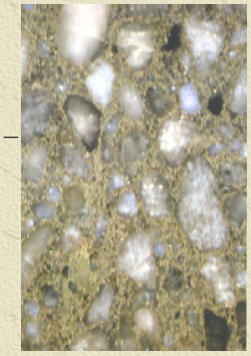
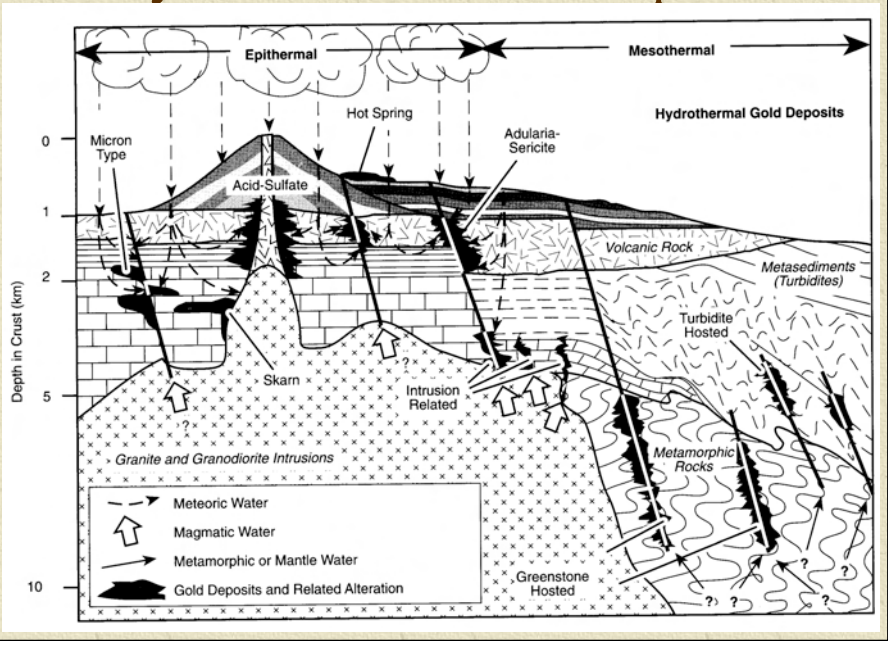
Orogenic Gold Deposits

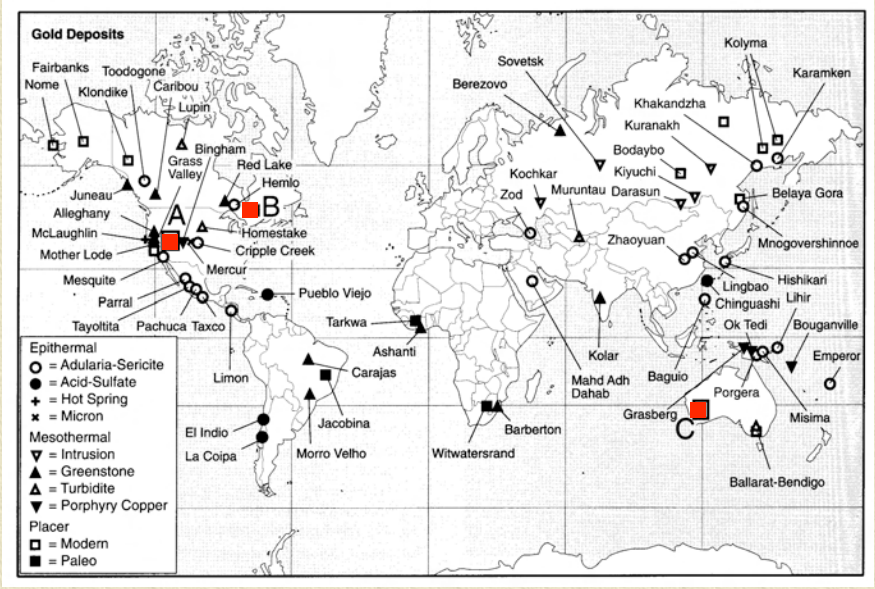


- Overview of gold deposits:
  - 1. Some statistics
  - 2. Genetic model
  - 3. Worldwide occurrence
  - 4. Orogenic (mesothermal) gold deposits
  - 5. Epithermal gold deposits
  - 6. Skarns
  - 7. Carlin-type deposits
  - 8. Placer deposits

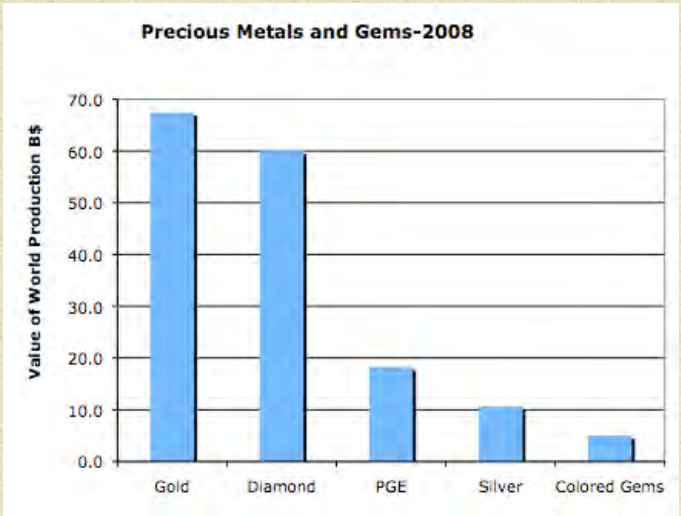
Hydrothermal Gold Deposits

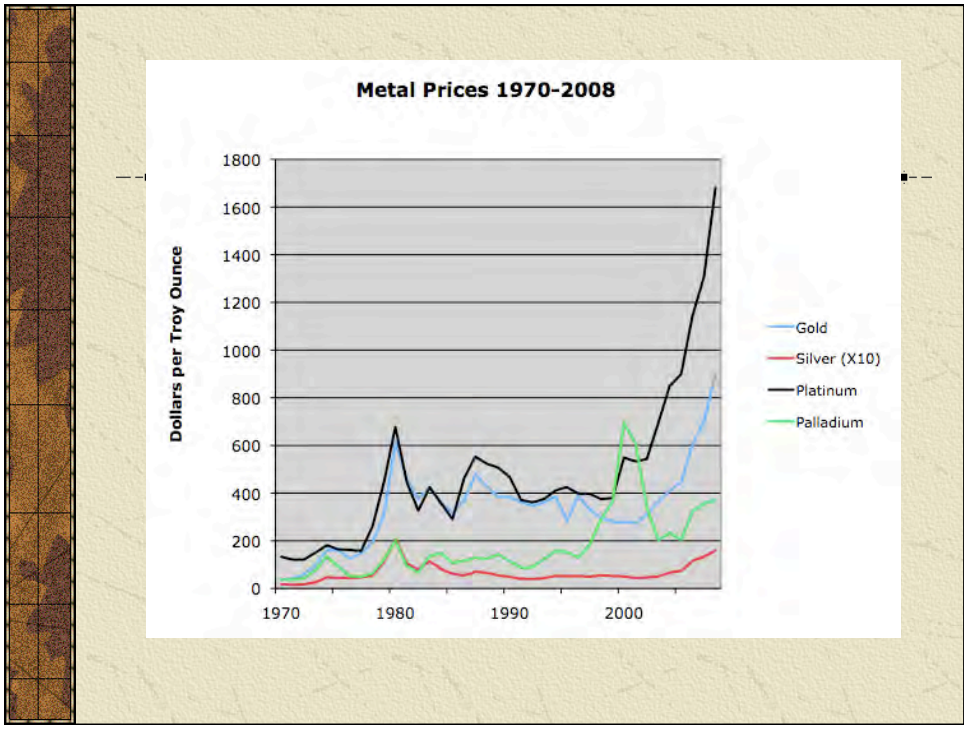


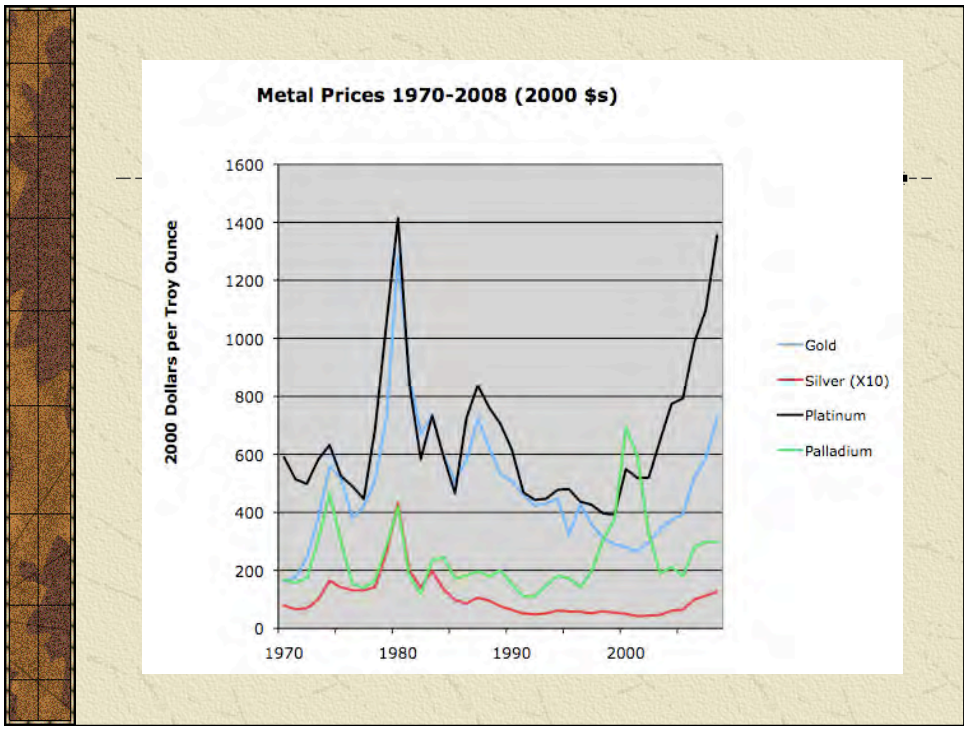
Gold Deposits - Global



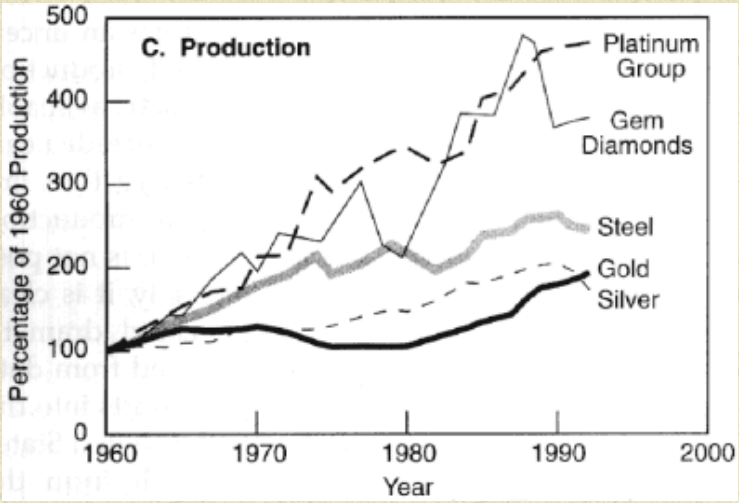
World Production Value



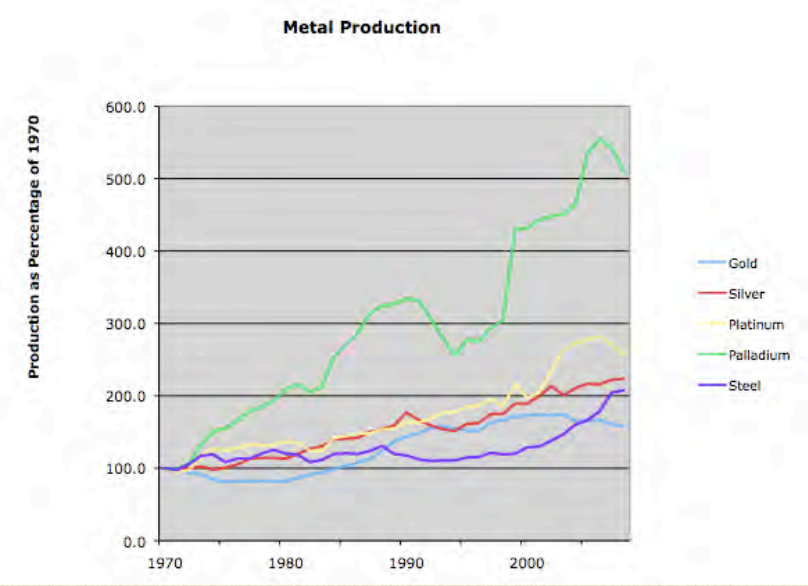

Metal Prices 1970-2008
Dollars per Troy Ounce
1800
1600
1400
1200
1000
800
600
400
200
0
1970
1980
1990
2000
Gold
Silver (X10)
Platinum
Palladium


Metal Prices 1970-2008 (2000 $s)
2000 Dollars per Troy Ounce
1600
1400
1200
1000
800
600
400
200
0
1970
1980
1990
2000
Gold
Silver (X10)
Platinum
Palladium

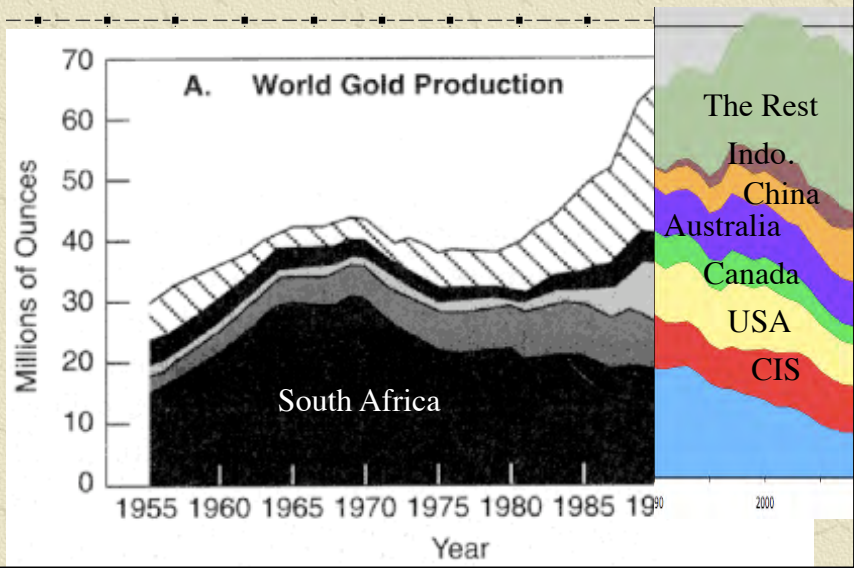
Precious Metals/Gems-Production



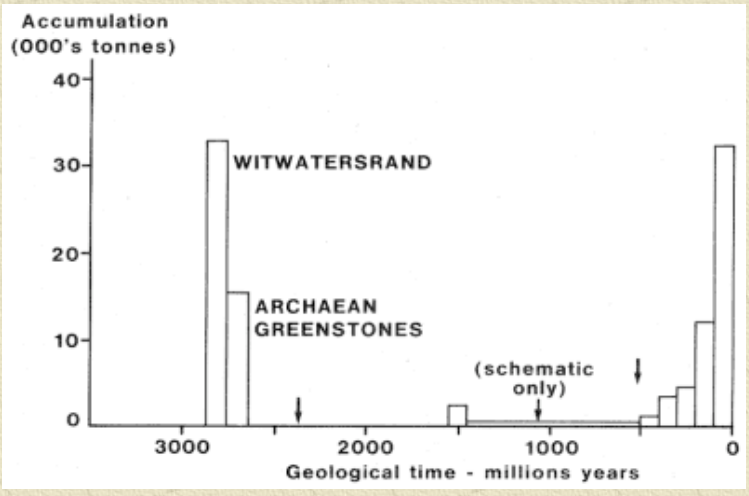
Precious Metals/Gems-Production



World Gold Production

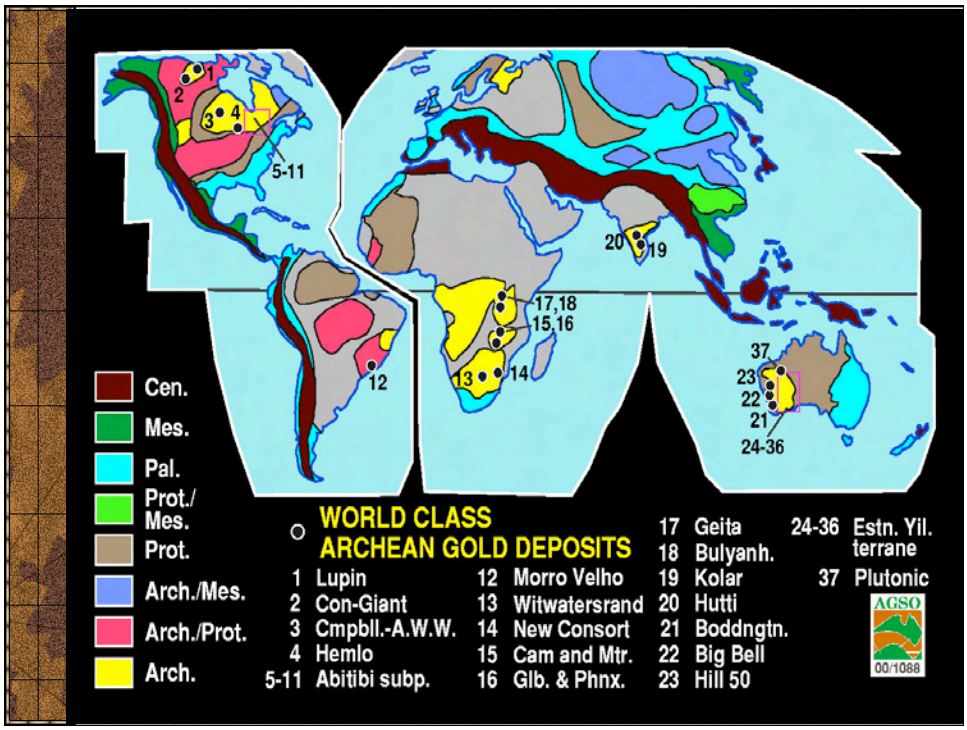


Distribution of Au through time



Archean Au Deposits

- ~20% of world production (excluding Witwatersrand deposits)
- 'Giant' deposits: Golden Mile (Yilgarn), Hollinger-McIntyre (Superior), Kolar (Dharwar)
- Deposits cluster in gold 'camps'; majority of production from camps
- Abundant in many Archean cratons - Superior, Yilgarn, Tanzania, Dharwar, Zimbabwe, Kaapvaal
- Limited in other cratons - Karelian, Pilbara, Greenland
- Deposit classes: Orogenic Au, intrusion-related/porphyry Cu-Mo-Au, Au-rich VHMS, ?epithermal



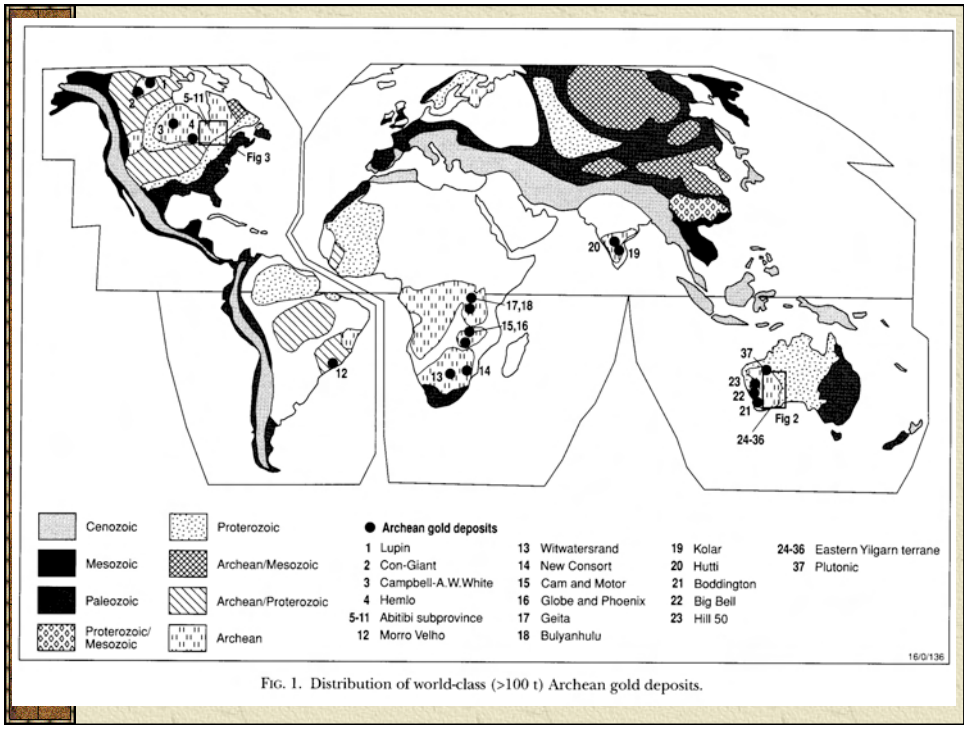


FIG. 1. Distribution of world-class (>100 t) Archean gold deposits.

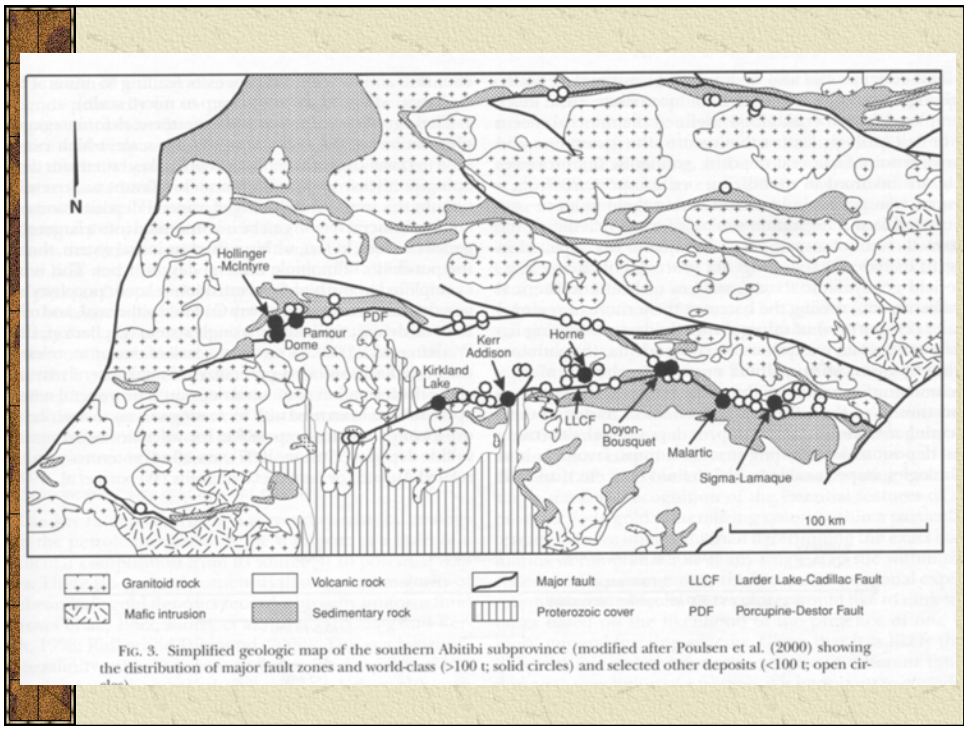
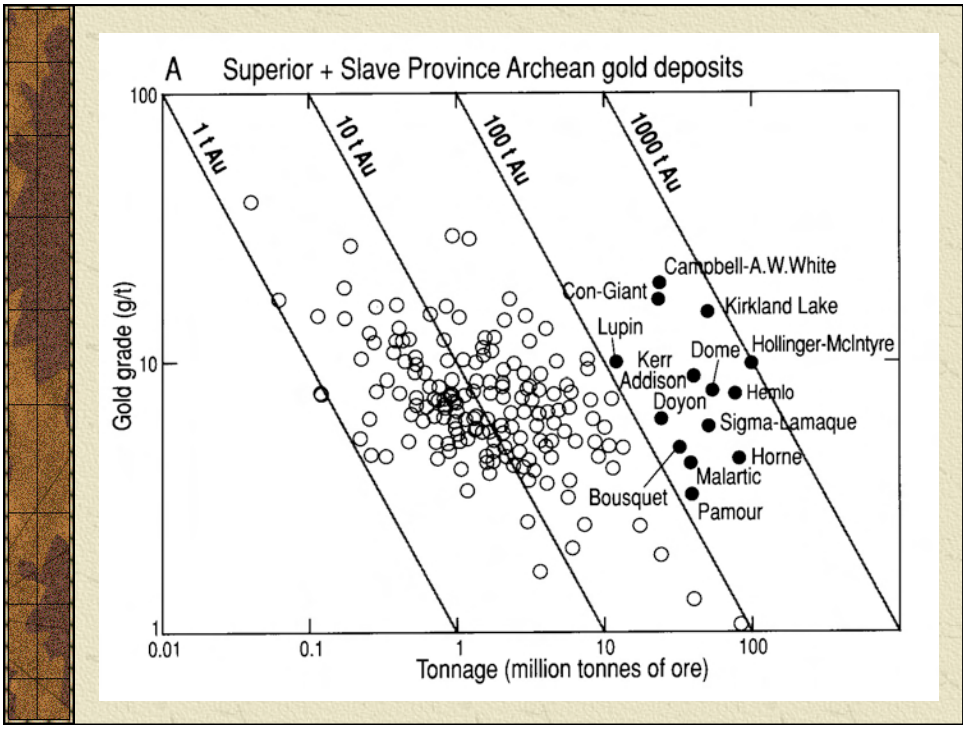
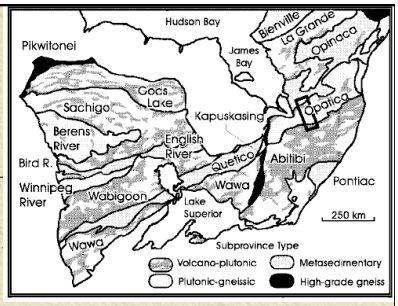


FIG. 3. Simplified geologic map of the southern Abitibi subprovince (modified after Poulsen et al. (2000) showing the distribution of major fault zones and world-class (>100 t; solid circles) and selected other deposits (<100 t; open cir-



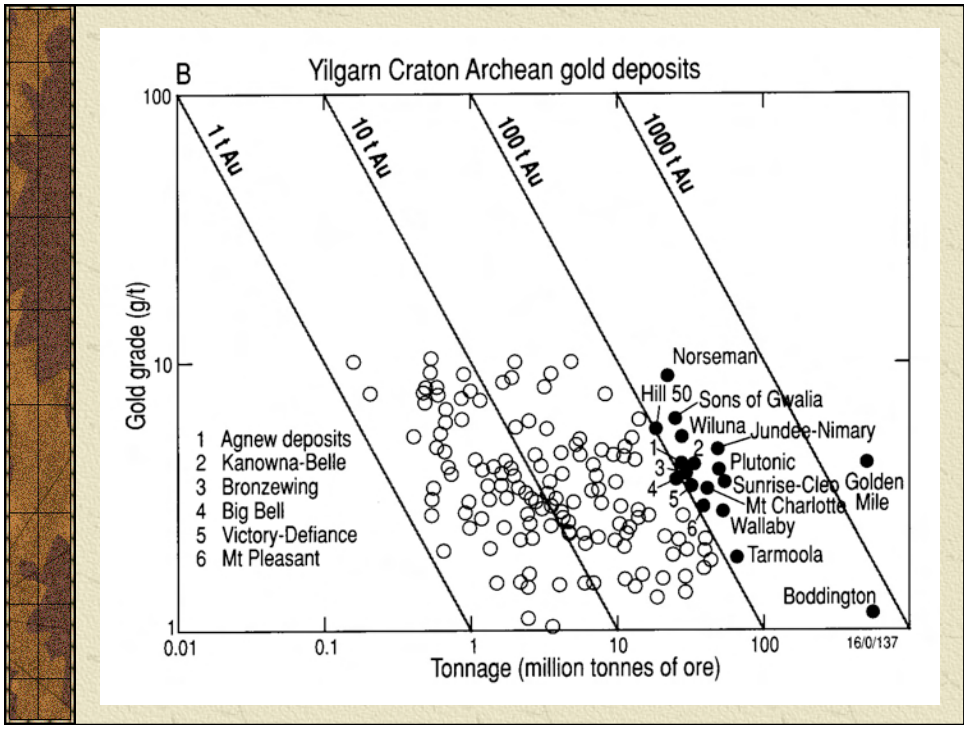
Superior Province



- **Largest resource and production from an Archean craton (~8000**
- **14 'world-class' (>100 t Au) deposits**
- **Concentrated in Abitibi subprovince (~5000 t Au); also Uchi**
- **Spatially associated with major 'breaks' - Destor-Porcupine, Cadillac-Larder Lake (giant deep faults)**
- **Major camps: Timmins, Kirkland Lake, Hemlo, Val d'Or, Bousquet, Campbell-A.W. White**
- **Deposit classes: Orogenic Au, Au-rich VHMS, porphyry Cu-Au, ? epithermal, disseminated sulfide, multistage**



Fig. 2. Simplified geologic map of the eastern Yilgarn Craton showing the distribution of major fault zones and world-class (>100 t; solid circles) and selected other deposits (<100 t; open circles).





Yilgarn Craton



- **Major Archean Au province (~5000 t Au); 15 world-class deposits**
- **Concentrated in Norseman-Wiluna belt; also Murchison province**
- **Spatially associated with major 'breaks' - Boulder-Lefroy, Laverton Tectonic Zone**
- **Major camps: Kalgoorlie (Golden Mile, Mt Charlotte), St Ives-Kambalda, Boddington, Plutonic**
- **Mainly Orogenic Au, limited other Au deposit classes (e.g., porphyry Cu-Au - ?Boddington)**

Mineral System Concept

- Analogous to very successful Petroleum Systems Concept
  - Provides predictive ability in individual basins
  - Combine geological characteristics at various scales (basin to local trap) with
  - Characteristics of specific basins to
  - Select individual targets
  - Identify favorable areas even before on-site examination

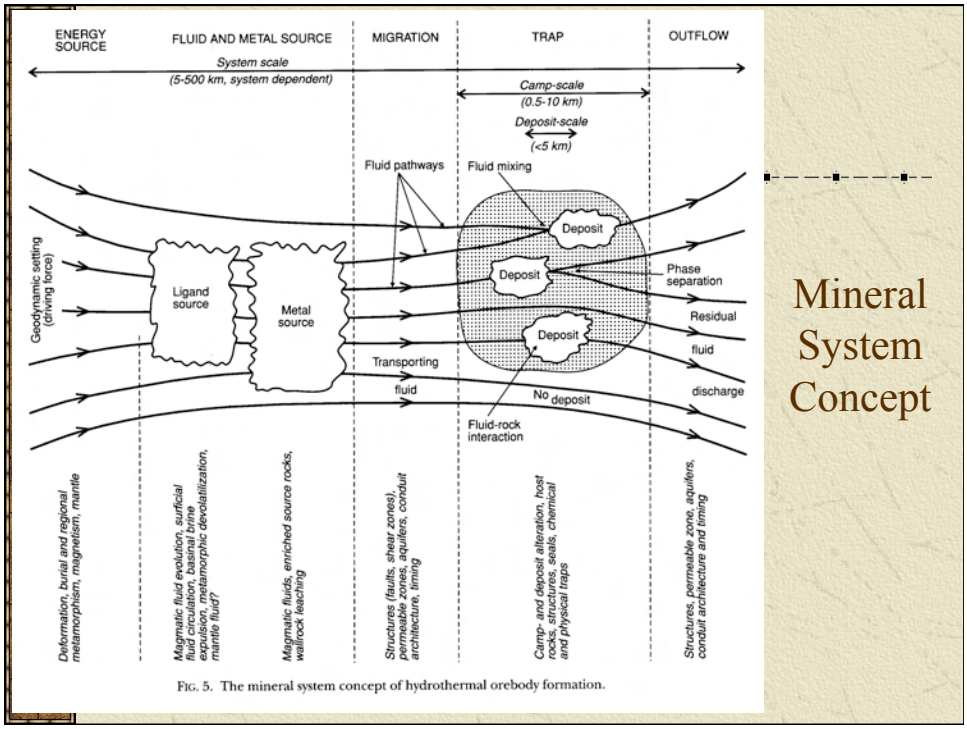


FIG. 5. The mineral system concept of hydrothermal orebody formation.

Mineral System Concept

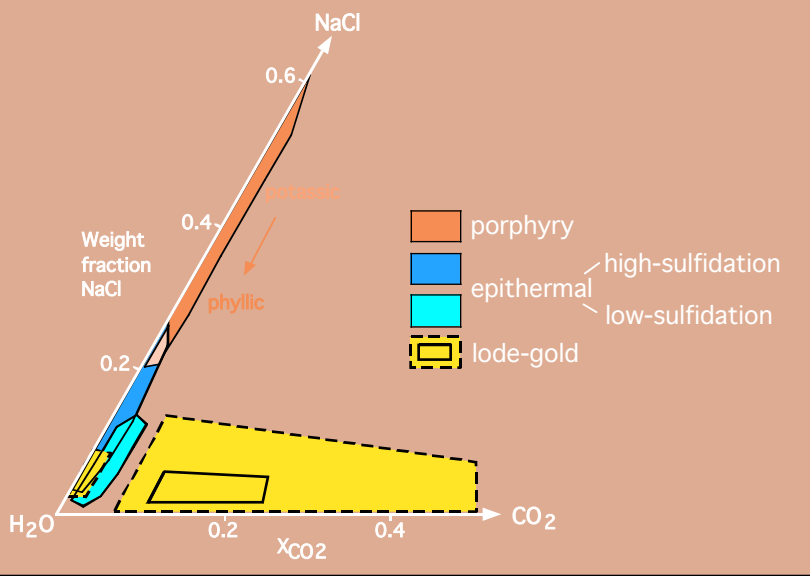
Table 1.1 Average gold content of igneous rock groups (ppb)

Rock group	Comment	$\bar{X}$	R	N	Ir/Au
Rocks from non-orogenic environments					
MORB	MAR, 98; EPR, 112	1.2	0.04–15	210	0.03
Intraplate basalt	Mainly Hawaii	2.0	0.2–6.6	69	0.38
Flood basalt	3 Provinces	3.5	0.5–11	49	0.02
Initial magma; layered gabbroic complex	Anakita, Bushveld, Jimberlana, Skaergaard	4.6	2.8–8.0	4	0.08[1]
Kimberlites and mantle xenoliths					
Kimberlites	Siberia; 50 pipes	3.1	0.8–9.1	55	
Garnet peridotite	Siberia	2.7	0.6–8.1	47	
Garnet peridotite[2]	Lesotho	0.85	0.08–2.7	10	7.3
Eclogite	Siberia	3.4	0.8–9.1	25	
Spinel lherzolites	Alkali basalt host	0.5	0.1–1.1	27	7.0
Alkaline plutons		2.8	0.64–4.5	291/21	
Rocks from orogenic environment					
Ophiolite harzburgite		2.8	0.3–6.4	138/14	3.2[3]
Mafic volcanics, convergent margins		2.2	0.5–5.6	315/10	
Felsic volcanics, convergent margins		1.55[4]	0.56–4.2	305/7	
Granitic plutons		2.6	0.5–6.9	969/66	
Igneous rocks of Precambrian greenstone belts					
Perioditic komatiite		4.2[5]	0.49–13.5	156/10	1.5
Komatiitic basalt		12.4	1.0–36	44/6	0.03[6]
Tholeiitic basalt		5.7	1.3–37	323/13	
Granitic plutons		1.5	1.1–2.3	232/45	

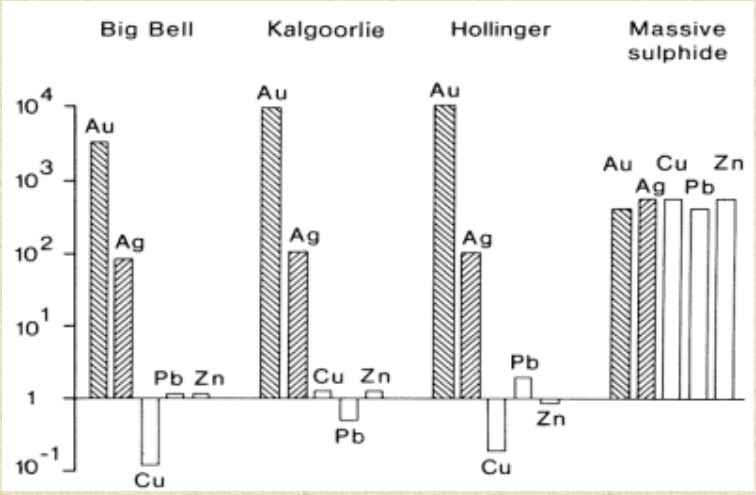
Orogenic Au Mineral System

- Fluid: low-moderate salinity, mixed aqueous-carbonic fluid
  - Some modification during transport but remains broadly uniform over long distances
- Timing: Epigenetic, late during active deformation and metamorphism of a volcano-plutonic terrane
- Trap: In any lithology, wide range of paleocrustal levels
  - Site specific physical and chemical processes

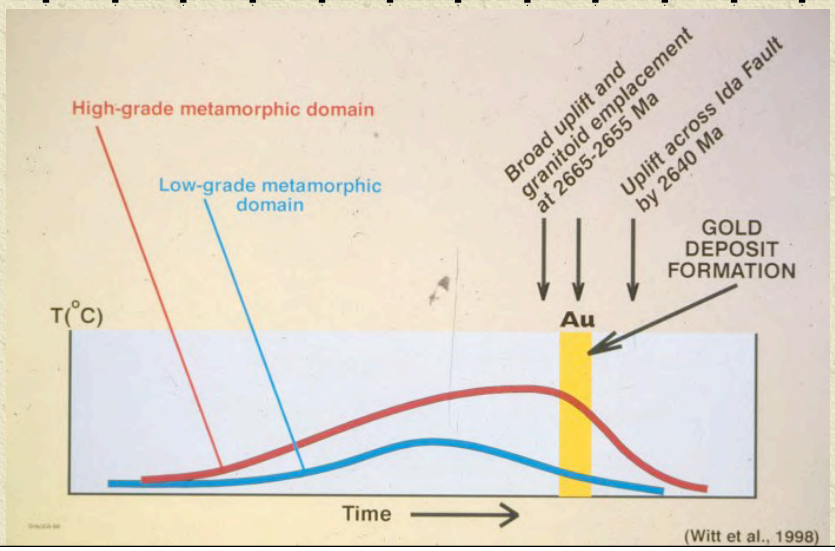
Fluids in different classes of Au deposits

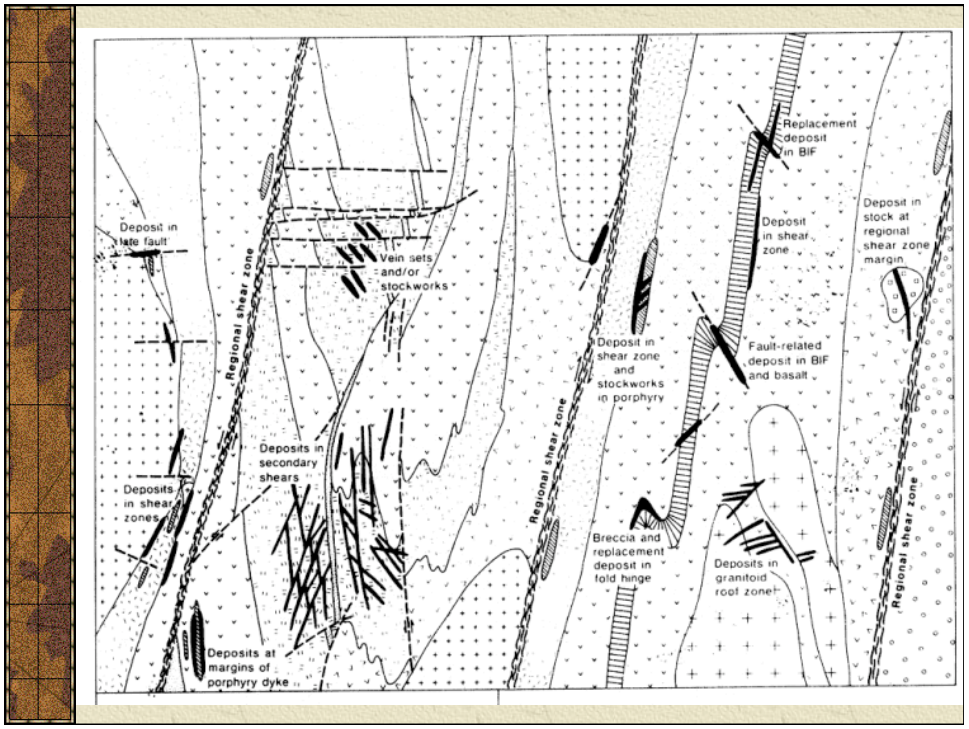


Metal Association



Yilgarn Deposit Timing

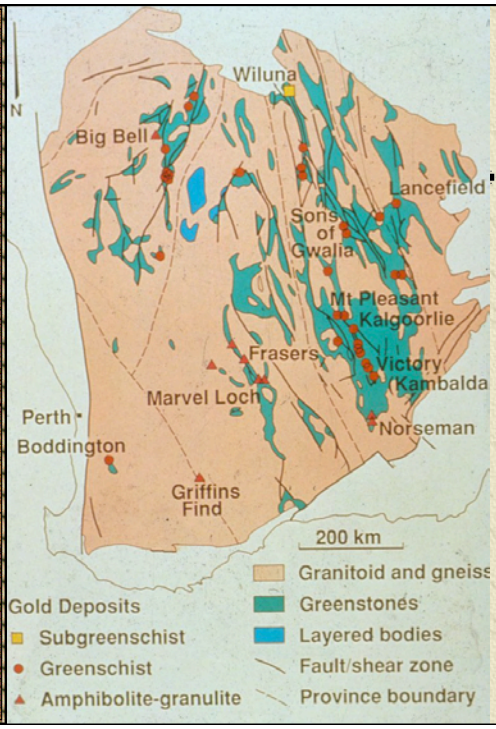




Trapping Sites - Variable

- Strike-slip faults: Wiluna, Golden Mile, Ross, Kirkland Lake
- Brittle-ductile shear zone: Victory-Defiance, Coolgardie
- Ductile shear zones: Kerr Addison, Sons of Gwalia, Yellowknife, Hemlo, Marvel Loch
- Thrust faults (granite-greenstone contact): Tarmoola, Granny Smith
- Veins (reef) hosted: Sigma, Hollinger, Dome, Kerr Addison, Kolar (Champion reef), Norseman, Westonia
- Sheeted quartz vein sets (stockwork): Mt Charlotte, Hill 50 Centenary
- Fold hinge zone: Musselwhite, Lupin, Nevoria, Copperhead

Yilgarn Craton



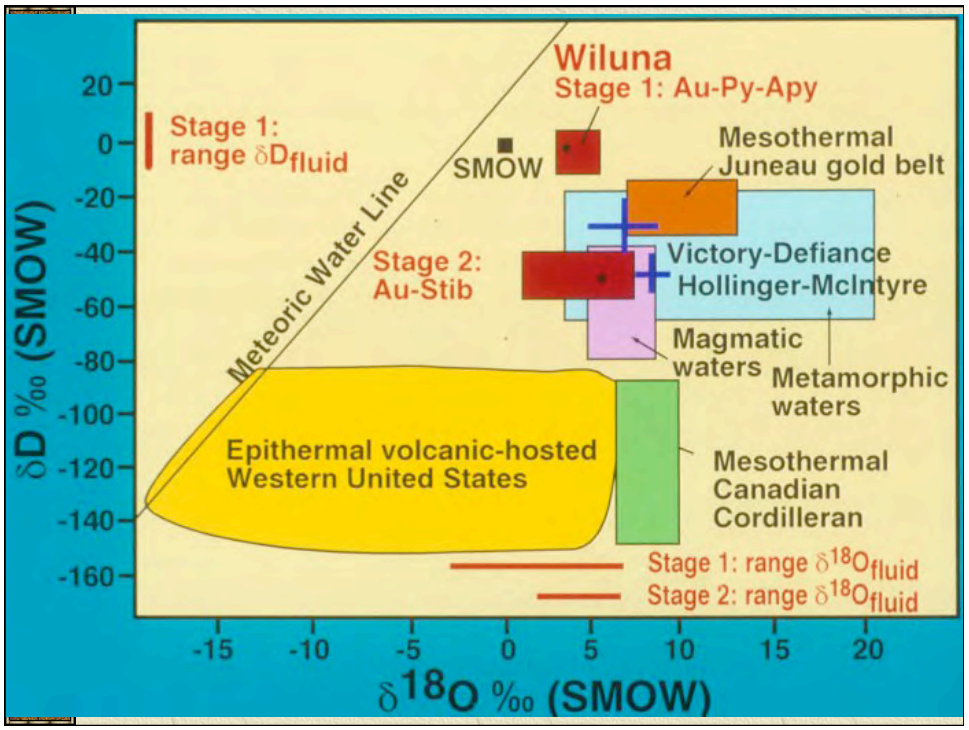
Hopes Hill Veins



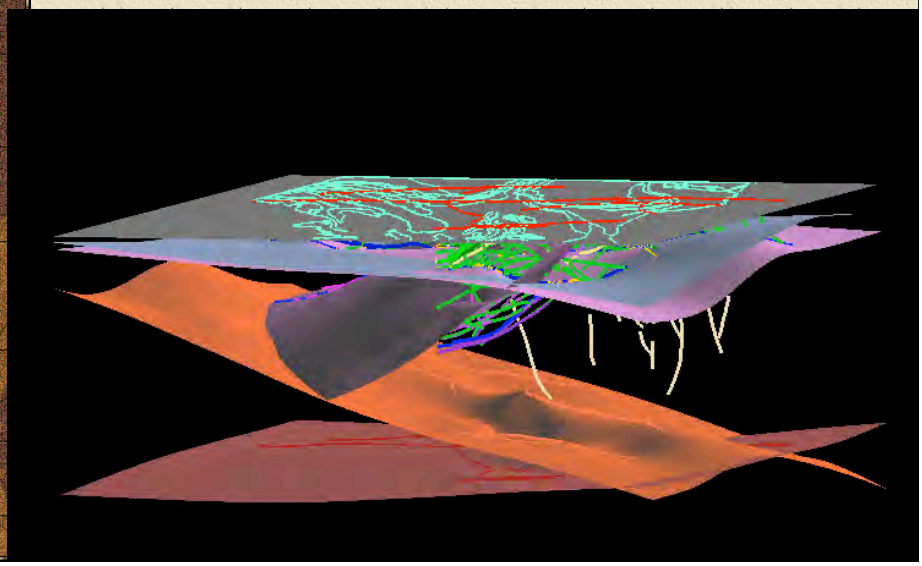


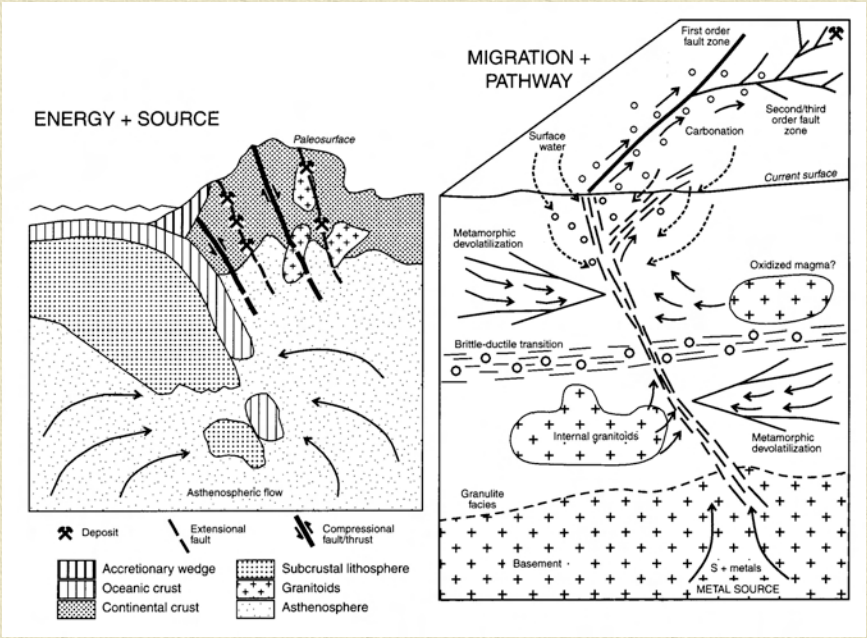

1 2 3 4 5 6 7 8 9 10 11


1 2 3 4 5 6 7 8 9 10 11


Wiluna
Stage 1: Au-Py-Apy
Stage 1:
range δDfluid
SMOW
Mesothermal
Juneau gold belt
Meteoric Water Line
Stage 2:
Au-Stib
Victory-Defiance
Hollinger-McIntyre
Magmatic
waters
Metamorphic
waters
Epithermal volcanic-hosted
Western United States
Mesothermal
Canadian
Cordilleran
Stage 1: range δ18Ofluid
Stage 2: range δ18Ofluid
δD ‰ (SMOW)
δ18O ‰ (SMOW)
20
0
-20
-40
-60
-80
-100
-120
-140
-160
-15
-10
-5
0
5
10
15
20

3D Model of the northern Kalgoorlie Terrane





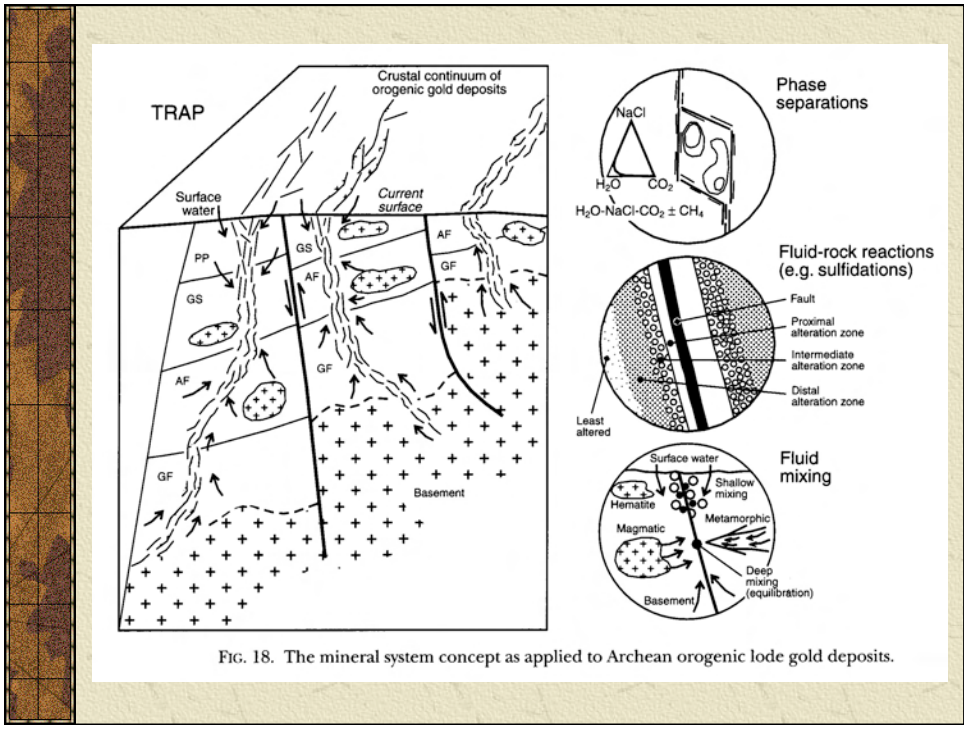
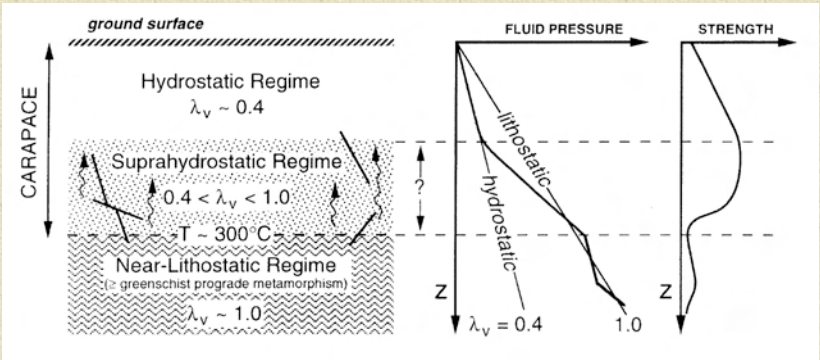
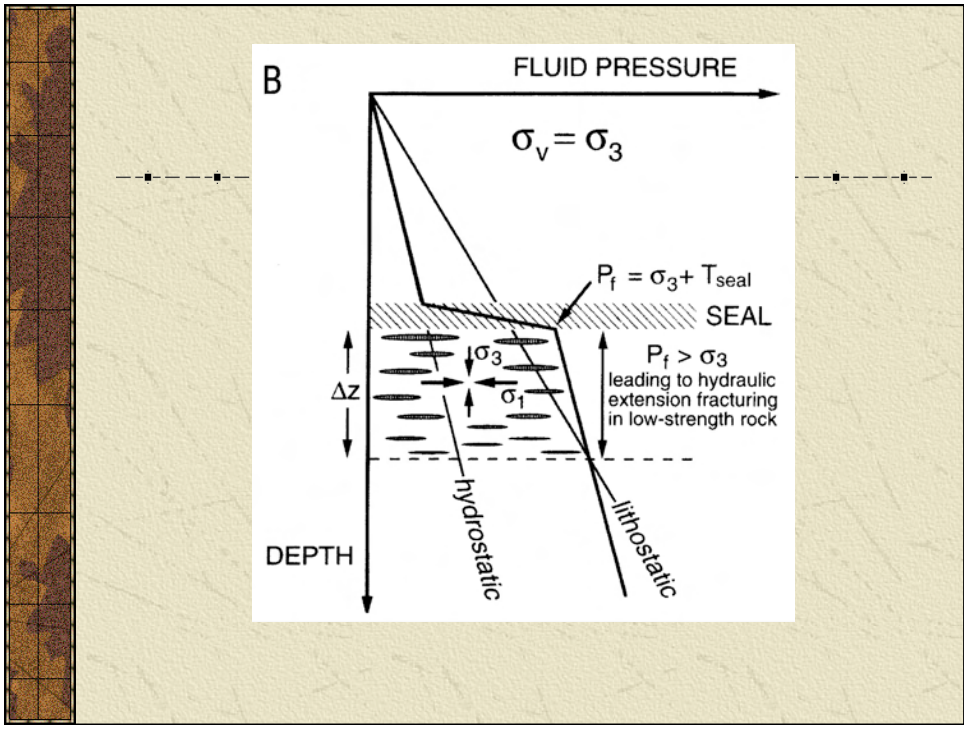
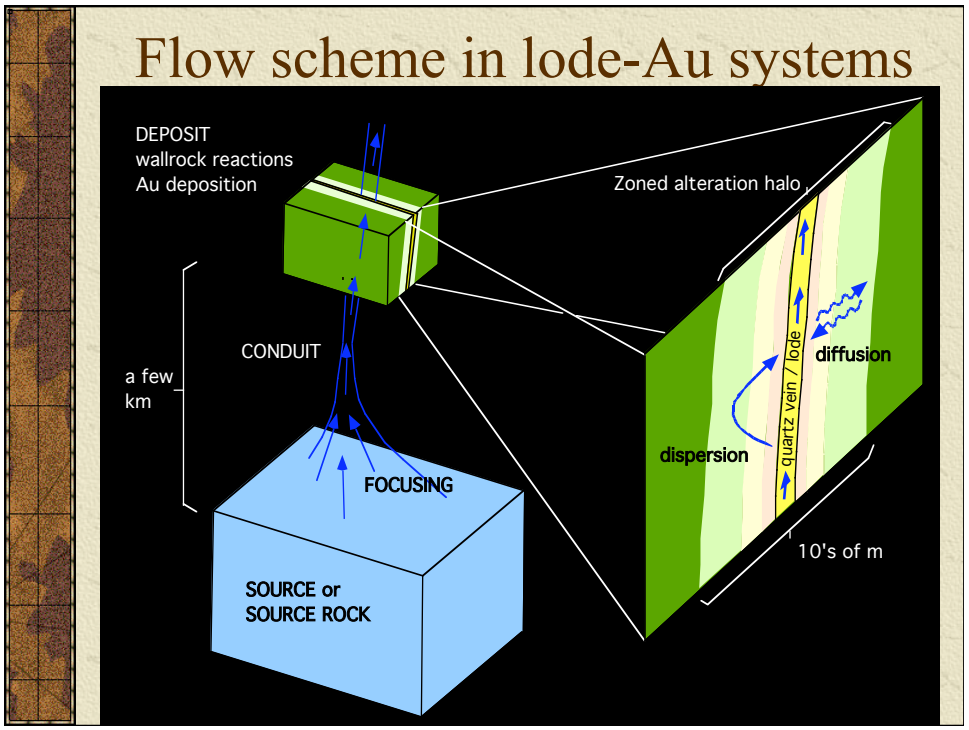


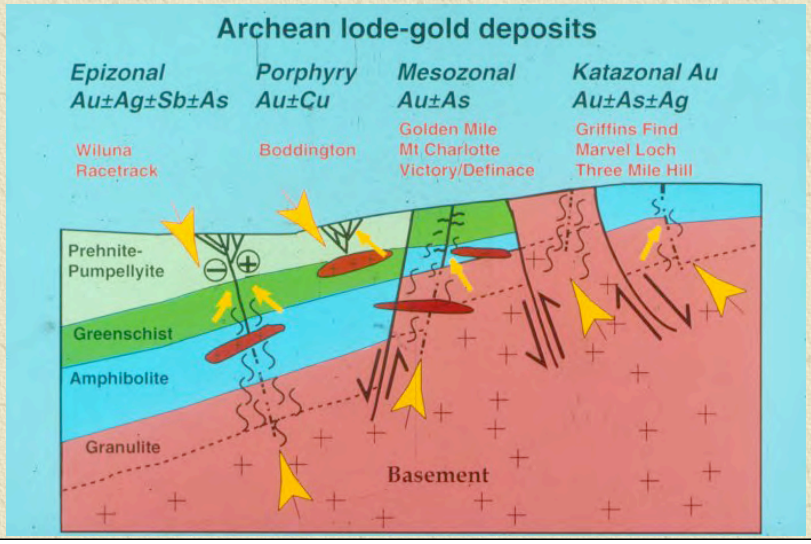
FIG. 18. The mineral system concept as applied to Archean orogenic lode gold deposits.



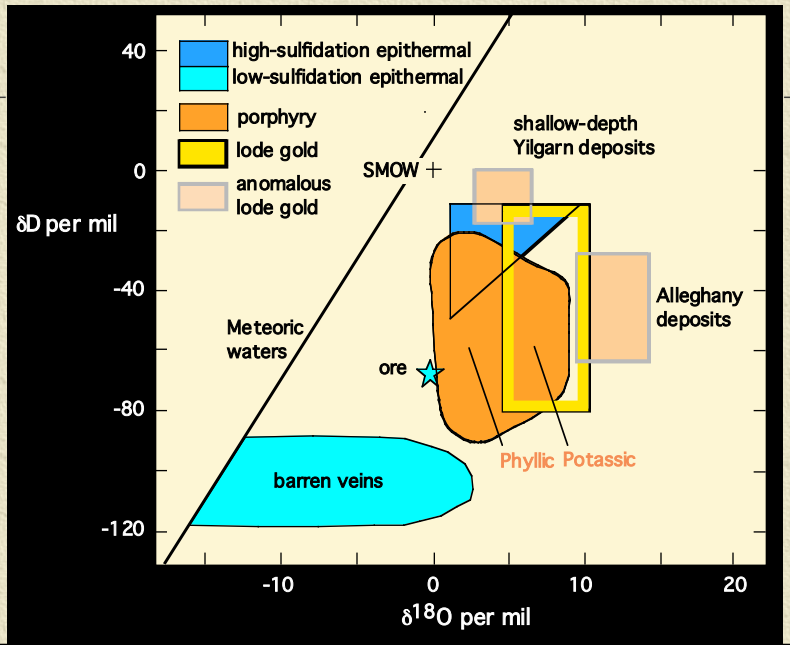

B
FLUID PRESSURE
$\sigma_v = \sigma_3$
$P_f = \sigma_3 + T_{seal}$
SEAL
$P_f > \sigma_3$
leading to hydraulic
extension fracturing
in low-strength rock
σ_3
σ_1
Δz
DEPTH
hydrostatic
lithostatic


Flow scheme in lode-Au systems
DEPOSIT
wallrock reactions
Au deposition
Zoned alteration halo
CONDUIT
a few
km
FOCUSING
SOURCE or
SOURCE ROCK
quartz vein / lode
diffusion
dispersion
10's of m

Schematic Continuum Model



H,O isotopes in different classes of gold deposits



Fluid Source Models

