

Hydrotermální ložiska

základní ložiskotvorné
procesy a jejich prostředí

Rozložník: kap.2.5, 2.6

Evans: kap. 15, 16, 17



Klasifikace hydrotermálních ložisek

- Vnitřní klasifikace podle různých kritérií
- Proč složitá klasifikace?
- Je srozumitelná pro vyhledávání a průzkum?

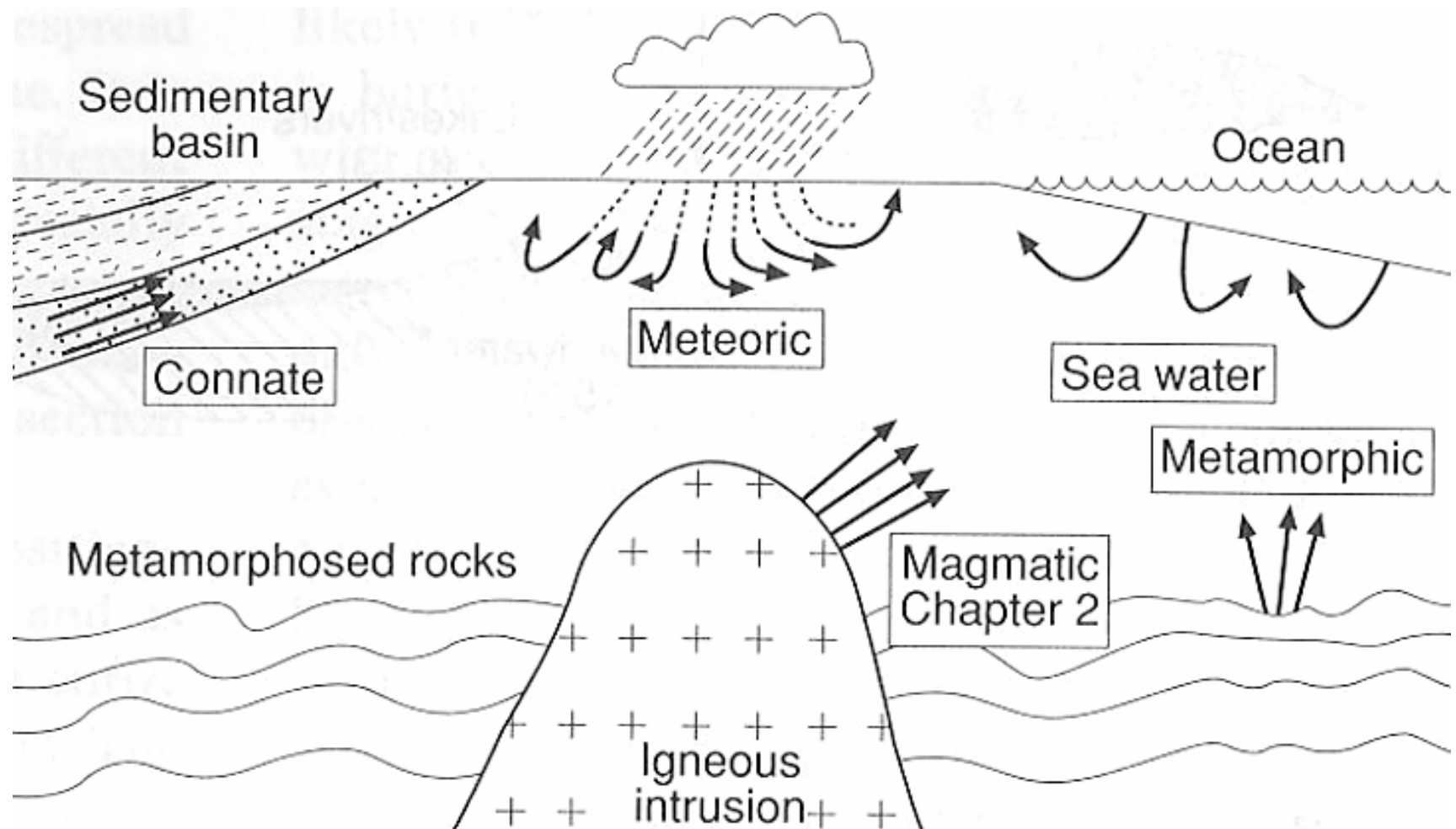


Hydrotermální roztok

základní atributy:

- 1. vznik roztoků
- 2. zdroje komponent
- 3. transport složek
- 4. srážení, vznik minerálních fází

Zdroj vodní fáze fluid



Vznik a migrace roztoků modely

black smokers



hydrothermal cells

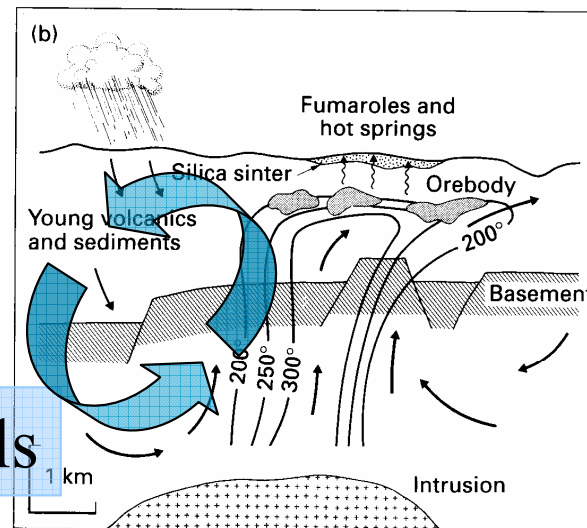
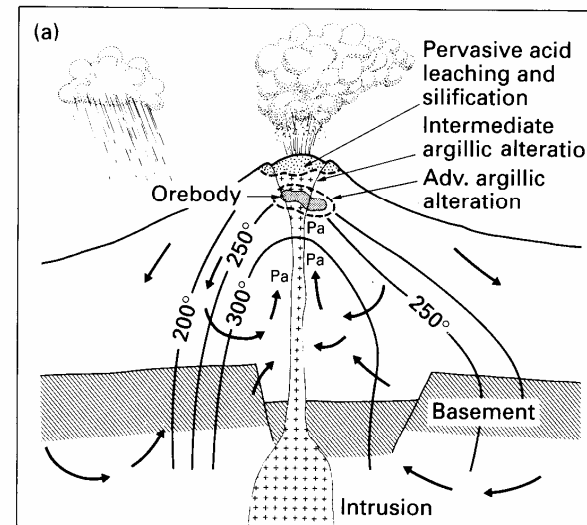
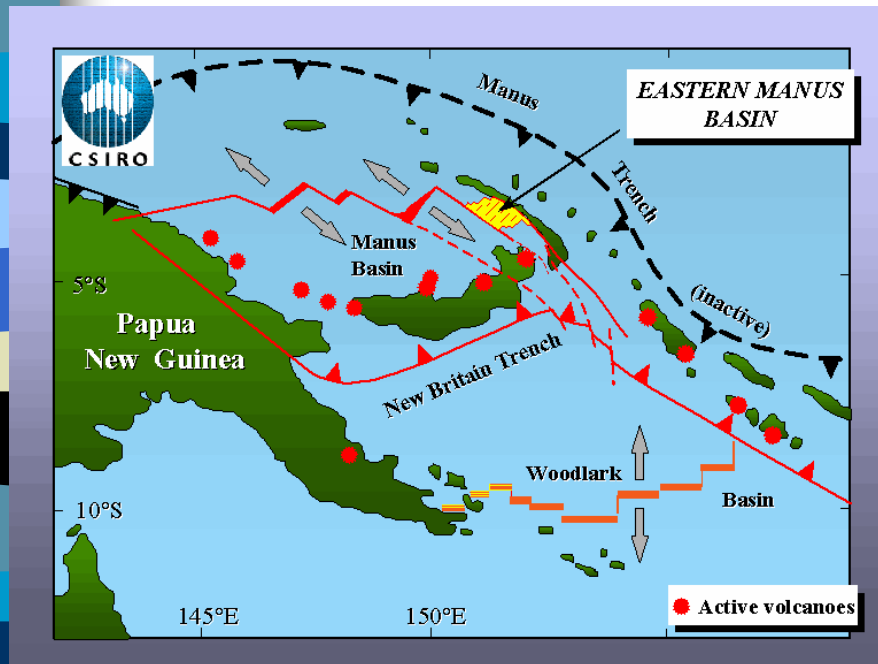


Fig. 17.5 Schemata for the formation of two types of precious metal deposits in volcanic terranes. (a) Acid sulphate type. Pa, propylitic alteration. Note that the mineralization occurs within the heat source. (b) Adularia-sericite type. The upwelling plum of hydrothermal fluid is outlined by the 200°C isotherm. The mushroom-shaped top reflects fluid flow in the plane of major fracture systems, a much narrower thermal anomaly would be present perpendicular to such structures. The heat source responsible for the buoyancy of the plume is shown as an intrusion several kilometres below the mineralized zone. In both schemata the arrows indicate the circulation of meteoric water. (a) Is at the same scale as (b).

Blacksmokers – recentní hydrotermy



Large complex chimney from Satanic Mills Hydrothermal Site, PACMANUS.

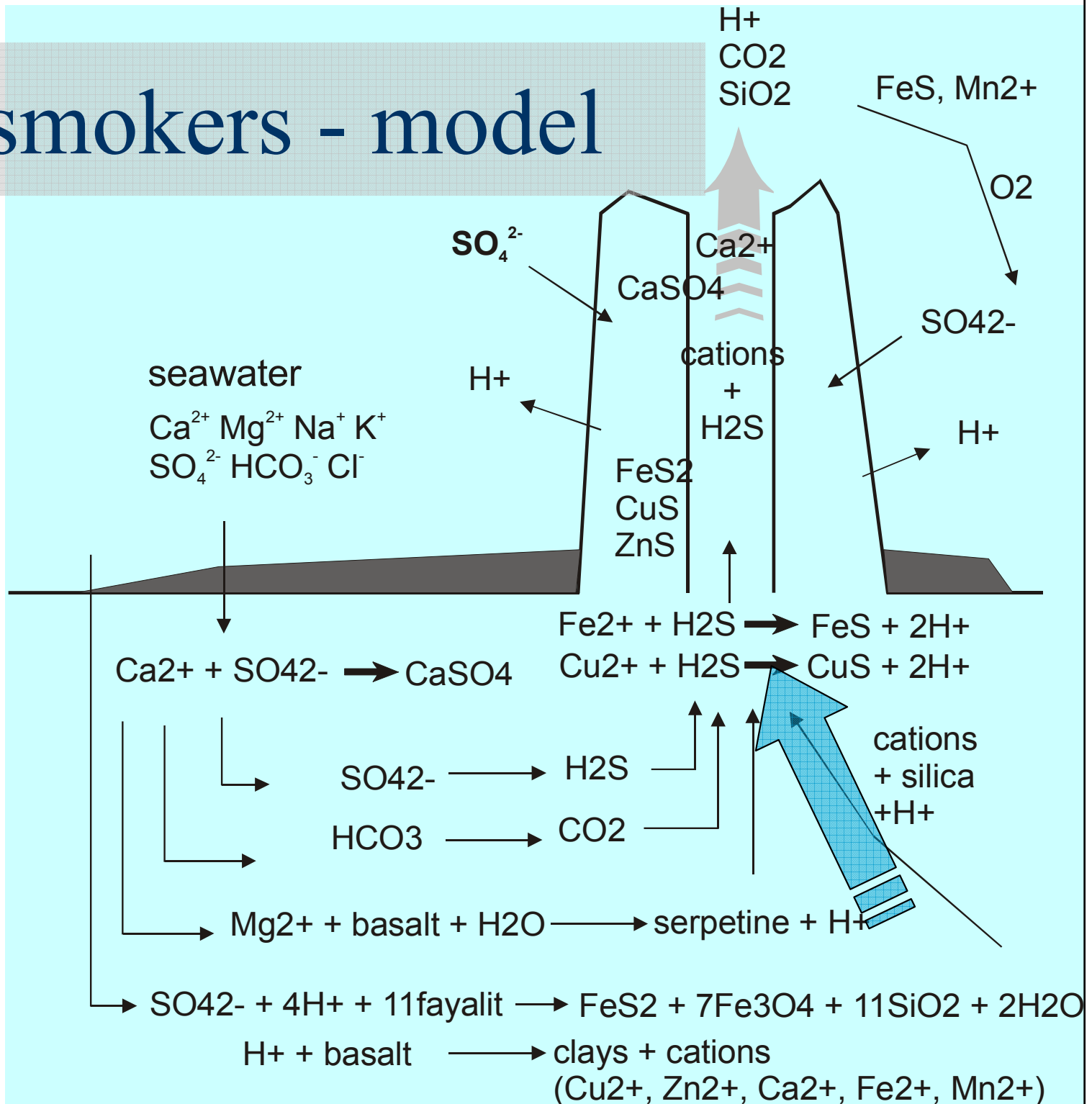
The lower portion of this multiple spired chimney comprises many smaller chimneys that have coalesced to form one major trunk. Towards the top of the structure the individual spires form slender bifurcating chimneylets. The presence of galatheid crabs on the chimney surface suggests that it is still, at least in part, active. Note the black smoke billowing from a very active chimney in the background.

Scale: chimney is approximately 5-6 m tall.

Picture produced using a collage of video images from Dive 297 at 1707 m depth



Black smokers - model





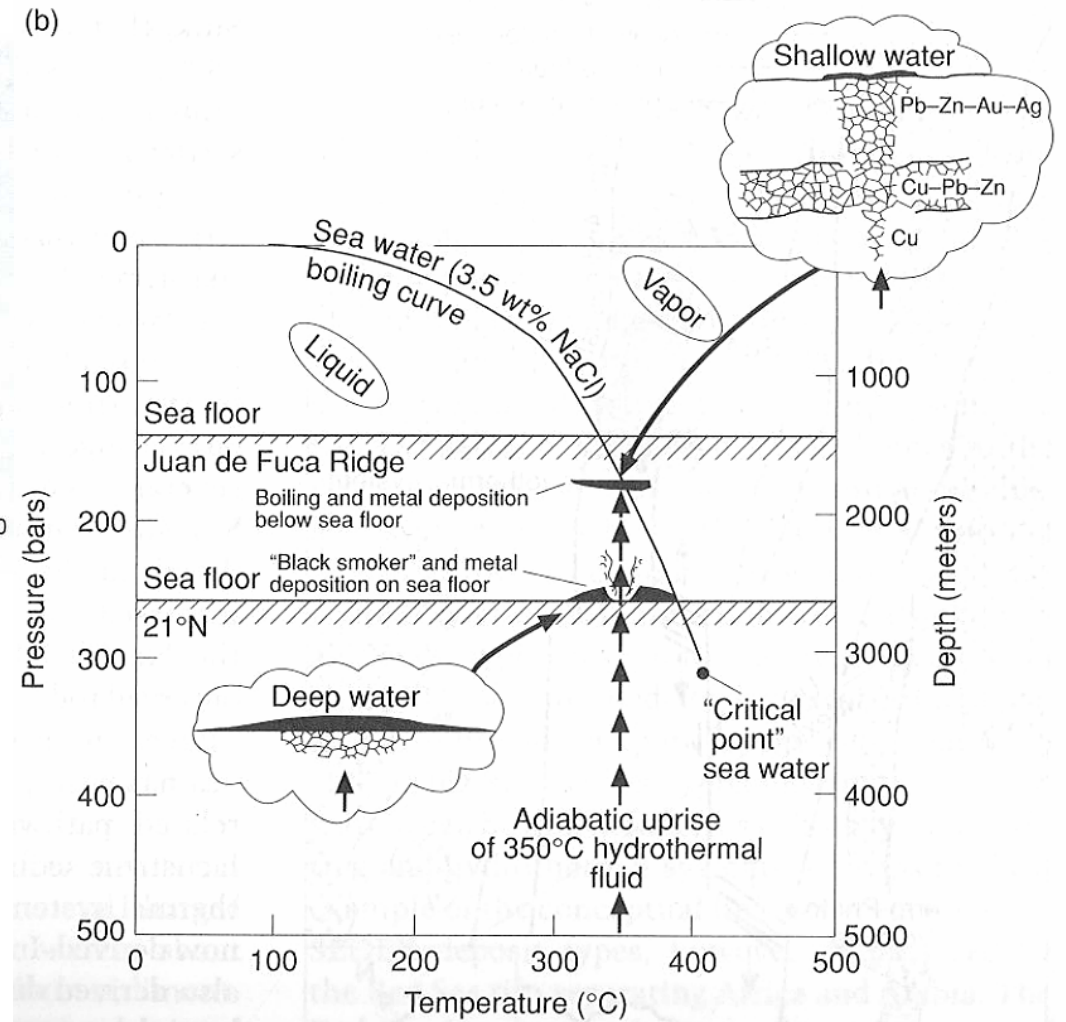
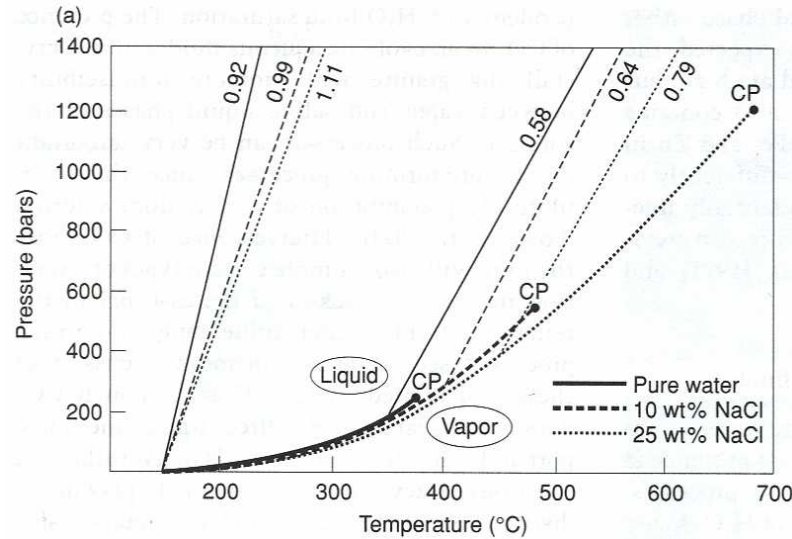
Recent hydrothermal fluids

The in situ pH of hydrothermal fluids at mid-ocean ridges

Kang Dinga et al. 2005

Here we report the first in situ pH of hydrothermal vent fluids at mid-ocean ridges. Measurements were made during dives with DSV Alvin to the Main Endeavour Field (Juan de Fuca Ridge) and the East Pacific Rise at 21°N, and 9°–10°N using solid-state electrochemical sensors. Vent fluid temperature and pressure ranged from 180 to 384 °C and 220 to 250 bar, respectively. pH (in situ) of the highest temperature vent fluid is only slightly acidic (5.1–5.4), although sharply lower values occur at the seawater/vent-fluid interface. Knowledge of pH (in situ) is essential for unravelling the complex geochemical and biogeochemical processes controlling the evolution of seafloor hydrothermal systems.

Podmínky pro „black smokers“

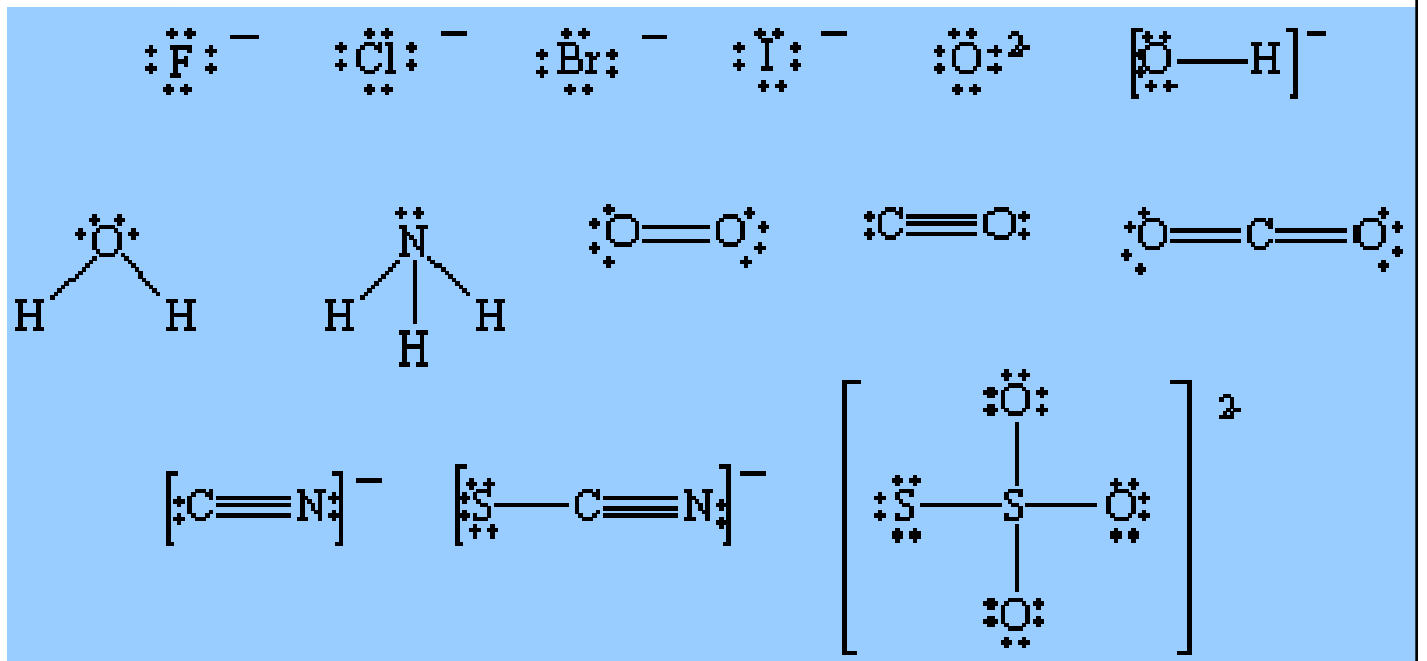
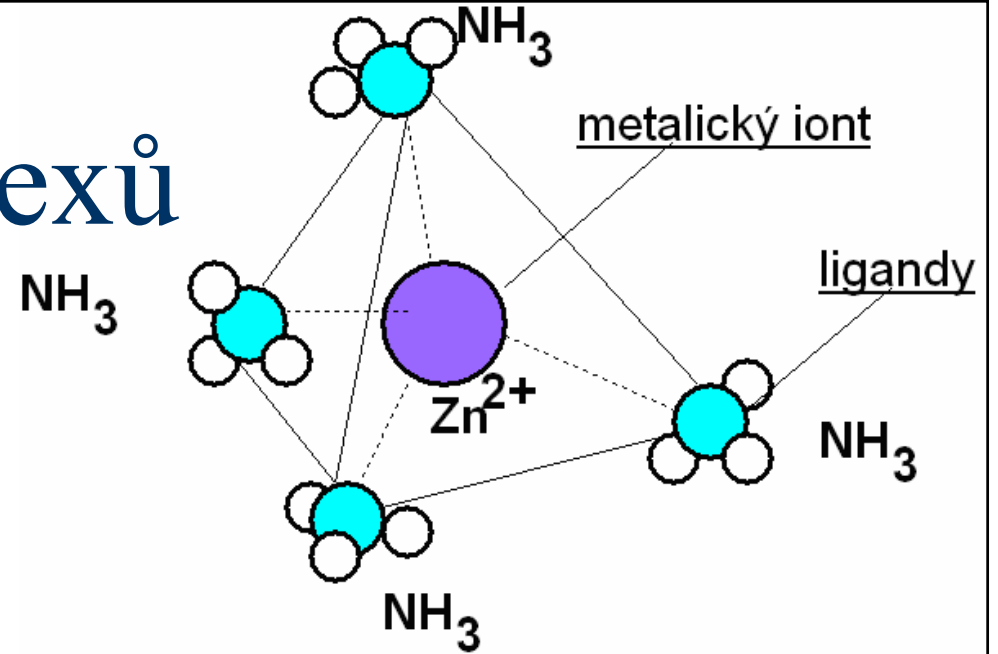
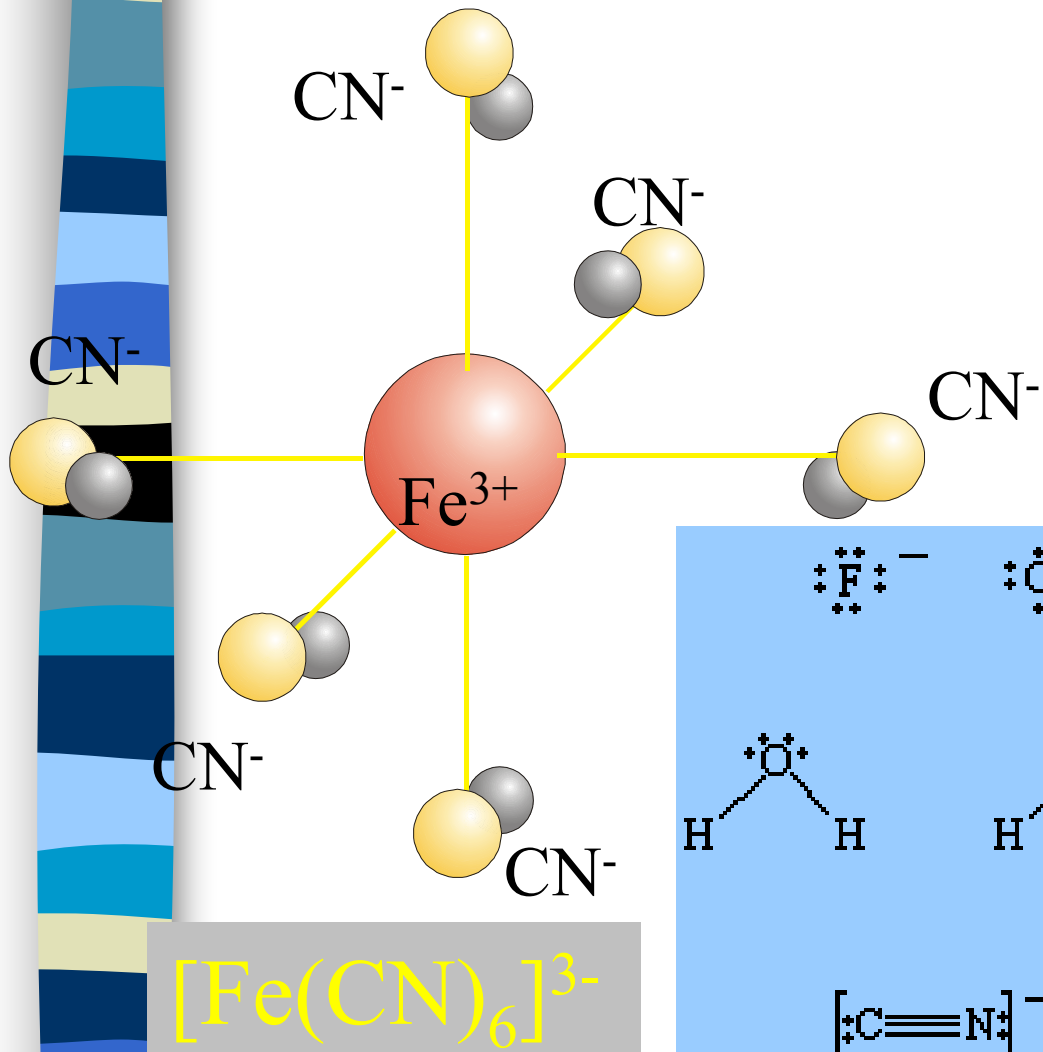


Přenos



1. **iontové roztoky** (minerály většinou těžko rozpustné – velmi omezený způsob)
2. **koloidní roztoky** (jen krátké vzdálenosti, problematika vysokoteplotních koloidů!)
3. **pravé roztoky** lehce rozp. sloučenin
4. **komplexní ionto-molekulární roztoky**,
komplexní ionty, komplexní bisulfidy, haloidní komplexy

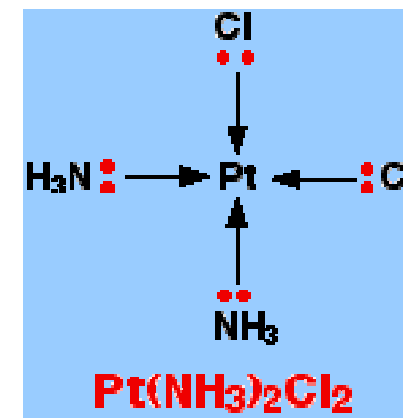
Struktury komplexů



Komplexy

Examples of Common Coordination Numbers

Metal		Ligand		Complex	Coordination Number
Ag ⁺ Ion	+	2 NH ₃	↔	Ag(NH ₃) ₂ ⁺	2
Ag ⁺	+	2 S ₂ O ₃ ²⁻	↔	AgCl ₂ ⁻	2
Ag ⁺	+	2 Cl ⁻	↔	Ag(S ₂ O ₃) ₂ ³⁻	2
Pb ²⁺	+	2 OAc ⁻	↔	Pb(OAc) ₂	2
Cu ⁺	+	2 NH ₃	↔	Cu(NH ₃) ₂ ⁺	2
Cu ²⁺	+	4 NH ₃	↔	Cu(NH ₃) ₄ ²⁺	4
Zn ²⁺	+	4 CN ⁻	↔	Zn(CN) ₄ ²⁻	4
Hg ²⁺	+	4 I ⁻	↔	HgI ₄ ²⁻	4
Co ²⁺	+	4 SCN ⁻	↔	Co(SCN) ₄ ²⁻	4
Fe ²⁺	+	6 H ₂ O	↔	Fe(H ₂ O) ₆ ²⁺	6
Fe ³⁺	+	6 H ₂ O	↔	Fe(H ₂ O) ₆ ³⁺	6
Fe ²⁺	+	6 CN ⁻	↔	Fe(CN) ₆ ⁴⁻	6
Co ³⁺	+	6 NH ₃	↔	Co(NH ₃) ₆ ³⁺	6
Ni ²⁺	+	6 NH ₃	↔	Ni(NH ₃) ₆ ²⁺	6



Typy komplexů

K nejdůležitějším třídám komplexů náleží: jsou schopny transportovat značné množství kovů

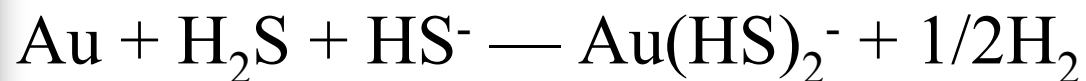
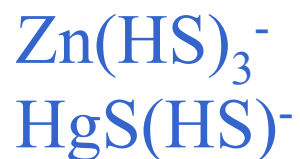
1. sulfidové — HS^- a H_2S

2. chloridové — Cl^-

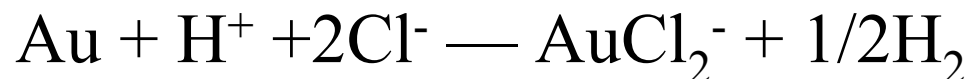
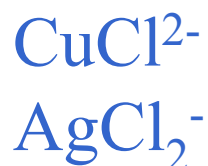
Další jsou: OH^- , NH_3 , F^- , CN^- , SCN^- , SO_4^{2-} , ... a organické komplexy

Pro přenos kovů je **aktivita ligand** důležitější než množství vázaného kovu.

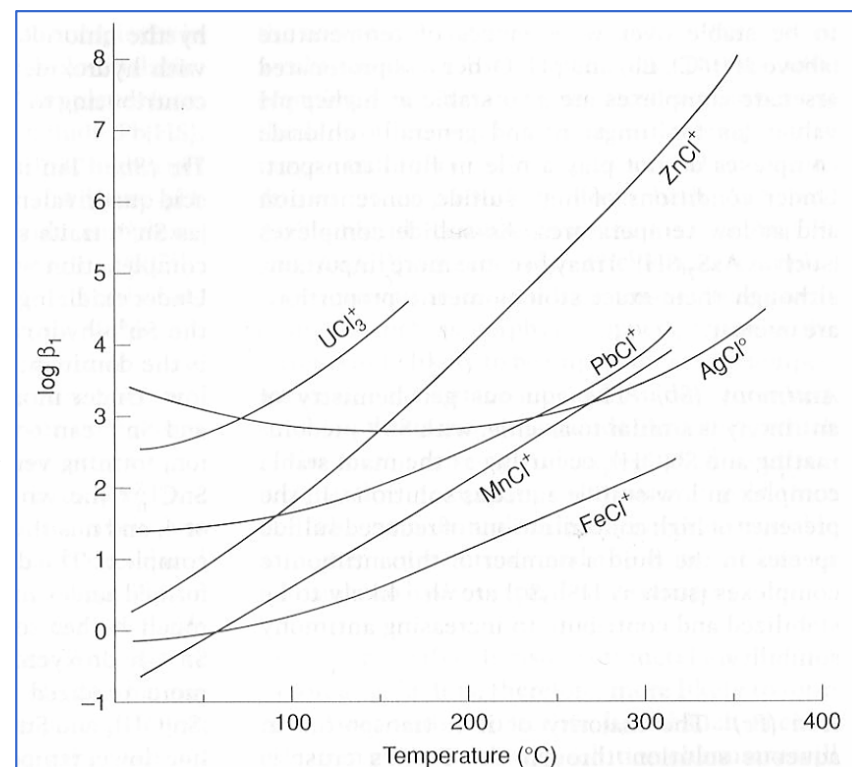
Příklady komplexů



(stabilní do 300°C a 1500 bar při pH 3-10)



Chloridové komplexy jsou stabilnější
(než sulfidické) za vyšších T (>350°C)
a při nižších a středních pH.





Srážení, ukládání kovů

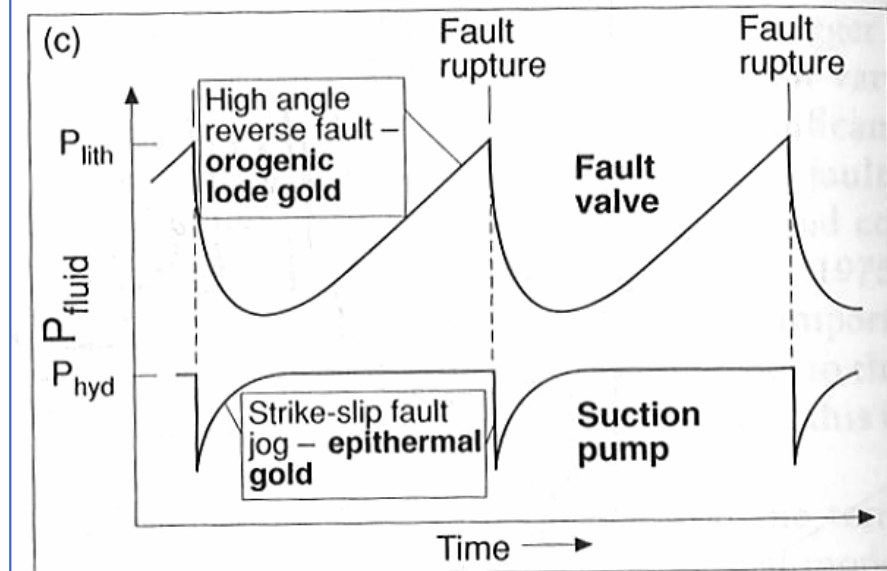
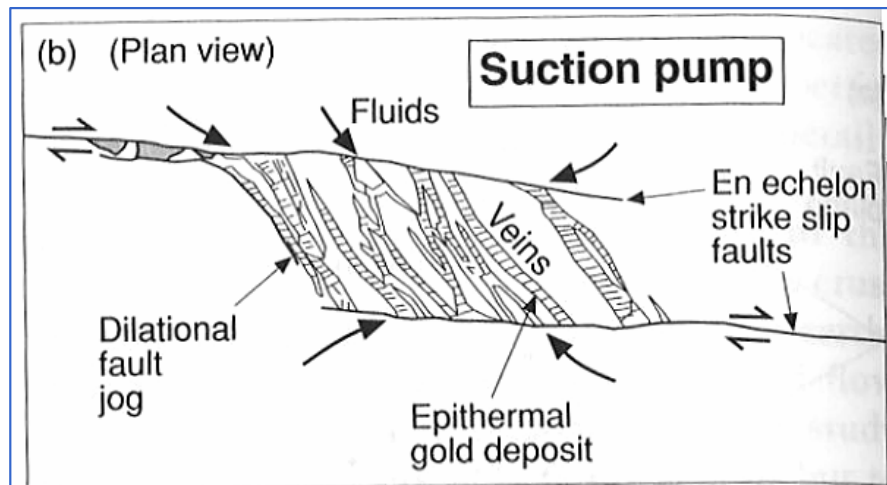
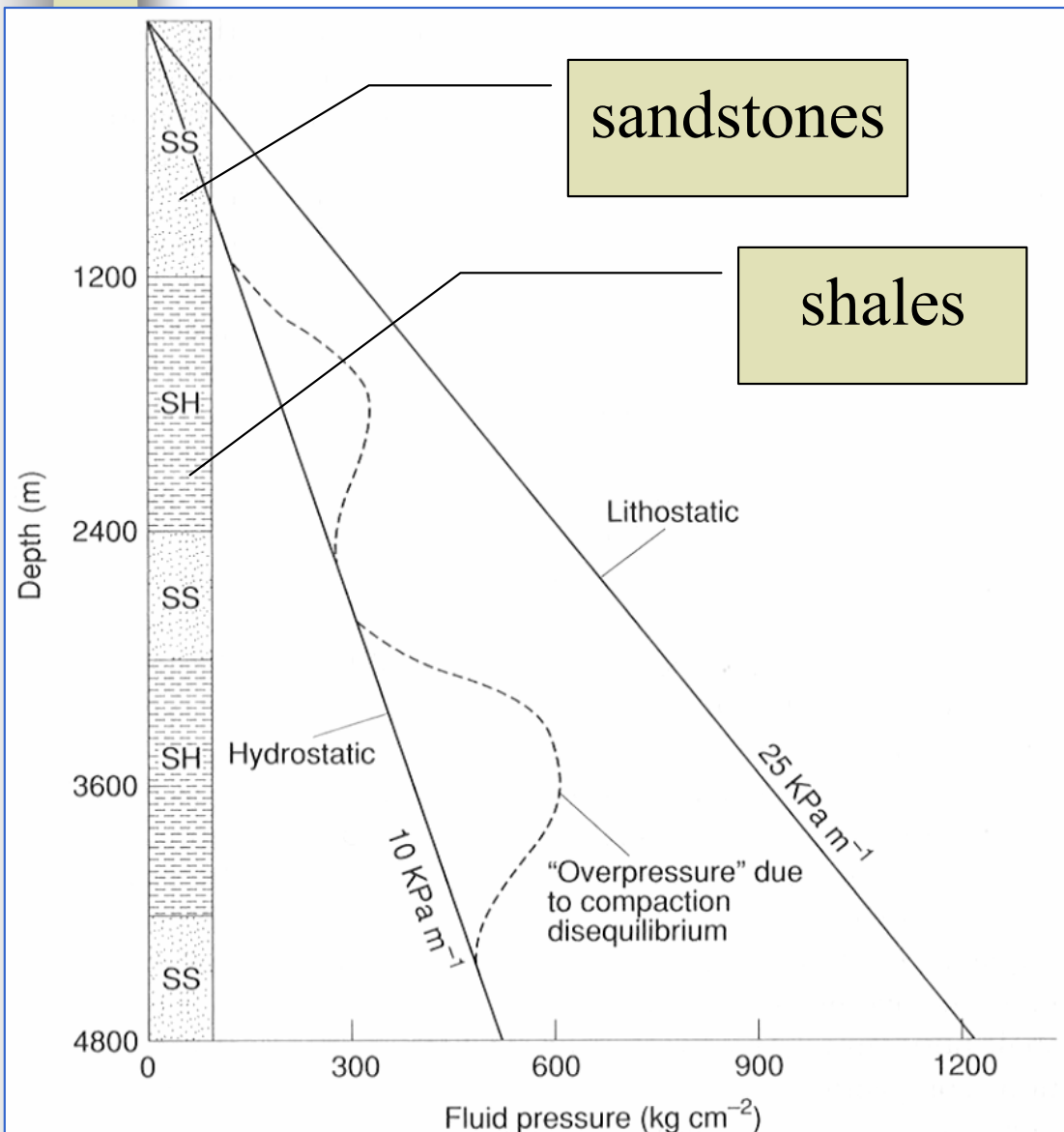
- kolísání T
- změny P a var
- reakce hornina-fluida
- změny chem. složení - mícháním fluid (př. black smokers)

var — únik plynné fáze:

$\text{HS}^- + \text{H}^+ \rightarrow \text{H}_2\text{S}_{(g)}$... zvyšuje se f_{O_2} a dochází k oxidaci

$\text{HCO}_3^- + \text{H}^+ \rightarrow \text{CO}_2(g) + \text{H}_2\text{O}$

Změny P



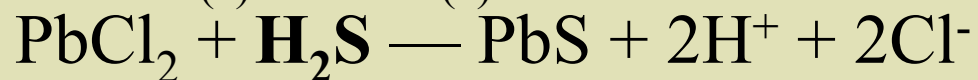
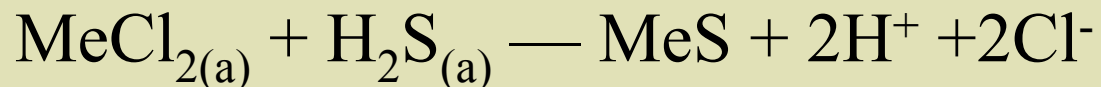
čtení a obr. 3.7, 3.9 v Robb 2006

Příklady srážení

ze **sulfidových** komplexů:



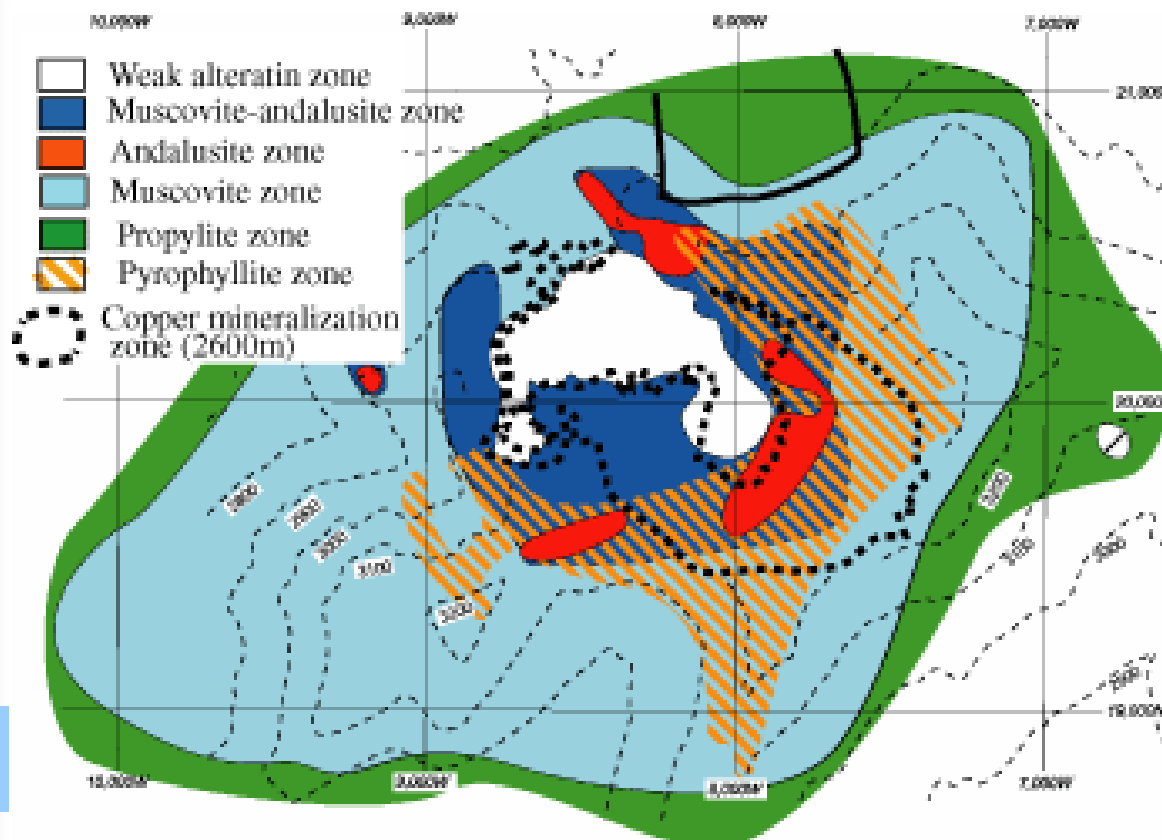
z **chloridových** komplexů: (př. pro ložiska typu MVT)



Rozpor s přítomností S v Cl-systemu!!! H₂S asi přichází později?! (model viz Evans: kap.4)

Zonálnost

zonálnost : (obecně: rudních pásem, rudních rajónů, polí, rudních těles), u hydrotermálních ložisek velmi běžný rys, geochemické aureoly, hydrotermální metasomatické okoložilné přeměny, **teleskopíng** – překrývání teplotních pater



Phyllic alteration above the porphyry Cu ore body. A concentric zonal structure of inner least-altered zone to an outer muscovite zone through a muscovite-andalusite zone were observed. This indicates that the center of a porphyry system can be detected by analyzing phyllic alteration.

Vznik mineralizací jinými procesy

- adsorpce
- biomineralizace

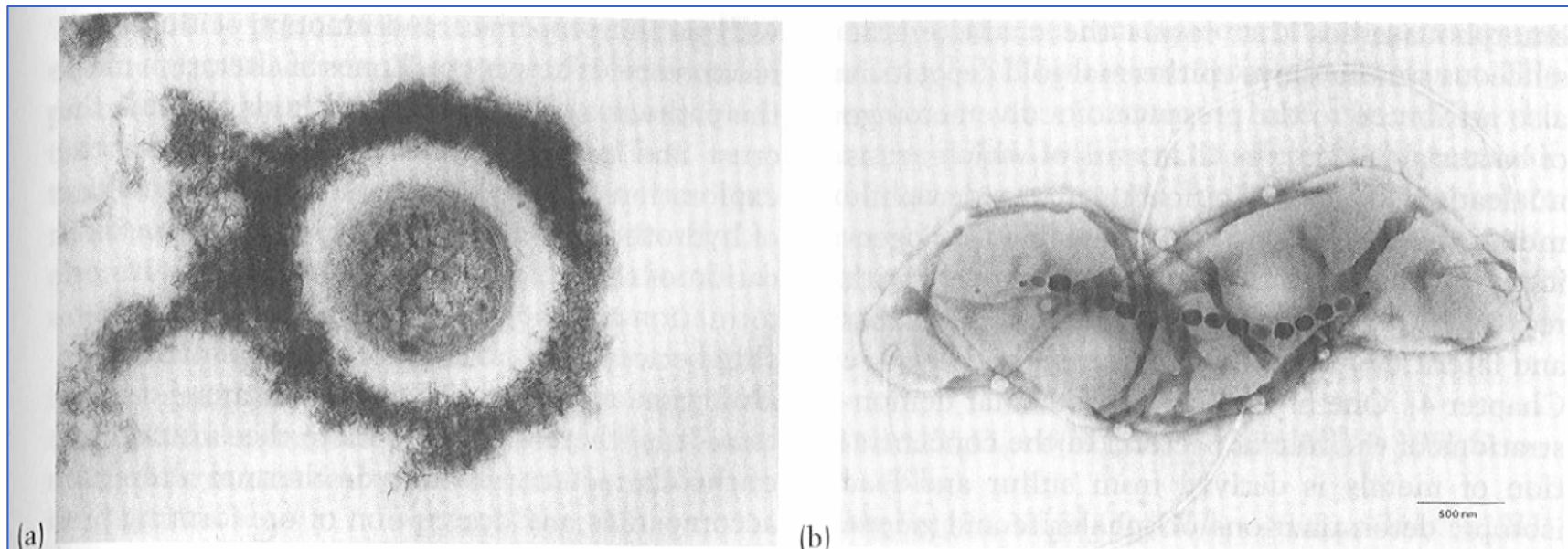


Figure 3.17 Microphotographs of (a) bacterial cell with amorphous ferric hydroxide replacing the cell walls, and (b) magnetotactic spirillum bacteria showing a chain of magnetite crystals developed along the longitudinal axis of the microorganism (photographs courtesy of Kurt Konhauser and Dennis Bazylinski).

Adsorpce

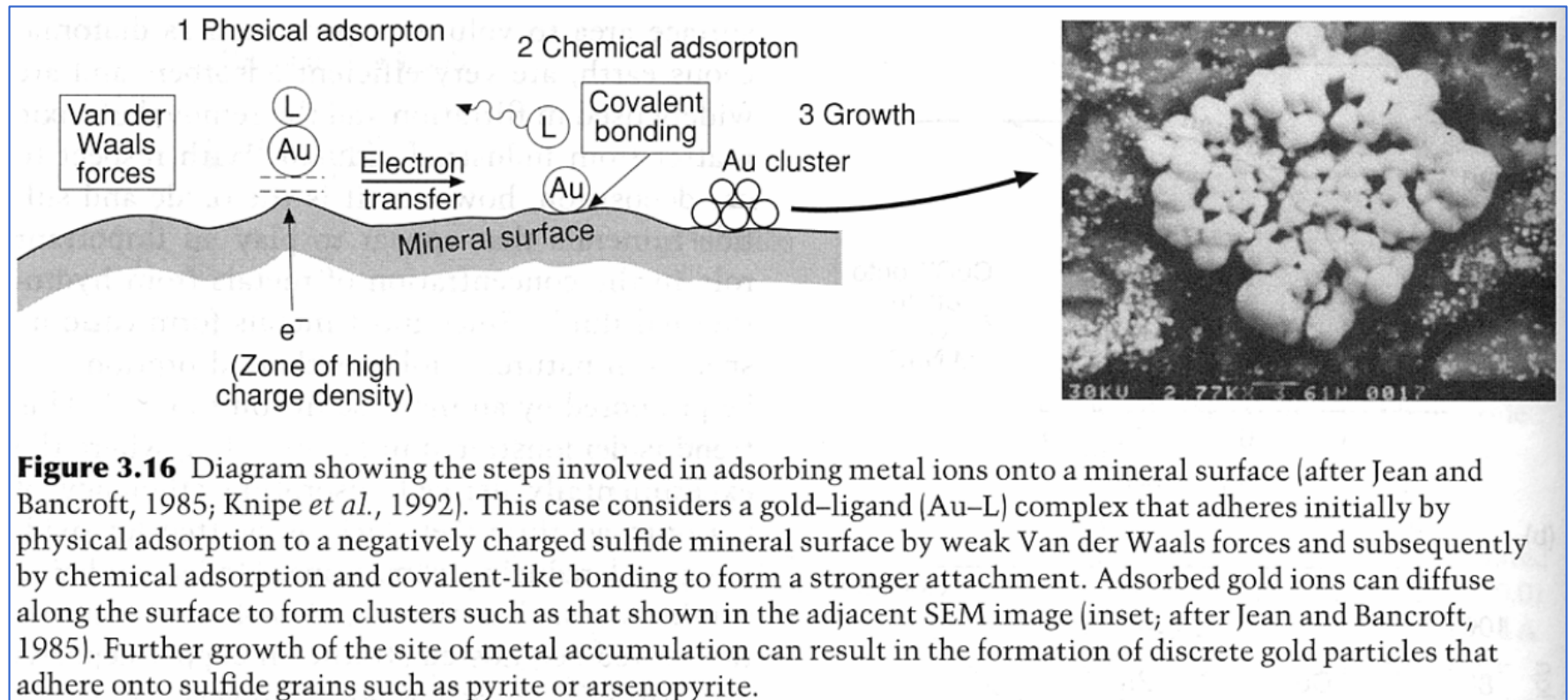


Figure 3.16 Diagram showing the steps involved in adsorbing metal ions onto a mineral surface (after Jean and Bancroft, 1985; Knipe *et al.*, 1992). This case considers a gold-ligand (Au-L) complex that adheres initially by physical adsorption to a negatively charged sulfide mineral surface by weak Van der Waals forces and subsequently by chemical adsorption and covalent-like bonding to form a stronger attachment. Adsorbed gold ions can diffuse along the surface to form clusters such as that shown in the adjacent SEM image (inset; after Jean and Bancroft, 1985). Further growth of the site of metal accumulation can result in the formation of discrete gold particles that adhere onto sulfide grains such as pyrite or arsenopyrite.

Vznik a vývoj rudních těles

cvičení

hydraulické trhliny
(hydrofracturing)

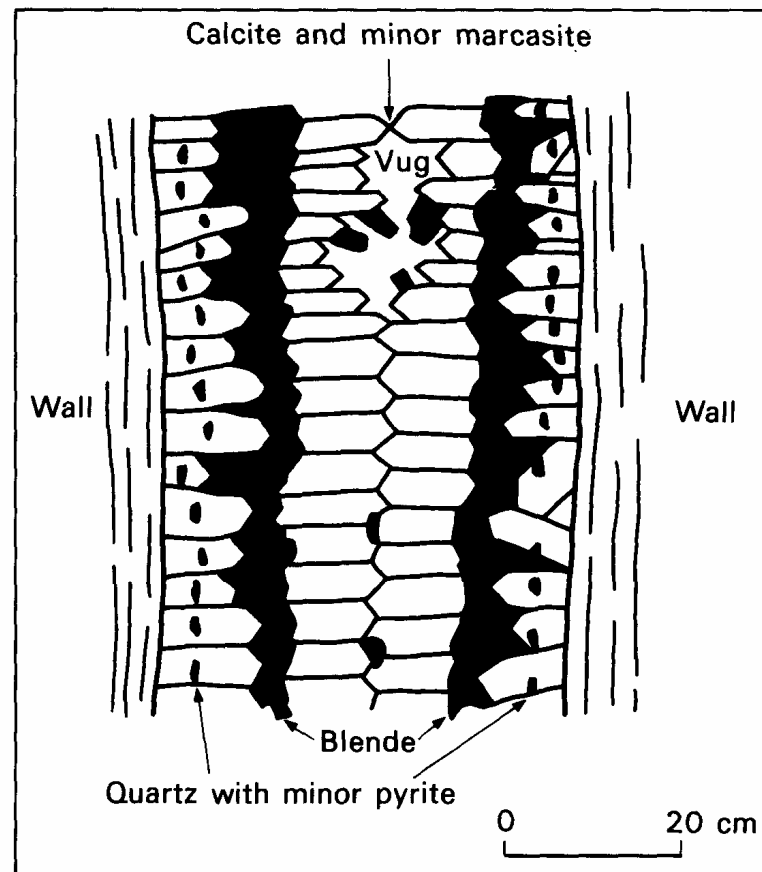
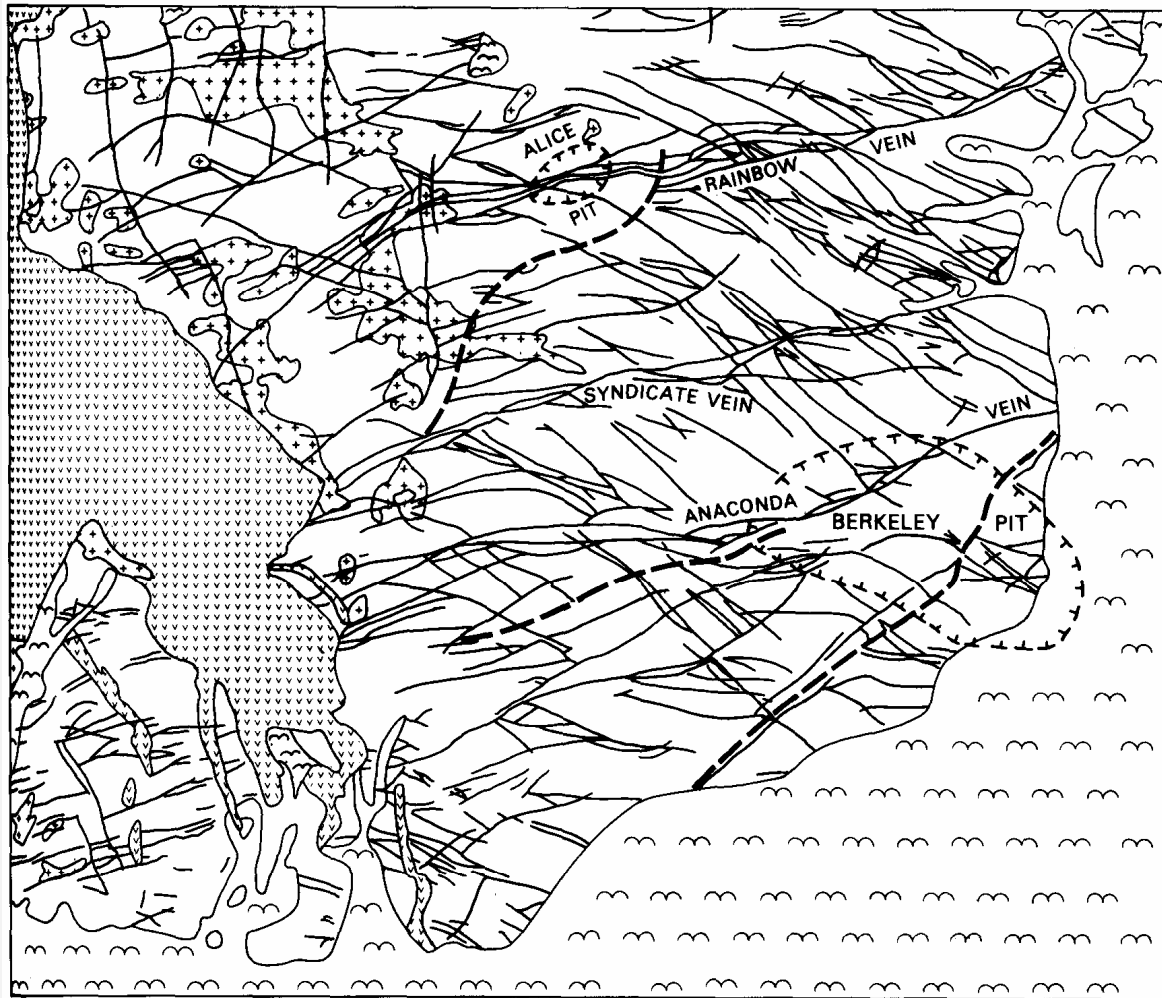


Fig. 5.2 Section across a vein showing crustiform banding.

Klasifikace

hydrotermální	plutonická
	subvulkanická
	teletermální
(subaerická)	vulkanoexhalační
	krustální
	hydratogenní
(submarinní)	vulkanosedimentární
	amagmatická hydrotermálně sedimentární
metamorfogenní	metamorfně hydrotermální

Plutonická h.l. - příklady



Žilný systém Butte,
Montana, USA

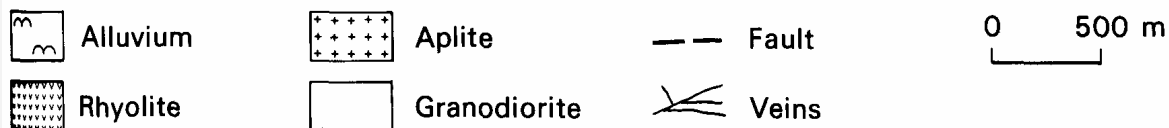
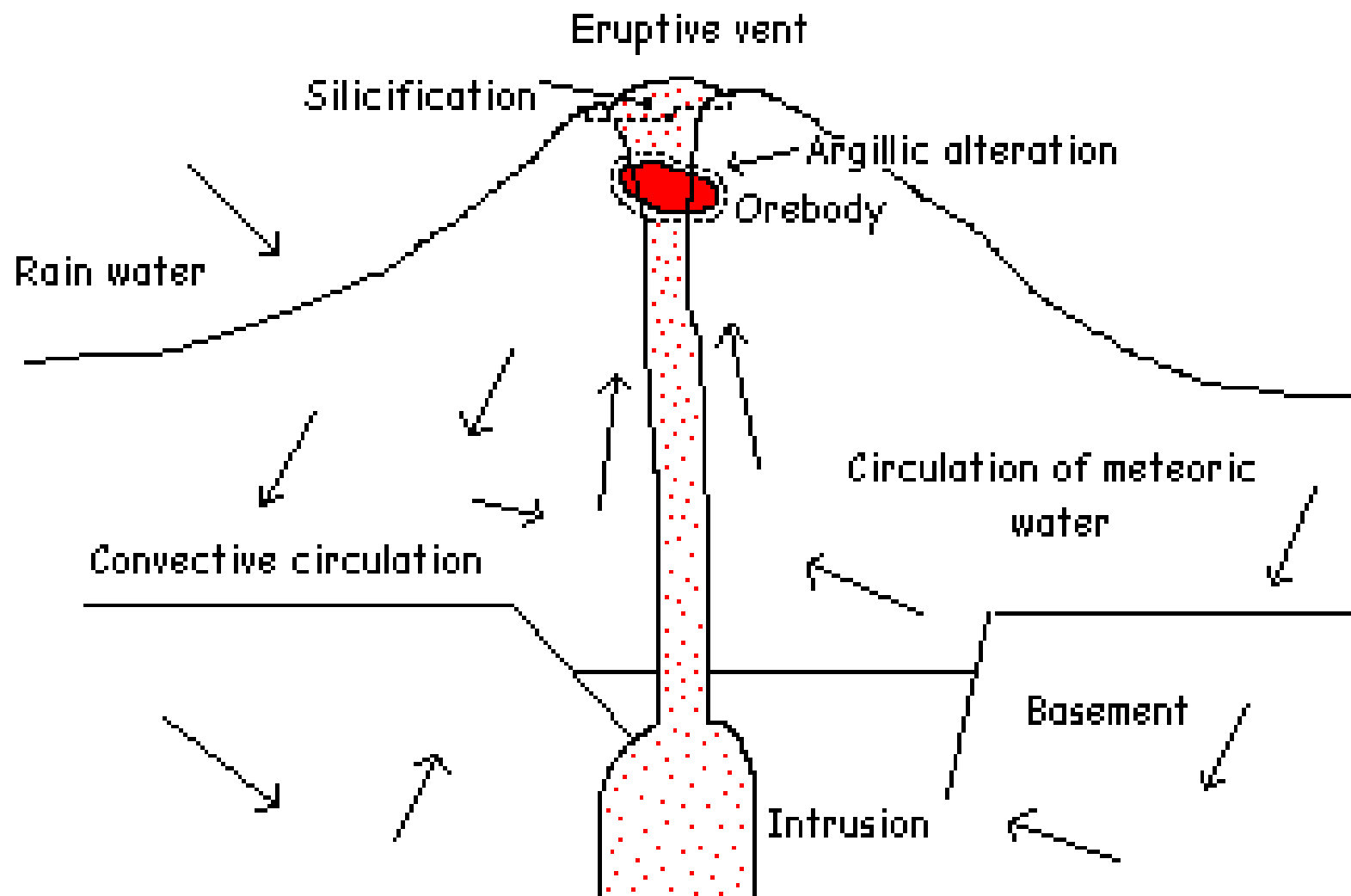


Fig. 17.2 Surface geology and veins of the Butte District, Montana.

Subvulkanická h.l.

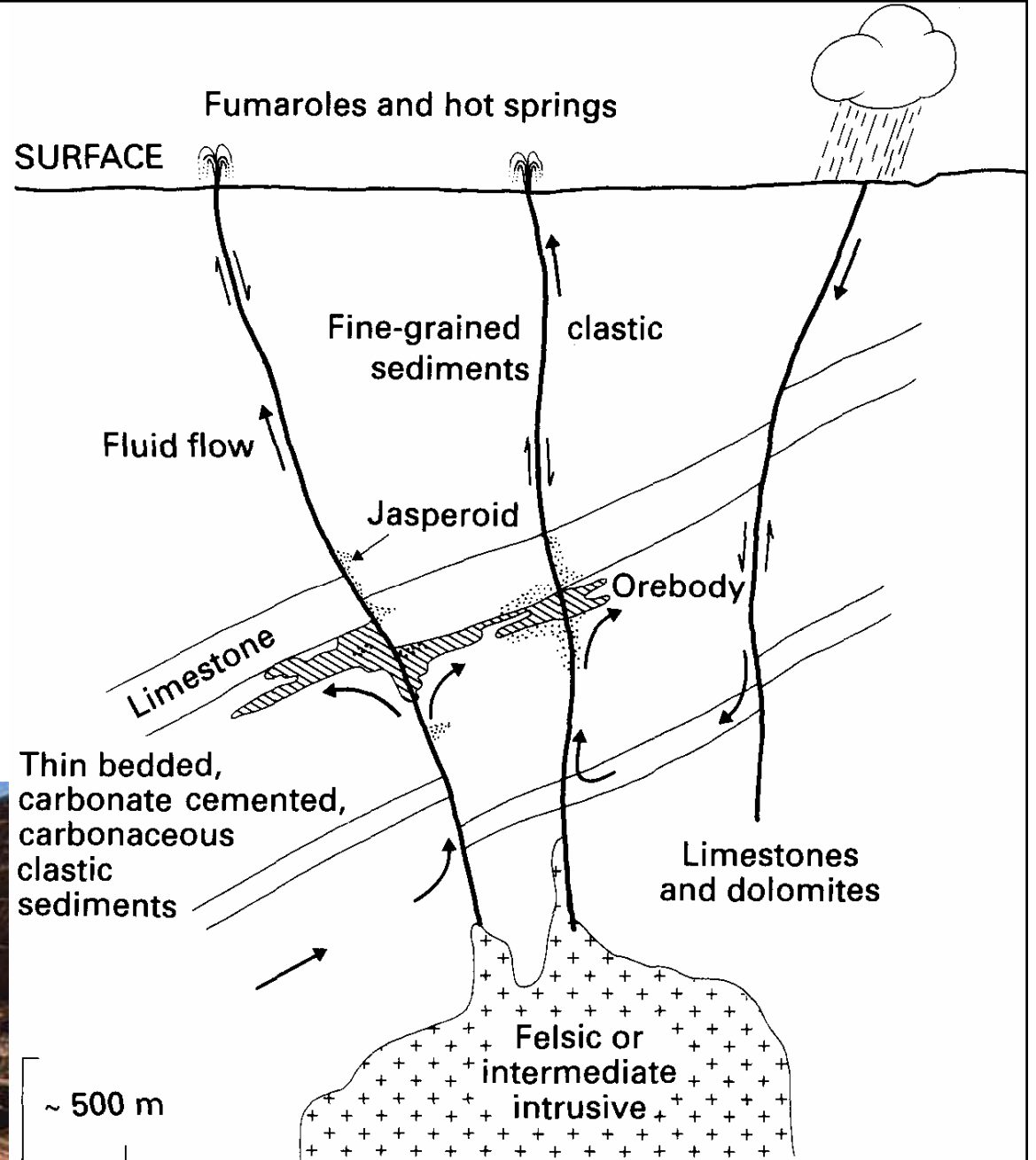




Subvulkanická 1. - příklady

- Banská Štiavnica
- Hishikari
- další formace Au-Ag

Carlin



Teletermální (amagmatická) - příklady

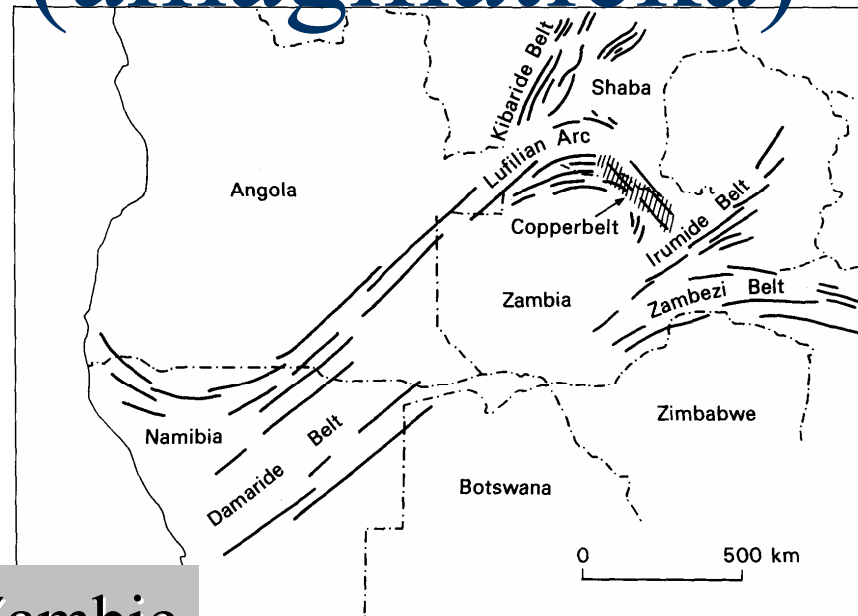
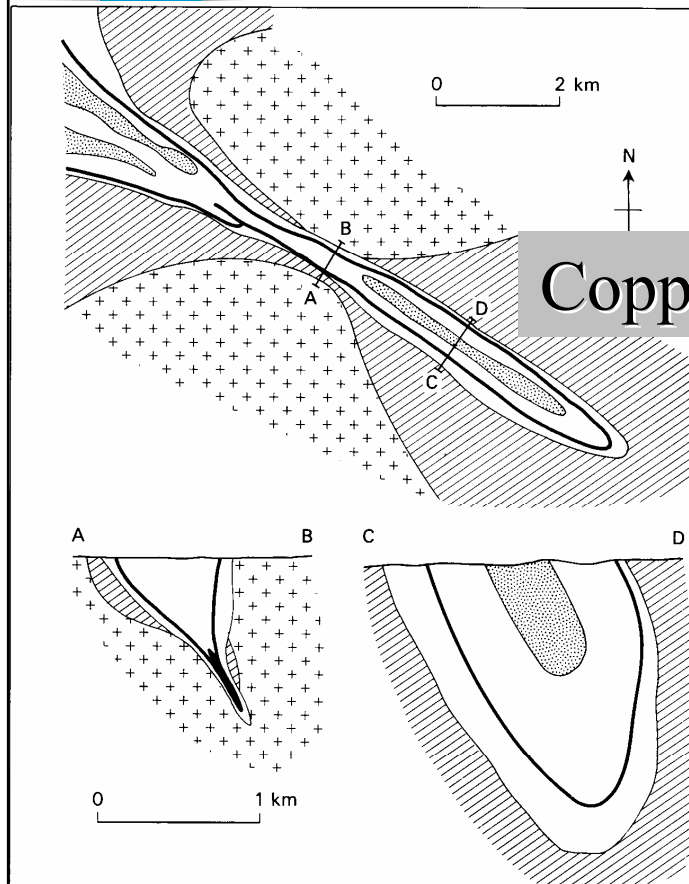


Fig. 16.3 Location of the Copperbelt in relation to the main tectonic trends of central Africa.



Copperbelt, Zambia

- Basement granite
- Upper Roan
- Basement schist
- Lower Roan with ore shale

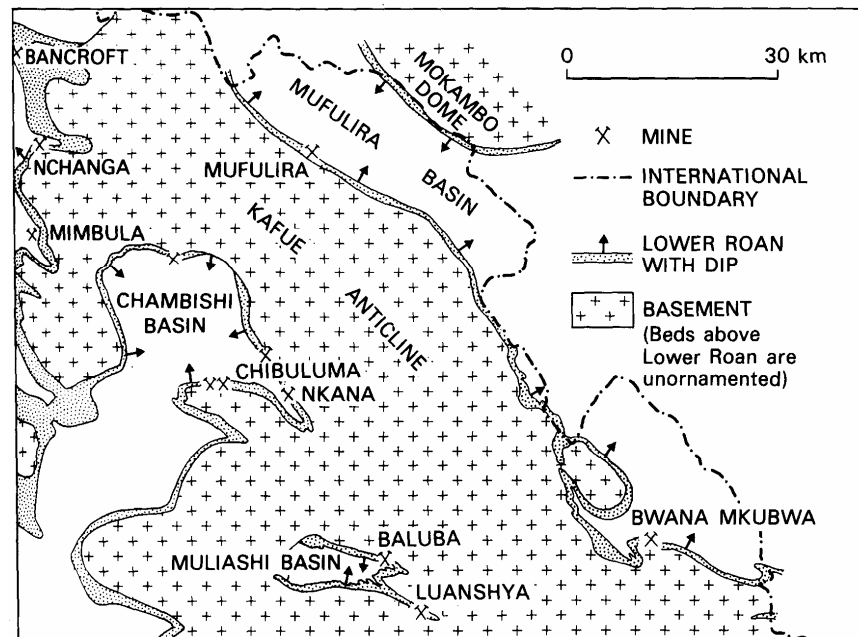


Fig. 16.5 Sketch map and sections of the Luanshya Deposit, Zambia.

Fig. 16.4 Location map for the Zambian Copperbelt showing the regional geology.



Teletermální lož. - příklady

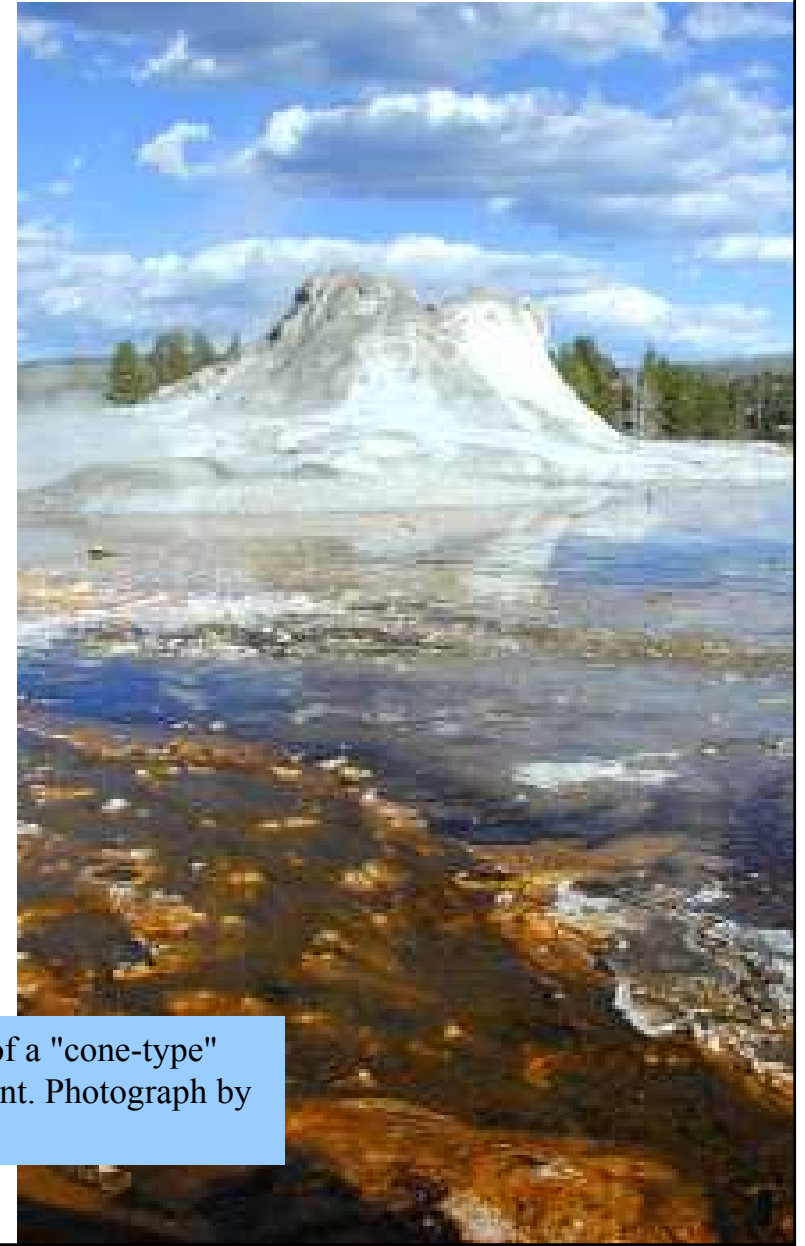
- MVT (literatura: Rozložník, Evans)
- mědinosné břidlice (Mansfeld)
- nízkoteplotní Hg-formace (Idria – Slovinsko, Almaden – Španělsko)



Cu-nosné břidlice - Mansfeld

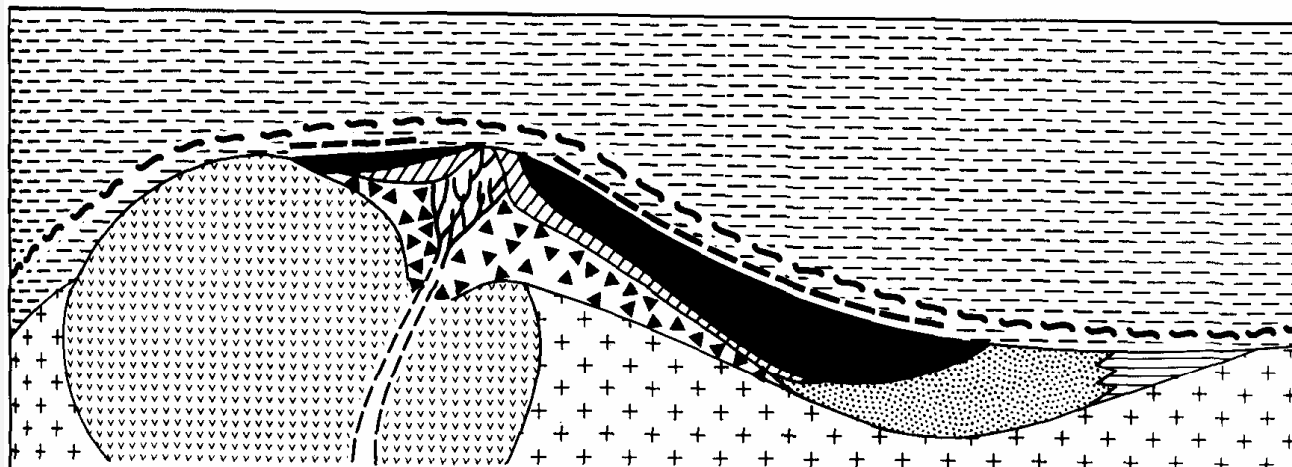
- amagmatická hydrotermálně sedimentární lož. (liter.:Rozložník)
- mansfeldské břidlice
- Lubin, Polsko
- Copperbelt, Zambie

Vulkanoexhalační, krustální, hydratogenní














Castle Geyser in the Upper Geyser Basin, a particularly good example of a "cone-type" geyser with a prominent cone of siliceous sinter enclosing the geyser vent. Photograph by S.R. Brantley, U.S.G.S., on 23 May 2001

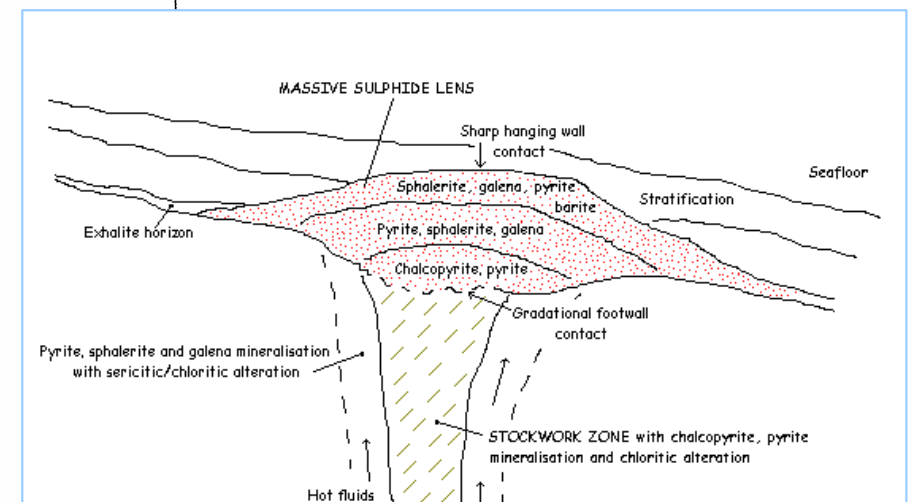
Vulkanosedimentární h.l. - příklady



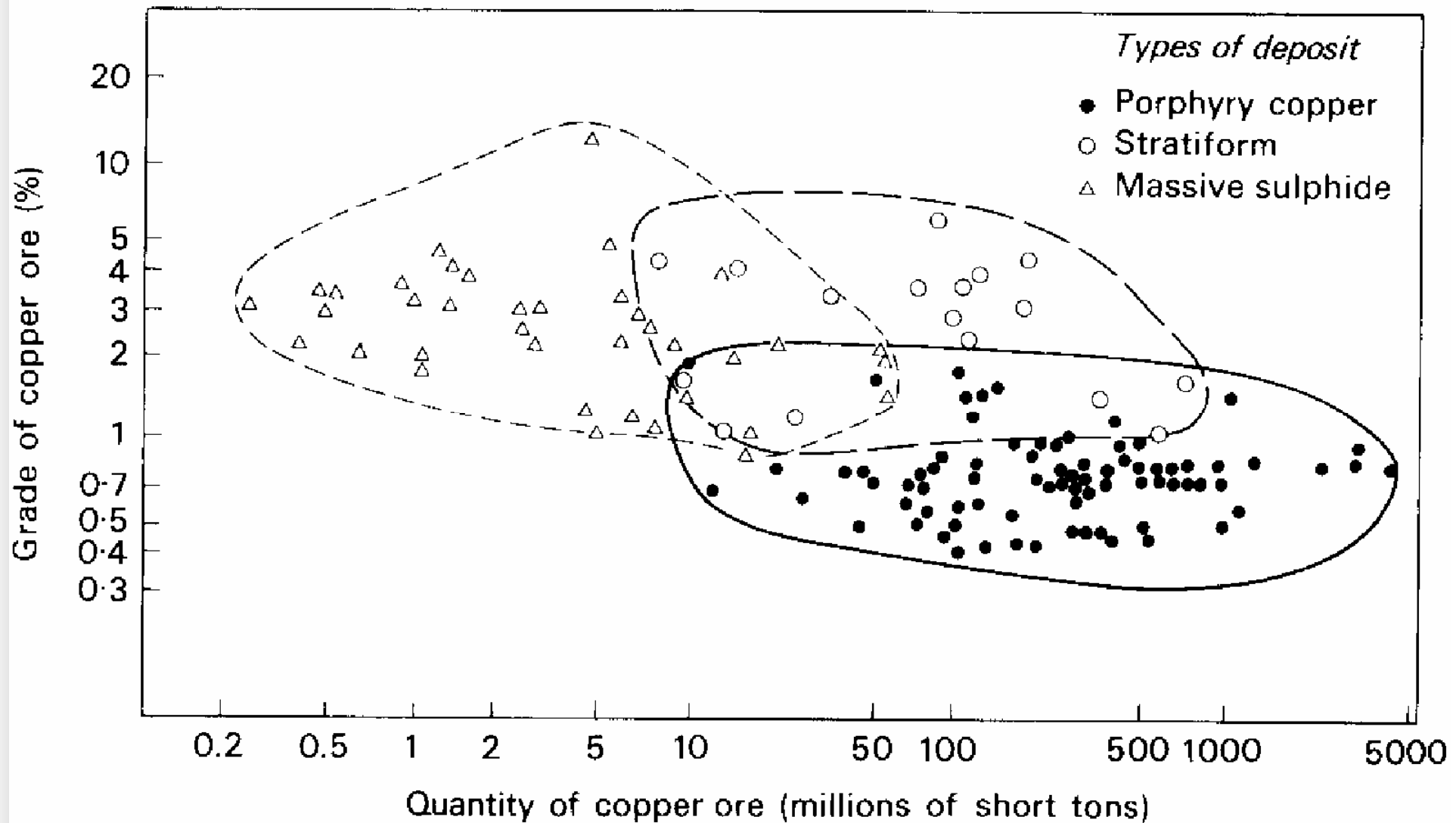
Kuroko

zonálnost rudních těles

- | | | | |
|---|--|---|-------------------|
|  | Acid tuff |  | Gypsum |
|  | Ferruginous chert zone |  | Clay |
|  | Baryte deposit |  | Explosion breccia |
|  | Stockwork |  | Rhyolite dome |
|  | Kuroko or black ore,
galena-sphalerite-baryte |  | Acid tuff breccia |
|  | Oko or yellow ore,
pyrite-chalcopyrite | | |



Tonáž a kvalita rud





Vulkanosedimentární - stratiformní

- v horninových komplexech různého stáří
- polymetalické formace, u distálních mineralizací často baryt
- minerály
- stavba těles, ložisek a rudních polí
- SEDEX (**s**edimentary **e**xhalative)
- VMS (**v**olcanogenic **m**assive **s**ulphides)



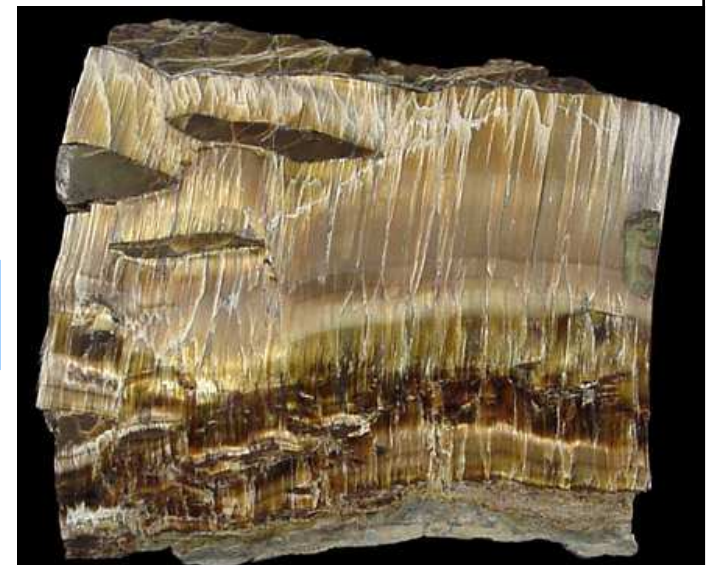
Příklady – vulkanosediment.1.

- Zlaté Hory, vrbenská skupina (D)
- Rio Tinto, Aznalcollar, Meggen, Rammelsberg (Hartz)

Příklady – metamorfně hydrotermální ložiska

- žíly „alpské parageneze“
- křemenné žíly v epimetamorfitech
- mastek, chrysotil (asbest)
- Au-křemenné žíly

chrysotil - $\text{Mg}_3(\text{Si}_2\text{O}_5)(\text{OH})_4$



Typy hydrotermálních ložisek s.l.

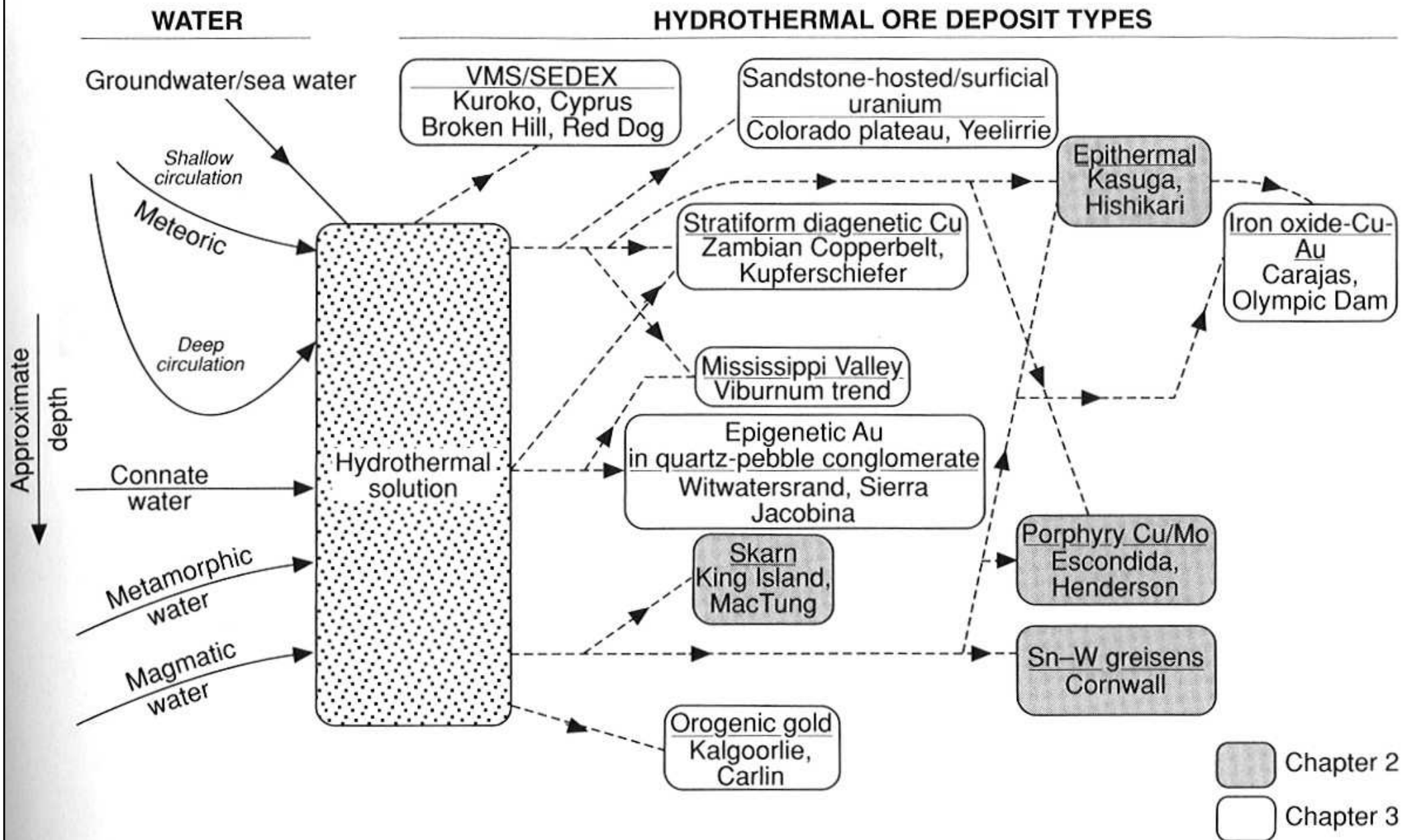
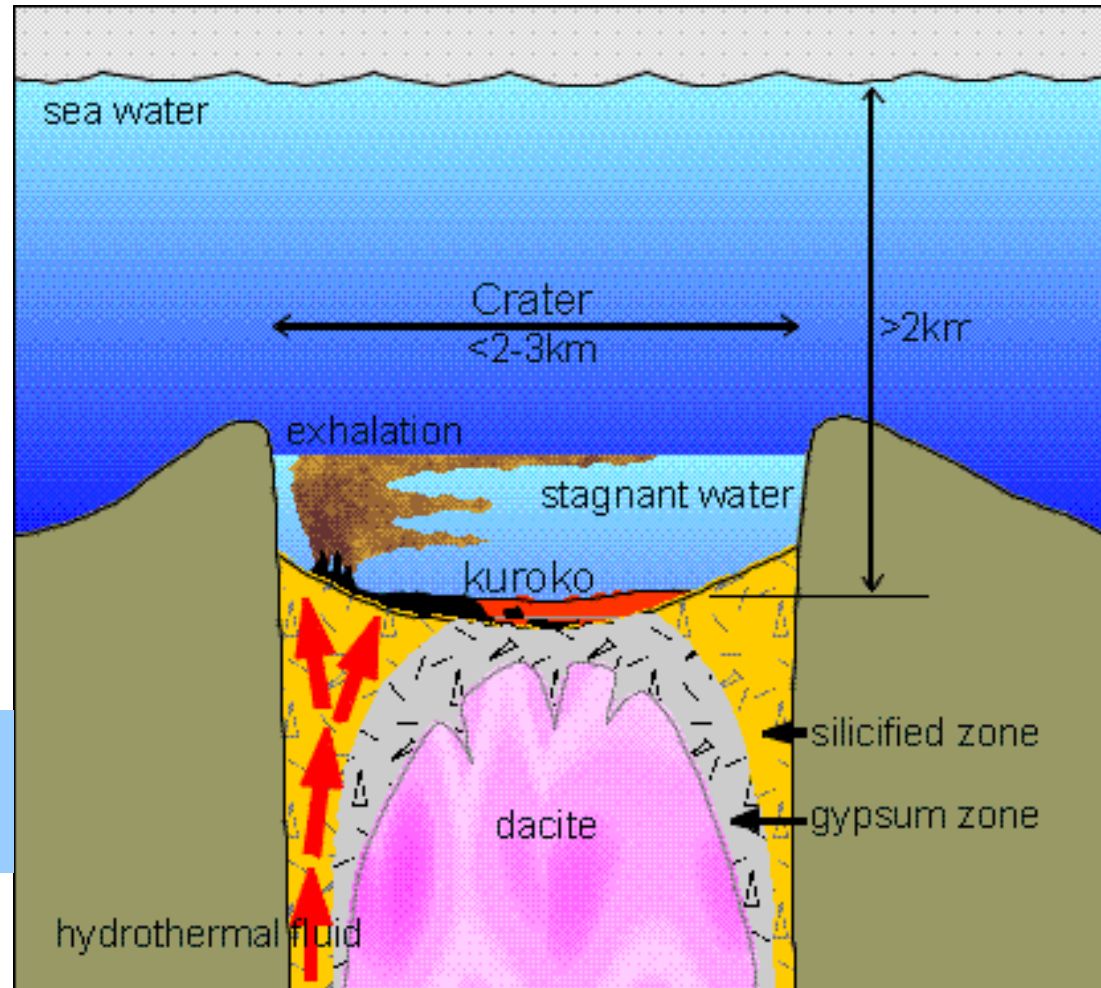


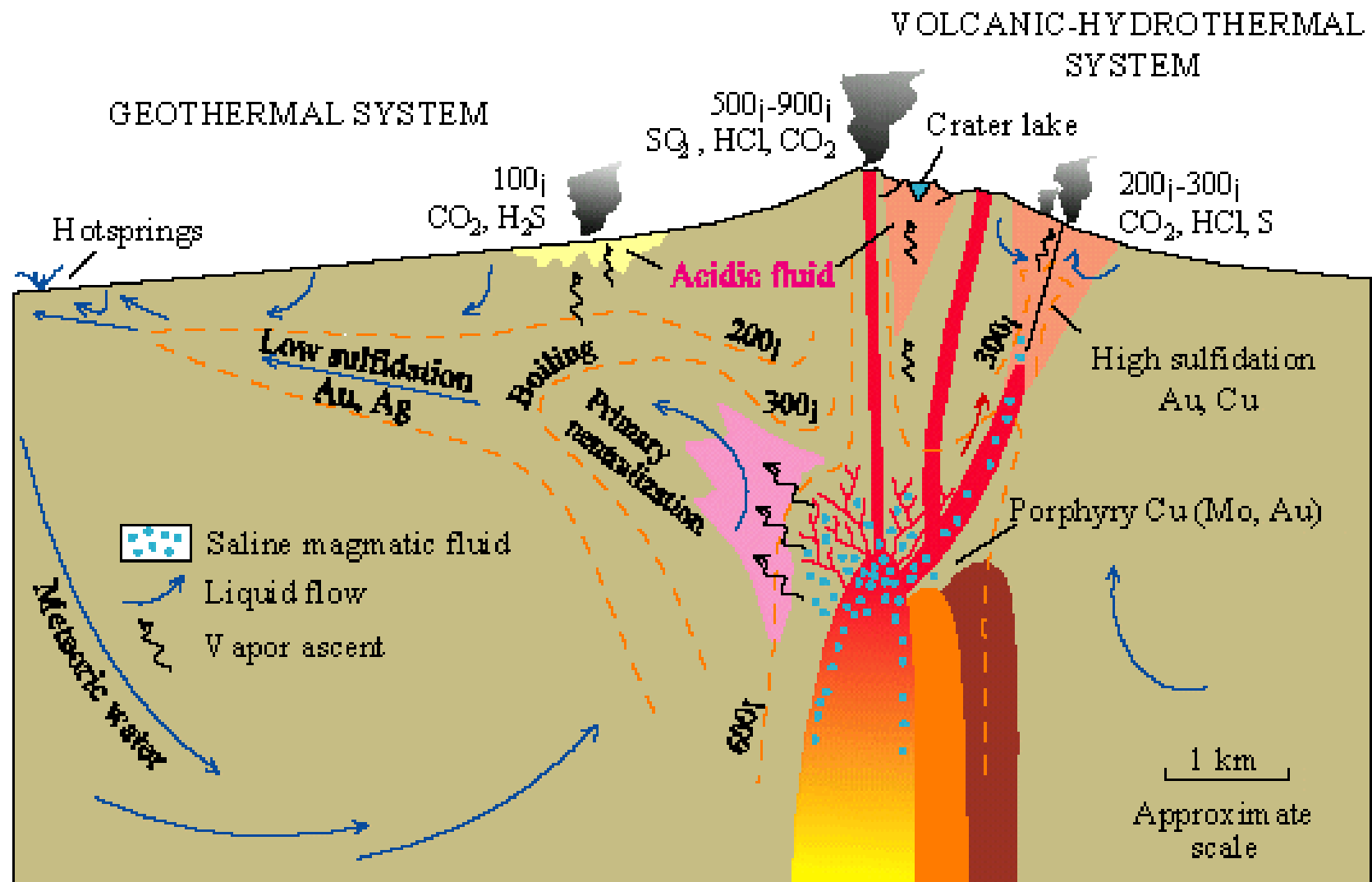
Figure 3.38 Diagram illustrating the relationship between different fluid types and various hydrothermal ore deposit types. The diagram is relevant to both Chapters 2 and 3, and is modified after Skinner (1997).

Kuroko

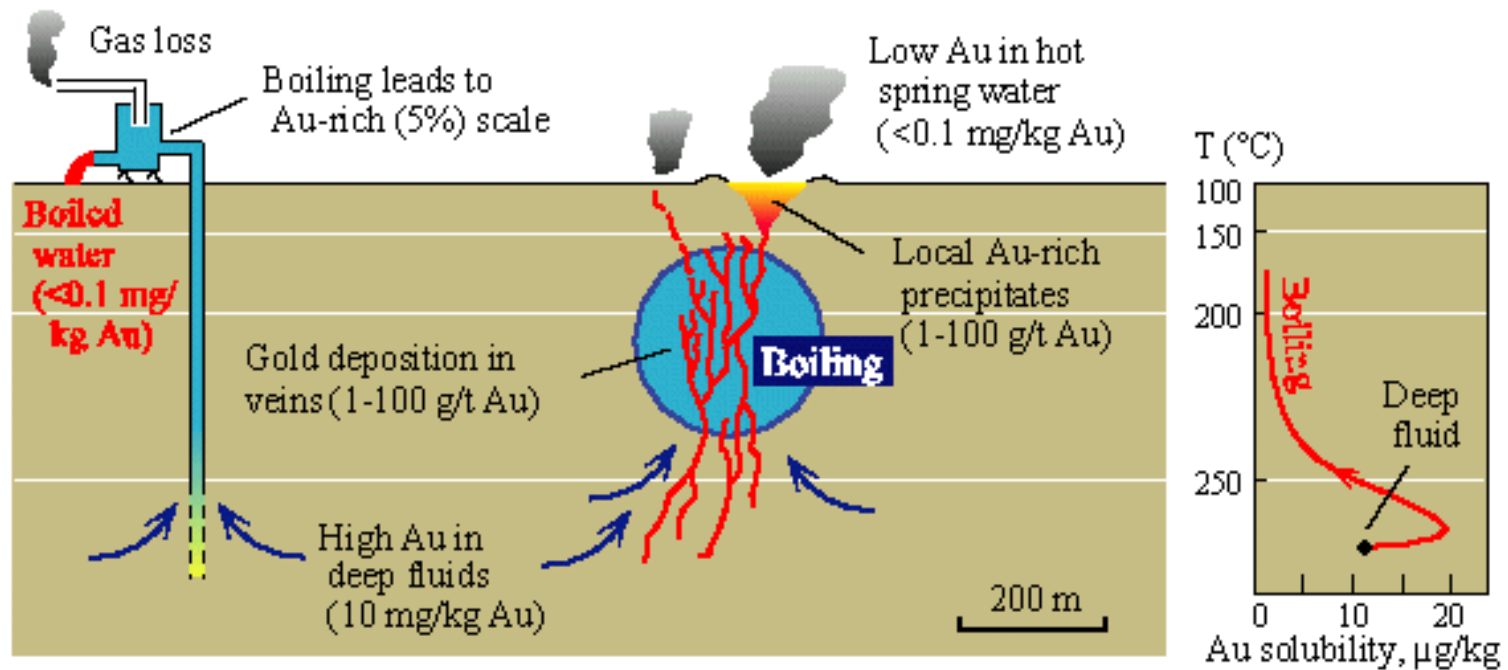
Kuroko Style "Black Smoker"
lead-zinc-silver deposits



Volcanic hydrothermal and geothermal systems

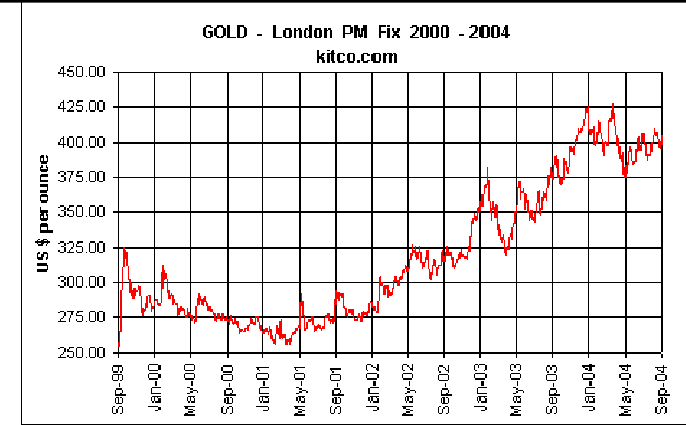


Epithermal - Au



Epithermal "Hot Springs"
Gold Deposits

Au – 2004-2005



1 Year Gold (\$USD)

March 09, 2004 to March 08, 2005

MAX \$454.20 on Dec 02, 2004 , MIN \$375.00 on May 10, 2004

