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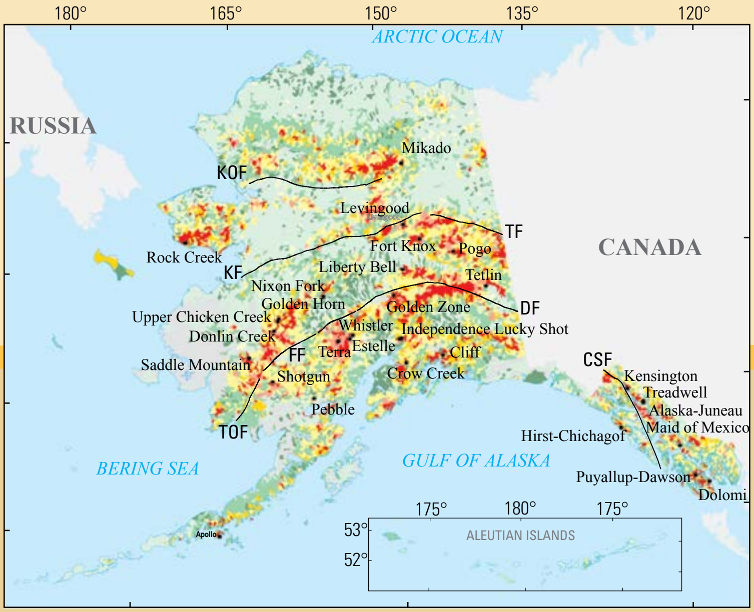
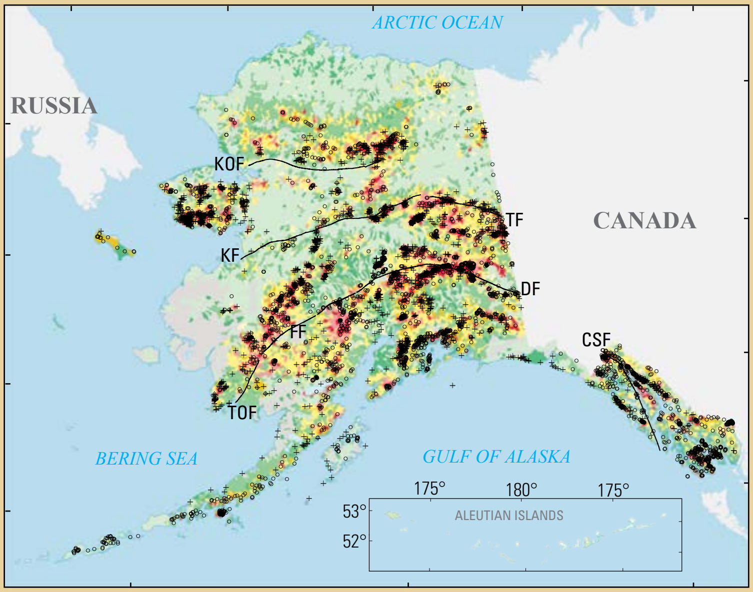
Geospatial Analyses Delineate Lode Gold Prospectivity in Alaska

- Data-driven geospatial analyses of geological data delineate lode gold potential for Alaska.
- Analyses indicate new potential lode source areas in gold placer districts and identify new areas in Alaska prospective for lode gold deposits.
- Adaptable geospatial analytical techniques can focus future investigations, data collection, and exploration strategies for gold and associated byproduct critical minerals, such as As, W, Sb, and Te.





Alaska Albers Equal Area Conic projection
North American Datum of 1983

0 150 300 KILOMETERS
0 150 300 MILES

EXPLANATION

High potential	Medium potential	Low potential
High certainty	High certainty	High certainty
Medium certainty	Medium certainty	Medium certainty
Low certanty	Low certanty	Low certanty

Unknown potential

Fault—Kobuk Fault (KOF); Kaltag Fault (KF); Tintina Fault (TF); Togiak Fault (TOF); Farewell Fault (FF); Denali Fault (DF); Chatham Strait Fault (CSF)

Locality type from Alaska Resource Data File
- ◦ Lode
- + Placer

• **Major gold-bearing deposits and occurrences**

GIS-Based Method of Analysis

For the geographic information system (GIS) analysis used to determine lode gold prospectivity in Alaska, key quantifiable characteristics of gold deposit types were identified using seven geologic, geochemical, and geophysical datasets, which we scored with respect to their importance for indicating gold potential. A data scoring and ranking process was tailored to critical parameters for 3 conventional lode gold deposit types, 2 lode gold system types, and 1 overarching undivided gold deposit group; scores were applied to drainage basins approximately 100 square kilometers in area statewide. For a detailed discussion of the scoring criteria for datasets of each deposit type and to access the geospatial data files, see https://doi.org/10.3133/ofr20211041. Criteria and scoring weights can be modified to implement different analyses of the datasets to address other types of inquiries.

A Python script combines individual parameter scores into cumulative scores for each drainage basin. The cumulative scores for each drainage basin were divided into three levels of prospectivity for gold potential (High, Medium, Low) on the basis of natural statistical breaks (qualified by the certainty of the analysis on the basis of the presence and abundance of favorable attributes for each deposit type); a fourth category of Unknown potential was applied to drainage basins that lack data. Owing to the uneven distribution of some datasets, our method assigns scores for certainty that are based on the number of datasets that contribute to each score. The product of each analysis is a map that indicates the relative level (High, Medium, Low) of gold potential, represented by red, yellow, and green, respectively, and the relative level (High, Medium, Low) of certainty, represented by dark, medium, and light shades of the colors, respectively, for each prospectivity exercise. The Unknown class is colored gray. The format and coding of the analytical criteria and data permit users to query individual scores for each drainage basin on the digital map products and compare with known gold occurrences.

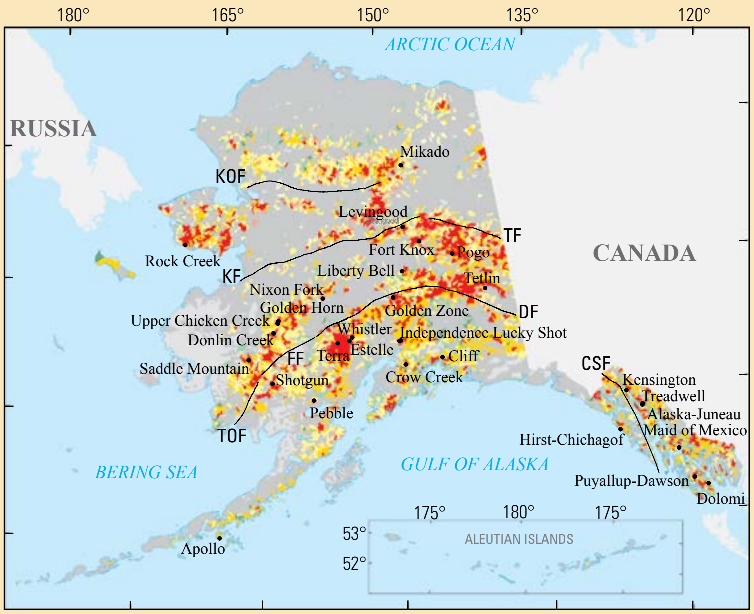
Photograph of Independance Mine northeast of Anchorage, Alaska, by S. Karl, U.S. Geological Survey (banner). Estimated resource potential and certainty for lode gold in undivided deposits (top right) and undivided deposits with Alaska Resource Data File locality type labeled (lower right).

Results of Prospectivity Analyses for Conventional Lode Gold Deposit Types in Alaska

We designed geospatial analyses to distinguish the main conventional lode gold deposit types likely to be found in Alaska, including orogenic, reduced-intrusion-related gold (RIRG), and epithermal. These deposit types have different trace element geochemical signatures that reflect characteristics of the geologic environment in which they formed and the chemistry of their ore-forming fluids. We applied multiple parameters that can discriminate types of gold deposits, but owing to the limits of available data, the compositional similarity of ore-forming fluids among some types of lode gold deposits, complex geologic history, and overlapping geologic environments in space and time, distinguishing deposit types at the state scale in Alaska is problematic. Nonetheless, the spatial overlap of deposit type prospectivity in specific drainage basins reinforces confidence for the presence of a gold resource in individual drainage basins.

Prospectivity Models for Lode Gold-Forming Systems in Alaska

To improve the precision of discrimination of potential for different lode gold deposit types in Alaska, we applied parameters indicative of ore-forming environments in the next iteration of analyses. A primary factor in gold ore-forming systems is the oxidation state of the mineralizing system. Gold deposits in orogenic and RIRG ore systems form in more reduced environments during the waning stages of orogenic tectonism, whereas gold deposits in epithermal and gold-bearing porphyry systems form in more oxidizing environments associated with calc-alkaline magmatism, principally in subduction-related arc settings. We combined environmental conditions with important ore-system components that foster gold deposits, such as sources of heat, metals, fluids, and the composition of hydrothermal fluids and their associated trace element suites. We built models to score parameters that could distinguish reducing and oxidizing gold ore systems (see https://doi.org/10.3133/ofr20211041 for further



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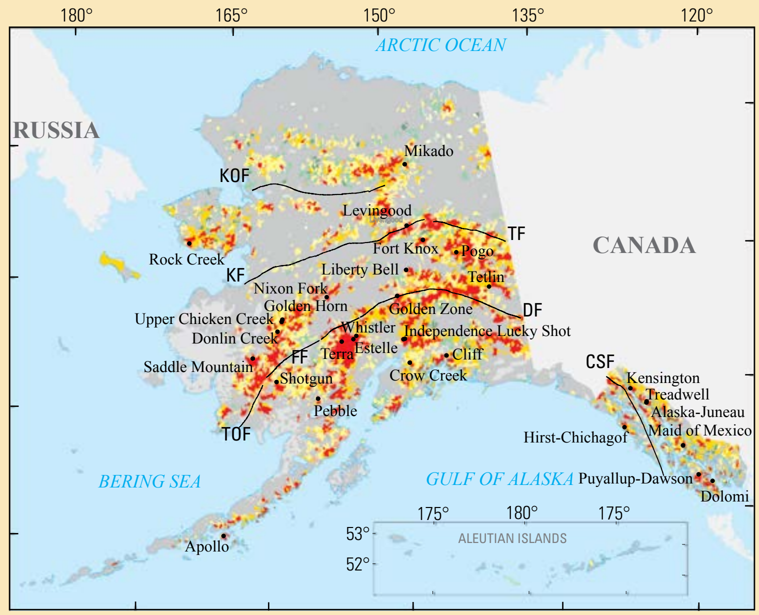

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• **Major gold-bearing deposits and occurrences**

Estimated potential and certainty for orogenic and reduced-intrusion-related gold ore systems (left) and for gold-bearing porphyry and epithermal ore systems (right). Gold-bearing quartz vein in the granite of the Fort Knox pluton (bottom). Photograph by G. Case, U.S. Geological Survey.

Primary results of prospectivity analyses indicate the following:

- The analysis for undivided lode gold deposits, in comparison with known mineralization, shows large areas in Alaska have medium to high prospectivity and may be underexplored for lode gold.
- Prospectivity analysis for orogenic, RIRG, and epithermal deposit types show considerable overlap owing to limitations of currently available geospatial datasets for Alaska.

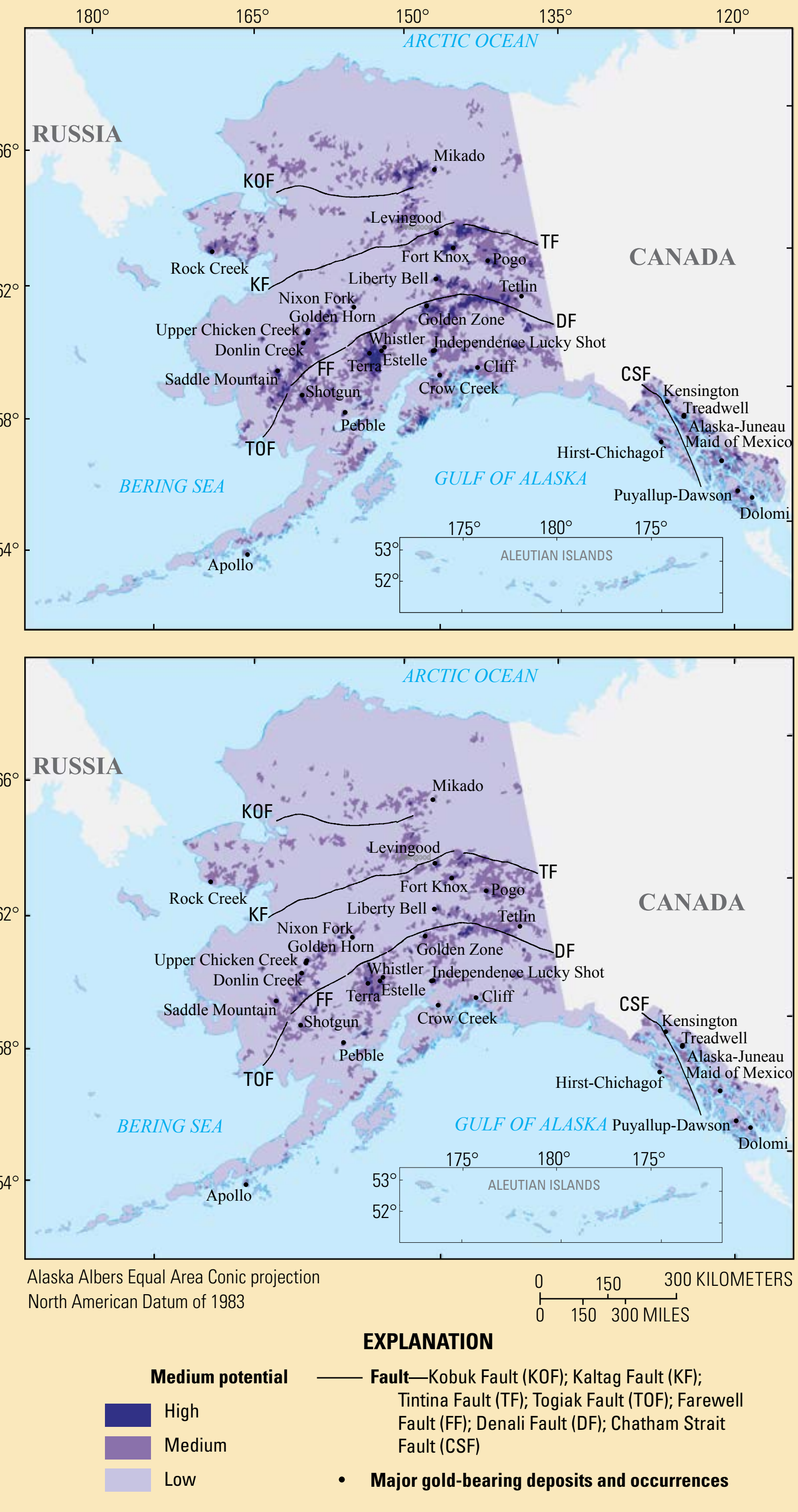
discussion of the scoring criteria). The reducing and oxidizing gold ore system prospectivity analyses scored only drainage basins that were identified in the lode gold-undivided model as having Medium or High prospectivity for lode gold deposits; drainage basins lacking Medium or High prospectivity in the undivided model were not analyzed and are shown in gray.

Reducing Gold Ore-Forming Systems

Although not genetically related, gold deposits in orogenic and RIRG ore systems often form in reducing environments in thickened crust during and after collisional events and the formation of these may overlap in time and space. Orogenic and RIRG ore systems are characterized by similar reducing conditions, CO_2-rich fluids, and cryptic alteration assemblages. Owing to the overlap in time, space, and conditions, we created an inclusive reducing-conditions gold system prospectivity model that scores characteristic element suites, such as tungsten-bismuth-tellurium (all soluble in CO_2-rich fluids) that typically occur in structurally controlled quartz veins in collisional tectonic settings that host both orogenic and RIRG deposit types. For example, using statewide tungsten geochemical data, tungsten concentrations in steps at multiple levels greater than background were applied to identify reducing environments prospective for this reducing ore systems model.

Oxidizing Gold Ore-Forming Systems

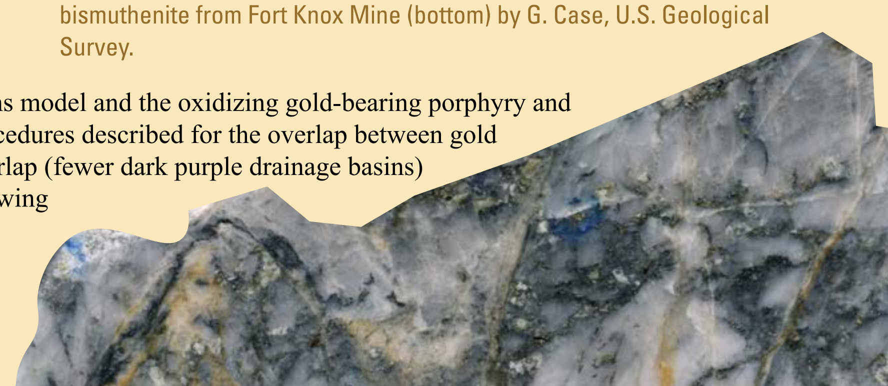
Gold-bearing porphyry and epithermal gold deposits, of gold-bearing porphyry and epithermal gold systems, respectively, form in oxidizing conditions and can have gradational transitions, which are influenced by factors such as temperature, pressure, and depth of emplacement. They share many characteristics, including primarily the element association of abundant copper and sulfur with gold and alteration assemblages characteristic of oxidizing conditions, such as quartz-calcite-adularia-illite and quartz-alunite-pyrophyllite-dickite-kaolinite. Owing to gradations in their environments of formation, we combined gold-bearing porphyry and epithermal gold systems in an oxidizing ore-forming system for spatial delineation in the prospectivity analyses. Parameters scored for oxidizing ore systems include (1) hypabyssal and plutonic rock types; (2) geochemical values that typify epithermal pathfinder elements (As, Sb, Hg, Se, Te, and Cu); (3) alteration mineral assemblages; (4) mineral suites including molybdenite (an indicator of favorable porphyry environments), high-sulfidation state copper minerals (characteristic of the magmatic-hydrothermal epithermal environment), and silver-bearing sulfosalts (characteristic of the geothermal-style epithermal systems); and (5) aeromagnetic data (scored only in drainage basins containing hypabyssal and granitoid intrusive rocks in the Alaska geologic map database at https://doi.org/10.3133/sim3340).



Maps of Alaska showing the overlap between orogenic, reduced intrusion-related, and epithermal lode gold deposit types (top right) and the overlap between gold-bearing porphyry epithermal and reduced intrusion-related ore-forming systems (middle right). Photograph of bismuthenite from Fort Knox Mine (bottom) by G. Case, U.S. Geological Survey.

Comparison of Gold Ore-Forming Systems

Overlap between the reducing orogenic and RIRG systems model and the oxidizing gold-bearing porphyry and epithermal systems model was determined using the same procedures described for the overlap between gold deposit types. This comparison indicates significantly less overlap (fewer dark purple drainage basins) than the comparison of individual gold deposit types, thus showing increased precision for defining areas that are prospective for reducing and oxidizing gold ore systems.



Visible gold, telluride, and sulfide minerals in quartz from Kensington Mine. Photograph by S. Karl, U.S. Geological Survey.

Brecciated gold-bearing quartz-arsenopyrite vein from the Pogo Mine in eastern interior Alaska, photograph used with permission.

Summary and Conclusions

- Prospectivity models for lode gold in Alaska identify known deposits and show areas with strong potential for discovery of new deposits.
- Our analyses for new areas of lode gold mineralization in Alaska indicate that, with available data, disciminating gold mineralization for targeted exploration at a regional scale is difficult and discriminating ore-forming systems is more effective.
- Our analyses for undivded lode gold mineralization has the most practical application for land-use decisions in which the primary goal is to delineate areas that have reasonable potential to host gold mineralization.
- Our results show ways that analyses can be tailored to answer different types of questions. For example, criteria used for gold prospectivity models could be tailored to emphasize gold pathfinder minerals and other critical commodities including Ag, As, Bi, Sb, Te, and (or) W, which are important potential byproduct resources in gold deposits.
- Adjustment of scoring parameters and application at smaller scales can highlight nuances of mineral systems for targeting at a district scale and focus future investigations and data acquisition at district and regional scales.

Further Reading

Detailed discussion of specific datasets, data resources, and scoring parameters are provided in:

Karl, S.M., Kreiner, D.C., Case, G.N.D., Labay, K.A., Shew, N.B., Granitto, M., Wang, B., and Anderson, E.D., 2021, GIS-based identification of areas that have resource potential for lode gold in Alaska (ver. 1.1, October 2021): U.S. Geological Survey Open-File Report 2021–1041, 75 p., 9 plates, https://doi.org/10.3133/ofr20211041.

Data and results for the GIS analyses are provided in:

Karl, S.M., Kreiner, D.C., Case, G.N.D., Labay, K.A., Shew, N.B., Granitto, M., Wang, B., and Anderson, E.D., 2021, Data and results for GIS-based identification of areas that have resource potential for lode gold in Alaska: U.S. Geological Survey data release, https://doi.org/10.5066/P9CAM3F9.

Alaska geologic map database is located at:

Wilson, F.H., Hults, C.P., Mull, C.G, and Karl, S.M., comps., 2015, Geologic map of Alaska: U.S. Geological Survey Scientific Investigations Map 3340, pamphlet 196 p., 2 sheets, scale 1:1,584,000, http://doi.org/10.3133/sim3340.

Sulfide vein in altered diorite from the Jualin Mine (top). Photograph by S. Karl, U.S. Geological Survey. Brecciated gold-bearing quartz-aresenopyrite vein from the Pogo Mine in eastern interior Alaska (bottom), photograph used with permission.

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