Magmatogenní ložiska

v horninách ultrabazických, bazických, karbonatitech, pegmatitech

Rozložník: kap.2.1, 2.2, 2.3
Evans: kap. 7 až 11

Genetická klasifikace magmatogenních ložisek

vývoj magmat: ultrabazických, bazických, alkalických, karbonatitových, pegmatitových

hlavní lož. teorie = procesy:	klasifikace - ložiska:
1. magmatická krystalizace	- raněmagmatická - pozdněmagmatická
2. magmatická segregace: - frakční krystalizace - likvace	- likvační - karbonatitová - pegmatitová

Hlavní průmyslové suroviny

- určité suroviny jen v magm.ložiskách
- Cr, Co, Ni, Cu, V, Au, REE, PGM (Pt, Pd, Rh, Ru, Ir, Os), diamanty
- Fe-Ti-V
- Nb, Li, Be, živce, slídy, křemen
- obecné hlavní rysy distribuce ložisek a zásob

Mechanismy vzniku magm.lož.

- frakční krystalizace
- filter-pressing (oddělení kap.fáze)
- nemísitelnost silikát/oxidická, silikát/sulfidická (fS_2, fO_2)
- clastering

faktory:

- magma mixing
- změny koncentrace např. S
- fO_2
- kontaminace magmatu

Raně magmatická ložiska (proto-)

- chromit – $FeCr_2O_4$
- diamanty
- titanit, magnetit – Ti, V

… krystalizace

Cr - chromit

- reefs – chromitové polohy (stratiformní)

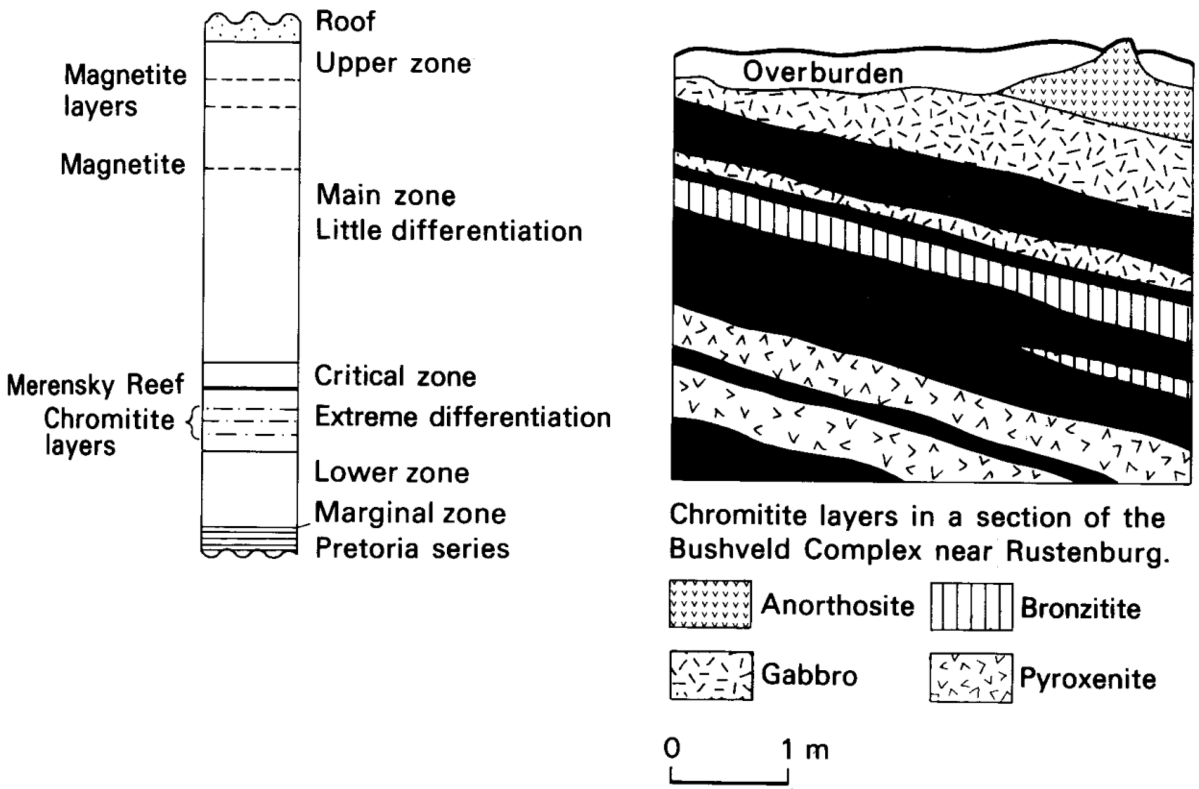
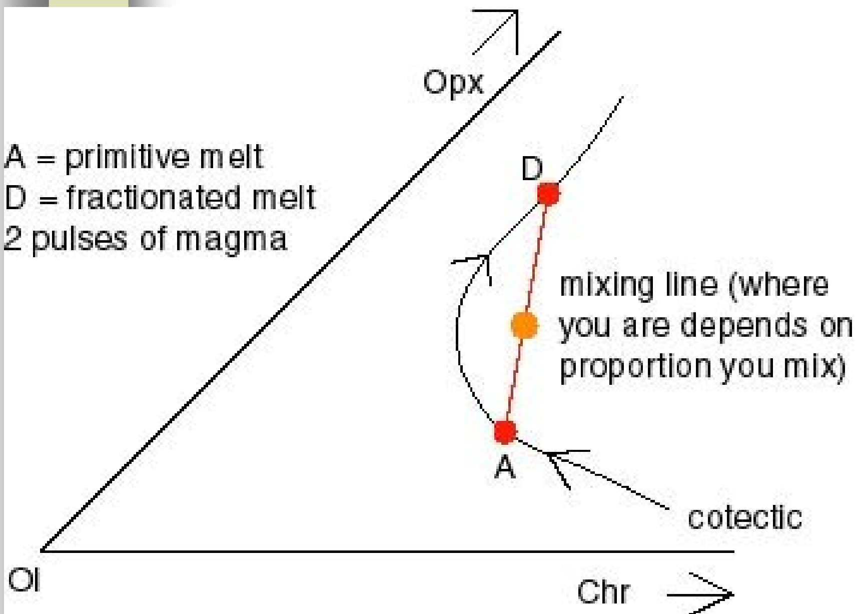
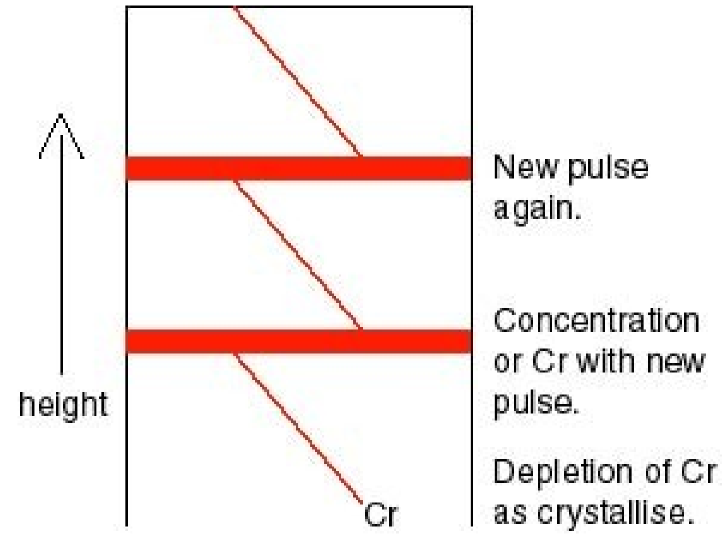


Fig. 12.2 Sections showing the occurrence of econonic minerals in the Bushveld Complex.

Vznik chromitových poloh



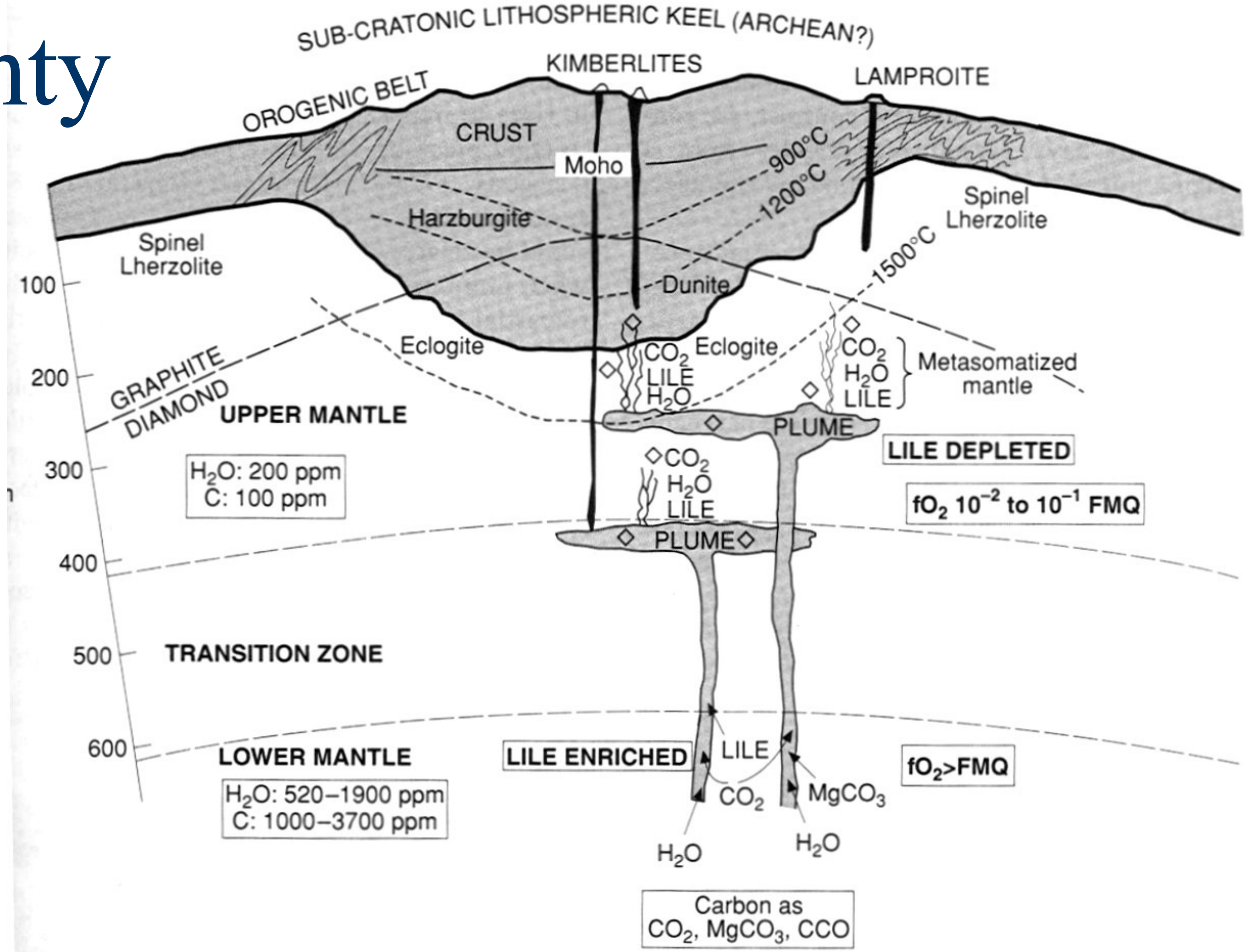


- petrologická rovnováha olivín-chromit-pyroxen

To form a chromite deposit you have to saturate in chrome. Basalts usually have some chrome in them but are not saturated. The way to do this is to mix melts. The first (primitive) melt is fractionated (A to D), then a new magma pulse introduces more primitive melt A to mix with D and so chrome saturation occurs. Chromite crystallises first out of the melt, and after that the melt is depleted in chrome. If you then add another Cr-rich melt to the remaining melt, you crystallise chromite again. Chrome doesn't go into sulfides.

Diamanty

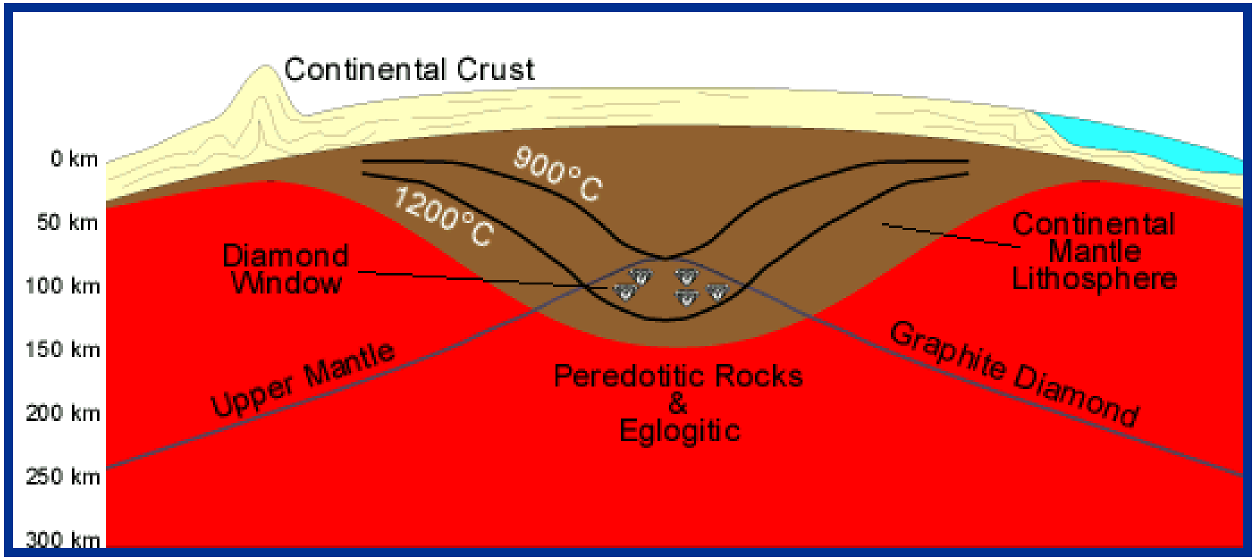
LILE: Light Element, Lithophile elements, (Cs, Rb, Ba, Th, U, K, Nb, Ta and the light REE.) What I once termed the "Residual Elements", those that are the last to form crystals in a cooling magma.

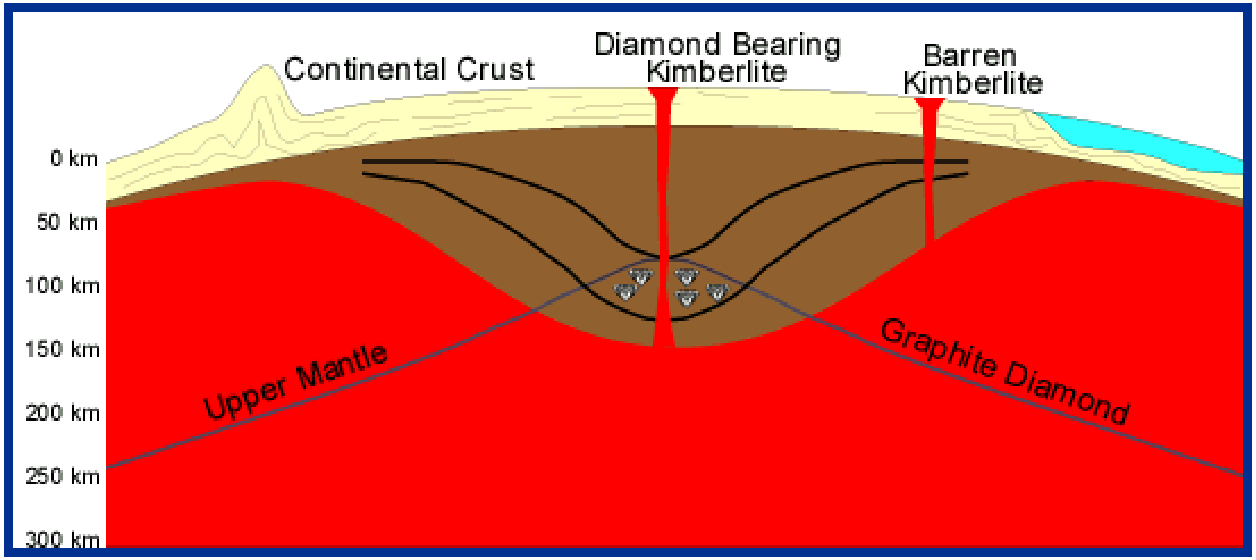


ure 1.8 Schematic diagram illustrating features pertinent to the formation of diamond and the fertilization he Earth's mantle by plume-related magmas and their associated aqueo-carbonic fluids (after Haggerty, 1999). E refers to the large ion lithophile elements; FMQ refers to the fayalite–magnetite–quartz oxygen buffer.

- proč jsou diamanty jen na určitých místech?
- lamproity (vys.obsah K, různé stáří) / kimberlity (v kratonech)

Diamanty


Continental Crust
0 km
50 km
100 km
150 km
200 km
250 km
300 km
900°C
1200°C
Diamond Window
Continental Mantle Lithosphere
Upper Mantle
Peredotitic Rocks & Eglogitic
Graphite Diamond


Continental Crust
Diamond Bearing Kimberlite
Barren Kimberlite
0 km
50 km
100 km
150 km
200 km
250 km
300 km
Upper Mantle
Graphite Diamond

Ložiska diamantů

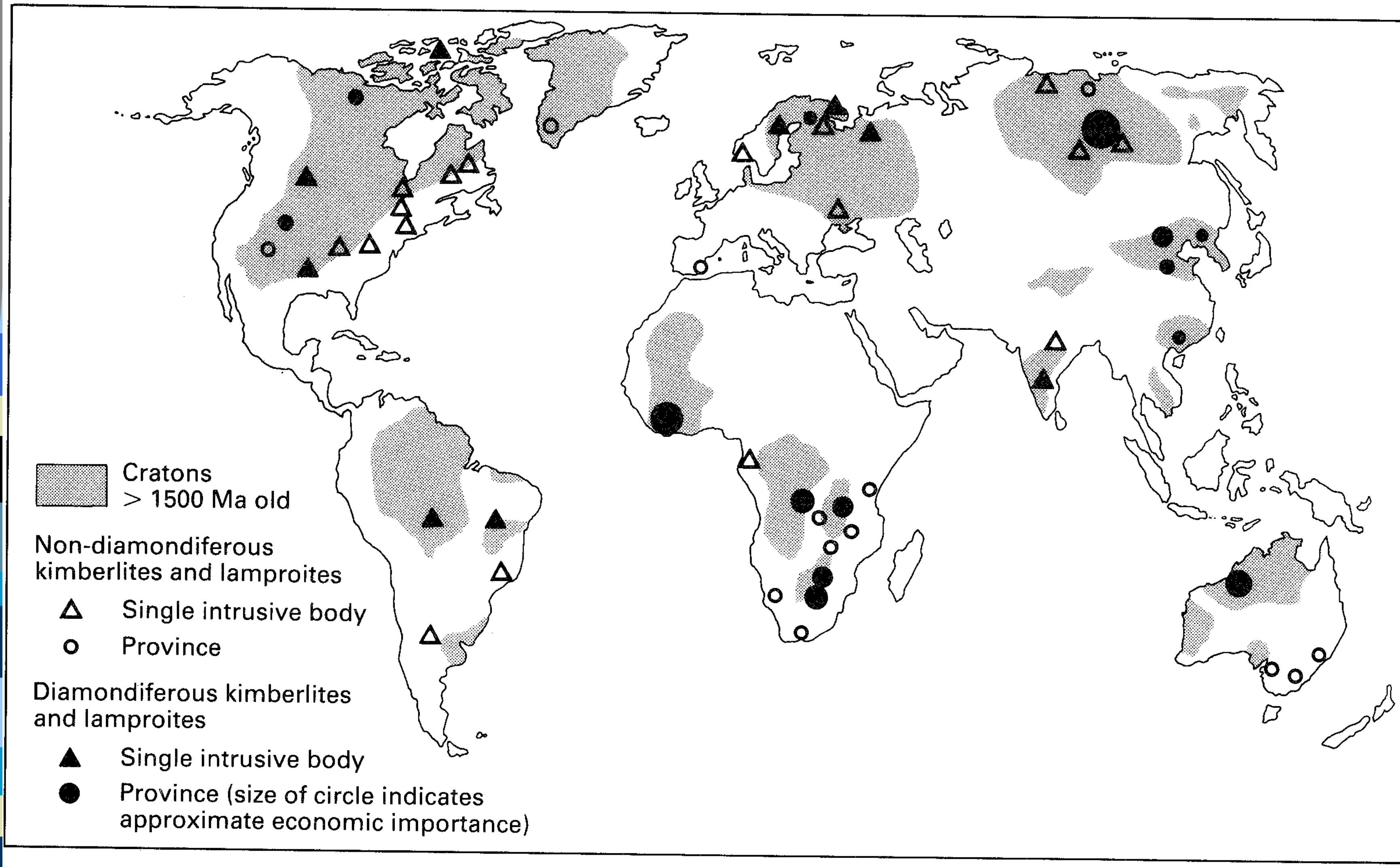


Fig. 9.1 Distribution of diamondiferous and non-diamondiferous kimberlites and lamproites.

Likvační ložiska

- původ magmatu a nemísitelnost
- Cu-Ni formace (cp, pentlandit)
- Pt formace (feroplatina aj.)

Norilsk

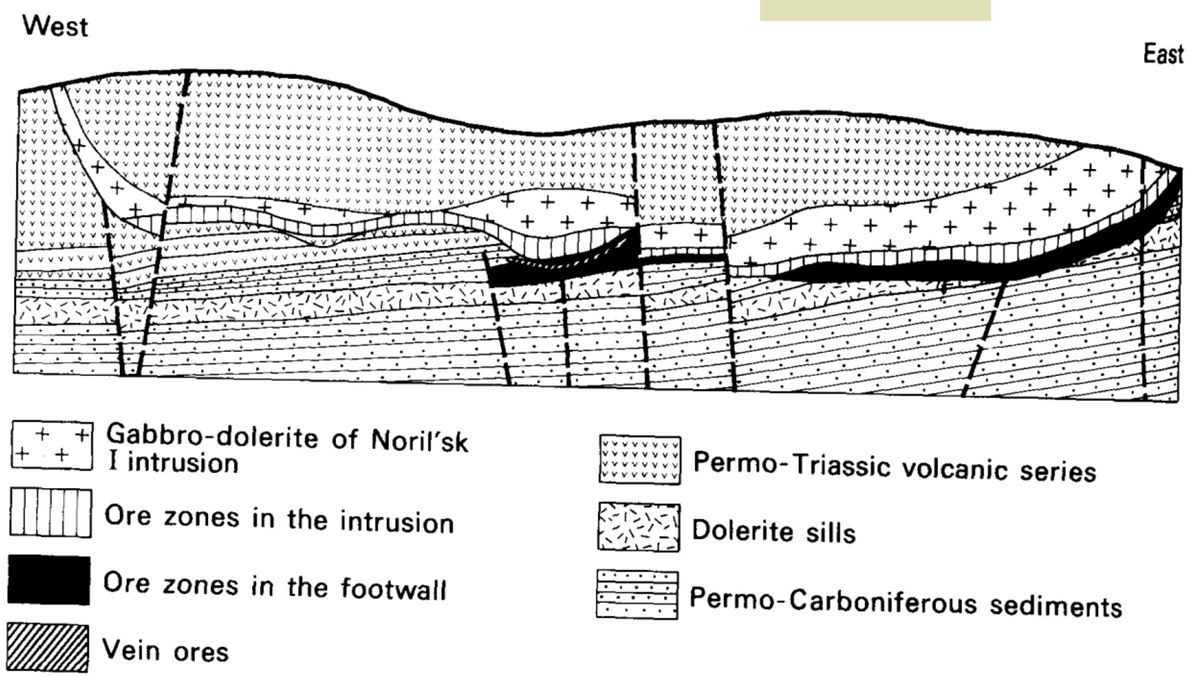
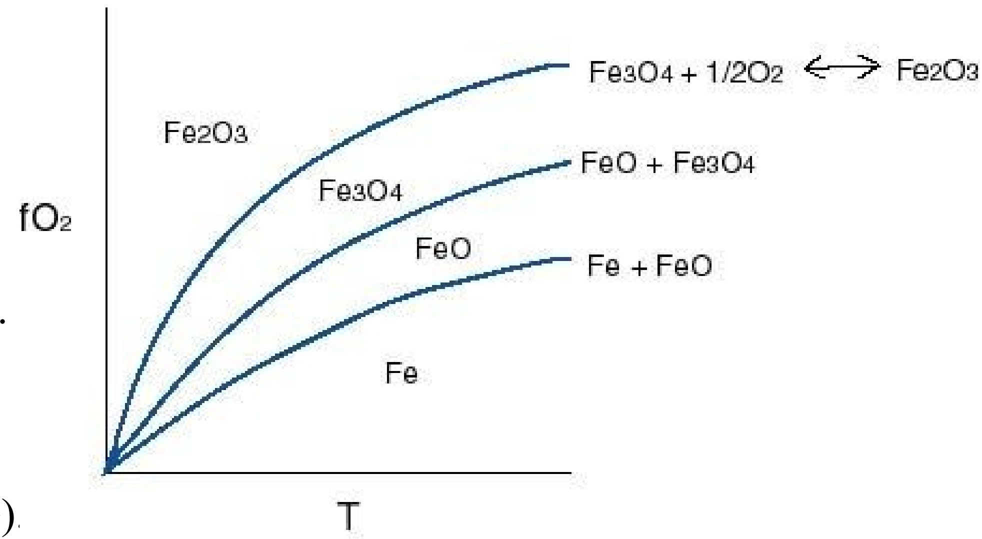


Fig. 13.8 Cross section through the Noril'sk I deposit.

Vliv Fe, Si na vlastnosti taveniny

The amount of sulfur in the melt depends on iron, fO_2, fS_2 :
$FeO + {}^1/_2S_2 = FeS + {}^1/_2O_2$
fO_2 is a function of the activity of oxygen as a function of temperature. The oxidation states of iron, in increasing oxidation state, are as follows: Fe (iron) - FeO (wustite) - Fe_3O_4 (magnetite) - Fe_2O_3 (hematite).



Frakcionace snižuje FeO v tavenině – krystaluje olivín - (Mg, Fe)$_2$SiO$_4$ – zvyšuje se koncentrace S.
Vliv SiO_2 – vysoká polymerizace taveniny vede ke zvýšení koncentrace S (neváže se v silikátech), příp. posun do pole nemísitelnosti silik. a sulf. taveniny.

PGE

tvorba klastrů

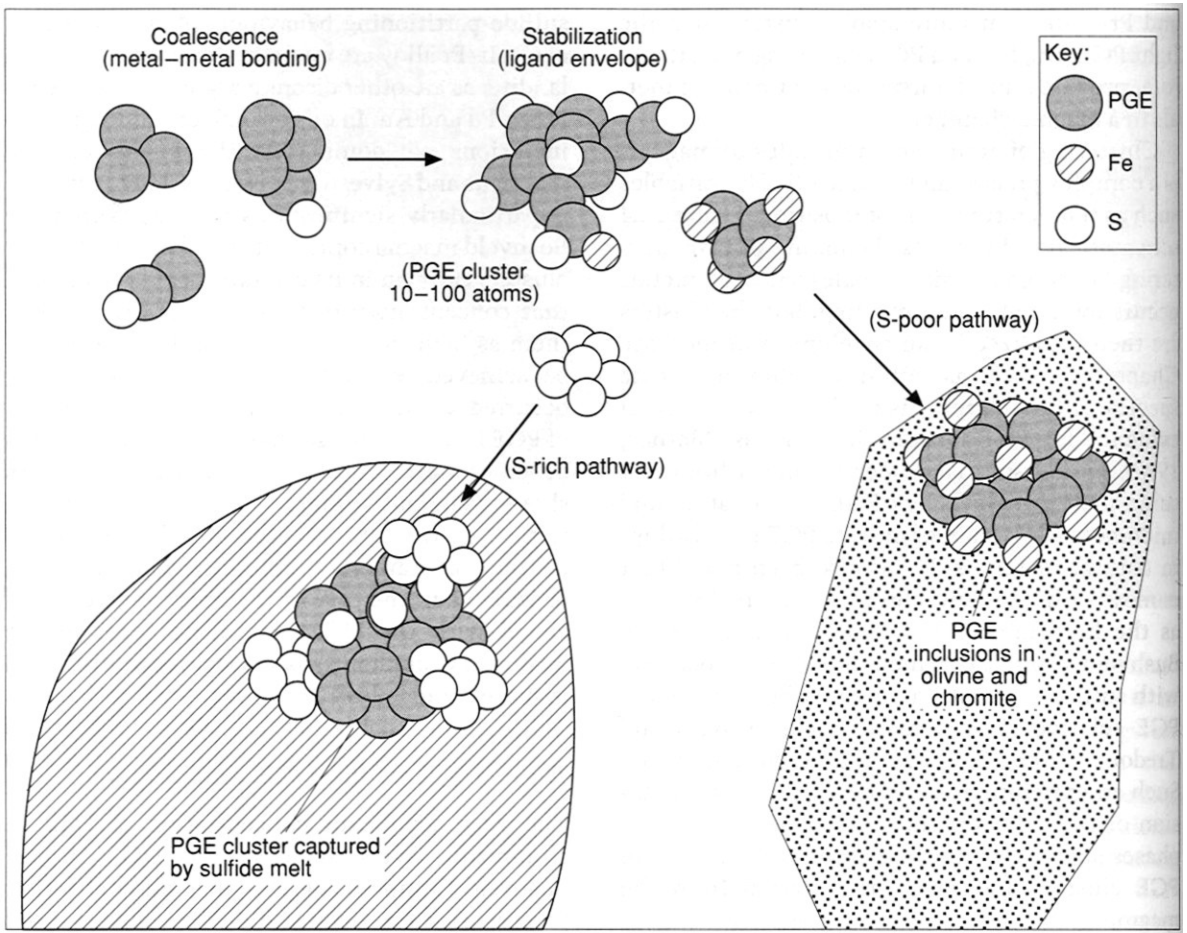
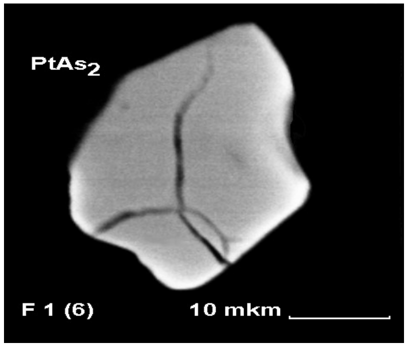
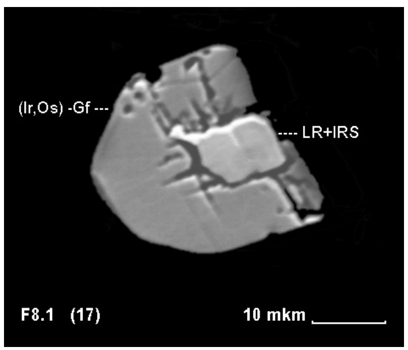


Figure 1.24 Schematic diagram illustrating the formation of PGE clusters in a magmatic system and their eventual inclusion either in an immiscible sulfide fraction (S-rich pathway) or in a silicate or oxide cumulus phase such as olivine or chromite (S-poor pathway) (after Tredoux *et al.*, 1995; Ballhaus and Sylvester, 2000).

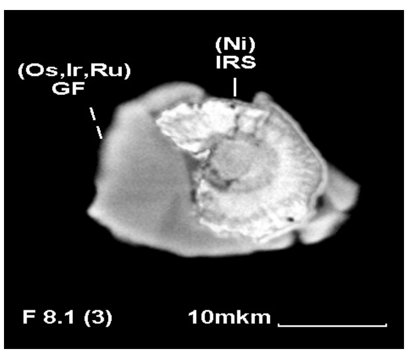
Platinum Group Minerals in Outocumpu Ophiolite Complex (Finland)



Euhedral grain of sperrylite (SP): $PtAs_2$



A grain of laurite (LR) with irarsite growth (fine long crystal adjoining at the left and above to LR) contained in (Ir,Os) gersdorffite(GF).).



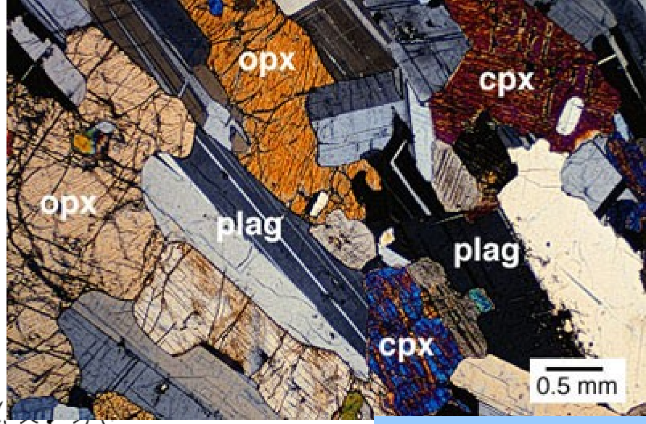
Irarsite of concretionary structure (Ni-IRS) contained in (Os,Ir,Ru) gersdorffite (GF): NiAsS. In irarsite is well defined hexagonal nucleus surrounded by radial and concentric zones of irarsite with variable contents of Os, Ir, Ru, Rh and Ni.

PGM - Outokumpu

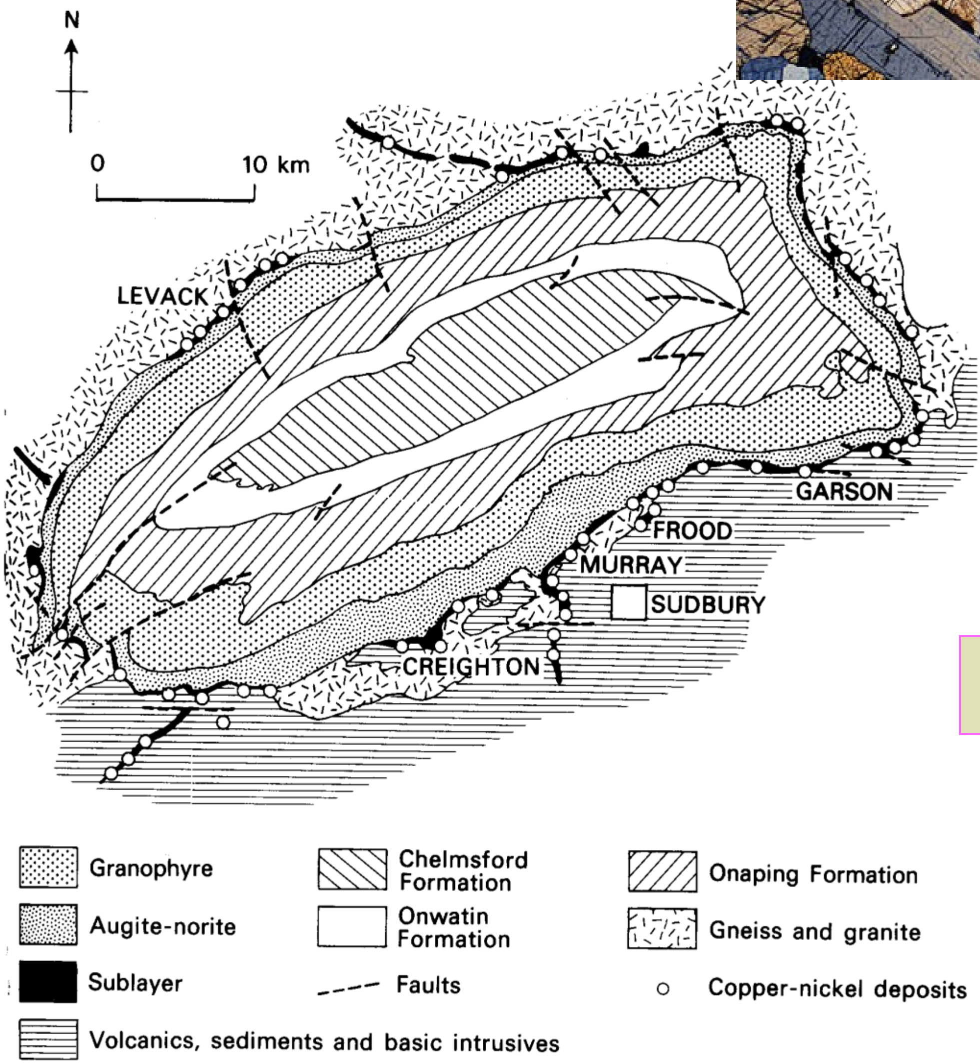
In heavy concentrates of samples were revealed the following minerals: chromite, ilmenite, pentlandite, nickeline, pyrite, gersdorffite, Co-gersdorffite, galenite, hedleyite, baddeleyite, native iron, tin, lead, cupper and also unknown Ni-Bi phases. As well were revealed well-known PGE minerals: erlichmanite, laurite, irarsite, osarsite, sperrylite, anduoite and also not mentioned in the reference mineralogical literature before - gersdorffite and Co-gersdorffite, containing Os, Ir, Ru and Rh in quantities - up to 15 mass % (Ru up to 1.7, Os up to 9.3, Ir up to 3.2, Rh up to 0.5).

Even at a sketchy analysis of enlisted minerals the attention is brought to the fact that the list contain minerals atypical for ultramafic sulphides: one's more common for metamorphic, metasomatic and hydrothermal rocks. Moreover, from the minerals enlisted above only pentlandite is typical and only for ultramafic complexes with copper-nickel specialization. From enlisted PGE minerals: laurite (RuS_2), erlichmanite (OsS_2) and sperrylite ($PtAs_2$) - are usual for Alpine-type ultramafic complexes. Sulphurasenides of osmium and iridium (irarsite, osarsite) and especially unusual phases (Os, Ir, Ru, Rh)-gersdorrfite were not described in a structure of chromitite deposits.

Sudbury district



norit



Cu-Ni±PGE

Fig. 13.5 Geological map of the Sudbury District.

Kambalda

Kambalda is a nickel deposit formed from a komatiite, a very ultramafic (MgO > 25% - 35%) magma that melts at about 1600°C (1 atm). In comparison, basalt contains ~ 12% MgO and melts at 1200°C (1 atm).

Cu-Ni

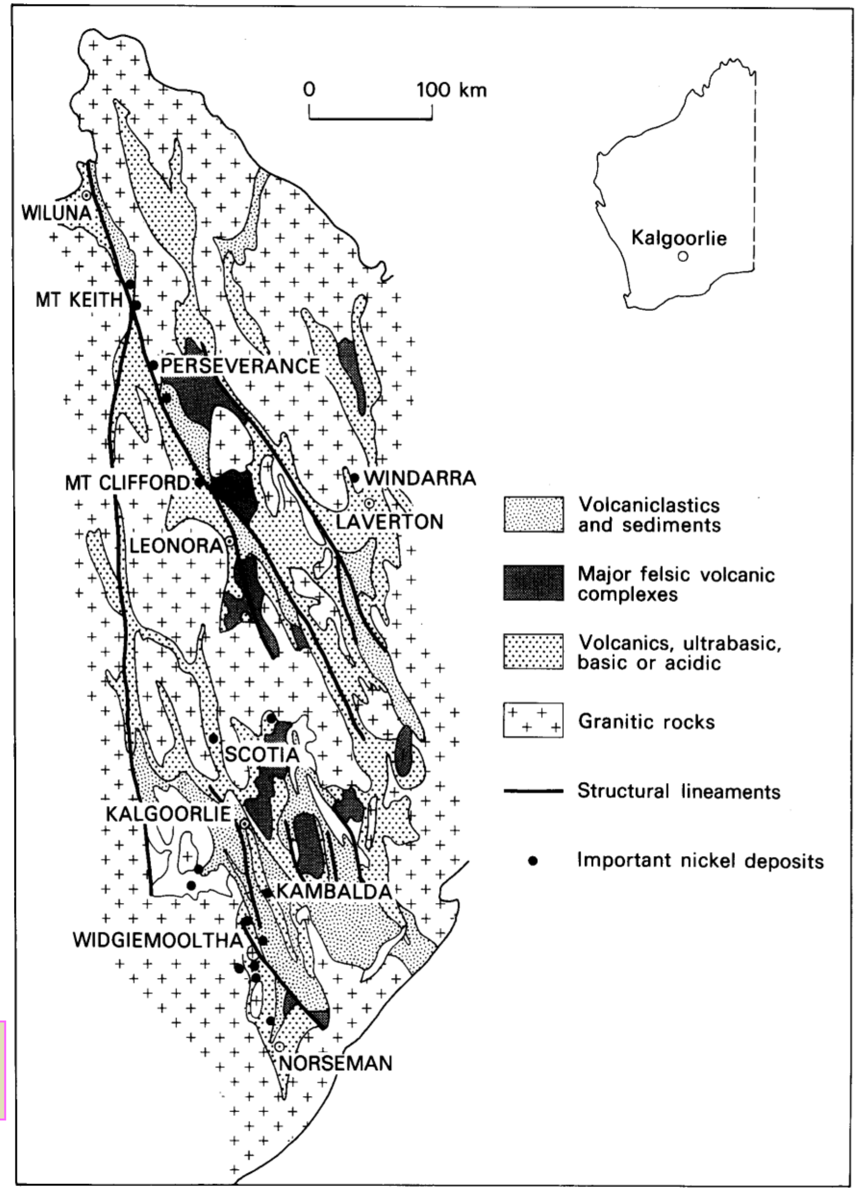


Fig. 13.3 Generalized geological map of the Eastern Goldfields Province of the Yilgarn Block showing some of the important nickel deposits.

Thin section of spinifex texture (needels of olivine, plagioclase, tremolite, chlorite) from a komatiite sampled from the Kaapvaal region of South Africa. Courtesy of Tim Grove.

Komatiite

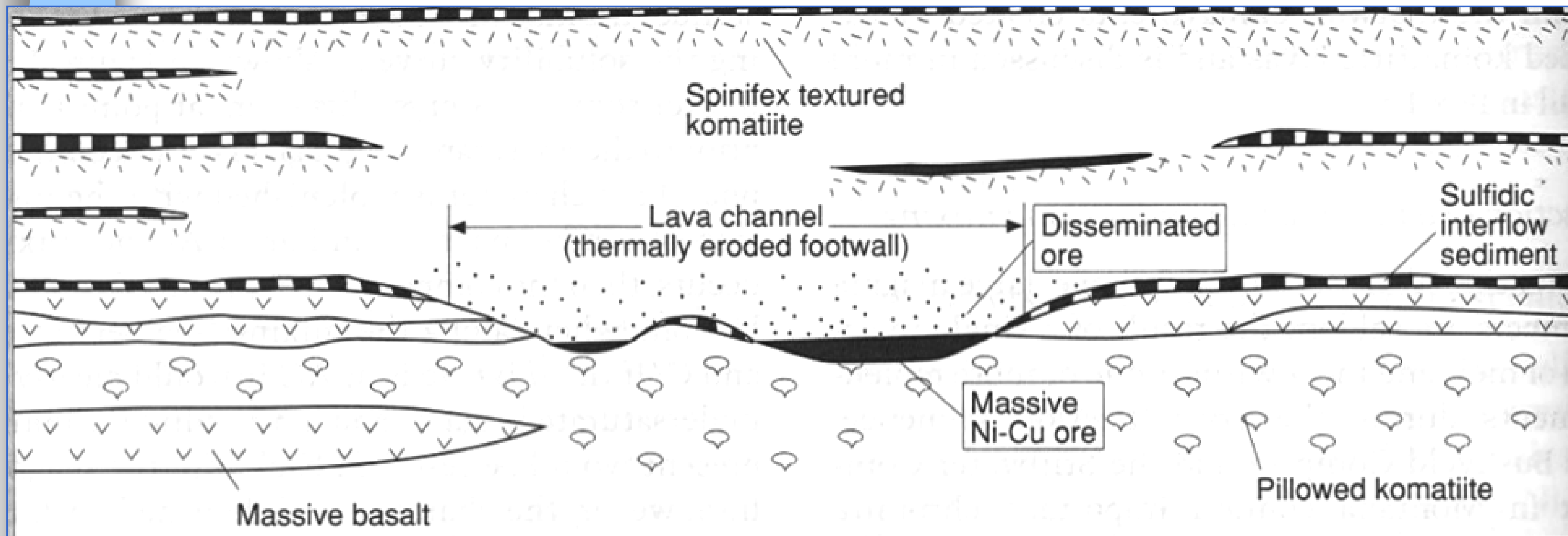
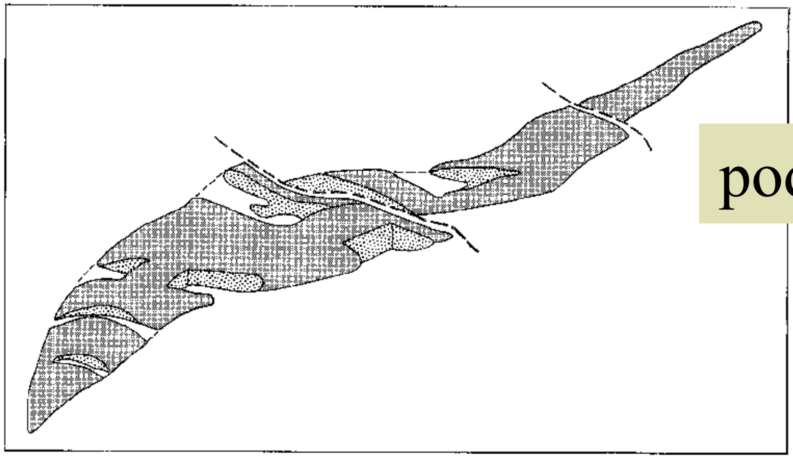


Figure 1 The characteristics of komatiite-hosted Ni–Ci deposits in the Kambalda region, Western Australia (after Solomon *et al.*, 2000).

Pozdněmagmatická ložiska

- Fe-Ti-V v anortositech (likvace?)
- Cr – chromit (podiformní tělesa), vznik s oceánskou kůrou, ale ložiska v ofiolitových formacích

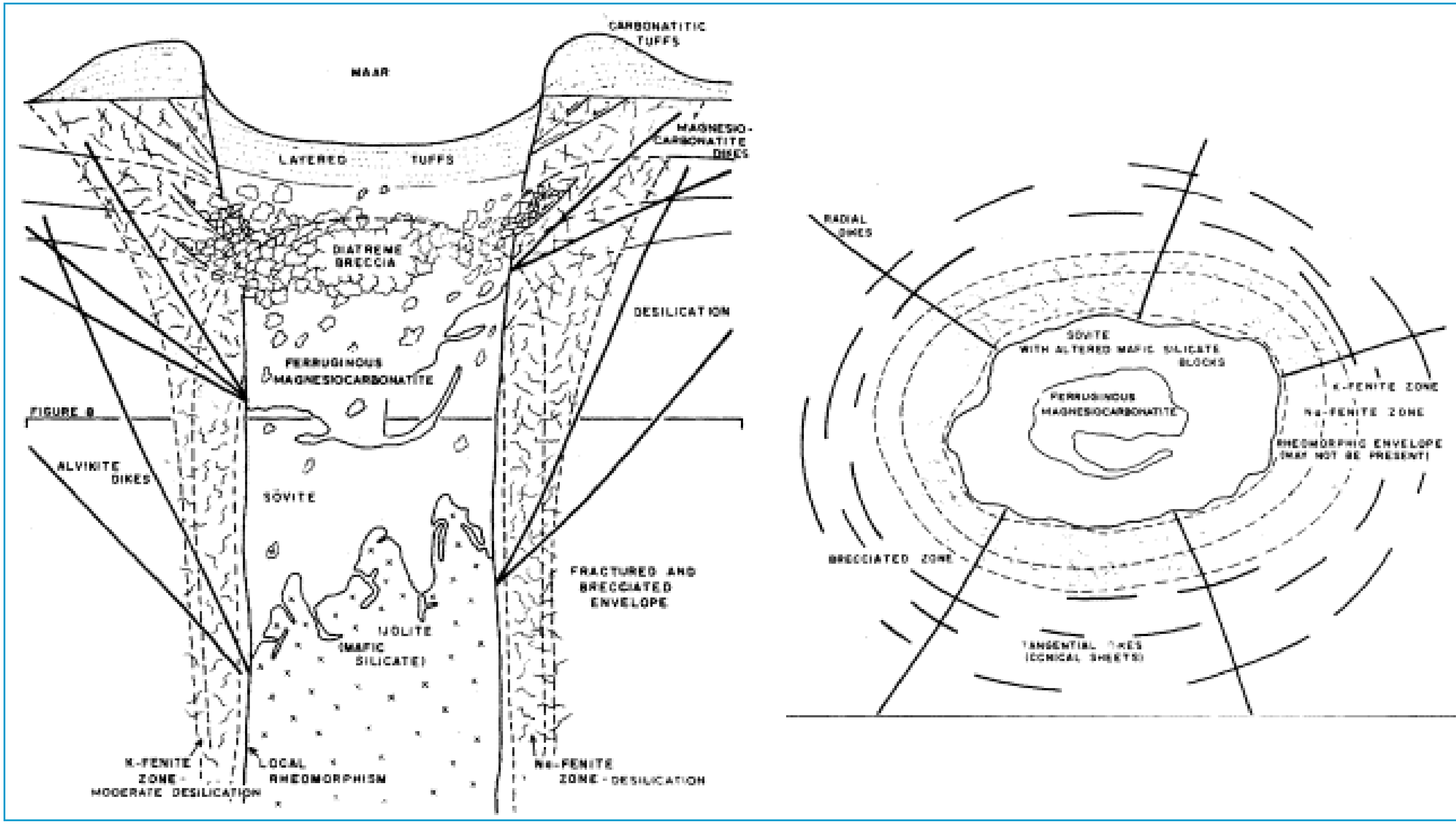


podiformní tělesa

Fig. 12.5 The Molodezhoe Orebody, Southern Urals. Length 1.4 km, width 200–300 m, maximum thickness 140 m, ore reserves about 90 Mt.

Karbonatity

- složení, průmysl
- ringové struktury
- petrologie – nemísitelnost, frakcionace
- pyrochlor, hatchettolit (Nb-Ta, +U) – oxidy monazit, bastnezit (karb.), parisit (karb.), magnetit
- Mountain Pass, Jacupiranga



Karbonatitový komplex

Schematic section and plan view (mid-level) of a carbonatite complex, showing cylindrical shape of intrusion that evolves upwards into a diatreme breccia and layered tuffs. Late dikes (bold lines) display a radial or concentric pattern. The intrusion consists of three phases: sövite (calcite-rich carbonatite), iron-rich magnesian carbonatite, and ijolite (nepheline-pyroxene rock). The host rocks are fenitized (alkaline metasomatism) and desilicified.

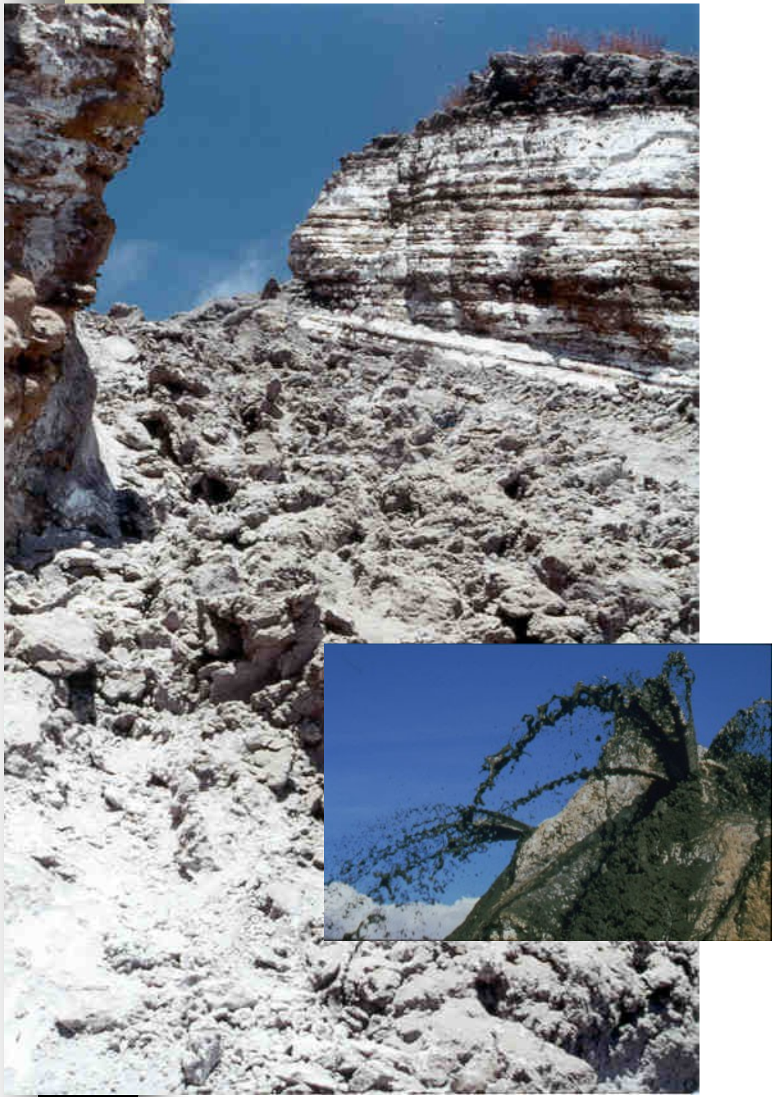
Karbonatitové magma

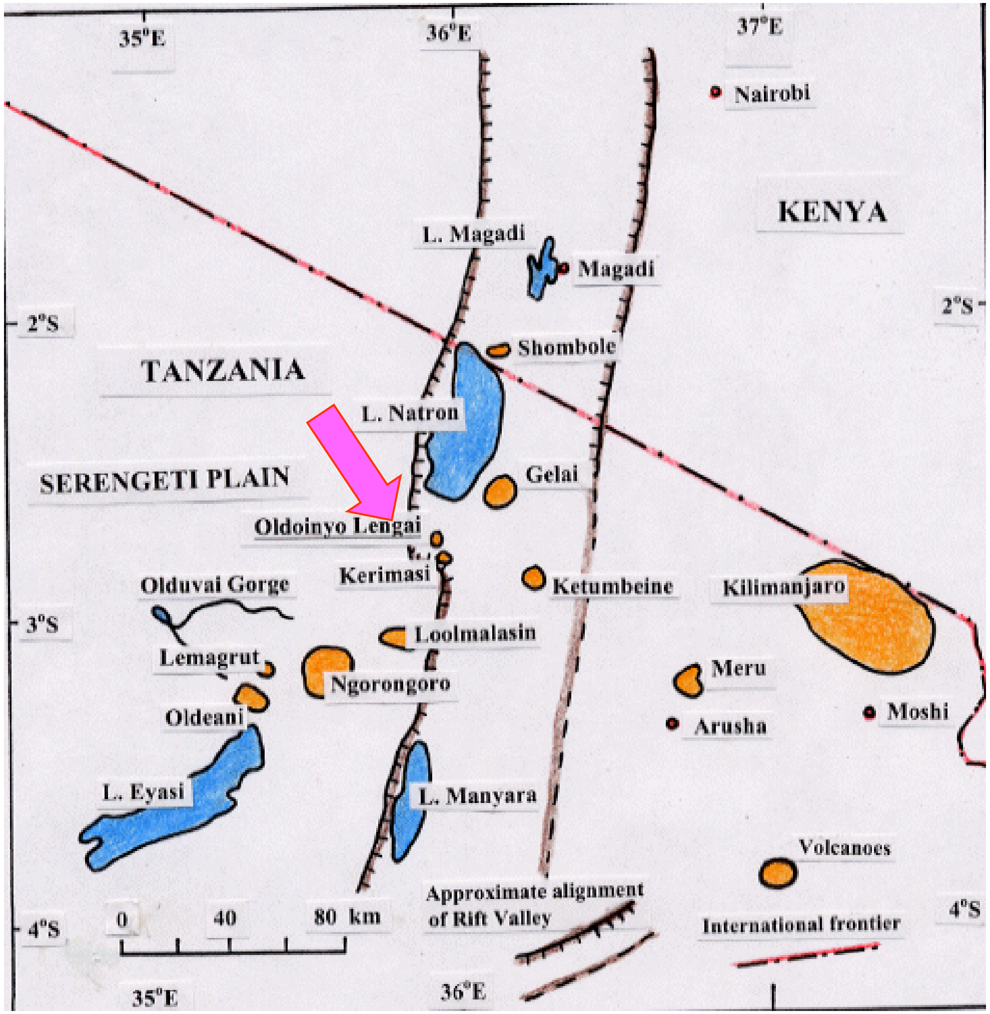
velmi nízká viskózita – nemá silikáty!

Natrocarbonatite is made up largely of two minerals, nyerereite and gregoryite. These minerals are both carbonates in which sodium and potassium are present in significant quantities. Both of these minerals are anhydrous (i.e they contain no water) and when they come into contact with the moisture of the atmosphere, they begin to react extremely quickly.

gregoryit - $(Na_2,K_2,Ca)CO_3$

Oldoinyo Lengai





Pegmatity

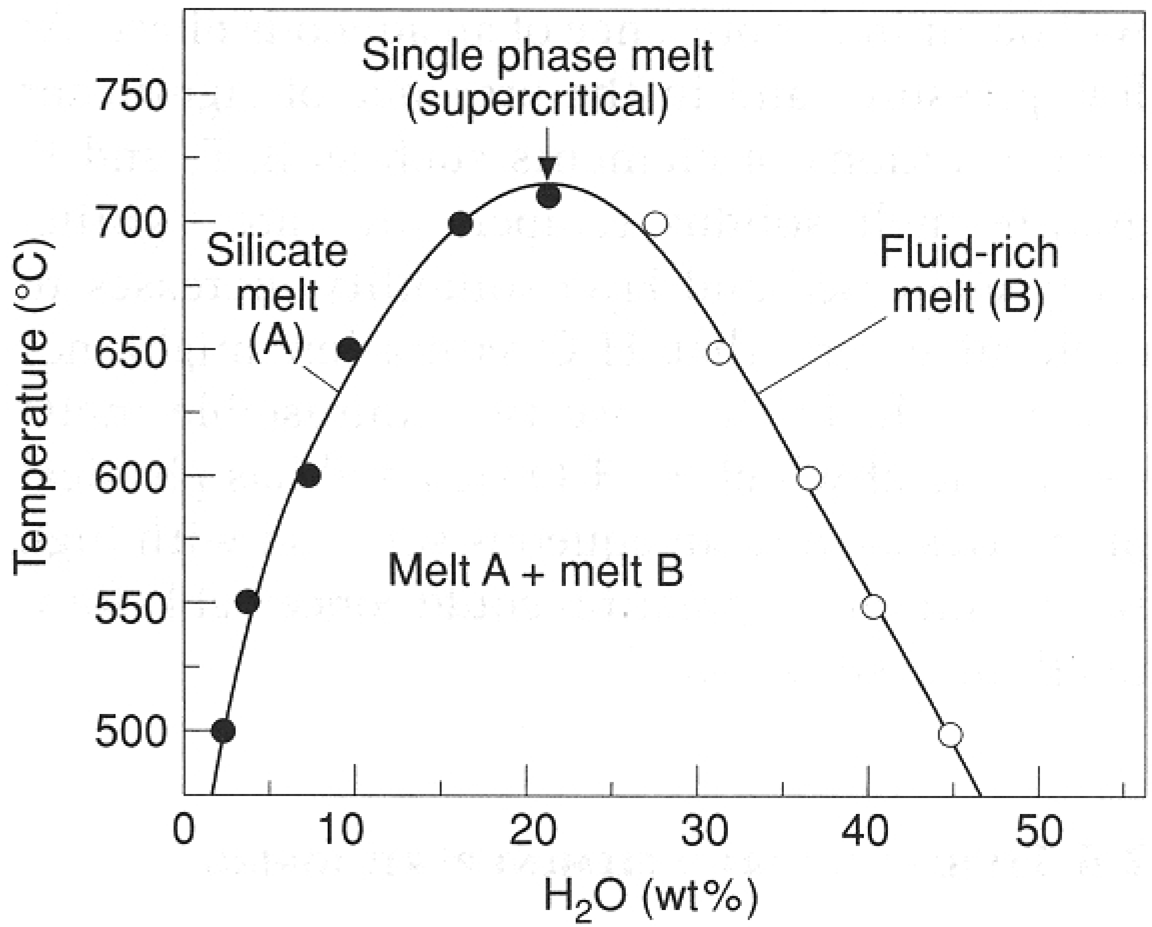
- souvislosti s magmatem (extrémní frakční krystalizace)
- zonálnost
- fluidní fáze bohatá na B, F, P, …

Jans-Burnham 1969 – model extrémní frakční krystalizace (vývoj od granitické stavby po pegmatitovou, oddělením nejmobilnějších komponent

Vznik pegmatitové stavby

- podchlazené magma – metastabilní podmínky krystalizace
- pomalá krystalizace – velká zrna
- nemísitelnost (immiscibility) fluid
- silikátová tavenina a fluidy bohatá tavenina s vodou (málo silikátů)

Fluid poor – fluid rich melt



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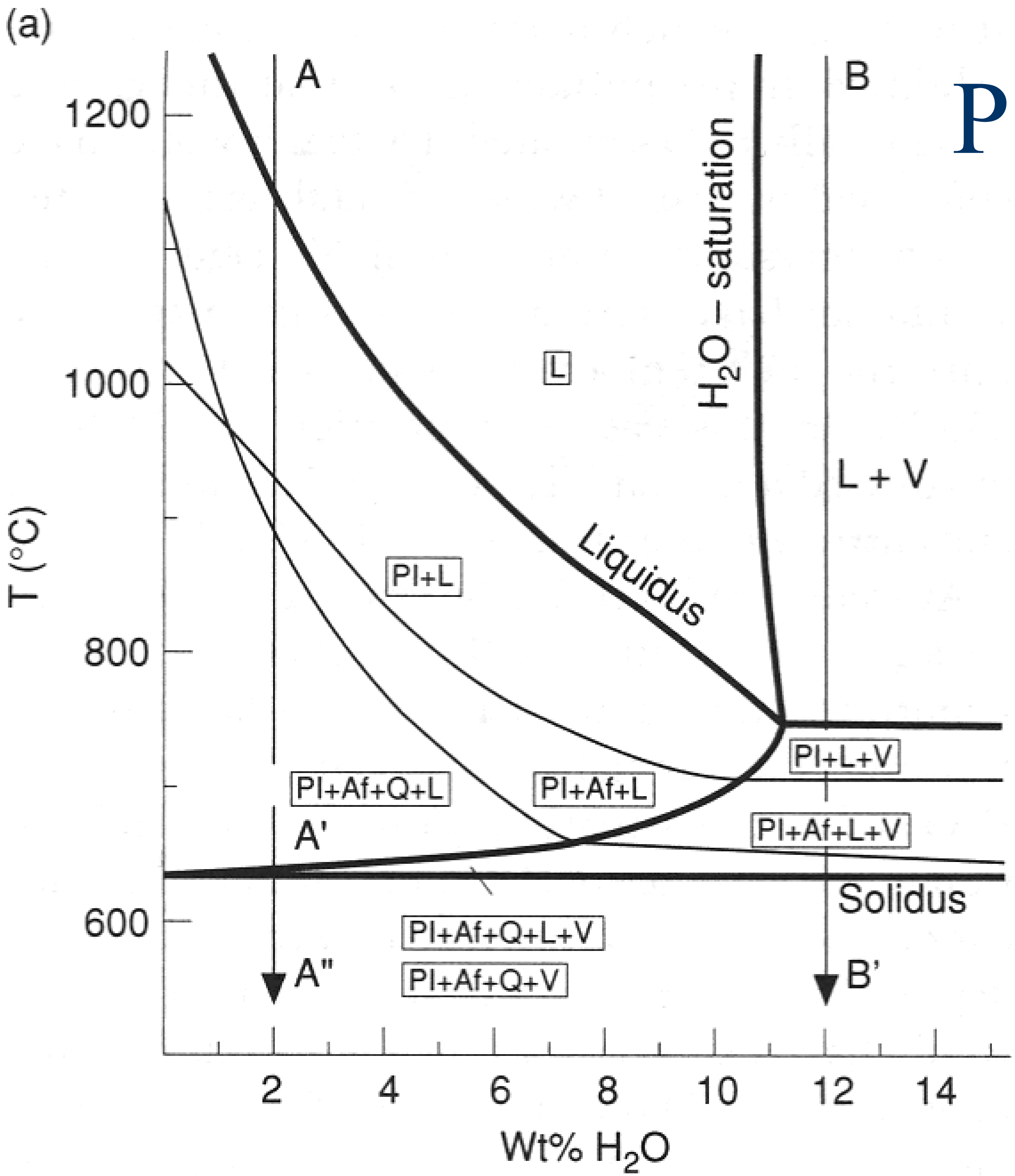

(a)
A
B
1200
1000
800
600
T (°C)
H$_2$O – saturation
L
L + V
Liquidus
Pl+L
Pl+L+V
Pl+Af+Q+L
Pl+Af+L
Pl+Af+L+V
A'
Solidus
Pl+Af+Q+L+V
Pl+Af+Q+V
A"
B'
2
4
6
8
10
12
14
Wt% H$_2$O

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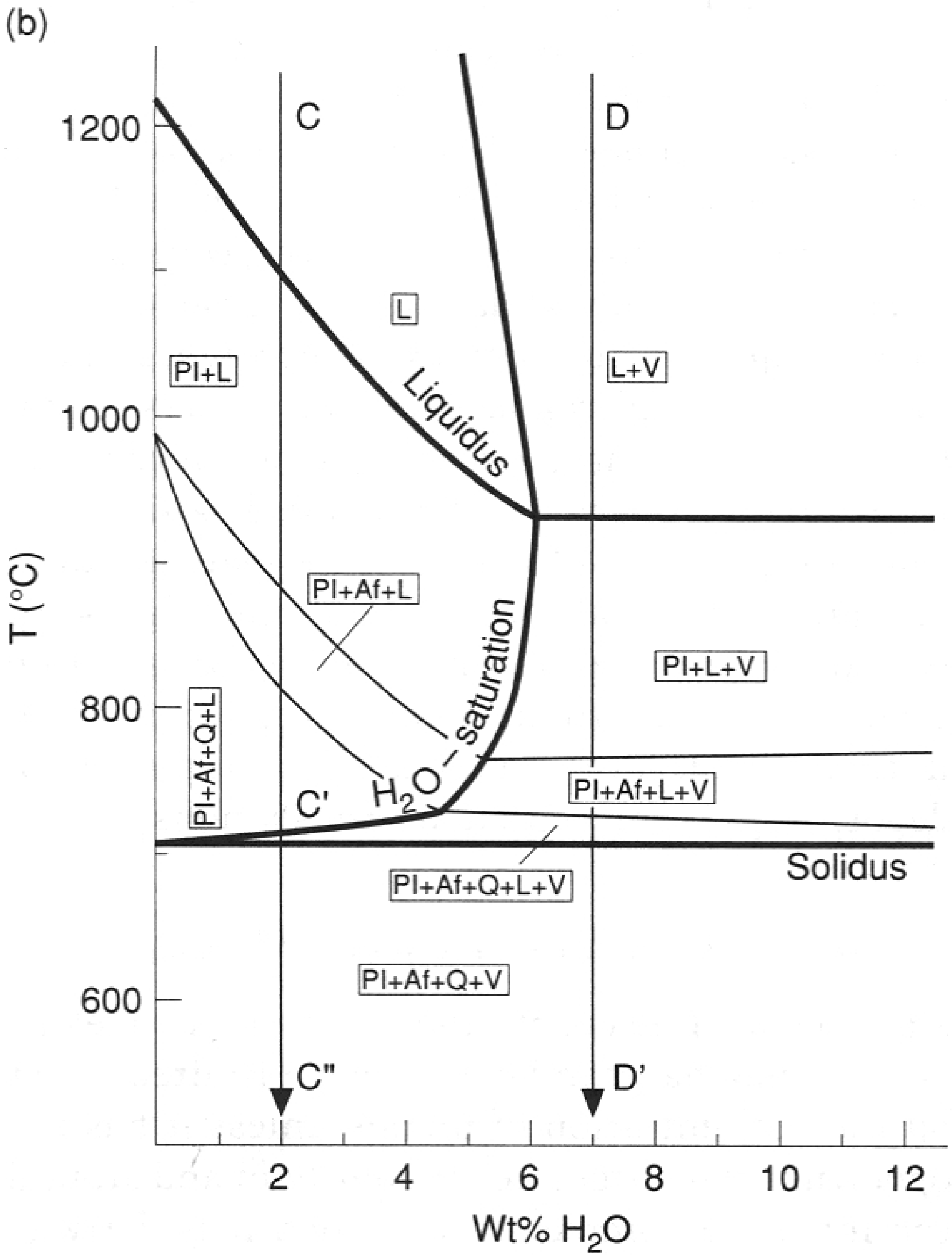

(b)
C
D
1200
1000
800
600
L
Pl+L
L+V
Liquidus
Pl+Af+L
Pl+L+V
H2O – saturation
Pl+Af+Q+L
C'
Pl+Af+L+V
Solidus
Pl+Af+Q+L+V
Pl+Af+Q+V
C"
D'
2
4
6
8
10
12
T (°C)
Wt% H2O

$P = 2$ kb

P = 2 kb

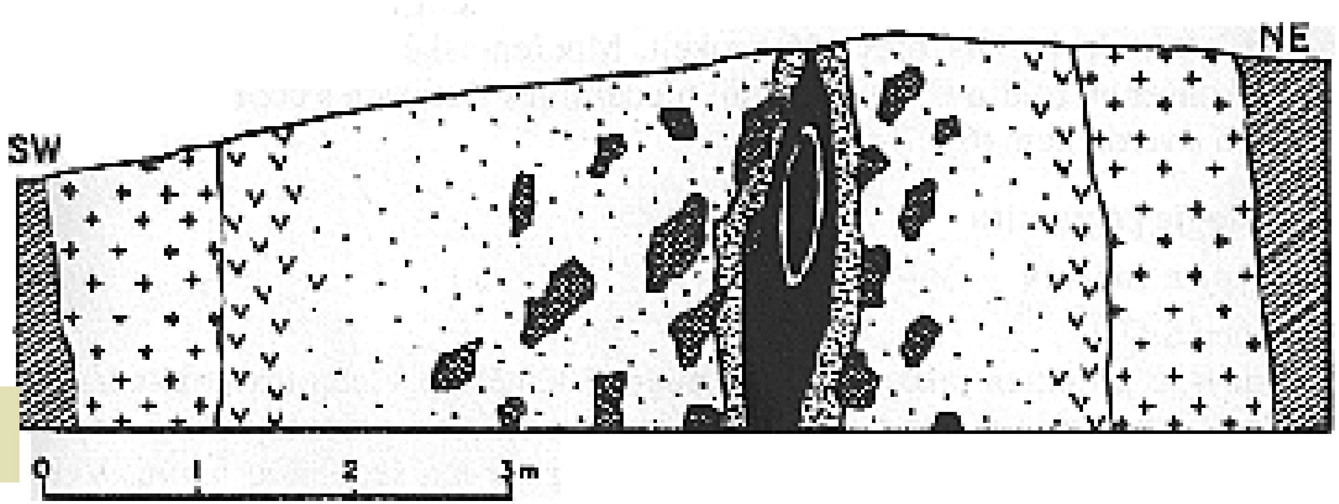
Pegmatitové formace, klasifikace

- klasifikace: P-T podmínky (Ginsburg-Černý)
- různé formace (z hlediska užitkových minerálů):

- jednoduché křemen-živcové
- slídonosné
- berylové
- litné pegmatity (metasomatické)
- drahokamové: beryl - $Be_3Al_2(Si_6O_{18})$, korund – Al_2O_3

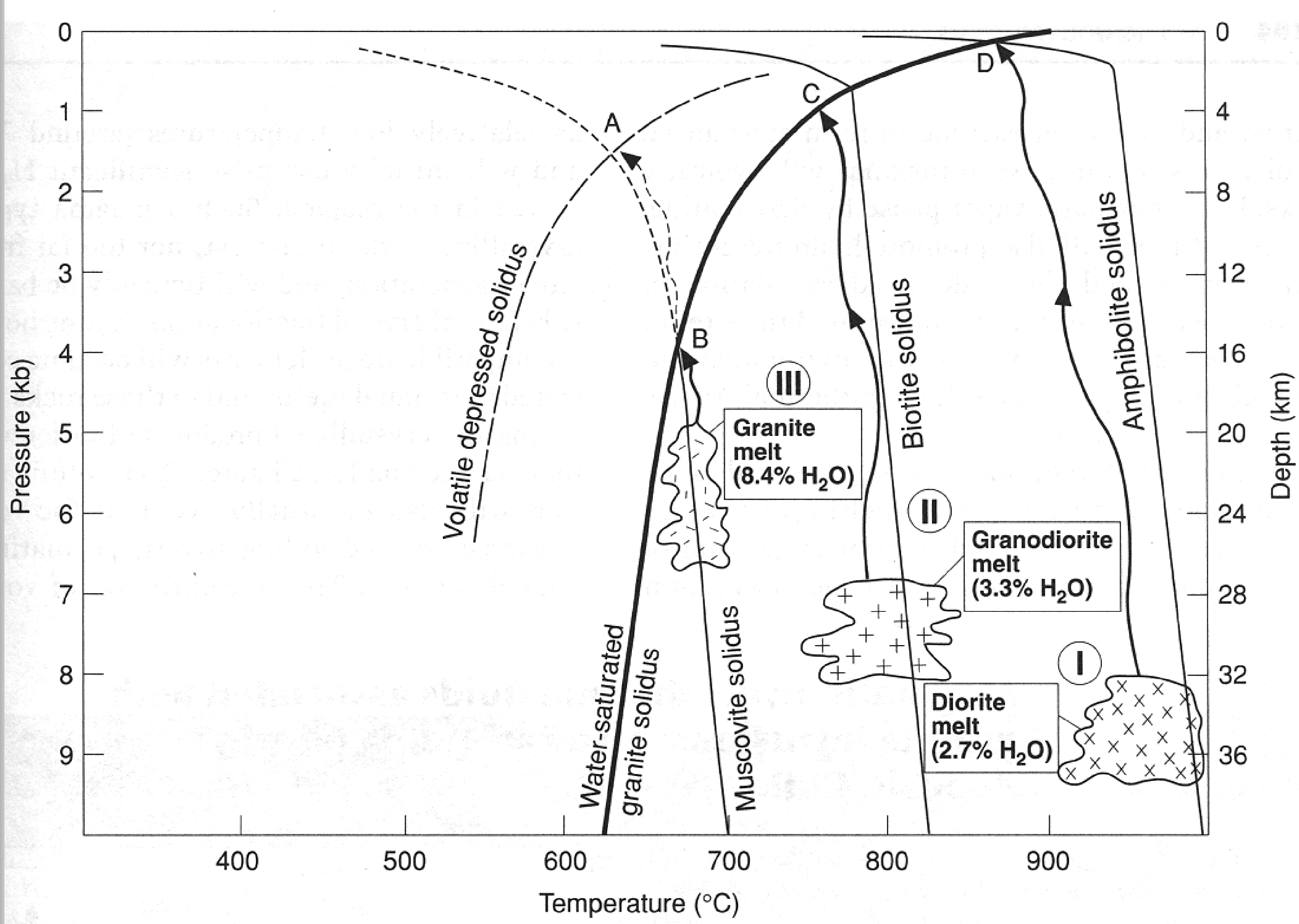
Příklad výskytů v ČR a ve světě

- magmatická ložiska: ranský masív
- karbonatity
- pegmatity: Dolní Bory, Rožná

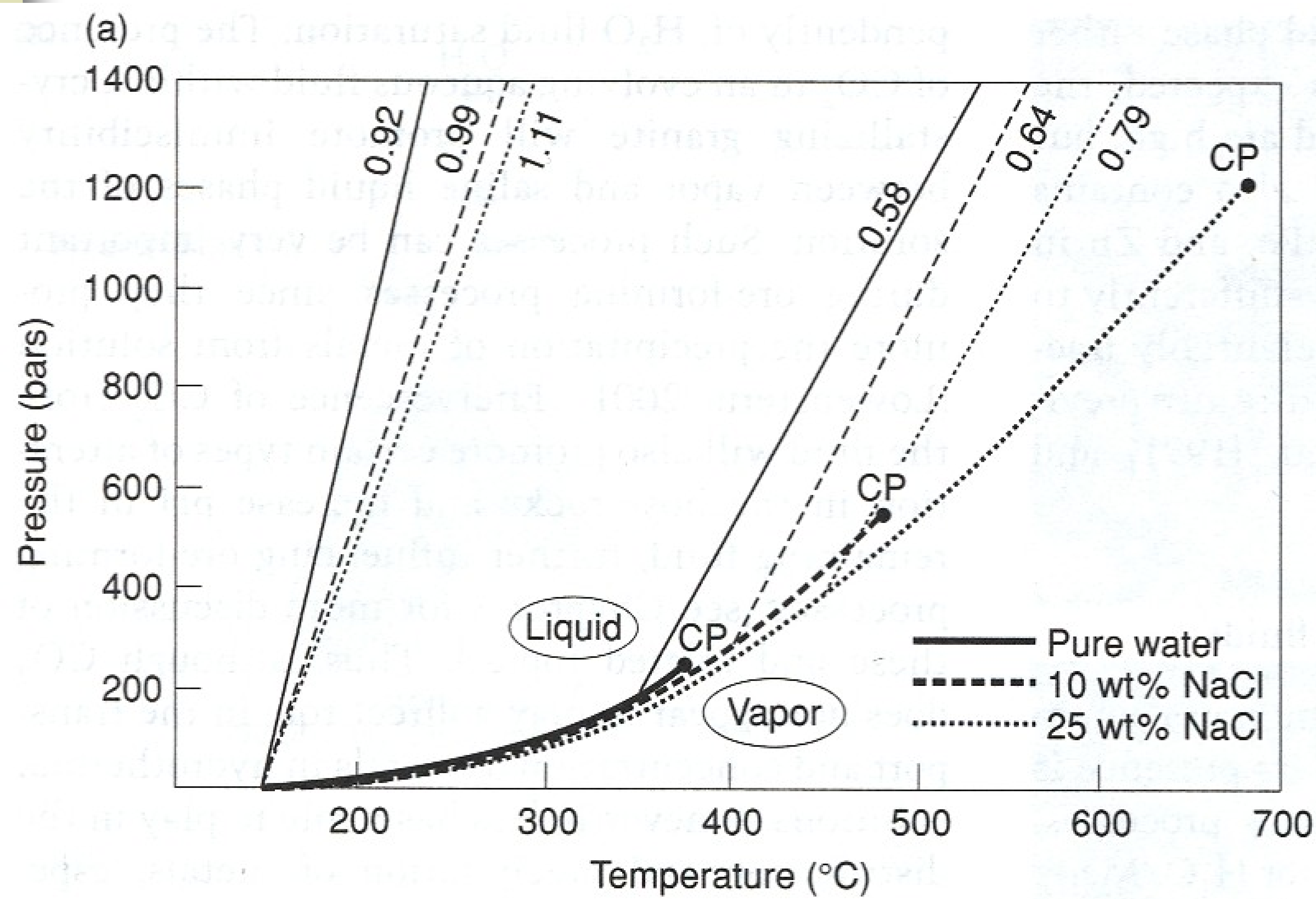


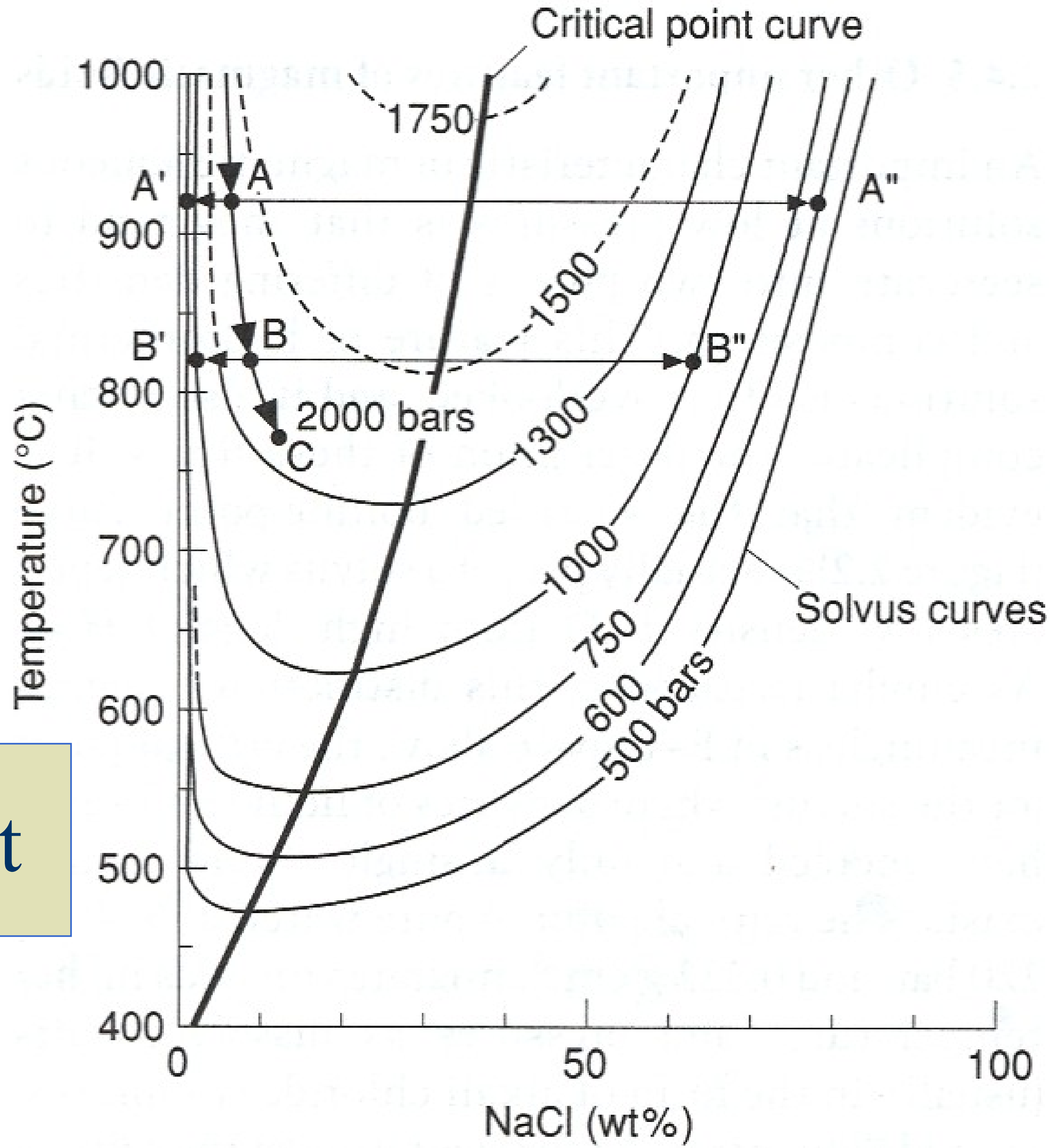
Rožná

Hloubkové úrovně tavenin



Zvýšení kritického bodu





nemísitelnost