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Advancing USGS Mineral Resource Assessment Techniques for Concealed Mineral Deposits in Southwest Alaska

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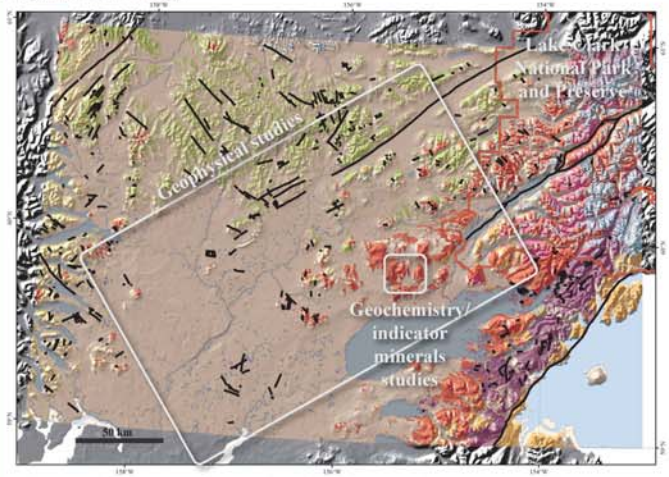
Introduction

An understanding of the distribution of mineral resources on public, state, or Federal lands is important for land management decisions and helps predict the natural environmental effects resulting from erosion and weathering of mineral deposits. Most remaining undiscovered mineral resources are not exposed at the Earth's surface but are instead concealed beneath surficial deposits. Using geophysical, mineralogical, and geochemical techniques, the U.S. Geological Survey (USGS) is refining assessment techniques for identifying concealed mineral resources. Field studies in 2010 were focused in the Lake Clark National Park; these results have been integrated with data collected further southwest, including the region containing the concealed Late Cretaceous Pebble porphyry Cu-Au-Mo deposit. Porphyry deposits often occur in space and time as clusters in linear, orogen-parallel belts suggesting the region is highly prospective for similarly aged porphyry deposits.

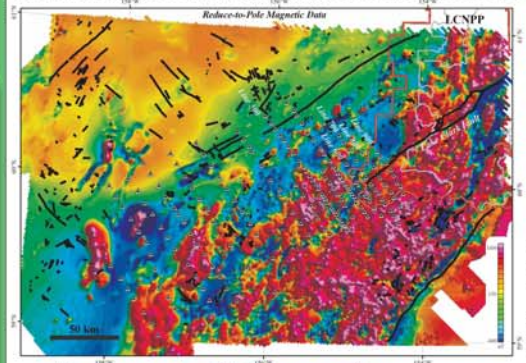
Regional Geology

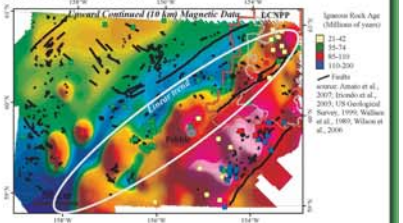


Southwestern Alaska consists of an amalgamation of lithotectonic terranes that have been accreted to the North American craton since the Paleozoic (see Paleoreconstructions). Overlapping these exotic terranes are syn- to post-collisional sedimentary rocks that formed in submarine environments. Subduction during the Mesozoic led to the formation of numerous igneous complexes that intruded the sedimentary rocks, some of which host porphyry copper deposits such as Pebble. Porphyry copper deposits often occur in linear, orogen-parallel belts suggesting additional deposits may be present in southwest Alaska.

Geophysics

Geophysical investigations include magnetic-field, gravity, and magnetotelluric (MT) measurements. Existing magnetic-field data show the Pebble deposit to be associated with highly magnetic rocks and a linear northeast-southwest trend of similar magnetic anomalies extends for over 350 km, including areas within the Lake Clark National Park. Models of magnetic-field, gravity, and MT data suggest an abundance of near-surface igneous rocks and a large electrically-conductive zone at depth below the Pebble deposit.



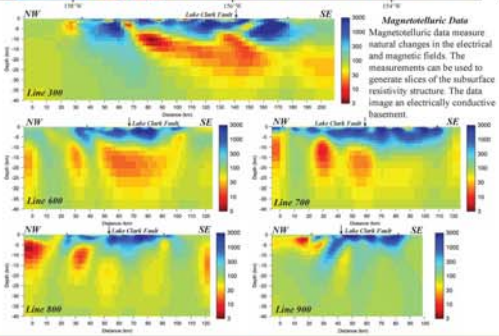


Magnetic Data

Magnetic data map the distribution of magnetic minerals such as magnetite, a common accessory mineral in igneous rocks. Porphyry deposits are associated with magnetite-series igneous rocks that can be mapped using aeromagnetic data. A strong correlation is found between areas of strong magnetic anomalies and igneous rocks with radiometric ages between 85-110 Ma.

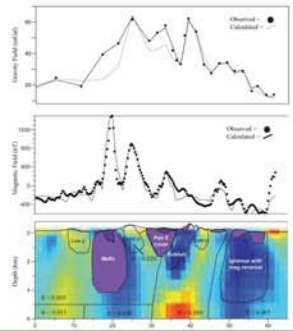
Gravity, Magnetic, and Magnetotelluric Data Modeling

Gravity data map density variations in the subsurface lithology. In general, igneous rocks are more dense than sedimentary rocks and mafic igneous rocks are more dense than felsic igneous rocks. Forward modeling constrained by gravity, magnetic, and magnetotelluric data suggest igneous rocks make up a large portion of the near surface lithology.



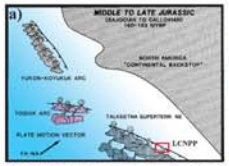
Magnetotelluric Data

Magnetotelluric data measure natural changes in the electrical and magnetic fields. The measurements can be used to generate slices of the subsurface resistivity structure. The data image an electrically conductive basement.



Paleoreconstructions

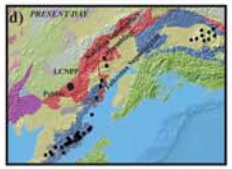
Schematic paleoreconstruction of southwestern Alaska modified from Wallace et al., 1989. The Pebble deposit is hosted in the Kahiltna sedimentary assemblage shown in red.



a) Middle to Late Jurassic showing formation of the Talkeetna Superterrane which includes the Peninsular, Wrangellia, and Alexander terranes of southern Alaska.

b) During the mid-Cretaceous sediments derived from the Talkeetna Superterrane were deposited forming the Kahiltna sedimentary assemblage. Subduction trench on outboard side of Talkeetna Superterrane. The Pebble deposit formed from igneous rocks that intruded the sedimentary rocks at 90 Ma.

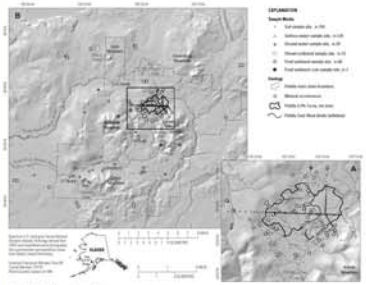
c) Magmatic arcs formed during the latest Cretaceous to early Tertiary. Tectonic forces (oroclinal bending) pushed LCNPP and the Pebble deposit towards present day southwestern Alaska.



d) Present day configuration of southwestern Alaska. The Kahiltna sedimentary assemblage is shown in red and the Talkeetna Superterrane in blue. Black circles represent present day subduction-related volcanoes.

Geochemistry

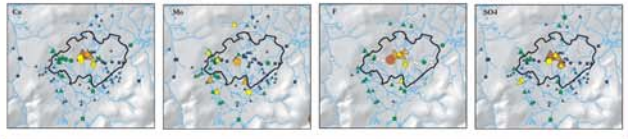
Water samples from lakes, ponds, streams, and seeps proximal to mineral deposits contain anomalous concentrations of dissolved Cu, Mo, F, and SO_4 compared to distal samples. The high concentrations of metals in water samples are due to natural weathering of the buried deposits. Depending on analytical methods used to determine trace elements, soil samples may be used to indicate the depth of the deposits.



Number of geochemical sample media collected from 2007 to 2010 near Pebble.

Media	Year 2007	2008	2009	2010
Tills (TIL)	11	16	22	22
Stream Sediments (STS)	8	12	0	0
Pond Sediments (PDS)	0	57	19	0
Pond Core Sediments (subsample intervals) (CR)	0	2*	5**	0
Rocks (R)	2	5	4	0
Vegetation				
Willow (VWI)	21	0	0	0
Bog Birch (VBB)	13	0	0	0
Alder (VAL)	12	0	0	0
Soil				
Enzyme Leach (SEZ)	85	102	23	0
TerraSol Leach (STL)	85	102	23	0
Mobile Metal Ion Leach (SMM)	77	0	0	0
Cold Hydroxylamine Leach (SCH)	77	79	23	0
Ionic Leach (SIL)	72	66	23	0
Aqua Regia (SAR)	77	60	23	0
Total Analysis (STO)	77	79	23	0
Soil pH and Conductivity(SPH)	77	79	23	0
De-ionized Water Leach (LFA)	77	0	0	0
Sodium Pyrophosphate Leach (SNP)	86	0	0	0
Soil Gas Hydrocarbons (SNG)	86	0	0	0
Bio Leach (SBL)	86	0	0	0
Waters				
Filtered acidified (FA)	42	77	21	27
Unfiltered acidified (RA)	41	77	21	27
HR-ICPMS-FA	42	77	21	27
HR-ICPMS-RA	0	77	21	27
ICPMS-FA	42	0	0	0

* subsampled 2 cm ** subsampled 2.5 cm



Indicator Minerals

Porphyry copper indicator minerals in glacial till samples can be used to identify the type, location, and distance to concealed deposits. The abundance and morphology of gold and jarosite grains are the best vectors.

Collected 8 kg samples from glacial moraine ridges

< 2 mm fraction concentrated, examined optically, verified by SEM