Genesis of ophiolitic chromitite ore bodies

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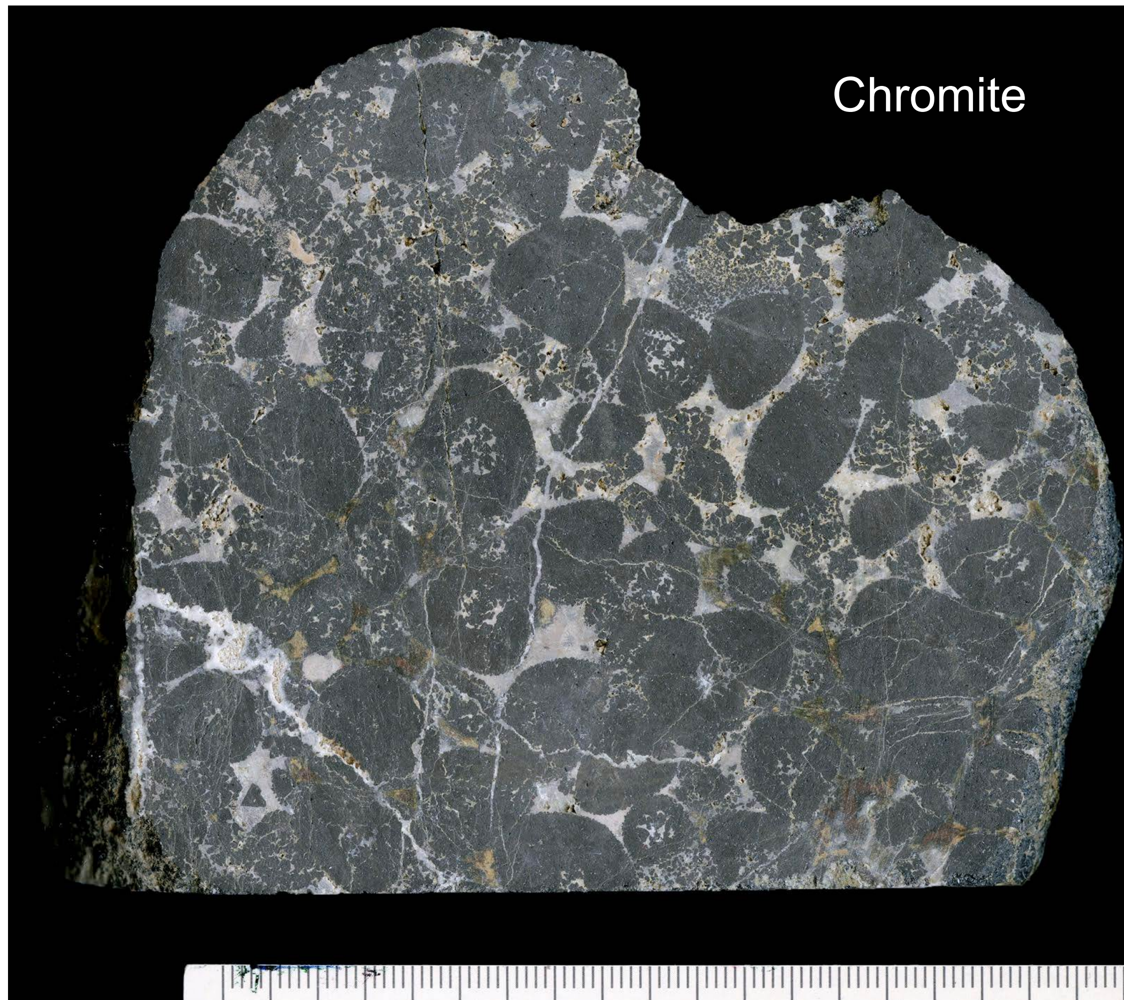
&

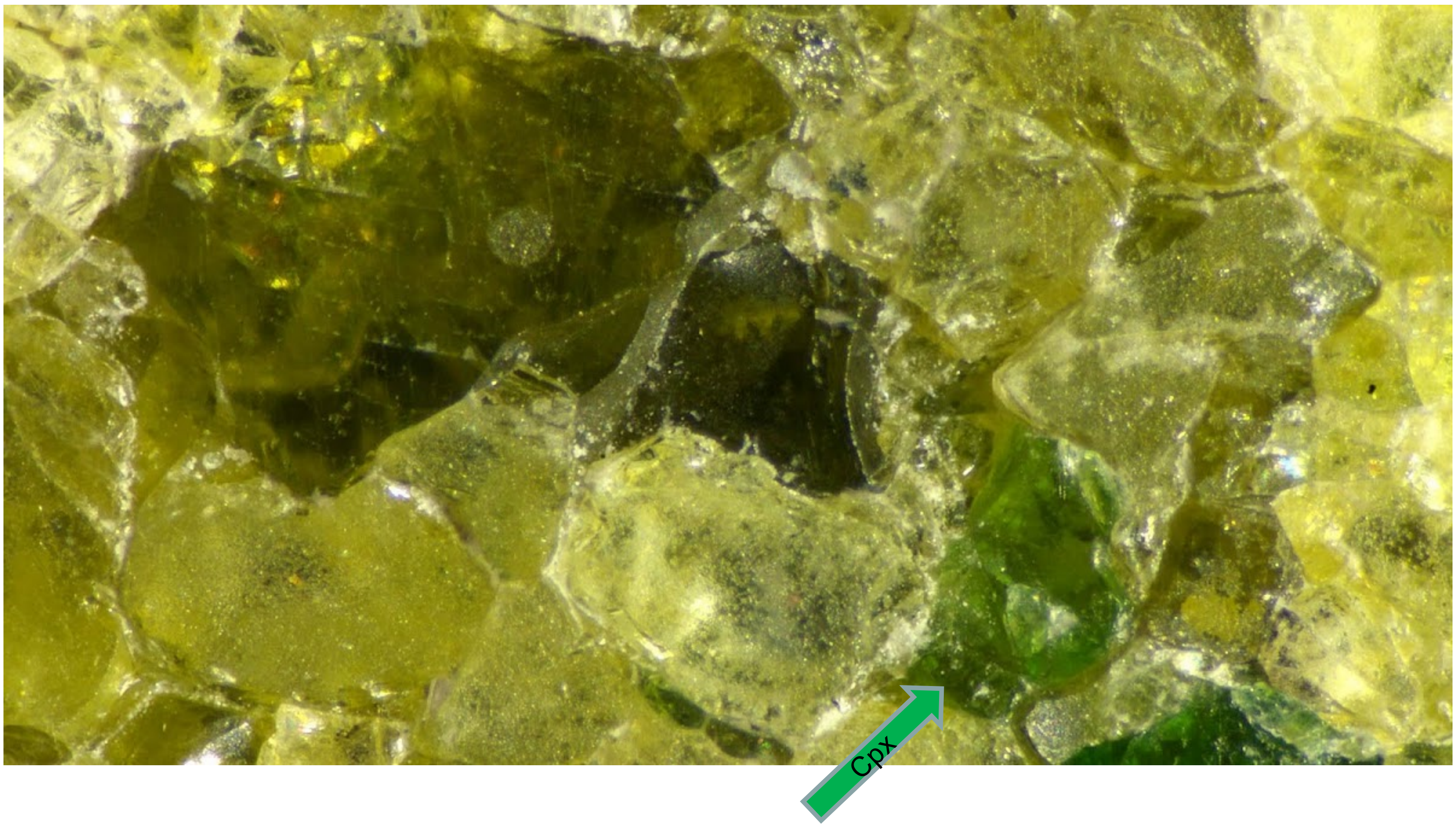
(possible) Solutions : Anastassia Borisova

Crocoïte



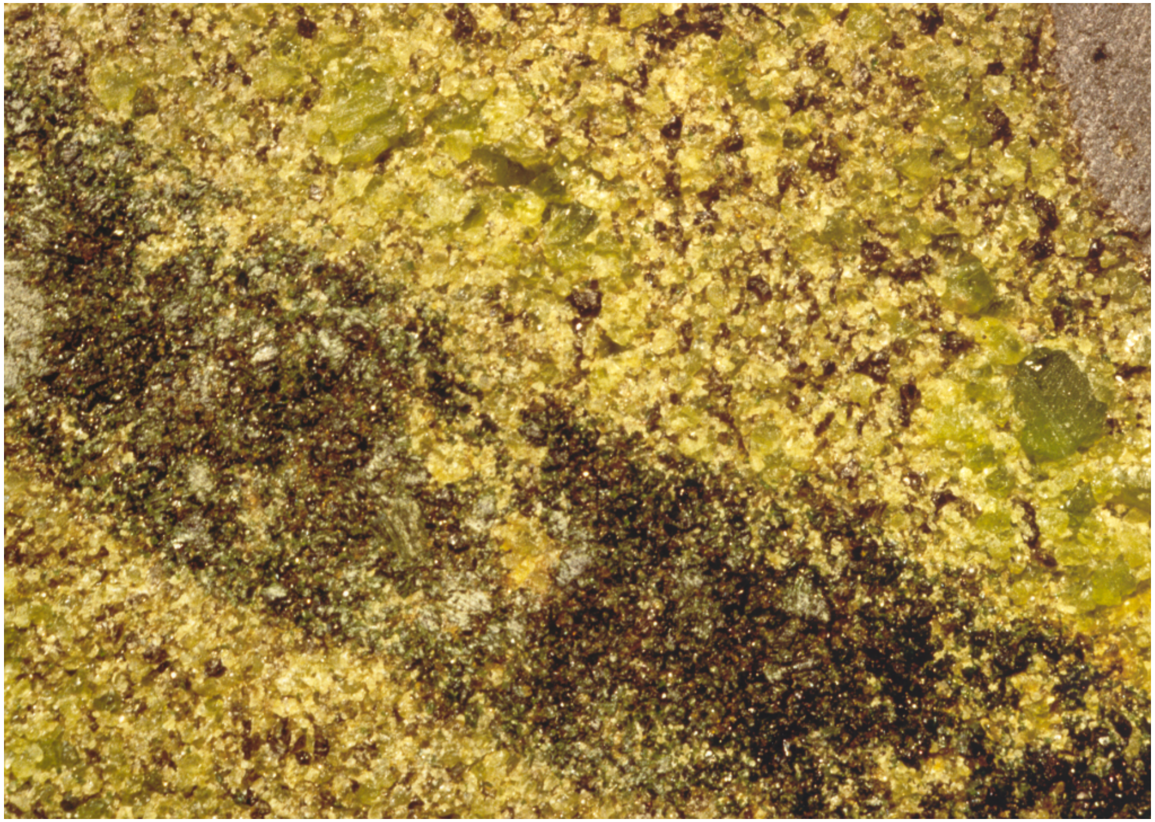
The reservoir of Cr in the « primitve » mantle is mostly Cpx (± Opx, garnet, spinel).

Si	Fe	Mg	Ca	Ti	Al	Cr	Mn	Na	K	
45,8	2,1	20,7	23,1	0,55	4,95	0,75	0,08	0,60	0	Typical mantle Cpx



Ambiguous bevaviour of Cr during partial melting:

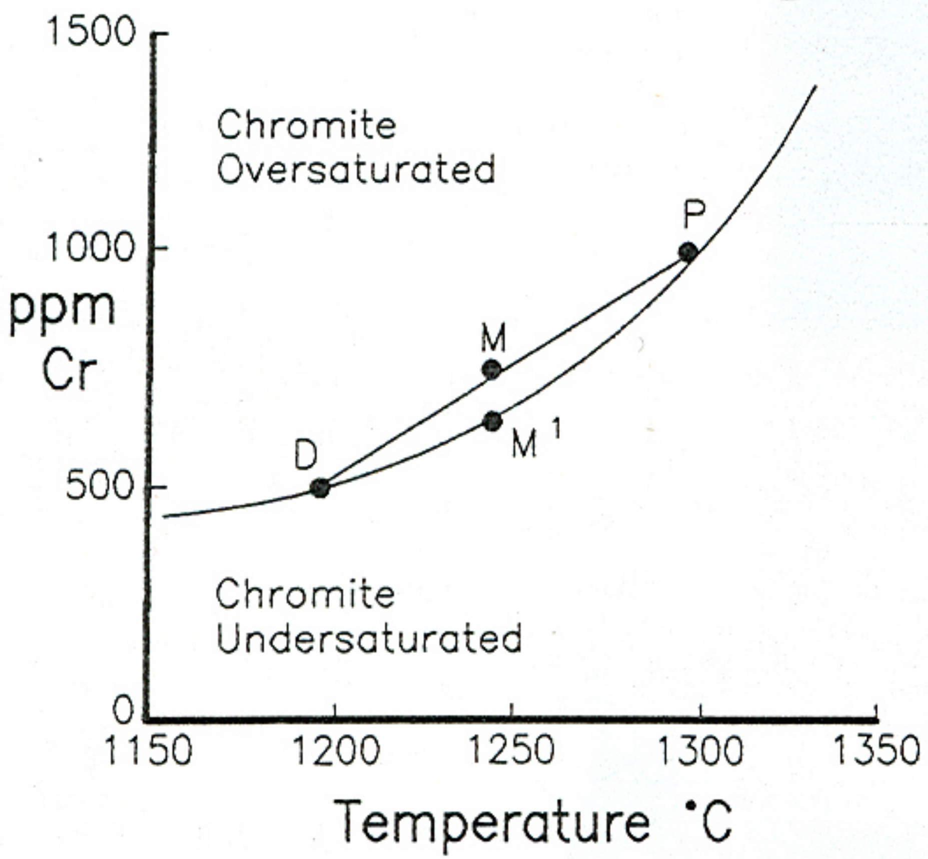
Cpx (± garnet, spinel) preferentially contibute to the genesis of basaltic melts.



But…

Cr solubility is quite weak in silicate melts

Huge problem of transport !



Chromite (ρ = 4.5) contains 300,000 ppm Cr.

1 m of chromite needs 4.5 km of magma

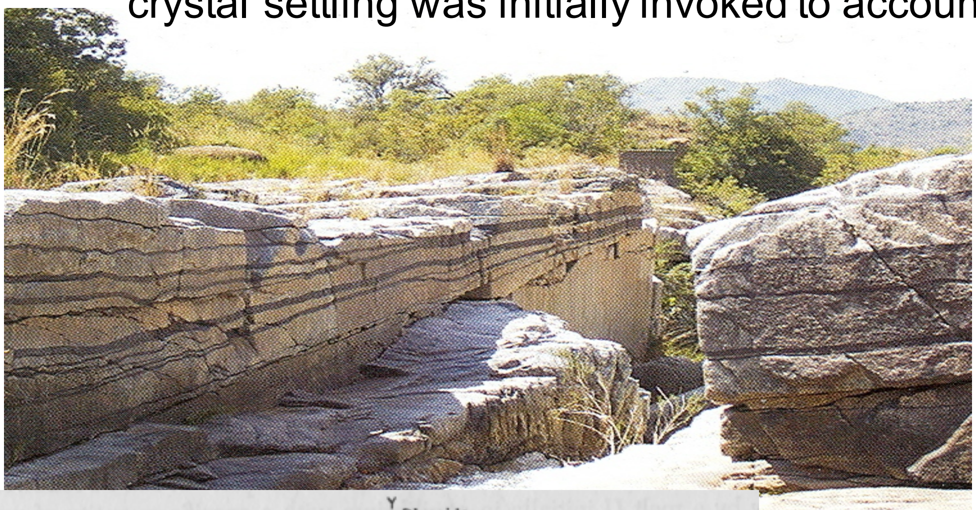
Scattered chromite in peridotitic residue of partial melting
No problem!

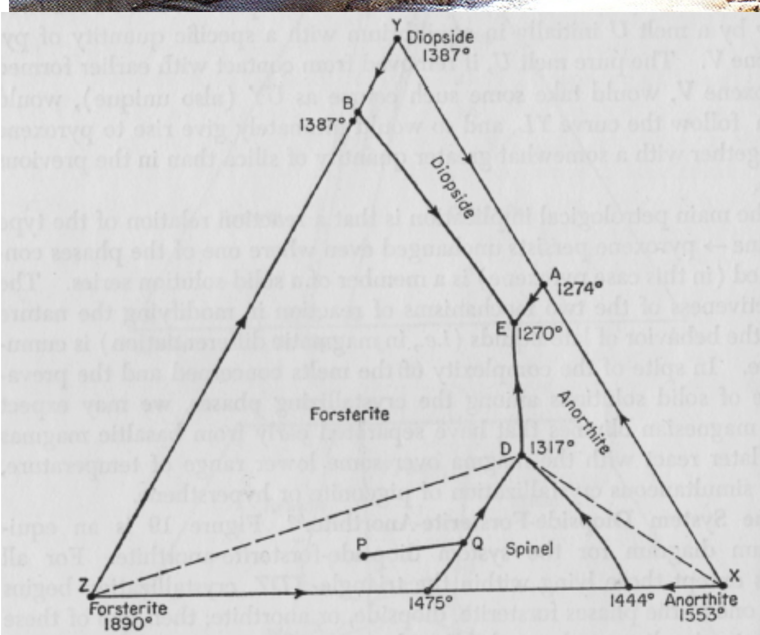
Scattered chromite in primitive troctolitic/gabbroic cumulate
No problem!

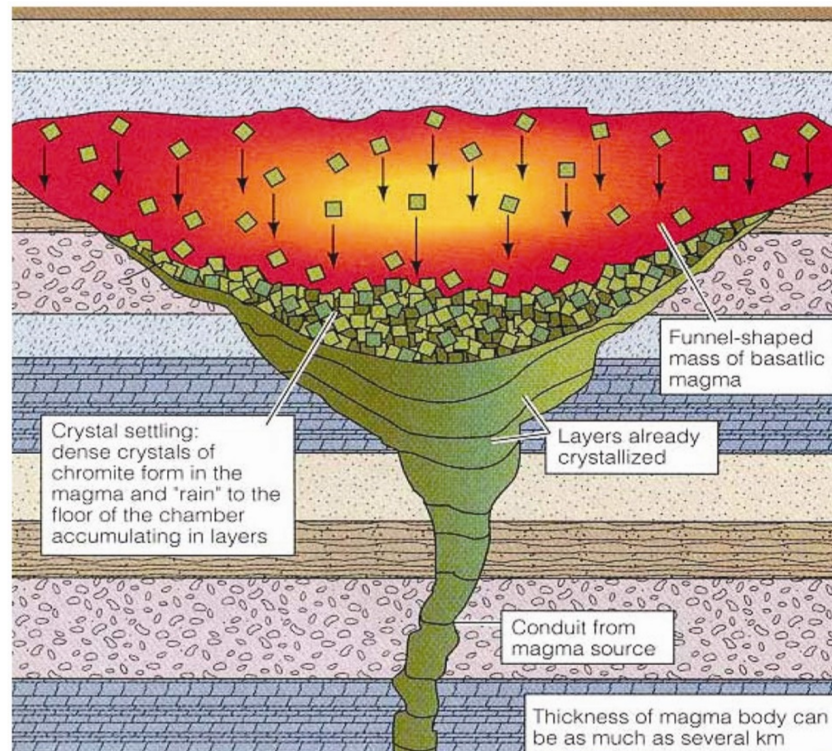
THE problem: how to concentrate chromite?

In theory, things could be so simple!

Fractional crystallization from huge volumes of primitive, dry basaltic melt followed by crystal settling was initially invoked to account for chromite beds in layered intrusions.

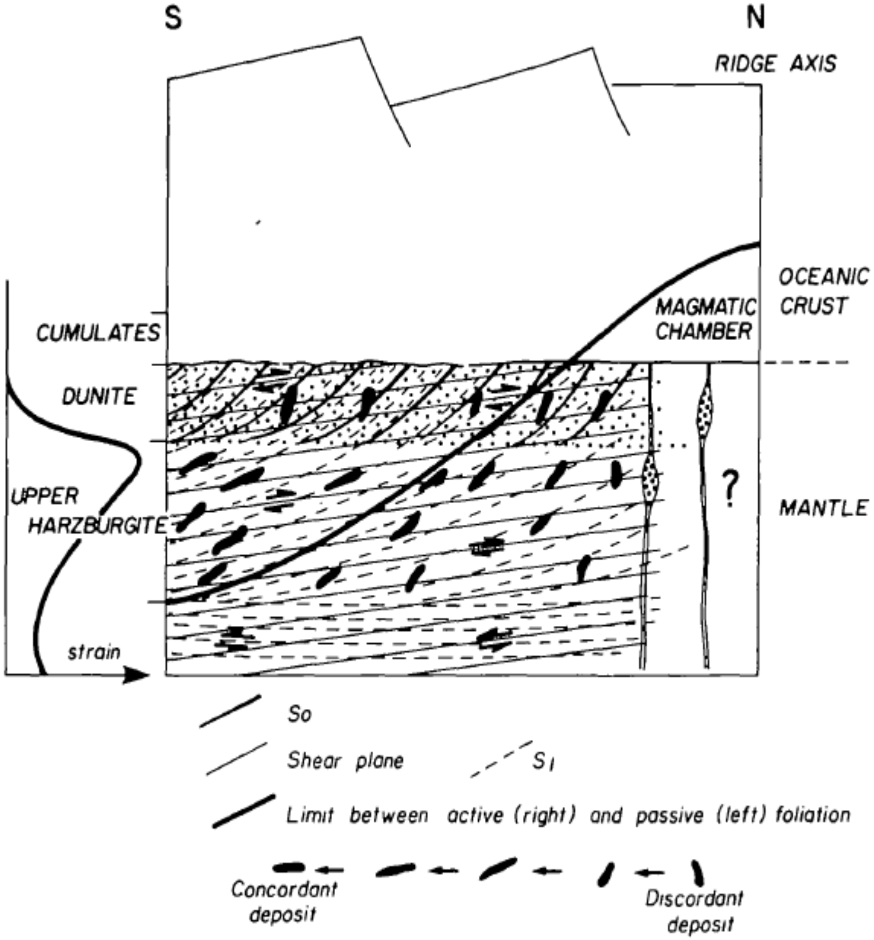






Dry system at low pressure (~ 2 Kbar)

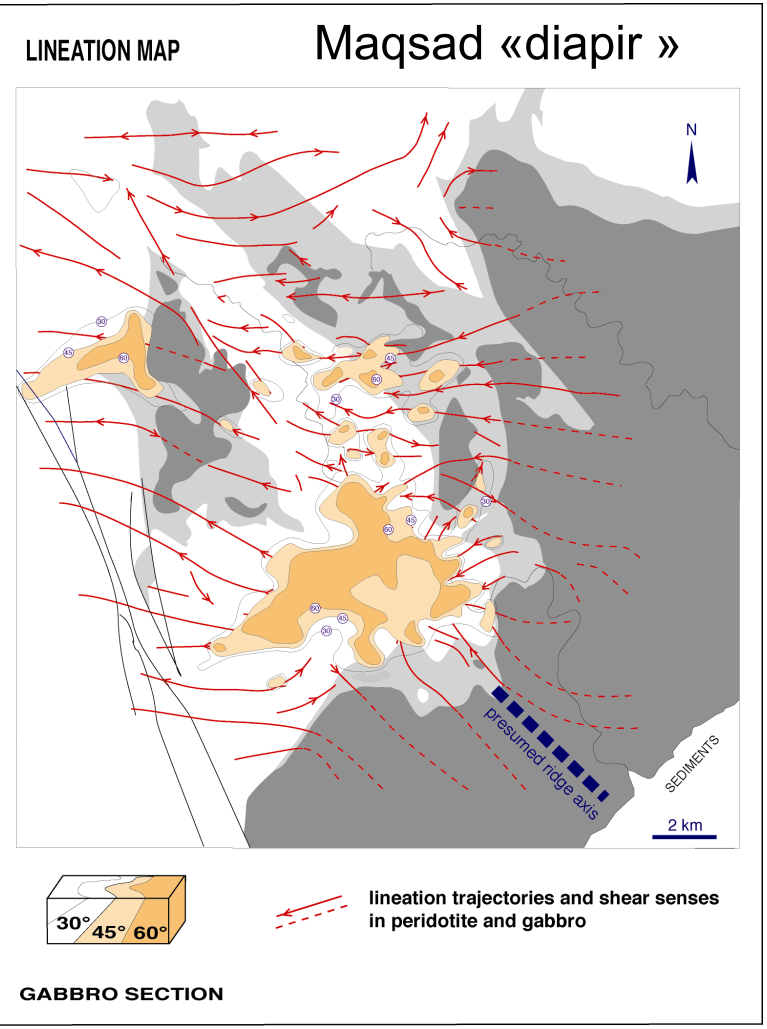
The same kind of simplistic petrologic model was invoked to explain the occurrence of « podiform » chromitite in the mantle section of ophiolites (i.e. former oceanic lithosphere).



In the Oman ophiolite, we have the opportunity to observe chromite ore bodies frozen at the top of a mantle upwelling before transposition in off-axis position and deformation by corner flow.

Unique situation!

The structures and delicate textures inherited from chromitite genesis are perfectly preserved.



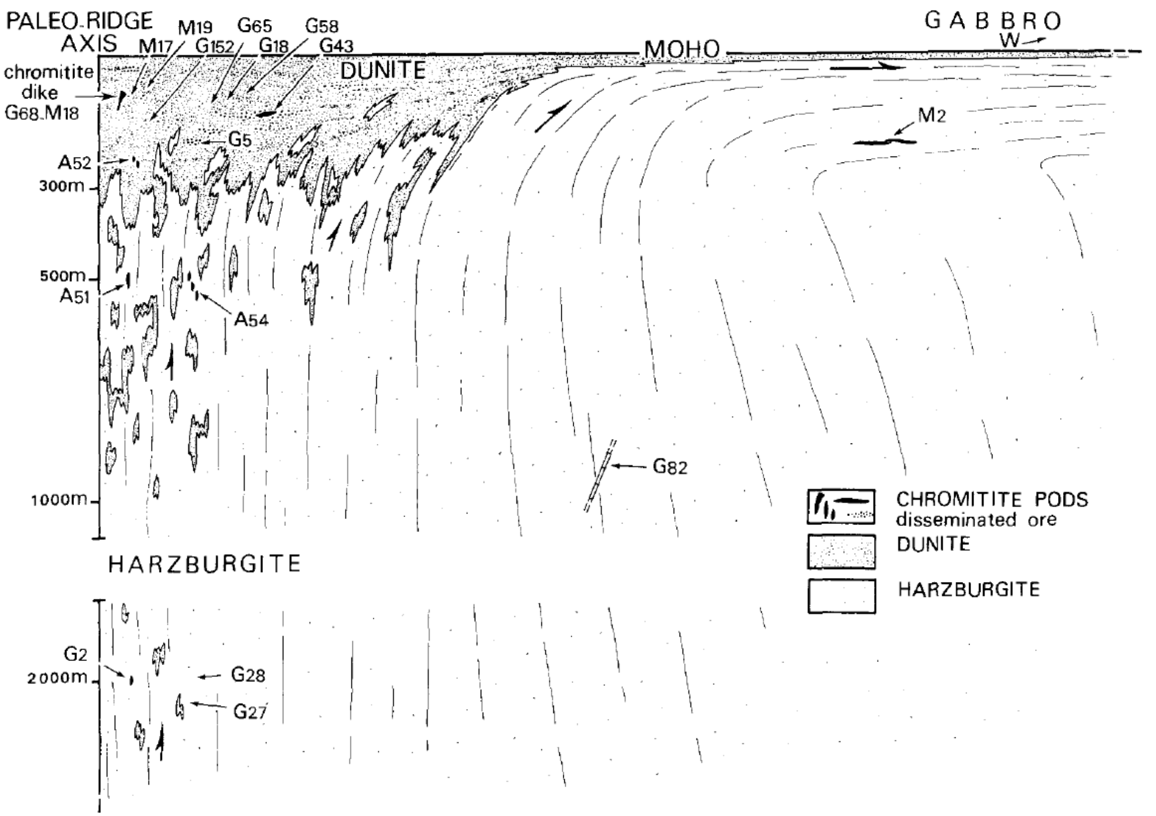
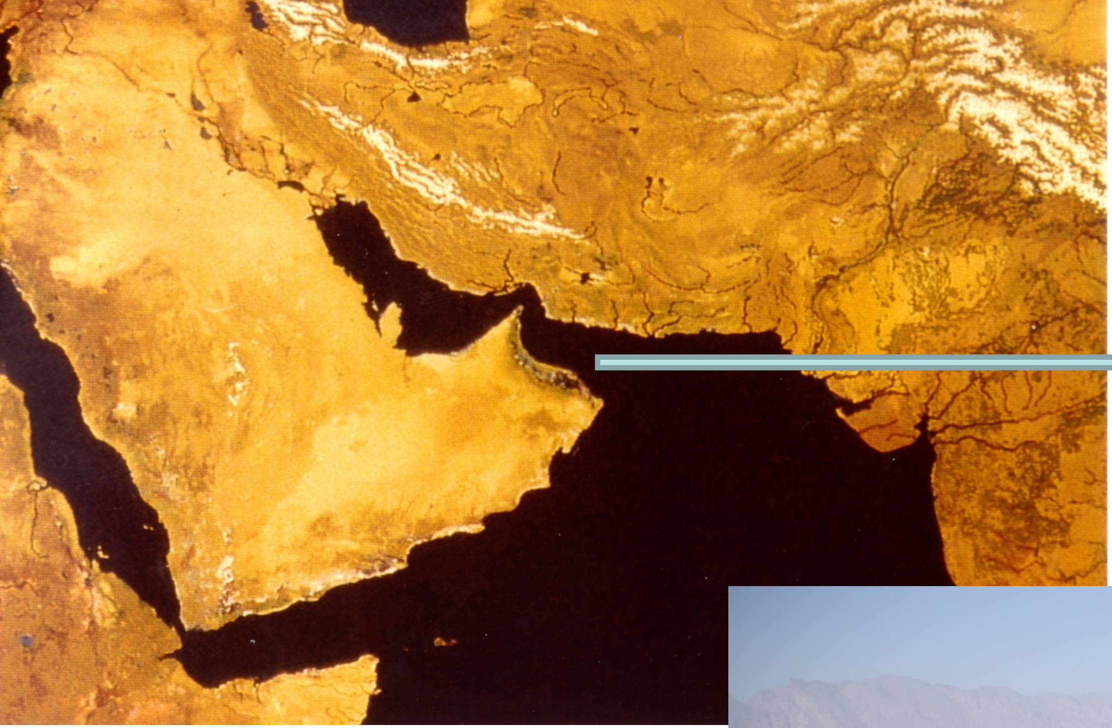
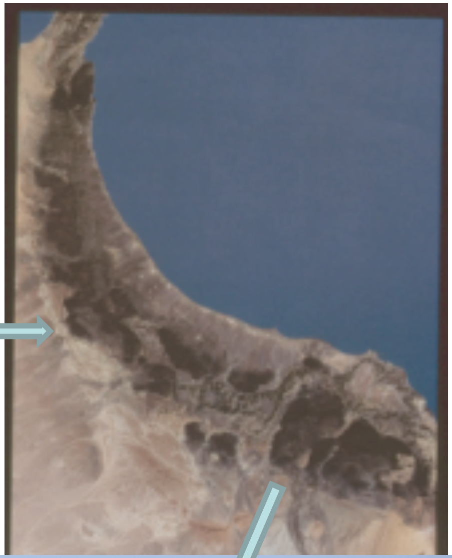
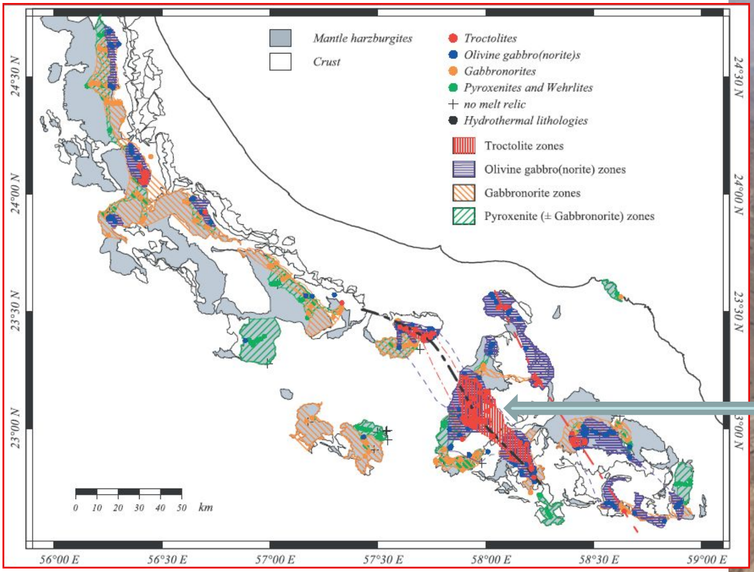


Fig. 2. Sketch cross-section of the upper part of the Maqsad diapir (half section) with localisation of the investigated samples. The chromitite pods are more or less at scale.

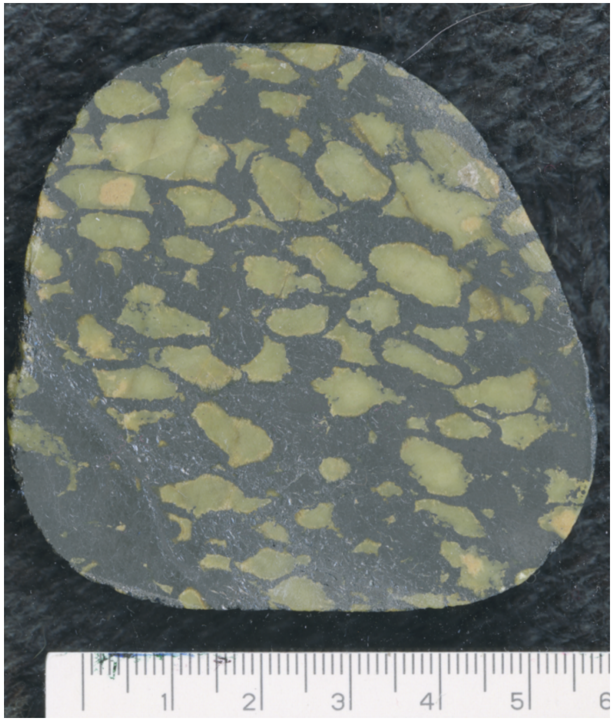


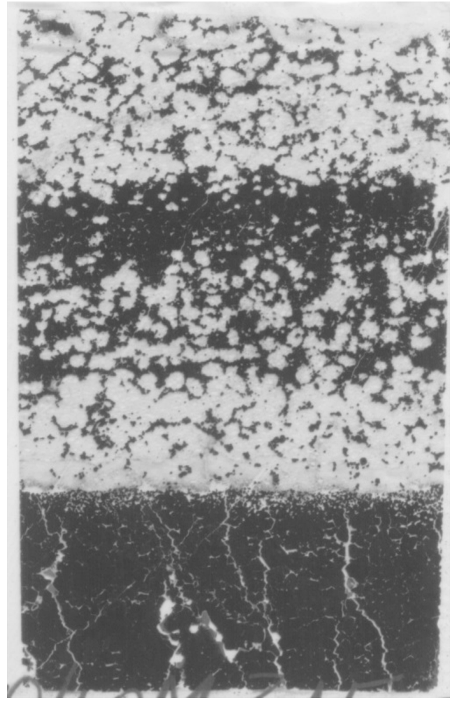



Maqsad area


Mantle harzburgites
Crust
Troctolites
Olivine gabbro(norite)s
Gabbronorites
Pyroxenites and Wehrlites
no melt relic
Hydrothermal lithologies
Troctolite zones
Olivine gabbro(norite) zones
Gabbronorite zones
Pyroxenite (± Gabbronorite) zones
0 10 20 30 40 50 km
24°30 N
24°00 N
23°30 N
23°00 N
56°00 E
56°30 E
57°00 E
57°30 E
58°00 E
58°30 E
59°00 E

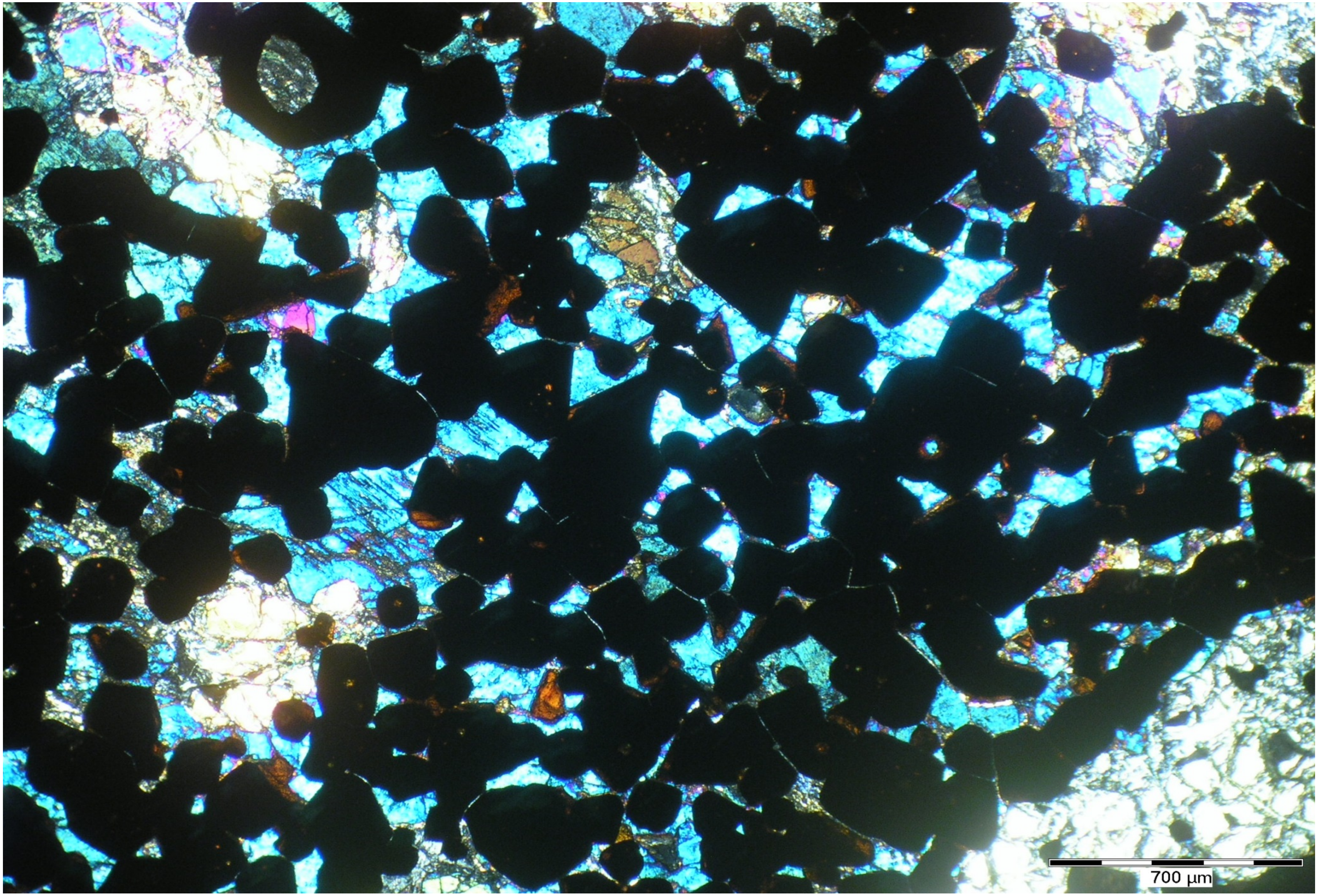
Some first order petrogenetic problems: observations that do not match the theory.



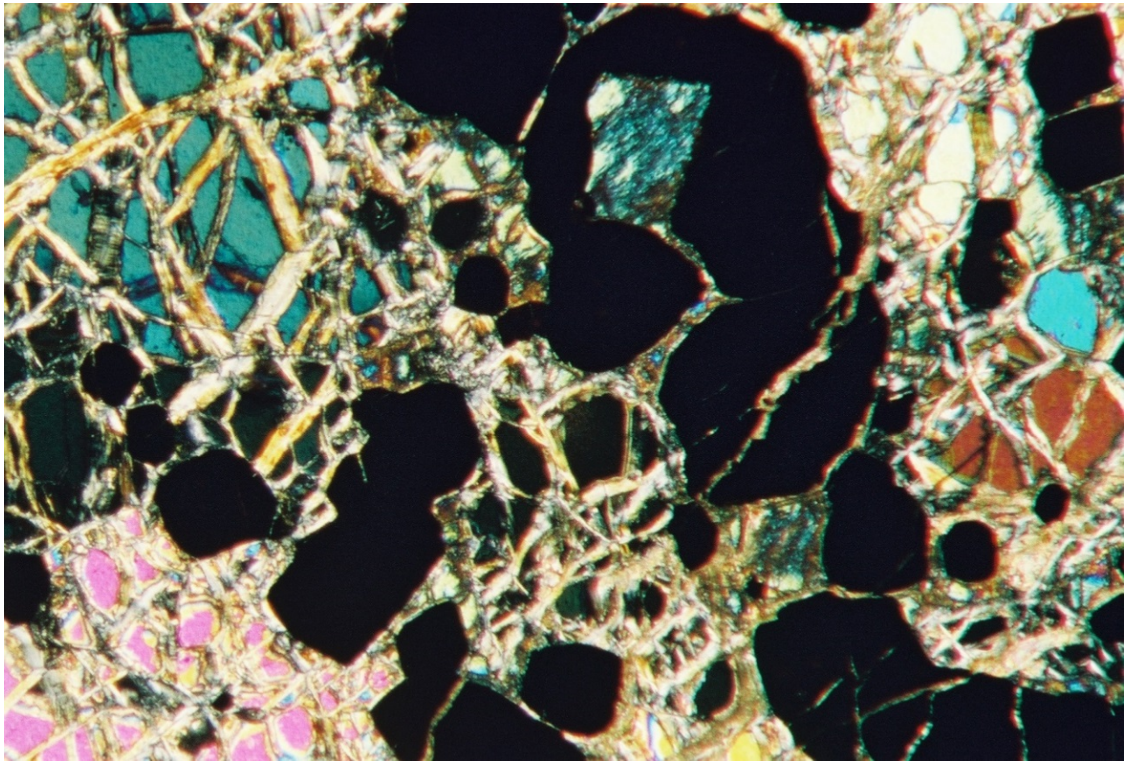


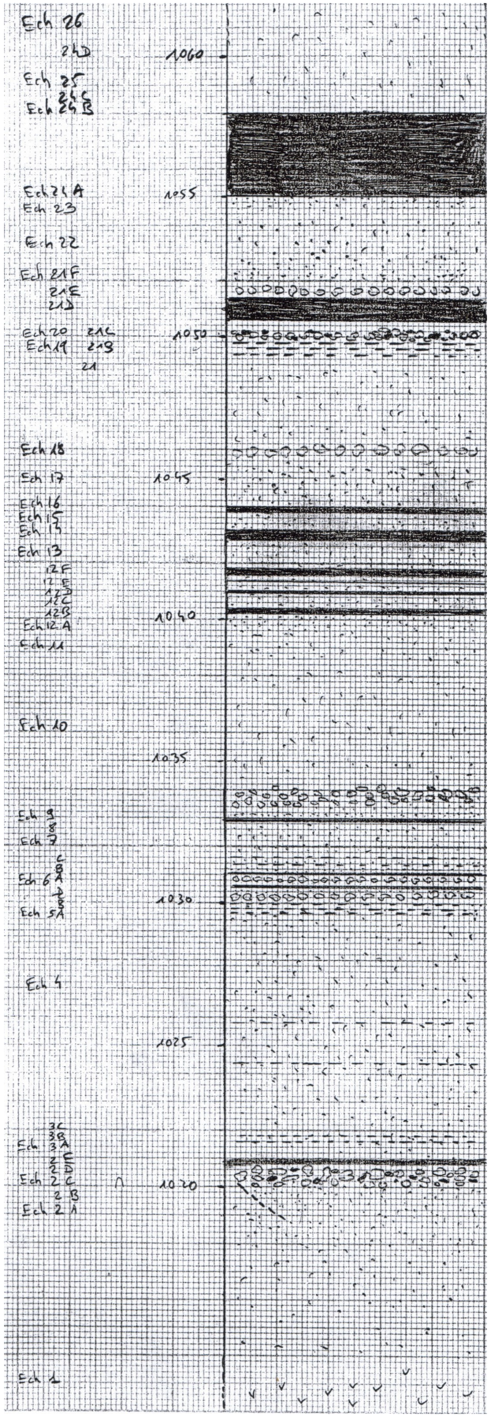
Antinodular structures are the most common and contradict the hypothesis of early crystallization of chromite.

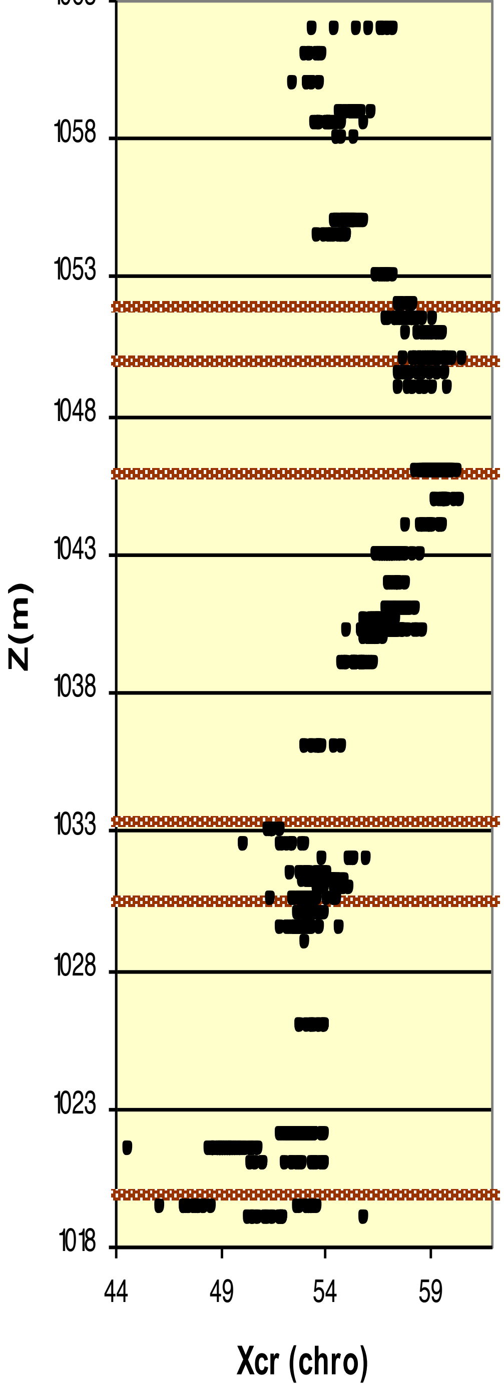
Chromite may be associated to significantly evolved (i.e. low T°) silicate parageneses.



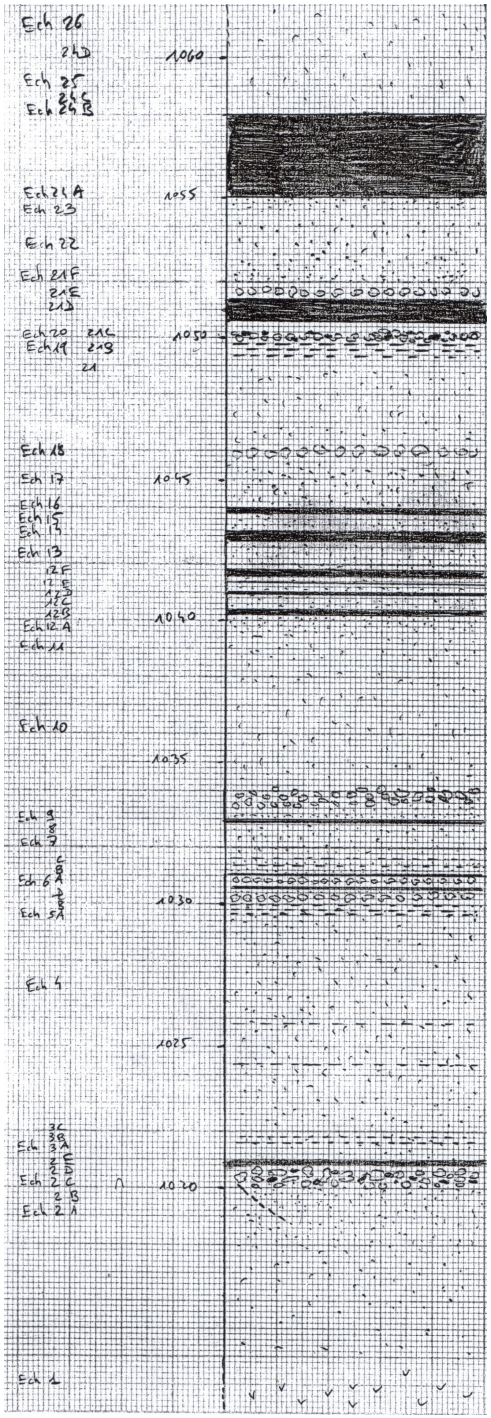
Chromite may even entrap silicates crystallizing from evolved (or exotic) melt.

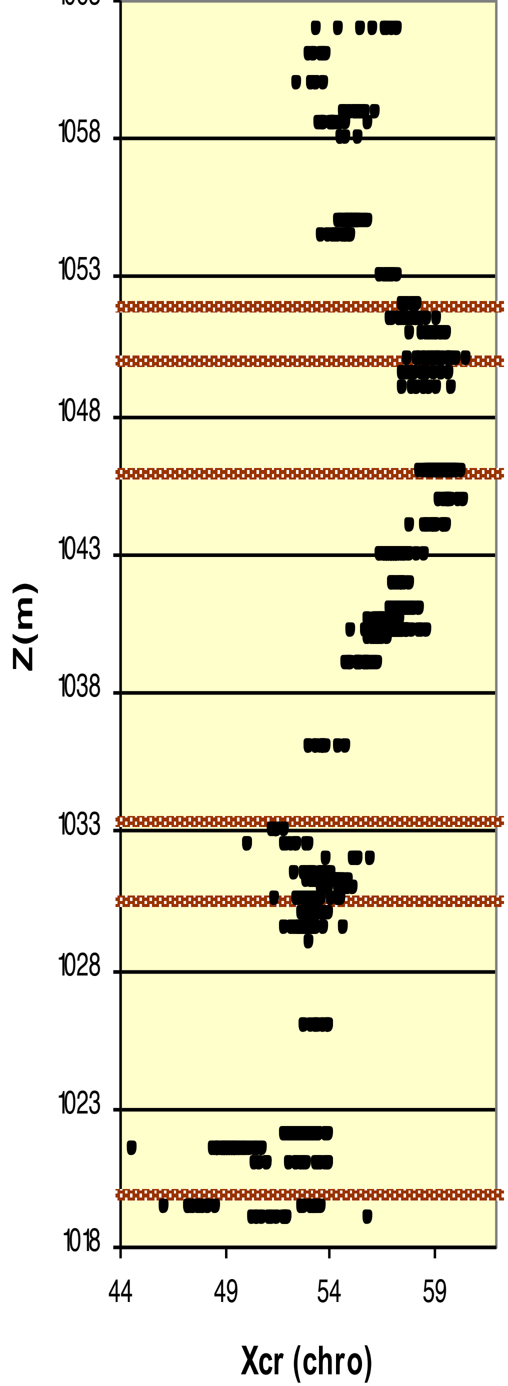






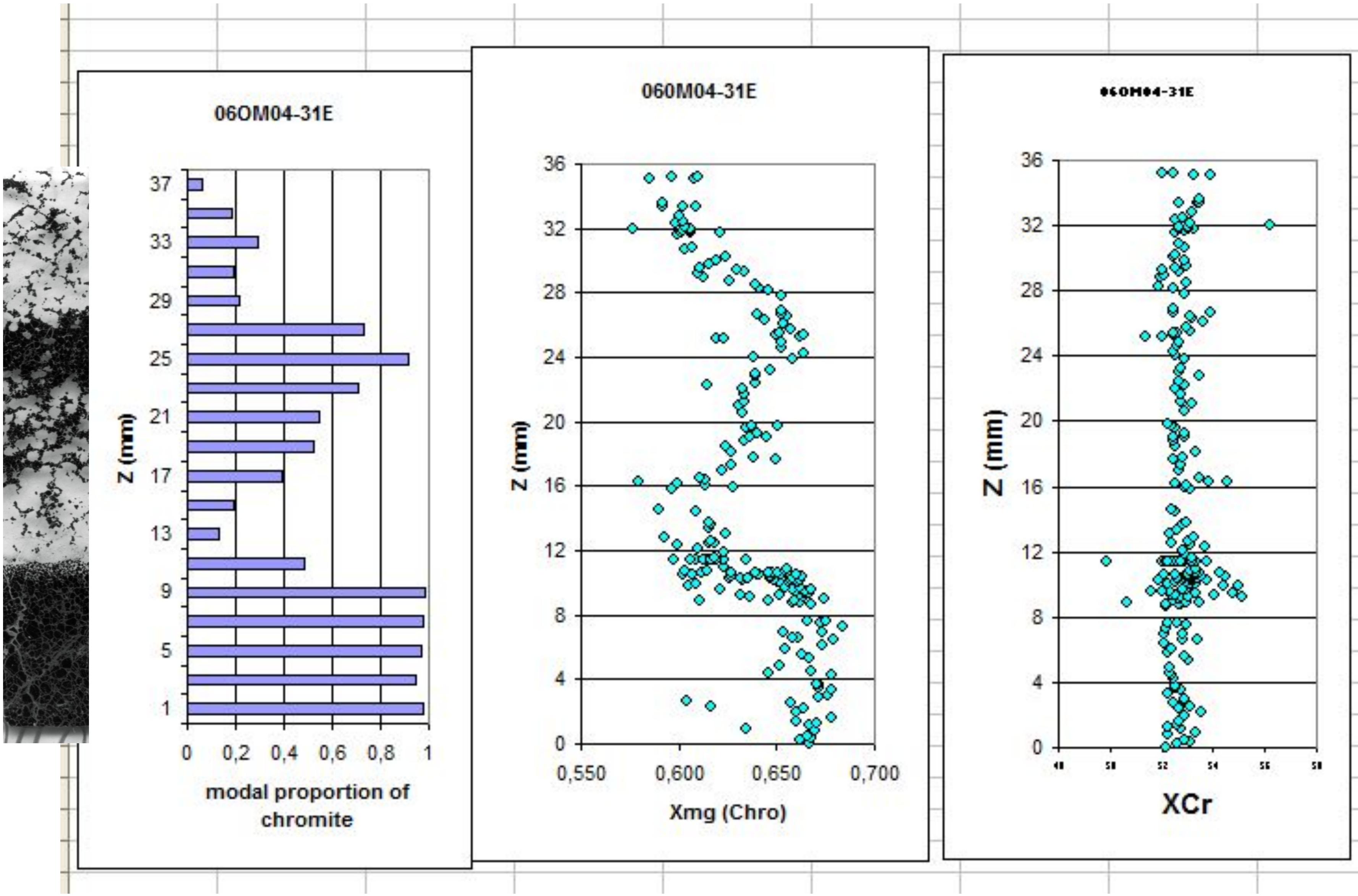
Lack of correlation between modal proportions and chemistry: contradicts model of pure fractional crystallization.





Highlights the importance of dynamic processes and of magma mixing.

This is true at small scale too…

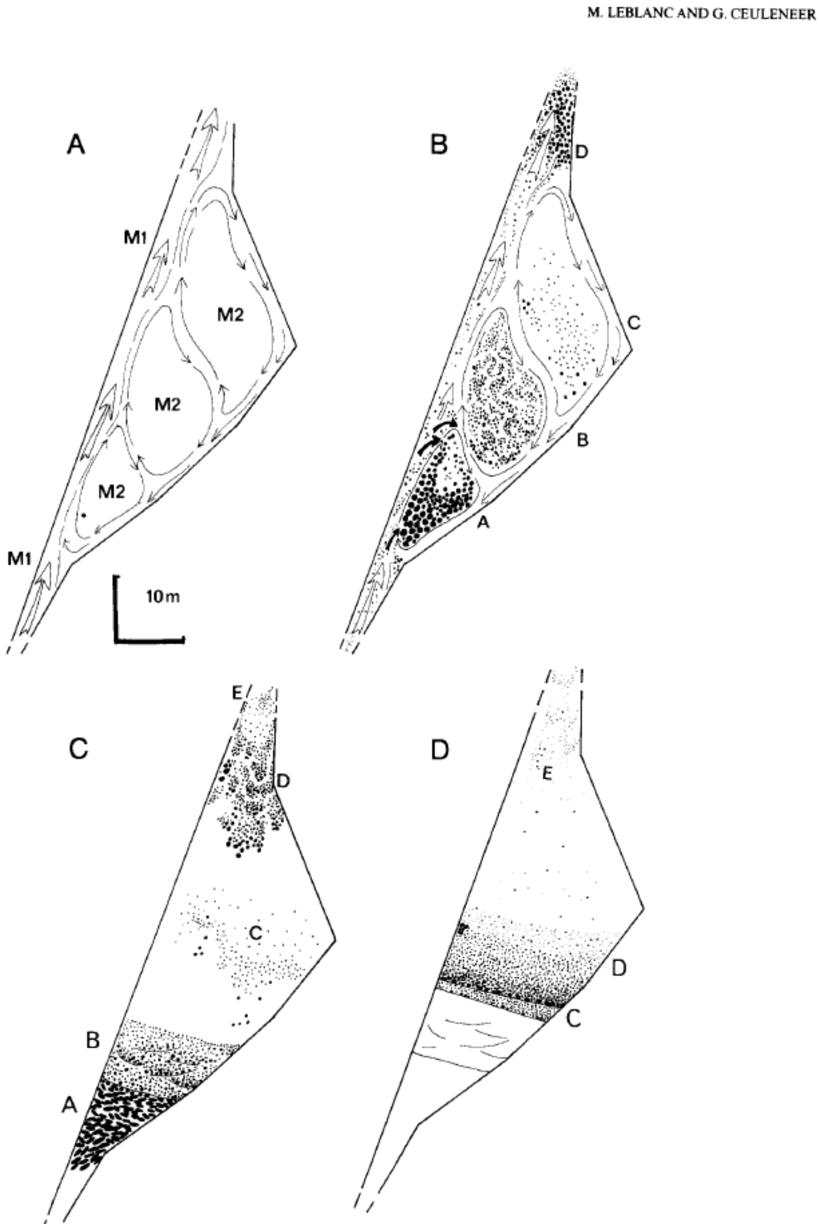


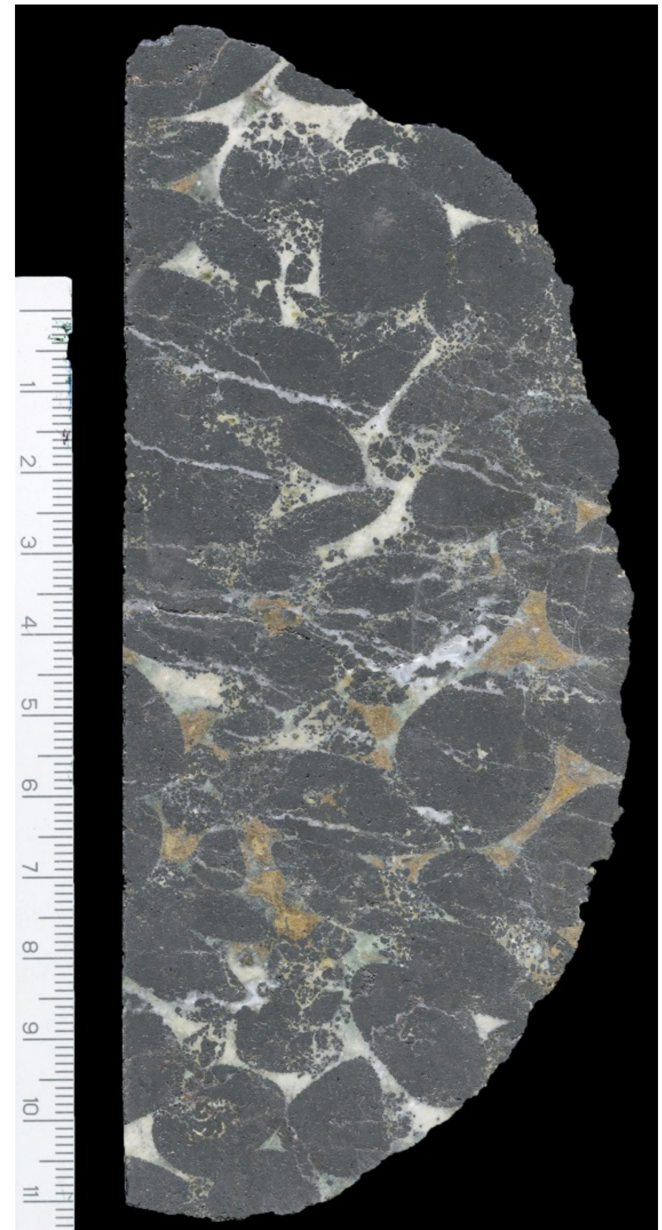
How to concentrate chromite by melt migration in the mantle?
Transport on short distances : small problem…

How to concentrate chromite by melt migration in the mantle?
Transport on long distances : big problem!

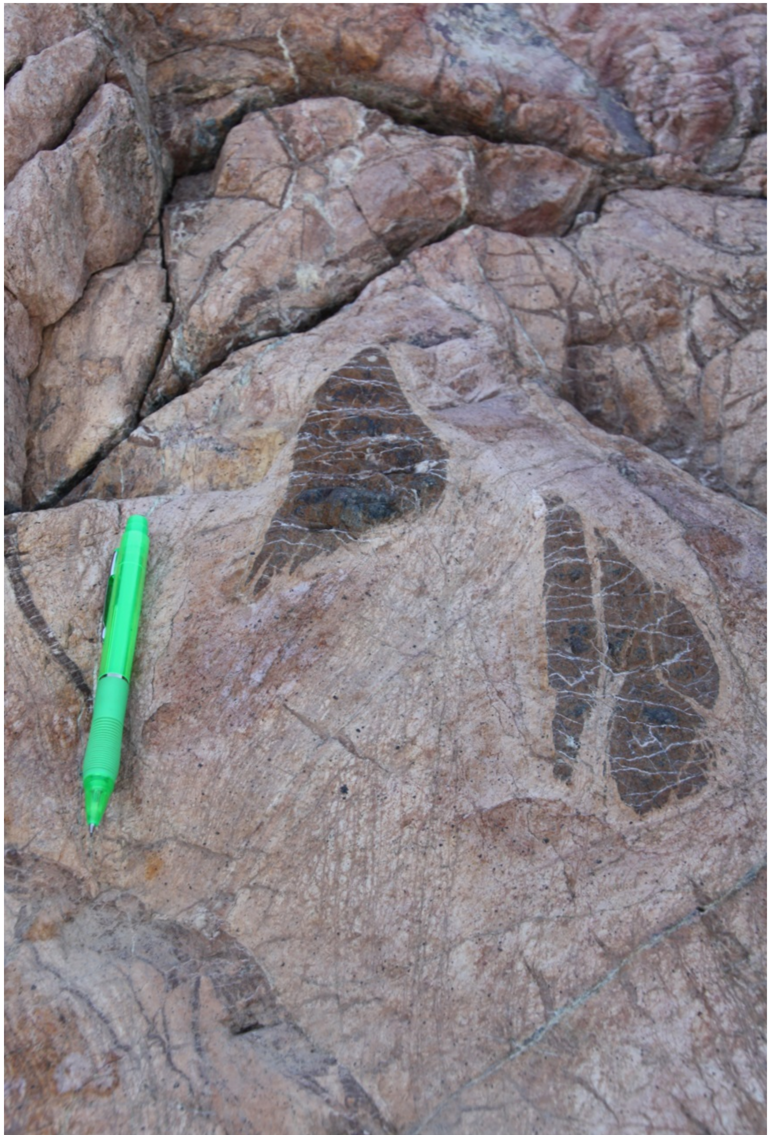
Chromite dyke with accumulation of centimetric nodules : extremely dynamic systems.

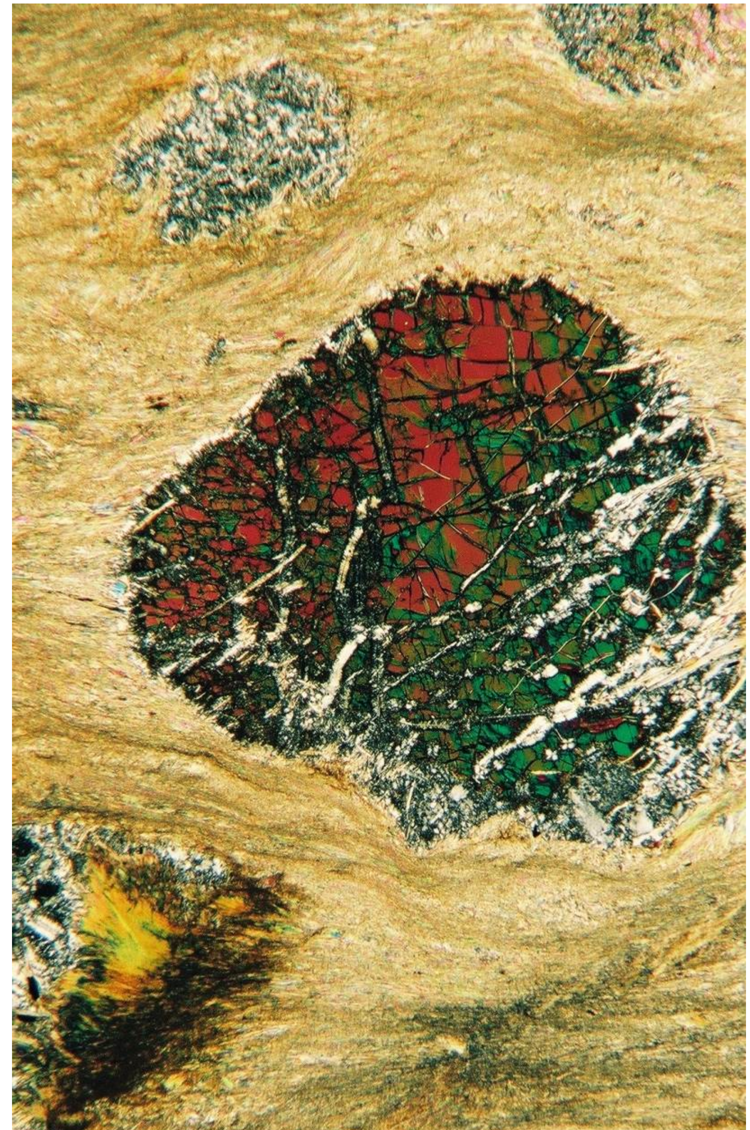
Extremely dynamic systems!





Intense hydrothermal circulation in the vicinity of chromite ore bodies.

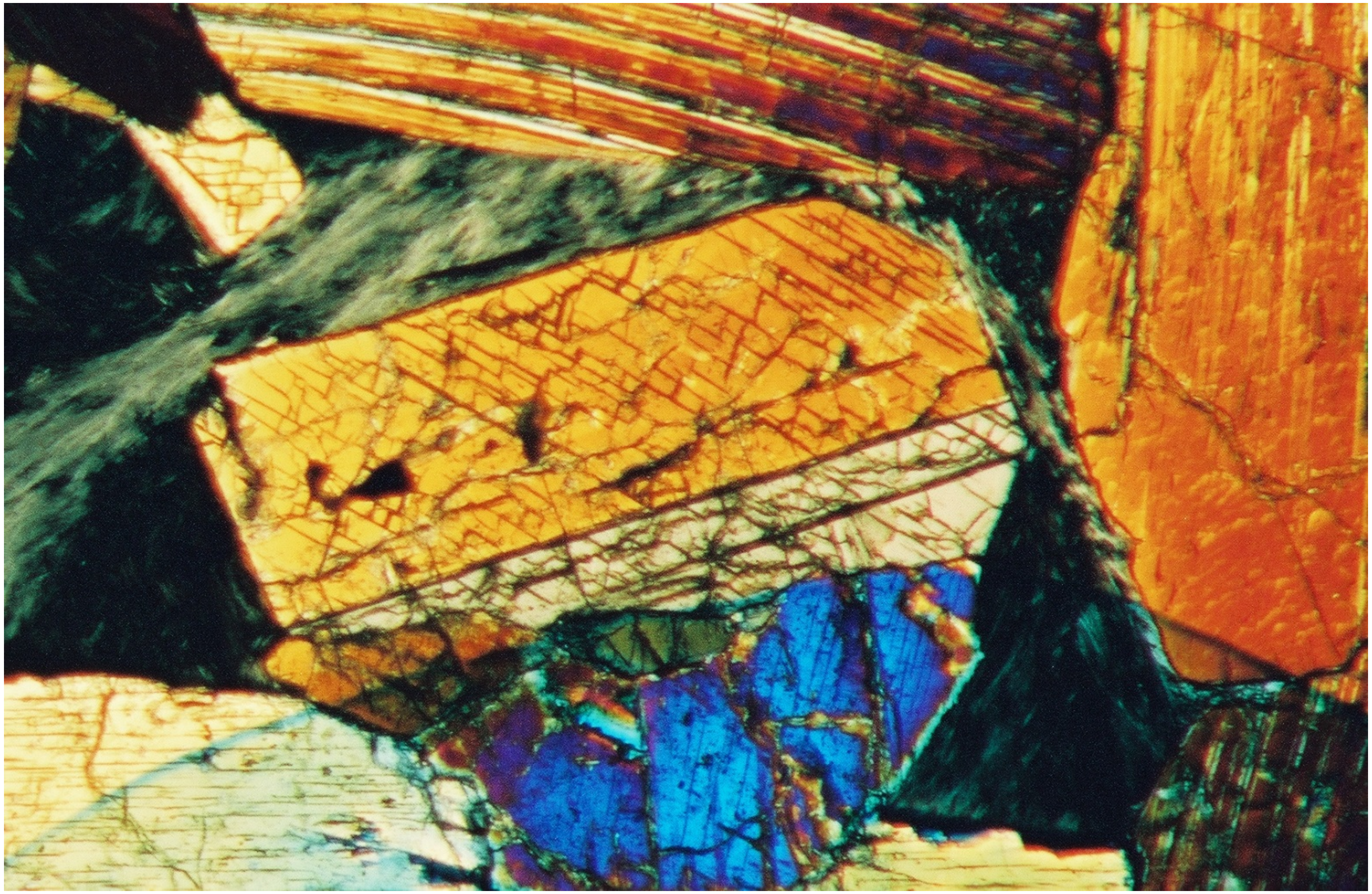




Where are the challenges?

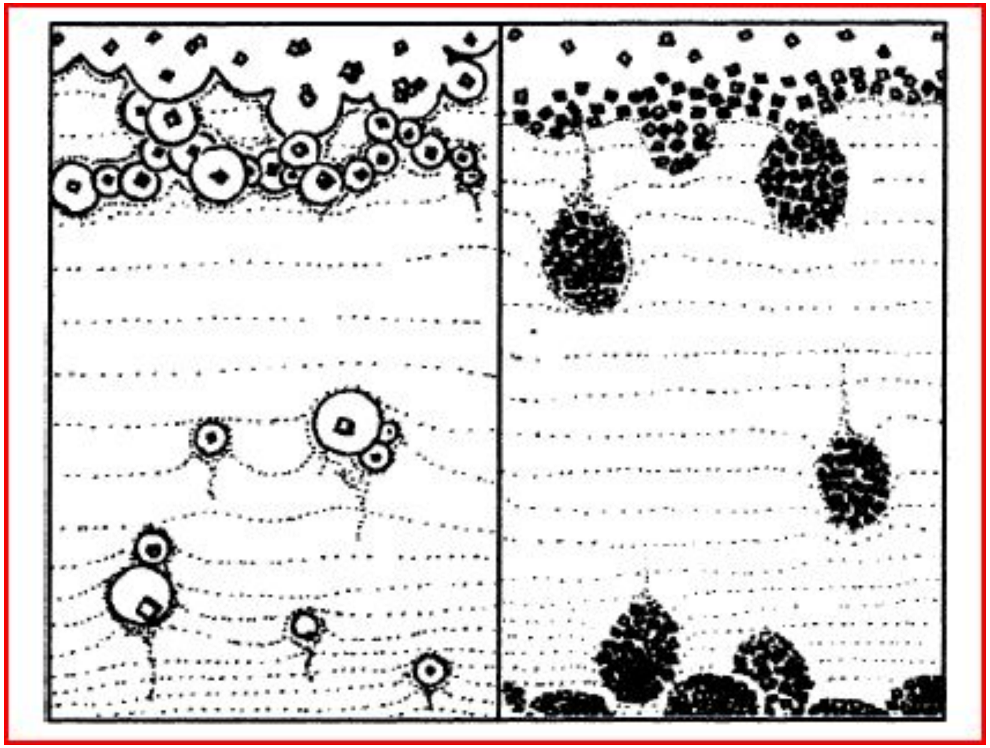
- What is the source of Cr and (mostly!) where is it located ?
- How to transport Cr on long distances ?
- How to concentrate huge quantities of Cr in a (relatively) small volume?
- Which processes trigger the sudden crystallization of chromite ?
- How to account for the violation of holly petrological rules ?

In which direction should we go?



Hydrothermal diopside growing at the expense of serpentine: very high T° water/rock interactions.

Possible clues:
add water in the system and forget about equilibrium crystallization (sorry Mr Bowen!...).



Look at the message from mineral inclusions in chromites…

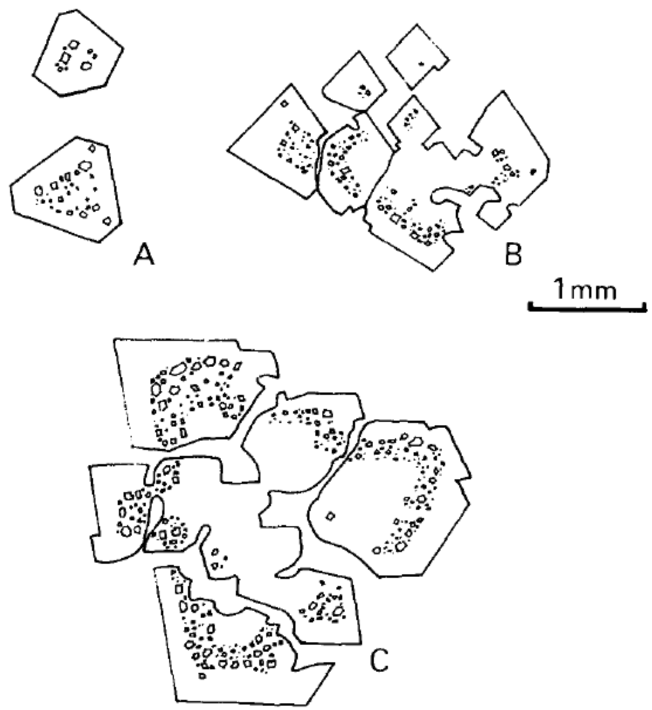


Fig. 7. Different possible stages fro chromite growth (sample M18C, layer B) from euhedral crystal (A) to skeletal dendritic crystal (B) then to octahedron-shaped nodule (C). Note the inclusion-rich zone and the late and deep dissolution cavities.