GEOLOGY OF THE WORLD'S MAJOR GOLD DEPOSITS AND PROVINCES

A Webinar on SEG Special Publication, No. 23

February 18, 2021

SOCIETY OF ECONOMIC GEOLOGISTS FOUNDED 1920

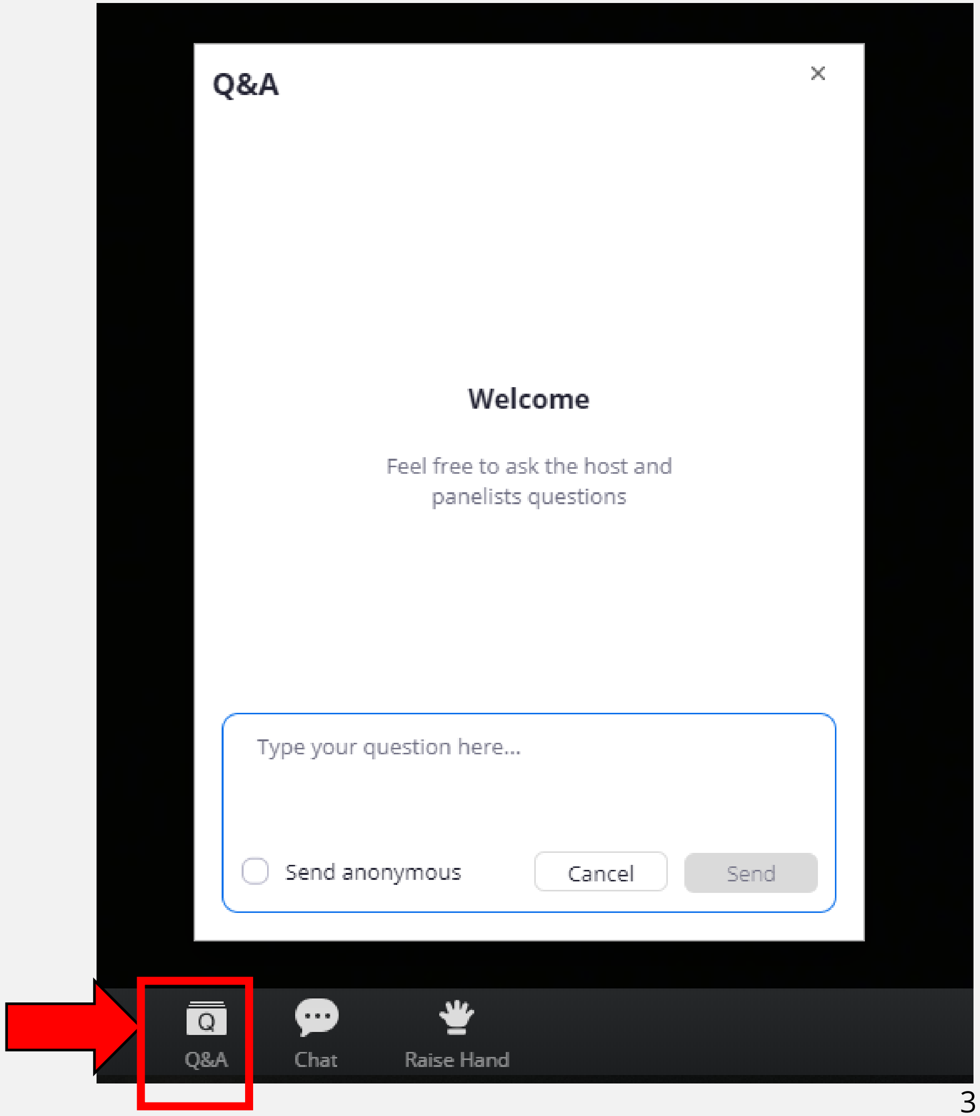
SEG Publication Webinar Series

Halley Keevil
Webinar Moderator

WELCOME

SUBMIT A QUESTION

- Find the Q&A button on the control bar and type a question
- Logistical questions will be answered in Zoom
- Questions on the presentation will be answered during the Q&A Session following the presentation (time permitting)



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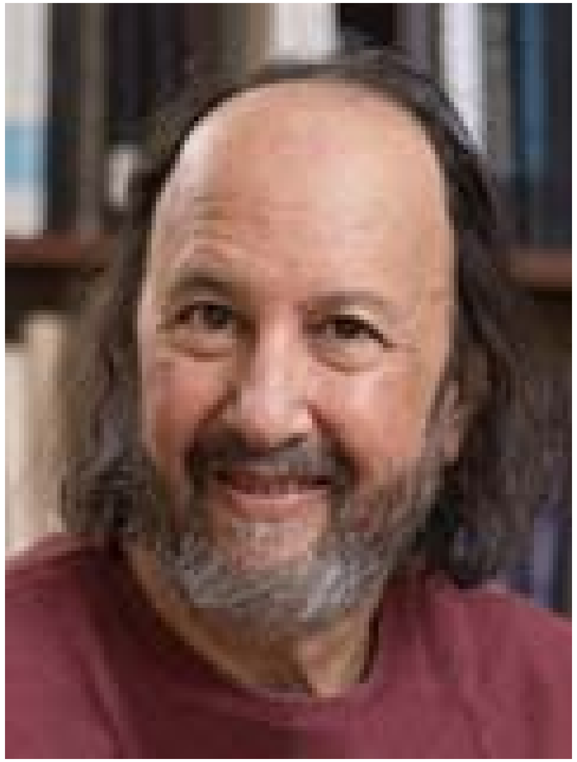
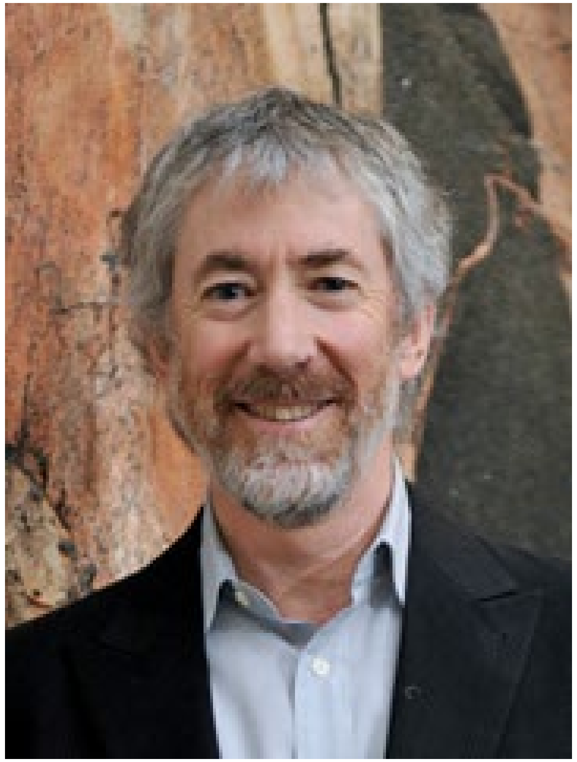
Speakers

Richard H. Sillitoe



Richard J. Goldfarb



François Robert

Stuart F. Simmons

AGENDA

Richard H. Sillitoe – *Introduction*

Stuart F. Simmons - *Porphyry-Epithermal*

Francois Robert - *Carlin & Archean Orogenic*

Richard J. Goldfarb - *Young Orogenic & Others*

Stuart Simmons - *Gold Deposition*

Q & A Panel Discussion

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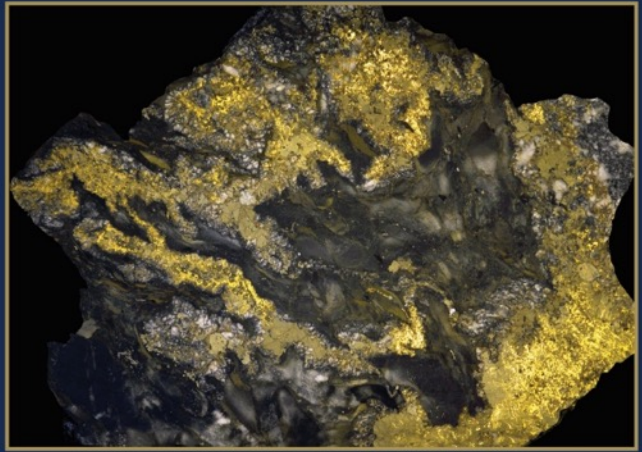
Geology of the World's Major Gold Deposits and Provinces



Richard H. Sillitoe, Richard J. Goldfarb,
François Robert, and Stuart F. Simmons, Editors

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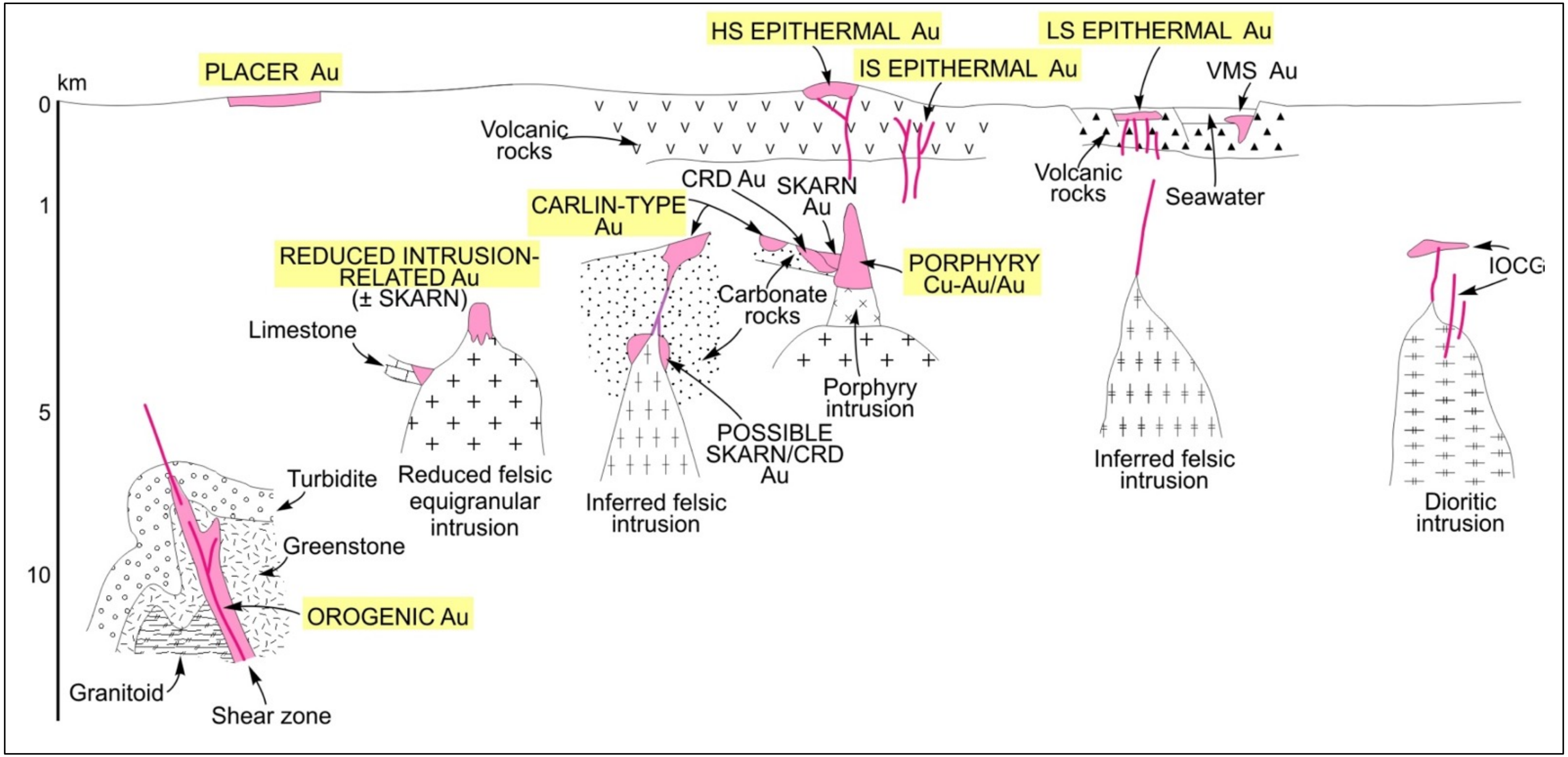
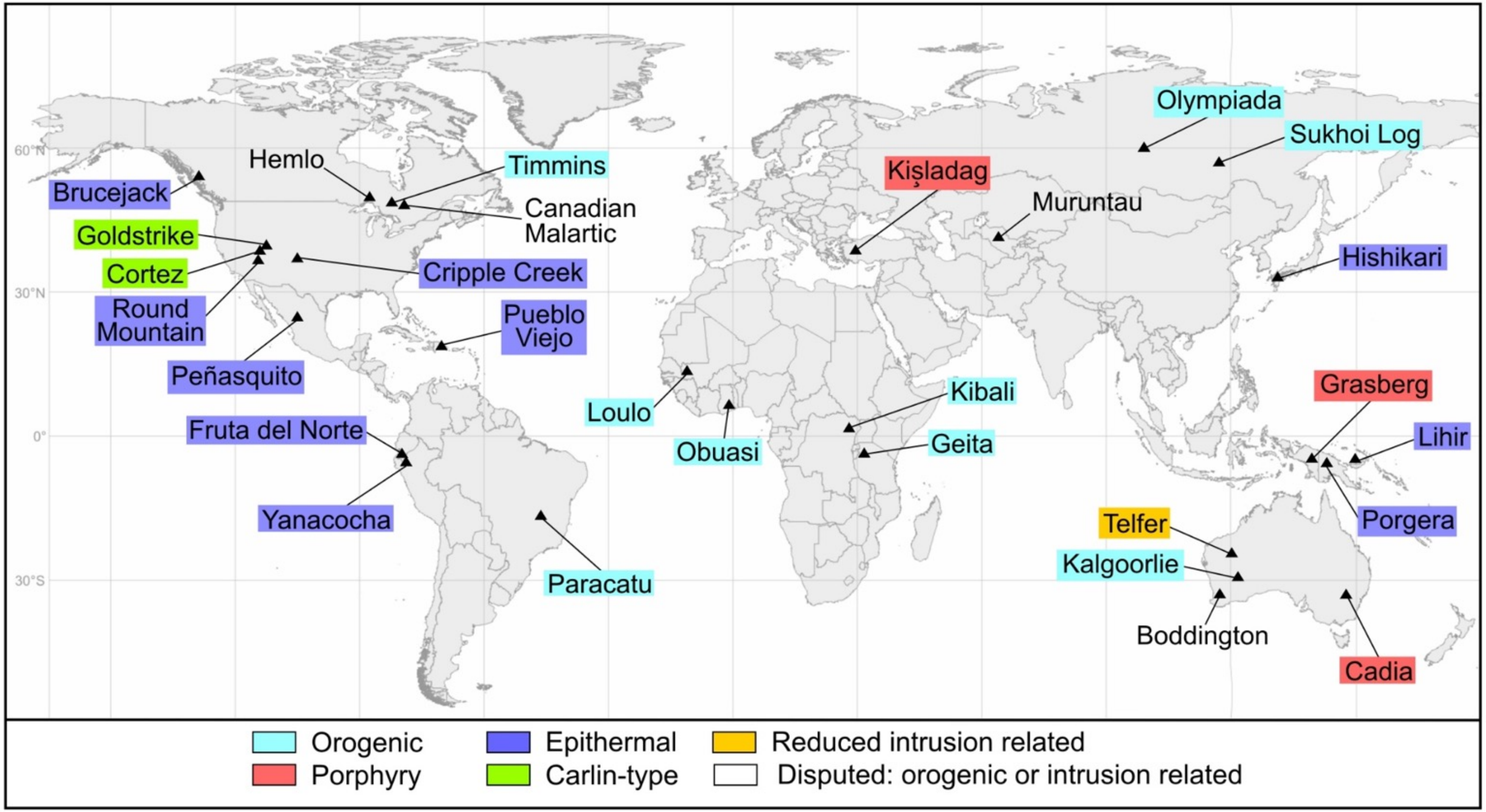
Gold deposit types



Gold deposits



Gold provinces

Porphyry-Epithermal

Stuart Simmons

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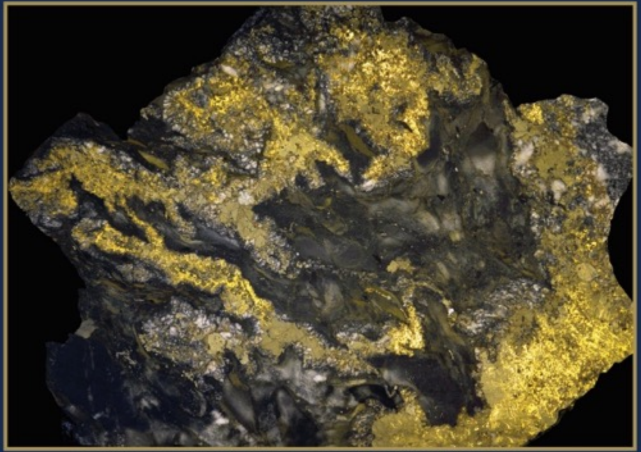
Geology of the World's Major Gold Deposits and Provinces



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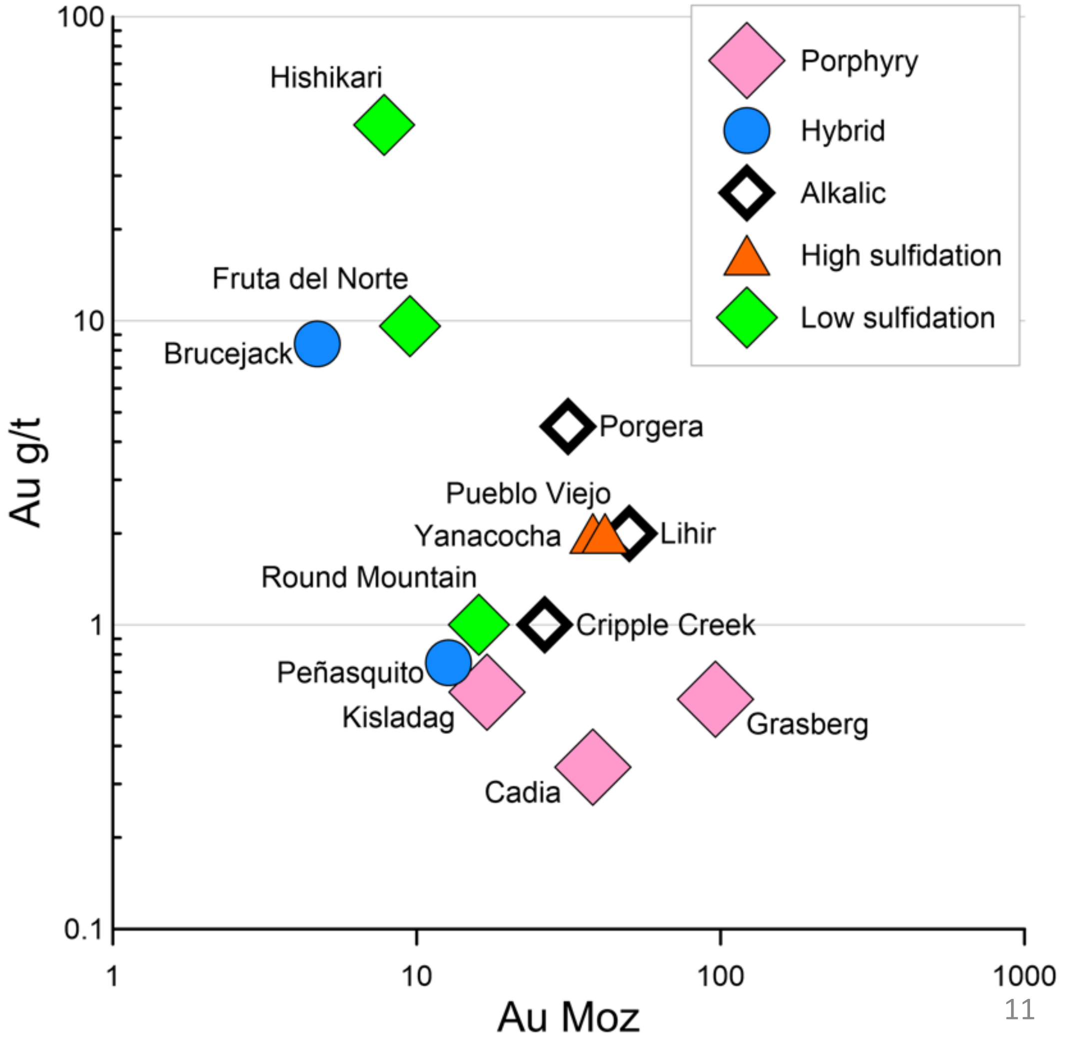
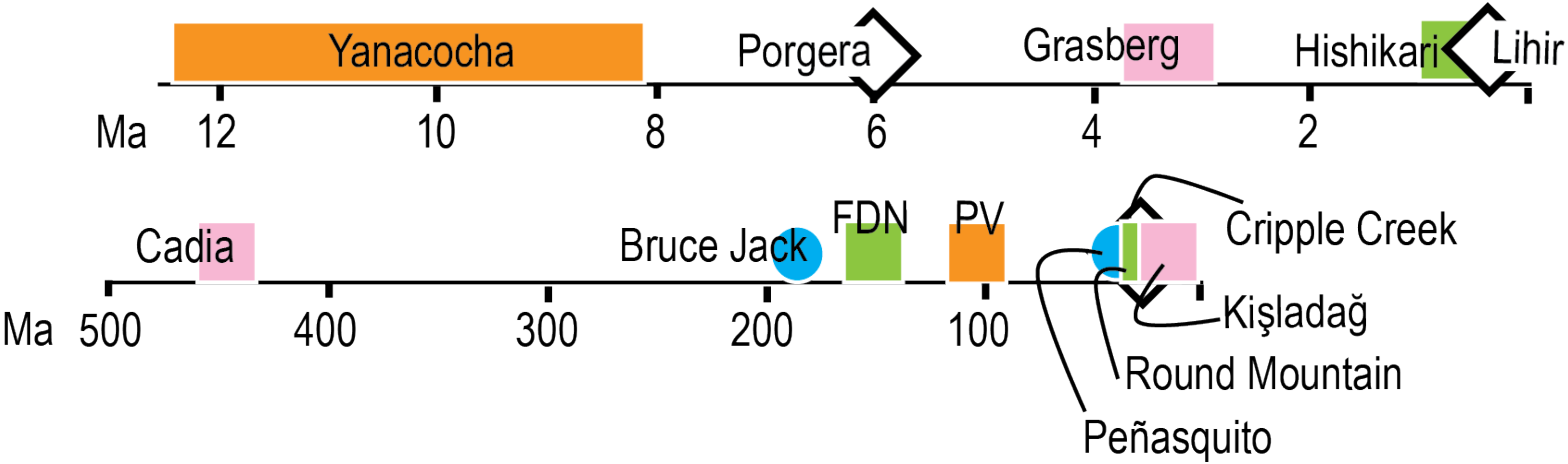
Intrusion-related: Porphyry to Epithermal Deposits

Kişladağ	West Tethyan Magmatic Belt
Grasberg	Irian Fold & Thrust Belt
Cadia	Macquarie Arc
Brucejack	Canadian Cordillera-Golden Triangle
Peñasquito	Sierra Madre Occidental
Cripple Creek	Front Range Rocky Mtns
Porgera	Papuan Fold Belt
Lihir	Tabar-Feni Island Chain
Yanacocha	Peruvian Andes
Pueblo Viejo	Greater Antilles Arc
Round Mtn	Southern Great Basin Ignimbrite Province
Fruta del Norte	Cordillera del Cóndor
Hishikari	Ryukyu Arc



Porphyry to Epithermal Deposits: *Age & Period*



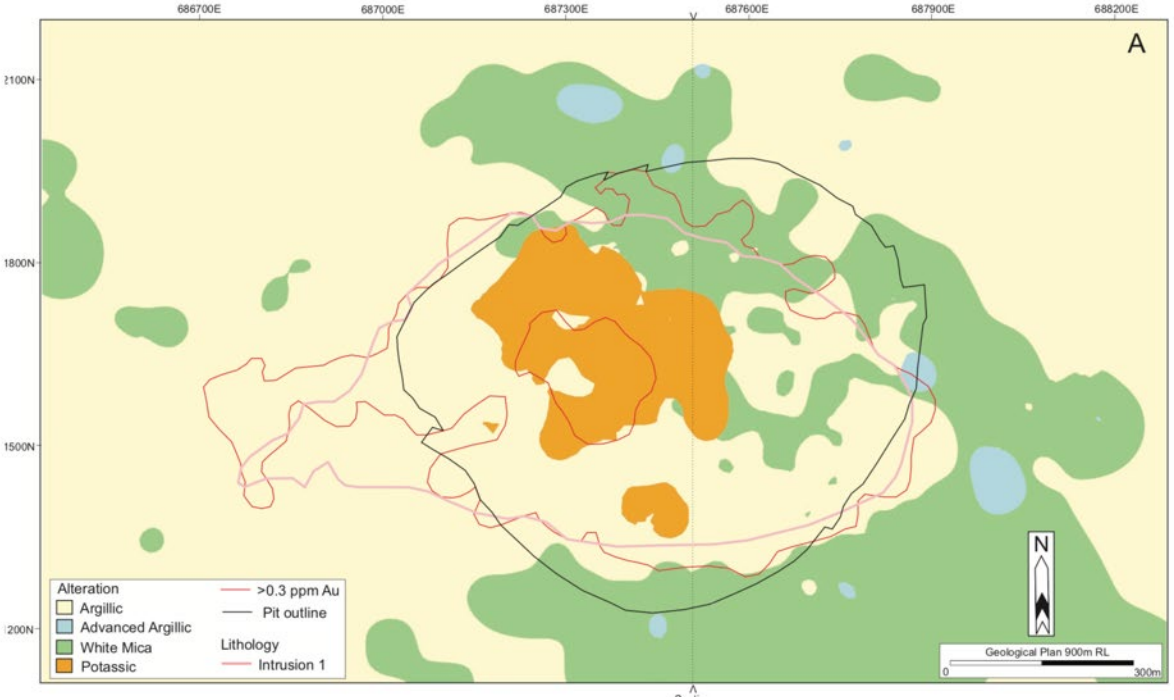
Alteration, Mineralization, and Age Relationships at the Kışladağ Porphyry Gold Deposit, Turkey

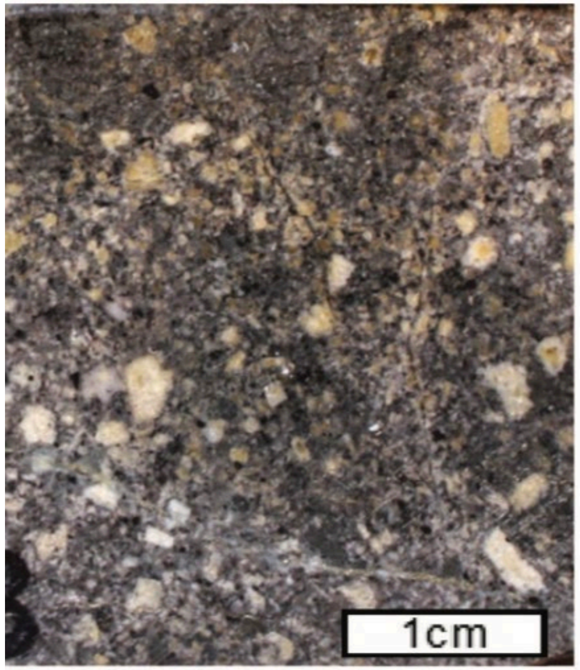
T. Baker,[1†] S. Mckinley,[1] S. Juras,[1] Y. Oztas,[2] J. Hunt,[3] L. Paolillo,[4] S. Pontual,[5] M. Chiaradia,[4] A. Ulianov,[6] and D. Selby[7,8]

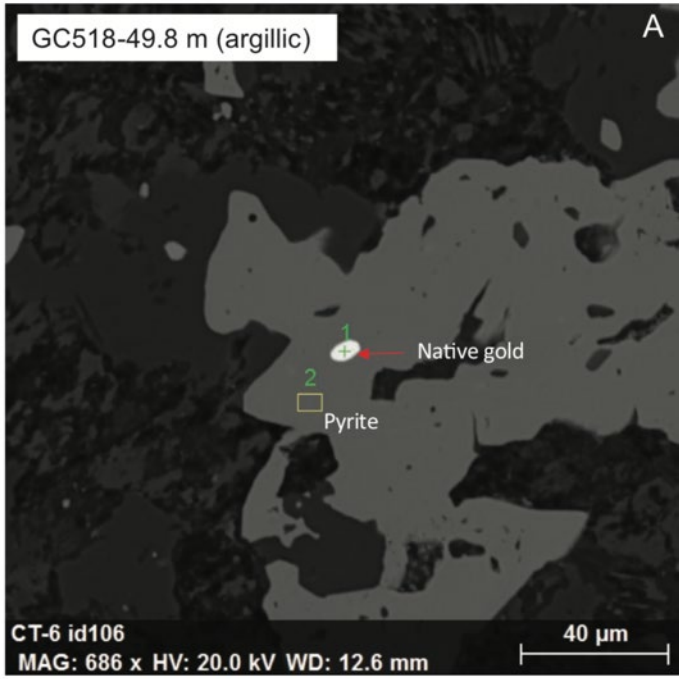
[1]*Eldorado Gold Corporation, 1188-550 Burrard Street, Vancouver, British Columbia V6C 2B5, Canada*

[2]*Tüprag Metal Madencilik San. Ve Tic A.S., Kışladağ, Turkey*

[3]*Mineral Deposit Research Unit, Department of Earth, Ocean and Atmospheric Sciences, 2020–2207 Main Mall, Vancouver, British Columbia V6T 1Z4, Canada*







Grasberg Copper-Gold-(Molybdenum) Deposit: Product of Two Overlapping Porphyry Systems

Clyde Leys,[1,†] Adam Schwarz,[2,*] Mark Cloos,[3] Sugeng Widodo,[2] J. Richard Kyle,[3] and Julius Sirait[1]

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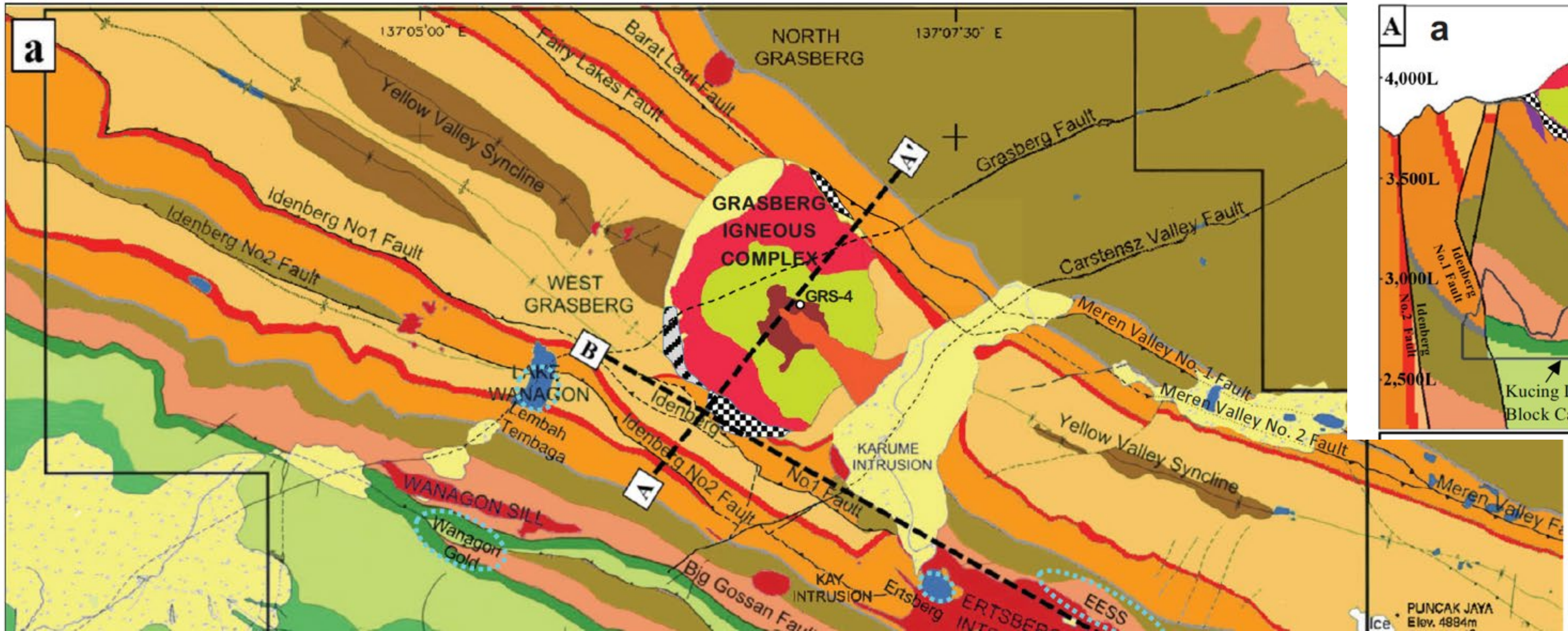
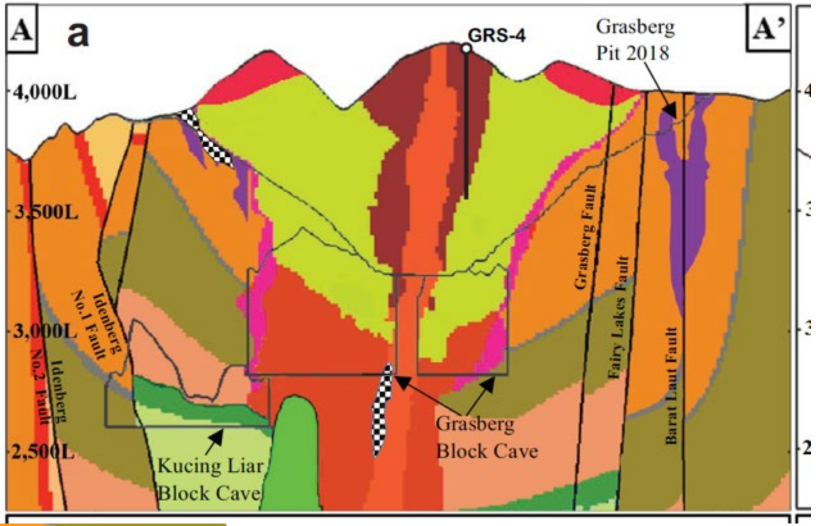
[2]*Freeport-McMoRan Inc., Phoenix, Arizona 85004*

[3]*Department of Geological Sciences, University of Texas at Austin, Austin, Texas 78712*





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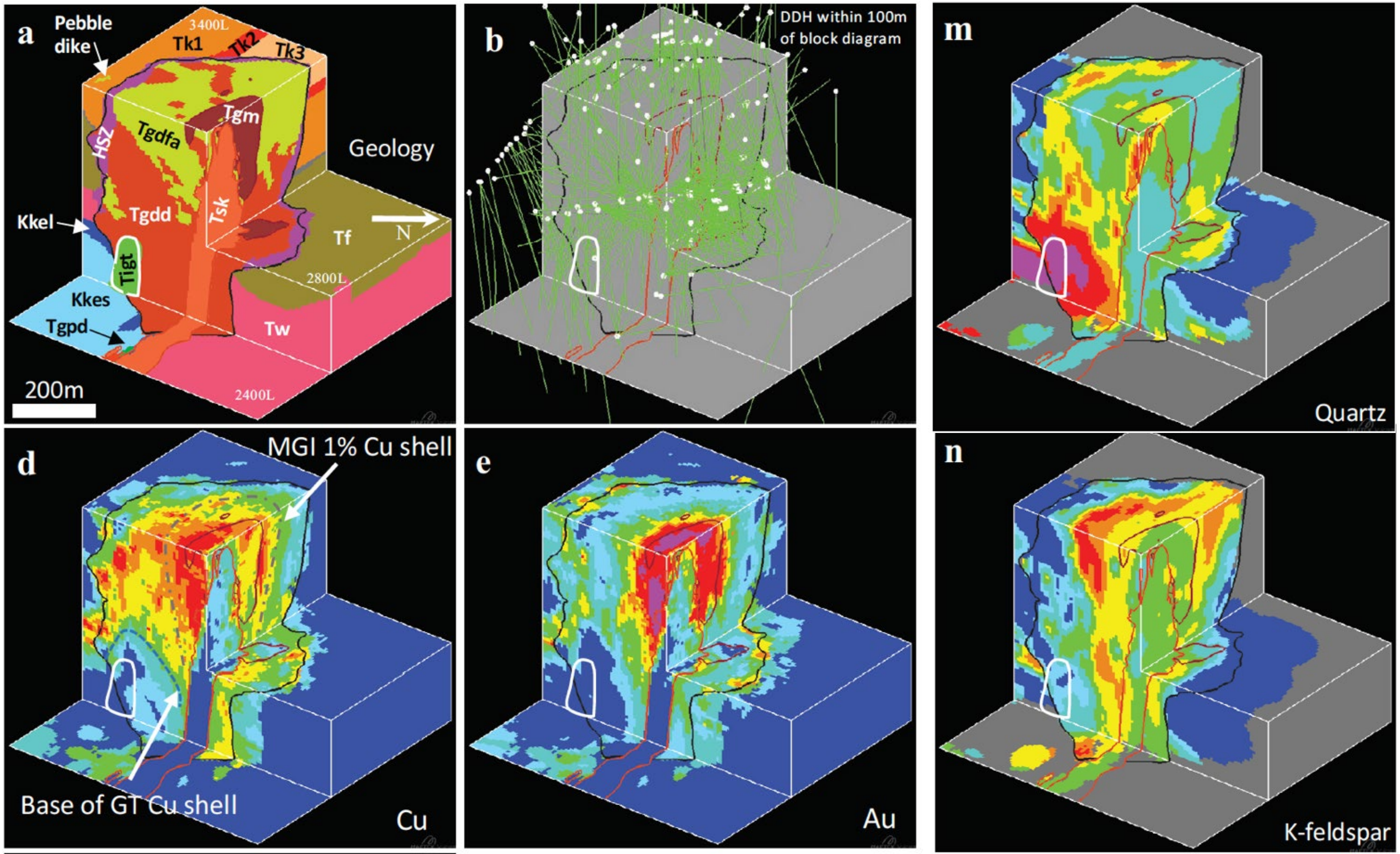

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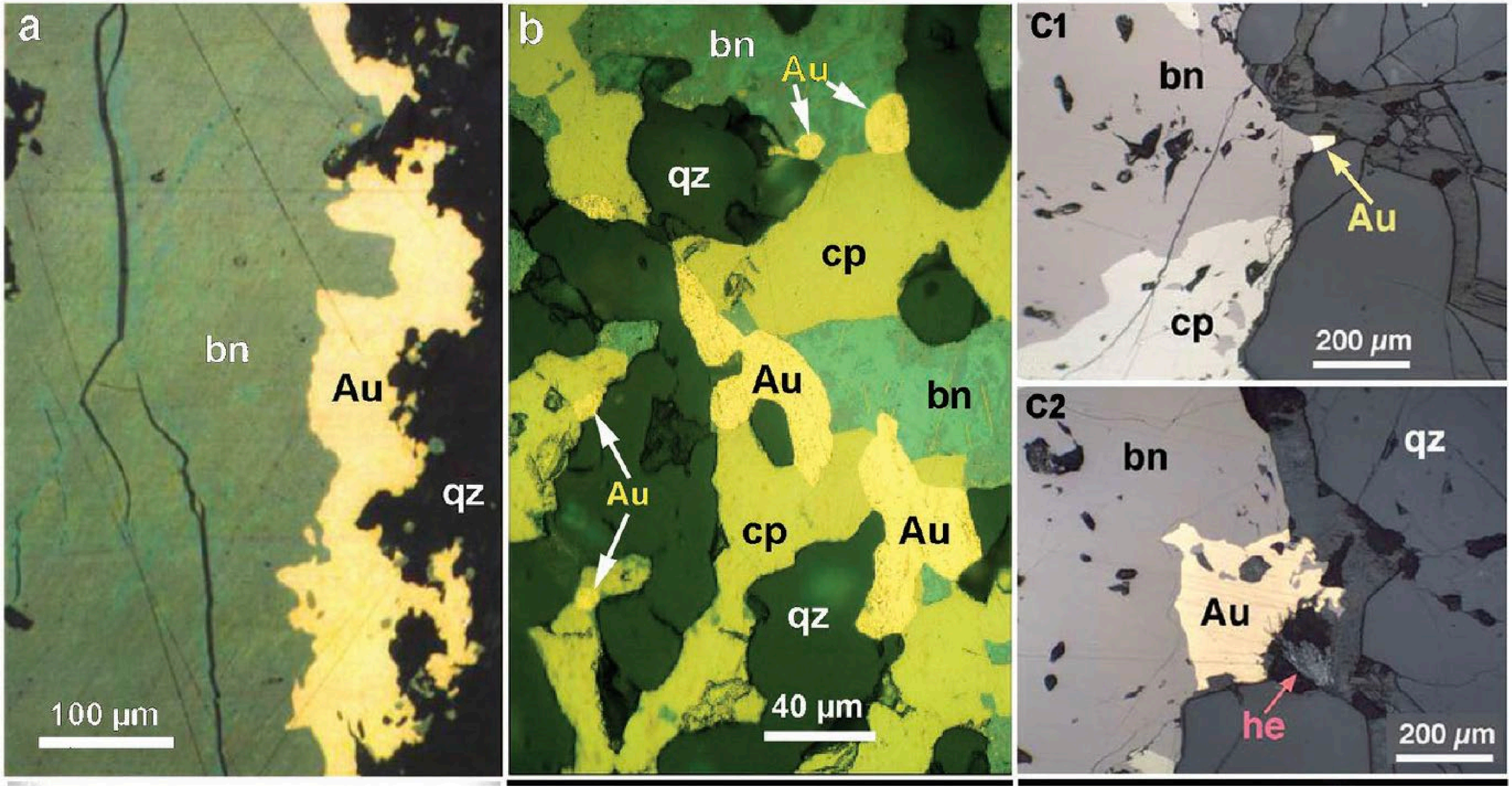

Geologic Evolution of Late Ordovician to Early Silurian Alkalic Porphyry Au-Cu Deposits at Cadia, New South Wales, Australia

Anthony C. Harris,[1,2] David R. Cooke,[2,3,†] Ana Liza Garcia Cuison,[2] Malissa Groome,[4] Alan J. Wilson,[5] Nathan Fox,[2] John Holliday,[5] and Richard Tosdal[4]

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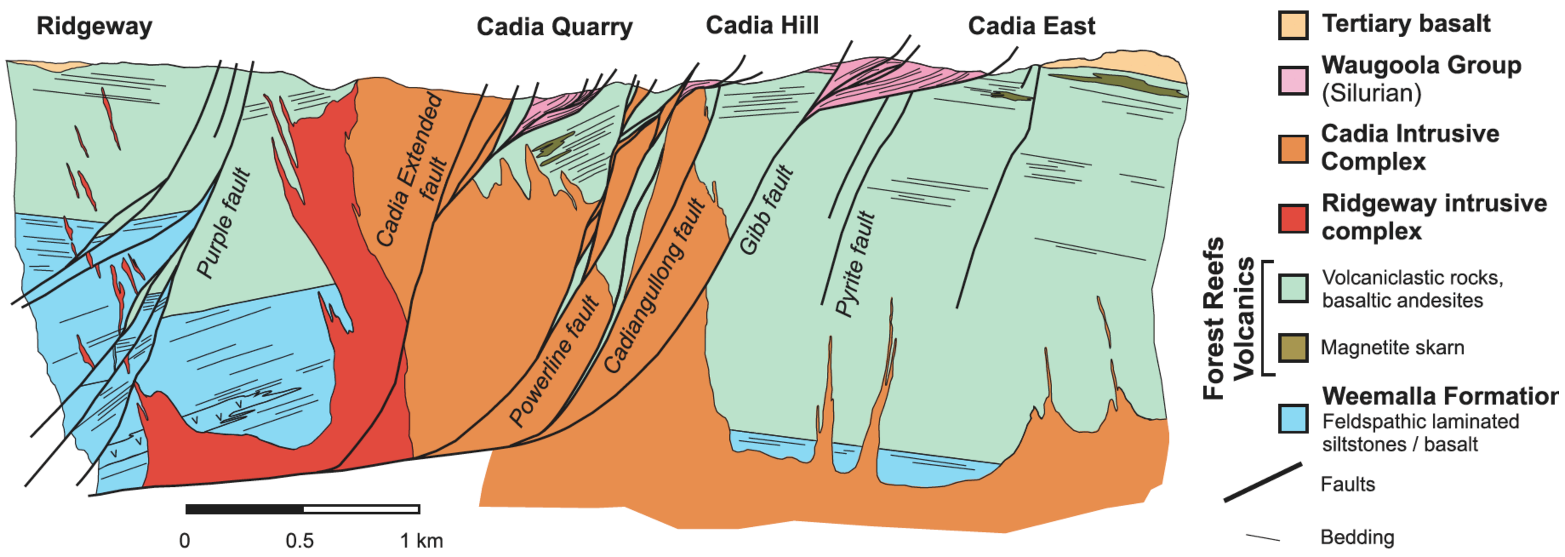
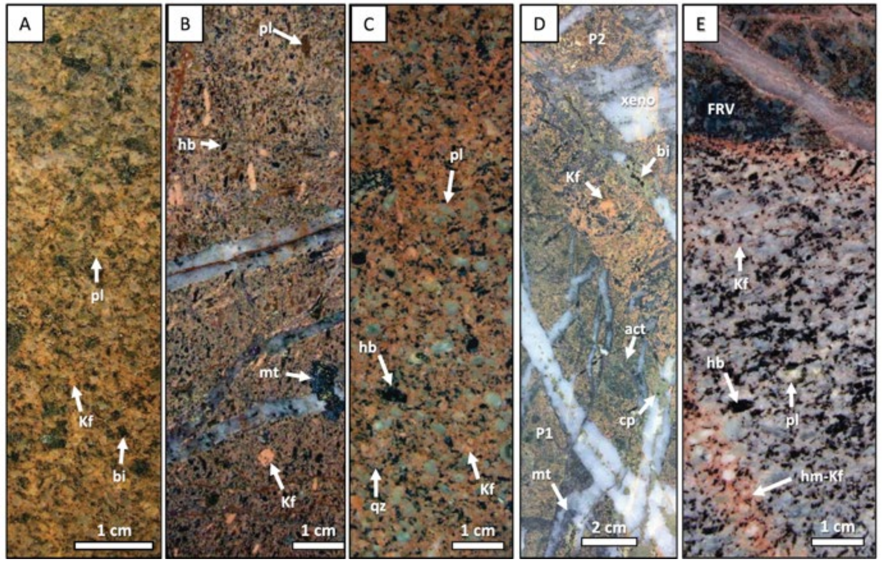
[2]*CODES, Centre for Ore Deposit and Earth Sciences, University of Tasmania, Private Bag 79, Hobart, Tasmania 7001, Australia*



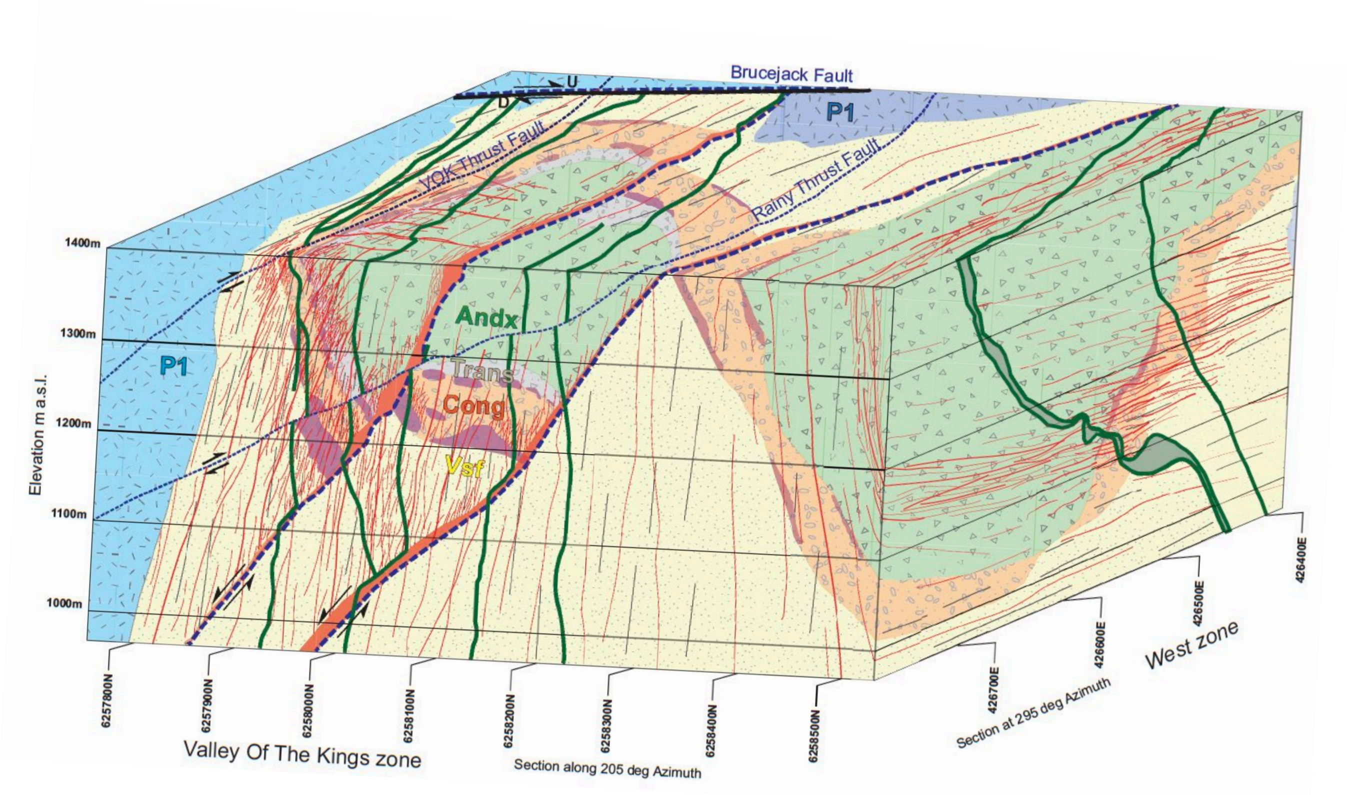


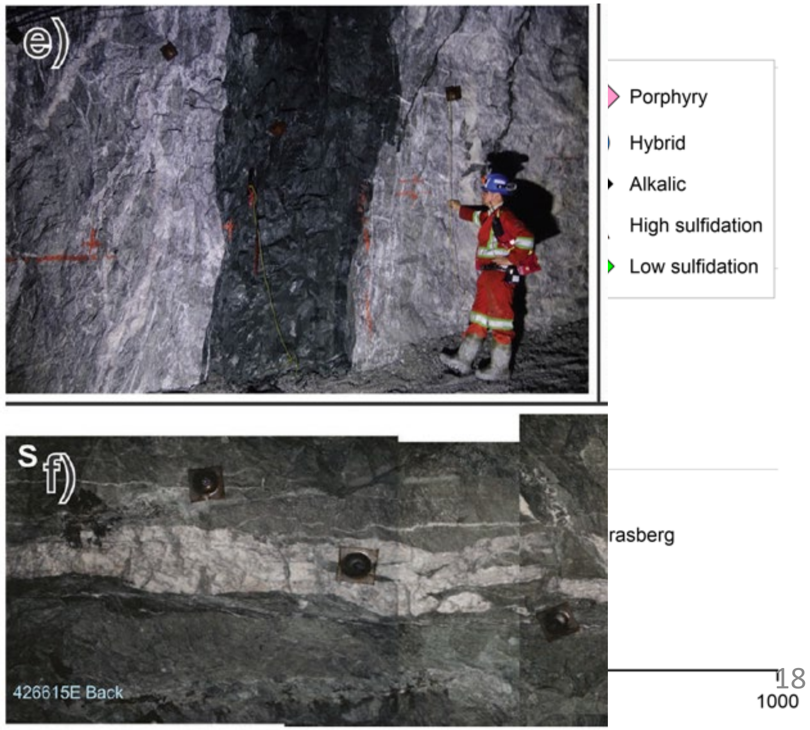
The Brucejack Au-Ag Deposit, Northwest British Columbia, Canada: Multistage Porphyry to Epithermal Alteration, Mineralization, and Deposit Formation in an Island-Arc Setting

Warwick S. Board,[1] Duncan F. McLeish,[2] Charles J. Greig,[3] Octavia E. Bath,[1] Joel E. Ashburner,[1] Travis Murphy,[1] and Richard M. Friedman[4]

[1]Pretium Resources Inc., 2300-1055 Dunsmuir Street, Vancouver, British Columbia, Canada V7X 1L4

[2]Department of Earth and Planetary Sciences, McGill University, Montreal, Quebec, Canada H3A 0E8



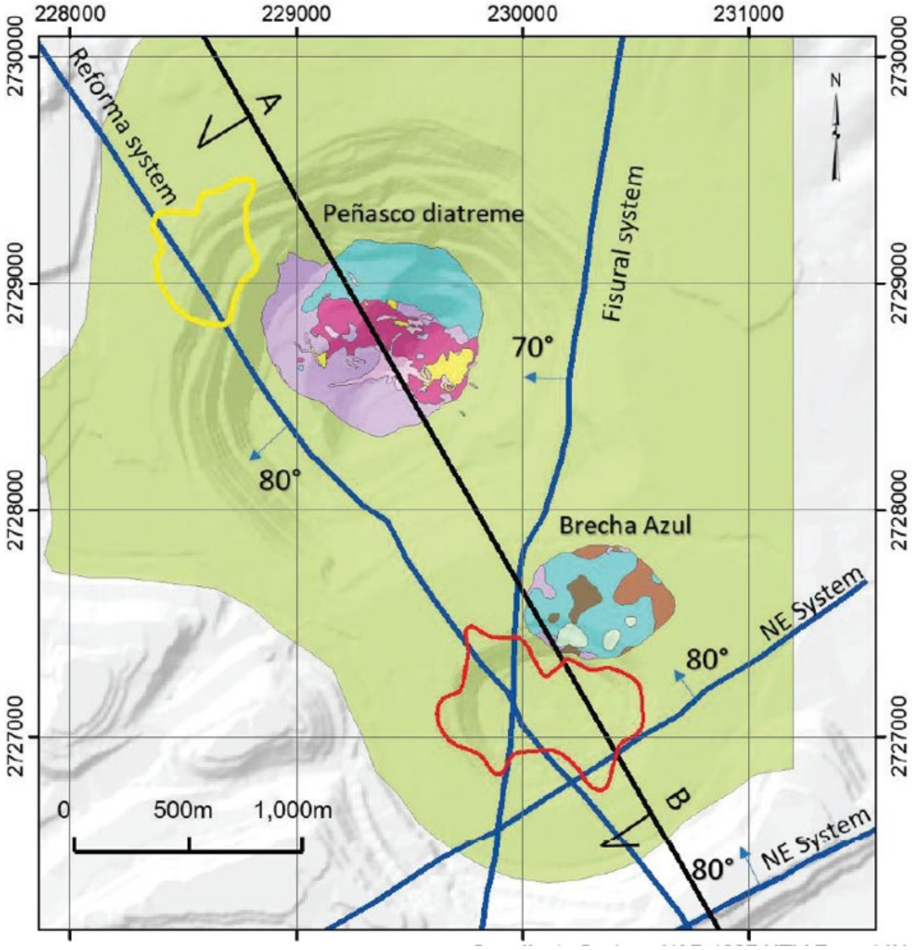


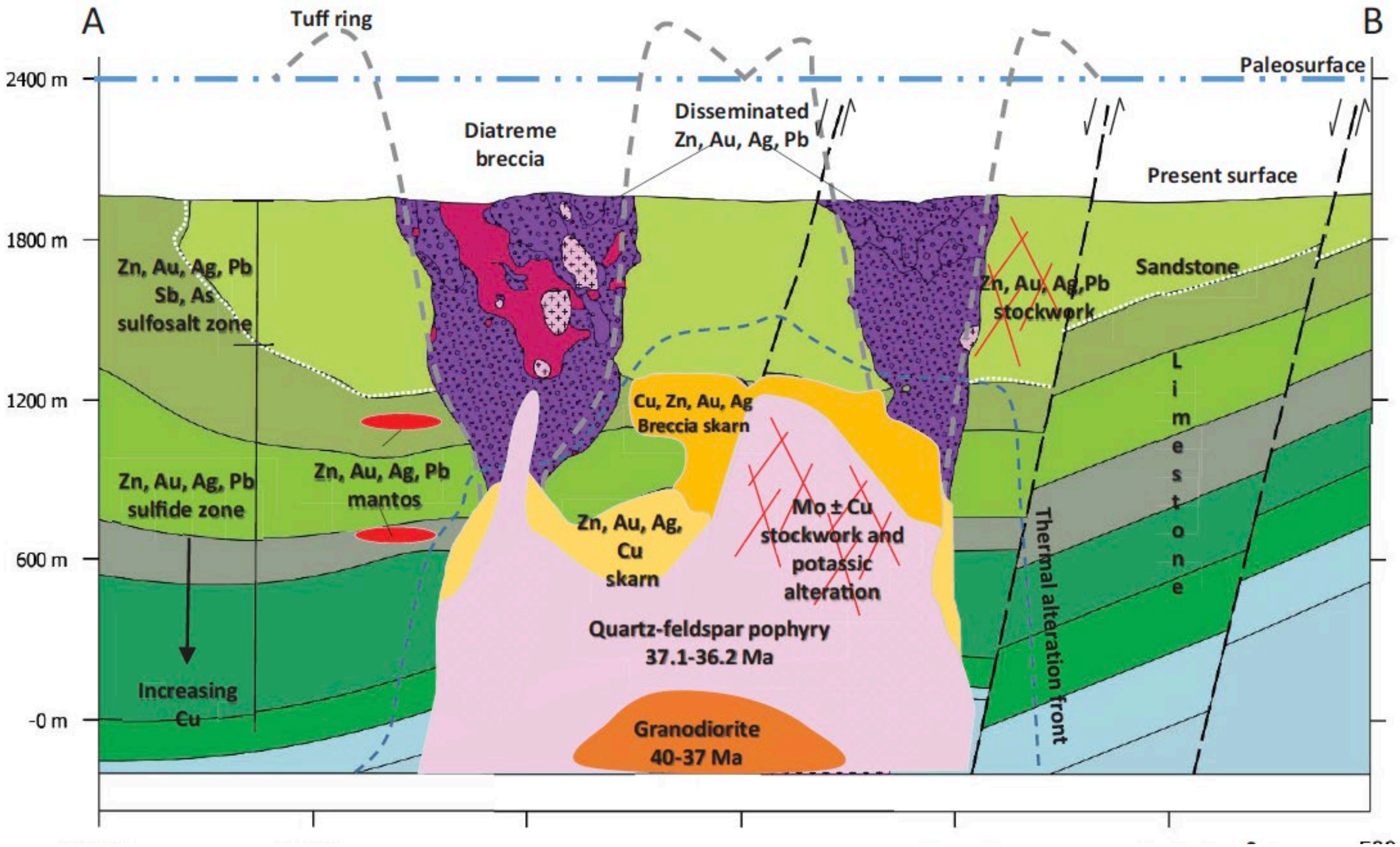
The Peñasquito Gold-(Silver-Lead-Zinc) Deposit, Zacatecas, Mexico

Omar Dromundo,[1,†] Sigfrido Robles,[1] Thomas Bissig,[2] Claudio Flores,[1] Maria del Carmen Alfaro,[1] and Lorenzo Cardona[1]

[1]*Minera Peñasquito, Prolongación 5 de mayo S/N, Mazapil, Zacatecas, Mexico*

[2]*Bissig Geoscience Consulting, Vancouver, British Columbia V6J 3S6, Canada*





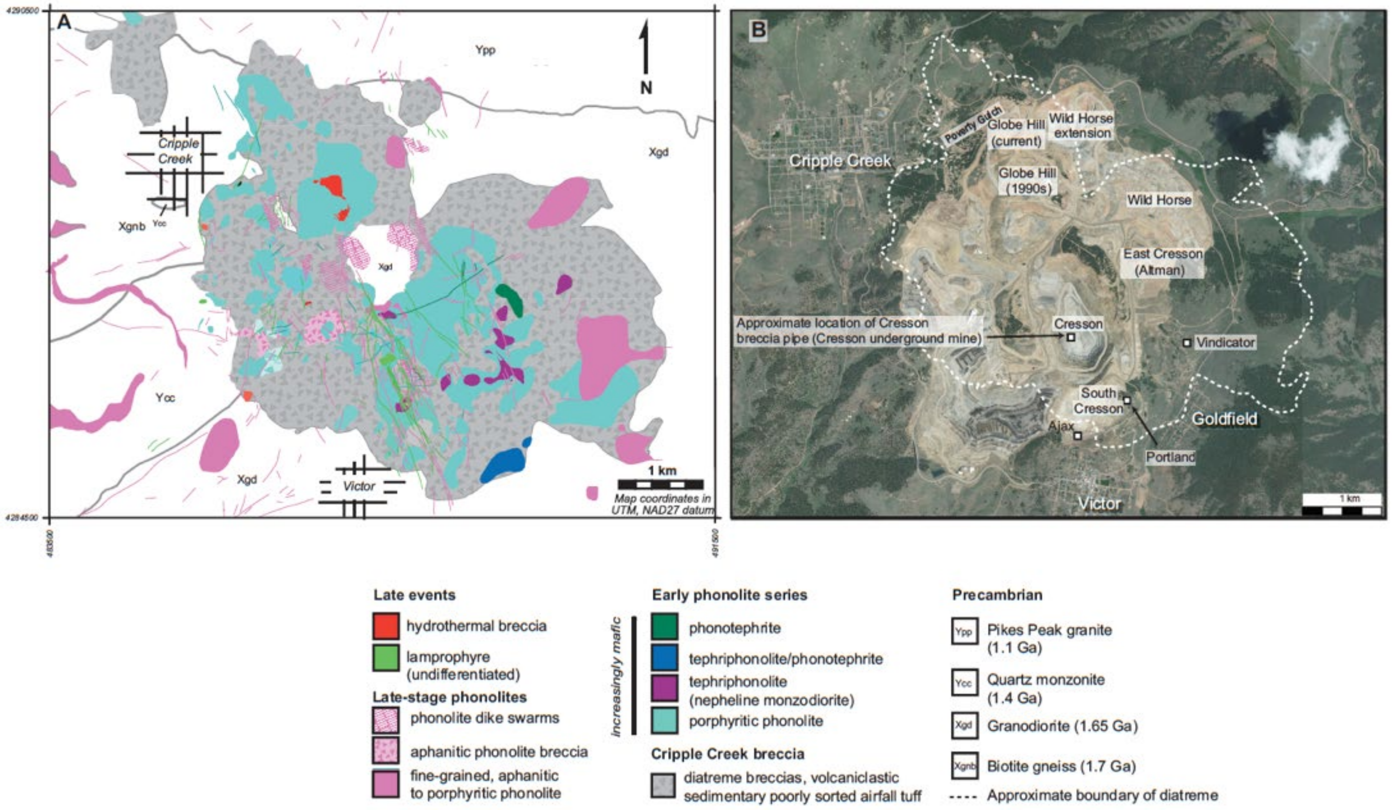
Epithermal Gold Deposits Related to Alkaline Igneous Rocks in the Cripple Creek District, Colorado, United States

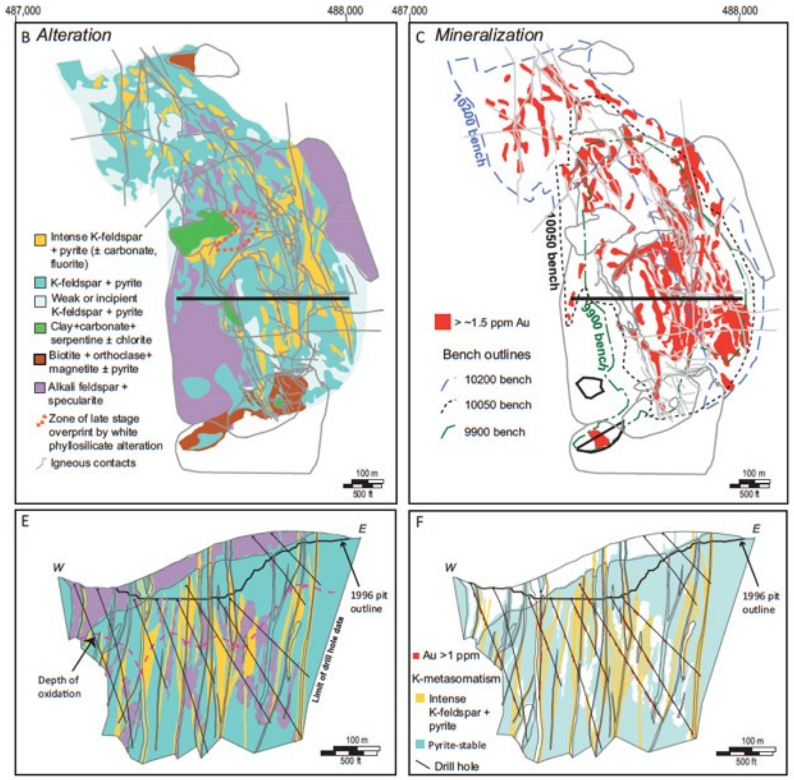
Karen D. Kelley,[1,†] Eric P. Jensen,[2] Jason S. Rampe,[3] and Doug White[3]

[1]*U.S. Geological Survey, Mail Stop 973, Denver, Colorado 80225*

[2] *EMX Royalty Corporation, 10001 W. Titan Road, Littleton, Colorado 80125*

[3] *Newmont Mining, 100 North 3rd Street, Victor, Colorado 80860*





Geology of the Porgera Gold Deposit, Papua New Guinea

Jonathan P. Hay,[1] Mark M. Haydon,[2,†] and François Robert[3]

[1]OZ Minerals, Prominent Hill Mine, South Australia

[2]Barrick (Niugini) Ltd, Porgera Joint Venture, Enga Province, Papua New Guinea

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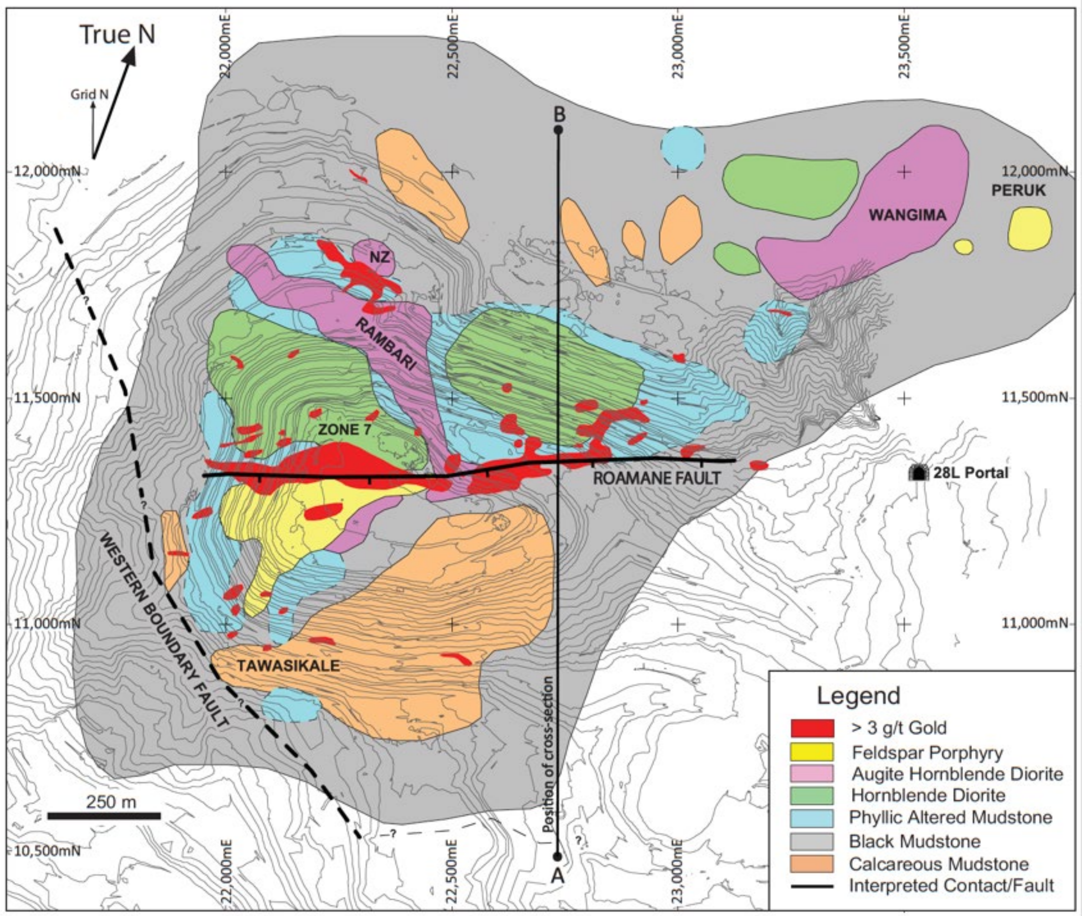

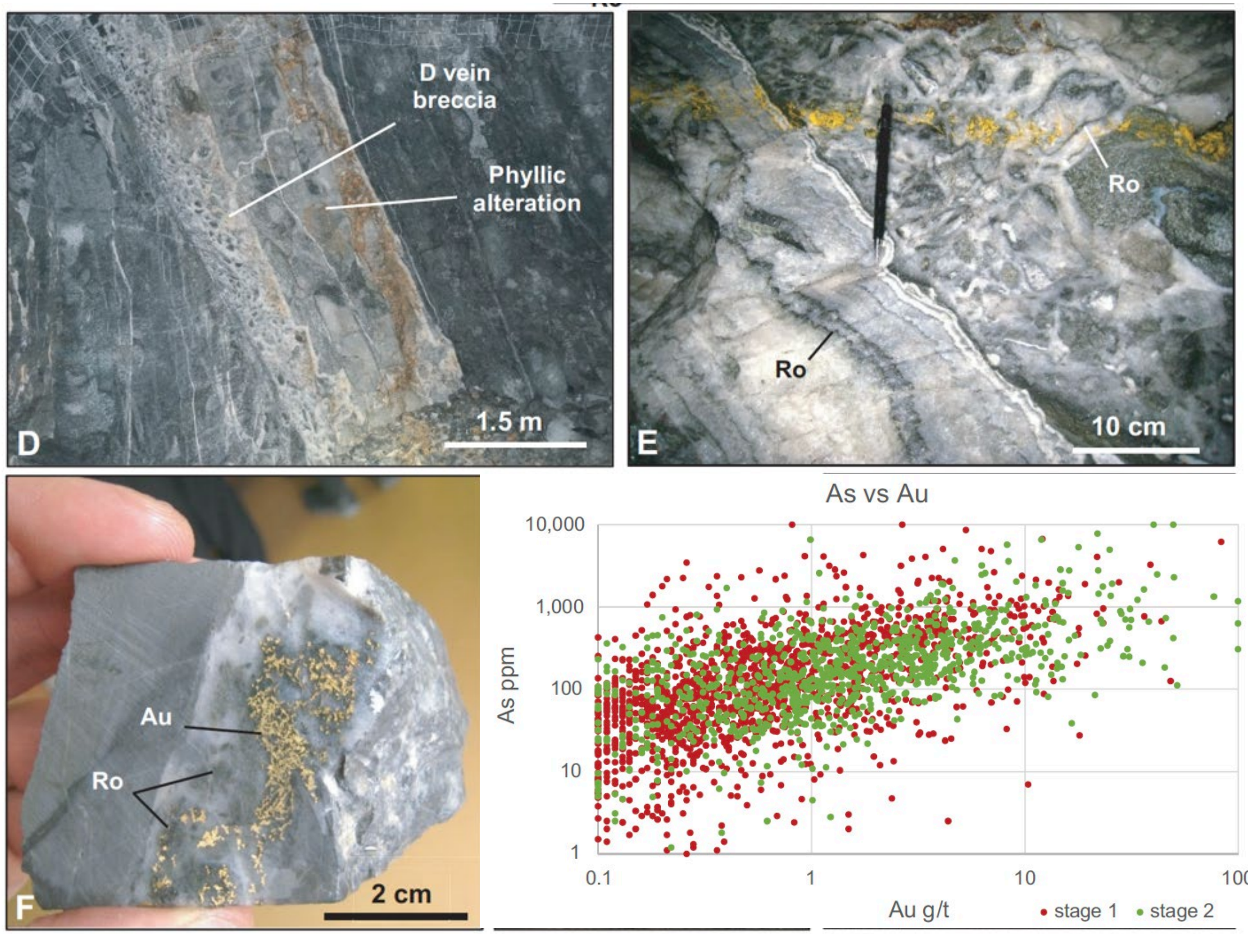

Lihir Alkalic Epithermal Gold Deposit, Papua New Guinea

David R. Cooke,[1,2] Stephanie Sykora,[1,2,*] Erin Lawlis,[1] Jacqueline L. Blackwell,[1,**] Mathieu Ageneau,[1,3] Nicholas H. Jansen,[1,***] Anthony C. Harris,[3] and David Selley[1]

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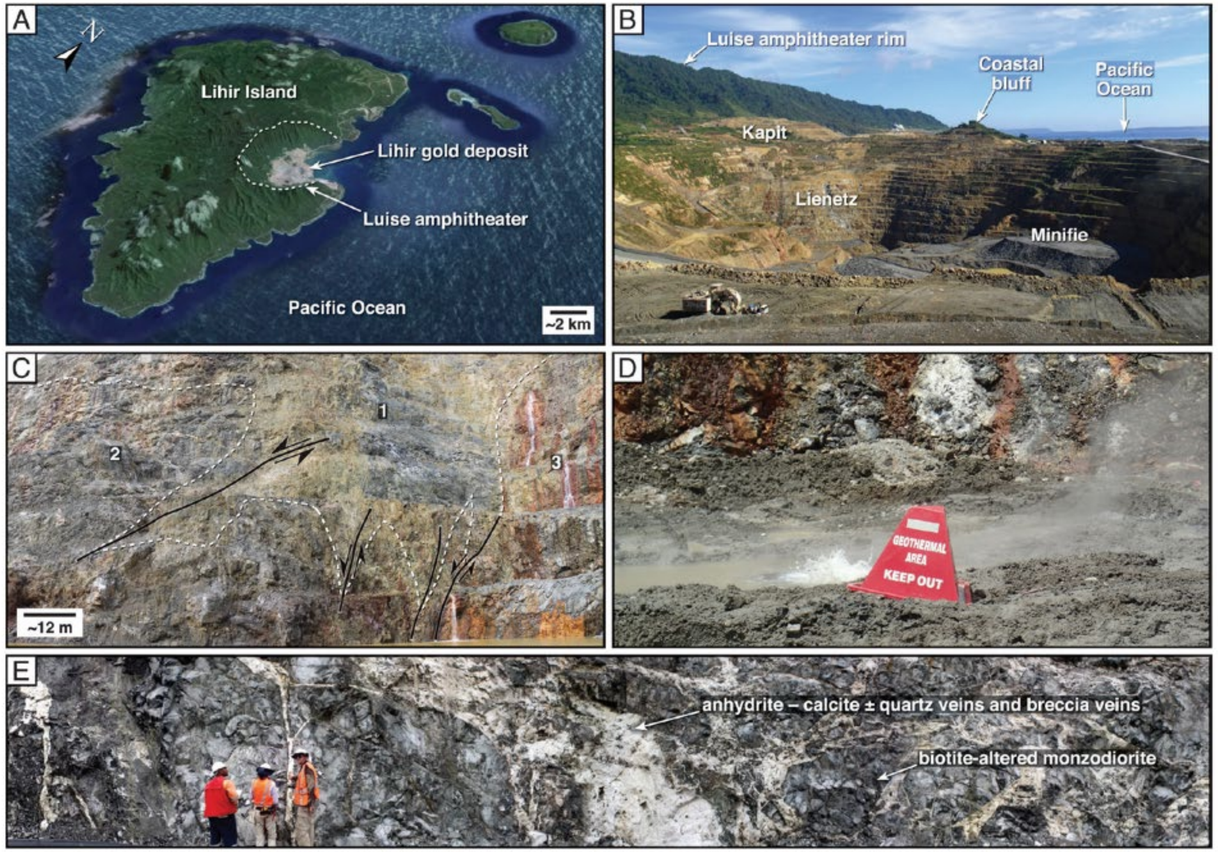
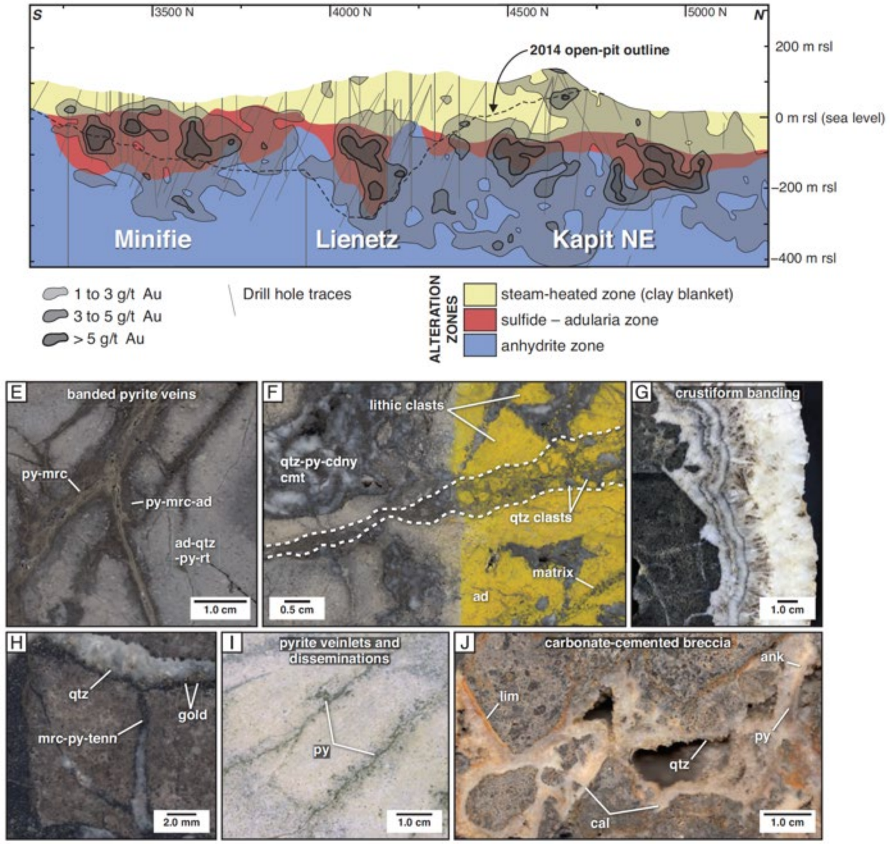
[2]*Transforming the Mining Value Chain, an Australian Research Council Industrial Transformation Research Hub, University of Tasmania, Private Bag 79, Hobart, Tasmania, 7001, Australia*

[3]*Newcrest Mining Ltd., 600 St Kilda Rd, Melbourne, Victoria 3004, Australia*

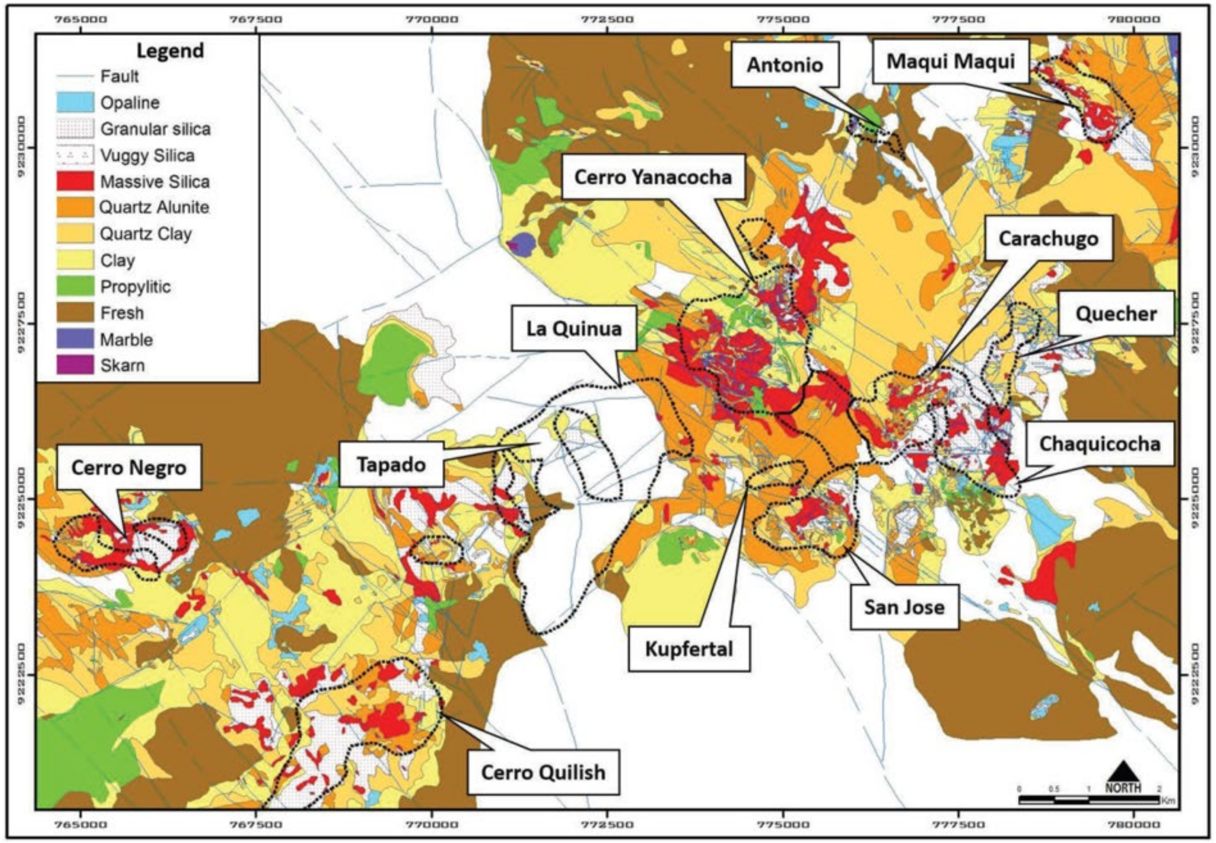


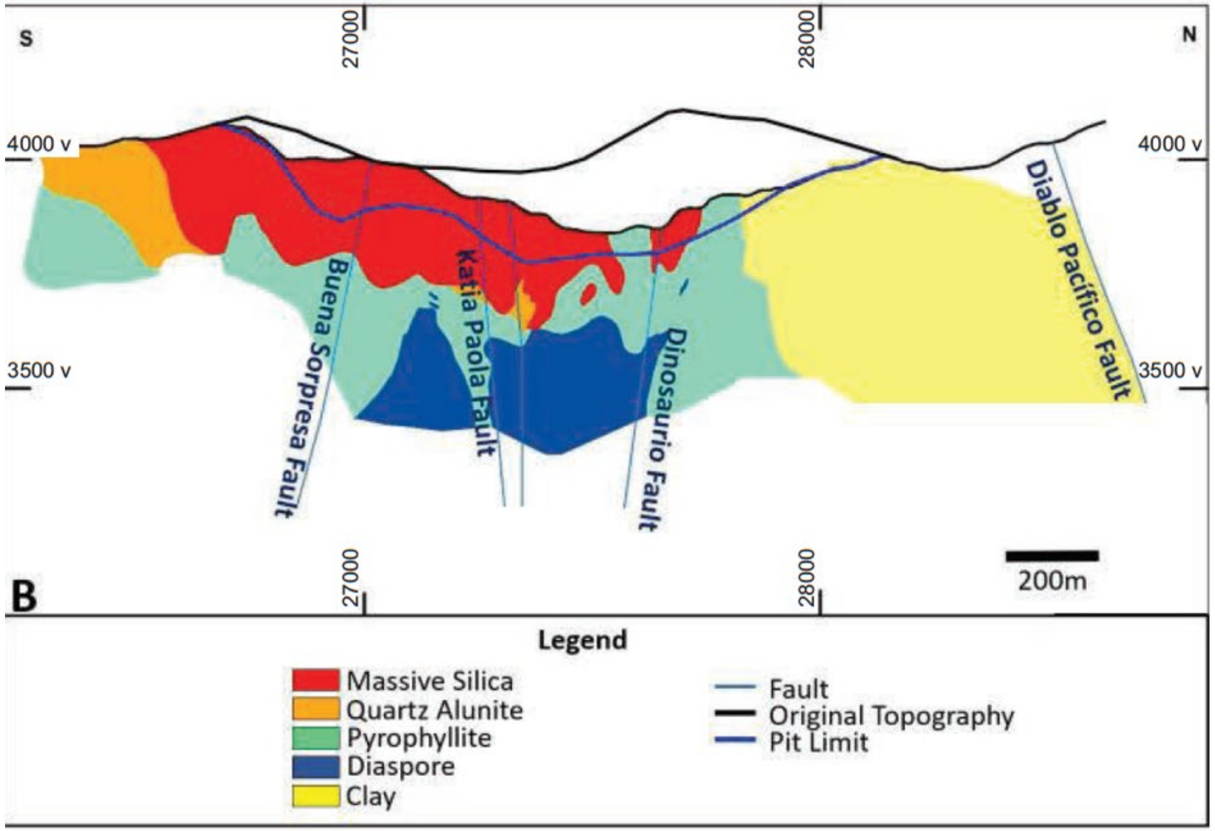


Gold Deposits of the Yanacocha District, Cajamarca, Peru

Richard Pilco† and Sean McCann

Newmont Perú Ltd., La Paz Av. No.1049, Urb. Miraflores, Lima, Peru





The Pueblo Viejo Au-Ag-Cu-(Zn) Deposit, Dominican Republic

Jeremy Vaughan,[1,†] Carl E. Nelson,[2] Guillermo Garrido,[1] Jose Polanco,[3] Valery Garcia,[3] and Arturo Macassi[3]

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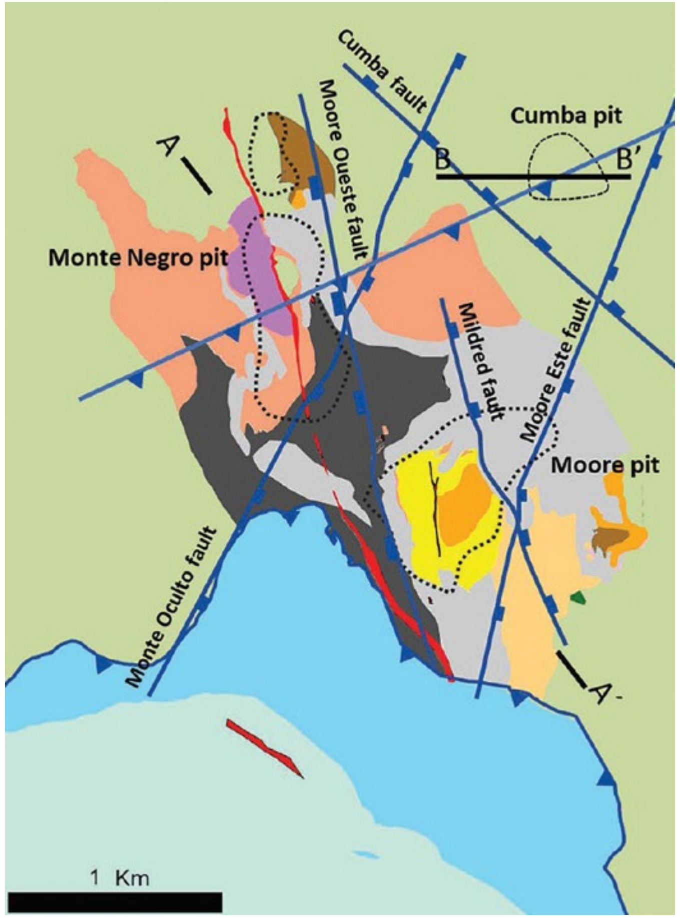

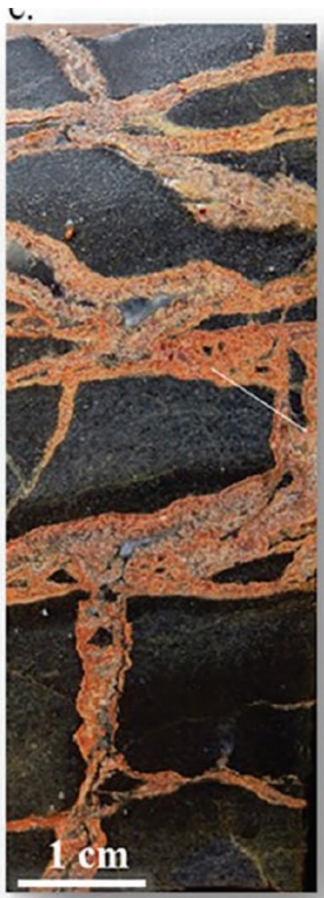

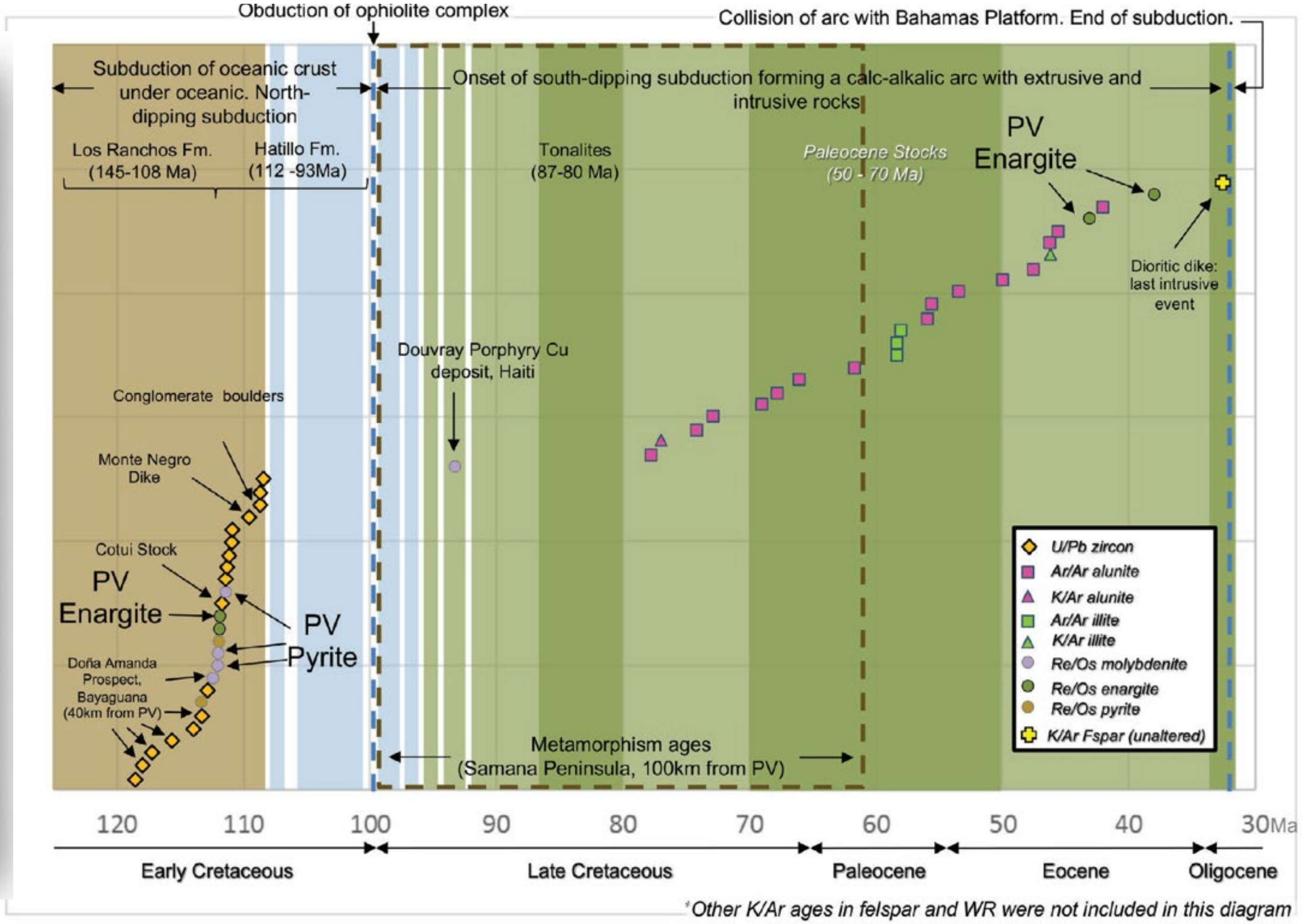

Geology of Round Mountain, Nevada: A Giant Low-Sulfidation Epithermal Gold Deposit

David A. Rhys,[1] Nadia St. Jean,[2] Rodolfo Lagos,[2] David Emmons,[3] George A. Schroer,[4] and Richard Friedman[5]

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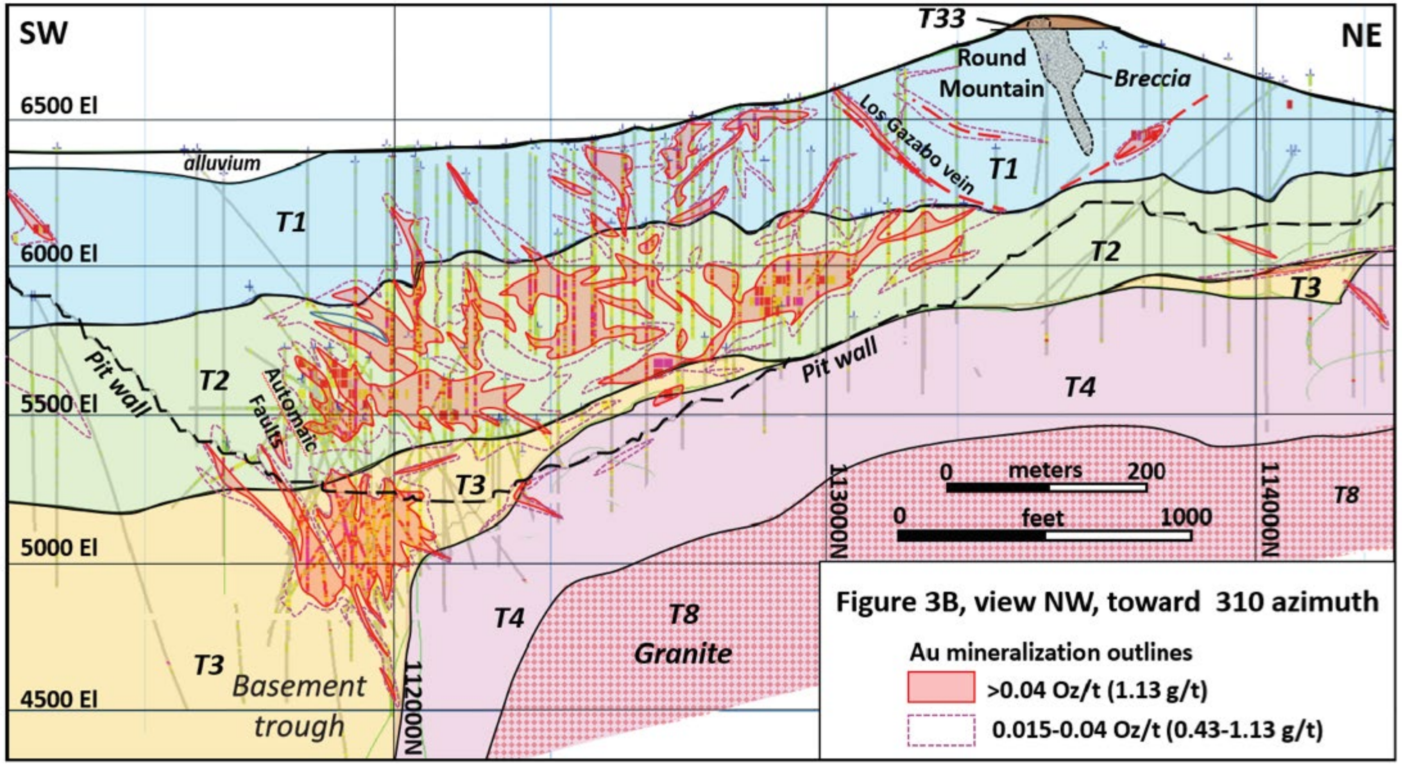
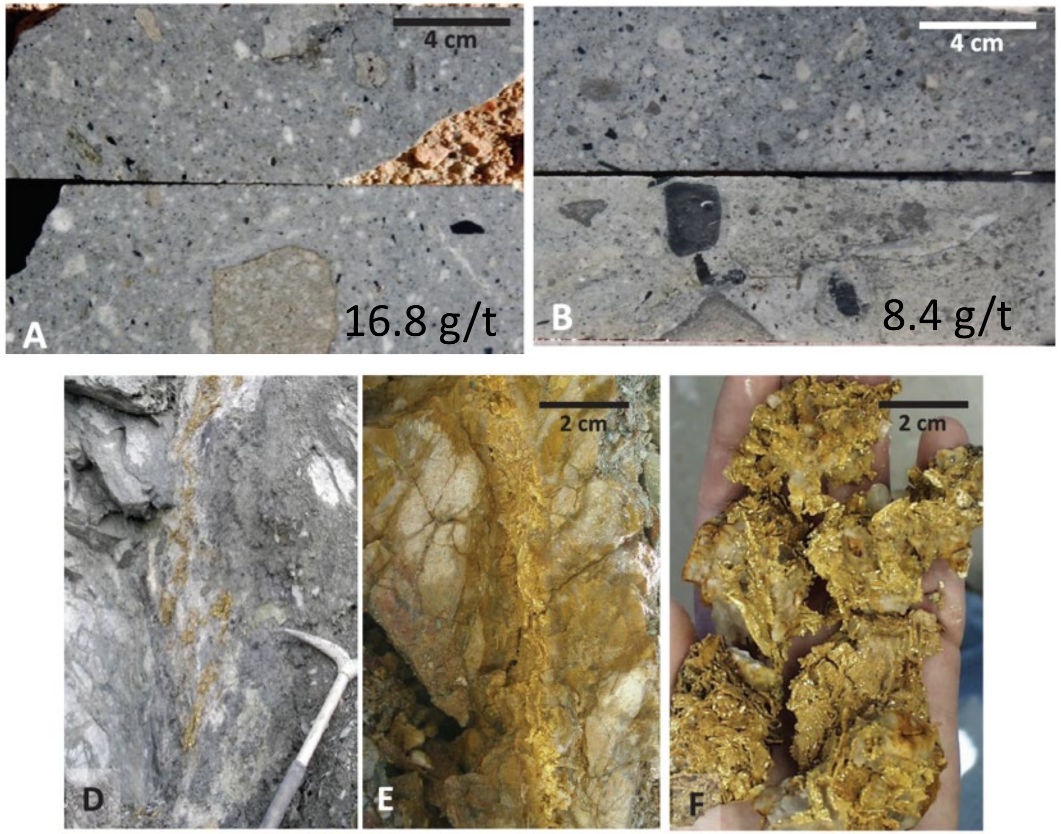
[2]Round Mountain Gold Corporation, P.O. Box 480, Round Mountain, Nevada 89045

[3]313 Golden Butterfly Drive, Leander, Texas 78641

[4]Kinross Gold USA, 1150 Financial Blvd., Reno, Nevada 89502

[5]Pacific Center for Isotopic and Geochemical Research, University of British Columbia, Vancouver, Canada V6T 1Z4





Geology of the Fruta del Norte Epithermal Gold-Silver Deposit, Ecuador

Stephen Leary,[1,†] Richard H. Sillitoe,[2] Jorge Lema,[3] Fernando Téliz,[4] and Diego Mena[3]

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[2]27 West Hill Park, Highgate Village, London N6 6ND, United Kingdom

[3]Lundin Gold Inc., Av. Amazonas N37-29 y UNP Edificio, Eurocenter, Piso 5, Quito, Ecuador

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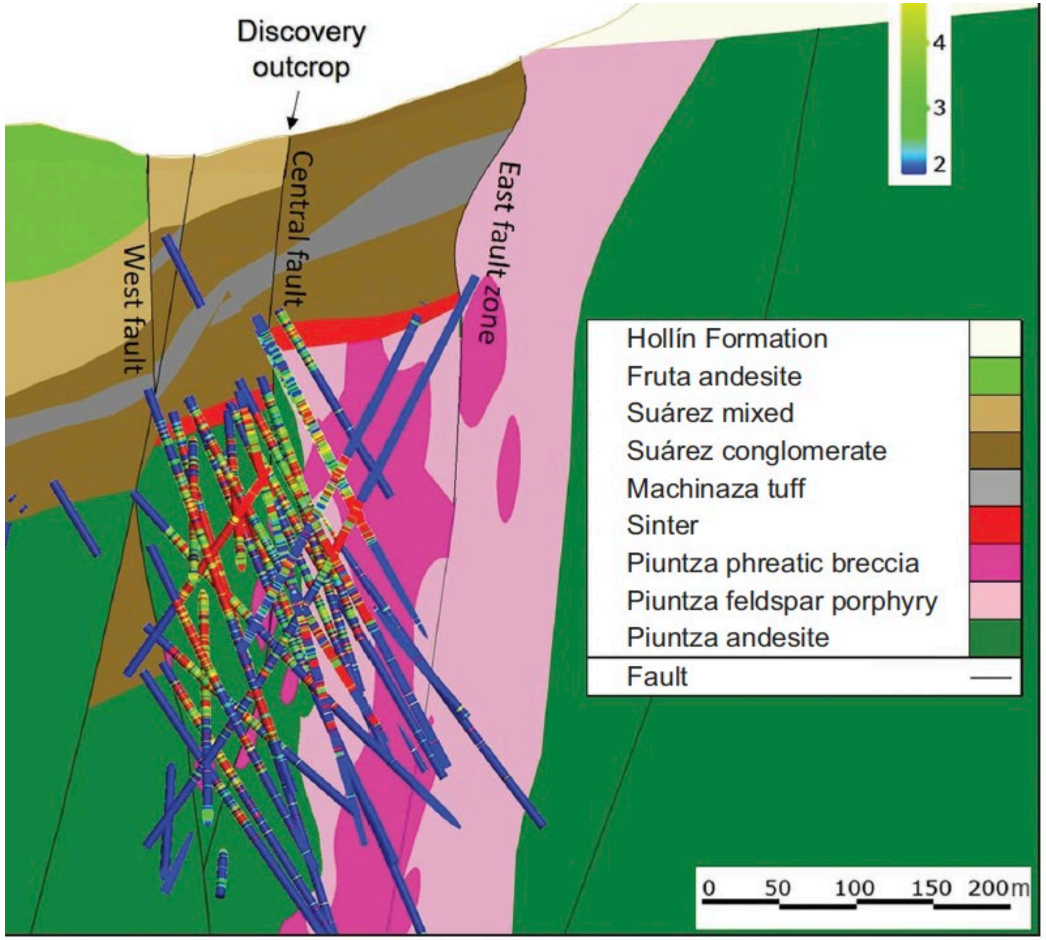
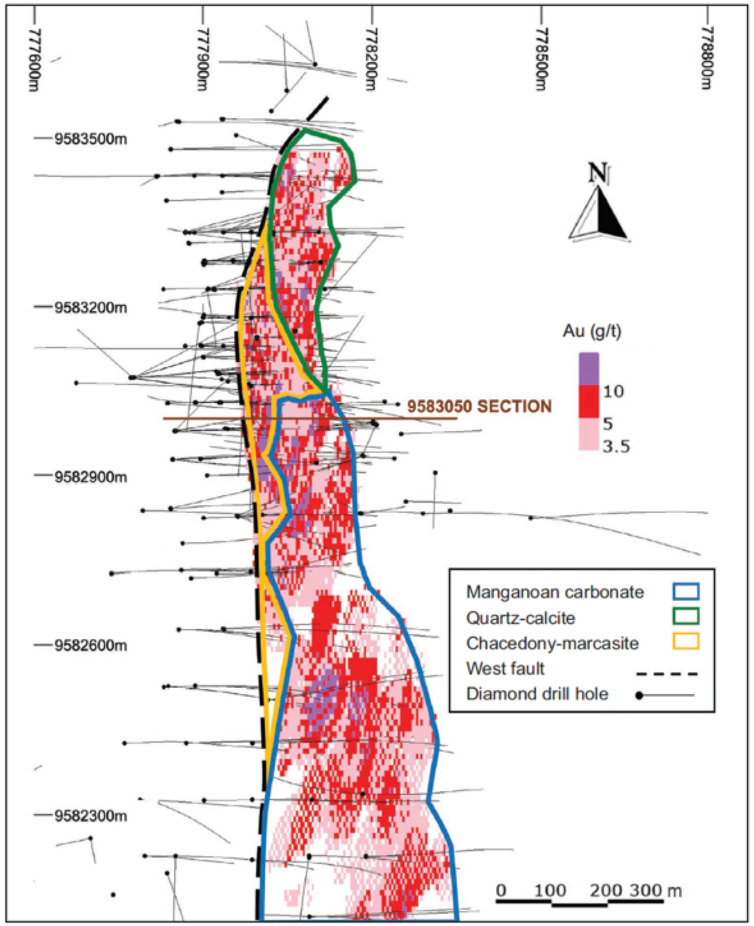
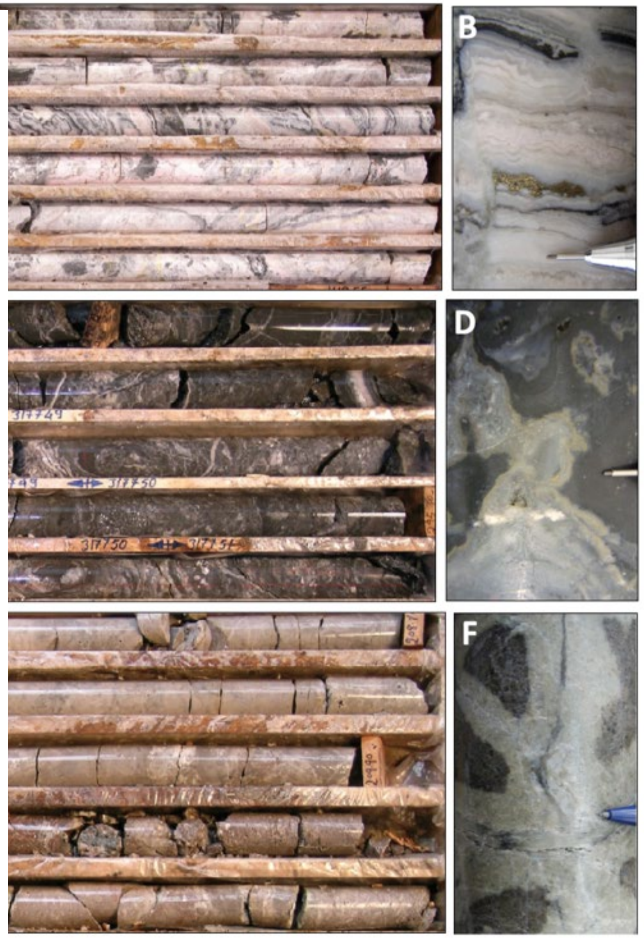






Geology of the Hishikari Gold Deposit, Kagoshima, Japan

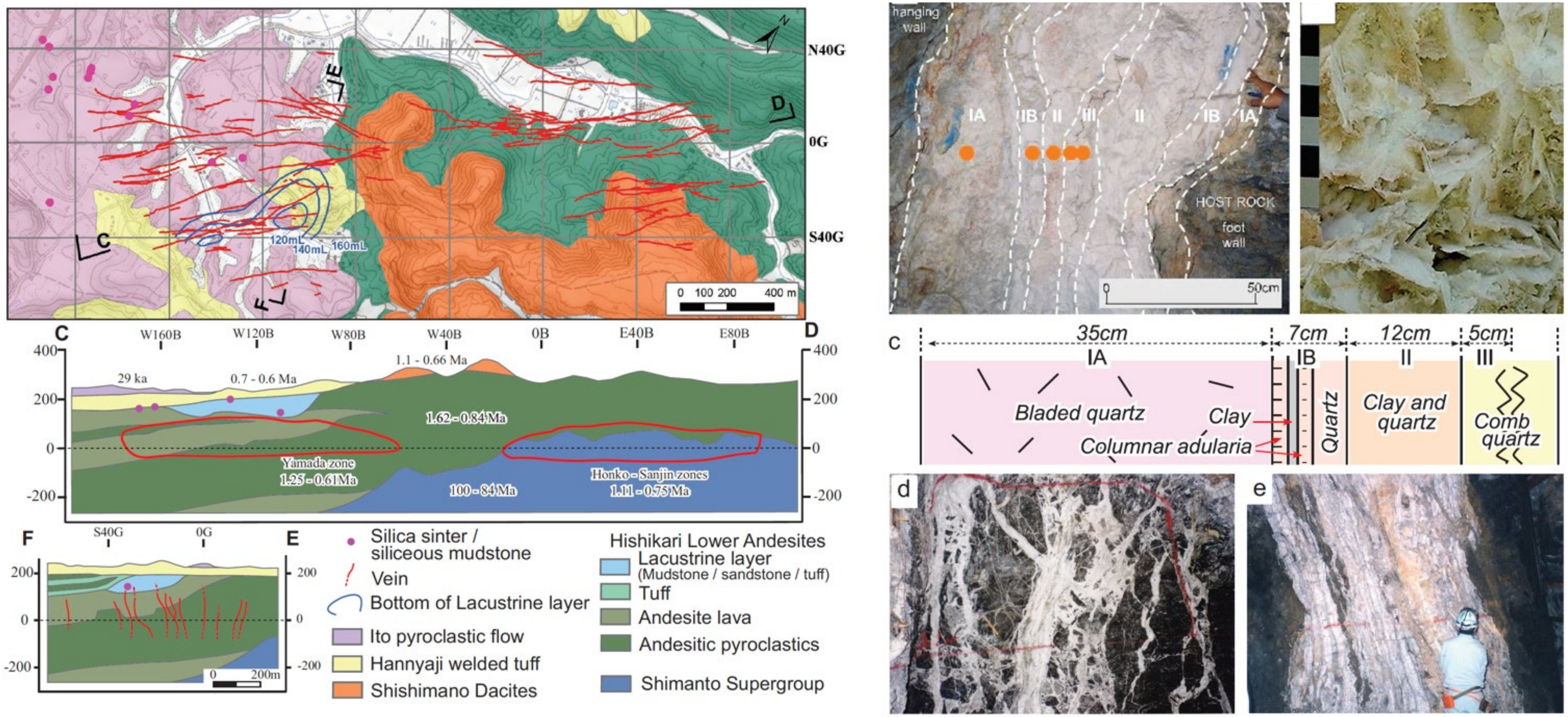
Takayuki Seto,[1] Yu Yamato,[2] Ryota Sekine,[3] and Eiji Izawa[4,†]

[1]Sumitomo Metal Mining Co., Ltd., Hishikari Mine, 3844, Hishikarimaeme, Isa, Kagoshima, 895-2701 Japan

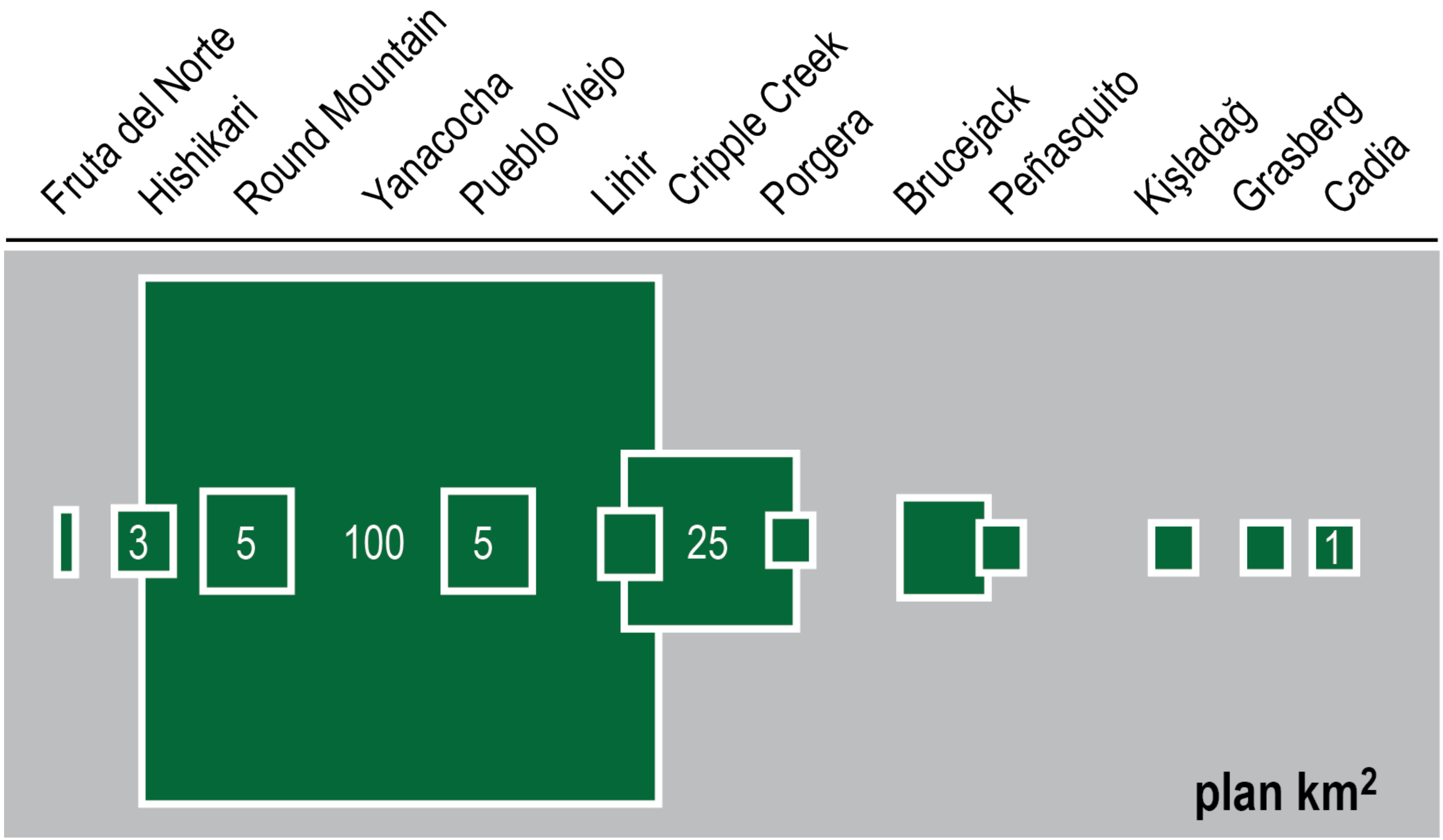
[2]Sumiko Resources Exploration and Development Co., Ltd., 8-21,3-Chome, Toranomon Minato, Tokyo, 105-0001 Japan

[3]Sumitomo Metal Mining Co., Ltd., 11-3 Shimbashi 5-Chome, Minato, Tokyo, 105-8716 Japan

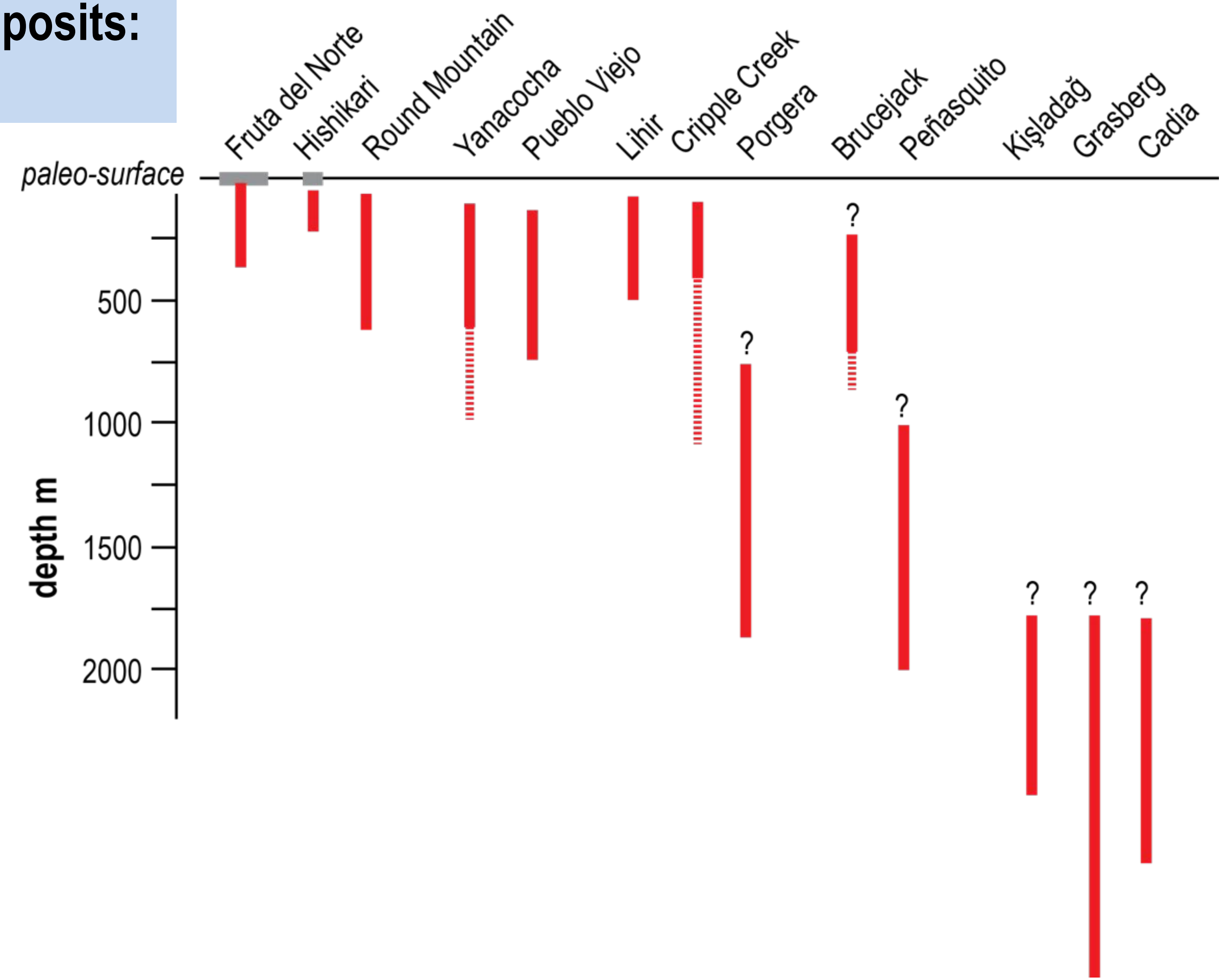
[4]2-15-4 Sakurayamate, Shingu, Fukuoka 811-0113 Japan



Porphyry to Epithermal Deposits: *Footprints of Ore Bodies*



Porphyry to Epithermal Deposits: *Depth & Interval*



Carlin & Archean Orogenic

Francois Robert

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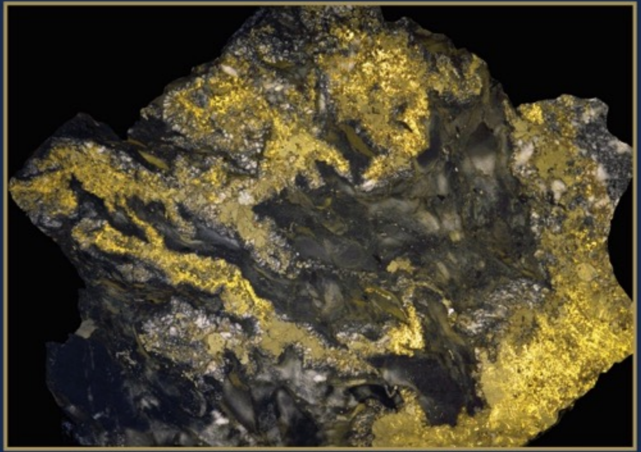

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Carlin deposits in Nevada (Muntean)

Prolific N Central Nevada

- **250 Moz** in 250 x 300 km
- Major production center: **~4.5 Moz/y**

Well-known characteristics

- Replacements & breccias in silty carbonate
- Au in As-pyrite rims; As-Hg-Sb-Tl-Ba
- Eocene, low-T and shallow crustal depth

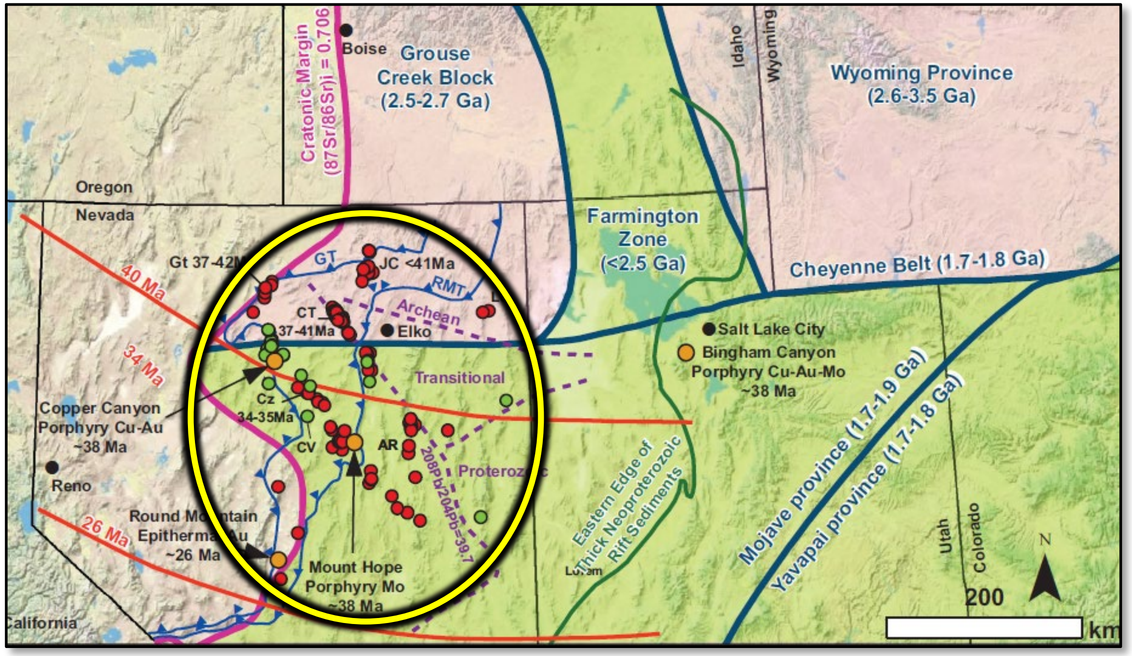
Unique regional setting

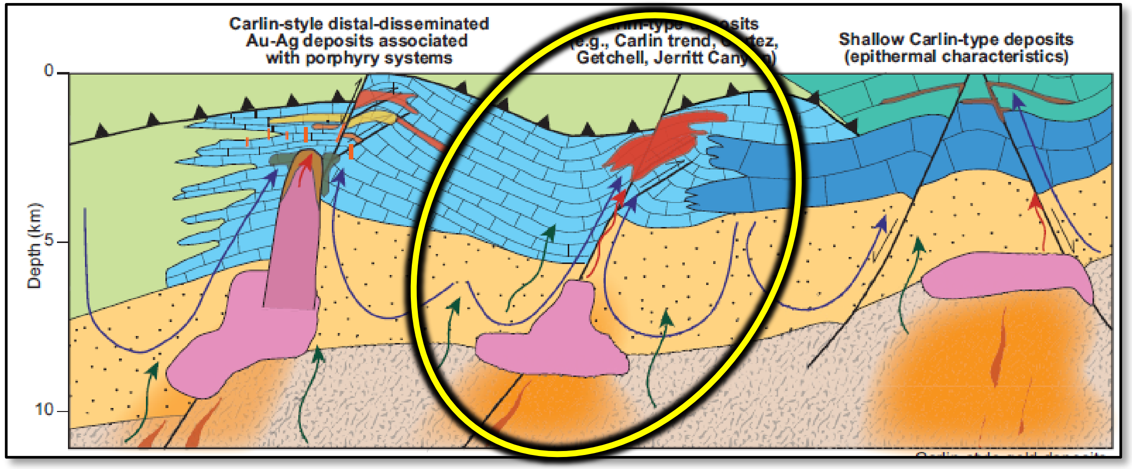
- Precambrian deep crustal architecture
- Favorable Eocene tectonics

Large deposits along 4 Trends

- Deep structures and magma conduits in J, K, E
- Eocene Carlin and Miocene epithermal

Link with deep processes, heat source and gold source?



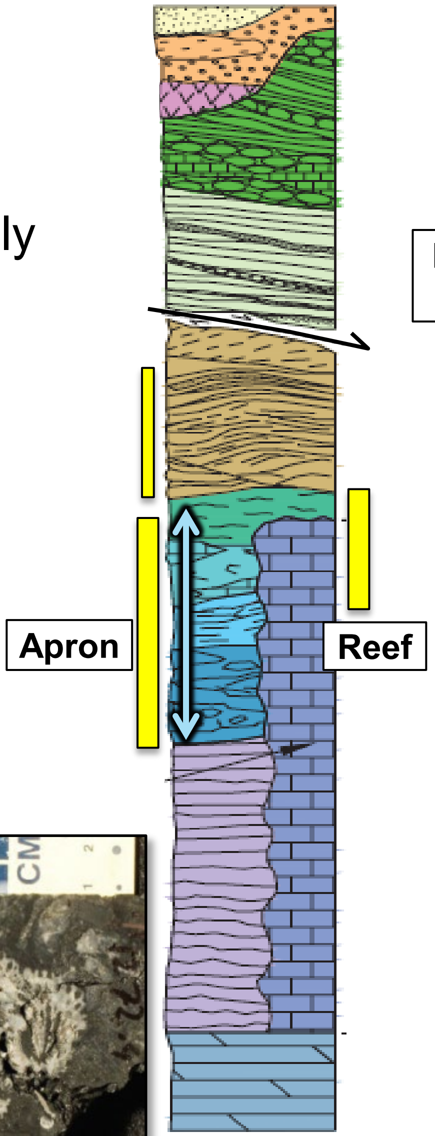


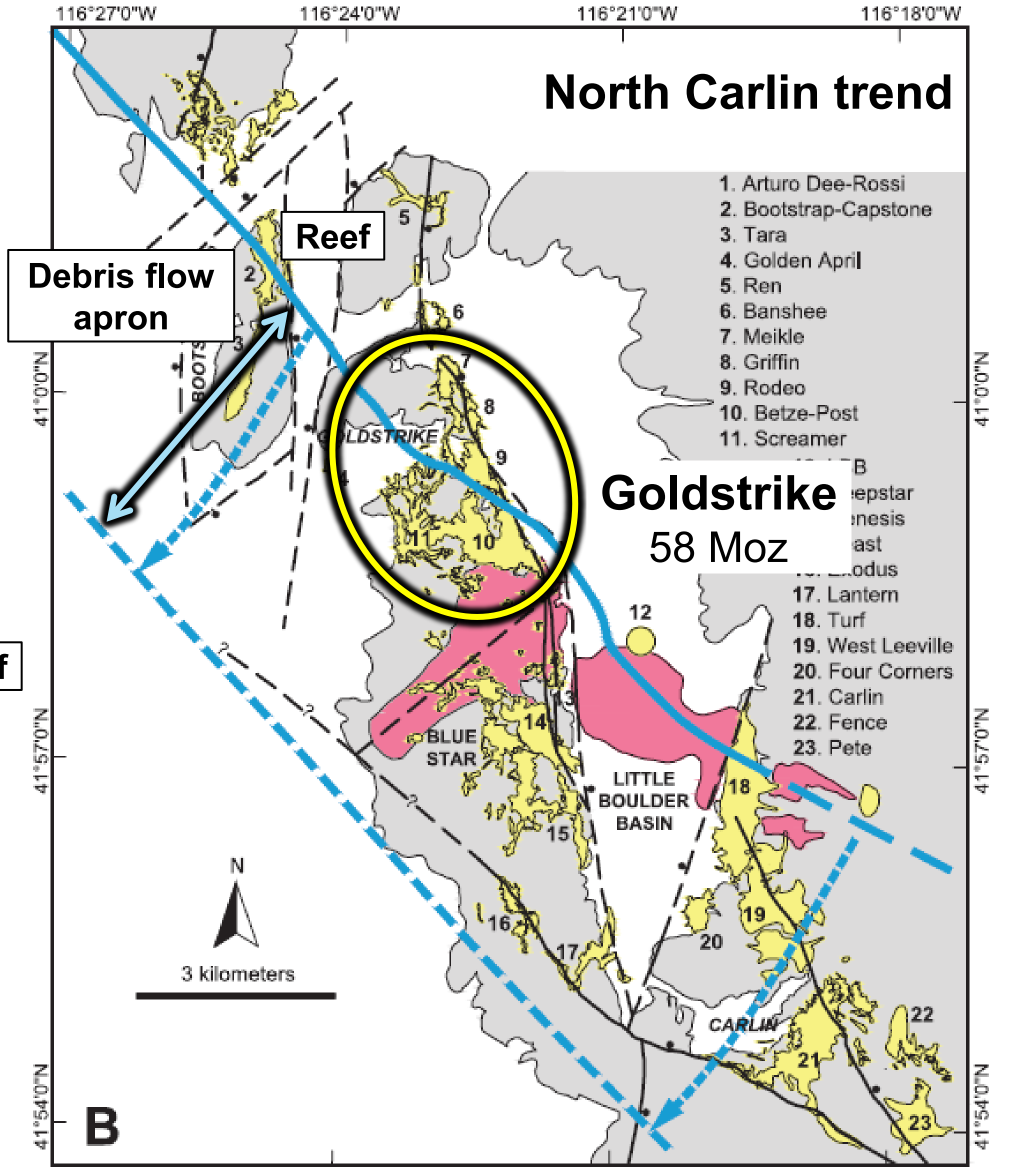
Goldstrike (Dobak et al.)

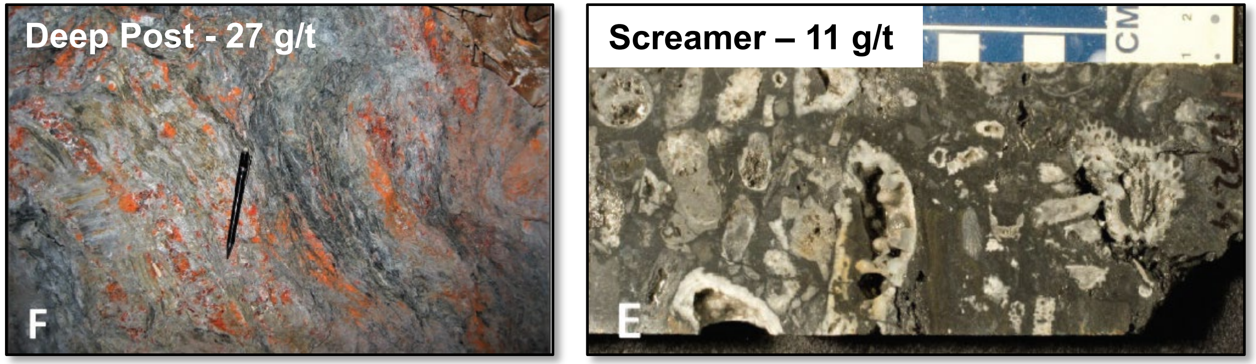
58 Moz @ 6 g/t Au
- Largest and type example
- 4.5 x 2 km within 20 x 40 km thermal anomaly

Unique pre-mineral structural confluence
- Trend-parallel J lamprophyre dike swarm
- Intersection of swarm with reef
- J stocks at intersection

Favorable sedimentary units
- Debris flows shedding from exposed reef
- Reactive rocks with elevated available Fe







Cortez district (Bradley et al.)

District = 47 Moz

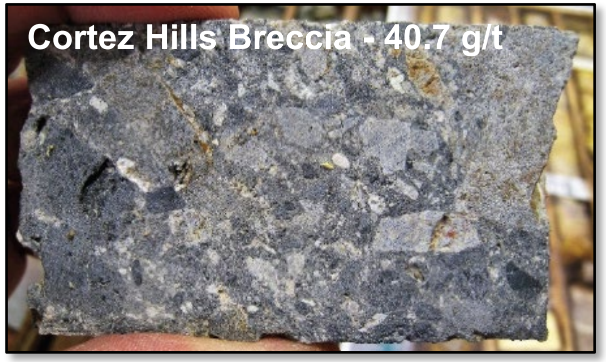
- 3 deposits >10 Moz
- Goldrush: 11.3 Moz @ 9.5 g/t; >5 km x ~400m

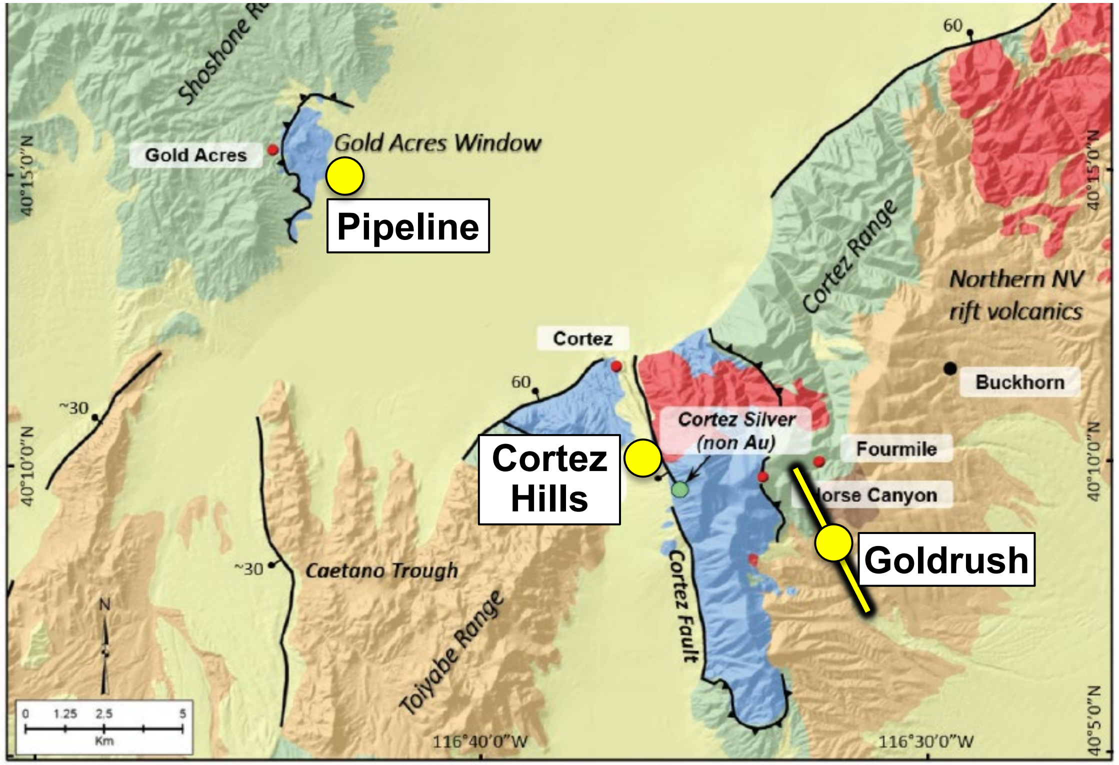
Typical Carlin characteristics

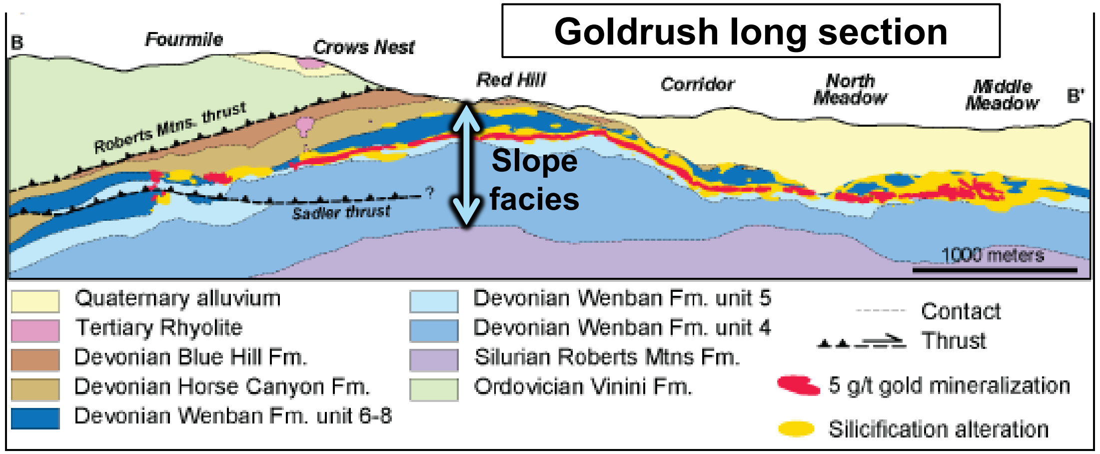
- Collapse bx to passive replacements
- From compact bx pipe to long linear zones

Controls

- EQ strata to Goldstrike: units with debris flow
- Open anticlines and thrusts
- K and J stocks and metamorphic haloes







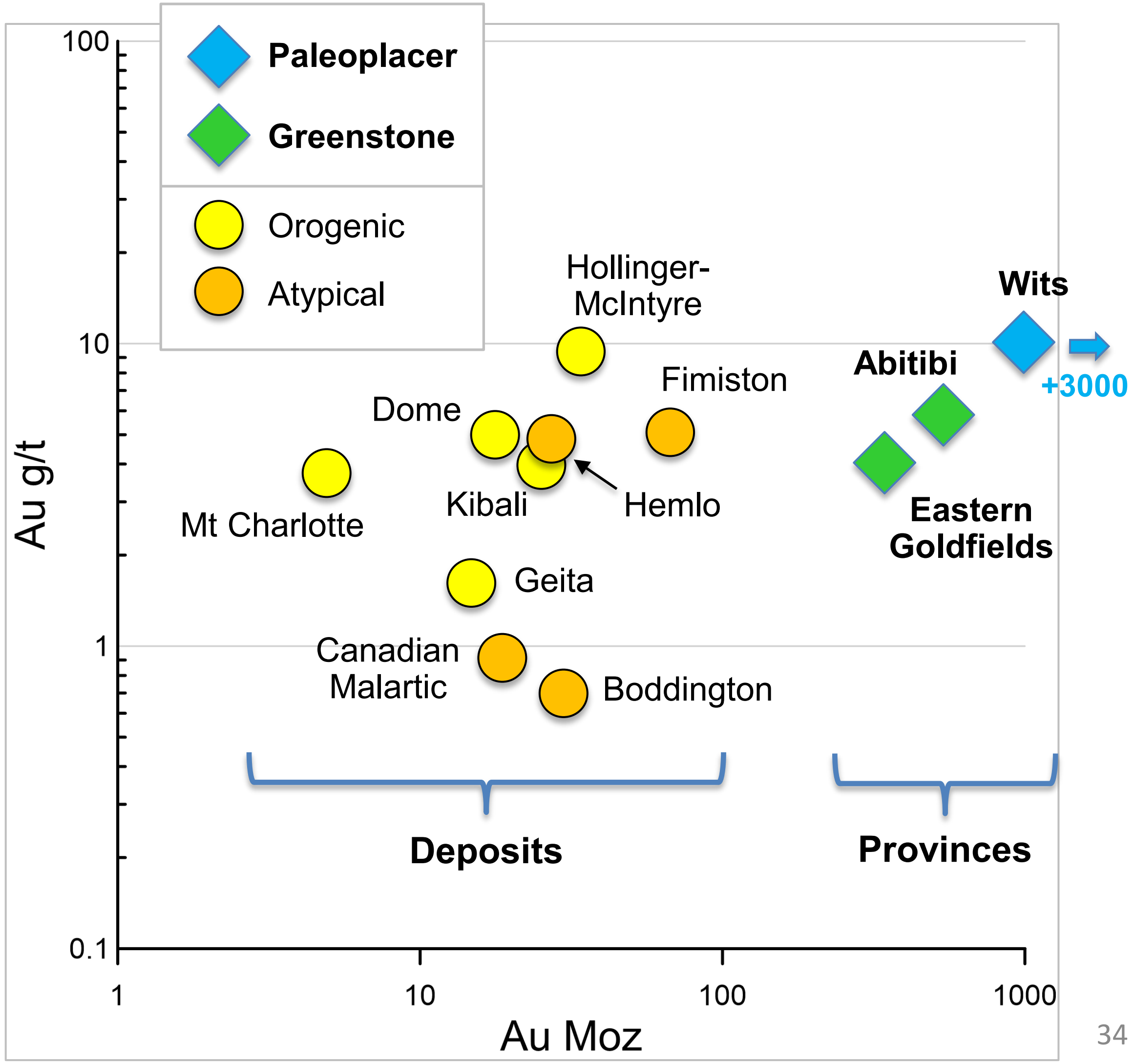
Archean deposits: paleoplacer and greenstone gold

Provinces
- Witwatersrand, Abitibi, Eastern Goldfields

Camps
- Timmins (Hollinger-McIntyre, Dome)
- Malartic (Canadian Malartic)
- Golden Mile (Mt Charlotte, Fimiston)

Deposits
- Orogenic: Hollinger-McIntyre, Dome, Geita, Kibali, Mt. Charlotte
- Atypical: Boddington, Canadian Malartic, Fimiston, Hemlo

Greenstone gold highlights
- Atypical deposits remain enigmatic
- Diversity and multiple ages recognized
- Overprinting of types in many deposits



Witwatersrand Goldfields (Frimmel and Nwaila)

Syngenetic origin proposed

- Initial fixation on microbial mats
- Reworking in fluvial channels & eolian deflation surfaces
- Subsequent local hydrothermal modification

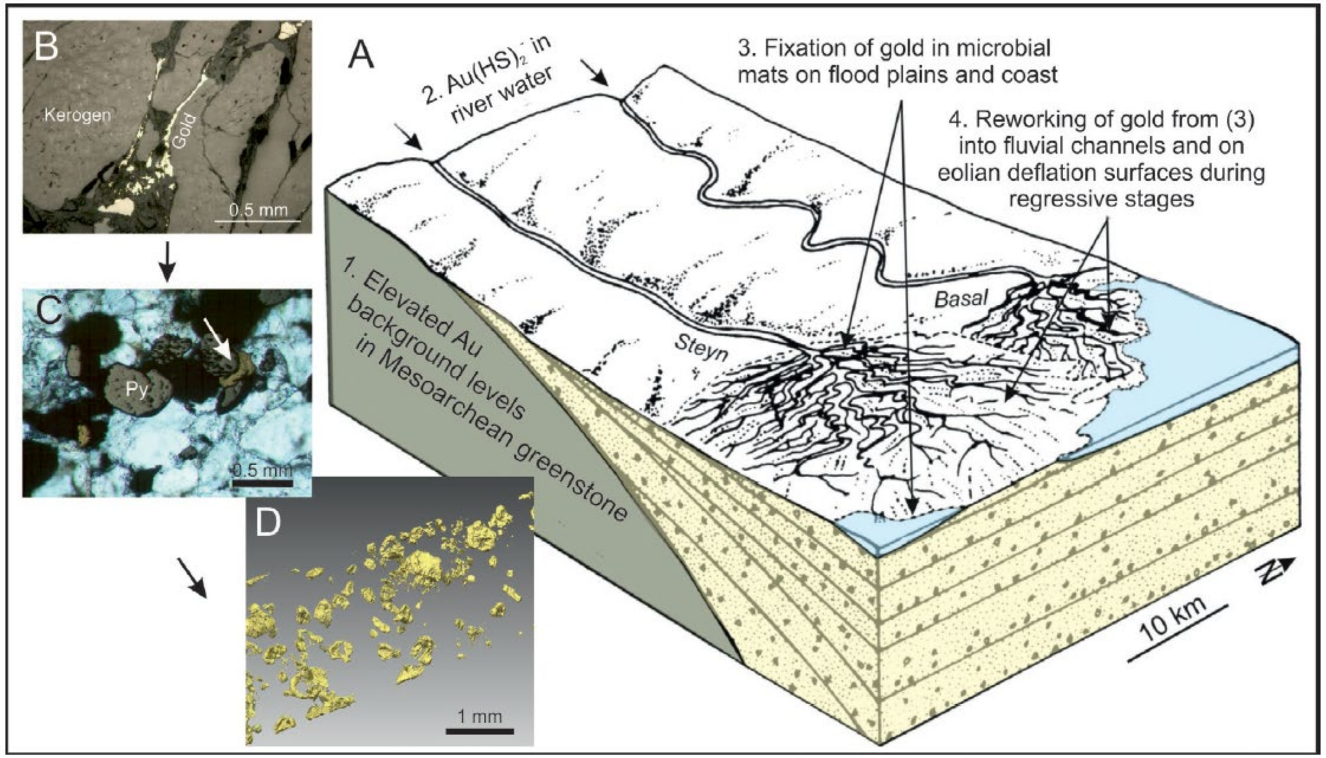
Supporting evidence

- Sedimentologic controls across scales
- Grade vs clast size correlation
- Mechanically deformed Au micro-nuggets with secondary Au overgrowths

Uniqueness

- Exceptional preservation of possibly more widespread Mesoarchean process

Schematic syngenetic model



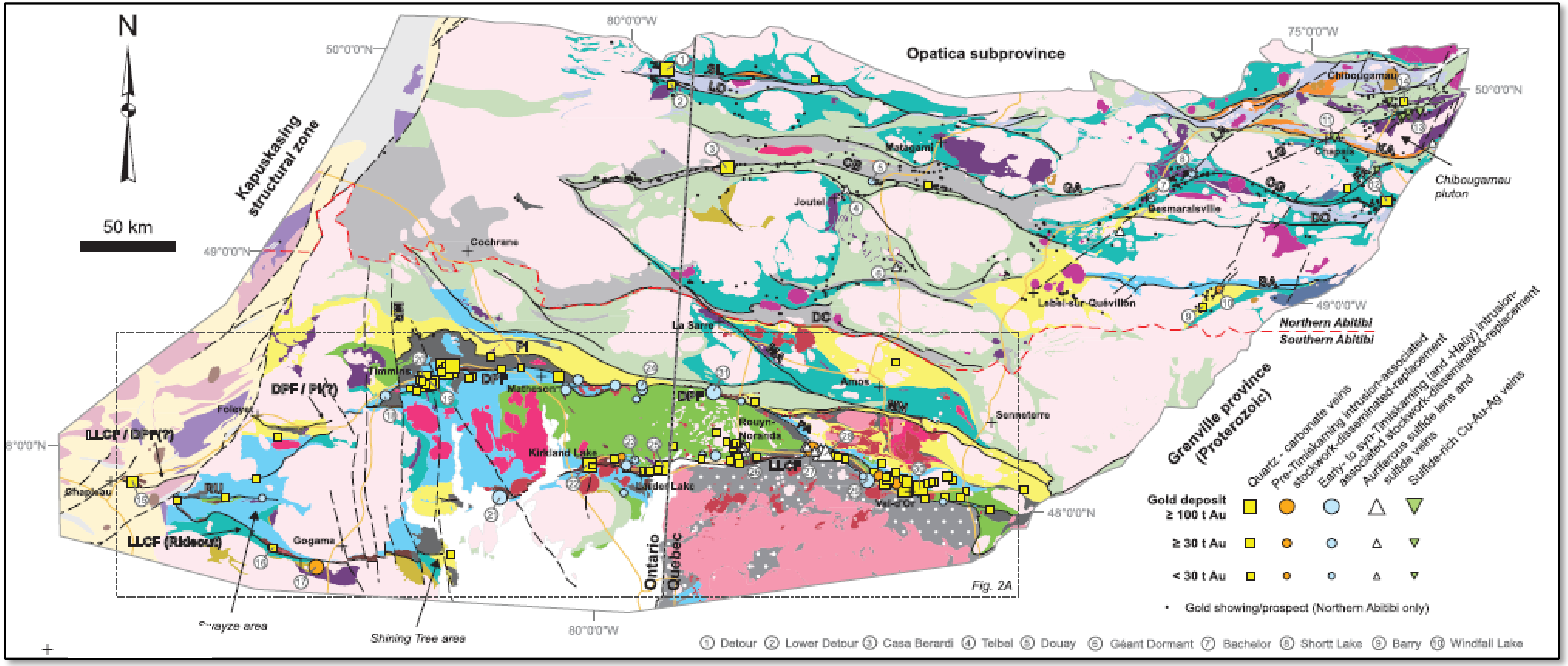
Abitibi Province (Dubé and Mercier-Langevin)

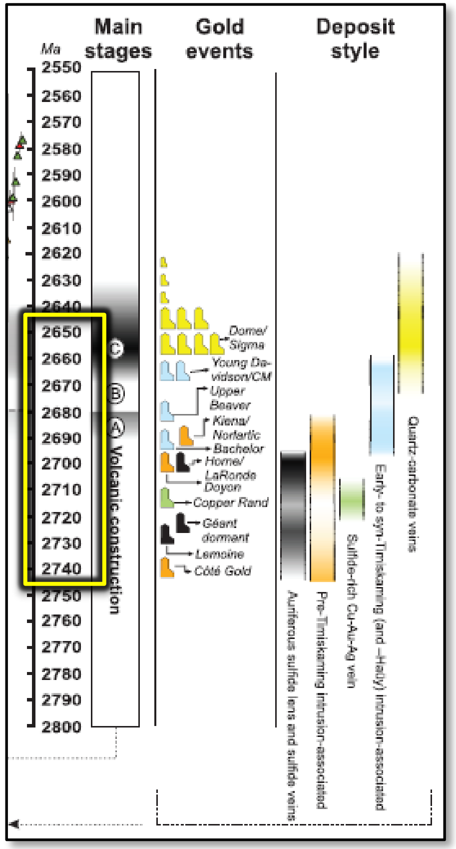
New synthesis of geology, evolution and gold

- Chronostratigraphic map
- Well-constrained evolution

Documents range of deposit types and ages

- Sulfidic (Au-VMS), intrusion-associated, orogenic
- Formed over ~90 my of Abitibi evolution



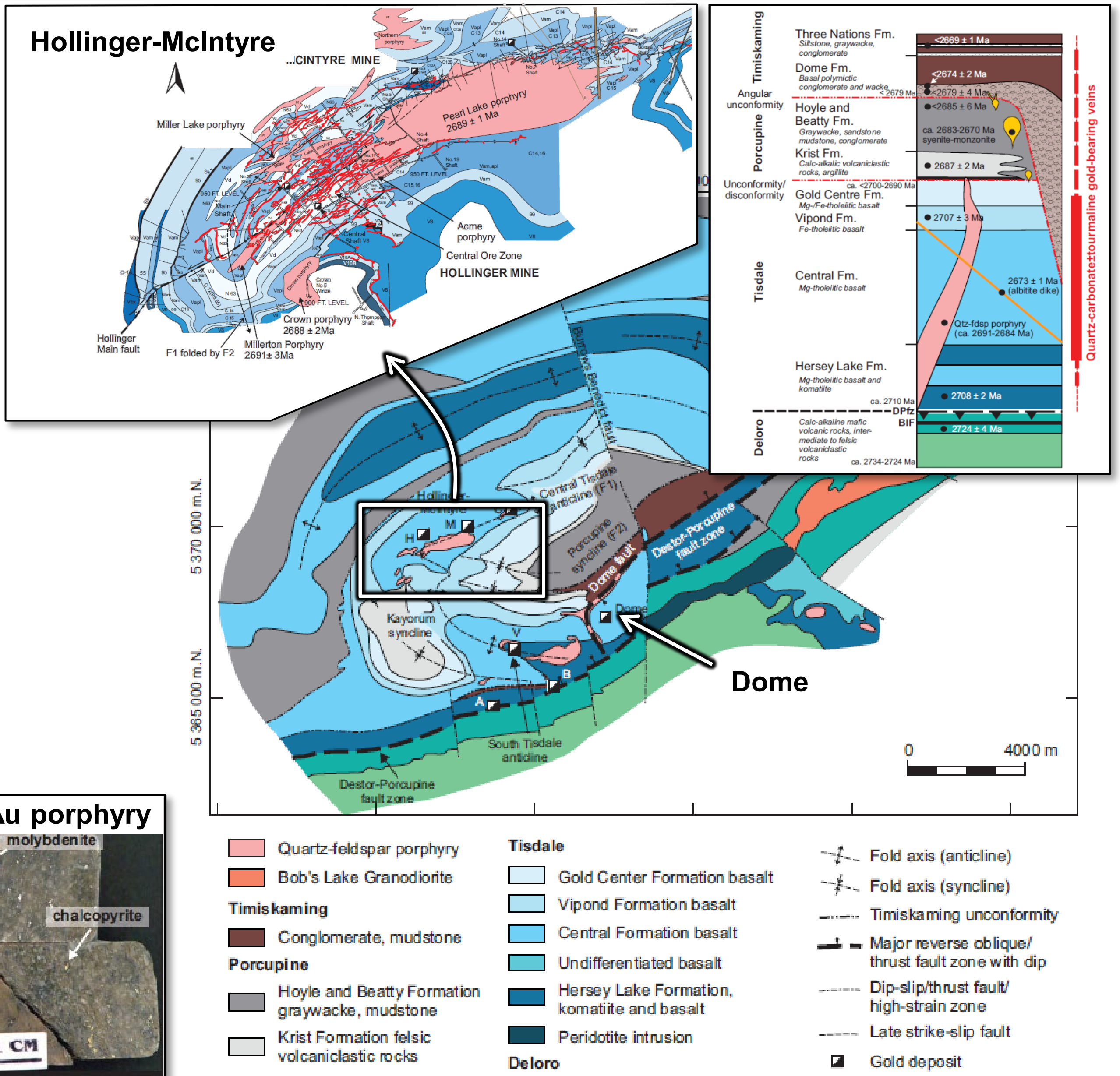


Timmins-Porcupine camp (Dubé et al.)

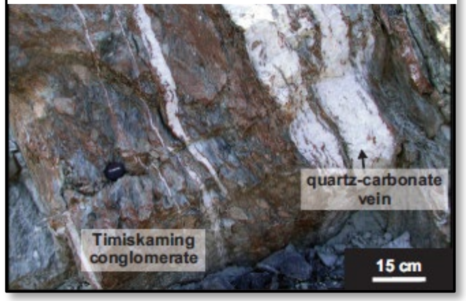
70.5 Moz; mainly orogenic qz-cb veins
- Hollinger-McIntyre = 33 Moz @ 9.5 g/t
- Dome = 17 Moz @ 4.8 g/t

Multiple Au styles and ages
- Dominant syn-shortening orogenic qz-cb veins
- Pre-unconformity ankerite veins (low Au)
- Pre-shortening Cu-Mo-Au porphyry

Updated stratigraphic / structural framework
- Folds, competency contrasts, anisotropy
- Unconformities marking favorable erosional depth

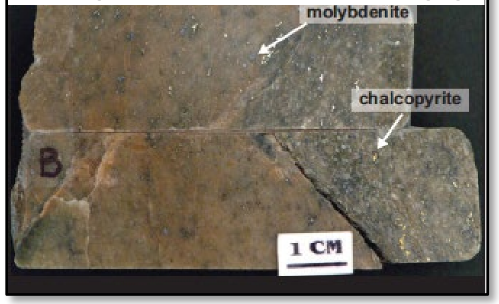


Dome - orogenic qz-cb veins



Dome - early ankerite vein

McIntyre - Cu-Mo-Au porphyry



Malartic camp (De Souza et al.)

32.5 Moz; mainly disseminated-stockwork

- Canadian Malartic = ~18 Moz @ 1 g/t

Canadian Malartic characteristics

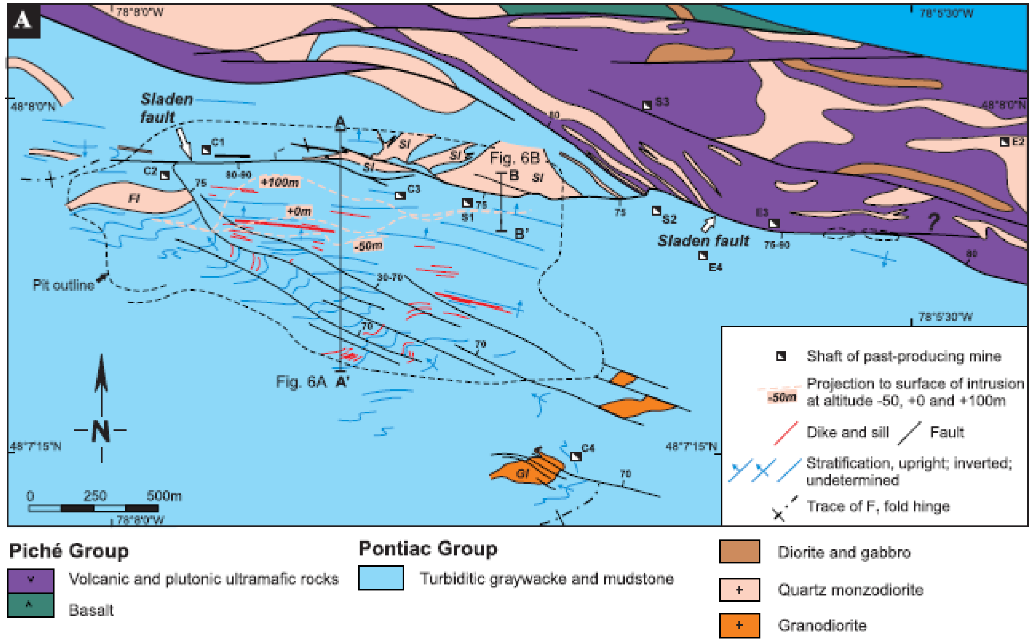
- Sediment-hosted, monzonite-associated
- Disseminated-stockwork/sheeted
- K-spar-carbonate alt'n
- Au-Ag (+/-Te, W, Bi, Mo, Pb)

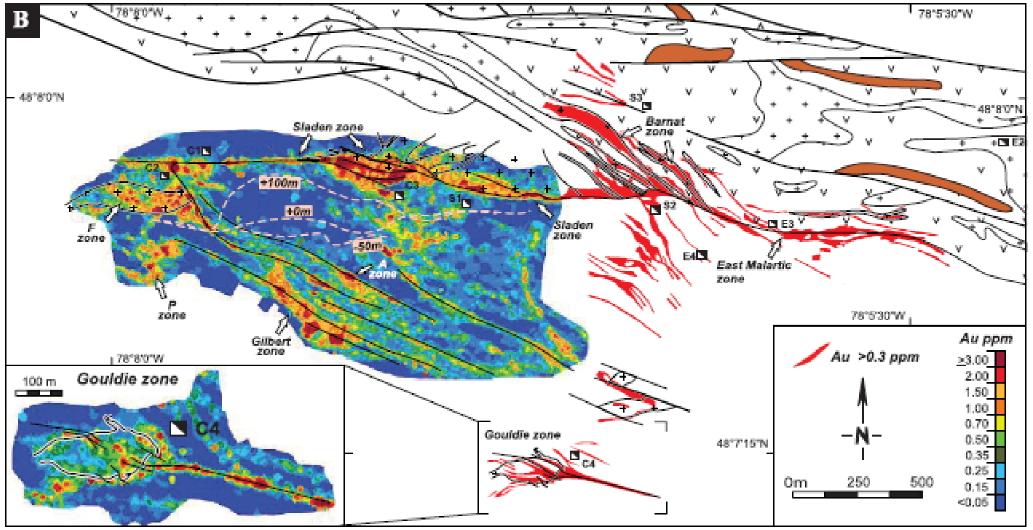
Timing constraints

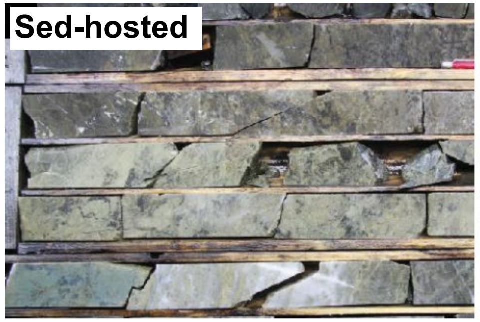
- Controlled by D_2 structures, cut by orogenic qz-cb-tm veins

Interpretation

- Syn- orogenic (D_2) deposit stockwork-disseminated







Hemlo (Poulsen et al.)

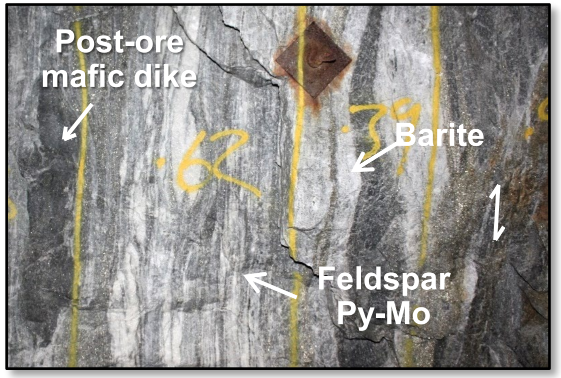
26 Moz @ 4.74 g/t

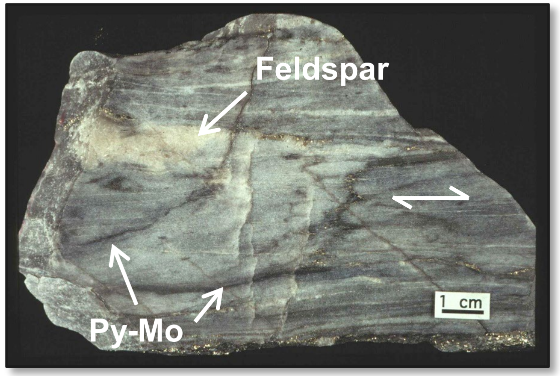
Characteristics

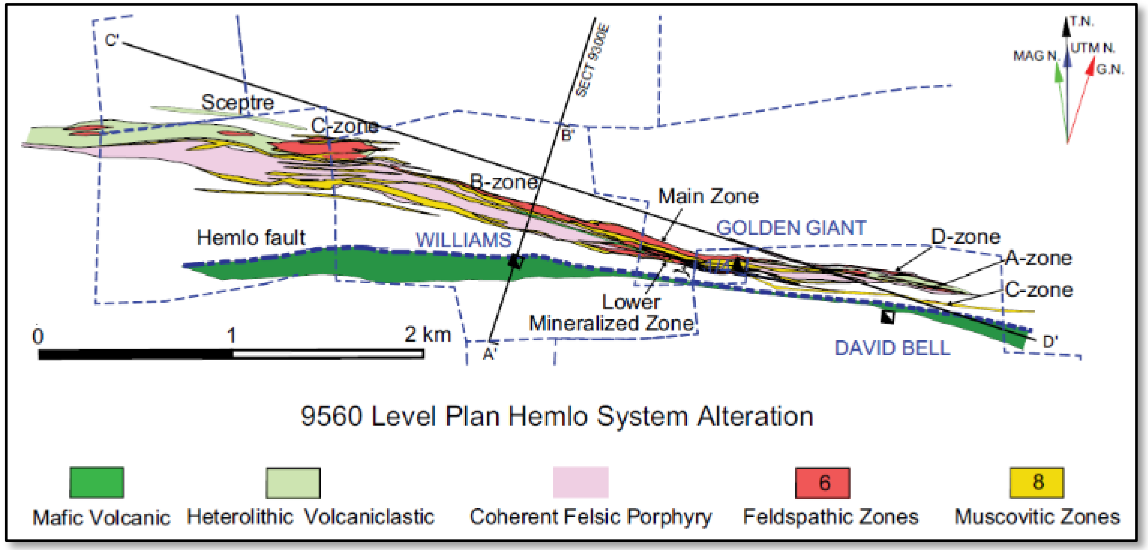
- Marginal to felsic porphyry in clastic rocks
- Disseminated-stockwork mineralization
- Au-Mo (V, Ba, Hg, Sb, Te)
- Feldspar (K, Na) + sericite alteration
- Highly strained with deformed post-ore dikes
- Overprinted by minor orogenic qz-cb veins

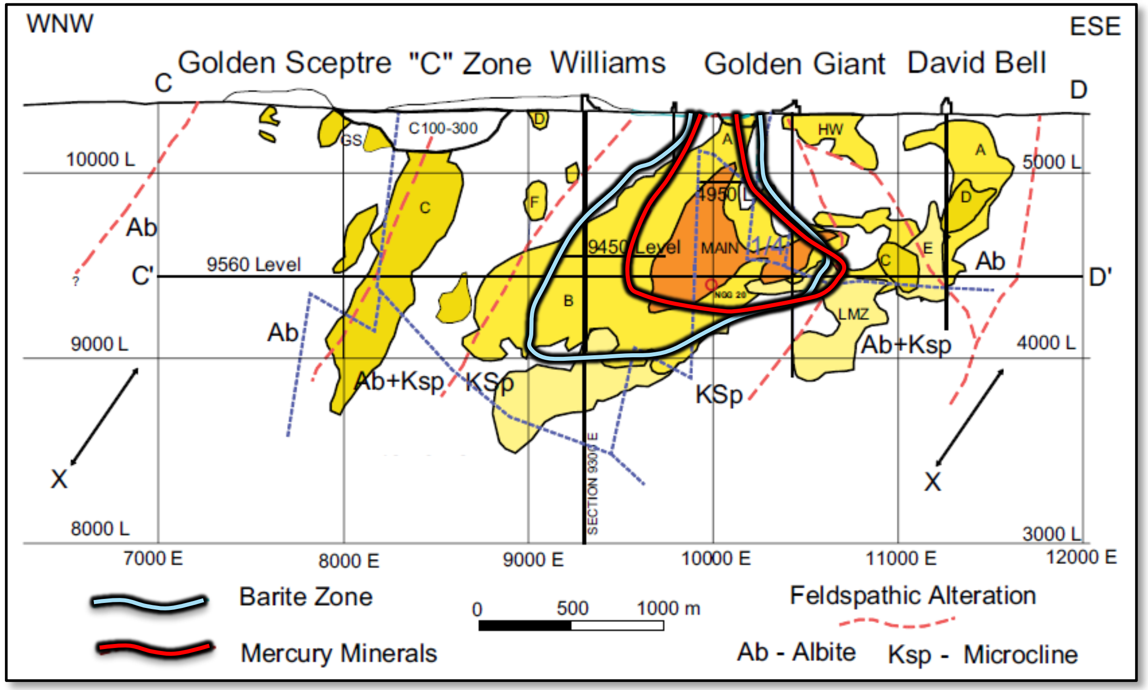
Interpretation

- Deformed/metamorphosed high-level system
- From oxidized hydrothermal fluid









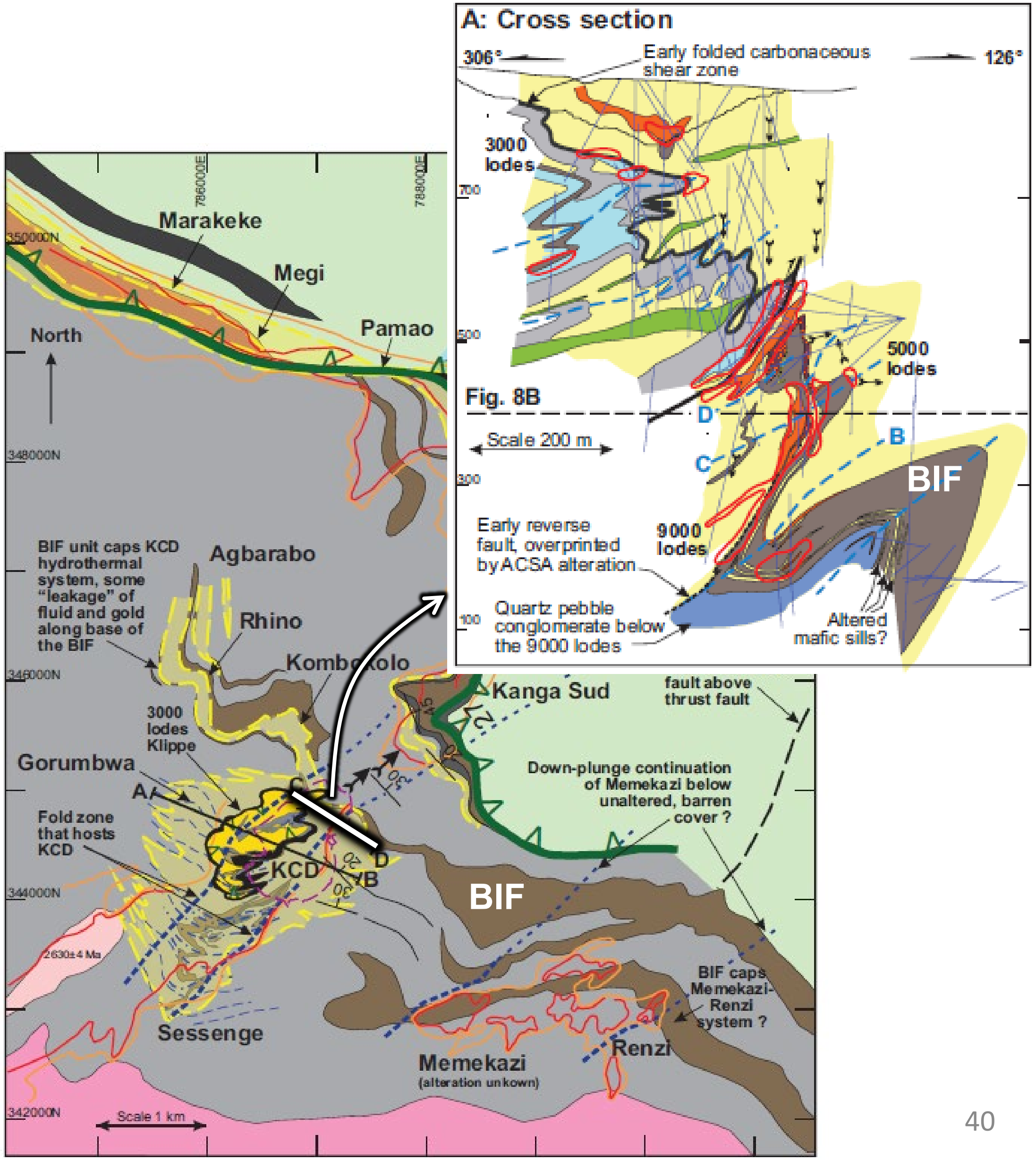
Kibali district (Allibone et al.)

23 Moz; ironstone replacement
- KCD = ~20 Moz @ 4.1 g/t

Characteristics
- In chert-magnetite BIF within clastic sequence
- Veinlet and replacement pyrite in BIF
- Proximal siderite-py-silica in BIF
- Broad halo of sericite-carbonate in host rocks
- Ore in hinges of stacked shallow-plunging folds
- Ore shoots +750 m down-plunge

Interpretation
- Typical BIF/Ironstone-hosted orogenic deposit

Typical ore: py-sid-qz and ghost BIF

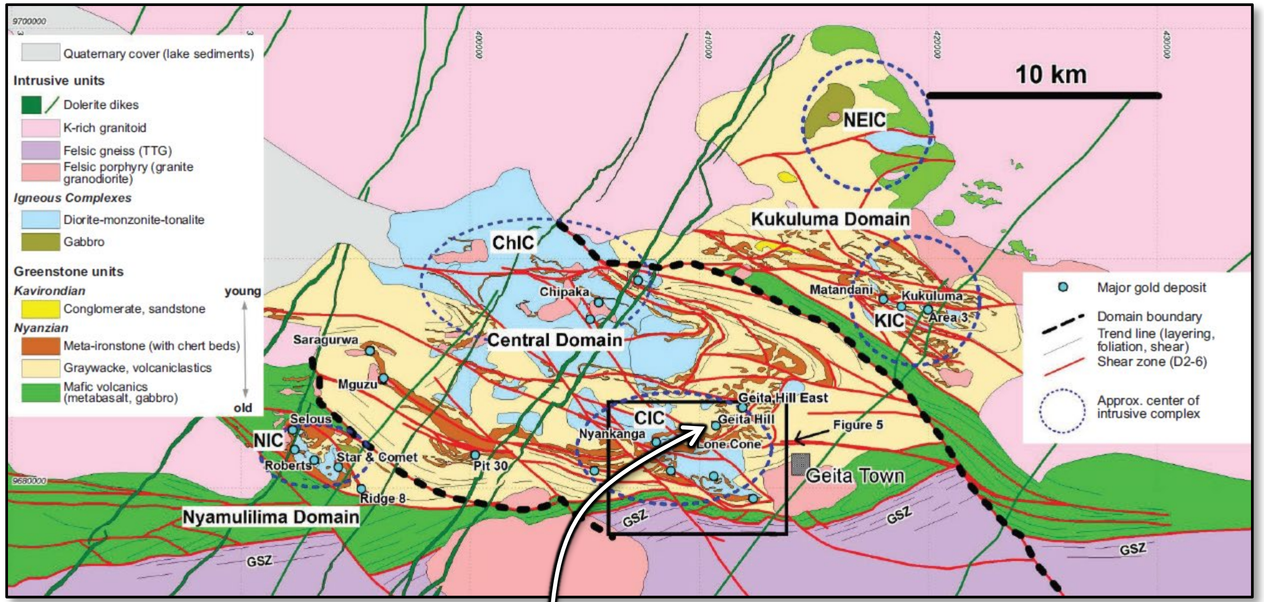


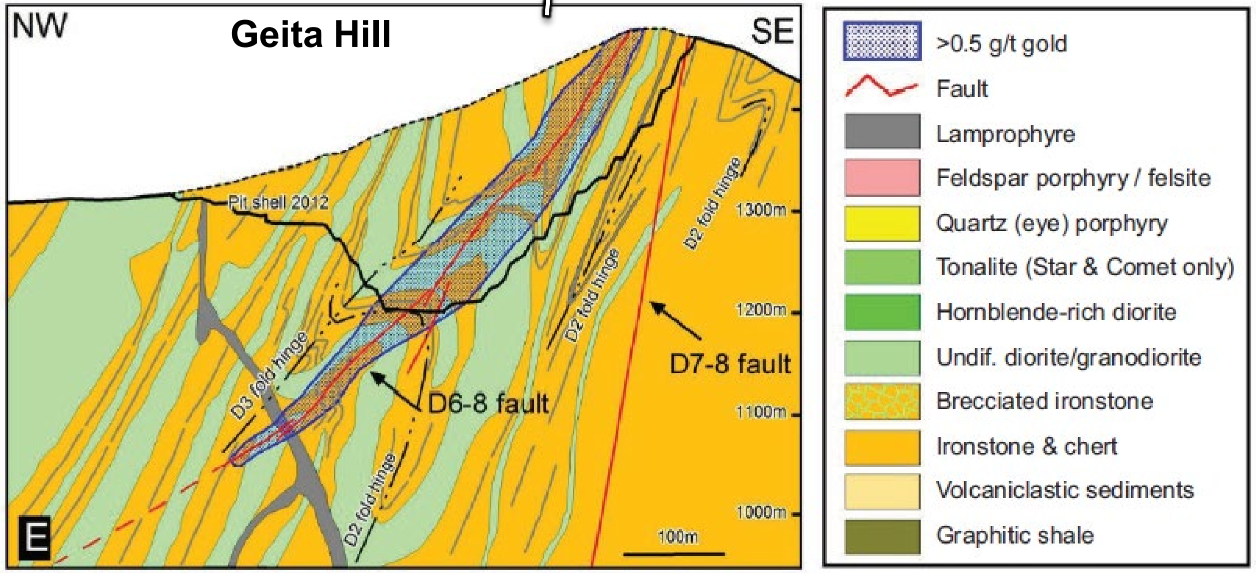
Geita district (Dirks et al.)

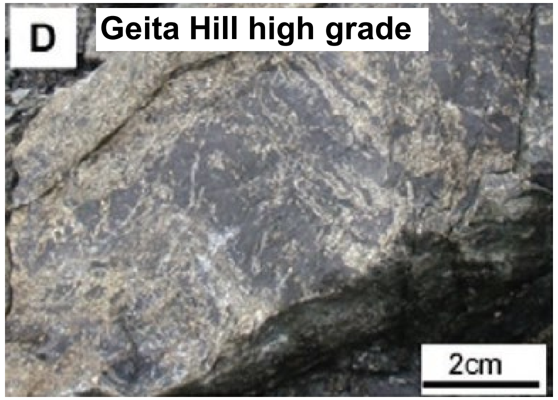
District = 15 Moz; ironstone replacement

Characteristics
- In chert-ironstone units & intruding diorite complex
- Py-qz veinlets/replacements in ironstone & diorite
- Biot-carb alteration in clastics; K-spar-Fe carbonate in diorite
- Controls: shear-BIF intersections, fold hinges

Interpretation
- Classic ironstone-hosted (late) orogenic deposit





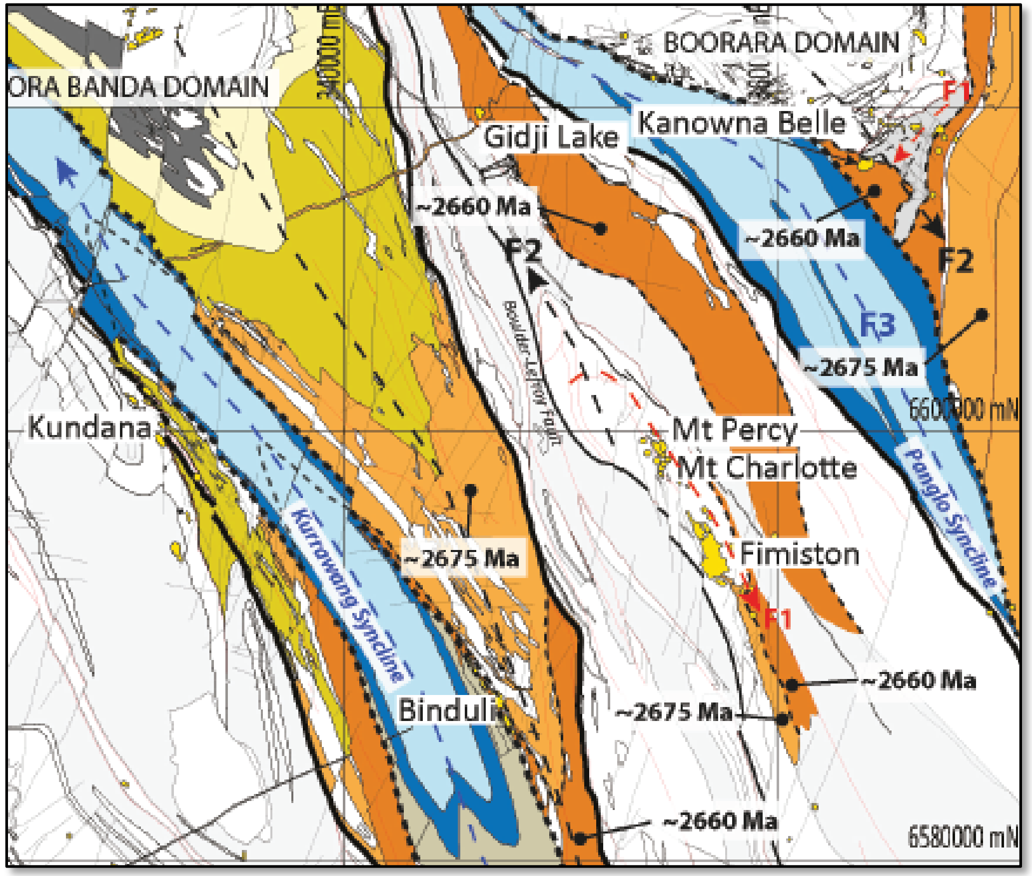


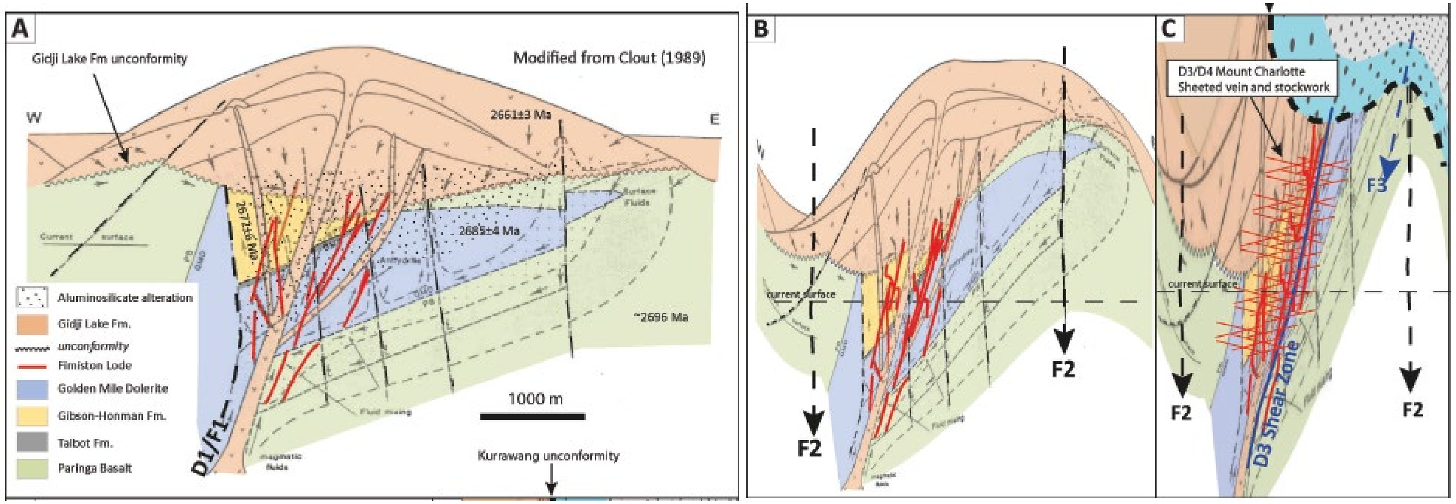
Eastern Goldfields Province (Tripp et al.)

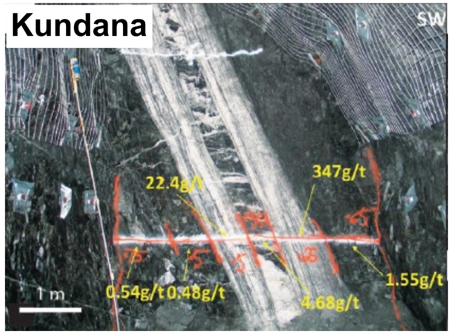
Updated synthesis - Kalgoorlie district as example
- 2 unconformities separating 3 sets of folds
- Improved framework for gold setting

Diversity of deposit styles and ages
- "Early" high-level: Kanowna Belle, Binduli, Golden Mile
- "Late" orogenic veins: Kundana, Mt Charlotte

Importance of unconformities
- Depth and time markers for gold







Kalgoorlie gold camp (McDivitt et al.)

~75 Moz; Golden Mile = 57 Moz produced

Fimiston / Oroya lodes:

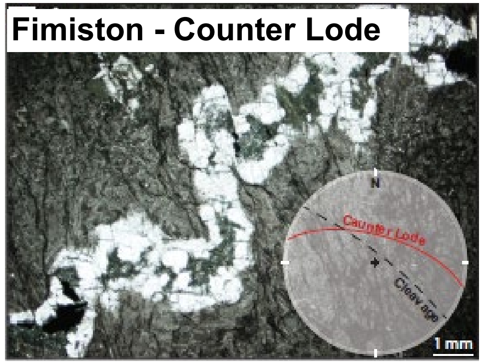
- Carb-qz-py veins & breccias; crustiform-colloform
- Accessory sulfosalts, anh, mt, hm
- Au-Te-Ag (Hg, Mo, Sb, As), +V in Oroya

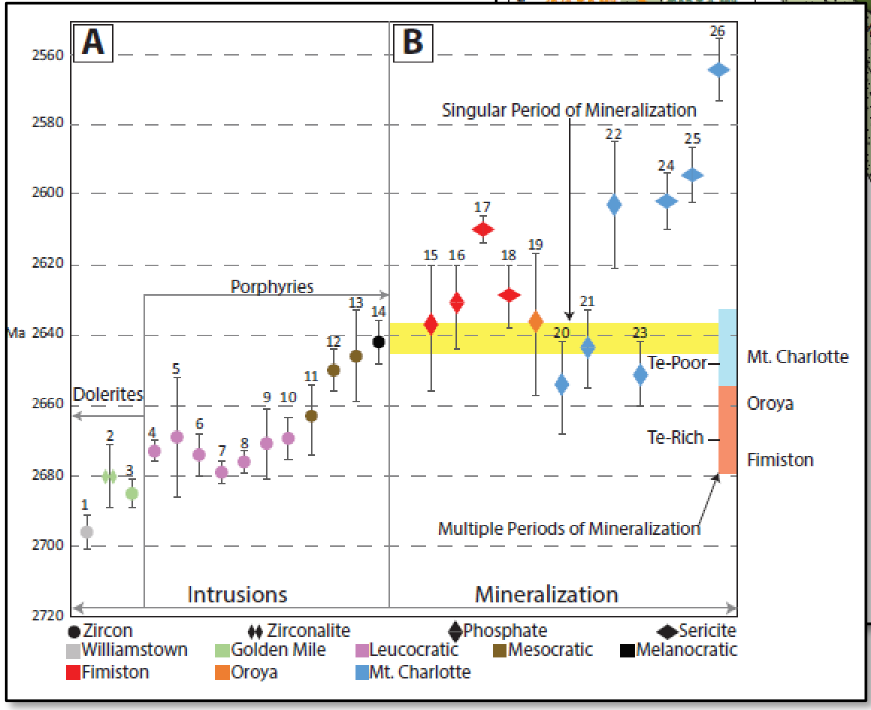
Mt Charlotte

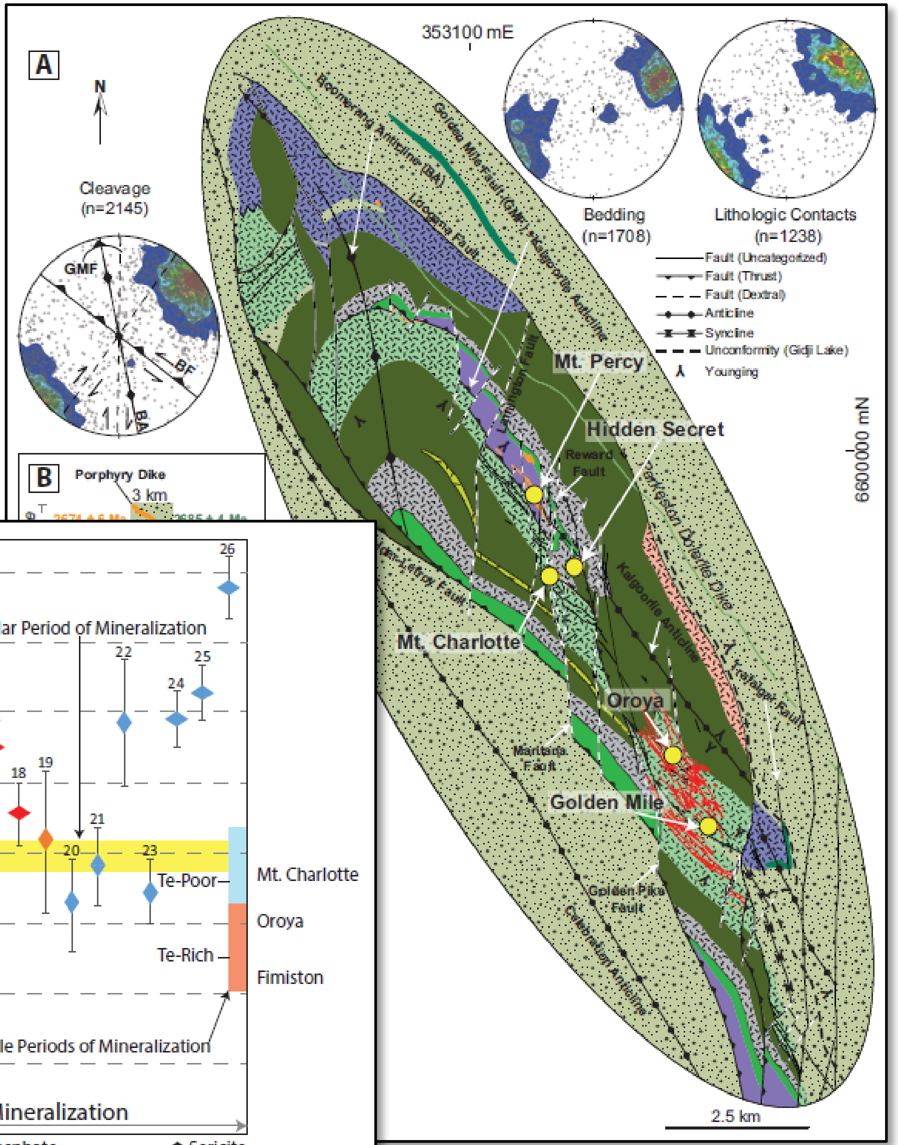
- Late quartz-carbonate veins; Au-Ag only

Interpretation

- Fimiston/Oroya: oxidized magmatic-hydroth
- Mt Charlotte: typical late-stage orogenic







Boddington Au-Cu deposit (Turner et al.)

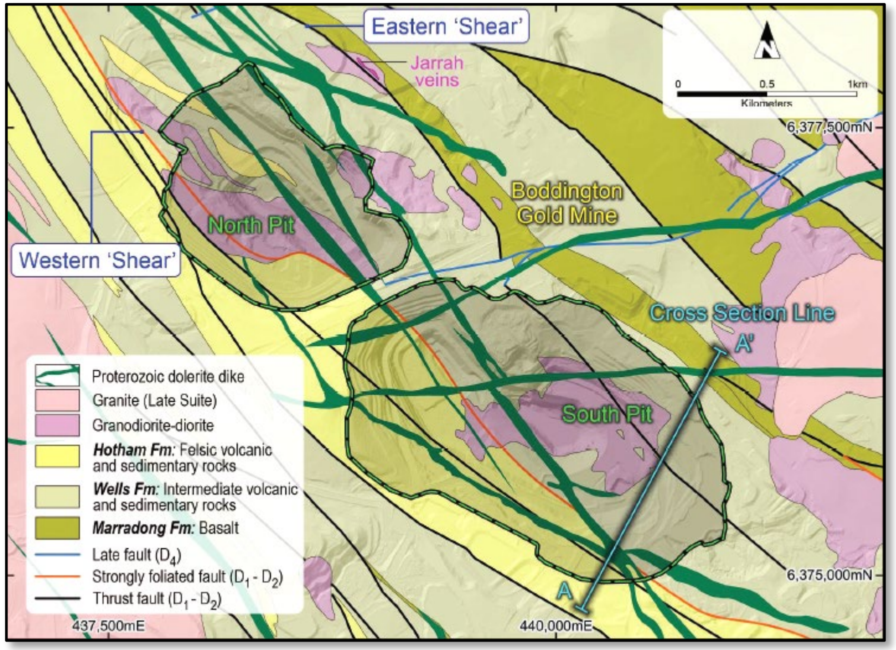
30.4 Moz @ 0.74 g/t (~0.10% Cu)

Characteristics

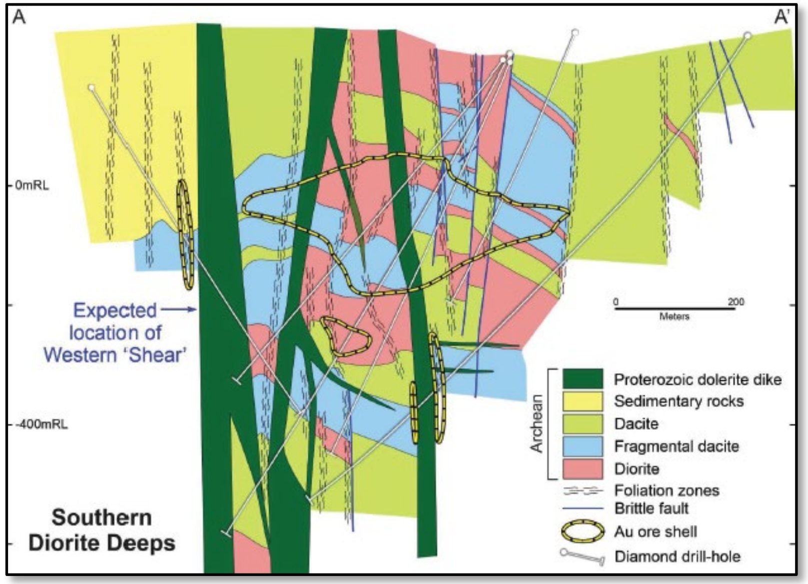
- Mainly diorite-hosted
- Fracture/veinlet stockworks – multiple stages
- Cu-Ag-Mo +/- Bi, W, Te
- Orogenic veins also present

Interpretation

- Protore of early Mo-Cu "dioritic" porphyry
- Orogenic veins
- Bulk of Au-Cu: late-orogenic high-T, magmatic-hydrothermal



Orogenic qz vein



Early qz-moly in bio-alb alteration

Late clino-chl-sulf – bulk of Au-Cu

Archean greenstone gold summary

Orogenic deposits

- Coherent group of deposits
- Well-defined characteristics
- Localization controls well understood

Atypical deposits

- Disparate group but…many show
  - Stockwork-disseminated ore & proximal feldspar alteration
  - Te, Mo, Cu, V, Hg, Sb; +/-sulphates, mt, he
  - Multiple hydrothermal stages
  - Overprinting strain and orogenic veins
- Formed early and preserved? "oxidized" Associated with pre-shortening intrusions
- Recurring "oxidized" flavor

Exploration considerations

- Camp-scale framework critical for targeting
- Unconformities important markers
- Range ore styles, signatures and controls
- Hydrothermal overprinting & complexity
- Supergiants can be unique and freaks

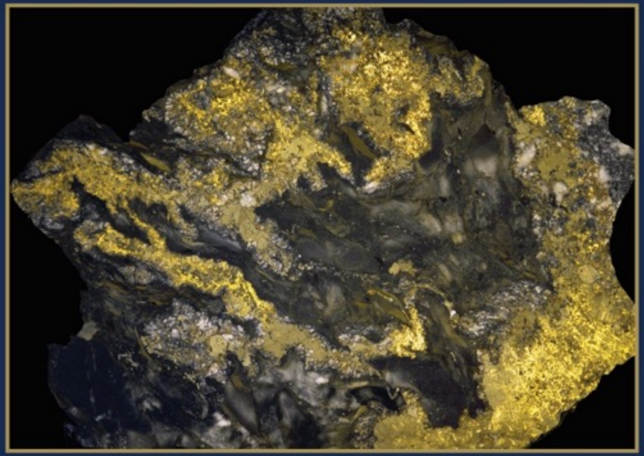
Young Orogenic & Others

Rich Goldfarb

www.segweb.org

BARRICK

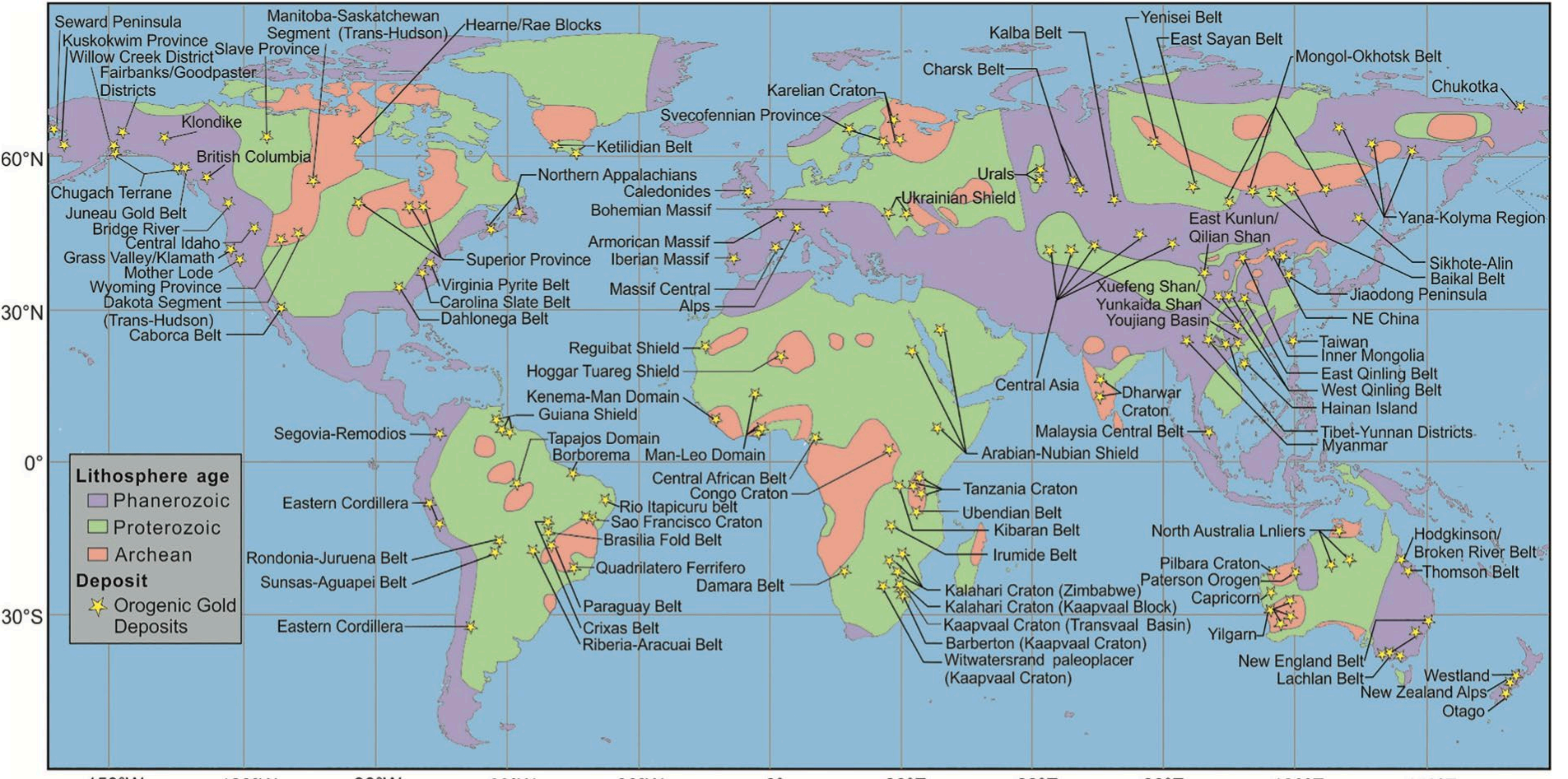
Geology of the World's Major Gold Deposits and Provinces



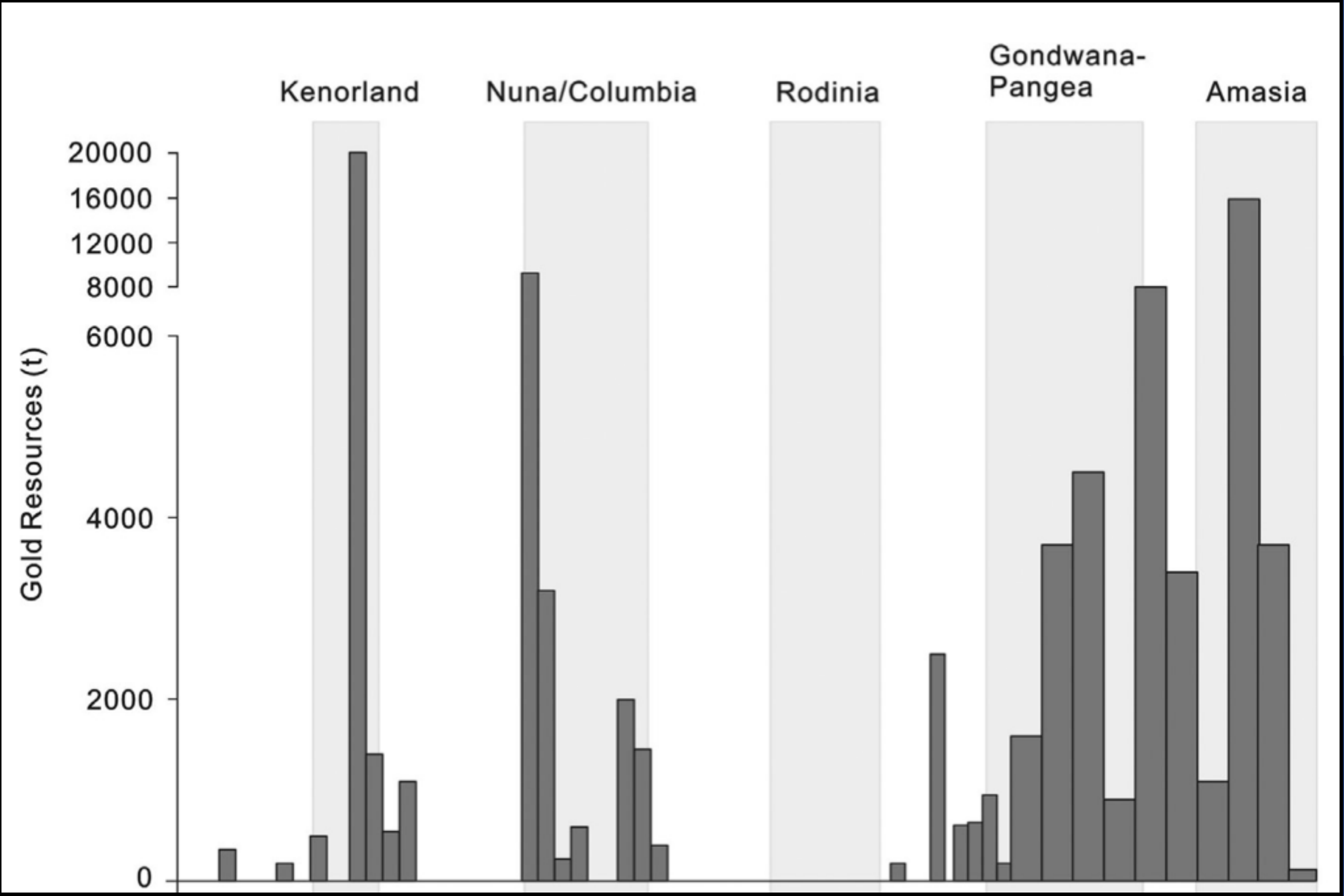
Richard H. Sillitoe, Richard J. Goldfarb, François Robert, and Stuart F. Simmons, Editors

Special Publication Number 23
Commemorating the 100th Anniversary of
The Society of Economic Geologists, Inc.

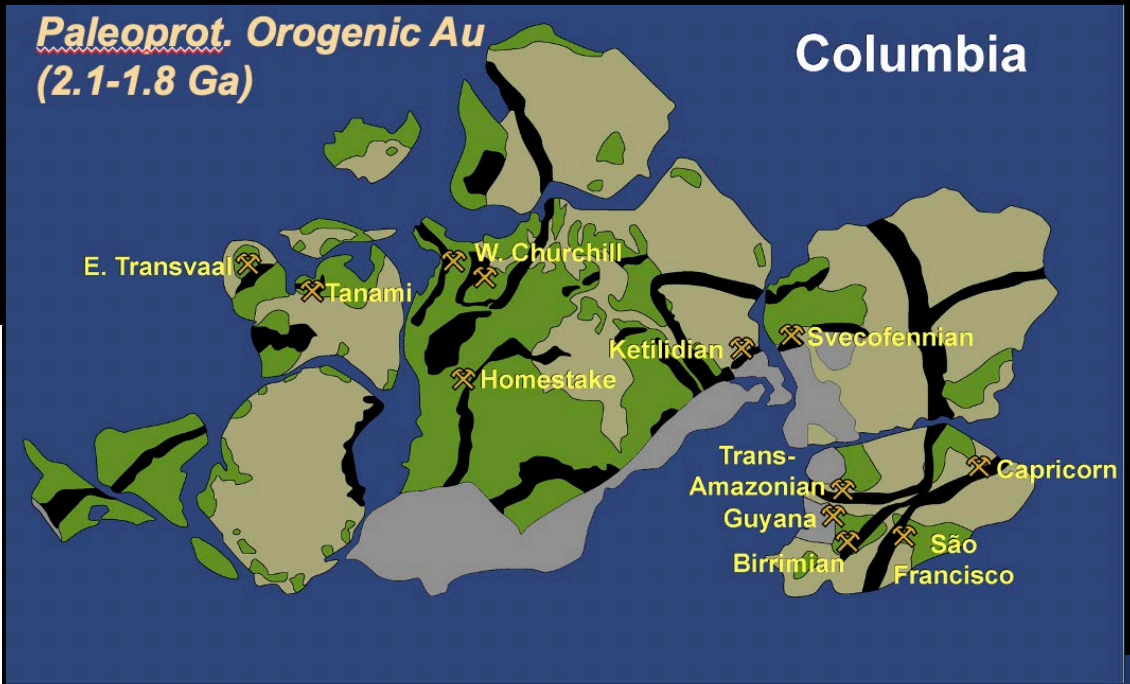
GOLD DEPOSITS IN METASED TERRANES: PROTEROZOIC & PHANEROZOIC

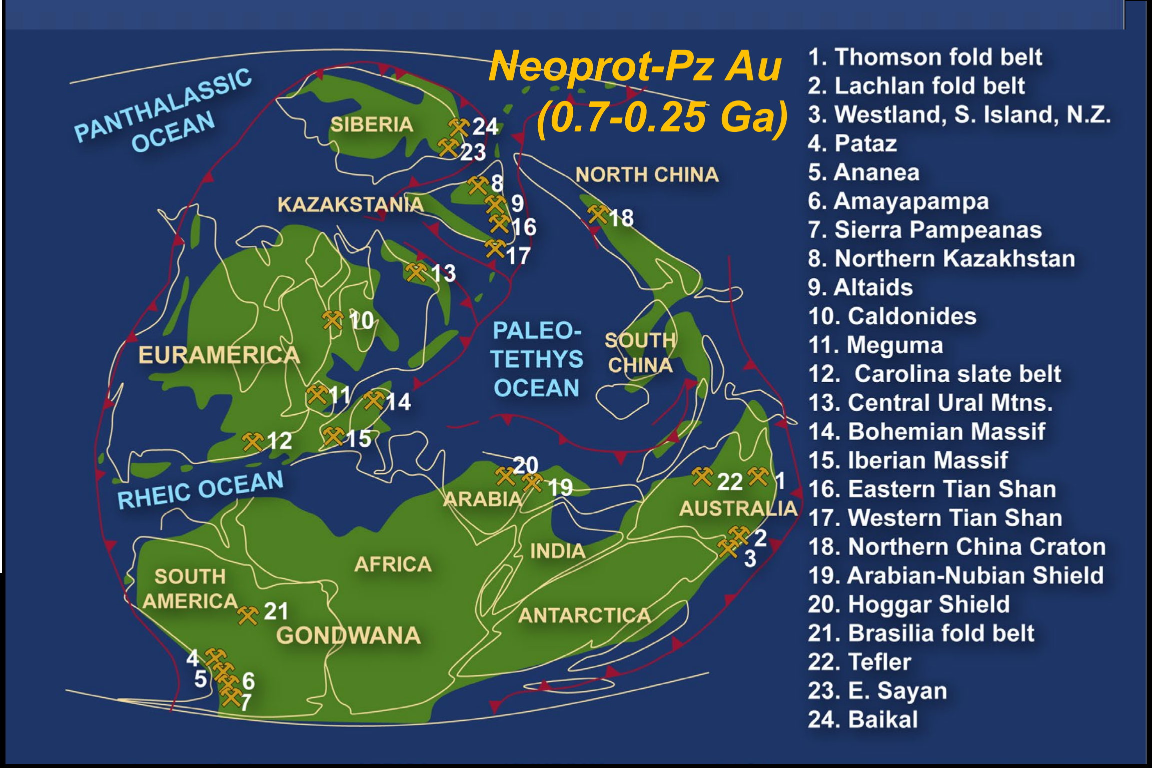


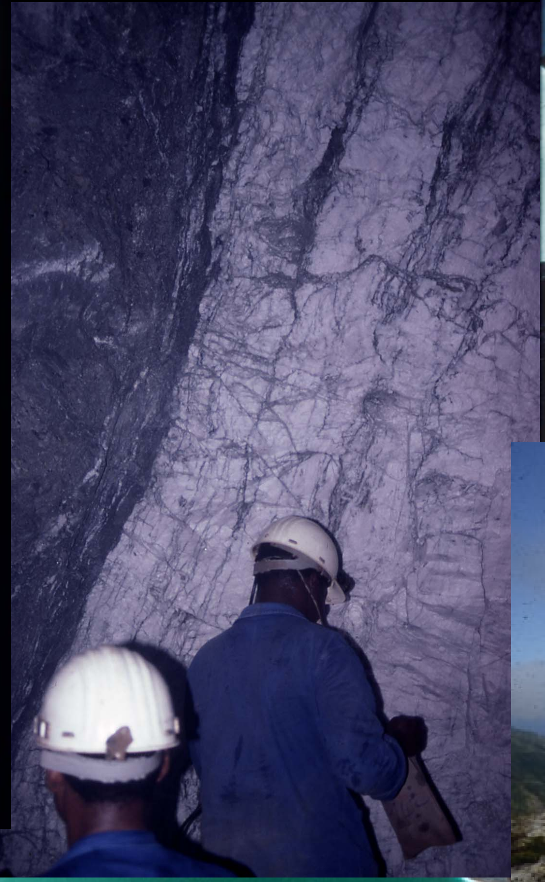
GOLD IN METASED. TERRANES
(extroverted & introverted oceans)



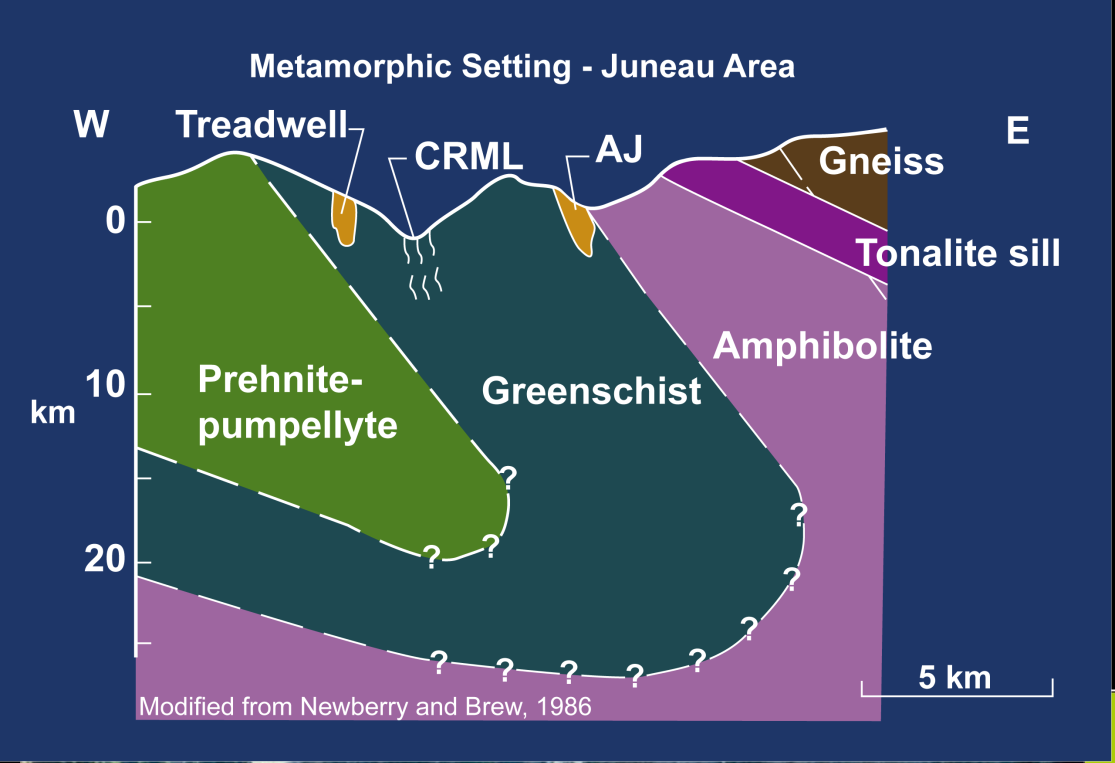
2.15-1.75 Ga **700-30 Ma**

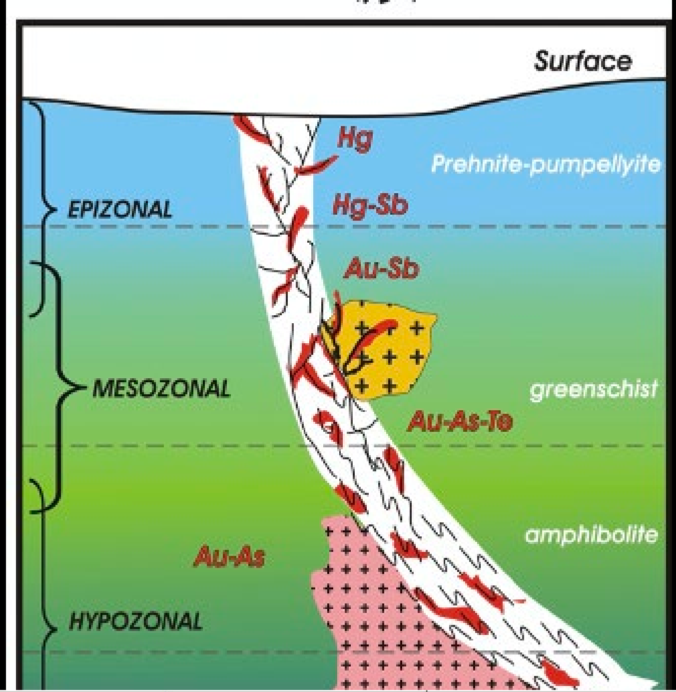






KEY FEATURES OF METASED. GOLD

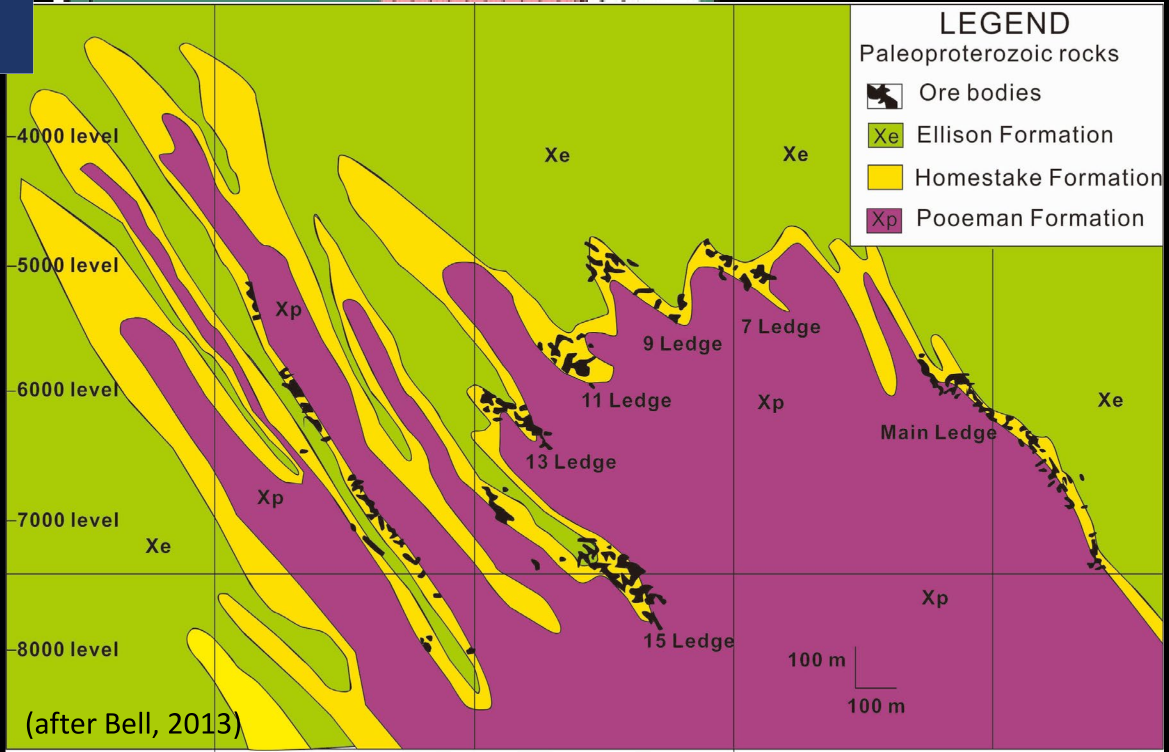


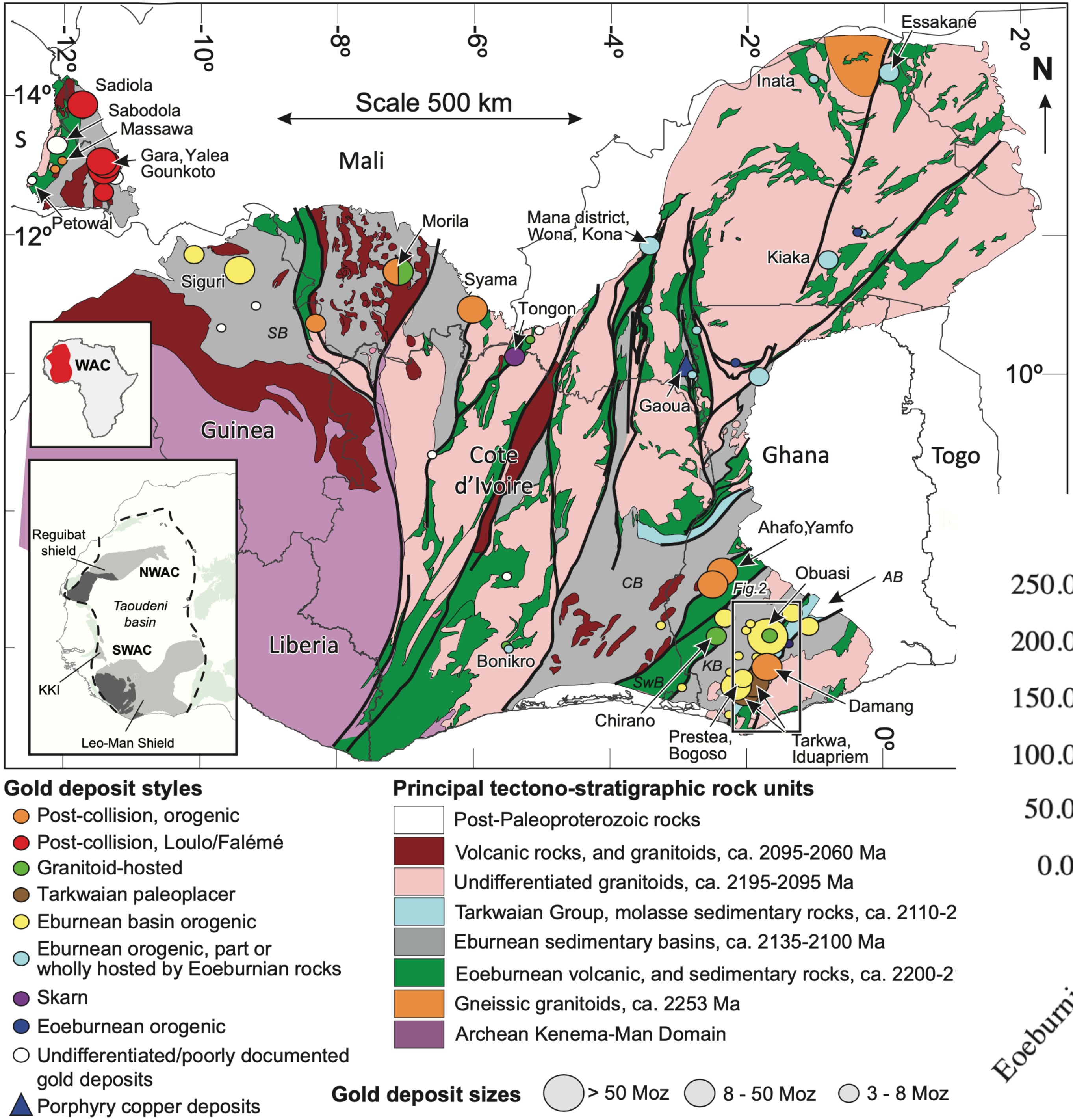


METAMORPHIC SETTING (Rarely Metamorphosed)

Greenschist facies
CO_2, $\delta^{18}O$ rich
3-15 km, 220-450^{o}C

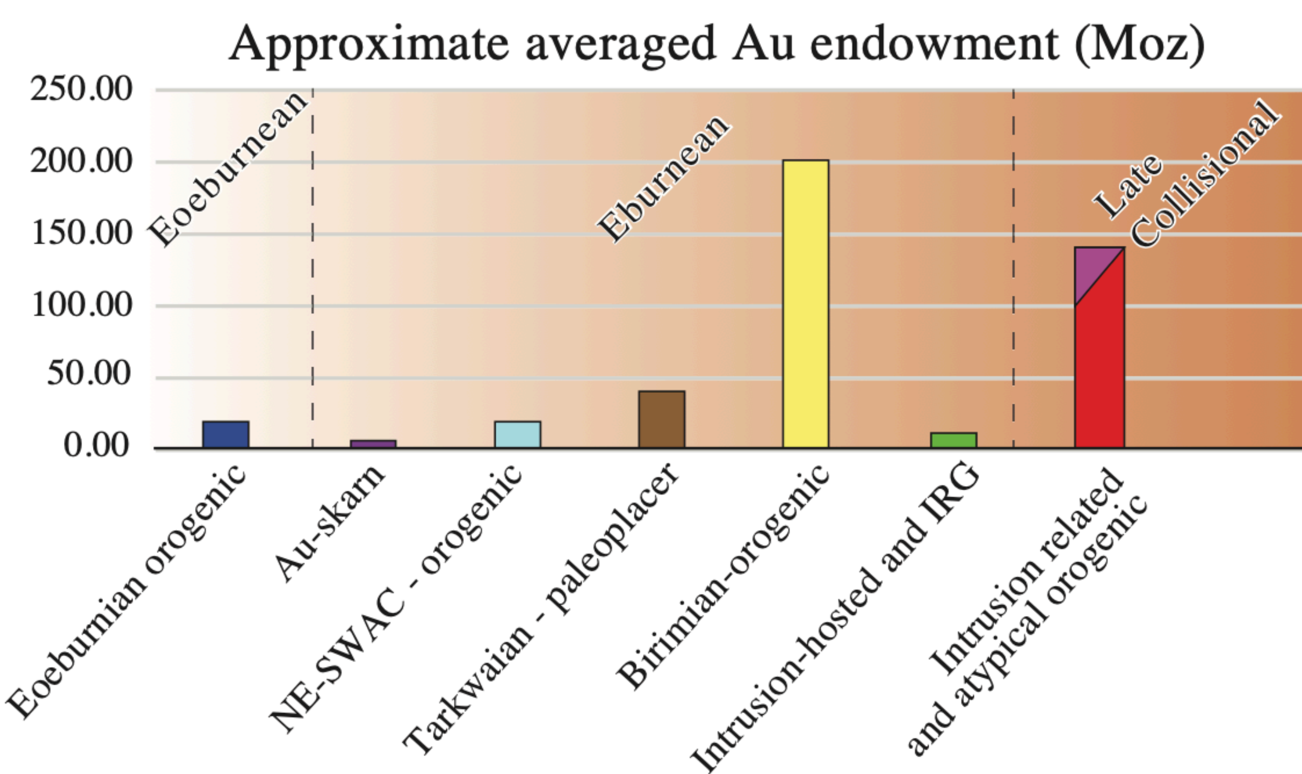
PHYSICAL & CHEMICAL TRAPS

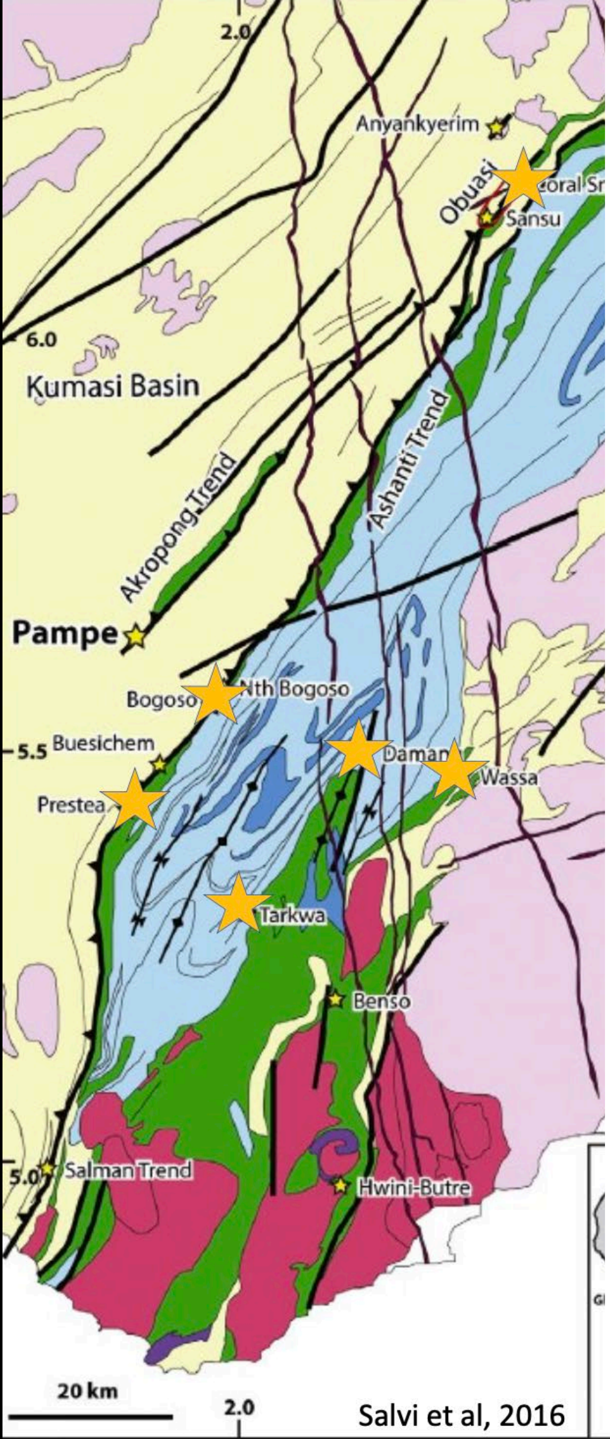


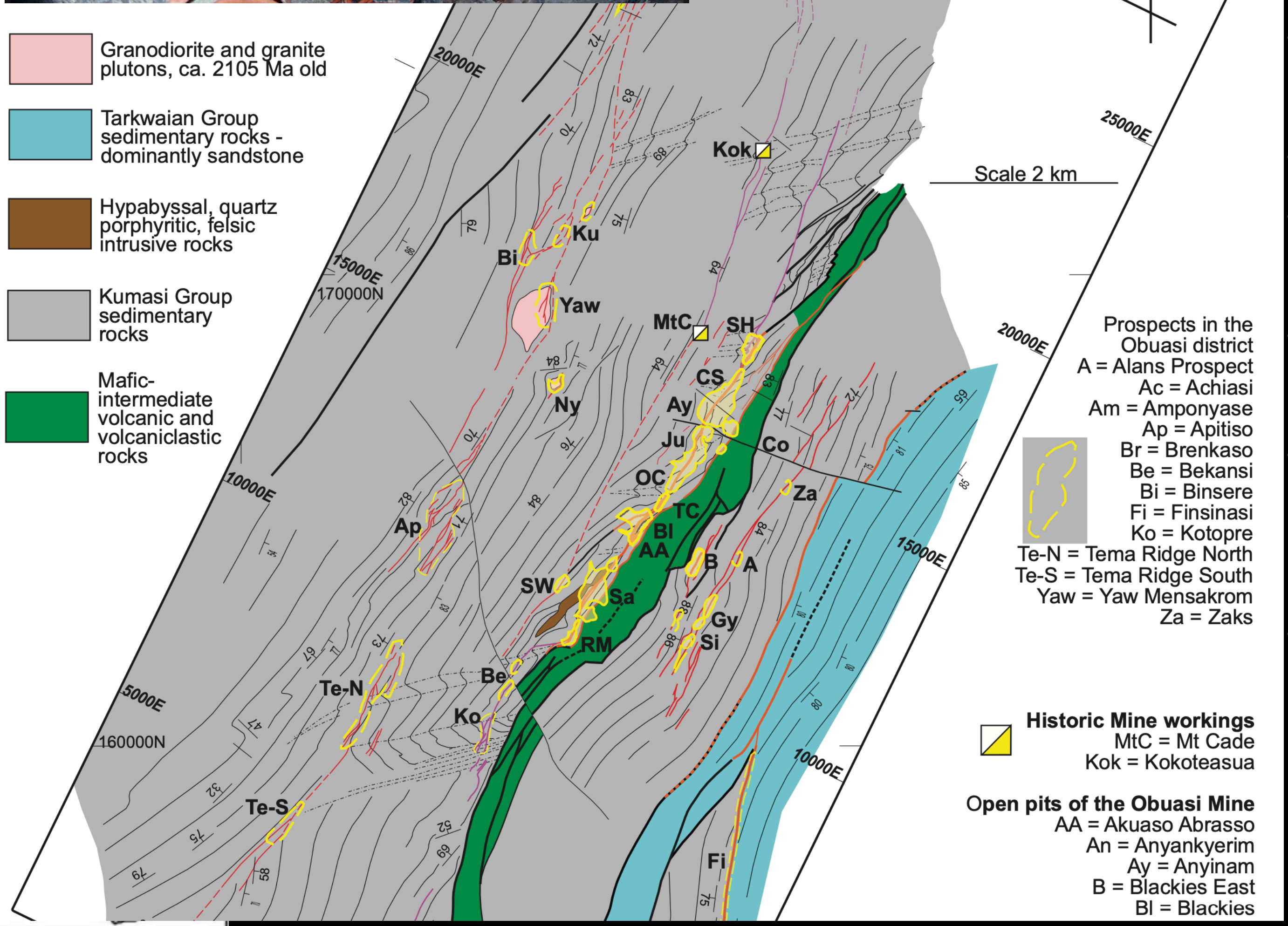


WEST AFRICA (Thebaud et al)

- Ca. 2160 Ma; Tarkwa source?
- Jogs, intersections, contacts (2110-2095 Ma)
- Tectonic switch: Contraction, basin inversion, mm & fault reactivation; then transpression (SW Ghana)
- Post collision K-magmatism, thermal aureole Au (Morila, Loulo; 2060 Ma)





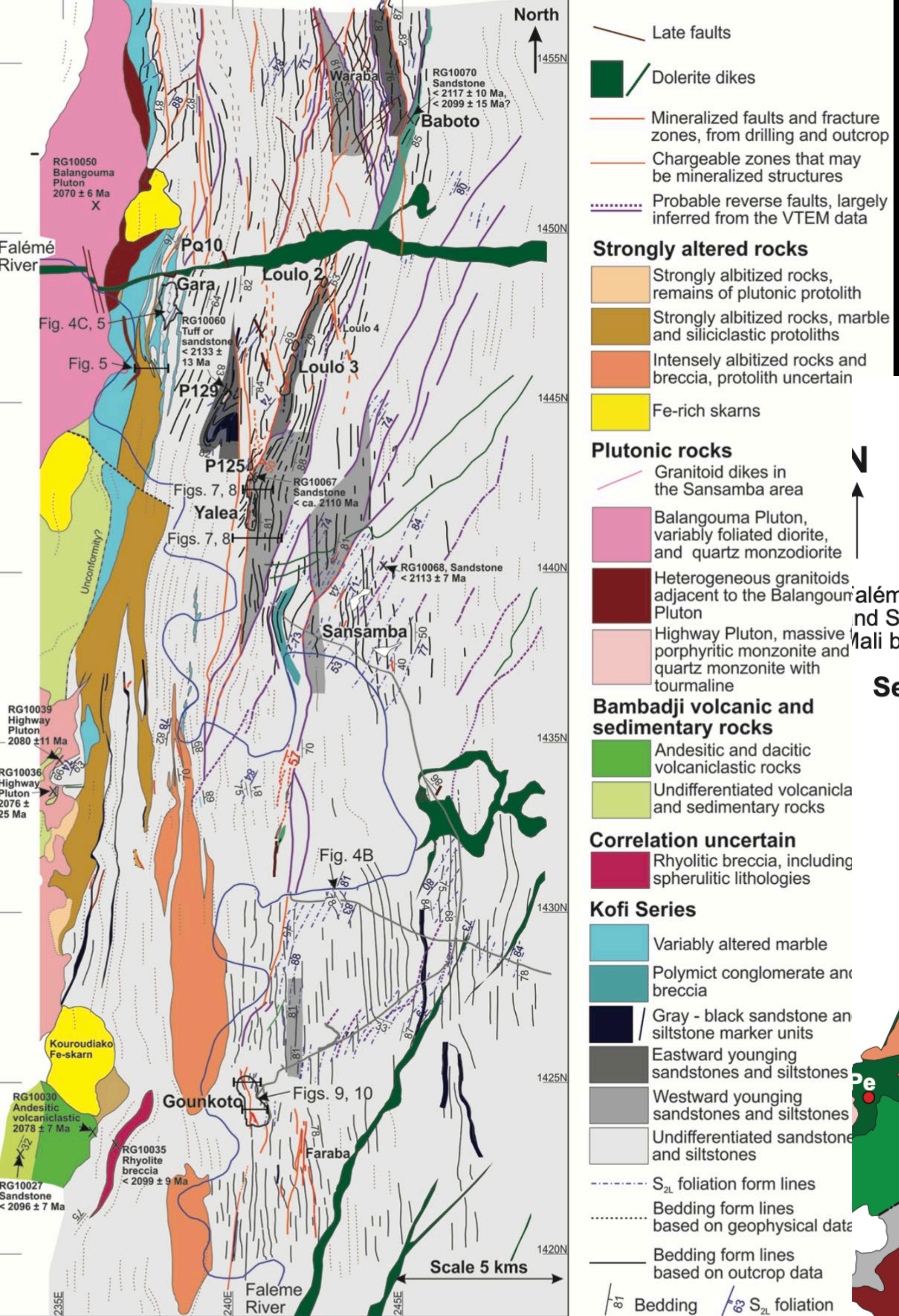


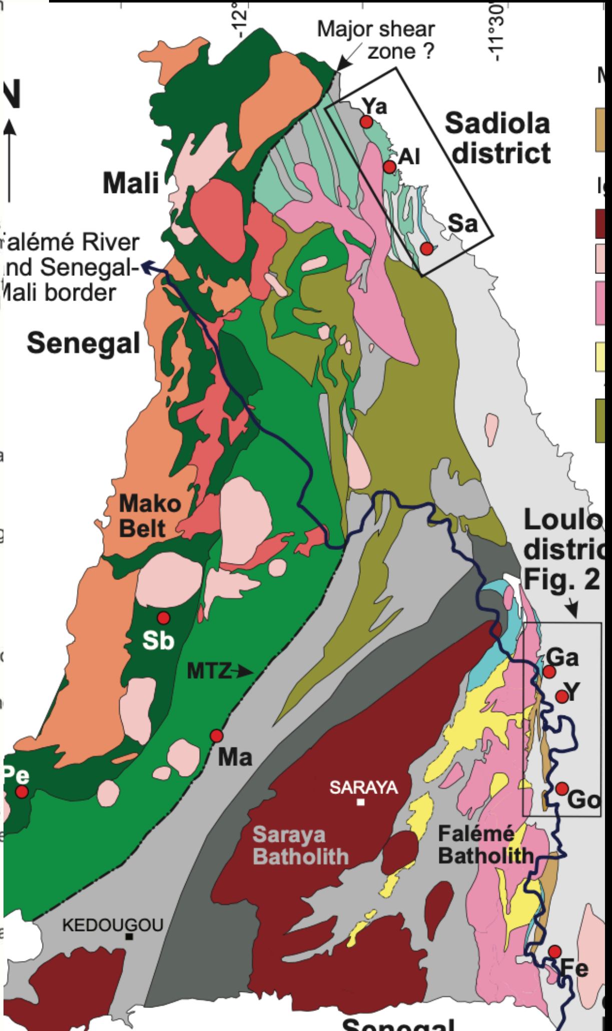
OBUASI (Oliver et al)

- 70 Moz; 8 km long, >2.5 km depth
- 2135-2115 Ma gwk & carb. phyll
- Inverted basin margin faults (plumbing)
- 2095 Ma Au & mm
- Early deformation & Au
- Mm model (but strange flincs)
- Carbonaceous material (fertility)--S, As, Au source
- Multiple Au events: D2, D4, D5 (and/or remobilization from early aspy

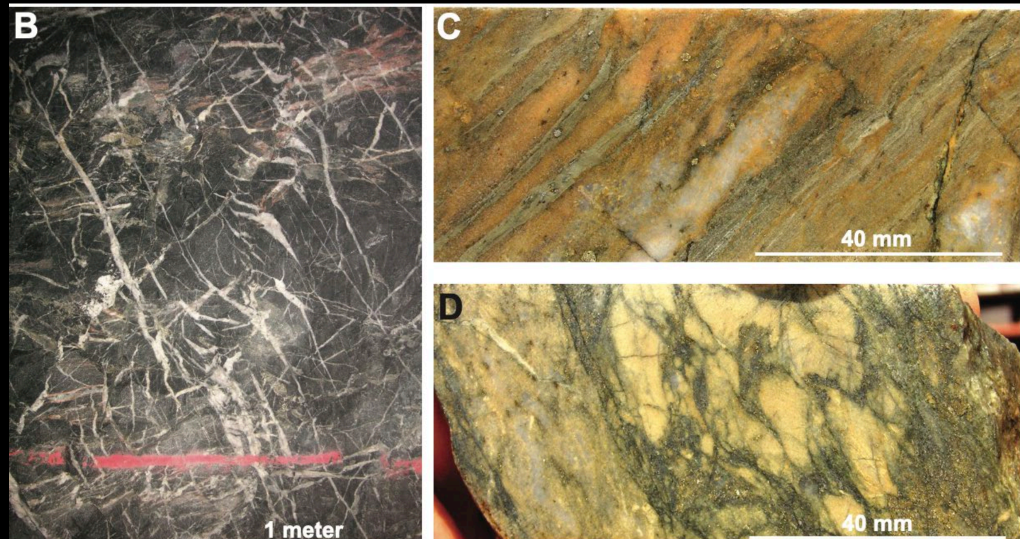
LOULO DISTRCT (Allibone et al)

- 250-km-long belt, 2nd most endowed area of W. Africa
- Loulo District=>17Moz in 2120-2110 Ma clastics±carb, evap
- D1 folding/reverse faulting; D2 transpression
- 2120-2070 Ma albite, carbonate, tourmaline pre-Au alteration



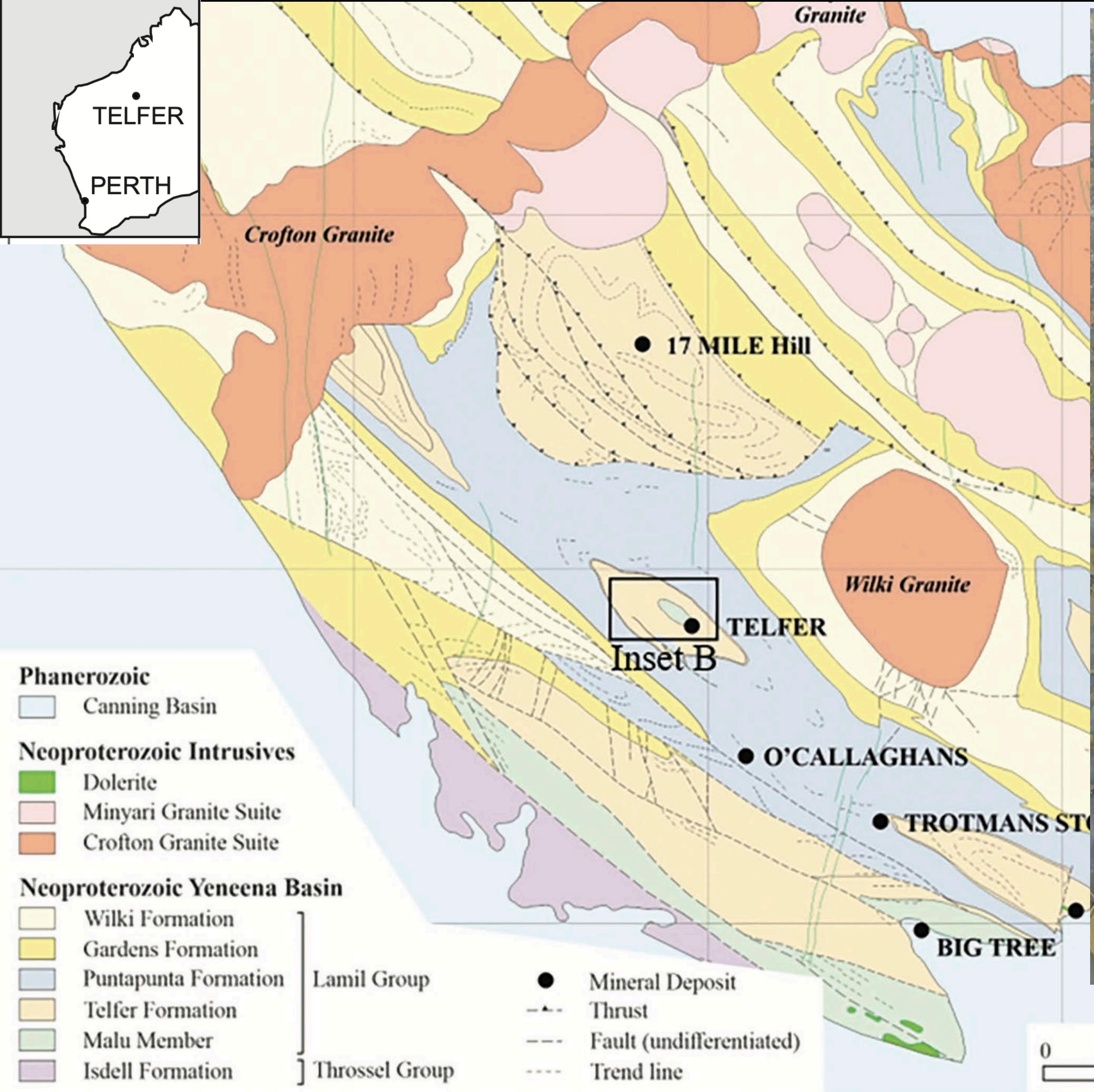


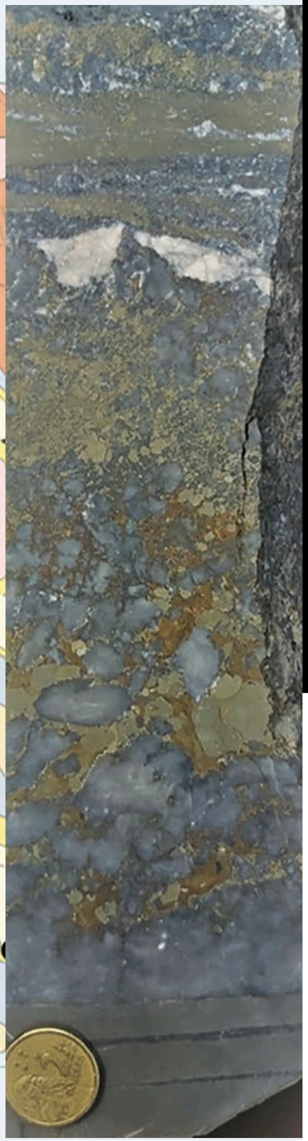
- 2090-2060 Ma batholith & Fe skarns
- Gold is late D2 (2070-2060 Ma)
- No regional Mali-Senegal shear zone
- Mm devol model BUT mixing of two fluids (contact mm Au?)
- Shoots where local shears intersect gentle folds in areas of early alteration

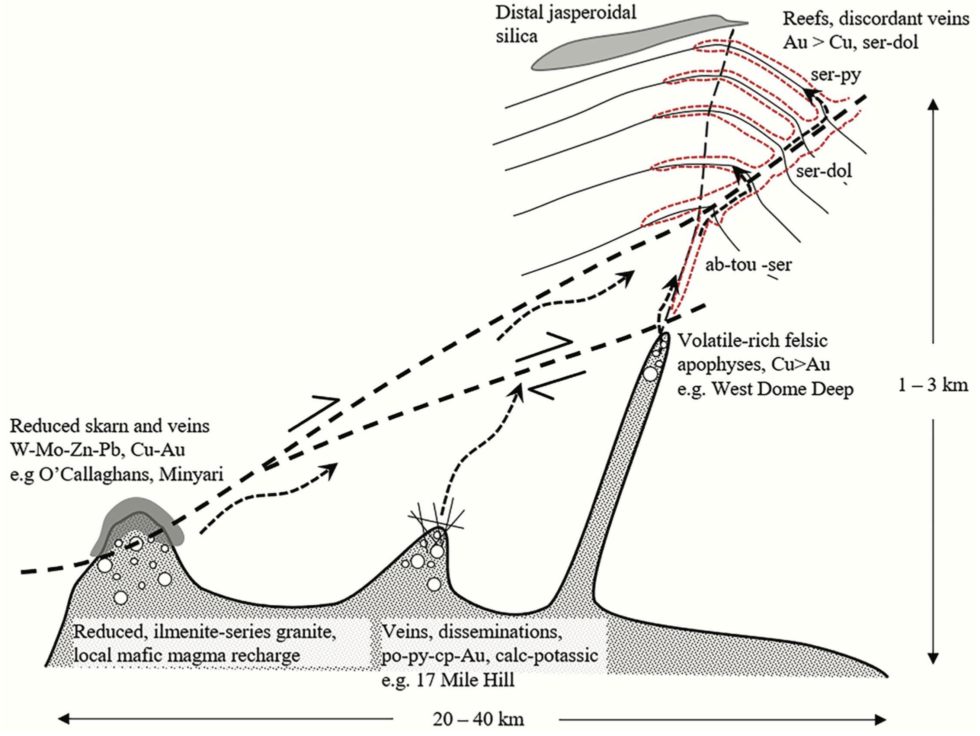


TELFER (Wilson et al)

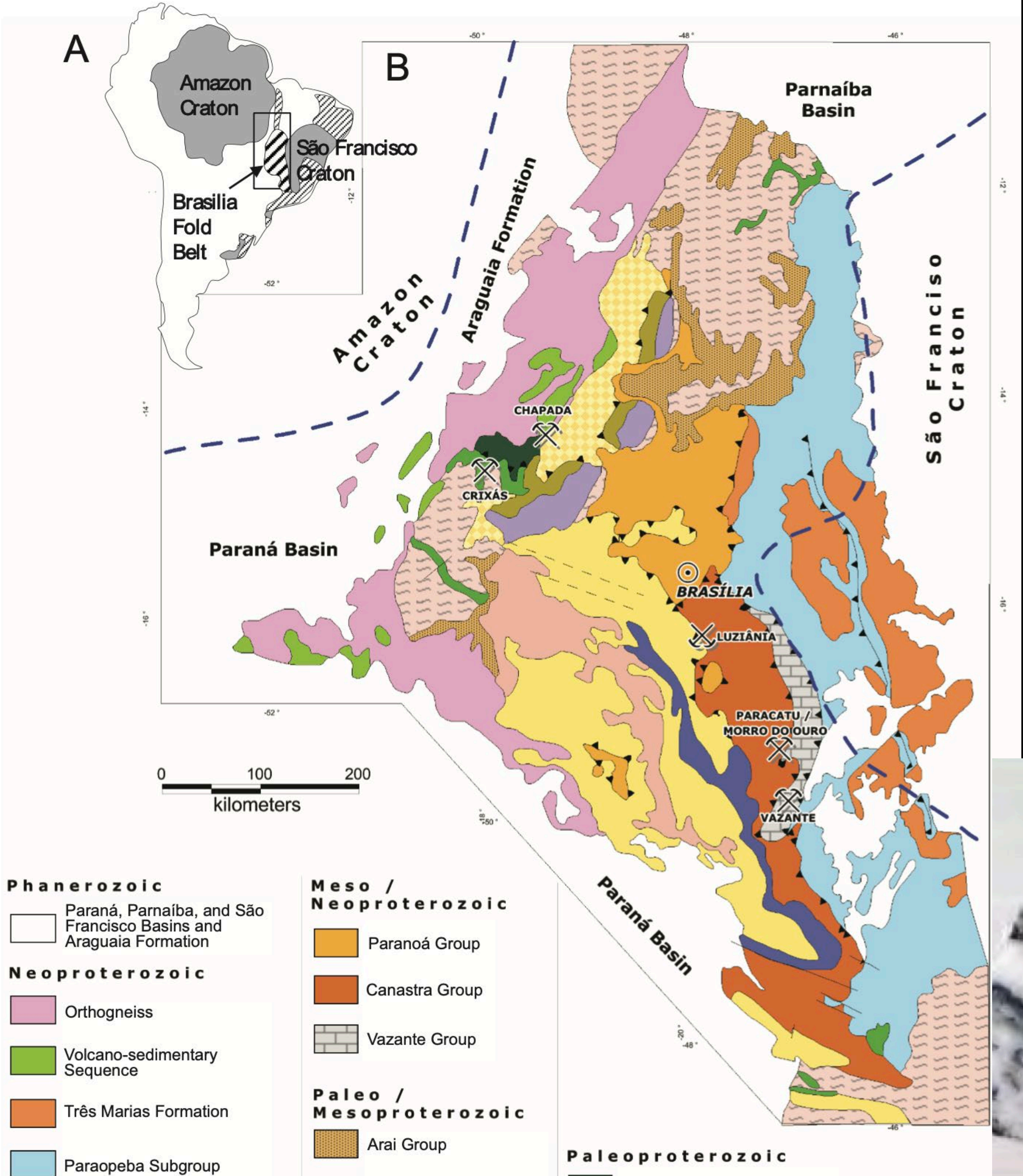
- >20 Moz Au (0.75 g/t); 0.7 Mt Cu (0.12%)
- Pre-650 Ma folds (D1-D3) & doming
- 650-600 Ma transpression (D4-D6)
- 645-605 I & S reg magmatism; cp-bearing dike in deep core
- Qtz-dolo-py-cp veins and stockworks in >20 stacked reefs in dome fold hinges
- Mx in silty units between thick quartzites
- Pyrite±cp as matrix to brecciated quartz
- High salinity, 85% CO2 fluids







- High Cu, Cu:Au zonation, jasperoid, large footprint=unusual RIRGD
- Fluids exsolved over 40 m.y. from large buried batholith



PARACATU (Oliver et al)

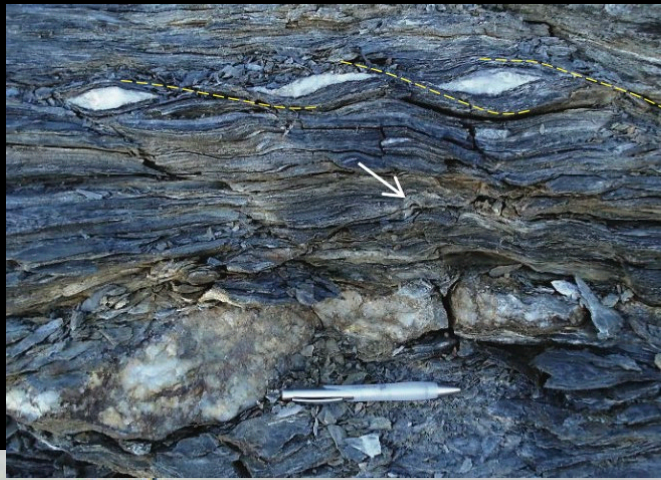
- Brasilia fold belt; 1.0 Ga carbonaceous phyllite (gs facies) thrust over passive margin carbonates
- Ca. 630 Ma Au; predates much of ductile deformation
- Subhorizontal orebody with 15 Moz @0.4 g/t
- No igneous rocks
- “Half-way house” of elements:

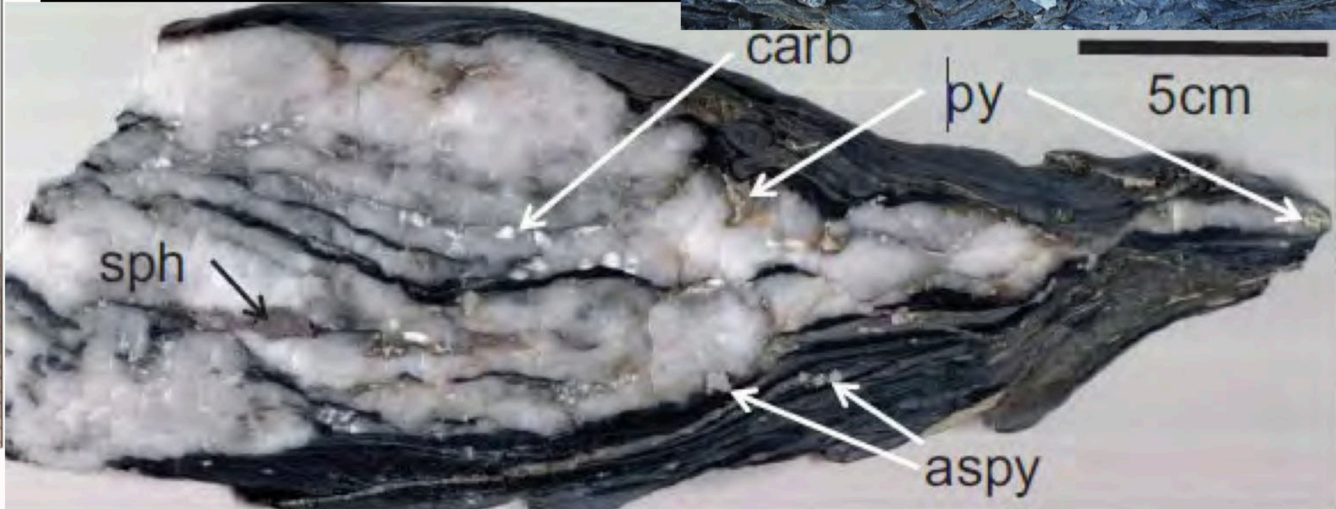
  Si, Ca, & Sr

  are local

  H-O-S-C-Au-As

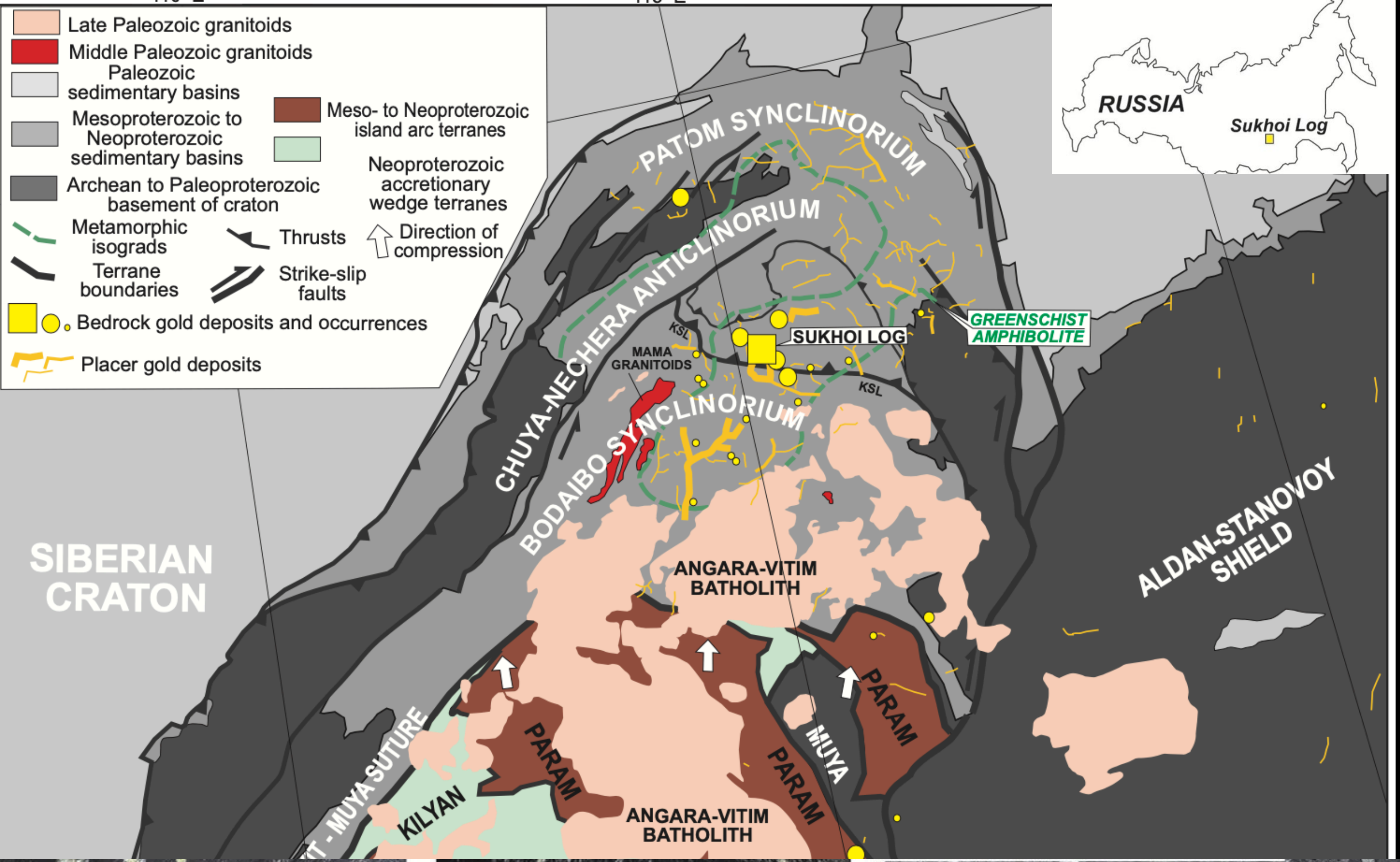
  are far-traveled

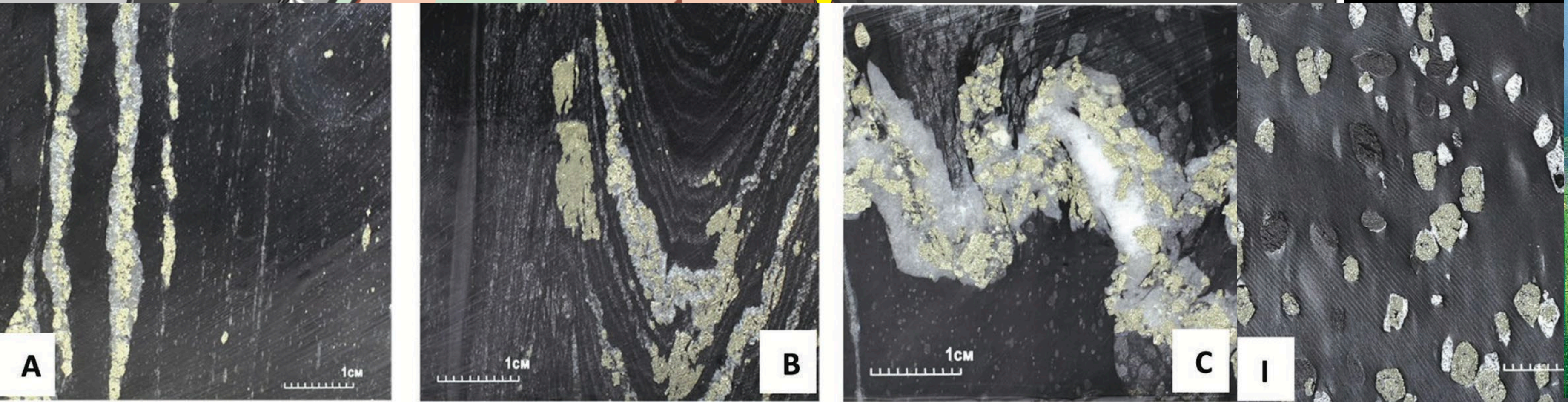


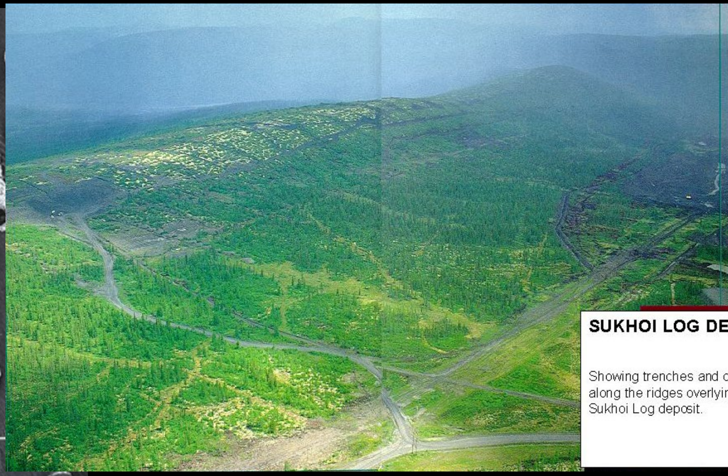


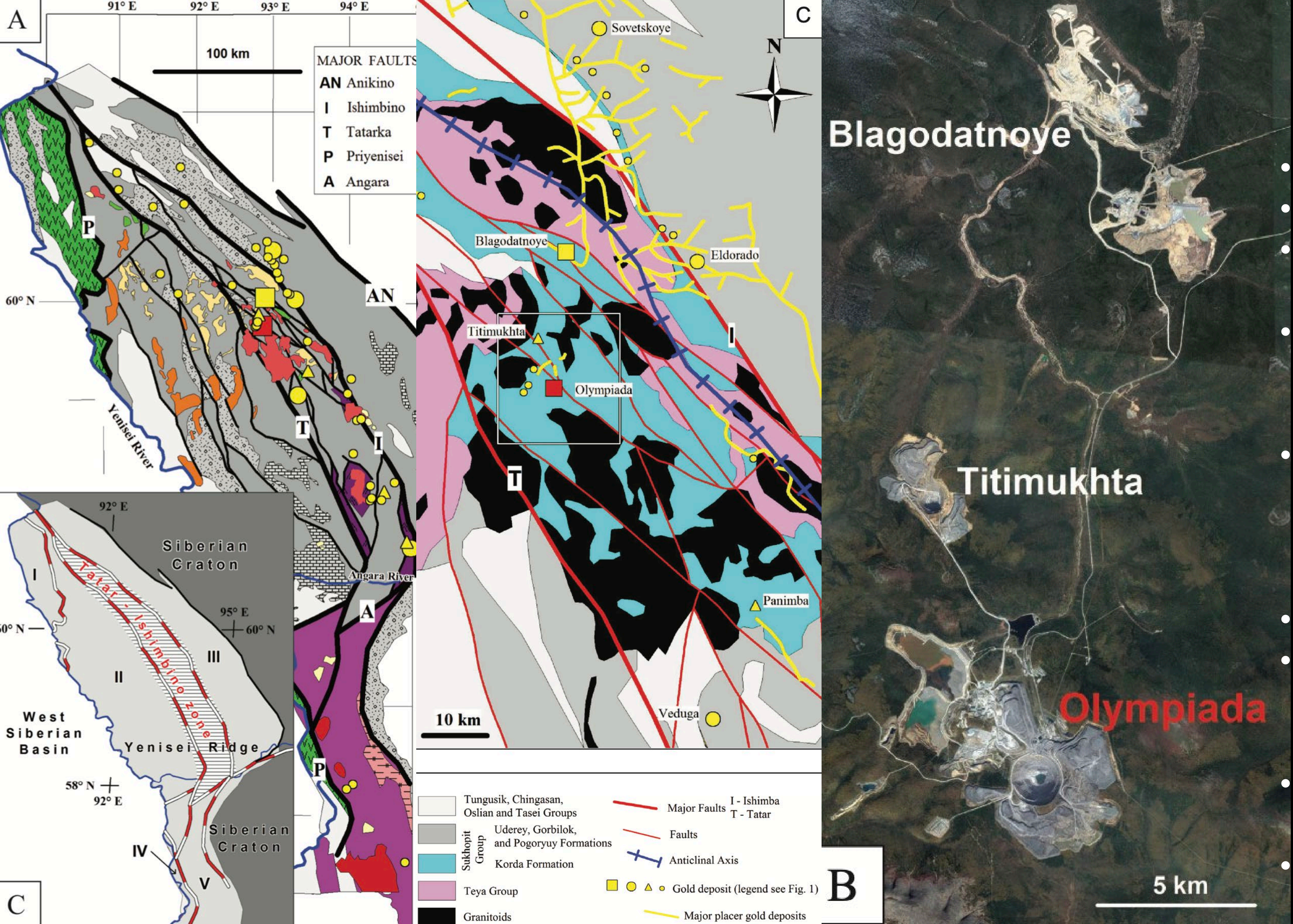
SUKHOI LOG (Vursiy et al)

- 63 Moz (>120 Moz Lena prov)
- Neoprot-Cambrian passive margin seds; E Pz terranes accrete
- 1960s=first metamorphic models
- Anticlinal dome in regional syncline
- Ores in highly carbonaceous clastics between competent carbonate along shears in axis for 5 km strike
- Many generations of auriferous pyrite with qtz rims; unique textures
- Complex genesis; ages spread from >600 Ma to 300 Ma for mm, mag, and Au; multiple events





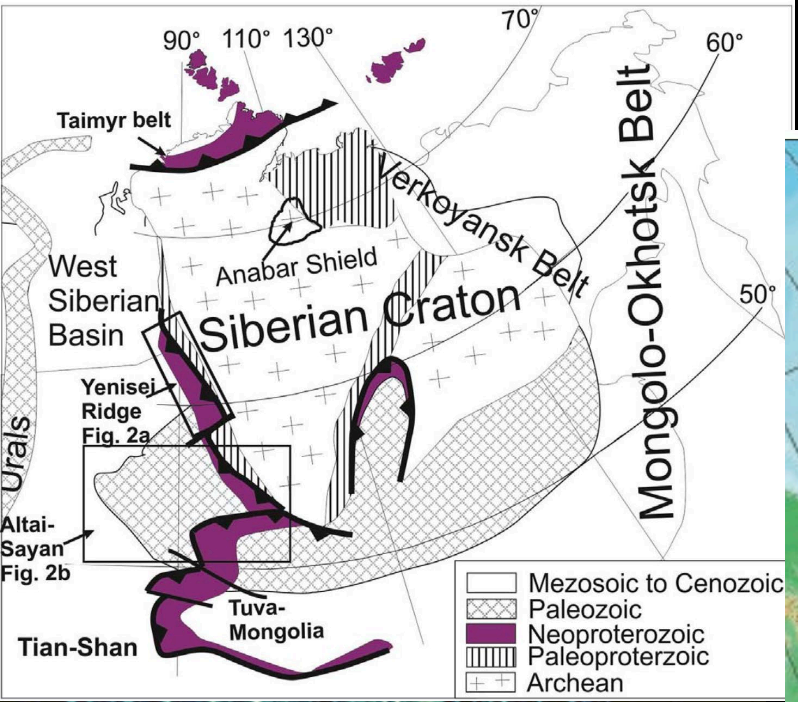


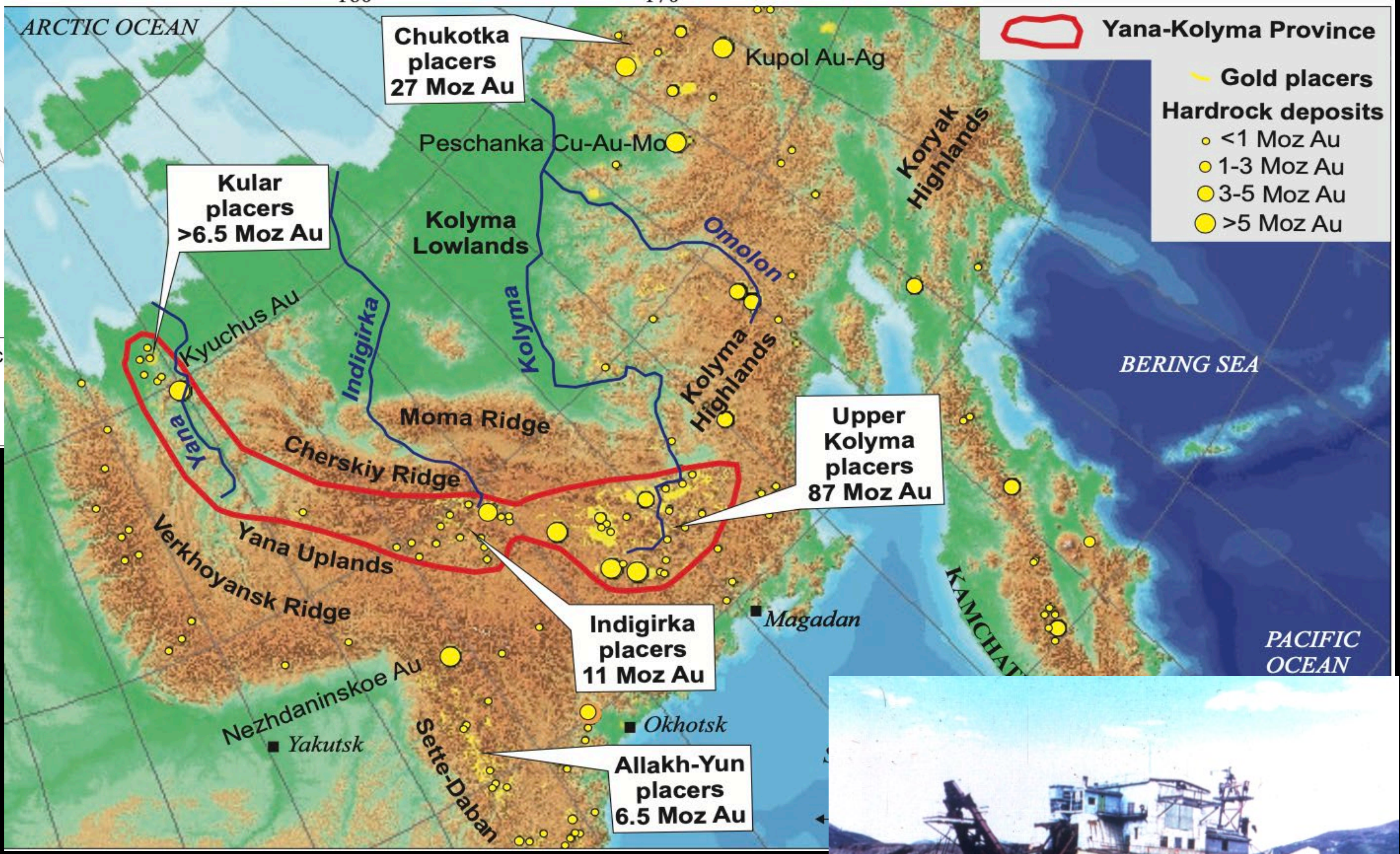


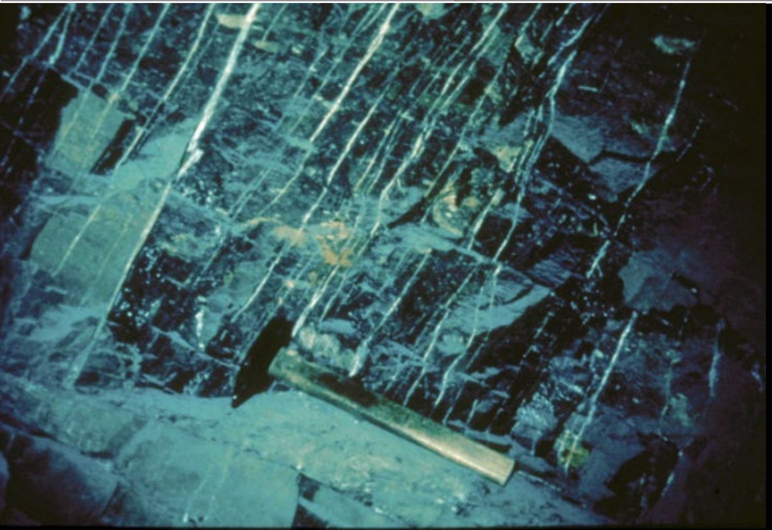
OLYMPIADA (Sazonov et al)

- 50 Moz@4-4.5 g/t
- Province=100s Moz
- 700 x 200 km Neoprot orogen
- Sheared anticlinal closure near major suture
- In amphib facies carbonaceous schist near carbonate contacts
- Aspy>po>>>py
- Late sulfosalts, stibnite,native Sb, aurostibite,tellurides
- 817-660 Ma mx events (150 my)?
- Mantle association?

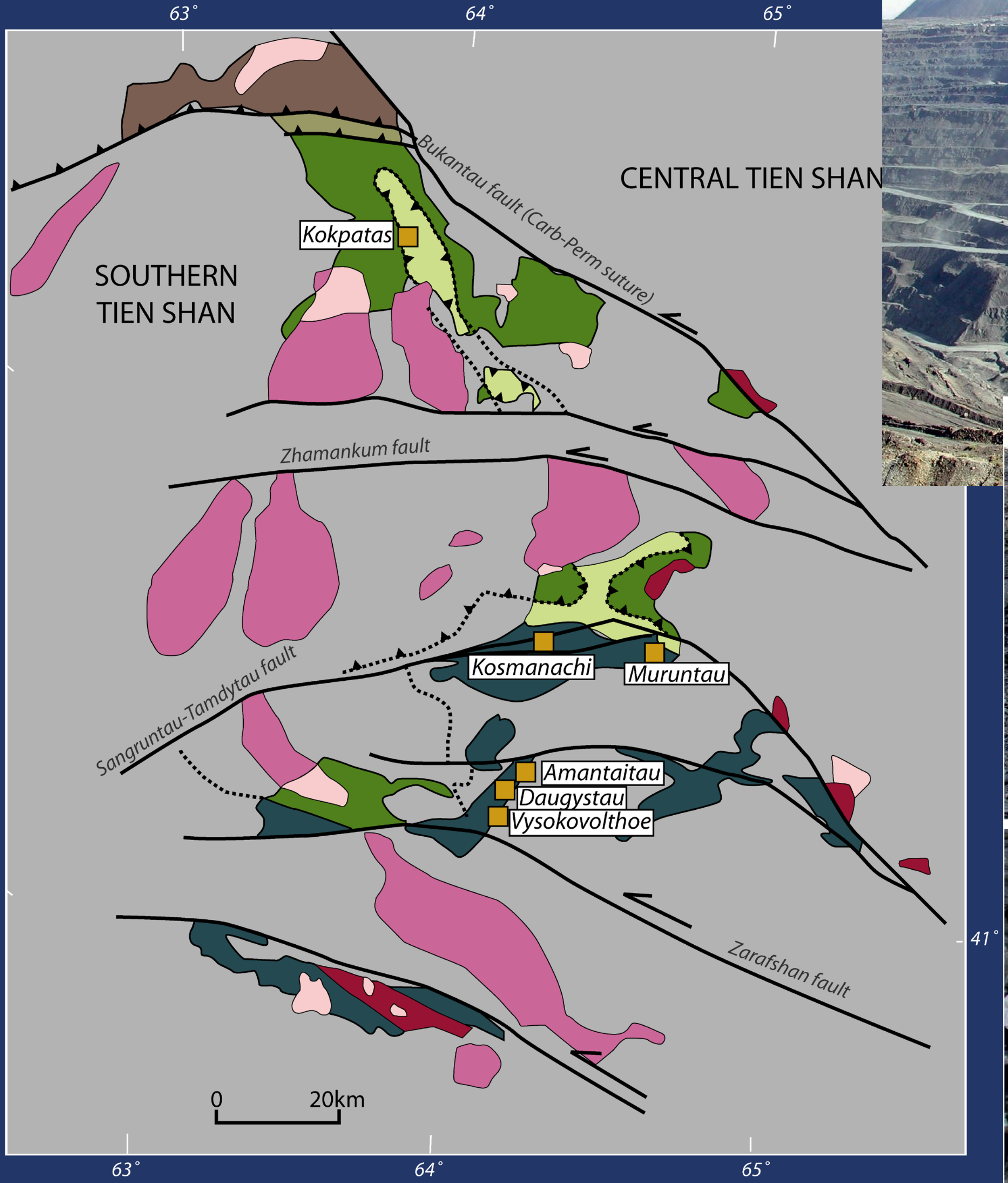
GIANT PLACERS, NE RUSSIA (Goryachev et al)

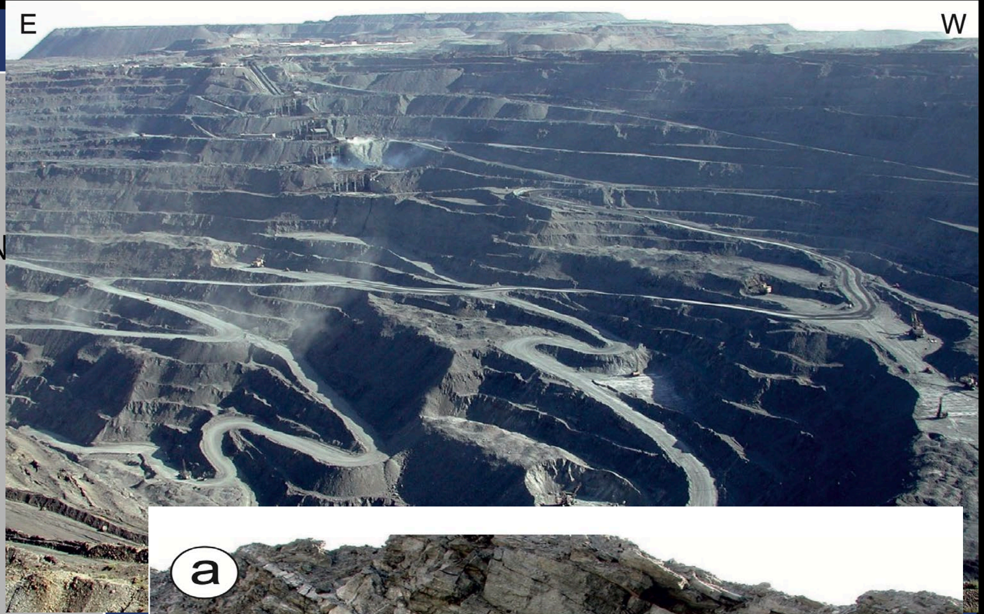


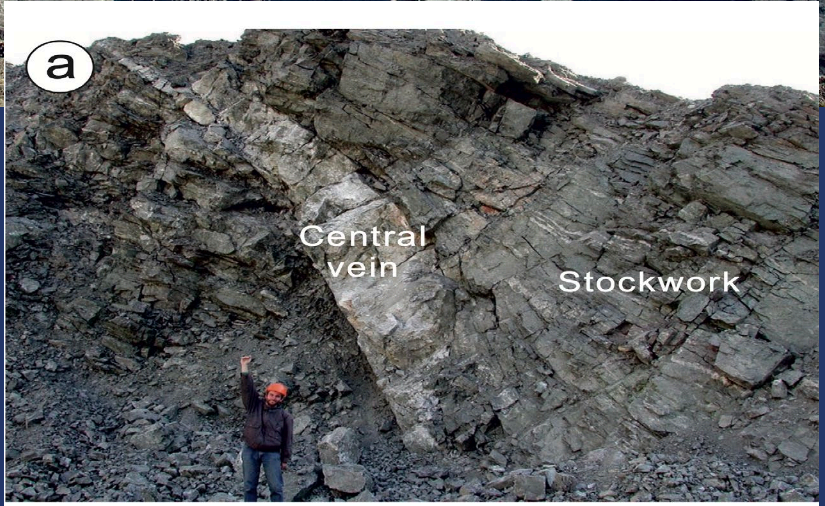




- Upper Kolyma watershed with huge lode potential (>200Moz lode+placer)
- 136-125 Ma strike-slip and lode Au in in Kular-Nera flysch of Kolyma & Allakh-Yun of S.Verkhoyansk craton margin; reactivated Jurassic thrusts

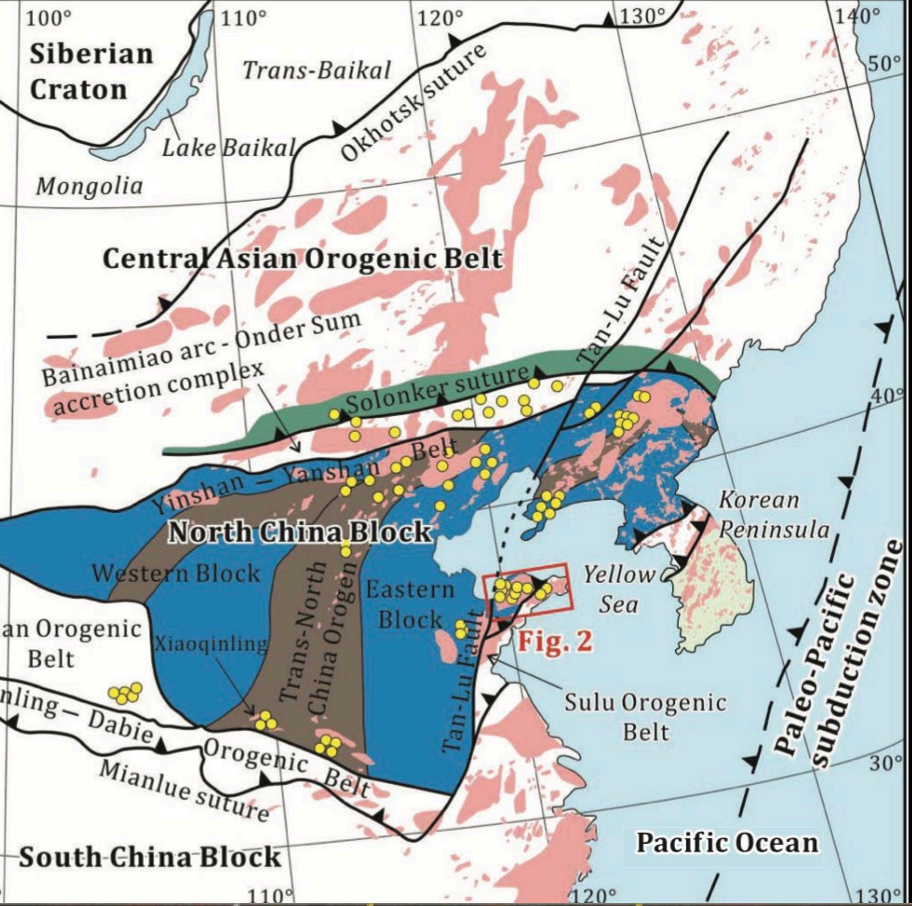


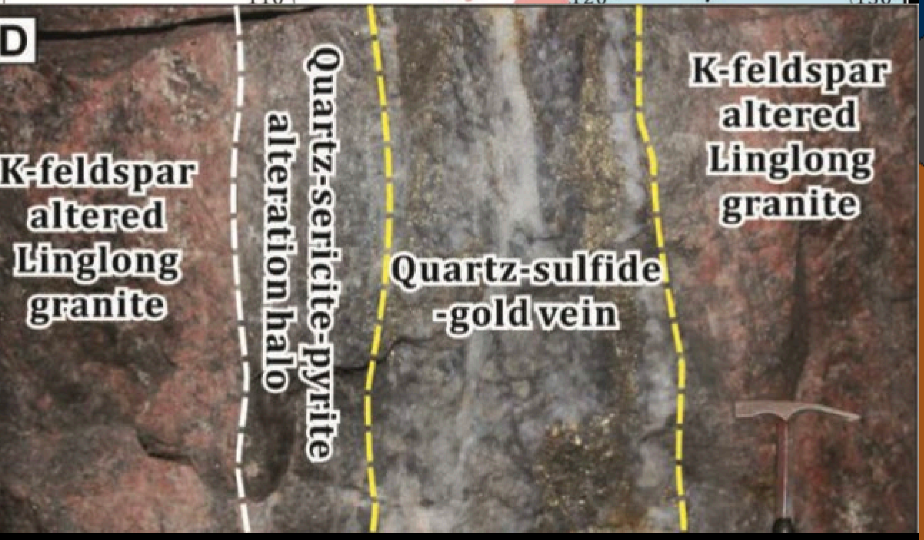


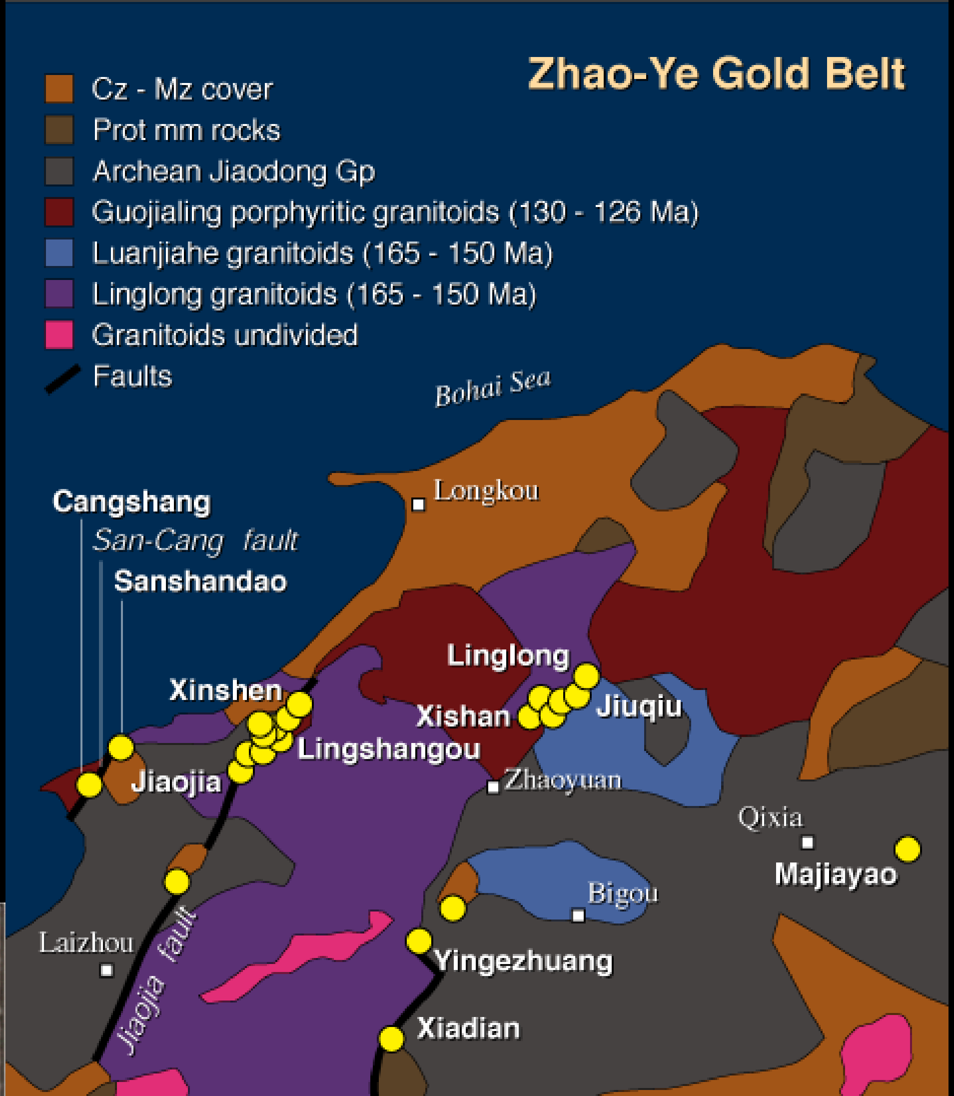


MURUNTAU (Seltmann et al)

- 170 Moz Au (3.5-4 g/t)
- Camb-Ord flysch deformed pre-300 Ma
- Left-lateral movement on splays and magmatism in large jog (300-275 Ma)
- Qtz-KF stockworks in large hornfels zone
- Fault intersections along plunging anticlinorium nose
- Carbonate seal?
- Bt, KF or albite, dolomite, aspy, py, po scheelite; late Sb, Te
- Ages of mx 370-220 Ma,; likely ca. 288 Ma—late defm
- MM vs TAG vs Mantle genetic models

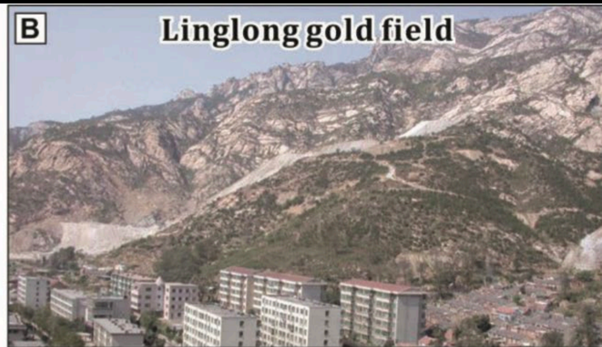






JIAODONG (Qiu et al)

- 150 Moz (2 Moz/yr)
- Archean & Pprot blocks
- 165-145 Ma batholiths; scattered 130-122, 119-110 Ma plutons
- Gold=ca. 120 Ma along margins of Jurassic batholiths exposed as MCC
- Young Au in old terranes & Au in extensional setting
- Mm model (subduction) or magmatic model or unique decratonization model?
- Classification?



EXPLORATION CONSIDERATIONS IN METASEDIMENTARY PROVINCES

- Unlikely isolated deposit (e.g., West Africa, Lena, Baikal, So. Tien Shan, Yensei Ridge); Large h-g oxide zone (Olympiada) or favorably oriented very l-g ore body (Paracatu) may be critical for a project's success
- Fault reactivations, basin inversions, changing stresses needed for fluid focusing
- Carbonaceous sedimentary sequences associated with giants (source?, trap?)
- Early timing (Paracatu, Obuasi) to late timing (Loulo, Kolyma) or perhaps just many tens of millions of years (Sukhoi Log? Olympiada? Muruntau?)
- Structures=jogs, fold noses, fault intersections, complex settings (Muruntau, Sukhoi Log, Jiaodong)
- Competency contrasts: Stratigraphy (Telfer), Hornfels (Muruntau), Pre-ore KF (Jiaodong), Pre-ore albite (Loulo)
- Magmatism: Almost always syn-Au but none at Paracatu
- Metamorphism: Consistent greenschist but not at Jiaodong
- Genetic model: Metamorphic? Magmatic? Maybe a local model on observed geology is always best

Gold Deposition

Stuart Simmons

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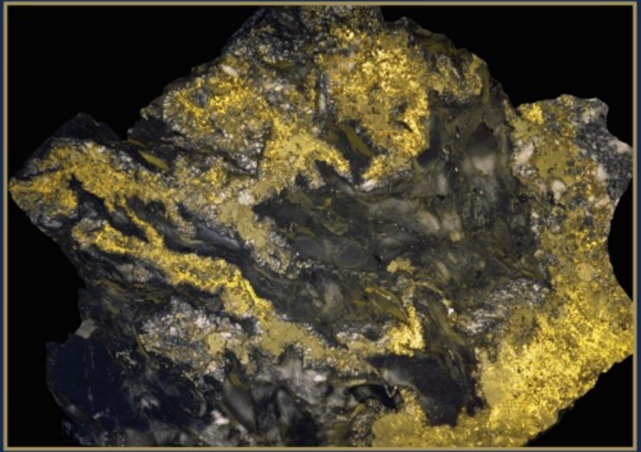
Geology of the World's Major Gold Deposits and Provinces



Richard H. Sillitoe, Richard J. Goldfarb,
François Robert, and Stuart F. Simmons, Editors

Special Publication Number 23
Commemorating the 100th Anniversary of
The Society of Economic Geologists, Inc.

Hydrothermal Gold Deposition in Epithermal, Carlin, and Orogenic Deposits

Stuart F. Simmons,[1,2,3,†] Benjamin M. Tutolo,[4] Shaun L.L. Barker,[5] Richard J. Goldfarb,[6,7] and François Robert[8]

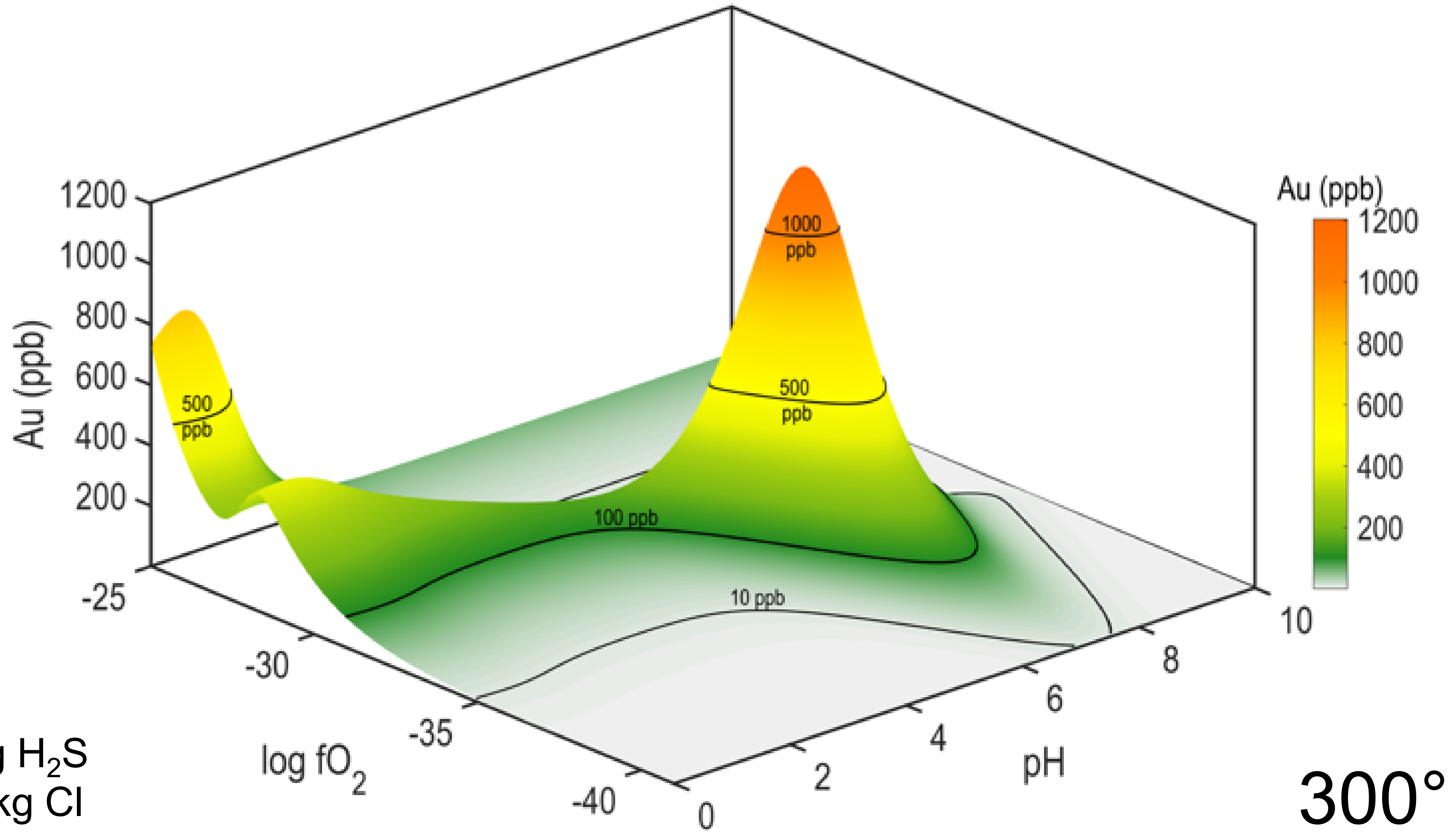
Metal precipitation is the ultimate & most important event, producing ores & geochemical anomalies.

Similar thermal & chemical characteristics permit comparison of Au depositing processes across all three deposit types.

Analysis

- -experimental data
- -metal transport-deposition in modern hydrothermal systems
- -mineralogical-geochemical-geological context of gold orebodies.

Gold solubility in sulfidic hydrothermal solutions



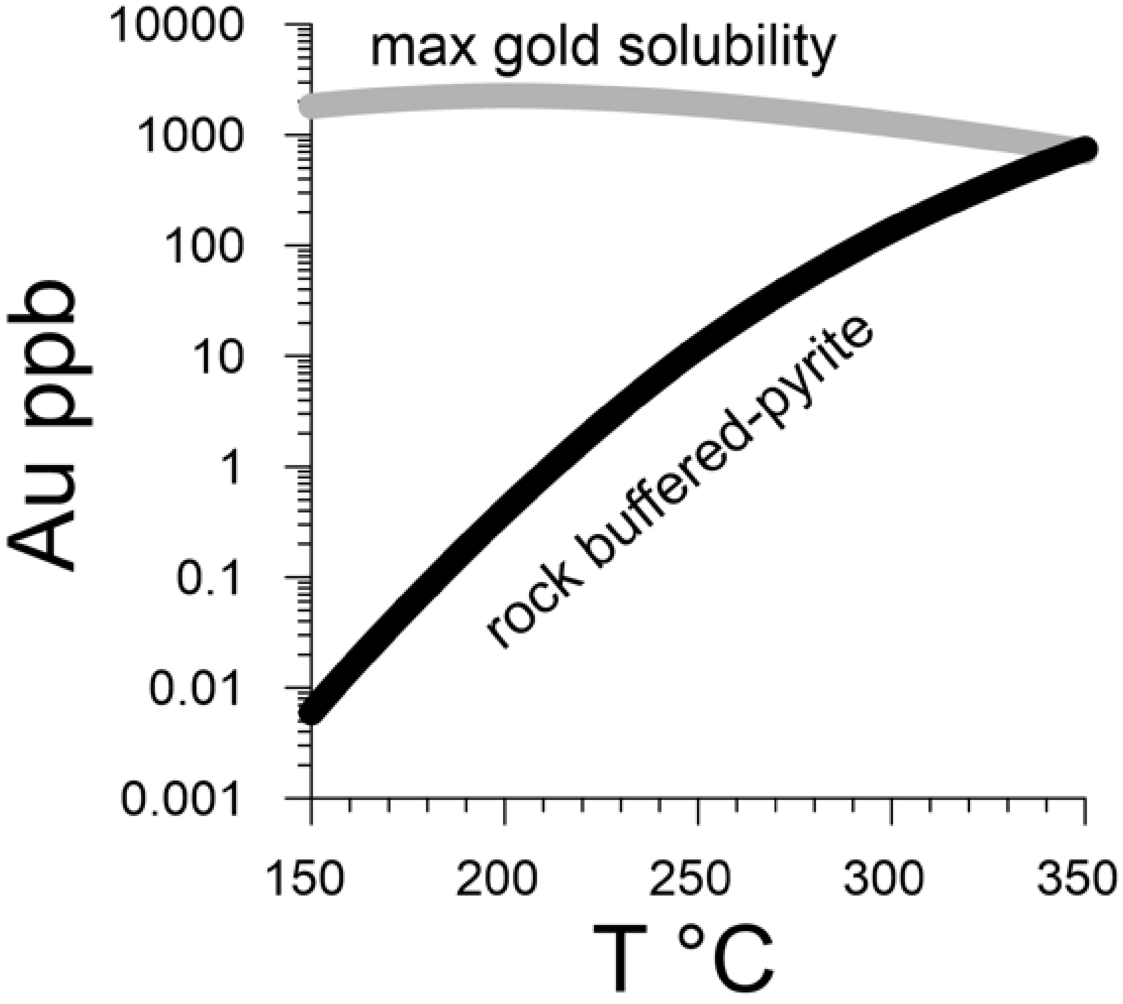
320 mg/kg H_2S
7000 mg/kg Cl

300°C

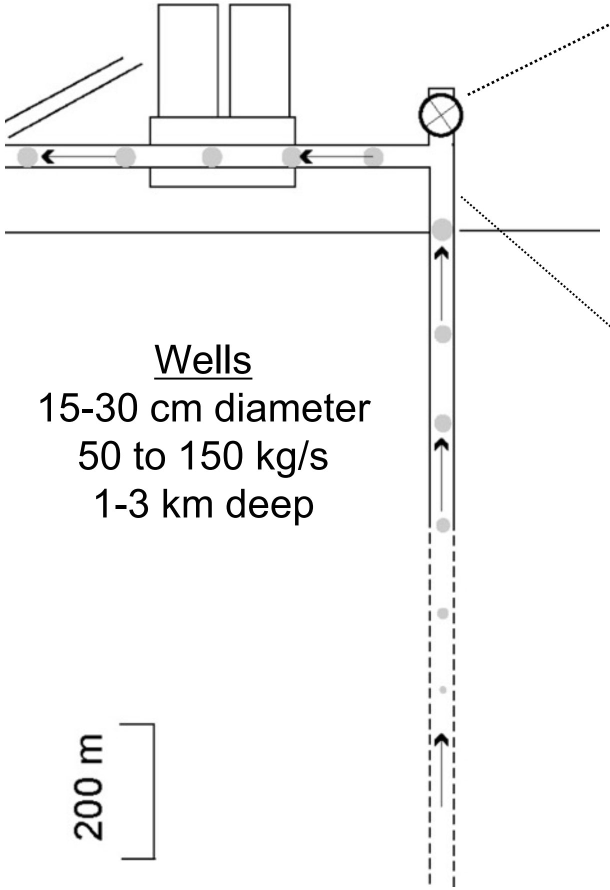
Gold solubility in sulfidic hydrothermal solutions

Optimal pH (near neutral)
Redox State (reduced S

320 mg/kg H_2S
7000 mg/kg Cl



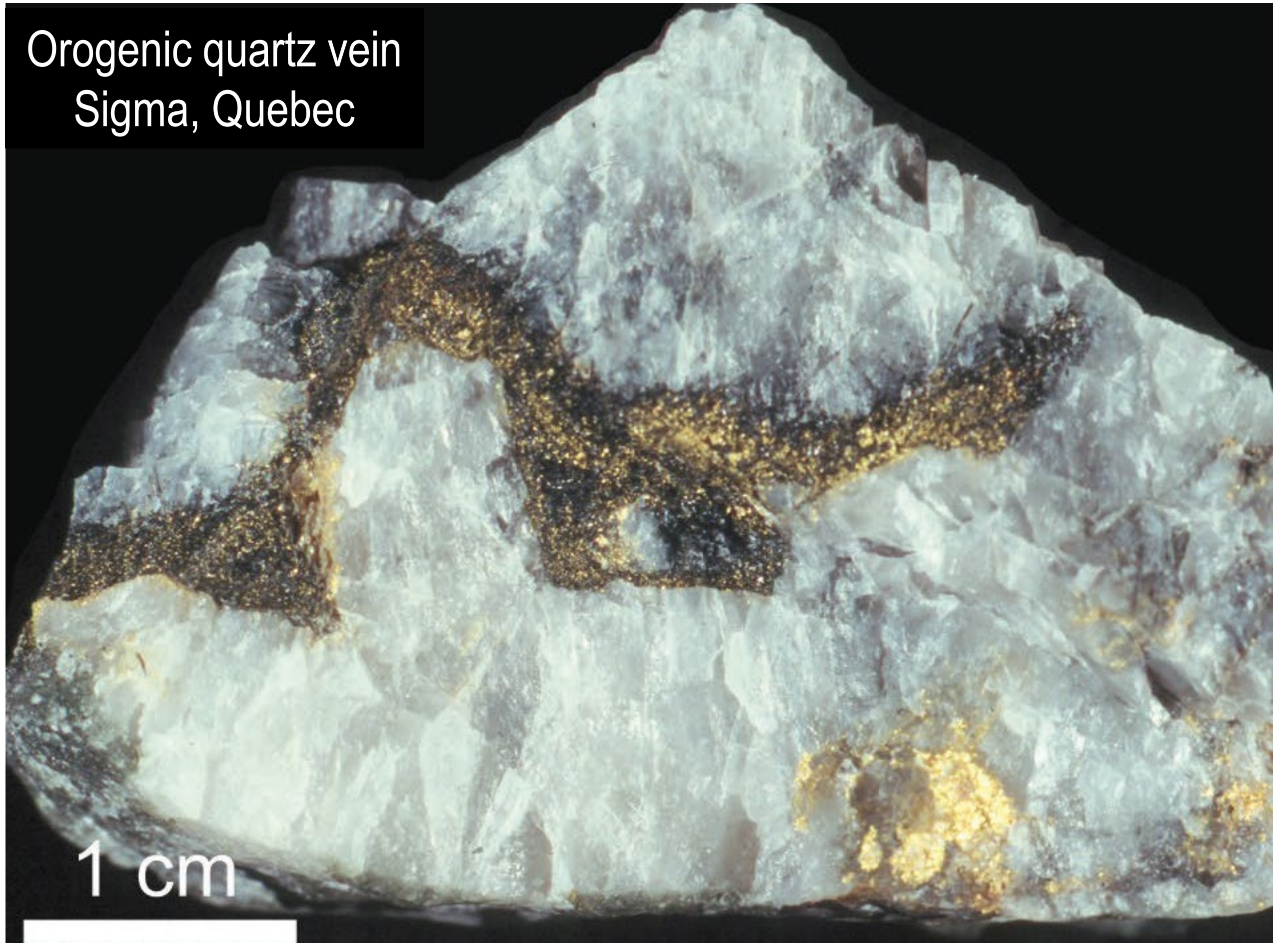
Gold deposition from sulfidic hydrothermal solutions

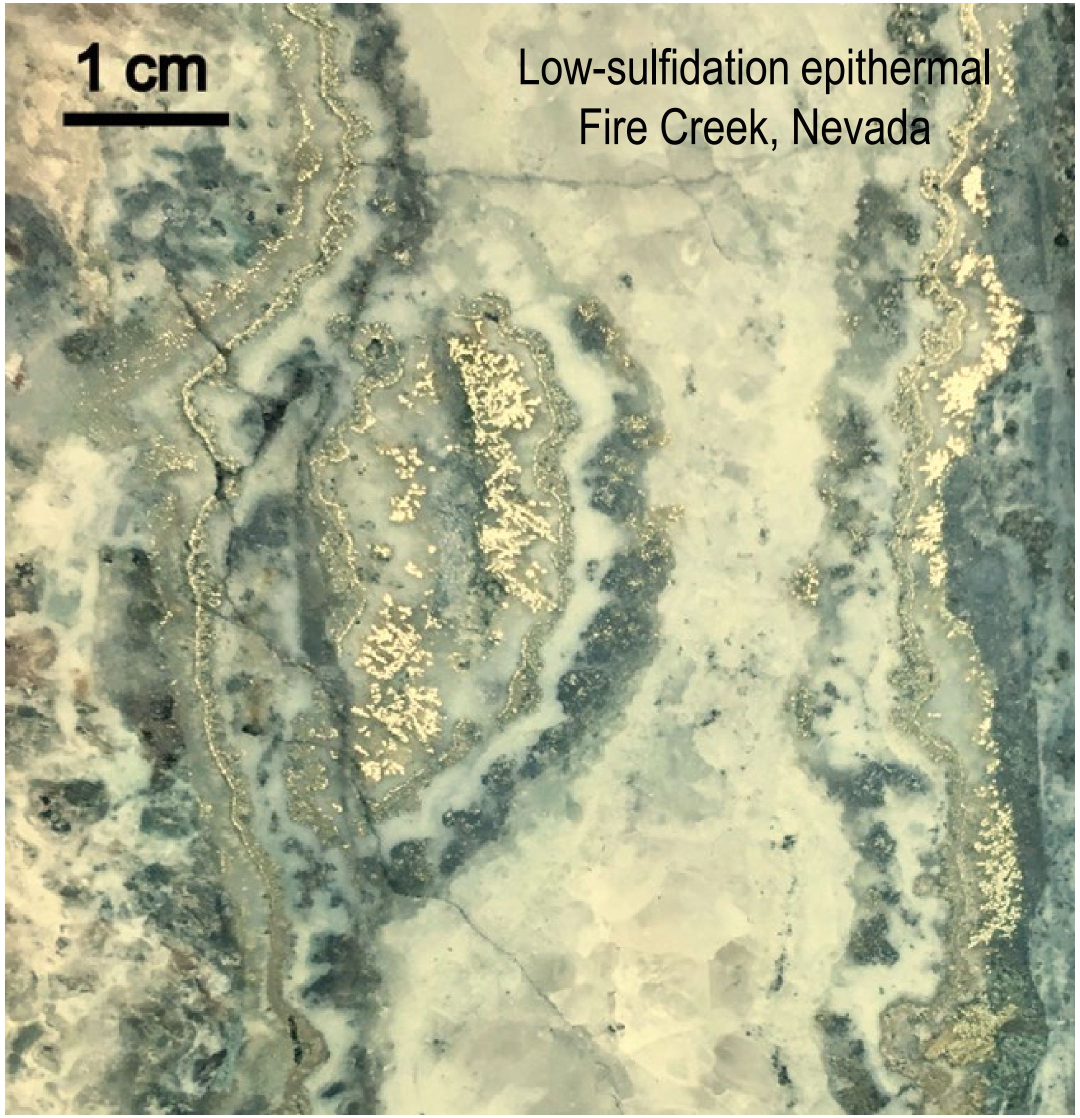


chalcopyrite scale	*solution*
60,000 ppm Au	1 ppb Au
>100,000 ppm Ag	8 ppb Ag

Brown, 1986 Economic Geology

Gold deposition from sulfidic hydrothermal solutions





Gold deposition from sulfidic hydrothermal solutions

Au deposition via chemisorption

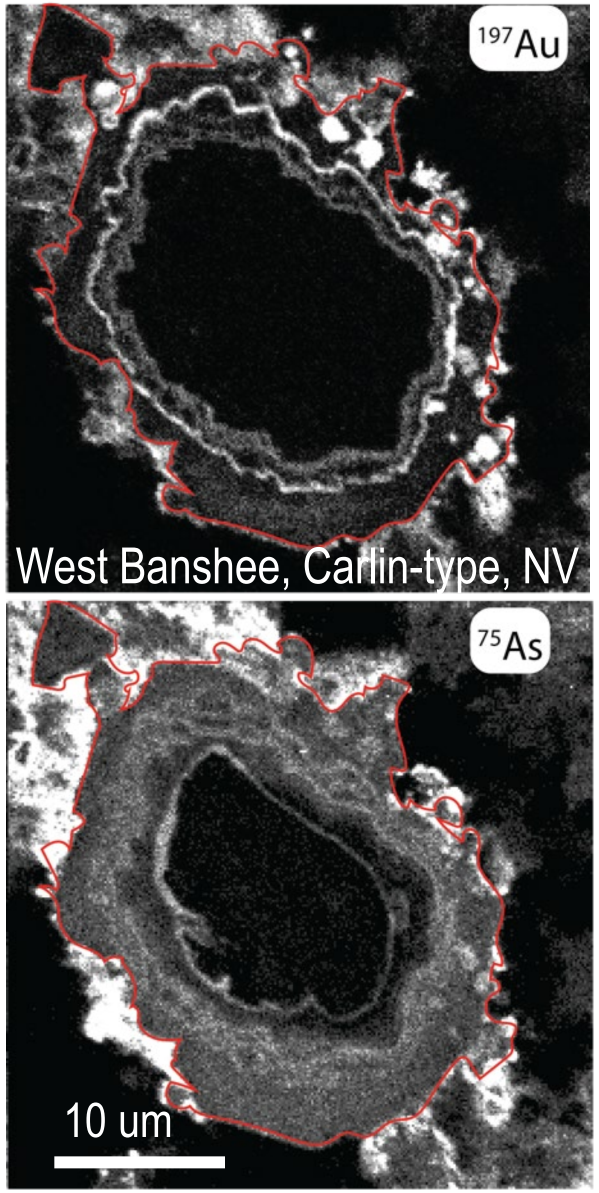
Chloride water: 74° C
pH ~5
2000 ppm Cl
3 ppm H_2S

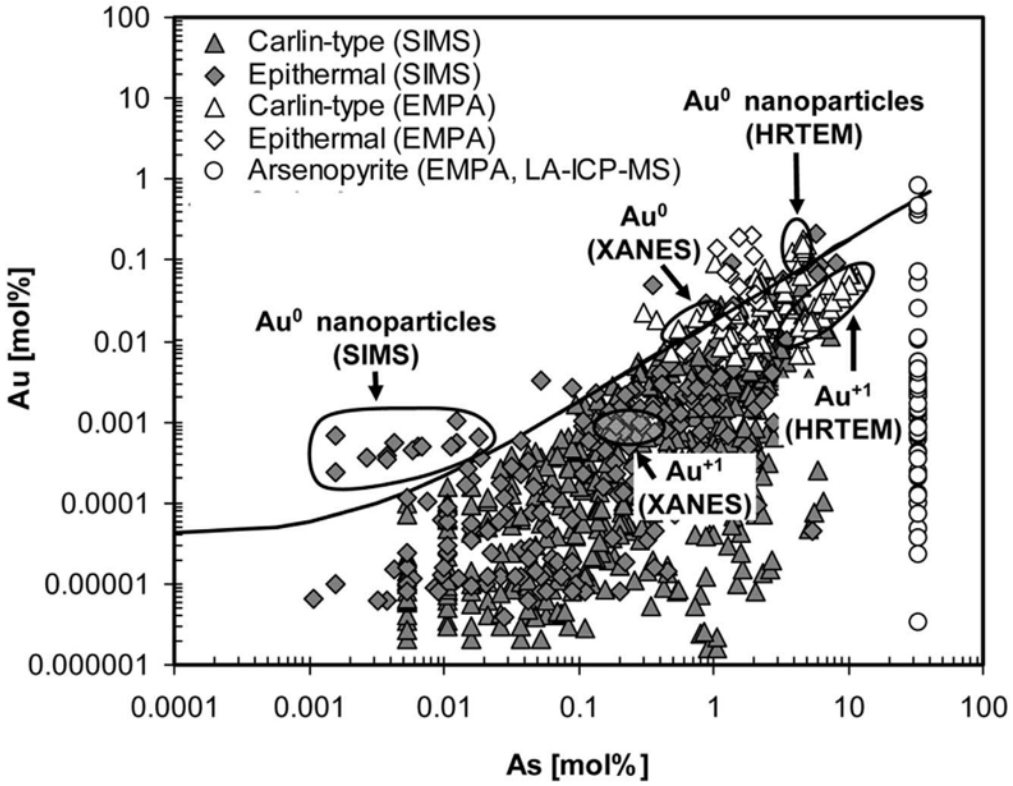
0.10 ppb Au
0.02 ppb Ag

Au & Ag deposit on As-Sb-S rich colloids
540 ppm Au
750 ppm Ag

Pope et al, 2005 Economic Geology

Gold deposition from sulfidic hydrothermal solutions





For Carlin ores, Au deposits on to As-rich pyrite rims due to chemisorption.

The evidence is supported by high magnification elemental maps & microbeam analyses.

Simon et al., 1999; Reich et al., 2005; Barker et al. 2009; Deditius et al., 2014.

Predominant Mechanisms of Au Deposition

Epithermal Ores

- –phase separation (boiling)
- –mixing

Carlin Ores

- –sorption of ionic Au on to the surfaces of As-pyrite

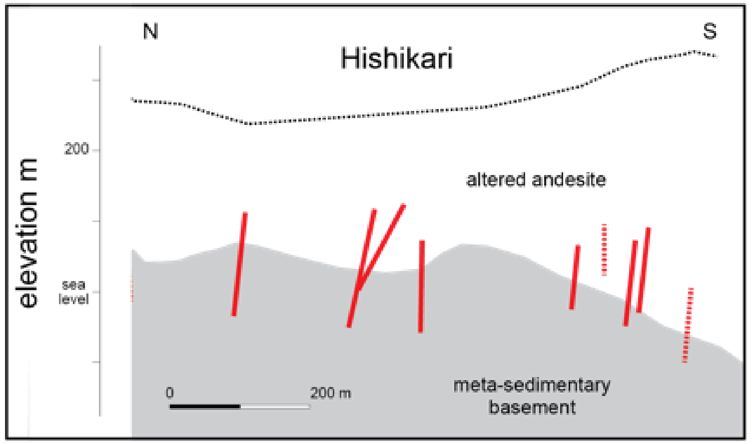
Orogenic Ores

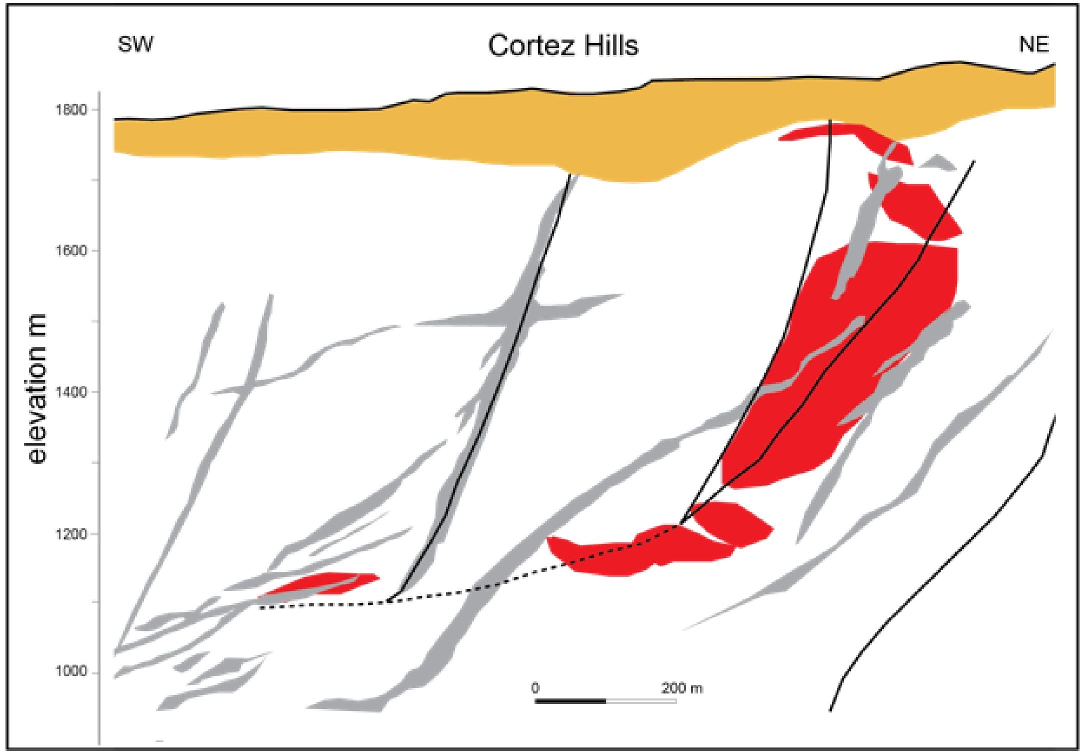
- –phase separation
- –pyritization (sulfidation) via water-rock interaction
- –reduction via interaction with graphitic rocks
- –co-precipitation As-pyrite & arsenopyrite

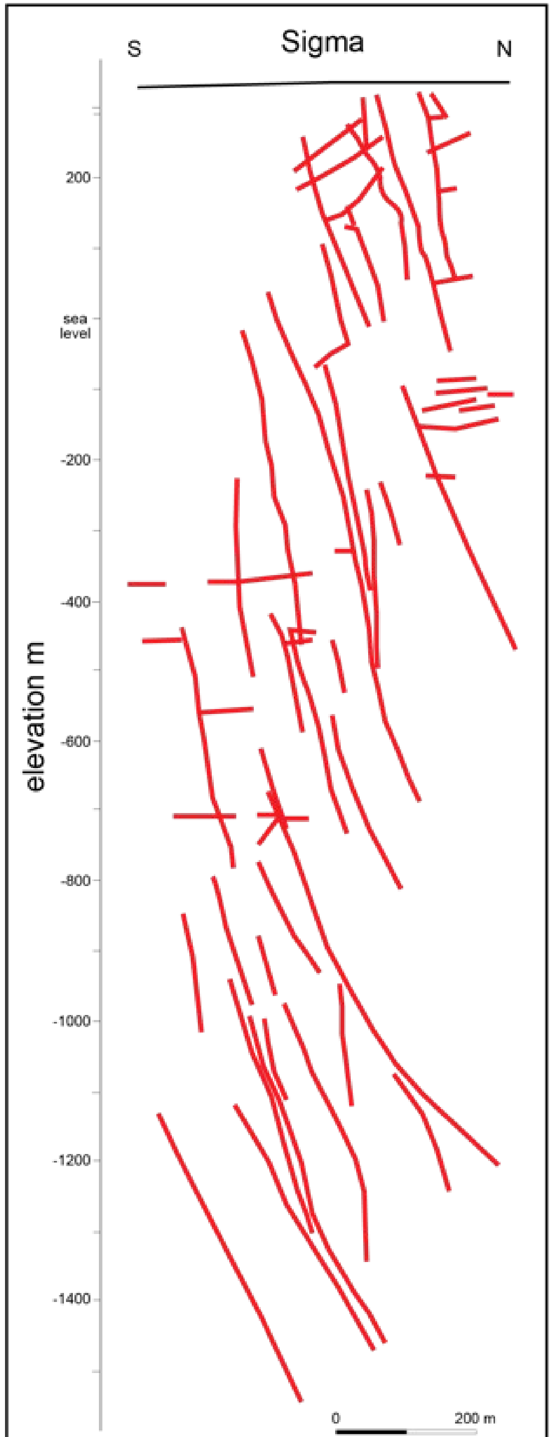
Ore body geometries/dimensions

Fluid flow rates/directions

Duration of mineralization (repeated/long lived mineralization)







- Descriptive papers on 29 important deposits & 7 major provinces
- Manuscripts authored by industry & research geologists
- Mature mining districts to recent discoveries
- Exploration histories
- Geological context
- Ore body geometries
- Structural & Lithological controls
- Mineralogical & geochemical associations
- Maps, sections & field/rock/mineral photos
- Comprehensive list of references

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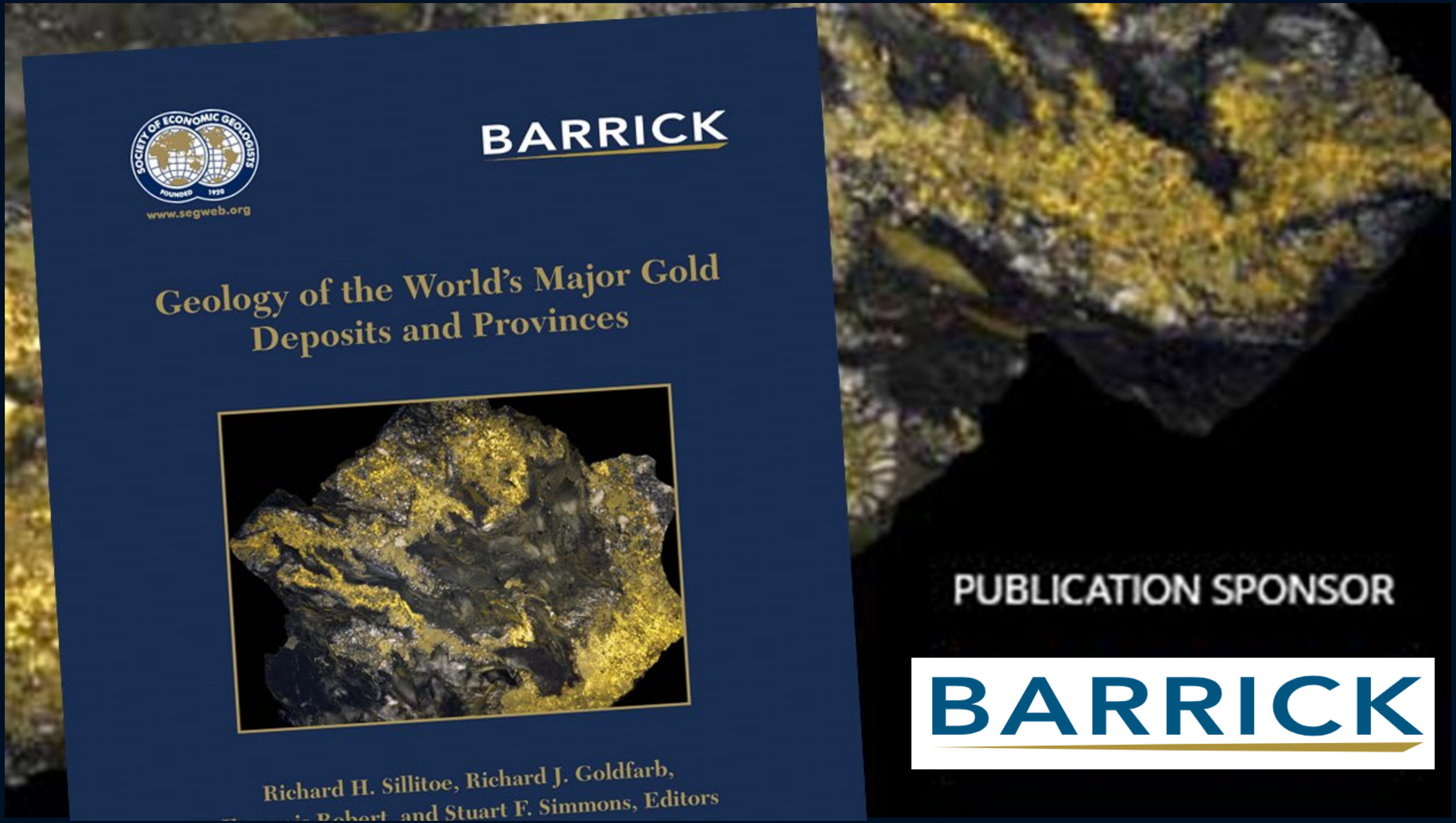

Q & A

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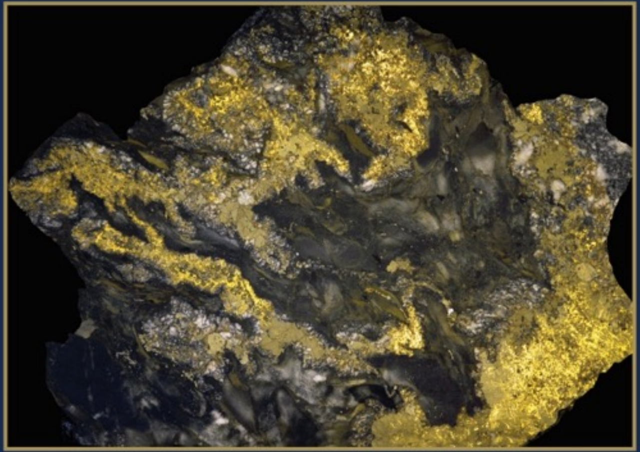

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