PEBBLE PROJECT
ENVIRONMENTAL BASELINE DOCUMENT
2004 through 2008

CHAPTER 3.
GEOLOGY AND MINERALIZATION
Bristol Bay Drainages

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ACRONYMS AND ABBREVIATIONS

API	aerial photograph interpretation
IP	induced polarization
NDM	Northern Dynasty Mines Inc./Northern Dynasty Minerals Ltd.

3. GEOLOGY AND MINERALIZATION

3.1 Introduction

This chapter discusses the baseline geology and mineralization characteristics of the mine study area in the Bristol Bay drainages. This discussion on geology and mineralization has been based largely on information obtained from the following reports:

- *2005 Summary Report on the Pebble Porphyry Gold-Copper Project* (NDM, 2006)
- *2006 Summary Report on the Pebble Porphyry Gold-Copper-Molybdenum Project* (NDM, 2007)
- *Technical Report on the 2007 Program and Update on the Metallurgy and Resources on the Pebble Copper-Gold-Molybdenum Project, Iliamna Lake Area, Southwestern Alaska, USA* (NDM, 2008)
- *Technical Report on the 2008 Program and Update on Mineral Resources and Metallurgy, Pebble Copper-Gold-Molybdenum Project, Iliamna Lake Area, Southwestern Alaska, USA* (NDM, 2009).

Geotechnical site investigations and desktop studies undertaken by various consultants are also referenced for this chapter.

The geology and mineralization discussion in this chapter includes bedrock and surficial geology, geologic structure, deposit types, alteration, and mineralization. Detailed discussions of the soils, hydrogeology, and geochemistry of the mine study area are found in Chapters 5, 8, and 11, respectively.

3.2 Study Objectives

The objectives of the geology and mineralization study are to provide baseline information to characterize the geology in the Bristol Bay drainages study area.

3.3 Study Area

The Bristol Bay drainages study area is located in southwestern Alaska, west of Cook Inlet and north of Iliamna Lake. The study area is bordered to the east by the boundary between the Bristol Bay and Cook Inlet drainages and to the north by the boundary of the Lake Clark National Park and Preserve (Figure 3-1). The area of interest for the geology and mineralization study is the smaller mine study area as shown on Figure 3-1.

3.4 Previous Studies

Cominco Alaska began reconnaissance exploration in the vicinity of the Pebble Deposit in the 1980s. The Sharp Mountain gold prospect near the southern margin of the mine study area was discovered in 1984. Geological, geochemical, and geophysical surveys were conducted in and around the current mine study area from 1985 to 2000. These studies have outlined a copper-gold-molybdenum-rich, hydrothermally altered sulfide system covering an area of approximately 90 square kilometers in the Bristol Bay drainages study area.

Examination and sampling of several prominent limonitic and hematitic alteration zones by Cominco Alaska in 1987 yielded anomalous gold concentrations (recognized as a precious metal, epithermal vein occurrence) at the Sill Prospect and at the Pebble Deposit area. The 1988 exploration program included 24 diamond drillholes at the Sill Prospect, soil sampling, geological mapping, and two diamond drillholes at the Pebble Deposit target. An expanded soil-sampling program, an induced polarization (IP) survey, and 12 diamond drillholes were completed at the Pebble Deposit target, and 15 diamond drillholes were completed at the Sill Prospect in 1989. The IP survey, although limited in scope, displayed a response characteristic of a large porphyry-copper system. The 1989 drilling by Cominco Alaska intercepted notable intervals of porphyry-style gold, copper, and molybdenum mineralization.

The exploration program at Pebble was accelerated in 1990 when it became apparent that a substantial copper-gold porphyry deposit had been discovered. Exploration drilling included 25 diamond drillholes in the Pebble Deposit area in 1990, 48 diamond drillholes in 1991, and 14 diamond drillholes in 1992. IP surveying and four diamond drillholes were completed in 1993 at a target located approximately 6 kilometers south of the Pebble Deposit. Cominco Alaska completed additional IP surveying, geochemical sampling, geological mapping, and 20 diamond drillholes in the vicinity of the Pebble Deposit in 1997.

Hunter Dickinson Inc., the parent company of Northern Dynasty Mines Inc./Northern Dynasty Minerals Ltd. (NDM)), staked additional claims, known as the “PEB claims” in 2001 to cover ground where a multi-element, soil-geochemical anomaly and high IP chargeability had been detected on two widely spaced reconnaissance lines. Hunter Dickinson Inc. collected and analyzed 601 soil samples and completed 30 line-kilometers of IP/resistivity surveying on the PEB claims.

3.5 Scope of Work

The geology and mineralization study consolidates existing geological data and newer exploration data collected up to the end of 2008 in the mine study area, where the Pebble Deposit is located.

3.6 Methods

This chapter of the environmental baseline document presents baseline geology and mineralization information collected between 2002 and the end of 2008 by Northern Dynasty Mines Inc. or Pebble Partnership; however, information from previous studies is also included, as NDM appropriated all prior baseline geology information upon taking over the project. The baseline information has been collected with an emphasis on the mine study area. Geologic information for surrounding areas, including the possible transportation corridor, was obtained from desktop studies and reviews of existing published information.

3.6.1 Drilling Programs

Exploration drilling programs have been completed in the mine study area every year from 2002 through 2008, as summarized below:

- 2002: NDM relogged approximately 16,000 meters of core from 104 holes drilled in previous years by Cominco Alaska to better model the porphyry deposit and assess the potential to host additional, higher-grade resources. The relogging program also facilitated a better understanding of the deposit geology, knowledge which could then be applied to the exploration of other targets on the property. NDM also completed 68 exploration drillholes on the Pebble claims in 2002 to test IP anomalies.
- 2003: The diamond-drilling contractor, Quest America Drilling Inc., completed 67 exploration drillholes for NDM in the mine study area; 58 of these were drilled in the Pebble Deposit area, and nine were completed in other zones on the claims. NDM also conducted surface exploration, including geological mapping, in 2003.
- 2004: Quest America Drilling Inc. completed 173 exploration drillholes in the Pebble Deposit and one exploration hole in a mineralized area known as the 308 Zone. Quest America Drilling Inc. also drilled 54 geotechnical drillholes around the Pebble claims in 2004. NDM also completed surface mapping of the geology and exploration area at a scale of 1:10,000.
- 2005: Quest America Drilling Inc. completed 28 exploration drillholes in the Pebble Deposit area and 15 geotechnical drillholes around the mine study area in 2005.
- 2006: American Recon Inc. and Boart Longyear completed 19 exploration drillholes in the Pebble Deposit area in 2006. Foundex Explorations Ltd., a specialist geotechnical and environmental drilling contractor, completed 17 geotechnical drillholes around the mine study area in 2006.
- 2007: American Recon Inc. and Boart Longyear completed 44 exploration drillholes and nine metallurgical drillholes in the Pebble Deposit area in 2007. Foundex Explorations Ltd. completed 26 geotechnical drillholes around the mine study area.
- 2008: American Recon Inc. and Boart Longyear completed 44 exploration/geotechnical drillholes in the Pebble Deposit area in 2008. Foundex Explorations Ltd. completed 105 geotechnical drillholes in various locations across the mine study area.

The locations of the drillholes from 2004 through 2008 are shown on Figures 3-2a and 3-2b.

The overburden was typically triconed for the exploration and Pebble Deposit oriented geotechnical drilling programs. There was no core recovery of the overburden materials. The depth to bedrock was augmented in some of these drillholes because the softer, weathered or fractured bedrock was also triconed, and the driller continued with this drilling method until more competent bedrock was reached.

The overburden portion of the geotechnical drillholes was cored and standard penetration test (SPT) samples were collected at select intervals until bedrock was reached; triconing was used in some of the geotechnical drillholes if the conditions encountered made coring ineffective. Geotechnical drillholes were advanced into the underlying bedrock to various depths—typically in the range of 30 meters below the bedrock surface—to provide zones for hydraulic-conductivity testing. When fractured rock was still encountered in the drillholes at 30 meters below the bedrock surface, the drillholes were often drilled deeper until more competent rock was reached. Field personnel assessed the geotechnical characteristics of all core collected.

All core from the exploration and geotechnical drillholes was also logged by NDM/Pebble Partnership geologists to evaluate the geology and mineralization. Some of the core was split, and samples were collected for assaying. The samples were transported to the ALS Chemex laboratory in Fairbanks and to the main ALS Chemex laboratory in North Vancouver, Canada, (an International Standards Organization [ISO] 9001:2000- and 9002-certified laboratory) for final preparation and laboratory analysis. The laboratories analyzed the samples for gold, copper, molybdenum, and 23 other elements using appropriate methods and following quality-control protocols. Reporting the results of the laboratory analyses is beyond the scope of this document, but the results are available in the 2004, 2005, and 2006 summary reports and the 2007 and 2008 technical reports (NDM, 2005, 2006, 2007, 2008, and 2009) submitted to the Canadian Securities Administrators.

All drillhole locations were accessed by helicopter and care was taken to minimize surface disturbance at the sites. The final activity at each site was to replace the surface material and vegetation to recreate, as much as possible, pre-investigation conditions.

3.6.2 Test Pit Programs

During 2004 through 2008, 317 test pits were completed in the mine study area (Figures 3-3a and 3-3b). The test pits were excavated to depths between 1.5 to 3 meters using a helicopter-portable excavator. The sites of the test pits were accessed using helicopters, and care was taken to minimize environmental disturbance during excavation of the test pits. Wherever possible, the surface organic material and vegetation was stripped before the test pits were excavated. After completion of each test pit, the excavation was backfilled with the original soil, and the surface was recontoured. The final activity at each site was to replace the surface material and vegetation to recreate, as much as possible, the pre-investigation conditions.

The exposed soils in the test pit walls and spoil piles were logged by field personnel, and samples were collected and submitted for laboratory testing. The results of the sampling programs are beyond the scope of this document, but are available in the 2004, 2005, and 2008 geotechnical site investigation reports (KP, 2005, 2007, and 2009).

3.6.3 Desktop Studies

Aerial photograph interpretation (API) for the mine study area was completed using 1:20,000-scale color aerial photographs taken in July 2004. Surficial terrain units were established based on morphology, the nature of exposed soils and rocks, surface drainage, and vegetative cover. Identification of geological features was also included in the API study. Field reconnaissance was completed in June 2005 to verify the API. A preliminary terrain-unit map was developed based on the API, the slope angle map, and the results for the 2004 and 2005 test pits and geotechnical drillholes. The preliminary terrain-unit map was further refined and updated in 2007 based on an extensive investigation of surficial geology conducted in that same year. The resulting map of the surficial geology in the mine study area (Figures 3-4a and 3-4b) and the accompanying report (Hamilton and Klieforth, 2010) are based on a review of available data, API, and subsequent field examination of surficial overburden materials using shallow auger borings and test pits. The interpretation of contacts and identification of small units and features were further refined using large-scale aerial photographs.

3.7 Results and Discussion

3.7.1 Regional Geology

Alaska is composed of an assemblage of northeast-trending terranes that amalgamated southward in response to long-lived, northeast-to-northwest-directed subduction beginning in the Late Paleozoic era (Goldfarb, 1997). The mine study area lies within the northern circum-Pacific orogenic belt with a complex structural setting created by the active continental margin. The structural fabric of the mine study area is broadly defined by northeast-trending faults related to translational motion along the Lake Clark Fault. The Lake Clark Fault marks a lithotectonic boundary between the Peninsular Terrane to the east and the Kahiltna Terrane to the west. The mine study area lies within the Kahiltna Terrane, just northwest of the contact with the Peninsular Terrane. The regional geology of the mine study area is illustrated on Figures 3-5a and 3-5b (Alaska Department of Natural Resources (ADNR), 2004).

The Kahiltna Terrane is one of several basins filled by Jurassic to Cretaceous volcanic and sedimentary formations (Plafker et al., 1989). This basin closed in the Middle Mesozoic era as a result of the approach of the Wrangellia Terrane from the south (Nokleberg et al., 1994). The southern part of the Kahiltna Terrane is dominated by turbidites of Late Jurassic to Early Cretaceous age that were deposited in a basinal setting, with lesser zones of Late Triassic and younger basalt, andesite, tuff, chert, shale, and limestone (Jones et al., 1987; Wallace, 1984). The Kahiltna Terrane was intruded in the mine study area by the Late Cretaceous (90 million years ago) Kaskanak Batholith of intermediate to felsic composition. A northeast-oriented zone of diverse, slightly older (approximately 97 million years ago), texturally and compositionally variable stocks, dikes, sills, and irregular bodies occurs on the east side of the Kaskanak Batholith. This is the host of the Pebble Deposit and other mineral showings.

The Peninsular Terrane contains Permian limestone; Upper Triassic limestone, chert, tuff, and agglomerate (that may correlate with similar rocks in the Kahiltna Terrane); Early to Middle Jurassic volcanic and intrusive rocks; and Middle Jurassic to Cretaceous clastic rocks. The Peninsular Terrane and the southeast part of the Kahiltna Terrane were intruded under compression by Cretaceous plutonic rocks as a result of northwest-dipping subduction (Engebretson et al., 1987; Goldfarb, 1997). Bedded rocks of the Peninsular Terrane are bound by a quartz diorite batholith of Middle to Upper Jurassic age of the Alaska-Aleutian Range to the east of Iliamna Lake.

Tertiary to Recent volcanic and associated sedimentary rocks formed in response to northward subduction of the Pacific plate beneath the North American plates on the modern Aleutian arc (Goldfarb, 1997; Young et. al., 1997). The region continued to be deformed along a series of thrust and transverse faults, which include the Lake Clark structure, in the Tertiary to Quaternary period. The region was also eroded by Quaternary to Recent glaciers, and most valleys were filled with sedimentary deposits, largely of glacial origin subsequent to the glaciation.

3.7.2 Surficial Geology of the Mine Study Area

Following is a summary of information presented in *Surficial geologic map of parts of the Iliamna D-6 and D-7 quadrangles, Pebble Project area, southwestern Alaska* (Hamilton and Klieforth, 2010). The surficial geologic map produced by Hamilton and Klieforth is shown on Figure 3-4a, with the corresponding legend shown on Figure 3-4b.

The mine study area was affected by Pleistocene glaciers from two sources. Ice moved southwestward down the Lake Clark structural trough and separated into two floes. These ice floes followed the present Chulitna and Newhalen drainages and entered the mine study area from the north and northeast, respectively. A second major glacier is thought to have flowed westward from Cook Inlet, filling the broad basin of Iliamna Lake and expanding northward into the southern portion of the mine study area. The glaciers blocked the three major drainages of the mine study area (Upper Talarik Creek, North Fork Koktuli River, and South Fork Koktuli River) at various times. The lowlands at the headwaters of each of the drainages were filled with ice-dammed lakes resulting from glacial blockages. Subsequent ice wastage was by stagnation rather than by glacial retreat, resulting in extensive areas of ice-contact meltwater deposits and many meltwater channels that today have been abandoned or contain only very small streams. Lakes enclosed behind moraine dams persisted in some lowland areas.

Arcuate end moraines, meltwater deposits with abundant kettle depressions, broad outwash aprons, elongate valley trains, and striking meltwater channels dominate the surficial geology of the mine study area. Broad expanses of unusually smooth, poorly drained, and gently sloping terrain that terminate abruptly upslope at a consistent elevation mark the locations of former glacier-dammed lakes. These former lake locations are commonly bordered by beach and deltaic deposits.

Four different episodes of glaciation in the mine study area have been recognized. Ice-abraded uplands with patches of drift and a conspicuous moraine in the southwest part of the mine study area mark the oldest episode, which preceded the Brooks Lake glaciation of Detterman and Reed (1973). The north and south forks of the Koktuli River were dammed by glaciers during that time. The three younger glacial advances correspond to the three oldest stades of the Brooks Lake glaciation, which Detterman and Reed (1973) equate with the late Wisconsinian glacial substage of the standard North American glacial succession. This interval is dated at about 26,000 to 10,000 radiocarbon years before present elsewhere on the Alaska Peninsula (Stilwell and Kaufman, 1996) and at about 25,000 to 10,000 radiocarbon years before present in the upper Cook Inlet region (Reger and Pinney, 1997). Detterman and Reed (1973) termed the two oldest stades the Kvichak and Iliamna stades. During these stades, ice filled the Lake Clark trough and coalesced with the huge glacial lobe that filled the basin of Iliamna Lake, and glaciers entered the mine study area from the north and south. Glaciers extended only short distances southwest and south of Lake Clark and did not fill the basin of Iliamna Lake during the preceding Newhalen stade. Glacial ice extended into the extreme northeast corner and east-central margin of the mine study area during this stade. No radiocarbon dates could be obtained from the mine study area, but broadly limiting dates elsewhere on the Alaska Peninsula and correlations with upper Cook Inlet suggest that Newhalen stade glaciation may have occurred about 14,000 to 13,500 radiocarbon years before present (Hamilton and Klieforth, 2010). The final melt out of stagnating glacier ice in the mine study area was probably complete by 10,000 radiocarbon years before present (Hamilton and Klieforth, 2010).

This glacial activity produced unconsolidated surficial deposits that cover most of the lower elevation portions of the area (Detterman and Reed, 1973). These surficial deposits are typically a few to several tens of meters thick. Most surficial deposits are covered by vegetation and organic soils, but some gravel deposits are exposed on terraces. Surficial organic soils are typically less than 30 centimeters thick in the mine study area and are often mixed with granular sand and gravel material.

Rubble or felsenmeer, formed by frost action on bedrock, covers many of the gently rounded hilltops and upland surfaces. Solifluction sheets or lobes, most common in plutonic rocks, initiate on the upper part of hills where they are thin and pile up on mid-slopes.

Downslope of the solifluction lobes are Early Wisconsinian terraced and modified moraine deposits, and further downslope are Late Wisconsinian recessional moraines. These moraines moved in a south to southwesterly direction. Holocene fluvial, glaciofluvial, and lacustrine deposits, composed mainly of alternating layers of gravel with lenses of cobbles and silt, fill the valley bottoms up to a depth of 50 meters. Locally these Holocene deposits are covered by thin swamp accumulations. These Holocene deposits have been eroded to depths of up to 10 meters in major creek valleys.

3.7.3 Bedrock Geology in the Mine Study Area

Bedrock types in the mine study area include a bedded sequence of Jurassic to Cretaceous, mainly andesitic, sedimentary rocks; coeval mafic extrusive and subvolcanic rocks; Cretaceous intrusive rocks of diverse composition; and stratified Tertiary volcanics, sedimentary rocks, and subvolcanic dikes. The distribution of these units is shown on Figure 3-6a and, in more detail around the Pebble Deposit area, on Figure 3-6b; the legend for these two figures is provided in Figure 3-6c.

A key feature of the district is a north-northeast-trending belt of stocks, sills, and dikes of diverse composition that include pyroxenite, gabbro, diorite, monzodiorite, monzonite, syenomonzonite, and granodiorite, as well as bodies of felsic to intermediate intrusion breccia. This belt has been traced for 22 kilometers in the mine study area and has not been constrained along strike. It cuts the andesitic sedimentary rocks on the eastern and southern margins of the Kaskanak Batholith and is localized along a potentially major northeast-trending structure of crustal scale that extends beyond the Pebble Deposit. Magmatic hydrothermal activity in this belt has produced many gold, copper-gold, and copper-gold-molybdenum mineral occurrences that have a close spatial and temporal relationship to more felsic intrusive phases.

The Upper Cretaceous Kaskanak Batholith consists of medium- to coarse-grained, porphyritic to very locally equigranular, hornblende quartz monzodiorite to hornblende granodiorite (NDM, 2009). The Kaskanak Batholith is located west of the Pebble Deposit, and it is similar in composition and age to the quartz monzodiorite to granodiorite stocks that are genetically associated with the Pebble Deposit. The majority of it is relatively fresh, but the southern part hosts hydrothermal mineralization of the 38 and 308 porphyry zones, as well as the adjacent skarn mineralization of the 37 Zone.

The Jurassic and Cretaceous strata and intrusive rocks have been overlain by Tertiary volcanic and clastic sedimentary rocks and/or by Quaternary glacial sediments. A swarm of Tertiary basalt, andesite, rhyolite monzonite, and latite dikes trends easterly across the western part of the Pebble Deposit.

A more detailed description of the rock types and stratigraphy in the mine study area is presented in the 2006 summary report on Pebble geology (NDM, 2007).

3.7.4 Structural Geology in the Mine Study Area

The Pebble Deposit is divided into three main zones: the Pebble West Zone, the Central Zone, and the Pebble East Zone. These zones manifest distinct combinations of geological and hydrothermal characteristics. (The seismicity of this area is discussed in Chapter 6). The primary large-scale structural feature of the Pebble West and Central zones is a broad, M-shaped anticline. This fold is defined by the distribution of diorite and granodiorite sills in the gently to moderately dipping sedimentary rocks in the Central Zone and may have influenced the highly variable thickness of the sills. Fold axes plunge gently to the southeast. Folding has not yet been recognized in the Pebble East Zone.

Tertiary faults and shear zones are evident in drill core and from surface mapping. The Pebble Deposit is cut by numerous brittle faults. Seven major fault zones (ZA to ZG) have been identified in the area of the Pebble Deposit from drill core data (Figure 3-6b). Faults ZA through ZF are brittle faults. Fault ZA is a steep reverse fault, and faults ZB, ZC, and ZD are normal faults. Displacement on Faults ZA to ZD is on the order of a few tens of meters. Fault ZE, along the south side of the Pebble Deposit, is a slightly curved, normal fault with an offset of approximately 50 to 90 meters in the west and up to approximately 300 meters in the east. Fault ZF is a major structural discontinuity and is interpreted to exist between the Pebble West zone and the 001 Gold Zone in gabbro-diorite to the northwest. It is interpreted as a steep, normal fault with an offset of approximately 50 to 90 meters. A brittle-ductile fault zone was identified by drilling in 2008. The fault was active during the formation of the Pebble Deposit and controlled the fluid flow associated with the highest-grade deposits. The brittle-ductile deformation took place in the east of the Pebble East Zone and strikes subparallel to the ZG1 fault. The brittle-ductile fault zone is at least 2.3 kilometers in length and extends to at least 1.6 kilometers depth. It is up to 200 meters wide in the northwest and is truncated and downdropped into the east graben by the ZG1 fault. Dextral-oblique movement is suggested, but the absolute displacement of the fault is not constrained. ZG2 is subparallel to the ZG1 fault and has normal displacement of at least 300 meters south of the ZE fault.

A narrow, steeply sided graben trending northeast subparallel to the regional Lake Clark structural zone extends along the valley northwest of Koktuli Mountain, including Frying Pan Lake, and is known as the east graben. Fault ZG1 is a steeply southeast-dipping normal fault that drops the Tertiary-Cretaceous contact by 600 to 900 meters and is located at the northwest side of the graben. To the northeast, this fault is thought to have controlled the right angle bend in Upper Talarik Creek. The ZG1 fault has been slightly overturned in the northern portion of the Pebble East Zone after tilting approximately 20 degrees eastward. Fault ZH is a steeply northwest-dipping normal fault that runs along the base of Koktuli Mountain. This fault is located at the southeast side of the graben. Fault ZI marks another step out of the graben. The Cretaceous rocks at the top of Koktuli Mountain are well over 1.6 kilometers above the Tertiary-Cretaceous unconformity in the core of the graben. Topographic features mainly on the north end of Koktuli Mountain suggest that Fault ZE produced a left lateral offset of up to 60 meters on Fault ZH.

The Koktuli Fault occupies a linear series of east-trending depressions in the south-central part of the mine study area and the displacement is unknown. The subparallel Sharp Mountain Fault occupies a similar depression further to the south. The offset of a diorite sill to the west of Sharp Mountain indicates that the fault has normal, south-side down movement. West of the diorite sill, a downthrust wedge of Tertiary andesite occurs in a graben between two strands of this structure.

3.7.5 Alteration in the Mine Study Area

The composition of the host rock has had a minor influence—mostly related to alteration and associated veins—on the mineralization of the Pebble Deposit. The major alteration types are pre-hydrothermal hornfels; deep sodic-calcic alteration; early potassium-silicate alteration; peripheral propylitic alteration;

an illite overprint on early potassium-silicate alteration; younger advanced argillic alteration and silicification; young peripheral quartz-sericite-pyrite alteration; and post Pebble Deposit, low temperature, propylitic and clay alteration related to young faults cutting through the area. Alteration zones of the mine study area are shown on Figure 3-7.

3.7.6 Pebble Deposit

Based on the available exploration data, the Pebble porphyry copper-gold-molybdenum deposit covers an area of 16 square kilometers. A detailed description of the porphyry deposit's geology, alteration, and mineralization is presented in the *2006 Summary Report on the Pebble Porphyry Copper-Gold-Molybdenum Project* (NDM, 2007). The subsurface geology in the Pebble Deposit area is shown on Figure 3-6b. The main members of the stratigraphic section for the mine study area are shown on Figure 3-8.

The Pebble Deposit is a typical copper-gold-molybdenum, calc-alkalic porphyry system. Mineralization is strongest in and around the upper parts of granodiorite stocks and is associated with strong, high temperature, potassic alteration (biotite and/or potassium-feldspar and, locally, magnetite) and the development of abundant quartz-vein stockworks. Sulphides present are mainly pyrite, chalcopyrite, and molybdenite, with minor bornite and tetrahedrite. Gold is mainly present with copper-bearing sulfides. Detailed results of studies on gold-copper porphyry deposits that relate to the Pebble Deposit are available in Kesler (2004). Casselman has summarized additional information on petrographic studies at Pebble in the *Summary Report on the Pebble Copper-Gold Porphyry Project* (Casselman, 2001).

Minor skarn bodies up to a few meters thick were formed along the borders of monzodiorite intrusions into andesitic sedimentary rocks. These mineralized bodies are dominated by a combination of epidote, magnetite, quartz, ankerite, and/or pyrite. Minor chalcopyrite is intergrown with magnetite in some skarn bodies. A limited number of replacement skarn zones in diorite consist of quartz, magnetite, pyrite, ankerite, and minor chalcopyrite.

As mentioned previously, the Pebble Deposit has three main zones with distinct combinations of geological and hydrothermal characteristics. The zones are discussed below.

The Pebble West Zone is dominated by a multiphase, intrusive complex (96 to 98 million years ago) that contains abundant intrusion breccias ranging in scale from microbreccia to megabreccia. These rocks were intruded into gently deformed andesitic sedimentary rocks and were subsequently (91 to 89 million years ago) intruded by granodiorite stocks and sills whose later-stage fluids produced potassium-silicate alteration and high-grade copper-gold-molybdenum mineralization. Mineralization has been found to extend to depths up to approximately 550 meters in the Pebble West Zone. The eastern margin of the early intrusive breccia complex terminates fairly abruptly along an irregular, steeply dipping discontinuity that marks the boundary between the Pebble West Zone and the Central Zone. A 2004 drillhole in the area penetrated through the intrusive breccia into a thick diorite sill overlying andesitic sedimentary rocks, suggesting a more complex contact than had been interpreted from previous drilling. The western zone of the Pebble Deposit contains a small but substantial zone of oxidation and supergene enrichment (NDM, 2006). The oxide zone commonly extends to a depth of 15 to 25 meters. The rock was leached pervasively, and abundant limonite occurs as irregular patches along fractures. A zone of intermediate copper abundance 3 to 10 meters thick is common between the leached cap and the high-grade supergene zone. The main supergene zone is below the oxide zone. The supergene zone is generally 20 to 40 meters thick and locally is up to 70 meters thick. The margins of the supergene zone are commonly a lower-grade supergene from 10 to 15 meters thick. Contacts with the oxide zone are irregular to diffuse.

The Central Zone and the Pebble East Zone are dominated by hornfelsed volcanosedimentary strata that were intruded by two main diorite sills, one granodiorite sill, and small stocks of granodiorite. The Central Zone contains mineralization of moderate grade related to potassium-silicate alteration developed within and around granodiorite in its upper portion; it is gradational to the Pebble East Zone, which contains intense potassium-silicate alteration and high-grade copper-gold-molybdenum mineralization that extends up to 1,676 meters below the surface. The western part of the Pebble East Zone also contains a few granodiorite and diorite sills that are deeper in the stratigraphic section than those in the Central Zone. The core of the Pebble East Zone is occupied by a large granodiorite stock that intruded bedded andesites.

The Pebble West and Pebble East zones each contain a distinct magmatic and hydrothermal center that is separated by the lower-grade Central Zone. A peripheral zone scattered with polymetallic veins extends up to about 5 kilometers beyond the center of the Pebble Deposit and is marked by strong sericitic alteration and to the northwest by propylitic alteration. Similar sericitic alteration partially overprints the potassic alteration in the high-temperature cores of the Pebble Deposit. The peripheral zone has consistently elevated concentrations of gold and, to the south, gold, zinc, and lead, with little to no copper. The drillholes display an annular distribution of high gold grades associated with sericite-quartz-pyrite veins at the deposit periphery, a feature common to classic porphyry systems. The distribution of alteration zones in the Pebble Deposit area is shown on Figure 3-7.

At a 0.3 percent copper-equivalent cutoff, the Pebble Deposit contains 5.1 billion metric tons of measured and indicated mineral resources grading 0.77 percent copper-equivalent, containing 48 billion pounds of copper, 57 million ounces of gold, and 2.9 billion pounds of molybdenum. The inferred mineral resources grade 0.55 percent copper-equivalent, containing 24 billion pounds of copper, 37 million ounces of gold, and 1.9 billion pounds of molybdenum. Mineral resource estimations fluctuate with ongoing exploration and market valuation.

3.7.7 Other Mineralized Zones in the Mine Study Area

3.7.7.1 Sharp Mountain

The Sharp Mountain showing contains small, scattered quartz veins with epithermal textures and highly anomalous grades for gold and silver (NDM, 2009).

3.7.7.2 Sill Zone

A Tertiary, epithermal gold deposit lies in the Sill Zone, 5.6 kilometers southeast of the Pebble Deposit on the southeast side of Koktuli Mountain (Figure 3-6a). It is hosted by hypabyssal latite and comprises several narrow, discontinuous quartz veins and strongly silicified breccia zones with multi-gram grades in gold and silver. The Sill Zone was examined briefly as part of the Pebble claim-mapping program in 2005.

3.7.7.3 001 Gold Zone

The 001 Gold showing is located immediately northwest of the ZF fault, adjacent to the Pebble West Zone (Figure 3-6b). Gold grades of greater than 1 gram per metric ton related to pyrite veins hosted by intense quartz-sericite-pyrite alteration and lesser propylitic alteration comprise the mineralization in this zone (NDM, 2009).

3.7.7.4 52 Porphyry Zone

The 52 Porphyry Zone is located in the southwestern part of the mine study area (Figure 3-6a). This zone has anomalous values of copper and molybdenum in granodiorite of the Kaskanak Batholith. Bedrock in this area is weakly propylitic and has undergone potassium-silicate alteration.

3.7.7.5 38 Porphyry Zone

The porphyry copper-gold-molybdenum 38 Porphyry Zone (Figure 3-6a) was discovered in 2002 as a result of reconnaissance drill testing of a previously unexplored 3-square-kilometer IP anomaly (Figure 3-9). (An IP anomaly is caused by the differing resistivity of concentrations of sulfide minerals; areas with higher concentrations of sulfides have higher electrical conductivity.) The 38 Porphyry Zone is located at the southeast margin of the Kaskanak Batholith. The main rock type in the 38 Porphyry Zone is a medium-grained, plagioclase hornblende, porphyritic quartz monzodiorite, with narrow dikes of fine- to medium-grained, sparsely porphyritic monzonite. The 38 Porphyry Zone is a substantial zone of copper-molybdenum-gold mineralization associated with quartz-sulfide veins and potassium-silicate, propylitic, and quartz-sericite-pyrite alteration. Alteration is characterized by an extensive zone of secondary biotite and lesser potassium feldspar, overprinted by more localized phyllic alteration. Potassic alteration gradually lessens below a depth of 213 meters, and propylitic alteration becomes proportionally stronger. Chalcopyrite concentration decreases with the weakening intensity of potassic alteration.

The highest copper grades coincide with increased fracture and quartz-vein density adjacent to and northeast of a small monzonite stock that intrudes into the southern end of the Kaskanak Batholith. The deposit is not constrained to the northeast. A detailed description of this zone is included in the 2003 summary report on Pebble geology (NDM, 2004).

3.7.7.6 37 Skarn Zone

The 37 Skarn Zone is hosted by mafic volcanic rocks near the southern margin of the Kaskanak Batholith (Figure 3-6a). Strong skarn-type copper and gold mineralization in veins, associated with calc-silicate alteration, was discovered in 2002 during reconnaissance drilling of a copper-gold soil geochemical anomaly located 5 kilometers west of the 38 porphyry deposit. Two drillholes were used to test a section across a combined magnetic/geochemical target in 2003; however, no further exploration in this zone is expected because the mineral assemblage encountered in the 2003 drillholes was of lower intensity than other mineralized zones in the mine study area and is located farther from the main deposit area. Details of the showings from the 2003 drillholes are described in the summary report on Pebble produced in 2004 (NDM, 2004). A complete description of the deposit geology, alteration, and mineralization is in the 2003 summary report on Pebble geology (NDM, 2004).

3.7.7.7 25 Gold Zone

The 25 Gold Zone is located approximately 5 kilometers south of the Pebble Deposit (Figure 3-6b). The 25 Gold Zone contains high gold and copper concentrations over an area of approximately 0.5 square kilometers in the southcentral portion of an 8-square-kilometer pyroxenite body that was intruded strongly by irregular bodies of very fine-grained monzonite. The host rock ranges from alkalic pyroxenite, biotite monzonite, or syenomonzonite to heterolithic breccias containing mixed and rotated fragments in the contact zones. Much of the zone has a moderate-intensity IP chargeability response (Figure 3-9).

Gold occurs in the following:

- Polymetallic veins and veinlets with sphalerite, galena, and chalcopyrite, with minor disseminated chalcopyrite in the wall rocks.
- Substantial zones of 3 to 8 percent pyrite associated with quartz-carbonate breccia and with exceptionally strong chlorite-epidote alteration.
- Quartz veins, replacement patches, and breccia with minor pyrite.

Higher-grade gold intervals are noticeably different from one another and cannot be correlated from drillhole to drillhole. All are associated with widespread pyritic propylitic/skarn alteration. Controls for the deposition of gold and structures hosting the gold are not well understood but are spatially associated with pyroxenite-monzonite contacts.

3.7.7.8 Northeast Pebble IP Anomaly Area

Three drillholes were drilled in 2003 to test a 1.6-kilometer strike length along the east flank of the IP chargeability anomaly that extends to the north from the northeastern portion of the Pebble Deposit (Figure 3-9), where the Cretaceous rocks become covered by onlapping Tertiary rocks. These holes intersected peripheral porphyry mineralization that decreases northward.

3.7.7.9 308 Porphyry Zone

A drillhole was completed in the southwestern part of the mine study area in 2004 to test the potential of an IP chargeability anomaly (308 Zone, Figure 3-9). The 308 Porphyry zone is located in an area where a monzodiorite dike from the Kaskanak Batholith intrudes a broad zone of gently to moderately southward-dipping, bedded, andesitic sedimentary rocks. The IP anomaly intersects porphyry-style alteration and copper-molybdenum-gold mineralization associated with potassium-silicate and quartz-sericite-pyrite alteration cut by quartz-sulfide veins similar to the 38 Porphyry Zone. Main-stage alteration consists of weak potassium-feldspar alteration with disseminated chalcopyrite and related quartz veins containing mostly low concentrations of chalcopyrite and molybdenite. This was overprinted by commonly strong sericite-pyrite alteration related to quartz-pyrite or pyrite veins. Evidence for epidote-bearing propylitic alteration is also present, and several narrow polymetallic veins were intersected. The abundance of chalcopyrite decreases markedly with depth, and the density of veins of all types are low throughout. The areal extent of this zone is, as yet, unknown.

3.7.8 Surficial Geology along the Transportation Corridor Study Area

A brief inspection of the available aerial photographs taken along the transportation corridor study area was conducted in 2004. The Quaternary surficial deposits along the possible route from the mine study area largely consist of glacial drift and outwash, with fluvial deposits present near stream channels and a few localized swamp deposits. There are also areas of colluvial deposits, and scattered bedrock outcrops are common.

3.8 Summary

Integrated geological, geochemical, and geophysical surveys have outlined a copper-gold-molybdenum-rich, hydrothermally altered sulfide system covering an area of approximately 90 square kilometers in the Bristol Bay study area. Exploration since 1987 has delineated the large-scale porphyry gold-copper-molybdenum Pebble Deposit, two smaller zones of somewhat similar but lower-grade porphyry-type mineralization (38 Zone and 308 Zone), a gold-copper skarn occurrence (37 Zone), and numerous gold zones associated with a multiphase, Late Cretaceous intrusive complex (the largest is the 25 Zone).

Bedrock types in the mine study area consist of a bedded sequence of Cretaceous andesitic sedimentary rocks; coeval mafic extrusive and subvolcanic rocks; intrusive rocks of diverse composition; and stratified Tertiary volcanics, sedimentary rocks, and subvolcanic dikes. The bedrock has undergone folding deformation and has been intruded by several diorite sills. The Kaskanak Batholith, in the southwest part of the Pebble Deposit area, was the source of repeated intrusion, from which several stocks extend into the overlying rocks. Localization of the Pebble Deposit was controlled by fault structures and alteration. The principal regional control is the northeast-trending, arc-oblique, crustal-scale Lake Clark Fault. Mineralization is associated with zones of strong phyllic, potassic, or argillic alteration; silicification; and peripheral zones of propylitic alteration.

The Quaternary surficial deposits in the mine study area and along the transportation corridor study area are predominantly glacial till and outwash, fluvial terraces, and glaciofluvial deposits. Most surficial deposits are covered by vegetation and organic soils, but some gravel deposits are exposed on terraces. Other overburden materials that occur less extensively in the Bristol Bay study area include swamp, colluvial, and solifluction deposits. Surficial organic soils are typically thin in the mine study area and are mixed with granular sand and gravel material.

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3.10 Glossary

Active continental margin—a margin of a continent that is also a plate margin.

Agglomerate—coarse-grained volcanic rock with rounded to subangular fragments that are mainly larger than 2 centimeters; the mixture is poorly sorted, and the matrix may be fine-grained.

Alteration zones—a zone of rock whose nature has been changed by geological processes.

Andesite—a type of fine-grained volcanic rock.

Ankerite — a calcium, iron, magnesium, manganese carbonate mineral.

Anticline—an arc-shaped fold on rocks closing upwards, with the oldest rocks in the core.

Assay—the analysis of minerals and samples to determine the concentrations of their components.

Basalt—a dark-colored, fine-grained, extrusive igneous rock containing no more than 53 percent by weight of quartz.

Batholith—a large (more than 100 square kilometers) igneous intrusion; most are granitic in composition, and their genesis is linked with plate tectonics; batholiths are generally discordant with the surrounding rocks.

Breccia—a coarse, clastic sedimentary or volcanosedimentary rock with angular constituent clasts.

Brittle fault—a fault that exhibits brittle behavior where competent rocks lose their internal cohesion along certain surfaces when the elastic limit is exceeded under an applied stress, gives rise to fractures, faults or joints.

Brittle-ductile fault—a fault that exhibits both brittle and ductile behavior.

Chert—a variety of quartz that occurs as nodules or irregular masses in a sedimentary environment.

Clast—fragment of sediment or rock that was formed by the deterioration of larger rocks.

Clastic—sediment composed of fragments of pre-existing rocks.

Coeval—of the same age or period; contemporary.

Colluvial deposits—material transported by gravity, typically deposited and accumulated on lower slopes and/or at the base of slopes.

Cretaceous—approximately 145.6 to 65 million years ago, the third of the three periods included in the Mesozoic Era.

Diamond drilling—drilling performed using diamond studded bits, usually for recovering core.

Dike—discordant or cross-cutting, tabular intrusion, usually vertical or near vertical having pushed their way through the overlying rock.

Diorite—an intermediate, coarse-grained igneous rock with up to 10 percent quartz.

Drift—any sediment laid down by, or in association with, glacial ice activity.

Ductile fault— a fault that exhibits ductile behavior where the response to applied stress is permanent deformation with no fracturing.

Epidote—a rock-forming mineral.

Epithermal—a type of vein deposit formed within approximately 1 kilometer of the surface by hot (50 to 200 degrees Celsius) ascending hydrothermal solutions that often produce shatter zones.

Extrusive—ejected material of volcanic origin, applies to lavas and flows rather than to fragmented volcanic rocks.

Felsenmeer—coarse, angular, frost-shattered rock debris in environments that are or were formerly at the immediate margins of glaciers.

Felsic—an adjective applied to light-colored igneous minerals and to igneous rocks that are rich in such minerals.

Fluvial deposits—material transported by moving water, typically deposited in a stream channel, along a stream bank, or on a floodplain.

Gabbro—a type of coarse-grained, basic igneous rock that results from slow crystallization of basaltic magmas.

Glacial till—collective term for the group of sediments laid down by the direct action of glacial ice without the intervention of water.

Glaciofluvial deposits—material transported by glaciers and subsequently sorted and deposited by streams flowing from the melting ice.

Graben—a block of the Earth’s crust that has moved downward between two parallel faults; a graben is typically a steep-sided, flat-bottomed valley between parallel faults.

Granodiorite—a type of coarse-grained igneous rock.

Hematitic alteration—an iron oxide alteration, typically red in color.

Holocene—the epoch that covers the last 10,000 years, often referred to as Recent or post-glacial.

Hornfels—produced when heat from an igneous intrusion recrystallizes the surrounding rocks.

Hydraulic conductivity—a measurement of the flow rate of water, by volume, through a cross-sectional unit of a porous subsurface medium.

Hydrothermal—pertaining to or associated with the action of very hot water; hydrothermal fluids can react with and alter the rocks through which they pass or can deposit minerals from solution.

Hypabyssal—applied to medium-grained, intrusive igneous rocks which have crystallized at a shallow depth below the surface.

Igneous rocks—rocks or minerals that were formed when molten material (magma) solidified; one of three main classifications of rock.

Indicated mineral resource—an estimate of ore resources computed from drillholes, outcrops, and developmental data and projected for a reasonable distance on geologic evidence.

Induced polarization—a method of geophysical surveying using an electrical current to determine indications of mineralization.

Inferred mineral resource—a estimate of ore resources based on the character of a deposit and past experience, without actual measurements or samples; the estimate should include limits between which the deposit lies.

Intrusion—a body of rock, usually igneous, that intrudes into pre-existing rock formations; intrusions are classified according to size, shape, and geometrical relationship to the surrounding rock.

Jurassic—from 208 to 145.6 million years ago, the Mesozoic period following the Triassic and preceding the Cretaceous.

Kettle depression—a depression that forms in the surface of glacial sediment as a result of the melting of an included ice mass; a depression may fill with water, forming a small lake.

Lacustrine deposits—material deposited by or settled out of lake waters and exposed by the lowering of water levels or the elevation of land.

Latite—a type of porphyritic extrusive igneous rock.

Leaching—the removal, in solution, of soluble materials from rock, ore, soil, or other medium.

Limonitic alteration—iron oxide-hydroxide alteration, typically yellow in color.

Lithotectonic boundary—a fault that separates terranes; a crustal block whose geologic history differs from the adjoining crustal blocks.

Mafic—applied to any igneous rock with such a high proportion of pyroxene and olivine that is a dark color.

Megabreccia—a breccia in which individual clasts may be more than 1 kilometer in their longest dimension.

Metamorphic rocks—rocks formed when temperature, pressure, or other environmental factors caused structural, chemical, or other transformations in pre-existing rocks; one of three major classifications of rocks.

Mesozoic—245 to 65 million years ago, the middle of the three eras that make up the Phanerozoic period.

Monzodiorite—a type of coarse-grained igneous rock.

Monzonite—a type of coarse-grained igneous rock.

Moraine—an accumulation of material that has been transported on the surface of ice, within ice, or beneath ice.

Normal fault—a high angle (more than 50 degrees) fault where displacement of the hanging wall is downward relative to the footwall.

Orogenic belt—a mountain range consisting of folded and faulted rocks.

Paleozoic—from 570 to 248 million years ago, the first of the three eras of the Phanerozoic eon; the Lower Paleozoic consists of the Cambrian, Ordovician, and Silurian periods, while the Devonian, Carboniferous, and Permian periods comprise the Upper Paleozoic.

Permian—from 290 to 248 million years ago, the final period of the Paleozoic era.

Plagioclase—one of the most important rock-forming silicate minerals.

Pleistocene—from 1.64 million years ago to about 10,000 years ago, the first of two epochs of the Quaternary sub-era.

Polymetallic—when three or more metals are present in commercially viable quantities.

Porphyry—medium-grained rock containing large, well-formed grains of any mineral.

Porphyry copper deposit—large copper deposits centered around stocks of intermediate to acid, porphyritic, igneous rocks; most occur in Mesozoic and Tertiary orogenic belts.

Propylitic alteration—a type of alteration that is found in surrounding rocks of copper and molybdenum porphyry deposits.

Pyrite—a common yellow sulfide mineral with a metallic luster.

Pyroxenite—a type of igneous rock with a silica content of less than about 45 percent.

Quaternary—a sub-era of the Cenozoic era that covers the past 1.64 million years and comprises the Pleistocene and Holocene epochs.

Radiocarbon dating—a dating method for organic material that relies on the known rate of decay of radioactive carbon.

Resistivity surveying—a method where very low-frequency or direct electrical current is injected into the ground and the potential distribution is measured.

Reverse fault—a low-angle fault in which the relative displacement of the hanging wall is upwards; thrust faults are a type of reverse fault.

Rhyolite—a type of fine-grained extrusive igneous rock.

Sedimentary rocks—rocks formed when sediments are consolidated by pressure; one of three major classifications of rocks.

Sericite—white, fine-grained potassium mica with a silky luster.

Shale—a fine-grained, fissile sedimentary rock composed of clay and silt-sized particles of unspecified mineral composition.

Shear zone—a narrow region in which rocks have undergone intense deformation.

Silicification—the introduction of silica into a non-siliceous rock via groundwater or hydrothermal fluids; the silica either fills pore spaces or replaces existing minerals.

Sill—a broad, flat igneous intrusion with contacts that are parallel to the surrounding strata.

Skarn—a mineral deposit at or near a contact between an intrusive body of rock and the surrounding rock.

Solifluction—the slow creeping of fragmented material down a slope as a result of the alternate freezing and thawing of the water contained in the material.

Stade—a short period (less than 10,000 years) characterized by climatic conditions associated with maximum glacial extent.

Stock—an igneous intrusion, approximately circular, with steep contacts to the surrounding rock and a surface area of 20 square kilometers or less.

Stockwork—a mineral deposit formed of a network of small, irregular veins so closely spaced that the deposit can be mined as a unit.

Stratigraphy—the relative spatial and temporal arrangement of rock strata.

Strike—the compass direction of a horizontal line on an inclined plane.

Subduction—the action of a tectonic plate descending below another plate at a convergent margin.

Sulfide—a group of minerals in which the element sulfur is in combination with one or more metallic elements.

Supergene enrichment—when acidic groundwater leaches sulfides and oxides from the surface zone of an ore deposit and carries them downward until they precipitate out of solution, thereby enhancing the grade of the ore deposit in that location..

Syenite—a type of saturated, coarse-grained igneous rock.

Terrane—a fault-bounded area or region characterized by a stratigraphy, structural style, and geologic history distinct from those of adjacent areas.

Tertiary— from 65 million years ago until 1.64 million years ago, the first sub-era of the Cenozoic era; the Tertiary comprises five epochs: Paleocene, Eocene, Oligocene, Miocene, and Pliocene.

Thrust fault—a low-angle (commonly less than 45 degrees) reverse fault where the hanging wall overhangs the footwall.

Translational motion—movement of a rigid body in such a way that the body remains parallel to its original direction.

Transverse fault—also known as a strike-slip fault, a fault where the major displacement is horizontal and parallel to the strike of a vertical or subvertical fault plane.

Triassic—from 245 to 210 million years ago, the earliest of the three periods of the Mesozoic Era.

Triconed—drilled with a tricone drill bit, which is composed of three cones with hard teeth mounted on bearings; triconing is typically used in overburden and in the upper part of a drillhole until bedrock is reached.

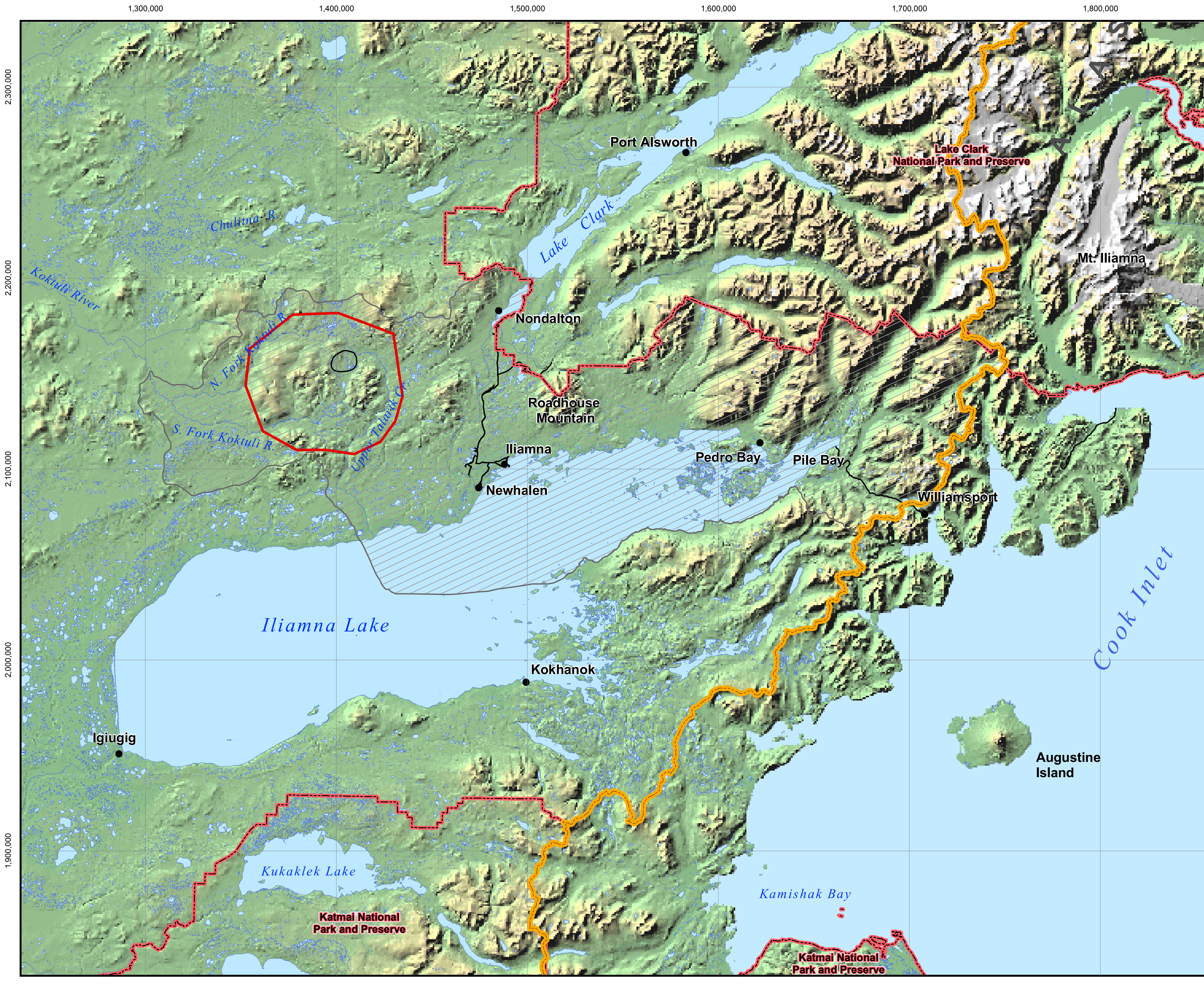
Tuff—a volcanic ash deposit that has been compacted until it has solidified into rock.

Turbidite—a sedimentary deposit laid down by a rapidly moving, sediment-laden current moving through water or another fluid.

Unconformity—contact surface between two groups of strata separated by a hiatus in the geologic record as a result of erosion, no sedimentation, etc.

Wisconsinian—from 80,000 to 10,000 years ago, the last of four glacial episodes recognized in North America.

FIGURES



THE pebble PARTNERSHIP

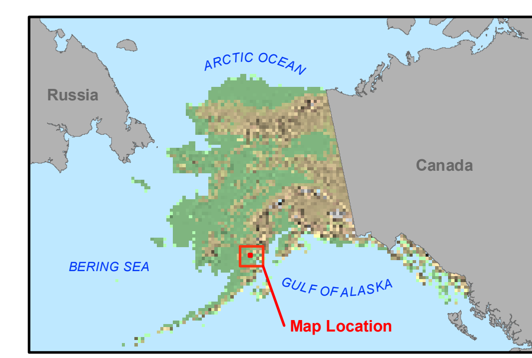
Figure 3-1
Geology and Mineralization Study Area
Bristol Bay Drainages

Legend

- General Deposit Location
- Bristol Bay Study Area
- Mine Study Area
- Population Centers
- National Park and Preserve Boundary
- BB / CI Drainages Boundary
- Existing Roads

Notes

1. BB/CI refers to Bristol Bay/Cook Inlet drainages.



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Kilometers: 5 0 5 10 15 20 25 30

N

Scale 1:600,000

Alaska State Plane Zone 5 (units feet)
1983 North American Datum

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Version: 2008-1	Author: Knight Piesold Ltd.

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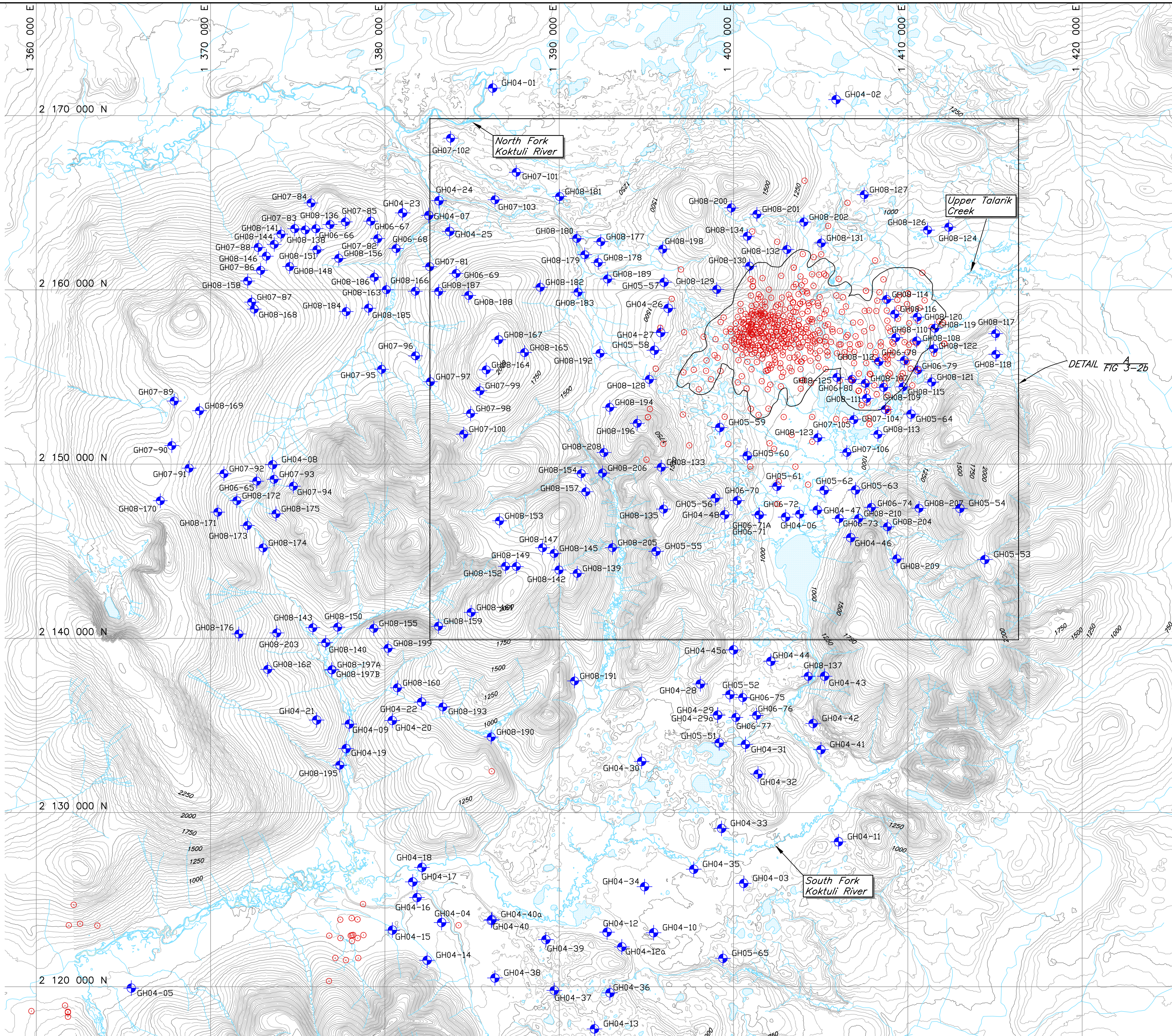
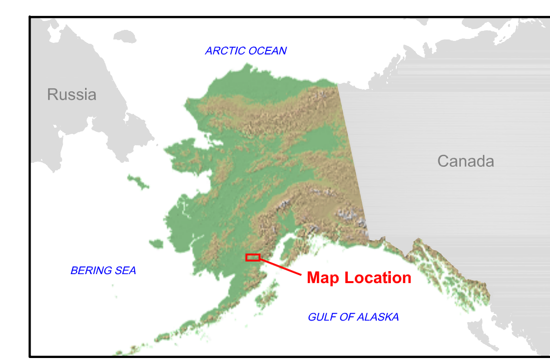


THE pebble PARTNERSHIP

Figure 3-2a
2004 through 2008 Exploration and Geotechnical Drillhole Locations, Geology and Mineralization Mine Study Area

Legend

- General Deposit Location
- Geotechnical Drillholes
- Exploration Drillholes



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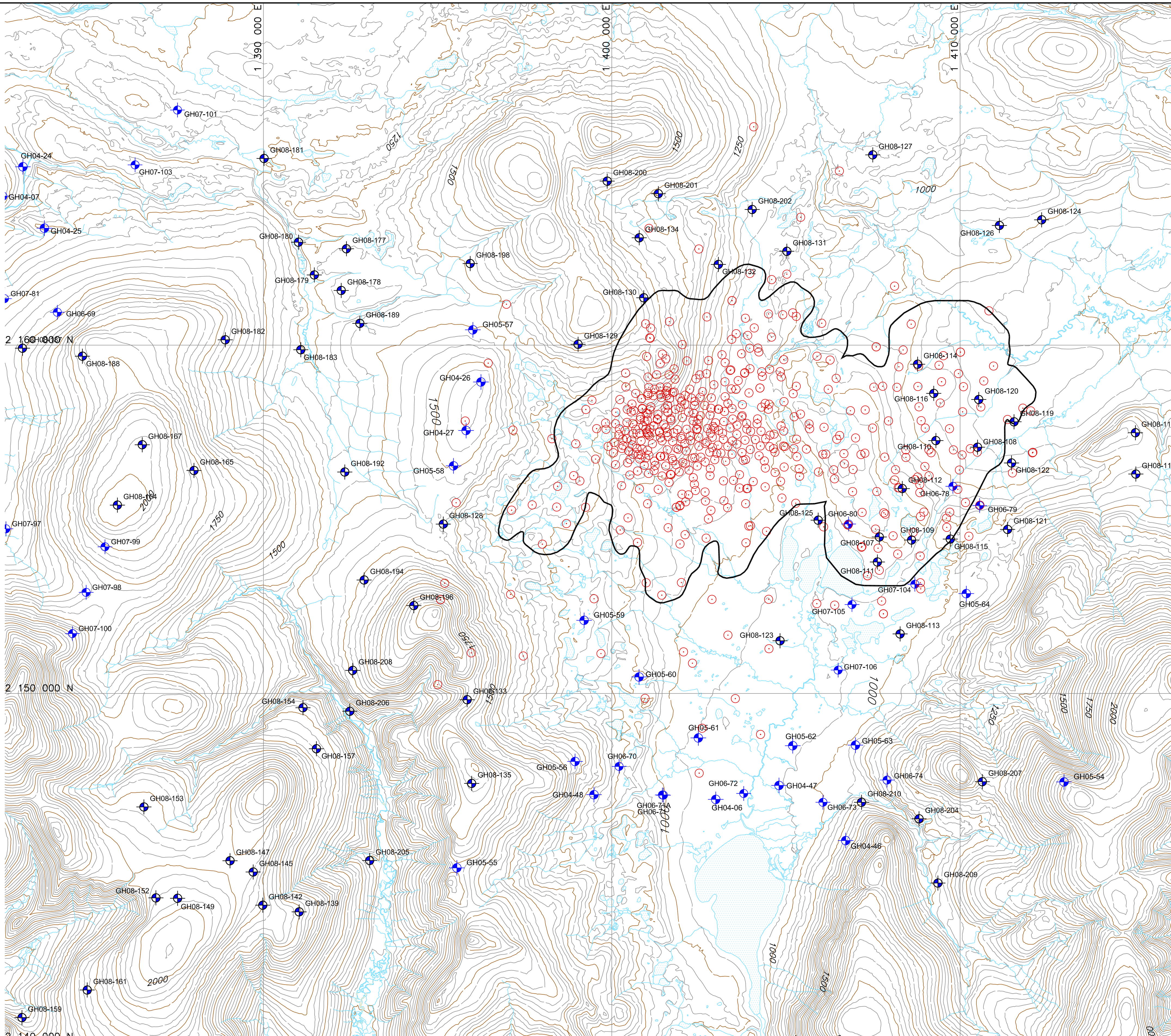


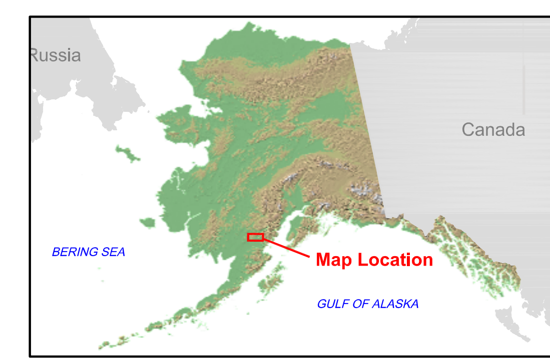
DETAIL $\frac{A}{\text{FIG 3-2a}}$

THE pebble PARTNERSHIP

Figure 3-2b
2004 through 2008 Exploration and Geotechnical Drillhole Locations, Geology and Mineralization Mine Study Area Detail

Legend

- General Deposit Location
- Geotechnical Drillholes
- Exploration Drillholes



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Feet: 1000 0 1000 2000 3000 4000

N

Alaska State Plane Zone 5 (units feet)
1983 North American Datum

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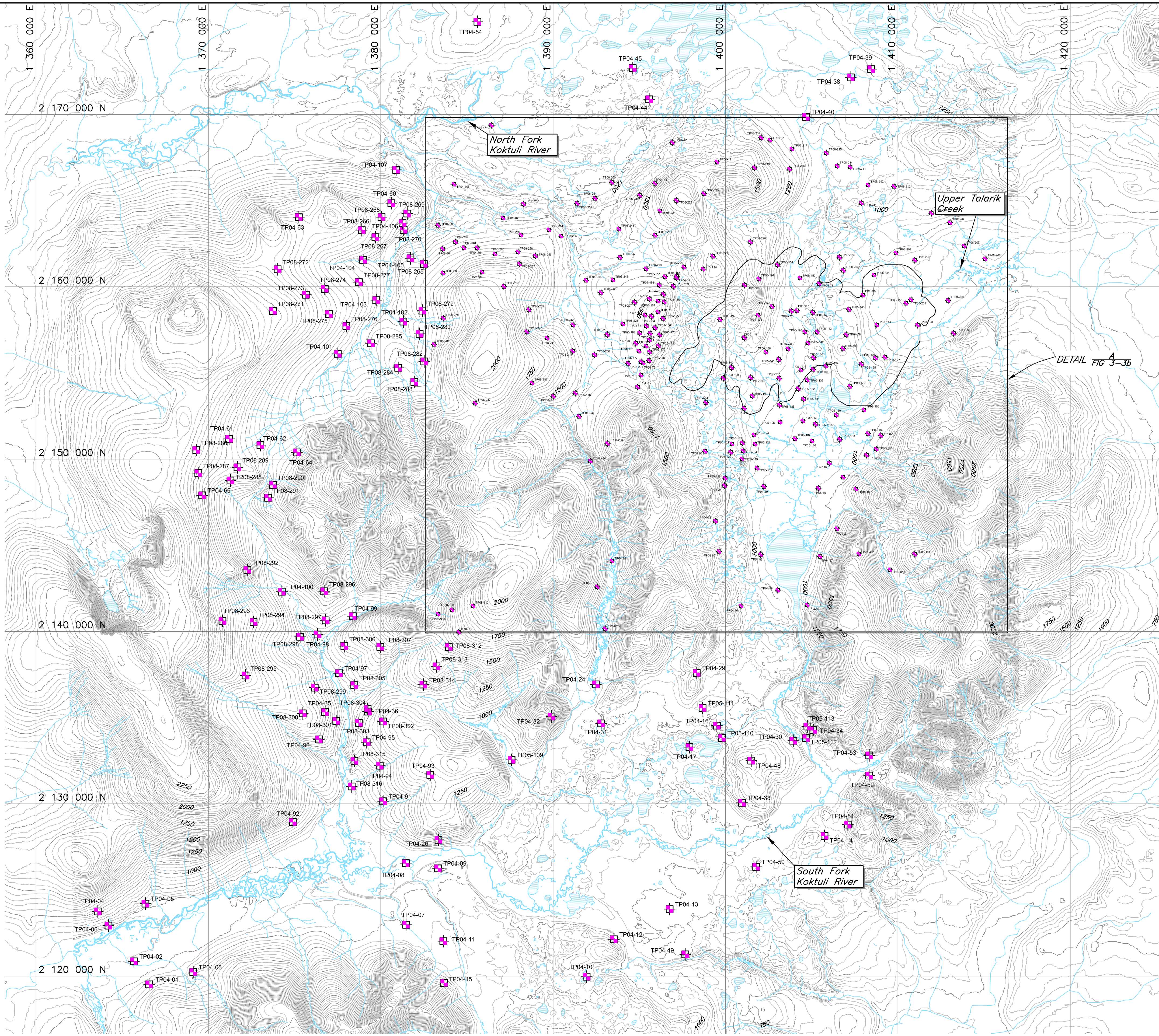

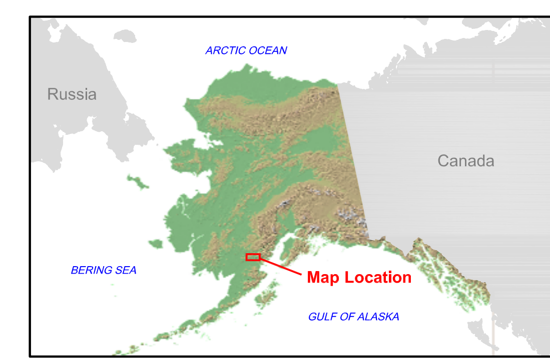

THE
pebble
PARTNERSHIP

Figure 3-3a
2004 through 2008 Test Pit Locations, Geology and Mineralization Mine Study Area

Legend

- General Deposit Location
- Test Pits

1000 0 1000 2000 3000 Metres

2500 0 2500 5000 7500 10000 Feet

N

Alaska State Plane Zone 5 (units feet)
1983 North American Datum

File: B14.dwg	Date: July 06, 2010
Version: 2008-1	Author: Knight Piesold Ltd.

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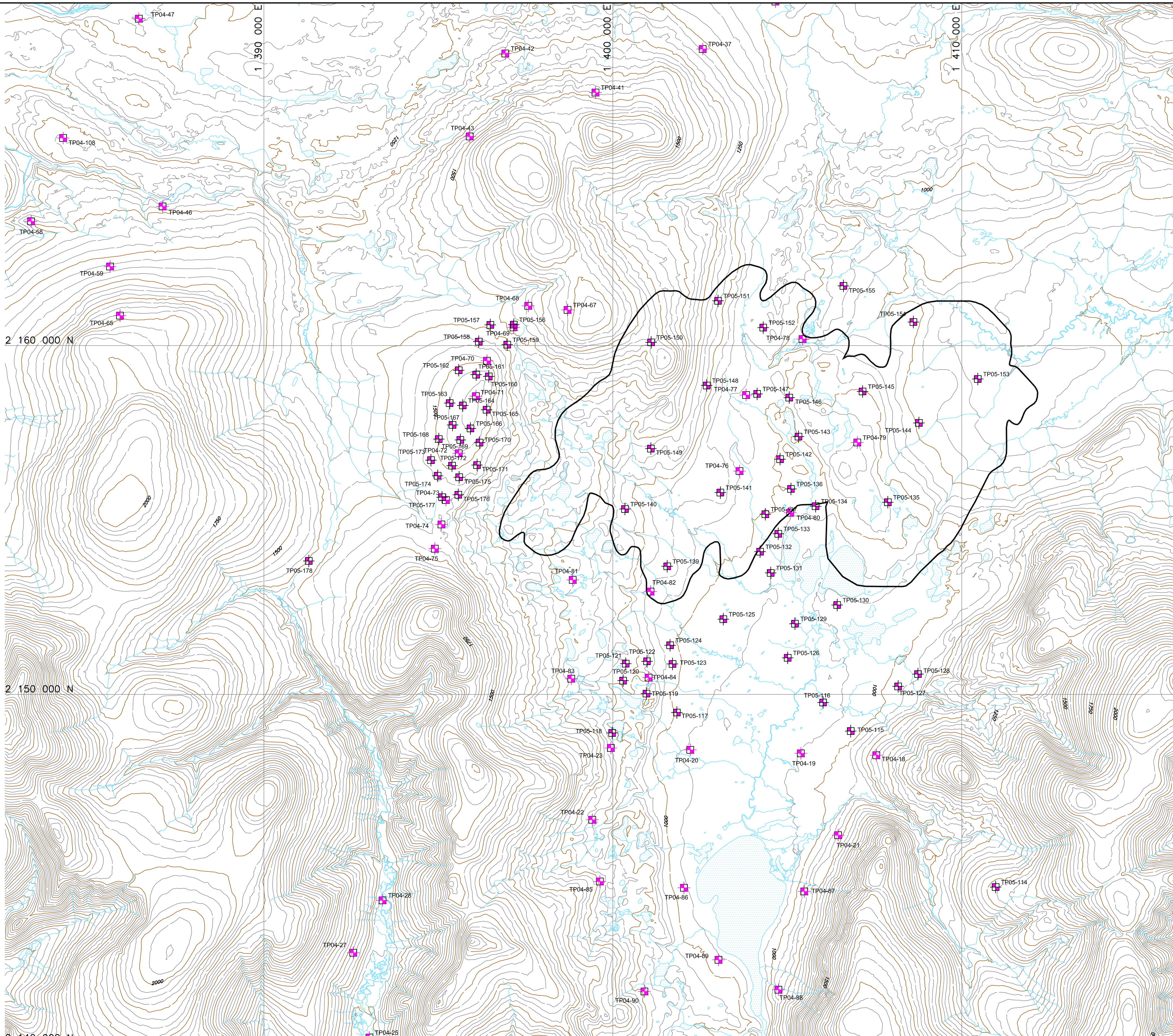


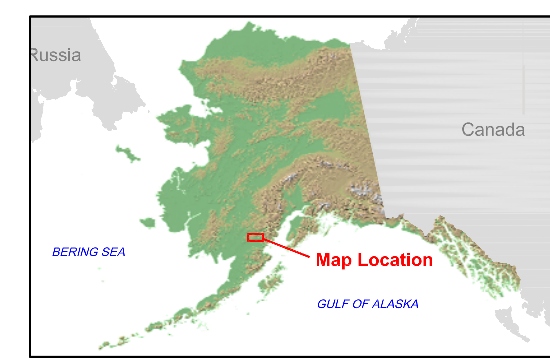
DETAIL A / FIG 3-3a

THE pebble PARTNERSHIP

Figure 3-3b
2004 through 2008 Test Pit Locations, Geology and Mineralization Mine Study Area Detail

Legend

- General Deposit Location
- Test Pits



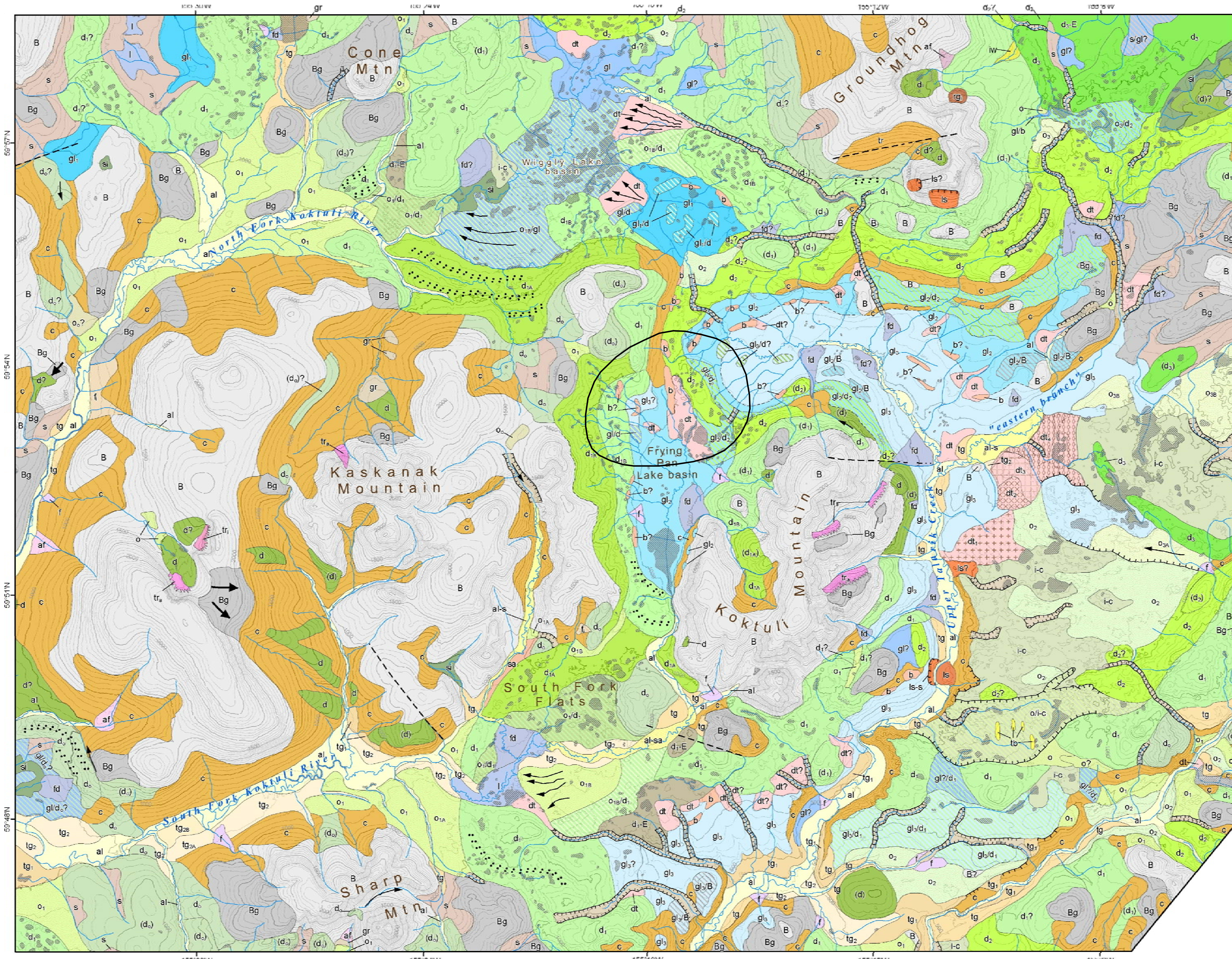
Metres: 1000 0 1000 2000 3000

Feet: 1000 0 1000 2000 3000 4000

N

Alaska State Plane Zone 5 (units feet)
1983 North American Datum

File: B15.dwg	Date: July 06, 2010
Version: 2008-1	Author: Knight Piesold Ltd.



MAP SYMBOLS

- Direction of glacier flow across topographic divide
- Meltwater channel, showing flow direction
- Crest of morainal ridge
- Contact - dashed where approximately located or inferred
- Lineament (no offset noted)
- Scarp
- Drainage channel - abandoned or containing underfit stream
- Lake

THE pebble PARTNERSHIP

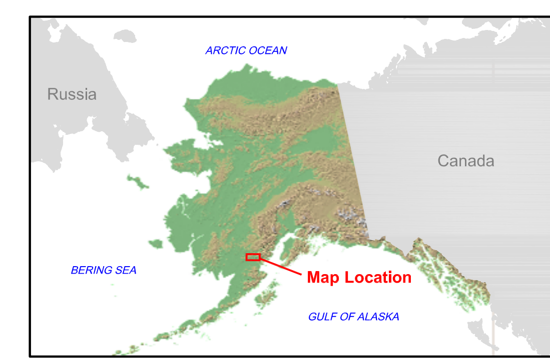
Figure 3-4a
Surficial Geology, Geology and Mineralization Mine Study Area

Legend

General Deposit Location

Notes

1. See Figure 3-4b for map legend.
2. Reproduced from Hamilton and Klieforth, 2010.



Miles: 1 0.5 0 1 2 3
Kilometers: 1 0.5 0 1 2 3 4 5

N

Alaska State Plane Zone 5 (units feet)
1983 North American Datum

File: B10.dwg	Date: July 06, 2010
Version: 2008-1	Author: Knight Piesold Ltd.

DESCRIPTION OF MAP UNITS

[Map units shown with slashes, such as **gl/d**, indicate deposits of the first unit over known or inferred deposits of the second unit. These compound units are depicted by diagonal patterns on map. Map units shown in parentheses, such as **(id)**, indicate thin and generally discontinuous deposits. These overlie bedrock unless an underlying surficial deposit is specified. Units of either type are described below only where additional explanation is necessary. Units are queried where uncertain.]

BEDROCK SURFACE FORMS

B — **Bedrock, undifferentiated**—May bear thin and discontinuous cover of rock rubble.

Bg — **Bedrock, glaciated**—Bedrock smoothed and abraded by overriding glacier ice. Generally well exposed rock surfaces; commonly streamlined in direction of ice flow and channeled by glacial meltwater. Dispersed glacial erratic boulders and cobbles typically present.

ALLUVIUM

al — **Alluvium, undivided**—Varies from moderately sorted, stratified, coarse gravel in upper valleys to muddy fine gravel or gravelly sand in depositional basins. Along smaller streams, unit includes fan, floodplain, and low terrace deposits that are too small to be designated separately.

al-sa — Subunit **al-sa** designates alluvium in which sand dominates. Mapped only in South Fork Flats.

al-s — Subunit **al-s** designates alluvium in which silt dominates. Mapped only on east fork of Upper Talarik Creek and on stream that flows south into South Fork Flats.

tb — **Transverse bars**—Alluvial gravel forming elongate deposits oriented normal to inferred former flow direction. Flanks facing downcurrent are steeper (20°-24°) than flanks facing upcurrent (14°-16°). Mapped only in broad west-trending outwash channel (map unit **o/i-c**) in southeast sector of map area.

TERRACE DEPOSITS

tg — **Terrace gravel**—Alluvial gravel and sandy gravel, capped locally by floodplain deposits of silt, sand, or peat. Older terrace deposits commonly have thicker mantles of eolian silt or thaw-lake deposits.

tg_2, tg_1 — Differentiated into $\mathbf{tg_1}$ (highest and oldest terrace) and $\mathbf{tg_2}$ (lower and younger terrace) where multiple terrace units present. Unit $\mathbf{tg_2}$ locally subdivided into $\mathbf{tg_{2A}}$ (higher and older) and $\mathbf{tg_{2B}}$ (lower and younger).

FAN DEPOSITS

f — **Fan deposits**—Range from poorly sorted, weakly stratified, silty, sandy coarse gravel at mouths of mountain valleys to gravelly sand and silt in lowlands.

f_i — Subunit $\mathbf{f_i}$ designates inactive fan deposits, as described above. These generally stand above modern stream levels, and commonly are graded to river terraces that rise above modern floodplains.

af — **Deposits of steep alpine fans**—Coarse, very poorly sorted, angular to subrounded silty sandy gravel at mouths of avalanche chutes and steep canyons. Upper segments generally channeled, with levees of angular to subangular coarse debris. Lower segments commonly littered with similar coarse debris. Subject to snow avalanches during winter, slushflows during spring snowmelt, and debris flows during heavy summer rainstorms. Surface gradients intermediate between talus cones and alluvial fans. Mapped only on west flank of Kaskanak Mountain block.

af_i — Subunit $\mathbf{af_i}$ designates steep alpine fan, as described above, that appears no longer active. Mapped only on east flank of Groundhog Mountain.

COLLUVIAL DEPOSITS

c — **Colluvium, undivided**—Widespread slope deposits consisting of rock rubble on upper slopes grading downslope into rock debris mixed with finer sediment. Frost creep may dominate on upper slope segments; solifluction on lower slopes.

ls — **Landslide deposits**—Very poorly sorted, nonstratified, coarse to fine angular rubble, commonly with matrix of finer debris. Forms lobes below detachment scars and slide tracks on steep rock walls. Commonly formed by rapid downslope movement followed by period of relative stability, but may alternatively form by slow and progressive creep. Recognized only on southeast corner of Groundhog Mountain block and along east side of Upper Talarik Creek.

ls-s — Subunit **ls-s** designates slump deposits (nearly intact blocks of rock or debris formed by sudden or progressive downslope movements, commonly with rotational component). Mapped only along west side of Upper Talarik Creek in southeast part of map area.

rg_i — **Inactive rock-glacier deposit**—Very poorly sorted, nonstratified, coarse angular rock debris, with matrix of silt and fine rubble; formerly contained abundant interstitial ice. Frontal slope stable, gradually rounding back to upper surface. Mapped only near southeast corner of Groundhog Mountain block, where it forms lobate deposit at base of steep north-facing valley wall.

s — **Solifluction deposits**—Slope deposits consisting of very poorly sorted, nonstratified to weakly stratified, stony silt and organic silt. Form smoothly graded, gently to moderately sloping sheets and aprons.

tr — **Talus rubble, undivided**—Angular, unsorted rock debris forming cones and aprons at bases of cirque headwalls and other steep bedrock slopes. Areas of active talus (unvegetated, unweathered to slightly weathered, with lichen cover sparse to absent) commonly are interspersed with vegetated talus that may have become stabilized following late Pleistocene (Brooks Lake) glaciation. Also forms thin and generally discontinuous sheets over many uplands mapped as "Bedrock".

tr_a, tr_i — Locally differentiated into $\mathbf{tr_a}$ (active talus) and $\mathbf{tr_i}$ (inactive talus), as described above, where these form sufficiently large mappable units. Within mountain valleys, approximate upper limit of active talus is designated by sawtooth pattern.

GLACIOLACUSTRINE AND LACUSTRINE DEPOSITS

gl — **Glacial-lake deposits, undifferentiated**—Stratified to weakly stratified silt, organic silt, and silty fine sand, commonly with dispersed dropstones. Grades into gravelly sand to sandy fine gravel near former stream mouths. Marked by smooth and poorly drained surface morphology, with sharp upper limit that coincides with beach and delta deposits (as described below). Mapped as compound unit (for example, **gl/d**) where it drapes or overlies bedrock or other glacial deposits.

gl_3 — **Glacial-lake deposits, youngest**—Glacial-lake deposits, as described above, rising to altitudes of 800-850 ft above sea level (asl) along Upper Talarik Creek, and to about 900 ft asl along the Talarik's east and west forks. Postdate Iliamna-stade glaciation; persisted into Newhalen stade.

gl_2 — **Glacial-lake deposits, intermediate age** as described above. Rise to altitudes of about 900 ft asl along Upper Talarik Creek near south margin of map and 1050 ft asl farther north along Upper Talarik Creek, in proposed Pit Area, and in basin north of Frying Pan Lake. Accompanied Iliamna-stade glaciation, and persisted during deglaciation.

gl_1 — **Glacial-lake deposits, oldest**—Glacial-lake deposits, as described above, rising to altitudes of about 1150 ft asl in Wiggly Lake area. A smaller remnant may also occur on northwest flank of basin that extends north from Frying Pan Lake. Accompanied Kvichak-stade glaciation, and persisted during deglaciation.

b — **Beach deposits**—Moderately well sorted gravelly sand or sandy fine gravel. Forms ridges parallel to topographic contours along upper margins of glacial-lake deposits; their steepest flanks face lake basin. Wave-abraded platform with dispersed relict glacial boulders commonly lies beyond beach face, with platform and beach face meeting at sharp angle.

dt — **Deltaic deposits**—Well sorted to very well sorted sand to sand with fine gravel. Form lobes with axes normal to topographic contours that extend across margins of former glacial-lake deposits. Where preserved, surface channels have digitate pattern. Generally border modern streams or abandoned meltwater channels. Queried where interpreted from aerial photographs but not field checked.

dt_4, dt_3, dt_2, dt_1 — Subunits $\mathbf{dt_1}$, $\mathbf{dt_2}$, $\mathbf{dt_3}$, and $\mathbf{dt_4}$ (highlighted by patterns) are successively lower and younger deltaic deposits built into moraine-dammed lake near junction of east and west forks of Upper Talarik Creek as lake level progressively lowered from 880 to 770 ft asl.

fd — **Fan-delta deposits**—Alluvial-fan deposits (as described in unit **f**) that grade downslope into deltaic and lacustrine facies (as described in units **dt** and **gl**). Generally have fan-shaped surface form, but distal (lower) segment is broader, more poorly drained, and more gently sloping than normal alluvial fan.

l — **Lake deposits**—Silt and silty fine sand, stratified to weakly stratified. Probably of postglacial (Holocene) age. Mapped only on floor of South Fork Flats and near northwest corner of map area.

OTHER GLACIAL DEPOSITS

d — **Drift, undifferentiated**—Unsorted to poorly sorted, generally nonstratified, compact till ranging in composition from muddy gravel to sandy coarse gravel. Contains local stratified ice-contact meltwater deposits consisting of moderately sorted sand and sandy gravel. Pebbles and small cobbles generally dominant, but faceted and striated stones up to boulder size are generally dispersed throughout deposit. Surface morphology commonly includes morainal ridges, dry and water-filled kettle depressions, conical to subdued mounds, and meltwater channels.

d_3 — **Drift of Brooks Lake glaciation, Newhalen stade**—Glacial deposits, as described above.Moraines sharp crested, with irregular topography little modified by weathering or erosion.Forms arcuate end moraines in northeast corner of map area and near its east-central margin.

d_2 — **Drift of Brooks Lake glaciation, Iliamna stade**—Glacial deposits, as described above. Moraine crests irregular, but generally less sharp than those of Newhalen stade. Forms large crescentic end moraine north of Frying Pan Lake basin that encloses proposed Pit Area and is traceable farther east along south and southeast flanks of Groundhog Mountain block. Other end moraines are present north of Wiggly Lake basin at north-central margin of map area and at southeast corner of map area.

d_1 — **Drift of Brooks Lake glaciation, Kvichak stade**—Glacial deposits, as described above. Moraine crests more subdued than those of younger Brooks Lake stades, and drift is more eroded on mountainsides. Form extensive end moraines that (1) cross North Fork Koktuli River near its head, (2) enclose South Fork Flats, and (3) extend west-southwest to Upper Talarik Creek in southeast sector of map area. A small portion of the massive Kvichak moraine around Iliamna Lake extends into extreme southwest corner of map area.

d_{1B}, d_{1A} — Subunits $\mathbf{d_{1A}}$ (older) and $\mathbf{d_{1B}}$ (younger) differentiated west and south of Frying Pan Lake and in Wiggly Lake area. The younger subunit, a recessional moraine, dams Frying Pan Lake.

d_i-E — Subunit $\mathbf{d_1}$**-E** designates areas of Kvichak-Stade drift that have been eroded by an uncertain agent (either flowing meltwater or wave action along margin of glacial lake).

d_o — **Drift of pre-Brooks Lake age**—Highly modified glacial deposits, generally remaining only as thin and discontinuous patches of drift on uplands beyond limits of younger glacial advances. A conspicuous moraine segment north of South Fork Koktuli River near southwest corner of map area was deposited by a glacier that expanded northward from Iliamna Lake area and dammed the South Fork. Drift and (or) outwash may also have dammed North Fork of Koktuli River at this time.

i-c — **Ice-contact meltwater deposits**—Meltwater-washed sand and gravel deposited in contact with stagnating glaciers. Commonly forms conical to subdued mounds with well drained surfaces interspersed with dry and water-filled kettle depressions and abandoned meltwater channels.

iw — **Inwash deposit**—Alluvial sand and gravel, commonly with interstratified silt, deposited where stream partly dammed against moraine flank. Mapped only on east flank of Groundhog Mountain at western edge of Newhalen stade drift (unit $\mathbf{d_3}$).

o — **Outwash, undifferentiated**—Moderately well sorted and stratified sandy gravel forming broad aprons and elongate valley trains in front of moraines, and also terrace remnants farther downvalley. Largest stones decrease in size downvalley from large cobbles and very small boulders near moraine fronts to pebble-small cobble gravel in more distal locations.

o_3 — **Outwash associated with drift of Newhalen stade**—Gravel aprons and valley trains, as described above. Associated with moraines of Newhalen stade in northeast and east-central sectors of map area.

o_{3B}, o_{3A} — Subunits $\mathbf{o_{3A}}$ and $\mathbf{o_{3B}}$ differentiate outwash generated during maximum Newhalen advance (o_{3A}) from recessional outwash that formed during glacier retreat (o_{3B}).

o_2 — **Outwash associated with drift of Iliamna stade**—Valley train, as described above. Mapped only in southeast sector of map area, where broad terrace remnants extend west-southwest toward Upper Talarik Creek from end moraines near southeast corner of map.

o_1 — **Outwash associated with drift of Kvichak stade**—Extensive outwash aprons and valley trains, as described above. Mapped in and west of South Fork Flats and west of Wiggly Lake at head of North Fork drainage. Also associated with Kvichak moraine in extreme southwest corner of map area.

o_{1B}, o_{1A} — Subunits $\mathbf{o_{1A}}$ (older) and $\mathbf{o_{1B}}$ (younger) are differentiated only southwest of Frying Pan Lake and in South Fork Flats, where they are related to older and younger end moraines of Kvichak stade.

o_o — **Outwash associated with drift of pre-Brooks Lake age**—Gravel apron, as described above. Mapped only near northwest corner of map area, where extends southeastward from inferred end moraine of pre-Brooks Lake age.

OTHER DEPOSITS

gr — **Gravel, undifferentiated**—Isolated, gravelly erosion remnants of uncertain composition and origin. Mapped in north-trending valley that bisects Kaskanak Mountain block. Also present on floor of abandoned or underfit drainage channels.

sa — **Sand deposits, undifferentiated**—Well sorted fine to medium sand of uncertain origin near north margin of South Fork Flats.

si — **Silt, ice-rich**—Poorly drained areas on lowlands that contain abundant small ponds interpreted as thaw lakes. Common on floors of lake basins in proposed Pit Area and north of Wiggly Lake, where they generally are not differentiated from glaciolacustrine deposits.

THE pebble PARTNERSHIP

Figure 3-4b
Surficial Geology Legend

Notes

1. See Figure 3-4a for corresponding map.
2. Reproduced from Hamilton and Klieforth, 2010.

File: B11.dwg	Date: July 06, 2010
Version: 2008-1	Author: Knight Piesold Ltd.

XREF FILE(S): IMAGE FILE(S): PLP Logo May 2008 Surficial_Geology_2009

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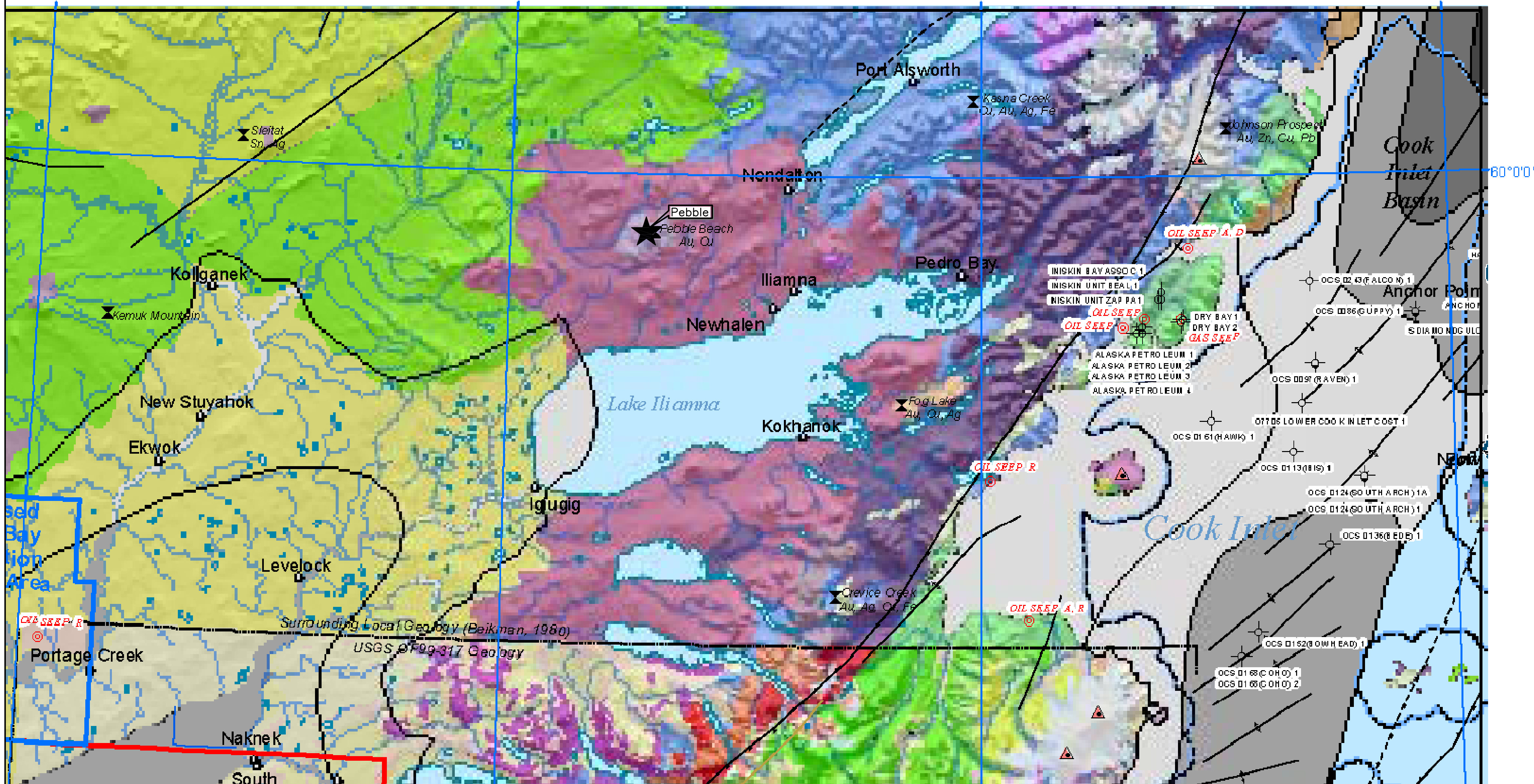
THE pebble PARTNERSHIP

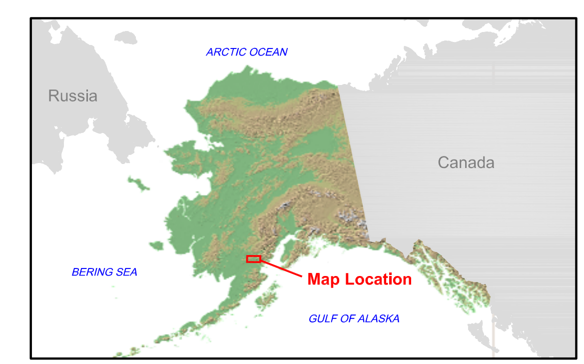
Figure 3-5a
Geology of Bristol Bay Region



★ General Deposit Location

Notes

1. See Figure 3-5b for rest of map legend.
2. Reproduced from ADNR, 2004.



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N

Alaska State Plane Zone 5 (units feet)
1983 North American Datum

Alaska Peninsula Geologic Structure

- Anticline - Certain.
- Anticline - Inferred.
- Anticline - Concealed.
- Syncline - Certain.
- Syncline - Inferred.
- Syncline - Concealed.
- Dikes and Sills.
- Fault
- Fault - Inferred
- Fold
- Normal Fault
- Normal Fault - Inferred
- Thrust Fault
- Thrust Falut - Inferred

Sedimentary Basins (Kirschner 2002)

- 0 km - 1 km
- 1 km - 3 km
- 3 km - 5 km
- > 5 km

Administrative Boundaries & Infrastructure

- Proposed Exploration License Area
- Proposed Lease Sale Boundary
- AK State Ownership 3 Mile Limit

Towns & Villages

- Population > 1000
- Population < 1000

File: B03.dwg	Date: July 06, 2010
Version: 2008-1	Author: Knight Piesold Ltd.

THE pebble PARTNERSHIP

Figure 3-5b
Regional Geology Legend

Alaska Peninsula Geology (OF99-317)

Unconsolidated Deposits

- Qa - Alluvial deposits (Holocene and Pleistocene)
- Qb - Marine beach and estuarine deposits
- Qmt - Marine terrace deposits (Holocene and Pleistocene)
- Qm - Moraines and other glacial deposits (Holocene and Pleistocene)
- Qaf - Alluvial fan and landslide deposits (Holocene and Pleistocene)

Sedimentary

- Tmr - Milky River Formation (Pliocene)
- Tta - Tachilni Formation (late Miocene)
- Th - Hemlock Conglomerate (late Oligocene)
- Tbl - Bear Lake Formation (late and middle Miocene)
- Tu - Unga Formation (middle Miocene to late Oligocene)
- Tbe - Belkofski Formation (middle Miocene? to late Oligocene?)
- Ts - Stepovak Formation (early Oligocene and late Eocene)
- Tt - Tolstoi Formation (middle Eocene to late Paleocene)
- Tc - Copper Lake Formation (early Eocene and Paleocene?)
- Ks - Shumagin Formation (Late Cretaceous; Maestrichtian)
- Ksm - Mudstone
- Kk - Kaguyak Formation (Late Cretaceous; Maestrichtian and Campanian)
- Kh - Hoodoo Formation (Late Cretaceous; Maestrichtian and Campanian)
- Kc - Chignik Formation (Late Cretaceous; Maestrichtian and Campanian)
- Kp - Pedmar Formation (Early Cretaceous; Albian)
- Khe - Herendeen Formation (Early Cretaceous; Barremian and Hauterivian)
- Kst - Staniukovich Formation (Early Cretaceous; Valanginian and Berriasian)
- KJcv - Chert and volcanic sequence (Early Cretaceous or Jurassic)
- Jk - Kialagvik Formation (Middle and Early Jurassic; Callovian to late Toarcian)
- Jnk - Katolinat Conglomerate Member (Tithonian)
- Jni - Indecision Creek Sandstone Member (Tithonian and Kimmeridgian)
- Jn - Naknek Formation (Late Jurassic; Tithonian to Oxfordian)
- Jns - Snug Harbor Siltstone Member (Kimmeridgian and Oxfordian)
- Jnc - Chisik Conglomerate Member (Oxfordian)
- Jnn - Northeast Creek Sandstone Member (Oxfordian)
- Js - Shelikof Formation (Middle Jurassic; Callovian)
- Jt - Talkeetna Formation (Early Jurassic)
- Trk - Kamishak Formation (Late Triassic; Norian)
- Trls

Igneous-Plutonic

- Qi - Intrusive rocks (Holocene and Pleistocene)
- Ti - Intrusive rocks (Pliocene and late Miocene)
- Tqd - Quartz diorite (Oligocene)
- Tgd - Granodiorite (Oligocene)
- Tg - Granodiorite (Paleocene)
- Tiu - Intrusive rocks, undivided (Tertiary)
- Jgb - Diorite and gabbro (Late? and Middle Jurassic)
- Jgd - Granodiorite (Late ? and Middle Jurassic)
- Jgr - Granite (Late? and Middle Jurassic)
- Jqd - Tonalite and quartz diorite (Late? and Middle Jurassic)

Igneous-Volcanic

- Qv - Volcanic rocks (Holocene and Pleistocene)
- Qpd - Pyroclastic and debris-flow deposits (Holocene and late Pleistocene?)
- QTv - Volcanic rocks (Quaternary and Pliocene?)
- QTp - Pyroclastic deposits (Pleistocene? and Pliocene)
- QTmv
- QTdv
- Tvu - Volcanic rocks, undivided (Tertiary)
- Tv - Volcanic rocks (late Miocene)
- Top
- Tm - Meshik Volcanics (early Oligocene and late Eocene)
- Trv - Volcanic rocks (Late Triassic)

Metamorphic

- QTc - Contact-metamorphosed rocks (early Quaternary or late Tertiary)
- JPK - Kakhonak(?) Complex (Late Jurassic? to Permian?)
- Trc - Cottonwood Bay Greenstone (Late Triassic; Norian?)

Other Surface Symbols

- g - Glaciers

Oil and Gas Wells

- Drill Hole
- Plugged & Abandoned
- Plugged & Abandoned - Oil Show
- Plugged & Abandoned - Oil and Gas Show
- Plugged & Abandoned - Gas Show

Minerals & Geohazards

- Volcanoes
- Metalliferous Load Deposits
- Coalfields
- Placer Deposits

Indicators of Petroleum

- Gas Seep
- Oil Seep
- Oil-bearing Outcrop
- A Approximate location of reported indication.
- D Reported indication regarded as doubtful or disproved on basis of field examination by the U.S. Geological Survey.
- R Reported indication not examined by the U.S. Geological Survey.
- U Reported indication regarded as doubtful because location is in unfavorable geologic setting.

Surrounding Local Geology (Beikman 1980)

Unconsolidated Deposits

- uTc - Continental sandstone, siltstone, claystone, minor conglomerate and coal beds (Upper Tertiary)
- mTc - Continental sandstone, siltstone, claystone and coal beds (Middle Tertiary)
- lTc - Continental claystone, siltstone, sandstone, conglomerate, and coal beds (Lower Tertiary)

Sedimentary

- Q - Alluvial, glacial, lake, eolian, beach, and volcanic deposits (Quaternary)
- Qh - Alluvial, glacial, lake, estuarine, swamp, landslide, flood plain, and beach deposits (Holocene)
- Qp - Alluvial, glacial, dune sand, loess (Pleistocene)
- T - Volcanogenic sedimentary rocks and flows, dikes and sills (Tertiary)
- Tp - Tachilni Formation (Pliocene)
- Tm - Bear Lake Formation (Miocene)
- lT - Interbedded sedimentary, volcanogenic, and volcanic rocks (Lower Tertiary)
- To - Meshik and Stepovak Formation (Oligocene)
- MzPz - Quartzite, schist and phyllite (Mesozoic and Paleozoic)
- K - Kaguyak Formation (Cretaceous)
- uK - Chignik and Hoodoo Formations (Upper Cretaceous)
- KJ2 - Staniukovich Formation and Herendeen Formation (Lower Cretaceous)
- KJ3 - Melange of flysch, greenstone, limestone (Lower Cretaceous and upper Jurassic (?))
- KJ1 - Graywacke, slate, argillite, and minor conglomerate (Cretaceous and upper Jurassic)
- KJ - Argillite, shale, graywacke, quartzite, conglomerate, lava, tuff, and agglomerate (Cretaceous and Jurassic)
- lK - Unnamed graywacke, argillite, conglomerate, and minor limestone (Lower Cretaceous)
- uJ - Sandstone, siltstone, shale, and conglomerate (Upper Jurassic)
- uTr - Limestone, tuff, tuffaceous conglomerate and breccias (Upper Triassic)
- mJ - Argillite, graywacke, and conglomerate (Middle Jurassic)
- lJ - Talkeetna Formation (Lower Jurassic)
- D - Limestone (Devonian)
- Z - Schist, gneiss, and small amounts of amphibolite and marble (Precambrian)

Igneous - Plutonic

- u - Ultramapic rocks (age unknown)
- Tif - Felsic Intrusive rocks (Tertiary)
- Tim - Mafic Intrusive rocks (Tertiary)
- mTii - Intermediate Intrusive rocks (Middle Tertiary)
- Txif - Felsic Intrusive rocks (Paleocene)
- TKi - Undifferentiated Intrusive rocks (Tertiary and/or Cretaceous)
- TKif - Felsic Intrusive rocks (Tertiary and/or Cretaceous)
- Ji - Intermediate Intrusive rocks (Jurassic)
- Jim - Mafic Intrusive rocks (Jurassic)

Igneous - Volcanic

- Qhvm - Mafic Volcanic rocks (Holocene)
- Qvm - Mafic Volcanic rocks (Quaternary)
- Qv - Undifferentiated volcanic rocks (Quaternary)
- QTv - Undifferentiated Volcanic rocks (Quaternary or Tertiary)
- Qvi -Intermediate Volcanic rocks (Quaternary)
- Tpv - Undifferentiated Volcanic rocks (Pliocene)
- Tvm - Mafic Volcanic rocks (Tertiary)
- Tv - Undifferentiated Volcanic rocks (Tertiary)
- TKvm - Mafic Volcanic rocks (Tertiary and/or Cretaceous)
- Jvi - Intermediate Volcanic rocks (Jurassic)

Metamorphic

- lJm - Metamorphic Intercalated Schist (Lower Jurassic)

Notes

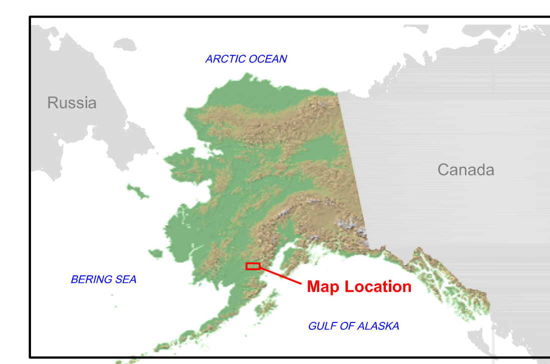
1. See Figure 3-5a for corresponding map.
2. Reproduced from ADNR, 2004.

File: B09.dwg	Date: July 06, 2010
Version: 2008-1	Author: Knight Piesold Ltd.

Figure 3-6a
Subsurface Geology
Geology and Mineralization
Mine Study Area

Notes

1. See corresponding legend on Figure 3-6c.



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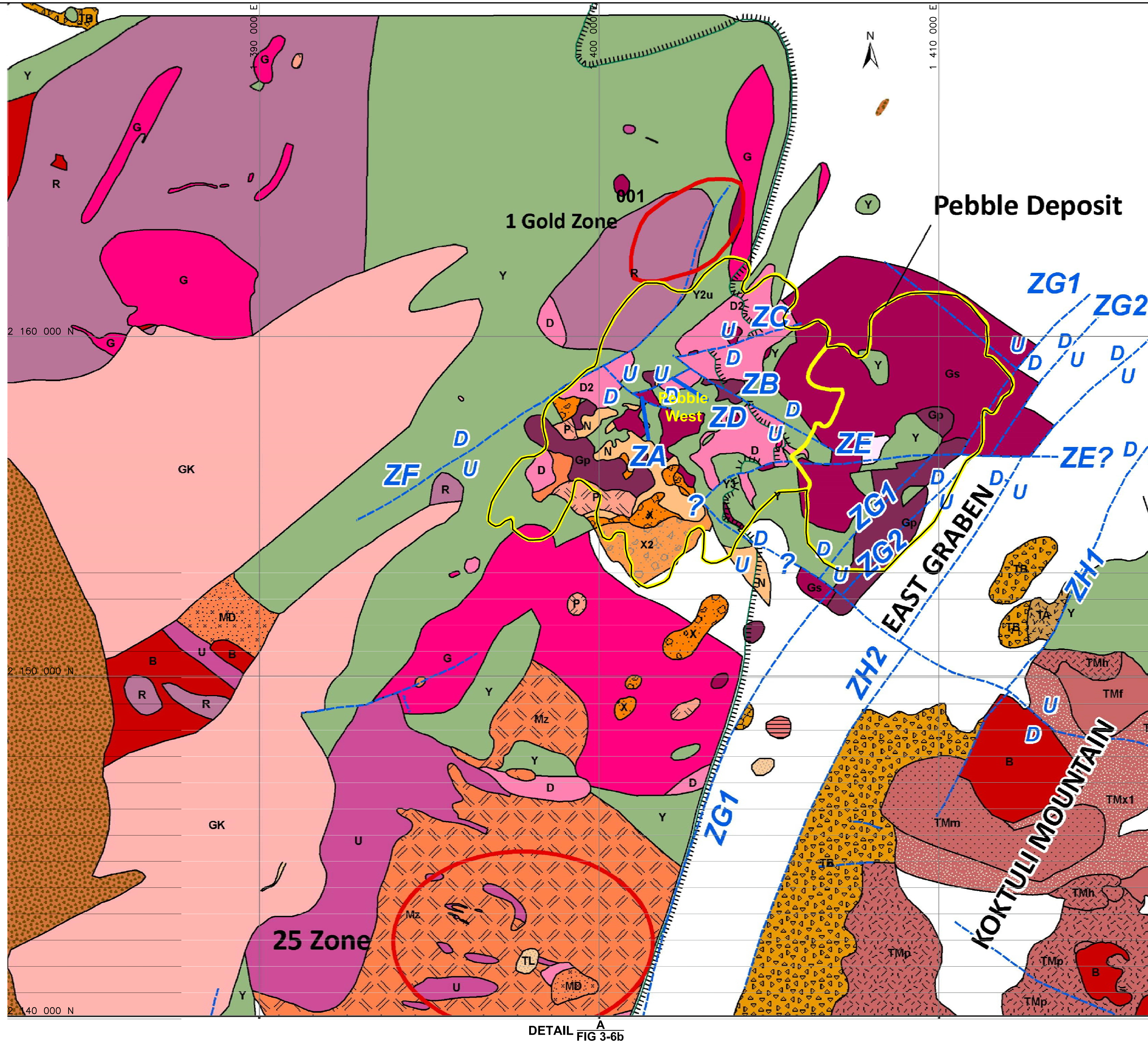
Feet: 4000 0 4000 8000 12,000

N

Alaska State Plane Zone 5 (units feet)
1983 North American Datum

File: B04.dwg	Date: July 06, 2010
Version: 2008-1	Author: Knight Piesold Ltd.

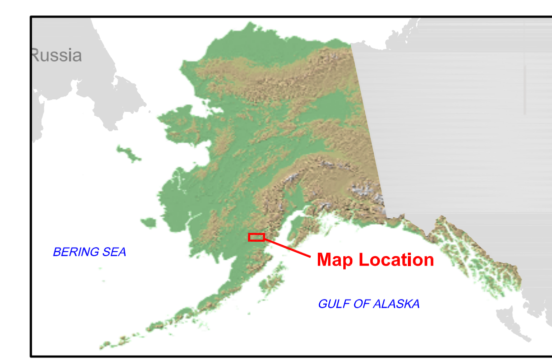


THE pebble PARTNERSHIP

Figure 3-6b
Subsurface Geology
Geology and Mineralization
Mine Study Area Detail

Notes

1. See corresponding legend on Figure 3-6c.



1000 0 1000 2000 3000 4000 5000 6000 7000 8000 Metres

1000 0 1000 2000 3000 4000 Feet

N

Alaska State Plane Zone 5 (units feet)
1983 North American Datum

File: B13.dwg	Date: July 06, 2010
Version: 2008-1	Author: Knight Piesold Ltd.

Pebble Bedrock Geology Legend

ROCK UNITS

Tertiary Intrusive Rocks

TMf	Monzonite, fine-grained
TMh	Monzonite, hornblende-bearing
TMm	Monzonite, medium-grained
TMp	Monzonite, medium-grained
TMx1	Fine-grained monzonite with medium-grained fragments
TMx2	Medium-grained monzonite with fine-grained fragments
TO	Gabbro

Tertiary Volcanic Rocks

TA	Andesite flow
TB	Basalt flow or dike
TBh	Hyaloclastic basalt flow
TL	Latite
TR	Rhyolite flow
TRb	Rhyolite flow, banded

Tertiary Sedimentary Rocks

TC	Conglomerate
TE	Fragmental rock, matrix dominant
TXA	Fragmental rock, angular fragment dominant
TW	Coarse wacke to fine-grained sandstone
TY	Mudstone

Cretaceous Intrusive Rocks

Q	Quartz-rich domain, >50% quartz vein material, logged as rock unit
G	Granodiorite, grain size intermediate between Units Gp and Gs
Gp	Granodiorite to quartz monzodiorite, coarse-grained
Gs	Granodiorite sill, fine-grained
N	Monzodiorite
X	Intrusion breccia, Unit N monzodiorite
X2	Intrusion breccia, Unit N Felsite
F/X2	Felsite with associated intrusion breccia
M	Monzonite
P	Monzodiorite, common K-feldspar megacrysts
Mz	Monzodiorite, porphyritic
Mz.U	Monzodiorite, porphyritic, locally with fragments of Unit U

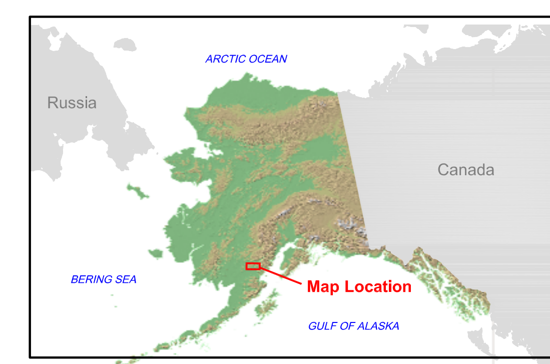
MD	Monzodiorite (south end of property)
D	Diorite
R	Gabbro
U	Pyroxenite, ultramafic
UxMz	Pyroxenite, locally brecciated with sparse matrix of Unit Mz
GK	Granodiorite-Kaskanak
MK	Granodiorite-Kaskanak

Jurassic/Cretaceous Volcanic, Sedimentary Rocks

B	Basalt
C	Conglomerate
W	Wacke to sandstone
Y	Silstone to mudstone
YY	Unit Y with angular and rounded fragments of Unit Y, minor fragments of Unit B
	Fault, inferred
	General Deposit Location
	Areas of known mineralization
	Claim boundary
?	Extent Uncertain

THE pebble PARTNERSHIP

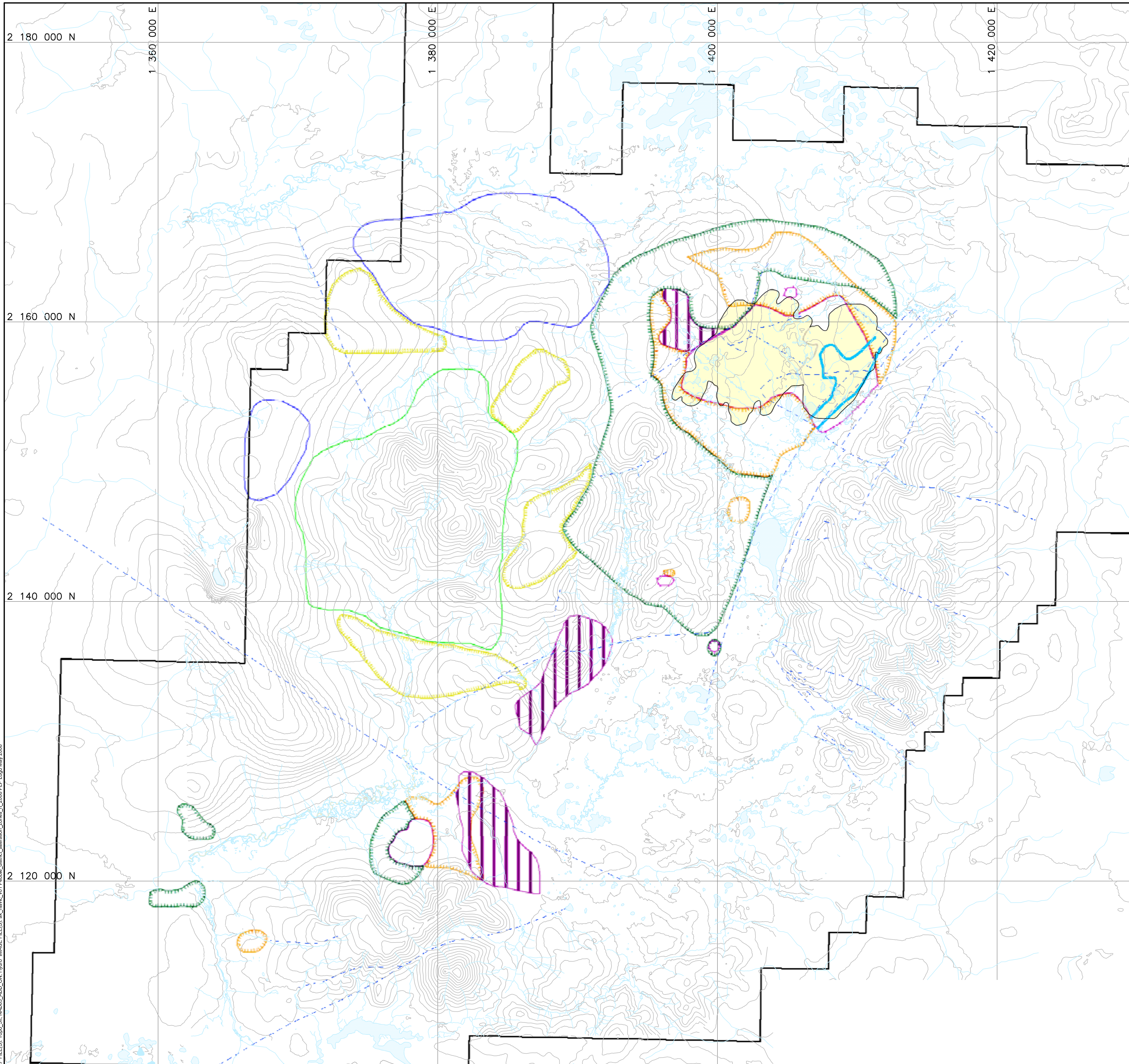
Figure 3-6c
Subsurface Geology
Geology and Mineralization
Legend



Metres: 5000 0 5000 10000 15000 20000 25000
Feet: 4000 0 4000 8000 12,000
N

Alaska State Plane Zone 5 (units feet)
1983 North American Datum

File: B16.dwg	Date: July06, 2010
Version: 2008-1	Author: Knight Piesold Ltd.



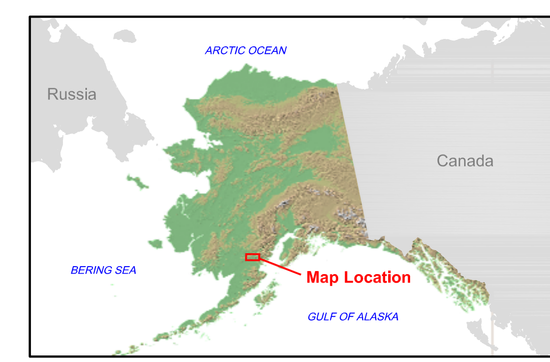
THE pebble PARTNERSHIP

Figure 3-7
Alteration Zones, Geology and Mineralization Mine Study Area

Legend

Alteration type

- Hornfels
- Potassic [K-SR2b]
- Not Altered
- Propylitic [PRP]
- Propylitic - weak [PRP]
- Phyllic [QSP]
- Tertiary Rocks
- Silicification
- Fault, inferred
- General Deposit Location
- Claim boundary



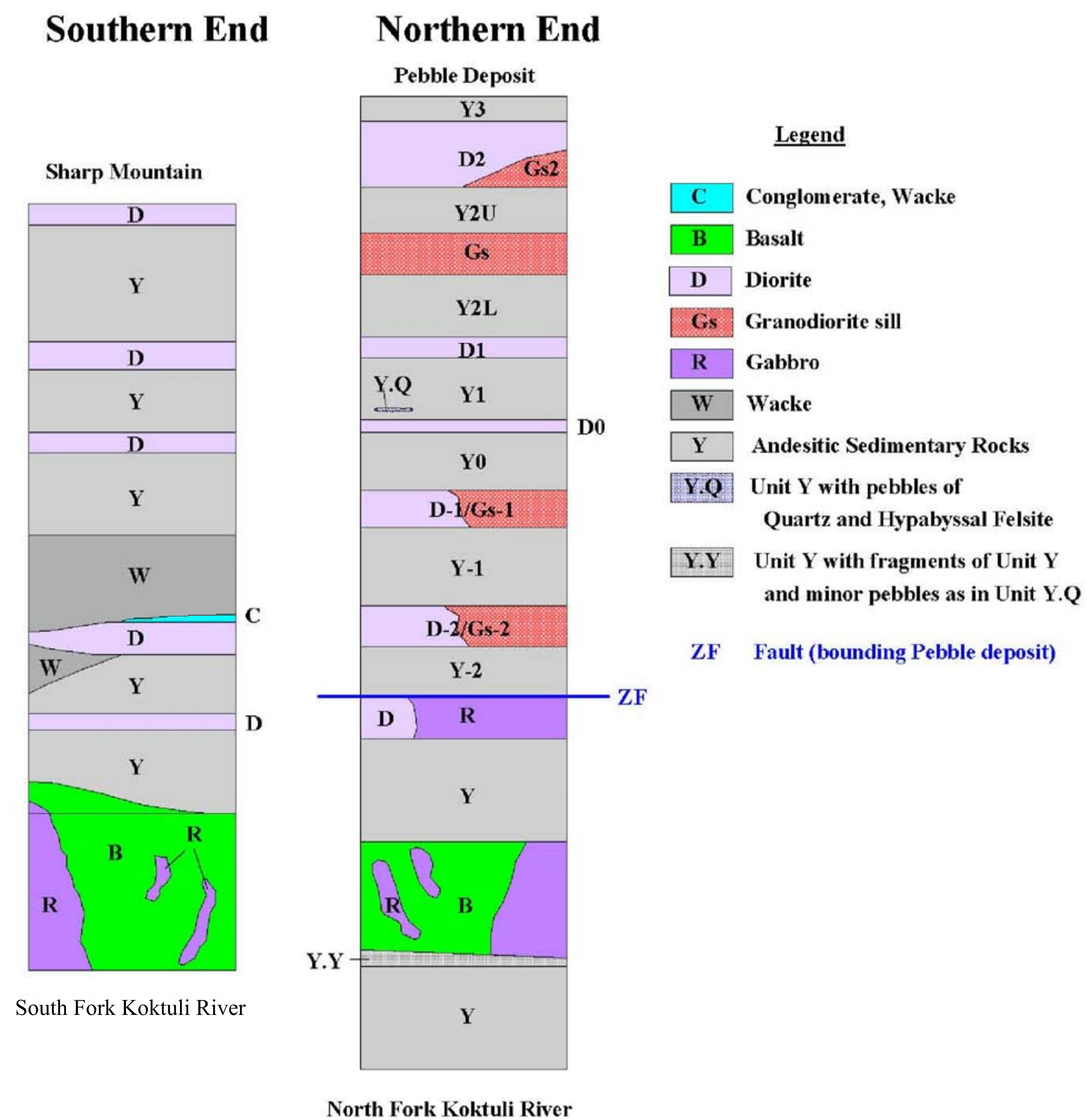
Kilometers: 1 0 1 2 3 4

Mile: 0.5 0 0.5 1 1.5 2 2.5

N

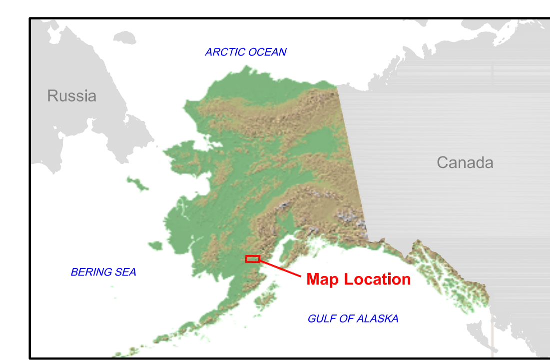
Alaska State Plane Zone 5 (units feet)
1983 North American Datum

File: B05.dwg	Date: July 06, 2010
Version: 2008-1	Author: Knight Piesold Ltd.



THE pebble PARTNERSHIP

Figure 3-8
Schematic of Stratigraphic Columns, Geology and Mineralization
Mine Study Area



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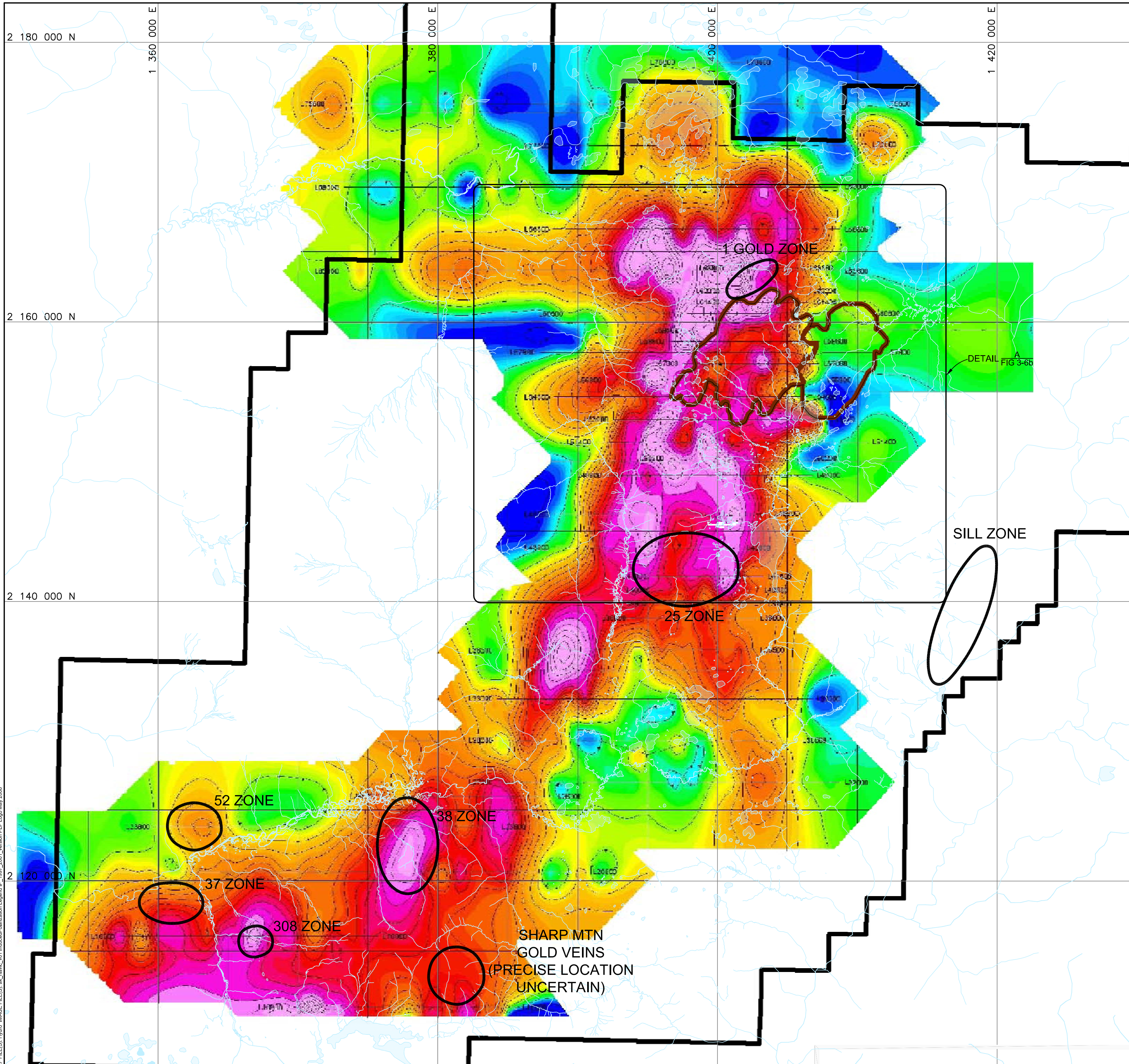
File: B06.dwg	Date: July 06, 2010
Version: 2008-1	Author: Knight Piesold Ltd.



THE pebble PARTNERSHIP

Figure 3-9
Induced Polarization, Geology and Mineralization Mine Study Area

Legend

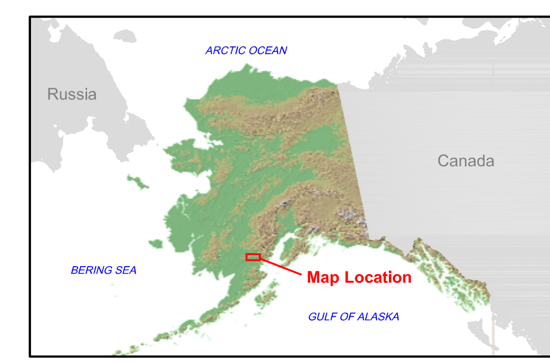
General Deposit Location

Areas of known mineralization

Claim Boundary

75
65
60
55
50
45
40
35
30
25
20
15
10
5

IP milliradian



Kilometers 1 0 1 2 3 4

Mile 0.5 0 0.5 1 1.5 2 2.5

N

Alaska State Plane Zone 5 (units feet)
1983 North American Datum

File: B08.dwg	Date: July 06, 2010
Version: 2008-1	Author: Knight Piesold Ltd.