Pebble Project
Environmental Baseline Document
Geotechnical, Seismicity and Volcanism

Agency Meetings, January 31 – February 3, 2011

Anchorage, Alaska

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Presentation Outline

- Introduction
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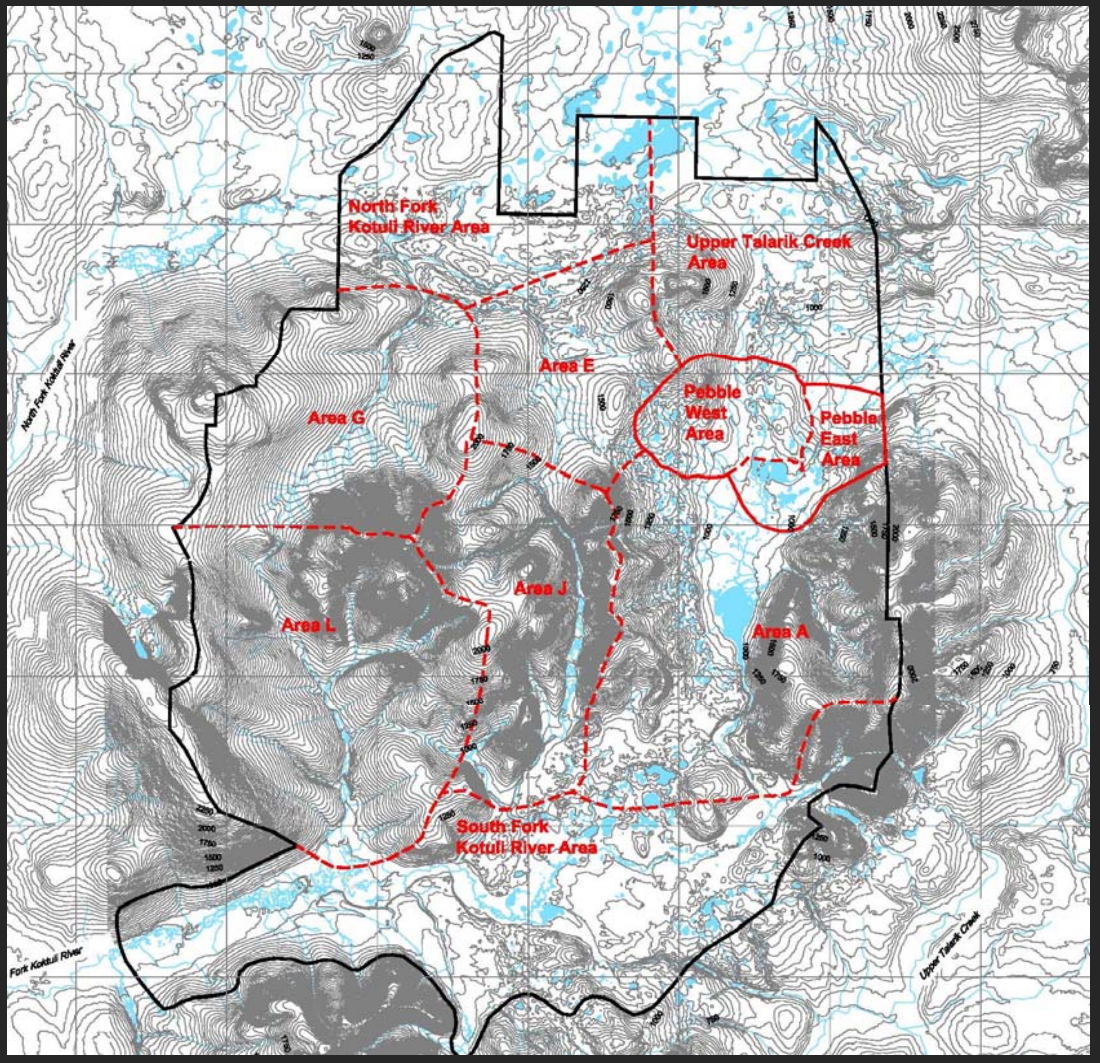
- Area G
- Area L
- South Fork Koktuli River Area
- Area J
- Area A
- Regional Volcanism
- Regional Seismicity

Introduction

- Information in this presentation is sourced from internal Northern Dynasty Mines Ltd., Pebble Partnership documents and published information.
- Geotechnical information in this report is based on data available to the end of 2008.

Introduction

- The mine study area has been divided into 10 geographical reference areas



Geotechnical Site Investigations

- Who:
  - SRK: 1991, 2006 to 2008, present
  - KP: 2004 to 2008, 2010 to present
- What:
  - Test Pits
  - Overburden and Bedrock geotechnical logging
  - Oriented Core Drilling
  - Piezometer/Well installations
  - Instrumentation installations
  - In situ testing
  - Geophysical surveys

Geotechnical Site Investigations

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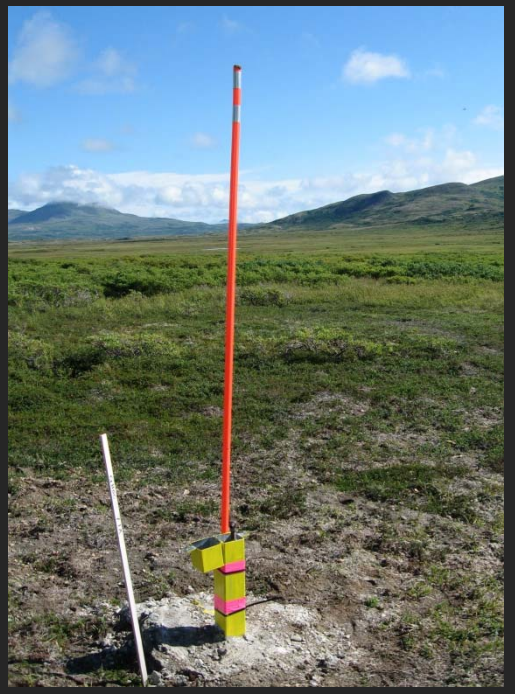
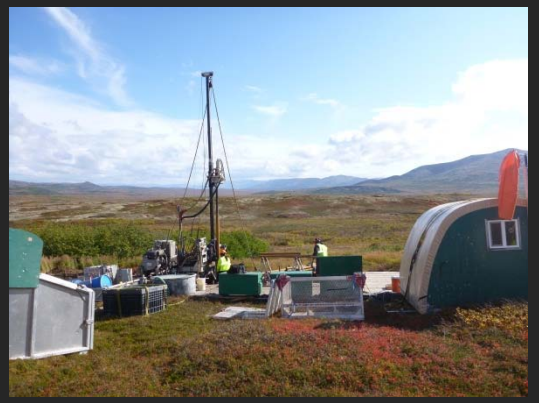
Geotechnical Site Investigations

- SRK
  - 8 Geotechnical Drillholes
  - 12 Open Pit Oriented Drillholes
  - 8 Seismic Refraction lines
- KP
  - 423 Test Pits
  - 228 Geotechnical Drillholes (not including redrills) and associated piezometer installations
  - 15 Open Pit Oriented Drillholes
  - 49 Seismic Refraction lines



General Site Geotechnical Conditions

- Most areas covered with typical tundra vegetation except for areas with exposed felsenmeer/bedrock (higher elevation ridges and hill tops)
- Typical 1 to 2ft layer of topsoil encountered, thicker peat in swampy areas



General Site Geotechnical Conditions

- Overburden consists of glaciofluvial, glaciolacustrine and glacial drift deposits with varying amounts of silt, sand, gravel and clay.
- Overburden thickness ranges from 0 to ~390 ft, deeper glacial deposits found in buried channels.

General Site Geotechnical Conditions

- Tertiary Volcanics and Sediments and Cretaceous Sediments and Intrusives are the major bedrock types
- Bedrock has been subjected to varying degrees of weathering
- Rock Mass Rating (RMR) values generally range from POOR to GOOD rock quality

General Site Geotechnical Conditions

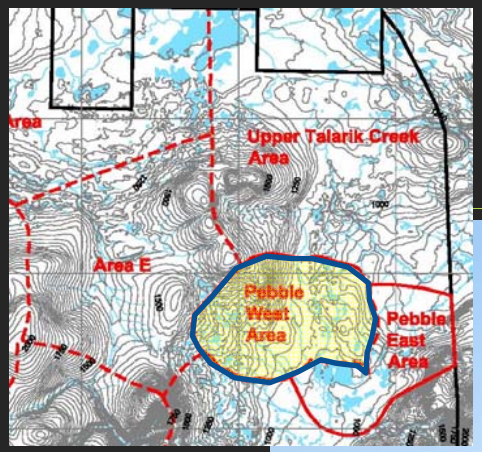
- Groundwater
  - Piezometric surface ranging from above ground level to various depths below grade
  - Dependent on surface topography and where aquifers are located, perched aquifers, etc.

General Site Geotechnical Conditions

- Hydraulic Conductivity – rate of movement of water through a material, ie overburden or bedrock
- Ranges of hydraulic conductivity (modified after Terzaghi and Peck, 1967)

• High	10^{-1} to 10 cm/s
• Medium	10^{-3} to 10^{-1} cm/s
• Low	10^{-5} to 10^{-3} cm/s
• Very low	10^{-7} to 10^{-5} cm/s
• Extremely low	10^{-10} to 10^{-7} cm/s

Pebble West Area



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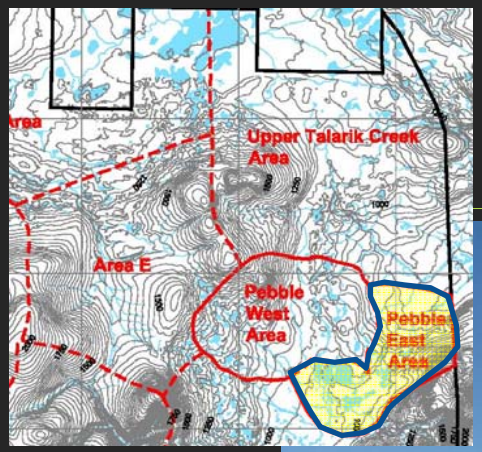
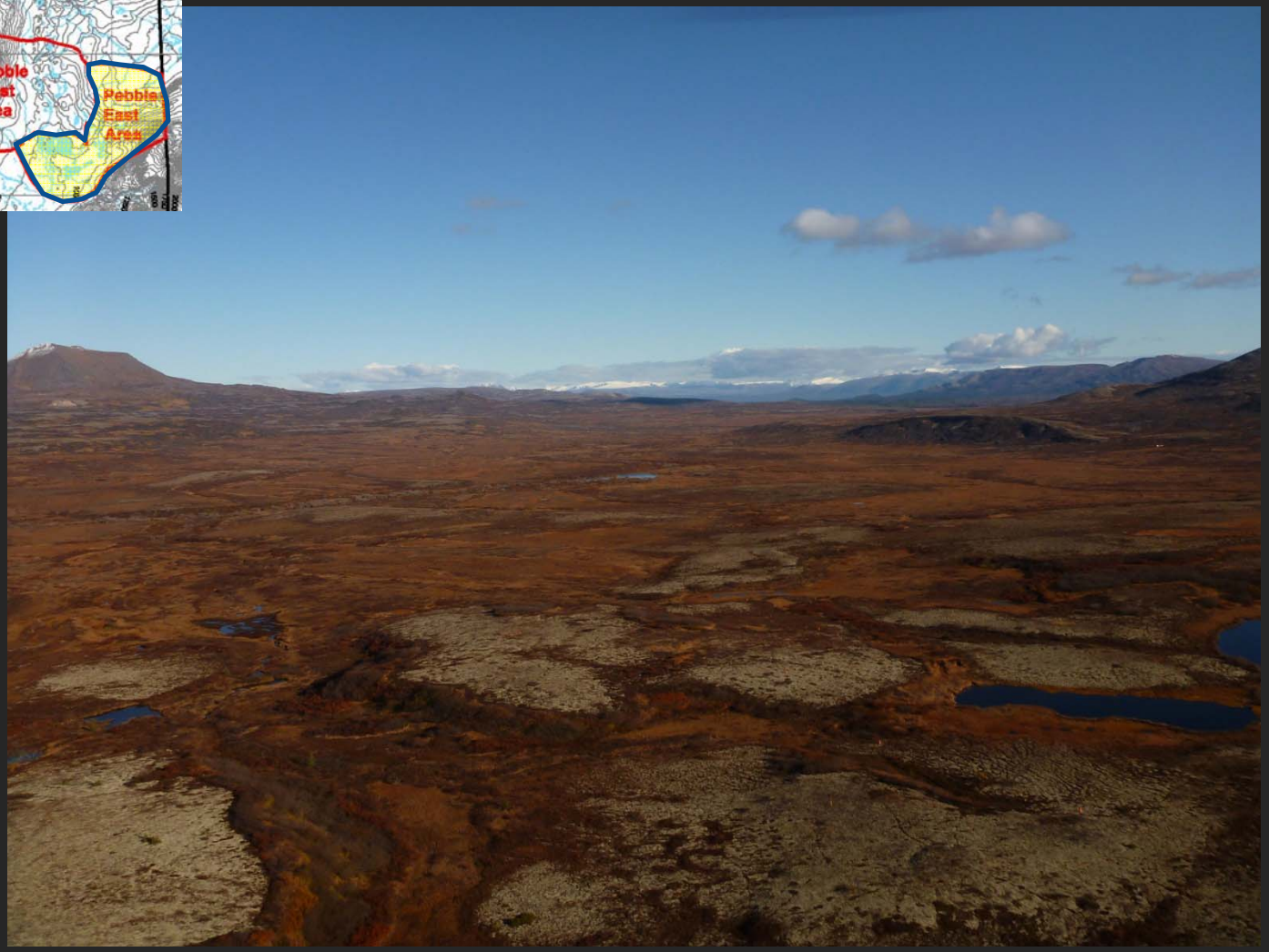
Pebble West Area

- Overburden
  - Overburden ranges to 250ft depth
- Bedrock
  - Rock Mass Rating (RMR) values ranging from 32 to 55 (POOR to FAIR rock quality)
- Groundwater
  - Piezometric surface ranging from above ground level to ~80ft below grade
  - Low to very low hydraulic conductivity in testing conducted in the bedrock
  - Low to medium hydraulic conductivity in testing conducted in the overburden

Pebble East Area





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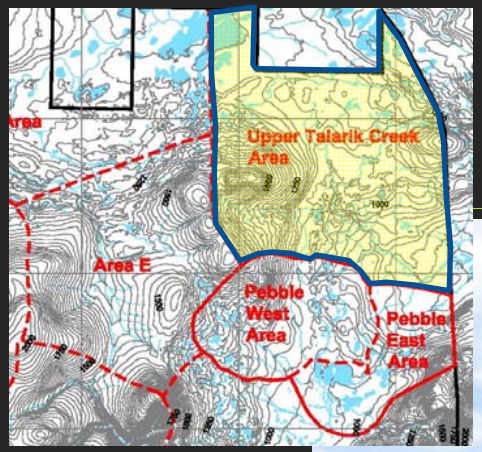
Pebble East Area

- Overburden
  - Overburden thickness: ~10 to >200ft
  - NE-SW buried paleochannel adjacent to Koktuli Mtn
- Bedrock
  - Thick Tertiary Volcanic and Sediment package overlying the Cretaceous
  - RMR values ranging from 32 to 56 (POOR to FAIR)
- Groundwater
  - Piezometric surface ranging from above ground level to ~63ft below grade
  - Medium to very low hydraulic conductivity in testing completed in the overburden and the bedrock

Upper Talarik Creek Area



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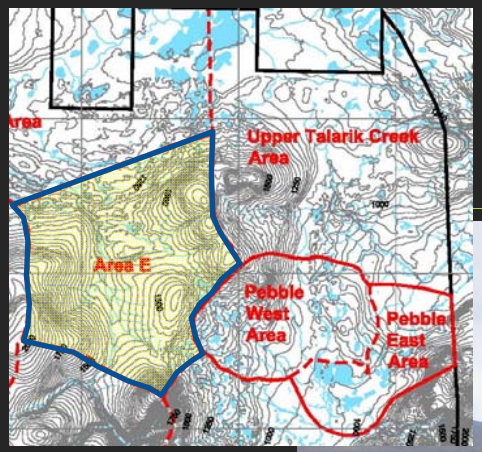
Upper Talarik Creek Area

- Overburden
  - Overburden thickness: ~3 to 145ft
- Bedrock
  - RMR values ranging from 29 to 61 (POOR to GOOD)
- Groundwater
  - Piezometric surface ranging from above ground level to ~40ft below grade
  - Low hydraulic conductivity in testing completed at the overburden/bedrock contact and in the bedrock

Area E



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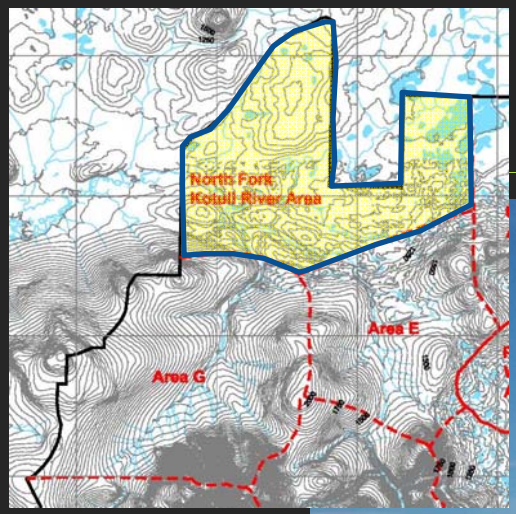
Area E

- Overburden
  - Overburden thickness: ~0 to ~190ft
- Bedrock
  - RMR values ranging from 30 to 58 (POOR to FAIR)
  - POOR bedrock was generally weathered and/or fractured to a considerable depth.
- Groundwater
  - Piezometric surface ranging from above ground level to ~84ft below grade
  - Low hydraulic conductivity testing results in the overburden low to very low hydraulic conductivity testing results in the bedrock

North Fork Koktuli River Area



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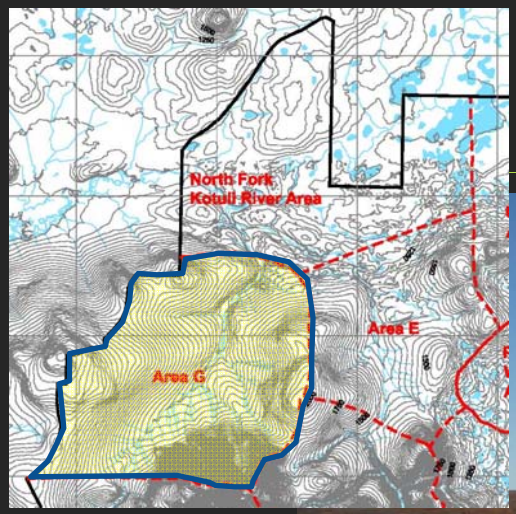
North Fork Koktuli River Area

- Overburden
  - Overburden thickness: ~22 to ~148ft
- Bedrock
  - RMR values ranging from 36 to 60 (POOR to FAIR)
- Groundwater
  - Piezometric surface ranging from ~15 to ~30ft below grade
  - Medium to very low hydraulic conductivity for testing completed in the bedrock
  - Low hydraulic conductivity values for tests conducted at the overburden/bedrock contact

Area G



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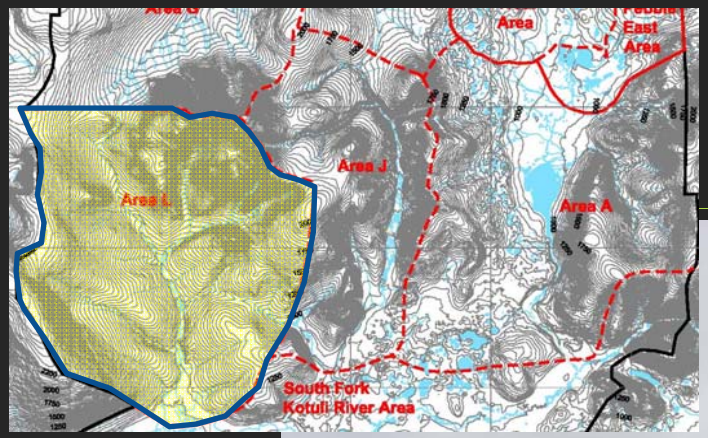
Area G

- Overburden
  - Felsenmeer on hills and ridge tops
  - Overburden thickness: ~2 to ~51ft
- Bedrock
  - RMR values ranging from 35 to 66 (POOR to GOOD)
  - Weathered up to 80ft depth in some locations
- Groundwater
  - Piezometric surface ranging from above ground level to ~85ft below grade
  - Medium to very low hydraulic conductivity in the bedrock
  - Very low to medium hydraulic conductivity at the overburden/bedrock contact

Area L



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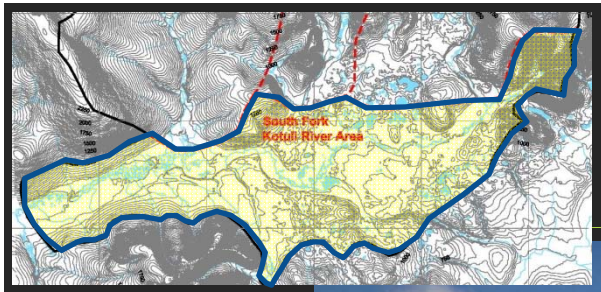
Area L

- Overburden
  - Overburden thickness: 0 to ~105ft
  - Felsenmeer on hills and ridge tops
- Bedrock
  - RMR values ranging from 39 to 66 (POOR to GOOD)
- Groundwater
  - Piezometric surface ranging from above ground level to ~290ft below grade
  - Deep water level measurement from vibrating wire
  - Medium to very low hydraulic conductivity testing in the bedrock

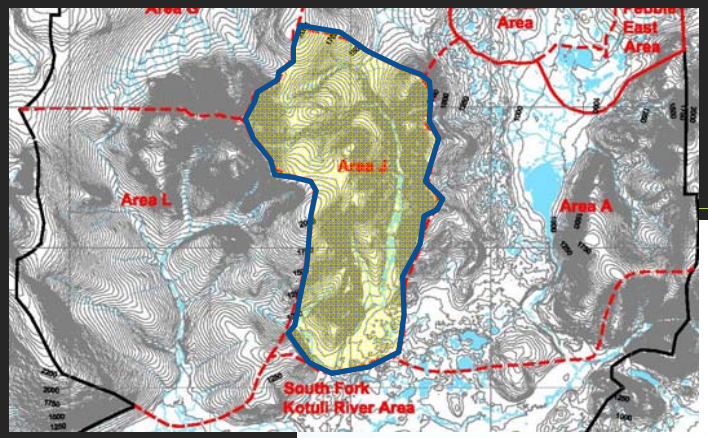


South Fork Koktuli River Area

South Fork Koktuli River Area

- Overburden
  - Overburden thickness: 12 to ~390ft
  - Buried channels
- Bedrock
  - RMR values ranging from 39 to 64 (POOR to GOOD)
- Groundwater
  - Piezometric surface ranging from 5 to ~125ft below grade
  - Low hydraulic conductivity in the bedrock
  - High hydraulic conductivity in the overburden

Area J



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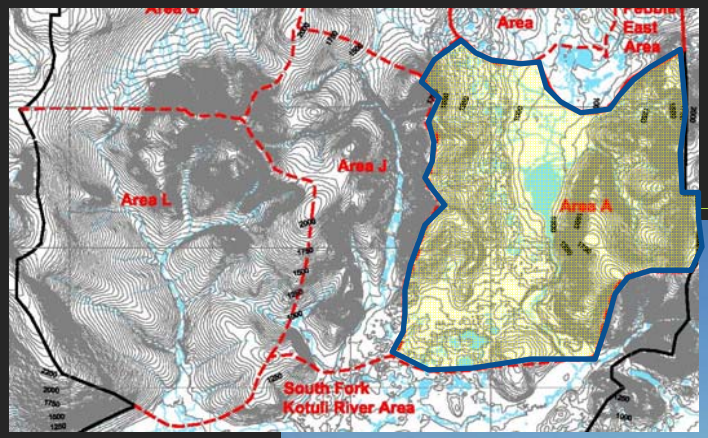
Area J

- Overburden
  - Overburden thickness: 0 to ~70ft
- Bedrock
  - RMR values ranging from 40 to 65 (FAIR to GOOD)
- Groundwater
  - Piezometric surface ranging from above ground to ~40ft below grade
  - Very low to Low hydraulic conductivity in the bedrock

Area A



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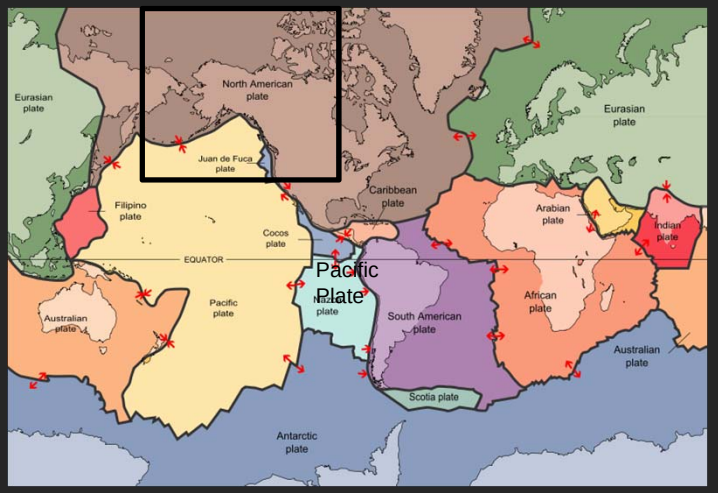
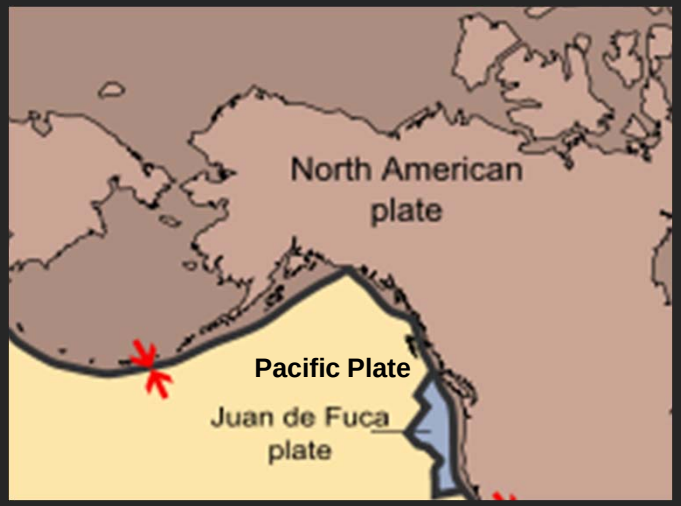
Area A

- Overburden
  - Peat up to ~15ft thick
  - Overburden thickness: 0 to ~390ft
  - Buried channels
- Bedrock
  - RMR values ranging from 41 to 68 (FAIR to GOOD)
- Groundwater
  - Piezometric surface ranges from above ground to ~140ft below grade
  - Very low to medium hydraulic conductivity in the bedrock
  - Low to high hydraulic conductivity in the overburden

Regional Seismicity & Volcanism

- Pacific (oceanic) tectonic plate is subducting under the North American plate ~2 to 3 inches per year
- Pressure builds between plates and is released as an earthquake
- Region is known as Alaska-Aleutian Megathrust





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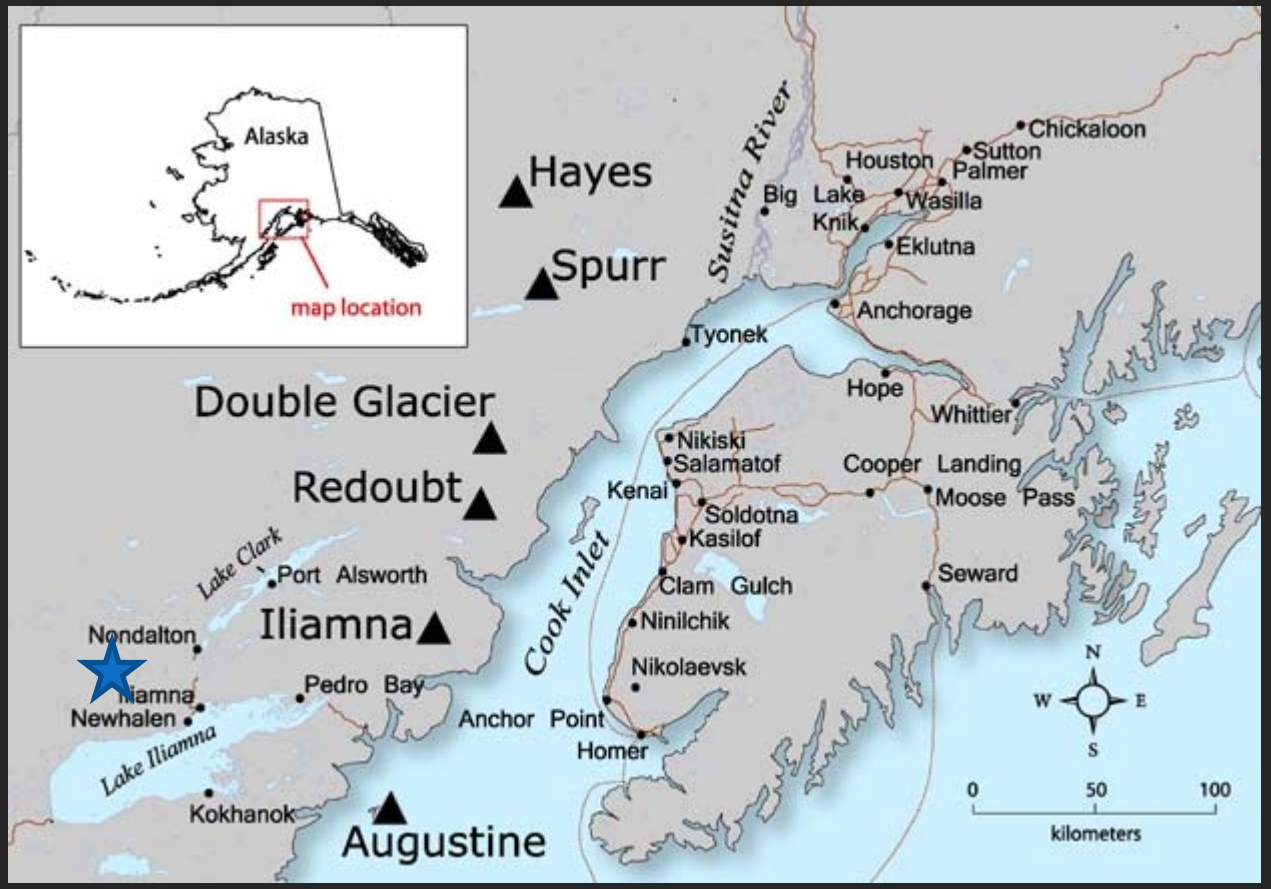
Regional Tectonics and Volcanism

- Volcanoes are associated with convergence of the North American and Pacific plates

Regional Volcanism

- Mine study area could be affected by active volcanoes near Cook Inlet



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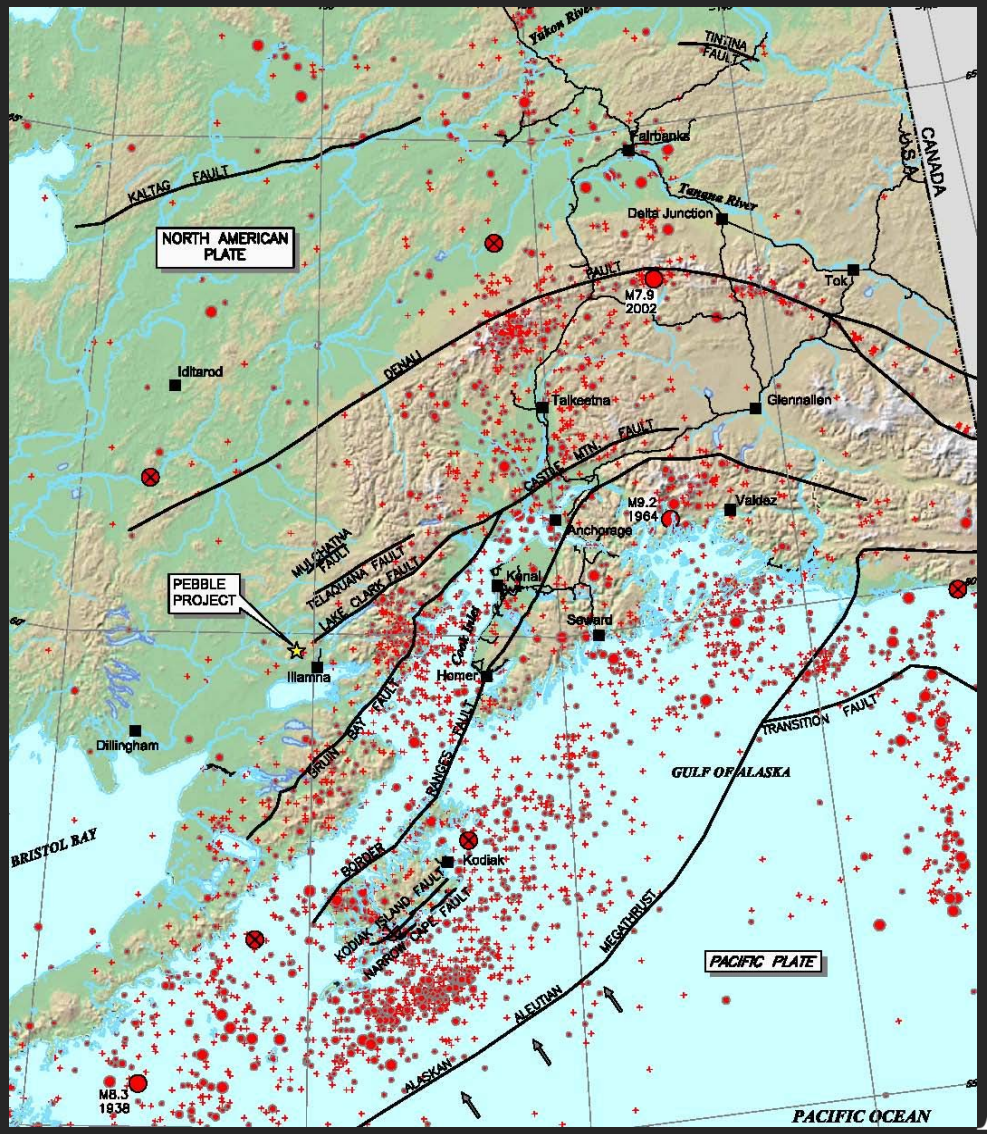
Regional Volcanism

- Mt Iliamna and Augustine are the closest to the mine study area, ~60 miles away
- Volcanic eruptions generally occurred every 10 to 35 years in the 20th century
- Last confirmed eruption of Mt. Iliamna 1876
- Augustine entered a new active phase in 2006
- Augustine has collapsed and regenerated every 150 to 200 years over the last 2000 years

Regional Volcanism

- Potential effects of volcanism:
  - Volcanic ash/debris
  - Corrosive rain
  - Noxious gas and dust clouds
  - Tsunamis due to debris avalanches
- The potential for these hazards is considered minor in the Cook Inlet Study Area

Seismicity of Southern Alaska



- Associated with interface (interplate) subduction earthquakes, in-slab (intraslab) earthquakes in the subducted oceanic plate and shallow crustal earthquakes within the North American continental crust.

Legend

- Mapped faults
- Zone of recorded earthquakes included on SECTION A-A

EARTHQUAKE FOCAL DEPTH

- Depth ≤ 25 miles
- Depth > 25 miles

EARTHQUAKE MAGNITUDE

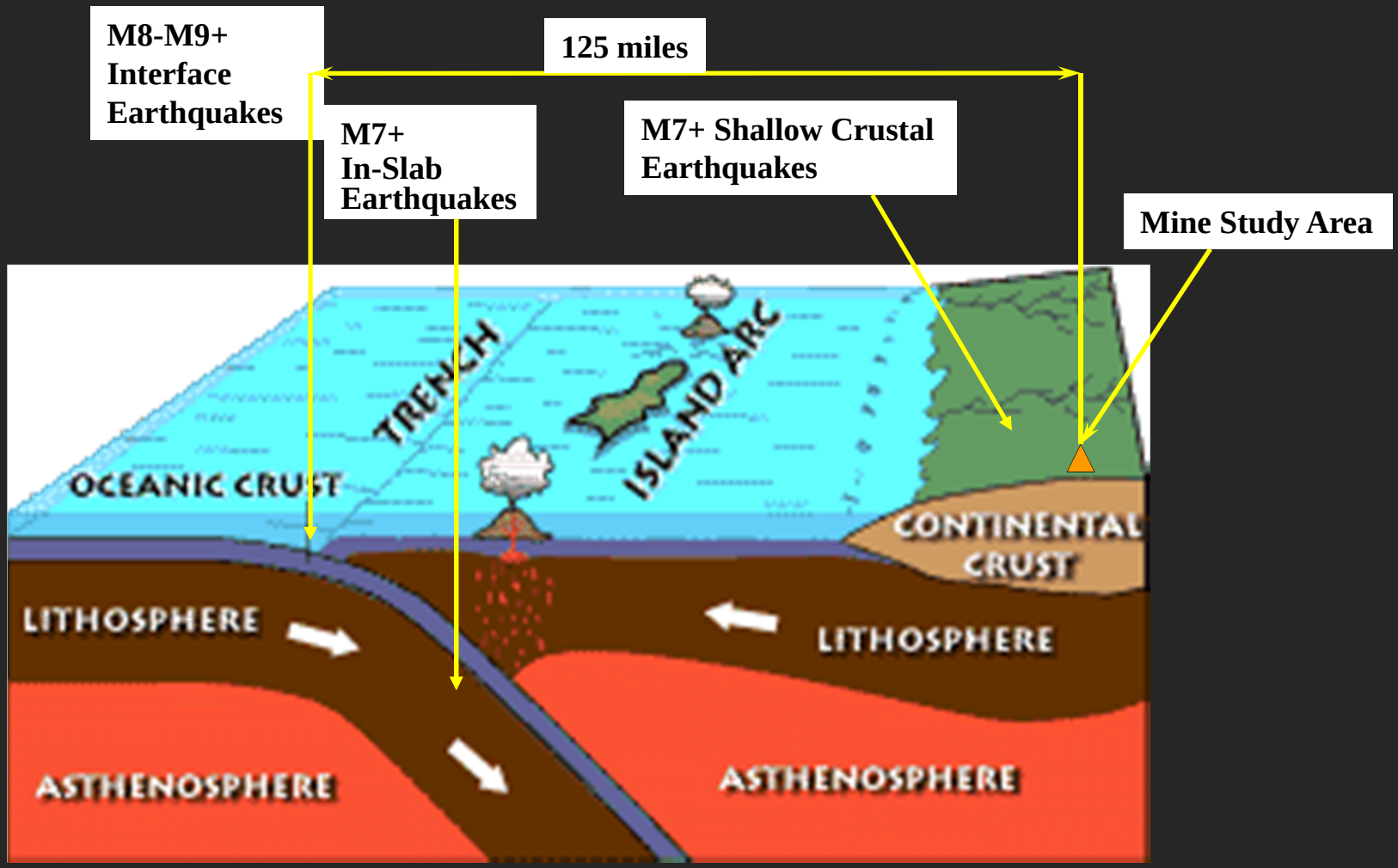
- 4.0 - 4.9
- 5.0 - 5.9
- 6.0 - 6.9
- 7.0 - 7.9
- 8.0 +
- Large magnitude earthquakes recorded between 1899 & 1904

 A note on Magnitude Scales (Richter vs Moment Magnitude)

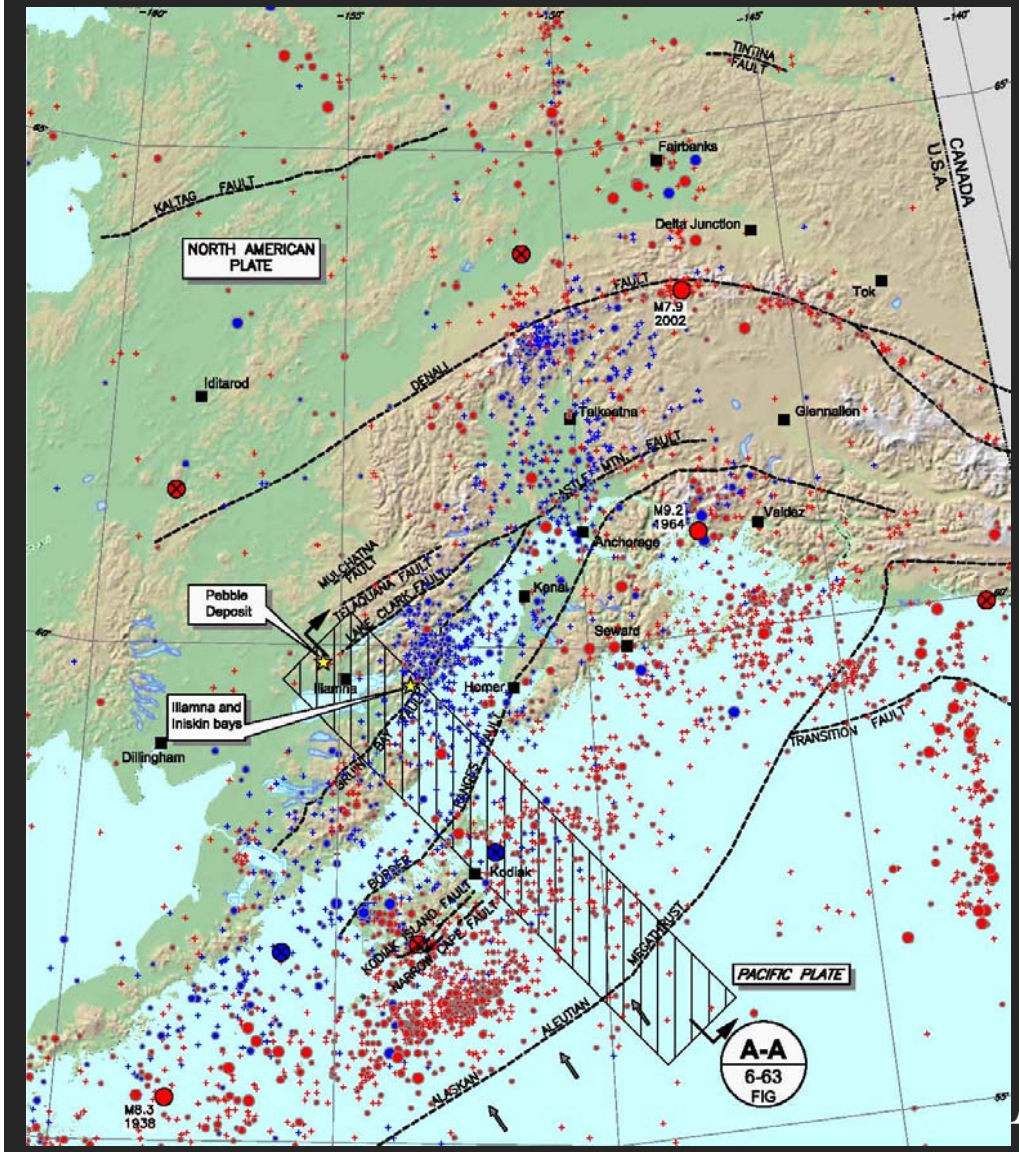
3 Types of Earthquakes

- Interface Subduction Earthquakes
  - Alaska-Aleutian Megathrust where two plates are colliding (Pacific and North American Plates)
- In-slab (Intraslab) Subduction Earthquakes
  - within the subducted oceanic Pacific plate
- Shallow Crustal Earthquakes
  - e.g. Denali and Castle Mountain Faults

Regional Tectonics and Seismic Sources



Regional Faults and Seismicity



- Seismicity of Southern Alaska, distribution of earthquakes by depth.

Legend

- Mapped faults
- Zone of recorded earthquakes included on SECTION A-A

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- Depth > 25 miles

EARTHQUAKE MAGNITUDE

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- 5.0 - 5.9
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- 7.0 - 7.9
- 8.0 +
- Large magnitude earthquakes recorded between 1899 & 1904
- Location and direction of view for Geological Section

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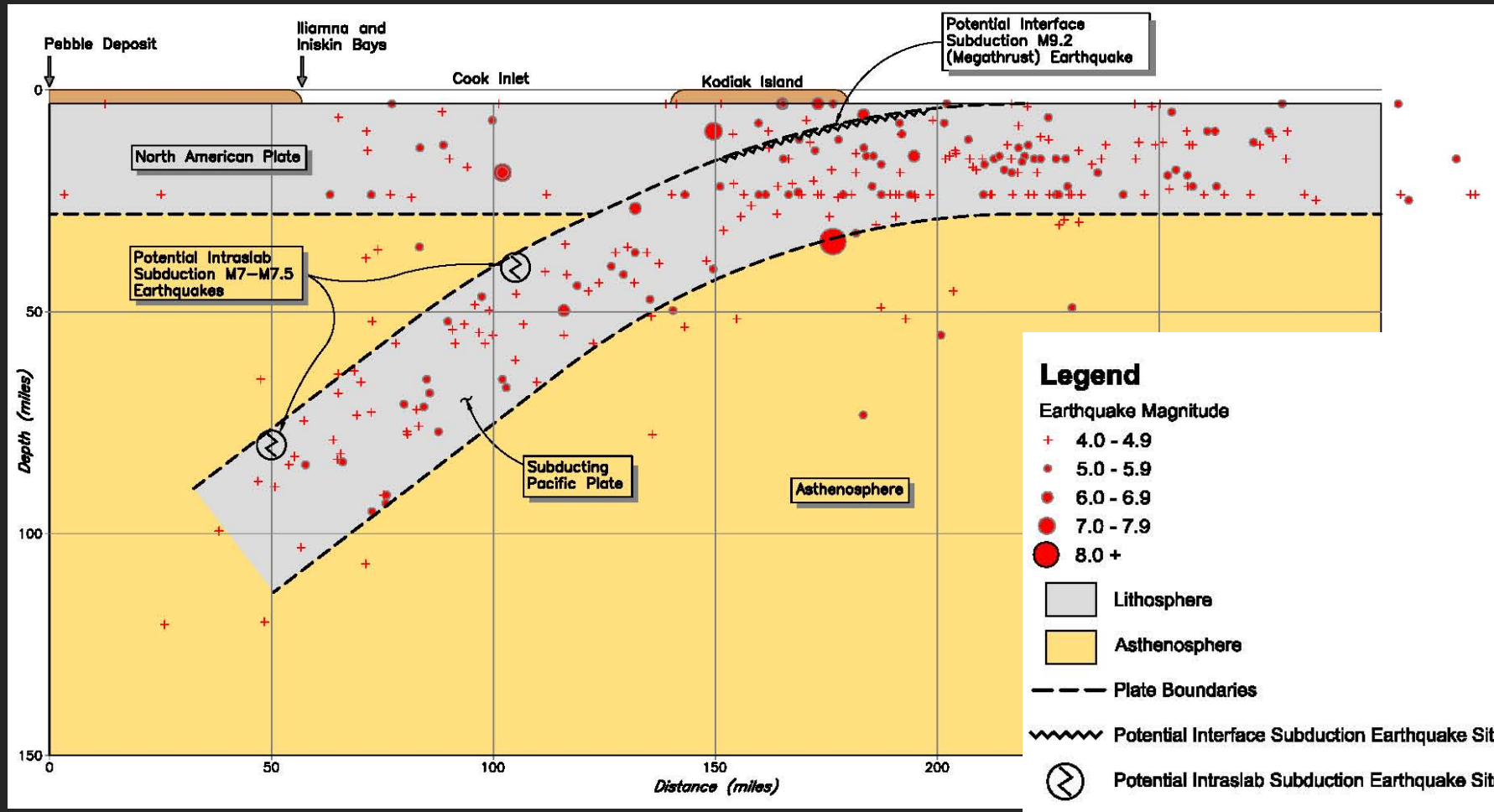
Schematic section through Subduction Zone



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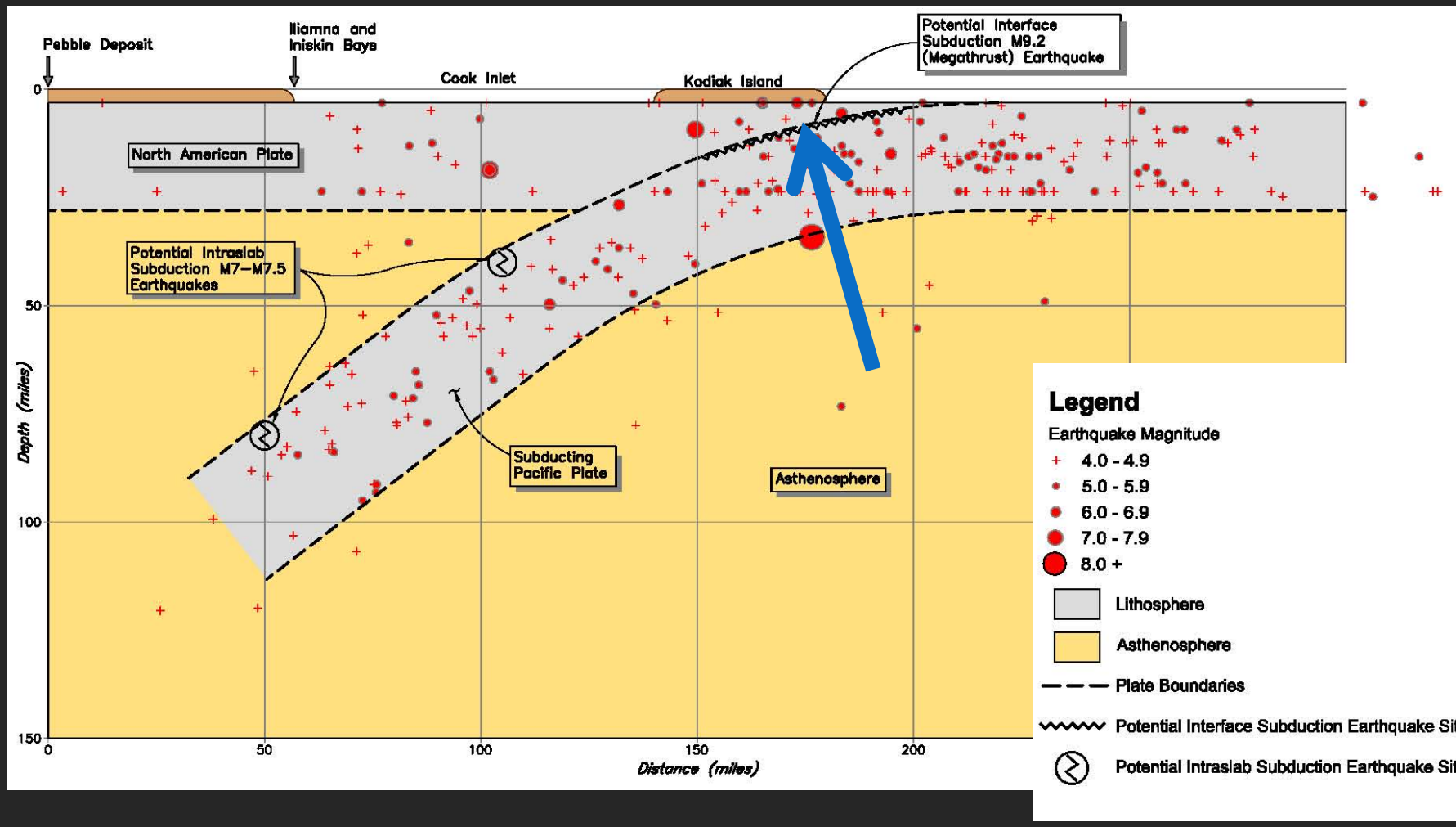
Interface Subduction Earthquakes



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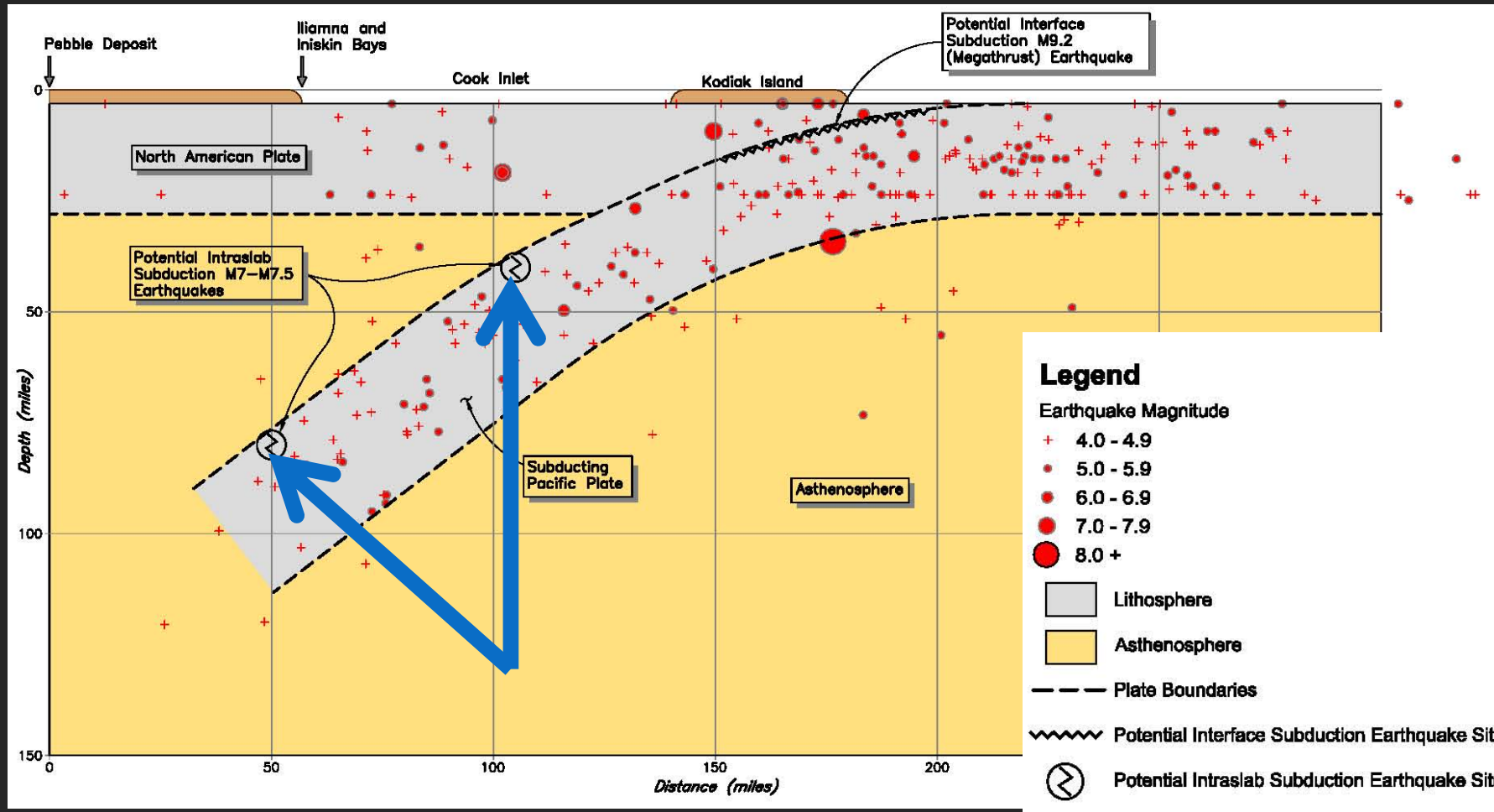
Interface Subduction Earthquakes

- Interface subduction earthquakes are generated when the tectonic plates lock and slip past each other – releasing built-up stress as an earthquake
- Often occur at relatively shallow depths (10 to 25 miles)
- Potential for M8 to M9+ interface subduction earthquakes in the region
- Large magnitude events can last for several minutes
- Estimated period of recurrence of a large interface subduction (M8+) earthquake in the region of southern coastal Alaska is ~650 years
- M9.2 Prince William Sound earthquake, 1964, the second largest earthquake ever recorded.

In-Slab Subduction Earthquakes



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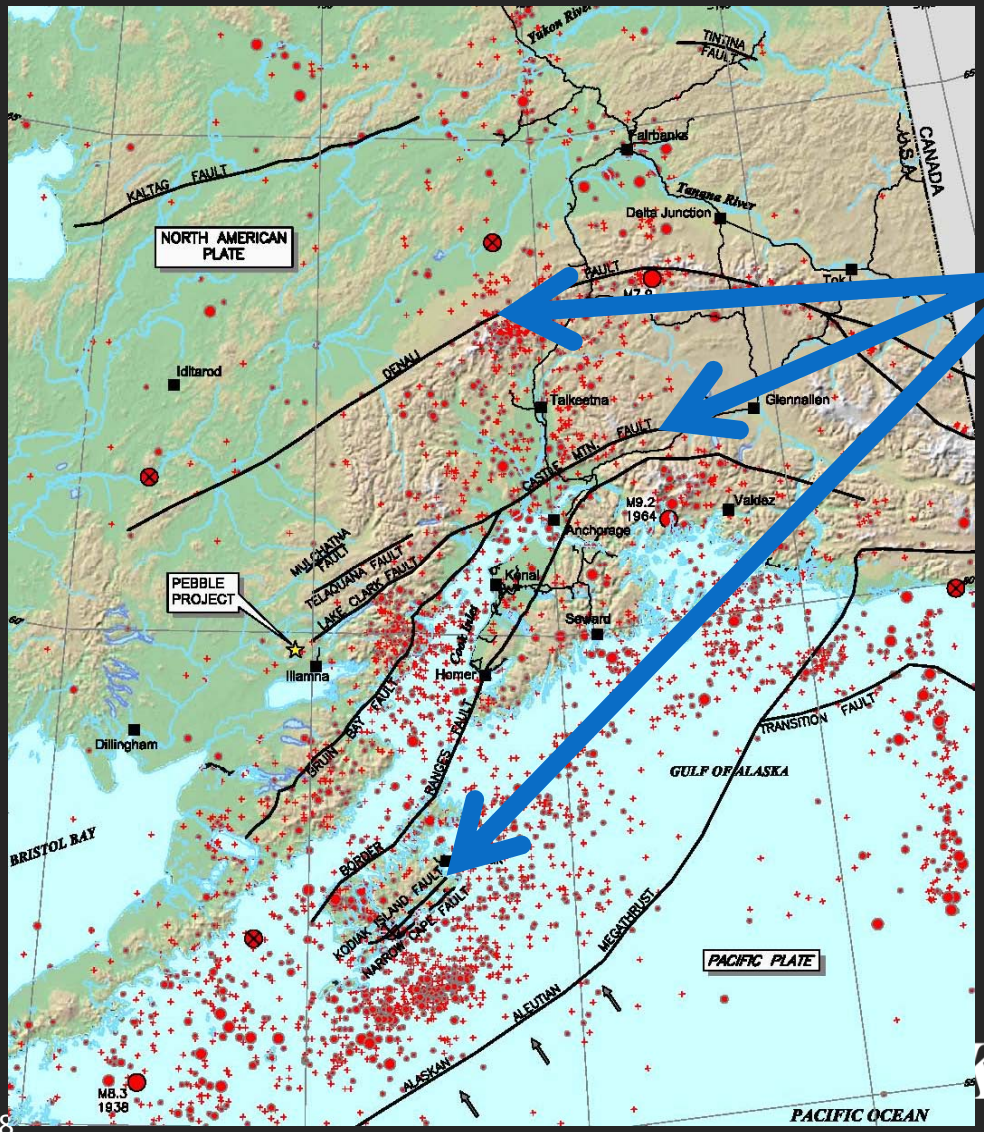
In-Slab Subduction Earthquakes

- In-slab earthquakes occur within the subducting plate (slab)
- Often occur deep in subducting Pacific plate (typically greater than 25 Miles)
- Several moderate to large magnitude in-slab subduction earthquakes have been recorded in the region over the last century
- M7 earthquakes in 1999 and 2001, located on or close to Kodiak Island.
- Potential for M7+ in-slab subduction earthquakes

Shallow Crustal Earthquakes

- Occur along active faults in earths crust (typically at depths less than 25 miles)
- Numerous fault systems in southern Alaska related to tectonic pressure and crustal flexure caused by the subduction zone
- Active Faults - moving over time due to buildup of stresses
- Inactive Faults - had movement at one time but no evidence of movement during the Holocene period (last ~11,000 years)

Crustal Faults



Legend

- Mapped faults
- Zone of recorded earthquakes included on SECTION A-A

EARTHQUAKE FOCAL DEPTH

- Depth ≤ 25 miles
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EARTHQUAKE MAGNITUDE

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- 5.0 - 5.9
- 6.0 - 6.9
- 7.0 - 7.9
- 8.0 +
- Large magnitude earthquakes recorded between 1899 & 1904

Location and direction of view for Geological Section

Crustal Faults

- Denali Fault – M7.9 (2002), 125+ miles from study area – largest recorded crustal earthquake in Alaska
- Castle Mountain Fault system – M7 (1933), M5 to M7+ earthquakes along this system ~every 700 years
- Kodiak Island and Narrow Cape Faults – capable of producing earthquakes up to M7.5
- Bruin Bay Fault – M7.3 (1943), active in late Jurassic (150Ma) and in mid to late Tertiary (25Ma)
- Border Ranges Fault, currently inactive, Cretaceous to early Tertiary (65Ma), potential for M7+

Lake Clark Fault

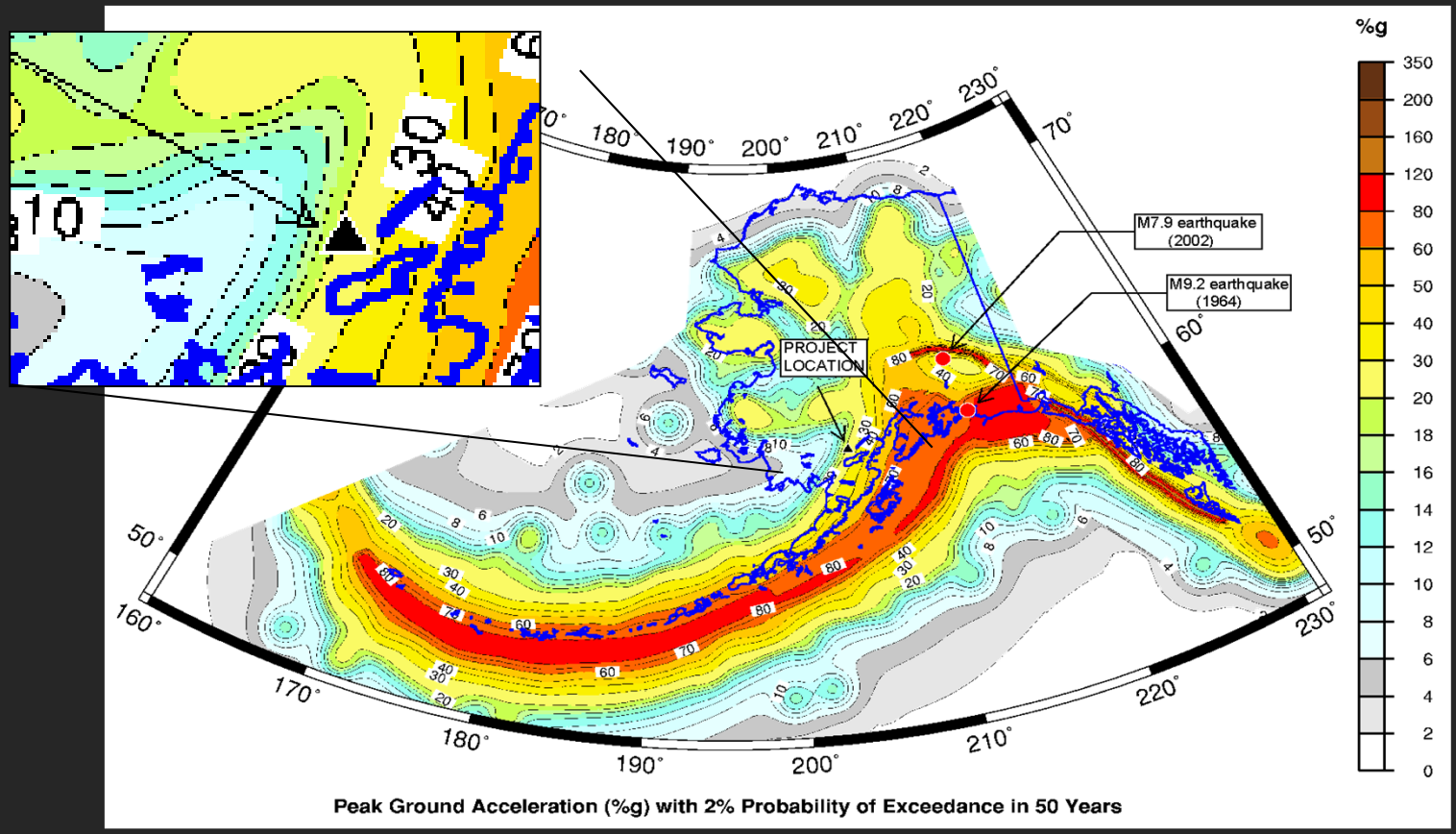
- Lake Clark Fault – westerly extension of Castle Mountain Fault system.
- Western end of mapped fault ~10+ miles from study area (Haeussler et al, 2004).
- Main fault and/or fault splays may extend farther to the SW, but there is no evidence due to a lack of bedrock exposure.
- Fault is inactive - no evidence of activity along this fault in the Holocene period – last 11,000 years (Haeussler et al, 2011).

Ground Motion Parameters

- The following are earthquake ground motion (shaking) characteristics
  - Amplitude (PGA, PGV)
  - Frequency Content (response spectrum)
  - Duration
- Characteristics are dependent on type and size (Magnitude) of earthquake, and the location relative to the mine study area.

Ground Motion Parameters

- Peak Ground Acceleration (PGA) at mine study area ~ 0.25g for 1/2500 year return period.



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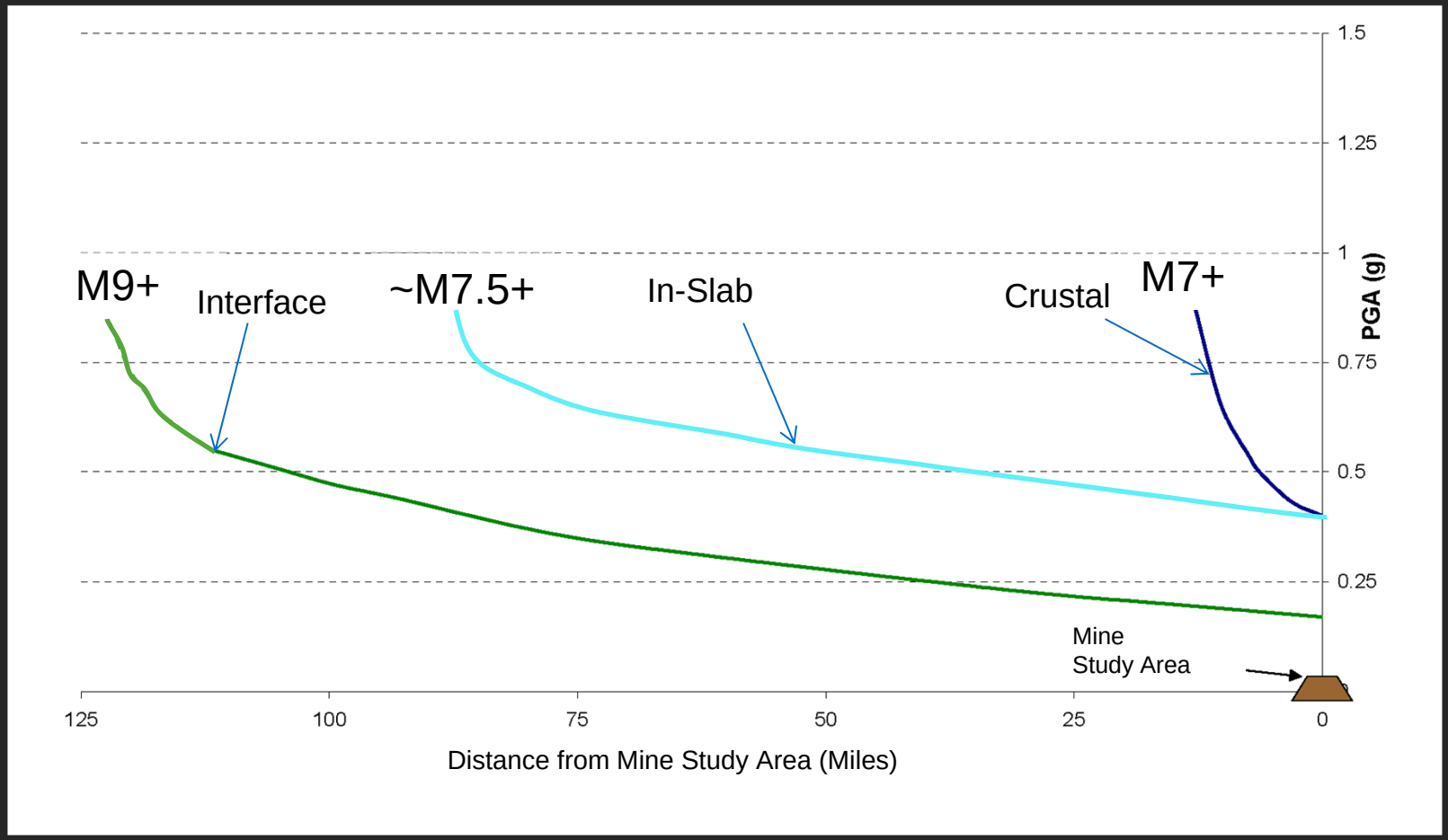
Peak Ground Acceleration (g) vs. Distance (miles from Mine Study Area)



Seismic Hazard for Pebble Site

- Seismic hazard at Pebble Site influenced by:
  - Large magnitude (~M7+) In-Slab Subduction and Shallow Crustal earthquakes, lower maximum magnitude and shorter duration compared to Interface Subduction events, but potentially larger ground shaking (higher PGA).
  - Large magnitude (M8 to M9+) interface subduction earthquakes - long duration but lower ground shaking (lower PGA) compared to closer In-Slab Subduction and Shallow Crustal earthquakes.

Questions