ALASKA
DEPARTMENT of
TRANSPORTATION
and
PUBLIC FACILITIES

STATEWIDE MATERIAL SITE INVENTORY, SITE INSPECTIONS & GEOLOGICAL INVESTIGATIONS

HARD AGGREGATE SOURCE LOCATION STUDY

FEDERAL PROJECT NO. STP-000S(823)
AKSAS PROJECT NO. 76149

Prepared by:

R&M CONSULTANTS, INC.
9101 Vanguard Drive
Anchorage, Alaska 99507

STATE OF ALASKA DOT&PF

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May, 2013

NOTE TO READERS

This Hard Aggregate Source Location Study has been prepared to provide useful information to multiple groups of readers, including executive decision-makers, geologists, engineers and planners, and materials end-users. As such, it contains information that may be highly useful to one group, yet too detailed or too broad for the next. The following guidelines are intended to help each group of readers quickly find the information that will be most useful to them.

Executive decision-makers will perhaps be most interested in the Executive Summary, the Conclusions (Chapter 7.0), the appended source reports, and the attached plate. Based on available time and interest, this group of readers may also glean useful information from Chapters 1.0 through 3.0.

Geologists will find the entire study to be of use. Depending on what their immediate need or interest may be, this group of readers may choose to focus on a particular region or area of study, or on a particular hard aggregate source. Before focusing on a geographic area, however, the geologist reader will be well served by reading Chapters 1.0 through 3.0. This group of readers will also find Chapters 4.0 through 6.0 to be condensed treatments of a broad cross section of geological areas; as such, these latter chapters will provide useful reference material. This group of readers will be able to utilize this study as a starting point for prospecting and planning the development of hard aggregate sources.

Engineers and planners will likely wish to focus on the Executive Summary, Conclusions (Chapter 7.0), and the two attached Plates. For project-specific or area-specific interests, this group of readers will also find utility in the appended source reports. Prior to using the information herein, engineers and planners will wish to become familiar with Chapters 1.0 and 2.0, with at least a cursory review of Chapter 3.0.

Materials end-users will be most interested in the appended source reports. Next in importance for this group of readers will be the Executive Summary and Conclusions (Chapter 7.0), followed by Chapters 1.0 through 3.0.

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HARD AGGREGATE SOURCE LOCATION STUDY

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HARD AGGREGATE SOURCE LOCATION STUDY

EXECUTIVE SUMMARY

The Alaska Department of Transportation and Public Facilities (DOT&PF) recognizes that using hard aggregate in pavement products significantly lengthens the performance life of asphalt surfaces. However, the State of Alaska lacks developed sources for supplying hard aggregate, and has had to rely on importation of such materials. The objective of this study is to identify and profile alternative sources in Alaska that contain materials potentially suitable for hard aggregate production. The definition of Hard Aggregate for the purposes of this study is: aggregates meeting or exceeding the Nordic Abrasion Ball Mill Specification for Class II, i.e. Nordic Abrasion test value is less than or equal to 10.

Nordic Abrasion test results are unavailable for many existing or potential material sites in Alaska. Other test results may be available including: Los Angeles Abrasion, Degradation Value, Specific Gravity, Absorption, Unconfined Compressive Strength, and others. These data may be helpful in identifying potential hard aggregate sources, but their correlation to Nordic Abrasion Values are generally poor.

Rock type and characteristics can provide important information on potential suitability of a rock source for producing hard aggregate. Rock weathering, origin, type, grain-size, presence of foliation or mineral orientation, and alteration or degree of metamorphism all affect rock durability and should be considered when identifying potential sources. Research indicates that the best performing hard aggregates are typically fine-grained rock without any foliation or mineral orientation, and are typically igneous or metamorphic in origin. Some of these materials are hornfels, porphyritic basalt, metamorphosed volcanics, amphibolite and quartzite.

Three sites were found in Southcentral Alaska that meet the criteria for hard rock potential and access. Much of the rock in Southcentral Alaska consists of the Valdez and Orca Groups which are generally highly foliated and not suitable. Much of the rock that appears to have potential is in locations that are difficult to access, such as Prince William Sound and the Talkeetna Mountains. Land development has not had a great impact on areas with hard aggregate potential. However, land withdrawals, particularly in Prince William Sound, have had an impact. There are many gravel sources with Nordic Abrasion test results less than 10 in Southcentral Alaska (although the test results are generally not consistent). Only the three potential sites were identified; 2 igneous, 1 hornfels.

The Alaska Peninsula, the Aleutian Islands east of Unalaska, Kodiak Island and the Shumagin Islands have a low potential for producing hard aggregate. The geology of the region is dominated by volcanic, sedimentary, and foliated metamorphic rocks which are generally not likely to be suitable. However, there are some intrusive bodies with associated contact metamorphic aureoles which may have potential for suitable material. With the exception of Kodiak Island and Unalaska, there is little infrastructure in place to mine and transport aggregates, and without port facilities weather conditions can make loading and shipping difficult. Much of the Alaska Peninsula and Aleutian Islands are part of wildlife refuges, monuments, parks, wilderness areas, or other designated restricted development areas. Several of the most promising remaining areas, including Unalaska, Sand Point and Chignik, had previous investigations and additional studies were not prepared for them. The few remaining alternative areas did not have promising potential sources and thus no potential hard aggregate source reports were prepared for the Alaska Peninsula and Aleutian Islands or Kodiak Island.

There appear to be significant numbers of sites with the potential to produce hard aggregate in Southeast Alaska, with many of them having road access and relatively sheltered harbors. Many of the sources in southeast Alaska were within the Tongass National Forest and would require permission of the U.S. Forest Service to use. About half of the potential sources in Southeast Alaska are within parks, monuments, wilderness areas, roadless areas and dedicated recreational areas, and likely would not be attainable. Where ever they could be identified these special use areas were not included in the study. Even with these limitations 27 individual sites were identified, including: 12 hornfels sites, 11 basalt sites, 1 gabbro, 1 possible gabbro, 1 possible syenite, and 1 gravel site with several overlapping areas.

Table 7-1 of this report presents a summary of potential hard aggregate sources. The table includes name of site, highway milepost, site status, ownership, location coordinates, Nordic Abrasion values and also includes an overall characterization of this site. These sources are also depicted on Plate 1 and described in more detail within the individual appendices.

Additionally, a separate feasibility study was performed to evaluate hard aggregate development at a site near Cantwell. That study is presented in a separate project report (Part 2 of this document).

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HARD AGGREGATE SOURCE LOCATION STUDY

1.0 INTRODUCTION

1.1 Background

The Alaska Department of Transportation and Public Facilities (DOT&PF) recognizes that using hard aggregate in pavement products significantly lengthens the performance life of asphalt surfaces. However, the State of Alaska lacks developed sources for supplying hard aggregate, and has had to rely on importation of such materials.

The object of the study is to identify and profile alternative sources in Alaska that contain materials potentially suitable for hard aggregate production. The general definition of <u>Hard Aggregate</u> for the purposes of this study is: aggregates meeting or exceeding the Nordic Abrasion Ball Mill Specification for Class II, i.e. Nordic Abrasion test value is less than or equal to 10. The definition of alternative sources for the purpose of this study are sites not covered in the previous investigations listed in Table 1-1. Table 1-2 (Hard Aggregate Data Table) contains a non-comprehensive compilation of Nordic Abrasion data that was provided by DOT&PF.

TABLE 1 - 1
PREVIOUS DOT&PF HARD AGGREGATE PROJECTS

Investigation Date	Project/Reference	DOT&PF Personnel	Product
1998-2000	Draft, Studded Tire Wear Resistant Aggregate Study, Final Report	Pavey and Johnson, May 2000	Final Report
2003	Statewide Aggregate Source Investigation	Fritz and Lewis	Draft Report and Pavement Summit Presentation
2004-2005	Material Site Reconnaissance Report – Denali Highway MP 110	Boeckman, Jan 2005	Final Report
May 2012	[Hard aggregate data integration]	Pavey, Finkbiner, Bingham	Web interface: http://10.200.100.100/hardaggregatestudy/ See Table 1-2
Aug 2012 - Current	Cantwell Hard Aggregate Development Feasibility Study	Wright, Saboundjian	Existing Task 7 of AKSAS 79434

TABLE 1 - 2
HARD AGGREGATE DATA TABLE
(From DOT&PF database http://10.200.100.100/hardaggregatestudy/)

Site ID	Site Description	Nordic Min.	Nordic Max.	Lat. (NAD83)	Lon. (NAD83)
INTERIOR/NORTHERN ALASKA					
36	Denali Highway	**6.5**	**8.1**	63.320909	-148.234264
47	MP 110 Denali Highway	**8.1**	19	63.299565	-148.139528
53	Brown's Hill	15	15	64.830704	-147.474224
56	Shaw Creek Quarry	**8**	17.9	64.285378	-146.130323
84	MP 261 Dalton Hwy	**6.8**	**6.8**	68.318205	-149.348318
85	MS 65-9-021-2 Atigun	12.5	12.5	68.31548	-149.344318
87	Nenana River	**9.5**	**9.5**	64.567336	-149.100531
102	MP 24 Denali Highway	**9.7**	**9.7**	63.068893	-146.101916
103	MP 20.5 Denali Highway	10.5	10.5	63.048127	-145.99745
109	Flag Hill, Fairbanks	**9.6**	**9.6**	64.409736	-146.960259
SOUTHCENTRAL ALASKA					
1	Skookum Pit MP 5.2 Old Glenn Hwy	**7.1**	22.5	61.37775	-149.493863
2	AAA Valley Gravel, Trunk Road	11.9	15.3	61.59047	-149.256618
3	Cange-Pittman	**9.3**	11.7	61.583028	-149.602339
4	N. Birchwood on Old Glenn Hwy	**7.4**	13.4	61.392136	-149.464042
5	Birchwood Pit	12.1	12.7	61.412783	-149.499325
6	42 Mile Pit Seward Hwy	17.5	18.7	60.589756	-149.549586
8	Ridgeway Pit, Soldotna	10.4	14	60.504563	-151.074751
9	Breeden Pit K-Beach Rd, Soldotna	11.4	12.5	60.505115	-151.1432
11	New K-Beach Pit, Soldotna	13.2	13.2	60.510436	-151.140794
12	Premier Pit, MP 10.4 Old Glenn Hwy	**9.3**	**9.3**	61.528236	-148.985341
13	MS 584-001-1 MP 6.3, Petersville Road	16	16	62.310612	-150.425766
14	Frontier Pit, Soldotna	12.3	12.8	60.500691	-151.070231
19	Lucas Pit, Palmer	15.3	42	61.594006	-149.13019
21	MP 101.5 Seward Hwy	13.5	18.9	60.974901	-149.471681
22	Dyno Nobel Pit, MP 8.1 Parks Hwy	11.9	11.9	61.856783	-150.07827
23	Spencer Pit	11.3	16.6	60.712704	-149.085201

Site ID	Site Description	Nordic Min.	Nordic Max.	Lat. (NAD83)	Lon. (NAD83)
SOUTHCENTRAL ALASKA (CONT.)					
28	Palmer	11.5	11.5	61.558785	-149.174042
31	MP 217 Parks Hwy	**6.2**	10.9	63.467533	-148.801696
32	Anchorage	**8.1**	22.1	61.56914	-149.168922
34	Eklutna	15.4	56.1	61.473461	-149.259882
42	MP 19.7 Hatcher Pass	13	13	61.772828	-149.293447
43	MP 22.8 Hatcher Pass	13.2	13.2	61.772985	-149.292793
45	Hicks Ck Matanuska R	26.9	26.9	61.789191	-147.936915
46	MP 60 Seward Hwy	11.2	11.2	60.7514	-149.38113
48	0.3 Exit Glacier Rd, Seward	14.5	16.9	60.153213	-149.439412
49	4th of July Ck., Seward	**8.5**	12.6	60.096505	-149.363575
51	Best Pit, MP 18.6 K Beach Rd	24.6	24.6	60.494816	-151.155233
64	Railroad Quarry, Eklutna	10.3	15.4	61.464275	-149.357482
65	Dan's Cove Quarry	26.4	26.4	59.450601	-151.707205
71	Wolf Pit, Hyer Rd, Wasilla	10.2	10.2	61.572389	-149.29557
72	MP 75.5 Glenn Hwy	**9.8**	11.4	61.774789	-148.503693
76	MP 66.2 Glenn Hwy	14.7	14.7	61.737767	-148.756073
88	MS 576-015-1 Old Glenn by Knik River Bridge	10.2	10.2	61.499556	-149.032174
98	MP 37 Parks Hwy	**6.3**	**9.6**	61.56967	-149.301984
108	Eklutna	12	12.2	61.45558	-149.371739
SOUTHWEST ALASKA					
10	Tununak	20.7	30	60.585249	-165.23494
15	Dome Quarry, Sand Point	14.4	14.4	55.3278	-160.502241
16	Knoll Quarry, Sand Point	19.1	19.1	55.326519	-160.498517
39	Ruth Shaisnikof Pit, Unalaska	**5.9**	**5.9**	53.826124	-166.609109
58	Castle Bay Quarry	24	24	56.203422	-158.349887
59	MP 1 Williamsport to Pile Bay	17	17	59.699429	-153.599434
63	Captains Bay Quarry, MP 4.0, Unalaska	**8.1**	**8.1**	53.835254	-166.58468
78	Manokotak Loop Rd Quarry	**9.1**	**9.1**	58.926629	-158.768576
86	MP 5 N. Camp Rd, King Salmon	16	16	58.665357	-156.543176

Site ID	Site Description	Nordic Min.	Nordic Max.	Lat. (NAD83)	Lon. (NAD83)
SOUTHWEST ALASKA (CONT.)					
92	Red Mountain Quarry, Platinum, AK	10.5	24.4	58.957351	-161.746147
96	Stebbins Pit, Stebbins	11.9	11.9	63.535954	-162.290341
100	Red Cove Quarry, Sand Point	12.8	12.8	55.326457	-160.426161
106	Margaret Bay Quarry	11.3	11.3	53.884055	-166.556419
107	Ugadaga Quarry	**10**	**10**	53.849825	-166.495249
KODIAK ISLAND					
7	Bells Flats #2 Kodiak	**9.3**	32.6	57.697655	-152.587538
17	Pasagshak Pit MP 9	19.7	19.7	57.453885	-152.447535
55	Shakmanof Bay, Kodiak	12.7	12.7	57.91243	-152.60141
90	MP 30.5 Chiniak Hwy, Kodiak	**8.4**	20.9	57.581908	-152.461077
SOUTHEAST ALASKA					
33	Lena Point Quarry	10.7	28.4	58.391127	-134.770282
38	Gas at Last Pit, Ketchikan	27.8	27.8	55.370122	-131.697651
62	Coffman Cove - Rock Ex	**9**	12.3	55.976533	-132.807419
74	Haines 4 Mile Quarry	**9.6**	**9.6**	59.248258	-135.535266
75	Kake City Pit	12.6	12.6	56.96475	-133.924854
OUTSIDE ALASKA					
18	DuPont, Washington	**6.1**	19	49.878421	-127.401103
60	Jervis Inlet, B.C., Canada	**6.9**	**9.9**	51.406161	-126.822637

Note: Bold results indicate Nordic Abrasion results that meet the “hard aggregate” definition.

1.2 Scope-of-Work

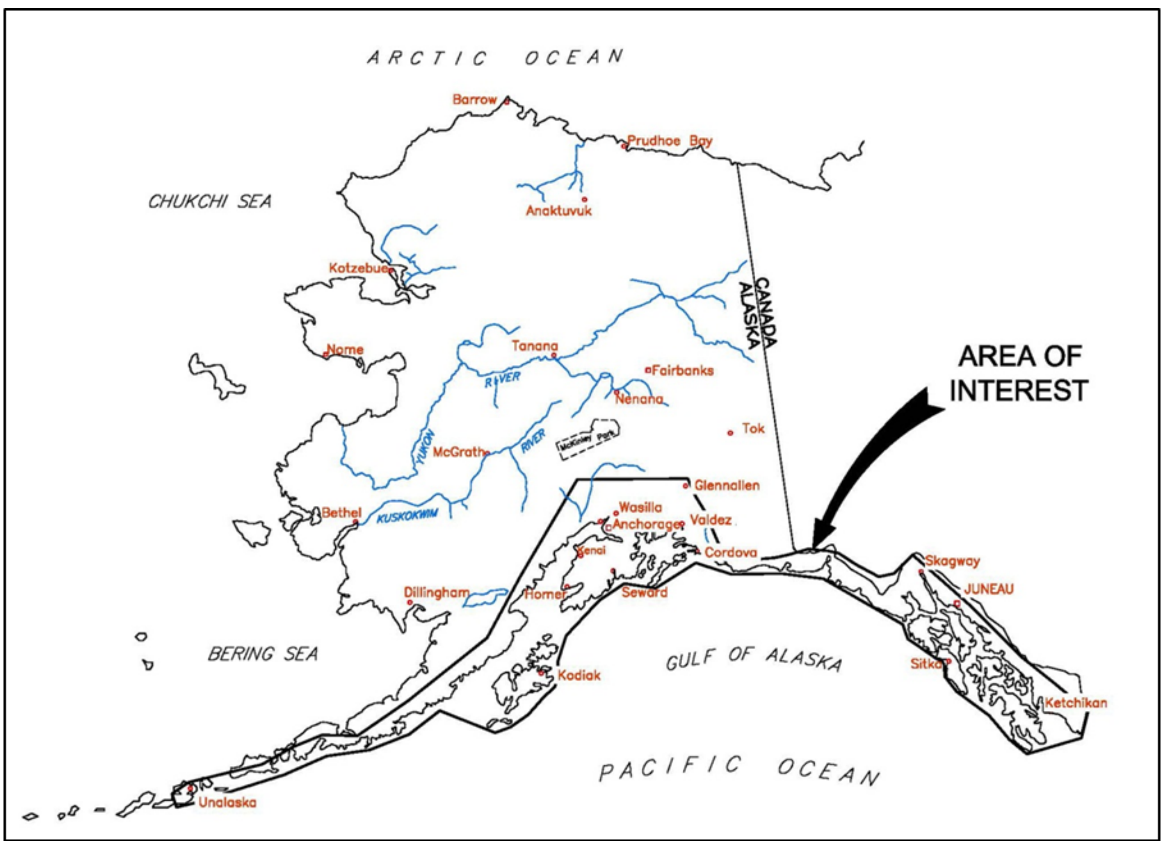
The basic approach to this study relies on geologic interpretation. R&M used collected expertise and available resources to identify prospects for development of hard aggregate sources.

Sites to be identified and profiled had to meet the following criteria:

- Located within the Southcentral Alaska area and accessible by road or railroad.
- Located within the following geographic areas accessible by water:
    - Aleutian Islands (east of Unalaska) and Alaska Peninsula
    - Kodiak Island
    - Prince William Sound
    - Southeast Alaska
- Situated within reasonable proximity to existing or planned roadways, railways or ports.
- Contains materials with demonstrated or anticipated test data that reflect Nordic Abrasion test values less than or equal to 10.

Figure 1-1 shows the area of interest for this study.

FIGURE 1 - 1
PROJECT MAP



1.3 Assumptions

The following assumptions were made during this study.

1. Land ownership was determined based on readily available, web-based public records and did not involve case file searches or formal title searches.
2. In Southcentral Alaska, sites north of Byers Lake on the Parks Highway were not considered, as highway haul would likely be too expensive to utilize them. Likewise sites north of Glennallen on the Richardson Highway, the Denali Highway and Tok Cutoff were also not considered for the same reason. The Hard Aggregate Site at Cantwell was studied in detail previously and was thus omitted from this study.
3. We avoided Wrangell- St. Elias National Park and Preserve, Glacier Bay National Park and Preserve, Admiralty Island National Monument, Misty Fiords National Monument, Kenai Fiords National Park, Lake Clark National Park and Preserve, Katmai National Park and Preserve, and Aniakchak National Monument and Preserve. We also avoided the wildlife refuges, wilderness areas and roadless areas within National Forests.

1.4 Contract Authorization

This study was conducted as part of Professional Services Agreement No. 02572001, Statewide Material Site Inventory, Site Inspections & Geological Investigations, between DOT&PF and R&M Consultants, Inc. (R&M). Work was performed under Amendment No 11, NTP No.12 and consists of Subtasks D and E of Task 7 of the agreement.

2.0 AGGREGATE / ROCK TESTING

Hard Aggregate is the coarse fraction (retained on the No. 4 sieve) of aggregate intended for asphalt concrete pavement; as mentioned previously, it should have a Nordic Abrasion value of 10 or less. Ideally any potential source would be identified based on Nordic Abrasion test results. However, Nordic Abrasion tests have only been performed on a limited number of material sources in Alaska. Most potential sources will not have available Nordic Abrasion results, so the potential for producing hard aggregate will need to be determined by other means. This section will discuss how other tests and rock properties may be used for predicting Nordic Abrasion values. Table 2-1 summarizes specific laboratory testing which may be available and its reliability for predicting Nordic Abrasion value.

TABLE 2 - 1
RELIABILITY OF SELECTED TESTS FOR PREDICTION OF NORDIC ABRASION VALUE

Test	Reliability for Predicting Nordic Abrasion Value
LA Abrasion (ASTM C 131)	Moderate
Degradation (ATM 313)	Low to Moderate
Specific Gravity and Absorption (ASTM C 128)	Low
Unconfined Compressive Strength (ASTM D 7012)	Good

2.1 Los Angeles Abrasion (ASTM C 131)

The Los Angeles Abrasion test (ASTM C 131) has been widely used to determine aggregate quality, but the results do not necessarily permit reliable comparisons to be made between different rock units. Therefore, Los Angeles Abrasion test loss specification limits should be assigned with consideration of source performance history, which may not be available for new sources. Where a positive correlation between Nordic Abrasion and Los Angeles Abrasion testing loss values has been established for a particular rock unit, the Los Angeles Abrasion test can be a strong indicator of suitable hard aggregate sources. Where this correlation has not been established, the Los Angeles Abrasion test should only be used as an indicator of potential hardness, and not associated directly with suitability for hard aggregate production. The compiled Los Angeles and Nordic Abrasion values for various rock types are illustrated on Figure 3-1 in Section 3.

2.2 Degradation Value of Aggregates (ATM 313)

The degradation value of aggregate test (ATM 313) was developed to determine the durability of an aggregate to resist degrading to detrimental clay-like fines when subjected to a prescribed Abrasion process in the presence of distilled or demineralized water. Materials that maintain high Degradation values will probably be more suitable for use as hard aggregates than those with low Degradation value, but the Degradation test is not specifically measuring hardness, only durability of a material to resist degradation to fine silt and clay particles. The problem with associating this test with hardness is that certain materials may readily break down into particles finer than the desired aggregate but not fine enough to produce poor Degradation results (fine sand size particles for example). As such, the Degradation value should only be used as a general indicator of hardness, and not associated directly with rock hardness.

2.3 Specific Gravity and Absorption (ASTM C 128)

The Specific Gravity and Absorption tests (ASTM C 128) are used to determine the density of the solid portion of an aggregate sample and potential of the aggregate to absorb and maintain water within pore spaces. The results of these tests provide an average value representing the Specific Gravity and Absorption for a given aggregate sample. Higher values for Specific Gravity and lower values for Absorption will tend to correlate with harder aggregates. However, Specific Gravity and Absorption tests do not address rock durability, and some rock units with attractive Specific Gravity and Absorption qualities have very low durability, and thus, hardness. Therefore, the results of Specific Gravity and Absorption testing are considered a poor indicator of aggregate hardness.

2.4 Unconfined Compressive Strength (ASTM D 7012)

Unconfined compressive strength testing can be useful in screening sites quickly and economically for their potential for producing hard aggregate. Many of the physical properties that result in high strength are also expected to result in low Nordic Abrasion values. Table 2-2 summarizes the classification of rock strengths. Rock in the very to extremely strong range would be expected to be a good candidate for a source of hard aggregate.

TABLE 2 - 2
CLASSIFICATION OF ROCK MATERIALS STRENGTHS (ISRM, 1977)

ISRM Grade	Field Identification	Hardness	Description	Approximate Range of Compressive Strength (p.s.i.)
R6	Specimen can only be chipped with geological hammer	Very hard	Extremely strong rock	>36,000
R5	Specimen requires many blows of geological hammer to fracture it		Very strong rock	15,000-36,000
R4	Specimen requires more than one blow with a geological hammer to fracture it	Hard	Strong rock	7,000-15,000
R3	Cannot be scraped with a pocket knife; specimen fractured with single blow of geological hammer	Moderately hard	Medium weak rock	3,500-7,000
R2	Can be peeled with a pocket knife; shallow indentations made by firm blow with point of geologic hammer	Medium	Weak rock	725-3,500
R1	Crumbles under firm blows with point of geological hammer; can be peeled with pocket knife	Soft	Very weak rock	150-725
R0	Can be indented by thumbnail	Very soft	Extremely weak rock	35-150

2.5 Selected References

Alaska Department of Transportation and Public Facilities (DOT&PF), 2012, Alaska Test Methods Manual.

American Society of Testing and Materials (ASTM), 2012, Annual Book of ASTM Standards, Vol. 04.02, Concrete and Aggregates.

American Society of Testing and Materials (ASTM), 2012, Annual Book of ASTM Standards, Vol. 04.02, Concrete and Aggregates.

3.0 GEOLOGY OF HARD AGGREGATES

Locating potential hard aggregate sources requires finding rock with the appropriate characteristics. These various characteristic are outlined below.

3.1 General

Rock type and characteristics can provide important information on potential suitability of a rock source for producing a durable (hard) aggregate. Rock weathering, origin, type, grain-size, presence of foliation or mineral orientation, and alteration or degree of metamorphism all affect rock durability and should be considered when identifying potential sources.

Research in the Nordic countries indicates that the best preforming hard aggregates are typically fine-grained without any foliation or mineral orientation. Their work also indicates that the most durable aggregates are “older” and of metamorphic origin. Some of these materials are hornfels, porphyritic basalt, metamorphosed volcanics, amphibolite and quartzite. Contact metamorphism (metamorphism produced when hot magma comes in contact with country or host rock) is responsible for many of these high quality aggregates (Johnson and Pavey, 2000).

3.2 Weathering

Weathering is one of the more important criteria for eliminating or accepting rock units for consideration of potential for hard aggregate sources. Rock formations that weather readily or extensively will not make good sources. Many of the older rocks in Alaska have been extensively weathered in areas without recent glaciation. These rocks generally lie within Alaska’s interior, north of the Alaska Range and outside of this study area. Conversely, many of the very young rocks are poorly consolidated and weather very rapidly. These include the Kenai and Tyonek Formations surrounding Cook Inlet, the Nenana Gravels in the Alaska Range and the Chickaloon Formation in the Matanuska Valley, to name a few.

The degree of weathering on a particular rock unit affects the rock hardness and can vary widely. A rock that may be hard in its fresh state may be prone to weathering and particularly weakened by the weathering. However, rocks that are good sources for hard aggregates tend to resist weathering compared to softer rock units. Therefore, rock masses that classify as anything more than slightly weathered would typically not be a good source for hard aggregate. Table 3-1 provides a description of the various grades of rock weathering.

Weathering action varies regionally across the state. Surficial rock units in interior and northern Alaska are exposed to much colder temperatures than southern portions of the state, therefore the effects of frost penetration intrude deeper within the rock. However, surficial rocks in maritime climates are typically exposed to harsher freeze-thaw conditions and chemical environments which enhance rock weathering. The fracture state of a particular rock unit also has a large effect on rock weathering. Highly fractured or jointed rock will enhance the effects and depth of weathering. Weathering also tends to vary widely across a rock unit. Additional removal of undesirable overburden and rock may be required at one site over another as an effect of different weathering regimes.

As weathering can vary widely across a site, samples must be selected with care to ensure the test rock is representative of the source rock, not showing a varying degree of weathering. To the extent possible, samples should be broken from the fresh rock face of a source or taken from a portion of the deposit, talus slope, stock pile, etc. showing representative weathering characteristics. Weathering and alteration grades of rock are shown in Table 3-1.

TABLE 3 - 1
WEATHERING AND ALTERATION GRADES (ISRM, 1977)

Grade	Term	Description	Hard Aggregate Production
I	Fresh	No visible sign of rock material weathering; perhaps slight discoloration on major discontinuity surfaces	Possible, Depends on rock hardness characteristics
II	Slightly weathered	Discoloration indicates weathering of rock material and discontinuity surfaces. All the rock material may be discolored by weathering and may be somewhat weaker externally than in its fresh condition	Possible, Depends on rock hardness characteristics
III	Moderately weathered	Less than half the rock material is decomposed and/or disintegrated to a soil. Fresh or discolored rock is present either as a continuous framework or as corestones	Not suitable
IV	Highly weathered	More than half the rock material is decomposed and/or disintegrated to a soil. Fresh or discolored rock is present as a discontinuous framework or as corestones	Not suitable
V	Completely weathered	All rock material is decomposed and/or disintegrated to soil. The original mass structure is still largely intact	Not suitable
VI	Residual Soil	All rock material is converted to soil. The mass structure and material fabric are destroyed. There is a large change in volume, but the soil has not been significantly transported	Not suitable

3.3 Origin and Type of Rock

Figure 3-1 shows compiled Los Angeles and Nordic Abrasion values by rock type in Norway. The geologic history in Norway is different than Alaska's, and rocks have been subject to different depositional histories and tectonic forces in the two locations. Mylonite is one example of this. Apparently in Norway mylonite is a hard fine-grained rock that would make suitable hard aggregate, whereas in Alaska it typically has been subjected to more shearing forces and has not consolidated to the extent it has in Norway. There are some rock types found in Norway that are uncommon in Alaska such as norite (found in association with gabbro on Chichagof and Admiralty Islands) and some differences in local nomenclature are also evident.

Table 3-2 presents a comparison of typical rock types and the potential for hard aggregate production in Alaska.

FIGURE 3 - 1
COMPILATION OF TEST RESULTS FOR HARD ROCK AGGREGATES IN NORWAY
(From Erichsen et al., 2008)

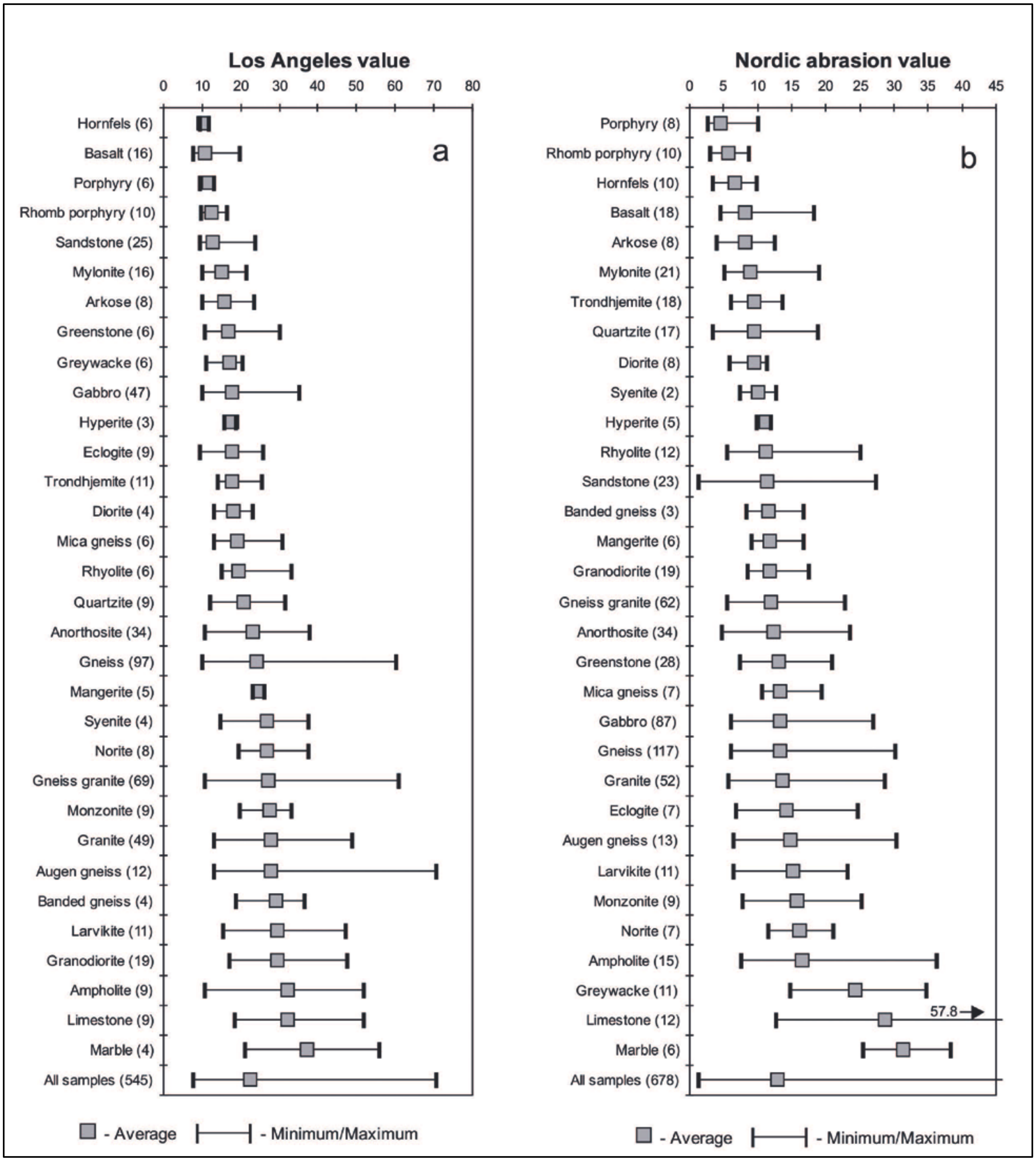


TABLE 3 - 2
TYPICAL ROCK TYPES AND POTENTIAL FOR HARD AGGREGATE DEVELOPMENT IN ALASKA
(Nordic Abrasion Value 10 or less)

Rock Origin	Typical Rock Types	Hard Aggregate Potential	Occurrence (In Study Area)
SEDIMENTARY	Conglomerate	Low to High	Common
	Sandstone	Low	Common
	Siltstone	None	Common
	Argillite	None to Low	Common
	Shale	None	Common
	Limestone	None	Common
IGNEOUS (fine-grained*)	Granite	Moderate	Less Common**
	Trondhjemite	Moderate	Less Common**
	Syenite	Moderate	Less Common**
	Monzonite	Moderate	Less Common**
	Granodiorite	Moderate	Less Common**
	Tonalite	Moderate	Less Common**
	Diorite	Moderate to High	Less Common**
	Gabbro	Moderate to High	Less Common**
	Ultramafics	Moderate to High	Less Common**
	Basalt/Andesite	High	Common
METAMORPHIC	Hornfels	Moderate to High	Common
	Greenstone	Moderate to High	Common
	Gneiss	Low to Moderate	Common
	Schist	None	Common
	Phyllite	None	Common
	Slate	None	Common
	Quartzite	Moderate to High	Common
	Marble	None	Common
	Mylonite	None to Moderate	Common
UNCONSOLIDATED MATERIALS	Gravel	Low to High	Common
	Sand	None	Common

* Medium and coarse-grained igneous rocks have low hard aggregate potential, but are more common.
** Fine-grained rock only

3.3.1 Sedimentary Rocks

For the most part sedimentary rocks are too weakly cemented to be useable. Typically, only where they are cemented by silica do they have the strength necessary to resist fracturing by tire studs. The conglomerates and sandstones found along the Dalton Highway in the Atigun Valley (Brosge et al, 1979) are a good example of this type of material (Dalton Highway Mile 261 - Nordic Abrasion value 6.8). Other sandstones are cemented with calcite and have higher Nordic Abrasion values in the plus 10 range, such as Mile Post 60 on the Seward Highway (11.2), or are subject to minor cataclastic deformation (shearing). This shearing forms weak foliation not visible to the eye which apparently can cause Nordic Abrasion values to reach into the high teens or higher as seen along the Seward Highway (Pavey et al., 2012).

3.3.2 Igneous and Volcanic Rocks

For igneous and volcanic rocks, material quality is essentially a function of grain size, mineralogy, weathering and the presence or lack of foliation. Most of the granitic rocks are medium to coarse-grained and generally have Nordic Abrasion values in the teens or low twenties when fresh or slightly weathered. Many of the igneous rocks, particularly in southeast Alaska, are foliated and are thus unsuitable for that reason. The best igneous rocks located in Alaska to date are fine-grained basalts and andesites found in large volcanic flows in the Alaska Range and in southeast and southwest Alaska. Other igneous rocks that have potential are fine-grained diorites and gabbro intrusives, although they appear to be more limited in extent and occurrence. All of these fine-grained igneous rocks can produce consistently low Nordic Abrasion values and can make excellent sources of hard aggregates.

Minerals within igneous rocks that produce low Nordic Abrasion values are generally hard. The most abundant rock in the deep ocean crust and often found in continental crusts is the intrusive gabbro, primarily composed of plagioclase feldspar, clinopyroxine augite and minor olivine. Feldspar, augite and olivine have Mohs hardnesses of 5, 5.5 to 6 and 6.5 to 7, respectfully, making all the minerals fairly hard overall. Basalt, the extrusive equivalent of gabbro, is just as suitable as an aggregate source, if not better because of the fine aphanitic nature of the minerals within the rock. The less mafic intrusive diorite and its equivalent extrusive andesite are typically found in continental areas. These rocks are less iron-rich with amphibole minerals often appearing at the expense of olivine. Hornblende, a typical amphibole mineral, has a Mohs harness of 5 to 6, a bit softer than olivine. Hence these less mafic rocks may produce slightly lower Nordic Abrasion values.

3.3.3 Metamorphic Rocks

Most metamorphic rocks in Alaska have developed foliation (cleavage or schistosity) as a result of deformation and will typically produce Nordic Abrasion values in excess of 10. This is particularly true of southern Alaska where terranes have accreted to each other and transform faulting has causing extensive shearing and deformation creating foliation which weakens the rock structure. In southcentral Alaska, this includes the Valdez and Orca Formations which underlie much of the Kenai Mountains and Prince William Sound, and the Kodiak Formation on Kodiak Island. In southeast Alaska, many of the older sedimentary and volcanic rocks have been metamorphosed to phyllite and schist. Exceptions to this process include quartzite, which in Alaska is typically associated with the schists and gneisses of interior Alaska. A discussion of various metamorphic rocks is presented in the following sections.

3.3.3.1 Hornfels

One of the most common types of hard rock in Alaska is hornfels. These are rocks that are formed by contact metamorphism when an igneous rock intrudes into country rock. A contract aureole is formed consisting of fine-grained to aphanitic unoriented mineral grains. Typically hornfels is more developed and harder near the edge of an igneous body, and the rock strength can drop off quickly as one moves away from the edge of the igneous rock. The aureoles are often mapped up to four miles from the igneous bodies, but hard rock capable of providing hard aggregate may only occur within thousands of feet or even hundreds of feet from the igneous bodies.

In contrast to schists and gneisses, hornfelses show little or no foliation or layering. They form under conditions of approximately anisotropic (directionless) stress, so there is no tendency for the crystals to align in any particular direction. Traces of bedding may remain in a hornfels due to chemical differences in the parent (country) rock but is not caused by contact metamorphism.

Hornfelses are defined by the process of origin (contact metamorphism), not by composition, so one must establish that a rock has originated in a contact aureole to classify it as a hornfels. Although hornfelses may be chemically altered by the magma that metamorphoses them, they generally reflect the chemical composition of their parent rocks. A parent rock most suitable for recrystallization into a hornfels will be a sedimentary rock with a wide range of chemical components, such as a mudstone, shale or slate. These rocks are chemically stable at or near the earth's surface with minerals that have incorporated water in their crystalline makeup. In the presence of intense heat of contact metamorphism the water component is driven off, and hard compact minerals more stable in the new environment are formed. Little hornfelsing occurs when a magma body intrudes a preexisting igneous rock, since the environment of formation for the country rock is similar to the one created by the new intrusive. The minerals stable in hornfelses include feldspar, biotite, muscovite, and pyroxenes. Typically quartz, andalusite, garnet, and cordierite are also present, and these minerals are very hard, all having a Mohs hardness ranging between 6.5 and 7.5. Rocks with simple chemical compositions such as a pure limestone or a clean quartz sandstone change little with thermal metamorphism. The limestone turns into marble and the sandstone to a quartzite, a process largely involving recrystallization into larger mineral grains.

The nature and quality of hornfels for hard aggregate use may vary considerably within a deposit. The presence of soft calcareous zones within a rock may make the hornfels unsuitable. Later regional metamorphism may have imprinted schistosity on the hornfels, or the rock may have developed joint patterns or have been subjected to shearing or crushing by tectonic forces making the hornfels unsuitable.

Problems with pyritic rock were encountered in the construction of a two lane road (FS 3030) near Sweetwater Lake at Coffman Cove. Pyrite in the rock used for fill created an acidic solution that dissolved metals from the rock which contaminated ground and surface waters. Approximately 100,000 cubic yards of road embankment was removed and replaced with limestone to neutralize the acid. Along with the intrusives, and metamorphic rocks in Alaska, many of the hornfels may have mineralized zones associated with them. Therefore, testing for potential acid rock drainage should be conducted at all quarries in which mineralization is apparent.

Contact aureoles are found surrounding many of the igneous intrusives in Alaska and may be potential sources of hard aggregates. During this location study they were located along the Aleutian Peninsula from Lake Iliamna to Unalaska, and in southeast Alaska where over 20 were identified. Hornfels sources have also been noted along the Denali Highway in previous studies. Reports for several of these potential hornfels sources are included in this study, including Copper River Highway, Kruzof Island, Wrangel Island, Kuiu Island, Zarembo Island, Etolin Island, Revillagigedo Island and three sources on Prince of Wales Island.

3.3.3.2 Quartzite and Gneiss

Quartzite is typically associated with the schists and gneisses developed in areas of regional metamorphism within interior Alaska. Quartz is one of the most abundant minerals in continental rocks with a hardness of 7 on the Mohs hardness scale. A sandstone of mostly pure quartz will transition by metamorphism to a quartzite when the rock fractures through the original quartz grains rather than along the original grain boundaries. While the Quartzite may provide a source of hard aggregate, it often occurs interbedded with soft weathered schist and would likely be useable only where found in thicker beds. Shaw Creek Quarry is apparently an example of this type of situation. Nordic Abrasion values range from 8 (quartzite?) to 17.9 (schist?) (Pavey et al., 2012). Quartzite can also grade into siliceous gneisses that can be equally as hard.

3.3.3.3 Greenstone

Greenstone is a term generally applied to mafic, mostly extrusive igneous rocks that have been modified by regional metamorphism, and frequently as well by hydrothermal alteration. The parent rock is generally interpreted to come from ancient oceanic spreading centers and island arc terranes. Through plate tectonics these rocks are frequently accreted to continental crusts. The mafic minerals pyroxene and olivine typically found in these rocks become altered to greenish chlorite, actinolite and other amphibole minerals. In the process the rock loses the distinct grain boundaries of its former parent minerals, and a tough new fibrous mass of much smaller minerals forms, often very resistant to erosion.

3.3.4 Unconsolidated Material

One other often overlooked source of hard aggregate is unconsolidated material. The material from DuPont Washington, which has reported Nordic Abrasion values as low as 6.1, is from a glaciofluvial gravel source. The first consideration is that the gravel must be coarse enough to meet the specification. Sand or gravelly sand is not acceptable. The second is that the gravel must meet the Nordic Abrasion value. Several pits in Alaska have recorded Nordic Abrasion values at 10 or less. This may be because there is significant hard rock in the source area of the gravel and the river/outwash has eroded and removed much of the weaker rock. Certain grain sizes may need to be screened out to achieve lower Nordic Abrasion values at otherwise promising sites containing unconsolidated material.

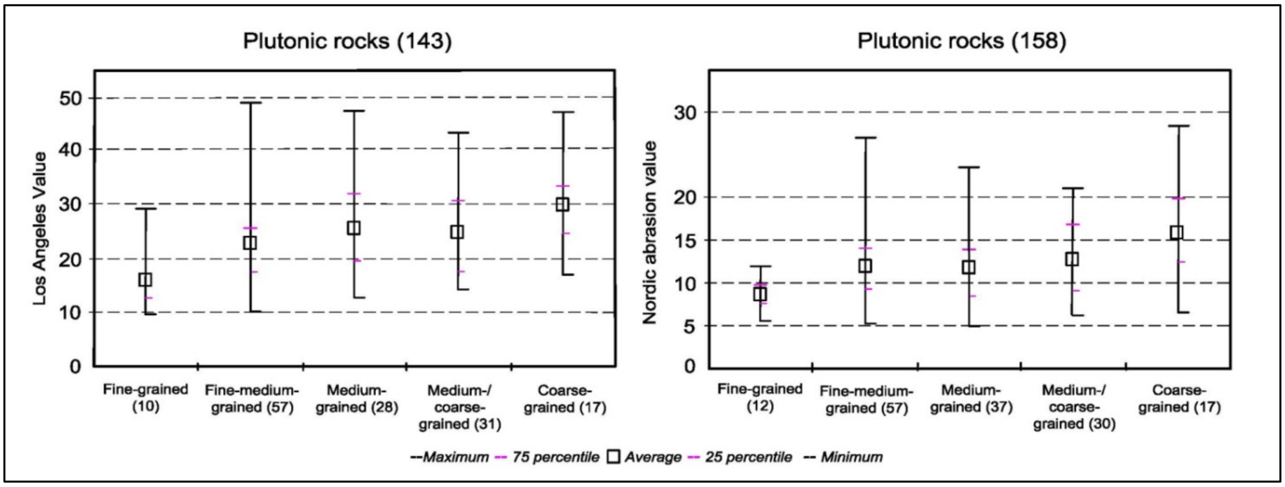
3.4 Porosity, Grain-Size, and Grain Shape

Table 3-3 presents the typical unconfined compressive, tensile, and shear strengths for a variety of rock types. From this table, it can be seen that each rock type can exhibit considerable variation. These variations are the result of a number of factors, which include porosity, grain size, grain shape, grain and crystallographic preferred orientation, mineralogy, and moisture content. In most rocks the main factors controlling rock hardness are porosity, grain size, and grain shape. All three of these factors affect the surface area of the interlocking bond forces at mineral grain to grain contacts. In most rocks, the higher the surface area of mineral grain to grain contact, the harder the rock becomes, for example:

1. Decreasing porosity in rock increases the surface area of grain contacts.
2. Decreasing the size of mineral grains in the rock increases surface area of grain contacts.
3. The surface area of equant or irregular grains is greater than that of angular grains.

Sedimentary rocks generally have high porosity, a reflection of the processes of their formation and the nature of the cementing agent. As a result they are generally low in rock hardness and their grains are less tightly held together. Fine-grained and lower porosity igneous rocks, such as basalt and diabase (dolerite) are generally higher in rock hardness than coarser-grained igneous rocks, such as granite, diorite, and gabbro. As a result, the mineral grains of fine-grained igneous rocks are more tightly held together than in coarse-grained igneous rocks. In metamorphic rocks, where strong foliations have developed, rock hardness is generally lower due to the preferred orientation of mineral grains and the structural weaknesses these impose. However, in low-grade metamorphism where foliation does not develop, but the rock becomes more indurated (i.e. more compacted and lower porosity), rock hardness increases. This is the case for slate, which is the indurated metamorphic form of the sedimentary rock shale. Grain-size has been identified as being one of the most important characteristics of a rock in identifying whether or not it will be suitable for hard aggregate.

FIGURE 3 - 2
LOS ANGELES AND NORDIC ABRASION VALUES
FOR DIFFERENT GRAIN SIZES OF PLUTONIC ROCK IN NORWAY
(From Erichsen et al., 2008)



(Nos. in parentheses are number of tests)

TABLE 3 - 3
TYPICAL ROCK PARAMETERS
(From Attewell and Farmer, 1976)

Typical Rock Types	Compressive Strength (PSI)	Tensile Strength (PSI)	Shear Strength (PSI)	Bulk Density (PCF)	Porosity %
Granite	15,000-36,000	1,000-3,600	2,000-7,000	162-180	0.5-1.5
Diorite	20,000-44,000	2,000-4,500	NA	NA	NA
Diabase	15,000-50,000	2,000-5,000	3,600-9,000	168-190	0.1-0.5
Gabbro	20,000-44,000	2,000-4,500	NA	175-193	0.1-0.2
Basalt	15,000-44,000	1,500-4,500	3,000-9,000	175-180	0.1-1.0
Gneiss	7,000-30,000	700-3,000	NA	175-187	0.5-1.5
Marble	15,000-36,000	1,000-3,000	NA	162-168	0.5-2
Slate	15,000-30,000	1,000-3,000	2,000-4,500	162-168	0.1-0.5
Quartzite	20,000-44,000	1,500-4,500	3,000-9,000	162-168	0.1-0.5
Sandstone	3,000-25,000	600-3,600	1,000-6,000	125-162	5-25
Shale	700-15,000	300-1,500	450-4,500	125-150	10-30
Limestone	4,000-36,000	700-3,600	1,500-7,000	137-162	5-20
Dolomite	4,000-36,000	2,000-3,600	NA	137-162	1-5

3.5 Selected References

Attewell, P.B., Farmer, I. W., 1976, Principles of engineering geology, Chapman and Hall, 1045 p.

Brosge, W.P., Reiser, H.N., Dutro, J.T., Jr., and Detterman, R.L., 1979, Bedrock geologic map of the Philip Smith Mountains quadrangle, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map 879-B, 2 sheets, scale 1:250,000.

Erichsen, E., Ulvik, A, Wolden, K., Neeb, P-R., 2008, Aggregates in Norway – Properties defining the quality of sand, gravel and hard rock for use as aggregate for building purposes, Geological Survey of Norway, In Stagstad, T.(ed.) Geology for Society of Geological Survey of Norway Special Publication, 11, pp 37-46.

Morian, D.A, Anderson, G.F, Stoffels, Shelley, S.M., Frith, D.J. 2003, Cost effectiveness of hard aggregate sources, Alaska hard aggregate performance study: Final Report, Prepared for Alaska Department of Transportation and Public Facilities, By Quality Engineering Solutions, Inc., Report No. FHWA-AK-RD-02-10., 50p.

Johnson, E.G., Pavey, D.R, 2000, Draft studded tire wear resistant aggregate study, Final Report.

Pavey, Finkbiner, Bingham, 2012, Web interface: http://10.200.100.100/hard/aggregatestudy/ (Note this web interface is available only to DOT&PF personnel).

4.0 SOUTHCENTRAL ALASKA

A series of geologic terranes accreting to Alaska by thrust and right lateral strike-slip faulting have formed about five geologic terranes comprising Southcentral Alaska. These areas can be accessed via the road and railroad systems in the interior, and by marine transport along the southern coastal areas. A vicinity map for southcentral Alaska is presented as Figure 4-1.

4.1 General Geology

Along the western Talkeetna Mountains some of the more favorable rocks for producing low Nordic Abrasion values are basaltic to andesitic metavolcanic rocks. Fine-grained intrusives and hornfelses in the southwestern most part of the Talkeetna Mountains and the Petersville area may form suitable aggregate as well. Most of the rocks along the southern margin of the Talkeetna Mountains have been pervasively faulted and sheared from contact with the Chugach Mountains as the terranes grind past one another.

A series of northeast trending steeply fault bounded formations south of the Matanuska River show promising lithologies to suggest the presence of potential hard aggregate rock. Resistant outcrops of fine-grained mafic intrusive that survived glacial scour are exposed in the Burnt Butte area. These mostly mafic rock types look promising, and they extend from Eagle River east to Chickaloon, and possibly beyond.

The western Kenai Peninsula offers outwash gravels that may be suitable as hard aggregate. The Kenai Mountains contain a number of thrust fault bounded formations containing sedimentary and volcanic rocks. Mapped intrusives offer preliminary candidates for hard aggregate sources, especially fault bounded units of ultramafic rocks. The majority of the rocks within the Kenai Mountains are undivided metasedimentary rocks of the Valdez Group. These rocks form a broad arch, also including the core of the Chugach Mountains. Within this arch to the south, surrounding the Prince William Sound, are the undivided sedimentary rocks of the Orca Group. These two groups incorporate basalt and andesite flows, often altered to greenstone, offering potential as hard aggregate sources, if not too deformed by tectonic forces. In Prince William Sound there are a number of large Tertiary intrusives with hornfels aureoles in sedimentary rock sequences up to 0.5 miles wide, which may also offer suitable hard aggregate sites.

4.2 Kenai Peninsula

Areas accessible on the Kenai Peninsula by road and railroad include the northern portion of the Kenai Mountains and the lowlands of the peninsula to the west. The northern part of the lowlands is largely covered by glaciolacustrine and glacial outwash deposits as well as moraines from various glacial advances. Nearly horizontal sedimentary bedrock units of the Kenai Group are found south of Tustumena Lake. Along ocean bluffs and in the Homer area rocks of the Beluga Formation are exposed. These are interbedded, poor consolidated sandstone, siltstone, mudstone, calcareous shale, coal and minor volcanic ash of Miocene age. Overlying the Beluga Formation is the Sterling Formation of Miocene to Pliocene age, composed of interbedded, poorly consolidated sandstone, siltstone, mudstone, carbonaceous shale, lignite coal and minor volcanic ash. This formation is exposed in higher topographic areas around Homer (Hartman and et al., 1974). Nordic Abrasion values ranging from 11.4 to 13.2 were reported for alluvial and outwash gravels in the vicinity of Soldotna (Pavey et al., 2012). There are only limited conglomerates in the Kenai Group and what gravels are there tend to be weathered and friable.

The Kenai Mountains, north of the Kenai Fiords National Park, contain two major assemblages of rocks, separated by the Eagle River Fault. Along the western edge of the mountains are the rocks of the McHugh Complex. These rocks are part of the Valdez Group, mapped as undivided, including a complexly deformed assemblage of argillite, tuff, graywacke, basalt, chert, mesoscale (outcrop–scale) mélange, conglomerate, gabbro, and limestone, and are of Triassic to Mid-Cretaceous in age. Between the Eagle River Fault and Prince William Sound extensive sequences of undivided metasedimentary rocks of the Valdez Group are present. These rocks contain turbidic sandstone, siltstone, and slate, plus subordinate conglomerate. There were apparently no Nordic Abrasion values available for the McHugh Complex. It appears that values for the undivided Valdez Group ranged from 11.2 to 18.9 with what appears to be values of 8.5 to 16.9 in alluvial gravels (Pavey et al., 2012). It is possible the 8.5 value at 4th of July Creek near Seward may be a reflection of some of the mafic rocks in the upper drainage. However, there is little room for mining at the site.

Further south, near Seward, is the Resurrection Peninsula, composed of four formations within ophiolitic rocks of Prince William Sound. These rocks contain pillow basalts, sheet basalt dikes, gabbro, and ultramafic rocks. Some of the ophiolites within this assemblage may be of interest, given the proximity to the town of Seward. However, the lack of road access and the precipitous steepness of rocks on the peninsula would make them very difficult to access. The two other nearby units, minor in size, include a tuff in one formation and some interbedded metavolcanic and metasedimentary rocks in a second formation. It appears that there is little to no potential for hard aggregate on the Northern Kenai Peninsula.

FIGURE 4 - 1
SOUTHCENTRAL VICINITY MAP

4.3 Seldovia Area

Rock exposures on the southern part of the Kenai Peninsula in the vicinity of Seldovia are composed of three major assemblages. To the west side of Seldovia are two formations ranging in age from Upper Triassic to Jurassic age. One of those is the Talkeetna Formation consisting of massive volcanic breccia, agglomerate, tuff, andesitic lava flows and volcaniclastic sedimentary rocks. The other is the Port Graham Formation, characterized by dark-gray, carbonaceous limestone and silty limestone. Also included in this formation is tuff, tuffaceous sedimentary rocks and chert. Smaller sedimentary rock outcrops of the typically poorly consolidated Tyonek Formation also occur but none of these bedded formations appear to offer hard aggregate potential.

Three exposures of igneous rocks on the western tip of the Kenai Peninsula are described in the attached Point Bede / Nanwalek Potential Hard Aggregate Source Report. Small igneous exposures are present near Koyuktolik Bay, one consisting of tonalite, the other a light grey felsite. A larger intrusive mass in the Point Bede area is judged as having hard aggregate potential.

Thrust fault bounded rocks of the Valdez Group are found east of Seldovia forming the majority of the Kenai Mountains. The oldest rock assemblages of the Valdez Group form the McHugh Complex. Prior to being metamorphosed, the original rocks were predominantly Triassic, Jurassic and Early Cretaceous in age. The McHugh Complex is mapped as including a complexly deformed assemblage of argillite, tuff, graywacke, basalt, chert, mesoscale (outcrop–scale) mélange, conglomerate, gabbro, and limestone, mapped as a graywacke and conglomerate, as is a basalt and chert formation within the McHugh Complex. Fault bounded bodies of gabbro occur within the McHugh Complex, containing dark green medium to coarse-grained gabbro and plagiogranite. One major exposure is found along the shore of Halibut Cove, but the larger grain sizes reported suggests these rocks are unlikely candidates as sources for hard aggregates. South and east of McHugh Complex rocks are the undivided metasedimentary rocks of the Valdez Group of Upper Cretaceous age. These rocks contain turbidic sandstone, siltstone, and slate, plus subordinate conglomerate.

Ultramafic plutonic rocks of probable Triassic to mid-Cretaceous age are accessible by road about 20 road miles from Seldovia. These rocks are predominantly layered, variably serpentinized dunite, with rare to locally abundant layers of chromite and pyroxene, and fault slices of garnet pyroxenite and serpentine. These ultramafic rocks occur in at least seven known bodies within the McHugh Complex, all of them known or interpreted to be fault bounded. Red Mountain, mined in previous years for chrome, is part of an intrusive body bounded on all sides by subvertical, later stage faults. A thrust fault may bound the body at depth. Ultramafic rocks at the Snow Prospect to the west are bounded below and above by such low angle thrust faults. The unweathered ultramafic minerals dunite and associated assemblages are very hard on Mohs hardness scale. With recent glacial scour at higher elevations around Red Mountain, fine-grained unweathered exposures may provide rocks with low Nordic Abrasion values. However, careful inspection of the potential for naturally occurring asbestos and for acid rock drainage problems should be performed prior to any mining.

The peninsula east of McCarty Fiord contains the Nuka Pluton, exposed as a series of rugged mountains and islands. The pluton is an Eocene granodiorite, medium to coarse-grained. While there is a possibility of hornfelsed rocks in one area, it lies within the Kenai Fiords National Monument.

4.4 West Chugach Mountains – Anchorage to Eklutna

The western Chugach Mountains lie north of Turnagain Arm east of Knik Arm and south of the Knik River. They form the mountain range immediately to the east of Anchorage.

As shown in Figure 4-2, the Chugach Mountains, east of the Border Ranges Fault, contain two major assemblages of rocks. Along the western edge of the mountains are the rocks of the McHugh and Uyak Complex (blue-KMm). These rocks are part of the Valdez Group, mapped as undivided, including a complexly deformed assemblage of argillite, tuff, graywacke, basalt, chert, mesoscale (outcrop–scale) mélange, conglomerate, gabbro, and limestone, and are of Triassic to Mid-Cretaceous in age. Between the McHugh Complex and Prince William Sound extensive sequences of undivided metasedimentary rocks of the Valdez Group (green – Kvs) are present. These rocks contain turbidic sandstone, siltstone, and slate, plus subordinate conglomerate. There is a Nordic Abrasion test result of 10.2 in an area mapped as the McHugh Complex (Pavey et al., 2009) near the south abutment of the Old Glenn Highway Bridge over the Knik River. The sample was reported to be from the quarry MS 576-015-1. The rock was reported to be a greenstone and metaconglomerate in a material site file.

West of the Border Range Fault bedrock was mapped outcropping only in the northeast corner of the area near Eklutna.

Geology: Two rock types have been mapped in the northwest corner of the area, near Eklutna. The following units were mapped as shown on Figure 4-2 (Winkler, 1992).

> Jum: (purple) Ultramafic and Mafic and ultramafic rocks undivided (Middle and Early Jurassic). They are mapped as a complexly intermixed series of mafic and intermediate plutonic rocks. Plutons consist of gabbronorite, hornblende gabbro, diorite, quartz diorite, and tonalite. Generally xenoliths or schlieren of more mafic rock are present in less mafic rock. Xenoliths of gabbro show ductile deformation as though they still were warm when intruded by more silicic magmas, and migmatitic textures are common at contacts between lithologies. Hence, much of the mixing may have been caused by multiple intrusions, and entire series of plutonic rocks may have been mostly coeval (Burns, 1985). This alteration may contribute to the rock being able to produce low Nordic Abrasion values.

> JPzm: (gray) Metamorphic Rocks (Jurassic to Middle Paleozoic?). Diverse metasedimentary and metavolcanic rocks along northern flank of Chugach Mountains, cropping out near the Jum unit. Rocks are strongly to weakly foliated and variably metamorphosed from middle greenschist to amphibolite facies. Rocks are intruded by mafic and intermediate plutons of units Jmip and Jg. Sedimentary protoliths consist of shale chert, tuffaceous arenite, and limestone, and volcanic protoliths are most probably basalt. Diversity of protoliths may indicate tectonic mixing prior to metamorphism. In most places the fabric is cataclastic or recrystallized.

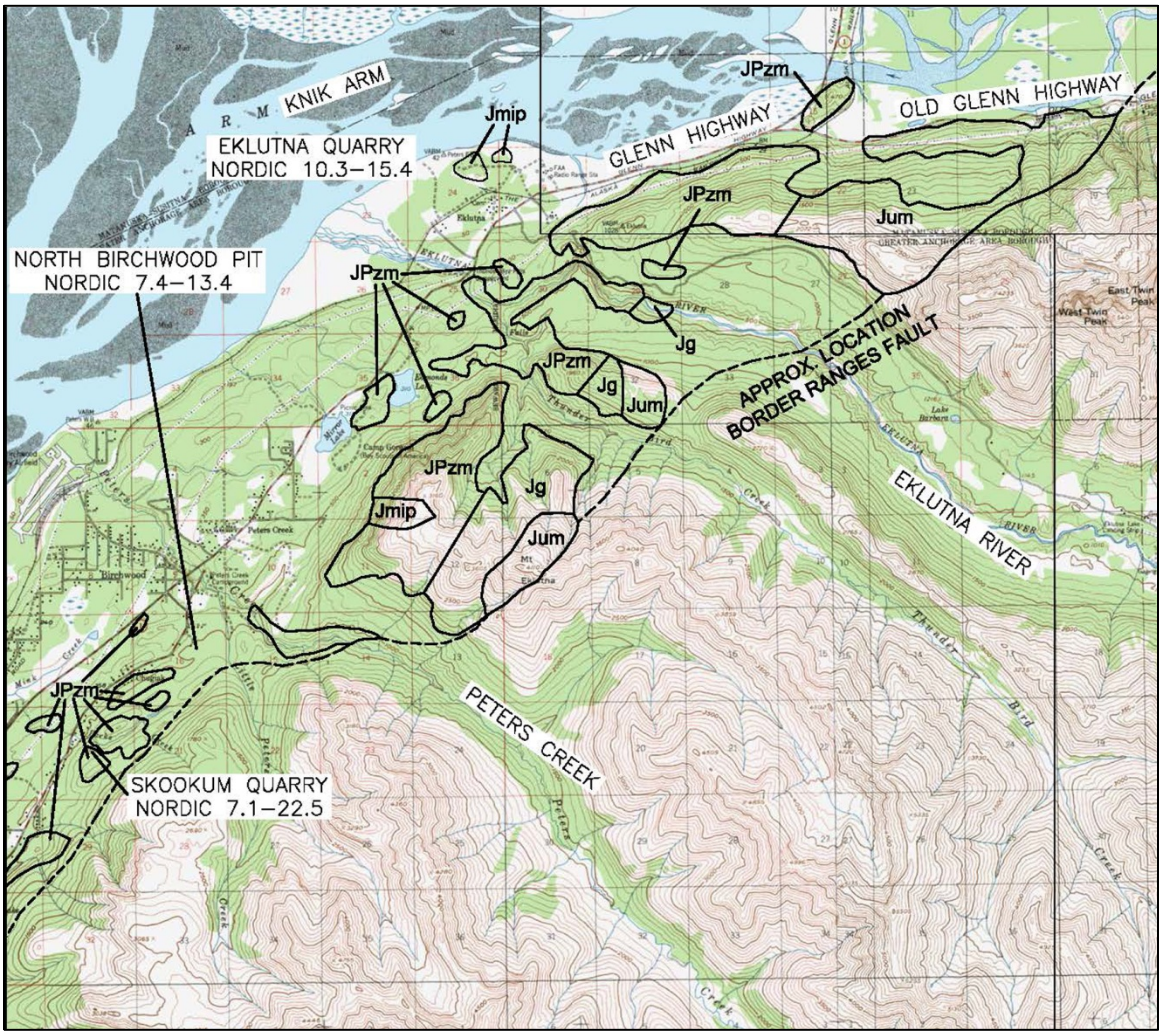
Jmip: Mafic and intermediate plutonic rocks (Middle and Early Jurassic) complexly intermixed series of mafic rocks. Plutons consist of gabbronorite, hornblende gabbro, diorite, quartz diorite and tonalite.

Jg: Gabbronorite (Middle and Early Jurassic) Fine to coarse-grained gabbroic rocks, exposed as fault-bound slices, or layers and dikes in the Eklutna ultramafic complex. Primarily consist of gabbronorite, leucogabbronorite, and pyroxene-hornblende gabbro.

FIGURE 4 - 2
GEOLOGY OF WESTERN CHUGACH MOUNTAINS
(From Wilson et al., 2012)

As shown in Figure 4-3, the Eklutna Railroad Quarry is in the Jmip Mafic and intermediate plutonic rock unit and is reportedly a quartz diorite. L.A. Abrasion results varied from 17 to 26, specific gravities from 2.77 to 2.80, absorptions from 0.4 to 0.7, and T-13 Degradations from 69 to 70. Reported Nordic Abrasions values ranged from 10.3 to 15.4 (Pavey et al., 2012).

FIGURE 4 - 3
GEOLOGY OF MAFICS AND ULTRAMAFICS IN EKLUTNA AREA
(Modified From Winkler, 1992)



The Skookum Quarry is in the JPzm undivided metamorphic rocks in Chugiak on Parks Creek. Nordic Abrasion results ranging from 7.1 to 22.5 have been reported (Pavey et al., 2012). The quarry has reportedly produced high quality rock in the past and it can only be assumed that the quarry is established in one of the intrusives or in the basalt.

The North Birchwood Pit has reported Nordic Abrasion results ranging from 7.4 to 13.4 in what appears to be either glaciofluvial gravel or abandoned terrace gravel of Peters Creek.

The quarries and pits in the Eklutna area, while they have material that can provide Nordic Abrasion values of less than 10, they apparently do not have the geology to provide it consistently. The area is becoming developed and new areas to mine are becoming scarcer and areas to the northeast would likely be more promising for finding sites with more potential for hard aggregate production. Many of the undeveloped rock units that have some potential for hard aggregate production lie within Chugach State Park.

4.5 East-Central Chugach Mountains – Knik/Matanuska

The eastern-Central Chugach Mountains lie north of the Knik River and Prince William Sound, south of the Matanuska River and east of the Richardson Highway. For all practical purposes the area considered lies east of Nelchina Glacier as this is the only area close enough to the Glenn Highway to be accessible. The areas of general interest are the igneous intrusives and volcanics that form the Buttes and are found between Palmer and Carpenter Creek, including Wolverine Creek, north of the Borders Range Fault zone.

The east-central Chugach Mountains, south of the Border Ranges Fault, contain the Valdez Group, consisting of two major assemblages of rocks. Along the southern edge of the fault are the rocks of the McHugh Complex. These rocks include a complexly deformed assemblage of argillite, tuff, graywacke, basalt, chert, mesoscale (outcrop–scale) mélange, conglomerate, gabbro, and limestone, and are of Triassic to Mid-Cretaceous in age. Between the McHugh Complex and Prince William Sound extensive sequences of undivided metasedimentary rocks of the Valdez Group are present. These rocks contain turbidic sandstone, siltstone, and slate, plus subordinate conglomerate. The Borders Range Fault is defined as a zone in this area and may contain several faults or shear zones several kilometers wide (Pavlis, 1986).

Geology: Rock types mapped near Matanuska Peak and shown in Figure 4-4 (Winkler, 1992).

> Jmip: Mafic and intermediate plutonic rocks (Middle and Early Jurassic) – Mapped as a complexly intermixed series of mafic and intermediate plutonic rocks. Plutons consist of gabbronorite, hornblende gabbro, diorite, quartz diorite, and tonalite. Diorite is the predominate lithology in the Wolverine Creek area. These rocks form the southern half of Bodenburg and Burnt buttes and project northeast into Matanuska Peak. Xenoliths of gabbro show ductile deformation. Migmatitic textures are common at contacts between lithologies. Hence, much of the mixing may have been caused by multiple intrusions, and entire series of plutonic rocks may have been mostly coeval (Burns, 1985). The rocks on Bodenburg's south side have also been hydrothermally altered, turning the mafic minerals a lighter green with diffuse grain boundaries. This alteration may contribute to the rock reportedly being extremely strong and almost impossible to break with a rock hammer.
>
> Jqt: Quartz diorite and tonalite (Middle Jurassic) – Series of discordant intermediate plutons. Plutons are relatively homogeneous, fine to medium-grained quartz diorite and tonalite. Large areas are sheared and altered.
>
> Kt/Kit: Leucotonalite and trondhjemite (Early Cretaceous) – Medium-grained plugs and elongate, irregular-shaped, sill-like bodies of leucocratic plutonic rocks in a zone about 5 km wide near Border Ranges fault. Rocks generally are foliated and contain less than 10

percent mafic minerals including muscovite, biotite, or hornblende. Due to the foliation these rocks typically would make poor hard aggregate sources.

Jg: Gabbronorite (Middle and Early Jurassic) - Fine to coarse-grained gabbroic rocks, exposed as fault-bound slices, or layers and dikes in the Wolverine ultramafic complex. Primarily consist of gabbronorite, leucogabbronorite, and pyroxene-hornblende gabbro.

Jum: Ultramafic and mafic rocks (Middle and Early Jurassic) - A small exposure of Late Cretaceous ultramafics rocks is exposed just east of Bodenburg Butte.

TKc: Cataclasite (Eocene and Early Cretaceous) – Chlorite-rich fine-grained granular rocks formed by cataclasis alteration of mafic and ultramafic plutonic rocks and mafic volcanic rocks. May represent central zones or major strands of Border Ranges fault system where rocks from both upper and lower plates were cataclastically deformed, mixed, and metamorphosed.

JTRk: Talkeetna Formation (Early Jurassic and Late Triassic) – Andesitic, dacitic, and basaltic flows, flow breccia, tuff, shallow sills, and agglomerate. Contains subordinate interbedded volcaniclastic sandstone, conglomerate, and fossiliferous marine siltstone and shale. The Talkeetna is altered in many places. An isolated exposure (Sec. 17 and 18, T18N, R4E, SM) in Lower Wolverine Creek, contains fine-grained, highly altered, massive greenstones that presumably are a mafic part of the Talkeetna Formation (Pavlis, 1986).

JPzm: Metamorphic Rocks (Jurassic to Middle Paleozoic?). Diverse metasedimentary and metavolcanic rocks along northern flank of Chugach Mountains, cropping out near the Jum unit. Rocks are strongly to weakly foliated and variably metamorphosed from middle greenschist to amphibolite facies. Rocks are intruded by mafic and intermediate plutons of units Jmip and Jg. Sedimentary protoliths consist of shale chert, tuffaceous arenite, and limestone, and volcanic protoliths are most probably basalt. Diversity of protoliths may indicate tectonic mixing prior to metamorphism. In most places the fabric is cataclastic or recrystallized.

Tc: Chickaloon Formation (Eocene and Paleocene) Predominately fluvatile and alluvial carbonaceous mudstone, siltstone, conglomeratic sandstone, and polymictic conglomerate; contains beads of bituminous coal.

Rock exposures in the northeastern trending sequence containing Bodenburg Butte and Burnt Butte show promising rock lithologies likely to produce low Nordic Abrasion values. The rock exposures are readily accessible by existing roads. While Bodenburg Butte is a State Park, Burnt Butte in on land apparently owned by Eklutna, Inc. (subsurface), CIRI (subsurface). A Potential Hard Aggregate Source Report was prepared for Burnt Butte.

Rocks in the Chugach Range between Wolverine Creek and Carpenter Creek to the east may also contain rock units that would produce hard aggregate. The land in the flats surrounding the mountains is generally owned by private and municipal entities, the foothills by Native Corporations and the interior of the mountains themselves by the State of Alaska. Access may be a problem, however the area is open to mining under the Susitna-Matanuska Area Plan.

Some of the glaciofluvial gravels in the area may also contain hard gravels that can produce low Nordic Abrasion values. Premier Pit near Mile 10.4 of the Old Glenn Highway had a reported Nordic Abrasion value of 9.3. Other gravel pits in the area had Nordic Abrasion values ranging from 8.1 to 15.3 (Pavey et al., 2012). It may be possible to find gravel pits that with processing can consistently meet low Nordic Abrasion values.

FIGURE 4 - 4
GEOLOGY OF MAFICS AND ULTRAMAFICS IN WOLVERINE CREEK AREA
(Modified from Winkler, 1992)

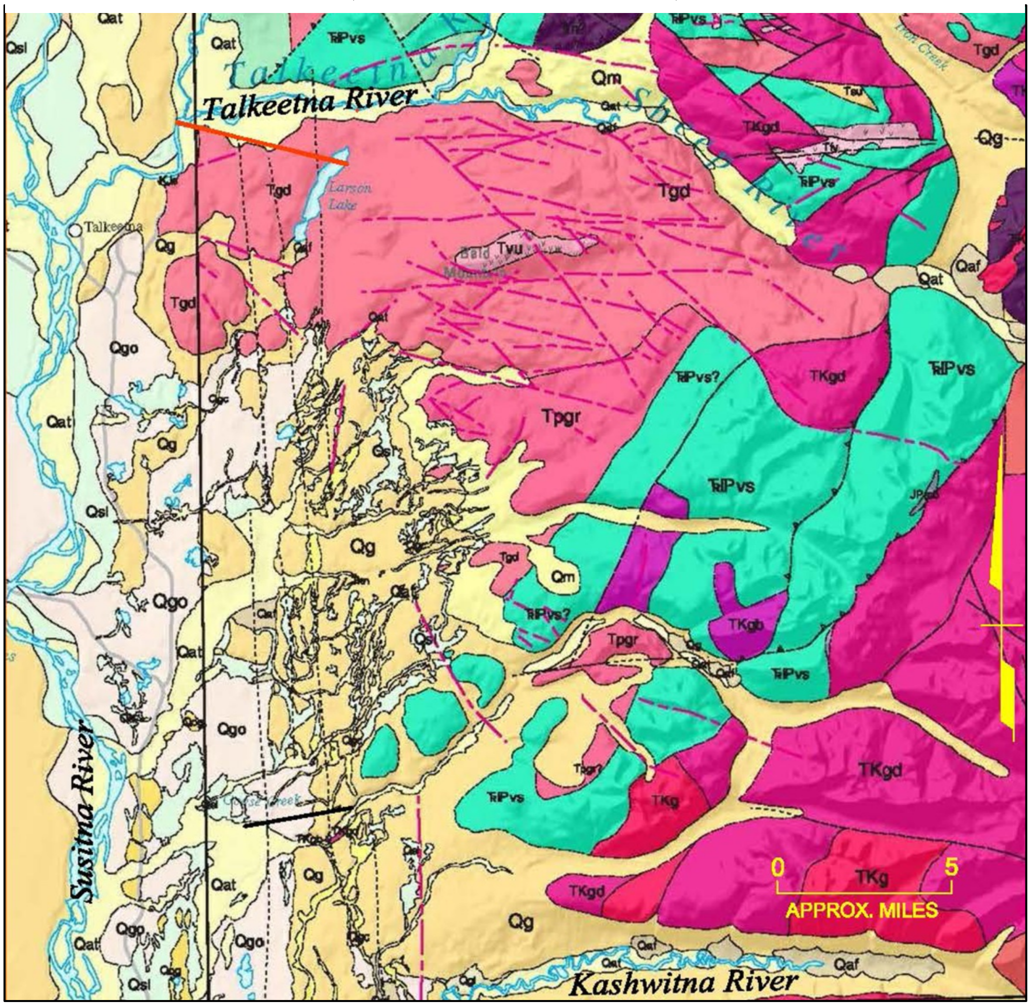
4.6 Western Talkeetna Mountains

The George Parks Highway provides access to hard aggregate deposits from Cantwell to Houston along the western slopes of the Talkeetna Mountains. From Cantwell to Talkeetna, sedimentary rocks of the Kahiltna flysch sequence (earliest Late Cretaceous to Late Jurassic?) are exposed. These rocks are a sequence of intensely deformed and locally highly metamorphosed turbidites described by and Reed and Nelson (1980). They include dark-gray to black argillite, fine- to coarse-grained, generally dark-gray graywacke, dark-gray polymictic pebble conglomerate, subordinate black chert pebble conglomerate, a few thin layers of dark-gray to black radiolarian chert and thin, dark-gray impure limestone interbeds. Locally, the presence of interbedded light tuffaceous deposits indicates contemporaneous volcanism. The northern portion of these exposures between Cantwell and Honolulu Creek encompass a large folded klippe or thrust sliver that may be as large as 30 by 60 km, perhaps a remnant of a much larger thrust sheet (Csejtey, et al., 1992).

From Honolulu Creek south to Talkeetna the flysch sequences are intruded by large, mostly Tertiary to Cretaceous granitic plutons. Major sequences include biotite-muscovite granite to quartz monzonite (Wilson et al., 1998). Most of the plutons are likely too coarse-grained to produce acceptable hard aggregate. Although no discussions of developed hornfels zones were found in literature, such zones are likely to exist in flysch sequences exposed to contact metamorphism from plutons, and might provide promising locations for hard aggregate extraction.

From the northern banks of the Talkeetna River south to the Kashwitna River there are a series of basaltic to andesitic metavolcanics of Mesozoic to Cenozoic age (T_RPvs) (Figure 4-5). These units are interlayered heterogeneous, dominantly marine sequences over 15,000 feet thick (Csejtey et al., 1978). They consist primarily of metamorphosed flows and tuffs of basaltic and andesitic composition, subordinate mudstone, bioclastic marble, and dark-gray to black phyllite. These extrusive rocks are in fault and intrusive contacts with plutons, varying between granite, granodiorite, quartz diorite, tonalite and diorite, ranging in age between Mesozoic to Cenozoic. The metavolcanics are likely to have a “greenstone” appearance, and they may produce acceptable Nordic Abrasion values.

FIGURE 4 - 5
GEOLOGY TALKEETNA TO KASHWITNA RIVER AREA
(From Wilson et al., 2009)

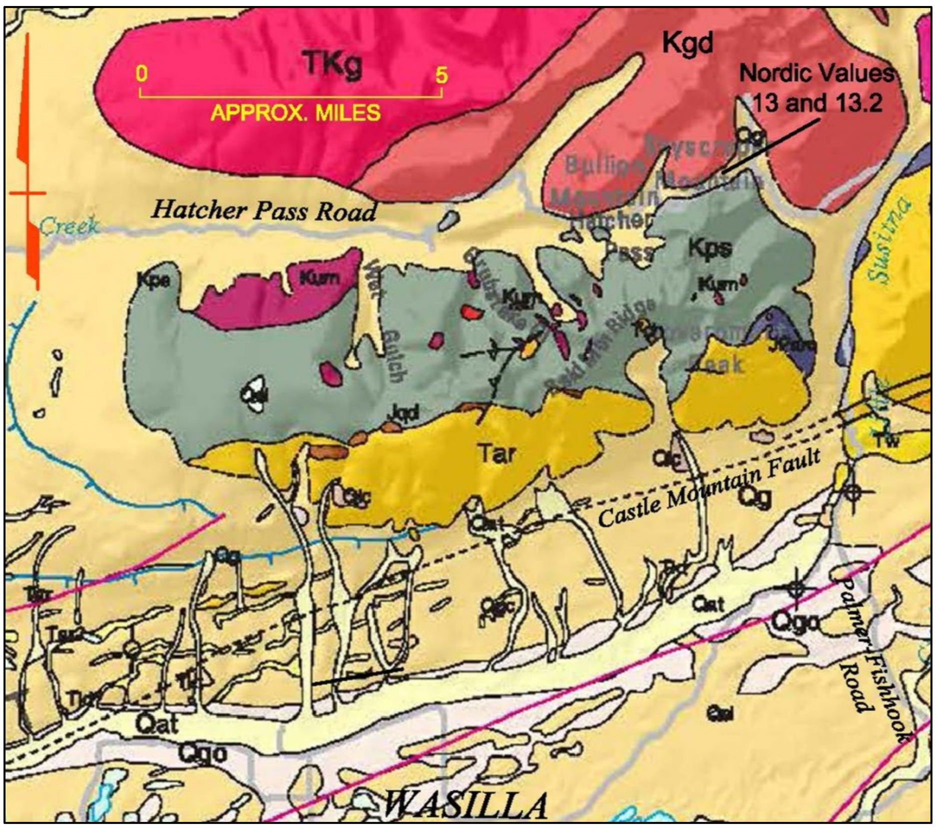


TRPvs – Metavolcanics (blue-green on map)

South of the Kashwitna River to Willow Creek, the majority of bedrock exposures are from the Arkose Ridge Formation, Lower Eocene to upper Paleocene in age. These outcrops are composed of fluviate and alluvial feldspathic and biotic sandstone, conglomerate, siltstone, and shale containing abundant plant fragments (Csejtey et al., 1978 and Winkler, 1992). Coarsening upward, the sequence was deposited on alluvial fans and by braided streams carrying sediment derived from rapid erosion of uplifted mountains to the north (Winkler, 1992). Thickness is as much as 2,300 feet. Granitic rocks are exposed in Willow Creek and further to the east, but no mention of hornfelsed rocks was encountered in the literature.

Between Willow and Houston, the southern portion of the western Talkeetna Mountains includes Bald Mountain Ridge. The Arkose Ridge Formation (Tar), Lower Eocene to Upper Paleocene, is exposed along the southern slopes of Bald Mountain Ridge (Figure 4-6). The ridge crest and most of the northern slopes contain a pelitic schist formation (Kps) (Cretaceous?). This schist is a quartz-muscovite-albite-chlorite schist which is remarkably uniform in lithology. No correlative rocks are known (Albanese et al., 1983 and Winkler, 1992). Mineralogy indicates greenschist metamorphism, which Winkler (1992) interpreted as probably retrograde from amphibolite facies metamorphism. Smaller outcrops contain Tertiary or Cretaceous granitic rocks (Tkg), Late Cretaceous serpentinized ultramafic rocks (Kum), as well as a Lower Jurassic or older unit comprising dark gray to dark-green, fine- to coarse-grained hornblende-plagioclase amphibolite, quartz-rich amphibolite, and mafic schist (JPam). A series of small Jurassic hornblende-biotite tonalite intrusions (Jqd) are present near the main pelitic schist (Kps) /Arkose Ridge Formation (Tar) boundary (Wilson et al., 2012). Hornfelses may have developed adjacent to the sedimentary rocks. These hornfelses and the fine-grained intrusions within the ridge may produce low Nordic Abrasion values. The ridge is accessible via Hatcher Pass Road.

FIGURE 4 - 6
GEOLOGY BALD MOUNTAIN RIDGE (HATCHER PASS ROAD)
(From Wilson et al., 2009)



The Arkose Ridge Formation is exposed along the southern slopes. The ridge crest and most of the northern slopes contain Pelitic schist (Cretaceous?). This schist is a quartz-muscovite-albite-chlorite schist which is remarkably uniform in lithology. No correlative rocks are known (Albanese et al. and 1983, Winkler, 1992). Mineralogy indicates greenschist metamorphism, which Winkler (1992) interpreted as probably retrograde from amphibolite facies metamorphism. Smaller outcrops contain Tertiary or Cretaceous granitic rocks, Late Cretaceous serpentinized untramafic rocks, as well as Lower Jurassic or older dark-gray to dark-green, fine- to coarse-grained hornblende-plagioclase amphibolite, quartz rich amphibolite, and mafic schist. The amphibolite is intruded by a foliated Jurassic hornblende-biotite tonalite. This latter intrusive rock is mapped along the ridge together in the same formation as other outcrops containing quartz diorite, tonalite and diorite (Wilson et al., 2012). Hornfelses may have developed adjacent to intrusives in the Arkose Ridge Formation and the pelitic schist. The fine-grained intrusions within the ridge may also produce low Nordic Abrasion values. The ridge is directly accessible via Hatcher Pass Road. Two Nordic Abrasion values of 13 and 13.2 were reported for the granodiorite (Kgd) in Hatcher Pass (Pavey et al., 2012) as shown in Figure 4-6.

4.7 Petersville Road

The Petersville area, located approximately 50 miles west of the George Parks Highway, is covered by numerous placer and hard rock metallic mineral mines. Capping both the Dutch and Peters hills are the turbiditic sedimentary rocks of the Kahiltna Flysch sequence (Cretaceous, Aptian and Valanginian or younger to Upper Jurassic?). These rocks are a sequence of intensely deformed and locally highly metamorphosed turbidites (Csejtey et al., 1992, and Reed and Nelson, 1980). Included are dark-gray to black argillite, fine- to coarse-grained, generally dark-gray graywacke, siltstone, and shale turbidites, thinly bedded and dense cherty argillite, dark-gray polymictic pebble conglomerate, subordinate black chert pebble conglomerate, a few thin layers of dark-gray to black radiolarian chert and thin dark-gray impure limestone interbeds. Sandstone includes greywacke in beds up to six feet thick and feldspathic sandstone. These rocks are locally metamorphosed along the margin of intrusives. A pluton is mapped atop the northern portion of the Dutch Hills. This intrusive is part of predominantly medium-grained series of composite plutons classified as granite, syenite, tonalite, quartz monzonite, quartz monzodiorite, quartz diorite, granodiorite, and minor diorite. Biotite is the chief mafic mineral. The plutons are locally weakly foliated or contain flow structures (Wilson, 2012). These plutonic rocks are likely present at shallow depth underneath both the Dutch and Peters hills, giving rise to the metallic mineralization as well as hornfelses. These hornfelses may be shown to have low Nordic Abrasion values.

Along the flanks of the Dutch and Peters hills is the younger Sterling Formation of Pliocene and Miocene age. These rocks are weakly lithified massive sandstone, conglomeritic sandstone and interbedded siltstone and claystone. The unit includes interbedded lignite coals typically less than three feet thick in the upper part of the unit, but may be as much as ten feet thick in the lower parts (Calderwood and Fackler, 1972). Along the lower flanks and valley bottoms of the Dutch and Peters hills is the Tyonek Formation of Miocene to Oligocene. Present is carbonaceous nonmarine conglomerate and subordinate sandstone, siltstone, and local coal (Winkler, 1992 and Bradley et al., 1998). The Tyonek Formation is identified by massive sandstone beds and lignite to subbituminous coal beds as much as 30 feet thick (Calderwood and Fackler, 1972). Contact with the overlying Beluga Formation is believed to be a disconformity where the sandstone beds and coal beds become markedly thinner (Calderwood and Fackler, 1972). Prominent older but modified morainal deposits of Knik and Eklutna glaciations are found along the eastern flanks of the Peters Hills (Karlstrom, 1964).

4.8 Southern Talkeetna Mountains

From Bald Mountain Ridge, the Glenn Highway follows the southern Talkeetna Mountains past Slide Mountain and onto broad interior lowlands before reaching Glennallen. On Bald Mountain Ridge the Arkose Ridge Formation, Lower Eocene to Upper Paleocene, is exposed along the southern slopes. The ridge crest and most of the northern slopes contain a pelitic schist formation (Cretaceous?). This schist is a quartz-muscovite-albite-chlorite schist which is remarkably uniform in lithology. No correlative rocks are known (Albanese et al., 1983 and Winkler, 1992). Mineralogy indicates greenschist metamorphism, which Winkler (1992) interpreted as probably a retrograde from amphibolite facies metamorphism. Smaller outcrops contain Tertiary or Cretaceous granitic rocks, Late Cretaceous serpentinized ultramafic rocks, as well as a Lower Jurassic or older unit comprising dark-gray to dark-green, fine- to coarse-grained hornblende-plagioclase amphibolite, quartz rich amphibolite, and mafic schist. A series of small Jurassic hornblende-biotite tonalite intrusions are present near the main pelitic schist /Arkose Ridge Formation boundary (Wilson et al., 2012). Hornfelses may have developed adjacent to the sedimentary rocks. These hornfelses and the fine-grained intrusions within the ridge may produce low Nordic Abrasion values. The ridge is accessible via Hatcher Pass Road. (See section on Western Talkeetna Mountains for more information).

To the east and bounded by the Little Susitna River and Moose Creek is Arkose Ridge, predominantly underlain by the Arkose Ridge Formation. The Castle Mountain Fault cuts across the southern slope of the ridge, marking the boundary with the Chickaloon Formation further to the south. This latter formation is Lower Eocene and Upper Paleocene in age, predominantly a fluviatile and alluvial carbonaceous mudstone, siltstone, conglomeratic sandstone, and polymictic conglomerate. Locally, upper and middle parts of the unit contain numerous beds of bituminous coal and fossils. Lower parts of the unit largely include conglomerate and lithic sandstone derived from Talkeetna Formation (Winkler, 1992).

Further east and south of the Castle Mountain Fault is Wishbone Hill, capped by the Tsadaka Formation of Miocene to Oligocene age. This unit is a poorly sorted cobble to boulder conglomerate, interbedded with lenses of feldspathic sandstone, siltstone, and shale (Winkler, 1992). Underlying the Tsadaka Formation is the Wishbone Formation of Eocene age, a fluviatile conglomerate having thick interbeds of sandstone, siltstone, and claystone, and it contains local partings of volcanic ash (Winkler, 1992). South of these formations, along the gentler slopes of the Matanuska Valley bottom, the valley is covered by outwash, valley trains, fans and eskers related to outburst floods from Glacial Lake Atna (Wiedmer et al., 2010).

From Knob Hill to Red Mountain there are extensive units of the upper Cretaceous Matanuska Formation, a well-indurated, thinly bedded, dark-gray fossiliferous shallow marine shale containing conspicuous calcareous concretions, volcanic-lithic siltstone, sandstone, greywacke, and subordinate conglomerate (Winkler, 1992). This formation is overlain by the Chickaloon Formation. Granitic plutons of Paleocene to Late Cretaceous age form the core of Red Mountain, composed of fine-to coarse-grained, epizonal, biotite and biotite-hornblende granite, quartz monzonite and alkali granite (Winkler, 1992).

Exposed at the crest of Castle Mountain, Puddingstone Hill and along the flanks of Anthracite Ridge are Tertiary volcanic rocks, composed of andesite, basalt, and dacite lava flows, tuff, lahar deposits, volcanic breccia, and hypabyssal intrusions. These units include small lenses of fluviate conglomerate. Crude stratification has been reported where felsic rocks and pyroclastic rocks occur stratigraphically lower in the section. Basaltic and andesitic flows occur in the upper part of the section (Csejtey et al. and 1978, Winkler, 1992). Both Castle Mountain and Puddingstone Hill are surrounded by rocks of the Wishbone Hill Formation, and further downslope by the Chickaloon Formation. Anthracite Ridge, farther to the east, is capped by the Matanuska

Formation, with coal rich Chickaloon Formation rocks along its southern flanks. There are numerous Paleocene to late Cretaceous granitic outcrops exposed within the Chickaloon Formation. No mention of hornfelsed zones in sedimentary rocks near intrusives from Red Mountain to Anthracite Ridge was found in the literature. Many of the igneous contacts are along erosional or fault contacts. Some of the intrusives are very coarse-grained with concentrations of large hornblende crystals, suggesting a view of the lower reaches of a batholith system.

Flanking the terminus of the Matanuska Glacier, the Glenn Highway passes through rocks of the Matanuska Formation before skirting Lion Head, an intrusive stock, which is one of a cluster of stocks in the area. From Caribou Creek, the highway passes along the base of Sheep and Gunsight mountains before entering the Glennallen Lowlands. Rocks along this stretch alternate between those of the Matanuska Formation and the Talkeetna Formation. This latter formation contains greenstones and tuff, forming the large orange and brown stained “stratigraphic color anomaly” seen near Sheep Mountain. The rocks vary from volcanics and volcaniclastic rocks consisting of lava, agglomerate, breccia, tuff, and interbedded sandstone and shale. Where more distal from volcanic sources the formation contains volcanic-sources sedimentary rocks. The unit is the extrusive product of an early Jurassic island arc, of which the Jurassic phase of the Alaska-Aleutian Range batholith is the plutonic core. Further east scattered outcrops of undifferentiated sedimentary rocks are present in the Glennallen Lowlands (Wilson et al., 1998).

Fine-grained intrusives and possible adjoining hornfelsed zones in the far southwestern portion of the Talkeetna Mountains around Bald Mountain may produce promising Nordic Abrasion values as discussed in more detail in Section 4.6. The Matanuska Valley forms the boundary between the Talkeetna and Chugach Mountains. Nordic Abrasion values ranging from 9.8 to 11.4 were reported for a small igneous bedrock source near Milepost 75.5 on the Glenn Highway that was mapped as dikes or sills. Two Nordic Abrasion values of 14.7 and 26.9 were reported for gravel at MP 66 (Kings River) and MP 96 (Hicks Creek), respectively (Pavey et al., 2012). In general, it appears that the southern Talkeetna Mountains do not have any potential sources of hard aggregate.

4.9 Prince William Sound

Prince William Sound lies between the Kenai Peninsula and the Chugach Mountains and is surrounded by some of the most rugged coast lines in Alaska. Geology is dominated by the sedimentary and volcanic rocks of the Valdez and Orca Groups. The two groups are very similar and can be difficult to differentiate. The Orca Group is thought to be less metamorphosed than the Valdez Group and contains both greenstones and conglomerates. Also, the Orca Group contains basalt and andesite flows (locally called greenstones) that are of potential interest for hard aggregates. However, the rocks are very highly deformed therefore it may not be possible to find large enough blocks of greenstone that can be utilized for hard aggregate. There are also several large Tertiary granite intrusives with thick contact aureoles around the edges of the sound that may provide suitable sources.

The western and northern edges of Prince William Sound are underlain by the Upper Cretaceous Valdez Group, an accretionary belt of rocks approximately 1,000 miles long that extends from southeastern Alaska to Kodiak and the Shumagin Islands. The entire belt is folded, deformed and metamorphosed to grades ranging from zeolite to lower greenschist and to the amphibolite facies. In this area the Valdez Group is composed of interbedded sandstone, siltstone with minor mudstone that pebble conglomerate. Mafic volcanic rocks consist of greenstone, basalt with intermixed metasedimentary rocks and tuffaceous units (Nelson et al., 1985).

Central and eastern portions of Prince William Sound are mapped as being underlain by a complexly deformed sequence of Eocene and Paleocene flysch and mafic volcanic rocks of the Orca Group in fault contact with the southern margin of the Valdez Group. The Orca Group is thought to be an accretionary sequence that may underlie the contiguous continental shelf. Sedimentary rocks of the Orca Group are made up of sandstone, siltstone, and mudstone showing abundant sedimentary structures. Tholeiitic basalt is the most common type of volcanic rock in the Orca Group, occurring as massive flows, interlayered with pillowed flows in some areas.

Intrusive plutons of Prince William Sound were associated with two main events, one Eocene and the other Oligocene. The intrusives are composed primarily of granite and granodiorite with smaller gabbro and diorite stocks and dikes. These intrusive rocks intrude both the Valdez and Orca Groups. Thermal aureoles extend outward from the pluton contacts up to 0.5 miles into the country rock (Nelson et al., 1985).

The principal landowner in Prince William Sound is the Federal Government. Most of the land is part of the Chugach National Forest and is managed by the U.S. Forest Service. The western part of Prince William Sound (west of Montague Island and Valdez Arm) lies within the Nellie-Juan-College Fiord Study Area. Large sections of this area have been recommended for preservation wilderness. The regional native corporation in Prince William Sound is the Chugach Alaska Corporation. There are three village corporations Tatitlek Corporation, Chenega Corporation, and Eyak Corporation within the area. Each of these entities own lands with different levels of ownership within the National Forest. The State of Alaska also owns small parcels surrounding Prince William Sound, primarily near Whittier, Valdez and Cordova. A number of these areas have been designated as state parks.

<u>Knight Island Greenstones:</u> Knight Island is a rugged, glacially sculpted island on the east side of Prince William Sound. The island lies within Chugach National Forest with most of the land owned by the Federal Government. However, there are two large parcels of land at the south end and in the middle of the island owned or selected by native corporations. The predominate rock types on the island are basaltic and andesitic volcanics (sometimes referred to as greenstones) of the Orca Group (Kog) as shown in Figure 4-7. Orca Group sedimentary rocks (Kos) were mapped by Moffit on the south end of the island and included siltstone, mudstone and sandstone. A small area of conglomerate (Koc) was mapped on the south tip of the island (Moffit, 1954).

Knight Island volcanics were further subdivided as follows in 1985 by Nelson et al. in the Geologic map of the Chugach Forest:

1. Pillow Basalt (Top), associated broken pillow breccia, and massive flows make up large parts of Knight Island. This unit may be more than 5,000 feet thick on Knight Island where it is part of a larger mafic igneous complex. Interpillow material consists of siliceous mudstone, sandstone, or carbonate rocks. Pillow basalts are phophyritic with altered brown-colored volcanic glass making up much of the matrix, especially in the outer shells of the pillows. This unit grades into;

2. Pillow Basalt and Sedimentary Rocks (Tops) consisting of similar basalts interbedded with sandstone, siltstone and shale, which further grades into;

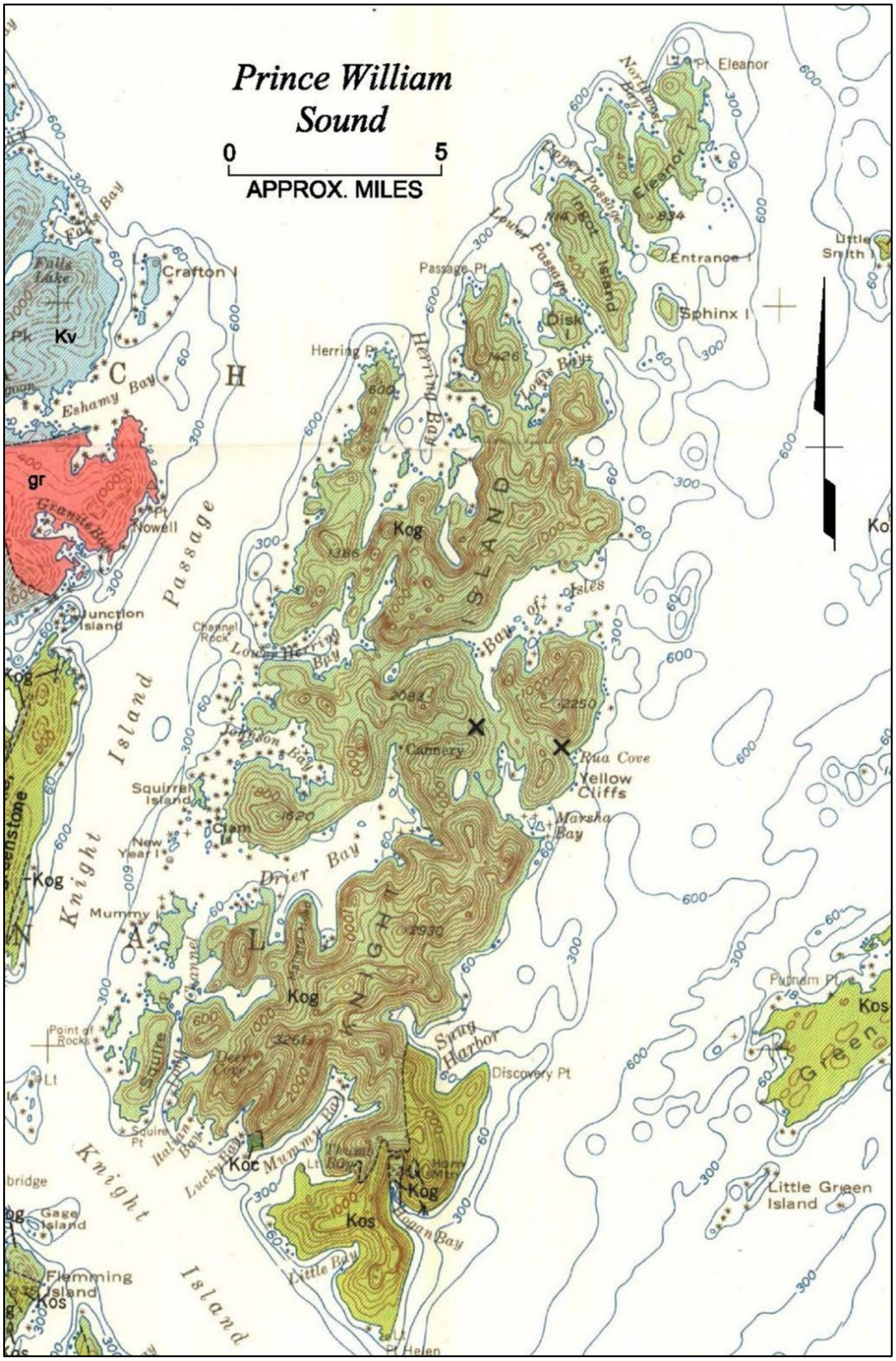
3. Interbedded Sedimentary and Mafic Volcanic Rocks (Tosv) consisting of massive basalt flows and sills intercalated with shale and argillite.

There are a number of shear zones running the length of the island from north to south (Richter, 1975). These shear zones would tend to weaken the rock, making it harder to find areas with the potential for producing hard aggregate. Large numbers of dikes and sills are noted intruding the country rock. Loarse-grained gabbro and diorite dikes were also reported. There were only a few reports of contact metamorphic alteration described in several reports.

While there is a possibility of locating an area where the basalt or andesite still has the durability to produce hard aggregate, it is not possible to predict where on the island this may occur. Even if an area is located, it may not be in a location where it would be accessible or where a permit to mine could be obtained.

Greenstones similar to those on Knight Island are also mapped on Bainbridge, Evans and Elrington Islands to the south of Knight Island Passage. There is a lower percentage of the volcanic rocks here than on Knight Island. They are also more interbedded with the sedimentary rocks.

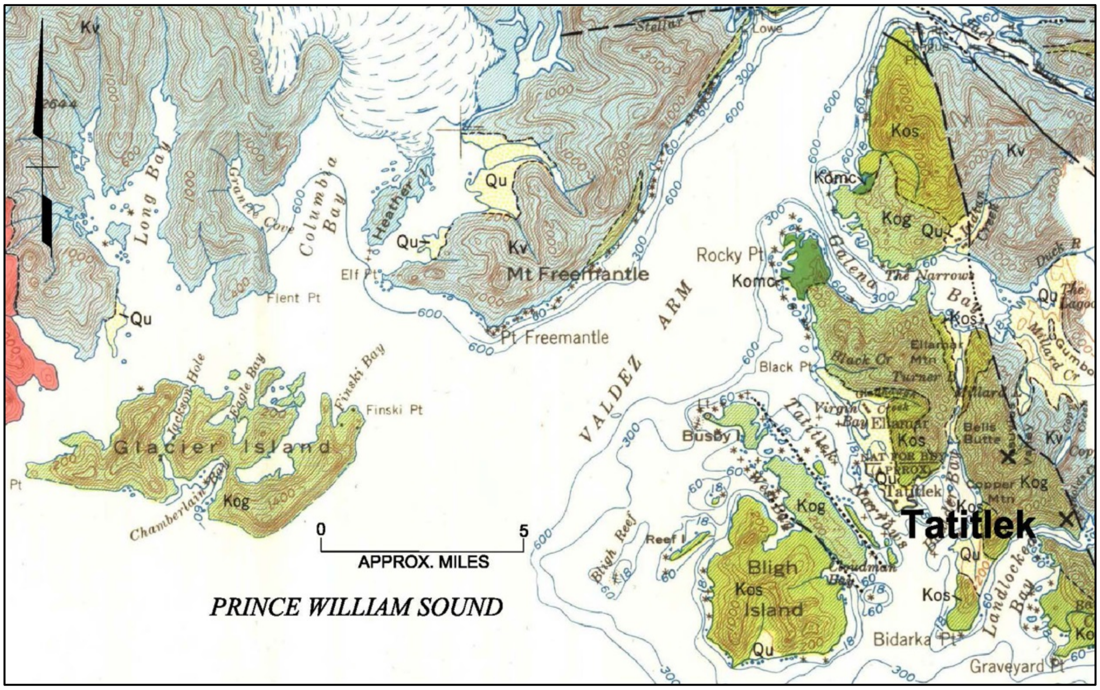
FIGURE 4 - 7
GEOLOGY OF KNIGHT ISLAND
(From Moffit, 1954)



Kog – Greenstones   Kos – Sedimentary rocks   Koc - Conglomerate

Tatitlek Greenstones: There are two large bodies of greenstone near Tatitlek, one on the west side the Tatitlek Narrows and the other east of the village between Landlocked Bay and Galena Bay Predominate rock types are basaltic and andesitic volcanics of the Orca Group (Kog) as shown in Figure 4-8. Orca Group sedimentary rocks (Kos) were mapped by Moffit on Bligh Island and included siltstone, mudstone and sandstone. A small area of conglomerate (Komc) was mapped on the south tip of the island. Similar rocks were mapped on Glacier Island along with a basaltic sheeted dike complex near Chamberlain Bay (Moffit, 1954).

FIGURE 4 - 8
GEOLOGY OF TATITLEK AND GLACIER ISLAND
(From Moffit, 1954)



The greenstones in Prince William Sound appear to exhibit alteration and weathering and therefore may not be retain enough of their original hardness to produce hard aggregate. There may be some areas where the rock is still hard enough to produce hard aggregate, but it is difficult to identify from mapping. While there may be some potentially useable rock in this area for producing hard aggregate, the land status near Tatitlek is unclear. Conservation easements in several areas including Bligh Island makes it difficult to determine if and where mining could occur. Glacier Island appears to be on Forest Service Land. It appears to be used as a sea lion pull out and therefore may not be available for mining.

Igneous Intrusives: There are nine (9) larger granitic plutons in Prince William Sound as shown on the following Figures 4-9 through 4-13 including several smaller gabbro stocks or dikes. The granitic plutons intrude both the Valdez and Orca sedimentary and volcanic rocks. Marginal zones of the granitic plutons contain inclusions of country rock with thermal aureoles extending outward from the pluton for distances up to 0.5 miles into the country rock.

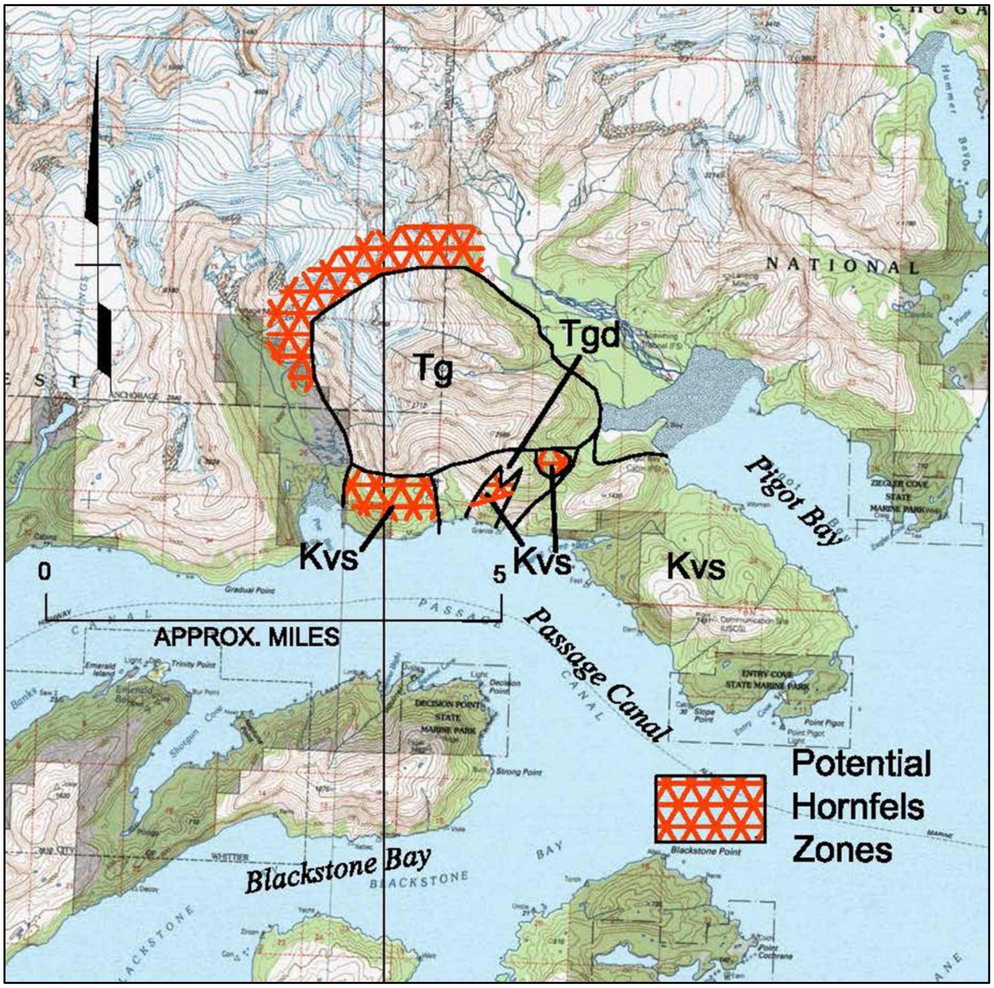
These Prince William Sound granite intrusive have been further subdivided as per Nelson et al., (1985):

> <u>Tg:</u> Granites and Granodiorite (Oligocene), “The central parts of the plutons are dominantly light-gray, medium to coarse-grained granite with color index ranging from 3 to 8. The plutons grade outward to fine to medium-grained, more mafic mineral-rich (color indices of 10 to 20) margins of granitic, granodiorite, and sometimes tonalite compositions” (Nelson et al., 1985). One-half mile thermal aureoles spread out from edges of plutons. Found near Billings Glacier on Passage Canal, on Ester Island, Perry Island, and Cupper Island,
>
> <u>Tgg</u>: Granites and Granodiorite (Eocene). The older of the two intrusive events is represented by plutons in the central parts of Prince William Sound, and intrudes both the Orca and Valdez Groups. Surface exposures range from less than 0.3 mile (Ragged Mountain) to greater than 55 miles at the Sheep Bay pluton. Faults truncate a few of the bodies, but elsewhere the plutons are surrounded by contact-metamorphic aureoles. Plutons of this unit are generally medium to coarse-grained, hypidiomorphic-granular biotite-granite with border phases of biotite- hornblende-granite to granodiorite and tonalite. Found on Wells Bay, Sheep Bay, and at Sheridan Glacier.
>
> <u>Tgd</u>: Gabbro and Diorite. “These rocks are dominantly medium to coarse-grained gabbro and subordinate diorite with finer-grained borders of quartz gabbro and quartz diorite. The color index varies from a range of 30 to 70 in the gabbro and diorite to a range of 20 to 40 in the quartz diorite” (Nelson et al., 1985). There is no mention of thermal aureoles surrounding the gabbros and diorites. Found on Ester Island, Eshamy Lagoon and Passage Canal.

<u>Billing Glacier Intrusive:</u> (Figure 4-9). The Bering Glacier Intrusive is one of the smallest granite (Tg) plutons in Prince William Sound and lies on the north side of Passage Canal. Potential hornfels zones lie on the southern, eastern and northern edges of the pluton. A gabbro (Tgd) is mapped on the south side of the pluton. Most of the potential hornfels zone is on Chugach National Forest land although some hornfelsmay be on State of Alaska land along the southeast and eastern edge of the pluton (dark green area on map).

<u>Ester, Culross, and Perry Island Intrusives:</u> (Figure 4-10). Granitic plutons are found on Ester, Culross and Perry Islands. They lie outside the portion of the Port Nellie-Juan College Fiord Wilderness Study Area that has been recommended as wilderness. There are two small State Parks on Esther Island, both of which appear to lie outside of the potential hornfels zone.

FIGURE 4 - 9
BILLING GLACIER INTRUSIVE
(Modified from Nelson et al., 1985)



Tg – Granite   Tgd – Gabbro   Kvs – Valdez Group sedimentary rock

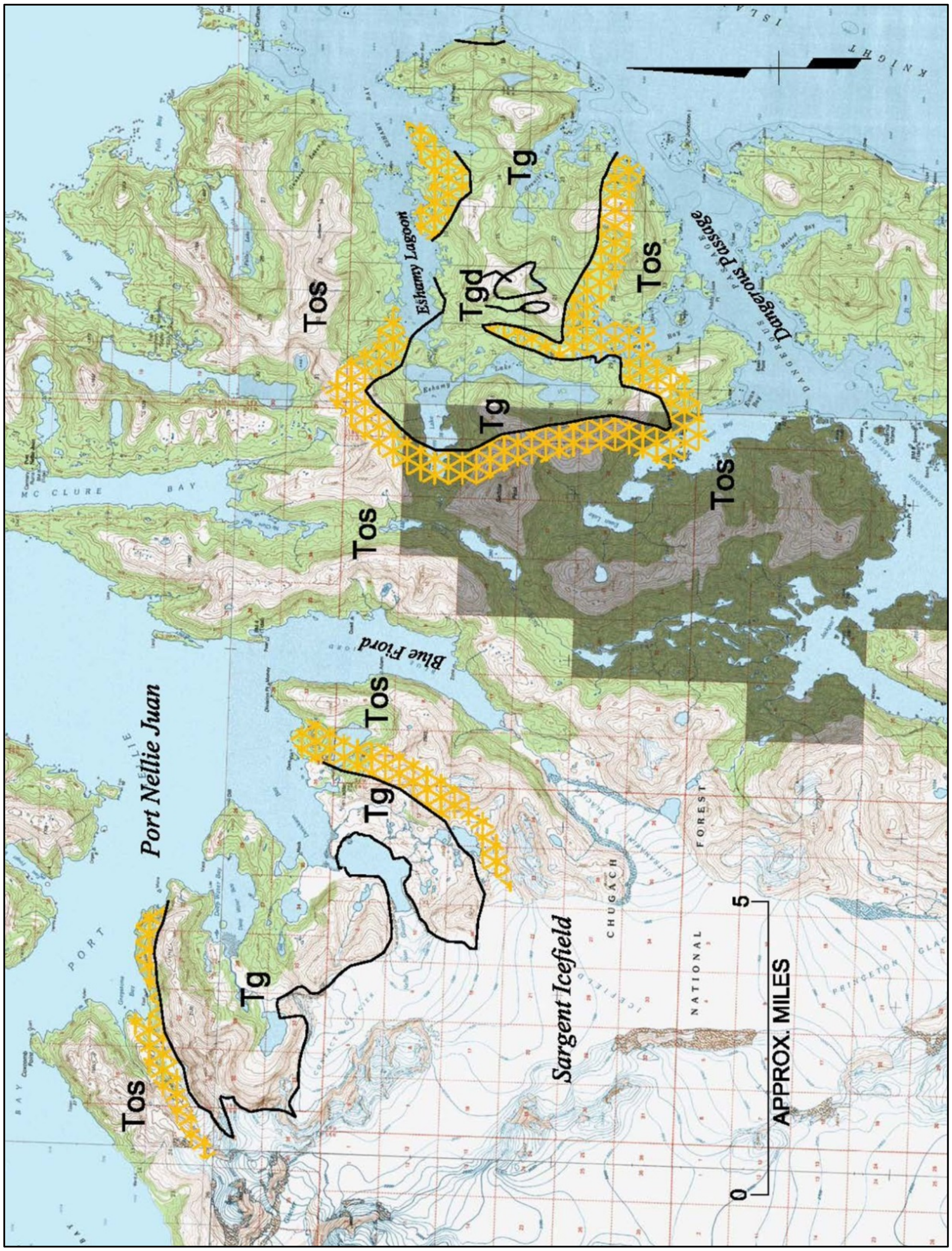
Port Nellie Juan and Eshamy Lagoon Intrusives: (Figure 4-11) The Port Nellie Juan Pluton lies between Port Nellie Juan and Blue Fiord. It is within the Port Nellie-Juan College Fiord Wilderness Study Area which has been recommended for inconclusion as wilderness. The area will likely not be permitted for mining. The Eshamy Lagoon pluton is a granitic intrusive that lies south of Eshamy Lagoon and north of Dangerous Passage. The surface estate was purchased by the State of Alaska from the Chenega Bay Corporation. The subsurface estate is owned by the Chugach Native Corporation. Covenants in the warranty deed to the State of Alaska appear to preclude any mining operations in the Eshamy Lagoon area (OSL 1159).

Wells Bay Intrusive: (Figure 4-12) The Wells Bay Pluton lies between Wells Bay and Glacier Island. It is within the Port Nellie-Juan College Fiord Wilderness Study Area. Therefore the area will likely will not be permitted for mining.

FIGURE 4 - 10
NORTHWEST PRINCE WILLIAM SOUND INTRUSIVES
(Modified from Nelson et al., 1985)

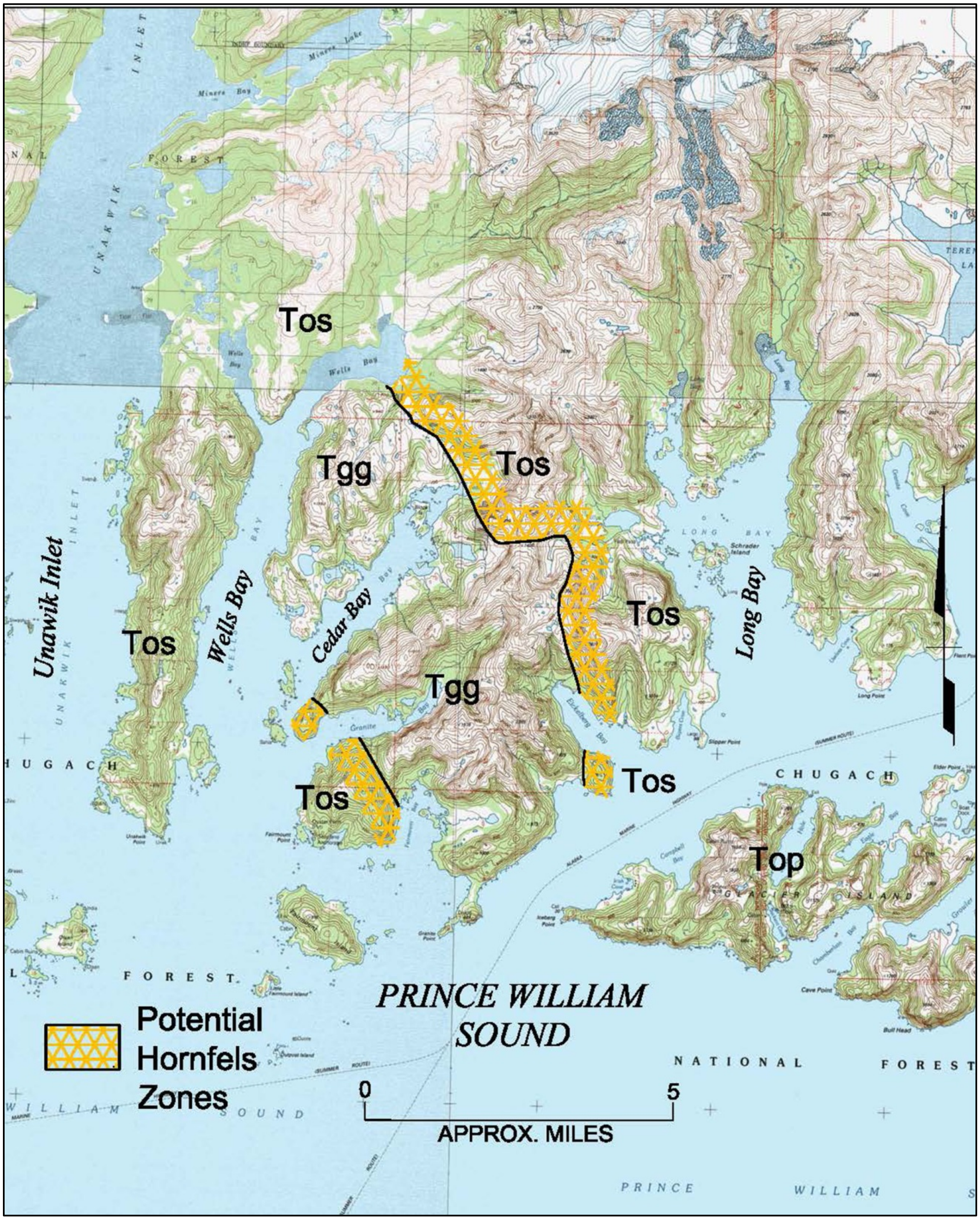
Tg – Granite Pluton   Tgd – Grabbro
Kvs – Valdez Group sedimentary Rocks   Tos – Orca Group sedimentary rocks

FIGURE 4 - 11
PORT NELLIE JUAN & ESHAMY LAGOON INTRUSIVES
(Modified from Nelson et al., 1985)



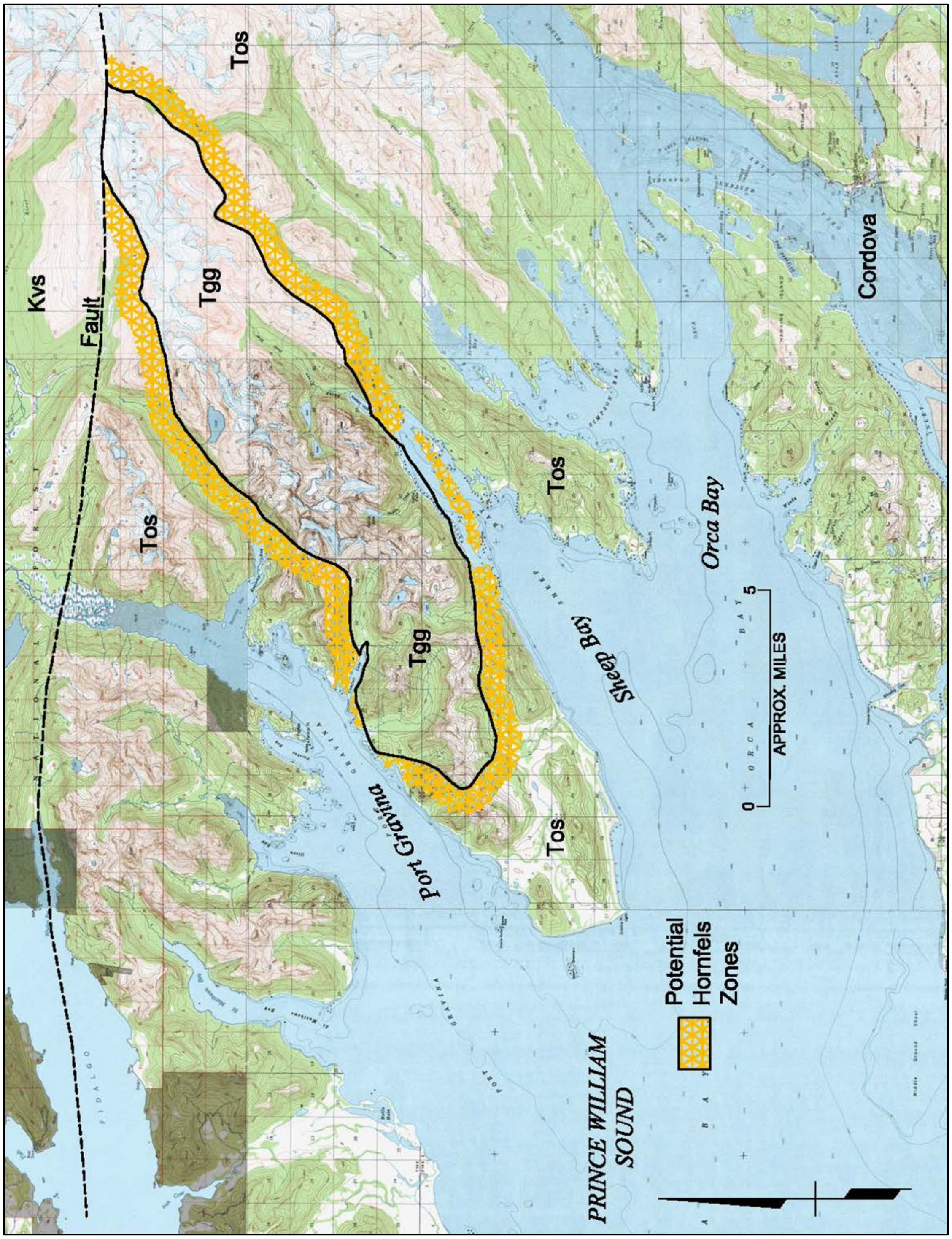
Tos – Orca Group sedimentary rocks Tg – Granite Tgd - Gabbro
The western intrusive lies within a wilderness study area. The eastern intrusive at Eshamy Lagoon lies on land with use restrictions that will not allow mining.

FIGURE 4 - 12
WELLS BAY INTRUSIVE
(Modified from Nelson et al., 1985)



Tos – Orca Group sedimentary rocks Top – Orca Group greenstone
The Tgg intrusive and associated hornfelses lie within a wilderness study area.

FIGURE 4 - 13
SHEEP BAY INTRUSIVE
(Modified from Nelson et al., 1985)



Tgg – Granite/Granodiorite   Tos – Orca Group sedimentary rocks
Kvs – Valdez Group volcanic rocks

Sheep Bay Intrusive: (Figure 4-13) The Sheep Bay Pluton is a large elongated granitic intrusive on a peninsula between Sheep Bay and Port Gravina approximately 10 miles north of Cordova. The east end of the pluton is cut by a fault. Hornfels may be potentially found around the southern and northern margins of the pluton. The State of Alaska appears to own land at the west end of the peninsula and the Chugach Native Corporation owns a parcel of land in the center of the pluton. The remainder of the pluton appears to be owned by the Federal Government which is part of the Chugach National Forest. Of all the plutons in the regions this area appears to have the most potential for providing a quarry to produce hard aggregate.

Sheridan Glacier Intrusive: The Sheridan Glacier Pluton is located on the east side of the Sheridan and Sherman Glaciers at MP19 of the Copper River Highway. The contact zone between the igneous granite and granodiorite and the Orca Group sedimentary rock (Tos) lies between two creeks and is mapped between the highway and the headwaters of Salmon Creek. The area lies on Chugach National Forest land and is apparently within the Scott-Sheridan Travel Management Area, which is open to motorized vehicles use yearlong, according to the U.S. Forest Service Motor Vehicle Use Map for Chugach National Forest Map #3. A Potential Hard Aggregate Source Report was prepared for this site.

4.10 Selected References

Albanese, M., Kline, J.T., Bundtzen, T.K., and Kline, K., 1983, Reconnaissance geology and geochemistry of the Willow Creek-Hatcher Pass area, Alaska: Alaska Division of Geological and Geophysical Surveys Public-Data File 83-9, 1 sheet 1:63,360.

Bradley, D.C., Parrisch, Randall, Clendenen, William, Lux, Daniel, Layer, P.W., Heizler, Matthew, and Donley, Thomas, 1998, New geochronological evidence for the timing of early Tertiary ridge subduction in southern Alaska, *in* Kelley, K.D. and Gough, L.P., Geological Studies in Alaska by the U.S. Geological Survey, 1998: U.S. Geological Survey Professional Paper 1615, p. 5-21.

Bradley, D.C., Kusky, T.M., Haeussler, P.J., Karl, S.M., and Donley, D.T., 1999, Geologic map of the Seldovia Quadrangle, south-central Alaska: U.S. Geological Survey Open-File Report 99-18.

Burns, L.E., Pessel, G.H., Little, T.A., Palvis, T.L., Newberry, R.L., Winkler, G.R., and Decker, J.E., 1991, Geology of the northern Chugach Mountains, south-central Alaska: Alaska Division of Geological and Geophysical Surveys Professional Report 94, 63 p., 2 sheets, scale 1:63,360.

Burns, L.E., Little, T.A., Newberry, R.J., Decker, J.E., and Pessel, G.H., 1983, Preliminary geologic map of parts of the Anchorage C-2, C-3, D-2, and D-3 quadrangles, Alaska: Alaska Division of Geological & Geophysical Surveys Report of Investigation 83-10, 3 sheets, scale 1:25,000.

Calderwood, K.W., and Fackler, W.C., 1972 Proposed stratigraphic nomenclature for Kenai Group, Cook Inlet basin, Alaska: American Association of Petroleum Geologist Bulletin, v. 56, no. 4, p. 739-754.

Clark, S.H.B., 1972, Reconnaissance bedrock geologic map of the Chugach Mountains near Anchorage, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map 350, 1 sheet, scale 1:250,000.

Clark, S.H.B., 1983, Reconnaissance geologic map of the Chugach Mountains in the Anchorage C-5 and C-6 quadrangles, Alaska: U.S. Geological Survey Open-File Report 83-336, 1 sheet, scale 1:63,360.

Clautice, K.H., Newberry, R.J., Blodgett, R.B., Bundtzen, T.K., Gage, B.G., Harris, E.E., Liss, S.A., Miller, M.L., Reifenstuhl, R.R., Clough, J.G., and Pinney, D.S., 2001, Bedrock geologic map of the Chulitna region, southcentral Alaska: Alaska Division of Geological & Geophysical Surveys Report of Investigation 2001-1A, 31 p., 1 sheet, scale 1:63,360.

Csejtey, Bela, Jr., Mullen, M.W., Cox, D.P., and Stricker, G.D., 1992, Geology and geochronology of the Healy quadrangle, south-central Alaska: U.S. Geological Survey Miscellaneous Investigations Series Map 1961, 63 p., 2 sheets, scale 1:250,000.

Csejtey, Bela, Jr., Nelson, W.H., Jones, D.L., Silberling, N.J., Dean, R.M., Morris, M.S., Lanphere, M.A., Smith, J.G., and Silberman, M.L., 1978, Reconnaissance Geologic map and geochronology, Talkeetna Mountains quadrangle, northern part of Anchorage quadrangle, and southwest corner of Healy quadrangle, Alaska: U.S. Geological Survey Open-File Report 78-558A. 62p., 1 sheet, scale 1:250,000.

Hartman, D.C., Pessel, G.H., and McGee, D.L., 1974, Stratigraphy of the Kenai group, Cook Inlet: Alaska Division of Geological & Geophysical Surveys Alaska Open-File Report 49, 7 p., 11 sheets, scale 1:500,000.

Karlstrom, T.N.V., 1964, Quaternary geology of the Kenai Lowland and glacial history of the Cook Inlet region, Alaska: U.S. Geological Survey Professional paper 443, 69 p., 7 plates, 1:250,000 and other scales.

Kelley, J.S., 1984, Geologic map and sections of the southwestern Kenai Peninsula west of the Port Graham Fault, Alaska: U.S. Geological Survey Open-File Report 84-152, 1 sheet, scale 1:63,360.

Moffit, F.H., 1954, Geology of the Prince William Sound region, Alaska: U.S. Geological Survey Bulletin 989-E, p. 225-310, 1 sheet.

Nelson, S.W., Dumoulin, J.A., and Miller, M.L., 1985, Geologic map of the Chugach National Forest, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map 1645-B, 16 p., 1 sheet, scale 1:250,000.

Pavey, Finkbiner, Binghan, 2012, Web interface http://10.200.100.100/hard/aggregatestudy/ (Note this web interface is available only to DOT&PF personnel).

Pavlis, T.L., 1986, Geologic map of the Anchorage C-5 Quadrangle, Alaska: Alaska Division of Geological & Geophysical Surveys Public Data File 86-7, 57 p., 3 sheets, scale 1:63,360.

Reed, B.L., and Nelson, S.W., 1980, Geologic map of the Talkeetna quadrangle, Alaska: U.S. Geological Survey, Miscellaneous Investigation Series Map I-1174, 15 pages, 1 plate, scale 1:250,000.

Richter, D.H., 1965, Geology and mineral deposits of central Knight Island, Prince William Sound, Alaska: Alaska Division of Mines and Minerals Geologic Report 16, 40 p., 1 sheet, scale 1:40,000.

Tysdal, R.G. and Case, J.E., 1979, Geologic map of the Seward and Blying Sound quadrangles, Alaska: U.S. Geological Survey Miscellaneous Investigations Series Map 1150, 12 p., 1 sheet, scale 1:250,000.

Wiedmer, Michael, Montgomery, D.R., Gillespie, A. R., and Greenberg, Harvey, 2010, Late Quaternary megafloods from Glacial Lake Atna, southcentral Alaska, U.S.A., Quaternary Research 73, p. 413-424, http://gis.ess.washington.edu/grg/publications/pdfs/Wiedmer_etal_2010.pdf.

Wilson, F.H., Dover, J.H., Bradley, D.C., Weber, F.R., Bundtzen, T.K., and Haeussler, P.J., 1998, Geologic map of Central (Interior) Alaska: U.S. Geological Survey Open-File Report 98-133-A.

Wilson, F.H., Hults, C.P., Labay, K.A., and Shew, Nora, 2008, Preliminary integrated geologic map databases for the United States: digital data for the reconnaissance geologic map for Prince William Sound and the Kenai Peninsula, Alaska: U.S. Geological Survey Open-File Report 2008-1002, 1 p.

Wilson, F.H., Hults, C.P., Schmoll, H.R., Haeusler, P.J.., Schmidt, J.M., Yehle, L.A., Labay, K.A. (Map Compilers) Wilson, F.H., Hults, C.P., Labay, K.A., Shew, N. (Digital Files Preparers), 2009, Preliminary Geologic Map of the Cook Inlet Region, Alaska-including parts of the Talkeetna, Talkeetna Mountains, Tyonek, Anchorage, Lake Clark, Kenai, Seward, Iliamna, Seldovia, Mount Katmai, and Afognak 1:250,000-scale quadrangles, U.S. Geological Survey Open-File Report 2009-1108, Version 1.

Wilson, F.H., Hults, C.P., Schmoll, H.R., Haeussler, P.J., Schmidt, J.M., Yehle, L.A., and Labay, K.A., 2012, Geologic map of the Cook Inlet region, Alaska, including parts of the Talkeetna, Talkeetna Mountains, Tyonek, Anchorage, Lake Clark, Kenai, Seward, Iliamna, Seldovia, Mount Katmai, and Afognak quadrangles: U.S. Geological Survey Scientific Investigations Map 3153, 76 p., 2 sheets, scale 1:250,000.

Winkler, G.R., 1992, Geologic map, cross sections and summary geochronology of the Anchorage 1 degree x3 degrees Quadrangle, southern Alaska, U. S. Geological Survey Miscellaneous Investigations Series Map I-2283, 1 sheet, scale 1:250,000.

Winkler, G.R. and Plafker, George, 1993, Geologic map of the Cordova and Middleton Island quadrangles, Southern Alaska: U.S. Geological Survey Miscellaneous Investigations Series Map 1984, 1 sheet, scale 1:250,000.

5.0 ALASKA PENINSULA, ALEUTIAN ISLANDS, AND KODIAK ISLAND

There is little to no local demand for hard aggregate in the Alaska Peninsula, Aleutian Islands or Kodiak Island. Kodiak Island has demand for acceptable paving aggregate, but it doesn't necessarily have to be hard aggregate. With the exception of Kodiak and Unalaska, there is little infrastructure in place to mine and transport aggregates and without port facilities, weather conditions can make loading and shipping difficult. For these reasons and the land issues discussed below, it is unlikely that hard aggregates for paving will be produced in significant quantities in this part of Alaska. The major demand for hard rock will likely be for armor stone.

Much of the Alaska Peninsula and Aleutian Islands are part of the Alaska Maritime National Wildlife Refuge (Aleutian Island and Alaska Peninsula Units), Aniakchak National Monument and Preserve, Katmai National Park and Preserve, Izembek National Wildlife Range, and the Becharof National Wildlife Refuge, plus several wilderness areas and other designated restricted development areas. These areas were precluded from this study. Several of the most promising remaining areas including Unalaska, Sand Point and Chignik had previous investigations, therefore additional studies were not prepared for them. The few remaining alternative areas did not have promising potential sources and thus no potential hard aggregate source reports were prepared for southwest Alaska or Kodiak Island.

Vicinity maps for the Alaska Peninsula, Aleutian Islands and Kodiak Island are presented as Figures 5-1 and 5-2.

5.1 General Geology

The Alaska Peninsula is part of the Aleutian arc which forms the northern rim of the Pacific Basin. Bedrock on the peninsula includes mostly Mesozoic to Holocene volcanic and plutonic rocks as well as shallow marine and continental deposits rich in volcanic detritus. The rocks are part of the Peninsular Terrane which occurs along the southern edge of South Central Alaska between the Alaska Peninsula and the Copper River Basin. Along the Alaska Peninsula the Peninsular Terrane is intruded by the Alaska Aleutian Range Batholith. Tertiary granitic intrusives and associated hornfels found throughout the Alaska Peninsula, Aleutian Islands and Kodiak Island are the primary potential source of hard aggregates in this part of Alaska. The more recent Cenozoic volcanic and sedimentary rocks generally are not expected to produce rock of the necessary hardness to produce hard aggregates.

5.2 Unalaska

Four existing quarries having Nordic Abrasion test values were found in close proximity to the town of Unalaska (Figure 5-3).

1. <u>Ruth Shaishnikoff Quarry (USS 8378):</u> This site appears to be located along the shoreline, 5.0 miles southwest of Unalaska.

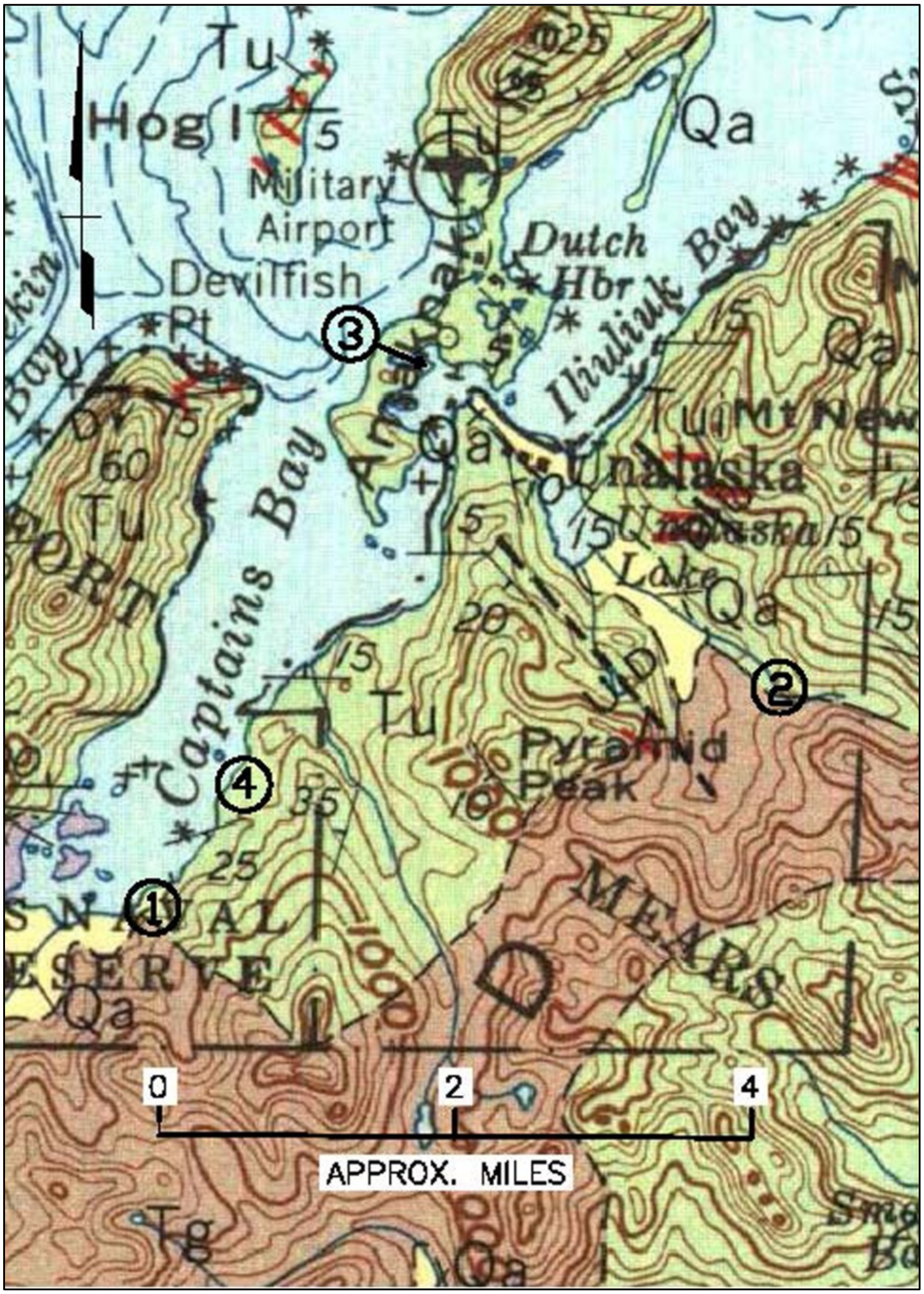
2. <u>Ugadaga Quarry:</u> Located atop a ridge about five miles by road southeast of Unalaska by road.

3. <u>Margarets Bay Quarry:</u> Located one mile southwest of the Unalaska Airport on Amaktak Island. This site is in a developed area that would be difficult to continue quarrying.

FIGURE 5 - 1
EASTERN ALASKA PENINSULA AND KODIAK ISLAND VICINITY MAP

FIGURE 5 - 2
WESTERN ALASKA PENINSULA AND ALEUTIAN ISLANDS VICINITY MAP

FIGURE 5 - 3
GEOLOGIC MAP OF UNALASKA
(Modified from Drewes et al., 1961)



Note: Numbers on map are keyed to the text.

4. Bering Shai Quarry: This quarry is located along the shore of Captains Bay, approximately 4 miles southwest of Unalaska. The quarry is apparently also known as the Captains Bay Quarry. Deep water is reported just offshore (U.S. Army Corps of Engineers, 2010).

Geology: Little documentation is available describing the lithology of rocks quarried in three of the four locations. That is particularly true of the rocks subjected to the Nordic Abrasion test for each site.

The quarries include rocks of the Unalaska Formation (Tu) and igneous rocks, predominantly granodiorite in composition (Tg), with contrasting border facies and assorted plutons (Drewes et al., 1961). The Unalaska Formation is composed of slightly altered andesite and basalt extrusive rocks, sills, and sedimentary rocks derived from similar igneous rocks. Conglomerates, graywackes and coarse breccias are the dominant sedimentary rocks in the northern and eastern part of the island. Finer epiclastic and pyroclastic rocks, particularly argillite, are dominant to the south. Belts of hydrothermal wallrock alteration surround the batholiths, which were themselves slightly altered by deuteric solutions, and several areas of wallrock have been dynamically metamorphosed when the adjacent batholiths were intruded. Significant hydrothermal alteration commonly occurs up to a distance of five miles from the nearest batholith. Minerals formed as a result of hydrothermal alteration include primarily epidote, albite, chlorite and uralite. Chalcedonic and cherty masses, as well as crystalline quartz masses, are common in some pillow lavas. Hornfelsed zones in sedimentary rocks have been reported in argillites adjacent to more mafic gabbros of the pluton.

1. Ruth Shaishnikoff Quarry, (USS 8378). The geologic map by Drewes et al. (1961), shows that the pit is located along the intrusive contact between the Unalaska Formation and a granodiorite batholith. The reported Nordic Abrasion test value was 5.9.

2. Ugadaga Quarry. This site is mapped as a cluster of three quarries atop a ridge overlooking the town of Dutch Harbor. Drewes et al. (1961), show the pits located along the intrusive contact between the Unalaska Formation and a granodiorite batholith. A reported Nordic Abrasion test value was 10.

3. Margarets Bay Quarry. Now inactive, the quarry is located in part of series of parallel glaciated bedrock ridges referred to as the Arch Rock Complex. The quarry is mapped by Drewes et al. (1961), as being composed rocks of the Unalaska Formation. Christie (1974), reported color anomalies caused by oxidation of disseminated pyrite in volcanic breccia, cut by small swarms of feldspar porphyry andesite and hornblende-biotite porphyry basalt (lamprophyre) dikes. Weakly mineralized dikes are oriented 010° dipping 80° E. Small quartz veins occur adjacent to some dikes, one of which has been reported as gold-bearing (Drewes et al, 1961). Rocks are regionally prophylitically altered or metamorphosed to low grade, locally highly iron stained with moderate to intense leaching. F.H. Wilson (1996) reported that an entire ridge at this location was being quarried for riprap and fill and being removed for commercial port development. The quarry site is now occupied by a series of buildings. The reported Nordic Abrasion test value was 11.3

4. Bering Shai Quarry: This site is located along the shore of Captains Bay and is mapped as being within a granodiorite pluton. Material has been reported to be a diorite but limited amounts of unweathered rock were reportedly observed in the quarry face in 2010 (U.S. Army Corps of Engineers, 2010). The reported Nordic Abrasion test value was 8.1.

The low Nordic Abrasion test results reported for the Unalaska Island sites appear to come from predominantly fine-grained igneous rocks that have been recrystallized by heat, including deuteric and hydrothermal solutions. One area likely to produce hard aggregates is the alteration zones along the boundary between the Unalaska Formation and the granodiorite batholith as seen in the Ruth Shaishnikoff and Ugadaga Quarries. However, alteration zones may occur within 5 miles of the batholith with low Nordic values such as that found in the Bering Shai Quarry. Thus, thorough field investigations are likely to uncover additional sites with low Nordic Abrasion test values in the vicinity of Unalaska.

5.3 False Pass, Cold Bay and King Cove

Bedrock in this area is dominated by Tertiary and Quaternary volcanic deposits which unconformably overlie Tertiary sedimentary rocks. Numerous small Tertiary intrusive bodies have been mapped in the area. These are described as small dikes, sills, and stocks of andesite, quartz diorite, or diorite containing phenocrysts of pyroxene or hornblende in a fine-grained groundmass. Additionally, a few outcrops of hypabyssal intrusions are described as being altered or hornfelsed.

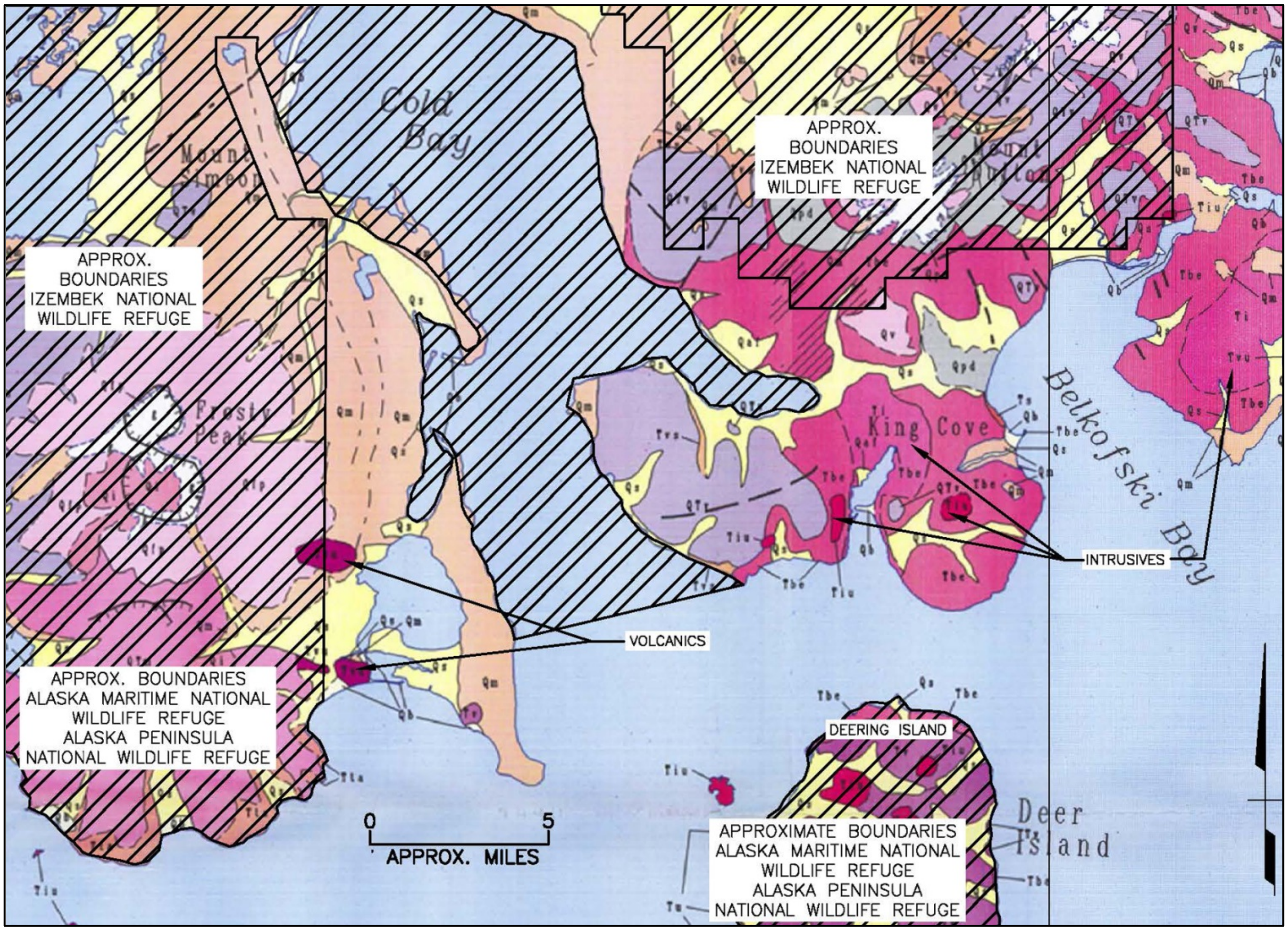
The most likely sources for hard aggregate in this area are the hydrothermally altered or Tertiary hornfelsed volcanic rocks (Tv or Tvu) or intrusive rocks surrounded by well-developed hornfels zones (Ti or Tiu) of Wilson et al. (1997). Many of these outcrops are within the Alaska Peninsula Unit of the Alaska Maritime National Wildlife Refuge and are likely unavailable. The only mapped outcrops of the volcanic rocks lying outside the refuge are south of Cold Bay in the vicinity of Thinpoint Lake as shown on Figure 5-4. These volcanics are noted as consisting of andesites, dacite, basalts, tuffs, lahar deposits, volcanic breccia and hypabyssal intrusions, all locally hornfelsed.

Tertiary intrusive rocks consisting of medium to coarse-grained, equigranular, granodiorite to quartz diorite plutons with stocks containing hornblende, biotite, and pyroxene and mafic minerals, are mapped in the vicinity of the village of King Cove, and on the east side of Belkofski Bay (Moss Cape pluton), as shown in Figure 5-4. These intrusives are typically surrounded by well-developed hornfels zones and sporadic hydrothermal alteration in country rock.

5.4 Sand Point and Shumagin Islands

Sand Point is located on Popof Island, part of the Inner Shumagin Islands. Bedrock on Popov Island is dominated by Tertiary volcanics, including lava flows, lahar deposits, debris-flow deposits, ash-flow tuff, and tuff. Tertiary sedimentary rocks of the Stepovak Formation are also present, consisting of siltstone and sandstone rich in volcanic debris. Several small intrusive bodies of Tertiary quartz diorite or diorite rocks are mapped on the east side of the island as shown in Figure 5-5.

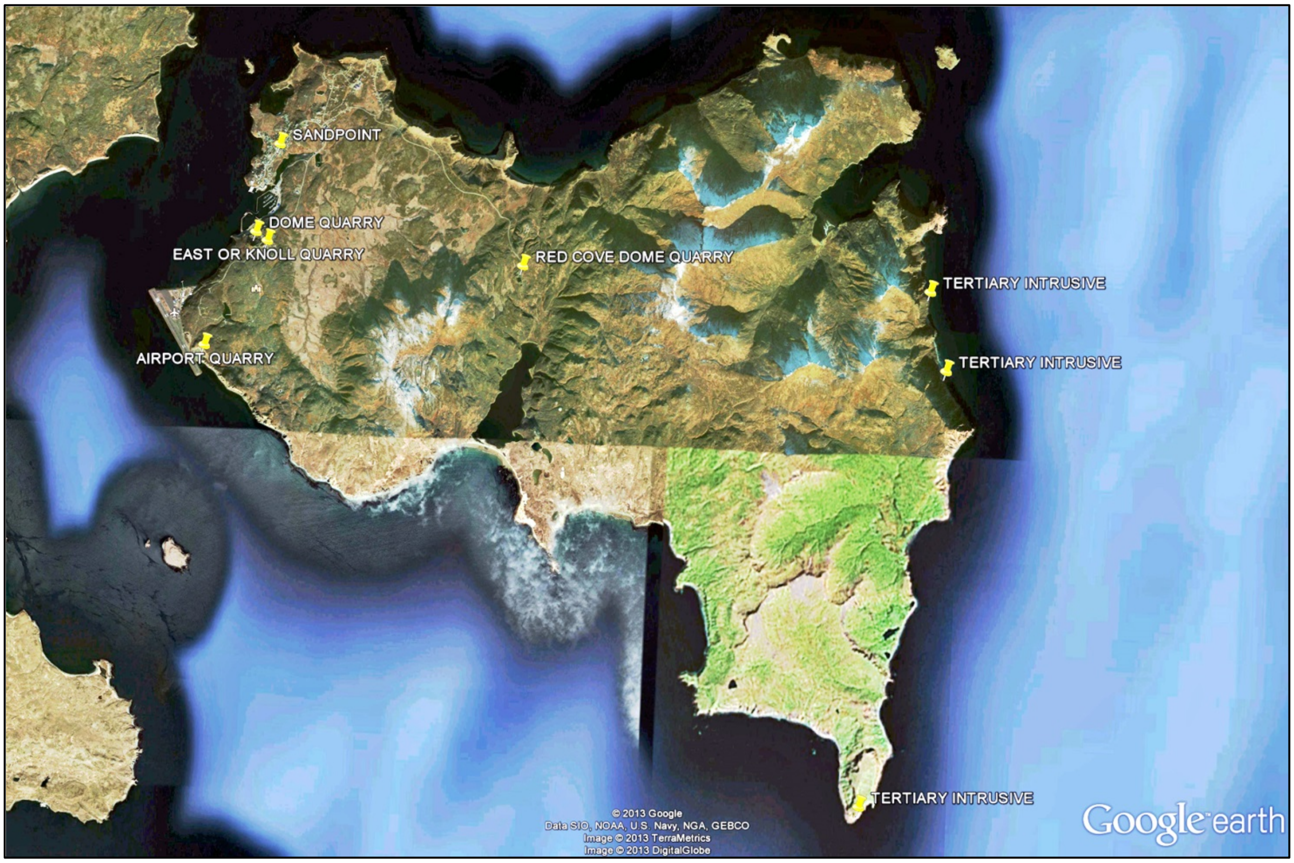
FIGURE 5 - 4
COLD BAY-KING COVE-BELKOFSKI-BAY VOLCANICS AND INTRUSIVE ROCKS
(Modified from Wilson et al., 1997)



Nordic Abrasion test results are available for three quarries on Popov Island as reported in Table 1-2. The three quarries (Dome Quarry, Knoll Quarry and the Red Cove Quarry) are all weathered basalt plugs with Nordic Abrasion values ranging from 12.8 to 19.1. The only rocks on Popof Island with potential for producing hard aggregate are interpreted to be the Tertiary intrusives. However, these rocks are of very limited extent, and there is no available information regarding the material properties or the presence of contact hornfels. Tertiary intrusions also appear to lie within the Alaska Peninsula Unit of the Alaska Maritime National Wildlife Refuge.

The Shumagin Islands are located to the southeast of Sand Point and consist primarily of the sedimentary Shumagin Formation and Tertiary granitic plutons. Minor hornfels were reported on the islands (Wilson et. al, 1995). The difficulty of access, and being in the Alaska Peninsula Unit of the Alaska Maritime National Wildlife Refuge make this an area of low potential for hard aggregate.

FIGURE 5 - 5
POPOV ISLAND AND SAND POINT



5.5 Perryville

Bedrock in the immediate vicinity of Perryville is dominated by Tertiary volcanic and sedimentary rocks. There is no indication from published mapping that these materials have been metamorphosed, nor are there any mapped intrusive rocks.

Well-developed hornfels and sporadic hydrothermal alteration in associated country rocks was noted surrounding Tertiary granodiorite to quartz diorite plutons at American Bay (approximately 40 miles to the southwest of Perryville) and on Mitrofania Island (approximately 14 miles east of Perryville) (Wilson et. al, 1995). However, both locations appear to lie within the Alaska Peninsula Unit of the Alaska Maritime National Wildlife Refuge and are likely unavailable for mining.

5.6 Chignik

Bedrock geology of the Chignik Bay area is dominated by a sequence of Upper Jurassic to Eocene sedimentary rocks which are unconformably overlain by Late Eocene to Early Oligocene volcanic rocks. The Tertiary formations consist predominately of non-marine, volcaniclastic, and carbonaceous sedimentary rocks. The underlying Mesozoic rocks are predominately marine sandstone, siltstone, and shale. These layered rocks are intruded by the Miocene age Devils Bay Batholith, consisting of medium to coarse-grained quartz diorite. A well-developed hornfels zone is mapped along the margins of the batholith as shown on Figure 5-6. The Devils Bay Batholith is mapped along the coast from Kuiukta Bay to Cape Kumlium, approximately 25 miles north of Chignik. Other small igneous intrusive bodies are mapped in the area, including andesite and basalt domes.

A Nordic Abrasion value of 24 was obtained from a sample of the Castle Bay Quarry at the head of Castle Bay. It appears that the sample came from an area that the sample was thermally altered, however the type of rock tested is not known. The mapped presence of hornfels in the Chignik area suggests that there is potential for hard aggregate in this area and further investigation is warranted.

5.7 Kamishak Bay to Iliamna Bay

Geology along the coast of Kamishak Bay is a complex mixture of sedimentary, metamorphic and igneous rock. The Bruin Bay Fault extends along the shoreline, dividing the area into two distinct geologic areas. Rocks west of the fault are dominated by the Alaska-Aleutian Range batholith and roof pendants of meta-volcanic, meta-sedimentary and sedimentary origin. East of the fault bedrock is entirely sedimentary, consisting of conglomerate, sandstone, siltstone and shale. These sediments have not been intruded or otherwise altered, and are therefore not a likely source for hard aggregate. Further discussion will be limited to the rocks west of the Bruin Bay Fault.

Jurassic age rocks of the Alaska-Aleutian Range batholith consist of medium to coarse-grained quartz monzonite and quartz diorite. These rocks are not expected to be a source for hard aggregate; however, the contact metamorphic zone in the country rocks around the pluton may contain potential sources. The most promising units are the Triassic age Cottonwood Bay greenstone (TRc), and the Jurassic age Talkeetna Formation. Outcrops of the Cottonwood Bay greenstone are present in Pile Bay, Cottonwood Bay, Iliamna Bay, and Ursus Cove (Figure 5-7). This rock unit is described as mainly mafic volcanic rocks altered to hornfels and chloritic greenschist, is extremely hard and forms massive, rugged outcrops. The Talkeetna Formation (Jtk) is a thick unit of volcanic rock outcropping in many locations along the coast of Kamishak Bay. While most of this formation consists of relatively unaltered volcanic breccia, agglomerate, lava flows and tuff, and is unlikely to produce hard aggregate, some of the lower portions close to the batholith may have been altered to hornfels (Detterman and Reed, 1980).

The other mapped units in the area are likely to be either too foliated, as is expected in the Kakhonak Complex, or too soft, as is expected in the sedimentary Kamishak Formation.

FIGURE 5 - 6
GEOLOGIC MAP OF CHIGNIK AND CASTLE BAYS
(Modified from Detterman et al., 1981)

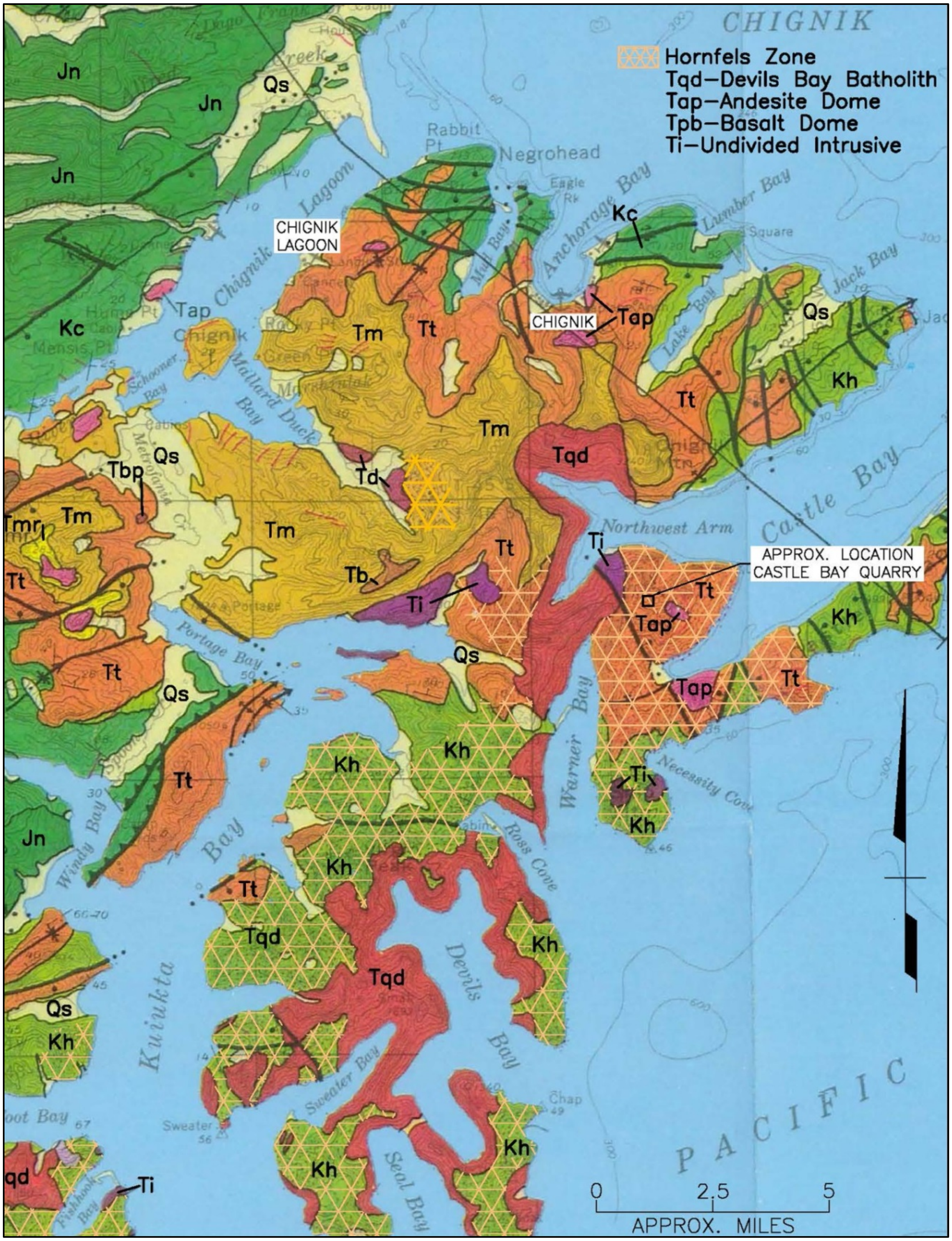
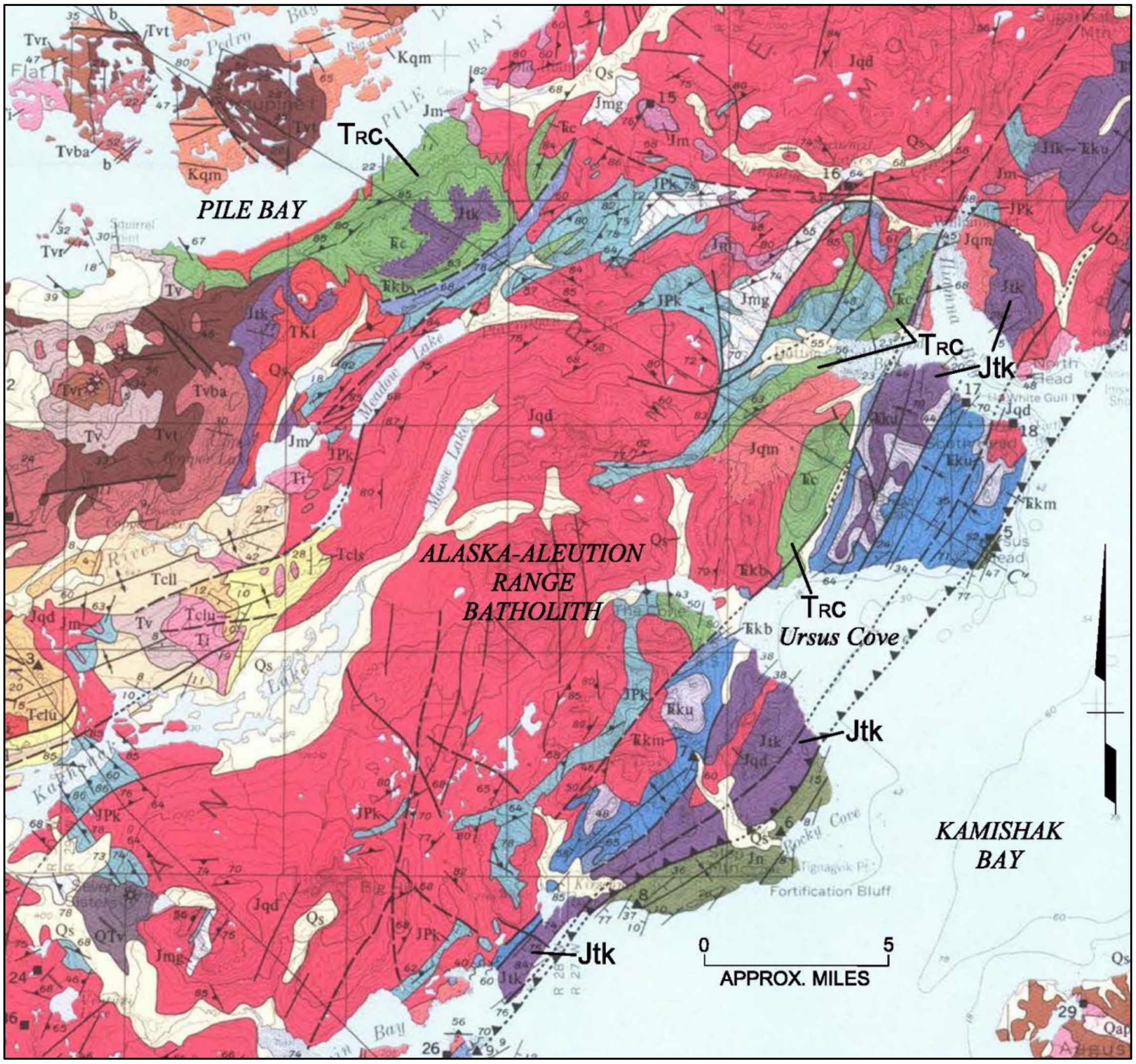


FIGURE 5 - 7
GEOLOGIC MAP OF KAMISHAK BAY TO PILE BAY
(Modified from Detterman et al., 1980)



Cottonwood Formation – TRc Talkeetna Formation – Jtk

5.8 Kodiak Island

Kodiak Island can be separated into three different belts of bedded rock. The southeastern belt is composed of Tertiary sediments separated from a sequence of Cretaceous rock by a northeast-trending normal fault. These sediments in turn are separated from older Triassic-Jurassic rocks by a northeast-trending thrust fault to the west. All three groups have been intruded by Tertiary granodiorite masses (Moore, 1967).

Tertiary sediments lie to the southeast of the Contact Fault, a major northeast trending normal fault extending from Kalsin Bay to Portage Bay and probably beyond to the south. The sediments include the entire Tertiary sequence from Paleocene to Pliocene. Both marine and continental sediments are represented including shales, sandstones, and conglomerates. Sandstones consist of subangular to rounded grains of predominantly quartz with minor feldspar, chert and other rock types. Conglomerates contain pebbles of chert, graywacke, limestone and granitic rocks. Northwest of the Contact Fault, rocks are predominately Upper Cretaceous flysch deposits consisting of turbidite sequences of argillite and graywacke. These sediments have been variably metamorphosed to zeolite to low-greenschist facies, and have been moderately to highly deformed. These unsorted sediments are bounded on the northwest by the Uganik and Border Ranges Faults, and cover extensive areas in the western part of Kodiak Island. Northwest of the Uganik and Border Ranges Faults, rocks consist of a Middle Cretaceous to Lower Jurassic mélange assemblage of basalt, schist, and oceanic sedimentary rocks. An elongate granodiorite mass occupies the axial core of Kodiak Island and is continuous from Kizhuyak Bay on the north to Alitak Bay on the south. Petrographic examination of samples from this granodiorite mass shows that the texture is coarse to medium-grained, consisting of quartz and light colored plagioclase feldspars with common darker minerals, predominantly biotite mica. The smaller intrusives are similar both in texture and chemical composition to the large granodiorite mass and represent satellite intrusives or genetically related rock masses. One of these intrusives is the proposed Shakmanof Cove Quarry on Kizhuyak Point between Anton Larsen Bay and Shakmanof Cove northwest of Kodiak. Nordic Abrasion values ranging from 10.3 to 20 were reported from this site (U.S. Army Corps of Engineers, Alaska District, 2010). Numerous dikes and sills that have similar chemical properties to the intrusives, but are of finer-grained texture, were noted and mapped by Capps (1937). These dikes and sills are usually associated with the intrusive bodies, but some occur without a direct relationship.

Generally, the geology of Kodiak Island does not appear conducive to hard aggregate production. Most of the island is composed of relatively soft sedimentary rock, or highly foliated low-grade meta-sediments. The igneous intrusives are generally too coarse-grained to have low Nordic Abrasion values. One area that may be suitable for the production of hard aggregate would be on the margins of the Tertiary granodiorite intrusive where contact metamorphism may have resulted in alteration to hornfels. To date these types of contact deposits have not been noted in the literature.

5.9 Selected References

Capps, S.R., 1937, Kodiak and adjacent islands, Alaska: U.S. Geological Survey Bulletin 880-C, p. 111-184, 1 sheet.

Collier, A.J., 1905, Auriferous quartz veins on Unalaska Island: U.S. Geological Survey Bulletin 259, p. 102-103.

Christie, J.S., 1974, Aleut-Quintata-Duval 1974 joint venture final report: unpublished Quintana Minerals Corporation report available from the Aleut Corporation, 24 p., appendices, 2 maps in pocket.

Detterman, R.L. and Reed, B.L., 1980, Stratigraphy, structure, and economic geology of the Iliamna quadrangle, Alaska. U.S. Geological Survey Bulletin 1368-B.

Detterman, R.L., Miller, T.P., Yount, M.E., and Wilson, F.H., 1981, Geologic map of the Chignik and Sutwik Island quadrangles, Alaska: U.S. Geological Survey Miscellaneous Investigations Series Map 1229, 1 sheet, scale 1:250,000.

Drewes, H.F., Fraser, G.D., Snyder, G.L., and Barnett, H.F., Jr., 1961, Geology of Unalaska Island and adjacent insular shelf, Aleutian Islands, Alaska: U.S. Geological Survey Bulletin 1028-S, p. 583-676, 4 sheets, scale 1:250,000.

Green, K. and Warren, G, 2007, Investigation of sources for armor stone and site conditions for Unalaska Airport Project: Prepared by CH2M HILL as part of Unalaska Airport Master Plan Update, 94 p.

Moore, G.W., 1967, Preliminary geologic map of Kodiak Island and vicinity, Alaska: U.S. Geological Survey Open-File Report 67-161, 2 sheets, scale 1:250,000.

Simpson, D.F., 1986, Aleutian Islands project 1985 final report, Kennecott-Alaska Exploration: unpublished report available from The Aleut Corporation, 54 p.

U.S. Army Corps of Engineers, Alaska District, 2010, Rock quarry potential, A preliminary investigation, State of Alaska: In cooperation with State of Alaska Department of Transportation and Public Facilities, 82p.

Wilson, F.H., 1996, Alaska resource data file; Unalaska quadrangle: U.S. Geological Survey Open-File Report 96-270, 48 p.

Wilson, F.H., Detterman, R.L., Miller, J.W., and Case, J.E., 1995, Geologic map of the Port Moller, Stepovak Bay, and Simeonof Island quadrangles, Alaska Peninsula, Alaska: U.S. Geological Survey Miscellaneous Investigations Series Map 2272, 2 sheets, scale 1:250,000.

Wilson, F.H., Weber, F.R., Dochat, T.M., Miller, T.P., and Detterman, R.L., 1997, Revised geologic map of the Cold Bay and False Pass quadrangles, Alaska Peninsula: U.S. Geological Survey Open-File Report 97-866, 34 p., 1 sheet, scale 1:250,000.

Vallier, T.L., Scholl, D.W., Fisher, M.A., Bruns, T.R., Wilson, F.H., von Huene, Roland , and Stevenson, A.J., 1994, Geologic framework of the Aleutian arc, Alaska, in Plafker, George, and Berg, H.C., The Geology of Alaska: Geological Society of America, p. 367-388.

6.0 SOUTHEAST ALASKA

Many of the potential hard aggregate sites in southeast Alaska are found along State highways, Forest Service roads or logging roads that can be used to access the coast and barge landings. Potential sites were generally located in the Tongass National Forest and on lands managed by the U.S. Forest Service. Areas in national parks and monuments, wilderness areas, and roadless areas, were eliminated from the potential study areas. A vicinity map for southeast Alaska is presented as Figure 6-1.

6.1 General Geology

Southeast Alaska is underlain by a complex and heterogeneous assemblage of rocks, and is cut by an intricate network of faults. The rocks record a long and complete geologic history beginning in the Proterozoic and continuing into the Holocene. These rocks can be subdivided into ten assemblages, five of which are terranes and five of which are in depositional or intrusive contact with the terranes. Stratified rocks in southeast Alaska consist of a series of northwest belts of various depositional ages and degrees of deformation and metamorphism. These belts occur along the east and west flanks of the Coast Mountains. The rocks along the east flank consist of schist, gneiss and marble with sedimentary and volcanic rocks extending eastward into British Columbia. Rocks along the west flank include an assemblage of metasedimentary and metavolcanic rocks. An extensive assemblage of pre-Jurassic strata occurs on the islands to the west, where a section of sedimentary and volcanic rocks is found that ranges in age from the Cambrian through the Late Triassic. Intrusive rocks mostly range from Cretaceous to Tertiary and occur on many of the islands west of the Coast Mountain batholith. Several phases of deformation and/or metamorphism have punctuated the evolution of southeastern Alaska, the most widespread event occurring during the Late Cretaceous and early Tertiary (Gehrels and Berg, 1994).

The northern cordillera of British Columbia and Alaska comprise the Coast Range and the Rocky Mountains. The Coast Range is underlain by the metamorphic plutonic rocks of the Coast Plutonic Complex. Less metamorphosed rocks lie west of the Coast Range in the insular superterrane and to the east in the intermontaine superterrane. The Coast Range is divided into three parallel belts that extend the length of southeast Alaska; the western metamorphic belt, the central pluton-gneiss belt and the eastern metamorphic belt. Rocks along the western metamorphic belt underlie the mountains along the inside passage and crop out along the Gravina Belt of the Insular super terrane. The central pluton-gneiss belt was created by collision of the insular and intermontaine super terrane of British Columbia, followed by magma intrusion during later subduction. Folding and faulting during the subduction and upthrust created metamorphic layering (foliation) that is generally subvertical.

The insular superterrane in southeast Alaska consists of four terranes west of the Coast Range. Three of these are parts of island arcs; the Alexander Terrane, the Wrangellia Terrane, and the Gravina Belt. The older Alexander Terrane may be between 500 and 240 million years old and stretches between the middle of the Alexander Archipelago from Prince of Wales Island through Admiralty Island through Haines. The Wrangellia Terrane may be between 150 and 250 million years old, and occurs in southeast only in the central portion of Chichagof Island. The youngest of the terranes is the Chugach, composed of sedimentary and metamorphic rocks,

FIGURE 6 - 1
SOUTHEAST ALASKA VICINITY MAP

which forms the western portion of Chichagof and Baranof Islands. Gravina Belt rocks formed a narrow marine basin on the eastern side of the Alexander Terrane (Stowell, 2006).

Moving toward the Coast Range, the rock generally becomes subject to more thermal alteration and recrystallization, which should make it harder, but it appears that it also subjects it to cataclastic deformation which weakens the rock. Foliation is common in rocks from Haines to Ketchikan. Foliated rocks are generally not strong enough to produce hard aggregates.

The best potential sources of hard aggregates in southeast Alaska are basalts with the two most extensive deposits along the Chilkat River near Haines and on Kupreanof Island. Pits in talus cones near the airport at Haines are being mined at present. Small quarries on Kupreanof Island have also been mined in the past. There are also scattered fine-grained intrusive igneous rocks throughout southeast Alaska, the most prominent being a gabbro near Herring Bay on Revillagigedo Island that may also provide sources of hard aggregate.

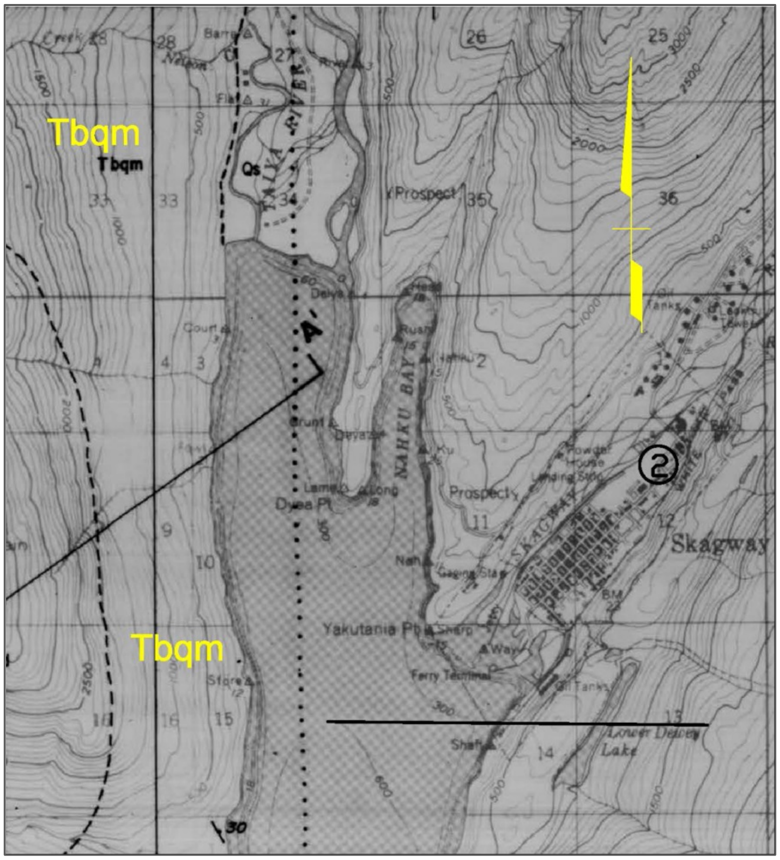
Hornfels is found in contact aureoles surrounding many of the igneous intrusives in southeast Alaska, making the most common potential sources of hard aggregate. Eight out of ten reports for potential sources included in this study involve hornfels, including, Kuiu Island, Zarembo Island, Etolin Island, Wrangell Island, Revillagigedo Island and three sources on Prince of Wales Island. Reports were not included for several other sources as they are located in wilderness areas, national monuments, roadless areas, or areas that would make for very difficult access.

6.2 Skagway Area

Bedrock in the Skagway area consists primarily of granitic rocks. Two mapped units were identified as fine-grained enough to have the potential for providing hard aggregates, but there is no test data available for either. A monzonite (Tbqm) near Dyea is accessible to the coast and may be worthy of further consideration. A fine to medium-grained granite (Tgr) is generally inaccessible. The two units are described below with further information being found in the referenced publications.

> Tbqm: Biotite quartz monzonite of the Burrow Creek Pluton. Rock is fine to medium-grained, subhedral granular with characteristic large poikoilitic plagioclase phenocrysts. Rock is 20% quartz, 15% biotite, 25% K-feldspar, and 40% plagioclase (Redman et. al., 1984). Found along the west side of Taiya Inlet near Dyea. See Figure 6-2.
>
> Tgr: Pink to buff, medium to fine-grained, equigranular biotite granite. Locally, near margins includes xenoliths of fine-grained diorite, diabase, and biotite gneiss, and is intruded by pegmatite dikes (Gilbert et al., 1990). This unit is found along the Canada border in locations that are generally inaccessible.

FIGURE 6 - 2
GEOLOGIC MAP OF SKAGWAY (Tbqm)
(Modified from Redman et al., 1984)

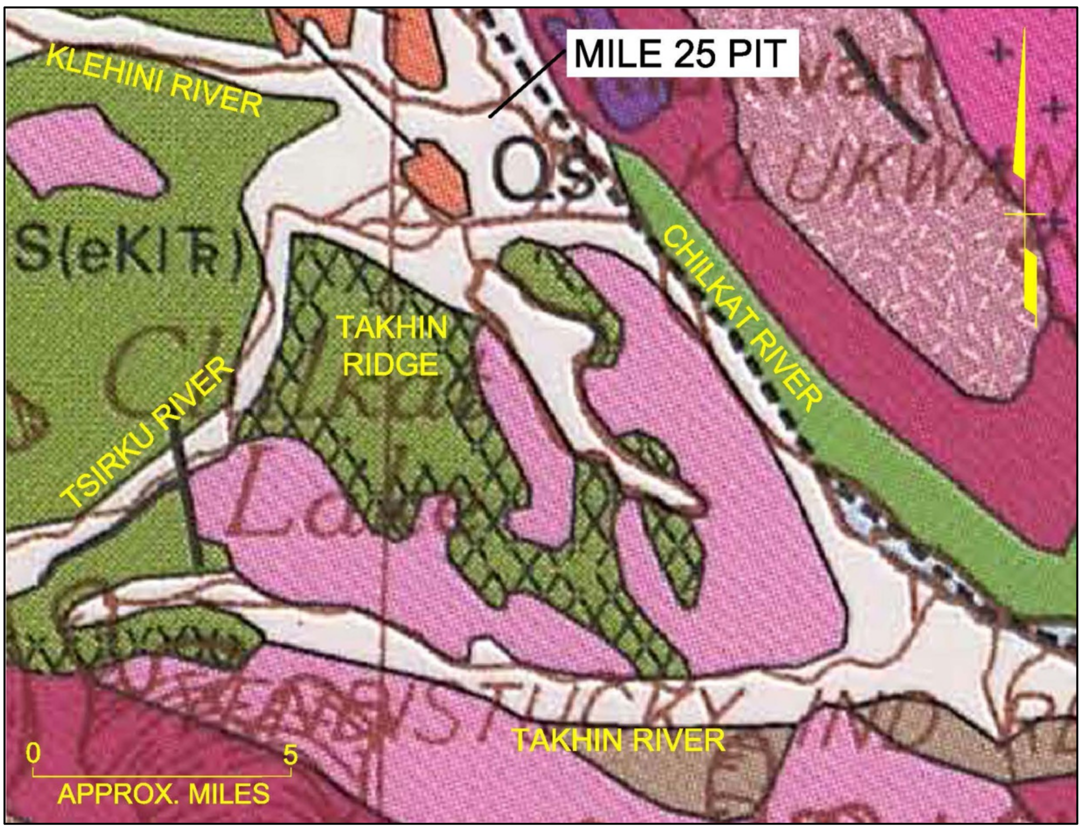


6.3 Haines Highway Area

Between Haines Airport and Klukwan, a metabasalt is exposed in a northwest-trending belt as much as one-half a mile wide along the base of the Takshanuk Mountains bordering the northeast side of the Chilkat River where it is in gradational contact with the gabbro-diorite complex. Most of the metabasalt in the Skagway B-3 Quadrangle near Klukwan is reportedly characterized by near-vertical foliation that strikes northwestward approximately parallel to the Chilkat River fault and the Takshanuk Mountains. A complex of altered gabbro and diorite occupies an extensive northwest-trending belt, as much as two miles wide, along the southwest flank of the Takshanuk Mountains. It is intruded by pyroxenite along sharp, steep contacts that strike mainly northwestward and generally transect foliation of the gabbroic rocks (MacKevett, Jr. et.al., 1974).

There are three known pits with Nordic Abrasion test values equal to or lower than 10 along this stretch of the highway. Potential Hard Aggregate Source Reports were prepared for these sources and are included in this report. It may also be possible to find other sources between 5.5 Mile and the Chilkat River Bridge. Two sites near Haines appear to be mining talus slopes and alpines fans composed of material fallen from the Takshanuk Mountains that is likely composed of metabasalt and diorite rocks. This material is a fine-grained igneous rock that typically can give low Nordic Abrasion values. However, the Nordic Abrasion values are not as low overall as one might expect for the rock types mapped, which may be due to local weakening of the rock during cataclastic processes that created the foliation throughout the region. Statements made by MacKevett, Jr. (1974) indicate that foliation may increase upriver and thus Nordic Abrasion values may increase as you go up river toward Klukwan. The area around Milepost 25 is in the floodplain of the Klehini River where a Nordic Abrasion value of 10 was achieved. This relatively low value in the Klehini floodplain may be due to hornfels eroded from Takhin Ridge into the abandoned Tsirku River floodplain between the two rivers, and thus into the Klehini River (see Figure 6-3). Other locations in the Tsirku and Takhin River floodplains to the south may have gravels with Nordic Abrasion values of less than 10. Portions of the Chilkat River floodplain may also be a potential source of hard aggregate.

FIGURE 6 - 3
TAKHIN RIDGE HORNFELS – KLEHINI RIVER MILE 25 PIT
(Modified from Dusel-Bacon et al., 1996)



Map showing the interpreted hornfels zones on Takhin Ridge. Cross hatch patterns are interpreted hornfels zones. These hornfels zones are subject to differing interpretations by different authors.

Most of the land adjacent to the Haines Highway along the Chilkat River is in Unit 7A of the Haines State Forest therefore land use issues may arise if mining is attempted on State lands. However, there are numerous private parcels along the highway.

Bedrock between Milepost 24 and the Canadian Border is highly foliated and thus would likely be too weak to be used in hard aggregate production (MacKevett, Jr. et al., 1974) and (R&M Consultants, Inc., 1992).

6.4 Juneau and Admiralty Island Area

The Juneau-Admiralty Island area stretches from Admiralty Island to Skagway along Stephens Passage and Lynn Canal and includes Douglas Island. The rocks along part of the coast consist of sedimentary, volcanic and igneous rocks of the Gravina Belt along Stephens Passage, against the metamorphosed and highly deformed Taku Terrane and the Coast Mountain Batholith to the east. The area around Juneau to Berners Bay is primarily mapped as mélange. Steep mountain slopes exist along the east side of Lynn Canal underlain by igneous rocks. Migmatites are found northeast of Haines. Potential hard aggregate sites were not identified within this area.

Most of Admiralty Island lies in the Admiralty Island National Monument and was thus excluded from this study.

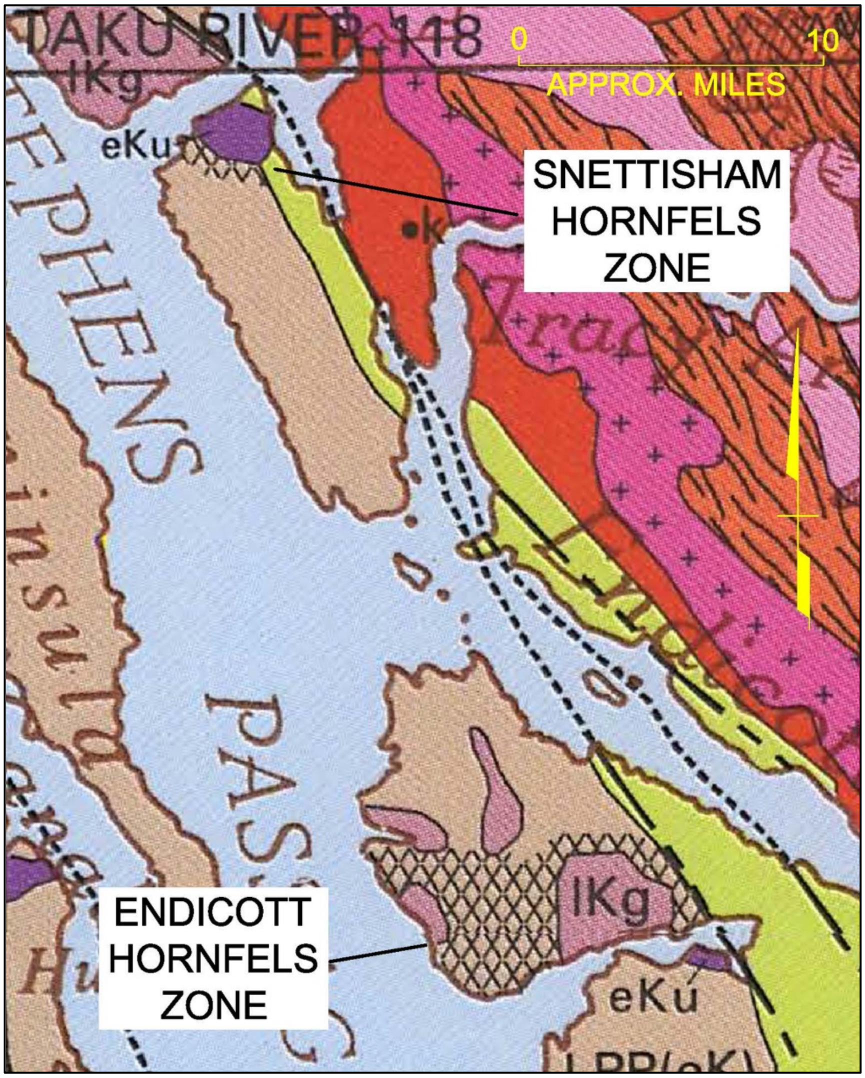
6.5 Snettisham and Endicott Peninsula Area

A hornfels contact metamorphic aureole one kilometer wide or more has been mapped adjacent to an ultramafic pluton on Snettisham Peninsula (Dusel-Bacon et al., 1996) as shown in Figure 6-4. Contact metamorphism was caused by the intrusion of a magnetically high ultramafic pluton (Brew et al., 1984) coming into contact with volcanic rocks and possibly sedimentary rocks (Gehrels et al. 1992). These thermally metamorphosed (or hornfelsed) rocks may have low Nordic Abrasion values. The area where the hornfels are mapped is steep and there are apparently no roads. The area is generally accessible only with great difficulty and thus has low potential for hard aggregate production.

An assemblage of low-grade metamorphic rocks on the Endicott Peninsula between Sumdum and Windham Bay have been mapped as having being hornfelsed to a width of approximately one kilometer or more by a series of intrusive plutons (Dusel-Bacon et al., 1996) as shown in Figure 6-4. These contact metamorphosed rocks as well as fine-grained volcanic and intrusive rocks appear to have the potential to produce low Nordic Abrasion values. The challenge will be to find rocks where recrystallization from thermal overprinting has removed foliation produced by regional metamorphism. These rock exposures of interest occur on the peninsula west of the Chuck River Wilderness.

The Endicott Peninsula is part of the western metamorphic complex in Southeast Alaska. Rocks consist of low-grade metamorphosed detrital and volcanic rocks of probable Paleozoic or early Mesozoic age cut by complicated granite, diorite, and hornblendite intrusions with locally “extensive contact-metamorphic effects” (Brew and Grybeck, 1984). There are no existing roads on this part of the peninsula as the terrain dips steeply onto the coast. Investigation of new sources and access to such sources may be difficult.

FIGURE 6 - 4
SNETTISHAM-ENDICOTT PENINSULA METAMORPHIC FACIES MAP
(Modified from Dusel-Bacon et al., 1996)



Map showing the interpreted hornfels zones on Snettisham and Endicott Peninsulas. The pink/purple units are igneous intrusives, the green/yellow/orange/gray units are metamorphic rocks generally derived from sedimentary and volcanic units and the cross hatch among the intrusives are interpreted hornfels zones. These hornfels zones are subject to differing interpretations by different authors. The dotted areas are unmetamorphosed rocks.

6.6 Chichagof, Baranof and Kruzof Islands Area

Stratified bedrock on Chichagof, Baranof and Kruzof Islands consists of a wide range of sedimentary and volcanic rocks and metamorphic rocks ranging from Silurian to Cretaceous in age. Some fine-grained volcanic rocks are found on Kruzof Island but they appear to be too weathered to produce hard aggregate. Three belts of northwest trending granitic intrusives occur on the islands, some of which have hornfels aureoles (Looney et al., 1975).

On the west side of Chichagof, Baranof and Kruzof Islands hornfels aureoles were mapped or noted in three major locations. In the south, on the north side of Crawfish Inlet pluton, a hornfels is mapped on the north side of Redoubt Lake along on a steep mountain side. Early maps (Looney et al., 1975) show extensive hornfels throughout south Baranof Island. However, later maps (Dusel-Bacon et al., 1996) show much less. Most of the mapped hornfels lies within the South Baranof Wilderness.

Hornfels are mapped surrounding Tertiary gabbro and diorite plutons in the Yokobi Island area, but they lie within the West Chichagof Yokobi Wilderness (Dusel-Bacon et al., 1996). Some hornfels are also mapped north of Mount Edgecumbe on Kruzof Island that may be accessible using Forest Service roads. A Potential Hard Aggregate Source Report was prepared for this area and is included in this report.

6.7 Mitkof, Kupreanof and Kuiu Island Area

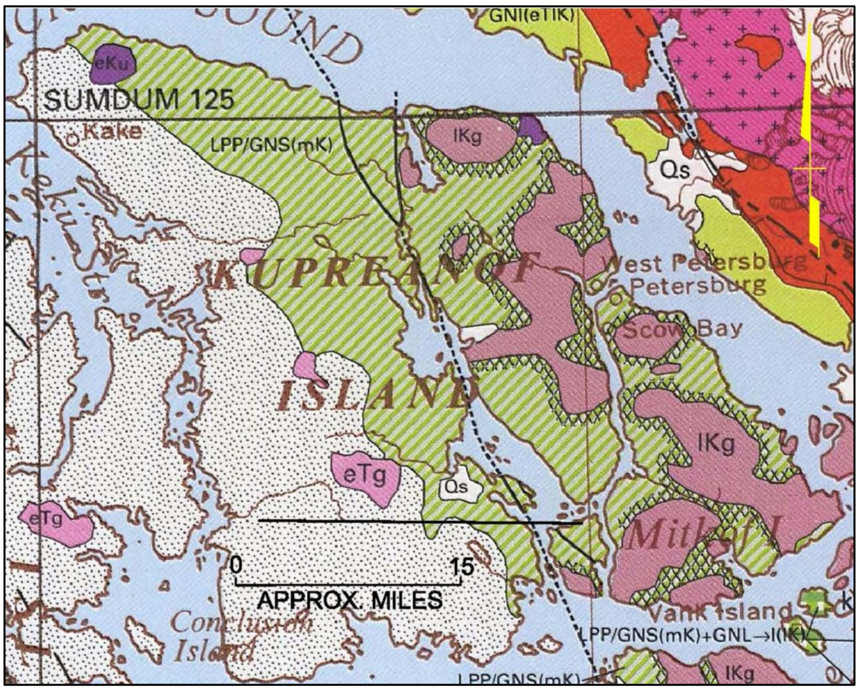
Bedrock mapping on Mitkof Island and eastern Kupreanof Island (east of the Duncan Canal Fault Zone) generally shows Cretaceous phyllite derived from fine-grained sedimentary rocks and schist intruded by igneous Cretaceous diorite and tonalite plutons (Brew et.al., 1984). Some strongly hornfelsed rocks close to plutons were noted by Brew, although the locations were not indicated on the maps. Dusel-Bacon et al. mapped the presence of hornfels surrounding all the intrusives (see Figure 6-5). Much of the area on Mitkof Island is accessible by logging roads. The central portion of the eastern part of Kupreanof Island is designated as Petersburg Creek Duncan Salt Chuck Wilderness, but the remainder of the area appears to be accessible by logging roads.

Mapping on western Kupreanof Island generally shows Devonian to Cretaceous phyllites and schists derived from fine-grained volcanic and sedimentary rocks on the north end of the island and Tertiary to Quaternary volcanics on the southern portion of the island (Brew et al., 1984). With the exception of the Quaternary basalts on the south part of the island, most of these rocks do not appear to have the potential for producing hard aggregate. The Quaternary basalts as mapped by Brew et al. (1984) and Brew (1997) are generally dense to very dense and aphanitic. A Potential Hard Aggregate Source Report was prepared for these sources and is included in this report.

Bedrock mapping on Kuiu Island generally show Silurian sedimentary rocks and Quaternary volcanics with Cretaceous and Tertiary intrusives (Brew et al., 1984). Reconnaissance maps prepared by Muffler (1967) and Brew et al. (1984) show that two small plutons have intruded the sandstones between Rowan Bay and Security Bay on the northwest corner of Kuiu Island. Hornfels were mapped between the intrusives. A Potential Hard Aggregate Source Report was prepared for this source and is included in this report. Brew also mapped small granitic intrusives on the southern portion of the island but does not map hornfels surrounding them. There were no other obvious potential sources of hard aggregate found on Kuiu Island during our research.

Figure 6-5 shows interpreted hornfels zones on Kupreanof and Mitkof Islands. The purple units are igneous intrusives, the green units are metamorphic rocks generally derived from sedimentary and volcanic units and the cross hatch areas along the intrusives are interpreted hornfels zones. These zones are subject to differing interpretations by different authors. The dotted areas are unmetamorphosed rocks.

FIGURE 6 - 5
KUPREANOF-MITKOF ISLANDS METAMORPHIC FACIES MAP
(Modified from Dusel-Bacon et al., 1996)



6.8 Wrangell, Zarembo and Etolin Islands Area

Mapping on Wrangell Island generally shows Cretaceous phyllite derived from fine-grained sedimentary rocks and schist intruded by igneous tonalite plutons (Brew et al., 1984). Some strongly hornfelsed rocks were noted as being close to plutons in the northern part of the island (Dusel-Bacon et al., 1996). If these hornfels can be located, they may be possible sources of rock for the production of hard aggregates. Two Nordic Abrasion test values (7 and 17) were found for the Wrangell Airport quarry. A Potential Hard Aggregate Source Report was prepared for this source and is included in this report. Much of Wrangell Island is accessible by existing roads. Hornfels are indicated for the northern portion of the island and on the southern portion on some maps, but not on others.

Zarembo Island is located to the west of Wrangell Island and south of Kupreanof Island. Bedrock on Zarembo Island can be separated into two parts; a northern portion generally composed of Cretaceous granodiorite to diorite intrusives surrounded by semischist and phyllite and a southern portion generally composed of Tertiary to Quaternary volcanic and igneous rocks. The two parts are separated by a wide valley that cuts across the island from northwest to southeast. Hornfels zones are mapped along the edges of the intrusives in the northern part of the island (Dusel-Bacon et al., 1996). A Potential Hard Aggregate Source Report was prepared for this source and is appended to this report. Mapping also shows some hornfels on the south shore of the island.

Etolin Island is located to the southwest of Wrangell Island and southeast of Zarembo Island. The island is generally composed of Cretaceous and Tertiary granitic rocks of the Kuiu-Etolin Volcanic Plutonic Belt, surrounded by semischist and phyllite of the Seymour Canal Formation. Hornfels are inferred along the edges of the intrusives (Dusel-Bacon et al., 1996). A Potential Hard Aggregate Source Report was prepared for this source and is appended to this report.

Parts or all of Wrangell, Zarembo and Etolin Islands are within the Tongass National Forest and appear to be managed by the U.S. Forest Service. There are numerous existing quarries shown on the U.S.G.S. topographic maps. The U.S. Forest Service may have information available concerning these sites. There appear to be numerous logging roads and several harbors on the islands.

6.9 Cleveland Peninsula, Revillagigedo and Annette Islands Area

Mapping indicates that the bedrock geology on the Cleveland Peninsula, Revillagigedo, Gravina and Annette Islands consists of igneous intrusives, metasedimentary and metavolcanic rocks. These intrusives are more variable in composition than the igneous rocks in Wrangell, Kupreanof and surrounding islands, and they appear to be more foliated. Thermal alteration was mapped surrounding only one stock (Dusel-Bacon et al., 1996), a gabbro intrusive near Ketchikan where a spotted hornfels was observed. There were few igneous intrusives noted on Gravina Island and most of those on Annette Island have been metamorphosed with the rock thus apparently weakened. Much of the area east of these islands, including the eastern edge of Revillagigedo Island, was excluded from this study as it lies within the Misty Fiords National Monument.

6.10 Prince of Wales Island Area

Bedrock geology on Prince of Wales Island and associated islands (lying south of Sumner Strait and west of Clarence Strait) consists primarily of Devonian to Silurian sedimentary rocks including the Bay of Pillars Formation, the Descon Formation, and the Karheen Formation. There are extensive limestone formations including the Heceta Limestone in addition to volcanic and volcaniclastic deposits. Also, there are smaller igneous intrusive bodies than elsewhere in southeast Alaska, although the extent of thermal alteration appears to be similar or greater than most places. Hornfels has been mapped in the northern part of the island, near Coffman Cove, at a small area near Klawock, and on Sukkwan Island. Potential Hard Aggregate Source Reports were prepared for the first of these hornfels sources and appended to this report. The Sukkwan Island source was excluded as it lies within a roadless area.

6.11 Selected References

Barker, Fred, 1957, Geology of the Juneau (B-3) quadrangle, Alaska: U.S. Geological Survey Geologic Quadrangle Map 100, 1 sheet, scale 1:63,360.

Berg, H.C., 1972, Geologic map of Annette Island, Alaska: U.S. Geological Survey Miscellaneous Geologic Investigations Map 684, 8 p., 1 sheet, scale 1:63,360.

Berg, H.C., 1973, Geology of Gravina Island, Alaska: U.S. Geological Survey Bulletin 1373, 41 p., 1 sheet, scale 1:63,360.

Berg, H.C., Elliott, R.L., and Koch, R.D., 1988, Geologic map of the Ketchikan and Prince Rupert quadrangles, southeastern Alaska: U.S. Geological Survey Miscellaneous Investigations Series Map 1807, 27 p., 1 sheet, scale 1:250,000.

Brew, D.A. and Grybeck, Donald, 1984, Geology of the Tracy Arm-Fords Terror Wilderness Study Area and vicinity, Alaska, in U.S. Geological Survey, Mineral resources of the Tracy Arm-Fords Terror Wilderness Study Area and vicinity, Alaska: U.S. Geological Survey Bulletin 1525, p. 19-52.

Brew, D.A., Ovenshine, A.T., Karl, S.M., and Hunt, S.J., 1984, Preliminary reconnaissance geologic map of the Petersburg and parts of the Port Alexander and Sumdum 1:250,000 quadrangles, southeastern Alaska: U.S. Geological Survey Open-File Report 84-405, 43 p., 2 sheets, scale 1:250,000.

Brew, D.A. and Ford, A.B., 1985, Preliminary reconnaissance geologic map of the Juneau, Taku River, Atlin, and part of the Skagway 1:250,000 quadrangles, southeastern Alaska: U.S. Geological Survey Open-File Report 85-395, 23 p., 1 sheet, scale 1:2,500,000.

Brew, D.A., 1996, Geologic map of the Craig, Dixon Entrance, and parts of the Ketchikan and Prince Rupert quadrangles, Southeastern Alaska: U.S. Geological Survey Miscellaneous Field Studies Map 2319, 53 p., 1 sheet, scale 1:250,000.

Brew, D.A., 1997, Reconnaissance geologic map of the Petersburg B-4 quadrangle, southeastern Alaska: U.S. Geological Survey Open-File Report 97-156-F, 20 p., 1 sheet, scale 1:63,360.

Brew, D.A., 1997, Reconnaissance geologic map of the Petersburg B-5 quadrangle, southeastern Alaska: U.S. Geological Survey Open-File Report 97-156-G, 19 p., 1 sheet, scale 1:63,360.

Brew, D.A., 1997, Reconnaissance geologic map of the Petersburg C-4 quadrangle, southeastern Alaska: U.S. Geological Survey Open-File Report 97-156-J, 21 p., 1 sheet, scale 1:63,360.

Brew, D.A., 1997, Reconnaissance geologic map of the Petersburg C-5 quadrangle, southeastern Alaska: U.S. Geological Survey Open-File Report 97-156-K, 18 p., 1 sheet, scale 1:63,360.

Brew, D.A., 1997, Reconnaissance geologic map of the Petersburg D-5 quadrangle, southeastern Alaska: U.S. Geological Survey Open-File Report 97-156-M, 22 p., 1 sheet, scale 1:63,360.

Decker, John, 1980, Geologic map of western Chichagof Island, southeastern Alaska: U.S. Geological Survey Open-File Report 80-150, 2 sheets, scale 1:63,360.

Dusel-Bacon, Cynthia, Brew, D.A., and Douglass, S.L., 1996, Metamorphic facies map of southeastern Alaska; distribution, facies, and ages of regionally metamorphosed rocks: U.S. Geological Survey Professional Paper 1497-D, p. 1-42, 2 sheets, scale 1:1,000,000.

Gehrels, G.E., 1992, Geologic map of the southern Prince of Wales Island, southeastern Alaska: U.S. Geological Survey Miscellaneous Investigations Series Map 2169, 23 p., 1 sheet, scale 1:63,360.

Gehrels, G.E. and Berg, H.C., 1992, Geologic map of southeastern Alaska: U.S. Geological Survey Miscellaneous Investigations Series Map 1867, 24 p., 1 sheet, scale 1:600,000.

Gehrels, G.E. and Berg, H.C., 1994, Geology of southeastern Alaska: In the Geology of North America Chapter 13, Vol. G-1, The Geology of Alaska, The Geologic Society of America.

Gilbert, W.G., Burns, L.E., Redman, E.C., and Forbes, R.B., 1987, Preliminary bedrock geology and geochemistry of the Skagway B-3 quadrangle, Alaska: Alaska Division of Geological & Geophysical Surveys Report of Investigation 87-2, 2 sheets, scale 1:36,200.

Gilbert, W.G., Clough, A.H., Burns, L.E., Kline, J.T., Redman, E.C., and Fogels, E.J., 1990, Reconnaissance geology and geochemistry of the northeast Skagway quadrangle, Alaska: Alaska Division of Geological & Geophysical Surveys Report of Investigation 90-5, 2 sheets, scale 1:125,000.

Herreid, G.H., 1975, Geology of the Craig A-2 quadrangle and vicinity, Prince of Wales Island: Alaska Division of Geological & Geophysical Surveys Alaska Open-File Report 35, 2 p., 1 sheet, scale 1:63,360.

Johnson, B.R. and Karl, S.M., 1985, Geologic map of western Chichagof and Yakobi Islands, southeastern Alaska: U.S. Geological Survey Miscellaneous Investigations Series Map 1506, 15 p., 1 sheet, scale 1:125,000.

Johnson, B.R. and Karl, S.M., 1982, Reconnaissance geologic map of the western Chichagof and Yakobi Islands Wilderness Study Area, southeastern Alaska: U.S. Geological Survey Miscellaneous Field Studies Map 1476-A, 1 sheet, scale 1:125,000.

Karl, S.M., 1996, Preliminary geologic map of Northeast Chichagof Island, Alaska: U.S. Geological Survey Open-File Report 96-53, 12 p., 1 sheet, scale 1:63,360.

Karl, S.M, Haeussler, P.J., and McCafferty, A., 1999, Reconnaissance Geologic Map of the Duncan Canal-Zarembo Island area, southeastern Alaska: U.S. Geological Survey Open-File Report 99-168, 30p., 1 sheet, scale 1:150,000.

Koch, R.D., and Elliott, R.L., 1984, Late Oligocene gabbro near Ketchikan, southeastern Alaska, in Coonrad, W.L., and Elliot, R.L., eds., The U.S. Geological Survey in Alaska: Accomplishments during 1981: U.S. Geological Survey Circular 868, p. 126-128.

Lathram, E.H., Pomeroy, J.S., Berg, H.C., and Loney, R.A., 1965, Reconnaissance geology of Admiralty Island, Alaska: U.S. Geological Survey Bulletin 1181-R, p. R1-R48, 2 sheets, scale 1:250,000.

Loney, R.A., Berg, H.C., Pomeroy, J.S., and Brew, D.A., 1963, Reconnaissance geologic map of Chichagof Island and northwestern Baranof Island, Alaska: U.S. Geological Survey Miscellaneous Geologic Investigations Map 388, 7 p., 1 sheet, scale 1:250,000.

Loney, R.A., Brew, D.A., Muffler, L.J.P., and Pomeroy, J.S., 1975, Reconnaissance geology of Chichagof, Baranof, and Kruzof Islands, southeastern Alaska: U.S. Geological Survey Professional Paper 792, 105 p., 4 sheets, scale 1:250,000.

Loney, R.A., Condon, W.H., and Dutro, J.T., Jr., 1963, Geology of the Freshwater Bay area, Chichagof Island, Alaska: U.S. Geological Survey Bulletin 1108-C, p. C1-C54, 2 sheets, scale 1:63,360.

MacKevett, E.M., Jr., Robertson, E.C., and Winkler, G.R., 1974, Geology of the Skagway B-3 and B-4 quadrangles, southeastern Alaska: U.S. Geological Survey Professional Paper 832, 33 p., 1 sheet, scale 1:63,360.

Muffler, L.J. Patrick., 1967, Stratigraphy of the Keku Islets and neighboring parts of Kuiu and Kupreanof Islands, southeastern Alaska: U.S. Geological Survey Bulletin 1241-C, p. C1-C52, 1 sheet, scale 1:63,360.

Redman, E.C., Retherford, R.M., and Hickok, B.D., 1984, Geology and geochemistry of the Skagway B-2 quadrangle, southeastern Alaska: Alaska Division of Geological & Geophysical Surveys Report of Investigation 84-31, 34 p., 4 sheets, scale 1:40,000.

Redman, E.C., Gilbert, W.G., Jones, B.K., Rosenkrans, D.S., and Hickok, B.D., 1985, Preliminary bedrock-geologic map of the Skagway B-4 quadrangle, Alaska: Alaska Division of Geological & Geophysical Surveys Report of Investigation 85-6, 1 sheet, scale 1:40,000.

R&M Consultants, Inc., 1992, Haines Highway rock slope evaluation Milepost 24 to Border Haines Highway, Alaska, Prepared for Alaska Department of Transportation and Public Facilities, 2 volumes.

Smith, J.G., 1977, Geology of the Ketchikan D-1 and Bradfield Canal A-1 quadrangles, southeastern Alaska: U.S. Geological Survey Bulletin 1425, 49 p., 1 sheet, scale 1:63,360.

Stowell, H.H., 2006, Geology of Southeast Alaska, Rock and Ice in Motion, University of Alaska Press, 140p.

7.0 CONCLUSIONS

7.1 General Overview

A detailed review of the geology of three areas in southern Alaska, including Southeast Alaska, the Alaska Peninsula (including Kodiak Island and Unalaska) and southcentral Alaska (including Prince William Sound) has revealed a significant number of sites with the potential for hard aggregate production that meet the criteria laid out in the scope-of-work. A potential hard aggregate report was prepared for each of these sites (Appendix A thru N). Many of the sites listed in Table 1-2 were discussed in context with other sites or sites covering much larger areas. Other sites that did not meet all of the criteria but might interest someone in the future were discussed in the text. Sites that were in areas that appeared to be unavailable for mining such as national parks and wilderness areas were mentioned where they were encountered, but no special effort was made to identify specific locations. There were approximately two to three potential hard aggregate sites found that did not meet the criteria in the scope-of-services for each one that did.

The majority of the potential hard aggregate source locations consisted of hornfels. Several locations were basalts or fine-grained igneous rocks. Fourteen (14) locations were identified and Potential Hard Aggregate Source reports were prepared for individual sites or groups of potential sites within these 14 areas. A total of 27 individual sources were identified within the 14 locations. Thirteen new Nordic Abrasion values (not part of Table 1-2) were available for these sites, most having been supplied by Mr. Mitch McDonald of DOT&PF Southeast Region.

Three sites were found in Southcentral Alaska that meet the criteria for hard rock potential and access. Much of the rock in Southcentral consists of the Valdez and Orca Groups which is generally highly foliated and not suitable. Much of the rock that appears to have potential is in locations that are difficult to access such as Prince William Sound and the Talkeetna Mountains. Land development surprisingly has not had a great impact on areas with hard aggregate potential. However, land withdrawals, particularly in Prince William Sound, have had an impact. There are many gravel sources with Nordic Abrasion test results less than 10 in Southcentral Alaska, although the test results are generally not consistent. Only the three potential sites were identified; 2 igneous, 1 hornfels.

With the exception of Unalaska, there do not appear be any potential sites for hard aggregate production along the Alaska Peninsula or Kodiak Island. While there does appear to be material suitable for making the hard aggregate, much of it is located within wildlife refuges, monuments or preserves and was therefore excluded from this study. What remained outside the refuges, etc. was in areas with limited local infrastructure, and with the exception of Kodiak Island and Unalaska has little to no local demand. The quarries in Unalaska that have rock with low Nordic Abrasion test values are a great distance from areas requiring hard aggregate.

A significant number of sites with the potential to produce hard aggregate were found in Southeast Alaska, with many of them having road access and relatively sheltered harbors. Many of the sources in Southeast Alaska were within the Tongass National Forest and would require permission from the U.S. Forest Service for their use. About one-half of the sources in Southeast Alaska are located within parks, monuments, wilderness areas, roadless areas or dedicated recreational areas and likely would not be attainable for use. Wherever they could be identified, these areas were removed from the current study. Even with these limitations, we identified eleven groups of sites with 27 individual sites that included 12 hornfels quarries, 11 basalt quarries, 1 gabbro quarry, 1 possible syenite quarry, and 1 gravel pit with several areas overlapping.

7.2 Summary of Potential Hard Aggregate Sources

The following potential hard aggregate sources (Table 7-1) were identified in this study as meeting the criteria as laid out in the scope-of-work (See Section 1). These sources are also depicted on Plate 1 (attached) and described in detail in the appended Potential Hard Aggregate Source reports (Appendices A thru O).

Additionally, a separate feasibility study was performed to evaluate hard aggregate development at a site near Cantwell. That study is presented in a separate project report (Part 2 of this document).

TABLE 7 - 1
SUMMARY OF POTENTIAL HARD AGGREGATE SOURCES

	MS NUMBER	COMMON NAME	MILEPOST	PERMIT NO. (1)	SITE STATUS / EXPIRATION DATE (1)	OWNER (1)	GEOGRAPHIC COORDINATES WGS84 (2)		UTM COORDINATES WGS84-METERS (2)			STATE PLANE COORDINATES NAD83-US SURVEY FEET (2)			NORDIC VALUES(3)	CATEGORIZATION		
							LAT.	LONG.	ZONE	NORTH	EAST	ZONE	NORTH	EAST		CLASSIFICATION	STATUS	
	SOUTH CENTRAL ALASKA																	
1	HA-A1	Chugach Mountains / Burnt Butte	---	---	---	CIRI	61.561286	-148.968555	6	6,826,888	395,424	4	2,764,014	1,820,253	---	UNKNOWN	POTENTIAL	1
2	HA-B1	Nanwalek / Point Bede	---	---	---	CHUGACH ALASKA	59.311215	-151.986317	6	6,575,146	557,711	4	1,945,695	1,269,321	---	UNKNOWN	POTENTIAL	2
3	HA-C1	Copper River Highway / Sheridan Glacier	19	---	---	USFS	60.473414	-145.262355	6	6,705,397	595,526	3	2,395,685	2,494,731	---	UNKNOWN	POTENTIAL	3
	SOUTHEAST ALASKA																	
4	HA-D1	Haines Highway / Mile 4.5 Site	4.5	---	---	Private	59.253884	-135.538934	8	6,568,447	469,265	1	2,715,162	2,335,421	**6.6, 8, 9.3**, 11.4, 17.5	ACTIVE	POTENTIAL	4
5	HA-D2	Haines Highway / Mile 5.5 Site	5.5	---	---	Private	59.260689	-135.558706	8	6,569,214	468,144	1	2,717,750	2,331,791	**6.8**	ACTIVE	POTENTIAL	5
6	HA-D3	Haines Highway / Mile 25 Klehini River Site	25	---	---	SOA	59.407787	-135.964659	8	6,585,858	445,236	1	2,773,823	2,257,684	**10**	UNKNOWN	POTENTIAL	6
7	HA-E1	Kupreanof Island / Area "A" – Sumner Straits	---	---	---	USFS	56.445424	-133.650459	8	6,256,472	583,194	1	1,684,212	2,689,223	---	UNKNOWN	POTENTIAL	7
8	HA-E2	Kupreanof Island / Area "B" – Sumner Straits	---	---	---	USFS	56.439241	-133.520885	8	6,255,949	591,196	1	1,681,985	2,715,443	---	UNKNOWN	POTENTIAL	8
9	HA-E3	Kupreanof Island / Area "C" – Totem Bay	---	---	---	USFS	56.455001	-133.460536	8	6,257,784	594,877	1	1,687,774	2,727,638	---	UNKNOWN	POTENTIAL	9
10	HA-E4	Kupreanof Island / Area "D" – Totem Bay	---	---	---	USFS	56.505468	-133.437401	8	6,263,433	596,175	1	1,706,224	2,732,255	---	UNKNOWN	POTENTIAL	10
11	HA-E5	Kupreanof Island / Area "E" SE Kupreanof Island	---	---	---	USFS	56.457785	-133.196343	8	6,258,490	611,150	1	1,689,055	2,781,068	---	UNKNOWN	POTENTIAL	11
12	HA-E6	Kupreanof Island / Area "F" – Kah Sheets Bay	---	---	---	USFS	56.515122	-133.129981	8	6,264,980	615,065	1	1,710,098	2,794,326	---	ACTIVE	POTENTIAL	12
13	HA-E7	Kupreanof Island / Area "G" – Duncan Canal	---	---	---	USFS	56.672651	-133.170506	8	6,282,444	612,104	1	1,767,579	2,785,725	---	UNKNOWN	POTENTIAL	13
14	HA-E8	Kupreanof Island / Area "H" – Duncan Canal	---	---	---	USFS	56.708212	-133.253637	8	6,286,268	606,910	1	1,780,458	2,768,928	---	UNKNOWN	POTENTIAL	14
15	HA-E9	Kupreanof Island / Area "I" – Forest Service Quarry	---	---	---	USFS	56.763233	-133.523917	8	6,292,003	590,234	1	1,800,336	2,714,582	**7**	ACTIVE	POTENTIAL	15
16	HA-F1	Kuiu Island / Security Bay	---	---	---	USFS	56.808520	-134.360498	8	6,296,254	539,047	1	1,817,555	2,546,908	---	UNKNOWN	POTENTIAL	16
17	HA-F2	Kuiu Island / Rowan Bay	---	---	---	USFS	56.695866	-134.296529	8	6,283,753	543,082	1	1,776,279	2,559,348	---	UNKNOWN	POTENTIAL	17
18	HA-G1	Wrangell Island / Wrangell Airport Quarry	---	---	---	DOTPF	56.487009	-132.386582	8	6,263,345	660,916	1	1,701,819	2,944,632	**7**, 17.1	ACTIVE	UNKNOWN	18

	SOUTHEAST ALASKA (CONTINUED)																	
19	HA-H1	Zarembo Island / Northern Zarembo Island	---	---	---	USFS	56.401017	-132.785403	8	6,252,914	636,673	1	1,669,140	2,864,445	---	UNKNOWN	POTENTIAL	19
20	HA-I1	Etolin Island / Northern Etolin Island	---	---	---	USFS	56.246532	-132.470702	8	6,236,395	656,722	1	1,613,684	2,929,165	---	UNKNOWN	POTENTIAL	20
21	HA-I2	Etolin Island / Central Etolin Island	---	---	---	USFS	56.144496	-132.464071	8	6,225,058	657,550	1	1,576,442	2,931,166	---	UNKNOWN	POTENTIAL	21
22	HA-J1	Kruzof Island / Kruzof Island	---	---	---	USFS	57.200676	-135.713812	8	6,339,950	456,872	1	1,966,213	2,280,066	---	UNKNOWN	POTENTIAL	22
23	HA-K1	Revillagigedo Island / Ketchikan	---	---	---	SOA	55.333238	-131.507959	9	6,134,739	340,919	1	1,285,043	3,135,353	---	UNKNOWN	POTENTIAL	23
24	HA-L1	Prince of Wales Island / Coffman Cove	---	---	---	SOA/Private	56.010422	-132.818347	8	6,209,387	636,016	1	1,526,394	2,859,538	**5.6**, 13.7	UNKNOWN	POTENTIAL	24
25	HA-M1	Prince of Wales Island / Red Bay Mountain	---	---	---	USFS	56.217549	-133.382180	8	6,231,470	600,327	1	1,601,095	2,743,849	---	UNKNOWN	POTENTIAL	25
26	HA-M2	Prince of Wales Island / Tokeen Peak	---	---	---	USFS	56.117709	-133.406904	8	6,220,324	599,051	1	1,564,606	2,738,956	---	UNKNOWN	POTENTIAL	26
27	HA-N1	Prince of Wales Island / Klawock River Quarry	---	---	---	KLAWOCK HEENYA	55.545702	-133.096303	8	6,157,165	620,110	1	1,356,068	2,804,085	**8.4**	ACTIVE	POTENTIAL	27
	ALASKA RANGE (CANTWELL AREA) (4)																	
28	---	Athna Pit	216	---	---	AHTNA	63.464594	-148.792723	6	7,038,605	410,649	4	3,460,349	1,837,900	**9.1, 7.3**	INACTIVE	POTENTIAL	28
29	---	Cantwell Hard Aggregate Site (Caswell Pit)	216	---	---	SOA	63.464919	-148.788904	6	7,038,636	410,840	4	3,460,480	1,838,523	**6.2, 8.0, 7.0, 5.6, 9.1, 7.6, 6.2, 6.9, 8.6, 8.1, 7.3, 8.2,** 13.7, **6.2**	ACTIVE	POTENTIAL	29
30	52-2-046-2	Panorama Mtn. #1	217	F-29729	Indef.	AHTNA	63.467089	-148.807934	6	7,038,905	409,899	4	3,461,215	1,835,396	---	ACTIVE	OPEN	30
31	52-2-068-2	Panorama Mtn. #2	217	F-33438	Indef.	AHTNA	63.470705	-148.813608	6	7,039,315	409,627	4	3,462,520	1,834,443	---	ACTIVE	UNKNOWN	31
32	---	Site uphill of MS 52-2-068-2	217	---	---	AHTNA	63.471288	-148.811878	6	7,039,378	409,715	4	3,462,738	1,834,722	**7.0, 8.1, 7.9**	ACTIVE	POTENTIAL	32
	OUTSIDE ALASKA (4)																	
33	---	DuPont, Washington	---			Commercial	47.122228	-122.642356	10	5,218,809	527,129				**6.1, 19**	ACTIVE	OPEN	33
34	---	Jervis Inlet, B.C., Canada	---			Commericial	49.840299	-123.87524	10	5,521,242	437,068				**6.9, 9.9**	ACTIVE	OPEN	34

Notes:

1. Permit status and land ownership were taken from Central Region - R.O.W. spreadsheet Central Region MatSite Inventory 6-18-08.xls, BLM and DNR plats and case file abstracts.
2. Coordinates listed are taken from Google Earth Pro and are approximate. Minus numbers designate west longitude.
3. Test Results in bold are 10 or less.
4. Data for sites on lines 28, 29, 32, 33 & 34 are discussed in more detail in Part 2 of this report. Data for sites 30 and 31 were obtained from the Statewide Material Site Inventory.