Rift-related geothermal activity and epithermal gold veins

- NZ rift-related geothermal activity and characteristics
- Features of rift-related epithermal Au veins
- Controls on vein characteristics
- Potential for epithermal Au veins in Ethiopia

with thanks to: Stratex East Africa Ltd.

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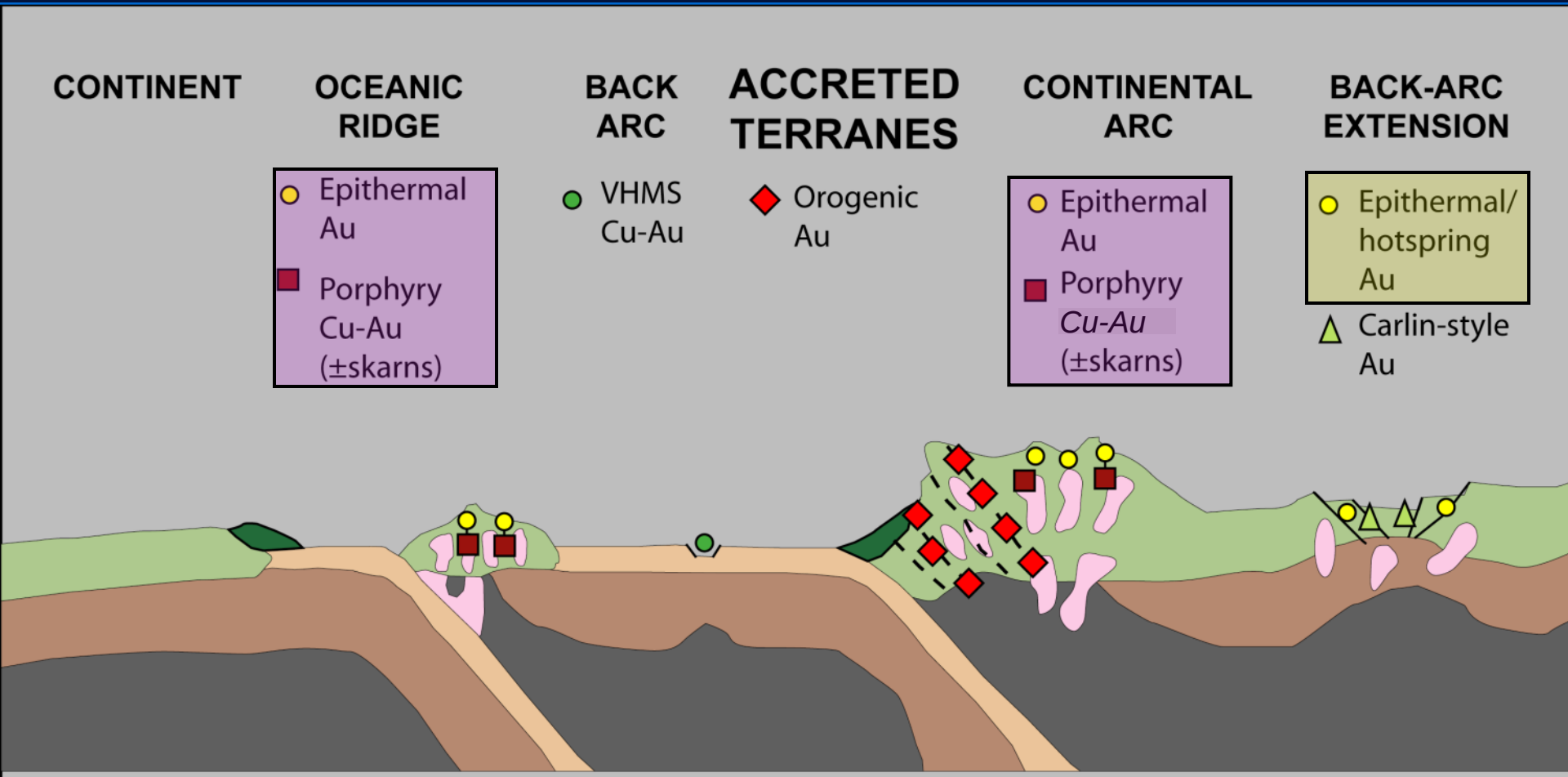
Tectonic settings of hydrothermal systems



after R. Goldfarb, from Groves et al. (2005)

Taupo Volcanic Zone, New Zealand

Looking NE: andesite arc to east, bimodal rhyolite-(basalt) in rift to west

~10,000 km^3,~1 M yrs: 97.8% rhyolite, 2% andesite, 0.2% basalt

Mt. Tarawera rhyolite dome, late basaltic dikes

Mt. Tarawera: Pink and White Terraces (silica sinter)

Tarawera and Waimangu, NZ

AD1315 rhyolite dome, driven by deep basalt

Nairn et al., 2006

Tarawera AD1886 dikes: basaltic fissure event

Destruction of Pink and White Terraces

Silica sinter: high Au, Ag, As, Sb, Hg, Tl; <0.2 wt% NaCl, high CO2 and H2S

Comparison of Taupo Volcanic Zone features with those of epithermal vein deposits

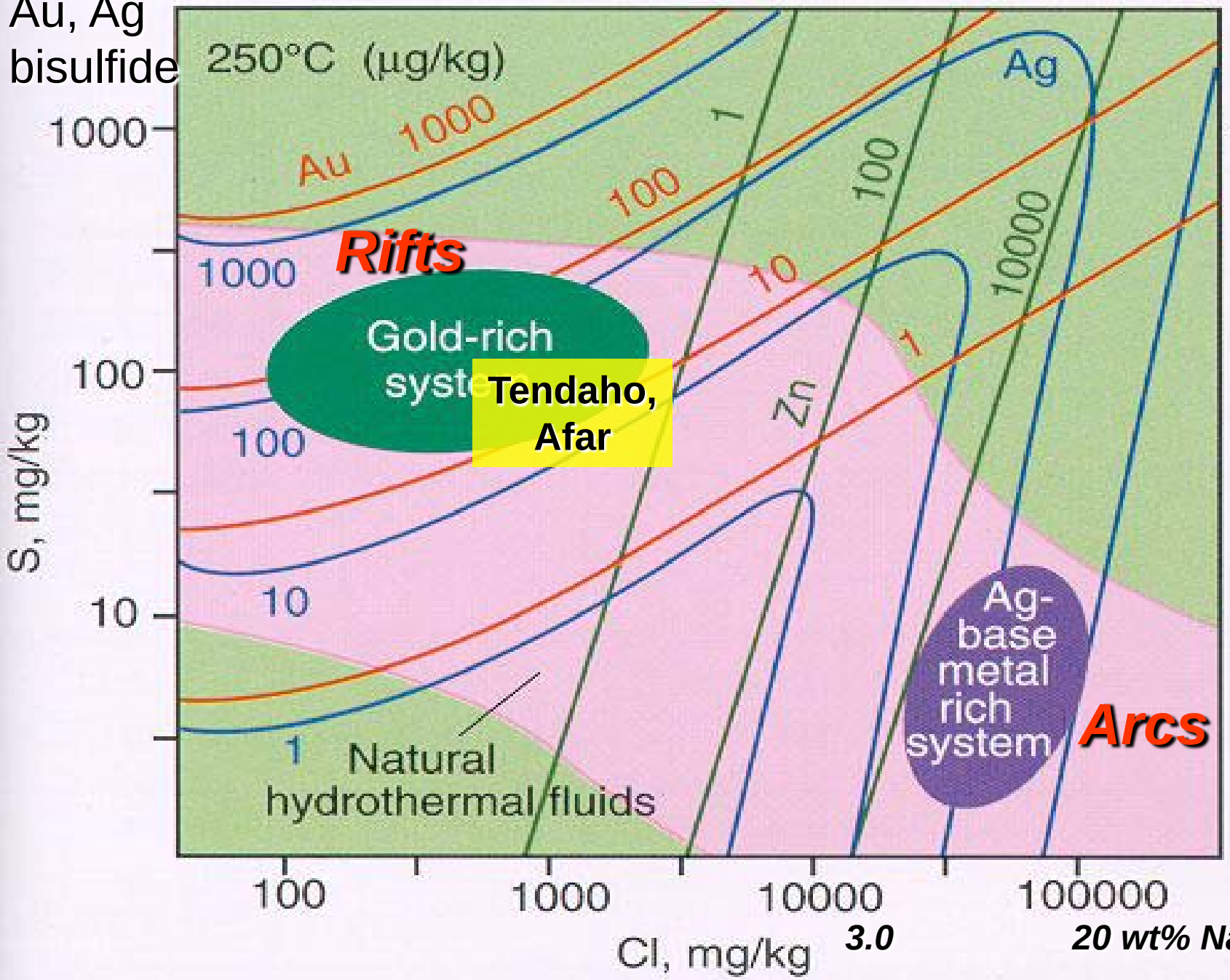
Taupo Volcanic Zone	**Back-arc extensional**	**Bimodal rhyolite-basalt**	**Au, Ag**	**<0.2 wt% NaCl, lo to hi CO_2, H_2S**

Epithermal style	**Tectonic setting**	**Magmatism**	**Metals**	**Fluids (NaCl, gases)**
Low sulfidation	Extensional; continental margin, back-arc or plume	Typically bimodal rhyolite-basalt, sub-alkaline	Au (Ag) Ag:Au ~ 1:1	0.1 to <2 wt% NaCl; CO_2, H_2S
Intermediate sulfidation	Neutral to extensional (or compressive) arcs	Andesite (dacite), calc-alkaline	Ag ± Pb, Zn (Au) Ag:Au > 20:1	3 to 7 (10 to 23) wt% NaCl; gases?

John, 2001; Sillitoe and Hedenquist, 2003

Henley, 1985, 1990

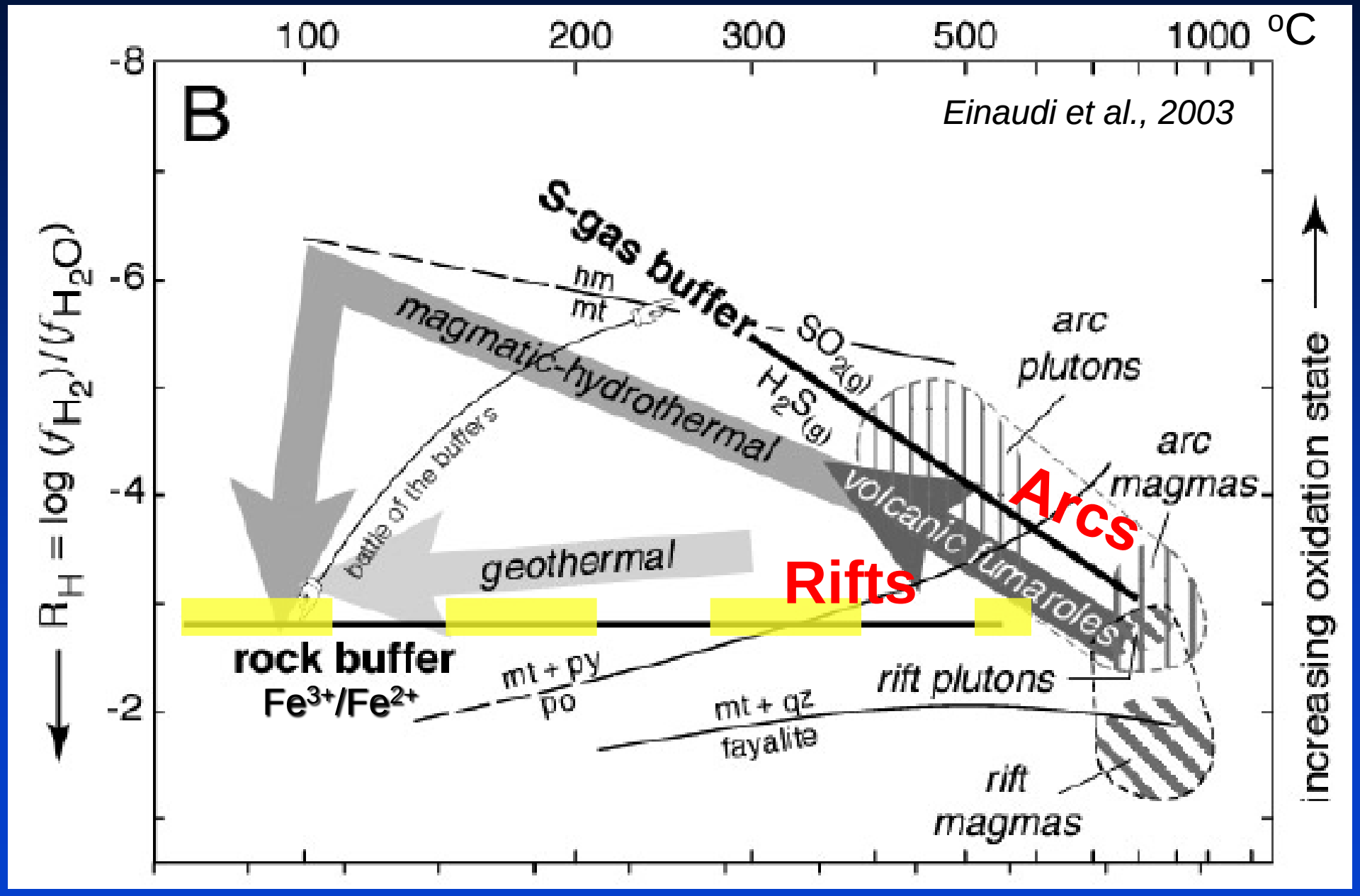
Au, Ag bisulfide

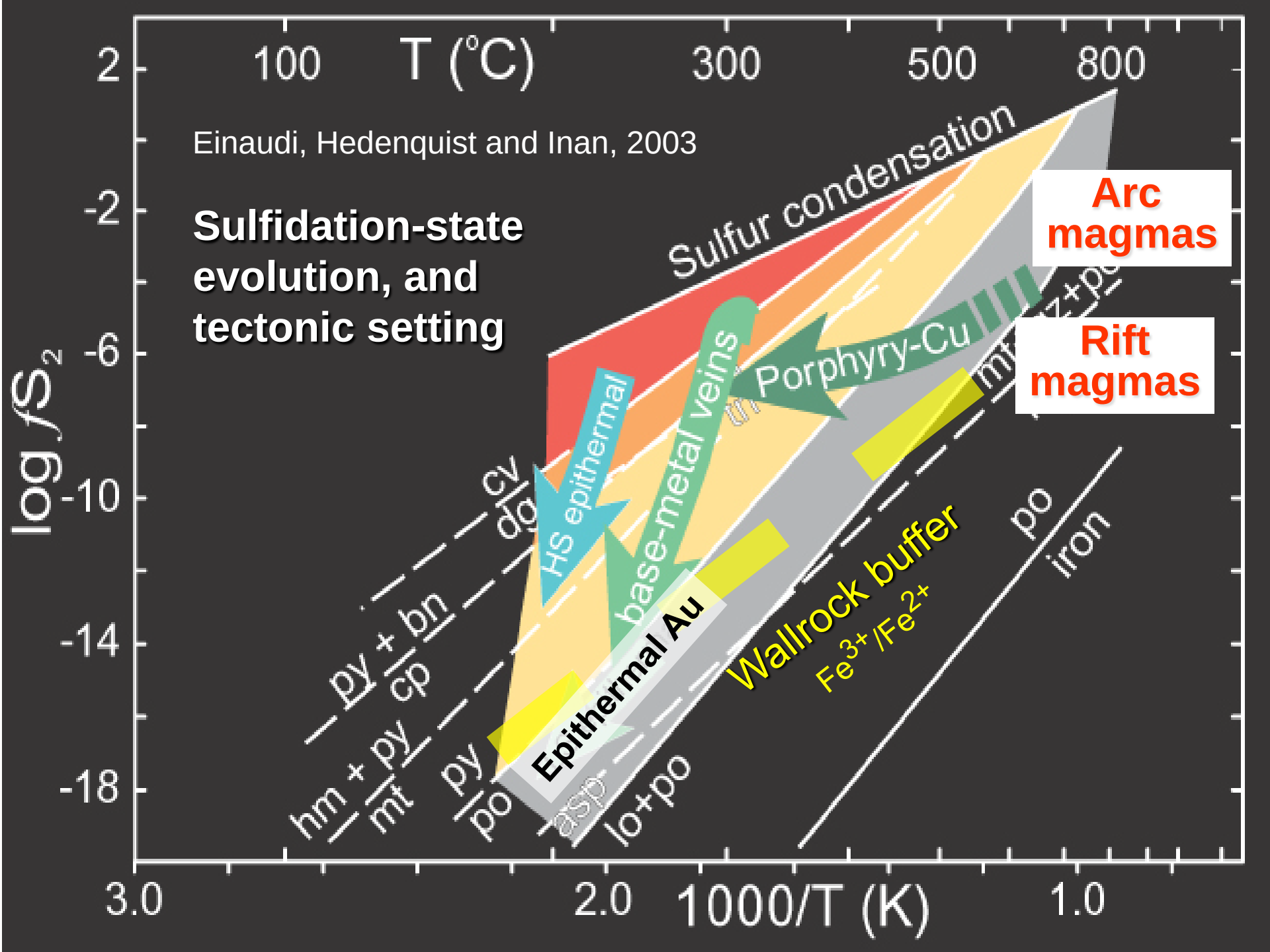


Ag, Zn chloride

3.0 ***20 wt% NaCl***

R_H (log fH_2/fH_2O) vs. 1/T

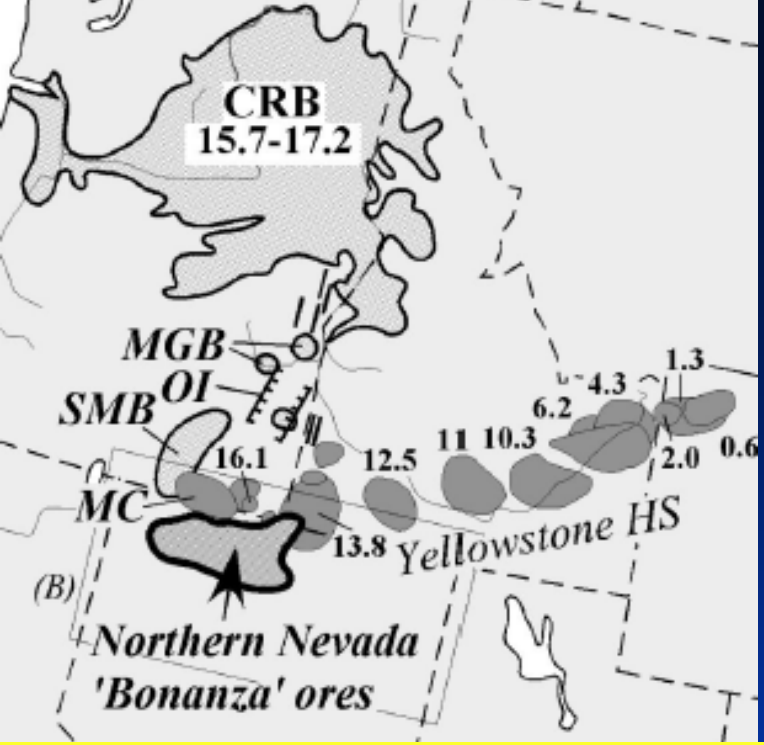


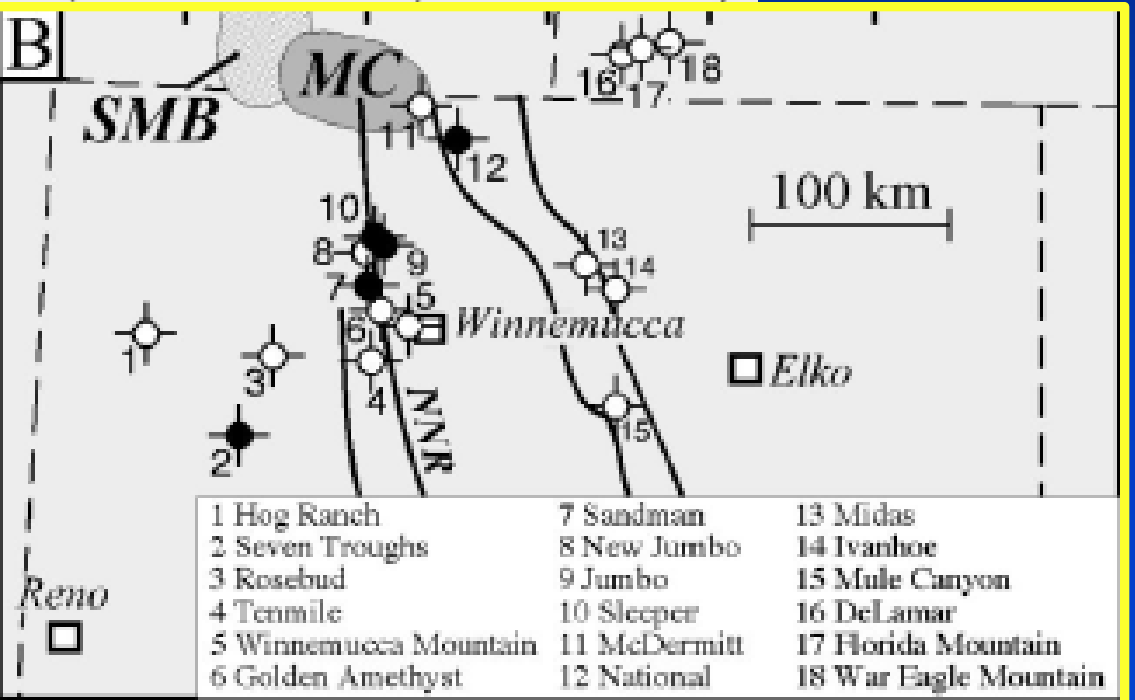

T (°C)
100
300
500
800
2
-2
-6
-10
-14
-18
log fS_2
3.0
2.0
1.0
1000/T (K)
Einaudi, Hedenquist and Inan, 2003
Sulfidation-state evolution, and tectonic setting
Sulfur condensation
Arc magmas
Rift magmas
Porphyry-Cu
HS epithermal
base-metal veins
Epithermal Au
Wallrock buffer
Fe^{3+}/Fe^{2+}
py + bn
cp
hm + py
mt
py
po
cv
dg
asp
lo+po
po
iron

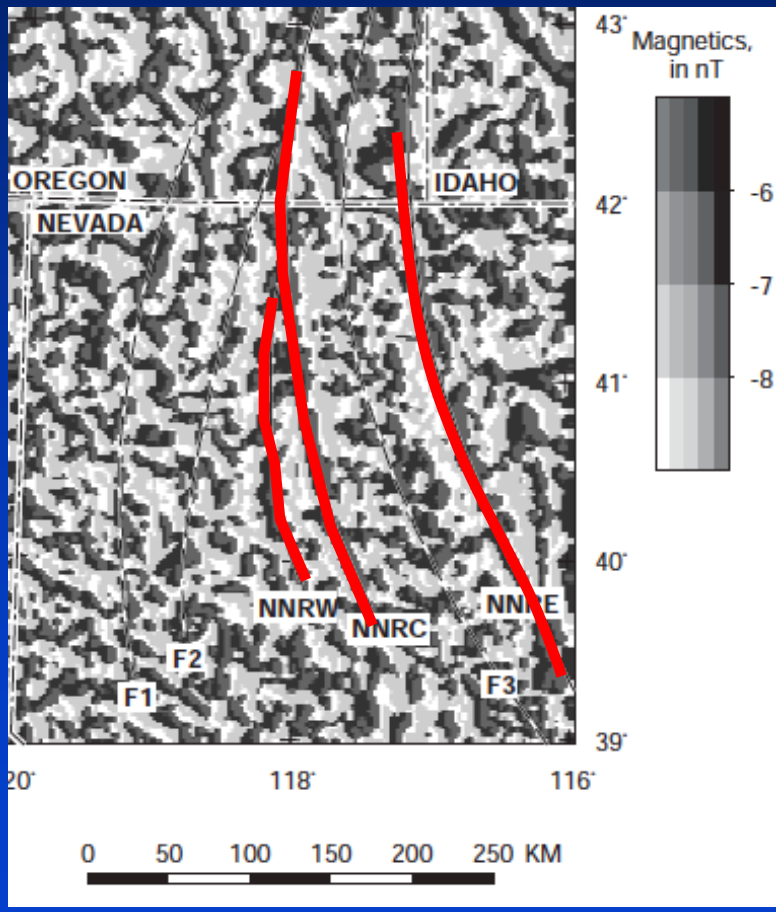
Northern Nevada rift: Plume driven

Rift-hosted epithermal Au deposits

Geist and Richards, 1993; Dickinson, 2006
Kamenov et al., 2007; Ponce and Glen, 2002

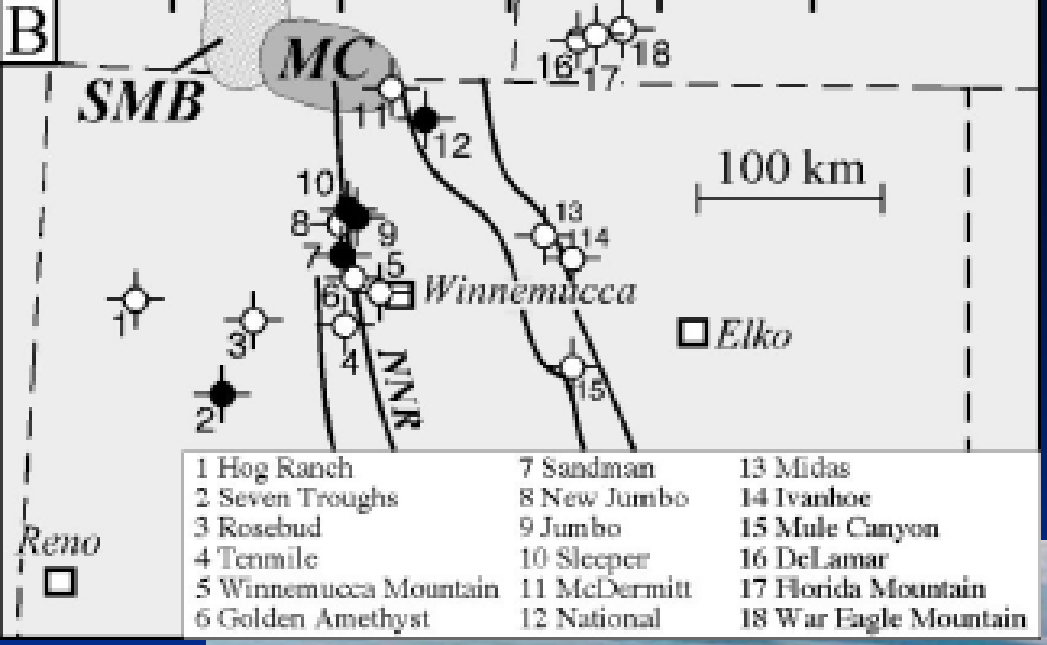






Northern Nevada rift and epithermal Au veins

Saunders et al., 2010



Sleeper low-sulfidation bonanza epithermal Au deposit, Nevada

Episodic events, extreme disequilibrium:

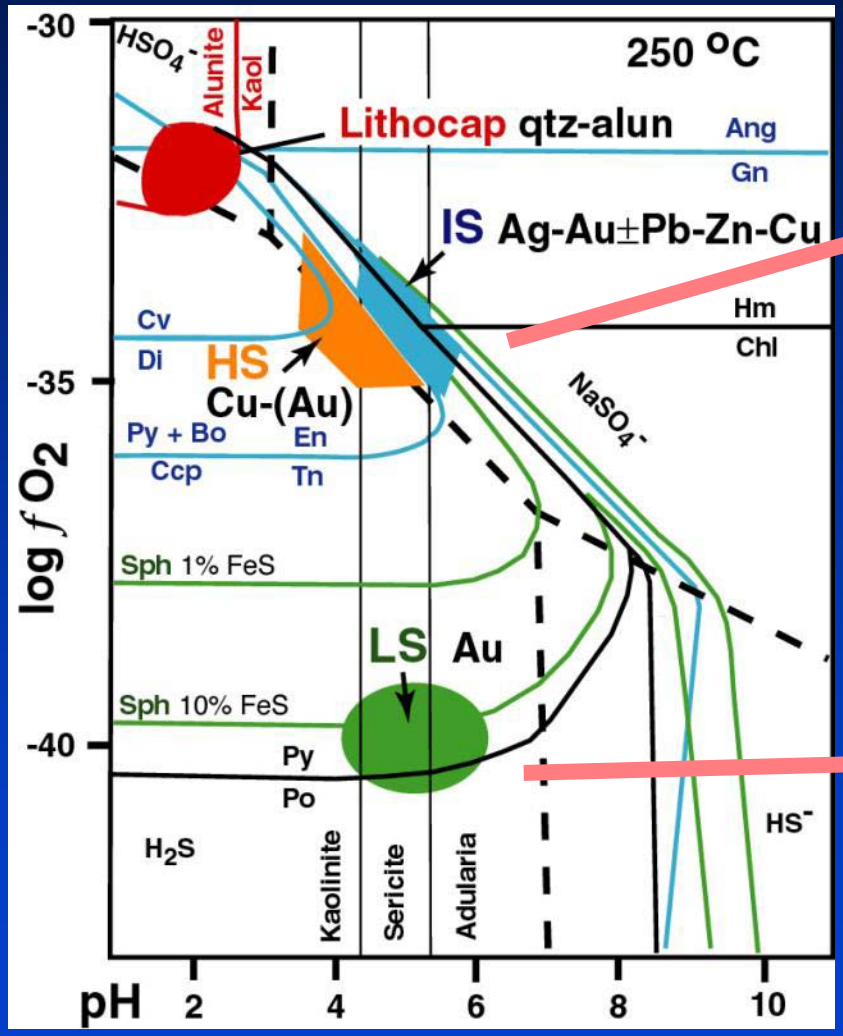
Rapid fluid ascent, vapor loss

Formation of amorphous silica colloidal gels (colloform)

Vapor + gas loss (H2S, CO2)

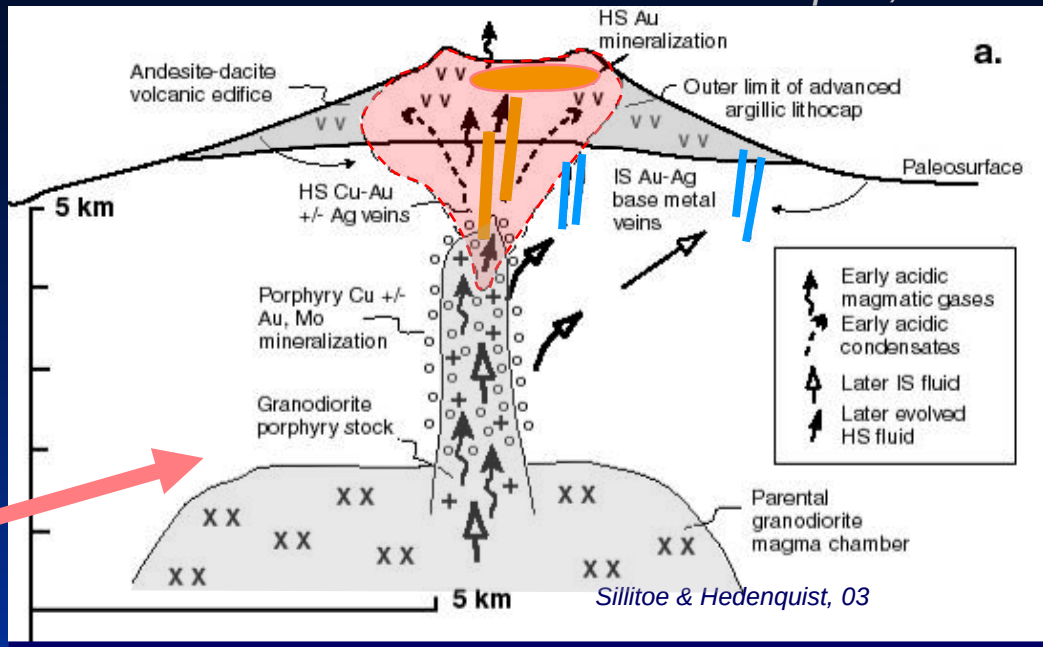
Gold dendrite growth from colloids

Epithermal deposit types: fundamental differences, arc vs. rift hosts

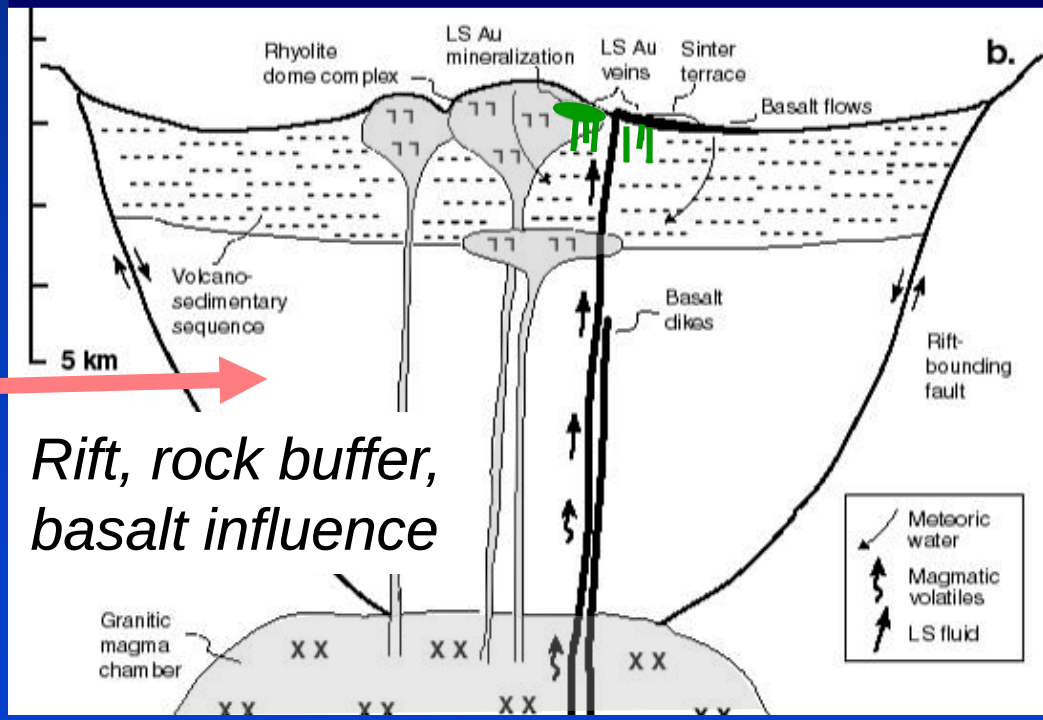


Hedenquist et al., 2001

Sillitoe and Hedenquist, 2003



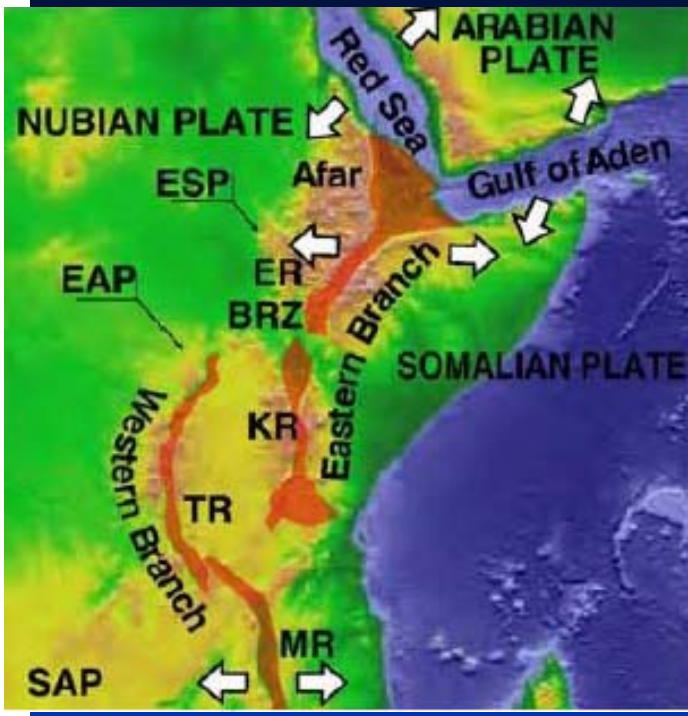
Sillitoe & Hedenquist, 03



Rift, rock buffer, basalt influence

Stratex compilation; Corti, 2009

Epithermal Au prospects of the Afar



39°E 40°E 41°E 42°E 43°E 44°E

15°N 14°N 13°N 12°N 11°N 10°N

Southern Red Sea

Arabian Peninsula

Danakil Block

Ethiopian Escarpment

Ethiopian Plateau

Megenta

Gulf of Aden

Tendaho-Gobaad Discontinuity

Ali-Sabieh Block

Main Ethiopian Rift

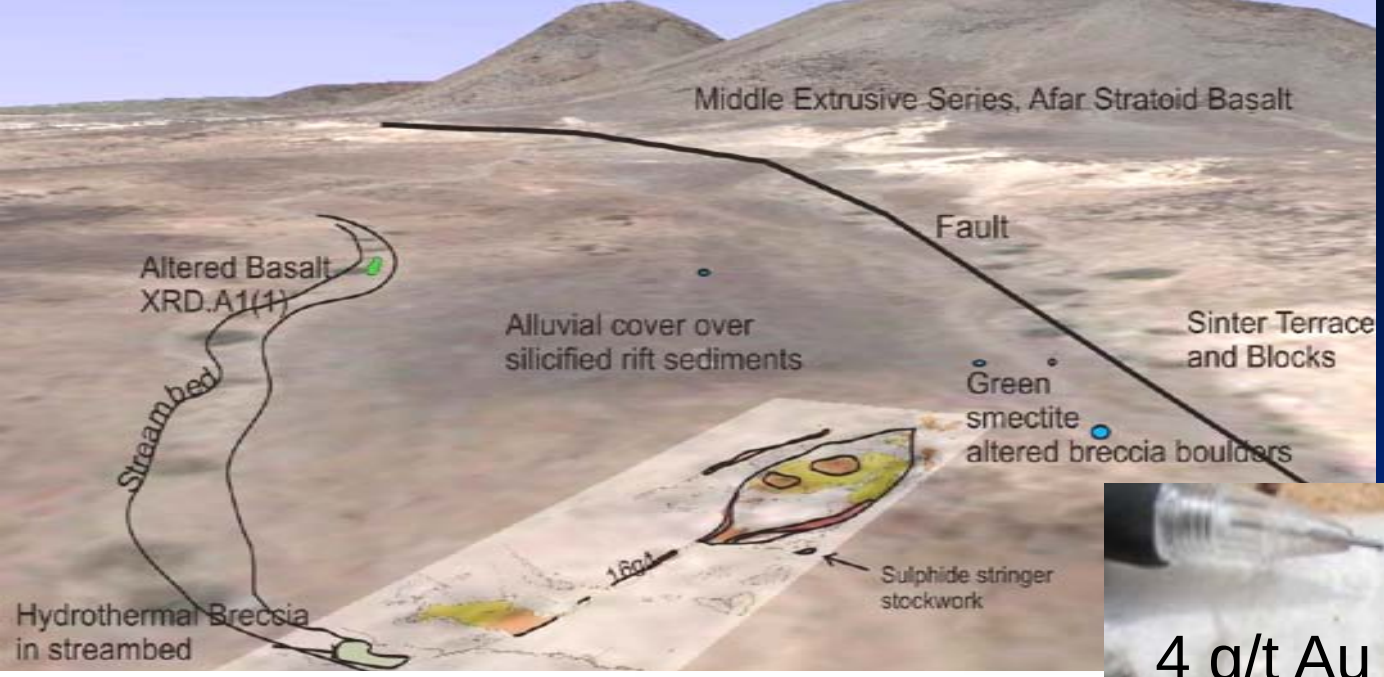
Somalian Plateau

Normal/strike-slip fault
Pliocene flood basalts
Pliocene - Recent sediments
Proterozoic basement / Eocene-Miocene flood basalts
Quaternary magmatic complexes

1. Erta'Ale volcanic complex
2. Tat'Ale volcanic complex
3. Alayta volcanic complex
4. Manda rift zone
5. Hararo rift zone
6. Gobaad rift
7. Asal-Ghoubbet rift
8. Manda-Inakir rift

Magenta epithermal Au prospect, Tendaho

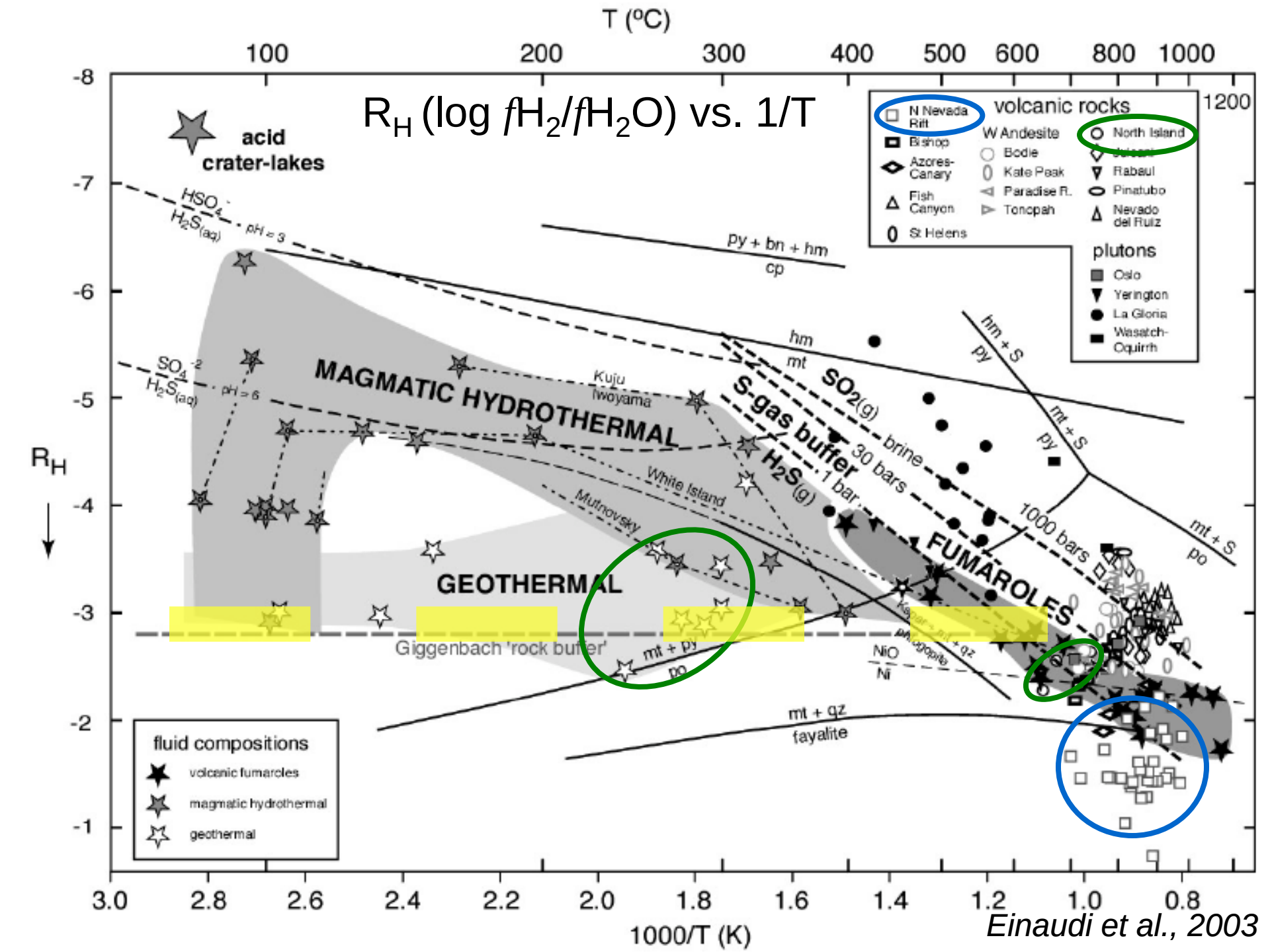
Lavelle, MSc 2010; Stratex, 2011



Conclusions: Volcanic-hosted epithermal Au veins

- **Rift-related geothermal systems:**
  - Thick rhyolite sequences; deep basaltic magma
  - Relatively reduced magmas and fluids; rock buffer control
  - Low salinity but variable (high) gases (particularly H2S)
  - Strong fault-related permeability, episodic opening
- **Low-sulfidation epithermal Au veins:**
  - Rifts: rhyolite-basalt bimodal products, dome hosts
  - Rock buffer control, low salinity; H_2S rich: high Au
  - Rapid ascent, boiling: Au and silica supersaturation
  - Basins, low relief: silica sinter aprons (steam-heated clays)

Ethiopia: right setting for bonanza Au veins



Einaudi et al., 2003

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