Recent U.S. Geological Survey Studies in the Tintina Gold Province, Alaska, United States, and Yukon, Canada—Results of a 5-Year Project

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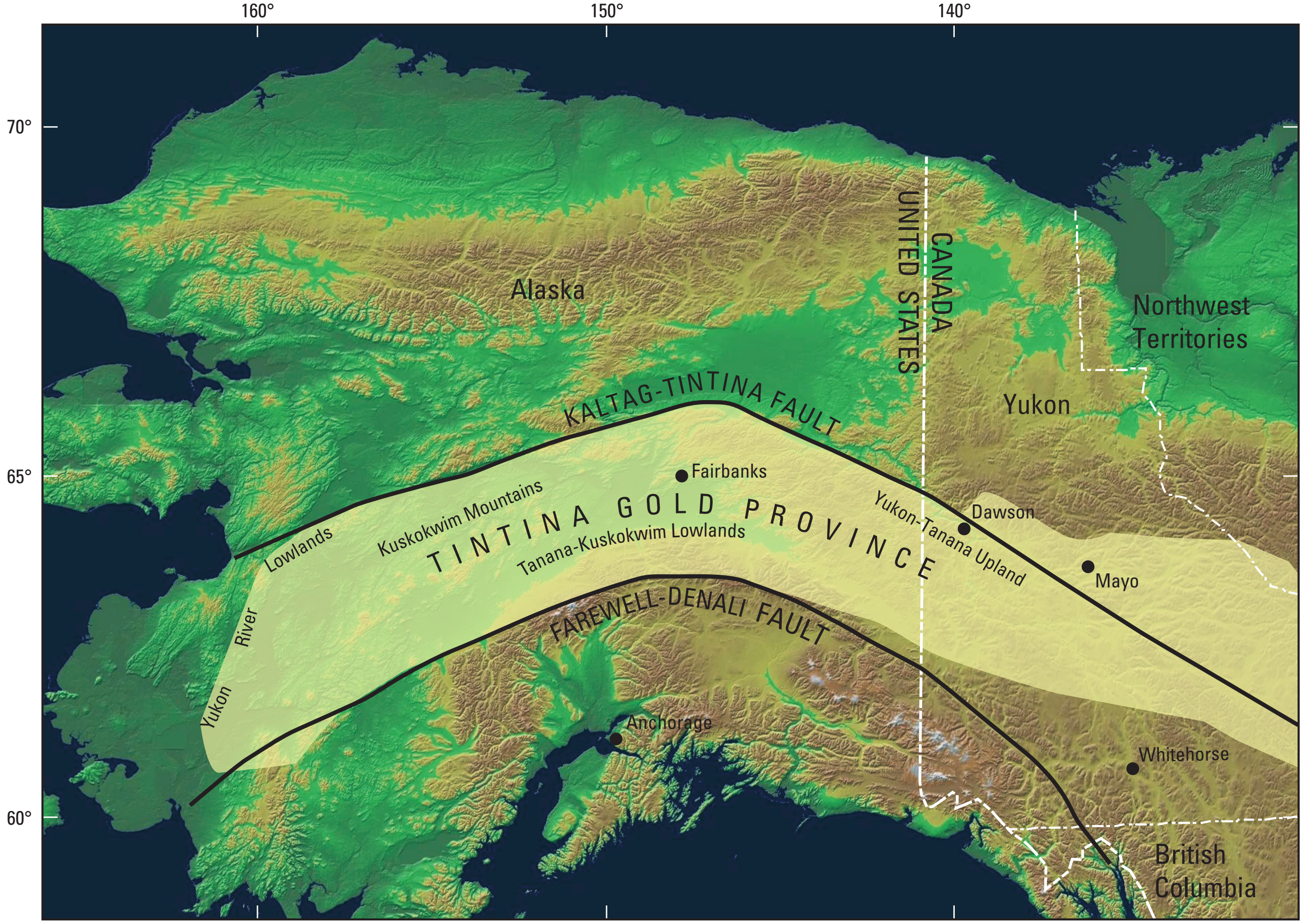

Landsat-based shaded-relief map of the Tintina Gold Province in Alaska and Yukon (courtesy of Craig J.R. Hart, University of Western Australia, Crawley).

Cover. View of a portion of the Black Mountain tectonic zone (ridge in background) looking northeast across the Tibbs Creek drainage within the Yukon-Tanana Upland. This zone, the subject of chapter D of this report, is the locus of almost all of the mineralized base and precious metal veins in the Big Delta B–1 quadrangle. The zone is characterized by complex faulting, shearing, intrusions, and zones of gold and antimony mineralization (photograph by Larry P. Gough).

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Tintina Gold Province Project — Editors' Preface and Overview

By Larry P. Gough and Warren C. Day

This report presents summary papers of work conducted between 2002 and 2007 under a 5-year project effort funded by the U.S. Geological Survey Mineral Resources Program, formerly entitled "Tintina Metallogenic Province: Integrated Studies on Geologic Framework, Mineral Resources, and Environmental Signatures." As the project progressed, the informal title changed from "Tintina Metallogenic Province" project to "Tintina Gold Province" project, the latter being more closely aligned with the terminology used by the mineral industry. As Goldfarb and others explain in the first chapter of this report, the Tintina Gold Province (TGP) is a convenient term used by the mineral exploration community for a "region of very varied geology, gold deposit types, and resource potential."

The TGP encompasses roughly 150,000 square kilometers (km^2), bounded by the Kaltag-Tintina fault system on the north and the Farewell-Denali fault system on the south. It extends westward in a broad arc, some 200 km wide, from northernmost British Columbia, through the Yukon, through southeastern and central Alaska, to southwestern Alaska (fig. 1; Goldfarb and others, 2000; Smith, 2000). The climate is subarctic and, in Alaska, includes major physiographic delineations and ecoregions such as the Yukon-Tanana Upland, Tanana-Kuskokwim Lowlands, Yukon River Lowlands, and the Kuskokwim Mountains (Nowacki and others, 2002).

Although the TGP is historically important for some of the very first placer and lode gold discoveries in northern North America, it has recently seen resurgence in mineral exploration, development, and mining activity. This resurgence is due to both new discoveries (for example, Pogo and Donlin Creek) and to the application of modern extraction methods to previously known, but economically restrictive, low-grade, bulk-tonnage gold resources (for example, Fort Knox, Clear Creek, and Scheelite Dome; see Chapter A by Goldfarb and others in this volume). In addition, the TGP hosts numerous other mineral deposit types, possessing both high and low sulfide content, which are currently not in development.

Until the recent increase in exploration activity at the huge Pebble porphyry copper-gold deposit near Iliamna Lake in 2001, by far most of the exploration dollars spent over the past decade, in Alaska and the Yukon for the identification of new gold resources, have been in the TGP. Chapters A and C of this report present new research that improves our understanding of the regional tectonic and hydrologic processes that localized these low-grade, high-tonnage gold resources. Chapter B describes the tectonic setting and metallogenesis of volcanogenic massive sulfide deposits in the Bonnifield mining district south of Fairbanks and provides the geologic framework for Chapters E and J.

The TGP covers a vast region with very limited road or navigable river access. Thus, remote sensing techniques are critical for characterizing the geologic framework for the region. Geophysical studies, such as aeromagnetic surveys employed to help define the Black Mountain tectonic zone described in Chapter D, are often the only technique available to rapidly detect major tectonic features at the regional scale. Chapter E presents the results of satellite-borne remote sensing techniques using the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) sensor mapping of hydrothermal alteration patterns associated with volcanogenic massive sulfide and porphyry deposits in the Bonnifield mining district. The technique detected some of the known mineral deposits in the region, as well as mineralogically similar targets that may represent potential undiscovered deposits. The research presented demonstrates that the ASTER technique is an extremely powerful tool for remotely characterizing the bedrock mineralogy, and hence, rock type, in areas with minimal to no vegetation cover within the TGP.

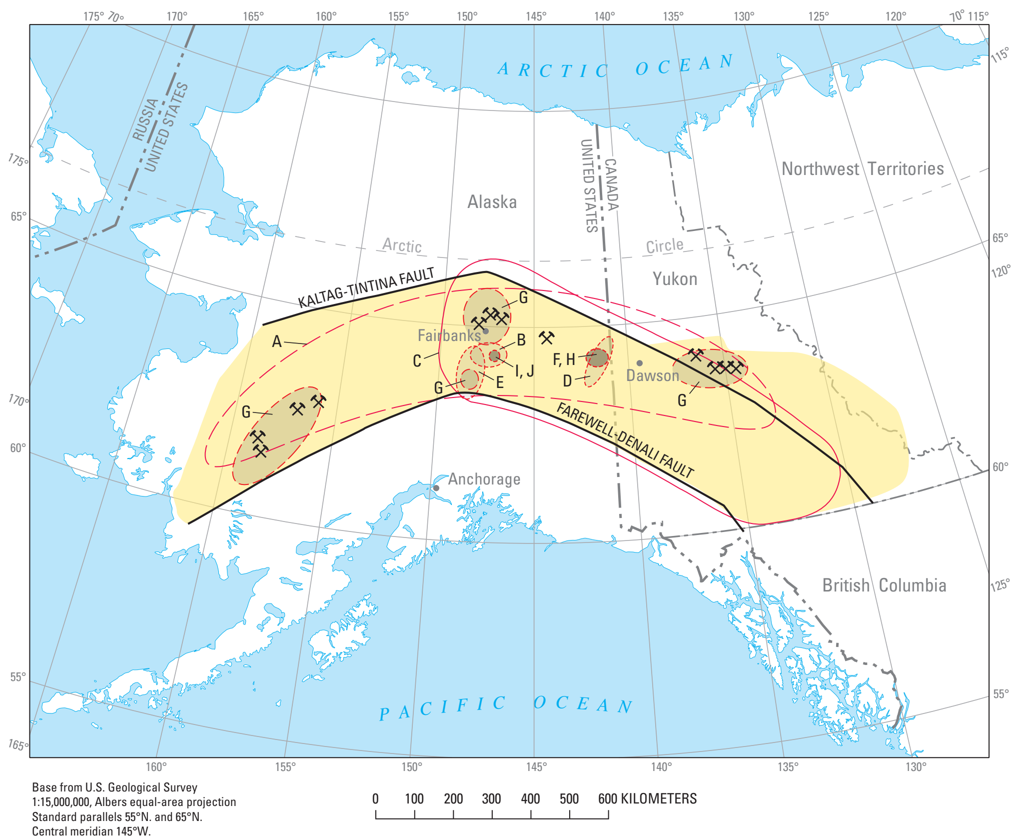
In addition, geochemical, hydrogeochemical, and biogeochemical signatures are presented for both regional, unmineralized areas, and more localized deposit-specific areas throughout the TGP. Sampled media include soils, sediments, surface water, ground water, and vegetation. These signatures are interpreted in the context of bedrock mineralogy and geochemistry, weathering, and soil-forming processes, as well as bioavailability considerations. The information obtained assists in understanding the transport and mobility of trace elements—some of which are important in an environmental context. The environmental signature studies were designed to incorporate the expertise and research capabilities of several disciplines. All such studies rely on an understanding of the geologic and hydrogeologic framework of the region.

Chapter F demonstrates a creative approach using aufeis ("ice" fields localized in drainage basins) as an unconventional proxy for the location of faults along high-gradient alpine drainages. The concept is that aufeis is an accumulation of winter ice, up to several meters thick, along stream and river valleys in arctic and subarctic environments, and is preferentially associated with high-gradient streams. This aufeis formed as a result of discharge of ground water from beneath a permafrost layer within the stream channels. Recent bedrock geologic mapping of the Big Delta B–2 quadrangle indicates that the streams in which aufeis occurs are underlain by throughgoing, high-angle brittle faults, suggesting that the faults are hydraulically conductive to ground water flow. Minor or no aufeis accumulations were observed contemporaneously in other drainage valleys where no extensive fault structures have been mapped, implying that aufeis formation results from more than a topographic effect or discharge from bank storage. Thus, the presence of thick and extensive aufeis in high-gradient streams may be a useful aid to identifying geologic structures in arctic and subarctic climates.

Epigenetic gold deposits are the principal exploration targets within the TGP at this time. Characterizing the geochemical dispersion of pathfinder elements associated with mineralizing systems in the natural environment is a powerful exploration tool. Chapter G synthesizes the efforts to study the natural dispersion of the pathfinder elements arsenic (As) and antimony (Sb) associated with several epigenetic gold mineralizing systems in the TGP. Arsenic and antimony also have garnered attention from the scientific community and the general public due to their potential toxicity. Understanding the fundamental geochemical controls on the natural and anthropogenic distribution of arsenic and antimony in the environment is critical for both mineral exploration and human health communities. This study found that the mobility of arsenic and antimony is controlled primarily by the local reduction-oxidation reaction (redox) environment, with arsenic being less mobile in oxidized surface waters relative to antimony, and arsenic more mobile in reduced ground waters.

A broad approach to landscape geochemistry is presented in Chapter H, which investigates the geochemical linkage among stream waters, streambed sediments, soils, and vegetation with that of regional bedrock. This study provides important premining data for any future mineral development in the Goodpaster River watershed, which lies in the heart of the Yukon Tanana Upland of east-central Alaska. A more focused study is provided in Chapter I, which characterizes the geochemical signature of a volcanogenic massive sulfide (VMS) deposit in the Bonnifield district of central Alaska. The Red Mountain base-metal deposit is a rare, natural laboratory that allows study of an acid-generating, metal-leaching VMS mineral deposit exposed in an undisturbed environment. Dissolution of pyrite and associated secondary reactions under near-surface, oxidizing conditions are the primary causes for the acid generation and metal leaching of the rocks at Red Mountain. However, the acidic waters mix with surrounding alkaline waters that have interacted with carbonate veinlets, resulting in self-mitigation via dilution, neutralization, and attendant co-precipitation. This process limits downstream hydrogeochemical evidence of the deposit to within a few kilometers. Chapter J reports on the occurrence and biogeochemistry of unusual plant species, and of their supporting sediment and soils, in the area of the Red Mountain deposit. Field studies of these occurrences are important for understanding the habitat requirements of rare or unusual species and for a full appreciation of the ecology and biogeochemical diversity of mineralized areas.

Finally, Chapter K is a bibliographic listing of all reports that have been published by USGS personnel since inception of the TGP project in 2002. As noted in the acknowledgments, many of the reports are the result of the work with colleagues from other government agencies as well as academia and industry.



EXPLANATION

- Tintina Gold Province
- G — Study area—Letters identify chapters in this report
- Major geologic fault system
- ⚒ Major mineral deposit

Figure 1. Study areas within the Tintina Gold Province of Alaska and Yukon covered by the individual chapters (letters) in this compilation (see table of contents).

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Goldfarb, R.J., Hart, C.J.R., Miller, M.L., Miller, L.D., Farmer, G.L., and Groves, D.I., 2000, The Tintina gold belt: a global perspective, *in* Tucker, T.L., and Smith, M.T., eds., The Tintina gold belt—Concepts, exploration and discoveries: British Columbia and Yukon Chamber of Mines Special Volume 2, p. 5–34.

Nowacki, G.J., Spencer, Page, Fleming, Michael, Brock, Terry, and Jorgenson, Torre, 2002, Unified ecoregions of Alaska, 2001: U.S. Geological Survey Open-File Report 02–297, scale 1:4,000,000.

Smith, M.T., 2000, The Tintina gold belt: an emerging gold district in Alaska and Yukon, *in* Tucker, T.L., and Smith, M.T., eds., The Tintina gold belt—Concepts, exploration, and discoveries: British Columbia and Yukon Chamber of Mines Special Volume 2, p. 1–3.

Contents

[Letters designate the chapters]

Conversion Factors and Notes

Multiply	By	To obtain
	Length	
centimeter (cm)	0.3937	inch (in.)
millimeter (mm)	0.03937	inch (in.)
meter (m)	3.281	foot (ft)
kilometer (km)	0.6214	mile (mi)
	Area	
square kilometer (km^2)	247.1	acre
	Volume	
liter (L)	33.82	ounce, fluid (fl. oz)
cubic meter (m^3)	35.31	cubic foot (ft^3)
ounce, fluid (fl. oz)	0.02957	liter (L)
	Pressure	
kilobar	1000	kilopascal (kPa)
	Flow rate	
cubic meter per second (m^3/s)	35.31	cubic foot per second (ft^3/s)
liter per second (L/s)	15.85	gallon per minute (gal/min)
	Mass	
microgram (µg)	0.00000003527	ounce avoirdupois (oz)
milligram (mg)	0.00003527	ounce avoirdupois (oz)
gram (g)	0.03527	ounce avoirdupois (oz)
megagram (Mg) = metric ton (t)	1.102	ton, short (2,000 lb)
megagram (Mg) = metric ton (t)	0.9842	ton, long (2,240 lb)
	Density	
kilogram per cubic meter (kg/m^3)	0.06242	pound per cubic foot (lb/ft^3)
	Ore grade	
gram per metric ton (g/t)	0.032	ounce avoirdupois, per ton (oz/ton)
ounce avoirdupois, per ton (oz/ton)	31.25	gram per metric ton (g/t)

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows:

$°F=(1.8\times°C)+32$

Specific conductance is given in microsiemens per centimeter at 25 degrees Celsius (µS/cm at 25 °C).

Concentrations of chemical constituents in water are given either in milligrams per liter (mg/L), micrograms per liter (µg/L), or parts per million (ppm).

Concentrations of chemical constituents in soil are given in milligrams per kilogram (mg/kg).

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