

Pebble Project

Environmental Baseline Document

Geology and Mineralization

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Anchorage, Alaska

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Presentation Outline

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- Alaska Regional Geology
- Regional Geology of Mine Study Area
- Bedrock Geology
- Alteration
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- Surficial Geology

Introduction

- Geology of the Cook Inlet Area is not covered in this presentation as most baseline data has been collected in the mine study area.
- Information in this presentation is sourced from internal Northern Dynasty Mines Ltd., Pebble Partnership documents and published information.

Introduction

- Exploration has outlined a Cu-Au-Mo rich, hydrothermally altered porphyry system surrounded by an IP anomaly covering an area of 90km² in SW Alaska
- Exploration since 1985 has delineated the Pebble Deposit, two smaller zones of lower grade porphyry type mineralization (38 and 308 Zones), a Au-Cu skarn occurrence (37 Zone), and numerous Au zones associated with a multiphase, Late Cretaceous intrusive complex.

Exploration

- Who:
 - Cominco Exploration: 1985 to 1997
 - NDM: 2001 to 2007
 - PLP: Mid 2007 to present
- What:
 - Geological Mapping
 - Geophysical Surveys
 - IP, EM and Magnetometer
 - Soil Sampling
 - Diamond Drilling



Exploration

- Overburden and weathered bedrock typically triconed
- Core is boxed and depth markers inserted at the drill
- All core logged by PLP geologists and technicians in core shack
- Rock type, alteration, veins, mineralization, structure, geotechnical data are recorded
- All core is photographed prior to being cut and sampled



Exploration

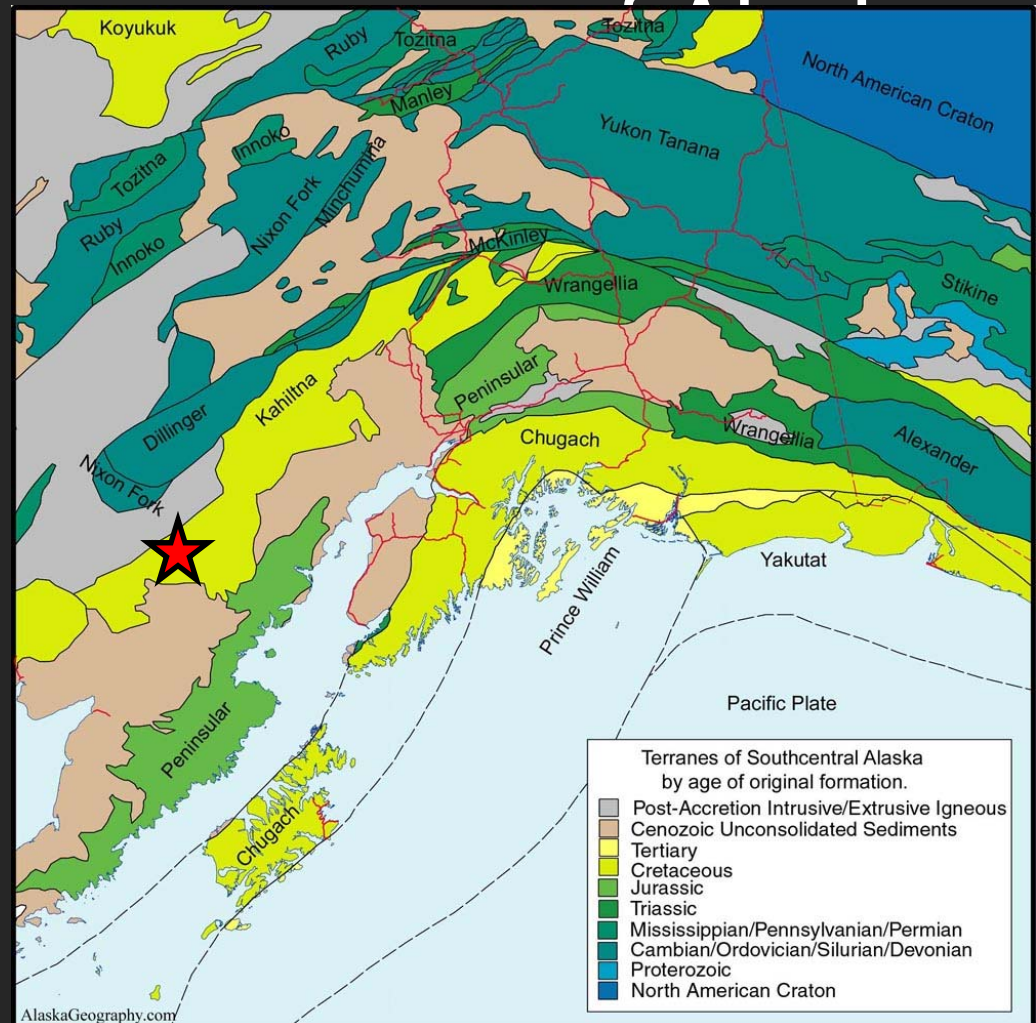
- Assay samples taken on 10' intervals in Cretaceous rock (mineral potential) and 20' intervals in Tertiary rock
- Samples analyzed by ALS Minerals formerly ALS Chemex Laboratory (ISO 9001:2000 and 9002)
- Samples analyzed for Au, Cu, Mo and 23 other elements
- Quality control protocols in place that meet industry standards (43-101)



Alaska Regional Geology

- Assemblage of NE-trending crustal blocks or terranes that amalgamated due to subduction beginning in the Late Paleozoic era (Goldfarb, 1997)

Permission to use figure
obtained from David Snyder,
November 14, 2011



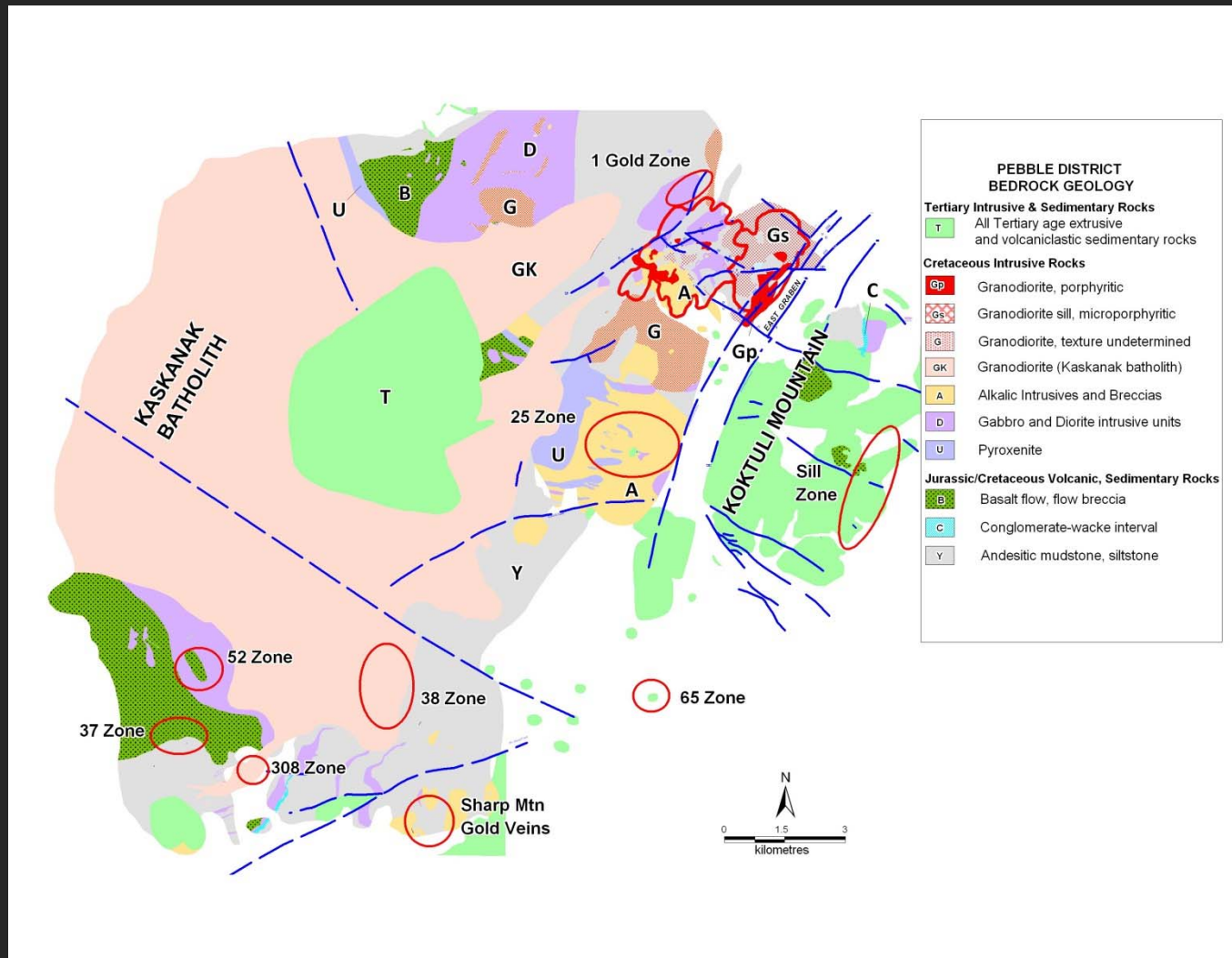
Regional Geology of Mine Study Area

- Located in the Northern circum-Pacific orogenic belt with a complex structural setting created by the tectonic plates converging
- Study area lies within the Kahiltna Terrane, northwest of the contact with the Peninsular Terrane
- Regional structure is broadly defined by NE-SW trending faults related to translational motion

Regional Geology of Mine Study Area

- The Kahiltna Terrane is a basin filled by Jurassic to Cretaceous volcanic and sedimentary rocks
- These rocks were intruded during the Cretaceous (~96 to 97Ma) by compositionally variable stocks, dikes, sills and irregular intrusive bodies and by 90Ma plutonic rocks (ie Kaskanak Batholith); all host the Pebble Deposit and other mineral showings
- The region was subjected to extensive erosion and deposition of Tertiary sedimentary and volcanic rocks

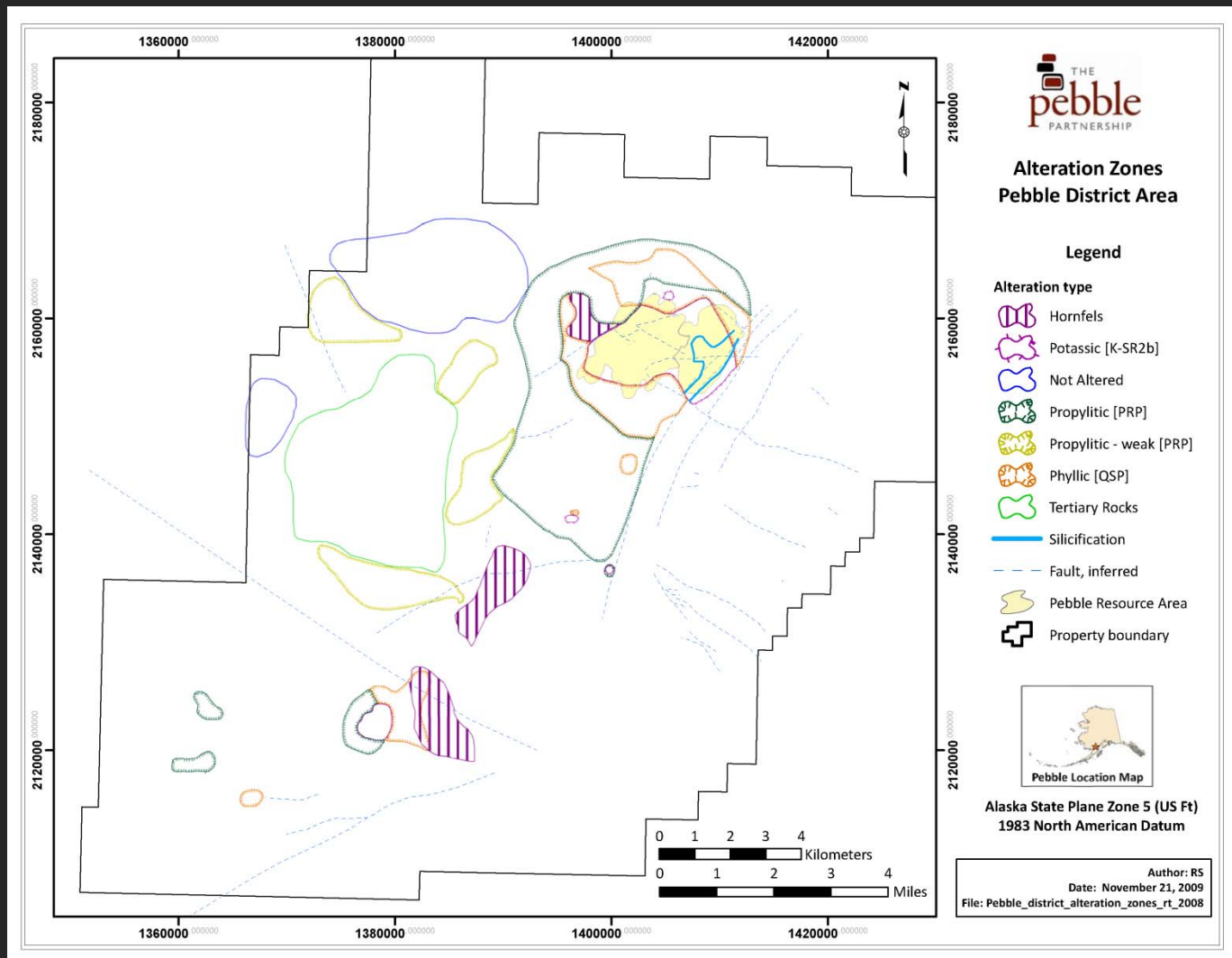
Bedrock Geology



Alteration

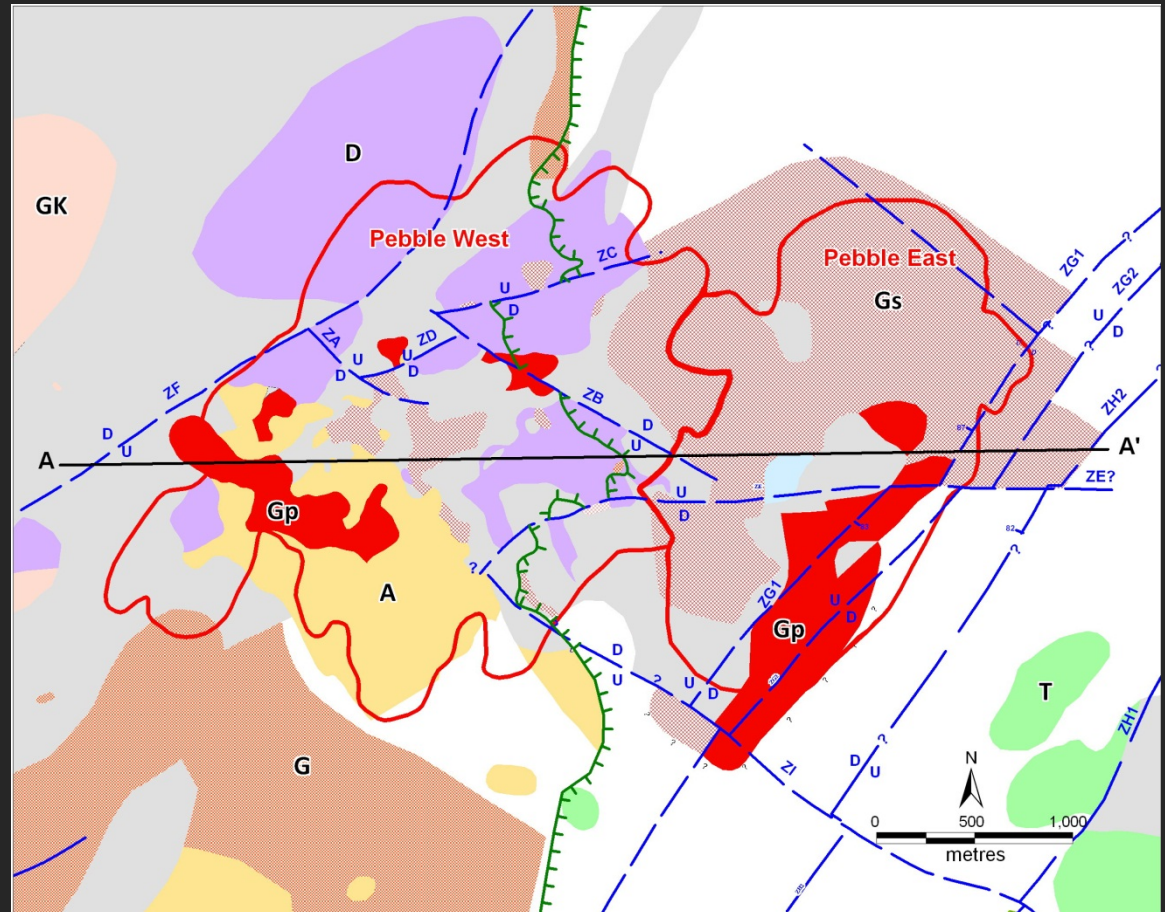
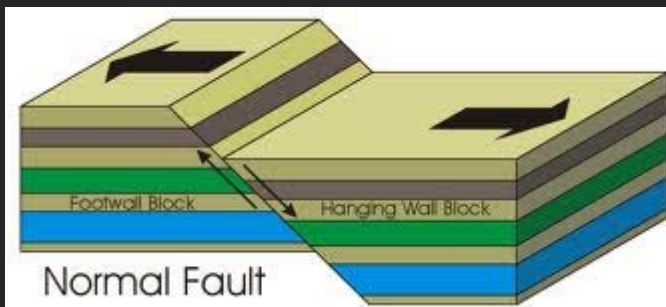
- The rocks of the Pebble area have been subjected to several different types of alteration including
 - Pre-hydrothermal hornfels
 - K-silicate
 - Propylitic – epidote, chlorite, pyrite, hematite, magnetite
 - Clay alteration – illite, argillite
 - Silicification
 - Quartz-sericite-pyrite alteration

Alteration



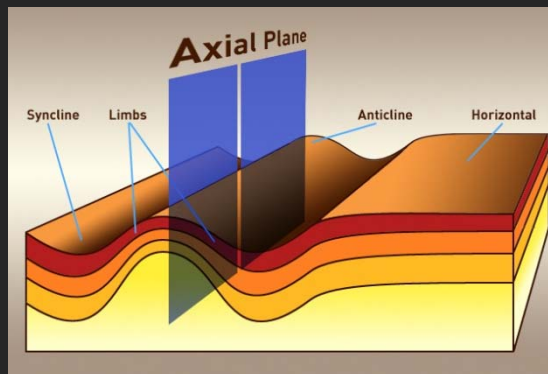
Deposit Structure

- Seven post-mineralization structures are mapped in the deposit area, most are normal faults which are inactive



Deposit Structure

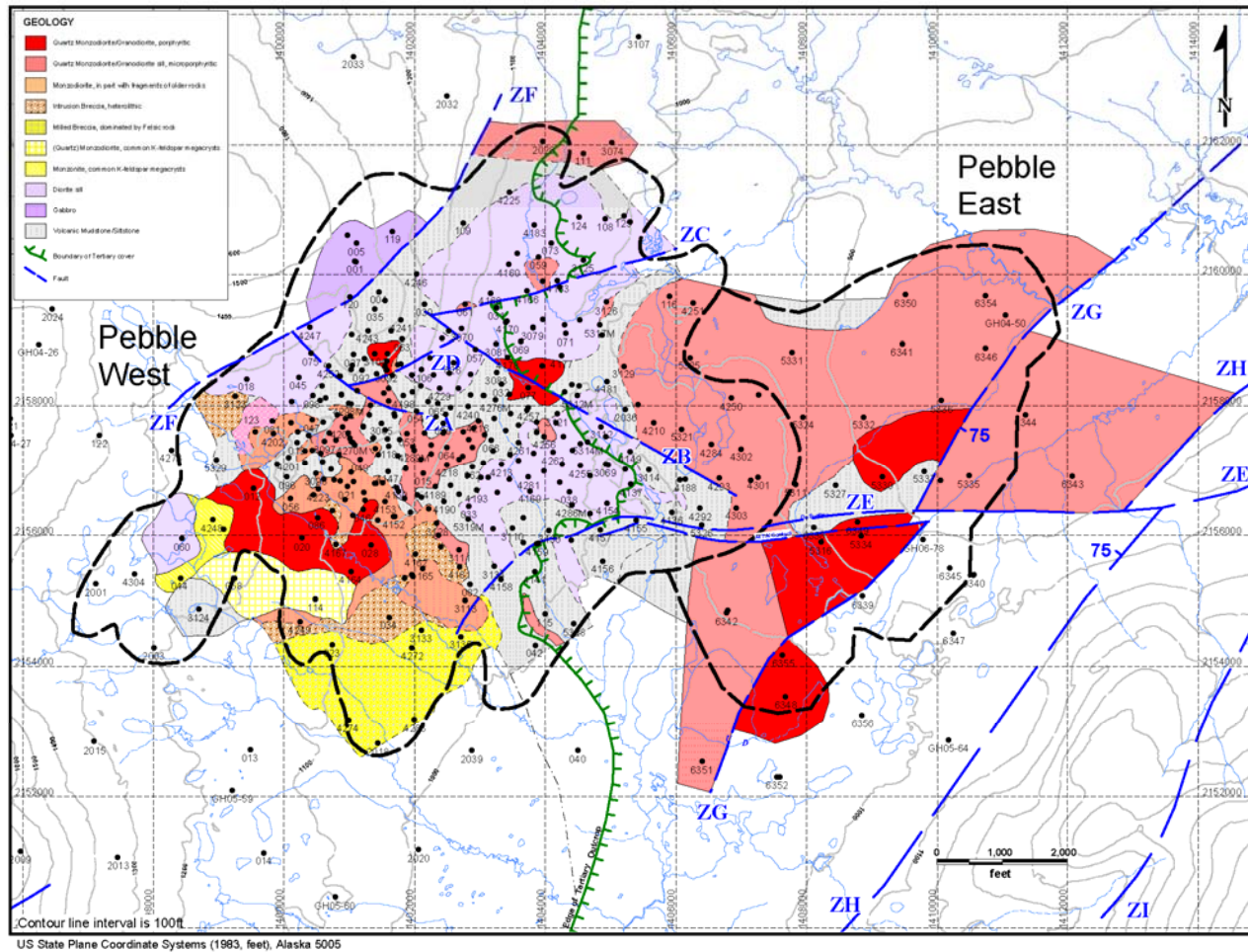
- Primary large scale structure in Pebble West and Central zones is a broad, M-shaped anticline, fold axes plunge gently to the SE
- Tertiary faults and shears are evident in drill core and from surface mapping
- Displacement ranges from a few tens of meters to over 1.6km (Koktuli Mtn)
- Structures are inactive



Deposit Geology and Mineralization

- Approximately 16km²
- Mineralogy and mineralization typical of Cu-Au-Mo porphyry systems
- Mineralization is associated with potassic alteration and quartz veining in and around the upper parts of granodiorite stocks
- Mineral assemblage includes Pyrite, Chalcopyrite, Molybdenite, minor Bornite and Tetrahedrite
- Gold is hosted mainly by sulfide minerals
- Rare skarn is host to minor chalcopyrite

Deposit Geology and Mineralization



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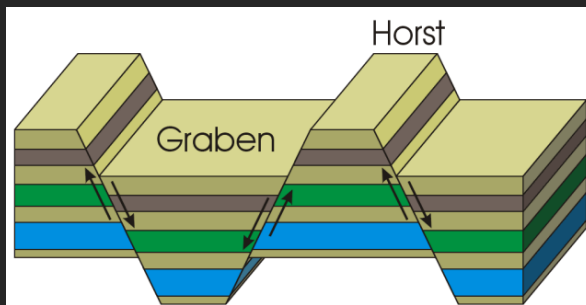
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Deposit Geology and Mineralization

- Pebble West Zone
 - Hornfelsed volcanosedimentary strata intruded by granodiorite and diorite sills and a multiphase intrusive complex
 - Dominantly K-silicate alteration and low grade Cu-Au-Mo mineralization
 - Mineralized to at least 2000ft depth
 - Mostly deeper mineralization with a small but substantial zone of oxidation and shallow enrichment in Pebble West
 - A leached zone overlies the shallow zone

Deposit Geology and Mineralization

- Pebble East Zone
 - High-grade mineralization below eastward-thickening wedge of Tertiary cover
 - Mineralization related to intense K-silicate and quartz-pyrophyllite alteration extending to at least 6400ft
 - On the eastern side, Pebble East is downdropped on normal faults which bound a northeast-trending graben



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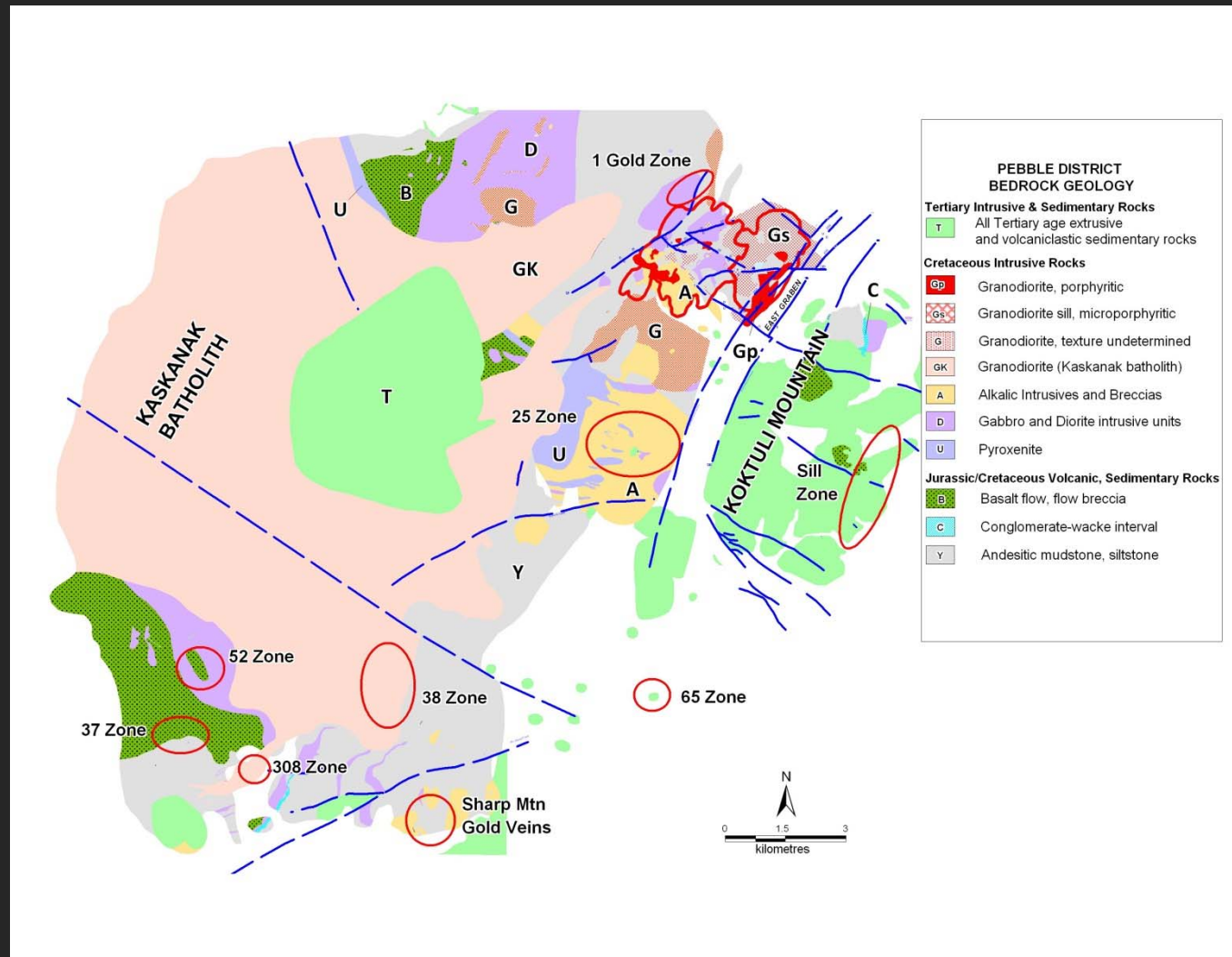
Mineral Resource Estimation

- Mineral resource estimations are routinely updated with most recent exploration results and economic parameters
- Cu-equivalent is a manner of expressing polymetallic deposits as a grade of the principle mineralization (by value)
- The other metals are expressed as part of the Cu grade based on estimated mineral prices for each metal
- These values are not adjusted for metallurgical recovery until after metallurgical testing has been completed

Mineral Resource Estimation

- Mineral resource estimations are routinely updated with most recent exploration results and economic parameters
- Current 43-101 compliant mineral resources, at 0.3% Cu-equivalent cutoff:
 - 5.942 Billion tonnes of measured and indicated mineral resource grading 0.42% Cu, 0.35 g/t Au, and 250 ppm Mo
 - 4.835 Billion tonnes of inferred mineral resource grading 0.24% Cu, 0.26 g/t Au, and 215 ppm Mo (2009 NDM Technical Report)

Other Mineralized Zones



Other Mineralized Zones

- Sharp Mountain
 - Small, scattered quartz veins, highly anomalous grades for Au and Ag
- Sill Zone
 - Au in several narrow discontinuous quartz veins and strongly silicified breccia zones (Ag and Au)
- 001 Gold Zone
 - Au related to pyrite veins hosted by quartz-sericite-pyrite alteration and lesser propylitic alteration.

Other Mineralized Zones

- 52 Porphyry Zone
 - Anomalous Cu and Mo in granodiorite with weak propylitic and K-silicate alteration
- 38 Porphyry Zone
 - Cu-Au-Mo porphyry associated with quartz-sulfide veins and K-silicate, propylitic, and quartz-sericite-pyrite alteration.
- 37 Skarn Zone
 - Strong skarn type Cu-Au mineralization in veins associated with calc-silicate alteration.

Other Mineralized Zones

- 25 Gold Zone
 - Au and Cu concentrations in polymetallic veins, pyritic zones associated with quartz-carbonate breccia and strong chlorite-epidote alteration and in quartz veins
- 308 Porphyry Zone
 - Cu-Mo-Au mineralization associated with K-silicate and quartz-sericite-pyrite alteration cut by quartz-sulfide veins.
- NE Pebble IP Anomaly
 - Peripheral porphyry mineralization

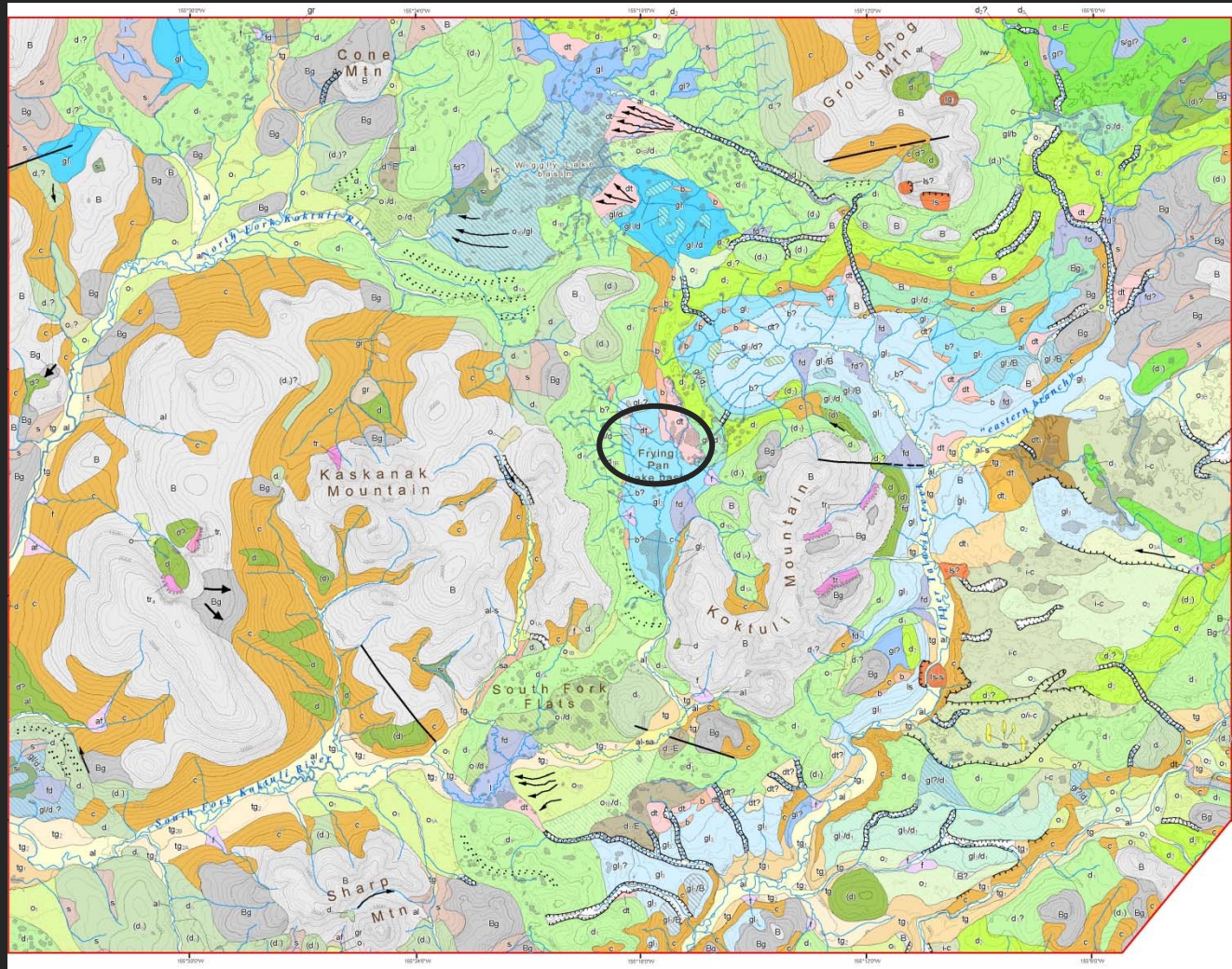
Other Mineralized Zones

- 65 Zone
 - characterized by a large area of strong hydrothermal alteration.
 - alteration includes a pyrite-rich K-silicate assemblage, sericite, illite and/or clay assemblages, and propylitic alteration.
 - Strongest mineralization is related to breccia bodies or to stockworks of brecciated veins and/or fractures filled mostly by quartz and/or pyrite.

Surficial Geology Study

- Air photo interpretation of the area has been completed along with an extensive surficial geology investigation conducted by Hamilton and Klieforth including a review of all available surficial geology data along with test pits and shallow auger boreholes
- A surficial geology map of the mine study area was produced by Hamilton and Klieforth (USGS, 2010)

Surficial Geology Study



Surficial Geology

- Low lying areas are covered with unconsolidated glacial deposits from four different episodes of glaciation
- Pleistocene ice moved southwestward down Lake Clark structural trough and separated into two floes which followed the present day Chulitna and Newhalen drainages entering the area from the north and northeast
- A second major glacier is thought to have flowed westward from Cook Inlet expanding northward from the Iliamna Lake Basin

Surficial Geology

- The glaciers blocked the three main drainages of the mine study area (UTC, NFK, and SFK) at various times filling the drainages with ice dammed lakes
- Former glacier dammed lake locations are bordered by beach and deltaic deposits

Surficial Geology

- Arcuate end moraines, abundant kettle depressions, broad outwash aprons, elongate valley train and striking meltwater channels dominate the surficial geology of the mine study area



Surficial Geology

- Surficial glacial deposits range from a few feet to hundreds of feet thick
- Most are covered with typical tundra vegetation and organic soils but some are exposed on surface
- Surficial organic soils are typically less than 30cm thick and are often mixed with granular sand and gravel material



Surficial Geology

- Rubble or felsenmeer, formed by frost action on bedrock, covers many of the gently rounded hilltops and upland surfaces



Surficial Geology

- Solifluction lobes initiate on the upper part of some hills and pile up on the mid slopes.
- Holocene deposits fill the valley bottoms up to 160 ft (50m) deep and are locally covered by thin swamps.



Questions



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Glossary

- Alteration zones—a zone of rock whose nature has been changed by geological processes.
- 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.
- 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
- Cretaceous—approximately 145.6 to 65 million years ago, the third of the three periods included in the Mesozoic Era.
- Crustal—term applied to the thin outermost solid layer of the earth.
- Dike—discordant or cross cutting, tabular intrusion, most are 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.
- Felsenmeer—coarse, angular, frost-shattered rock debris in environments that are or were formerly at the immediate margins of glaciers.
- Glacial outwash—the stratified sands and gravels deposited at or near ice margins.

Glossary

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

Glossary

- 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.
- Mafic—applied to any igneous rock with such a high proportion of pyroxene and olivine that is a dark color.
- 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.
- Overburden—the material that lies above the bedrock.
- 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.
- Plate—a segment of the lithosphere with little volcanic or seismic activity that is bounded by continuous belts of earthquakes and volcanic activity.

Glossary

- Pleistocene—from 1.64 million years ago to about 10,000 years ago, the first of two epochs of the Quaternary sub-era.
- Plutonic—a loosely defined term to describe igneous rock bodies which have crystallized at great depth, or to describe a large intrusion, also used to describe the origin of magmas and gas derived from near the base of the crust or in the upper mantle.
- Polymetallic—when three or more metals are present in commercially viable quantities
- Porphyry—medium-grained rock containing large, well-formed grains of any mineral.
- 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.
- Sericite—white, fine-grained potassium mica with a silky luster.
- 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.

Glossary

- Stock—an igneous intrusion, approximately circular in plan with steep contacts to the country 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.
- Strata—lithological term applied to materials that form layers or beds.
- 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.
- 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.
- Translational motion—movement of a rigid body in such a way that the body remains parallel to its original direction.
- Triconed—drilling that is completed with a tricone bit.