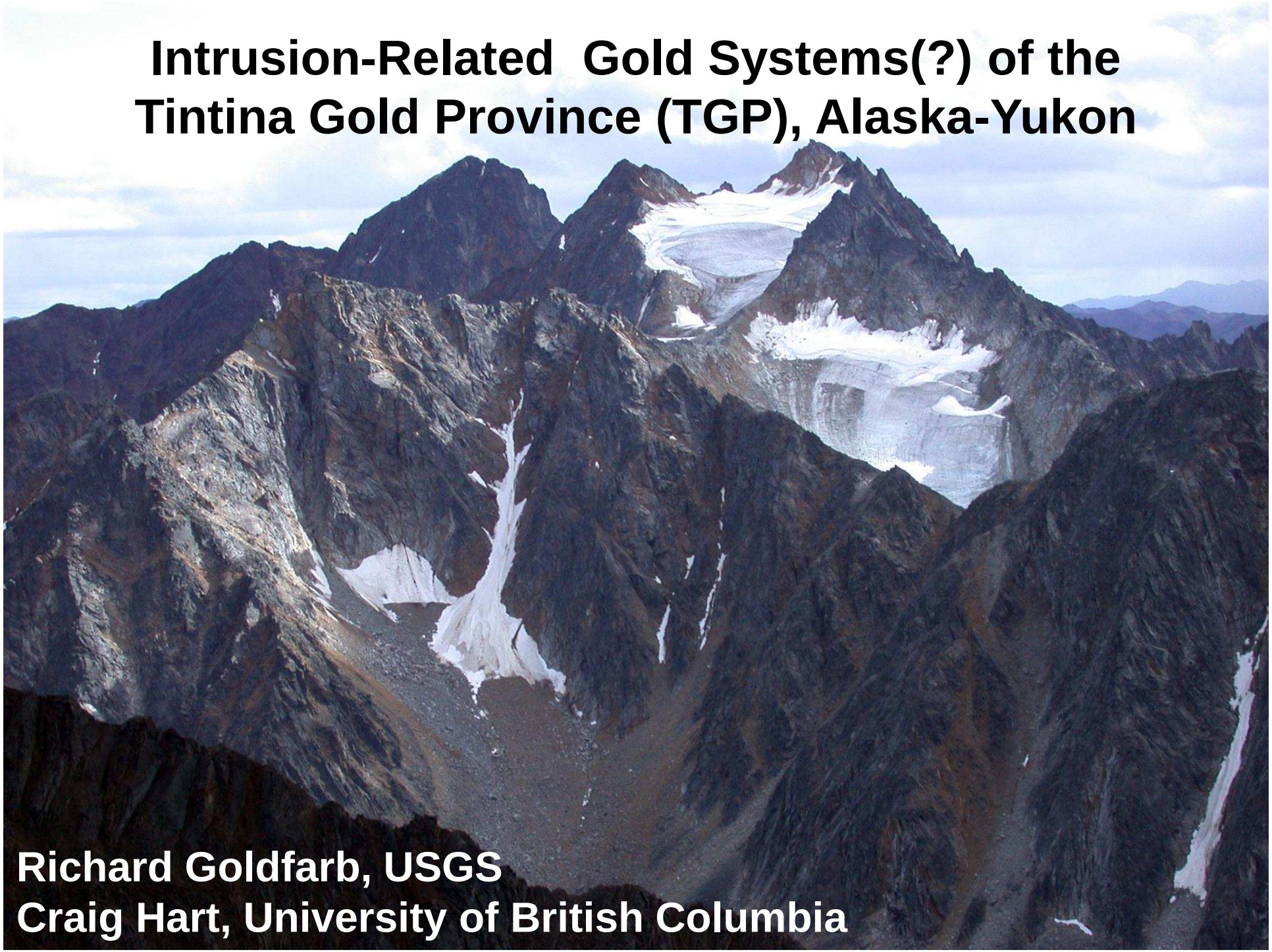
Intrusion-Related Gold Systems(?) of the Tintina Gold Province (TGP), Alaska-Yukon



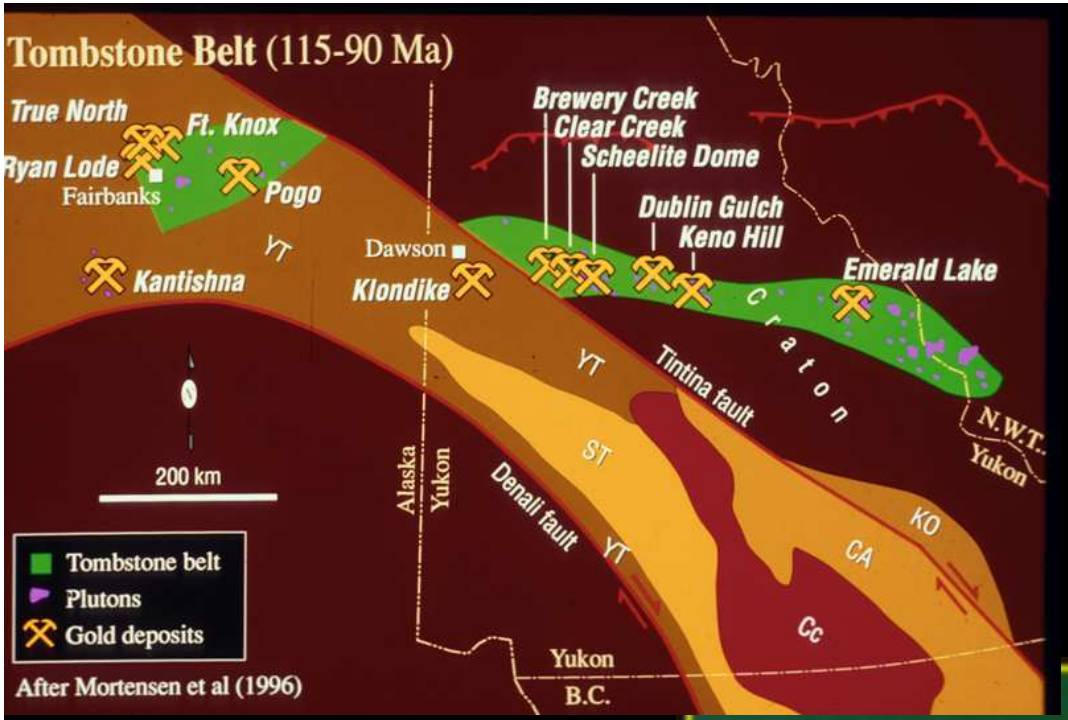
Richard Goldfarb, USGS
Craig Hart, University of British Columbia


Intrusion-Related Gold Systems?

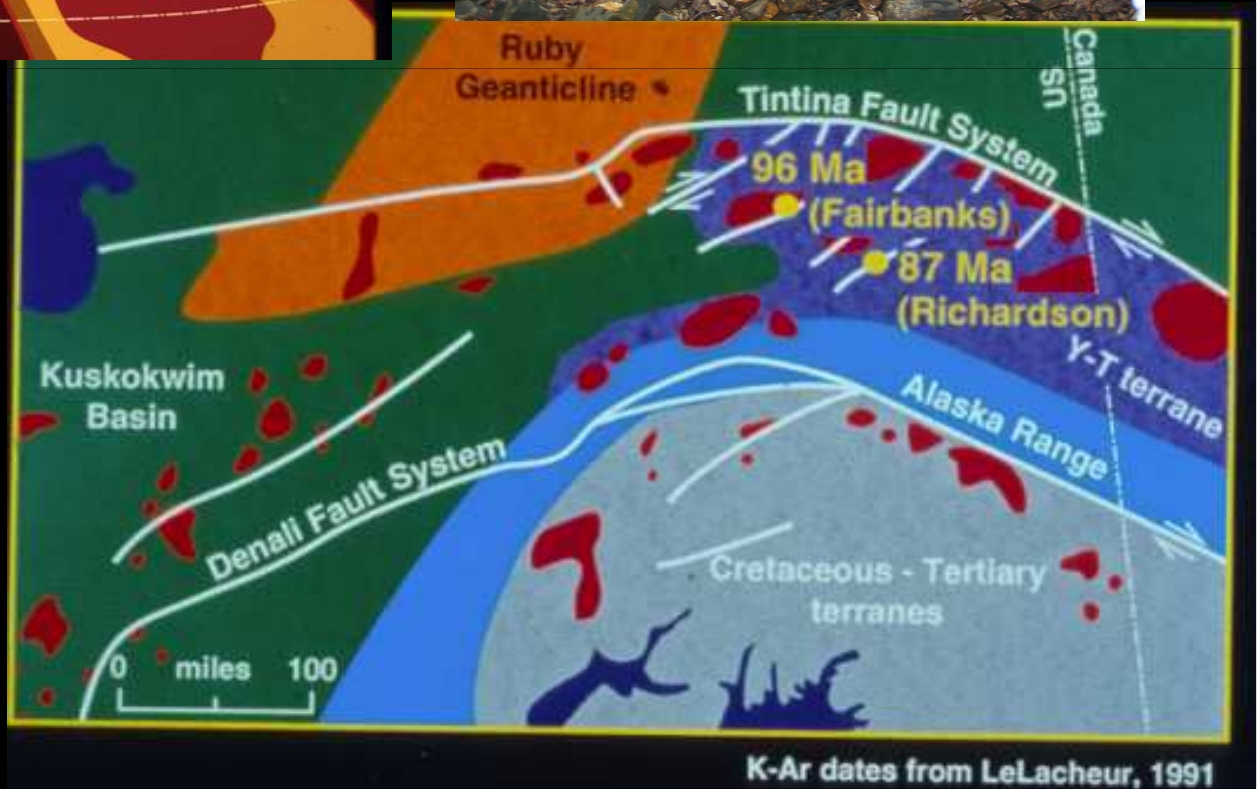
HOWEVER, There is a Very Common Spatial/Temporal Association of Orogenic Gold with Granitoids

SO, Does that Imply Orogenic Gold is "Intrusion-Related"?


Tintina Gold Belt
True North
1.3 Moz
Golden
Summitt
1.2 Moz
Ryan Lode
1.0 Moz
Fort Knox
7.2 Moz
Illinois Creek
KALTAG
TINTINA
Antimony Mtn.
Clear Creek
Scheelite Dome
McQuesten
Marn
Dublin Gulch
>1.2 Moz
Emerald Lake
Mactung
Vinisale
Pogo
>5.2 Moz
Brewery Ck.
>1.3 Moz
Flat
Donlin Creek
25 Moz
Shotgun
Longline
DENALI
FAULT
Mt. Freegold
Mt. Nansen
Ketza River
Cantung
0
500
kilometres
YUKON
GEOLOGY PROGRAM

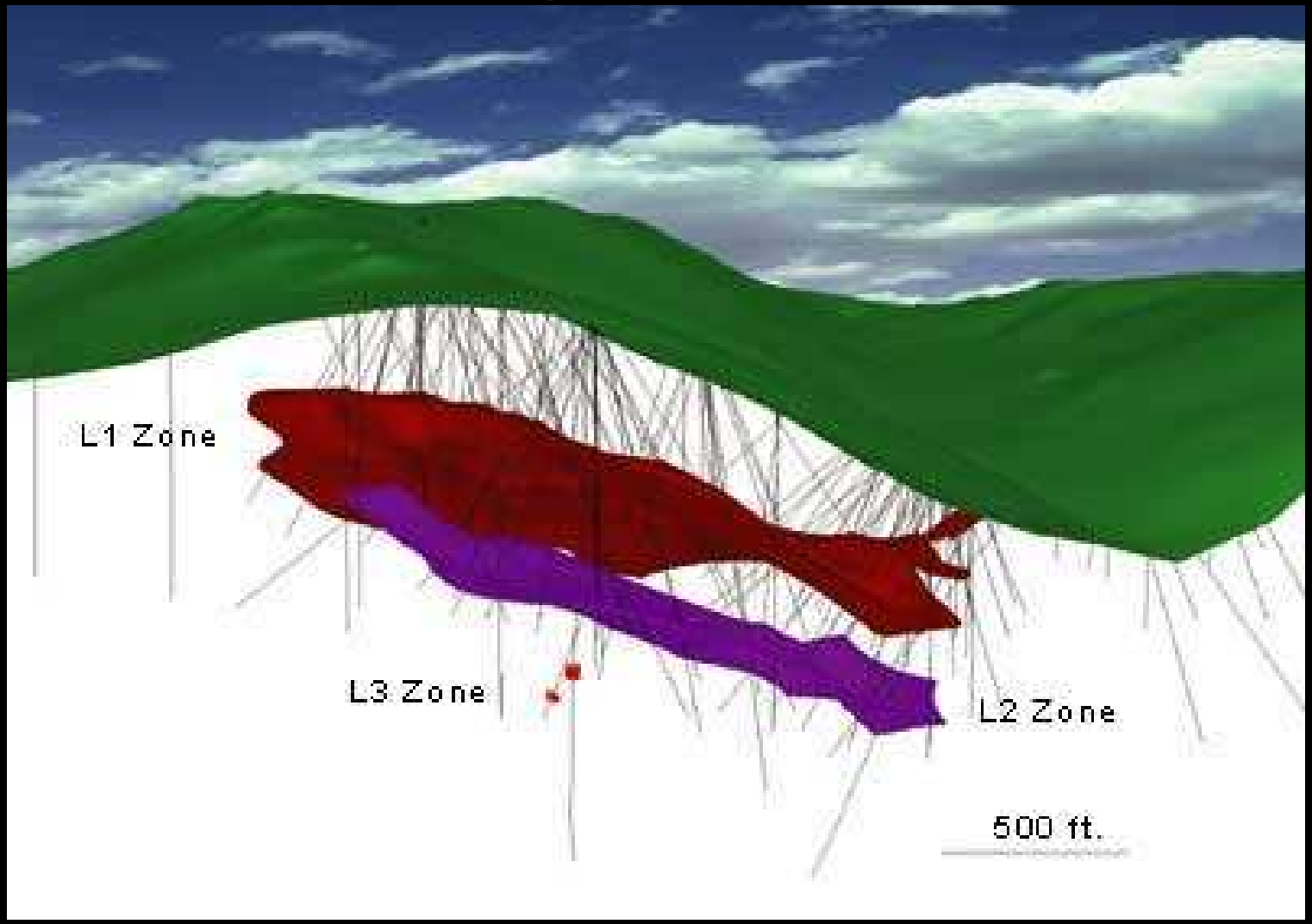


MID-K OROGENIC Au & IRGS, EASTERN ALASKA (Central TGP)



Shear-related Veins

Pogo, Alaska

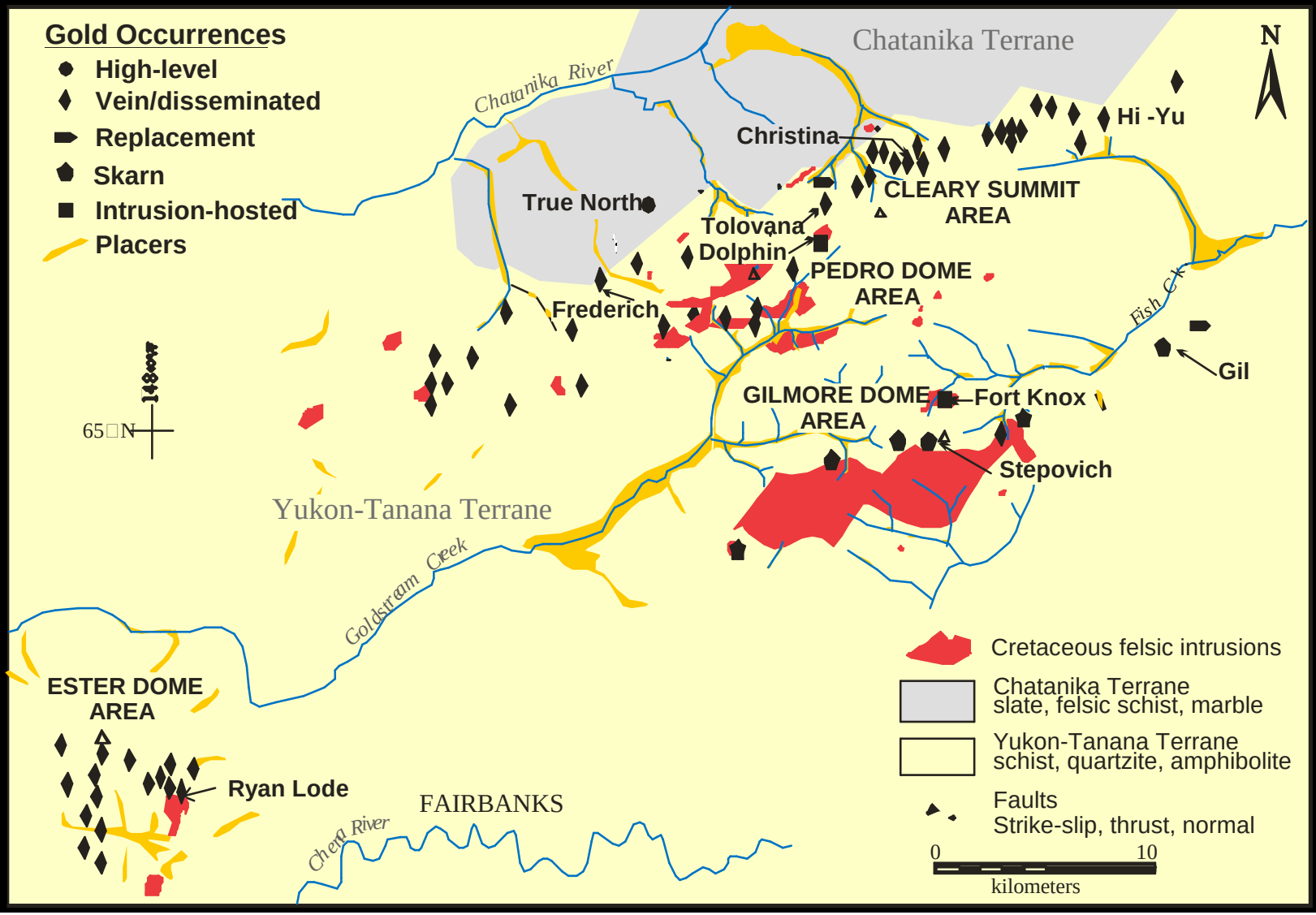


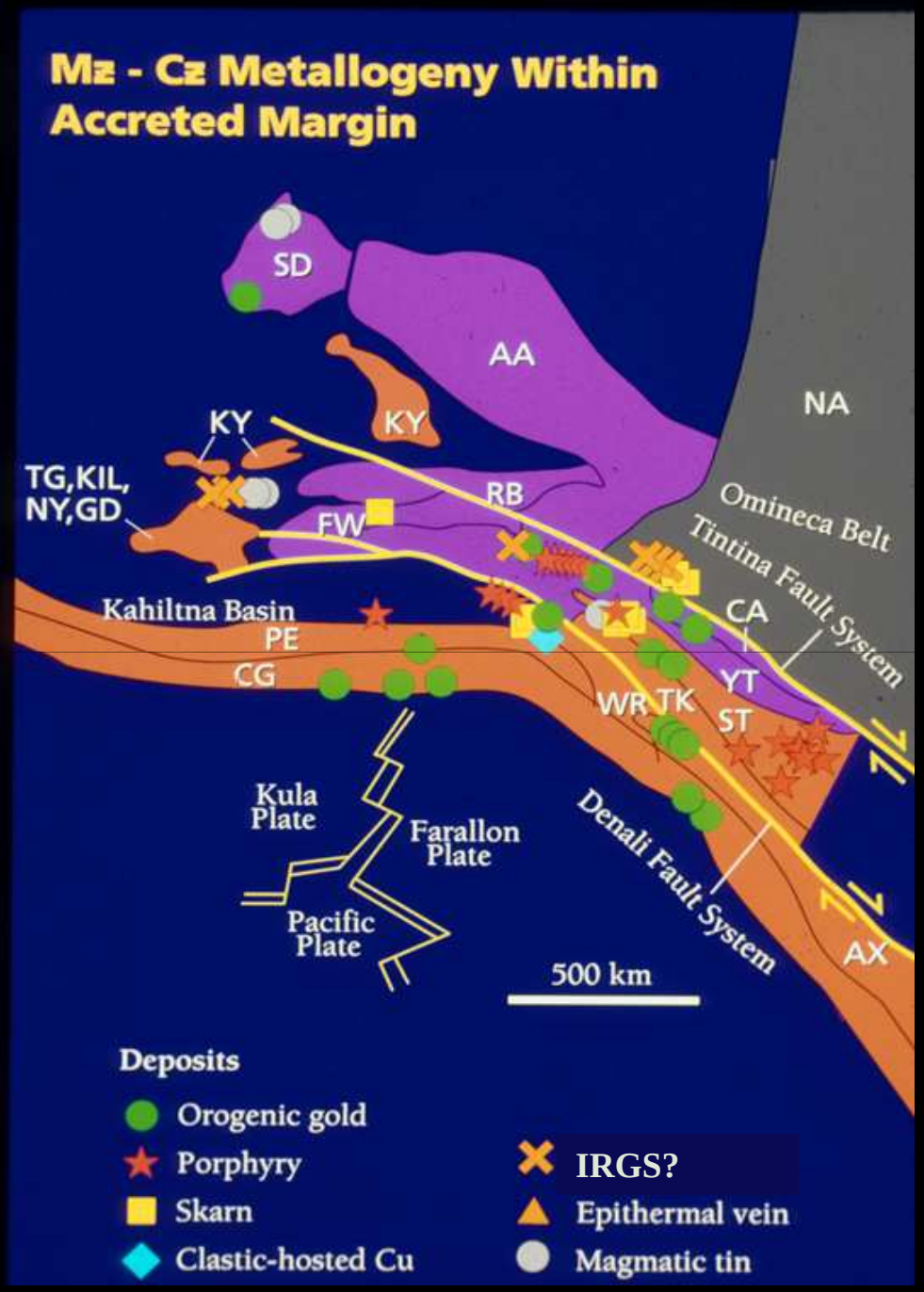
POGO

IRGS?
Proximal TAG?
Orogenic?

- **16.2 g/t; 5.8 Moz=high-grade**
- **Tabular, shear-hosted, shallow veins; 104 Ma**
- **Pz orthogneiss and paragneiss hosts**
- **Regional: Late-Defm Granites=109-107 Ma, Post-Defm Tonalite=107-103 Ma, Batholith=94 Ma**

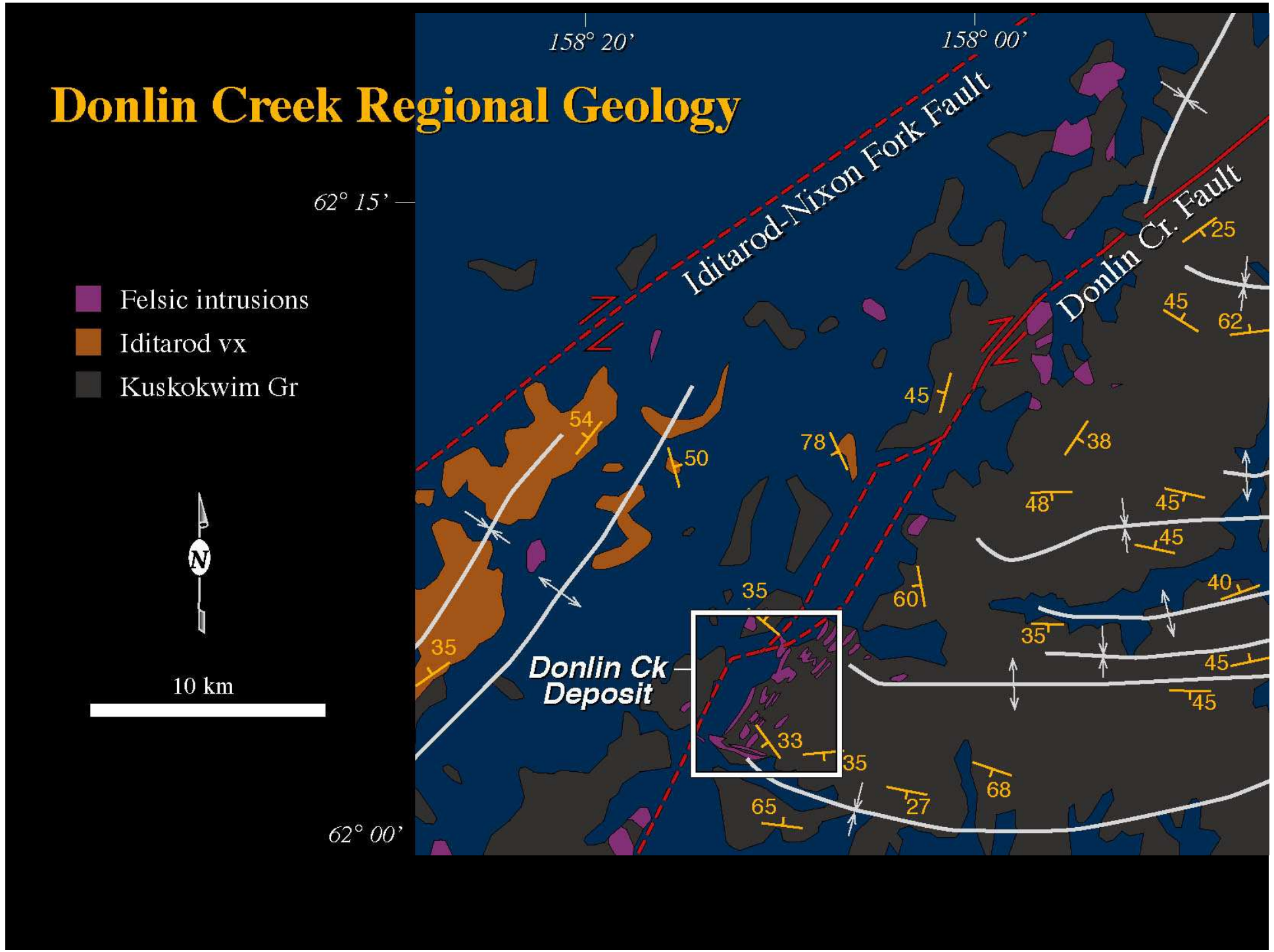
Shear-related Veins, Fairbanks District, E. Alaska



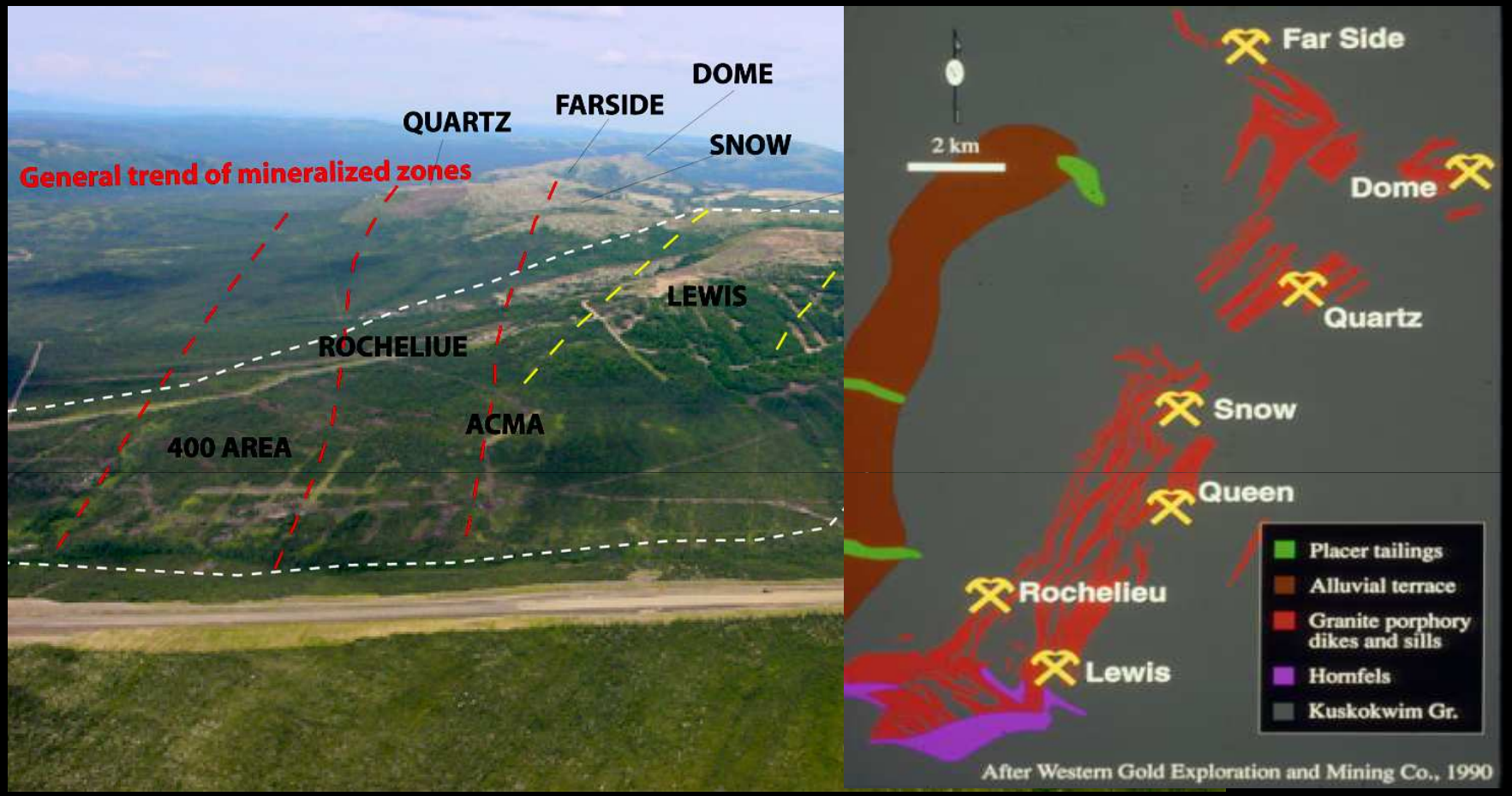

Mz - Cz Metallogeny Within Accreted Margin
SD
AA
KY
KY
NA
TG,KIL, NY,GD
RB
FW
Omineca Belt
Tintina Fault System
Kahiltna Basin
PE
CG
CA
YT
WR
TK
ST
Kula Plate
Farallon Plate
Pacific Plate
Denali Fault System
AX
500 km
Deposits
Orogenic gold
Porphyry
Skarn
Clastic-hosted Cu
IRGS?
Epithermal vein
Magmatic tin

EPIZONAL Hg-Sb, SW ALASKA

Donlin Creek Regional Geology

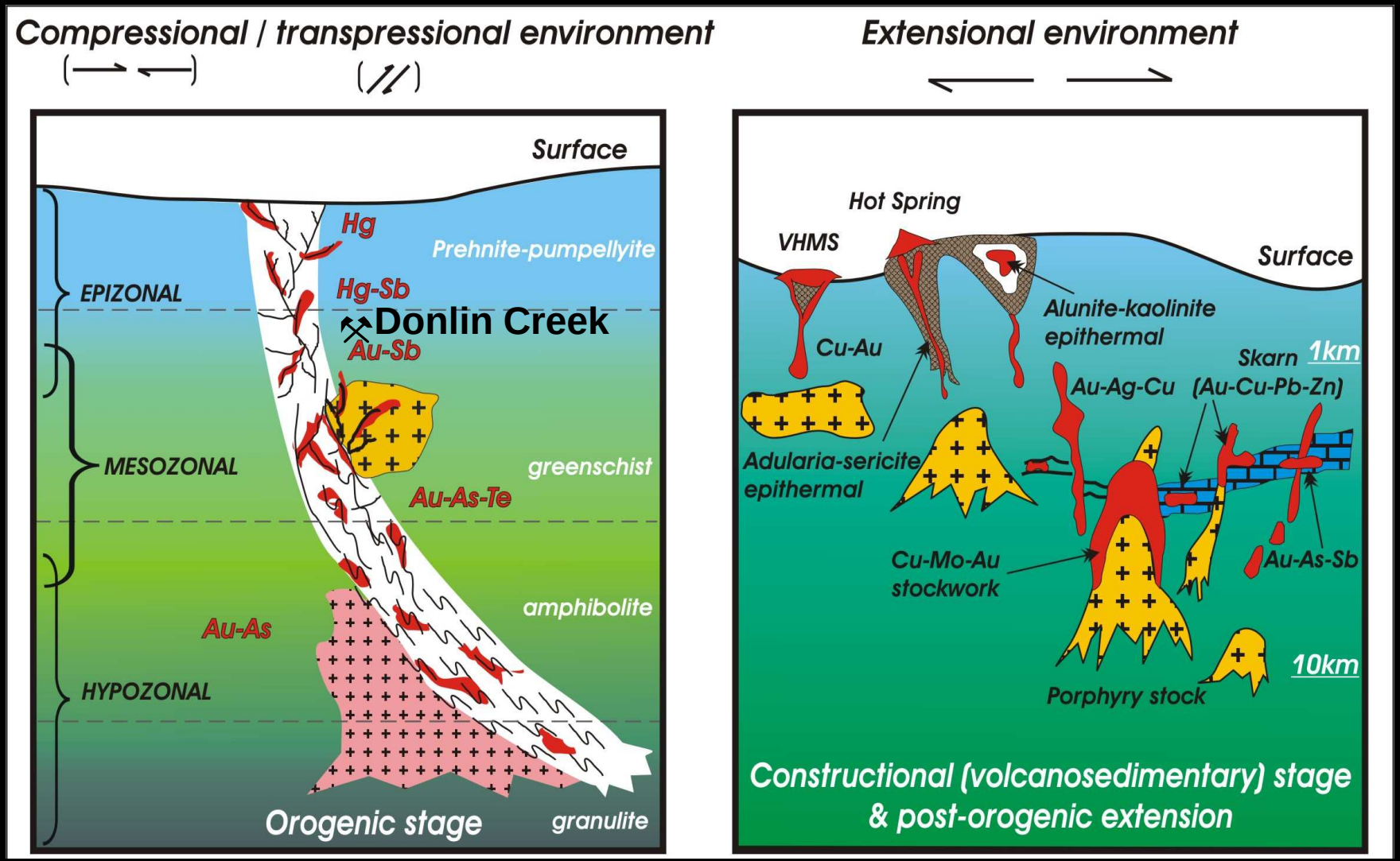


Donlin Creek Deposit



- 38 Moz, ca. 70 Ma epizonal Au deposit
- Qtz-carb veinlets in ca. 74-66 Ma porphyritic, dike complex=competency
- Ore fluids: 3-7% $CO_2 \pm CH_4$, low salinity, 275-300°C, 1-2 km, $\delta^{34}S$: -10 to -20 per mil=non-magmatic

Hydrothermal Environments



Distinguishing Intrusion-Related from Orogenic Gold Systems

- Murutau ?
- Jilau?
- Pogo ?
- Donlin Creek ?
- Victoria ?
- Macraes?
- Reefton?

- Characteristics vs Distinguishing Features
- Exploration Implications

Historical Development of Intrusion-related Gold Models and Classifications

NO SUCH MODEL:

- **Cox and Singer USGS Model Book**
- **GAC Ore Deposit Models volumes**
- **BCGS Mineral Deposit Models**
- **SEG 75th Anniversary Volume**

- **Gold-rich porphyries, gold-only skarns but NO intrusion-related gold models**

- **Does a model exist? Or are their characteristics just too variable?**

Models, Classification, Mess…

- Gold-rich Porphyries
- Gold–only Porphyries
- Intrusion-related Gold Deposits
- Plutonic Gold
- Intrusion-related Gold Veins
- Intrusion-related Gold in Sn-W districts
- Intrusion-related Gold Systems
- Reduced Cu-Au Gold Porphyry Deposits
- Thermal Aureole Gold
- Reduced Intrusion-related Gold Systems
- Alkalic Gold-rich Porphyries
- Alkalic Gold Intrusive Complexes

HELP!

Intrusion-Related Gold Deposits

- First suggested by Sillitoe (1991)
- 6 sub-classes, first indication of system
  - porphyry, intrusion-hosted, skarn, carb-replacement, non-carb replacement, breccia, vein
- Of 25 examples, most are associated with Cu, most are I-type, metaluminous, oxidized…..most are arcy
- Included Muruntau as a non-carb replacement (±stockworks, disseminated)

Reduced Intrusion-related Gold Systems

- Thompson, Sillitoe et al. (1999) IRG with W-Sn in MD; Thompson and Newb ld in 2000" volume; Lang et Newsletter
- Recognized gold-mineraliz th more reduced, more felsic typey), more lithophile-ric
- No associated copper
- Emphasized low-oxidation associated plutons and flu from IRGDeposits of Sillit

SEG NEWSLETTER

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AN EXPLORATION MODEL FOR
Intrusion-Related Gold Systems

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Gold mineralization generated by magmatic-hydrothermal systems has traditionally been associated either with porphyry base and precious metal deposits within and peripheral to calc-alkalic intrusions, or with intrusions of alkalic composition. These systems form in convergent margins and are characterized by highly oxidized, I-type or magnetite-series plutons of predominantly intermediate composition; pervasive alteration associated with mineralization is extensive. More recently a new, globally widespread class of intrusion-related deposits in which gold is the principal commodity has been proposed (Fig. 1; Sillitoe, 1991; Hollister, 1992; Newberry et al., 1995; Lang et al., 1997; McCoy et al., 1997; Thompson et al., 1999). Collectively this class manifests an association of gold mineralization with: (1) metaluminous, subalkalic intrusions of intermediate to felsic composition that span the boundary between ilmenite- and magnetite-series, (2) carbonic hydrothermal fluids, (3) a metal assemblage which variably combines gold with Bi, W, As, Mo, Te and/or Sb, and typically has a low base metal concentration, (4) comparatively restricted zones of

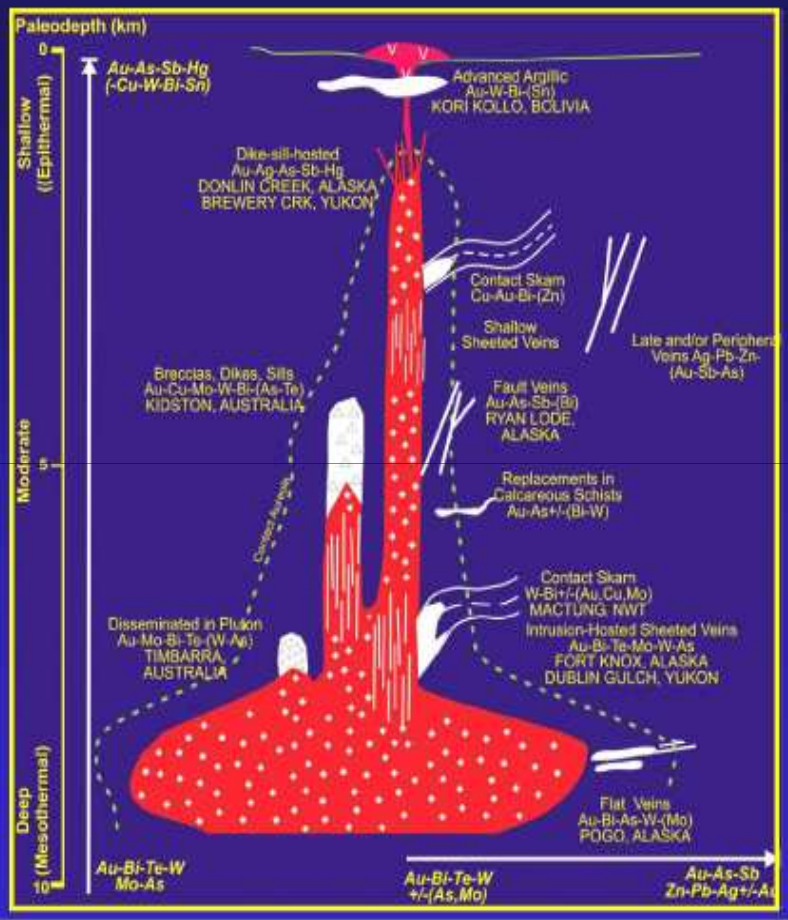
to page 6

Figure 1. Location of significant examples of intrusion-related Au systems discussed in the text. Modified from Thompson et al. (1999).

LOCATION OF MAJOR INTRUSION RELATED GOLD DEPOSITS

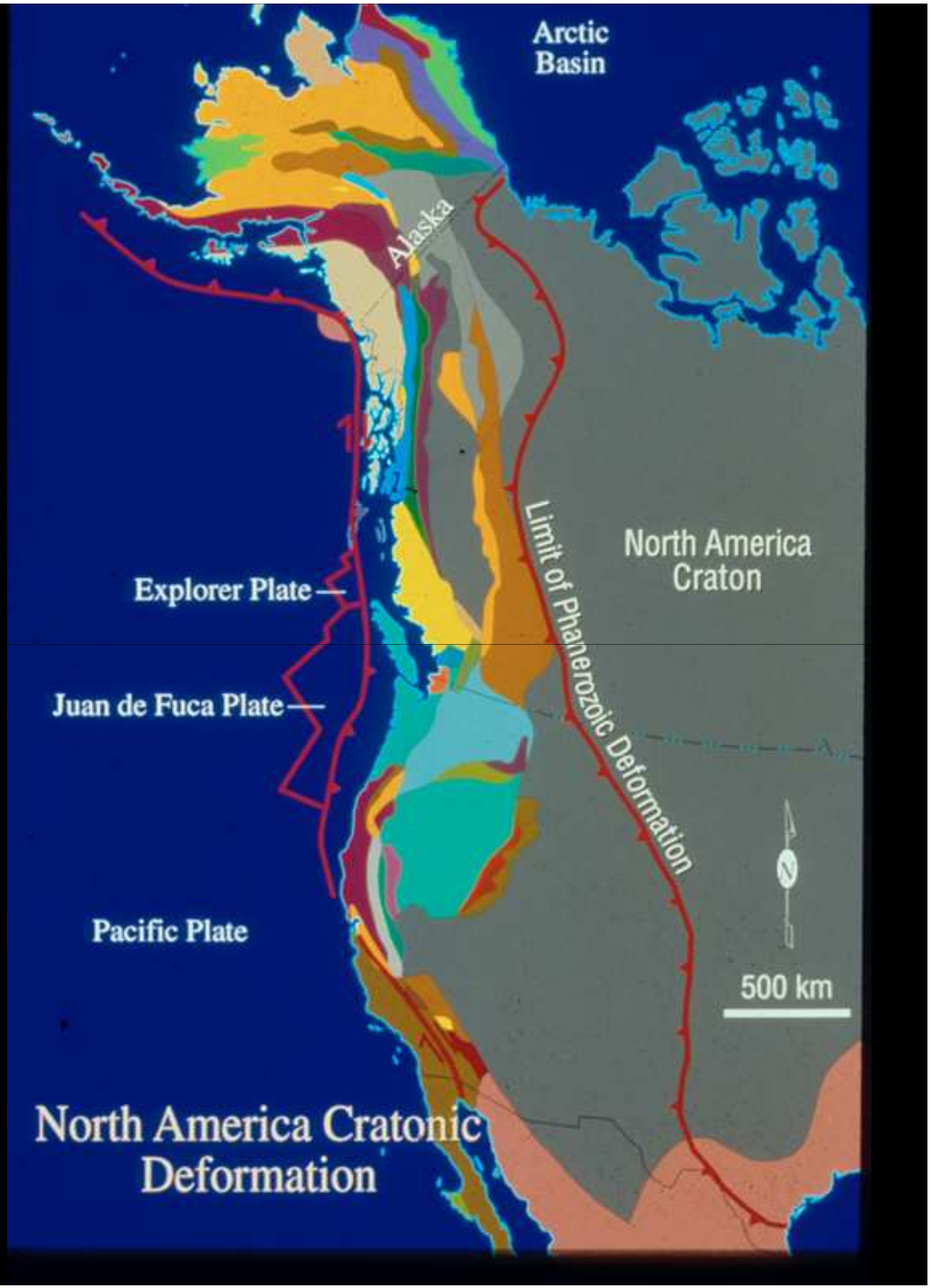
(Lang & Baker, 2001)

IRGS MODEL



(Lang et al., 2000)

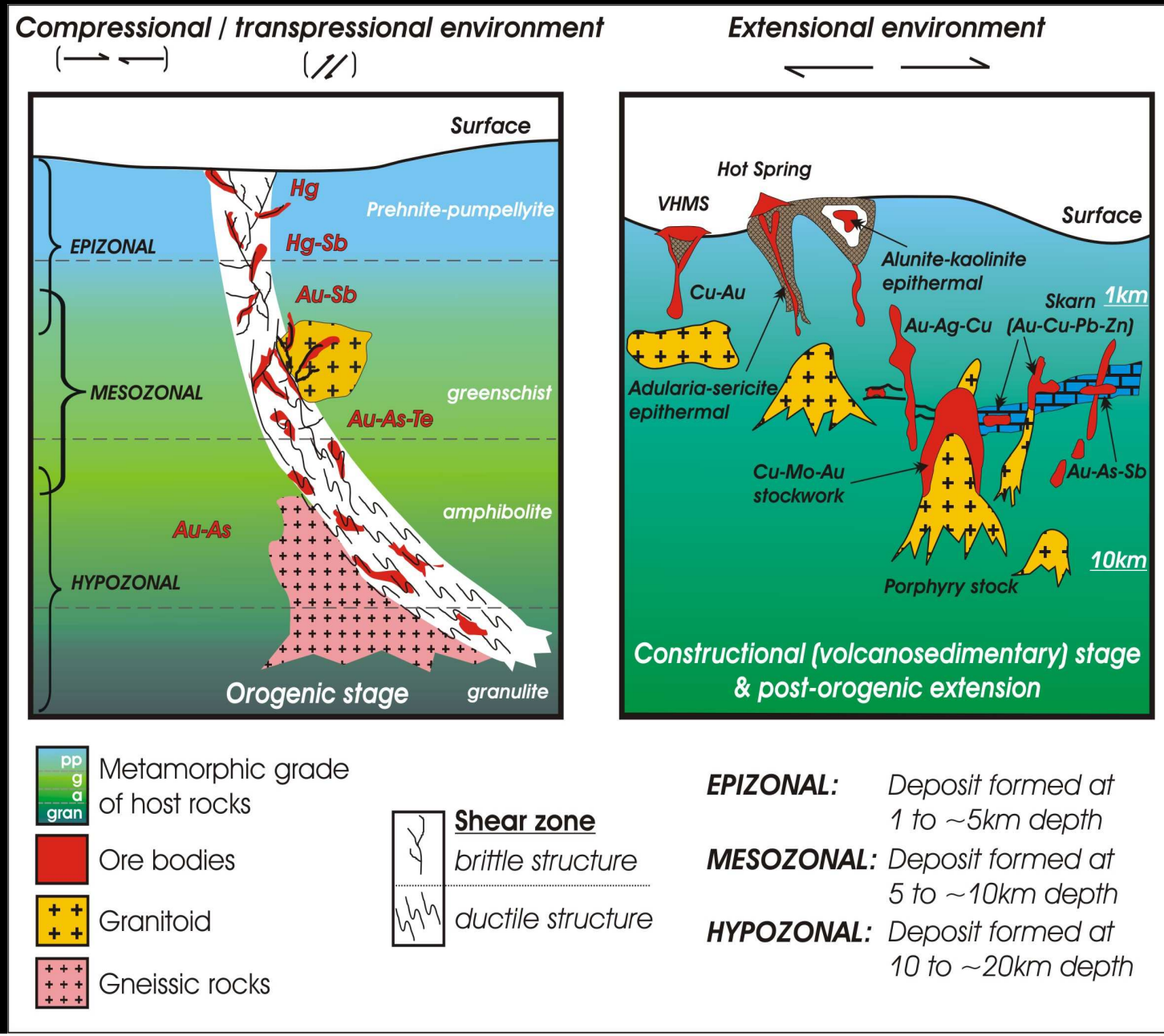
Tectonic Setting of Western North America

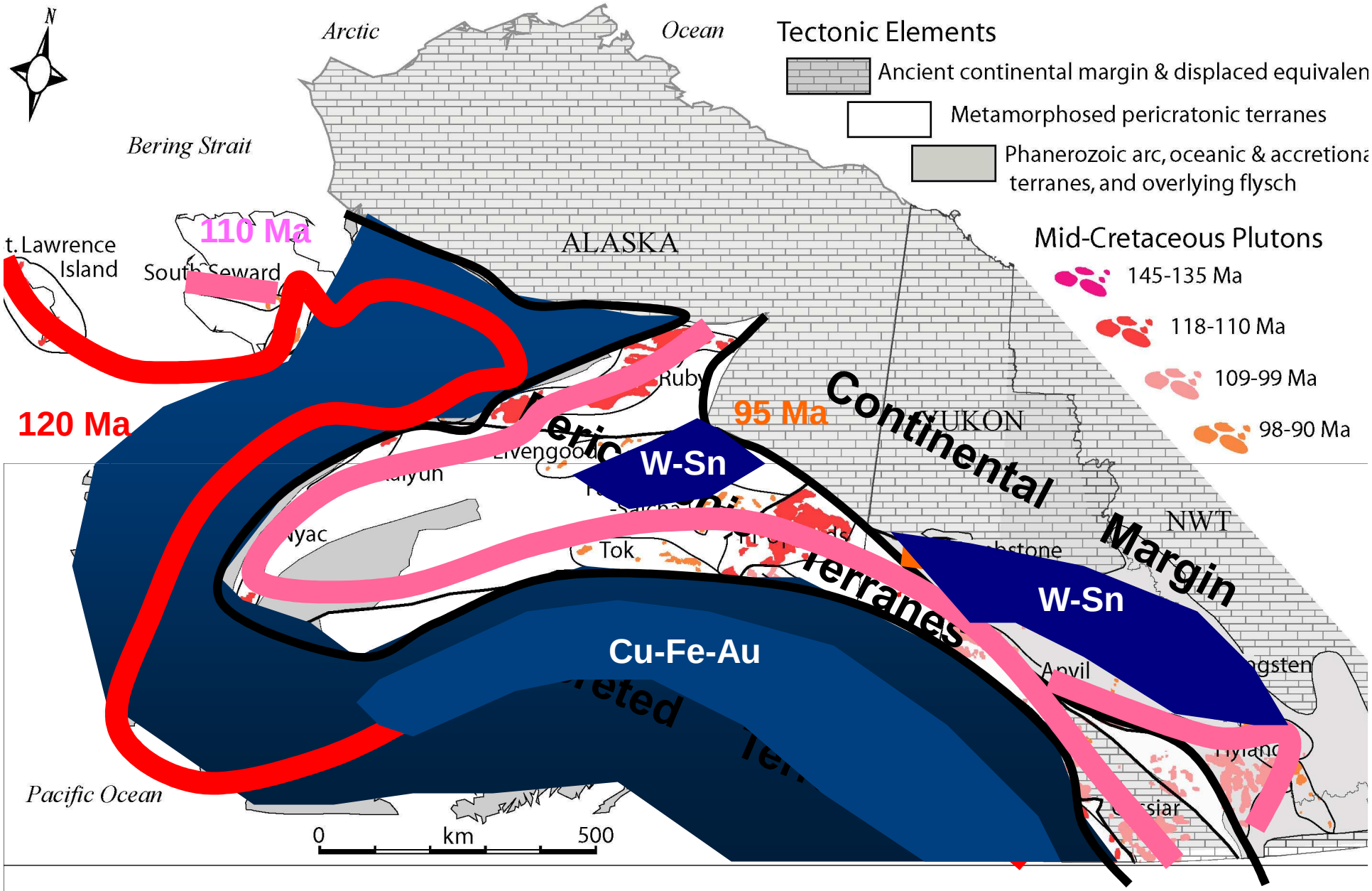


Tectonic Setting

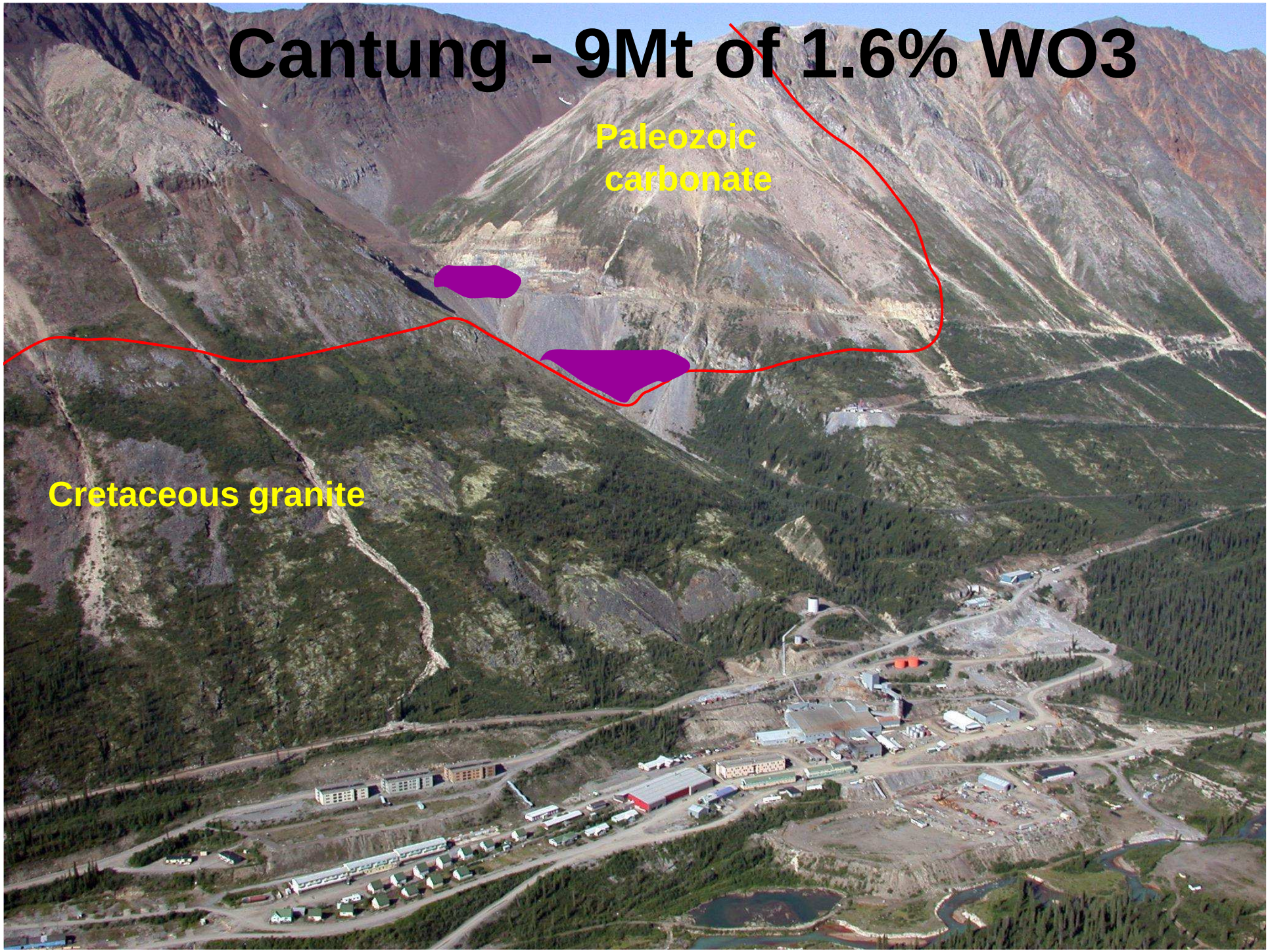
Reduced IRGS position far inboard from the arc, continental margin plutonic belts are best

Fluid Flow Environments & Au

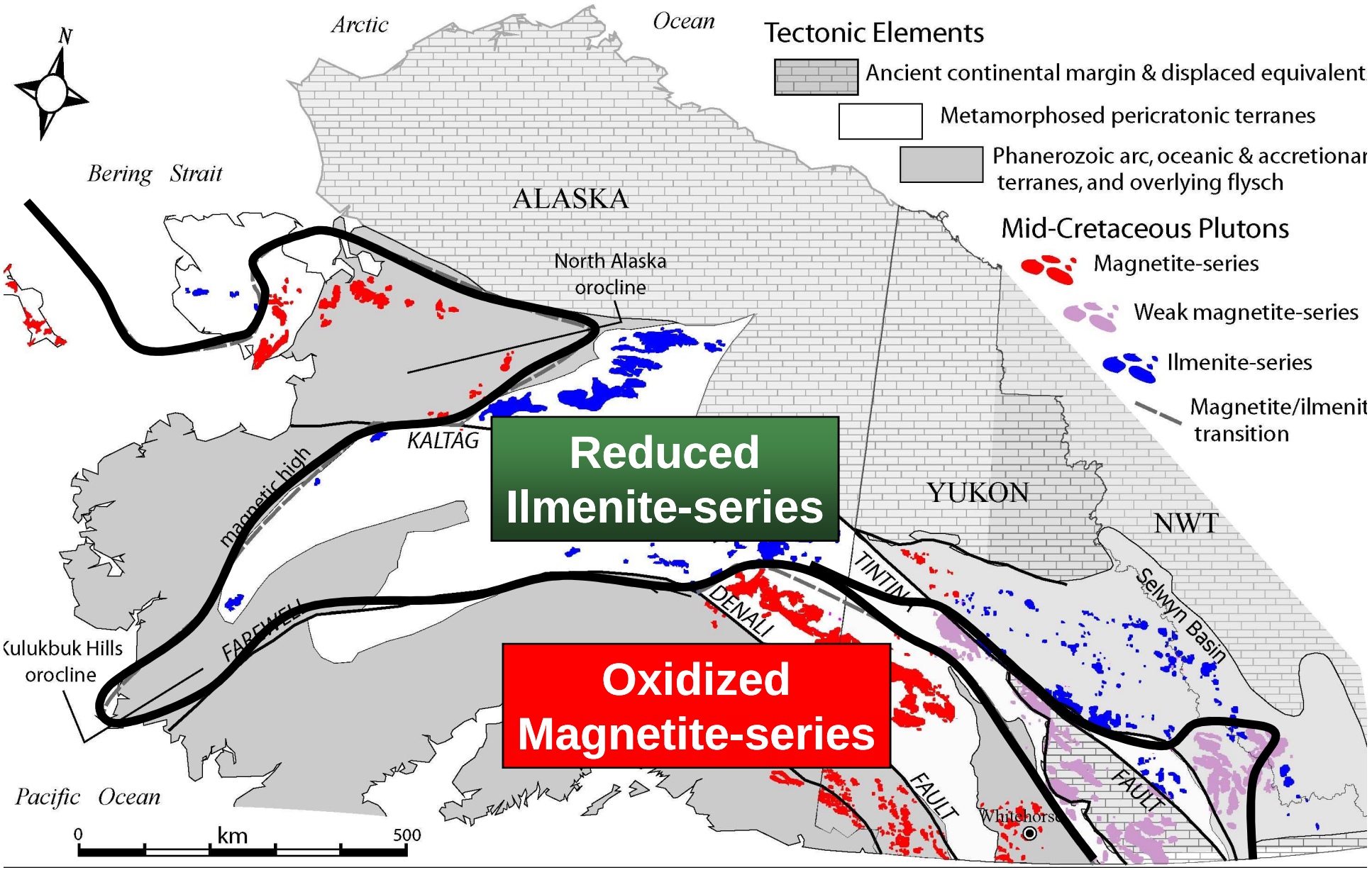


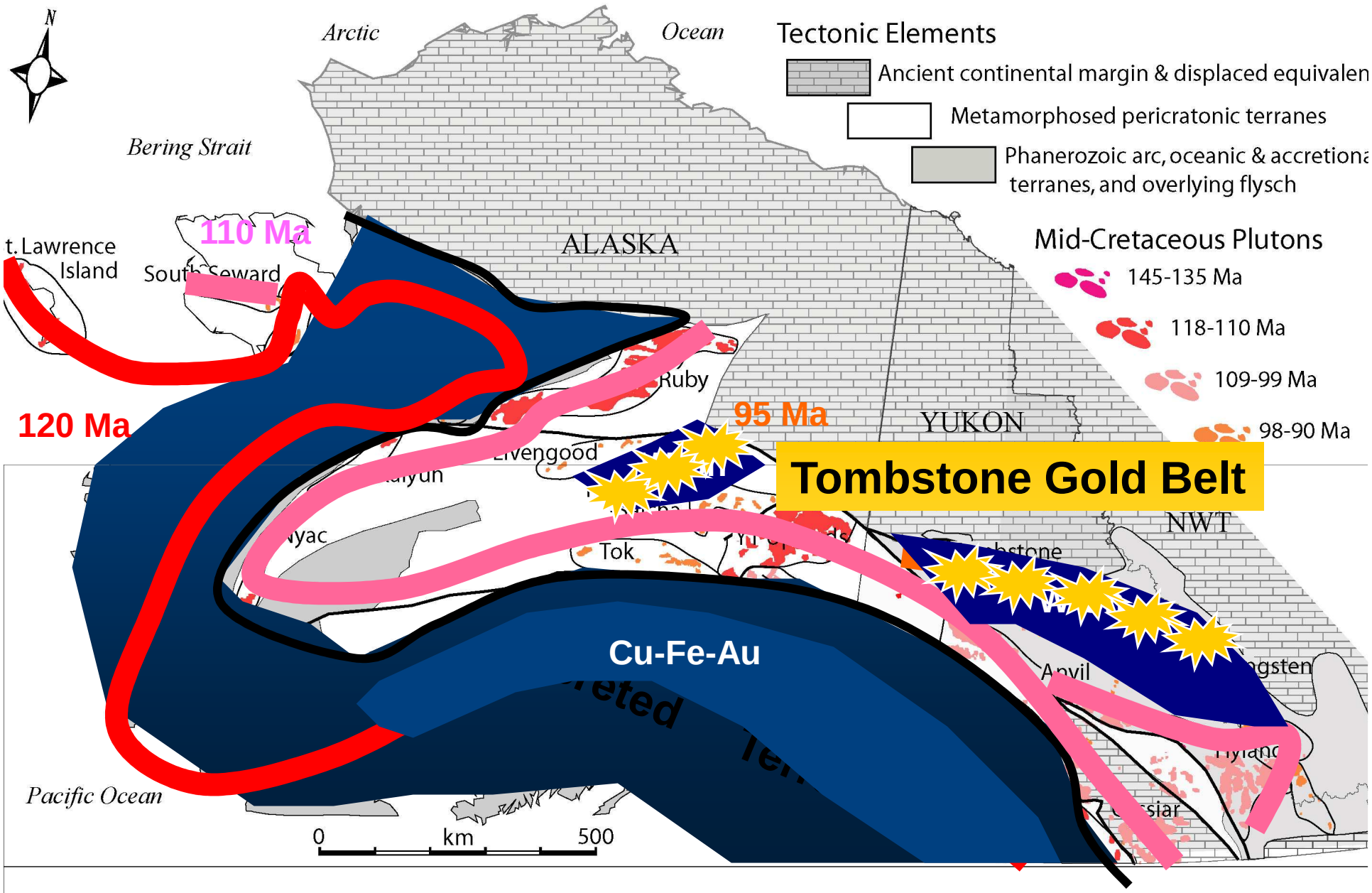


Alaska-Yukon Mid-Cretaceous Plutonic Suites


Cantung - 9Mt of 1.6% WO3
Paleozoic carbonate
Cretaceous granite

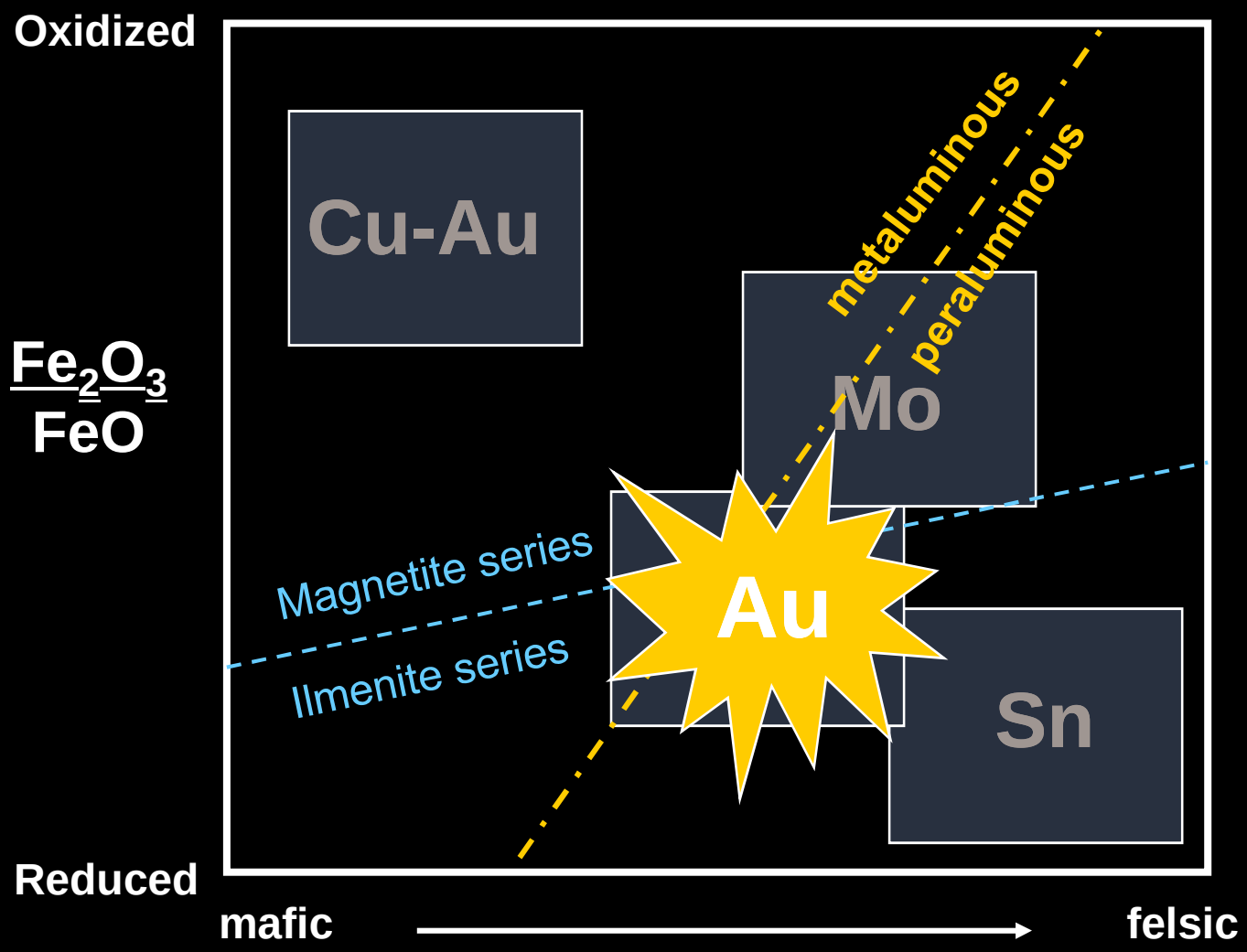
Alaska/Yukon Redox State





IRGS along Ancient Continental Margin

Granite Series & Metallogeny



Reduced Redox State

Ilmenite-series, low ferric:ferrous, low mag susc and weak airborne response

How Reduced?

- Intrusions are ilmenite NOT magnetite series
- Low Fe_20_3/FeO ratios (0.1-0.3)
- Granites have low magnetic susc (0-0.5 x .001 SI)
- Flat aeromagnetic signatures
- Fluids locally have CH_4
- Pyrrhotite-lollengite-arsenopyrite-pyrite
- fO_2 -14 to -17, NNO-QFM

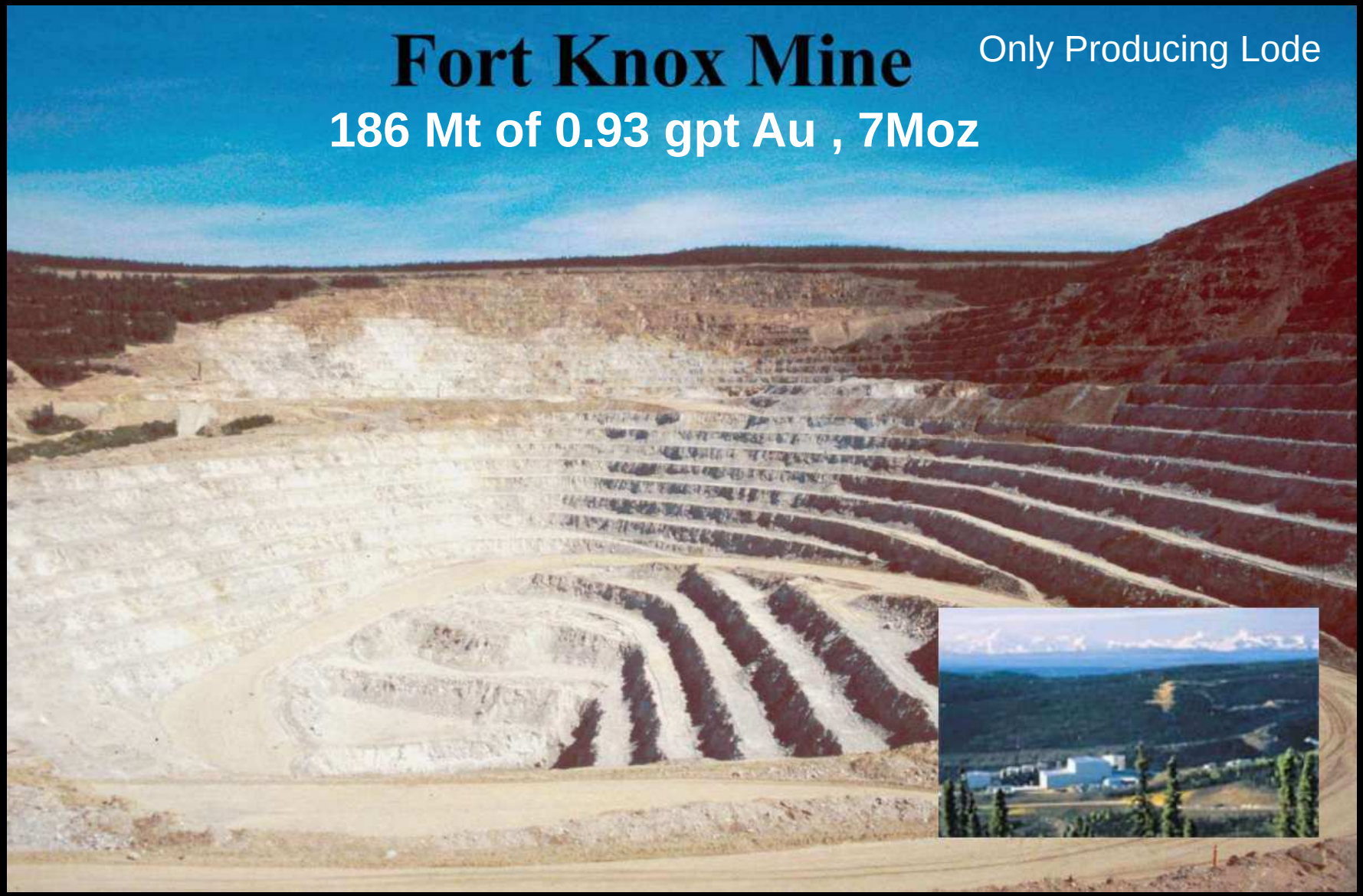
Reduced IRGS Characteristics

- **Associated Plutons: Metaluminous to peraluminous, sub-alkalic to alkalic, intermediate to felsic compositions**
- **Metals: Bi, Te, W, As and/or Sb, with low base metals**
- **Sulphides: Low total sulphide content, reduced assemblage po-py-aspy**
- **Fluids: Carbonic, low salinity fluids**
- **Associated with W, or less commonly, Sn**
- **SIMILAR TO OROGENIC GOLD!!!!!**

Fort Knox Mine

Only Producing Lode

186 Mt of 0.93 gpt Au , 7Moz

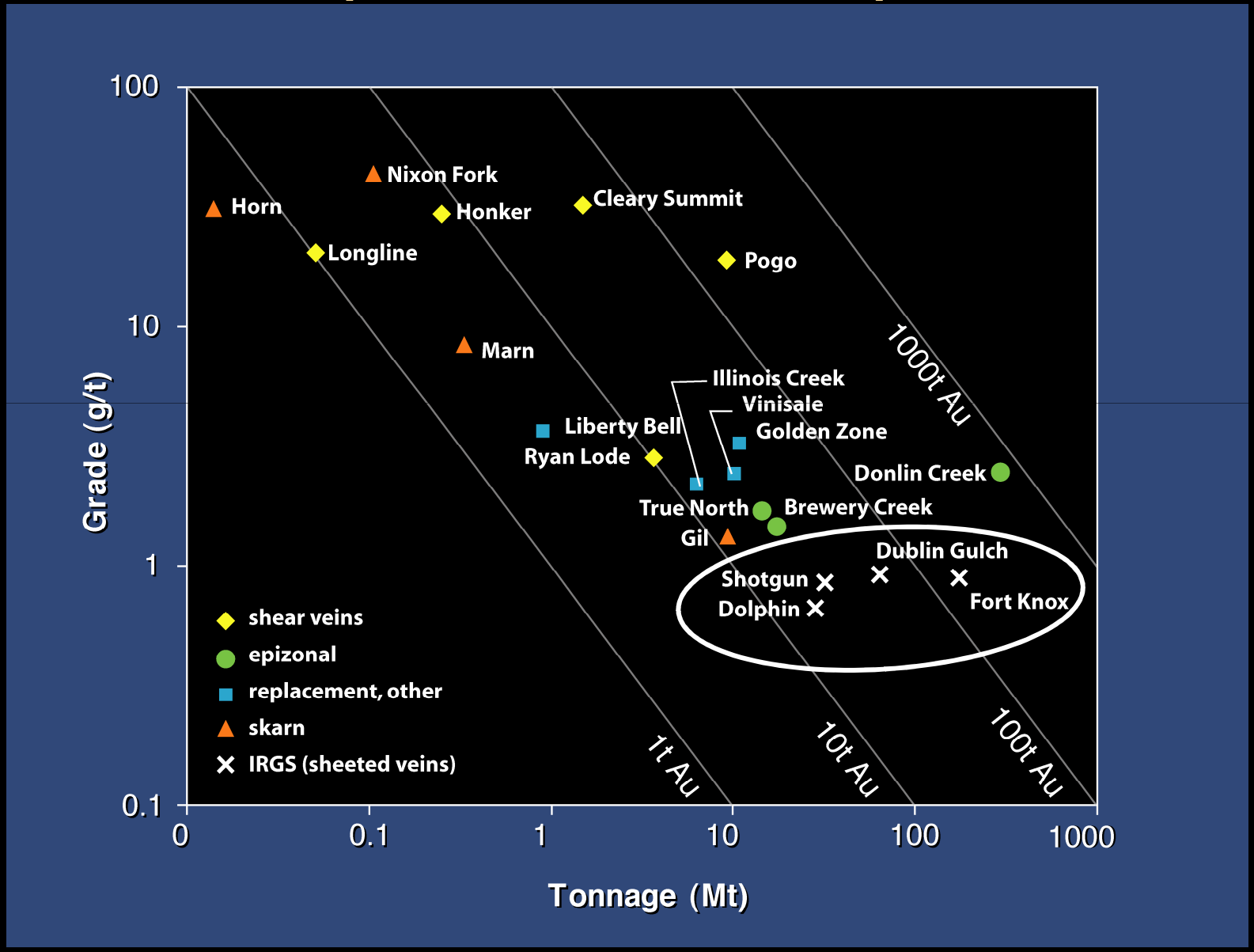


FORT KNOX DEPOSIT

- IRGS (92 Ma)
- Shears and sheeted veins
- 5.0 Moz prod (1996-2010)
- 3.6 Moz reserves, 0.45 g/t Au

IRGS: Low Grade, High Tonnage

(Tintina Gold Province)

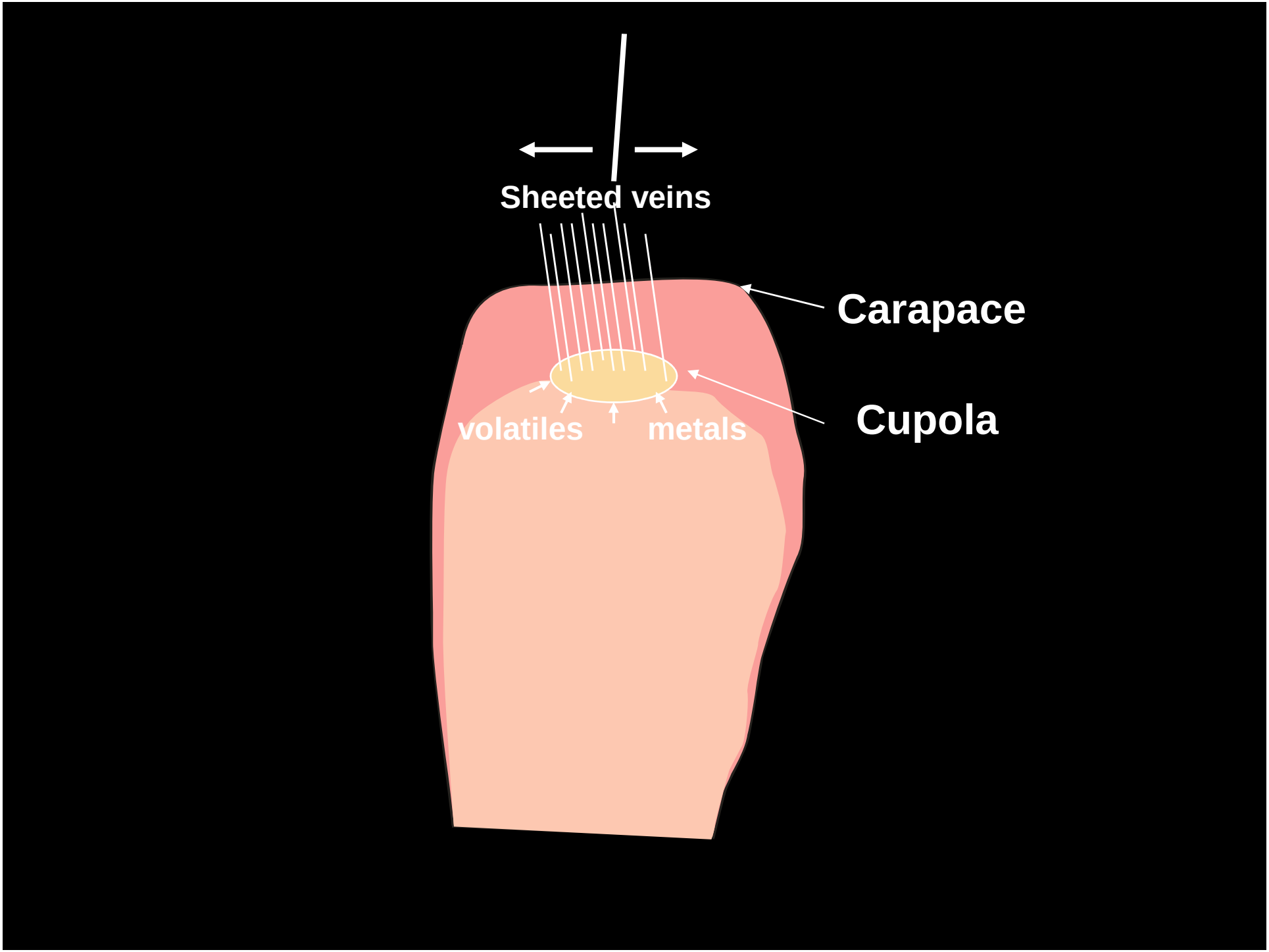


Diverse Deposit Types

Evolving one-shot, opportunistic fluids depositing metals across steep thermal and geochemical gradients zoned around a central pluton

Sheeted Veins

The most distinctive style of associated mineralization…always in the cupola


Sheeted veins
Carapace
Cupola
volatiles
metals

Fort Knox Mine

186 Mt of 0.93 gpt Au , 7Moz

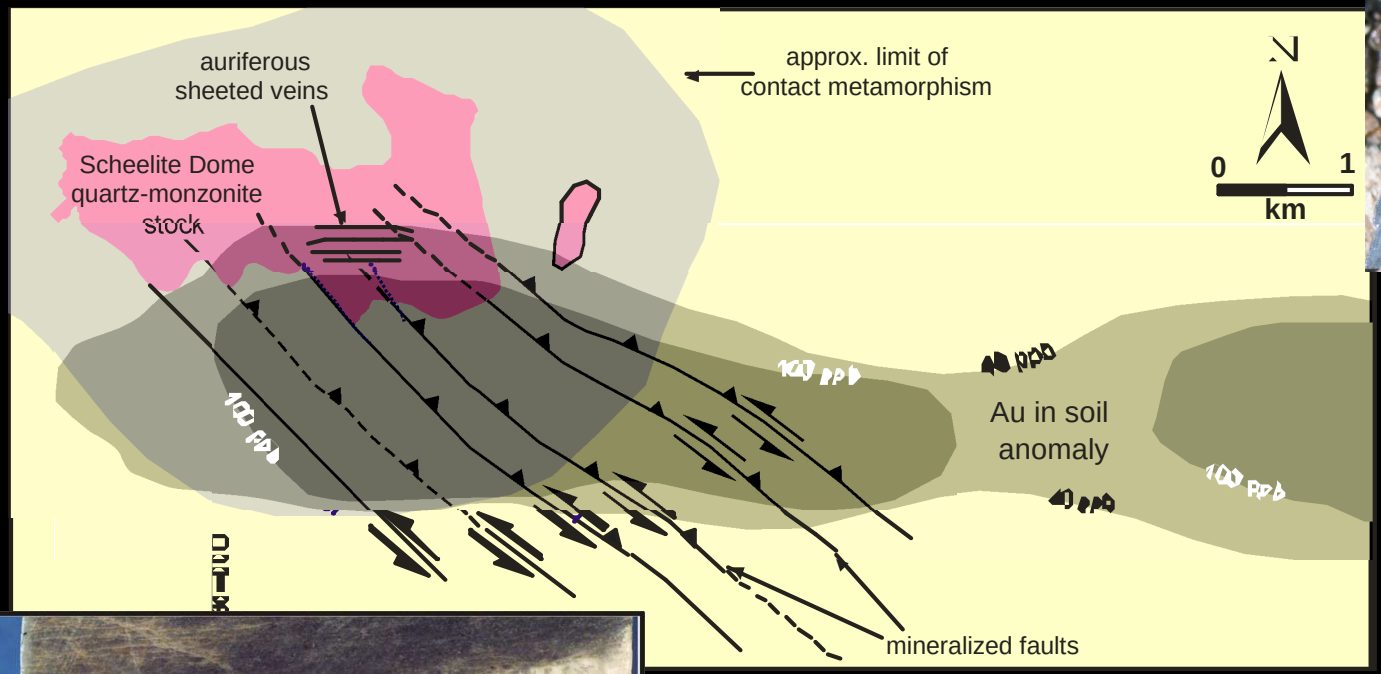
Intrusion-hosted
Sheeted Veins

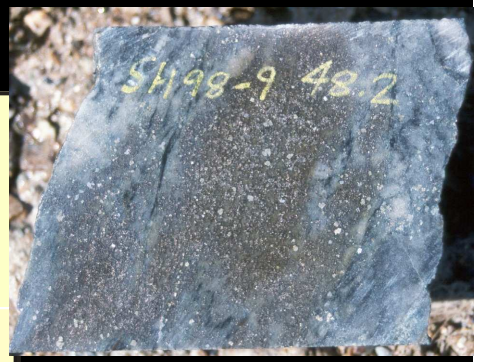
Sheeted Veins

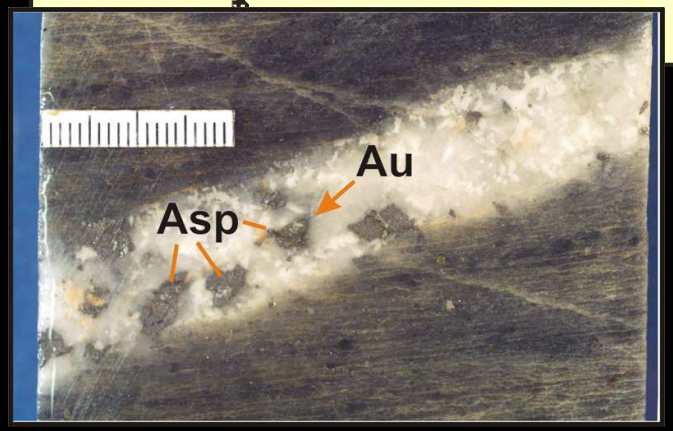
Reduced Au Skarns

Horn, Yukon

Stockwork, breccia & replacement gold in thermal aureole



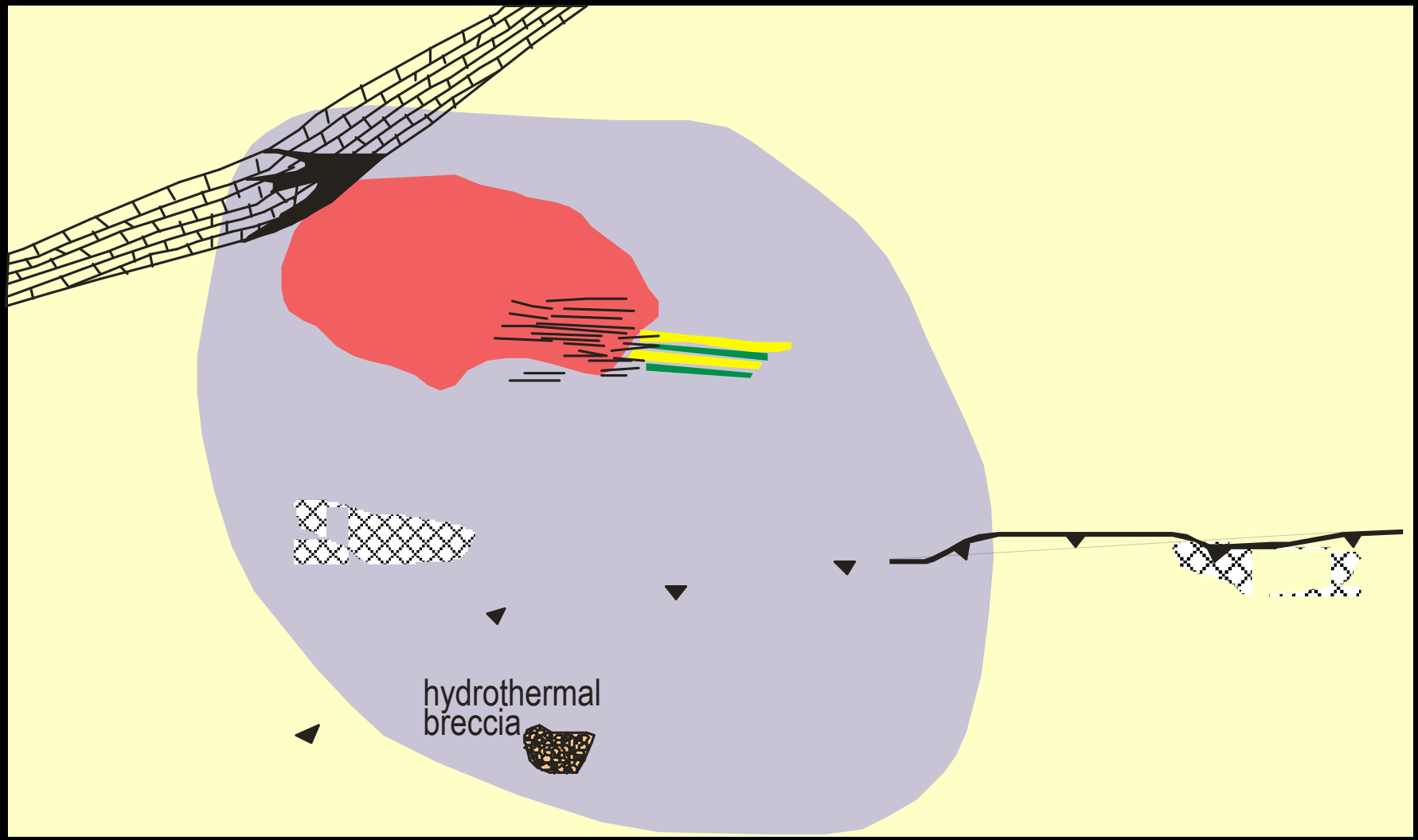




Silver Veins

>200 Moz Ag, Keno Hill, Yukon

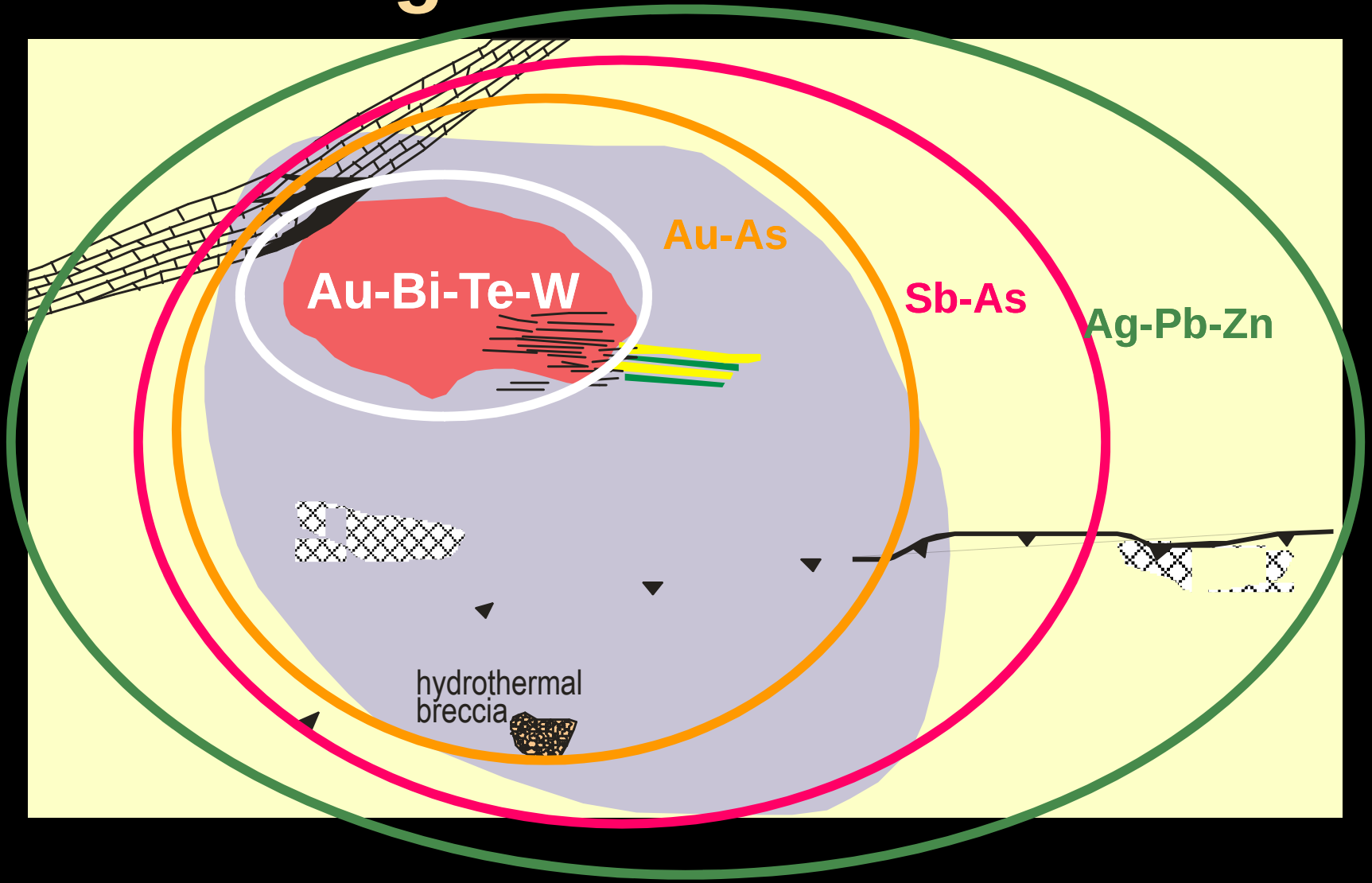
Zoned Reduced Intrusion-Related Gold Model



Metal Zoning

- **Au-Bi-Te (W) intrusion-hosted**
- **Au-As (±Sb) country-rock (aureole) hosted**
- **Pb-Zn-Ag distal**

Metallogenic Zonation - lateral



Smoking Gun Pluton

Features indicative of high fluid/ volatile contents and exsolution

Features Not Suitable for Discrimination

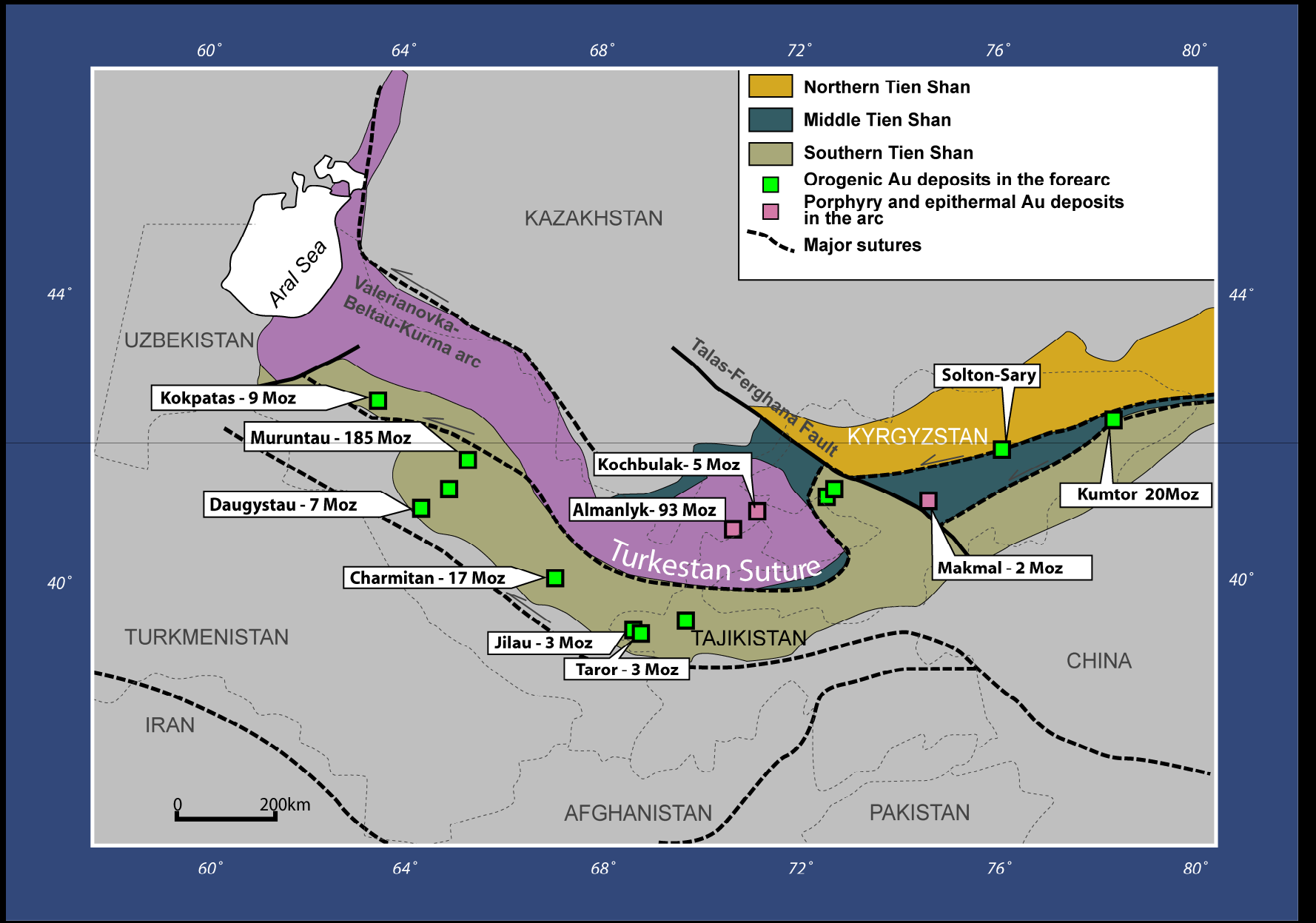
- Anomalous Bi, W, and Te
- Reduced sulfide mineralogy
- Low-salinity, CO_2-rich ore fluids
- Lodes are coeval with magmatism
- Shallow or flat vein systems
- Spatia/temporal association with granitoids

Distinguishing Intrusion-related Au SYSTEMS from Orogenic Au DEPOSITS

- Location=Deformed shelf sequences
- Relative Timing=Post-deformational
- Zoning=Deposit styles & metals
- Main Style=Sheeted veins
- Gold Grade=≤1g/t
- Igns Features=Magmatic-to-hydrothermal transition, Anomalous mantle mafic alkaline

- No single feature is enough, but the weights of evidence of several
- So what about Pogo, Donlin Ck, Central Asia, China, NZ…?

Mid-Late Paleozoic Au - Tien Shan



after Yakubchuk et al (2005)

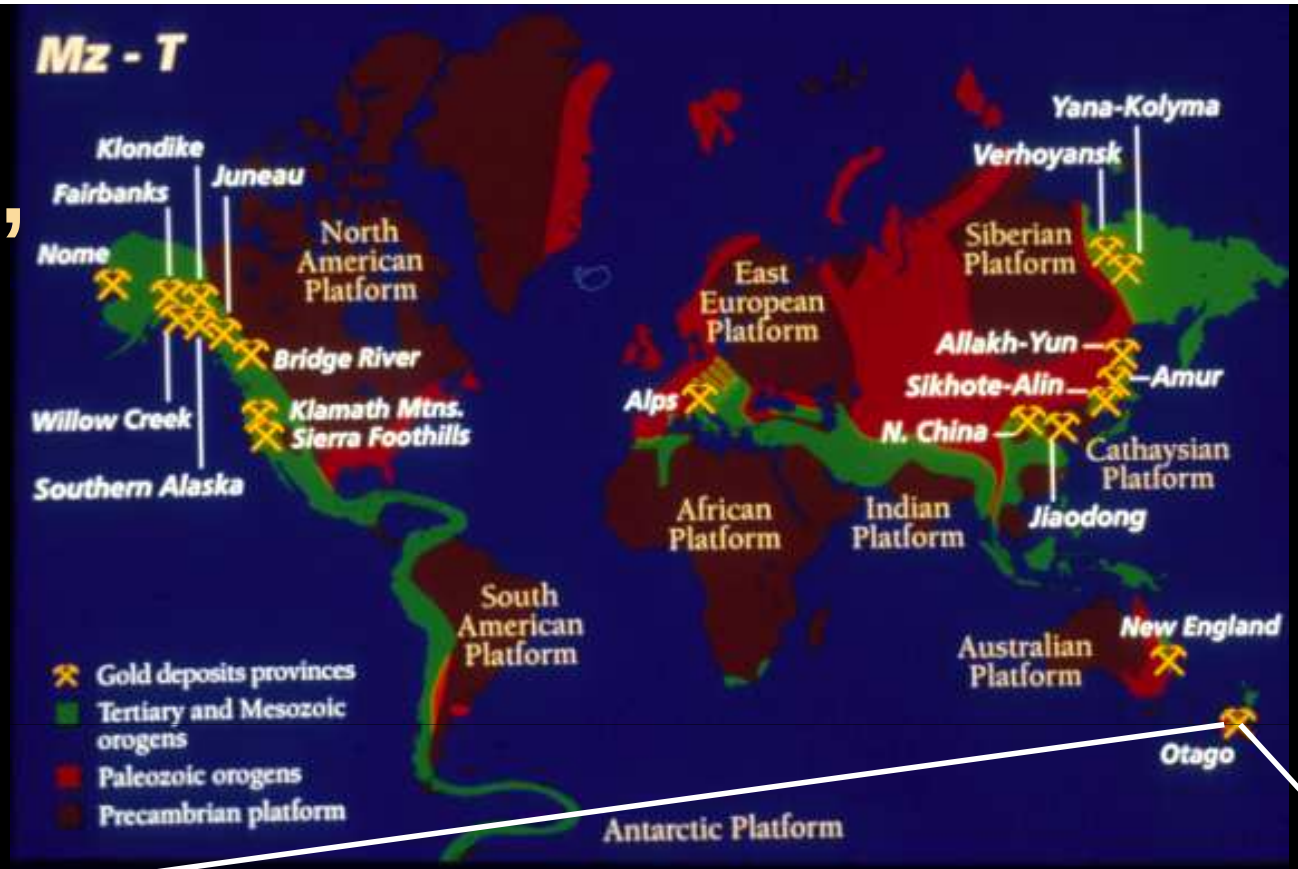
Muruntau (W. Tien Shan)

- Early Pz carbonaceous siltstone; dissem. pyrrhotite; ≥ 20-50 ppb Au?
- Au-py-aspy±po ores; W pre-gold?
- Early albite-biotite; later sericite-chlorite-carb
- 285 Ma regional mag./ defmtn/ gold
- 175 Moz Au; 3.5-5 g/t
- Where's igneous source?

Linglong Goldfield, Jiaodong

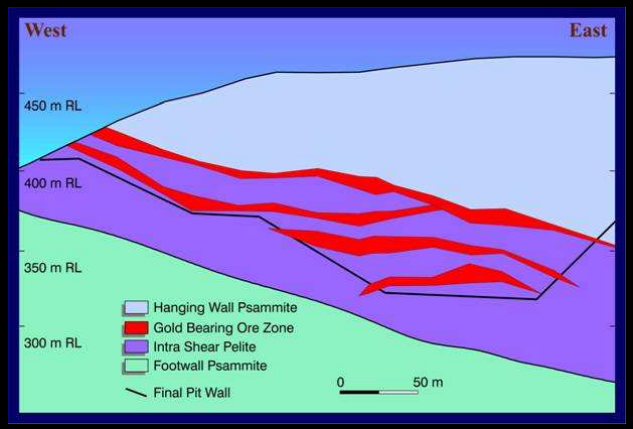
- Deposits **along contacts and between intrusions**
- **E. Linglong, W. Linglong, Taishang, Lignan, Dongfeng deposits**
- **Large quartz veins fill brittle fractures along reactivated shears**

Otago Goldfields, S. Island, NZ



Macres Flat
>5 Moz Au

Macraes: Orogenic? IRGS?



Consistencies with orogenic model (Craw and co-workers):

- Major shear, jogs, brittle - ductile
- Greenschist facies
- Vein P-T, mineralogy, $\delta^{18}O$, $\delta^{34}S$

Inconsistencies (de Ronde et al., 2000):

- >99% H_2O, light hydrogen isotopes, 1-2 wt% NaCl eq.=Like Broadlands
- BUT CH_4, N_2; some clathrate and 4 wt% NaCl eq. flincs

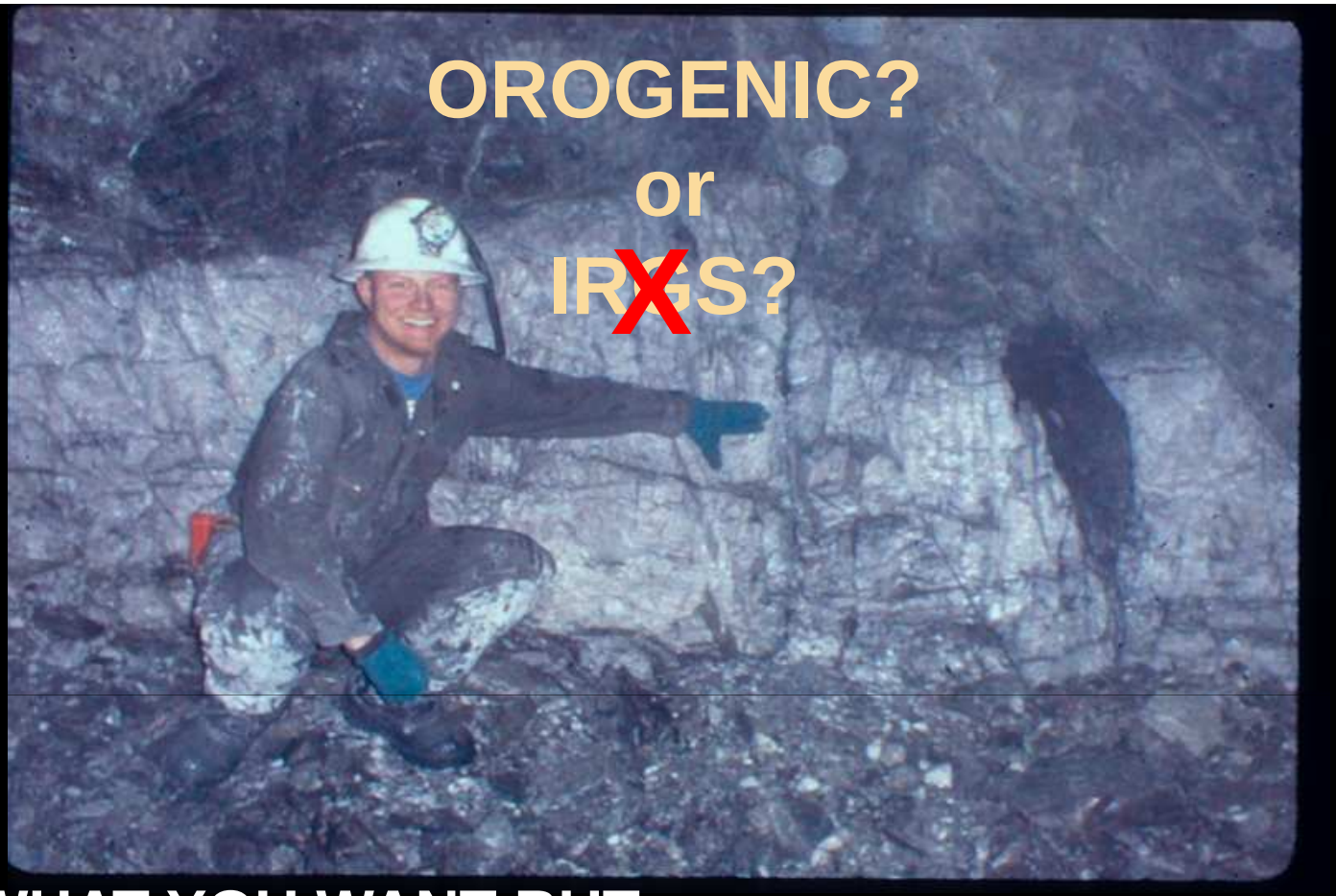
TINTINA GOLD PROVINCE

Fort Knox IRGS

- 0.45-0.93 g/t; 8.5 Moz
- Bi, Te, W
- Sheeted vein
- Pluton and veins=92 Ma
- Zoned systems

Pogo OGD

- 18.9 g/t; 5.8 Moz
- Tabular, shear-hosted, shallow veins=104 Ma
- Orthogneiss and paragneiss hosts
- Veins=104 Ma; Dikes=107 Ma; Batholith=94 Ma



CALL IT WHAT YOU WANT BUT:

1) Know what ore style you are talking about.
2) OGD represent an important target, with specific exploration criteria.
3) Exploration criteria are similar whether you chose a metamorphic or magmatic model for OGD.
4) IRGS are typically not good targets.