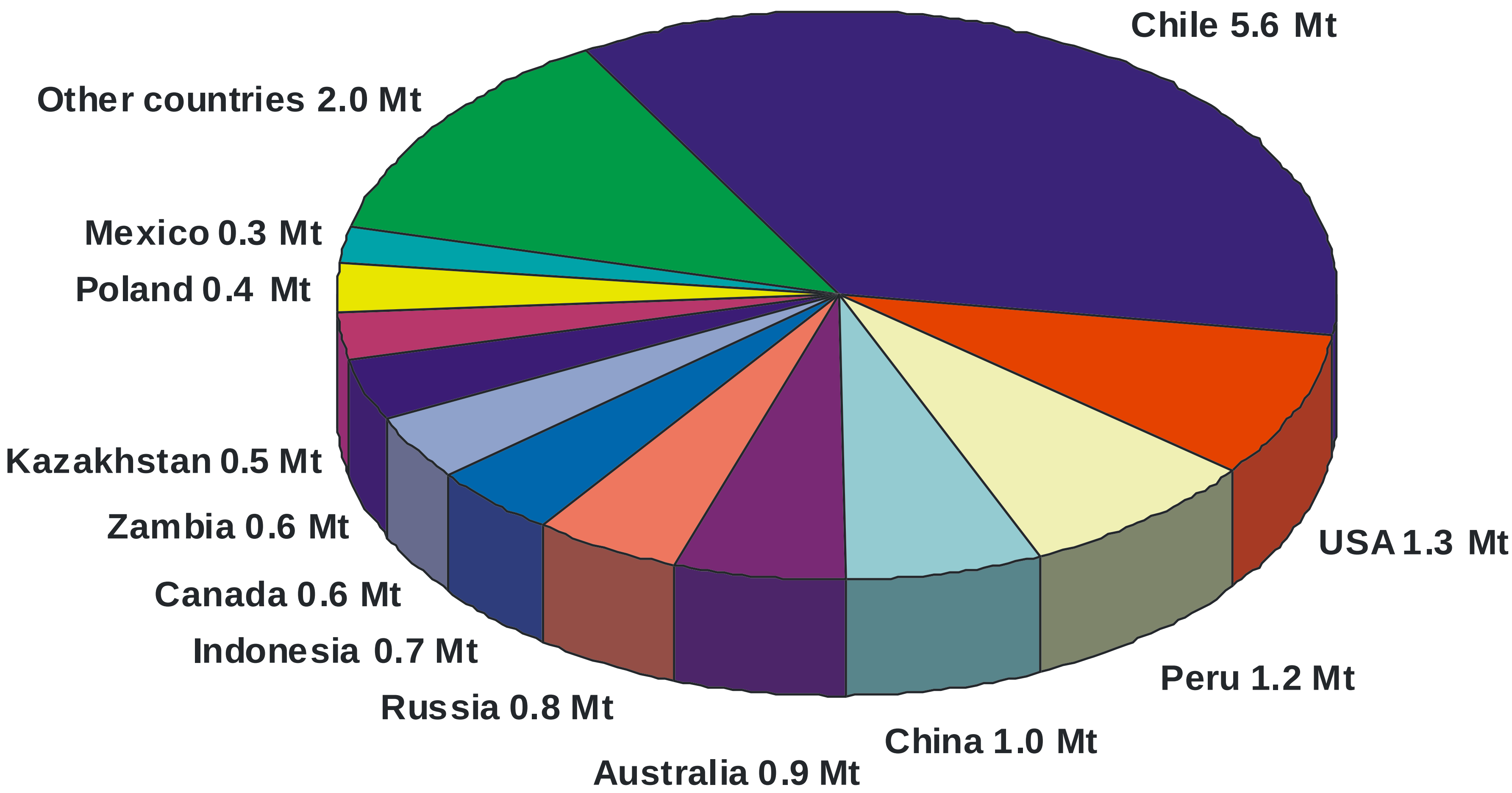
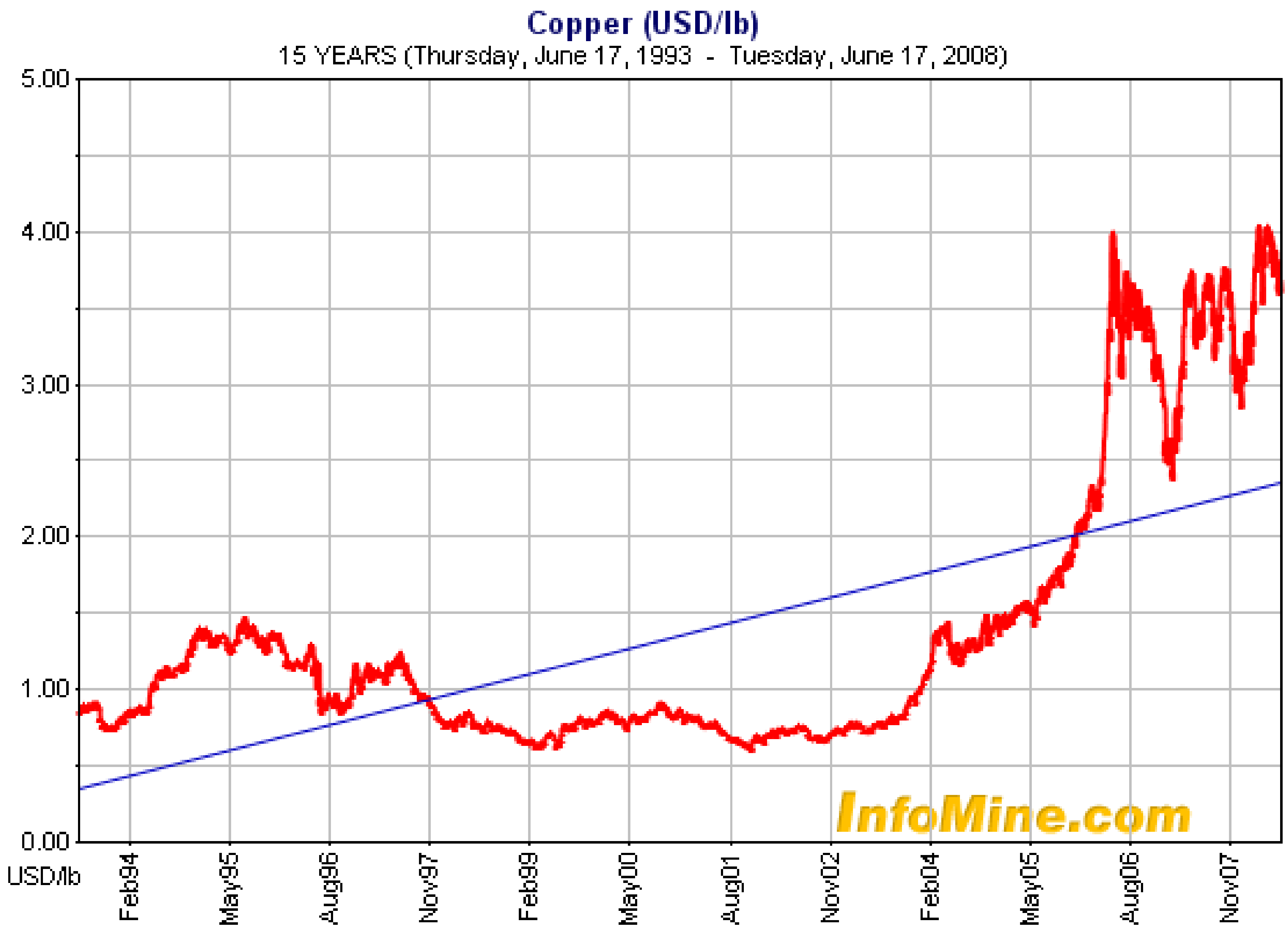
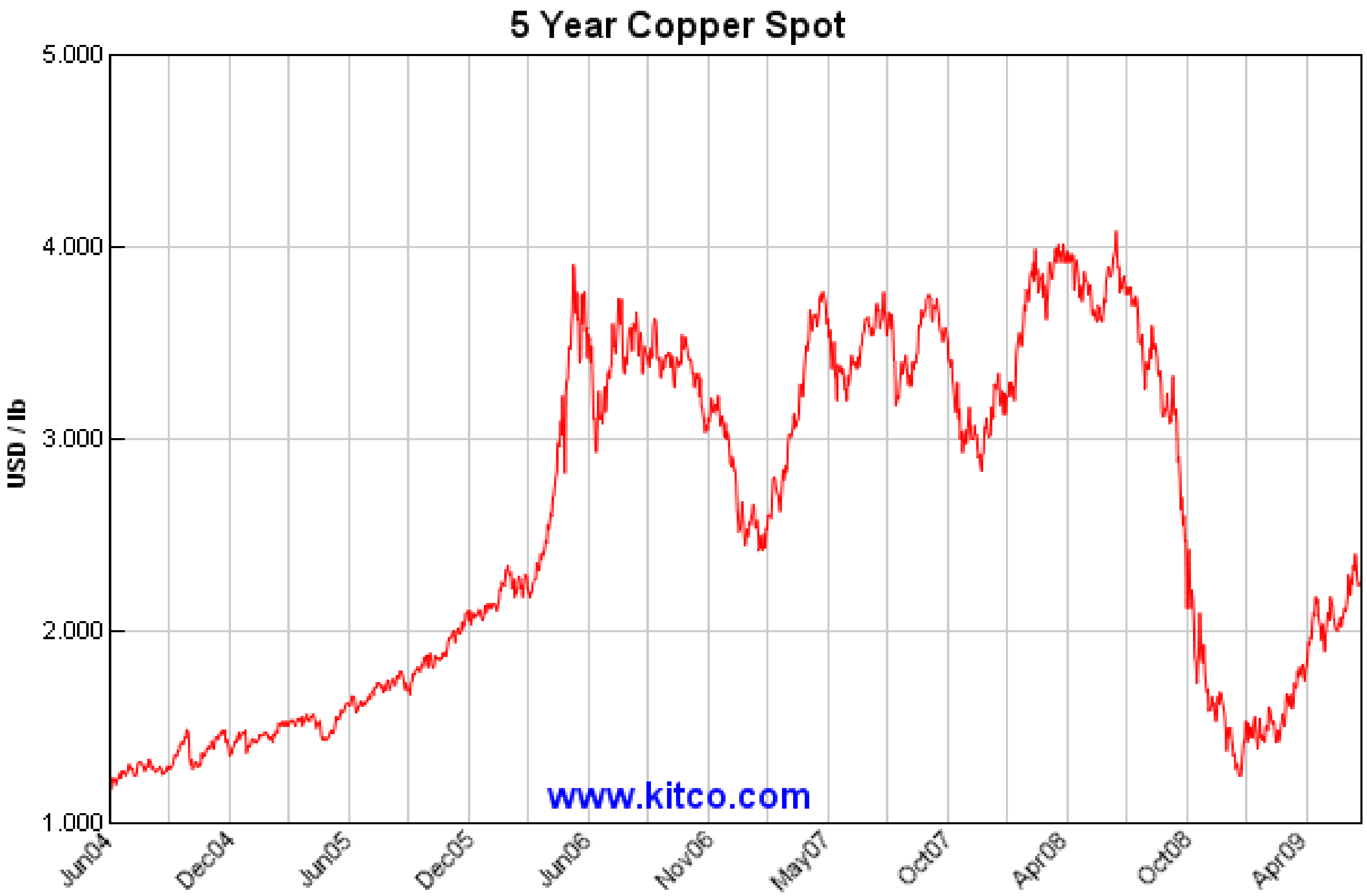
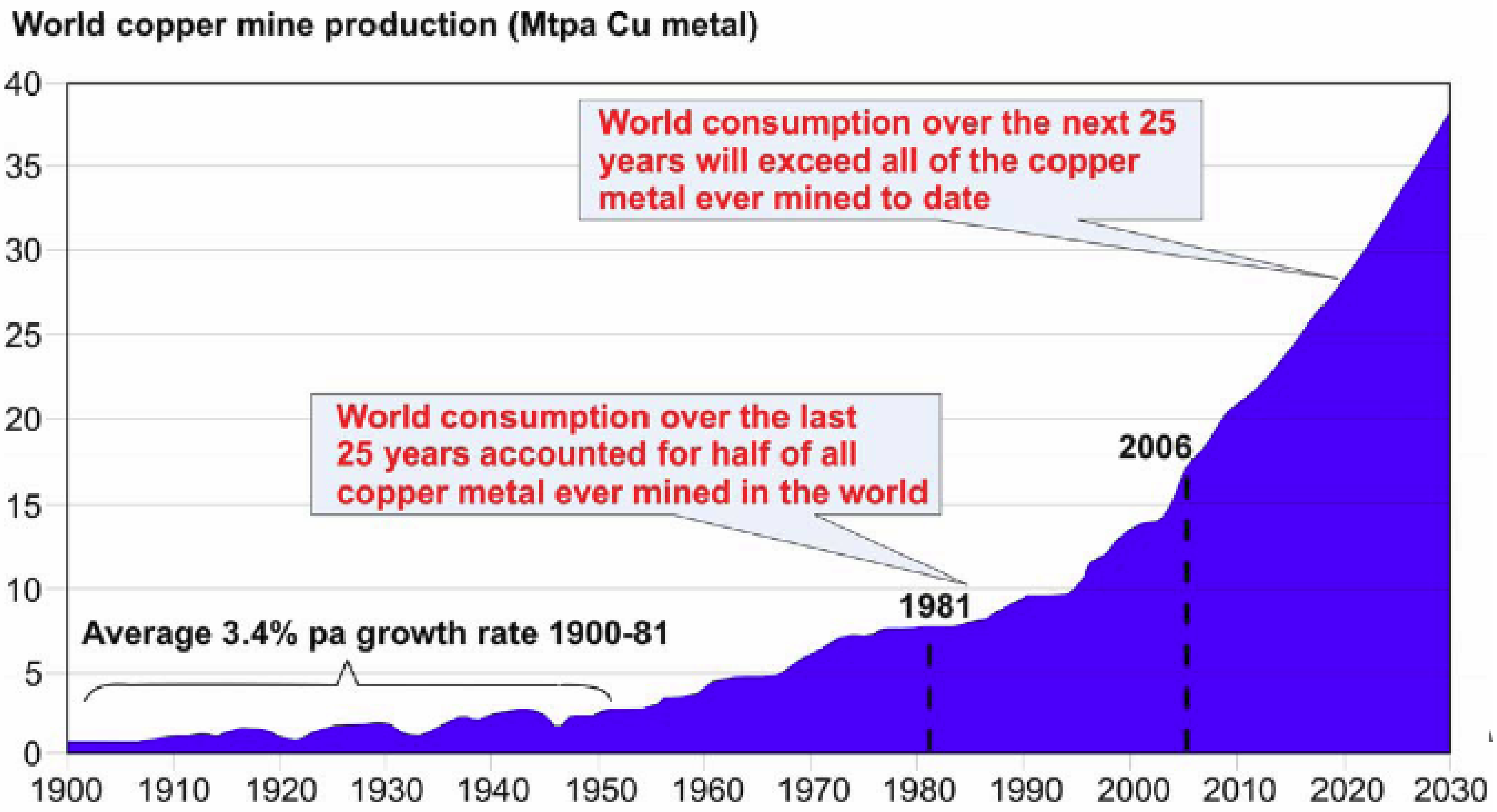
COPPER WORLD MINE PRODUCTION 2008 (15.7 Mt)




Copper (USD/lb)
15 YEARS (Thursday, June 17, 1993 - Tuesday, June 17, 2008)
5.00
4.00
3.00
2.00
1.00
0.00
USD/lb
Feb94
May95
Aug96
Nov97
Feb99
May00
Aug01
Nov02
Feb04
May05
Aug06
Nov07
InfoMine.com



5 Year Copper Spot
USD / lb
5.000
4.000
3.000
2.000
1.000
Jun04
Dec04
Jun05
Dec05
Jun06
Nov06
May07
Oct07
Apr08
Oct08
Apr09
www.kitco.com



RTZ projection

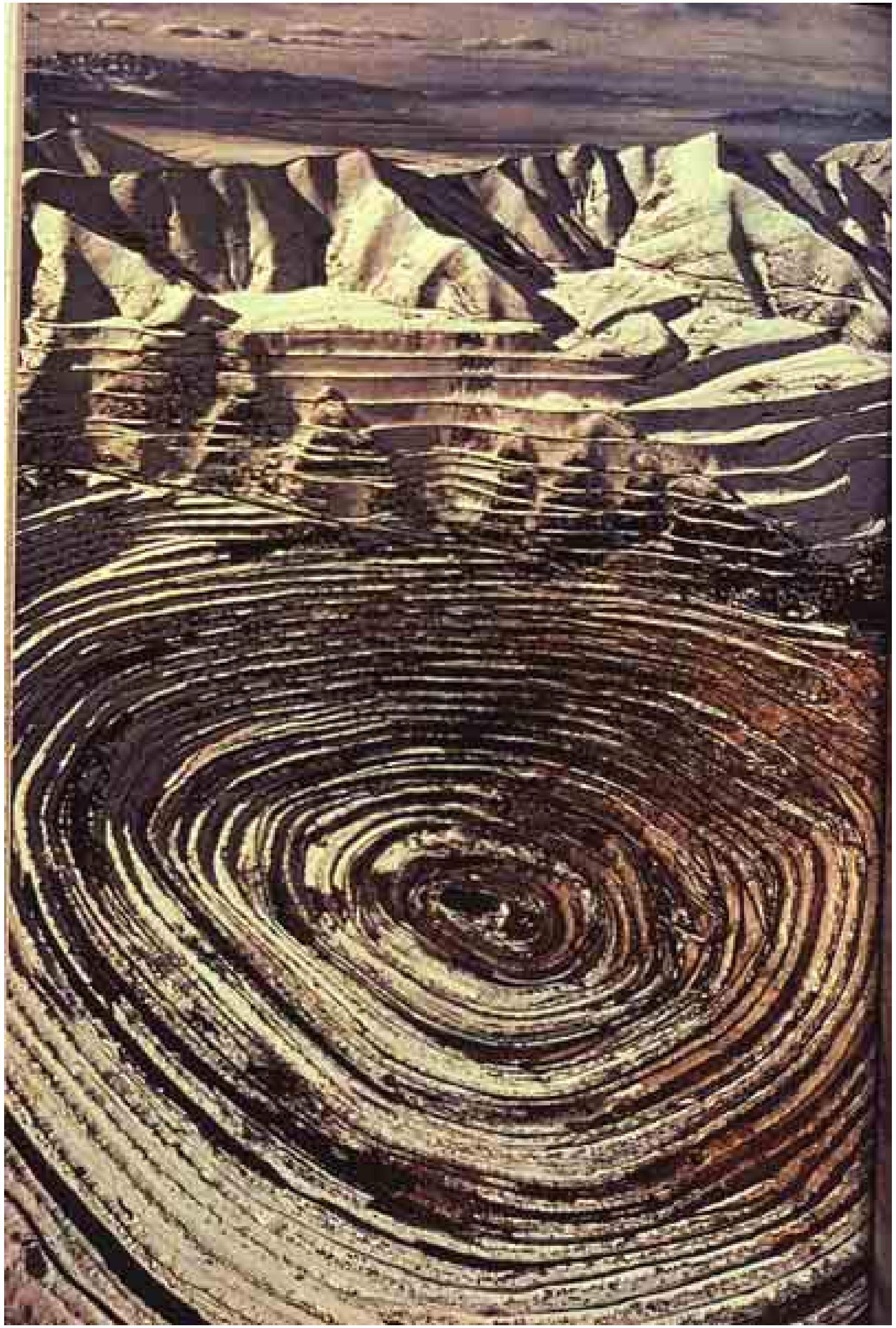
Bisbee, Arizona (Jan 1973)

Great Salt Lake, Utah

Great Salt Lake

Bingham, Utah

Bingham (Aug 1993)

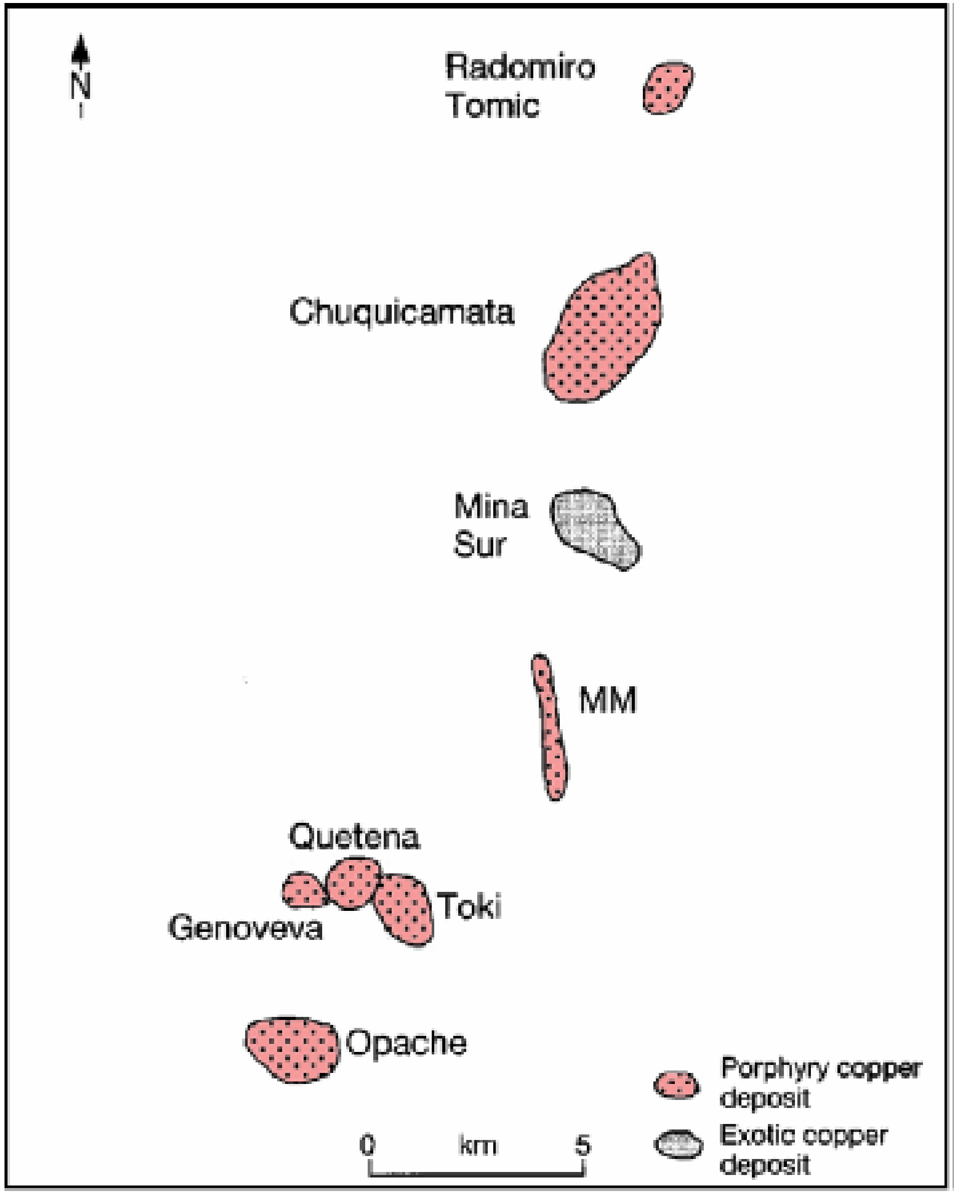


Bingham, Utah

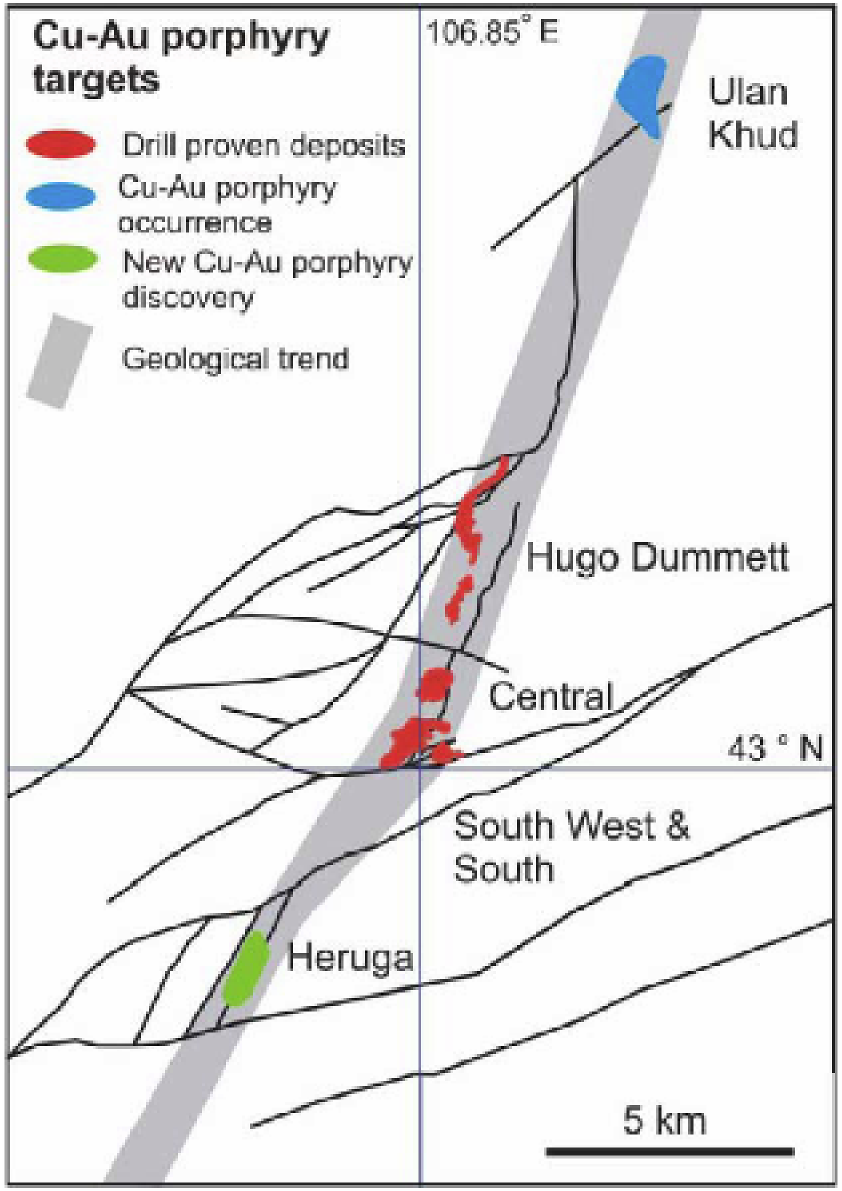
Bingham-Gesamtprod. + Reserven: 22 Mio t Cu, 560.000 t Mo, 1.000 t Au (Bache, 1982:50)

Wert in 2008:
Cu: 132 Mrd USD
Au: 25 Mrd USD
Mo: 33 Mrd USD

Kounrad, Kazakhstan



Chuquicamata ore cluster, Chile



Oyu Tolgoi ore cluster, Mongolia

Chuquicamata, Atacama desert, Chile

Radomiro
Tomic

Chuqui

MM

Calama

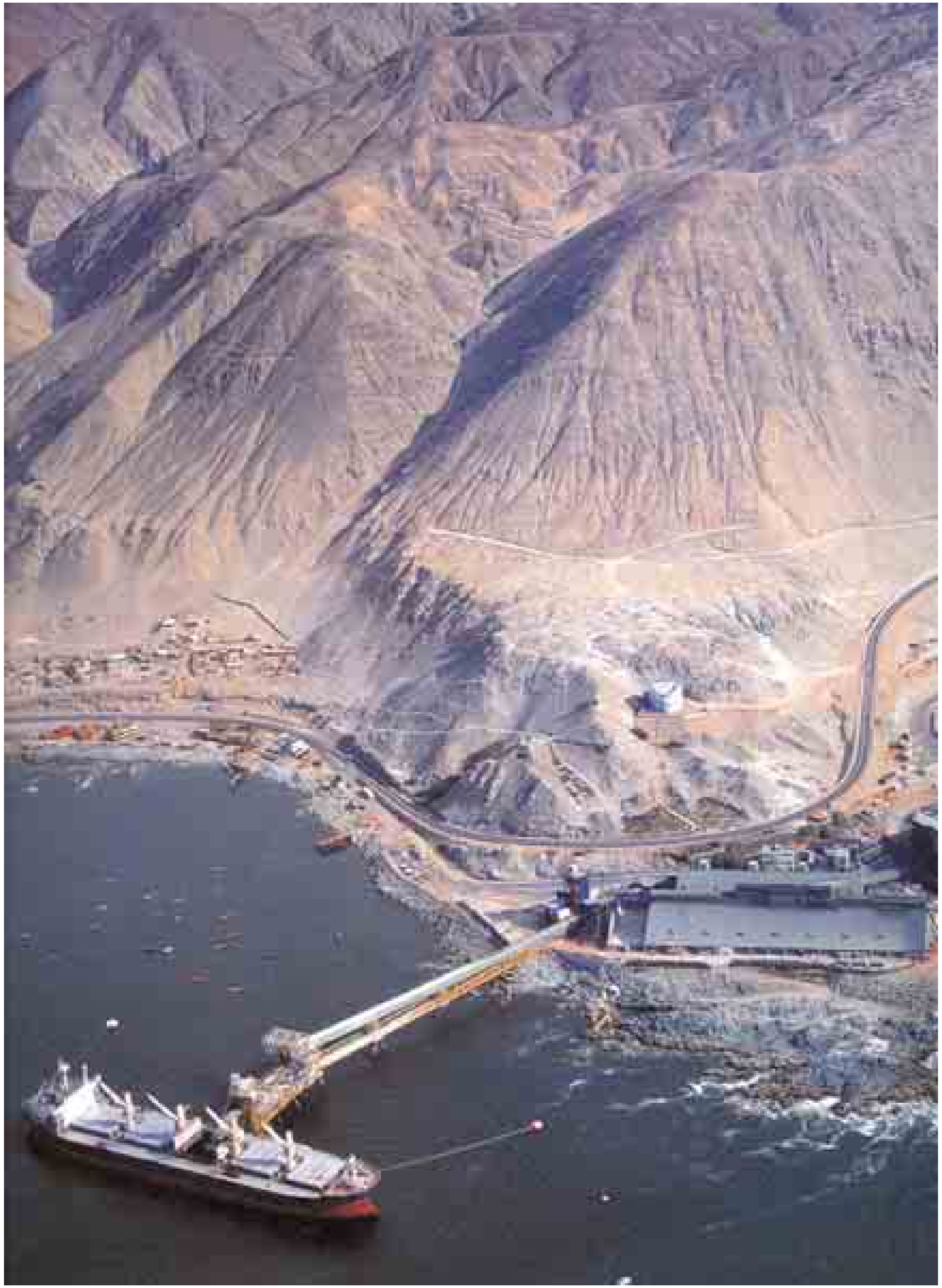
**Chuqui-
camata,
Chile**

**350.000 t
ore at
1 % Cu=
~3.500 t
Cu/day**

Radomiro Tomic, Chile

Escondida, Chile

Escondida: world‘s largest copper producer (1Mt Cu/year)
2 Gt @ 1.2 % Cu (sulfide), 300 Mt @ 0.71 % Cu (oxide)



Hafen
Escondida, Chile

Collahuasi project, Chile (1.76 billion USD investment): 3 Gt @ 0.82 % Cu

Collahuasi, Chile


Quebrada Blanca, Chile

Panguna (Papua New Guinea)

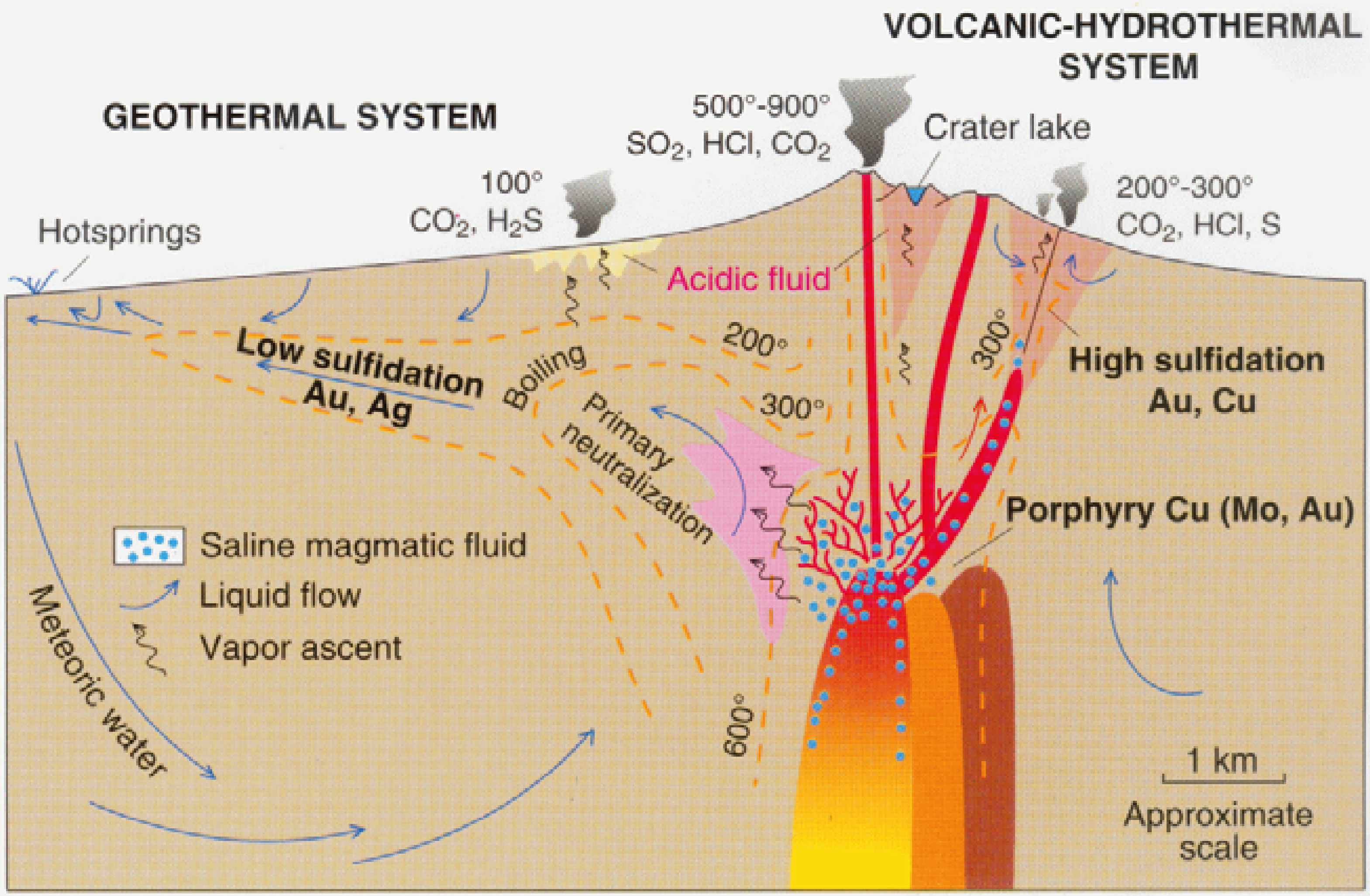
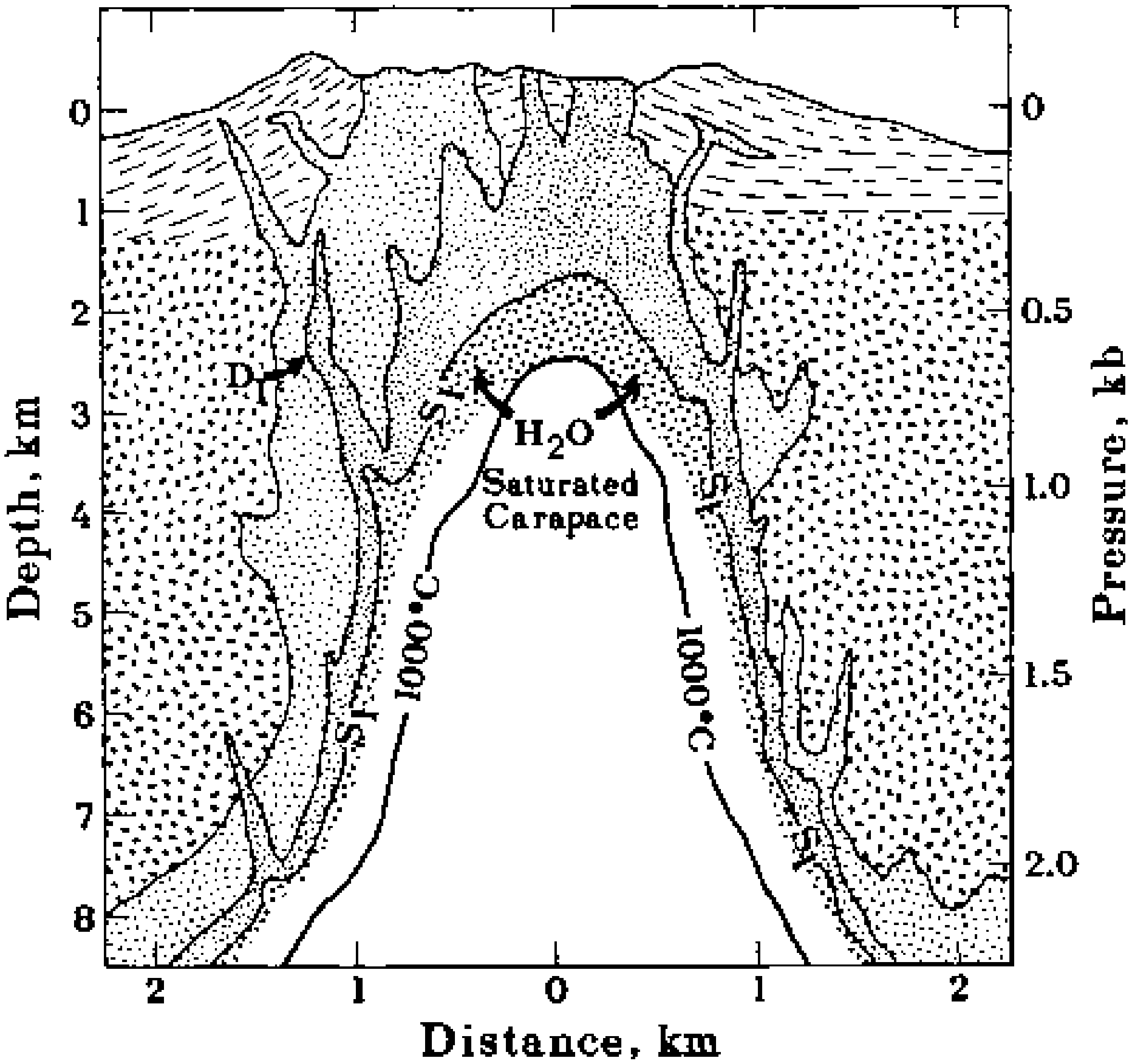
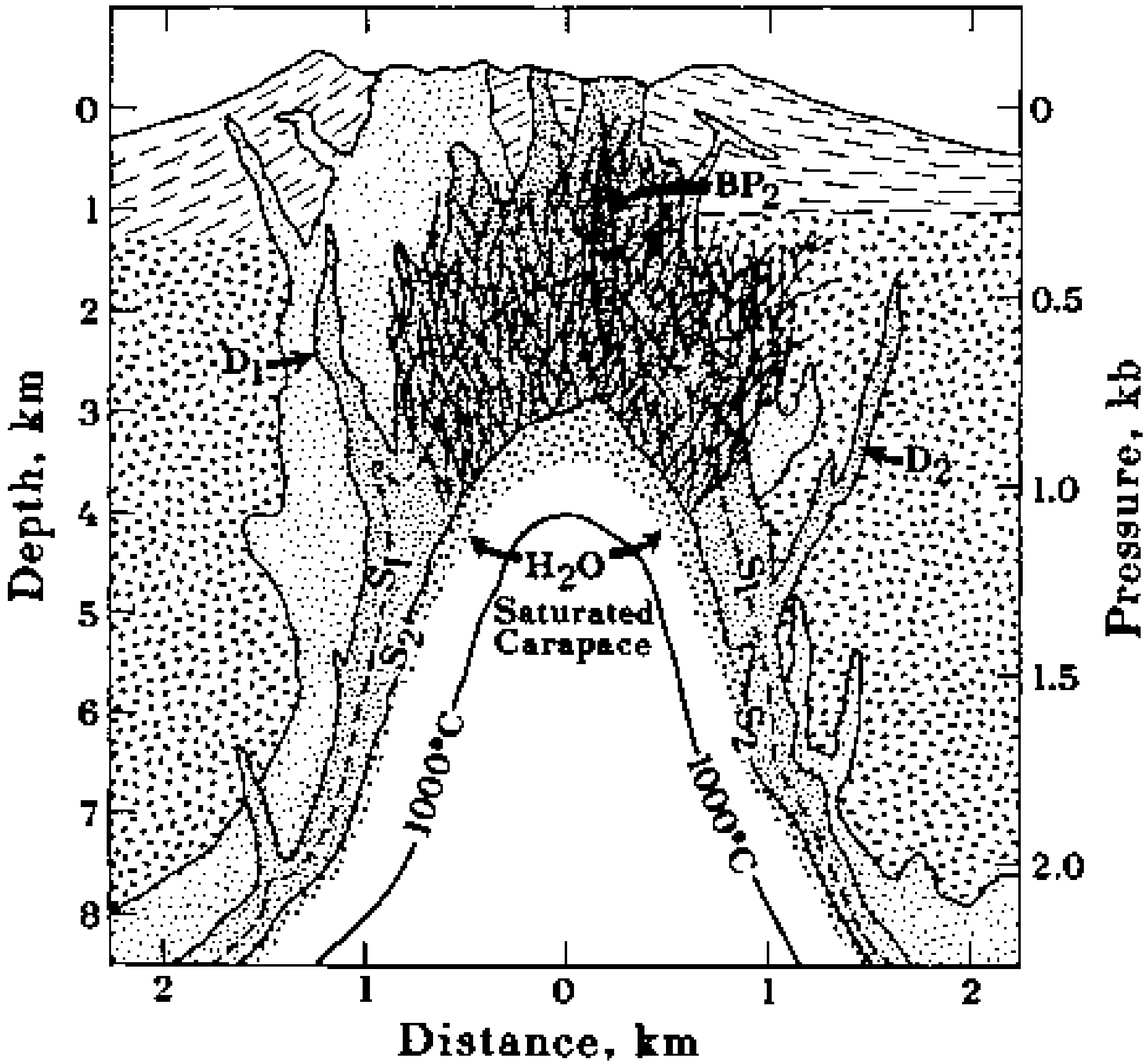


Fig. 1.1 Schematic cross-section showing shallow sub-volcanic intrusions and associated stratovolcano, and environments deduced for formation of porphyry Cu, and high- and low-sulfidation epithermal ore deposits [20,25]. Active volcanic-hydrothermal systems extend from degassing magma to fumaroles and acidic springs, and incorporate porphyry and/or high-sulfidation ore environments, whereas low-sulfidation ore deposits form from geothermal systems characterized by neutral-pH waters that may discharge as hot springs.

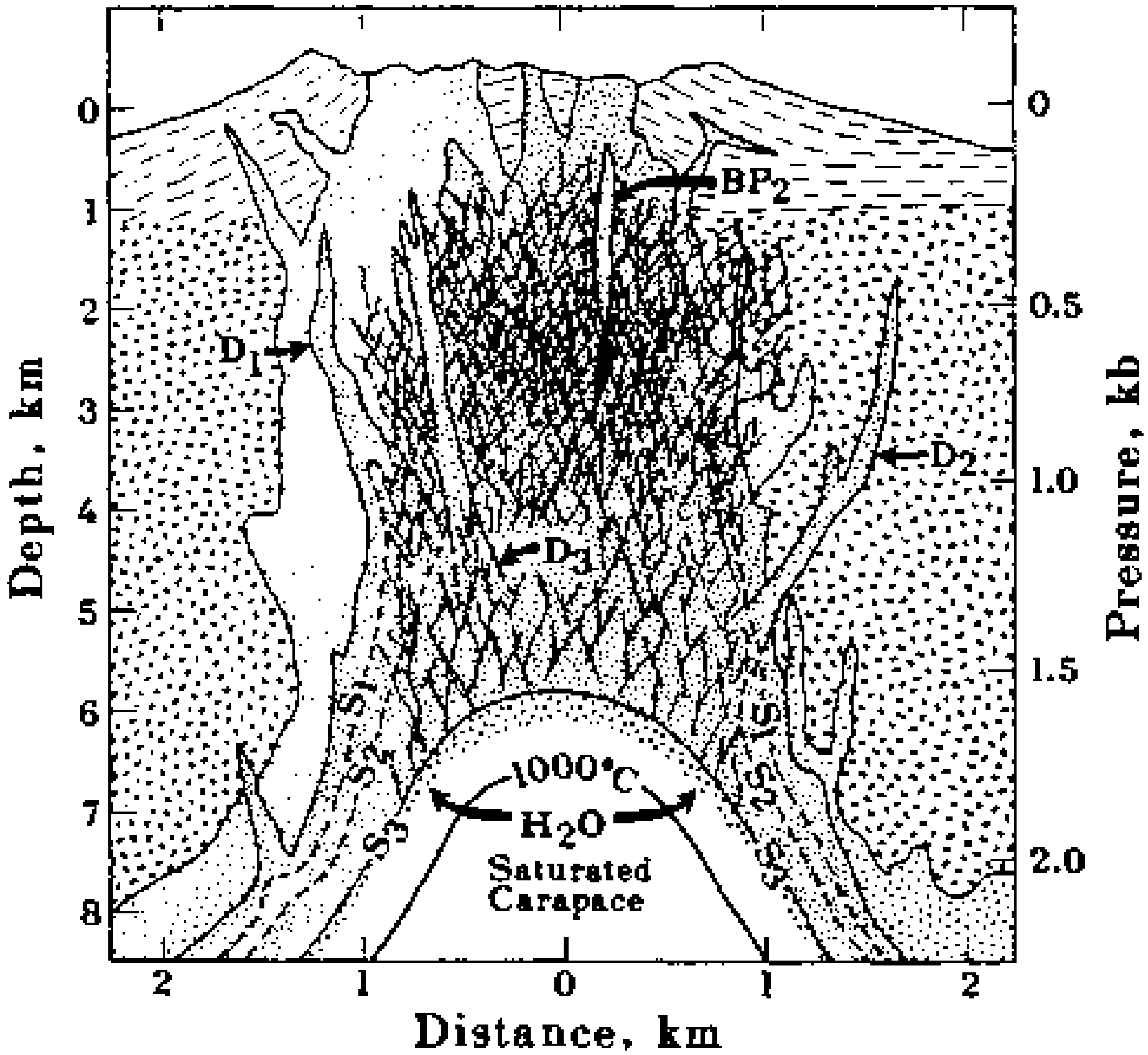
Hedenquist et al. (1996) Soc Res Geol Japan



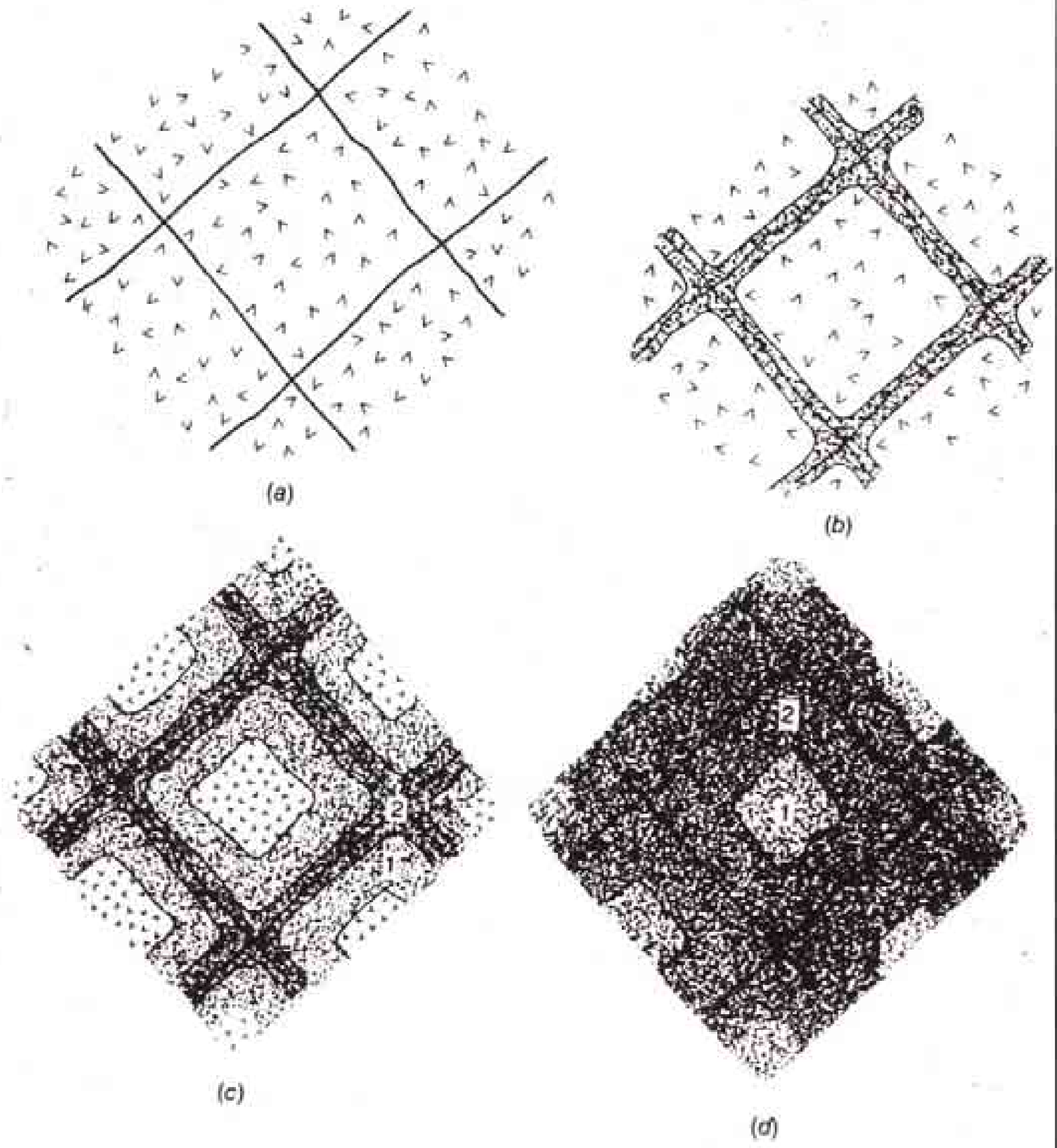
Burnham (1979)



Burnham (1979)

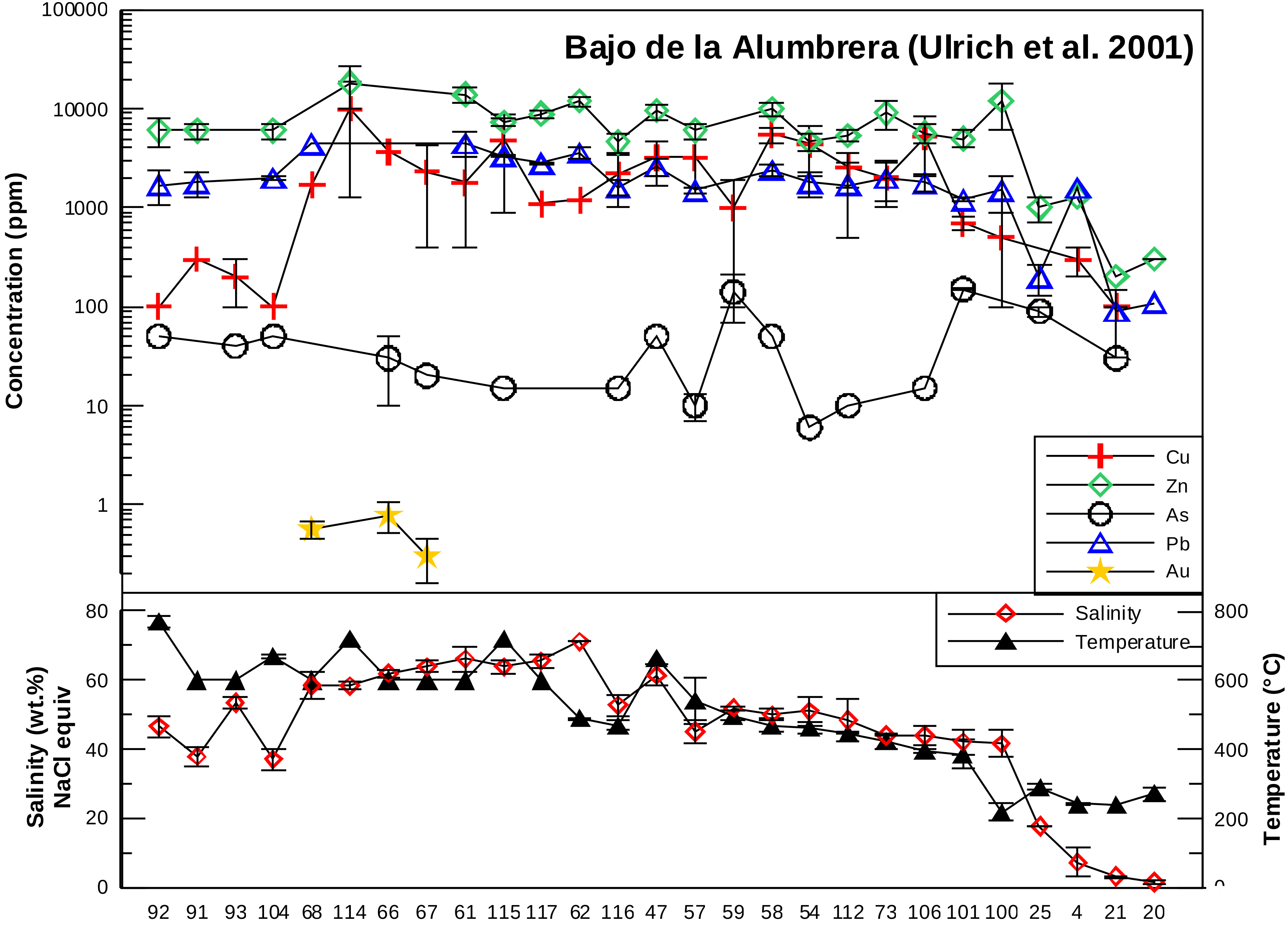


Burnham (1979)



Entwicklungsmuster
Hydroth. Überprägung

Guilbert a. Park
(1986), Fig. 5-8


Bajo de la Alumbrera (Ulrich et al. 2001)
Concentration (ppm)
100000
10000
1000
100
10
1
Cu
Zn
As
Pb
Au
Salinity
Temperature
Salinity (wt.%) NaCl equiv
Temperature (°C)
80
60
40
20
0
800
600
400
200
92 91 93 104 68 114 66 67 61 115 117 62 116 47 57 59 58 54 112 73 106 101 100 25 4 21 20

Chuquicamata open pit in 2003: 2 x 3 km wide, 810 m deep. Total metal value: 45 billion USD
Historic mining: 1.5 Gt @ 1.5 % Cu + 0.07 % Mo. Reserves: 1.3 Gt @ 0.6-0.7 % Cu.
Current production/day: 350,000 t ore (1.0-1.1 % Cu + 200 g/t Mo+Re) plus 350,000 t waste.

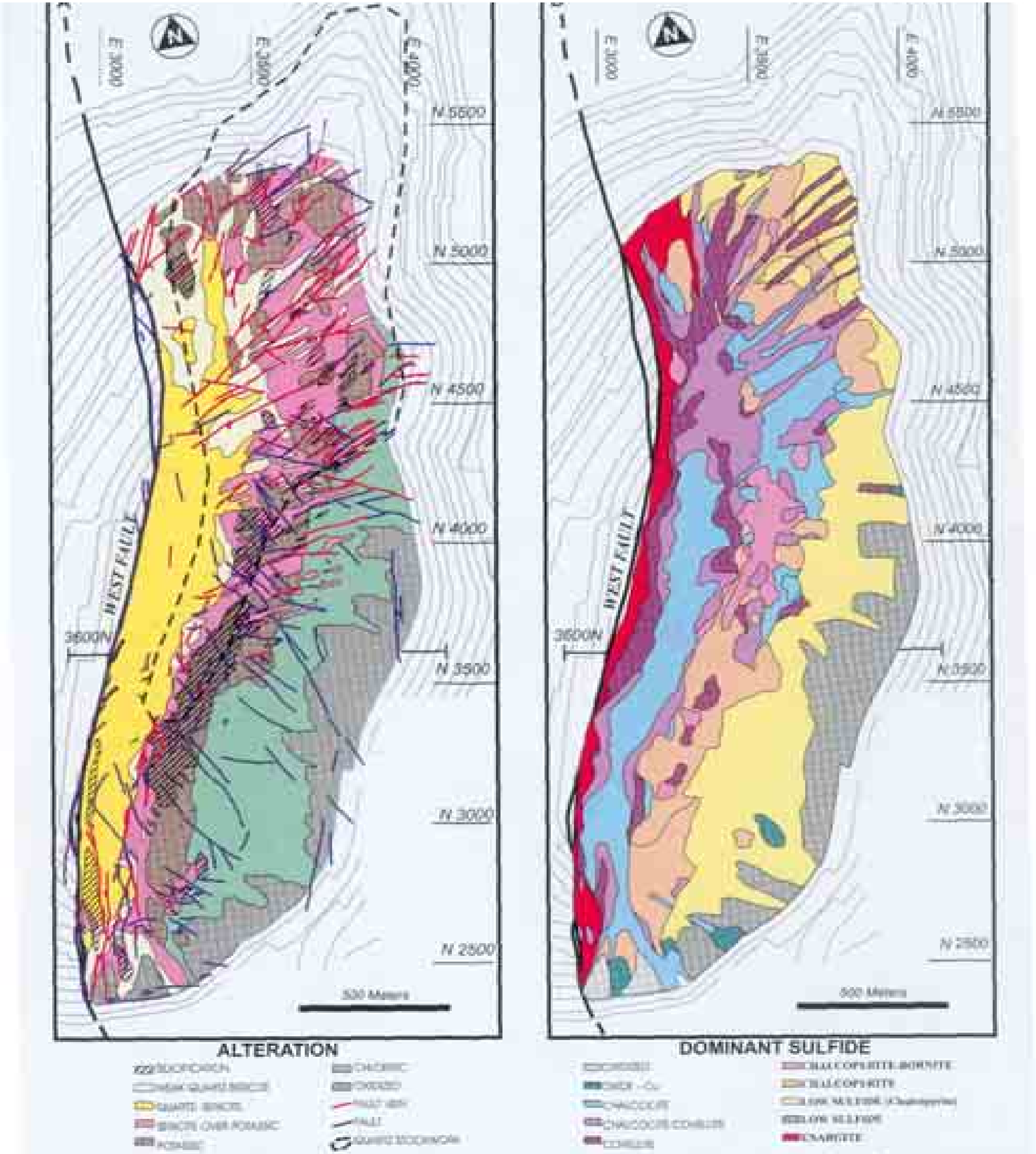
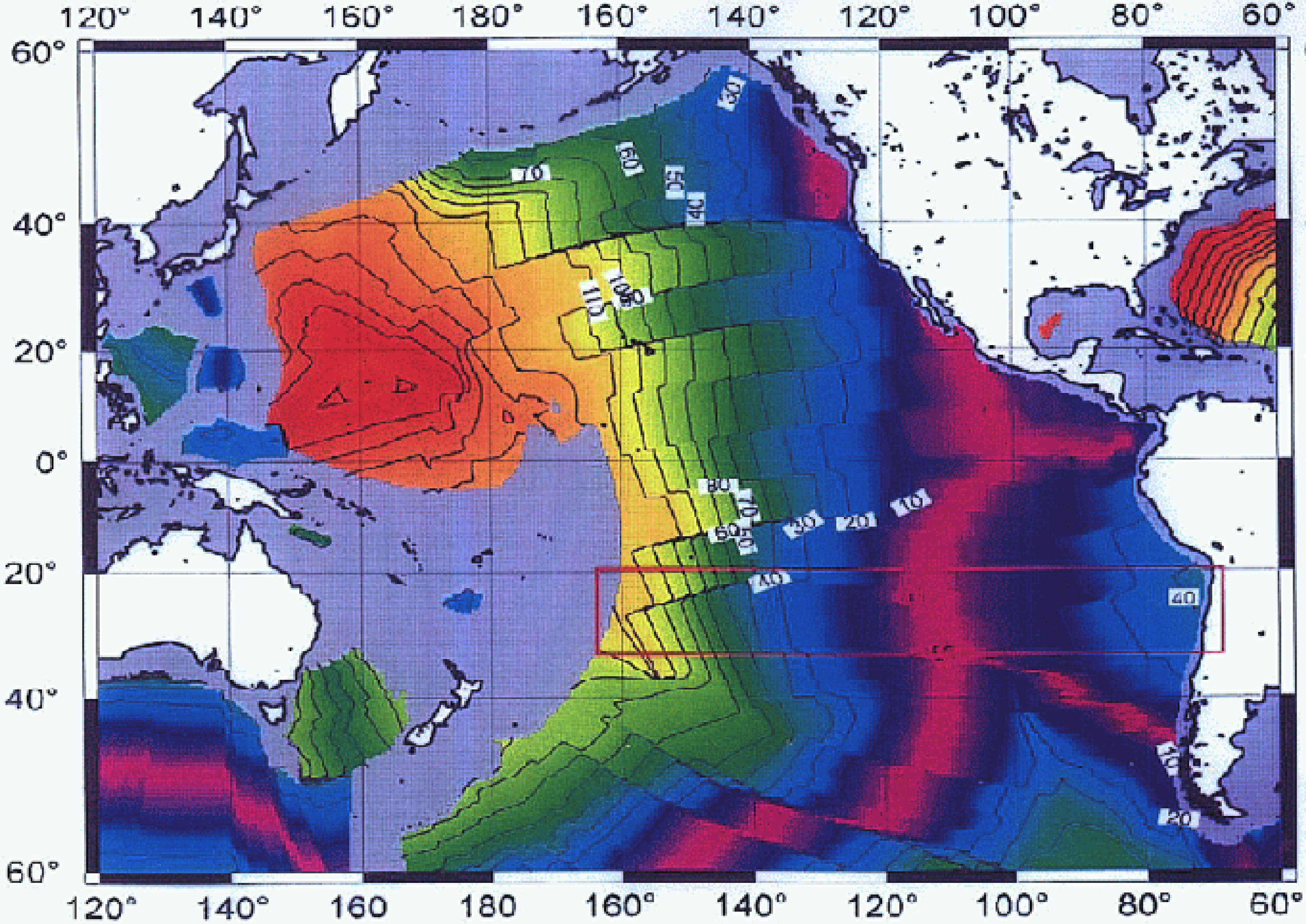


FIG. 5. A. Dominant alteration type and major structures exposed in open pit as of 1995, in area of orebody; from 1:2000

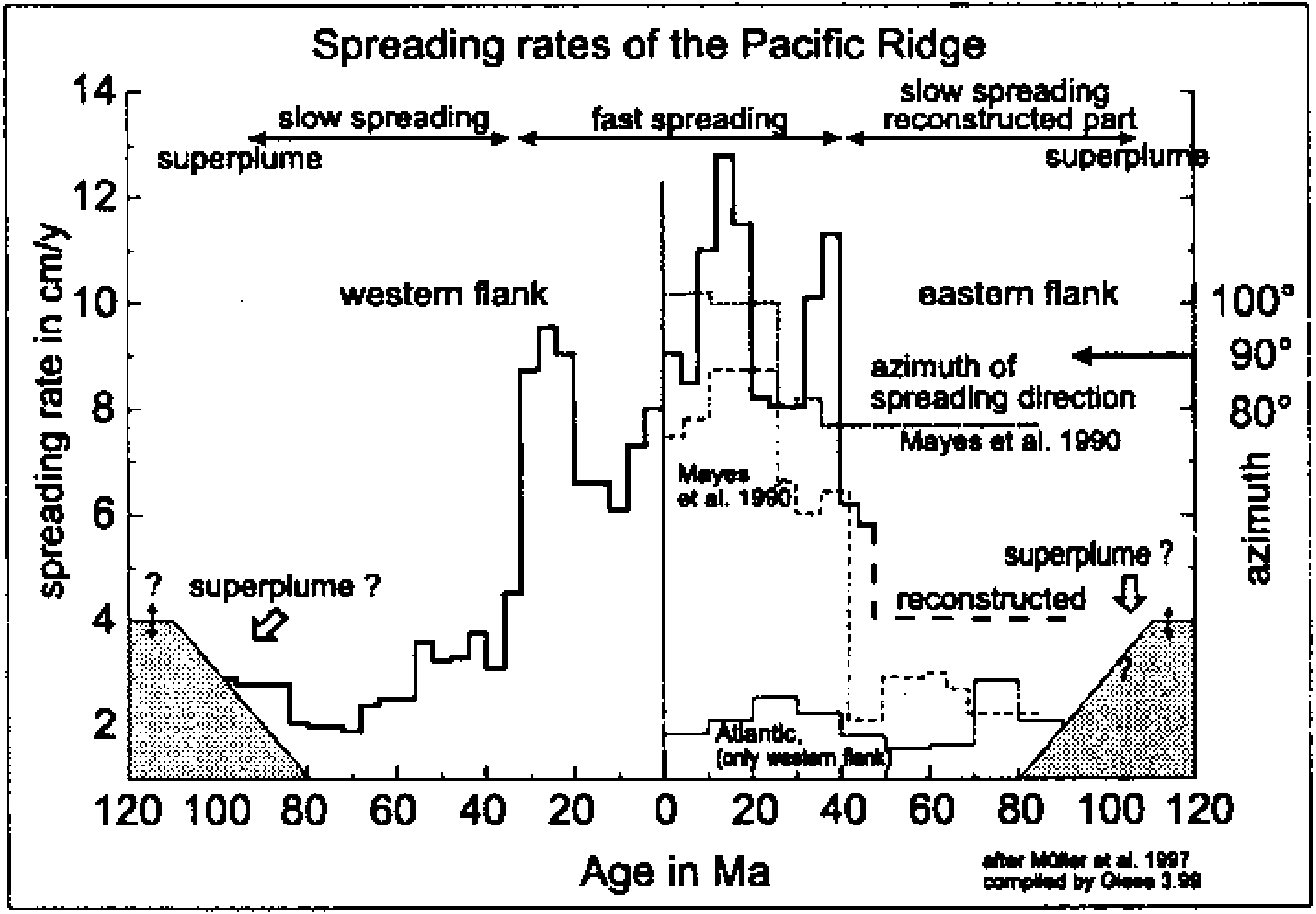
Ossandón et al. (2001)
EG 96: 249-270

Simkin et al. (1989)

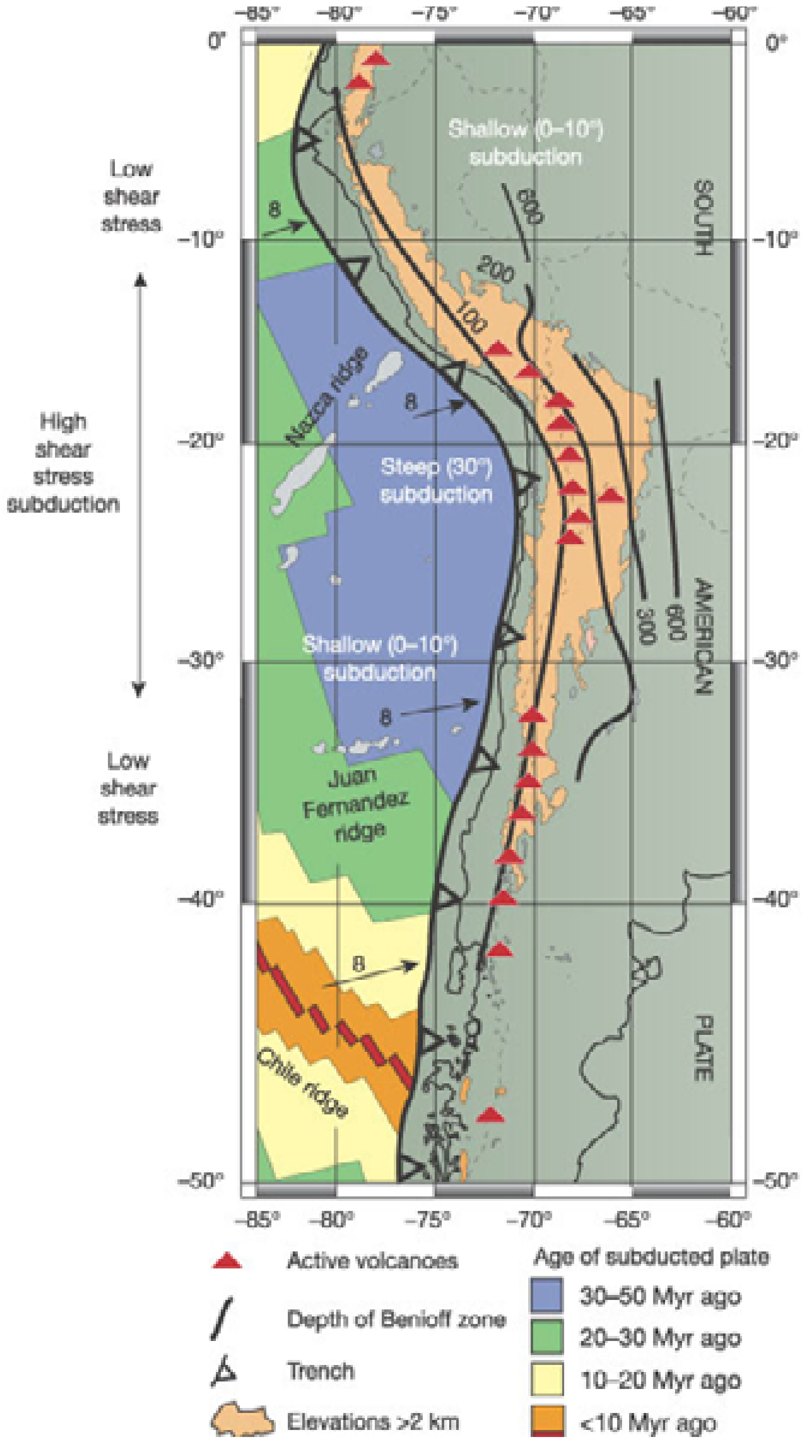
Seafloor spreading in the Pacific



Mueller et al 1997

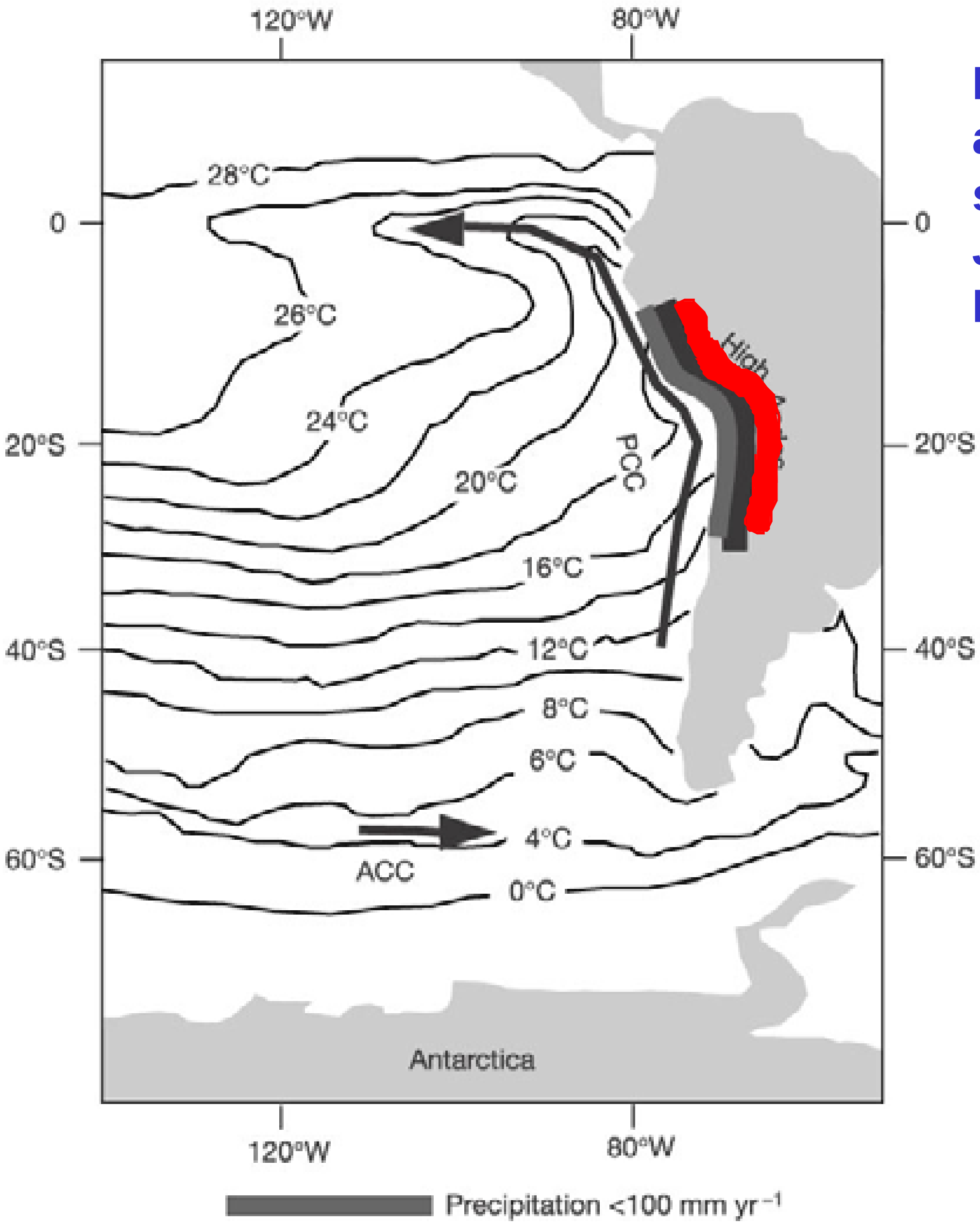


Giese et al. (1999) Ext Abstr 4th ISAG, p. 274



At 24°S:
13 km elevation contrast
from trench to high Andes

Lamb and Davis (2003)
Nature 425: 792-797



Peru–Chile current system and oceanic upwelling: sea surface temperatures July 2002, National Oceanographic Data Center

Lamb and Davis (2003) Nature 425: 792-797

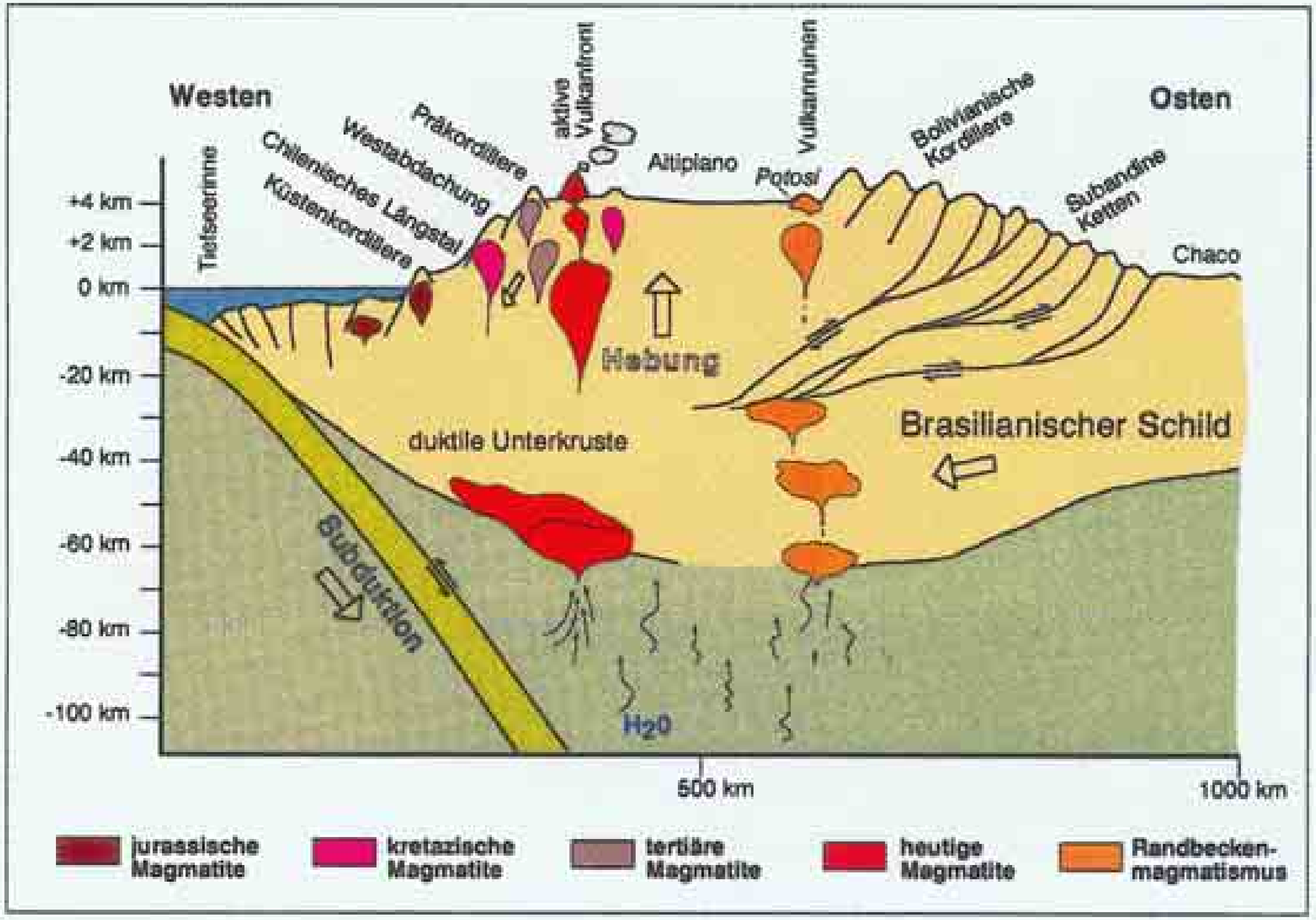
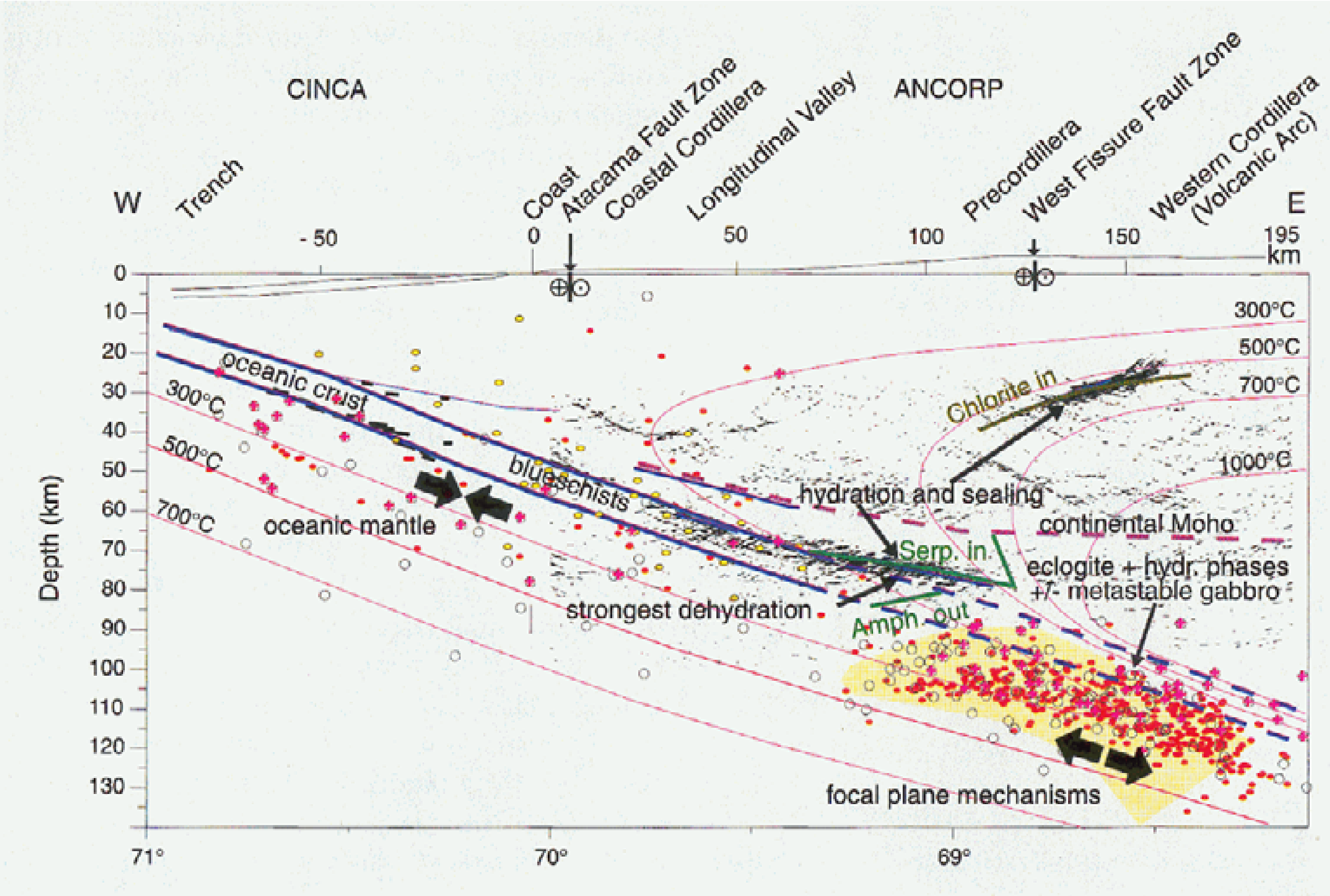


Abb. 2: Ein Querschnitt durch die zentralen Anden auf der Höhe von Arica veranschaulicht die wahrscheinliche Ursache der Gebirgsbildung. Durch das stetige Hineinpumpen von Magma in den Rand des Kontinents wurde die Unterkruste duktil, so daß sich von Osten her der kalte (und damit steifere) Brasilianische Schild in diese hineinschieben konnte und dabei die Oberkruste des Kontinentalrandes nach oben drückte. Als Folge dieser Hebung kam es im Westen zu gewaltigen Abschiebungen und im Osten zum Ausfließen eines verschuppten Deckenstapels auf das Vorland des Gebirges. Die Abbildung ist nicht maßstäblich und nichtlinear überhöht.

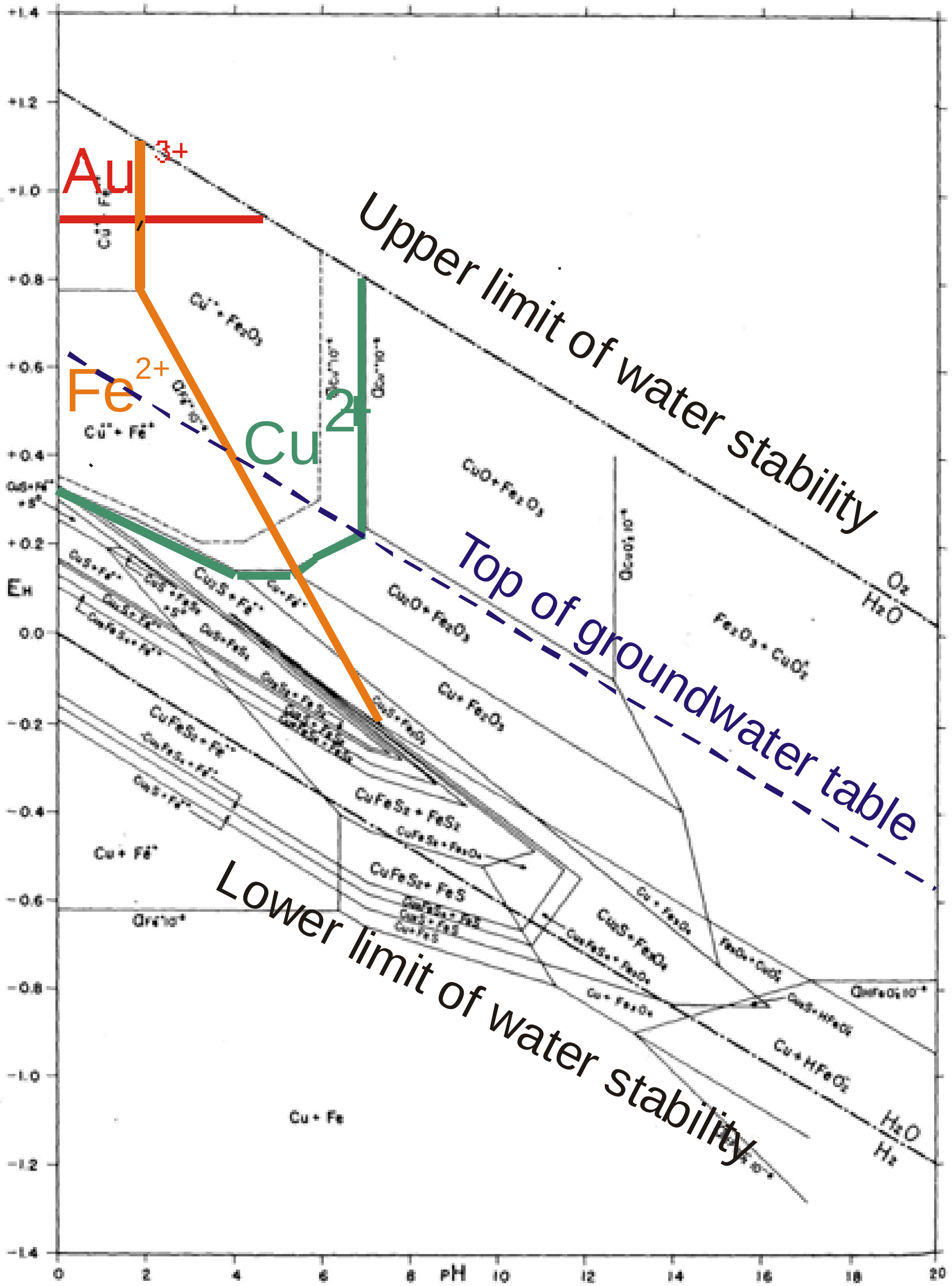
Seyfried et al (1994) Jb Univ Stuttgart: 60-71



Oncken et al. (1999) Nature 397: 343

Diercke und Gaebler: Schul-Atlas über alle Teile der Erde (1883)

Salar de Uyuni, Bolivia



The system Cu-Fe-S-O-H

at 25°C and 1 bar.

Total dissolved sulfur = 10^{-4} m

From Garrels and Christ (1965: 231)

The colored solubility limits of

Au^{3+}, Fe^{2+} and Cu^{2+} are drawn

at 10^{-6} m Fe (56 ppb Fe), 10^{-6} m Cu

(64 ppb Cu) and 10^{-8} m Au (2 ppb Au).

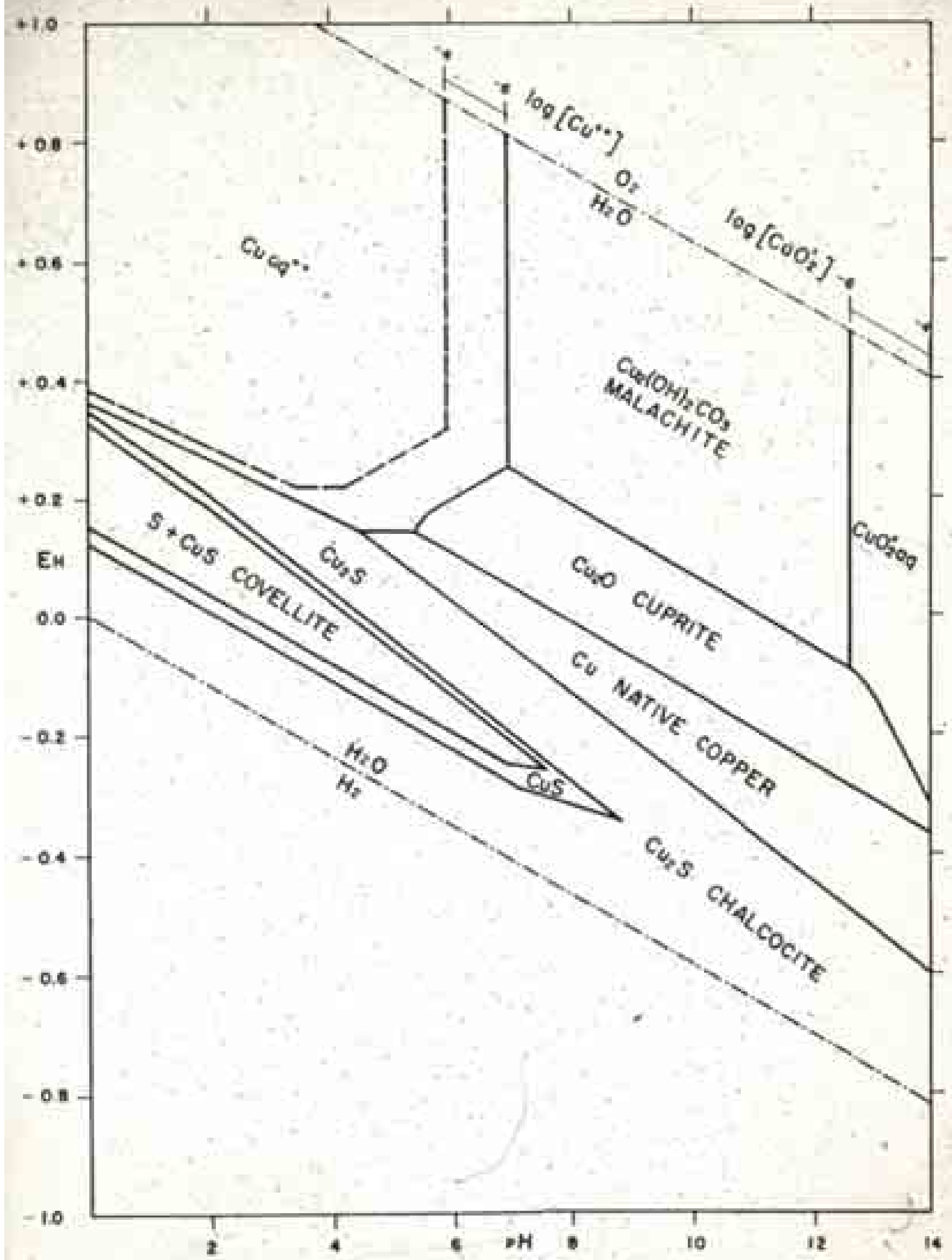
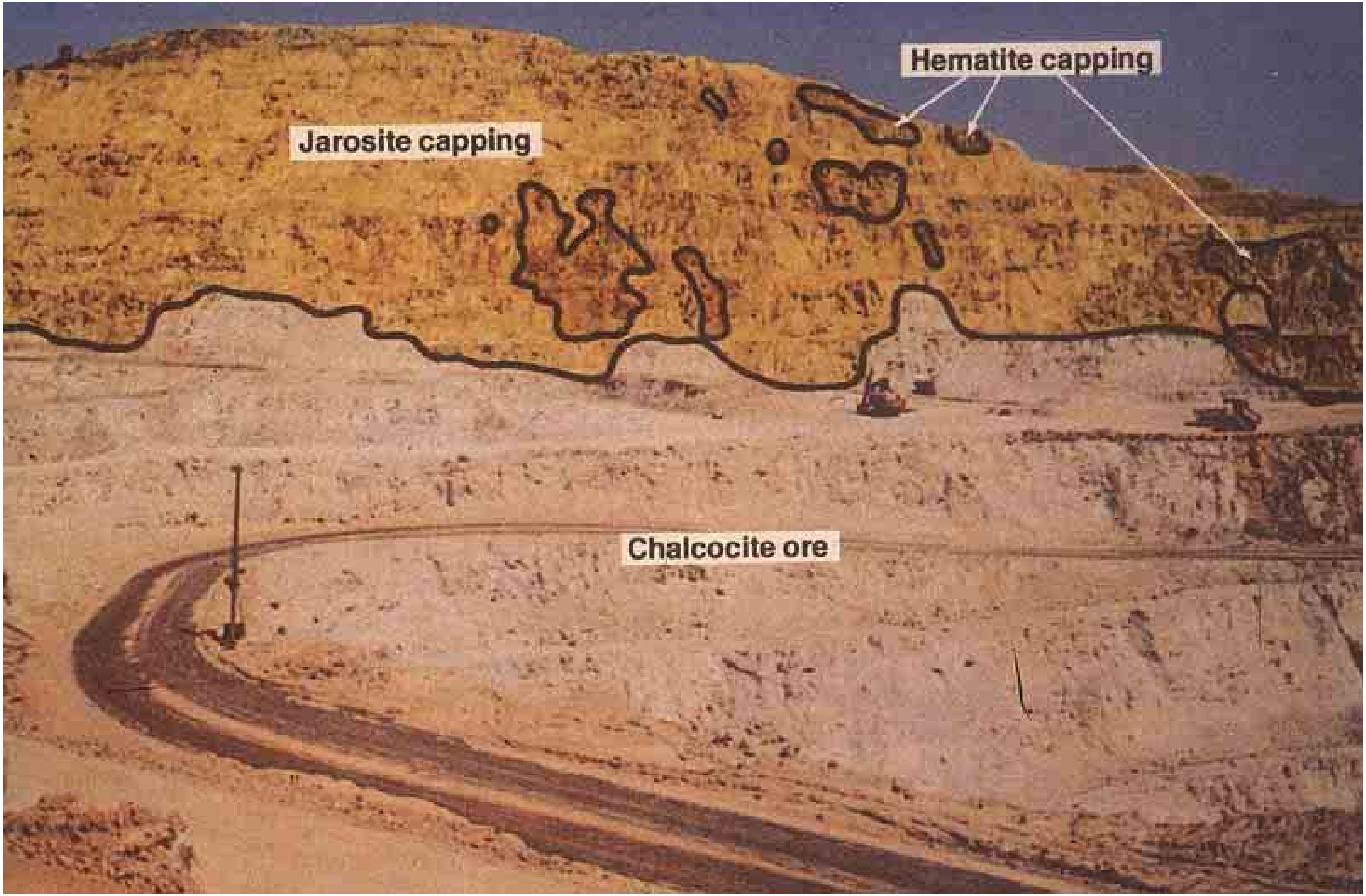
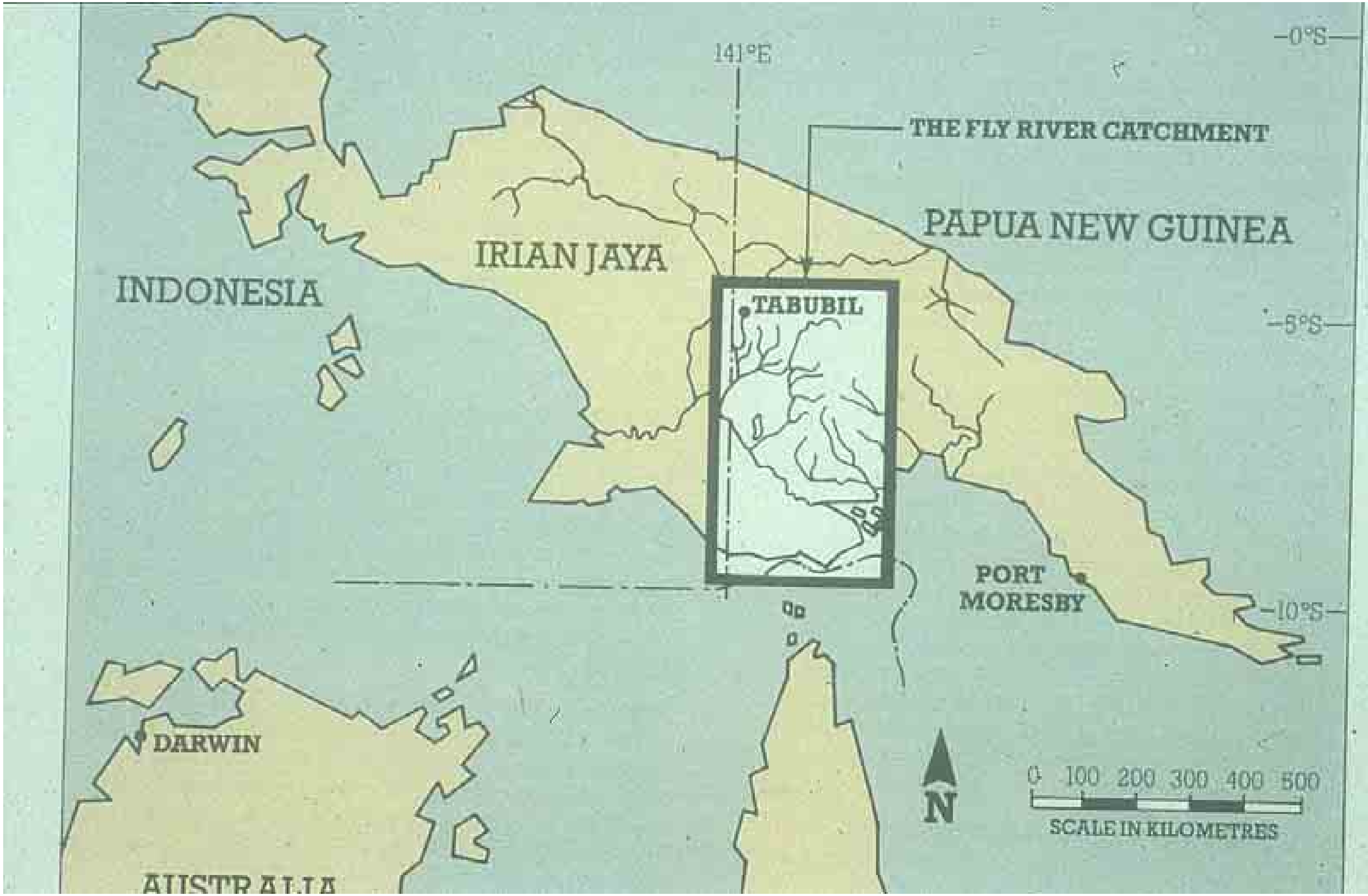


FIG. 7.27b. Stability relations among some copper compounds in the system $Cu\text{-}H_2O\text{-}O_2\text{-}S\text{-}CO_2$ at 25 °C and 1 atmosphere total pressure. $P_{CO_2} = 10^{-3.5}$, total dissolved sulfur species = 10^{-1}. [Courtesy J. Anderson.]



Leached Capping Butte, Montana
Anderson, in: Titley, ed., 1982

Leached capping Chino (Santa Rita), N-Mex.
Anderson, in: Titley, ed., 1982


141°E
0°S
THE FLY RIVER CATCHMENT
PAPUA NEW GUINEA
IRIAN JAYA
INDONESIA
TABUBIL
5°S
PORT
MORESBY
10°S
DARWIN
N
0 100 200 300 400 500
SCALE IN KILOMETRES

Near Pt. Moresby

Oberlauf Kikori River
Highlands
bis 4.500 m Höhe

PNG ´94

Ok Tedi
open pit

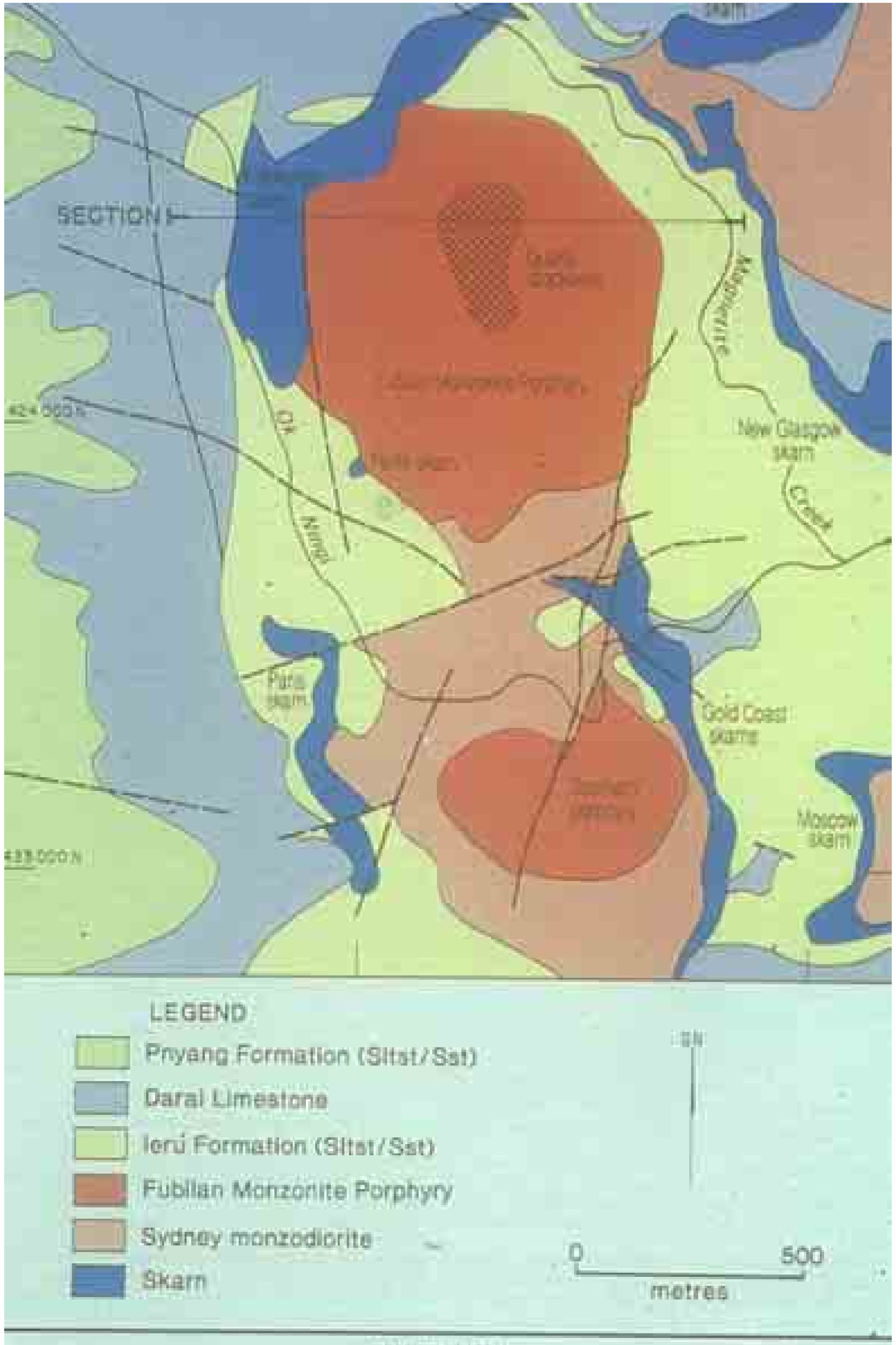
OK Tedi (1976) Drill sites, helicopter landing pads
EG 73: 597 (1978)

OK Tedi 1991

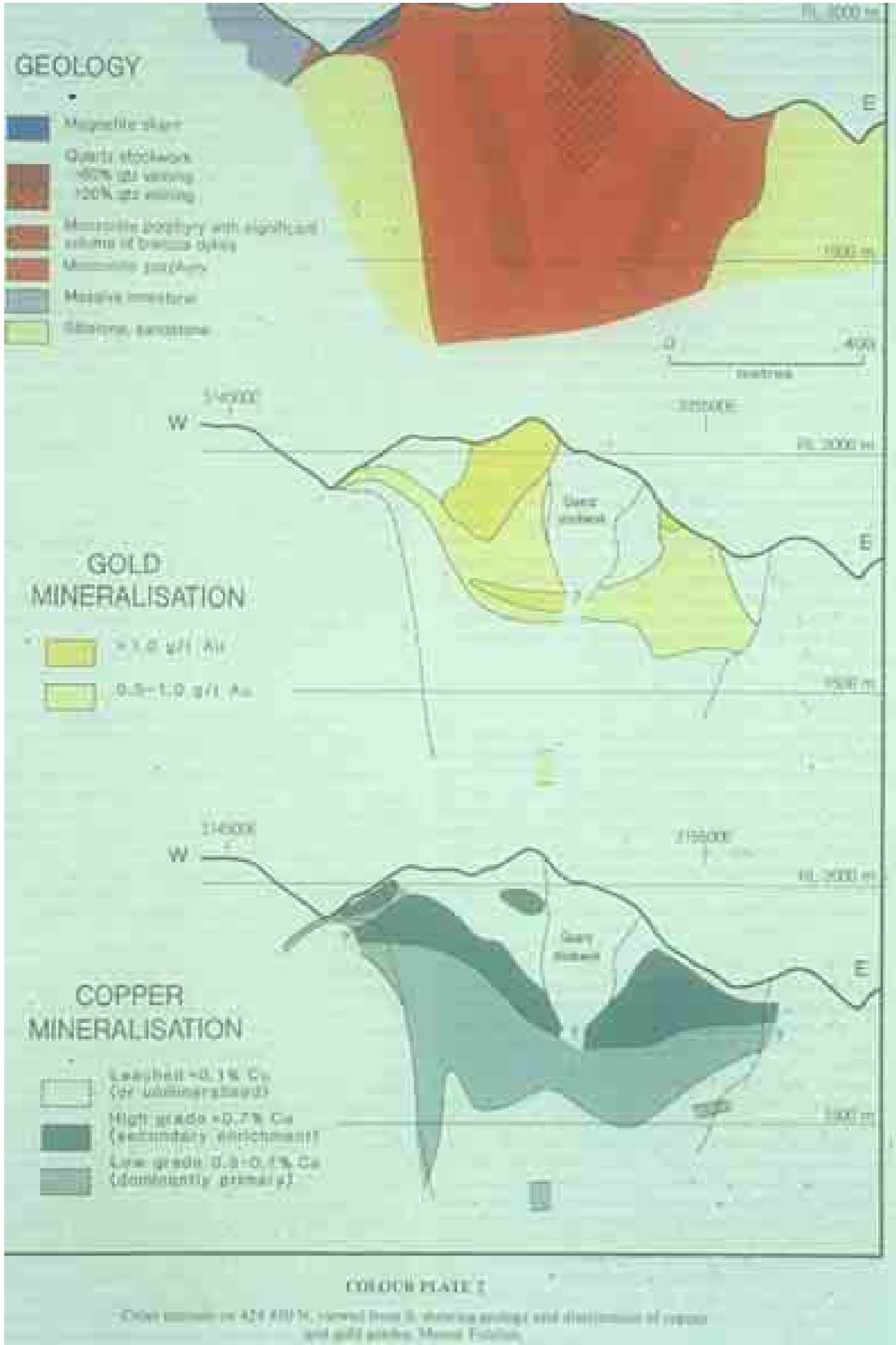
OK Tedi pit 1994

OK Tedi pit 1994

OK Tedi



COLOUR PLATE 1



Ok Tedi/
Papua New Guinea

460 Mt @ 0.72 % Cu,
0.7 g/t Au

Gossan ore:
30 Mt x 3 g/t Au =
90 t Au
~ 2.5 billion USD

Secondary enrich-
ment zone:
265 Mt x 0.82 % Cu =
2 Mt Cu
~ 14 billion USD

265 Mt x 0.65 g/t Au =
170 t Au

Protore:
0.2-0.4 % Cu
0.3-0.5 g/t Au

Davies et al. (1978)
Econ Geol 73: 796-
809

OK Tedi: „Silica core“ with CuS_2

OK Tedi „Erodible dump“ main site (1994)

OK Tedi „Erodible dump“ (1994)

OK Tedi „Erodible dump“

OK Tedi „Erodible dump“

OK Tedi (1994)

OK Tedi river near Tabubil

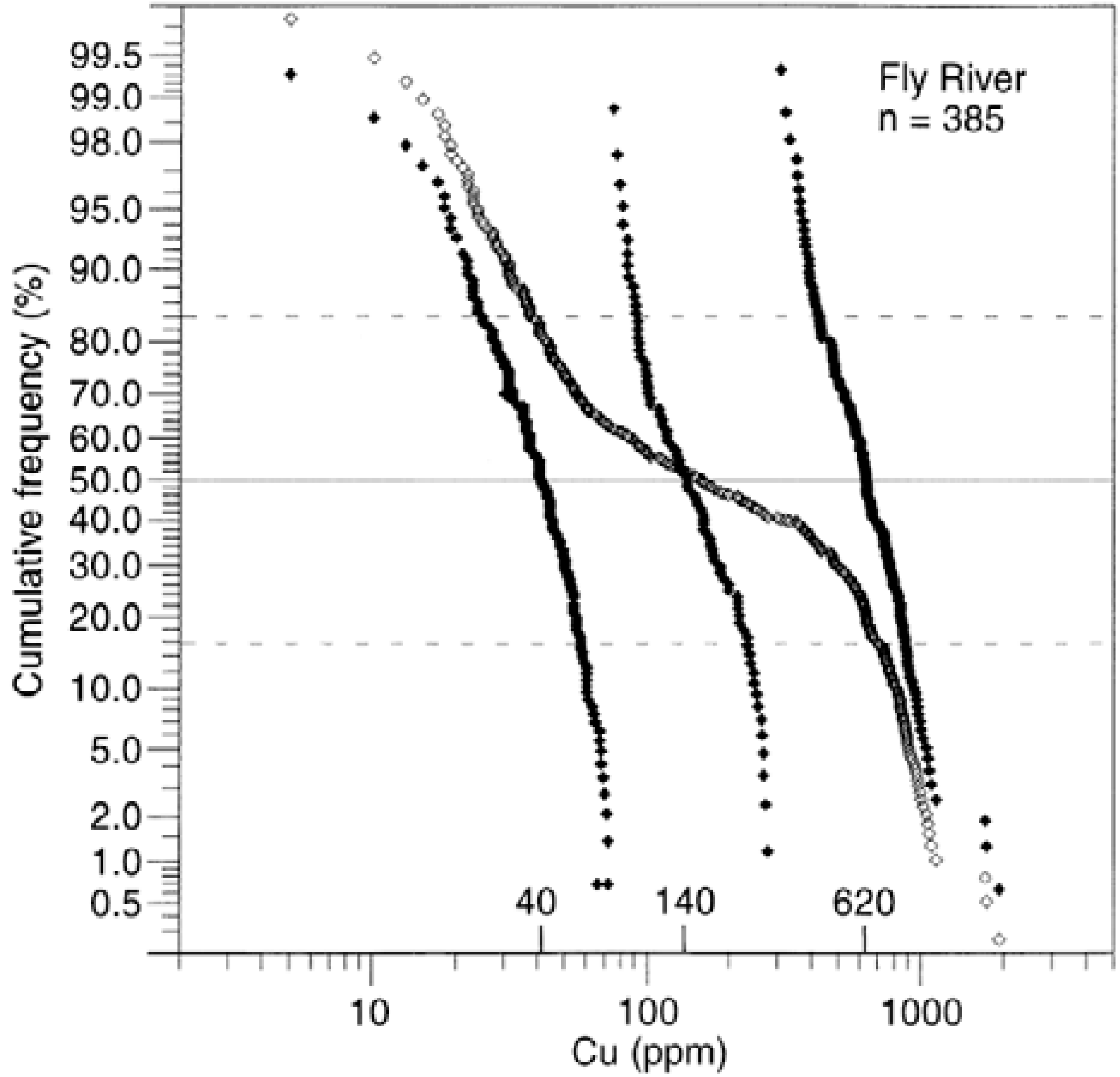


Fig. 5 Lognormal probability plot of the copper distribution in alluvial sediments in the Middle Fly River floodplain. The probability graph of the composite population of 385 data points (*open squares*) separates into three approximately lognormal subpopulations (*solid squares*). Median copper values for the subpopulations are shown above the x-axis

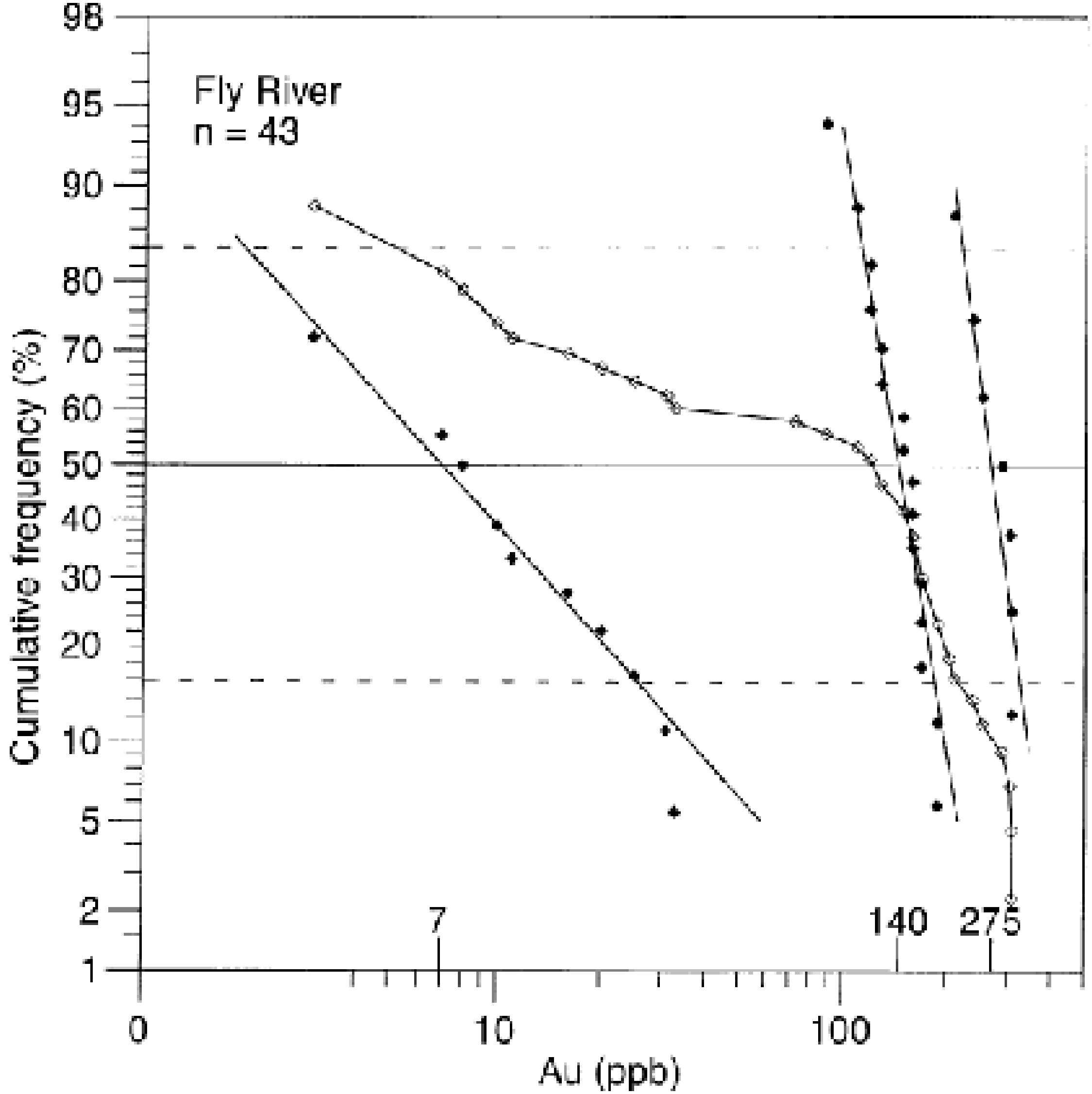


Fig. 7 Lognormal probability plot for gold concentrations in the Middle Fly River floodplain. The composite population of 43 data points (*open squares*) separates into three approximately lognormal subpopulations (*solid squares*). Median gold values for the subpopulations are shown above the x-axis

Grasberg Cu-Au porphyry deposit, Irian Jaya/Indonesia: 3.5 Gt @~1 % Cu, ~1 g/t Au

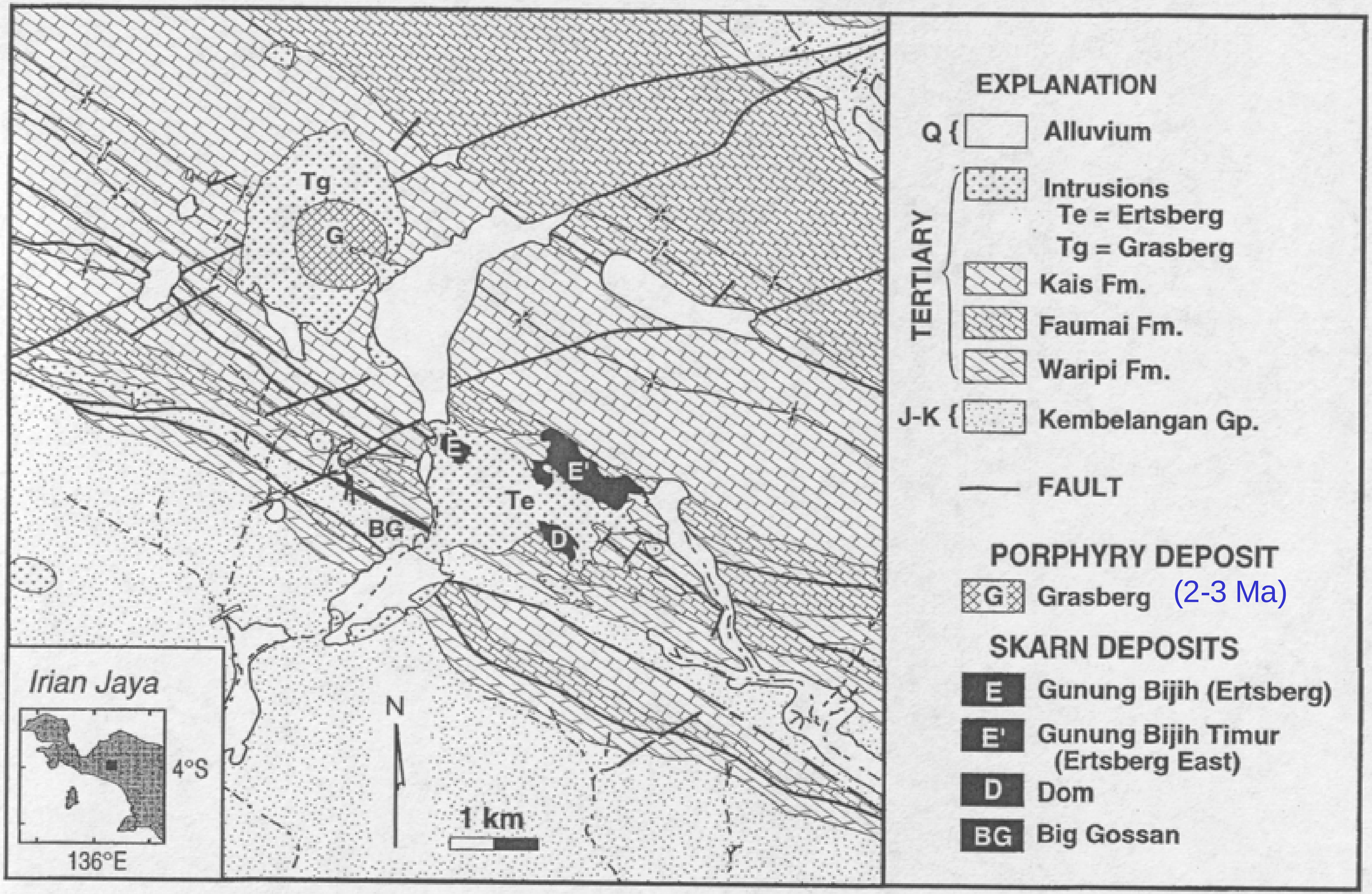


FIG. 2. Geologic map of the Ertsberg district showing locations of ore deposits. Generalized from 1:10,000 mapping of Freeport Indonesia geologists from 1970–1996. Limited areas of glacial ice are omitted from the northeastern part of the area.

Grasberg road (Aug 99)

Grasberg road (Aug 99)

Grasberg (Aug 99)

Grasberg (Aug 99)

Grasberg (Aug 99)

Grasberg Open Pit

View Looking South

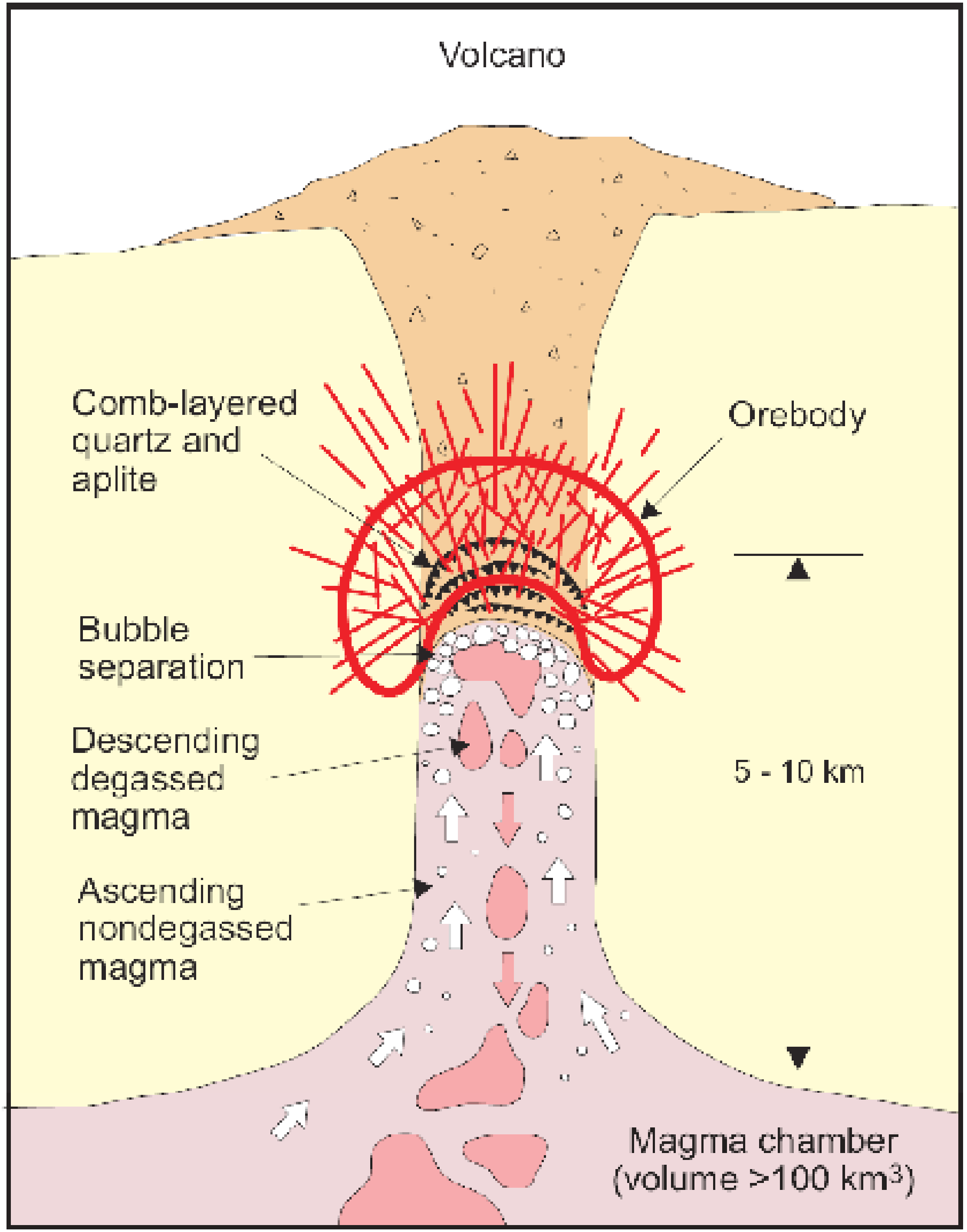
October 9, 2003

Hi-grade mt-cpy ore, Grasberg

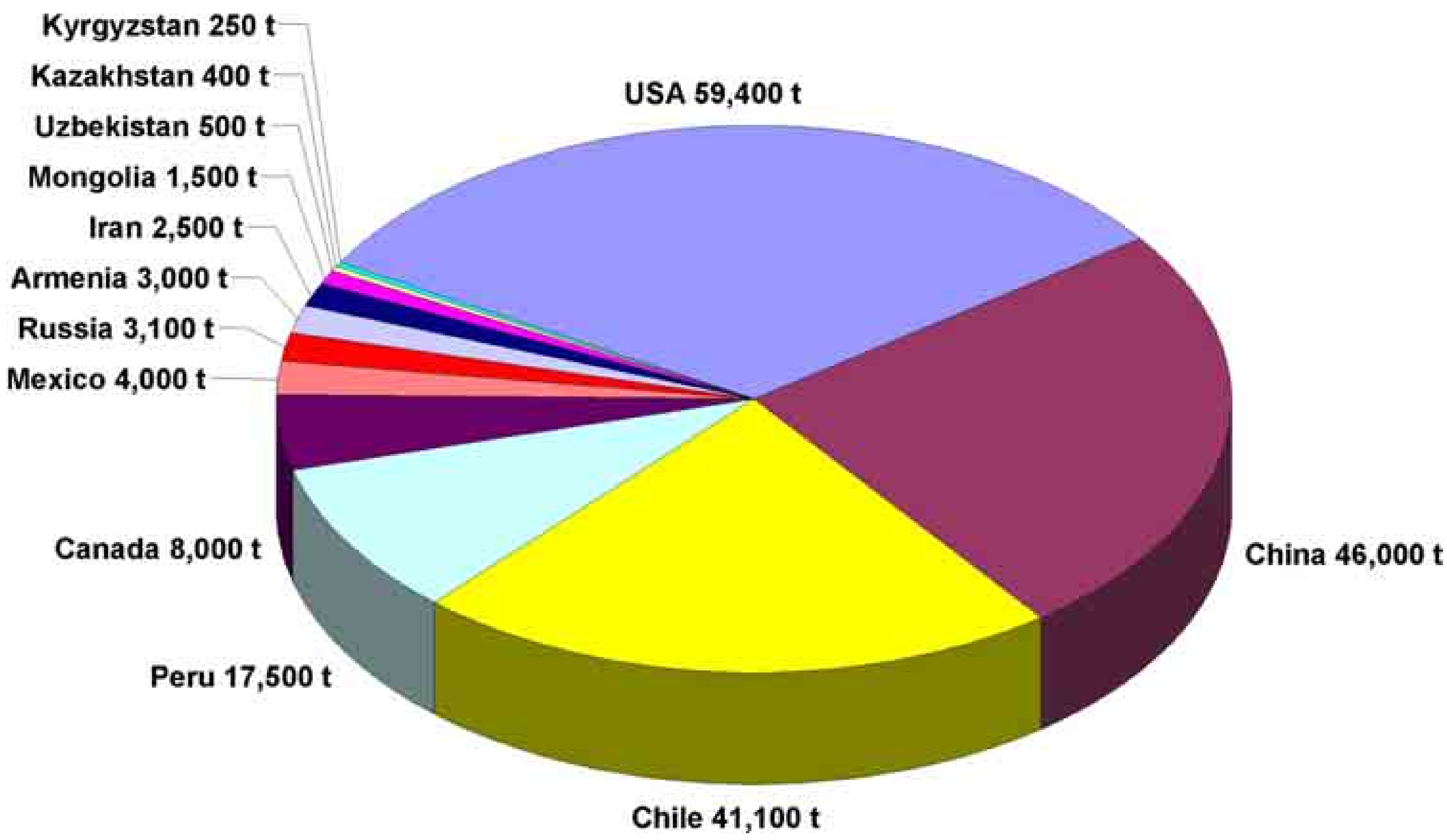
Hi-grade mt-cpy ore, Grasberg

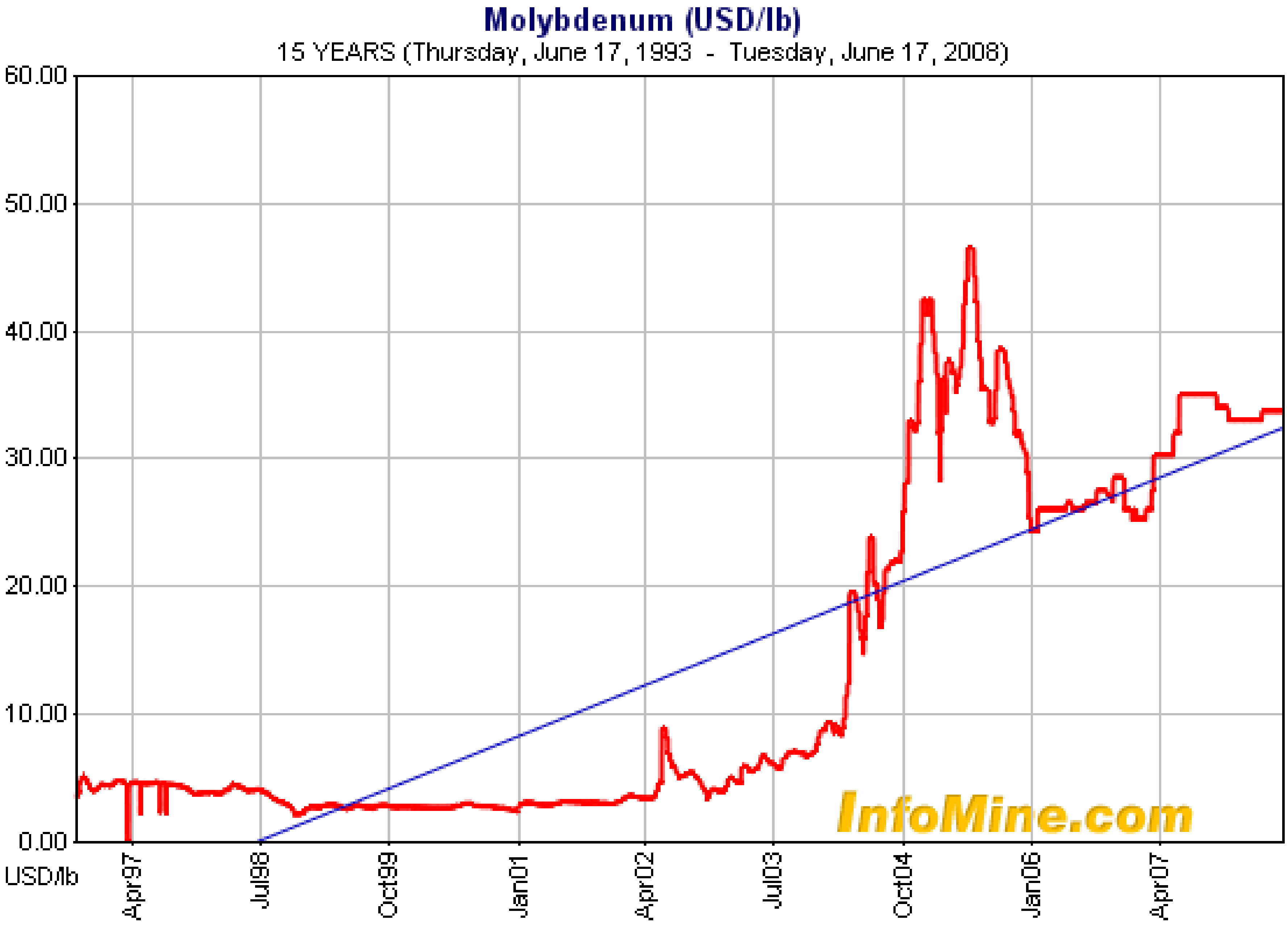
Schematic diagram of a convecting magma that is feeding a small subvolcanic intrusion below a porphyry deposit (modified from Shinohara et al., 1995). Fluid separation from the degassing magma occurs near the top of the magma column, forming pockets of magmatichydrothermal fluid in which comb-quartz layers grow inward from intrusion margins. Mineralized vein and fracture stockworks form when the fluid pressure exceeds litho-static pressure and tensile strength of the surrounding rocks.

Sinclair (2007)



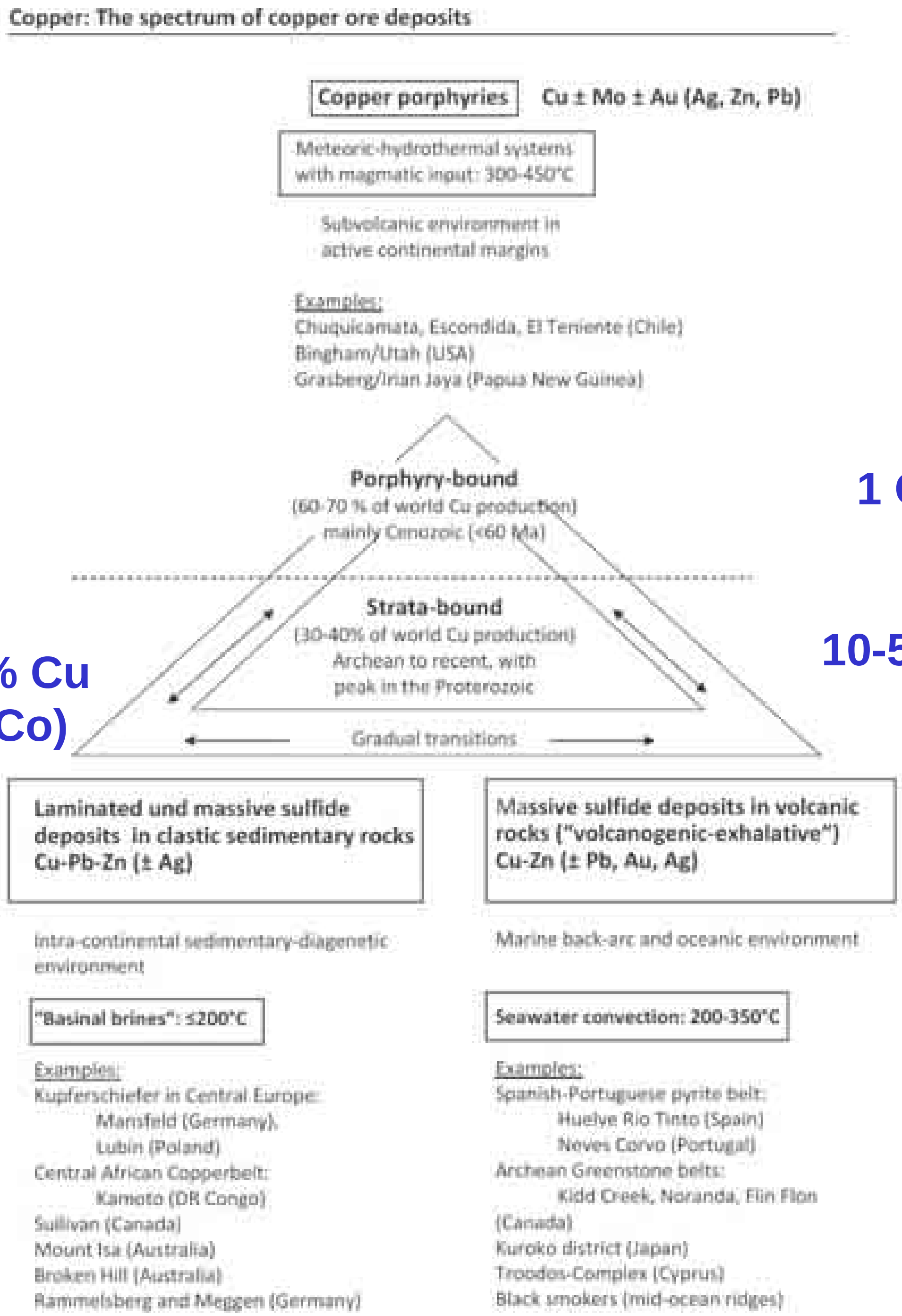
MOLYBDENUM WORLD MINE PRODUCTION 2007 (187,250 t)





Molybdenum (USD/lb)
15 YEARS (Thursday, June 17, 1993 - Tuesday, June 17, 2008)
60.00
50.00
40.00
30.00
20.00
10.00
0.00
USD/lb
Apr97
Jul98
Oct99
Jan01
Apr02
Jul03
Oct04
Jan06
Apr07
InfoMine.com

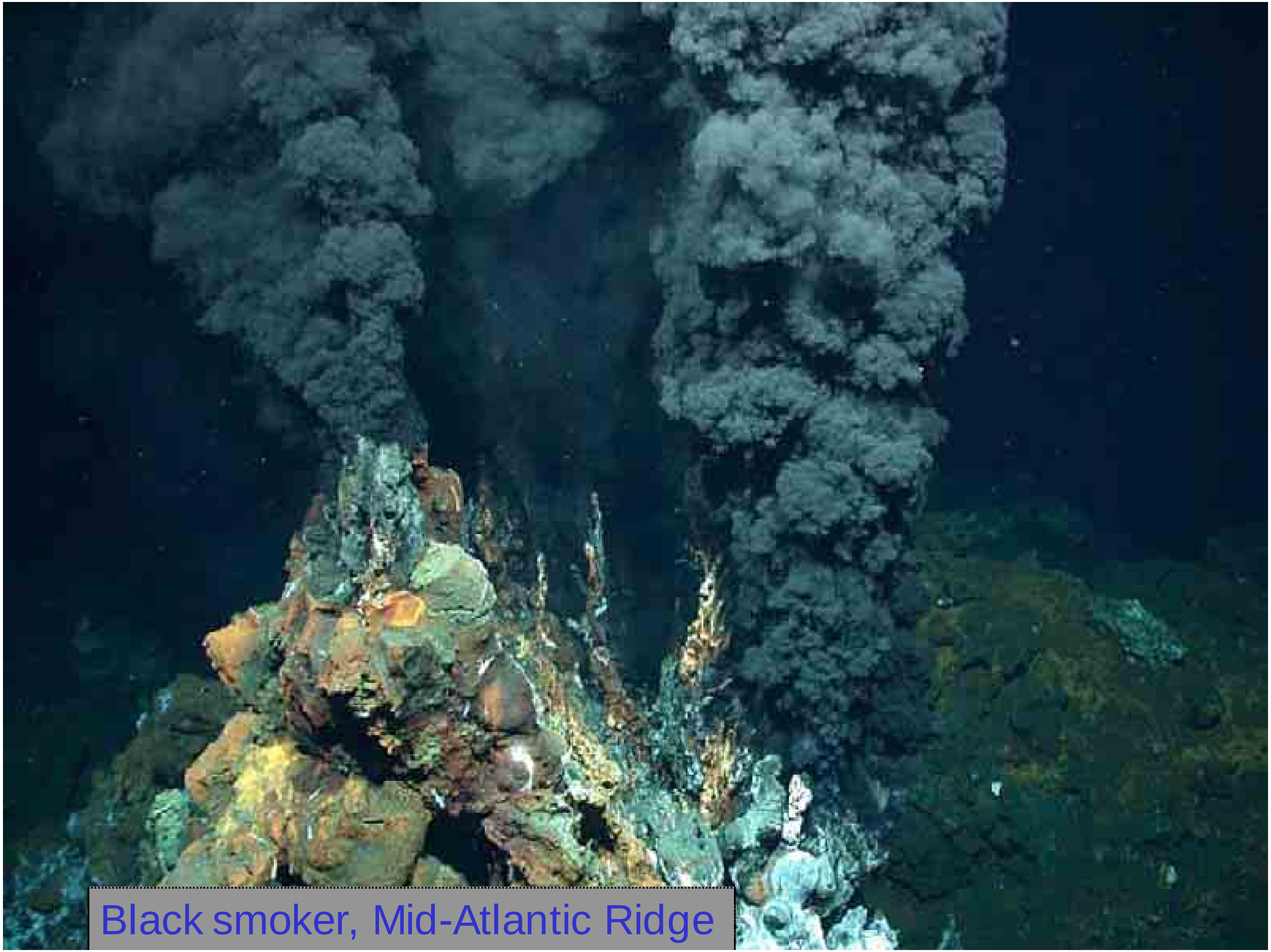
MOLYBDENUM
15 YEARS (Jun 23, 1994 - Jun 22, 2009)
Molybdenum (USD/lb)
55
50
45
40
35
30
25
20
15
10
5
0
Jun 23 1994
Dec 9 1996
May 28 1999
Nov 13 2001
May 1 2004
Oct 18 2006
Apr 5 2009
InfoMine.com



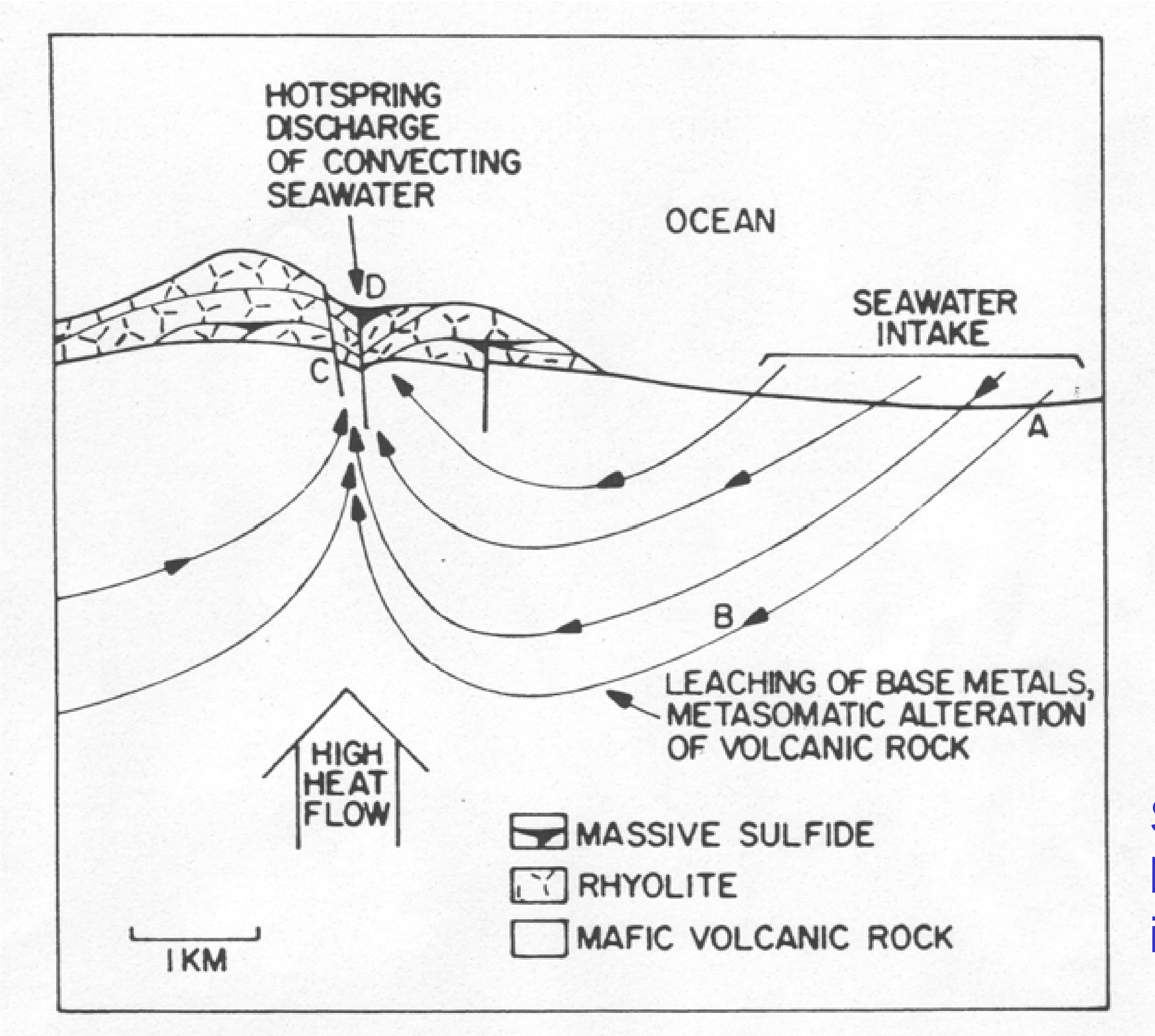
1 Gt @ 0.5-1 % Cu

1 Gt @ 1-4 % Cu (Ag, Co)

10-50 Mt @ 1-10 % Cu, 1-10 % Zn, (1-10 % Pb)

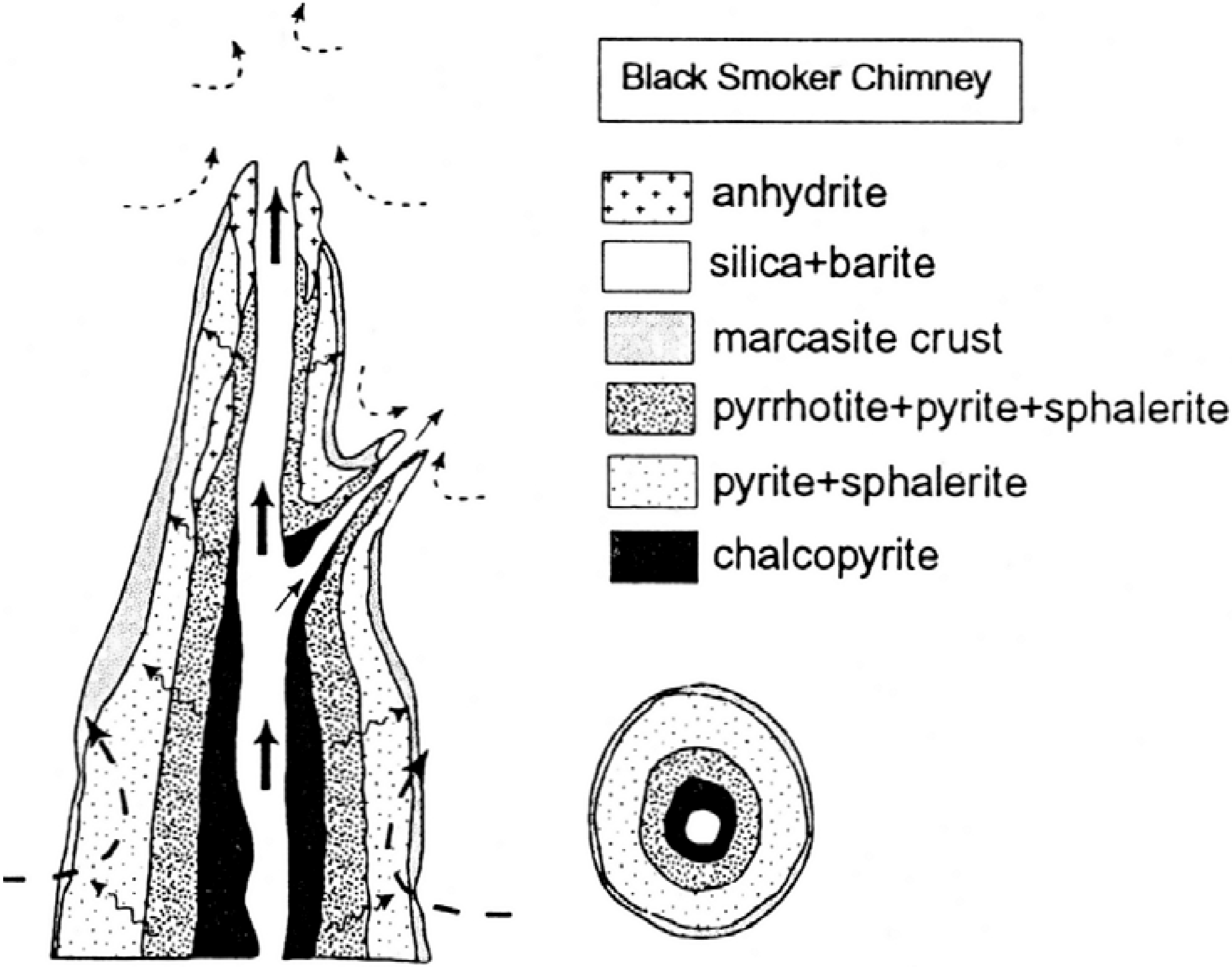


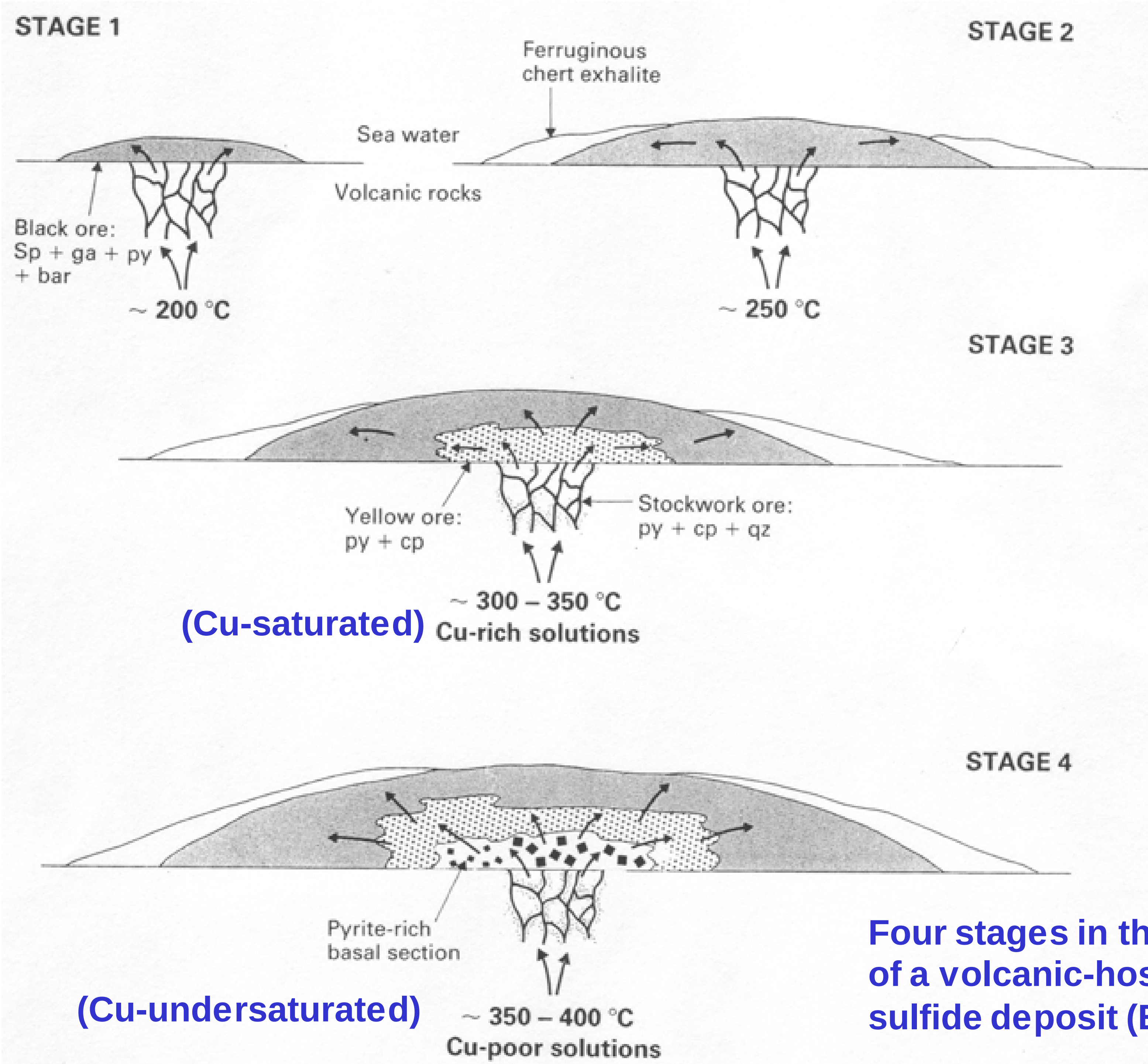
Black smoker, Mid-Atlantic Ridge



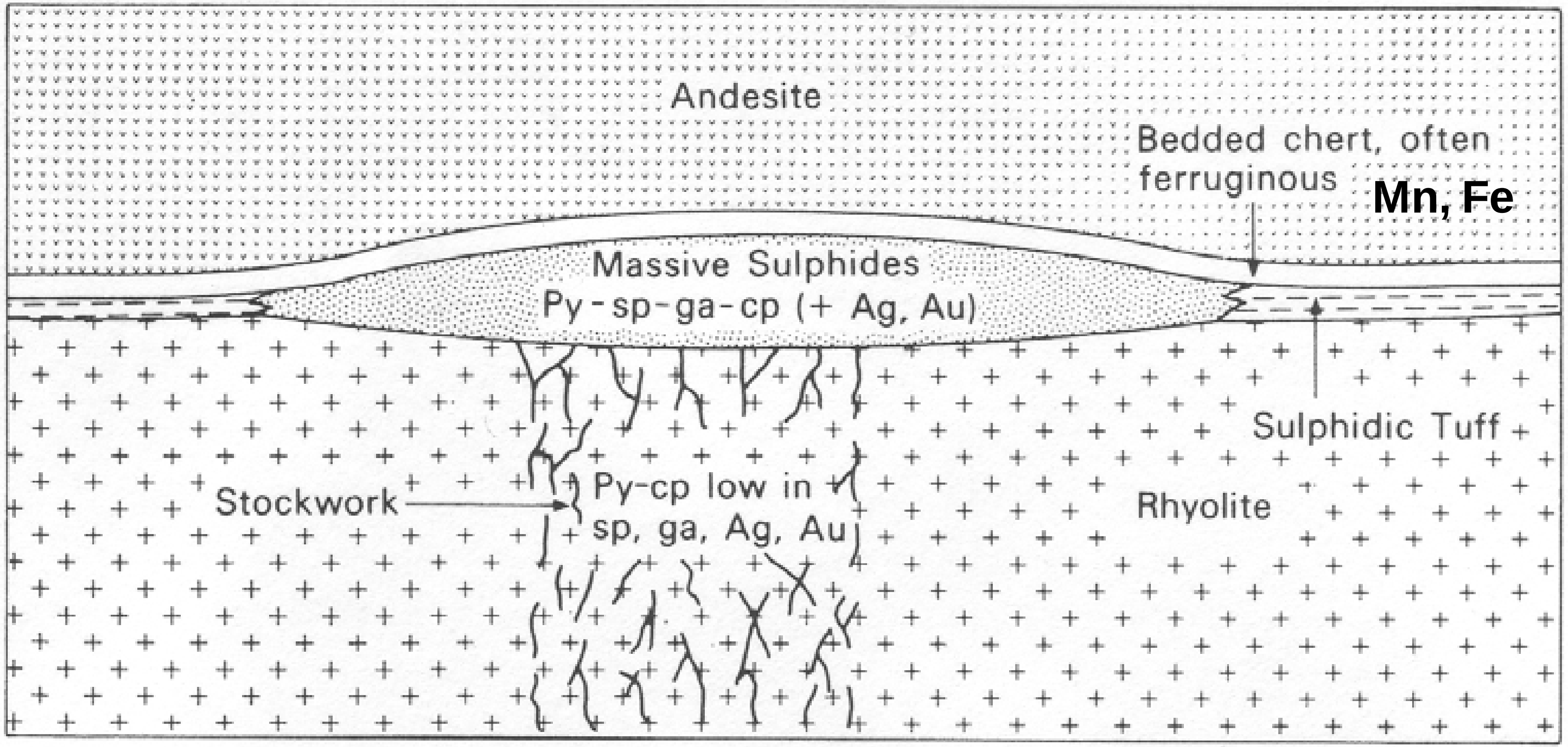
Seawater-basalt interaction

Reed (1983) EG 78: 466-485

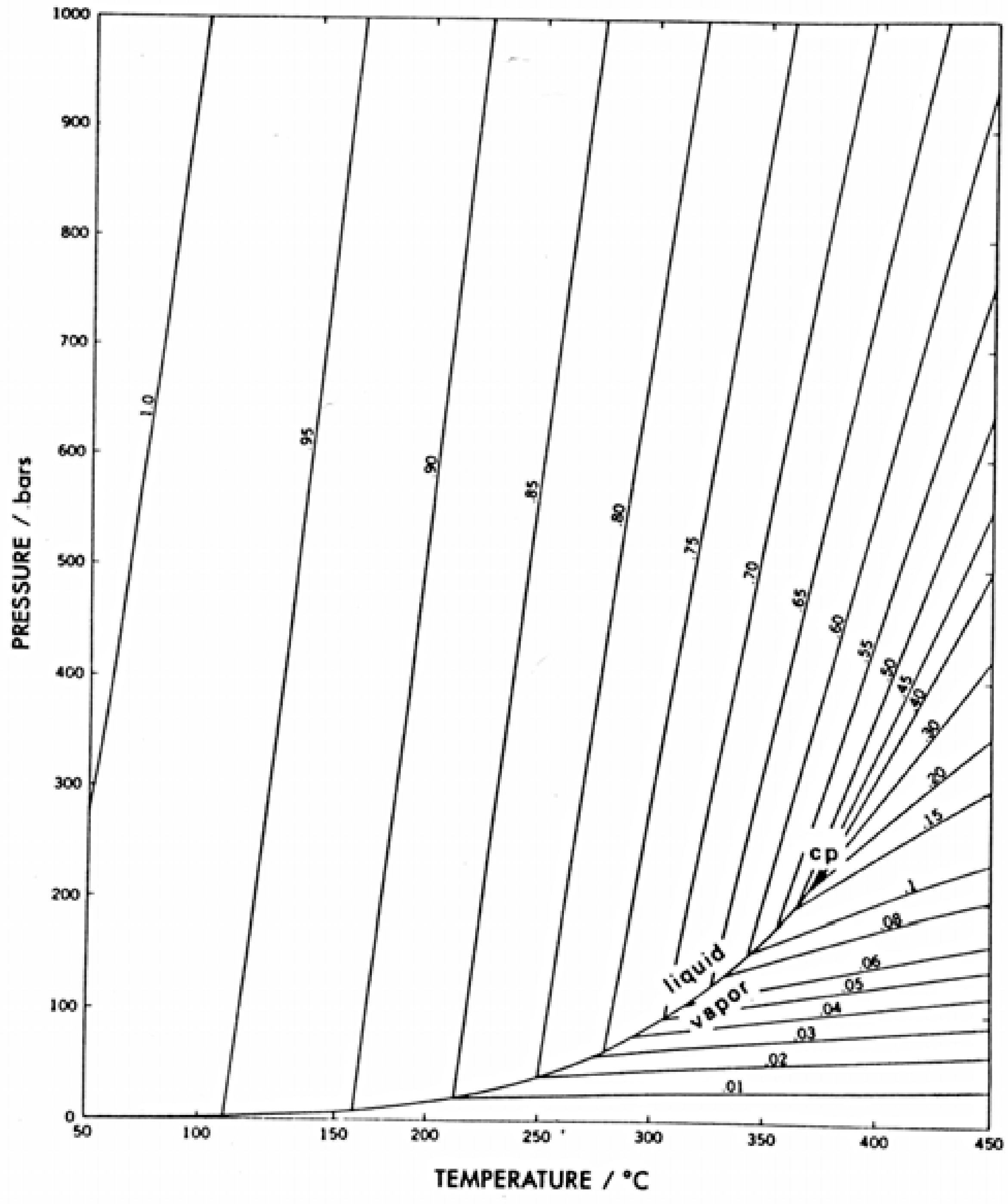

Black Smoker Chimney
anhydrite
silica+barite
marcasite crust
pyrrhotite+pyrite+sphalerite
pyrite+sphalerite
chalcopyrite



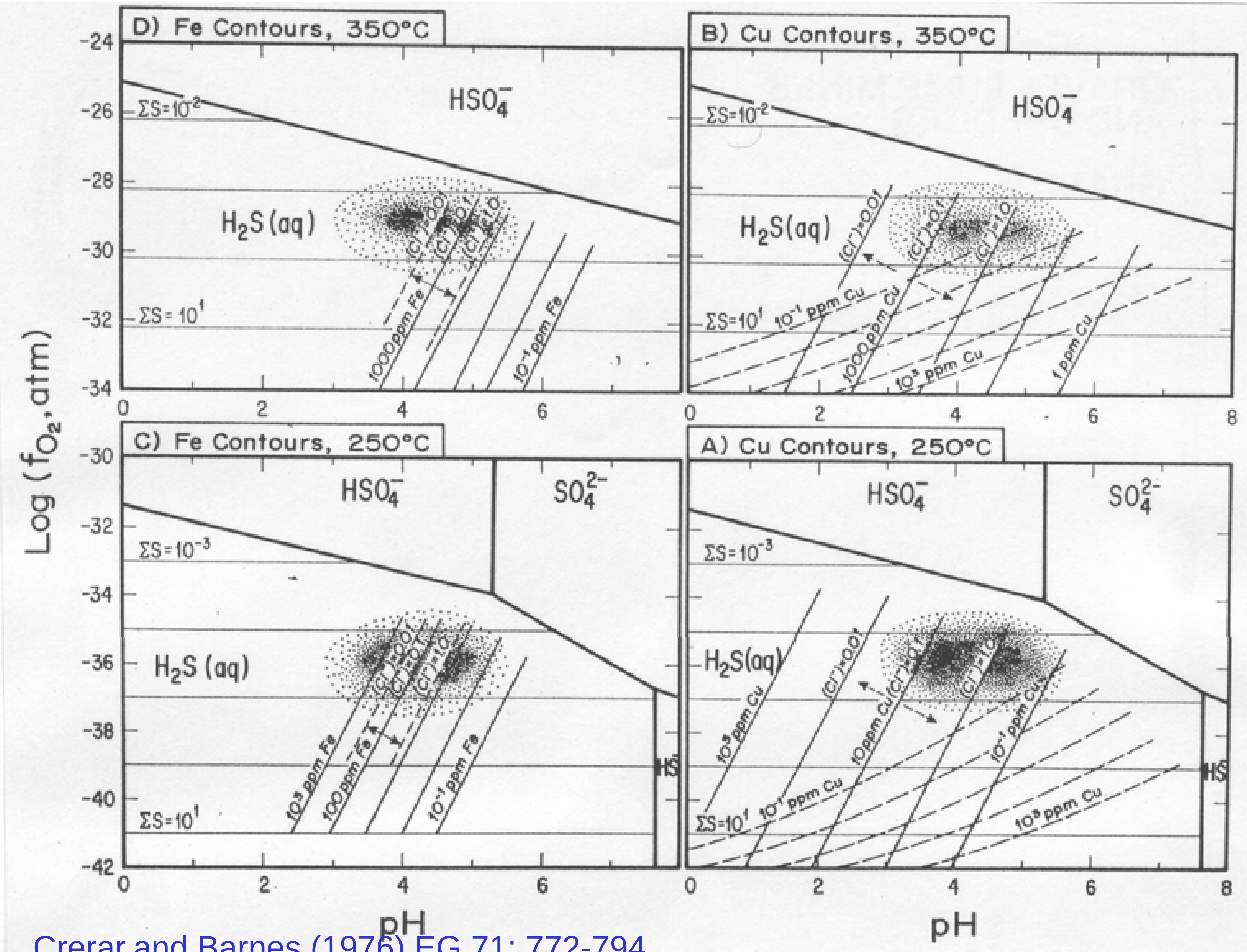
Four stages in the evolution of a volcanic-hosted massive sulfide deposit (Evans 1992: 74)



Idealized cross-section through a volcanic-hosted massive sulfide deposit
(Evans 1992: 39)


PRESSURE / bars
TEMPERATURE / °C
1000
900
800
700
600
500
400
300
200
100
0
50
100
150
200
250
300
350
400
450
1.0
.95
.90
.85
.80
.75
.70
.65
.60
.55
.50
.45
.40
.30
.20
.15
.1
.08
.06
.05
.04
.03
.02
.01
cp
liquid
vapor

Water



Crerar and Barnes (1976) EG 71: 772-794

Rio Tinto, Spain

Rio Tinto stockwork

Rio Tinto
(stockwork/feeder zone)

Huelva province:
Jamón ibérico


San Miguel (Cu-Au-Ag)


San Miguel (gossan: Au+Ag, massive sulfide: Cu)


San Miguel: Feeder zone/stockwork


Submarine ash-flow tuff


Tharsis


Tharsis


Neves Corvo, Corvo orebody


Neves Corvo, Corvo orebody

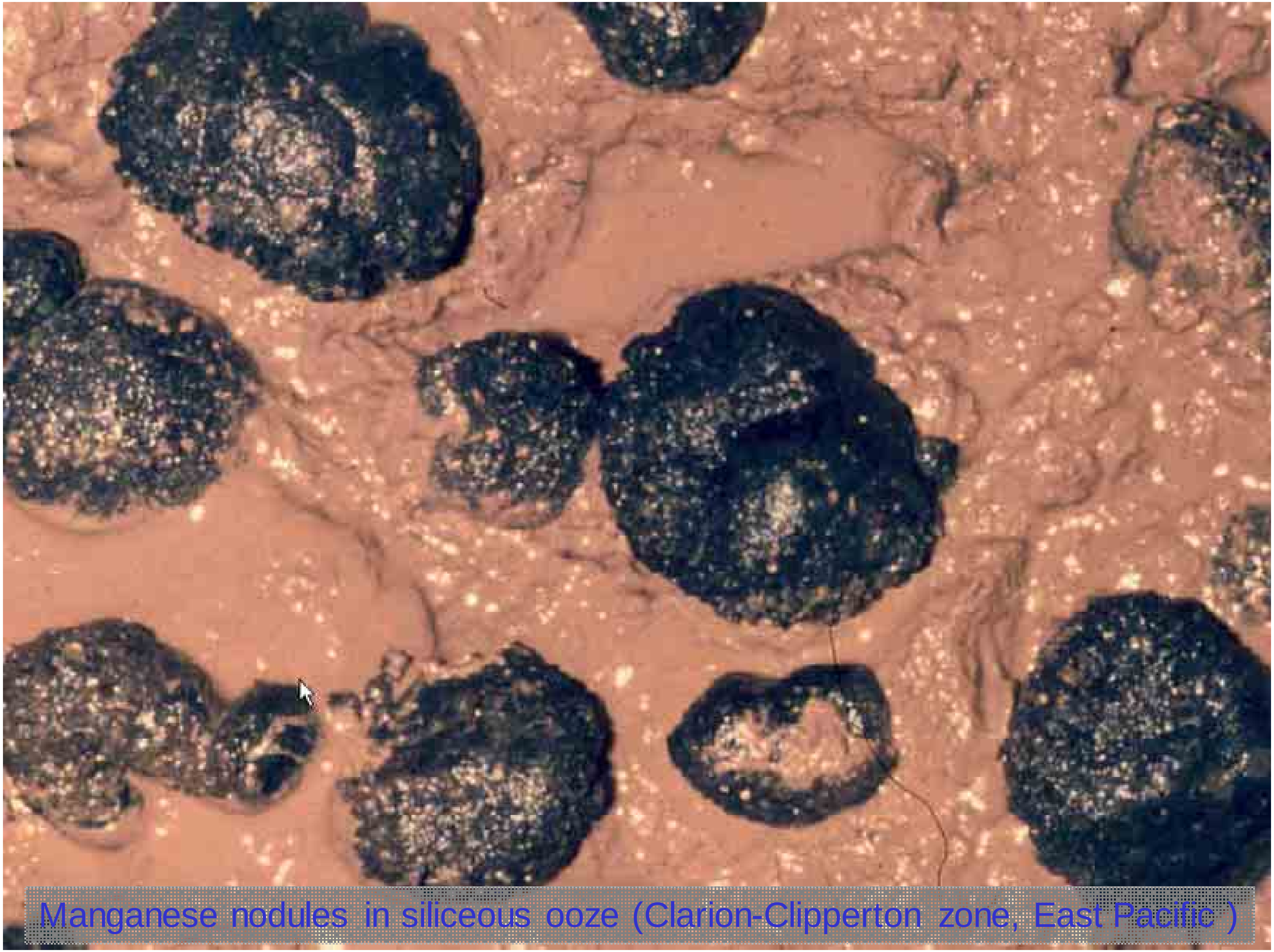
Neves Corvo, Corvo orebody


Rio Tinto

Rio Tinto: feeder/stockwork zone

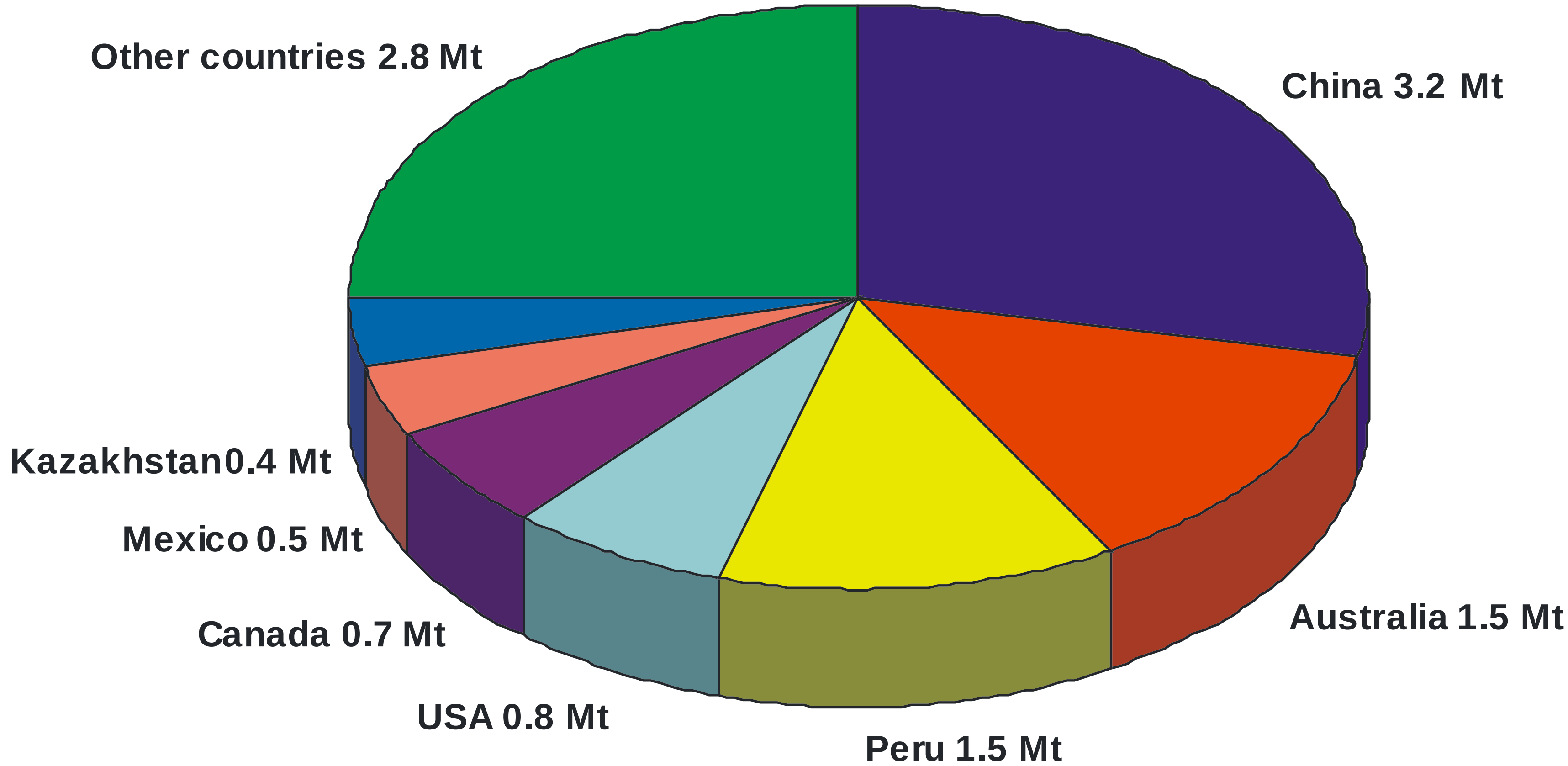

Rammelsberg

Cobalt-rich Fe-Mn crust on hyaloclastic substrate rock (Central Pacific)



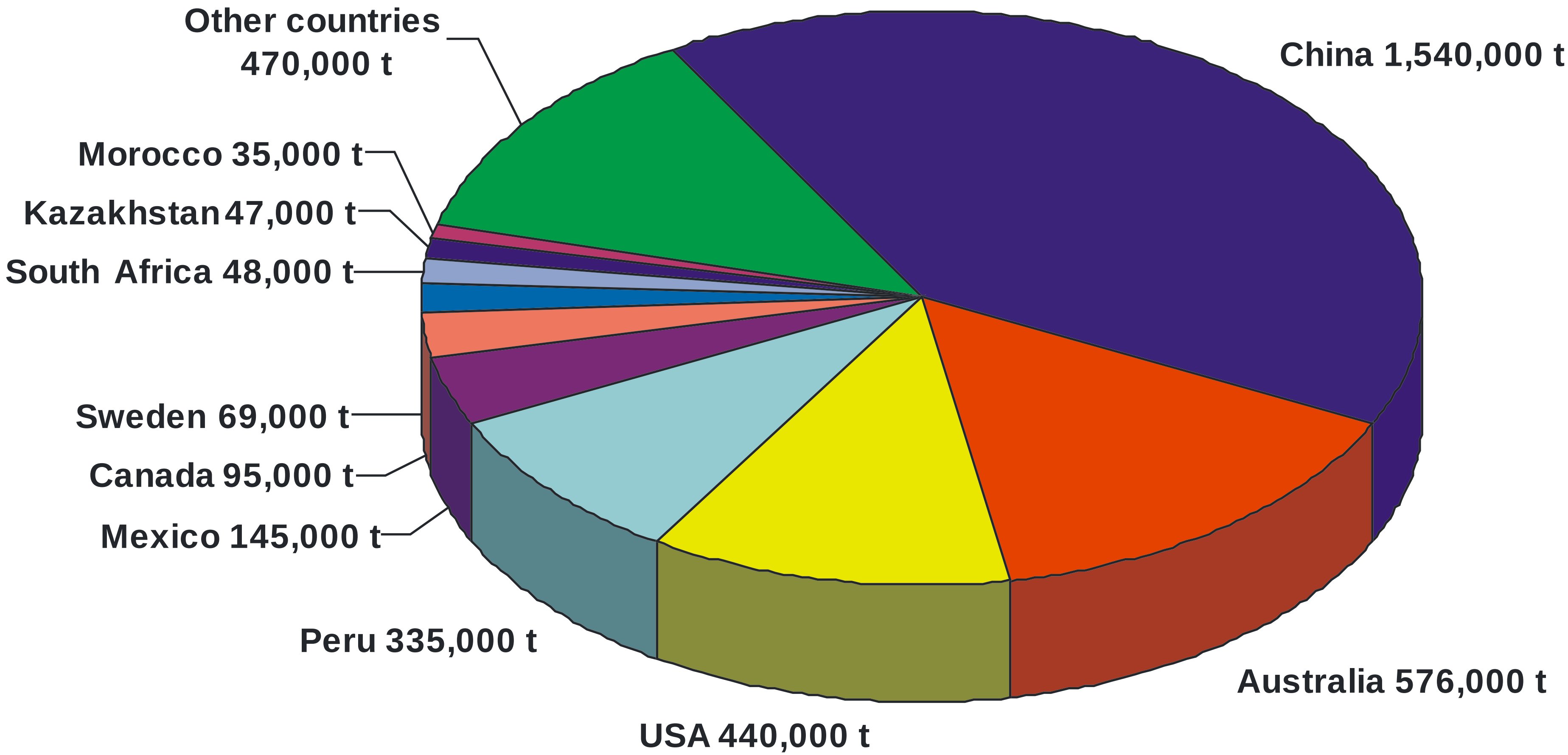
Manganese nodules in siliceous ooze (Clarion-Clipperton zone, East Pacific)

ZINC WORLD MINE PRODUCTION 2008 (11.3 Mt)



Feb 2008: ca 1 USD/lb Zn; Jun 2009: ca 0.7 USD/lb Zn

LEAD WORLD MINE PRODUCTION 2008 (3.8 Mt)



Feb 2008: 1.36 USD/lb Pb; Jun 2009 0.75 USD/lb Pb


LEAD
10 YEARS (Jun 28, 1999 - Jun 27, 2009)
Lead (USD/lb)
InfoMine.com
Jun 28 1999
Feb 17 2001
Oct 10 2002
Jun 1 2004
Jan 22 2006
Sep 14 2007
May 6 2009


COPPER
10 YEARS (Jun 28, 1999 - Jun 27, 2009)
Copper (USD/lb)
InfoMine.com
Jun 28 1999
Feb 17 2001
Oct 10 2002
Jun 1 2004
Jan 22 2006
Sep 14 2007
May 6 2009


ZINC
10 YEARS (Jun 28, 1999 - Jun 27, 2009)
Zinc (USD/lb)
InfoMine.com
Jun 28 1999
Feb 17 2001
Oct 10 2002
Jun 1 2004
Jan 22 2006
Sep 14 2007
May 6 2009


COBALT
10 YEARS (Jun 28, 1999 - Jun 27, 2009)
Cobalt (USD/lb)
InfoMine.com
Jun 28 1999
Feb 17 2001
Oct 10 2002
Jun 1 2004
Jan 22 2006
Sep 14 2007
May 6 2009