Geothermal and Gold

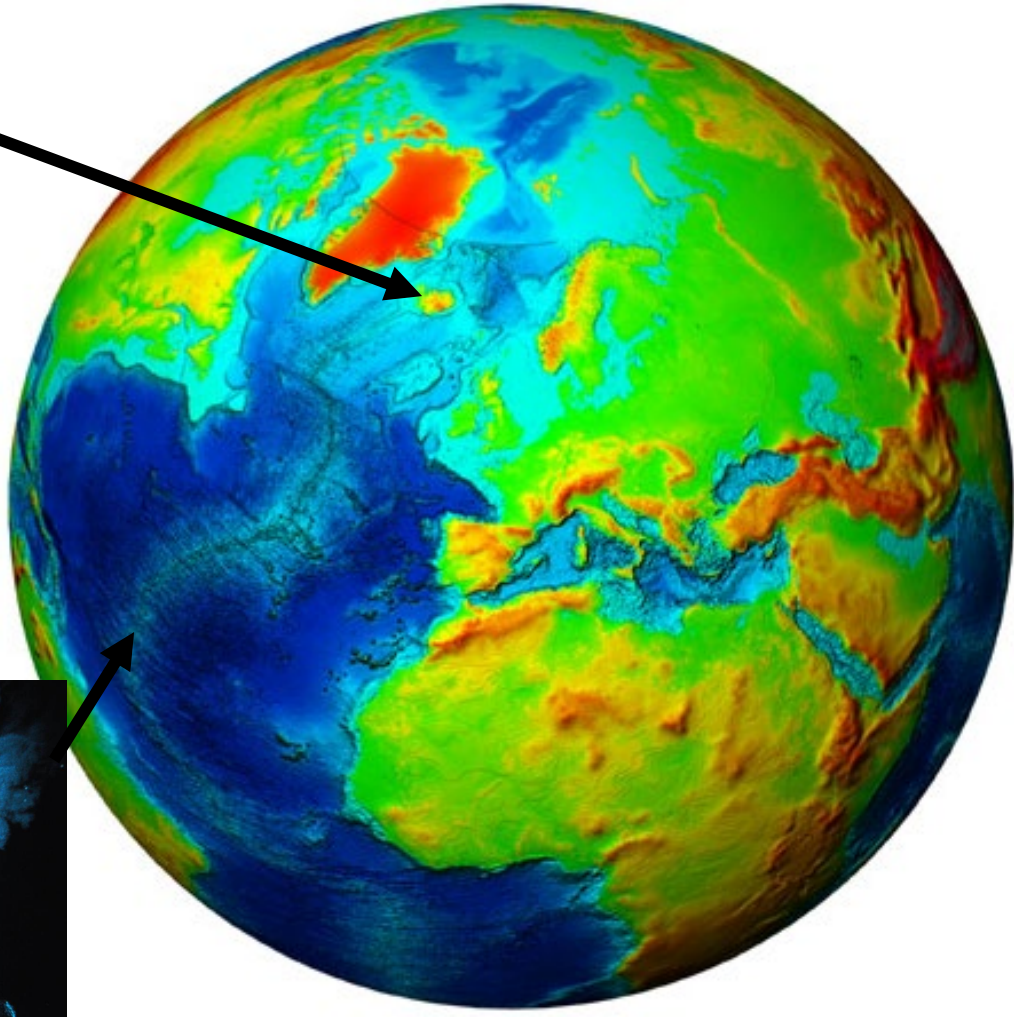
Lecture 20
Fundamentals of Earth Resources

Resources from Earth's Internal Energy

L. M. Cathles

2007

Geothermal: Consider Rifts on Land



RIFTS ADVECT FAR MORE MAGMATIC HEAT PER YEAR AND DO SO INTO A TENSIONAL ENVIRONMENT

ARC

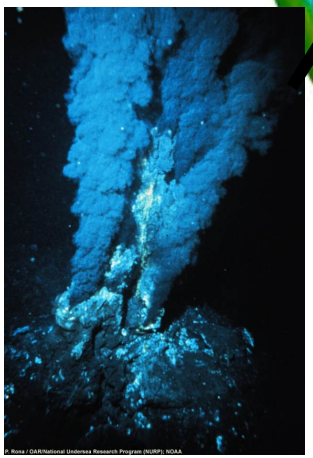
RIFT

15km → 1cm/y

1-10 $km^3/km/my$ << 150 $km^3/km/my$

Intrusives + Extrusives

(Marsh, 1968)

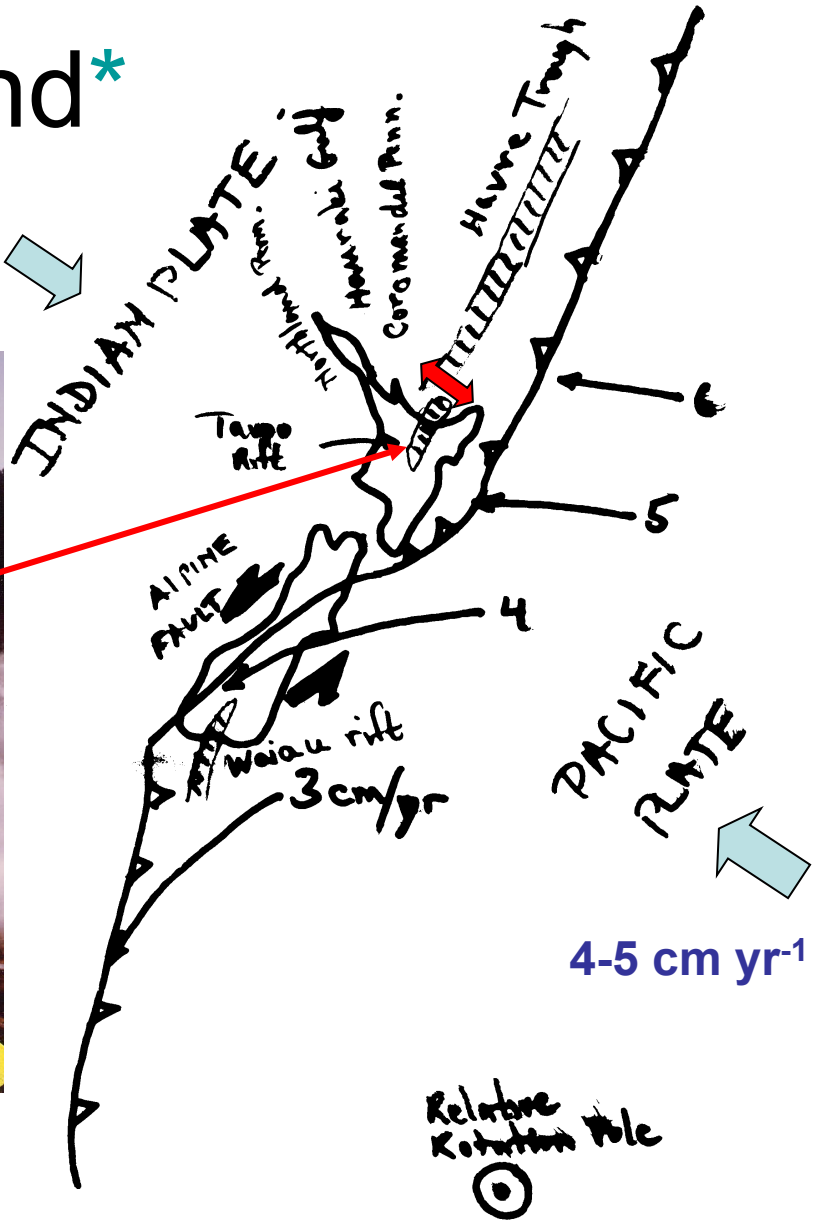


Human energy Consumption = 15 TW

Human electrical consumption = 1.7 TW

Consider New Zealand*

Present back arc extension ~0.75 cm yr^{-1}



Material summarized in this lecture is largely from a 1983 field conference organized by Henley, Roberts and Hedenquist (1983)

After Walcott (1978) and Cole & Lewis (1981)

Volcanic centers in Havre Trough

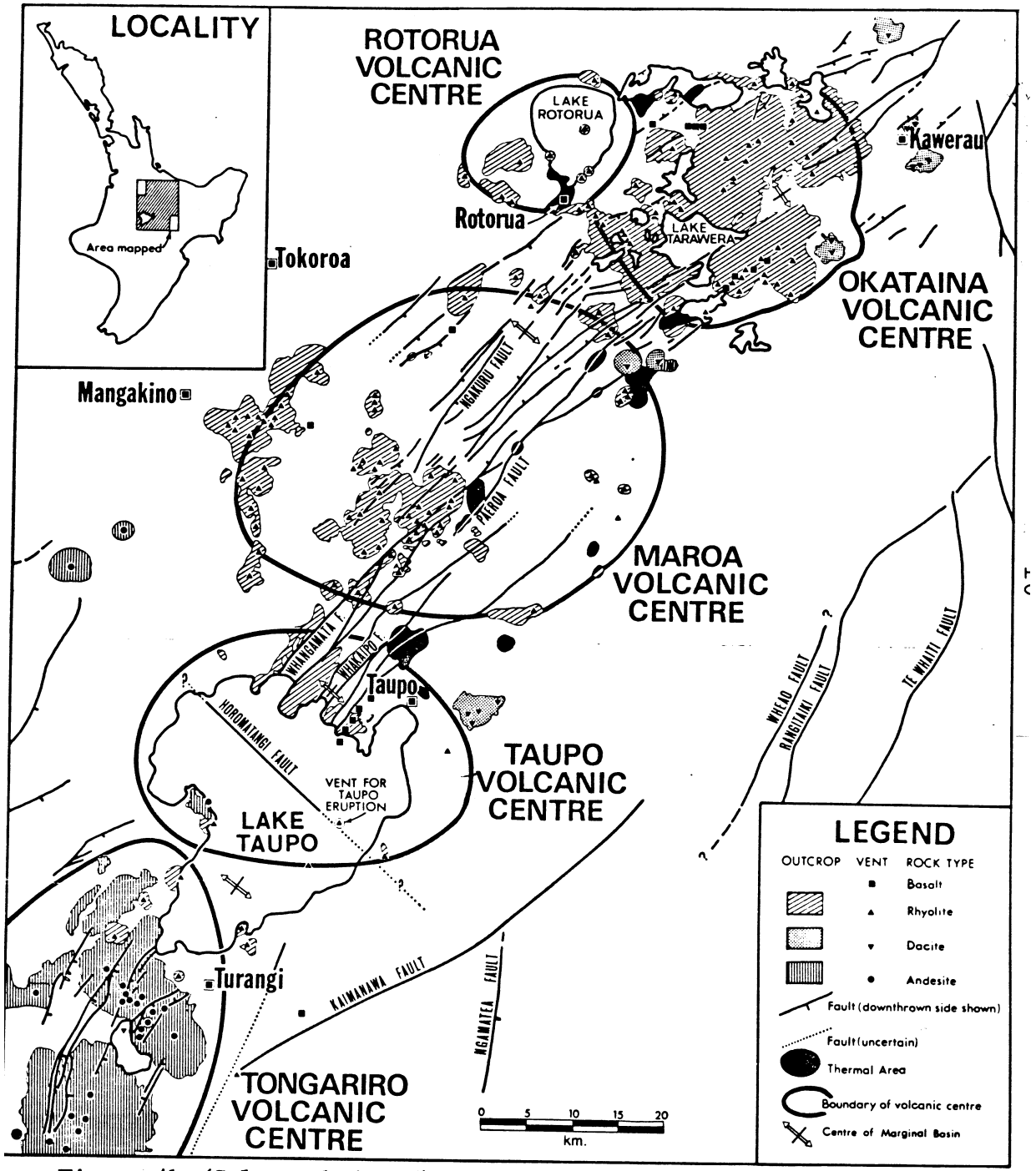
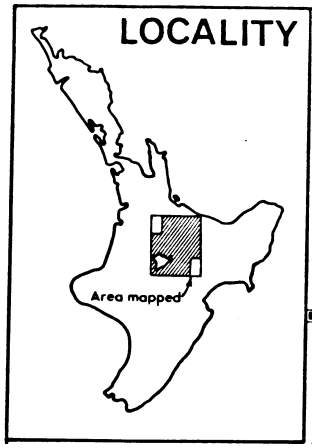


Figure 4b (Cole, submitted)



3480 Megawatts of thermal outflow
18×10^6 bbl oil equiv/yr
0.07% of 25×10^9 bbl oil/yr consumption

Back arc spreading of 0.75 cm yr^{-1} can account for ~50% of heat output– suggests thermal output may vary somewhat with time

Geothermal areas and hot water occurrences in the Rotorua-Taupo geothermal region. (Based on a figure by W. J. P. Macdonald).

Volcanic centers in Havre Trough

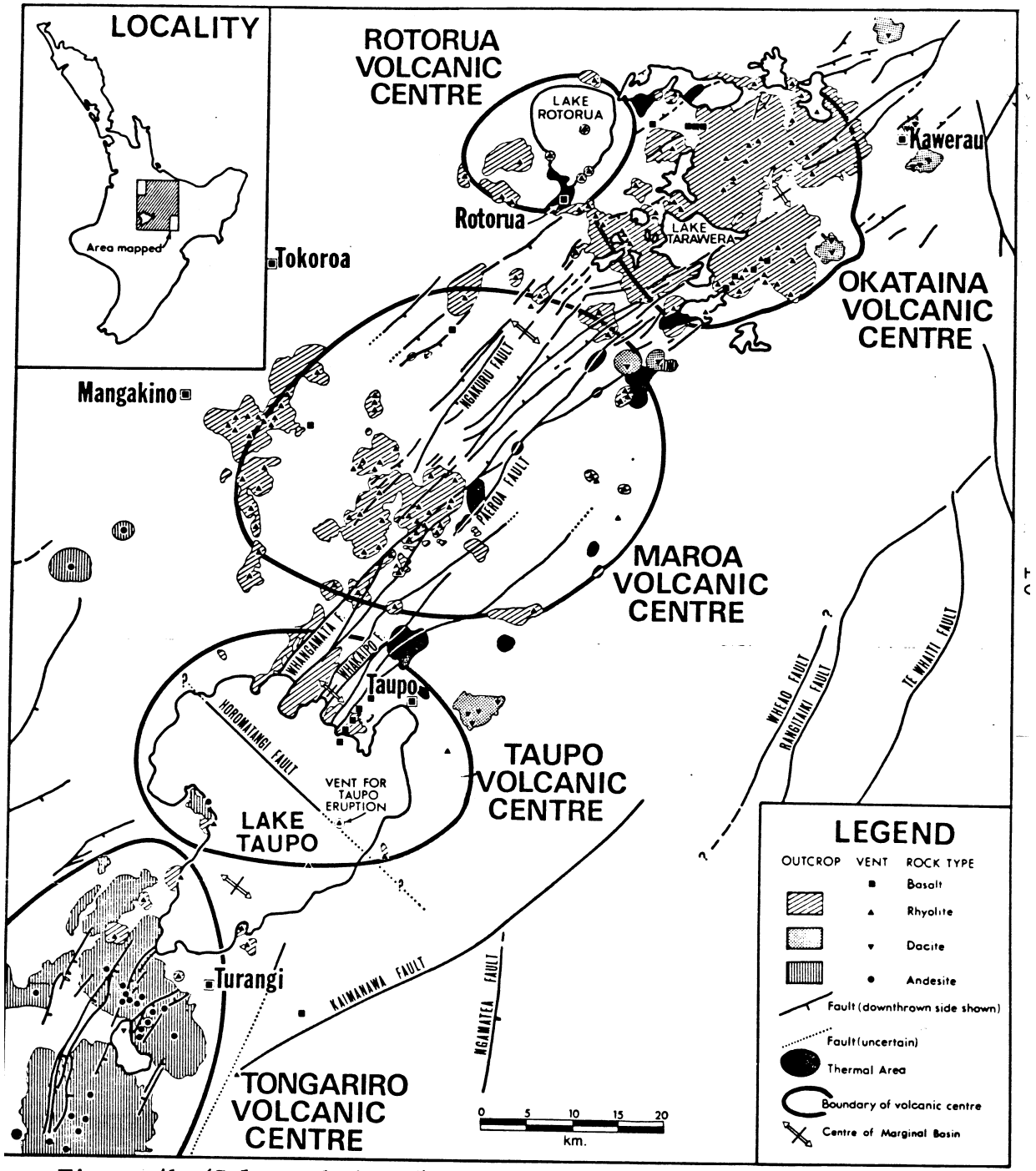
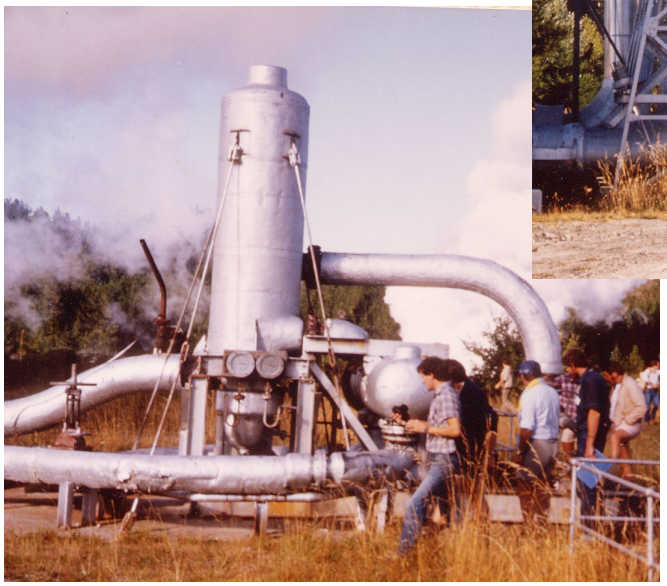


Figure 4b (Cole, submitted)

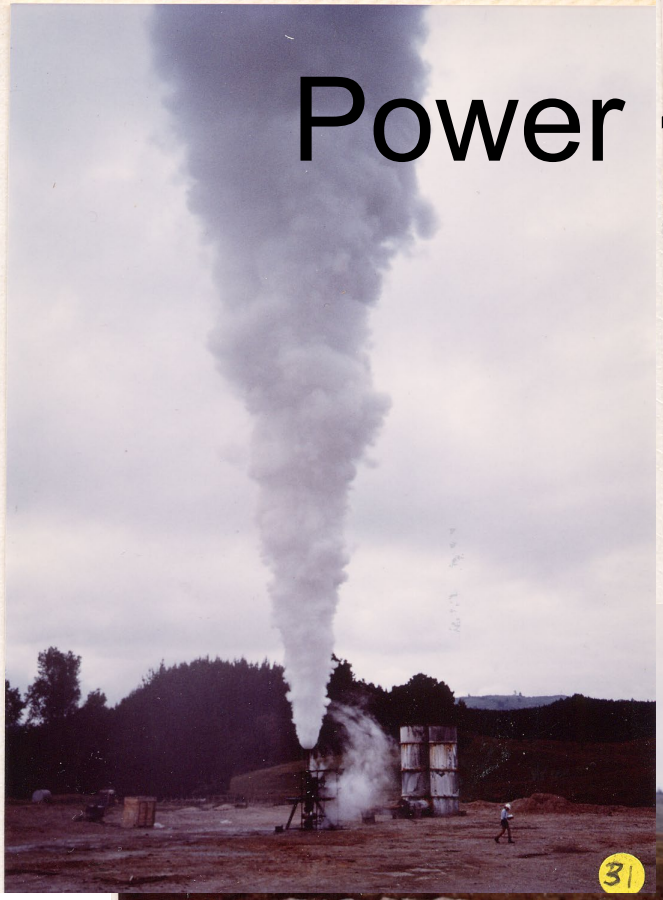
Wairakei

Old-style drainage ditches

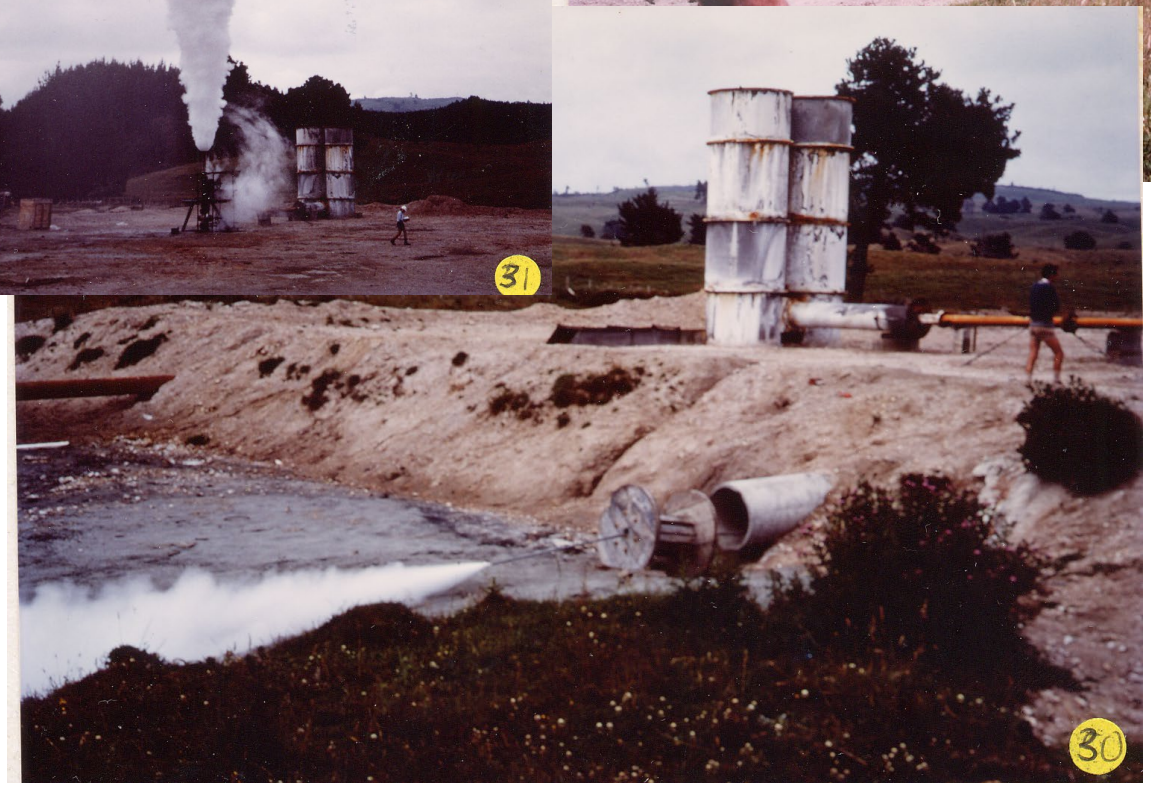


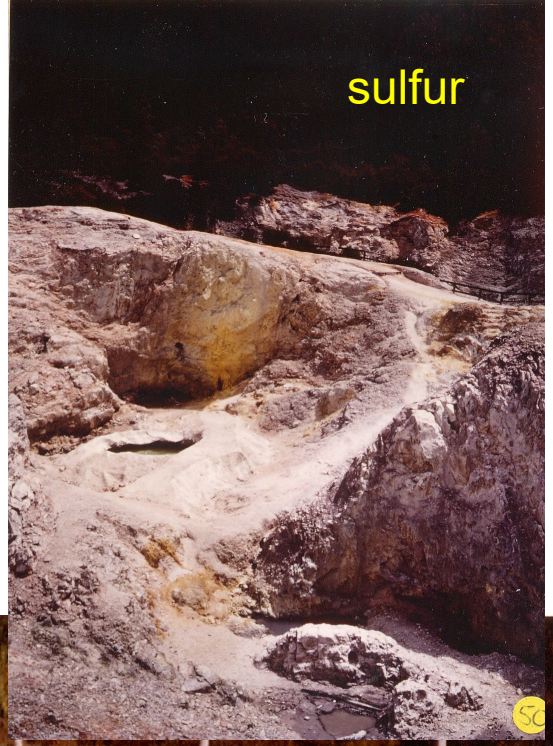
Silicified grass

Power ~747 at full throttle



Sheep in full flight



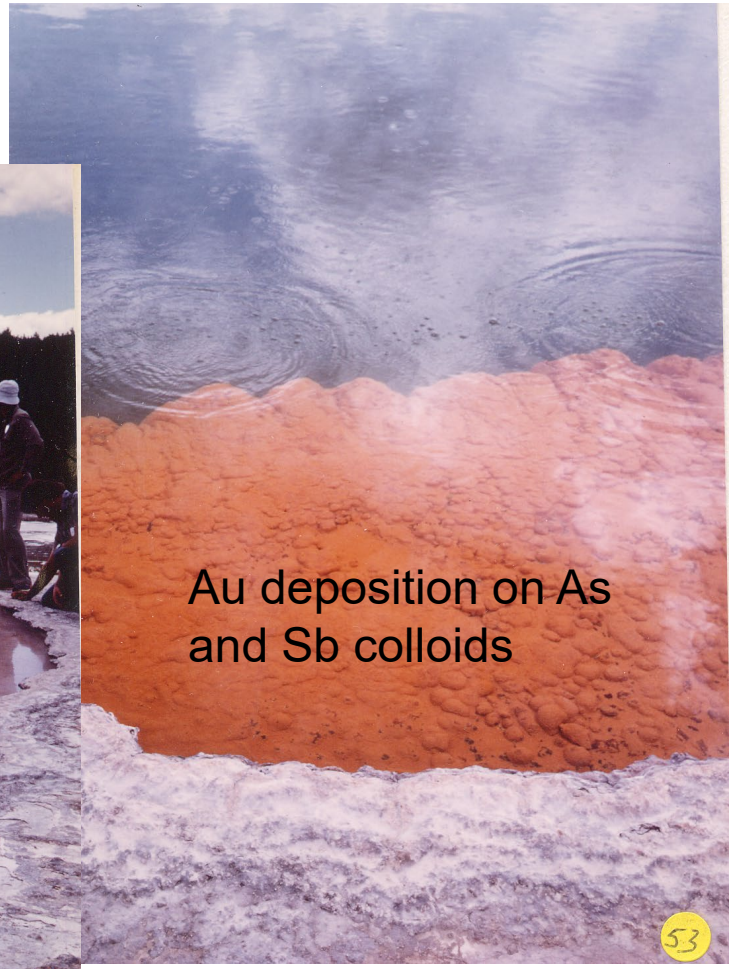


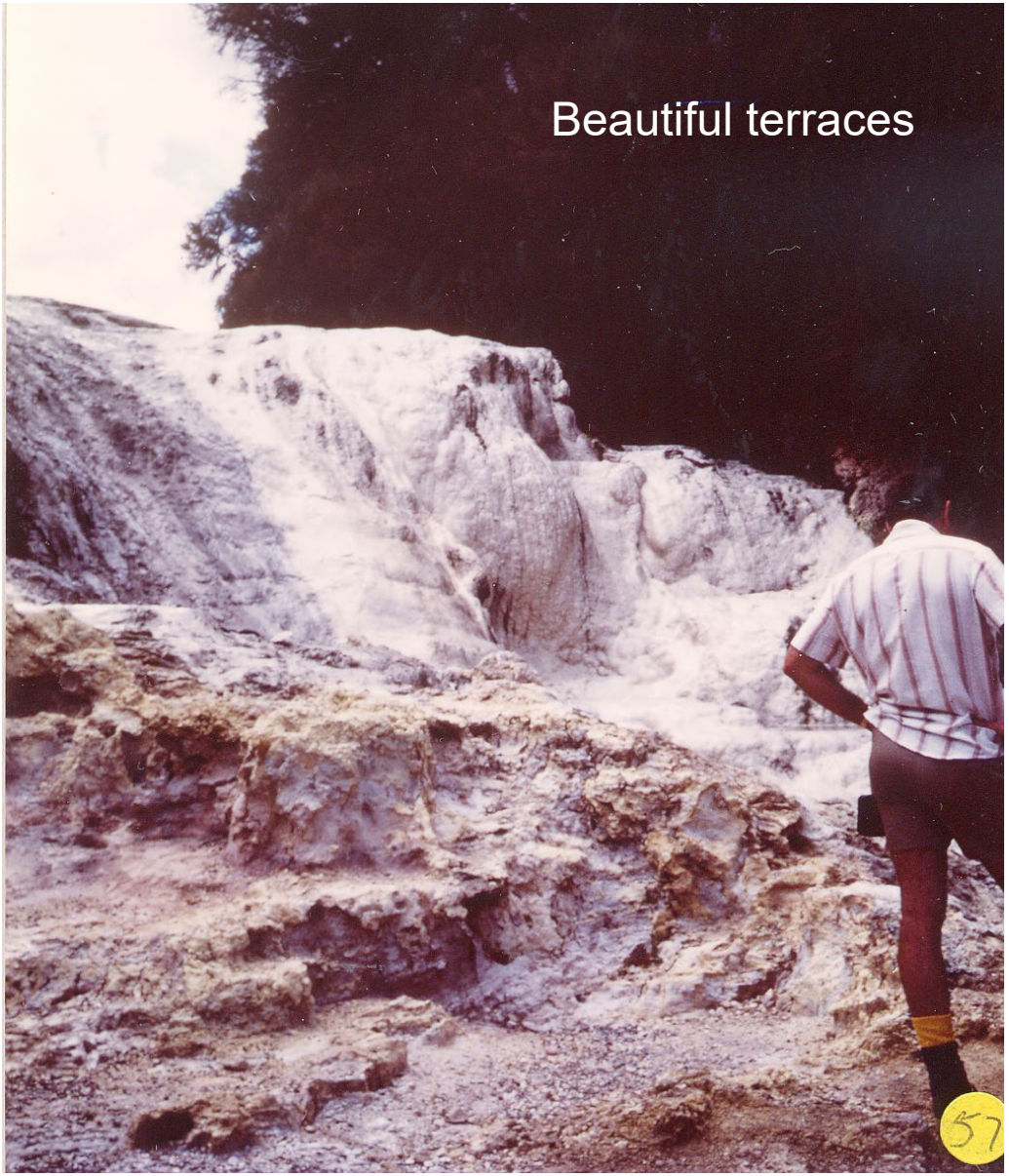
Profusion of colors:

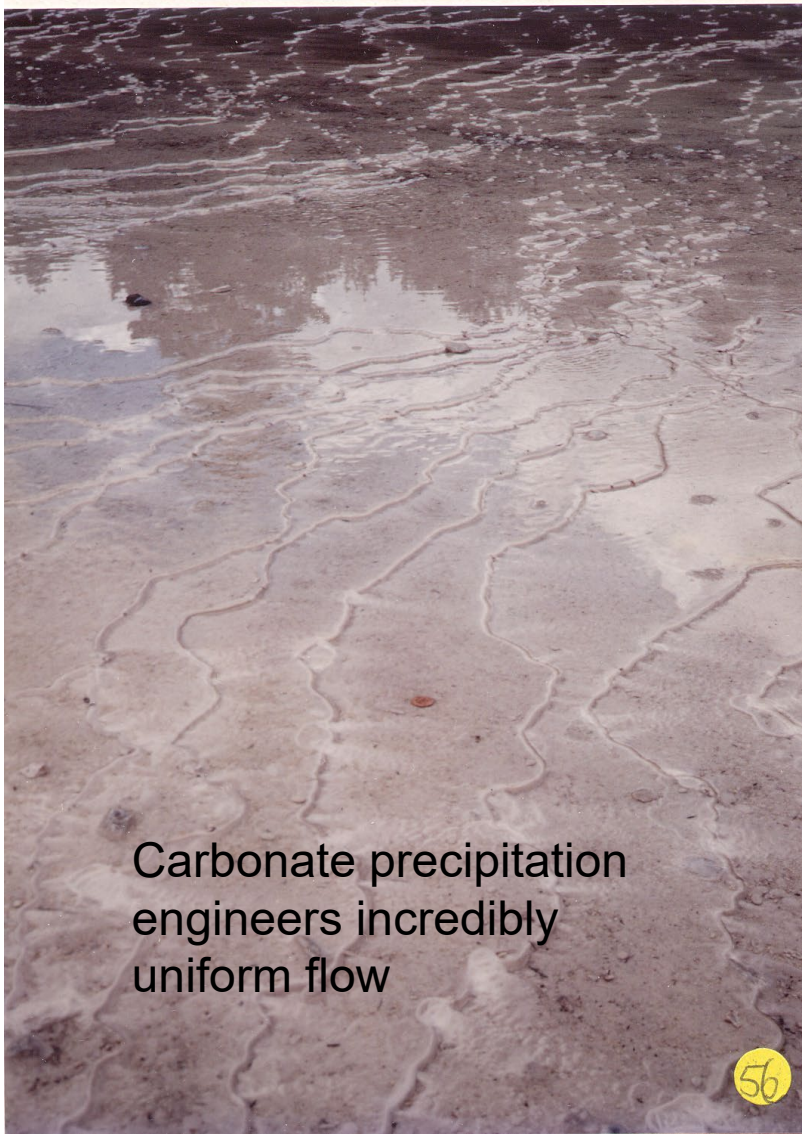
- y,b,r iron oxides and hydrox
  - orpiment (As_2S_3)
- y orthorhombic sulfur
- orange realgar (AsS)
- purple cinnabar (HgS)
- grey (py and monoclinic S)

Pool colors: Sb and SbS orange, S yellow, Fe^{2+} green

Champaign Pool




Beautiful terraces
57

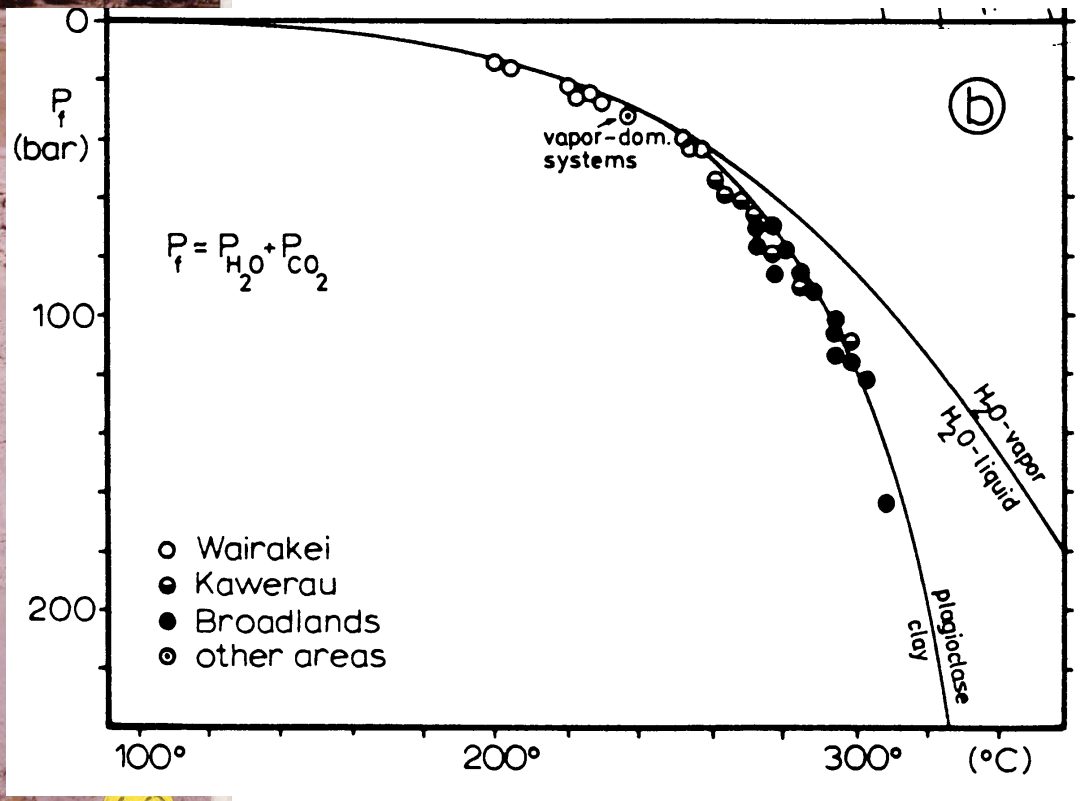

Carbonate precipitation engineers incredibly uniform flow
56


Rock altered in 2 years in
this recently-activated area


vigorous boiling

small explosions

situation inherently unstable

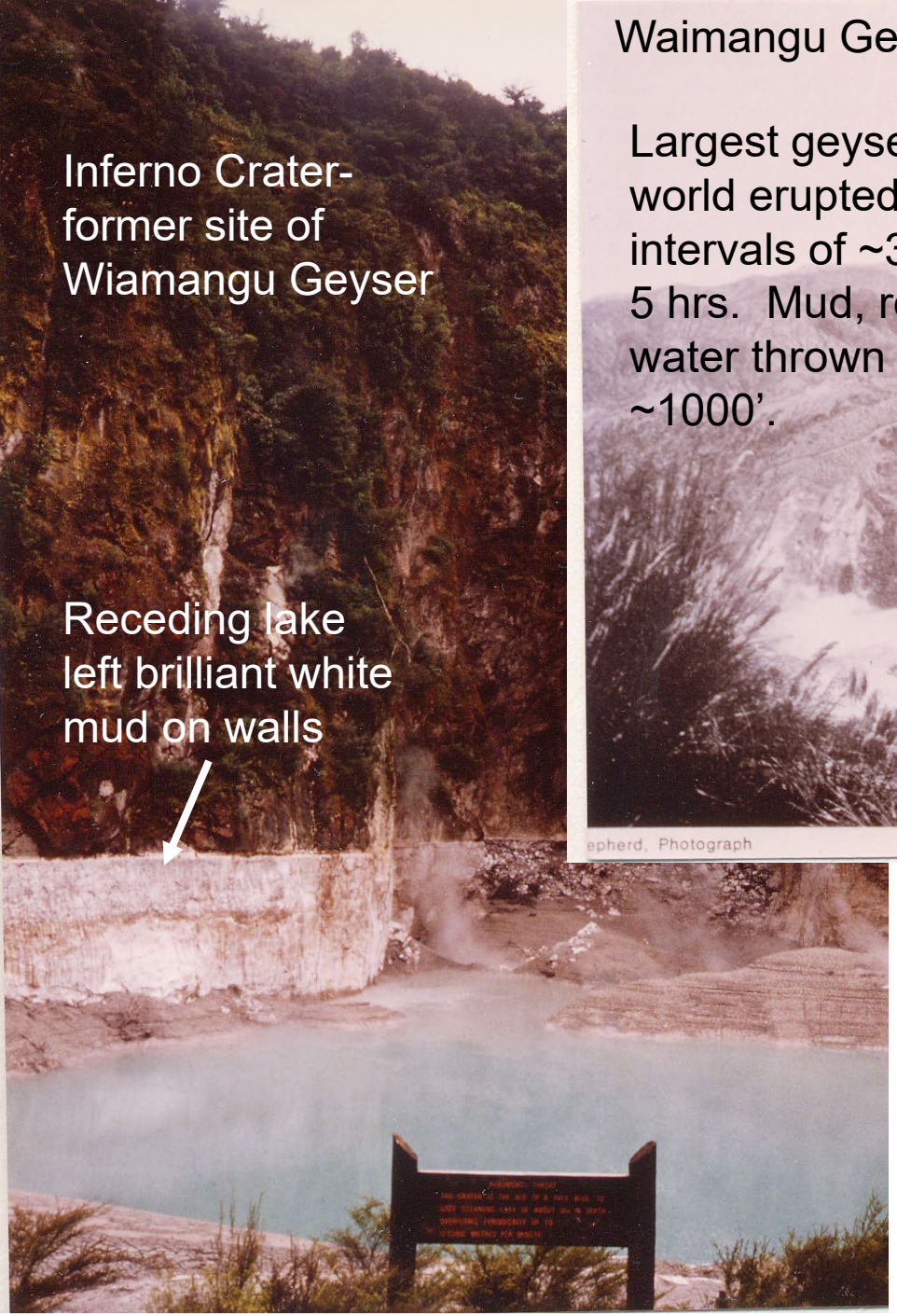


The rogue bore

250 MW, excavated hole 30m deep and 150m diameter

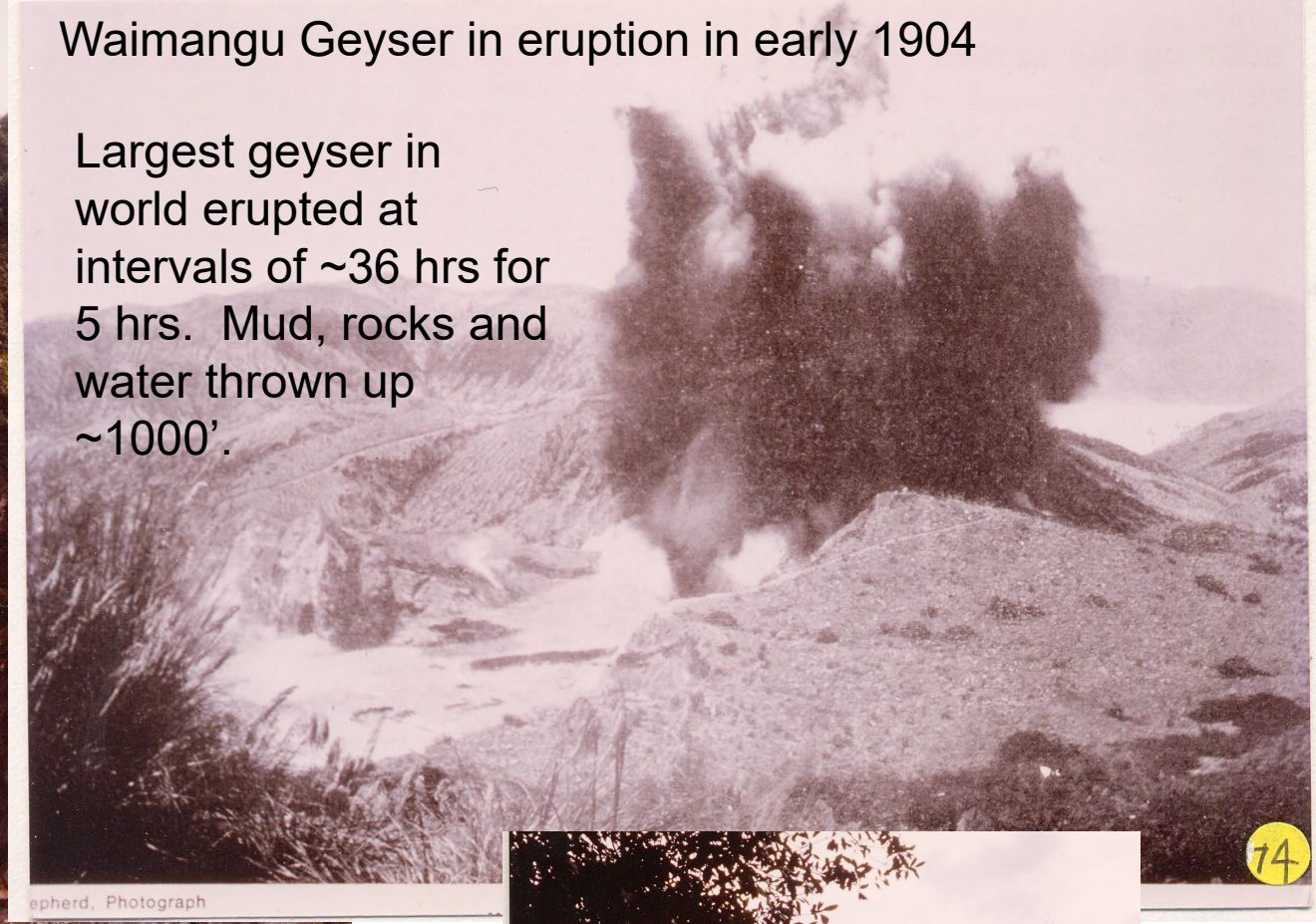
Inferno Crater- former site of Wiamangu Geyser

Receding lake left brilliant white mud on walls



Waimangu Geyser in eruption in early 1904

Largest geyser in world erupted at intervals of ~36 hrs for 5 hrs. Mud, rocks and water thrown up ~1000'.

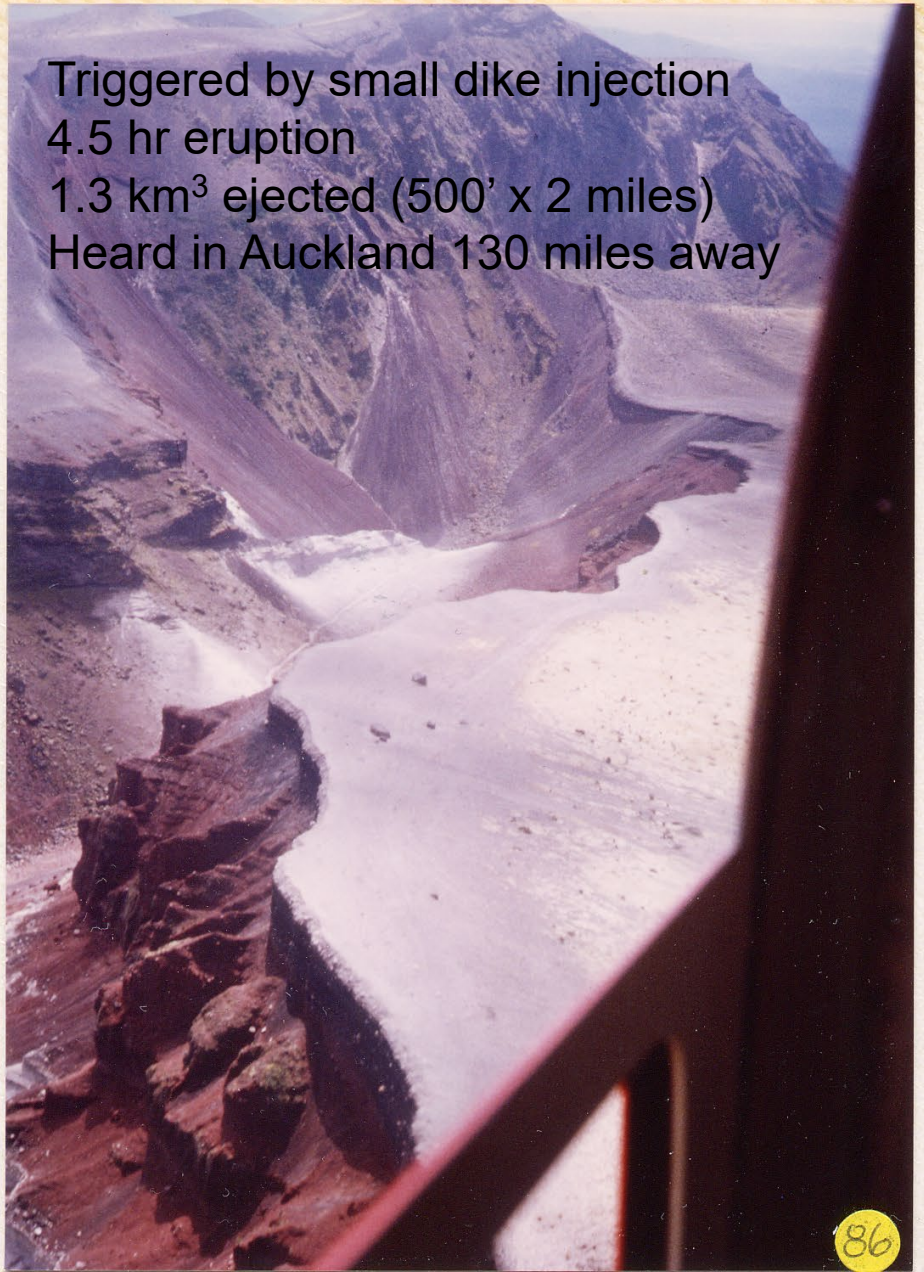


Pink Terrace today

One of 7 wonders of the world blew up in 1886

But this was just the tip…

The Tarawera eruption of 1886



Waste high mud impeded rescue

Keam (1981) 89

Weight of mud collapsed houses

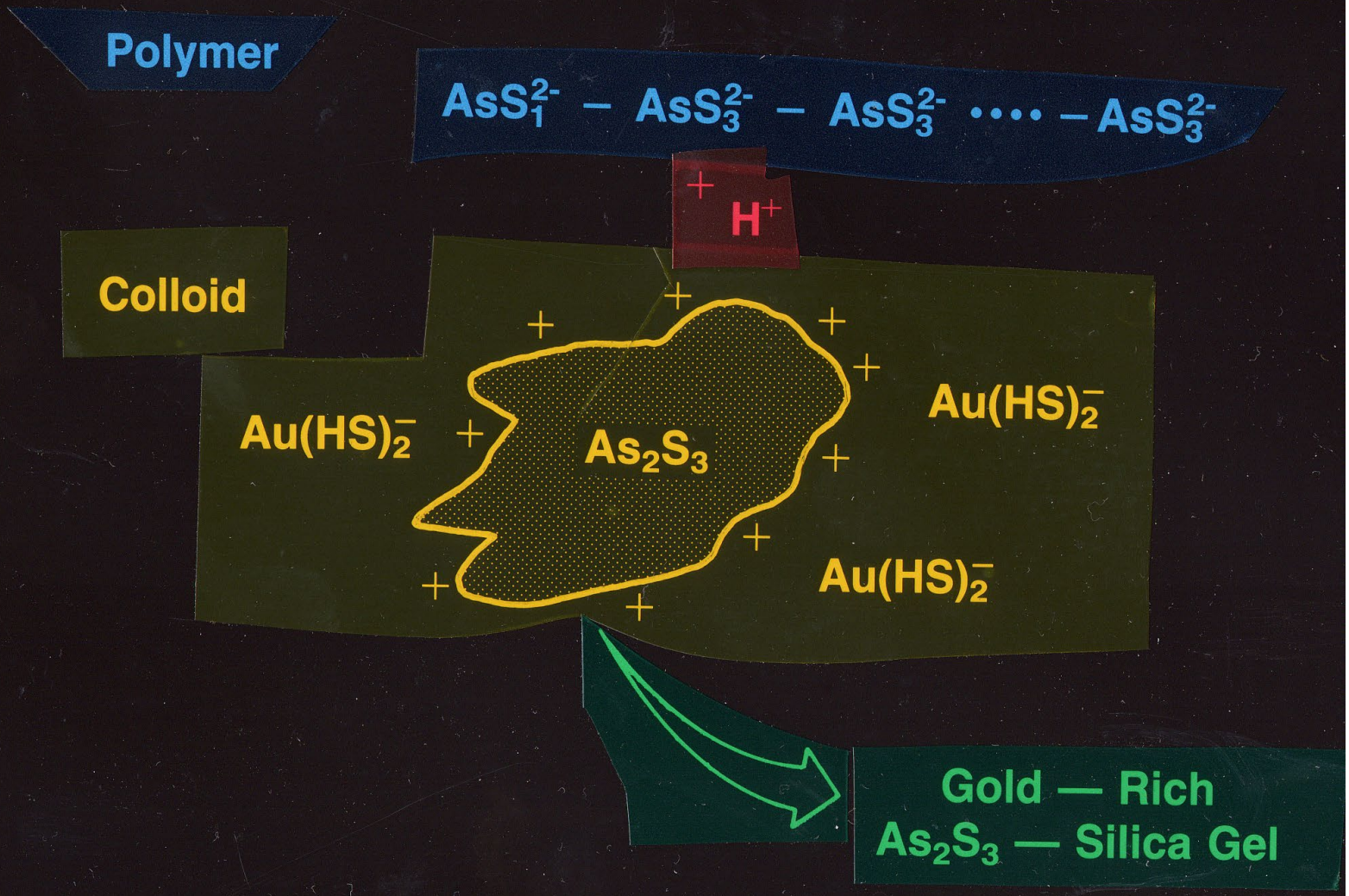
New Zealand is, in fact, a very dangerous place

* "flat" volcano- most dangerous
Pummice 1.8m thick
80% material ejected >200 km
Fluidized pyroclastic flows traveled 80 km

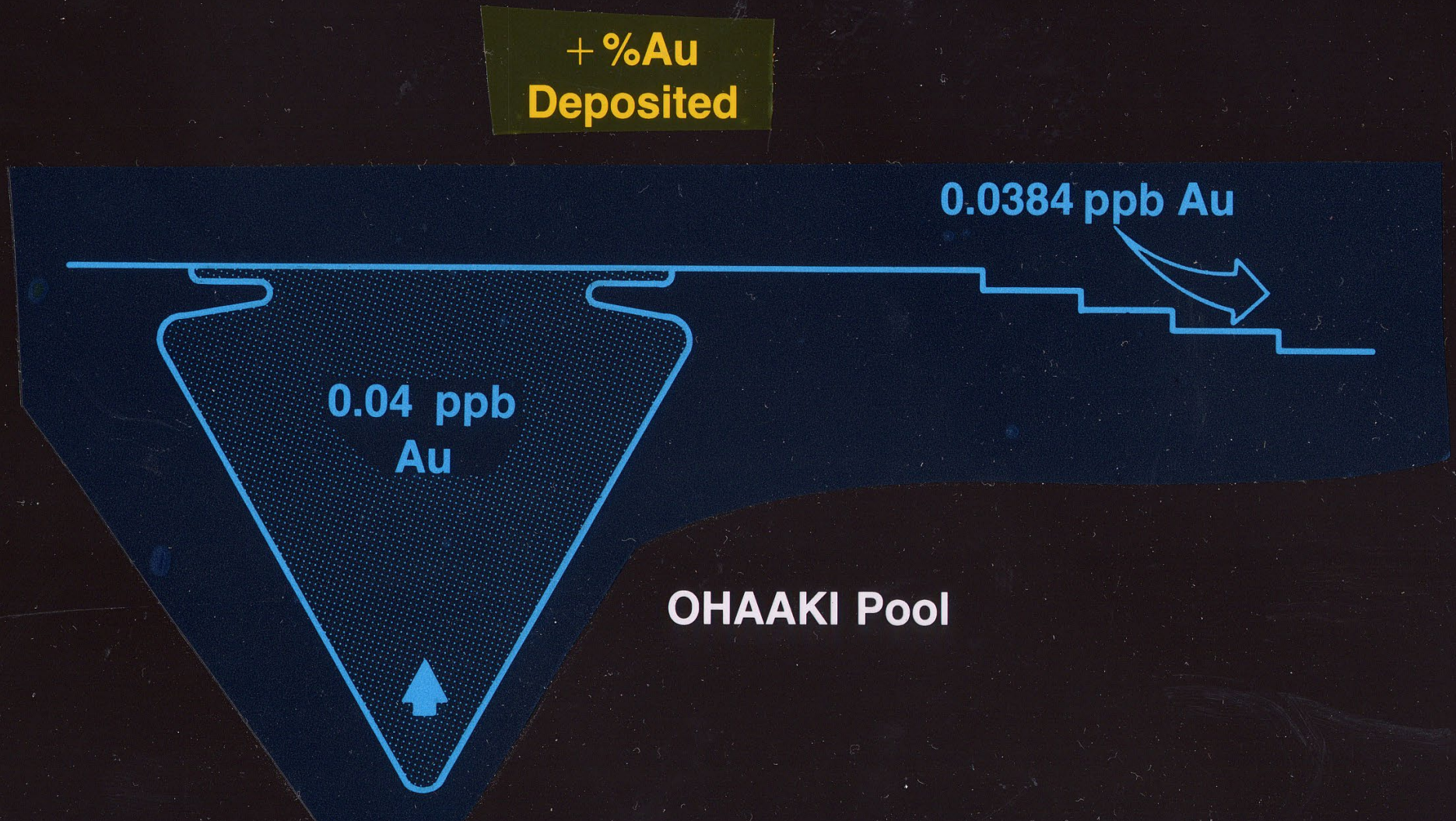
Eruption and Age	Volume in cubic kilometers
Ngauruhoe 1975	0.003
White Island 1976-1980	0.02
Tarawera 1886	1.3
St. Helens (USA) May 1980	3
Kaharoa eruption (Tarawera) 700-900 years ago	7.5
Krakatoa (Indonesia) 1883	8
Taupo Pumice 1800 years ago	110*

Au precipitated with As and Sb in Champaign pool, New Zealand

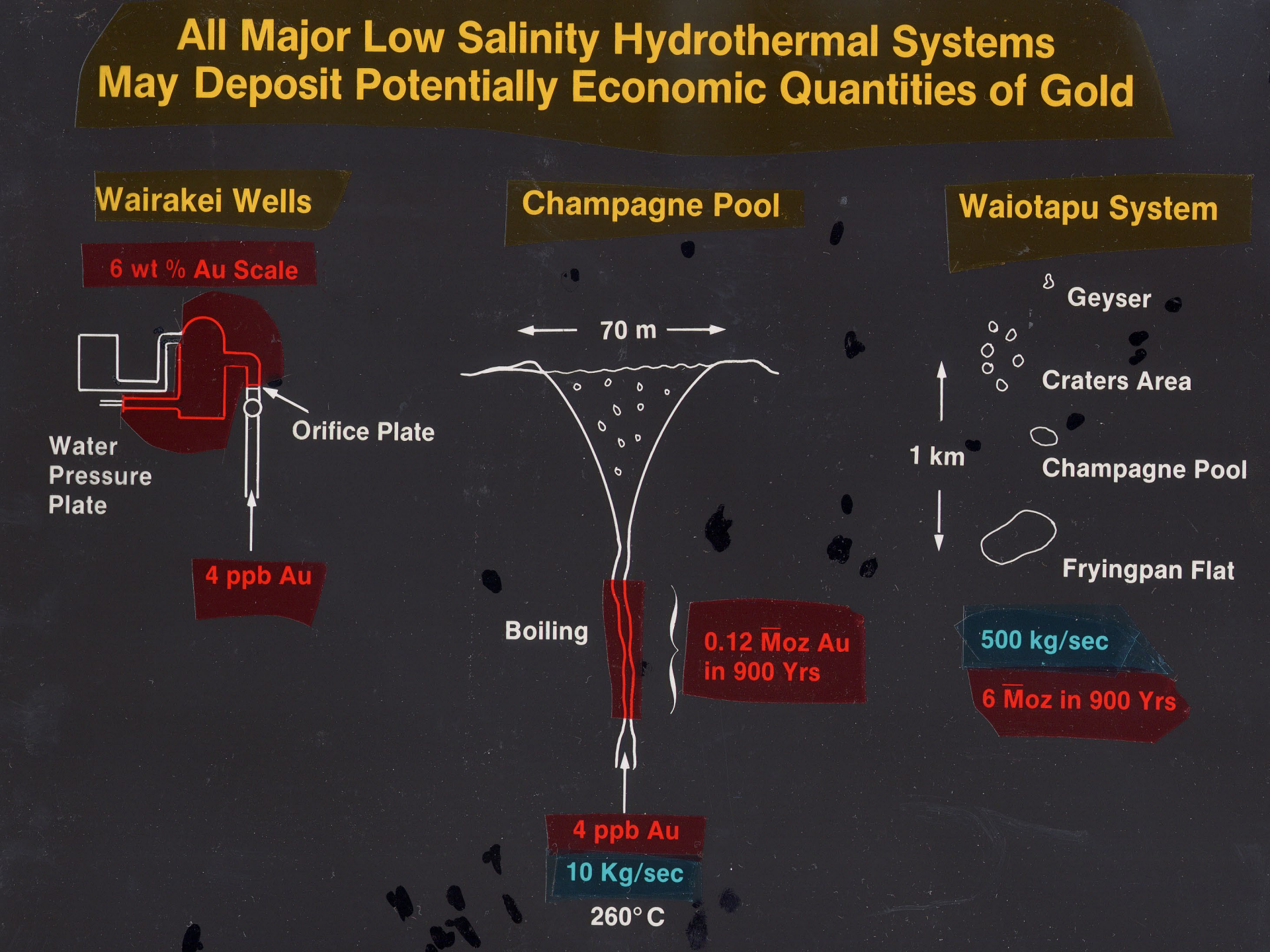
Acid Destruction of As or Sb Polymers Produces Colloid Which is Extremely Effective Scavanger of Gold



Colloid Gold Precipitation Efficiency is Very Low at Broadlands

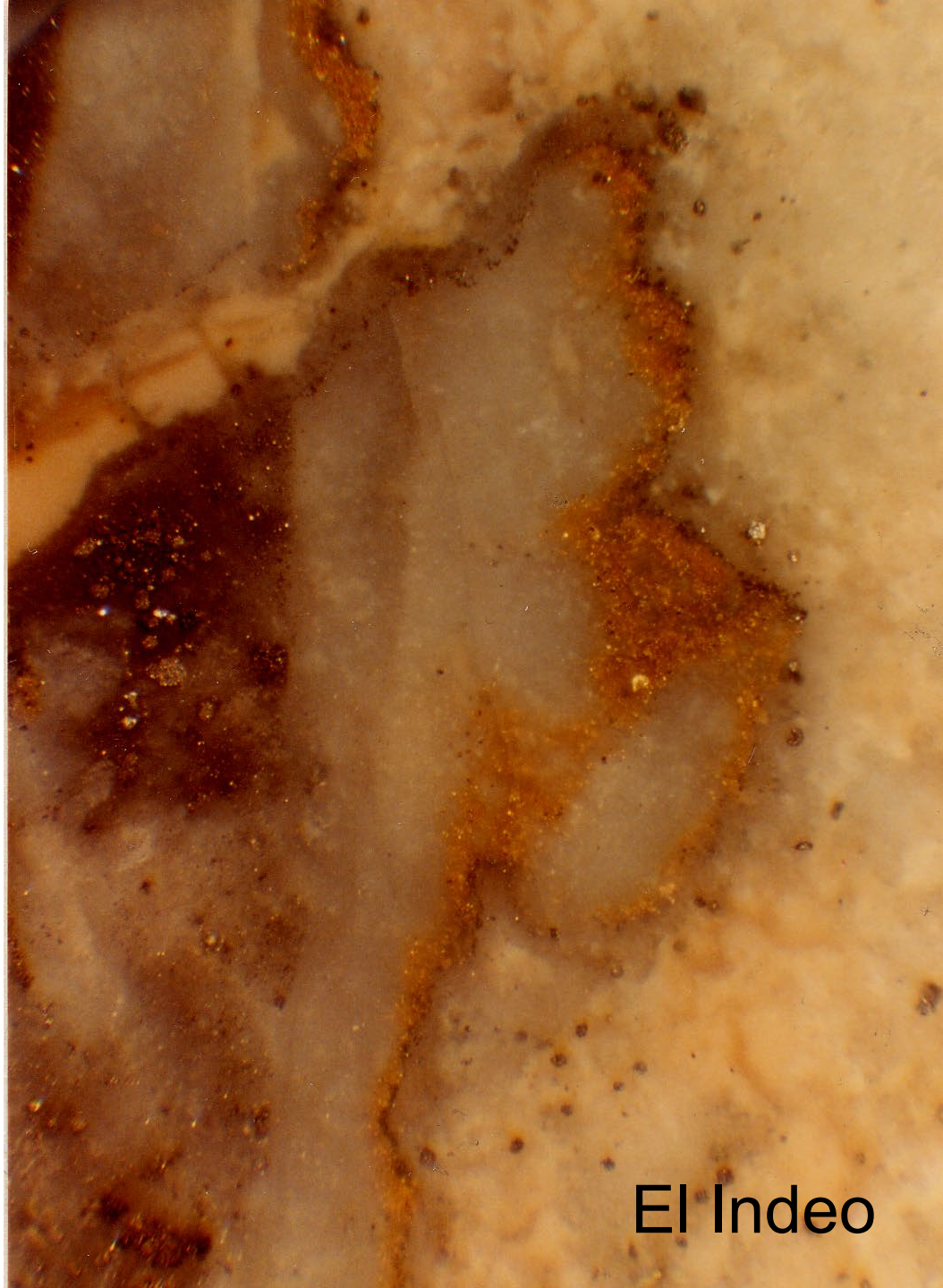


All Major Low Salinity Hydrothermal Systems May Deposit Potentially Economic Quantities of Gold



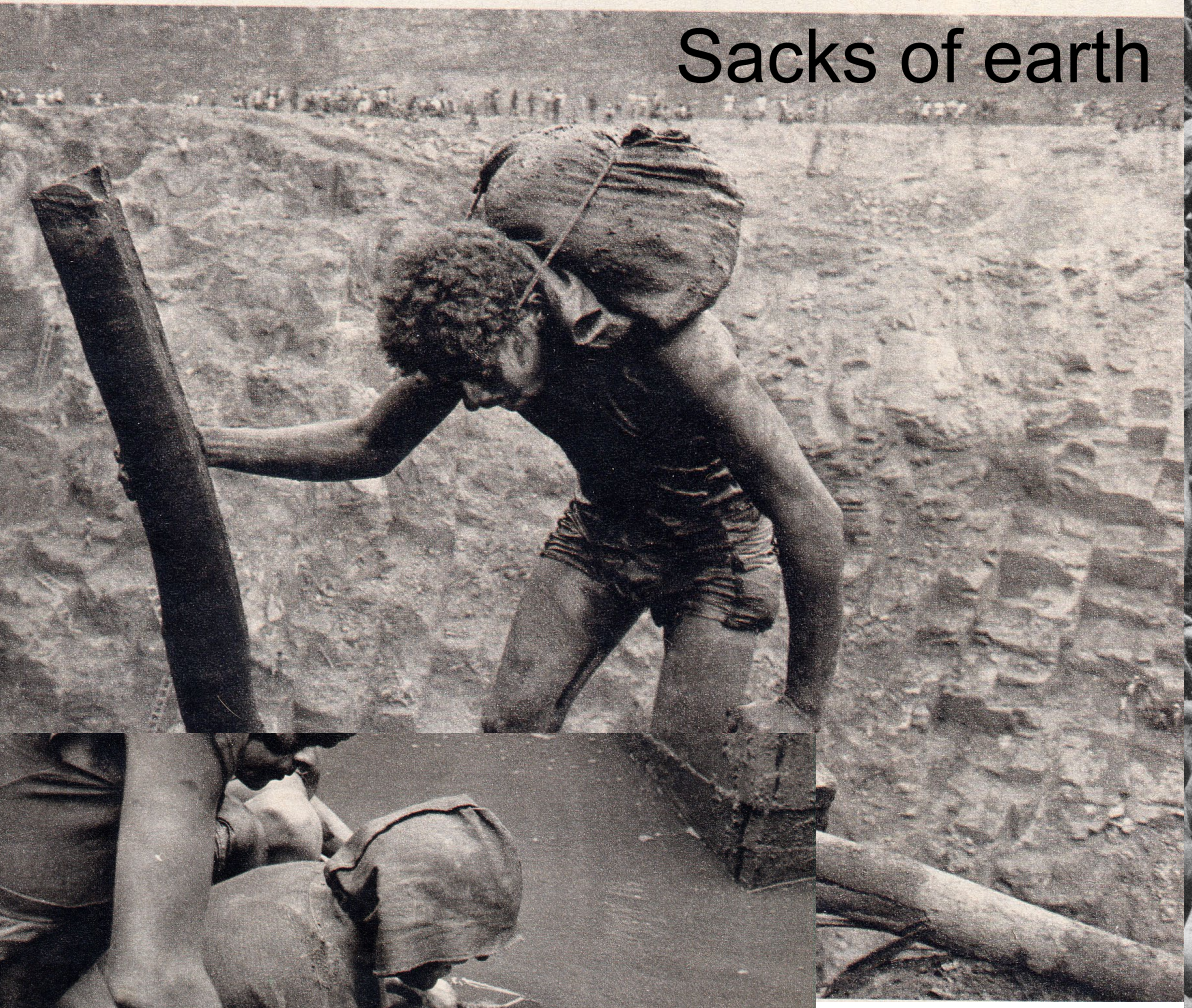
Gold

Few things motivate like Au



Nuggets discovered in Amazon forests of **Serra Pelado**, Para, **Brazil** in **1980**. Mountain→ 600’ pit, 0 → town of 100,000.
42t Au from 6400 small claims by 61,000 workers

Sacks of earth



The California Gold Rush
January 24, **1848** John Marshall discovers gold at Sutter's Mill

http://homepages.wmich.edu/~nwitschi/teaching/crowd.jpg

http://www.legendsofamerica.com/photos-california/CaliforniaGoldMiners.jpg

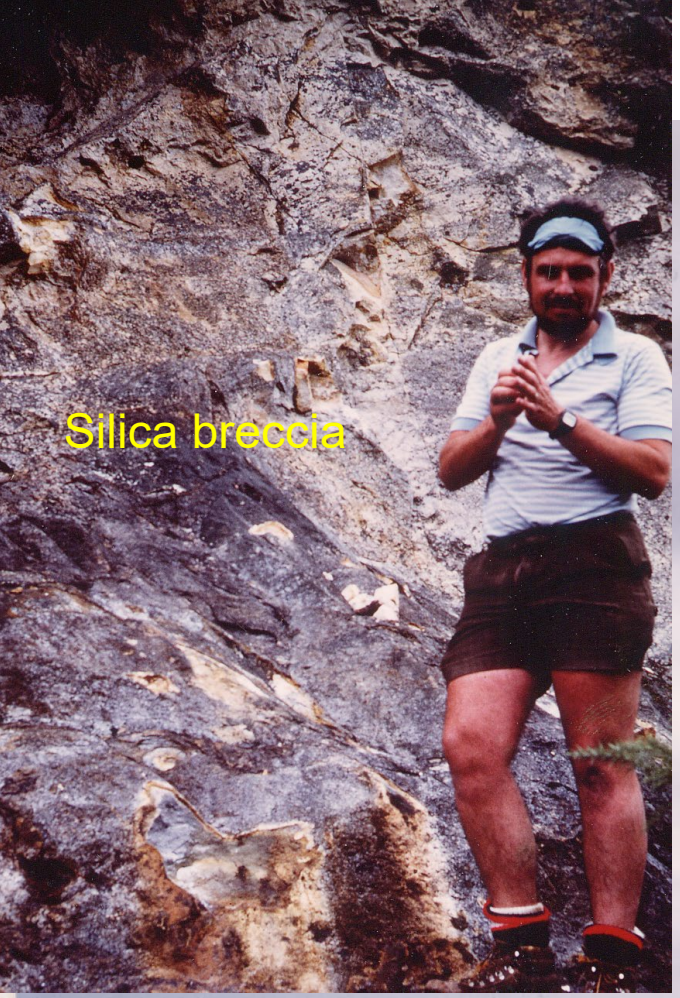
Barrowman crosses Australia in 1980's

One generation explored the world for gold

1880's Paddy Hannan discovers Au in Kalgoorlie, 1891 Tom Cue at Murchison goldfields

Au veins scruffy looking- not the more dramatic wide bull qtz veins

Deposits with silica…

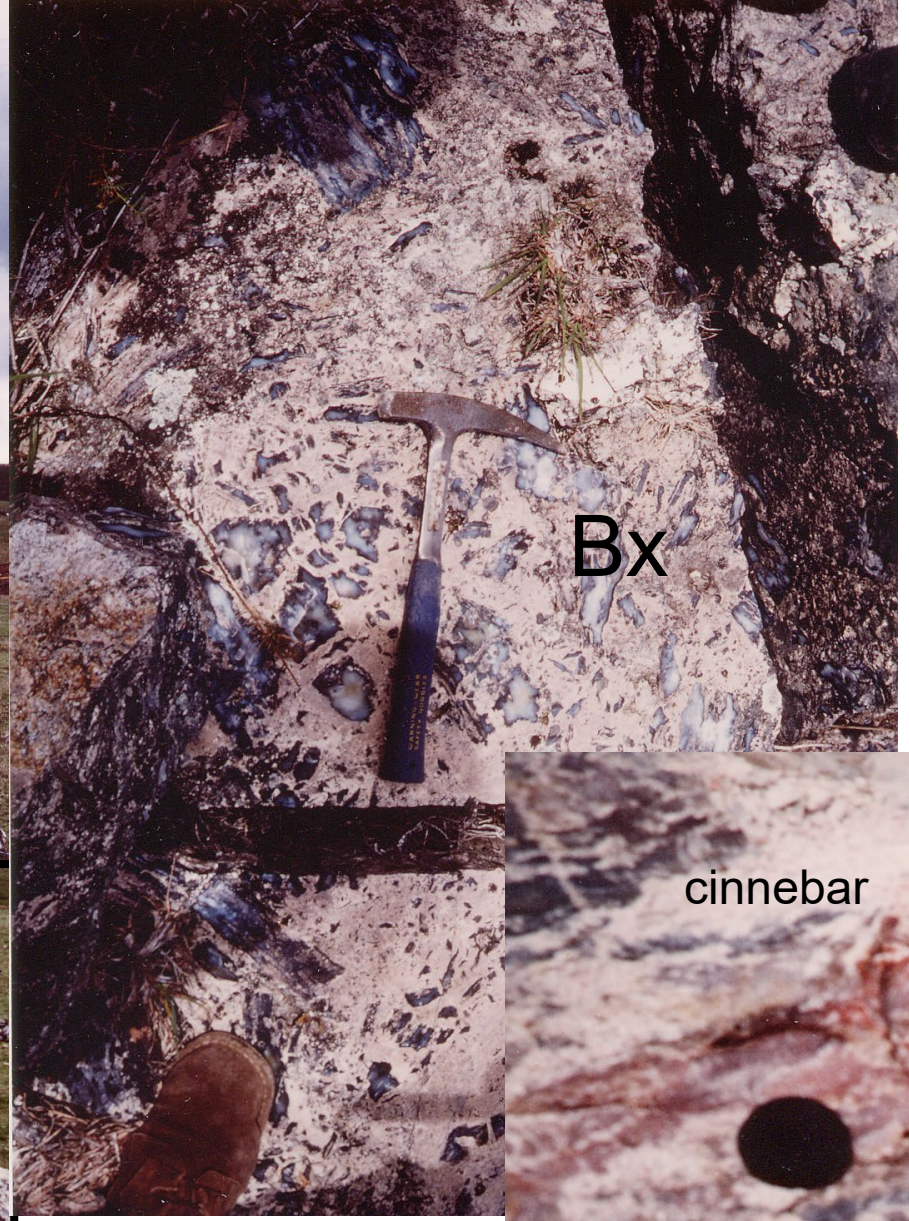


Alteration produces weird surface forms

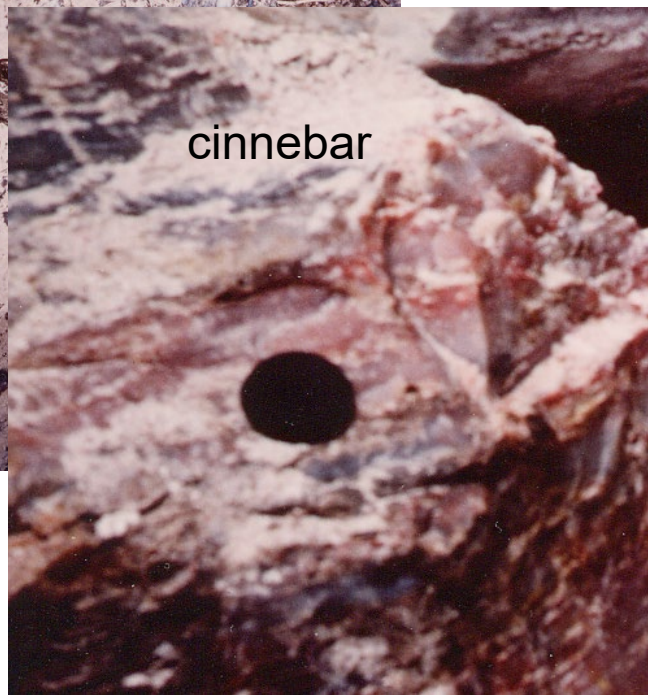
Silica spires

Hg transported in vapor

Silica boulders on hill

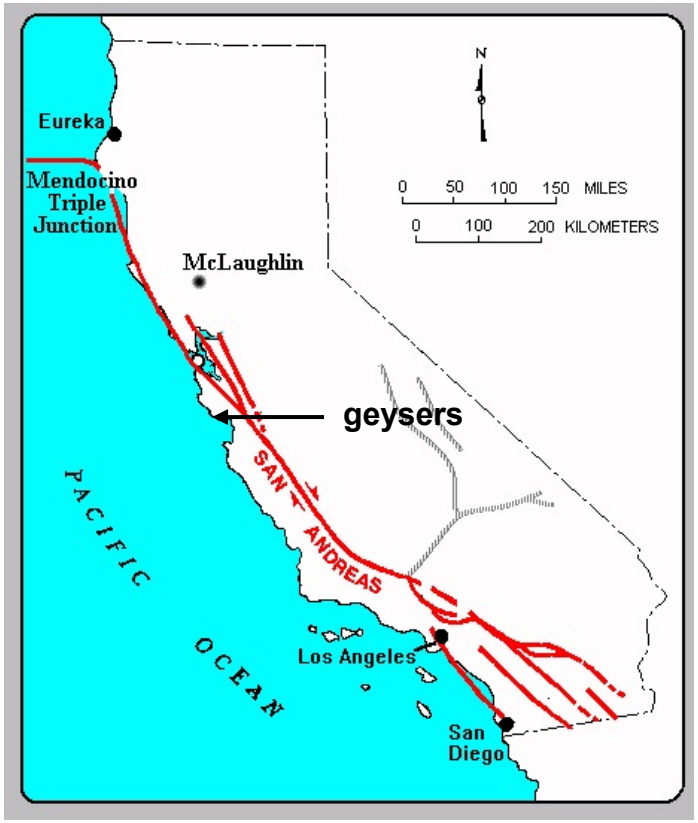


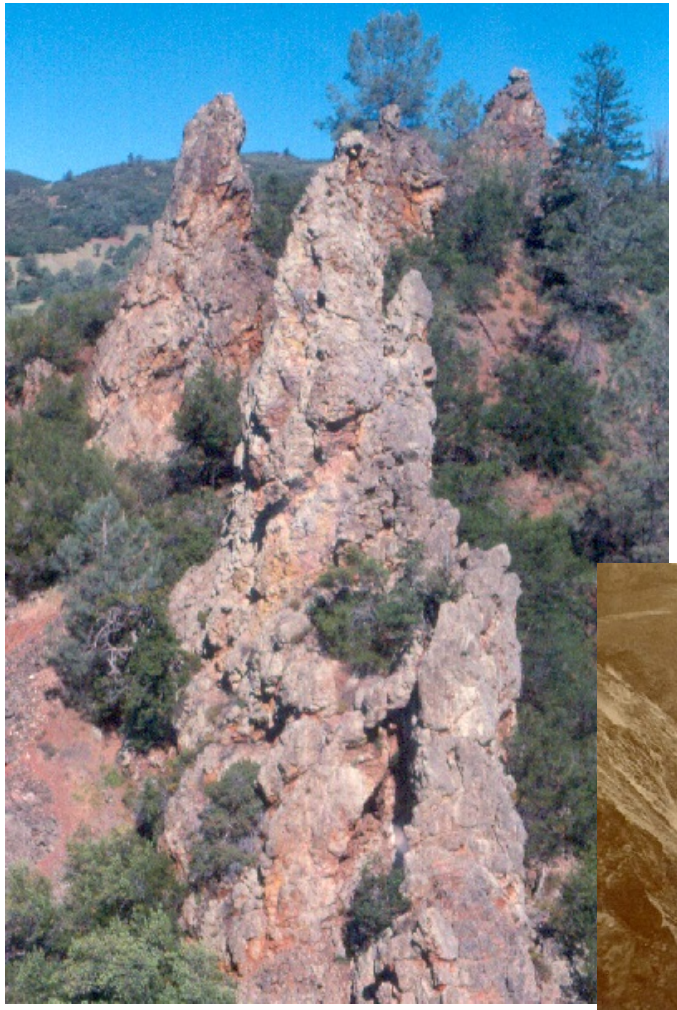
Bx



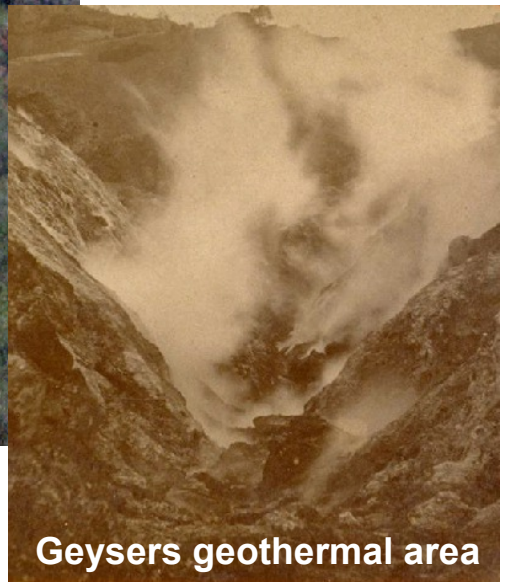
cinnebar

McLaughlin epithermal gold deposit

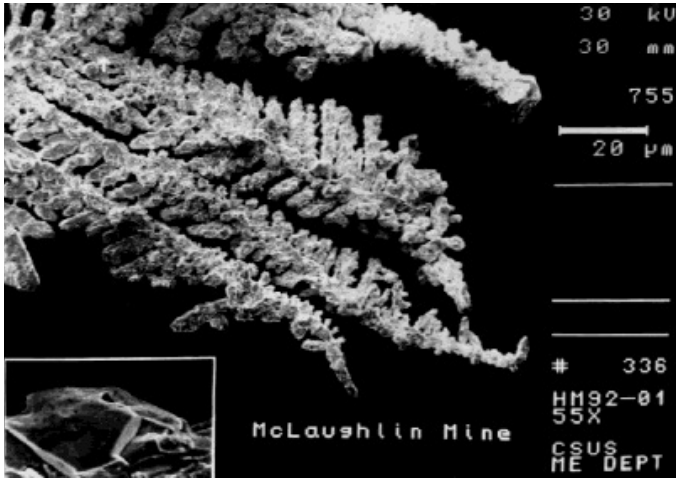


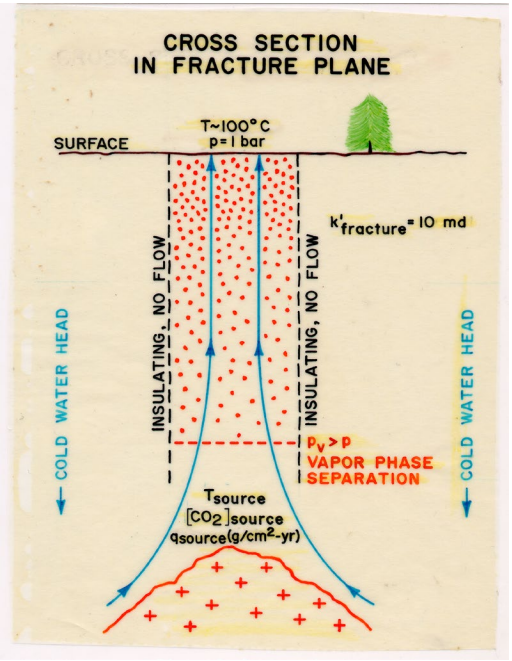


Serpentine replaced by silica and carbonate →"silica-carbonate" pinnacles called "eagle rocks"



http://nrs.ucdavis.edu/mclaughlin/naturalhis/region/region2.htm



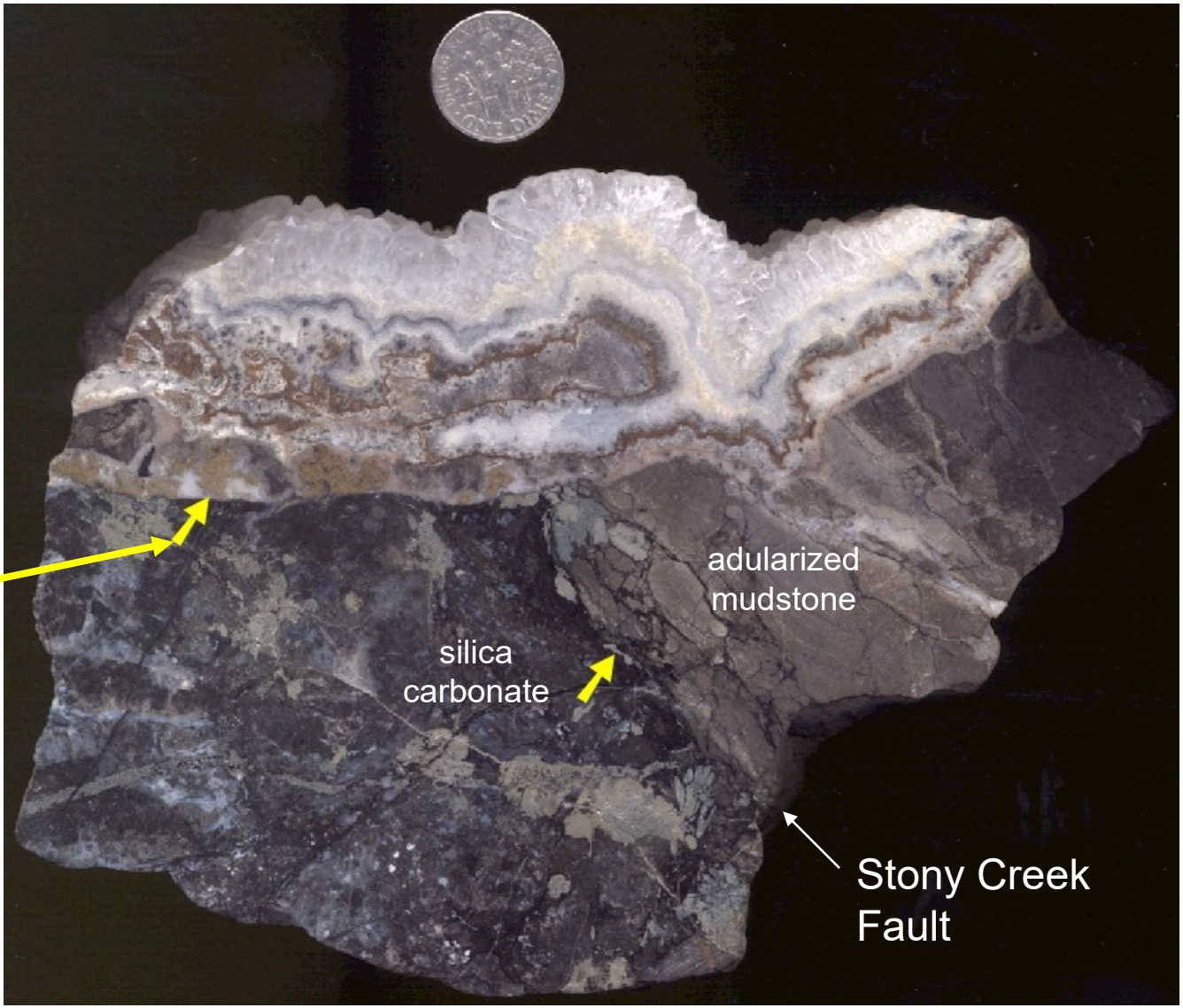


Gold deposits as H_2S lost to vapor phase in boiling system

Silica bubbles containing globules of bitumen, tar, or flowing oil. Redington mine cavity yielded several bbls green oil

McLaughlin Gold

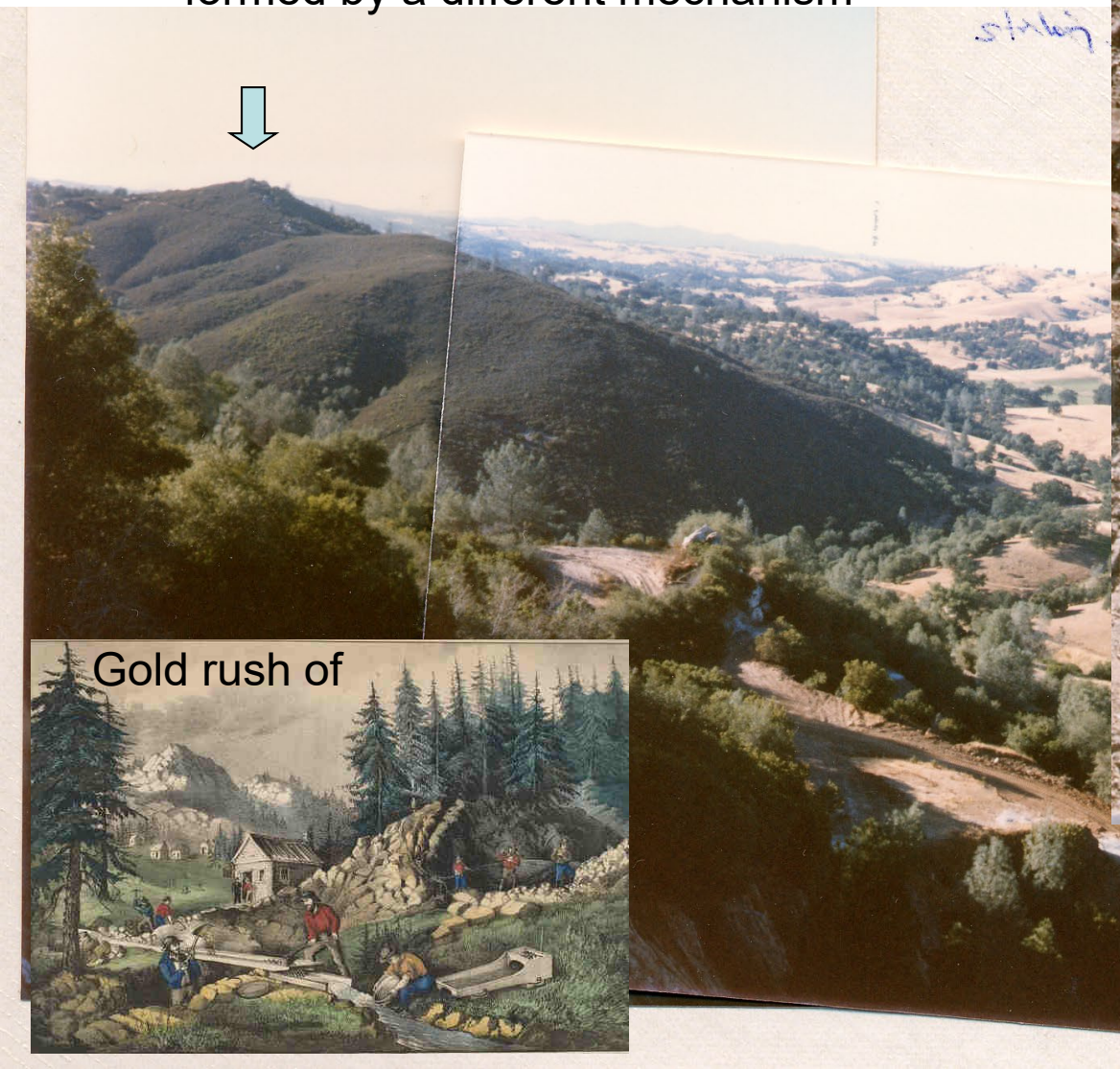
Gold dendrites in qtz (calcedony) vein

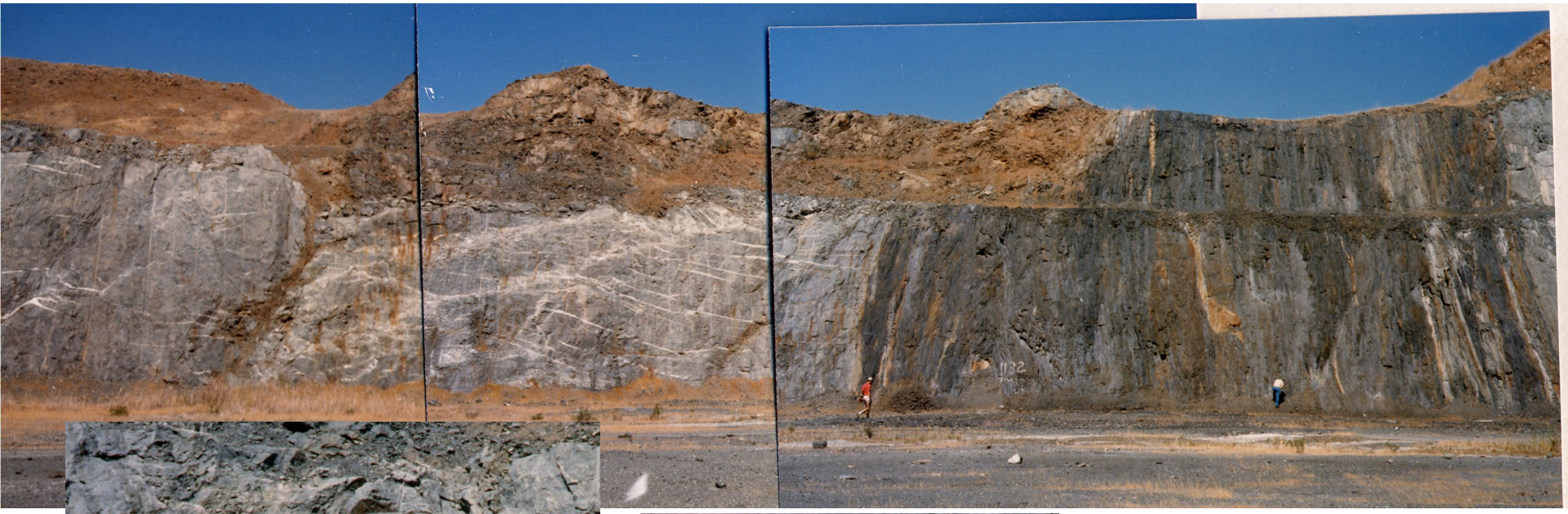


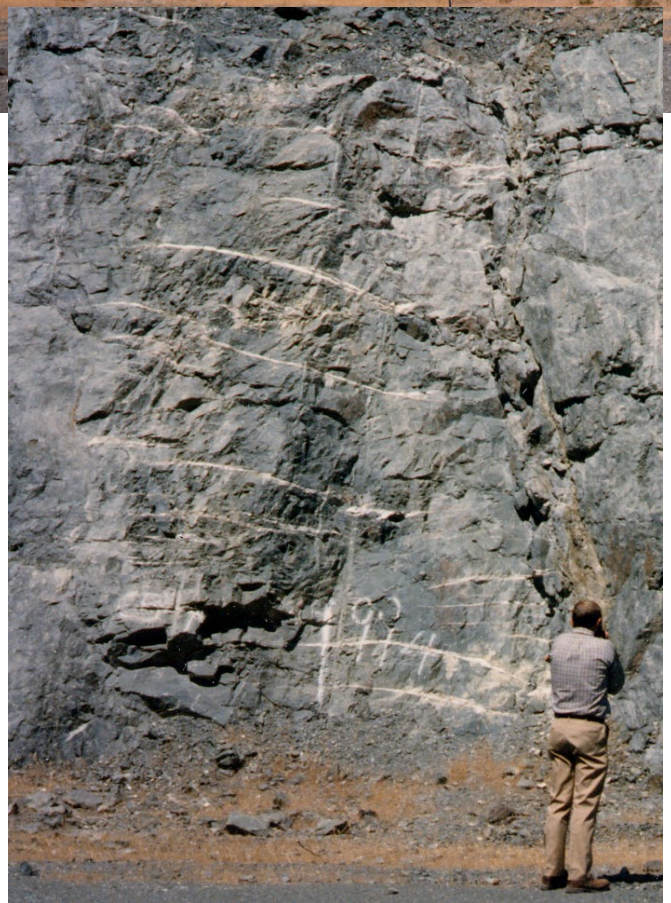
http://nrs.ucdavis.edu/mclaughlin/naturalhis/gold/gold1.htm

The Mother Lode, Ca

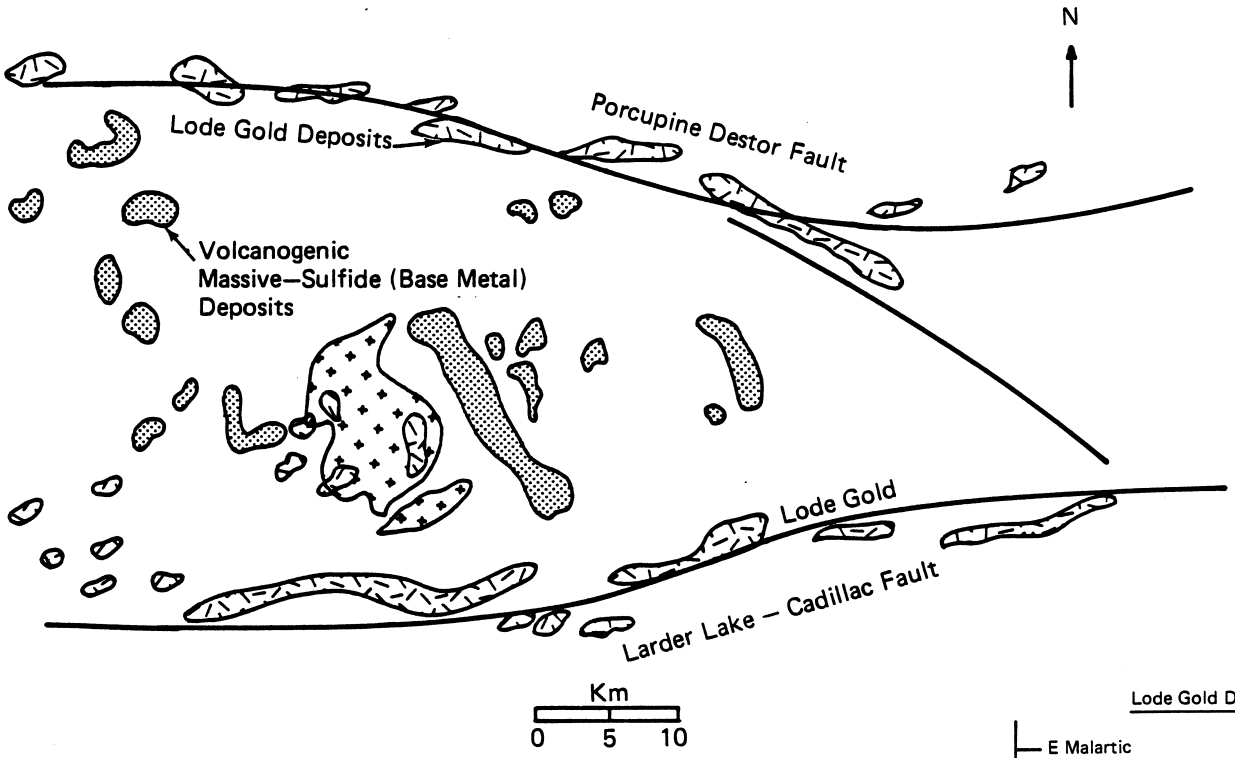
m wide vein strikes across countryside
formed by a different mechanism







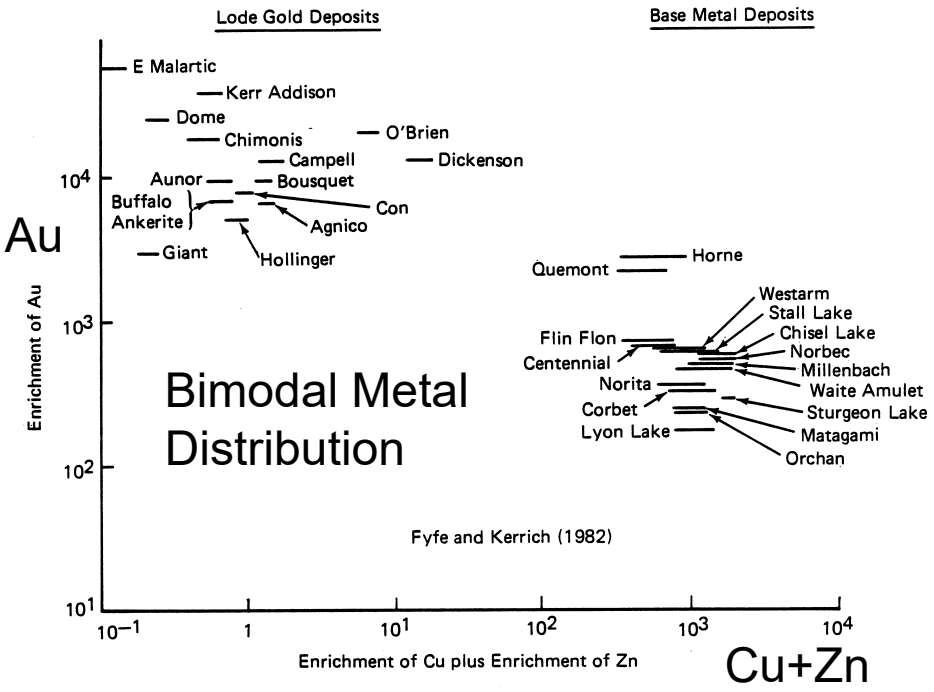
Ladder structures indicate overpressured fluids- jack open veins



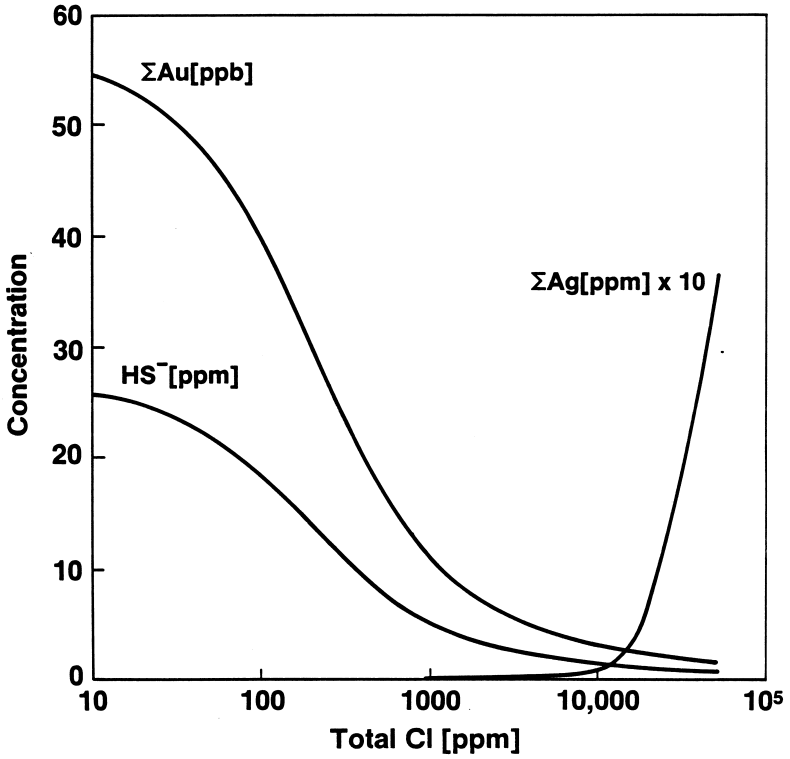
Noranda Camp, Abitibi Greenstone Belt, Quebec

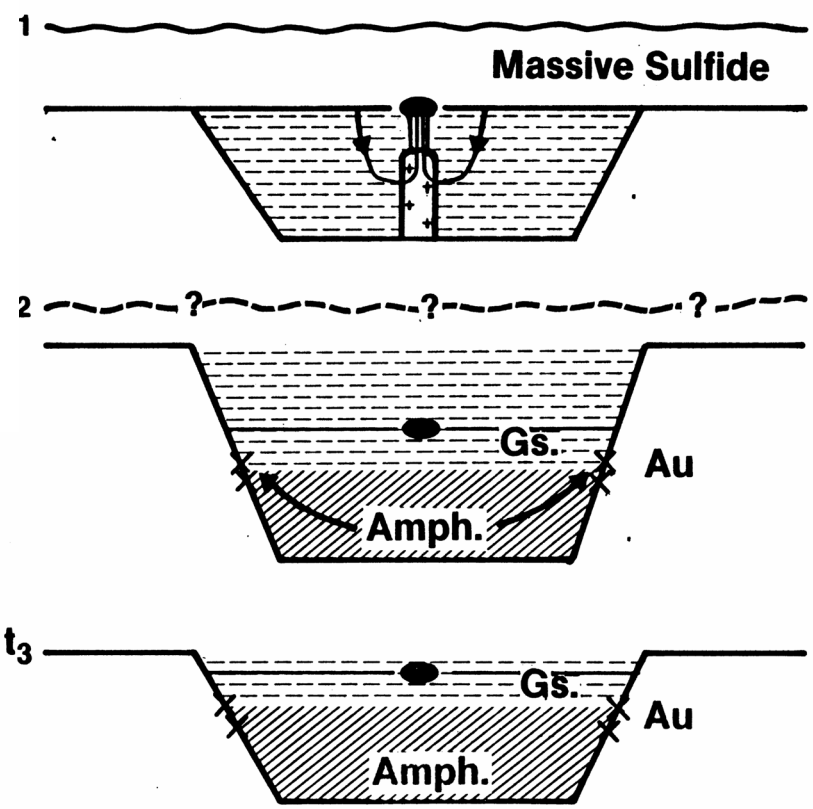
Abitibi Greenstone Belt
Quebec

Same areas contains lode gold and VMS base metal deposits



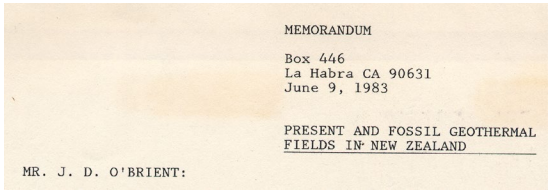
Gold Modeling Shows Low Salinity Fluids Are Best Able to Transport Gold





Summary

1. Geothermal power impressive locally but of small potential and poorly located
2. Geothermal areas are extraordinarily hazardous in the long run
3. Geothermal systems can form epithermal gold (Hg-Ag-…) deposits
4. Key to Au is low-salinity waters
5. Connections to hydrocarbons and basins- high grade and HC, overpressures in lode Au systems
6. Basins are analogues for metamorphic petrology



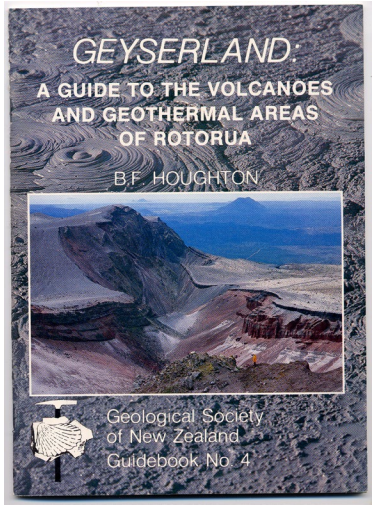
MEMORANDUM

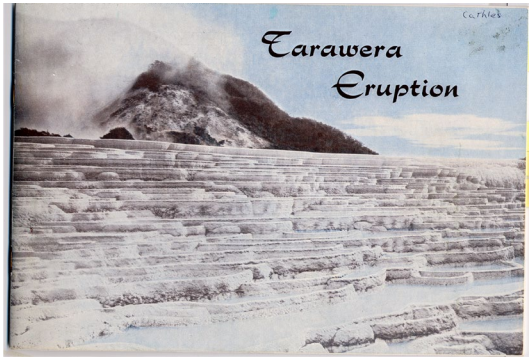
Box 446
La Habra CA 90631
June 9, 1983

PRESENT AND FOSSIL GEOTHERMAL FIELDS IN NEW ZEALAND

MR. J. D. O'BRIENT:

References





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2. Houghton, B. F., 1982, Geyserland: a guide to the volcanoes and geothermal areas of Rotorua, Geol. Soc. New Zealand Guidebook No 4, 48p.
3. Keam, R. F., 1981, Tarawera Eruption: The volcanic ourburst of June 10, 1886; Waimangu Geyser; the round trip today, Auckland Museum, 5th edition, 48p.
4. Cathles, L. M., June 9 1983, Chevron Oild Field Research Memorandum, Present and fossil geothermal fields in New Zealand, 70p.
5. Cathles, L. M., 1986, The geologic solubility of gold from 200-350C, and its implications for gold-base metal ratios in vein and stratiform deposits, in Clark. L. A. and Francis D. R., eds, Gold in the Western Shield, Special Vol. 38, The Canadian Institute of mining and metallurgy, p. 187-210
6. Sebastiao Salgado and Marlise Simons, 1987, An epic struggle for gold, New York Times Magazine, June 7, p34 -41.