

Lodes, placers, faults, gold, & how they tie together in the Livengood area
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Placer (concentrations in sediments) deposits require a lode (at least a weak concentration in bedrock) source. Duh. Historically, prospectors have explored for gold lodes by chasing placer concentrations up stream to their source. Which—interestingly—only works some of the time. Pogo (Fig. RL-1), one of Alaska's highest-grade and largest gold deposits, has no associated placer. Conversely the sources of most Interior Alaskan placers (e.g. those in the Tofty area) have not been located. The Livengood-Eureka-Tofty-Rampart placers illustrate these problems. We'll look at some possible solutions during the field trip.

The vast bulk of lode gold deposits in Interior Alaska are spatially and genetically associated with mid-Cretaceous intrusive rocks (Fig. RL-1). As a starter, then, Au placers can only be expected where such intrusions are present. There are two such 'belts' in Interior Alaska: a larger one containing quartz-rich 'subduction type' granitic bodies with ages of about 110 to 90 Ma and a narrow belt of quartz-poor, alkalic, 'back arc' intrusions with ages of about 90 Ma (Fig. RL-1). The larger one accounts for lode and placer gold in the Fairbanks-Fox area; the narrow one for gold in the Livengood-Eureka-Tofty region. The gap in gold deposits and prospects between the Chatanika River and the Tolovana River (Fig. RL-1) is due to the lack of mid-Cretaceous intrusions in that region. As you drove in, you (perhaps) glanced at an altered mid-Cretaceous body along the Elliot. It's no coincidence that the first placer operation in the Livengood area that you see is just down the road....

Known placer deposits and lode deposits/prospects in the immediate Livengood area are shown on Fig. RL-2. What's not shown is the incredible extent of the recently discovered and still-being-defined Money Knob Deposit. You perhaps got a sense of that from driving in and seeing all the drill stations that have been cut into Money Knob. Another perspective is the air photo (Fig. RL-3), looking south from the Livengood Bench area—the whole top of the knob is underlain by gold-bearing rocks. A third is given by the extent of significant gold in soil (Fig. RL-4). Examination of the placer map (Fig. RL-2) shows most of the placer gold in the Livengood area is in the so-called "Livengood Bench", located several hundred feet ABOVE present Livengood Creek and considerably wider than present day Livengood Creek. We'll be looking at the sediment stratigraphy as part of the field trip; pollen evidence (Karl et al., 1988) indicates that the Livengood Bench placers are about 10 million years old (late Miocene). Here are three problems in relating the placers to the lodes: (1) there's no known source for the Bench placers above Amy Creek (2) the fineness in the Livengood Bench INCREASES upstream, (3) if there are placer deposits west of Myrtle Creek, they're very deeply buried.

The source problem is obvious. Further, one would think—given the size of the Money Knob Deposit—that there would be a lot of placer gold downstream in Livengood creek or a continuation of the Livengood Bench. What's all that gold doing upstream???

Fineness is $1000 \times \text{wt\% Au}/(\text{Au}+\text{Ag})$, e.g., 900 fine = 90% Au...sort of. (Gold also can contain significant amounts (percents) of Hg and rarely of Cu. Those are ignored for fineness calculation.) Silver is susceptible to oxidation (hence, silverware 'tarnishes'). Gold isn't. Being bounced around in an aerated stream exposes the gold particle to oxygen, which causes the silver 'dissolved' in the gold (solid solution) to be oxidized and diffuse out of the gold. The net result is that placer gold particles develop Ag- (and Hg-) leached rims and the overall fineness decreases. This effect apparently is restricted to when the gold is being transported in the alluvial environment and consequently the pattern—seen (in general) around the world—is that gold fineness INCREASES DOWNSTREAM OF THE SOURCE. Note, that—in contrast—the fineness of gold in the Livengood Bench INCREASES upstream! And it's not just gold that acts strangely... Getting chromite (a Cr-rich spinel mineral) upstream of chromite sources (Fig. RL-5) is similarly problematic (uhm...impossible??) Fig. RL-5 shows the concentrations of the element Cr (pretty much has to be the mineral chromite) in panned concentrates and placer samples from the area. Elevated Cr in the stream with all the sources DOWNSTREAM is just wrong. (The obvious sources for chromite are the former ultramafic rocks of the ophiolite complex, now serpentinite; Fig. RL-8).

Both the average fineness from old reports (Fig. RL-2) and the Cr concentrations in concentrates are bulk properties of a sediment sample. Another way to look at the problem is to gather data on individual gold grains (Fig. RL-6). This figure shows the results of a microprobe investigation of gold grains from individual sites. The procedure is to take several grains from a site, mount them together in epoxy on a glass slide, then mount another cluster of gold grains....With dexterity one can mount a dozen or so such clumps. Following that, polish the gold grains until all one has is a cross-section of the grain. Pure gold is considerably yellower and brighter in reflected light than is a gold-silver alloy, so one can literally see a leached rim (leached of Ag, so Au-rich) on a gold grain in reflected light if one is present. One can quantify the degree of leaching by determining the compositions of interior and rim portions of individual grains (via the microprobe). One additional trick is to create a 'backscattered

electron' (BSE) image of a grain under the microprobe. Such an image is sensitive to surface roughness but especially to the MEAN ATOMIC NUMBER at any given point under the beam. Points with higher mean atomic number (in this case, Au-rich) appear brighter on a BSE image. Areas with really low mean atomic number (e.g., epoxy) appear black. Figure RL-6 was created using such images and analyses. What's VERY EVIDENT is that the thickness of the leached rim increases systematically downstream (as is typical) for samples from small drainages (e.g., Glenn Gulch) and INCREASES SYSTEMATICALLY UPSTREAM for the Livengood Bench. Examples of BSE images of grains and fineness measurements on Fig. RL-7 show the extreme differences encountered in grains from the Livengood area—from pristine in upper Glenn Gulch to extensively rimmed on the uppermost Livengood bench.

A final piece of information to note: ALL the grains have essentially the same CORE compositions: fineness of ~ 880-890 and little (usually below detection) Hg. This is the same composition as the one (sigh) sample of lode gold I've been able to microprobe ('Old Smokey'; Fig. RL-2). All this strongly suggests that ALL the placer gold in the area is derived from a common—and relatively consistent—hydrothermal system. In contrast (for example) lode gold at the Fort Knox deposit varies in fineness from 980 to 850, almost certainly with changes in temperature of the system. One can certainly make a strong case that the gold in the Livengood Bench was derived from Money Knob which ultimately REQUIRES that ancestral Livengood Creek was flowing W → E. The high Cr content in lower Goldstream Creek s(Fig. RL-5) suggests that this drainage dumped into Goldstream at one time, too.

So, how does one manage this drainage reversal??? Fault-related tilting is the most obvious possibility and the obvious candidate is the 'Myrtle Creek' (AKA 'Minto') Fault (Fig. RL-8). Athey and Crow (2004) BELOW discuss this fault and the possibility for it having caused the reversal. The Minto fault is a huge topographic feature—the turnoff to Livengood is in this valley of this fault—and it shows up well in the airborne geophysical surveys flown in the area (Figs. RL-9 and RL-10.) The key feature of the resistivity map (Fig. RL-9) is that a series of ~ E-W faults are apparently cut—but not offset—by the Minto fault. In contrast, the ~ E-W fault between the Cretaceous flysch basin and the Paleozoic rocks of the Livengood area is displaced by the Minto fault. The easiest way around this apparent contradiction is if BOTH the Minto fault and the un-named faults to the north are essentially vertical and have mostly vertical dip-slip displacement. Dip-slip motion on the Minto fault then causes the tilting which is ultimately responsible for the variations in flow direction of Livengood Creek. (The aeromagnetic map also shows up the highly magnetic ophiolite units very well. Unfortunately, the Amy Unit contains chert, siliceous dolostone and a highly magnetic greenstone, and quite a few of the aeromagnetic "highs" are due to that greenstone.)

We'll consider these and similar problems over the course of Saturday, September 4th. As a summary of the above, here's Athey and Crow (2004) verbatim on placers in the Livengood district.

"The Livengood subdistrict, located 75 miles northwest of Fairbanks, is the most productive part of the Tolovana mining district. Approximately 530,000 ounces of placer gold have been mined from the region since 1914 (Szumigala and others, 2003). Deposition of the known Livengood placer deposits spans 10 million years with the bulk of the placers, although not the bulk of the gold, probably being deposited within the past 250,000 years. Livengood Bench, located to the north and slightly topographically above the present Livengood Creek, is the richest gold placer in the district (Bundtzen and others, 1982) and the oldest dated placer at ~10 Ma (Karl and others, 1988). The Amy Creek placer may also be of Tertiary age (about 10 Ma). A large debris fan ~1,160 m across at its widest dimension may either truncate or bury the Amy Creek placer, indicating that the placer gravel was deposited first. We believe both the fan and Amy Creek gold placer are relatively old deposits.

The Gertrude Creek placer was probably deposited during the Pleistocene or earlier, as the host gravels are overlain by a thick bed of loess. Woolly mammoth, Saiga antelope (Péwé, 1975), and other Pleistocene fauna were found in Lillian Creek, indicating that this deposit is probably of Late Pleistocene or earlier age. The ages of placer gravels in Lucky, Ruth, and Olive creeks are unknown. The proximity of lode gold prospects (for example, Old Smokey, Sunshine No. 2, and Griffin prospects; Freeman and Schaefer, 1999) allows for the possibility of recent placer deposition in Ruth, Lillian, and Olive creeks. Placer gold in current Livengood Creek is reworked from other gold-bearing gravels present in the existing Livengood watershed.

Mertie (1917) proposed that a portion of Livengood Creek once drained northeast into Hess Creek (Yukon River drainage) and was subsequently captured by the Tanana River drainage, reversing its flow into the drainage pattern present today. Livengood Creek currently flows to the southwest into the Tolovana River (Tanana River drainage). Placer gold nugget compositions and morphologies from Livengood Bench compared with grains from other Livengood placers substantiate a drainage reversal hypothesis and restrict the reversal timing to within the past 10 million years.

The historic headwaters of Livengood Creek probably drained from the Money Knob area, an obvious potential lode source of gold for the formation of Livengood Bench. In the Money Knob area, gold grains sampled from a quartz vein (average fineness 891; Newberry, unpubl.) and an intrusive body (average fineness 902; Newberry, unpubl.) have finenesses remarkably similar to Livengood Bench placer gold grain cores (average fineness 895). Rounding and fineness of nuggets increase down first-order streams draining the Money Knob–Amy Dome ridge (average rim + core finenesses of 854–915; Smith, 1941; Glover, 1950; Cathrall and others, 1987; Minehane and Rogers, 1997). In Livengood Creek, nugget rounding and fineness increase toward the creek’s present headwaters (average rim + core finenesses of 902–925; Smith, 1941; Glover, 1950; Cathrall and others, 1987; Minehane and Rogers, 1997), which is away from the Money Knob area. This trend is more pronounced in the morphology and composition of gold nugget rims (Newberry, unpubl.). Silver-depleted rims on gold nuggets collected toward the present headwaters of Livengood Creek are progressively thicker (no rim to a 100-micron-thick rim) and higher in fineness (from essentially a pristine core fineness of 872 to an average rim fineness of 996).

Although Livengood gold nugget composition and morphology data suggest the stream capture hypothesis is valid, the current southwesterly slope of Livengood Bench is inconsistent with a reversal of drainage direction. Because the existing surface of Livengood Bench parallels the surface of present Livengood Creek, one would expect the older stream to have had a southwesterly flow as well. To restore Livengood Bench to its presumed past northeasterly flow along the paleo-surface, the bench must be raised up ~260 m on its southwestern end. A paleo-surface restored to horizontal requires ~120 m of uplift, and a paleosurface with a gradient similar to that of the current Livengood Creek requires an additional ~140 m of uplift. This suggests an equivalent, and not unreasonable, amount of subsidence has occurred since about 10 Ma to create the current Livengood Creek drainage conditions. A subsidence rate of only 0.026 mm/year for the past 10 million years is required to change the stream gradient from northeast-flowing to southwest-flowing.

The Myrtle Creek Fault shows evidence of tectonism within the past 10 million years. This fault, which bounds the western edge of Livengood valley and truncates the southwestern end of Livengood Bench, appears to have only vertical movement and no associated strike-slip movement. Our interpretation of geophysical data (DGGS and others, 1999) indicates no apparent offset in the strike-slip faults that are bisected by the Myrtle Creek Fault immediately north of Livengood. On the west side of the Myrtle Creek Fault, and not present to the east, a gravel layer that is barren of gold and greater than 45–60 m thick indicates subsidence (drill results from west of the town of Livengood; B.I. Thomas, written commun., 1972; Karl Hanneman, oral commun., 2003). According to Ronald Tucker (oral commun., 2003), the surface of the bedrock steps down to the west 17 m in two places (for a total of 34 m) on lower Lillian Creek. Tucker indicated about 15 m of horizontal distance between the two faults, which are located on the trace of the Myrtle Creek Fault. Changes in base level as a result of tectonic lowering of the Nenana basin (Barnes, 1961; Péwé and others, 1966; Reger, 1987) may also have influenced erosion rates in the Livengood area.

In addition to tectonism, southwesterly headward erosion may have been a contributing mechanism of ancient Livengood Creek’s capture by the Tanana River drainage system. Headward erosion of the formerly northeast-flowing Livengood Creek may have allowed the creek to break through a former drainage divide and flow southwestward to the topographically lower Minto flats, the northern branch of the Nenana basin. “

PARTIAL REFERENCE LIST

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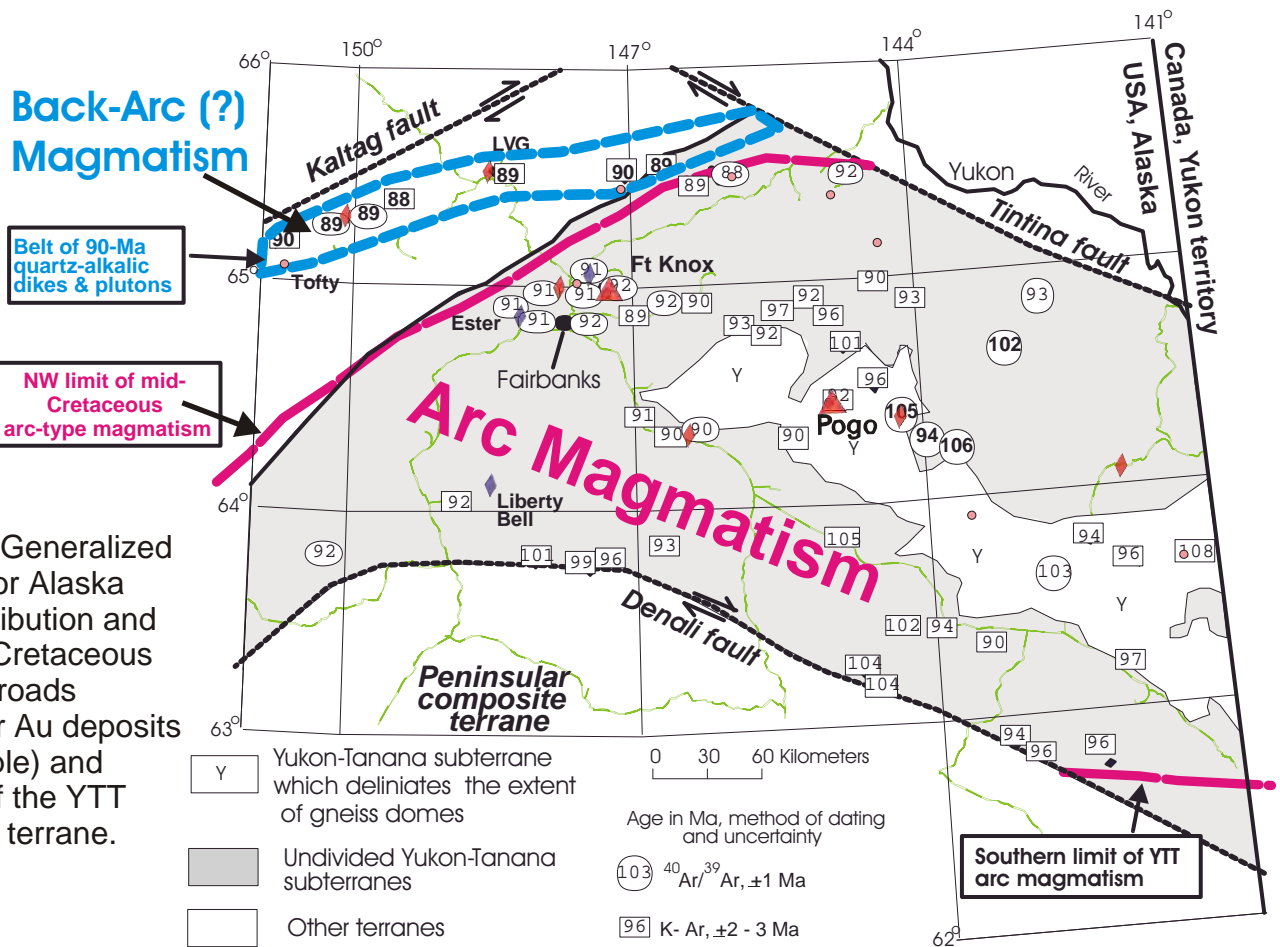
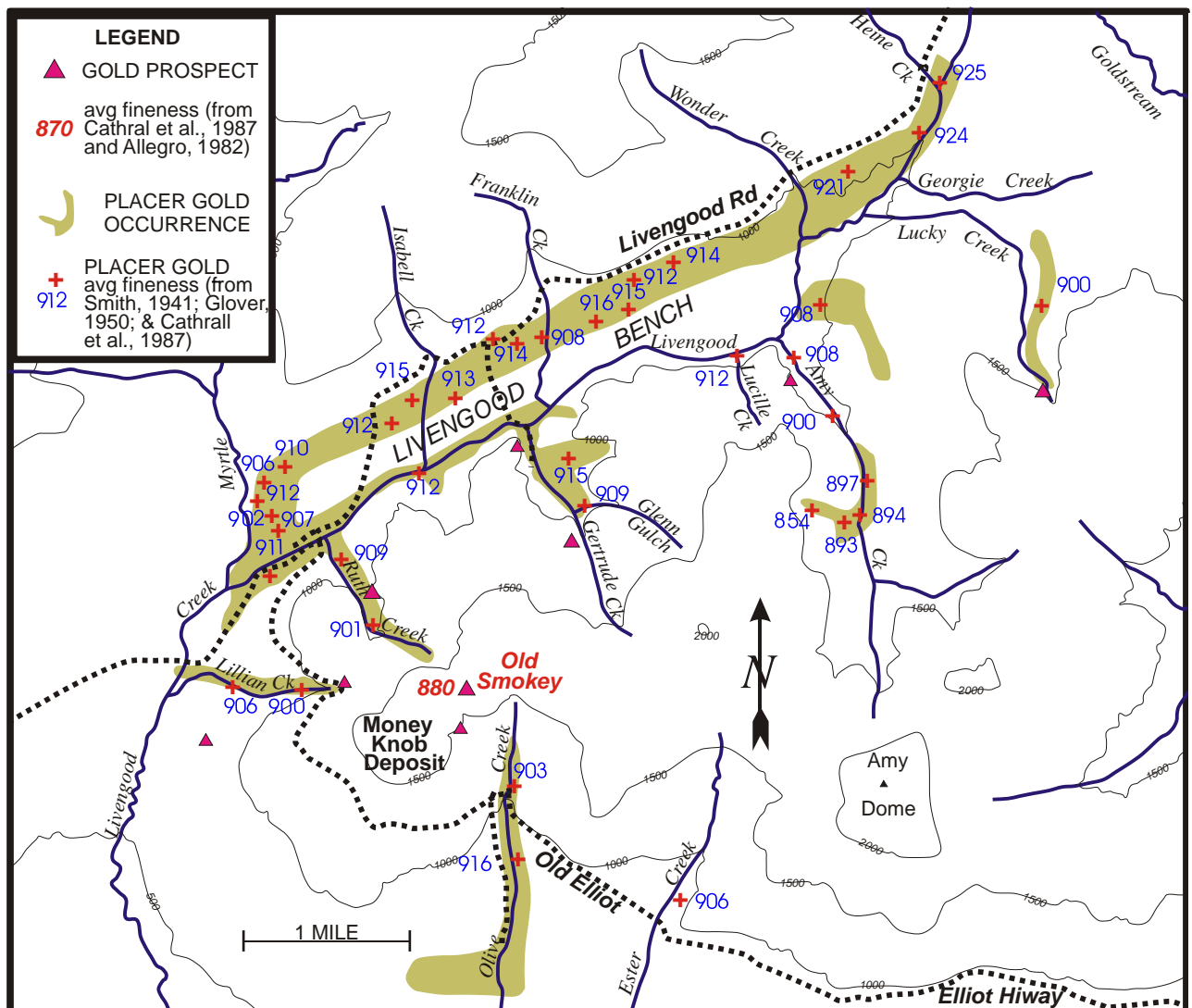


Figure RL-2: Generalized map of the Livengood area showing placer deposits (green), streams (blue), roads (dotted black), known lode gold occurrences (triangles), and gold fineness (numbers adjacent to red +). Fineness is 1000x Au/(Au+Ag).



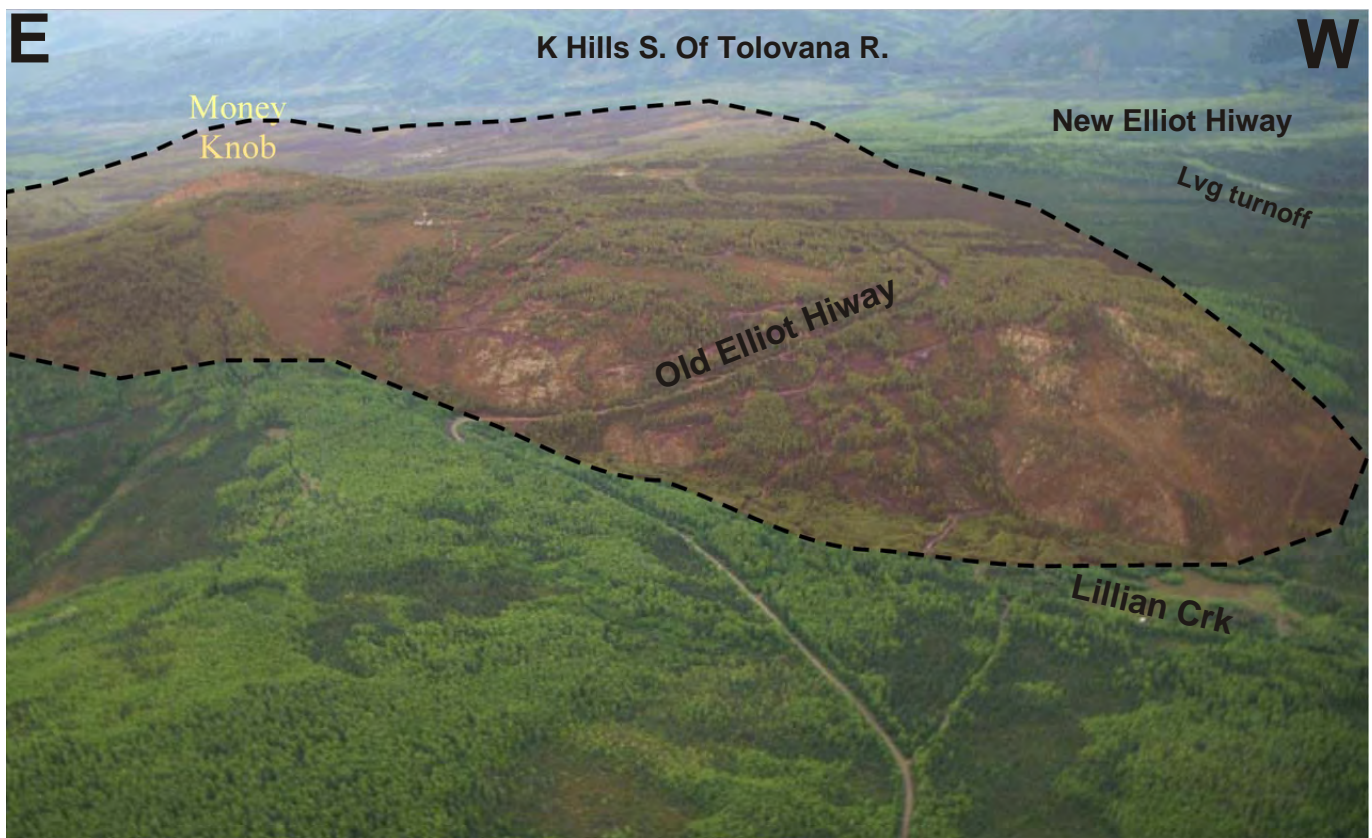


Fig. RL-3: Aerial view looking south at the Money Knob Deposit with the current extent of the drill defined deposit. Modified from ITH 2010 Report. Note that the DEPOSIT is terminated to the north by the Lillian Creek Fault.

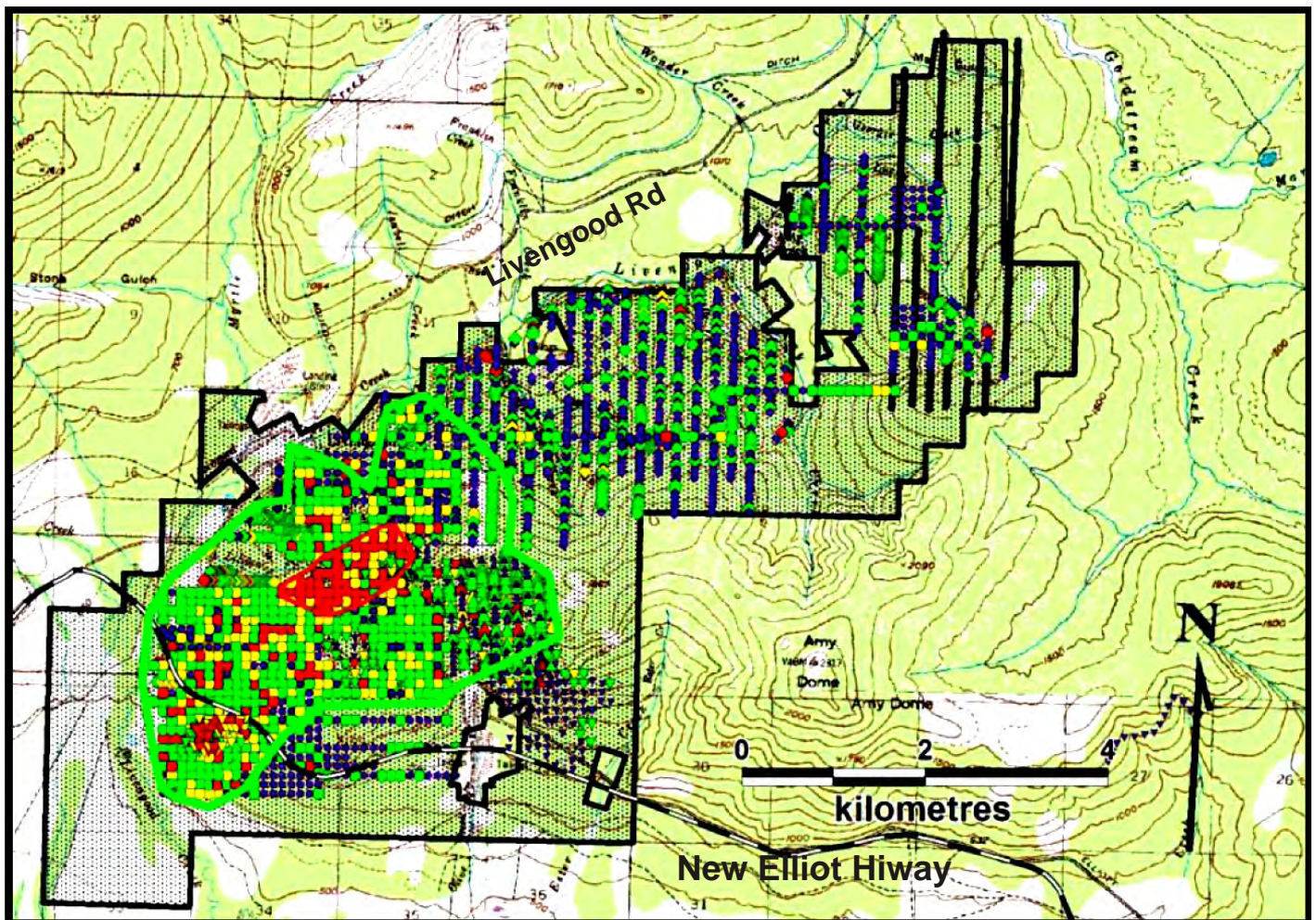


Fig. RL-4: Map showing soil sample results for much of the Livengood area. Symbols are coded by the gold content of soil (in parts per million) at that spot: red = .1-5 ppm, yellow = .04-.1 ppm, green = .01-.04 ppm, blue = < .01 ppm (i.e., below detection). Red line outlines the 'core' area of the deposit.

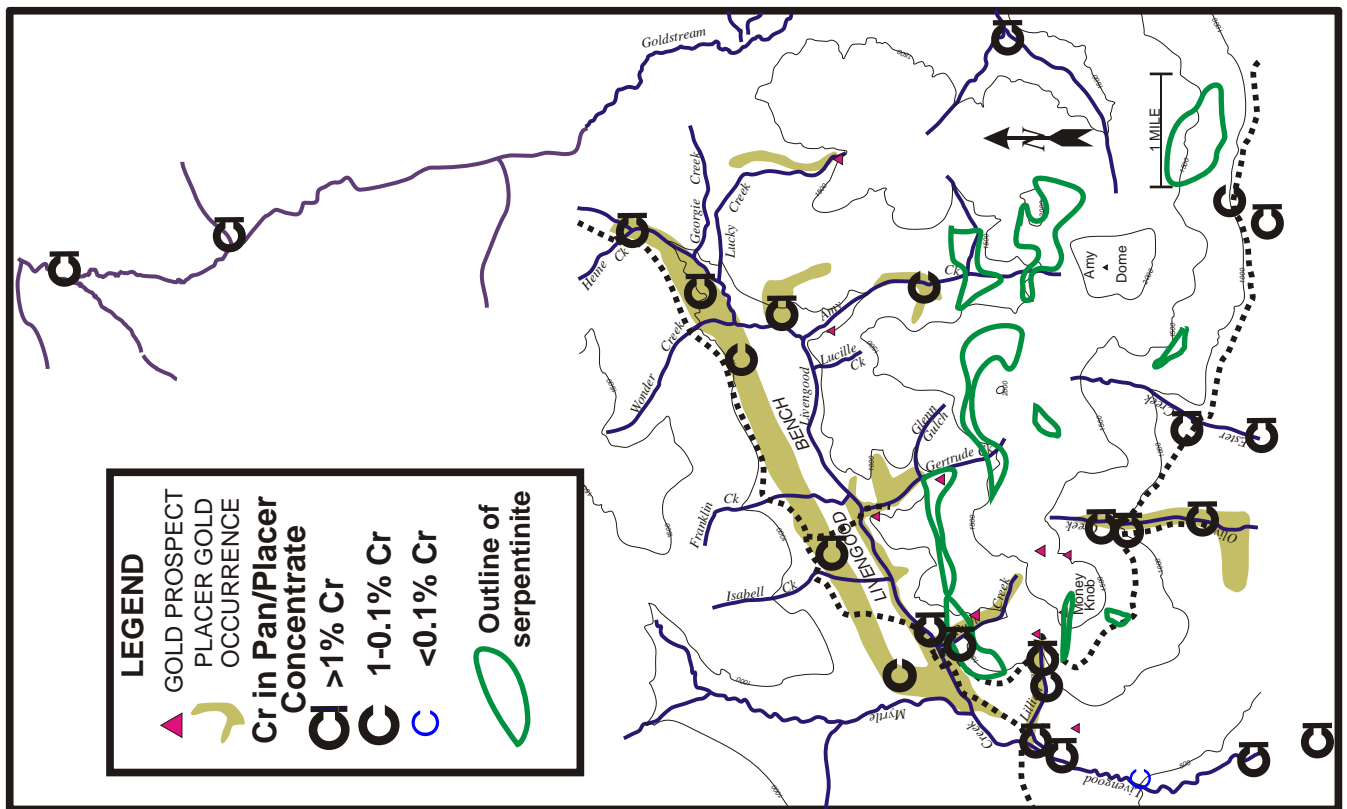


Fig. RL-5: Cr concentrations in pan concentrates and placer concentrates in the Livengood area relative to known serpentinite bodies (the only chromite-bearing rocks in the area). Data from USGS.

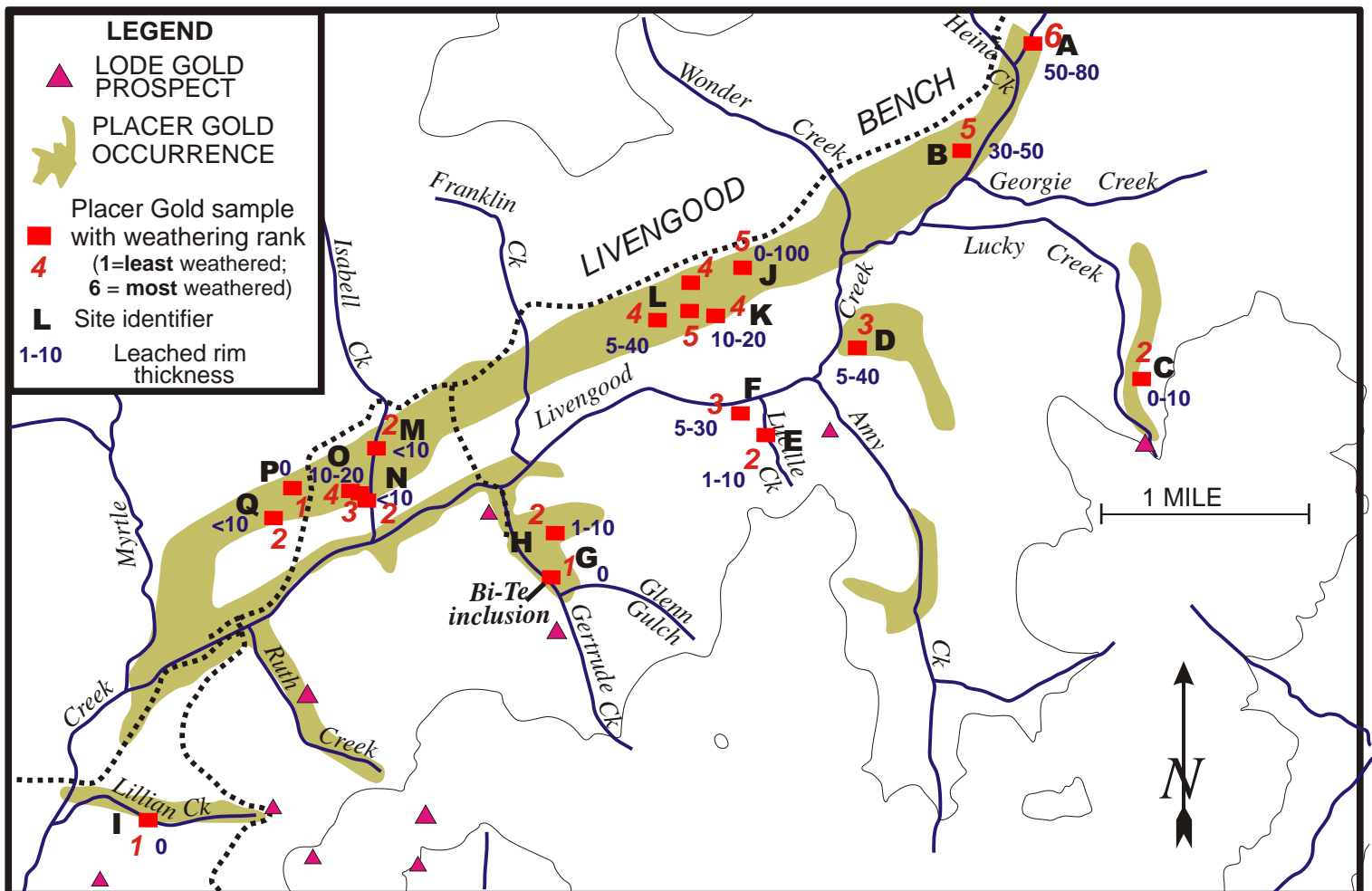
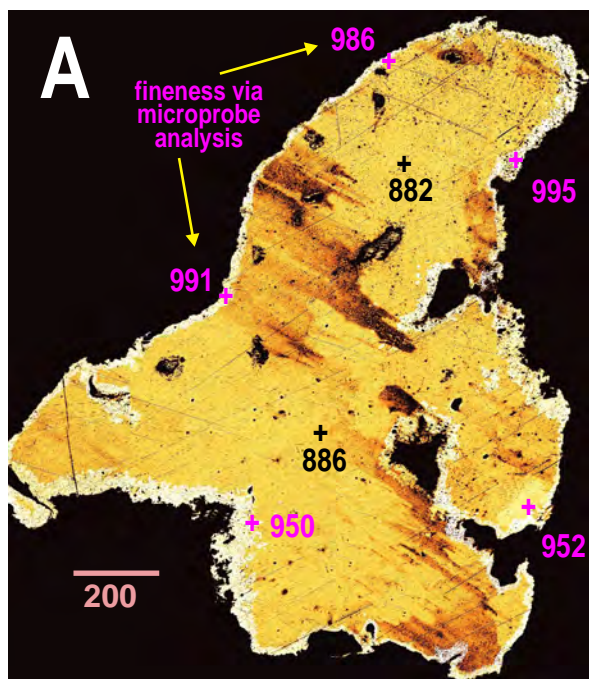
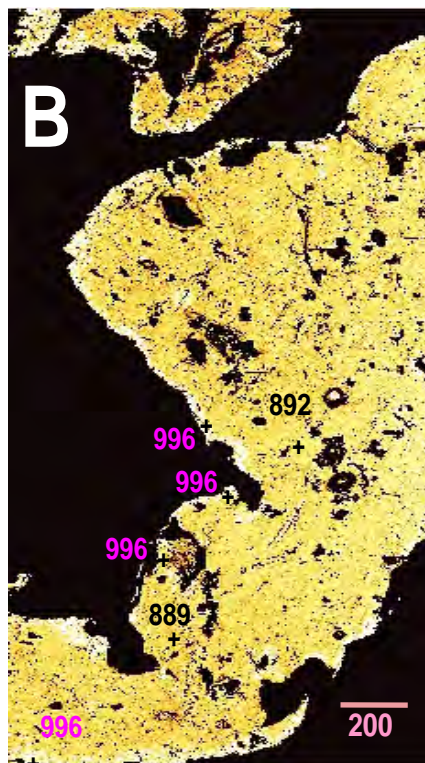


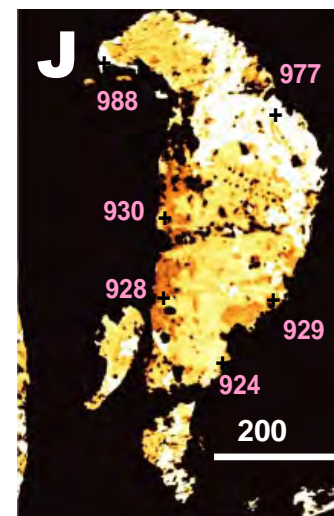
Fig. RL-6: weathering ranks of placer gold grains from specific locations in the Livengood area. Leached rim thickness () on gold grains from microprobe BSE images.



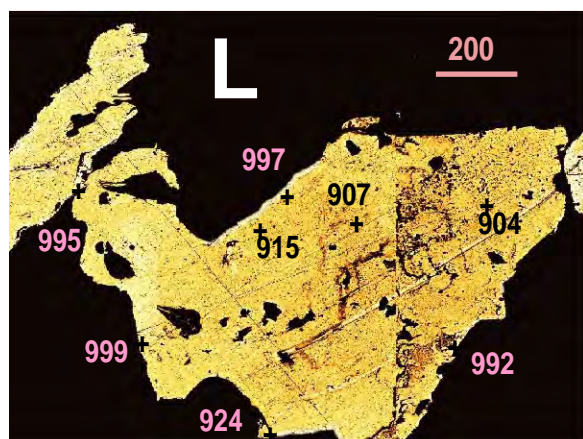
Continuous 50-80 wide Ag-depletion rim



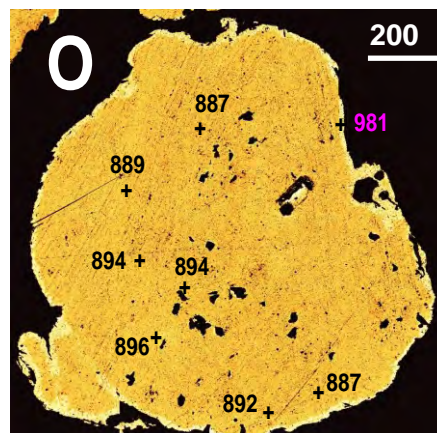
30-50 wide Ag-depletion rim



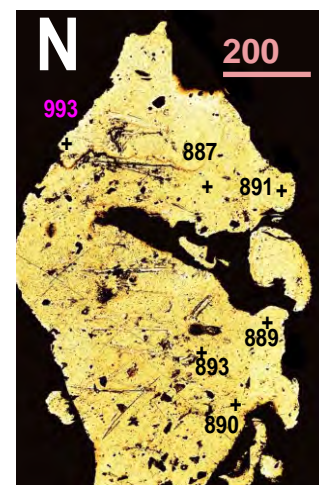
0-100 wide depletion rim



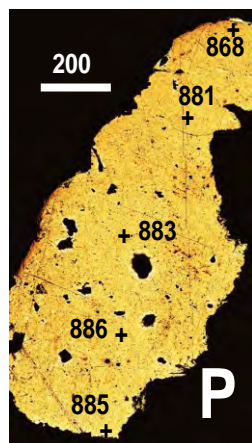
5-40 wide Ag-depletion zone



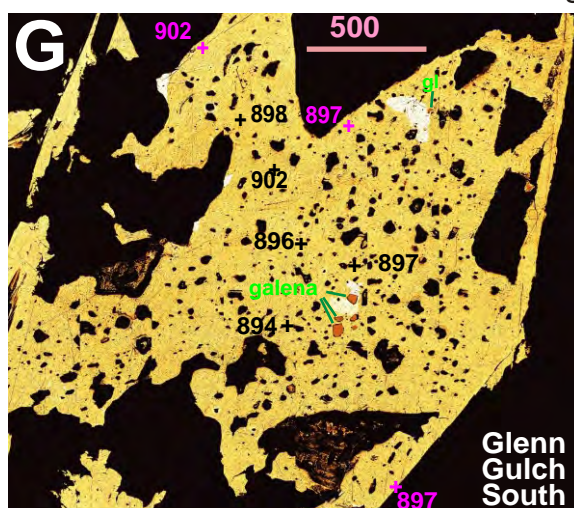
10-20 wide Ag-depletion rim



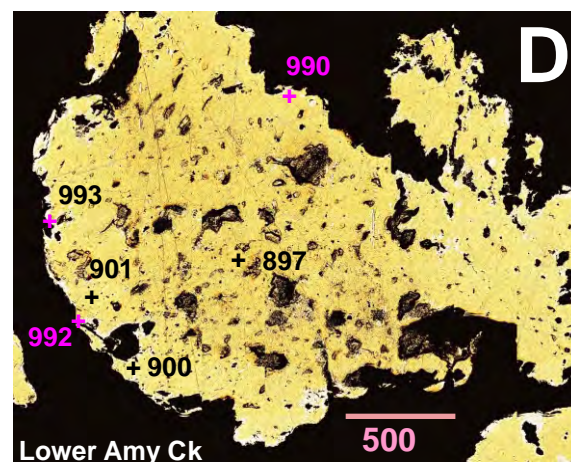
0-10 wide Ag-depletion rim



no rim



pristine grain with original zoning & inclusions



5-40 wide Ag-depletion rim

Figure RL-7: Electron microprobe backscattered electron images of placer gold grains from the Livengood area showing extremely variable degree of leached rim formation. See text for explanations. Letters are keyed to locations on Figure RL-6

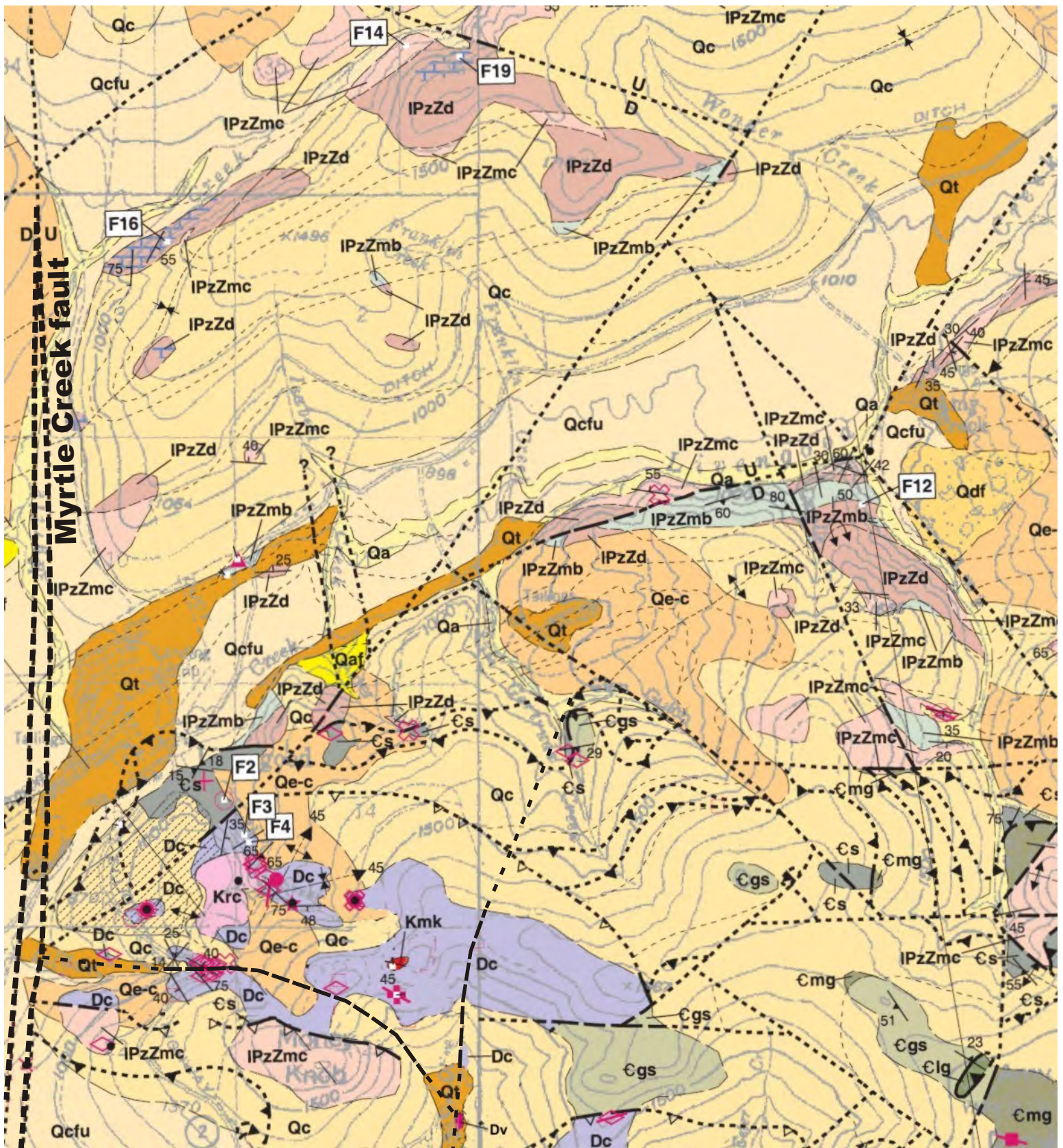


Fig RL8: Geologic map of the Livengood field trip area, modified from Athey et al. (2004)
 Qt = placer mine tailings, Qa = alluvium
 K = Cretaceous igneous rock; funky red symbols = Cretaceous dikes
 Dc = Devonian clastics unit; Dv = Devonian peralkaline volcanic rocks
 € = early Cambrian ophiolite: s = serpentinite, mg = gabbro; gs = greenstone, lg = layered gabbro
 IPZ = Amy unit (age poorly constrained): mc = mudstone & chert; d = dolostone; mb = metabasite

Fig RL-9: Airborne resistivity map (900 Hz) of the Livengood area, modified with generalized units and major faults.

The map displays resistivity data using a color scale from 100 (dark blue) to 250 (dark red). Key features include the Livengood Dome, Money Knob, and the Victoria Crk Flt. Major faults are labeled, including the Minto Flt and the Victoria Crk Flt. The map also shows various creeks and glaciers, such as the Livengood Creek, Money Knob Creek, and the Victoria Crk. A 5 km scale bar is provided for reference.

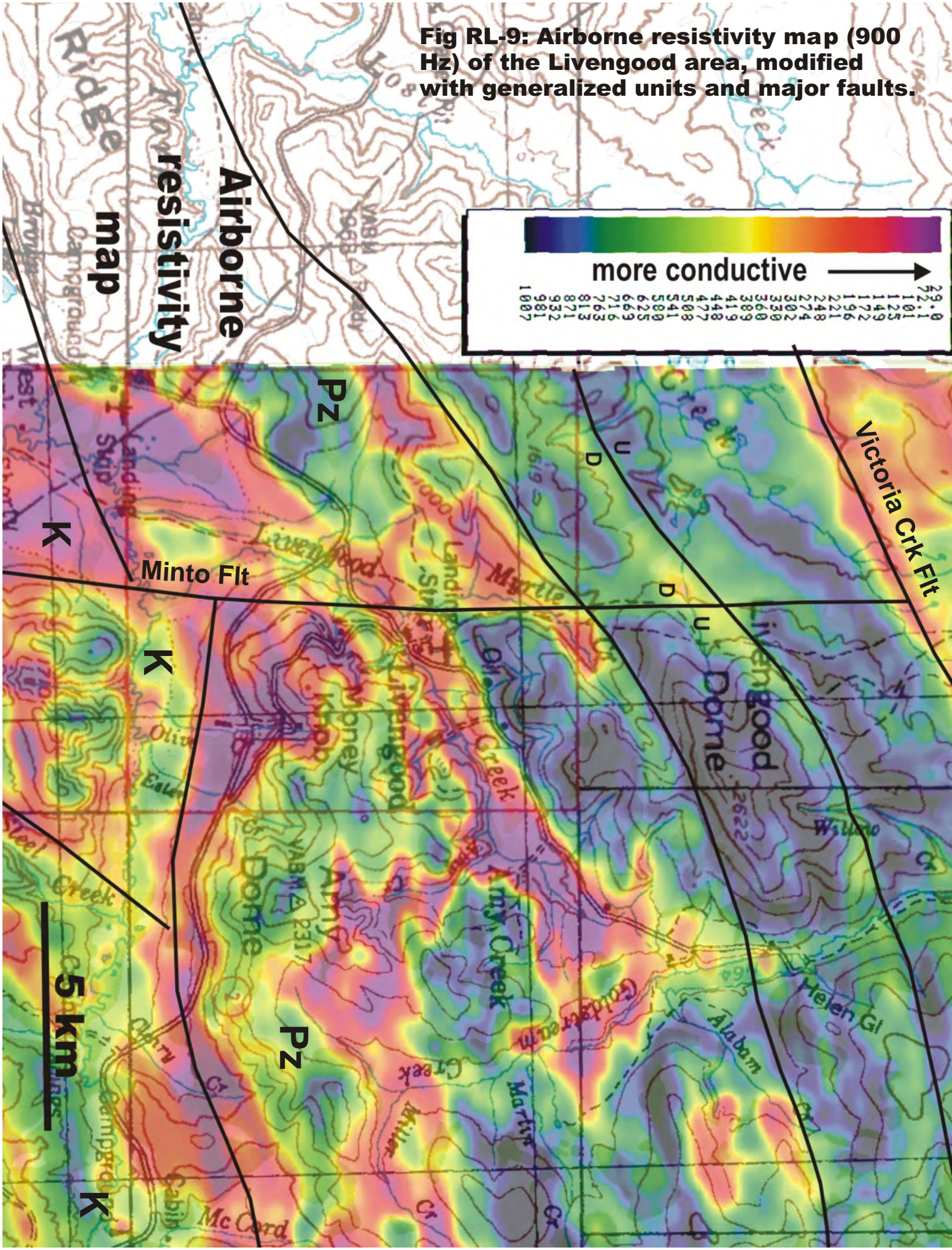


Fig. RL-10: Aeromag map of the Livengood area, showing several geologic units and major faults.

