Bundtzen, 1983) |
| **119** | **205372** | mafic dike | Beaver Creek fault area |
| **120** | **205373** | mafic dike | Pzdg (Bundtzen, 1983) |
| **121** | **205410** | sandstone | Wilbur Creek flysch (Weber and others, 1992) |
| **122** | **205411** | schist | Fairbanks schist (Robinson and others, 1990) |
| **123** | **205412** | schist | Fairbanks schist (Robinson and others, 1990) |
| **124** | **205413** | schist | Fairbanks schist (Robinson and others, 1990) |
| **125** | **205414** | schist | Fairbanks schist (Robinson and others, 1990) |
| **126** | **205415** | phyllite | Wickersham grit (Weber and others, 1992) |
| **127** | **205416** | phyllite | Wickersham grit (Weber and others, 1992) |
| **128** | **205417** | phyllite | Wickersham grit (Weber and others, 1992) |
| **129** | **205418** | phyllite | Wickersham grit (Weber and others, 1992) |
| **130** | **205419** | hornfels | hornfels/Wilbur flysch (this study) |
| **131** | **205420** | hornfels | hornfels/Wilbur flysch (this study) |
| **132** | **205421** | conglomerate | Wilbur Creek flysch (Weber and others, 1992) |
| **133** | **205422** | porphyry | Tertiary intrusion (this study) |
| **134** | **205423** | serpentenite | Cambrian ophiolite (Weber and others, 1992) |
| **135** | **205424** | pyroxenite | Cambrian ophiolite (Weber and others, 1992) |
| **136** | **205425** | sandstone | Wilbur Creek flysch (Weber and others, 1992) |
| **137** | **205426** | phyllite schist | Fairbanks schist (Robinson and others, 1990) |

| Count | Station # | Rock Type | Geologic Unit |
|---|---|---|---|
| **138** | **205427** | phyllite schist | Fairbanks schist (Robinson and others, 1990) |
| **139** | **205428** | phyllite schist | Fairbanks schist (Robinson and others, 1990) |
| **140** | **205429** | phyllite schist | Fairbanks schist (Robinson and others, 1990) |
| **141** | **205430** | grit(?) flysch(?) | mapped as Czwa (Wilson and others, 1998) |
| **142** | **205431** | grit(?) flysch(?) | mapped as Czwa (Wilson and others, 1998) |
| **143** | **205432** | quartzite | Globe quartzite (Weber et al, 1992) |
| **144** | **205433** | quartzite | Globe quartzite (Weber et al, 1992) |
| **145** | **205434** | limestone | Tolovana limestone (previously mapped as grit, Weber et al, 1992) |
| **146** | **205435** | limestone | Tolovana limestone (previously mapped as grit, Weber et al, 1992) |
| **147** | **205436** | phyllite schist(?) | previously mapped as grit |
| **148** | **205437** | metavolcanic | $\mathrm{T_R}$m - mafic igneous rocks (Weber, 1992) |
| **149** | **205438** | phyllite | Wickersham grit (Zwg, Weber and others, 1992) |
| **150** | **205438** | Wickersham grit(?) | Wickersham grit (Zwg, Weber and others, 1992) |
| **151** | **205439** | Wickersham grit(?) | Wickersham grit (Zwg, Weber and others, 1992) |
| **152** | **205440** | hornfels | hornfels/Wilbur flysch (this study, Bundtzen, 1983) |
| **153** | **205441** | granodiorite | TKg (Weber and others, 1992) |
| **154** | **205442** | diorite | intrusion in Cambrian mafic (€Zum, Weber and others, 1992) |
| **155** | **205443** | limestone | Tolovana limestone (Weber and others, 1992) |
| **156** | **205461** | meta-volcanic | Sovs(?) (Weber and others, 1992) |
| **157** | **205462** | quartzite | Globe quartzite (Weber and others, 1992) |
| **158** | **205463** | quartzite | Globe quartzite (Weber and others, 1992) |
| **159** | **205487** | quartzite schist | Fairbanks schist (Robinson and others, 1990) |
| **160** | **205488** | slate | flysch |

| Count | Station # | Rock Type | Geologic Unit |
|---|---|---|---|
| **161** | **205489** | schist | Fairbanks schist (Robinson and others, 1990) |
| **162** | **205490** | schist | Fairbanks schist (Robinson and others, 1990) |
| **163** | **205491** | chloritic quartzite | Fairbanks schist (Robinson and others, 1990) |
| **164** | **205492** | greywacke | Wilbur Creek flysch (Weber and others, 1992) |
| **165** | **205494** | slate | Wilbur Creek flysch (Weber and others, 1992) |
| **166** | **205495** | hornfels | Wilbur Creek flysch (Weber and others, 1992) |
| **167** | **205496** | granodiorite | TK intrusion (Weber and others, 1992) |
| **168** | **209260** | chert | Livengood Dome chert (Weber and others, 1992) |
| **169** | **10GL100** | loess | n/a |
| **170** | **10GL101** | loess | n/a |
| **171** | **10GL102** | mica-schist | Fairbanks schist (Robinson and others, 1990) |
| **172** | **10GL103** | mica-schist | Fairbanks schist (Robinson and others, 1990) |
| **173** | **10GL104** | schist |  |
| **174** | **10GL105** | limestone | Tolovana limestone (Bundtzen, 1983) |
| **175** | **10GL106** | loess |  |
| **176** | **10GL109** | phyllite | KJst (Bundtzen, 1983) |
| **177** | **10GL110** | sandstone | KJst (Bundtzen, 1983) |
| **178** | **10GL111** | conglomerate | KJcg (1983) |
| **179** | **10GL112** | phyllite | KJst (Bundtzen, 1983) |
| **180** | **10GL113** | phyllite | KJst (Bundtzen, 1983) |
| **181** | **10GL114** | phyllite | KJst (Bundtzen, 1983) |
| **182** | **10GL115** | gabbro/diorite | OCg (Bundtzen, 1983) |
| **183** | **10GL116** | gabbro/diorite | OCg (Bundtzen, 1983) |

| Count | Station # | Rock Type | Geologic Unit |
|---|---|---|---|
| **184** | **10GL117** | gabbro/diorite | OCg (Bundtzen, 1983) |
| **185** | **10GL119** | meta-quartzite | OCq (Bundtzen, 1983) |
| **186** | **10GL120** | gabbro/diorite | OCg (Bundtzen, 1983) |
| **187** | **10GL121** | meta-quartzite | OCq (Bundtzen, 1983) |
| **188** | **10GL122** | meta-quartzite | OCq (Bundtzen, 1983) |
| **189** | **10GL123** | gabbro/diorite | OCg (Bundtzen, 1983) |
| **190** | **10GL124** | gabbro/diorite | OCg (Bundtzen, 1983) |
| **191** | **10GL125** | phyllite | KJst (Bundtzen, 1983) |
| **192** | **10GL126** | phyllite | KJst (Bundtzen, 1983) |
| **193** | **10GL127** | phyllite | KJst (Bundtzen, 1983) |
| **194** | **10GL128** | phyllite | KJst (Bundtzen, 1983) |
| **195** | **10GL129** | phyllite | KJst (Bundtzen, 1983) |
| **196** | **10GL130** | phyllite | KJst (Bundtzen, 1983) |
| **197** | **10GL131** | phyllite | KJst (Bundtzen, 1983) |
| **198** | **10GL132** | phyllite | KJst (Bundtzen, 1983) |
| **199** | **10GL133** | phyllite | KJst (Bundtzen, 1983) |
| **200** | **10GL134** | phyllite | KJst (Bundtzen, 1983) |
| **201** | **10GL135** | phyllite | KJst (Bundtzen, 1983) |
| **202** | **10GL136** | phyllite | KJst (Bundtzen, 1983) |
| **203** | **10GL137** | phyllite | KJst (Bundtzen, 1983) |
| **204** | **10GL138** | phyllite | KJst (Bundtzen, 1983) |
| **205** | **10GL139** | phyllite | KJst (Bundtzen, 1983) |

| Count | Station # | Rock Description |
|---|---|---|
| **1** | **204683** | mica-quartz schist to quartzite |
| **2** | **204684** | mica-quartz schist to quartzite |
| **3** | **204685** | gray, quartz-laminated, mica-quartz schist |
| **4** | **204686** | greenish-gray to brown chlorite-mica-quartz schist |
| **5** | **204687** | green-gray, feldspar eye, chlorite-quartz schist; high mica content |
| **6** | **204688** | orange-tan, quartz-rich schist |
| **7** | **204689** | gray-brown, mica-quartz schist |
| **8** | **204691** | calcareous meta-sediments interlayered with chlorite schist, quartzite, and meta tuff(?); beds average 10-25cm thick |
| **9** | **204692** | muscovite-quartz schist; calcite in fractures; some weathered surfaces; meta-volcanic(?) |
| **10** | **204925** | weathered muscovite-quartz schist with abundant fe-ox staining |
| **11** | **204926** | silver-white, medium grained, mica-quartz schist; minor fe-ox staining |
| **12** | **204927** | silver-gold to black, folded schist with quartz boudins, pyrite remnants, and light fe-ox staining on exposed surfaces and fractures |
| **13** | **204928** | gray-green, very fine grained, laminated phyllite interlayered with slightly coarser grained, silica-rich, schistier, more resistant-looking beds; does not appear to have rip-rap potential; low priority bulk sample collected here |
| **14** | **204929** | recemented limestone breccia with copious calium-carbonate veining - does not look like it would do well in an LA abrasion test |
| **15** | **204930** | dark gray to black limestone (weathers light gray to white); abundant calcite veinlets; more cohesive than at the west end of the dome, but still extremely fractured and jointed - no structural measurments possible |
| **16** | **204931** | dark gray to black limestone (weathers light gray to white); fresher and better than the limestone at the west end of the dome - fewer calcite veins, does not appear to have been recemented, but still very fractured - easy to turn large boulders into shards with a rock hammer - doubtful that the limestone here would make riprap |
| **17** | **204932** | dark gray, very fractured limestone with abundant calcium-carbonate veining |
| **18** | **204933** | light gray, very fractured limestone with abundant calcium-carbonate veining; fe-ox staining along the larger fractures |

| Count | Station # | Rock Description |
|---|---|---|
| **19** | **204934** | cobbles of fine grained, well cemented quartzite gathered from the root balls of overturned trees in a recent burn; cobbles have a polished exterior, and a tan to red colored weather rind; most of the rock is tan to tan gray - showing signs of weathering; the freshest surfaces are a light gray; material sample collected here should test pretty well in spite of weathering; one piece of black, quartz-veined chert (~ 7cm x 3cm x 3cm) was found at the site, but not included in the sample |
| **20** | **204935** | very weathered, and fire-baked red; copious stockwork veinlets; lightly foliated; possibly grit, but the outsized quartz grains found in the nearby grit are not recognized in this sample |
| **21** | **204936** | dark gray to black, laminated chert |
| **22** | **204937** | dark gray to black, laminated chert |
| **23** | **204938** | gray-brown, medium grained (with outsized quartz grains), lightly foliated Wickersham Grit, with cross-cutting quartz veins and minor fe-ox staining |
| **24** | **204939** | extremely weathered, orange-brown, medium grained (but with copious outsized quartz grains), lightly foliated Wickersham Grit |
| **25** | **204940** | extremely weathered, orange-brown, medium grained (but with copious outsized quartz grains), lightly foliated Wickersham Grit; very heavy fe-ox staining; thin layers of green-brown slate/phyllite(?) found in this hole |
| **26** | **204941** | brown-gray, medium grained grit, with larger quartz grains (to 1mm across); abundant fe-ox stained stockwork quartz veinlets |
| **27** | **204942** | extremely weathered (and burned), orange to red , medium grained (but with copious outsized quartz grains), lightly foliated Wickersham Grit; very heavy fe-ox staining |
| **28** | **204950** | gray limestone; white to cream on weathered surfaces; iron oxide in fractures; recemented breccia; close to fault |
| **29** | **204951** | blocky weathering, laminar, gray limestone |
| **30** | **204952** | greenish-gray to gray meta chert(?); dug from tree roots; altered quartzite(?) |
| **31** | **204953** | gray to greenish-gray feldspar-quartz schist; lithic component and iron oxide; rods of feldspar parallel to foliation |
| **32** | **204954** | black phyllite; platey, foliated, iron oxide, deformed tight folds |
| **33** | **204955** | orangish cream to white, amygdaloial rhyolite with quartz crystals and iron oxide filling amygduals |
| **34** | **204956** | black shale/phyllite flysch; Fe-oxide in foliations and fractures; one quartz boulder with boxwork cavities |
| **35** | **204957** | green-gray, fine grained, pyrite-bearing, micaceous lithic sandstone interlayered with shale |
| **36** | **204958** | stretch pebble conglomerate; 10% of the cobbles are flint, quartzite, and quartz; clasts subrounded to rounded to flat |

| Count | Station # | Rock Description |
|---|---|---|
| **37** | **204959** | light gray, brecciated, recemented limestone; sub-angular boulders centimeters to meters across; calcite veins at about 6cm spacing, 1cm thick; random orientation |
| **38** | **204960** | black pyroxene altered gabbro/diorite; sausseritized albite quartz viens; slickensides associated with veins; orange FeO and ZnO(?) in fractures; trace chalcopyrite |
| **39** | **204961** | light gray meta-quartzite with secondary quartz viens; high FeO content in veins and pods; possibly some meta-chert(?) |
| **40** | **204962** | dark brown-green, aphanitic, boarder phase(?) gabbro/diorite; in root bulb with meta-quartzite |
| **41** | **204963** | black pyroxene altered gabbro/diorite; sausseritized albite; quartz veins; orange FeO in fractures |
| **42** | **204964** | fine grained lithic sandstone and siltstone; FeO in fractures |
| **43** | **204965** | phyllite, schist with quartz vein; FeO throughout fractures and in pods |
| **44** | **204974** | predominantly extremely weathered, orange-brown, medium grained (outsized quartz grains), Wickersham grit |
| **45** | **205100** | light gray, porphyroclastic, quartz-rich meta-sandstone |
| **46** | **205221** | tan to gray porphyroclastic phyllite |
| **47** | **205242** | |
| **48** | **205243** | |
| **49** | **205244** | |
| **50** | **205245** | minor quartzite and black phyllite |
| **51** | **205246** | |
| **52** | **205247** | |
| **53** | **205248** | |
| **54** | **205249** | |
| **55** | **205250** | |
| **56** | **205251** | minor quartzite |
| **57** | **205252** | minor quartzite |
| **58** | **205253** | |

| Count | Station # | Rock Description |
|---|---|---|
| **59** | **205254** | |
| **60** | **205255** | |
| **61** | **205256** | |
| **62** | **205257** | |
| **63** | **205258** | |
| **64** | **205259** | minor mudstone |
| **65** | **205261** | |
| **66** | **205262** | |
| **67** | **205263** | |
| **68** | **205264** | |
| **69** | **205265** | |
| **70** | **205266** | minor muscovite quartzite |
| **71** | **205306** | greenish-gray, lithic sandstone and phyllite in rubble |
| **72** | **205307** | hornfels black phyllite; very Fe altered purple-gray siliceous overprint; locally laminated, with some coarser layers |
| **73** | **205308** | grayish dark green, aphanitic gabbro/diorite border phase; quartz veins at 6cm spacing in 50cm boulder |
| **74** | **205309** | light gray hornfels; quartz veined, FeO rich, in fractures and pods, meta-quartzite |
| **75** | **205310** | light gray hornfels; quartz veined, FeO rich, in fractures and pods, meta-quartzite |
| **76** | **205311** | altered black pyroxene diorite/gabbro; plagioclase altered to albite; equigranular, fresh, hard |
| **77** | **205312** | black phyllite and shale interlayered with volcanics(?) and/or volcaniclastics; fine grained |
| **78** | **205313** | elongate pebble conglomerate of flysch unit; probably an anomalous, coarse grained layer in the KJst unit |
| **79** | **205314** | black phyllitic shale; FeO altered; weathers to orangish-tan |
| **80** | **205315** | cream to tan meta-quartzite; brownish actinolite, quartz veins and Fe alteration |
| **81** | **205316** | fresh flysch suite of hand samples from pipeline material site |

| Count | Station # | Rock Description |
|---|---|---|
| **82** | **205317** | medium to fine grained, quartz-mica, lithic sandstone interlayered with siltstone and shale; quartz veins, clasts and FeO locally |
| **83** | **205318** | medium to fine grained, quartz-mica, lithic sandstone interlayered with siltstone and shale; quartz veins, clasts and FeO locally |
| **84** | **205319** | meta-turbidites; hornfels of sands and muds; laminated, cross beds |
| **85** | **205320** | fine grained, light gray to gray, biotite granite; subrounded boulders on surface |
| **86** | **205321** | amphibole bearing biotite granite; orthoclase crystals appear to be zoned |
| **87** | **205322** | spherical weathering in part due to very fine crystals of plagioclase and biotite; equal biotite and amphibole to about 10% |
| **88** | **205323** | 1 meter of schorl, and 3 meters of quartz in N55E trending zone of rubble; tourmaline crystals to 5cm |
| **89** | **205324** | quartz lithic pebble conglomerate; a coarse layer in the flysch unit; interlayered with coarse sandstone and shale |
| **90** | **205325** | dark gray, quartz bearing, mica schist; FeO in fractures; elongate quartz porphroblasts |
| **91** | **205326** | dark gray micaceous siltstone (70%) and mudstone (30%) |
| **92** | **205327** | fresh, medium gray, medium grained lithic sandstone |
| **93** | **205328** | fresh, aminated, light gray, micaceous siltstone |
| **94** | **205329** | fresh and unaltered, light gray, fine to medium grained sandstone |
| **95** | **205330** | medium gray mudstone (50%) and siltstone (50%) |
| **96** | **205331** | gray, fine grained lithic sandstone (80%) and siltstone (20%); below organic layer |
| **97** | **205332** | semi-siliceous, fine grained sublithic sandstone |
| **98** | **205333** | dark gray mudstone |
| **99** | **205334** | dark gray, quartz vein-rich mudstone - possibly hornfels development |
| **100** | **205335** | a dark gray, fissile mudstone in the Wilbur Creek flysch unit |
| **101** | **205336** | gray mudstone (50%) and micaceous siltstone (50%) |
| **102** | **205337** | ferric-stained, siliceous mudstone and granular quartzite |
| **103** | **205338** | light gray-green, varigated, banded chert; abundant rubble-crop exposure |
| **104** | **205339** | chips of micaceous siltone (70%) and dark gray mudstone (30%) |

| Count | Station # | Rock Description |
|---|---|---|
| **105** | **205340** | abundant coarse-grained rubble of pebble sandstone and conglomerate |
| **106** | **205341** | pebble sandstone forms resistant top of ridge; abundant clasts of chert; quartzite |
| **107** | **205342** | very light gray, fine grained, sugary quartzite - nearly pure |
| **108** | **205343** | light gray, Fe-stained, sugary quartzite |
| **109** | **205344** | light gray, Fe-stained, sugary quartzite |
| **110** | **205345** | light gray, molted, recrystalized, carbonate veined limestone - fossil hash locally |
| **111** | **205346** | light gray, massive micritic limestone; less veined; larger material than at sample site #205345 |
| **112** | **205365** | broken, brecciated, FeO altered cap of pluton; igneous textures in relict flysch layering; trace black and silver sulphides |
| **113** | **205366** | white to orange quartzose quartzite; contact metamorphism(?); very hard; tight matrix; about 1% flint |
| **114** | **205367** | meta-quartzite conglomerate; secondary quartz viens throughout at several centimeter spacing; greenish gray to gray quartzite clasts to 6cm, with crude orientation; top of bedrock |
| **115** | **205368** | schisty, foliated grit; low mica, blocky, large, rounded boulders; elongate quartz porphroblasts give grit texture |
| **116** | **205369** | gray to dark gray, locally pink, veined calcite |
| **117** | **205370** | gabbro/diorite sill rubble crop along the Elliott Highway |
| **118** | **205371** | white to light gray bleached, and dark gray fresh, low mica quartzite; relict laminations on weathered surface |
| **119** | **205372** | altered amphibolite diabase dike; minor amount of serpentine and secondary quartz |
| **120** | **205373** | dolorite dike; gray, aphanitic groundmass with secondary quartz; plagioclase crystals to 0.5cm |
| **121** | **205410** | bleached, light gray, fine grained sandstone (30%) and micaceous siltstone (70%) |
| **122** | **205411** | light gray, porphyroclastic, quartz-rich meta-sandstone |
| **123** | **205412** | light green-gray, chloritic, quartz-rich schist |
| **124** | **205413** | light green-gray, chloritic, quartz-rich schist |
| **125** | **205414** | distinctly Fe-stained, porphyroblastic mica shist |
| **126** | **205415** | porphyroclastic phyllite; non-calcareous |

| Count | Station # | Rock Description |
|---|---|---|
| **127** | **205416** | fissile, non-resistant micaceous phyllite |
| **128** | **205417** | 1) quartz-rich laminated phyllite; 2) quartz vein float |
| **129** | **205418** | fissile, laminated phyllite with meta-sandstone beds |
| **130** | **205419** | very hard, tan weathered, conchoidal-fractured hornfels |
| **131** | **205420** | very hard, tan weathered, conchoidal-fractured hornfels |
| **132** | **205421** | dark green-gray, hard, bocky, chert pebble conglomerate |
| **133** | **205422** | bleached, porphyro-aphanitic, feldspar porphyry |
| **134** | **205423** | dark gray, serpententized ultramafic rock; light weight - low specific gravity |
| **135** | **205424** | slightly altered, pyroxenite or peridotite |
| **136** | **205425** | medium to dark gray, micaceous, fine grained, lithic sandstone and siltstone |
| **137** | **205426** | reddish to tan colored, highly siliceous |
| **138** | **205427** | dark grayish, fine to medium grained, chloritic mica-quartz schist |
| **139** | **205428** | very weathered, siliceous, chloritic(?) schist with quartz veins |
| **140** | **205429** | tan, fine to medium grained, silica-rich, somewhat blocky appearance |
| **141** | **205430** | highly weathered, fine to medium to coarse grained, white-greyish, laminated, folded, coarse clayed feldspar |
| **142** | **205431** | light to dark gray, fine to coarse grained, foliated, abundant quartz veins |
| **143** | **205432** | light gray, well cemented quartzite, very hard, vitreous |
| **144** | **205433** | light gray, well cemented vitreous quartzite, Fe-staining |
| **145** | **205434** | fossiliferous, black |
| **146** | **205435** | dark to light gray, fossiliferous, brecciated Tolovana limestone, moderately weathered |
| **147** | **205436** | regolith; greenish-grayish schist(?), phyllite(?) with quartz veins; clay-rich |
| **148** | **205437** | coarse-grained, greenish metavolcanic, weathered |
| **149** | **205438** | greenish, fine grained phyllite regolith |

| Count | Station # | Rock Description |
|---|---|---|
| **150** | **205438** | .3m x .3m float cobble of grit |
| **151** | **205439** | |
| **152** | **205440** | hard, fine-grained, Fe-stained hornfels |
| **153** | **205441** | moderately weathered, coarse grained, porphyritic granodiorite |
| **154** | **205442** | extremely hard, greenish-blackish, altered diorite |
| **155** | **205443** | grayish-whitish, brecciated limestone with iron staining |
| **156** | **205461** | gray-green to green intermediate meta-volcanics; moderate to weak orientation of quartz and feldspars |
| **157** | **205462** | see notes for sample #205367; black gray quartzite |
| **158** | **205463** | see notes for sample #205367; black gray quartzite |
| **159** | **205487** | grey quartzite-schist, weathered slightly, medium grained; laminations 1/4 to 2 inches thick; weak along laminations, but otherwise well bonded; massive, and not that jointed; joint spacing is 18 inches to 6 feet (~298) |
| **160** | **205488** | rubble outcrop; dark grey, fine-grained slate; weathered a rusty red on surfaces; exhibits fissility |
| **161** | **205489** | completely weathered schist, quartz-rich, with a weathered dark zone that is harder than steel |
| **162** | **205490** | completely weathered schist containing scattered quartz pebbles (~2% by volume) remnant quartz boudins |
| **163** | **205491** | light green, slightly to moderately weathered, fine-grained chloritic quartzite |
| **164** | **205492** | relatively soft; dark brown to black; slaty to gneissic, fine to medium grained slate and greywacke slate |
| **165** | **205494** | relatively soft, dark brown and black slate |
| **166** | **205495** | relatively hard, tan, medium grained, recrystalized, brecciated hornfels |
| **167** | **205496** | relatively hard, white and grey, aphanitic, medium to coarse grained granite-granodiorite |
| **168** | **209260** | |
| **169** | **10GL100** | |
| **170** | **10GL101** | |
| **171** | **10GL102** | |

| Count | Station # | Rock Description |
|---|---|---|
| **172** | **10GL103** | |
| **173** | **10GL104** | |
| **174** | **10GL105** | |
| **175** | **10GL106** | |
| **176** | **10GL109** | |
| **177** | **10GL110** | |
| **178** | **10GL111** | |
| **179** | **10GL112** | |
| **180** | **10GL113** | |
| **181** | **10GL114** | |
| **182** | **10GL115** | |
| **183** | **10GL116** | |
| **184** | **10GL117** | border phase, dark green, fine grained |
| **185** | **10GL119** | hornfels-quartzite mixed rubble |
| **186** | **10GL120** | |
| **187** | **10GL121** | very white quartzose plus iron |
| **188** | **10GL122** | |
| **189** | **10GL123** | |
| **190** | **10GL124** | |
| **191** | **10GL125** | |
| **192** | **10GL126** | |
| **193** | **10GL127** | |
| **194** | **10GL128** | |

| Count | Station # | Rock Description |
|---|---|---|
| 195 | 10GL129 | |
| 196 | 10GL130 | |
| 197 | 10GL131 | |
| 198 | 10GL132 | |
| 199 | 10GL133 | |
| 200 | 10GL134 | |
| 201 | 10GL135 | |
| 202 | 10GL136 | |
| 203 | 10GL137 | |
| 204 | 10GL138 | |
| 205 | 10GL139 | |

| Count | Station # | Hand Sample | Material Sample | Major Oxide Sample | Petrographic Sample | Remarks |
|---|---|---|---|---|---|---|
| **1** | **204683** | yes | yes | no | yes | material sample of quartzite; probable low yield - 10%(?); suite of hand specimens |
| **2** | **204684** | yes | no | no | yes | poor exposure; mixed with loess on logging road |
| **3** | **204685** | yes | yes | no | yes | low priority material sample; high mica content, oriented along foliation planes; high yield |
| **4** | **204686** | yes | no | no | yes | iron oxide in foliation planes and rims cross cutting quartz veins |
| **5** | **204687** | yes | no | no | yes | high mica content |
| **6** | **204688** | yes | yes | no | yes | quartz layers and boudins to 10%; overall low yield; good check of quartz schist in area; low priority |
| **7** | **204689** | yes | no | no | yes | high mica content in foliation planes and in fractures; rubble from bear den on vegetated slope |
| **8** | **204691** | yes | no | no | yes | highly friable and weathered; poorly consolidated; terrible material for rip-rap or ballast |
| **9** | **204692** | yes | no | no | yes | north side of Washington Creek |
| **10** | **204925** | yes | no | no | yes | |
| **11** | **204926** | yes | no | no | yes | |
| **12** | **204927** | yes | no | no | yes | |
| **13** | **204928** | yes | no | no | yes | |
| **14** | **204929** | yes | no | no | yes | |
| **15** | **204930** | yes | no | no | yes | |
| **16** | **204931** | yes | no | no | yes | |
| **17** | **204932** | yes | no | no | yes | |
| **18** | **204933** | yes | no | no | yes | |

| Count | Station # | Hand Sample | Material Sample | Major Oxide Sample | Petrographic Sample | Remarks |
|---|---|---|---|---|---|---|
| **19** | **204934** | yes | yes | yes | yes | |
| **20** | **204935** | yes | no | no | yes | |
| **21** | **204936** | yes | no | no | yes | |
| **22** | **204937** | yes | no | no | yes | |
| **23** | **204938** | yes | no | no | yes | |
| **24** | **204939** | yes | no | no | yes | |
| **25** | **204940** | yes | no | no | yes | |
| **26** | **204941** | yes | yes | yes | yes | |
| **27** | **204942** | yes | no | no | yes | |
| **28** | **204950** | yes | yes | no | yes | rubble on side hill; homogeneous; just above bedrock |
| **29** | **204951** | yes | yes | no | yes | 130 meters above sample site #204951 and further away from faulting |
| **30** | **204952** | yes | no | no | yes | very poor exposure in an old burn; near gabbro/diorite intrusive |
| **31** | **204953** | yes | no | no | yes | strong foliation, uncommon in the flysch unit, possibly due to a proximal fault(?) |
| **32** | **204954** | yes | no | no | yes | beginning of the 'pencil' formation |
| **33** | **204955** | yes | yes | no | yes | old flow structures(?); Mn in parallel bands; flysch unit with quartz lenses |
| **34** | **204956** | yes | no | no | yes | n/a |
| **35** | **204957** | yes | no | no | yes | very fractured and broken; weathers to light tan |
| **36** | **204958** | yes | yes | no | yes | well consolidated; good marker unit |
| **37** | **204959** | yes | yes | no | yes | material sample taken from the most competent zone at the base of a hill above the floodplain |
| **38** | **204960** | yes | yes | yes | yes | ridge trend N70E; probable trend of sill body |
| **39** | **204961** | yes | no | no | yes | probable contact metamorphism from diorite/gabbro; poor exposure |

| Count | Station # | Hand Sample | Material Sample | Major Oxide Sample | Petrographic Sample | Remarks |
|---|---|---|---|---|---|---|
| **40** | **204962** | yes | no | no | yes | poor exposure |
| **41** | **204963** | yes | yes | no | yes | rubblecrop on fire trail; eastern extent of gabbro/diorite body/sill(?); 400 meters from a veined outcrop |
| **42** | **204964** | yes | no | no | yes | very thin layered, platey, friable, broken rubble |
| **43** | **204965** | yes | no | no | yes | possible galena in quartz vein |
| **44** | **204974** | yes | no | no | yes | |
| **45** | **205100** | yes | yes | no | no | 60 foot thick section sampled for materials testing; joint spacing up to 4 feet; class 3 riprap, moderate yield |
| **46** | **205221** | yes | yes | yes | yes | in road cut |
| **47** | **205242** | yes | yes | | yes | note - all structural data in azimuths |
| **48** | **205243** | yes | yes | | yes | with right hand rule - dip to the right |
| **49** | **205244** | yes | no | | yes | |
| **50** | **205245** | yes | no | | yes | |
| **51** | **205246** | yes | no | | yes | |
| **52** | **205247** | yes | no | | yes | |
| **53** | **205248** | yes | no | | yes | |
| **54** | **205249** | yes | no | | yes | highly fractured limestone |
| **55** | **205250** | yes | no | | yes | highly fractured limestone |
| **56** | **205251** | yes | no | | yes | |
| **57** | **205252** | yes | no | | yes | |
| **58** | **205253** | yes | no | | yes | |
| **59** | **205254** | yes | no | | yes | |

| **Count** | **Station #** | **Hand Sample** | **Material Sample** | **Major Oxide Sample** | **Petrographic Sample** | **Remarks** |
|---|---|---|---|---|---|---|
| **60** | **205255** | yes | no | | yes | |
| **61** | **205256** | yes | no | | yes | |
| **62** | **205257** | yes | no | | yes | |
| **63** | **205258** | yes | yes | | yes | note - this is a strike and dip of bedding |
| **64** | **205259** | yes | yes | | yes | note - this is a strike and dip of bedding |
| **65** | **205261** | yes | yes | | yes | |
| **66** | **205262** | yes | yes | | yes | |
| **67** | **205263** | yes | yes | | yes | |
| **68** | **205264** | yes | no | | yes | |
| **69** | **205265** | yes | no | | yes | |
| **70** | **205266** | yes | no | | yes | |
| **71** | **205306** | yes | no | no | | rock found in place in the Livengood trail; large pencils |
| **72** | **205307** | yes | yes | no | | near old drill pad and above mapped TKgd unit; breaks easily to small pieces; brittle and weak; very low priority material sample |
| **73** | **205308** | yes | yes | no | | very hard; low sulphides; yield unknown; little exposure; on surface in fire road |
| **74** | **205309** | yes | no | no | | rubble on fire road; between diorite/gabbro outcrops |
| **75** | **205310** | yes | yes | no | | large boulder in tree roots; the only place to date that has had enough fresh rock for a materials size sample |
| **76** | **205311** | yes | yes | no | | FeO in fractures and quartz veins which are at about 6cm spacing; breaks into nice 10x5x7.5cm blocks; high yield |
| **77** | **205312** | yes | no | no | | poor exposure; appears to have elongated flysch clasts oriented in volcaniclastics or flows; check in thin section |
| **78** | **205313** | yes | no | no | | pebbles have random orientation in a flysch matrix |

| Count | Station # | Hand Sample | Material Sample | Major Oxide Sample | Petrographic Sample | Remarks |
|---|---|---|---|---|---|---|
| **79** | **205314** | yes | no | no | | in a landing zone cut for an old soil sample |
| **80** | **205315** | yes | yes | no | | no known intrusive in the area; surrounded by flysch; near the Pipeline; locally high yield; very hard; high iron content |
| **81** | **205316** | yes | no | no | | fine sand to laminated mud |
| **82** | **205317** | yes | no | no | | Livengood Trail; appears slightly altered to be regional metamorphism |
| **83** | **205318** | yes | no | no | | good sample for point count |
| **84** | **205319** | yes | yes | no | | very hard; high yield hornfels on the west side of Tolovana Hot Springs Dome; fractured at about 1 meter intervals |
| **85** | **205320** | yes | yes | no | | no sulphides; high yeild; equigranular, with a hard, tight, crystalline matrix. |
| **86** | **205321** | yes | no | no | | more porphoritic texture at this location; orthoclase >1cm and plagioclase and mica <0.5cm |
| **87** | **205322** | yes | no | no | | much softer due to very fine biotite component; slickensides parallel to joints common; quartz viens and tourmaline greissens |
| **88** | **205323** | yes | no | no | | open area with small aspens; several small rounded outcrops of granite or quartz monzonite |
| **89** | **205324** | yes | yes | no | | from riprap stockpile at Pipeline material site; rough estimate of coarse material |
| **90** | **205325** | yes | no | no | | resembles the feldspar-mica schist found further downstream at base of this ridge; under the flysch unit(?) or part of KJcg(?) |
| **91** | **205326** | yes | no | no | yes | clasts average 2-3 inches in long; fissile sample collected for control of poorly exposed area |
| **92** | **205327** | yes | no | no | yes | sample taken for petrographic analysis of the Wilbur Creek flysch |
| **93** | **205328** | yes | yes | no | yes | bulk sample taken here for control of friable Wilbur Creek flyschoid sediments |
| **94** | **205329** | yes | yes | no | yes | resistant sandstone may be underlying the hill here |
| **95** | **205330** | yes | no | no | no | chips in soil covered by spaghnum moss |

| Count | Station # | Hand Sample | Material Sample | Major Oxide Sample | Petrographic Sample | Remarks |
|---|---|---|---|---|---|---|
| **96** | **205331** | yes | yes | no | yes | material sample; not large (<5 kg) but could be added to other samples as a composite |
| **97** | **205332** | yes | no | no | no | fresh, sub-lithic sandstone right beneath our feet (no vegetation, loess, or colluvium) |
| **98** | **205333** | no | no | no | no | on summit of unnamed hill with aspen trees but no outcrops |
| **99** | **205334** | yes | no | no | yes | samples from NW-striking trench that corresponds to lineament observed on air photo-fault(?) |
| **100** | **205335** | no | no | no | no | thick loess (>2.0 feet) overlies fragments of gray mudstone |
| **101** | **205336** | no | no | no | no | 30cm into hole are abundant rock fragments of Wilbur Creek flysch |
| **102** | **205337** | yes | no | yes | yes | saddle just north of this staion is probably the Beaver Creek fault zone |
| **103** | **205338** | yes | yes | yes | yes | mapped in quartzite band of the Globe unit; very hard with clasts to class 2 riprap size |
| **104** | **205339** | yes | no | no | no | chips are abundant, but none exceed 1.5 inches in diameter |
| **105** | **205340** | yes | no | yes | yes | fairly hard, coarse-grained sandstone with angular sedimentary clasts - good thin section sample |
| **106** | **205341** | yes | yes | yes | yes | some rock materials are as large as class 3 riprap, but yield for this size judged to be low |
| **107** | **205342** | yes | yes | yes | yes | in addition to a materials test, a major oxide analysis might document a high purity silica resource |
| **108** | **205343** | yes | no | yes | no | important control that estimates the width of a quartzite band (>65 meters) |
| **109** | **205344** | yes | no | no | no | extends the quartzite section 300 meters to the south - unit is larger than expected |
| **110** | **205345** | yes | yes | no | no | joint spacing limits potential to class 2 riprap |
| **111** | **205346** | yes | yes | no | no | pure end member limestone reminds me of lower Devonian of SW Alaska (Holitna Basin) |
| **112** | **205365** | yes | no | no |  | near meta-quartzite to west; unmapped pluton(?); possible exposure in creek to east |
| **113** | **205366** | yes | no | no |  | good material for a degradation test, but not enough exposure, or even rubble |

| Count | Station # | Hand Sample | Material Sample | Major Oxide Sample | Petrographic Sample | Remarks |
|---|---|---|---|---|---|---|
| **114** | **205367** | yes | yes | no | | combined with material from sample site #205463 to create a material sample; seven foot boulder sticking out of vegetation |
| **115** | **205368** | yes | yes | no | | off Elliott Highway; unit control sample |
| **116** | **205369** | yes | yes | no | | off Elliott Highway; unit control sample |
| **117** | **205370** | yes | no | no | | suite of hand specimens for thin section collected between limestone hills on the Elliott Highway; includes: gabbro/diorite, phyllite, quartz schist, and breccia limestone |
| **118** | **205371** | yes | yes | no | | Elliott Highway unit control sample |
| **119** | **205372** | yes | yes | no | | Elliott Highway unit control sample |
| **120** | **205373** | yes | yes | no | | Elliott Highway unit control sample; 100m exposed along the highway; high yield |
| **121** | **205410** | yes | no | no | no | station provides for bedrock control in an area where there was none previously |
| **122** | **205411** | yes | no | no | yes | 75 foot thick section of tan weathered, sub-schistose, quartz-rich meta-sandstone; class III riprap potential; moderate yield |
| **123** | **205412** | yes | no | no | yes | In ATV trail; no outcrops |
| **124** | **205413** | yes | no | no | yes | large boulders, up to 1 meter in diameter, and abundant rubble in ATV trail; fresh, no alteration |
| **125** | **205414** | yes | yes | no | yes | mappable unit of Fe-stained schist, structurally above chloritic schist; class 1 riprap potential; high yield |
| **126** | **205415** | yes | no | no | no | grit-like unit found in game trail near repeater site |
| **127** | **205416** | no | no | no | no | thick loess covers rock units in this area |
| **128** | **205417** | no | no | no | no | rock chips discovered in gully along hill side |
| **129** | **205418** | yes | yes | no | yes | large sample taken to demonstrate how bad material is; joints average 9 inch spacing |
| **130** | **205419** | yes | no | no | yes | very hard horfels to be tested in two locations - possible class 3 riparp possibilities (18 inches) |

| Count | Station # | Hand Sample | Material Sample | Major Oxide Sample | Petrographic Sample | Remarks |
|---|---|---|---|---|---|---|
| **131** | **205420** | yes | yes | no | yes | large sample collected for materials tests; locally sulfide rich |
| **132** | **205421** | yes | yes | no | yes | hard material collected for material tests - could out perform the normal Wilbur Flysch unit; 100' thick |
| **133** | **205422** | yes | no | yes | yes | mapped as granodiorite by previous workers;  purple hornfels float nearby |
| **134** | **205423** | yes | yes | no | yes | ubiquitous hydrous alteration indicates poor quality materials site |
| **135** | **205424** | yes | yes | no | yes | could test well for LA abrasion loss and T-13 degradation |
| **136** | **205425** | yes | yes | no | yes | maximum joint spacing 6 inches; only class 1 riprap potential; poor material site |
| **137** | **205426** | yes | | | | rubble along road for ~300m north of sample station, somewhat blocky, highly siliceous |
| **138** | **205427** | yes | no | no | no | along road, east side, up valley |
| **139** | **205428** | yes | no | no | no | outcrop close to surface, 2 meters long, ~1 meter high, along road; hand specimen; more siliceous than regolith |
| **140** | **205429** | yes | no | no | no | ~20m long rubblecrop along road, rubble is ~2cm x 2cm diameter, blocky/angular |
| **141** | **205430** | yes | | | | upper part of Knob north, facing west |
| **142** | **205431** | yes | | | | upper hillside, facing southeast |
| **143** | **205432** | yes | yes | | | southeast of knob, 1m x .3m float in wooded area |
| **144** | **205433** | yes | yes | | | on top of knob, landing zone, also sampled by Bundtzen/Bolz on 08/17/2010 |
| **145** | **205434** | yes | | | | |
| **146** | **205435** | yes | | | | |
| **147** | **205436** | yes | | | | tree rubble (underneath root bulb) |
| **148** | **205437** | | | | | |
| **149** | **205438** | | | | | |
| **150** | **205438** | yes | yes | | | |

| Count | Station # | Hand Sample | Material Sample | Major Oxide Sample | Petrographic Sample | Remarks |
|---|---|---|---|---|---|---|
| **151** | **205439** | | | | | |
| **152** | **205440** | yes | yes | | | a former drill location on top of a ridge - landing zone |
| **153** | **205441** | | | | | |
| **154** | **205442** | yes | yes | | | diorite extends ~350m, surrounded by serpentinized ultramafics |
| **155** | **205443** | yes | | yes | | |
| **156** | **205461** | yes | yes | no | | poor material, but sampled for control; north and west of the limestone found on the same ridge |
| **157** | **205462** | yes | no | no | | rubble of same quartzite found at sample site #205367 |
| **158** | **205463** | yes | yes | no | | combined with sample #205367 to create a material sample; six foot boulder sticking out of vegetation |
| **159** | **205487** | yes | no | no | yes | hand sample #10KO001 |
| **160** | **205488** | yes | no | no | no | rubble crop on north facing slope |
| **161** | **205489** | yes | no | no | no | soil like consistency, dense, displaying bands of alternating colors - photograph #5845 |
| **162** | **205490** | yes | no | no | no | test pit, 20 inches deep by 18 inches wide; quartz is likely remnant quartz boudins |
| **163** | **205491** | yes | no | no | yes | from 6 inches under the organic matte; loose, light brown silt fills, interstitial gaps |
| **164** | **205492** | | yes | yes | yes | |
| **165** | **205494** | | yes | | yes | |
| **166** | **205495** | | | | | |
| **167** | **205496** | yes | | | | |
| **168** | **209260** | yes | yes | | yes | |
| **169** | **10GL100** | | | | | |
| **170** | **10GL101** | | | | | |

| Count | Station # | Hand Sample | Material Sample | Major Oxide Sample | Petrographic Sample | Remarks |
|---|---|---|---|---|---|---|
| **171** | **10GL102** | | | | | |
| **172** | **10GL103** | | | | | |
| **173** | **10GL104** | | | | | |
| **174** | **10GL105** | | | | | joint interval is about 30cm |
| **175** | **10GL106** | | | | | |
| **176** | **10GL109** | | | | | |
| **177** | **10GL110** | | | | | |
| **178** | **10GL111** | | | | | |
| **179** | **10GL112** | | | | | |
| **180** | **10GL113** | | | | | |
| **181** | **10GL114** | | | | | |
| **182** | **10GL115** | | | | | |
| **183** | **10GL116** | | | | | |
| **184** | **10GL117** | | | | | |
| **185** | **10GL119** | | | | | |
| **186** | **10GL120** | | | | | |
| **187** | **10GL121** | | | | | |
| **188** | **10GL122** | | | | | |
| **189** | **10GL123** | | | | | |
| **190** | **10GL124** | | | | | |
| **191** | **10GL125** | | | | | |

| Count | Station # | Hand Sample | Material Sample | Major Oxide Sample | Petrographic Sample | Remarks |
|---|---|---|---|---|---|---|
| 192 | 10GL126 | | | | | |
| 193 | 10GL127 | | | | | |
| 194 | 10GL128 | | | | | |
| 195 | 10GL129 | | | | | |
| 196 | 10GL130 | | | | | |
| 197 | 10GL131 | | | | | |
| 198 | 10GL132 | | | | | |
| 199 | 10GL133 | | | | | |
| 200 | 10GL134 | | | | | |
| 201 | 10GL135 | | | | | |
| 202 | 10GL136 | | | | | |
| 203 | 10GL137 | | | | | |
| 204 | 10GL138 | | | | | |
| 205 | 10GL139 | | | | | |

| Count | Station # | Foliation Strike | Foliation Dip | Foliation_2 Strike | Foliation_2 Dip | Joint_1 Strike | Joint_1 Dip | Joint_2 Strike | Joint_2 Dip | Joint_3 Strike | Joint_3 Dip | Fold Axis Trend | Fold Axis Plunge |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **1** | **204683** | | | | | | | | | | | | |
| **2** | **204684** | | | | | | | | | | | | |
| **3** | **204685** | | | | | | | | | | | | 18SE |
| **4** | **204686** | N85E | 5SE | | | | | | | | | | |
| **5** | **204687** | | | | | | | | | | | | |
| **6** | **204688** | N85E | 17SE | | | | | | | | | | |
| **7** | **204689** | | | | | | | | | | | | |
| **8** | **204691** | N50E | N20NW | | | | | | | | | | |
| **9** | **204692** | N53E | 24NW | | | | | | | | | | |
| **10** | **204925** | | | | | | | | | | | | |
| **11** | **204926** | | | | | | | | | | | | |
| **12** | **204927** | | | | | | | | | | | | |
| **13** | **204928** | | | | | | | | | | | | |
| **14** | **204929** | | | | | | | | | | | | |
| **15** | **204930** | | | | | | | | | | | | |
| **16** | **204931** | | | | | | | | | | | | |
| **17** | **204932** | | | | | | | | | | | | |
| **18** | **204933** | | | | | | | | | | | | |
| **19** | **204934** | | | | | | | | | | | | |
| **20** | **204935** | | | | | | | | | | | | |
| **21** | **204936** | | | | | | | | | | | | |

| Count | Station # | Foliation Strike | Foliation Dip | Foliation_2 Strike | Foliation_2 Dip | Joint_1 Strike | Joint_1 Dip | Joint_2 Strike | Joint_2 Dip | Joint_3 Strike | Joint_3 Dip | Fold Axis Trend | Fold Axis Plunge |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **22** | **204937** | | | | | | | | | | | | |
| **23** | **204938** | | | | | | | | | | | | |
| **24** | **204939** | | | | | | | | | | | | |
| **25** | **204940** | | | | | | | | | | | | |
| **26** | **204941** | | | | | | | | | | | | |
| **27** | **204942** | | | | | | | | | | | | |
| **28** | **204950** | | | | | | | | | | | | |
| **29** | **204951** | N70E | vertical | | | | | | | | | | |
| **30** | **204952** | | | | | | | | | | | | |
| **31** | **204953** | | | | | | | | | | | | |
| **32** | **204954** | | | | | | | | | | | | |
| **33** | **204955** | | | | | | | | | | | | |
| **34** | **204956** | N15E | 28NW | | | | | | | | | | |
| **35** | **204957** | | | | | | | | | | | | |
| **36** | **204958** | EW | 29N | | | | | | | | | | |
| **37** | **204959** | N40E | 85NW | | | | | | | | | | |
| **38** | **204960** | | | | | N45E | 80NW | | | | | | |
| **39** | **204961** | | | | | | | | | | | | |
| **40** | **204962** | | | | | | | | | | | | |
| **41** | **204963** | | | | | | | | | | | | |
| **42** | **204964** | | | | | | | | | | | | |

| Count | Station # | Foliation Strike | Foliation Dip | Foliation_2 Strike | Foliation_2 Dip | Joint_1 Strike | Joint_1 Dip | Joint_2 Strike | Joint_2 Dip | Joint_3 Strike | Joint_3 Dip | Fold Axis Trend | Fold Axis Plunge |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **43** | **204965** | | | | | | | | | | | | |
| **44** | **204974** | | | | | | | | | | | | |
| **45** | **205100** | east-west | 32 south | | | N45E | 65SE | N34W | 82SW | | | | |
| **46** | **205221** | | | | | | | | | | | | |
| **47** | **205242** | 200 | 10 NW | | | 90 | vertical | 190 | 70 NW | 210 | 70 NW | | |
| **48** | **205243** | 40 | 10 SE | | | 70 | vertical | | | | | | |
| **49** | **205244** | horizontal | | | | 100 | 80 SW | 110 | 30 SW | | | | |
| **50** | **205245** | 25 | 10 SE | | | 30 | vertical | 90 | vertical | 10 | vertical | | |
| **51** | **205246** | | | | | | | | | | | | |
| **52** | **205247** | | | | | 340 | 80 NE | 60 | vertical | 180 | vertical | | |
| **53** | **205248** | | | | | 330 | 85 NE | 50 | 80 SE | | | | |
| **54** | **205249** | | | | | | | | | | | | |
| **55** | **205250** | | | | | | | | | | | | |
| **56** | **205251** | 310 | 35 NE | | | 180 | 70 NW | 115 | vertical | | | 100 | 20 SE |
| **57** | **205252** | 80 | 40 SE | | | 150 | vertical | 210 | 50 NW | 250 | 45 NW | | |
| **58** | **205253** | 105 | 40 SW | | | | | | | | | | |
| **59** | **205254** | 110 | 35 SW | | | 150 | vertical | 210 | 70 NW | | | | |
| **60** | **205255** | 120 | 40 SW | | | 360 | vertical | 60 | vertical | | | 140 | 20 SE |
| **61** | **205256** | 50 | 30 SE | | | 215 | 30 NW | 160 | vertical | | | 100 | 20 SE |
| **62** | **205257** | | | | | | | | | | | | |
| **63** | **205258** | 40 | 60 SE | | | horizontal | | 150 | 80 SW | 250 | 40 NW | | |

| Count | Station # | Foliation Strike | Foliation Dip | Foliation_2 Strike | Foliation_2 Dip | Joint_1 Strike | Joint_1 Dip | Joint_2 Strike | Joint_2 Dip | Joint_3 Strike | Joint_3 Dip | Fold Axis Trend | Fold Axis Plunge |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **64** | **205259** | 70 | 65 SE | | | | | | | | | | |
| **65** | **205261** | | | | | | | | | | | | |
| **66** | **205262** | | | | | | | | | | | | |
| **67** | **205263** | | | | | | | | | | | | |
| **68** | **205264** | 90 | 60 S | | | 305 | 75 NE | 225 | 60 NW | | | 205 | 45 SW |
| **69** | **205265** | | | | | 60 | 30 SE | 175 | vertical | | | 240 | 85 NW |
| **70** | **205266** | 105 | 20 SW | | | 260 | 80 NW | 5 | vertical | | | | |
| **71** | **205306** | | | | | | | | | | | | |
| **72** | **205307** | | | | | | | | | | | | |
| **73** | **205308** | | | | | | | | | | | | |
| **74** | **205309** | | | | | | | | | | | | |
| **75** | **205310** | | | | | | | | | | | | |
| **76** | **205311** | | | | | approximately east-west | steeply north | | | | | | |
| **77** | **205312** | | | | | | | | | | | | |
| **78** | **205313** | | | | | | | | | | | | |
| **79** | **205314** | | | | | | | | | | | | |
| **80** | **205315** | | | | | | | | | | | | |
| **81** | **205316** | | | | | | | | | | | | |
| **82** | **205317** | | | | | | | | | | | | |
| **83** | **205318** | | | | | | | | | | | | |
| **84** | **205319** | N80W | 33NE | | | | | | | | | | |

| Count | Station # | Foliation Strike | Foliation Dip | Foliation_2 Strike | Foliation_2 Dip | Joint_1 Strike | Joint_1 Dip | Joint_2 Strike | Joint_2 Dip | Joint_3 Strike | Joint_3 Dip | Fold Axis Trend | Fold Axis Plunge |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **85** | **205320** | | | | | | | | | | | | |
| **86** | **205321** | | | | | | | | | | | | |
| **87** | **205322** | | | | | N15W | 30NE | N15W | vertical | N30E | 50SW | | |
| **88** | **205323** | | | | | | | | | | | | |
| **89** | **205324** | N75E | 30SE | | | N75E | 67SE | | | | | | |
| **90** | **205325** | | | | | | | | | | | | |
| **91** | **205326** | | | | | | | | | | | | |
| **92** | **205327** | | | | | | | | | | | | |
| **93** | **205328** | | | | | | | | | | | | |
| **94** | **205329** | | | | | | | | | | | | |
| **95** | **205330** | | | | | | | | | | | | |
| **96** | **205331** | | | | | | | | | | | | |
| **97** | **205332** | | | | | | | | | | | | |
| **98** | **205333** | | | | | | | | | | | | |
| **99** | **205334** | | | | | | | | | | | | |
| **100** | **205335** | | | | | | | | | | | | |
| **101** | **205336** | | | | | | | | | | | | |
| **102** | **205337** | | | | | | | | | | | | |
| **103** | **205338** | | | | | | | | | | | | |
| **104** | **205339** | | | | | | | | | | | | |
| **105** | **205340** | | | | | | | | | | | | |

| Count | Station # | Foliation Strike | Foliation Dip | Foliation_2 Strike | Foliation_2 Dip | Joint_1 Strike | Joint_1 Dip | Joint_2 Strike | Joint_2 Dip | Joint_3 Strike | Joint_3 Dip | Fold Axis Trend | Fold Axis Plunge |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **106** | **205341** | N88E | 78NW | | | N45E | 65SE | N44W | 80SW | | | | |
| **107** | **205342** | | | | | N77E | 22NW | N65W | 77NE | N10W | 64SW | | |
| **108** | **205343** | | | | | | | | | | | | |
| **109** | **205344** | | | | | | | | | | | | |
| **110** | **205345** | N75E | vertical | | | N45W | 80SW | N55E | 80SE | | | | |
| **111** | **205346** | N72E | 77NW | | | N55W | 65SW | | | | | | |
| **112** | **205365** | | | | | | | | | | | | |
| **113** | **205366** | | | | | | | | | | | | |
| **114** | **205367** | | | | | | | | | | | | |
| **115** | **205368** | | | | | | | | | | | | |
| **116** | **205369** | | | | | | | | | | | | |
| **117** | **205370** | | | | | | | | | | | | |
| **118** | **205371** | | | | | | | | | | | | |
| **119** | **205372** | | | | | | | | | | | | |
| **120** | **205373** | | | | | N40W | 50SW | N25W | vertical | N70E | 5NW | | |
| **121** | **205410** | | | | | | | | | | | | |
| **122** | **205411** | N40E | 08SE | | | N55E | 70SE | N42W | 80SW | | | | |
| **123** | **205412** | | | | | | | | | | | | |
| **124** | **205413** | | | | | | | | | | | | |
| **125** | **205414** | horizontal | | | | | | | | | | | |
| **126** | **205415** | | | | | | | | | | | | |

| Count | Station # | Foliation Strike | Foliation Dip | Foliation_2 Strike | Foliation_2 Dip | Joint_1 Strike | Joint_1 Dip | Joint_2 Strike | Joint_2 Dip | Joint_3 Strike | Joint_3 Dip | Fold Axis Trend | Fold Axis Plunge |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **127** | **205416** | | | | | | | | | | | | |
| **128** | **205417** | | | | | | | | | | | | |
| **129** | **205418** | N50W | 27NE | | | N70E | 70NW | | | | | | |
| **130** | **205419** | N75W | 31SW | N82W | 35SW | N45E | vertical | N04W | 75SW | | | | |
| **131** | **205420** | N20E | 58SE | | | N70W | 82SW | N-S | 80W | | | | |
| **132** | **205421** | N65W | 18NE | | | N15E | 25SE | N70W | 65SW | N22W | 76SW | | |
| **133** | **205422** | | | | | | | | | | | | |
| **134** | **205423** | | | | | | | | | | | | |
| **135** | **205424** | | | | | | | | | | | | |
| **136** | **205425** | N20E | 58SE | | | N70E | vertical | | | | | | |
| **137** | **205426** | | | | | | | | | | | | |
| **138** | **205427** | | | | | | | | | | | | |
| **139** | **205428** | | | | | | | | | | | | |
| **140** | **205429** | | | | | | | | | | | | |
| **141** | **205430** | | | | | | | | | | | | |
| **142** | **205431** | | | | | | | | | | | | |
| **143** | **205432** | | | | | | | | | | | | |
| **144** | **205433** | | | | | | | | | | | | |
| **145** | **205434** | | | | | | | | | | | | |
| **146** | **205435** | | | | | 094 | 80 | | | | | | |
| **147** | **205436** | | | | | | | | | | | | |

| Count | Station # | Foliation Strike | Foliation Dip | Foliation_2 Strike | Foliation_2 Dip | Joint_1 Strike | Joint_1 Dip | Joint_2 Strike | Joint_2 Dip | Joint_3 Strike | Joint_3 Dip | Fold Axis Trend | Fold Axis Plunge |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 148 | 205437 | | | | | | | | | | | | |
| 149 | 205438 | | | | | | | | | | | | |
| 150 | 205438 | | | | | | | | | | | | |
| 151 | 205439 | | | | | | | | | | | | |
| 152 | 205440 | | | | | | | | | | | | |
| 153 | 205441 | | | | | | | | | | | | |
| 154 | 205442 | | | | | | | | | | | | |
| 155 | 205443 | | | | | | | | | | | | |
| 156 | 205461 | | | | | | | | | | | | |
| 157 | 205462 | | | | | | | | | | | | |
| 158 | 205463 | | | | | | | | | | | | |
| 159 | 205487 | | | | | | | | | | | | |
| 160 | 205488 | | | | | | | | | | | | |
| 161 | 205489 | | | | | | | | | | | | |
| 162 | 205490 | | | | | | | | | | | | |
| 163 | 205491 | | | | | | | | | | | | |
| 164 | 205492 | | | | | | | | | | | | |
| 165 | 205494 | | | | | | | | | | | | |
| 166 | 205495 | | | | | | | | | | | | |
| 167 | 205496 | | | | | | | | | | | | |
| 168 | 209260 | | | | | | | | | | | | |

| Count | Station # | Foliation Strike | Foliation Dip | Foliation_2 Strike | Foliation_2 Dip | Joint_1 Strike | Joint_1 Dip | Joint_2 Strike | Joint_2 Dip | Joint_3 Strike | Joint_3 Dip | Fold Axis Trend | Fold Axis Plunge |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **169** | **10GL100** | | | | | | | | | | | | |
| **170** | **10GL101** | | | | | | | | | | | | |
| **171** | **10GL102** | | | | | | | | | | | | |
| **172** | **10GL103** | | | | | | | | | | | | |
| **173** | **10GL104** | | | | | | | | | | | | |
| **174** | **10GL105** | | | | | N10W | 68SW | | | | | | |
| **175** | **10GL106** | | | | | | | | | | | | |
| **176** | **10GL109** | | | | | | | | | | | | |
| **177** | **10GL110** | | | | | | | | | | | | |
| **178** | **10GL111** | | | | | | | | | | | | |
| **179** | **10GL112** | | | | | | | | | | | | |
| **180** | **10GL113** | | | | | | | | | | | | |
| **181** | **10GL114** | | | | | | | | | | | | |
| **182** | **10GL115** | | | | | | | | | | | | |
| **183** | **10GL116** | | | | | | | | | | | | |
| **184** | **10GL117** | | | | | | | | | | | | |
| **185** | **10GL119** | | | | | | | | | | | | |
| **186** | **10GL120** | | | | | | | | | | | | |
| **187** | **10GL121** | | | | | | | | | | | | |
| **188** | **10GL122** | | | | | | | | | | | | |
| **189** | **10GL123** | | | | | | | | | | | | |

| Count | Station # | Foliation Strike | Foliation Dip | Foliation_2 Strike | Foliation_2 Dip | Joint_1 Strike | Joint_1 Dip | Joint_2 Strike | Joint_2 Dip | Joint_3 Strike | Joint_3 Dip | Fold Axis Trend | Fold Axis Plunge |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 190 | 10GL124 | | | | | | | | | | | | |
| 191 | 10GL125 | | | | | | | | | | | | |
| 192 | 10GL126 | | | | | | | | | | | | |
| 193 | 10GL127 | | | | | | | | | | | | |
| 194 | 10GL128 | | | | | | | | | | | | |
| 195 | 10GL129 | | | | | | | | | | | | |
| 196 | 10GL130 | | | | | | | | | | | | |
| 197 | 10GL131 | | | | | | | | | | | | |
| 198 | 10GL132 | | | | | | | | | | | | |
| 199 | 10GL133 | | | | | | | | | | | | |
| 200 | 10GL134 | | | | | | | | | | | | |
| 201 | 10GL135 | | | | | | | | | | | | |
| 202 | 10GL136 | | | | | | | | | | | | |
| 203 | 10GL137 | | | | | | | | | | | | |
| 204 | 10GL138 | | | | | | | | | | | | |
| 205 | 10GL139 | | | | | | | | | | | | |

# Appendix II Technical Specifications for Mainline Class 4 Ballast from the Alaska Railroad Corporation (ARRC)'s Data Sheets

# SECTION 352
## Railroad Ballast (Mainline Class 4)

Materials: the ballast shall be crushed shot rock or crushed pit-run rock composed of hard, strong, and durable particles, free from injurious amounts of deleterious substances and conforming to the following test standards:

| **Test** | **Test Procedure** | **Test Standards** |
|---|---|---|
| **Gradation Tests:** | | |
| Sampling Aggregates | ASTM D75<br>ASTM C702 | |
| Sieve With Square Openings | ASTM E11 | |
| Sieve Analysis | ASTM C136 | See table on next page |
| Material Finer Than No. 200 | ASTM C117 | See table on next page |
| **Material Quality Tests:** | | |
| Bulk Specific Gravity | ASTM C127 | 2.60 minimum |
| Water Absorption | ASTM C120 | 0.5% maximum |
| Magnesium Sulfate Soundness | ASTM C88<br>(Five Cycles) | 1.0% maximum |
| Clay Lumps & Friable Particles | ASTM C142 | 0.5% maximum |
| Flat and/or Elongated Particles | USACE CRD-C119 | 5.0% maximum |
| Degradation (L.A. Abrasion) | ASTM C535 | 20% maximum |
| Mill Abrasion | See description, next page | 4.0% maximum |
| Abrasion Number | See description, next page | 35% maximum |
| Fracture Particles | See description, next page | 50% minimum |

Processed ore material will maintain a Fracture Particle Standard with a minimum value of 10% less than that submitted and approved by the ARRC prior to the Bid Date (see Section D)

TYPE 4A BALLAST GRADATIONS

| Sieve Size | Percent Passing |
|---|---|
| 2-1/2 in. | 100 |
| 2 in. | 90-100 |
| 1-1/2 in. | 60-95 |
| 1 in. | 10-35 |
| 3/4 in. | 0-10 |
| 3/8 in. | 0-3 |
| No. 200 | 0-0.3 |

Mill Abrasion Test Description:

A representative sample is obtained and sized using the current ASTM Methods of Test. From the coarse aggregate, split a representative portion into a sample consisting of 3.3 lb. passing the 1-1/2 inch sieve and retained on the 1 inch sieve plus 3.3 lb. passing the 1 inch sieve and retained on the 3/4 inch sieve. The sample shall be washed and oven dried in accordance with the Los Angeles Abrasion procedure. The sample will then be placed in a 1.5 gallon, 9 inch external diameter porcelain or steel ball mill pot, along with 6.6 lb. of distilled water. The mill shall be rotated at 33 rpm for a total of 10,000 revolutions (five hours). The sample shall then be wash-sieved through a No. 200 sieve and oven dried before weighing. Mill abrasion shall be calculated as a percentage loss in weight by the following formula:

Mill Abrasion = (Loss in Weight / Original Weight) x 100

Abrasion Number:

The Abrasion Number is a number calculated with the results of the Los Angeles Abrasion Test and the Mill Abrasion Test given in this specification. The Abrasion Number shall be calculated by the following formula:

Abrasion Number = LA Abrasion Number + (5 x Mill Abrasion Number)

Fractured Particles Test Description:

The Fractured Particles Test is as follows:

A representative sample is obtained and sized using current ASTM Standard Methods D75 and C702, respectively. All fractured and non-fractured aggregate particles obtained by sampling shall be included for evaluation. ASTM Standard Method D5821 shall be used to determine the percentage, by mass, of coarse aggregate fractured particles.

The following fracture criteria shall apply:

A fractured particle shall be a particle with three or more fractured faces. Each of the fractured faces on the fractured particle must have a freshly exposed rock surface with a maximum dimension of at least one third the maximum particle dimension and a minimum dimension of at least one quarter of the maximum particle dimension. The included angle formed by the intersection of the average planes of adjoining fractured faces must be less than 135 degrees for each of the faces to be considered as separate fractured faces.

For example, a particle just retained on the two inch screen (i.e., particle size =2 inch) must have at a minimum:

1 A freshly exposed maximum face of between two-thirds of an inch and 2 inches, and
2. A second freshly exposed face with a minimum dimension of one-half inch, and
3. A third freshly exposed face ranging in dimension between the other two.

The angle formed between any two of these faces must not exceed 135 degrees.

Particles which do not meet the above criterion will be classified as non fractured faces.

Testing and Inspection:
Contractor shall obtain certification that the ballast furnished meets the above requirements.

Manufacturing, Handling, Delivery, and Stockpiling of Material:

The ballast shall be manufactured, handled, delivered, stockpiled, and placed in such a manner that it is kept clean and free from segregation. Processed ballast shall be washed and/or rescreened as necessary to remove fine particle contamination as defined by the specification prior to stockpiling. Stockpiling of ballast will only be allowed over firm stable base areas. In order to minimize segregation ballast shall be stockpiled in more or less horizontal layers with no dumping over the sides of the stockpile allowed. Travel of construction machinery and other vehicles over the top of the stockpiles shall be kept at a minimum. Contractor will be responsible for the control of dust when hauling to and from stockpile.

## CONSTRUCTION REQUIREMENTS

**352-3.01 GENERAL.** Ballast dumped on subgrade prior to track construction shall be kept free from material tracked in by construction equipment. Ballast dumped on skeleton track shall be distributed uniformly during the dumping operation to minimize the carrying or regulating required to provide the designed ballast section.

Contractor shall submit his plan for handling and placing ballast. This plan shall include source, type of equipment to be used, location of stockpiles, and method of distribution.

### 352-3.02 BALLAST PLACEMENT

1. Ballast shall be placed to the lines and grades indicated. The average thickness shall be within one-quarter inch of the thickness shown on the drawings. Ballast shall not be placed on soft, muddy, or frozen areas. Where the prepared subgrade (roadbed) is soft, muddy, rutted, exhibits severe depressions, or is otherwise damaged, the ballast shall not be placed until the damaged subgrade has been repaired and the Engineer has approved the area.

2. Forming of ruts that would impair proper drainage shall be prevented when distributing ballast from trucks and off track equipment. Any ruts formed greater than one (1) inch shall be leveled and graded to drain.

3. Ballast shall be unloaded as close as possible to the point of use so that unnecessary handling is prevented. Excess ballast shall be picked up and redistributed at the Contractor's expense. Ballast shall be handled in such a manner as to ensure it remains clean of deleterious materials and within specifications.

4. Minimum Ballast Depth: The minimum depth of ballast below the bottom of the tie shall be 12 inches or as shown on the plans. In concrete tie track the ends of track farthest from the bridge shall be tapered over the last 100 ft to have 10 inches of ballast under the tie to allow construction and surfacing of additional track in the future by others.

# Appendix III Technical Specifications for Riprap from the Alaska Railroad Corporation (ARRC) Data Sheets

5. USACE ETL Class 9

| Specified Rock Weight (pounds) | Equivalent Diameter* (inches) | Allowable Percent Smaller by Weight (%) |
|---|---|---|
| 1797 | 33 | 100 |
| 650 | 23.5 | 55 to 90 |
| 400 | 20 | 35 to 55 |
| 200 | 15.9 | 5 to 25 |
| 110 | 13 | 0 to 15 |

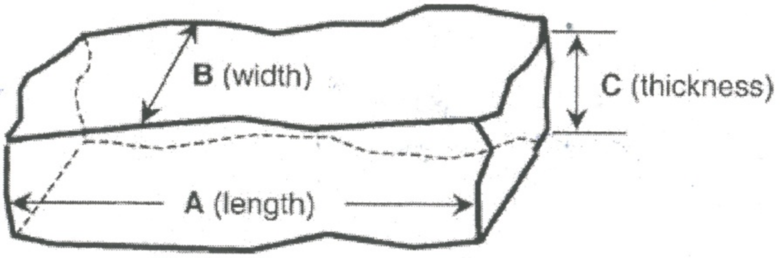
*The equivalent diameter is based on a specific gravity of 2.65 for a sphere shaped particle.

6. Proposed DOT&PF Class IIA

| Specified Rock Weight (pounds) | Equivalent Diameter* (inches) | Allowable Percent Smaller by Weight (%) |
|---|---|---|
| 775 | 24.9 | 100 |
| 630 | 23.2 | 70 to 90 |
| 500 | 21.5 | 35 to 65 |
| 400 | 20 | 0 to 50 |
| 25 | 7.9 | 0 to 15 |

*The equivalent diameter is based on a specific gravity of 2.65 for a sphere shaped particle.

The shape of a stone can be generally described by designating three axes of measurement: Major (length), Intermediate (width), and Minor (thickness), also known as the "A,""B," and "C" axes, as shown below:



Neither the width nor the thickness of any piece shall be less than one-third of its length.

Production Testing. Contractor shall provide certification from quarry, or other Contractor-developed site, that riprap meets the laboratory testing requirements. Laboratory tests and visual geologic examinations shall be made to determine acceptability of materials. Rock shall be composed of hard, strong, durable materials that will not slake or deteriorate upon exposure to the action of water or atmosphere; shall not contain cracks, joints, faults, seams, laminations, or bands of minerals or deleterious materials which would result in breakage during or after placement; and shall be free of expansive or other materials which would cause accelerated deterioration by exposure to project conditions. Materials shall meet the following test requirements for quality:

| Test Designation | Property | Allowable Value | Frequency | Comments |
|---|---|---|---|---|
| AASHTO T85 | Specific Gravity and Water Absorption | Average of 10 pieces: Sg > 2.65<br>Absorption < 2.5% | 1 per source | If any individual piece exhibits an Sg less than 2.65 or water absorption greater than 2.5%, an additional 10 pieces shall be tested. If the second series of tests also exhibits pieces that do not pass, the riprap shall be rejected. |
| AASHTO T96 | Resistance to Degradation by Abrasion and Impact | Maximum stone loss of 50% at 500 revolutions | 1 per source | |
| AASHTO T103 | Soundness by Freezing and Thawing | Maximum of 10 pieces after 25 cycles: < 0.5% | 1 per source | Required only if water absorption is greater than 0.5%. |
| AASHTO T104 | Soundness by Use of Sodium Sulfate or Magnesium Sulfate | Average of 10 pieces: < 17.5% | 1 per source | If any individual piece exhibits a value greater than 25%, an additional 10 pieces shall be tested. If the second series of tests also exhibits pieces that do not pass, the riprap shall be rejected. |
| AASHTO TP58 | Durability Index Using the Micro-Deval Apparatus | Value > 80<br>Moderate | 1 per source | Severity of application per Section 5.4, CEN (2002) moderate for riverine applications unless otherwise specified. |
| ASTM D 3967 | Splitting Tensile Strength of Intact Rock Core Specimens | Average of 10 pieces: > 6 MPa | 1 per source | If any individual piece exhibits a value less than 4 MPa, an additional 10 pieces shall be tested. If the second series of tests also exhibits pieces that do not pass, the riprap shall be rejected. |

## 611-3.01 CONSTRUCTION REQUIREMENTS.

Embankment Face Protection. All materials shall be placed in such a manner as to produce a well-keyed mass of rock with individual pieces tightly in contact with each surrounding stone, and with the least practicable amount of void spaces. The finished surface shall be free from pockets of single size rock. Placement of small rock to choke the spaces between large rock, or for leveling the surface, will not be permitted. Breaking of individual pieces in place by blasting or mechanical methods will not be permitted. Place riprap to the full course thickness at one operation and in such manner as to avoid displacing the underlying material. Placing by methods likely to cause segregation will not be permitted. The desired distribution of the various sizes of rock throughout the mass shall be obtained by selective loading at the quarry and by controlled placement of successive loads. Rearranging of individual pieces by mechanical equipment or by hand will be required to the extent necessary to correct deficiencies, and to provide a uniform, tightly knit slope.

Placement shall begin at the bottom of the slope and proceed up the slope placing rock to the full thickness in one operation. Placing riprap by methods likely to cause breakage, segregation of the various sizes, and/or negatively impacting the filter material will not be permitted. Rock shall not be placed on ice or snow.

When placing stone protection materials adjacent to completed portions of structures care shall be exercised to avoid damage to the structure. The Contractor shall submit a plan for placement adjacent to structures to the Engineer for review and approval.

When standing water is not present on the surface to receive protection, the filter shall be placed on undisturbed native soil, on excavated and prepared subgrade, or on acceptably placed and compacted fill. The areas to receive riprap shall be graded to establish a smooth surface and ensure that intimate contact is achieved between the subgrade surface and the filter, and between the filter and the riprap. Stable and compacted subgrade soils shall be prepared to the lines, grades, and cross sections shown in the plans. Transitions between slopes, embankment crests, benches, berms, and toes shall be compacted, shaped, and uniformly graded.

When water is present on the surface to receive protection, measures shall be used to ensure that the bed is free of logs, large rocks, construction materials, or other blocky materials that would create voids beneath the system. The subgrade shall be inspected immediately prior to placing the filter and riprap protection.

The filter shall be placed in a manner that provides continuous protection underneath the riprap. Refer to Section 631 and Section 729 for "Erosion Control" Geotextile materials and placement specifications.

A cover layer shall be placed on top of geotextile filter fabrics to provide protection against tearing during placement of riprap. The cover layer shall be Selected Type B material or as approved by the Engineer.

A tolerance of plus six (6) inches and minus zero (0) inches will be allowed in the thickness for the riprap. The extreme of any elevation or thickness tolerance shall not be continuous over an area greater than two hundred (200) square feet. Tracked or wheeled vehicles shall not be driven on previously placed riprap unless the Contractor can demonstrate to the satisfaction of the Engineer that the placed riprap and filter will not be negatively impacted.

Riprap placement shall proceed immediately behind the placement of the geotextile. A maximum lag of thirty (30) feet will be allowed between the placement of geotextile and the placement of riprap, unless otherwise authorized by the Engineer. See specification Section 631 for geotextile and surface preparation requirements. The Contractor shall maintain the riprap until accepted. Any material displaced prior to acceptance and due to the Contractor's negligence shall be replaced at his expense and to the lines and grades shown on the contract drawings.

<u>Launching Toe Protection.</u> Riprap shall be placed in a manner which will produce a well-graded mass of rock, with the minimum practicable percentage of voids, and well distributed large rocks. The finished launching toe shall be free from pockets of small rocks and clusters of larger rocks. No underlying bedding or geotextile layer is required under the launching toe but site preparation will be required to achieve the elevations shown on the plans. Rock shall not be placed on ice or snow.

The ability of the launching toe to protect project features against scour is dependent on placement of the base of launching toe at the elevations shown on the plans. If the existing grade at the time of construction is higher than the base of launching toe elevation shown on the plans, the contractor shall excavate the existing material to place the launching toe at the proper elevation. The bottom of launching toe installation shall be approximately level, shall be no higher than the elevation indicated on the plans, and shall be no lower than 12" below the elevation indicated on the plans. A leveling course made up of Type C material as defined in Section 703-2.07 shall be placed underneath the launching toe in areas where the existing grade is lower than the bottom of launching toe to achieve the required elevation. The Engineer shall be notified prior to placement of leveling course material when the existing grade is greater than 8 feet below the specified base of launching toe elevation. The top of launching toe elevation shall be approximately level, shall be no lower than the elevation specified on the plans, and shall be no more than 6" above the elevation specified on the plans.

Material shall be placed in such a manner as to ensure a relatively homogenous mass with a minimum of voids. Rearranging of individual rock may be required to obtain a well-graded distribution of rock sizes.

The finished launching toe riprap section shall be the thickness specified on the plans within plus 12 inches or minus 0 inches. Construction methods that break the individual rocks shall be avoided.

Operating equipment directly on the completed riprap protection shall be avoided. A sand and gravel cover made up of material from the project site or material approved by the Engineer may be placed over the final launching toe riprap section to allow construction traffic to operate on the launching toe. No more than one foot of cover material over the top of launching toe riprap shall be left in place upon project completion.

The Contractor shall not deposit excavated materials in adjacent stream channels or other bodies of water or in areas subject to flooding during high flows unless identified on plans.

### 611-3.02 INSPECTION.

General. Inspection of riprap placement includes visual inspection of the operation and the finished surface to ensure that a dense, rough surface of well graded rock of the specified quality and sizes is obtained, material is placed such that the layers are homogeneous with minimum of voids, and that the layers are the specified thickness.

The rock quality is determined at the quarry. If the rock delivered to the job site appears different than the approved material the Engineer may request quality tests be performed per section 611-2.01 and may reject the material if the minimum standards are not met. Rejected material shall be prevented from mixing with the satisfactory stone.

Gradation. The riprap gradation shall be produced at the quarry and not accomplished by mixing later in stockpiles or at the construction site. Inspection of the riprap gradation will occur at an area approved by the Engineer that is level and large enough to dump and sort typical loads of riprap. The Contractor shall assist the Engineer as needed to sort and measure the stones to determine if the riprap is within specifications. Reference rocks with the required gradation shall be placed at a convenient location where inspectors can see and develop a reference to judge by eye the suitability of the rock being placed.

If there is a question with the gradation the Engineer may select the most appropriate method for determining proper gradation including the Wolman count method, weighing individual particles, or photoanalysis software to determine whether the material meets the specified gradation.

The Wolman count method (Wolman, 1954) as described in the final report for NCHRP Report 568 (Lagasse et al., 2006) may be used as a field test to determine a size distribution based on a random sampling of individual stones within a matrix. This method relies on samples taken from the surface of the matrix to make the method practical for use in the field. The procedure determines frequency by size of a surface material rather than using a bulk sample. The middle dimension (B axis) is measured for 100 randomly selected particles on the surface.

The Wolman count method can be done by stretching a survey tape over the material and measuring each particle located at equal intervals along the tape. The interval should be at least

1 ft for small riprap and increased for larger riprap. The longer and shorter axes (A and C) can also be measured to determine particle shape. One rule that must be followed is that if a single particle is large enough to fall under two interval points along the tape, then it should be included in the count twice. An interval should be selected that is large enough that this does not occur frequently.

An alternative to the size-based method described above is to weigh all individual particles from a 10,000- to 15,000-lb (4536- to 6804-kg) sample. A platform scale at the quarry can be used to determine a weight-based gradation. A typical test of this kind takes 4 to 6 hours to complete.

The photoanalysis software consists of photographing the material with a reference object for scale. The photograph is then processed with a software package which outputs the material gradation.

**611-3.03 SURVEY.** The Contractor shall provide surveys as specified below and in accordance with the construction requirements in specification Section 642. Cross sections shall be surveyed at 100-foot stations along the levee and spur dike alignments. Cross sections shall be perpendicular to the alignment, shall consist of shots every 25 feet (at a minimum), and shall also capture significant grade breaks, channel braid boundaries, top of banks, toe of banks, water level, and other features relevant to construction as determined by the Contractor and the Engineer at the time of survey. The survey shall tie in to the project horizontal and vertical control provided on the plans.

Pre-Construction Survey. A pre-construction survey shall be conducted, submitted with paper copies including an edited point file representing the horizontal and vertical data from the survey, and an AutoCAD file. The survey shall be submitted to the Owner after clearing and grubbing, but 14 days prior to the start of levee construction activities. The pre-construction survey will include the area where construction is anticipated to occur in the first 30 days.

Interim Condition Surveys. Every 2 weeks where material is being placed, an Interim Condition survey shall be performed and submitted to the Engineer to quantify the volume of material required to construct the project features and verify construction is per plan. Due to the ongoing erosion at the project site the contractor shall expect cross-section changes from the bid set drawings. Only those sections built-on and altered during the two week time frame need to be included in the Interim Condition survey. Each section in the Interim Condition survey shall show the existing ground profile, water level, pay items, and the design template as it fits on the existing ground. The cross-sections and plan view of the surveyed area shall be submitted with paper copies including an edited point file representing the horizontal and vertical data from the survey, and an AutoCAD file to the Engineer within seven days of the completion of each Interim Condition Survey.

Post-Construction Survey. A post-construction survey shall be conducted immediately following completion of the revetment and shall be submitted to the Engineer within 10 days of completion.

The Contractor shall provide cross-sections of the material placed and the revetment design template drawn on the same axis using different line types for the material placed and the template. The cross sections scale shall match the construction plan set. Cross-sections and templates shall be provided on all 100-foot stations.

**611-4.01 METHOD OF MEASUREMENT.** By neat line volume.

# Appendix IV  Certified Analytical Results for Material Tests Conducted by Mappa, Inc., North Pole, Alaska

MAPPA TESTLAB
**1956 Richardson Hwy North Pole, Alaska 99705**
**Phone 907-488-1266 Fax 907-488-0772**

**Date:** November 10, 2010

**Client:** Paul Metz
Institute Northern Engineering
Duckering 525
P.O. Box 755910
Fairbanks, Alaska 99775-5910

**Client:** Pacific Rim Geological Consulting Inc
P.O. Box 81906
Fairbanks, Alaska 99708

**Subject:** Livengood Rail Samples

Gentlemen:

Enclosed are the results of aggregate samples submitted to our laboratory for Aggregate Quality Tests.

Each sample was tested for Specific Gravity, Abrasion Loss, Degredation, and Soundness in accordance with Standard ASTM & or Alaska Test Methods as required.

The client samples were identified as follows:

204685; 204934; 204941; 204959; 204960; 205242; 205259; 205260; 205262; 205263; 205268; 205308; 205311; 205315; 205319; 205320; 205324; 205338; 205367; 205371; 205372; 205420; 205421; 205432; 205433; 205442

Please contact our office it there are any questions.

Approved By: Stefan Mack
Stefan Mack, PE

11-10-10

STATE OF ALASKA
49TH
Stefan Mack
STEFAN MACK
No. CE11244
REGISTERED PROFESSIONAL ENGINEER

Institute Northern Engineering
University of Alaska Fairbanks

Livengood Rail Samples

Pacific Geo Consulting

| Client Sample #'s | Lab # | Bulk Sp Gr (SSD) | Bulk Sp Gr (Dry) | Apparent Sp Gr | Absorption (%) | Deg ATM T-13 | Abrasion Loss C-131 | Soundness Loss (%) |
|---|---|---|---|---|---|---|---|---|
| 204685 | 1603 | 2.657 | 2.646 | 2.675 | 0.40 | 91 | 28 | 0.19 |
| 204934 | 1604 | 2.604 | 2.585 | 2.634 | 0.72 | 90 | 23 | 0.12 |
| 204941 | 1605 | 2.592 | 2.565 | 2.635 | 1.04 | 65 | 35 | 0.42 |
| 204959 | 1366 | 2.697 | 2.687 | 2.712 | 0.35 | 30 | 29 | 0.40 |
| 204960 | 1367 | 2.970 | 2.923 | 3.069 | 1.63 | 77 | 16 | 0.18 |
| 205242 | 1368 | 2.588 | 2.555 | 2.644 | 1.30 | 44 | 32 | 0.89 |
| 205259 | 1369 | 2.611 | 2.593 | 2.640 | 0.69 | 84 | 23 | 1.34 |
| 205260 | 1370 | 2.579 | 2.537 | 2.648 | 1.66 | 96 | 26 | 0.66 |
| 205262 | 1371 | 2.920 | 2.904 | 2.950 | 0.54 | 82 | 13 | 0.47 |
| 205263 | 1372 | 2.691 | 2.675 | 2.718 | 0.59 | 82 | 14 | 0.10 |
| 205268 | 1373 | 2.705 | 2.697 | 2.720 | 0.31 | 42 | 27 | 1.20 |
| 205308 | 1606 | 2.981 | 2.960 | 3.024 | 0.72 | 61 | 15 | 1.00 |
| 205311 | 1377 | 2.998 | 2.978 | 3.038 | 0.67 | 70 | 13 | 0.65 |
| 205315 | 1378 | 2.614 | 2.576 | 2.677 | 1.47 | 91 | 22 | 0.10 |
| 205319 | 1379 | 2.704 | 2.687 | 2.733 | 0.62 | 90 | 15 | 0.62 |
| 205320 | 1380 | 2.724 | 2.706 | 2.756 | 0.68 | 84 | 28 | 1.20 |
| 205324 | 1607 | 2.769 | 2.757 | 2.790 | 0.43 | 74 | 14 | 0.40 |
| 205338 | 1381 | 2.577 | 2.555 | 2.611 | 0.84 | 87 | 43 | 0.58 |
| 205367 | 1382 | 2.629 | 2.619 | 2.646 | 0.38 | 95 | 23 | 0.17 |
| 205371 | 1608 | 2.560 | 2.534 | 2.603 | 1.05 | 82 | 20 | 0.65 |
| 205372 | 1609 | 2.871 | 2.856 | 2.899 | 0.51 | 20 | 22 | 0.94 |
| 205420 | 1374 | 2.702 | 2.657 | 2.781 | 1.59 | 95 | 17 | 0.37 |
| 205421 | 1610 | 2.705 | 2.672 | 2.763 | 1.24 | 48 | 22 | 0.25 |
| 205432 | 1376 | 2.634 | 2.623 | 2.651 | 0.40 | 95 | 18 | 0.29 |
| 205433 | 1375 | 2.637 | 2.528 | 2.651 | 0.33 | 95 | 19 | 0.27 |
| 205442 | 1611 | 2.807 | 2.780 | 2.857 | 0.97 | 77 | 18 | 0.71 |

MAPPA TESTLAB

11/10/2010

# Appendix V  ALS Minerals Certificate #FA10169937

ALS USA Inc.
4977 Energy Way
Reno NV 89502
Phone: 775 356 5395 Fax: 775 355 0179 www.alsglobal.com

To: PACIFIC RIM GEOLOGICAL CONSULTING
PO BOX 81906
FAIRBANKS AK 99708- 1906

Page: 1
Finalized Date: 28- DEC- 2010
Account: QOK

## CERTIFICATE FA10169937

Project: Livengood Rail

P.O. No.:

This report is for 29 Rock samples submitted to our lab in Fairbanks, AK, USA on 24- NOV- 2010.

The following have access to data associated with this certificate:

| | | |
|---|---|---|
| TOM BUNDTZEN | TINA LAIRD | |

## SAMPLE PREPARATION

| ALS CODE | DESCRIPTION |
|---|---|
| WEI- 21 | Received Sample Weight |
| PUL- QC | Pulverizing QC Test |
| LOG- 22 | Sample login - Rcd w/o BarCode |
| CRU- 31 | Fine crushing - 70% <2mm |
| SPL- 21 | Split sample - riffle splitter |
| PUL- 31 | Pulverize split to 85% <75 um |

## ANALYTICAL PROCEDURES

| ALS CODE | DESCRIPTION | INSTRUMENT |
|---|---|---|
| TOT- ICP06 | Total Calculation for ICP06 | ICP- AES |
| ME- ICP06 | Whole Rock Package - ICP- AES | ICP- AES |
| OA- GRA05 | Loss on Ignition at 1000C | WST- SEQ |
| ME- MS81 | 38 element fusion ICP- MS | ICP- MS |

To: PACIFIC RIM GEOLOGICAL CONSULTING
ATTN: TOM BUNDTZEN
PO BOX 81906
FAIRBANKS AK 99708- 1906

This is the Final Report and supersedes any preliminary report with this certificate number. Results apply to samples as submitted. All pages of this report have been checked and approved for release.

Signature:
Colin Ramshaw, Vancouver Laboratory Manager

ALS Minerals
ALS USA Inc.
4977 Energy Way
Reno NV 89502
Phone: 775 356 5395 Fax: 775 355 0179 www.alsglobal.com

To: PACIFIC RIM GEOLOGICAL CONSULTING
PO BOX 81906
FAIRBANKS AK 99708- 1906

Page: 2 - A
Total # Pages: 2 (A - D)
Finalized Date: 28- DEC- 2010
Account: QOK

Project: Livengood Rail

## CERTIFICATE OF ANALYSIS FA10169937

| Sample Description | Method | WEI- 21 | ME- MS81 | ME- MS81 | ME- MS81 | ME- MS81 | ME- MS81 | ME- MS81 | ME- MS81 | ME- MS81 | ME- MS81 | ME- MS81 | ME- MS81 | ME- MS81 | ME- MS81 | ME- MS81 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Analyte | Recvd Wt. | Ag | Ba | Ce | Co | Cr | Cs | Cu | Dy | Er | Eu | Ga | Gd | Hf | Ho |
| | Units | kg | ppm | ppm | ppm | ppm | ppm | ppm | ppm | ppm | ppm | ppm | ppm | ppm | ppm | ppm |
| | LOR | 0.02 | 1 | 0.5 | 0.5 | 0.5 | 10 | 0.01 | 5 | 0.05 | 0.03 | 0.03 | 0.1 | 0.05 | 0.2 | 0.01 |
| 205324 | | 1.55 | <1 | 402 | 24.1 | 18.8 | 100 | 0.74 | 46 | 4.23 | 2.52 | 1.29 | 14.5 | 4.11 | 2.8 | 0.83 |
| 205367 | | 0.58 | <1 | 38.8 | 6.6 | 0.8 | 30 | 0.16 | <5 | 0.60 | 0.41 | 0.11 | 1.0 | 0.64 | 5.6 | 0.13 |
| 205371 | | 1.35 | <1 | 146.5 | 15.5 | 0.5 | 30 | 0.30 | 6 | 1.38 | 0.95 | 0.26 | 2.2 | 1.31 | 6.8 | 0.31 |
| 205433 | | 1.02 | <1 | 56.5 | 14.5 | <0.5 | 50 | 0.05 | 5 | 0.95 | 0.69 | 0.14 | 1.3 | 1.08 | 8.9 | 0.20 |
| 205320 | | 0.98 | <1 | 2110 | 169.0 | 14.7 | 20 | 11.75 | 11 | 4.82 | 2.63 | 2.42 | 20.0 | 9.10 | 6.9 | 0.90 |
| 205372 | | 1.54 | <1 | 677 | 21.1 | 55.0 | 350 | 0.44 | 41 | 4.24 | 1.98 | 2.26 | 23.1 | 5.39 | 3.3 | 0.75 |
| 204959 | | 0.46 | <1 | 63.4 | 0.9 | 0.5 | <10 | 0.08 | <5 | 0.16 | 0.12 | 0.04 | 0.2 | 0.16 | <0.2 | 0.04 |
| 205338 | | 0.29 | <1 | 1085 | 4.6 | 16.2 | 20 | 0.46 | 27 | 0.37 | 0.21 | 0.10 | 2.8 | 0.36 | 0.4 | 0.07 |
| 205442 | | 0.44 | <1 | 148.5 | 10.2 | 30.6 | 80 | 0.54 | 98 | 3.96 | 2.51 | 0.98 | 18.9 | 3.22 | 2.1 | 0.84 |
| 205421 | | 0.30 | <1 | 827 | 32.1 | 22.9 | 110 | 3.54 | 57 | 4.58 | 2.88 | 1.48 | 17.5 | 4.76 | 3.6 | 0.98 |
| 205260 | | 0.18 | <1 | 240 | 3.2 | 0.9 | 20 | 0.14 | 6 | 0.33 | 0.14 | 0.10 | 1.5 | 0.40 | 0.2 | 0.06 |
| 205432 | | 0.23 | <1 | 83.1 | 13.8 | 0.6 | 40 | 0.19 | 5 | 0.73 | 0.56 | 0.14 | 1.7 | 0.88 | 8.6 | 0.16 |
| 205311 | | 0.58 | <1 | 208 | 16.4 | 46.0 | 160 | 0.28 | 190 | 4.64 | 2.69 | 1.39 | 20.0 | 4.27 | 2.6 | 0.94 |
| 205443 | | 1.59 | <1 | 131.5 | 1.7 | 0.6 | <10 | 0.41 | <5 | 0.15 | 0.09 | 0.04 | 0.5 | 0.20 | 0.2 | 0.03 |
| 205441 | | 1.59 | <1 | 8.8 | <0.5 | 104.0 | 2540 | 0.03 | 9 | <0.05 | <0.03 | <0.03 | 1.1 | <0.05 | <0.2 | 0.01 |
| 205261 | | 0.58 | <1 | 183.5 | 4.3 | 1.3 | 60 | 0.22 | 10 | 0.26 | 0.16 | 0.08 | 2.4 | 0.32 | 0.3 | 0.05 |
| 204951 | | 0.72 | <1 | 33.3 | 0.9 | <0.5 | <10 | 0.06 | <5 | 0.08 | 0.05 | <0.03 | 0.2 | 0.09 | <0.2 | 0.01 |
| 205310 | | 1.58 | <1 | 14.6 | 15.3 | 1.6 | 40 | 0.06 | 21 | 1.31 | 0.82 | 0.20 | 3.1 | 1.48 | 8.1 | 0.27 |
| 205262 | | 0.69 | <1 | 457 | 9.0 | 30.4 | 140 | 0.60 | 132 | 2.93 | 1.95 | 0.80 | 17.3 | 2.59 | 1.8 | 0.66 |
| 204960 | | 2.10 | <1 | 1330 | 28.0 | 47.8 | 30 | 0.63 | 225 | 5.70 | 3.14 | 1.98 | 22.1 | 5.97 | 4.1 | 1.11 |
| 204941 | | 1.17 | <1 | 87.1 | 12.6 | 0.7 | 30 | 0.10 | 5 | 0.90 | 0.63 | 0.24 | 1.5 | 1.13 | 6.8 | 0.20 |
| 204934 | | 1.07 | <1 | 305 | 45.1 | 5.2 | 40 | 0.74 | 14 | 2.49 | 1.49 | 0.62 | 9.2 | 2.97 | 7.1 | 0.50 |
| 204685 | | 1.11 | <1 | 4.7 | 1.3 | 0.6 | 30 | 0.04 | <5 | 0.16 | 0.10 | 0.03 | 0.6 | 0.17 | <0.2 | 0.03 |
| 205263 | | 0.61 | <1 | 1385 | 97.3 | 6.6 | 20 | 5.40 | 19 | 2.84 | 1.57 | 1.55 | 19.9 | 5.03 | 4.2 | 0.53 |
| 204259 | | 1.48 | <1 | 775 | 69.1 | 0.5 | 70 | 4.06 | 44 | 8.39 | 4.59 | 2.12 | 16.4 | 9.28 | 3.7 | 1.65 |
| 205242 | | 1.58 | <1 | 185.5 | 33.3 | 1.4 | 20 | 0.61 | 8 | 1.54 | 0.79 | 0.46 | 5.1 | 2.44 | 3.3 | 0.28 |
| 205308 | | 1.57 | <1 | 1175 | 20.0 | 44.8 | 230 | 0.69 | 163 | 4.51 | 2.38 | 1.50 | 17.9 | 4.41 | 3.3 | 0.87 |
| 205315 | | 0.91 | 5 | 133.5 | 67.7 | 2.8 | 150 | 2.89 | 51 | 2.85 | 1.81 | 0.59 | 20.2 | 4.01 | 4.1 | 0.58 |
| 205319 | | 0.99 | <1 | 1205 | 71.4 | 18.1 | 220 | 10.75 | 60 | 6.01 | 3.71 | 1.71 | 26.3 | 6.68 | 5.9 | 1.22 |

ALS Minerals

ALS USA Inc.
4977 Energy Way
Reno NV 89502
Phone: 775 356 5395 Fax: 775 355 0179 www.alsglobal.com

To: PACIFIC RIM GEOLOGICAL CONSULTING
PO BOX 81906
FAIRBANKS AK 99708- 1906

Page: 2 - B
Total # Pages: 2 (A - D)
Finalized Date: 28- DEC- 2010
Account: QOK

Project: Livengood Rail

# CERTIFICATE OF ANALYSIS FA10169937

| Method | ME- MS81 | ME- MS81 | ME- MS81 | ME- MS81 | ME- MS81 | ME- MS81 | ME- MS81 | ME- MS81 | ME- MS81 | ME- MS81 | ME- MS81 | ME- MS81 | ME- MS81 | ME- MS81 | ME- MS81 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Analyte | La | Lu | Mo | Nb | Nd | Ni | Pb | Pr | Rb | Sm | Sn | Sr | Ta | Tb | Th |
| Units | ppm | ppm | ppm | ppm | ppm | ppm | ppm | ppm | ppm | ppm | ppm | ppm | ppm | ppm | ppm |
| Sample Description LOR | 0.5 | 0.01 | 2 | 0.2 | 0.1 | 5 | 5 | 0.03 | 0.2 | 0.03 | 1 | 0.1 | 0.1 | 0.01 | 0.05 |
| 205324 | 11.2 | 0.37 | <2 | 5.0 | 15.2 | 33 | <5 | 3.36 | 24.1 | 3.85 | 1 | 208 | 0.3 | 0.69 | 1.58 |
| 205367 | 3.7 | 0.08 | <2 | 1.4 | 3.0 | <5 | <5 | 0.82 | 3.7 | 0.58 | <1 | 4.4 | 0.1 | 0.11 | 1.07 |
| 205371 | 8.0 | 0.16 | <2 | 2.9 | 7.3 | <5 | <5 | 1.94 | 8.7 | 1.26 | 1 | 14.7 | 0.3 | 0.25 | 2.36 |
| 205433 | 7.2 | 0.14 | <2 | 3.2 | 6.1 | <5 | <5 | 1.69 | 1.8 | 1.04 | <1 | 3.4 | 0.3 | 0.18 | 2.27 |
| 205320 | 88.8 | 0.35 | 3 | 52.1 | 66.4 | 5 | 18 | 19.15 | 242 | 10.05 | 4 | 936 | 3.1 | 1.07 | 33.0 |
| 205372 | 8.2 | 0.20 | <2 | 12.5 | 18.5 | 274 | <5 | 3.42 | 7.1 | 5.36 | 1 | 688 | 0.8 | 0.82 | 0.71 |
| 204959 | 0.9 | 0.01 | <2 | 0.2 | 0.6 | <5 | <5 | 0.15 | 0.7 | 0.12 | <1 | 128.5 | 0.1 | 0.04 | 0.08 |
| 205338 | 2.2 | 0.04 | <2 | 1.4 | 1.6 | <5 | <5 | 0.39 | 9.6 | 0.34 | <1 | 16.0 | 0.2 | 0.10 | 0.68 |
| 205442 | 3.5 | 0.35 | <2 | 1.2 | 8.3 | 36 | <5 | 1.59 | 15.5 | 2.63 | 1 | 386 | 0.2 | 0.64 | 0.53 |
| 205421 | 15.2 | 0.41 | <2 | 8.1 | 18.5 | 44 | 5 | 4.26 | 42.8 | 4.31 | 1 | 198.5 | 0.6 | 0.79 | 2.55 |
| 205260 | 1.0 | 0.02 | <2 | 0.4 | 1.4 | <5 | <5 | 0.33 | 3.0 | 0.35 | <1 | 13.7 | 0.1 | 0.08 | 0.29 |
| 205432 | 7.0 | 0.13 | <2 | 2.8 | 6.1 | <5 | <5 | 1.67 | 5.4 | 1.00 | 1 | 7.6 | 0.3 | 0.16 | 2.12 |
| 205311 | 6.6 | 0.36 | <2 | 7.9 | 12.2 | 83 | <5 | 2.46 | 8.9 | 3.52 | 1 | 272 | 0.6 | 0.80 | 0.60 |
| 205443 | 1.1 | 0.01 | <2 | 0.5 | 0.9 | <5 | <5 | 0.24 | 2.3 | 0.20 | <1 | 256 | 0.1 | 0.11 | 0.19 |
| 205441 | <0.5 | 0.01 | <2 | <0.2 | 0.1 | 2150 | <5 | <0.03 | 0.4 | 0.03 | <1 | 4.5 | 0.1 | 0.05 | <0.05 |
| 205261 | 1.7 | 0.03 | <2 | 0.7 | 1.5 | 9 | <5 | 0.39 | 7.7 | 0.32 | 1 | 9.9 | 0.1 | 0.11 | 0.51 |
| 204951 | 0.5 | 0.01 | <2 | <0.2 | 0.4 | <5 | <5 | 0.11 | 0.9 | 0.08 | <1 | 174.5 | 0.1 | 0.05 | 0.11 |
| 205310 | 7.7 | 0.14 | <2 | 2.9 | 7.0 | <5 | <5 | 1.86 | 0.6 | 1.34 | 1 | 3.5 | 0.3 | 0.28 | 2.44 |
| 205262 | 3.0 | 0.30 | <2 | 0.6 | 7.0 | 55 | <5 | 1.37 | 11.9 | 2.16 | 1 | 284 | 0.1 | 0.55 | 0.53 |
| 204960 | 11.4 | 0.37 | <2 | 13.8 | 20.1 | 51 | <5 | 4.17 | 10.5 | 5.44 | 2 | 426 | 1.0 | 0.99 | 1.05 |
| 204941 | 6.6 | 0.12 | <2 | 2.2 | 6.6 | <5 | <5 | 1.68 | 3.4 | 1.25 | <1 | 9.2 | 0.3 | 0.19 | 1.68 |
| 204934 | 21.7 | 0.21 | <2 | 6.7 | 17.8 | 15 | 16 | 5.00 | 41.5 | 2.90 | 1 | 35.7 | 0.7 | 0.46 | 9.21 |
| 204685 | <0.5 | 0.01 | <2 | <0.2 | 0.5 | <5 | <5 | 0.12 | 1.0 | 0.13 | <1 | 1.1 | 0.1 | 0.05 | 0.19 |
| 205263 | 55.8 | 0.20 | 2 | 15.1 | 35.8 | 9 | 22 | 10.55 | 105.5 | 5.52 | 5 | 682 | 1.0 | 0.60 | 15.55 |
| 204259 | 39.0 | 0.59 | 2 | 10.5 | 40.0 | <5 | 15 | 9.99 | 126.0 | 8.89 | 3 | 74.8 | 0.9 | 1.45 | 11.80 |
| 205242 | 13.7 | 0.11 | <2 | 2.6 | 13.2 | <5 | 5 | 3.49 | 17.7 | 2.53 | 1 | 35.9 | 0.3 | 0.31 | 6.89 |
| 205308 | 8.3 | 0.29 | <2 | 9.7 | 14.7 | 82 | <5 | 3.05 | 10.9 | 3.91 | 1 | 198.0 | 0.7 | 0.76 | 0.83 |
| 205315 | 39.2 | 0.33 | 8 | 16.1 | 25.2 | 6 | 87 | 7.35 | 218 | 4.32 | 28 | 20.2 | 0.9 | 0.53 | 4.83 |
| 205319 | 35.7 | 0.55 | <2 | 15.0 | 33.0 | 91 | 21 | 8.63 | 140.5 | 6.58 | 2 | 229 | 1.1 | 1.05 | 9.52 |

**ALS Minerals**

ALS USA Inc.

4977 Energy Way
Reno NV 89502
Phone: 775 356 5395 Fax: 775 355 0179 www.alsglobal.com

To: PACIFIC RIM GEOLOGICAL CONSULTING
PO BOX 81906
FAIRBANKS AK 99708- 1906

Page: 2 - C
Total # Pages: 2 (A - D)
Finalized Date: 28- DEC- 2010
Account: QOK

Project: Livengood Rail

## CERTIFICATE OF ANALYSIS FA10169937

| Sample Description | Method | ME- MS81 | ME- MS81 | ME- MS81 | ME- MS81 | ME- MS81 | ME- MS81 | ME- MS81 | ME- MS81 | ME- MS81 | ME- ICP06 | ME- ICP06 | ME- ICP06 | ME- ICP06 | ME- ICP06 | ME- ICP06 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Analyte | Tl | Tm | U | V | W | Y | Yb | Zn | Zr | SiO2 | Al2O3 | Fe2O3 | CaO | MgO | Na2O |
| | Units | ppm | ppm | ppm | ppm | ppm | ppm | ppm | ppm | ppm | % | % | % | % | % | % |
| | LOR | 0.5 | 0.01 | 0.05 | 5 | 1 | 0.5 | 0.03 | 5 | 2 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| 205324 | | <0.5 | 0.36 | 0.88 | 182 | 1 | 21.6 | 2.42 | 78 | 108 | 60.7 | 14.35 | 7.39 | 4.12 | 3.12 | 3.92 |
| 205367 | | <0.5 | 0.06 | 0.60 | 7 | 1 | 3.5 | 0.48 | 12 | 240 | 94.5 | 0.37 | 2.12 | 0.01 | 0.01 | 0.01 |
| 205371 | | <0.5 | 0.15 | 0.88 | 16 | 1 | 8.4 | 0.97 | 5 | 265 | 92.6 | 1.14 | 0.81 | 0.03 | 0.03 | 0.03 |
| 205433 | | <0.5 | 0.11 | 0.84 | 7 | 1 | 5.8 | 0.77 | <5 | 348 | 94.8 | 0.65 | 0.77 | <0.01 | 0.02 | <0.01 |
| 205320 | | <0.5 | 0.34 | 8.39 | 134 | 5 | 24.7 | 2.21 | 91 | 274 | 57.4 | 16.50 | 6.44 | 4.32 | 2.41 | 3.58 |
| 205372 | | <0.5 | 0.24 | 0.23 | 164 | 1 | 19.6 | 1.40 | 134 | 116 | 48.5 | 13.95 | 12.05 | 5.88 | 5.82 | 4.76 |
| 204959 | | <0.5 | 0.02 | 0.46 | 7 | 1 | 2.5 | 0.09 | 68 | <2 | <0.01 | 0.10 | 0.07 | 56.5 | 0.30 | 0.02 |
| 205338 | | 0.7 | 0.04 | 0.27 | 12 | 1 | 1.7 | 0.20 | 31 | 14 | 91.1 | 1.14 | 1.80 | 0.13 | 0.08 | 0.05 |
| 205442 | | <0.5 | 0.38 | 0.18 | 370 | 1 | 22.1 | 2.25 | 102 | 66 | 49.8 | 15.00 | 10.80 | 9.34 | 4.59 | 4.68 |
| 205421 | | <0.5 | 0.41 | 1.21 | 228 | 1 | 25.5 | 2.58 | 104 | 137 | 57.6 | 15.45 | 8.55 | 2.61 | 3.52 | 3.98 |
| 205260 | | <0.5 | 0.03 | 0.09 | 5 | 1 | 1.4 | 0.12 | 5 | 5 | 94.6 | 0.51 | 1.32 | 0.05 | 0.04 | 0.05 |
| 205432 | | <0.5 | 0.11 | 0.84 | 9 | 1 | 4.6 | 0.69 | 5 | 336 | 95.3 | 0.84 | 0.99 | 0.03 | 0.03 | 0.02 |
| 205311 | | <0.5 | 0.38 | 0.19 | 369 | 1 | 24.6 | 2.23 | 109 | 90 | 47.1 | 15.55 | 12.45 | 10.95 | 5.81 | 2.62 |
| 205443 | | <0.5 | 0.02 | 0.64 | <5 | 1 | 1.1 | 0.07 | 19 | 5 | 0.12 | 0.26 | 0.14 | 56.5 | 0.35 | 0.01 |
| 205441 | | <0.5 | 0.01 | <0.05 | <5 | 1 | <0.5 | 0.03 | 48 | <2 | 39.6 | 0.64 | 7.53 | 0.13 | 35.4 | 0.01 |
| 205261 | | <0.5 | 0.03 | 0.12 | 9 | 1 | 1.2 | 0.14 | <5 | 9 | 92.8 | 0.90 | 1.59 | 0.03 | 0.22 | 0.02 |
| 204951 | | <0.5 | 0.01 | 0.80 | <5 | 1 | 0.6 | 0.04 | <5 | 3 | <0.01 | 0.12 | 0.09 | 56.1 | 0.42 | 0.13 |
| 205310 | | <0.5 | 0.13 | 1.11 | 10 | 1 | 7.4 | 0.79 | 7 | 307 | 93.9 | 1.08 | 1.58 | 0.07 | 0.03 | <0.01 |
| 205262 | | <0.5 | 0.29 | 0.21 | 353 | 1 | 17.5 | 1.85 | 89 | 53 | 51.5 | 15.30 | 9.04 | 9.07 | 5.50 | 4.70 |
| 204960 | | <0.5 | 0.41 | 0.31 | 427 | 1 | 29.0 | 2.45 | 140 | 144 | 48.0 | 13.25 | 14.40 | 9.96 | 5.38 | 2.29 |
| 204941 | | <0.5 | 0.11 | 0.85 | 11 | 1 | 5.5 | 0.70 | 5 | 269 | 94.7 | 1.08 | 0.97 | 0.02 | 0.02 | 0.01 |
| 204934 | | <0.5 | 0.21 | 2.29 | 33 | 2 | 13.6 | 1.34 | 52 | 250 | 80.7 | 6.74 | 4.19 | 0.09 | 0.71 | 0.67 |
| 204685 | | <0.5 | 0.02 | 0.09 | <5 | 1 | 0.8 | 0.07 | <5 | <2 | 93.6 | 0.13 | 0.97 | 0.01 | 0.01 | 0.01 |
| 205263 | | 0.5 | 0.21 | 3.58 | 84 | 2 | 14.8 | 1.31 | 172 | 159 | 62.4 | 15.50 | 5.25 | 3.30 | 1.79 | 2.70 |
| 204259 | | 0.7 | 0.63 | 7.88 | 187 | 3 | 41.9 | 3.88 | 33 | 130 | 71.4 | 11.70 | 4.00 | 0.10 | 1.07 | 0.04 |
| 205242 | | <0.5 | 0.10 | 1.16 | 16 | 2 | 7.5 | 0.71 | 13 | 108 | 93.5 | 4.09 | 1.38 | 0.02 | 0.10 | 0.02 |
| 205308 | | <0.5 | 0.32 | 0.26 | 392 | 1 | 21.8 | 2.02 | 103 | 109 | 46.3 | 13.50 | 12.45 | 9.63 | 6.06 | 2.61 |
| 205315 | | 0.8 | 0.26 | 2.07 | 202 | 156 | 15.5 | 1.95 | 24 | 141 | 63.4 | 11.90 | 3.17 | 0.09 | 1.56 | 0.33 |
| 205319 | | 0.5 | 0.53 | 3.21 | 339 | 3 | 31.7 | 3.58 | 162 | 201 | 55.3 | 19.00 | 8.85 | 1.92 | 3.86 | 2.38 |

ALS Minerals

ALS USA Inc.
4977 Energy Way
Reno NV 89502
Phone: 775 356 5395 Fax: 775 355 0179 www.alsglobal.com

To: PACIFIC RIM GEOLOGICAL CONSULTING
PO BOX 81906
FAIRBANKS AK 99708- 1906

Page: 2 - D
Total # Pages: 2 (A - D)
Finalized Date: 28- DEC- 2010
Account: QOK

Project: Livengood Rail

# CERTIFICATE OF ANALYSIS FA10169937

| Sample Description | Method | ME- ICP06 | ME- ICP06 | ME- ICP06 | ME- ICP06 | ME- ICP06 | ME- ICP06 | ME- ICP06 | OA- GRA05 | TOT- ICP06 |
|---|---|---|---|---|---|---|---|---|---|---|
| | Analyte | K2O | Cr2O3 | TiO2 | MnO | P2O5 | SrO | BaO | LOI | Total |
| | Units | % | % | % | % | % | % | % | % | % |
| | LOR | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| 205324 | | 1.01 | 0.02 | 0.86 | 0.18 | 0.19 | 0.03 | 0.05 | 2.57 | 98.5 |
| 205367 | | 0.08 | <0.01 | 0.08 | 0.01 | 0.10 | <0.01 | <0.01 | 0.30 | 97.6 |
| 205371 | | 0.18 | 0.01 | 0.16 | 0.01 | <0.01 | <0.01 | 0.02 | 0.00 | 95.0 |
| 205433 | | 0.06 | 0.01 | 0.18 | 0.01 | <0.01 | <0.01 | 0.01 | 0.00 | 96.5 |
| 205320 | | 4.85 | <0.01 | 0.99 | 0.12 | 0.64 | 0.11 | 0.25 | 0.59 | 98.2 |
| 205372 | | 0.65 | 0.05 | 2.35 | 0.13 | 0.25 | 0.08 | 0.08 | 3.53 | 98.1 |
| 204959 | | 0.02 | <0.01 | 0.01 | <0.01 | 0.06 | 0.01 | 0.01 | 43.1 | 100.0 |
| 205338 | | 0.23 | <0.01 | 0.06 | 0.63 | 0.01 | <0.01 | 0.13 | 1.20 | 96.6 |
| 205442 | | 0.24 | 0.01 | 0.99 | 0.16 | 0.11 | 0.05 | 0.02 | 2.64 | 98.4 |
| 205421 | | 1.34 | 0.02 | 0.94 | 0.20 | 0.24 | 0.02 | 0.10 | 3.78 | 98.4 |
| 205260 | | 0.08 | <0.01 | 0.02 | 0.01 | <0.01 | <0.01 | 0.03 | -0.10 | 96.6 |
| 205432 | | 0.15 | 0.01 | 0.17 | 0.01 | <0.01 | <0.01 | 0.01 | 0.40 | 98.0 |
| 205311 | | 0.30 | 0.02 | 1.64 | 0.19 | 0.14 | 0.03 | 0.02 | 2.10 | 98.9 |
| 205443 | | 0.06 | <0.01 | 0.01 | 0.01 | 0.01 | 0.03 | 0.02 | 43.0 | 100.5 |
| 205441 | | <0.01 | 0.37 | 0.01 | 0.08 | <0.01 | <0.01 | <0.01 | 13.30 | 97.1 |
| 205261 | | 0.17 | 0.01 | 0.04 | 0.01 | <0.01 | <0.01 | 0.02 | 0.10 | 95.9 |
| 204951 | | 0.05 | <0.01 | 0.01 | <0.01 | <0.01 | 0.02 | <0.01 | 43.4 | 100.5 |
| 205310 | | 0.01 | 0.01 | 0.17 | 0.02 | 0.07 | <0.01 | <0.01 | 0.40 | 97.3 |
| 205262 | | 0.46 | 0.02 | 0.70 | 0.14 | 0.08 | 0.04 | 0.05 | 2.18 | 98.8 |
| 204960 | | 0.45 | <0.01 | 2.42 | 0.21 | 0.18 | 0.05 | 0.16 | 1.39 | 98.1 |
| 204941 | | 0.08 | <0.01 | 0.14 | 0.01 | <0.01 | <0.01 | 0.01 | 0.70 | 97.7 |
| 204934 | | 0.80 | 0.01 | 0.32 | 0.03 | 0.02 | <0.01 | 0.04 | 1.69 | 96.0 |
| 204685 | | 0.02 | <0.01 | <0.01 | 0.01 | <0.01 | <0.01 | <0.01 | 0.70 | 95.5 |
| 205263 | | 2.82 | <0.01 | 0.56 | 0.12 | 0.21 | 0.08 | 0.16 | 1.79 | 96.7 |
| 204259 | | 3.39 | 0.01 | 0.61 | 0.01 | 0.55 | 0.01 | 0.09 | 5.27 | 98.3 |
| 205242 | | 0.63 | <0.01 | 0.11 | 0.01 | 0.02 | <0.01 | 0.02 | 1.20 | 101.0 |
| 205308 | | 0.26 | 0.03 | 1.95 | 0.20 | 0.17 | 0.03 | 0.15 | 3.37 | 96.7 |
| 205315 | | 2.50 | 0.02 | 0.64 | 0.01 | 0.17 | 0.01 | 0.02 | 2.87 | 86.7 |
| 205319 | | 3.95 | 0.03 | 1.09 | 0.16 | 0.34 | 0.03 | 0.15 | -0.10 | 97.0 |