

Les skarns à magnétite: une synthèse

Yannick Branquet (institut des
Sciences de la Terre
d'Orléans/Géosciences
Rennes)

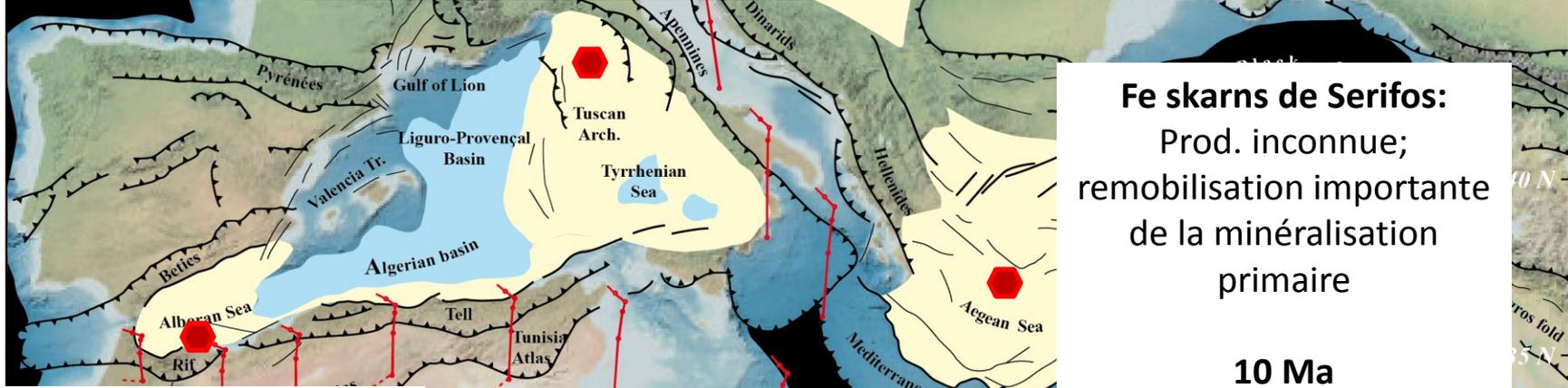
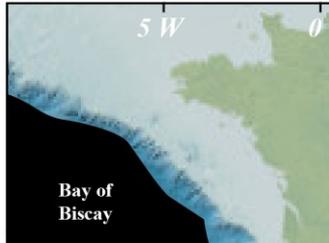
Contribution s'appuyant sur
les travaux de Doctorat et
Master ISTO de M. Ducoux, N.
Lebret et G. Li



Ecole Thématique du CNRS/INSU « Ressources Minérales: du Terrain à l'Expérimentation »
Toulouse 7-9 Juin 2016

Les « skarns à magnétite » méditerranéens: un intérêt économique local du passé

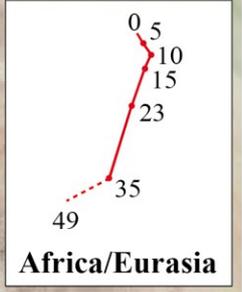
Fe-skarns d'Elbe:
 Prod. ancienne et non connue précisément car confusion avec d'autres types de minéralisations Fe + remobilisation des Fe skarns



Fe skarns de Serifos:
 Prod. inconnue; remobilisation importante de la minéralisation primaire

10 Ma

Fe- skarns de Nador : plus gros district de Fer du Maroc
 Prod. 60 Mt de mineral (45-60 % Fe) de 1915 à 1976.
 Res. 26.4 Mt (sur teneur de coupure à 37.5 %)



-> Tous associés directement à des intrusions

8 Ma

Modifié d'après Jolivet et al., 2006

Place actuelle des « skarns à magnétite » dans le marché du Fer

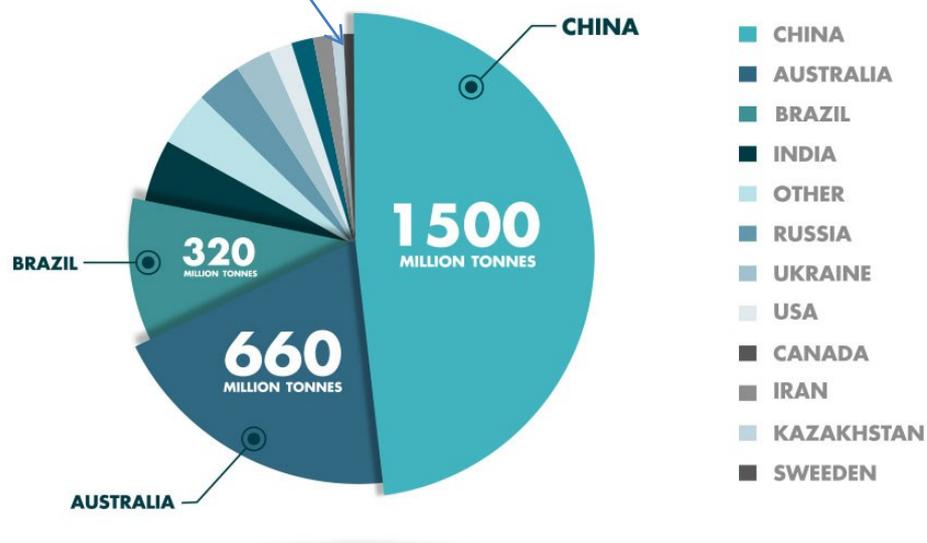
Minerai à Mgt/Apatite (Kiruna-type): Suède 3500 Mt réserves @60% Fe et 0,9% P (1,9% res. mond.). Prod annuelle 23 Mt.

NB: La plupart de gisements identifiés comme étant des « skarns géants » sont maintenant classés dans les IOCG

BIF (types Lac supérieur + Agglomera) = 80 % [production+réserves] mondiales à teneur moyenne de 60% Fe

	Major Owner	Country	Province / State	Iron ore production in 2014, Mt
Hammersley	Rio Tinto	Australia	Western Australia	163
Carajas	Vale	Brazil	Para	120
Chichester Hub	Fortescue Metals	Australia	Western Australia	90*
Yandi	BHP Billiton	Australia	Western Australia	79
Mount Whaleback	BHP Billiton	Australia	Western Australia	77
Solomon Hub	Fortescue Metals	Australia	Western Australia	58*
Area C	BHP Billiton	Australia	Western Australia	57
Hope Downs	Rio Tinto / Hancock	Australia	Western Australia	43
Mariana Hub	Vale	Brazil	Minas Gerais	39
Sishen	Anglo American	South Africa	Northern Cape	36

exemple ukrainien de Krivoï Rog: 2800 Mt (prod+res) @57% Fe



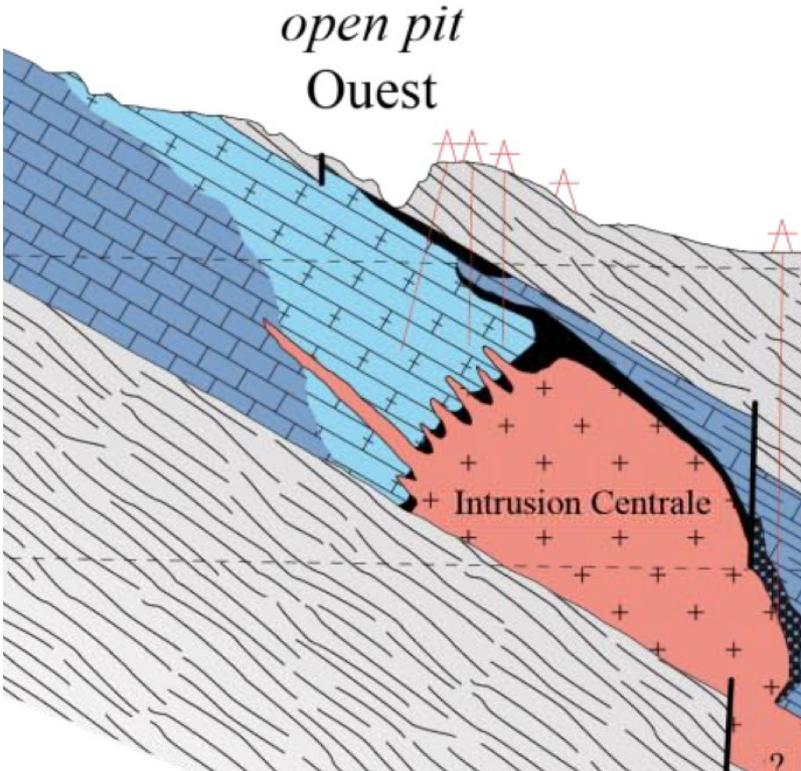
Production de minerai de fer en 2014. Prod. Chine en minerai total (brut + utilisable)

CHINE

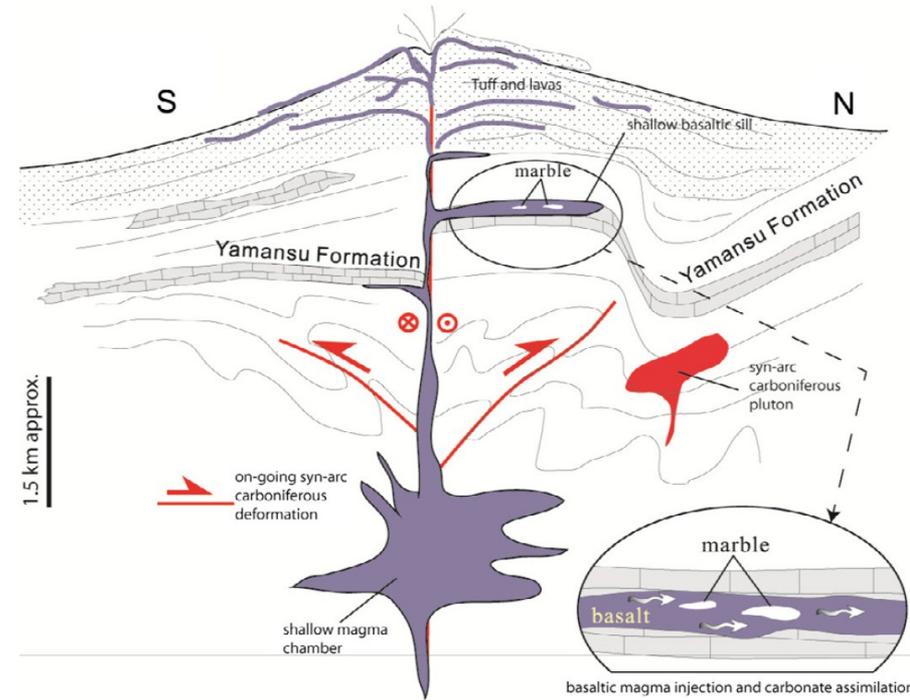
- > 43% prod: BIF pauvres (@30% Fe, e.g. Anshan)
- > 8% prod: minerai oolithique à P (@30% Fe, Yangtze plateforme)
- > 14% prod: Fe/Ti/V mafiques-ultramafiques intrusions (@30% Fe, 10% Ti₂O₅, 0,5% V₂O₅, e.g. gabbro lité de Panzhihua)

- > 35% prod: type « Submarine Volcanogenic Iron Oxide Deposits (SVIO) » incluant des « skarns à magnétite » (moy. @45 % Fe), magmatisme Carbonifère/Permien et mésozoïque. Nombreux petits gisements exploités (2 à 40 Mt de res.) (Hou et al., 2014)

.....Distinguo économique comme géologique entre.....



VS.

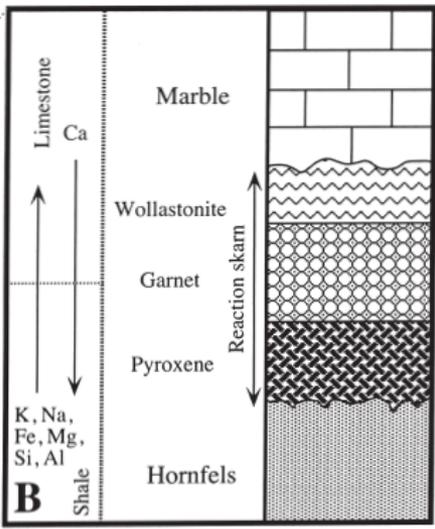
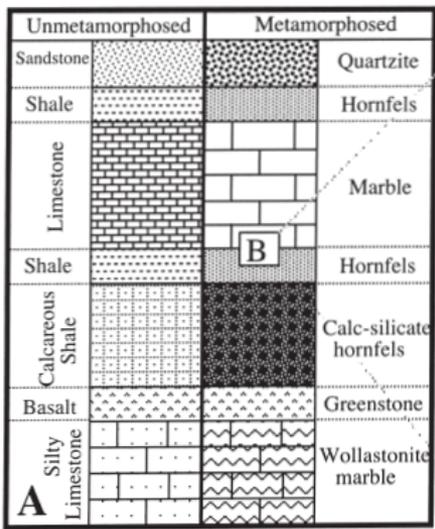


Skarns à magnétite en relation directe **avec** une intrusion plutonique (Nador au Maroc et Serifos en Grèce + Vegas peladas, argentine, Pons et al., 2009)

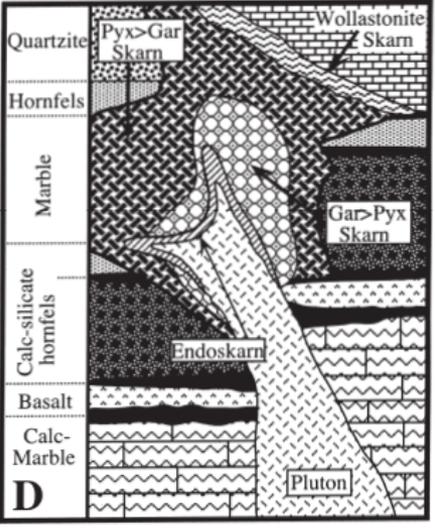
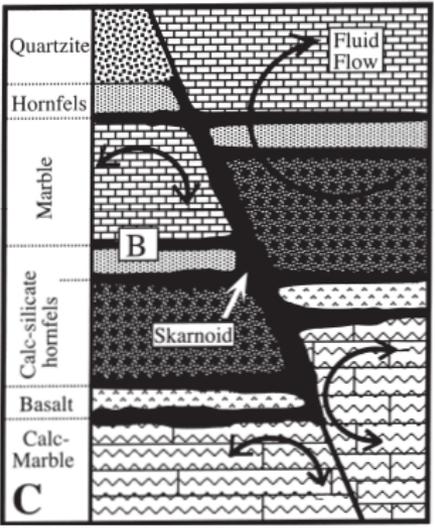
Gisements de magnétite associés à des skarns **encaissés au sein de séries volcano-sédimentaires sans** relation directe avec une intrusion plutonique (Yamansu et Cihai, Tianshan, Chine)

Skarns et minéralisations: définitions, principes et précautions

SKARN: roche constituée principalement de silicates calciques (grenats, pyroxènes essentiellement) -> aucune connotation génétique ni métallogénique



Li, 2012



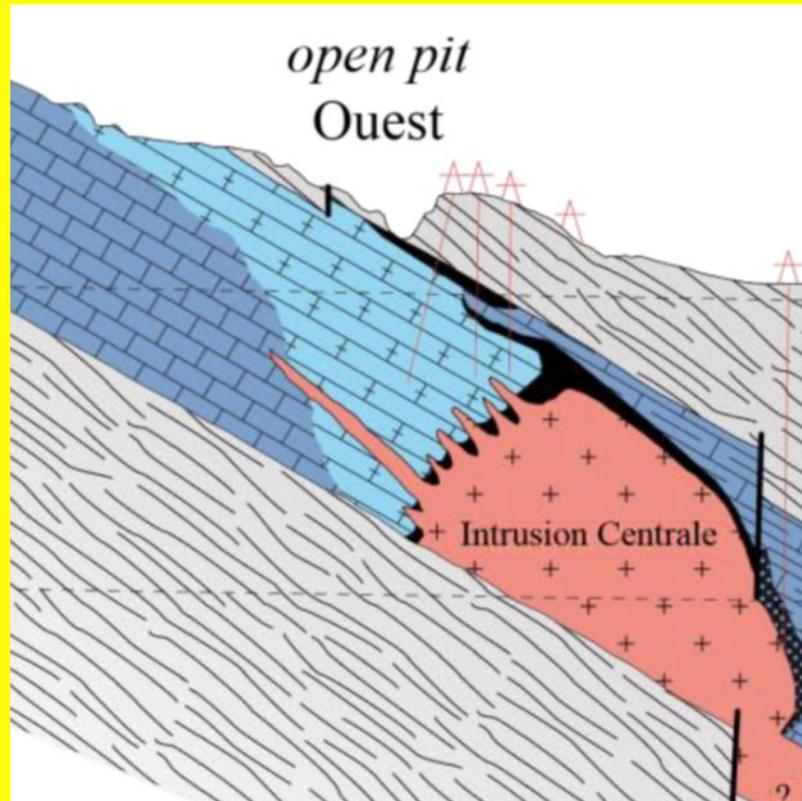
2 effets majeurs:

-> création de porosité/perméabilité + rhéologie compétente

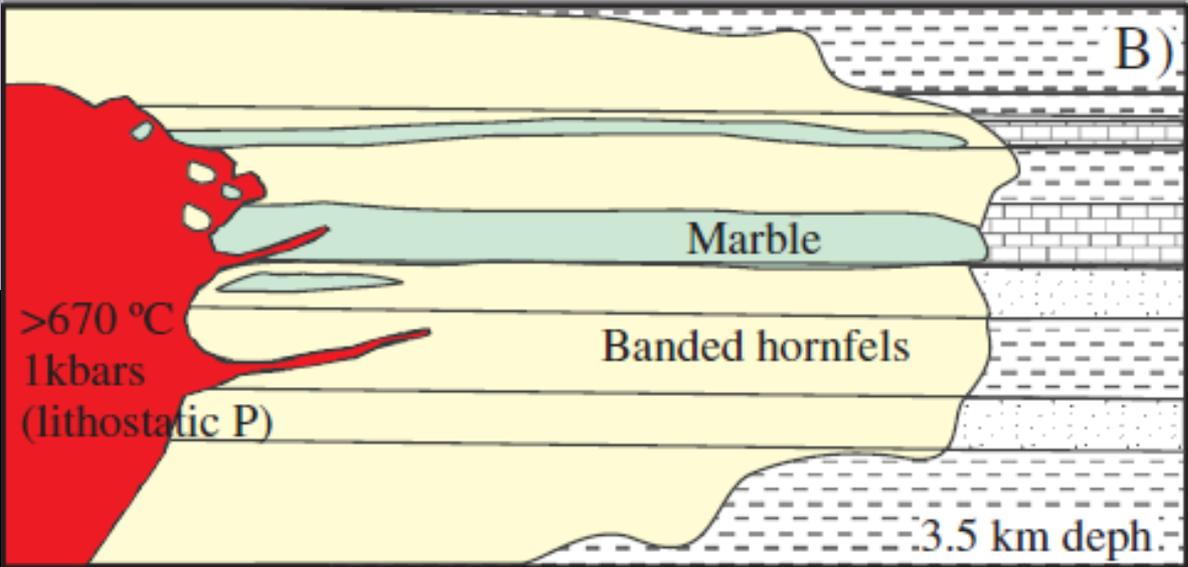
-> assimilation de carbonates par le magma, décarbonatation et donc changement potentiel de cond. physico/chimiques

-> pluton souvent absent, télescopages nombreux, fluides minéralisateurs précoces etc... minéralisation associée à des skarns

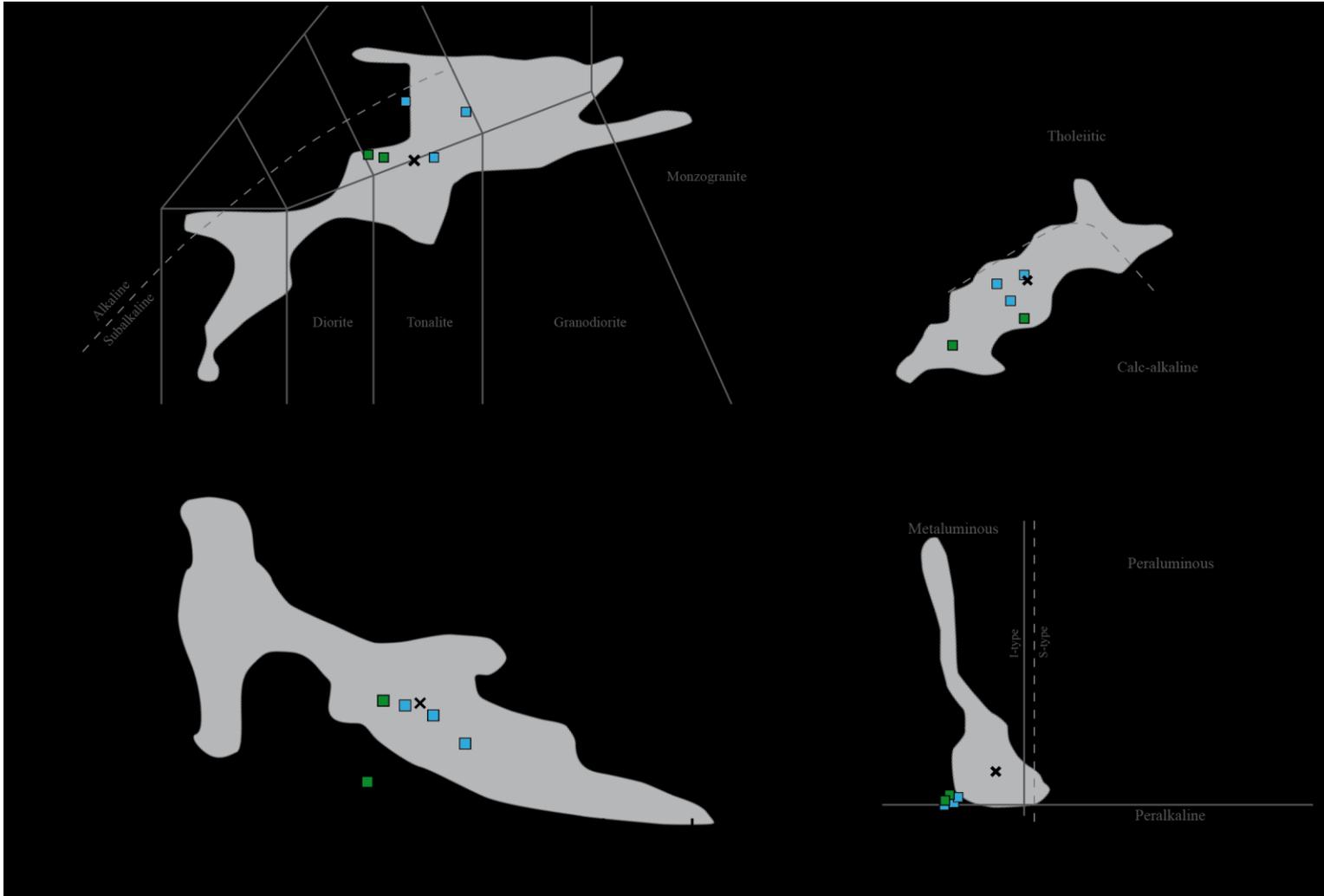
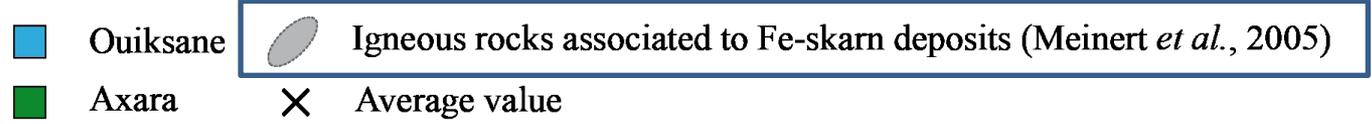
Skarns à magnétite en relation directe avec une intrusion plutonique



Modèle métallogénique: stade 1



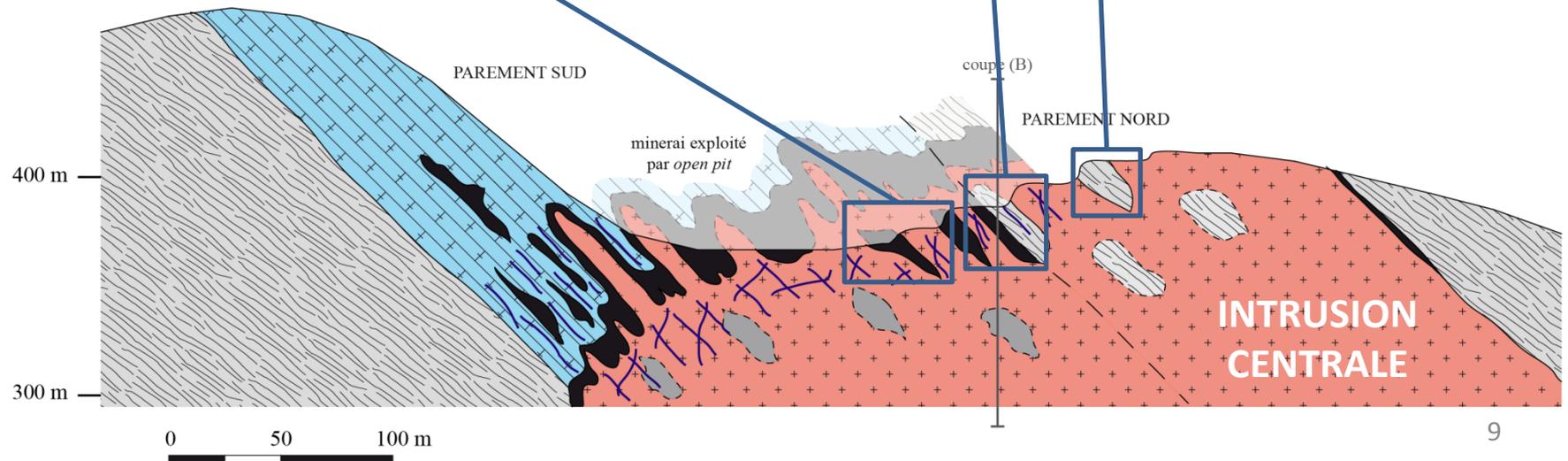
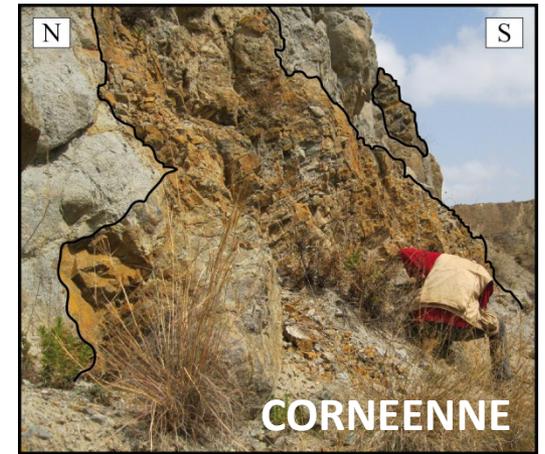
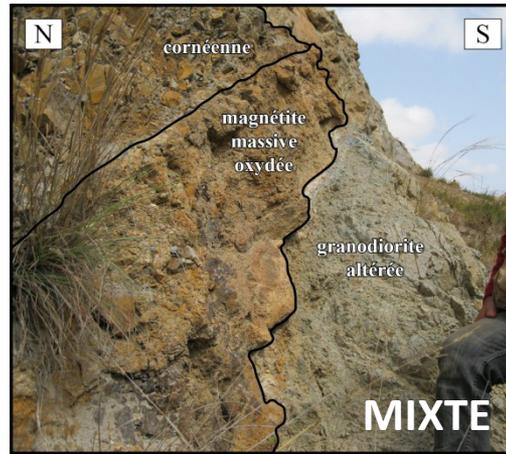
Géochimie du magmatisme associé



Architecture et géométrie des intrusifs

■ minerais massifs ■+ roches intrusives (Miocène) ■ marbres (Mésozoïque) ■ schistes (Mésozoïque)

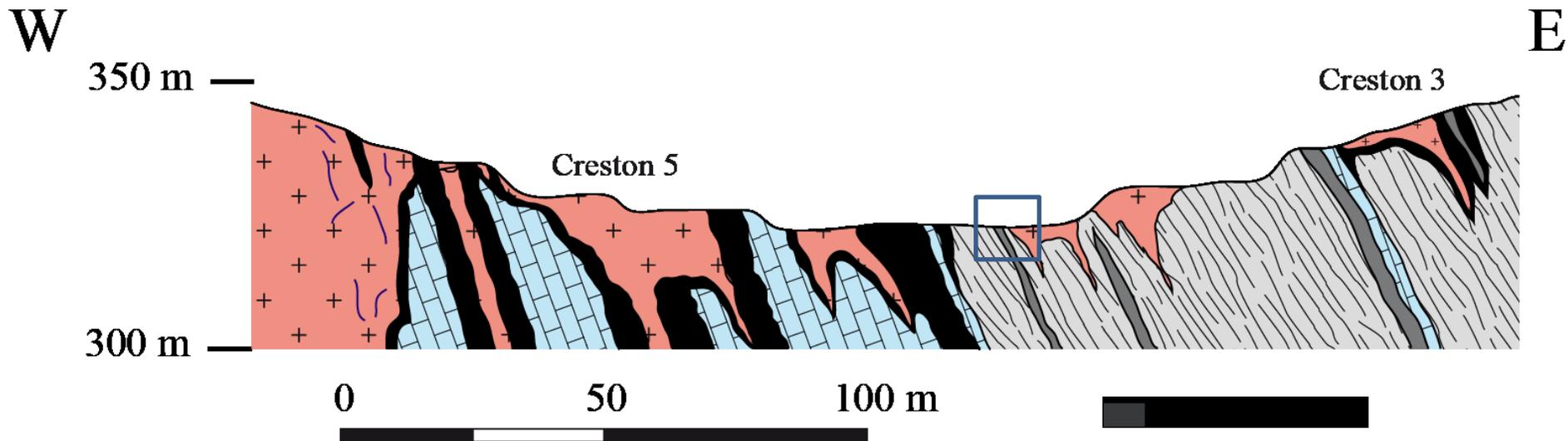
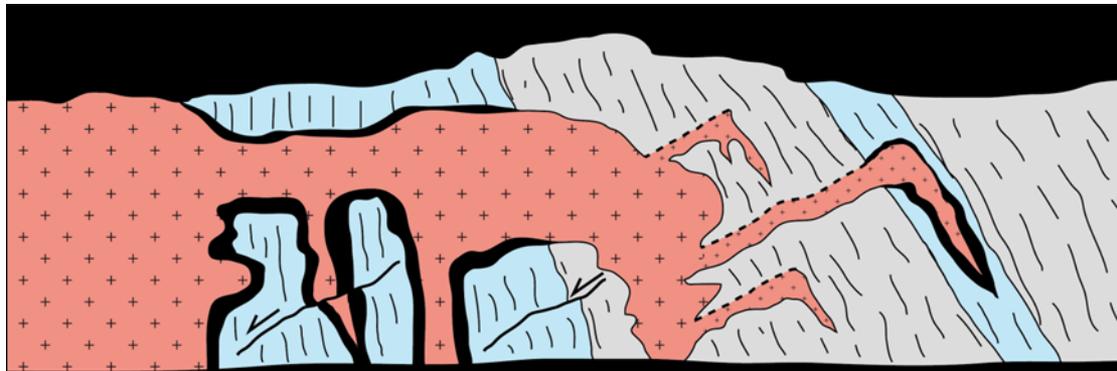
Le gisement de Ouksane (Nador)



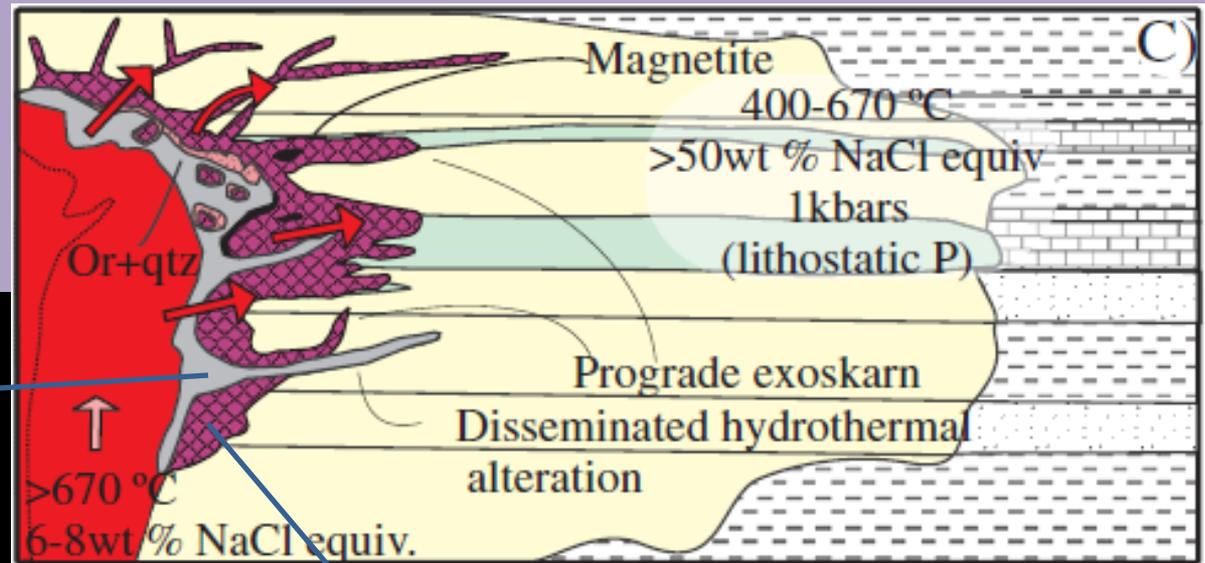
Architecture et géométrie des intrusifs

■ minerais massifs + roches intrusives (Miocène) ▨ marbres (Mésozoïque) ▩ schistes (Mésozoïque)

Le gisement de Axara (Nador)



Modèle métallogénique: stade 2



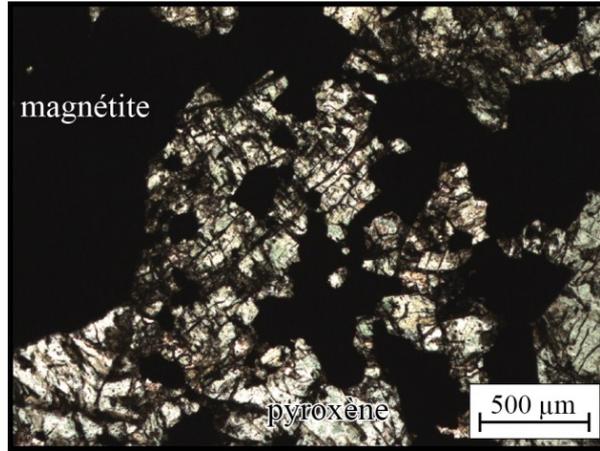
Endoskarns HT à grenats + hedenbergite (sills de Serifos)



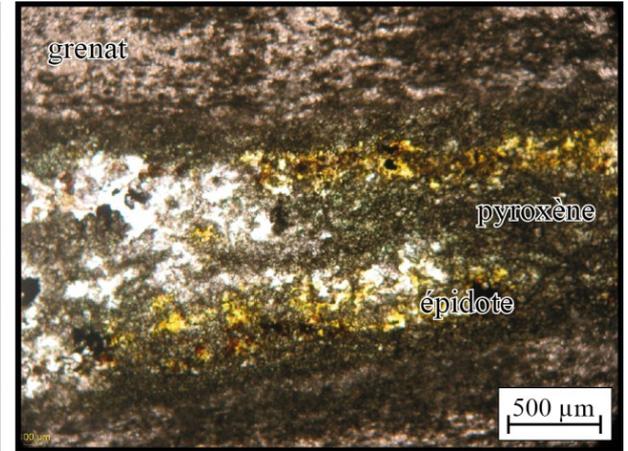
Exoskarns fissuraux HT et distaux MT (Serifos)



Compositions chimiques des pyroxènes des skarns à magnétites (Nador)



Endoskarn

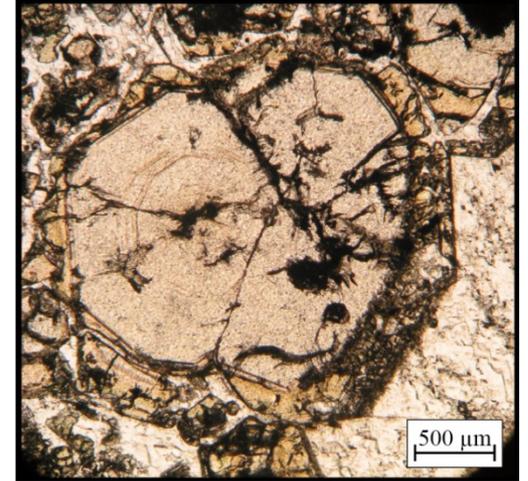
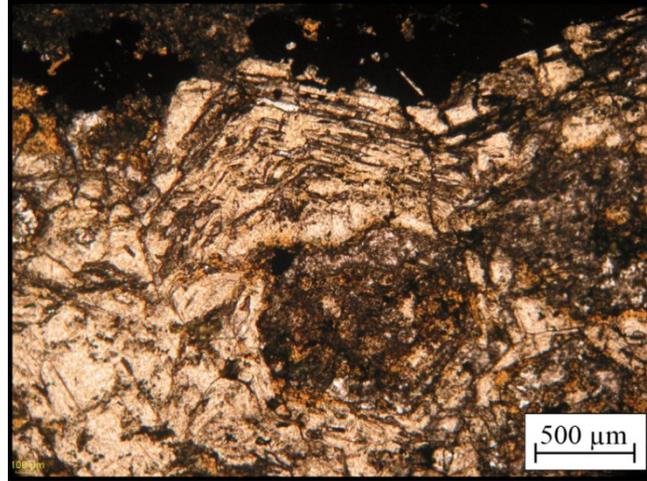


Exoskarn

Champ des pyroxènes
des skarns ferrifères
(Meinert *et al.*, 2005)



Compositions chimiques des grenats des skarns à magnétite (Nador)



Champ des grenats
des skarns ferrifères
(Meinert *et al.*, 2005)



Nature et composition des fluides progrades

E. 2651-Qtz

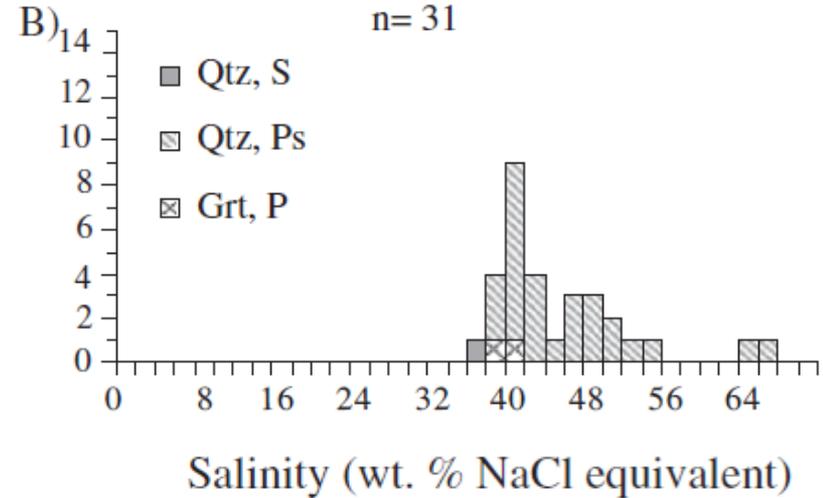
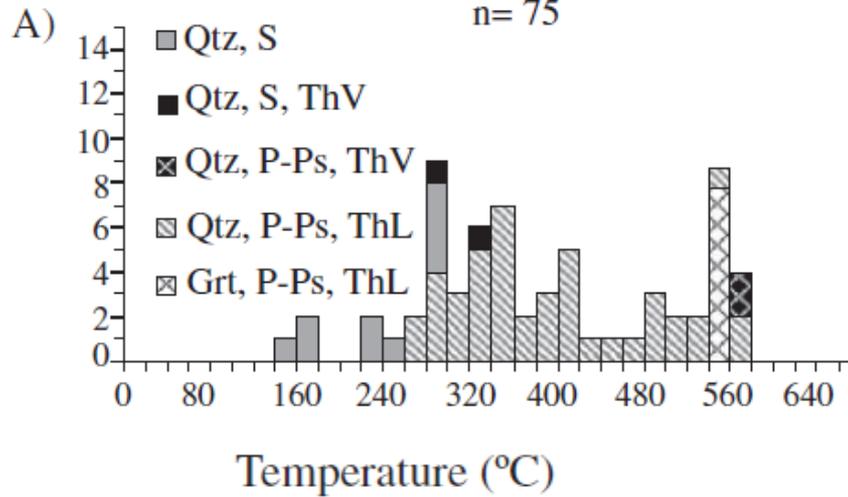
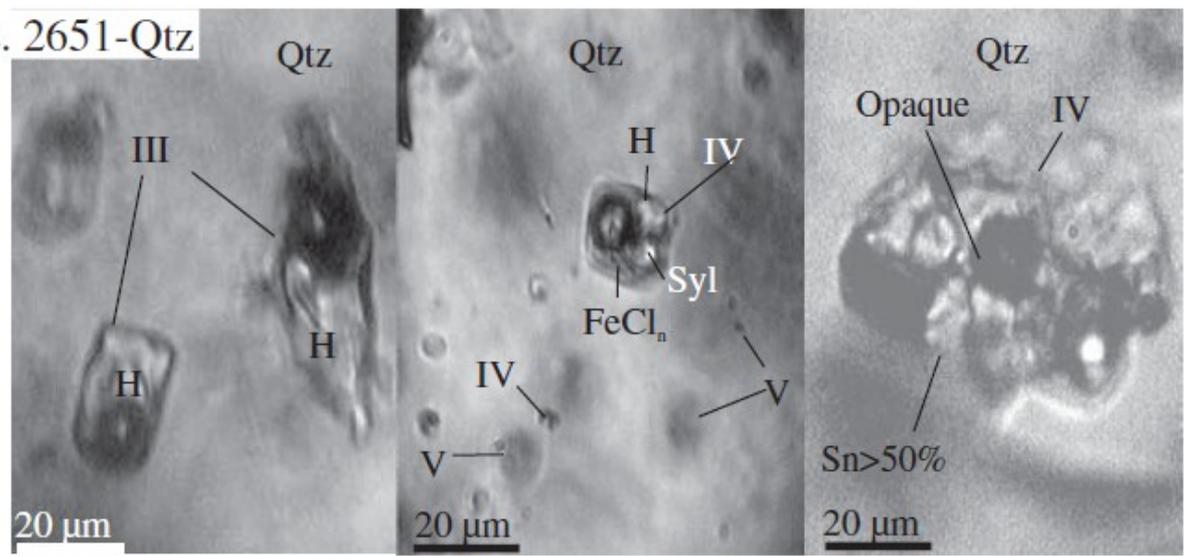
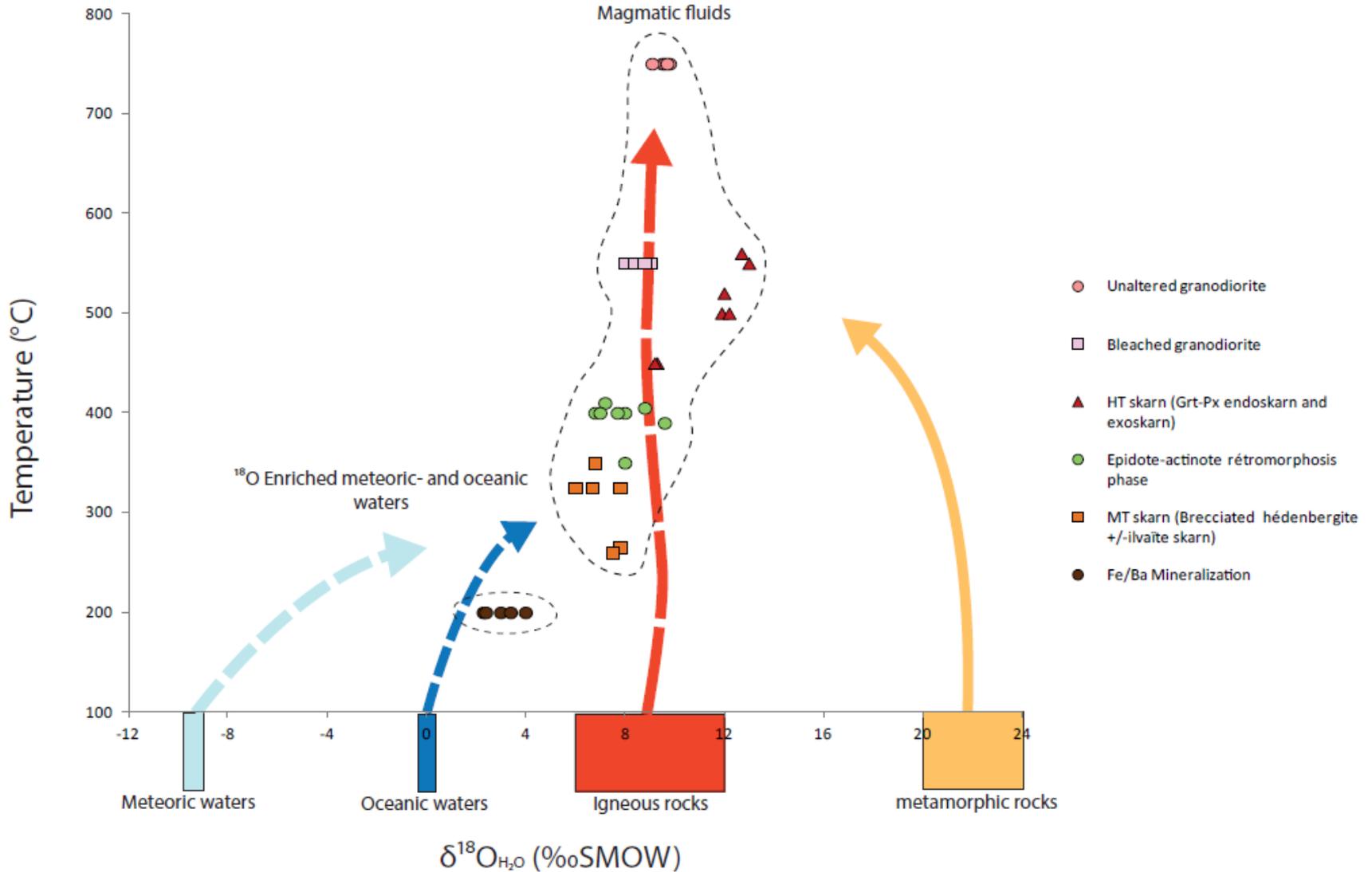


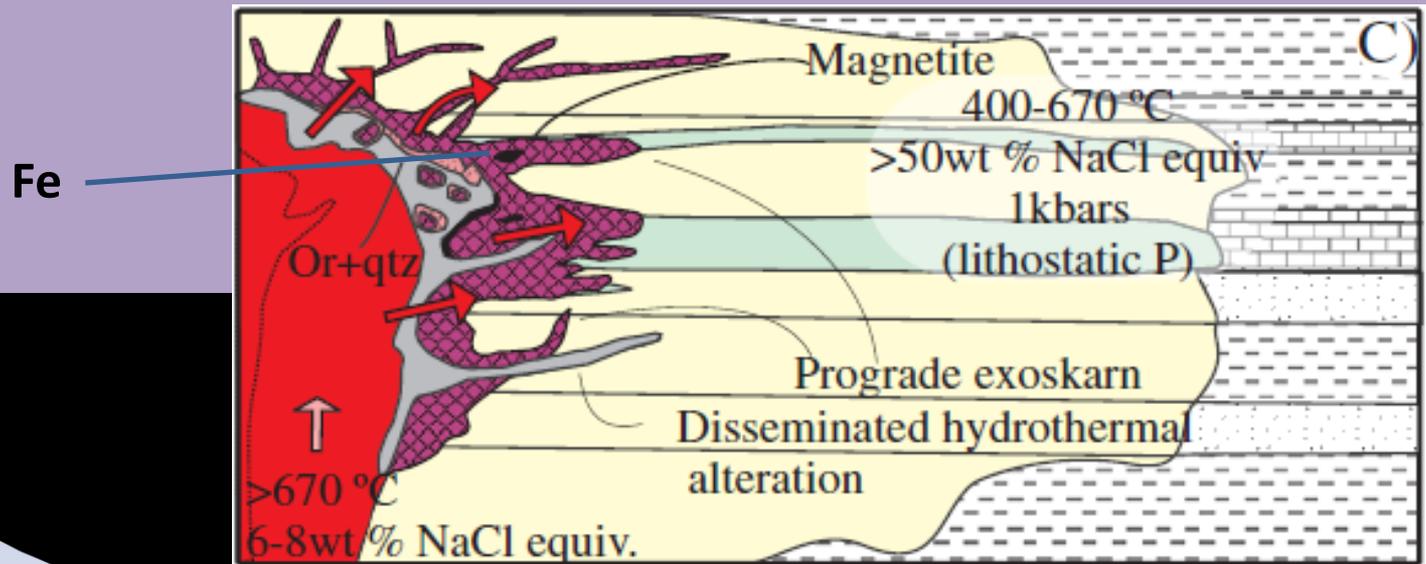
FIG. 15. Histograms summarizing calc-silicate, quartz, and calcite-hosted fluid inclusion homogenization temperatures and salinities from the Vegas Peladas skarns associated with diorite (A to H) and granite (I and J). Cal = calcite, Clpx = clinopyroxene, Grt = garnet, L = liquid, n = number of measured fluid inclusions, P = Primary, Ps = pseudosecondary, Qtz = quartz, S = secondary, Th = homogenization temperature, V = vapor.

Origine des fluides progrades

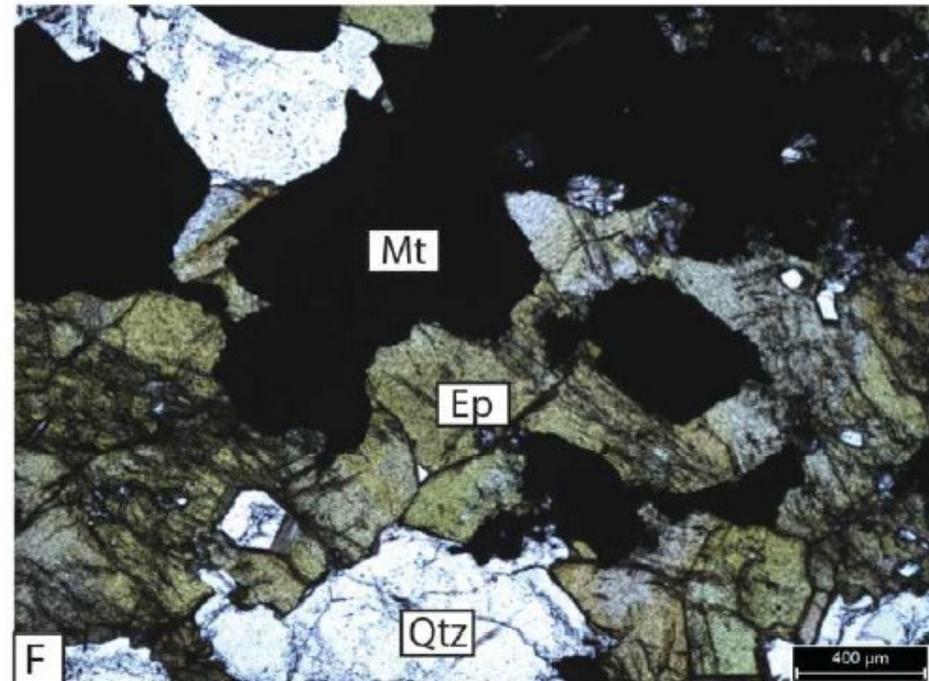
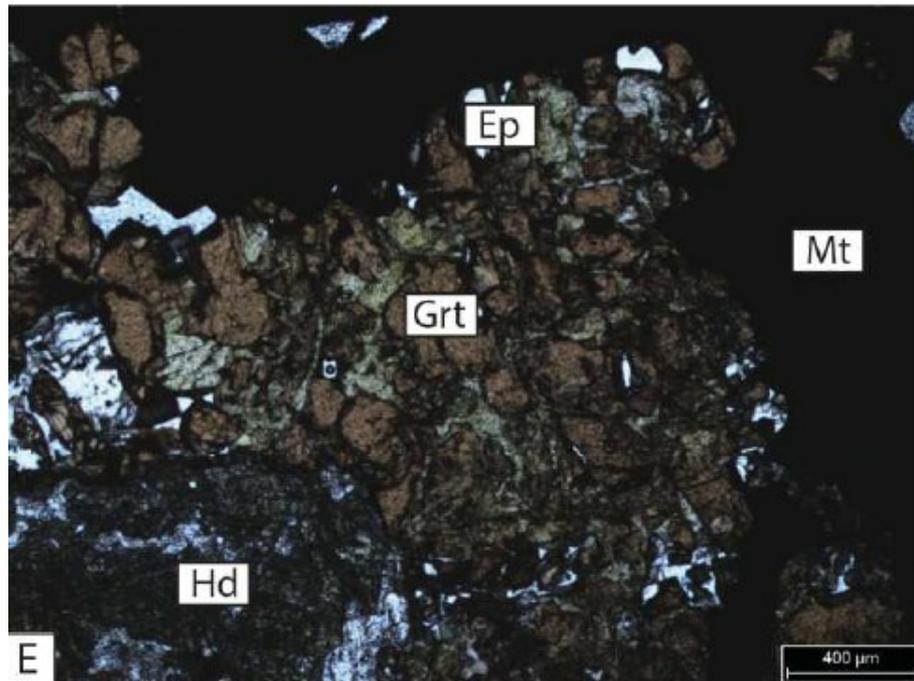
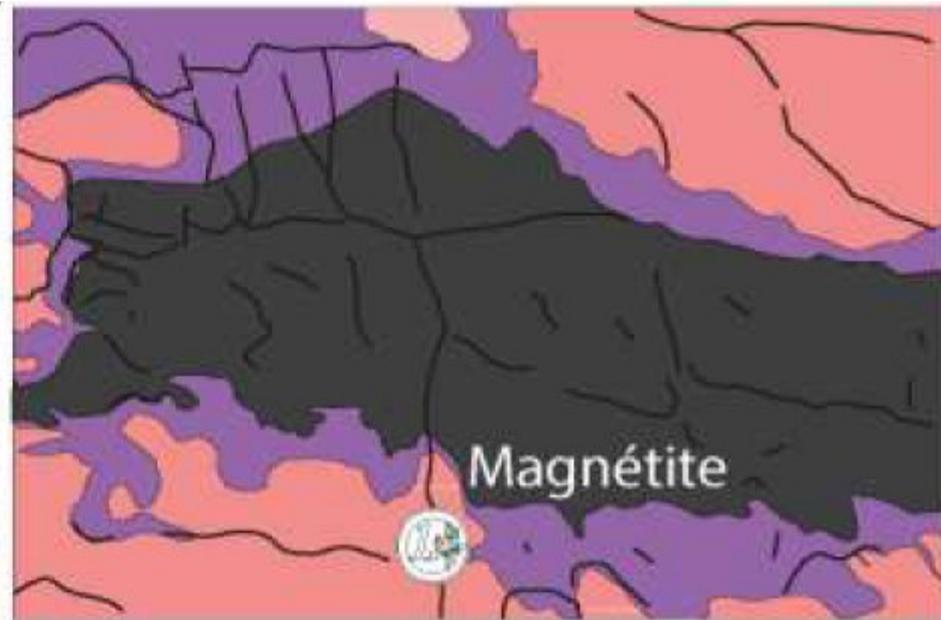


Serifos, Ducoux et al., soumis, compiled from Salemink, 1985.

Modèle métallogénique: stade 3

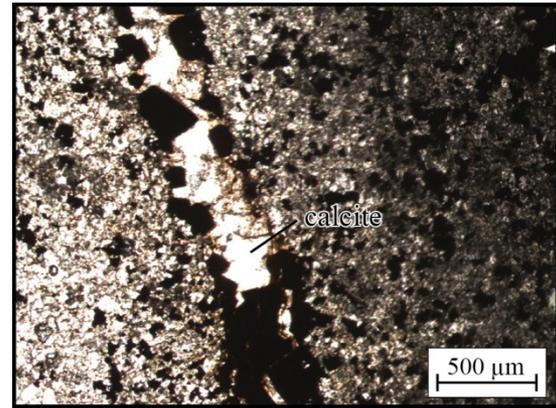


Stade de minéralisation à magnétite de la fin du prograde au début du rétrograde (endoskarn Serifos)

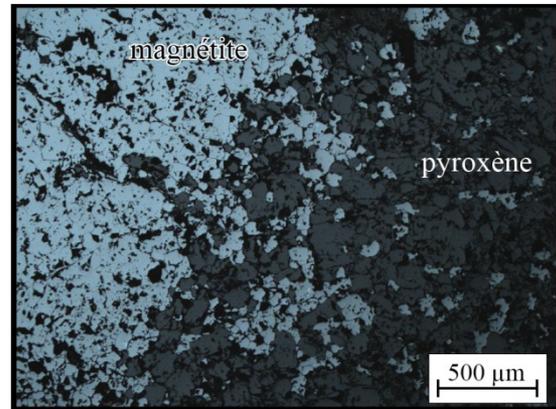


Compositions chimiques des magnétites (Nador) Plusieurs générations dans le détail

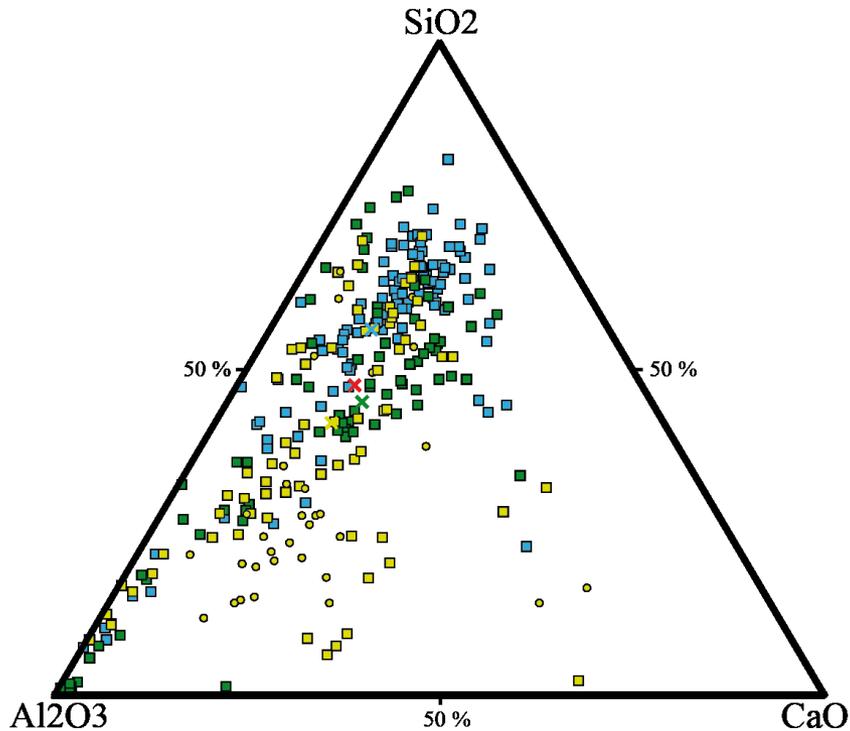
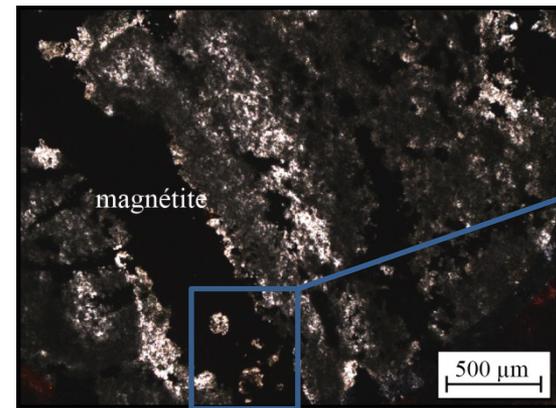
Magnétite I + Calcite I



Magnétite II



Magnétite II



Magnétites de remplacement

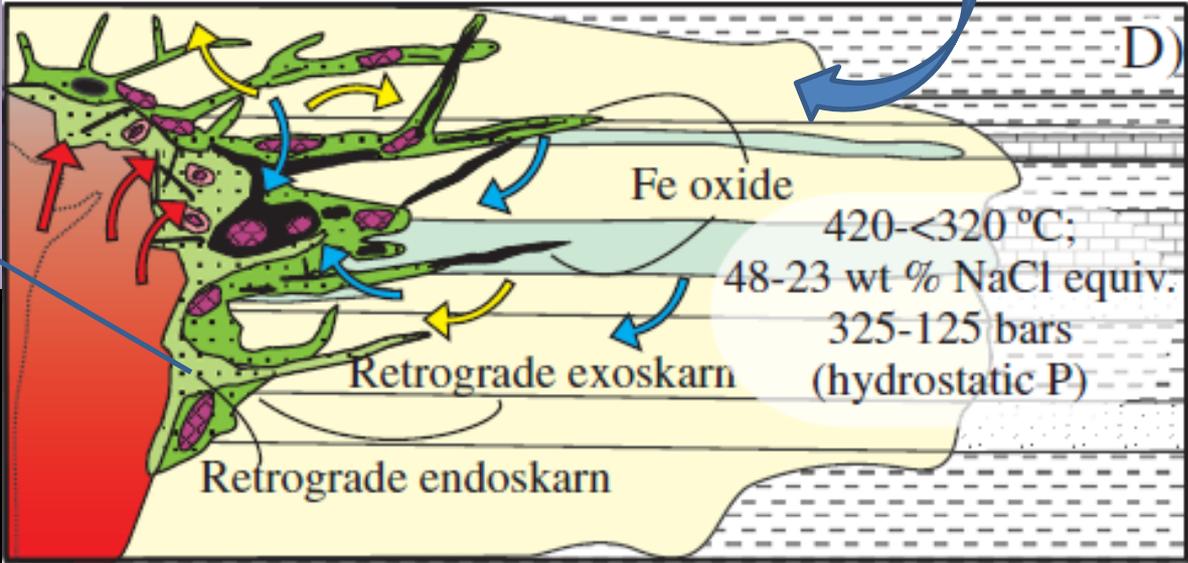
- Ouiksane
- Axara
- Setolazar

Grenats

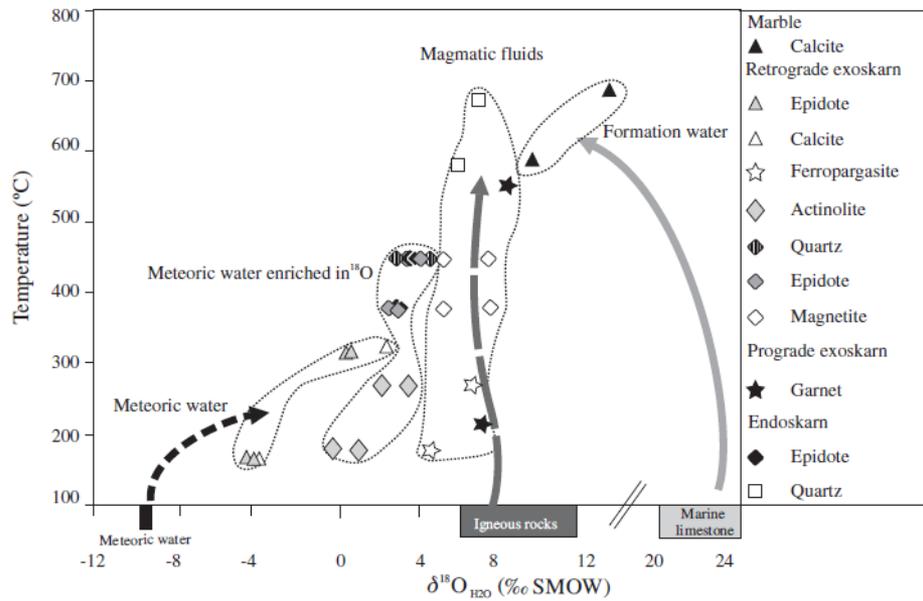
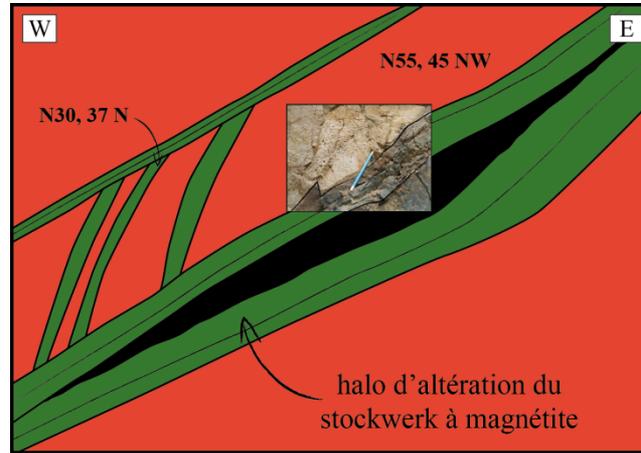
Modèle métallogénique: stade 4

Fluides météoriques

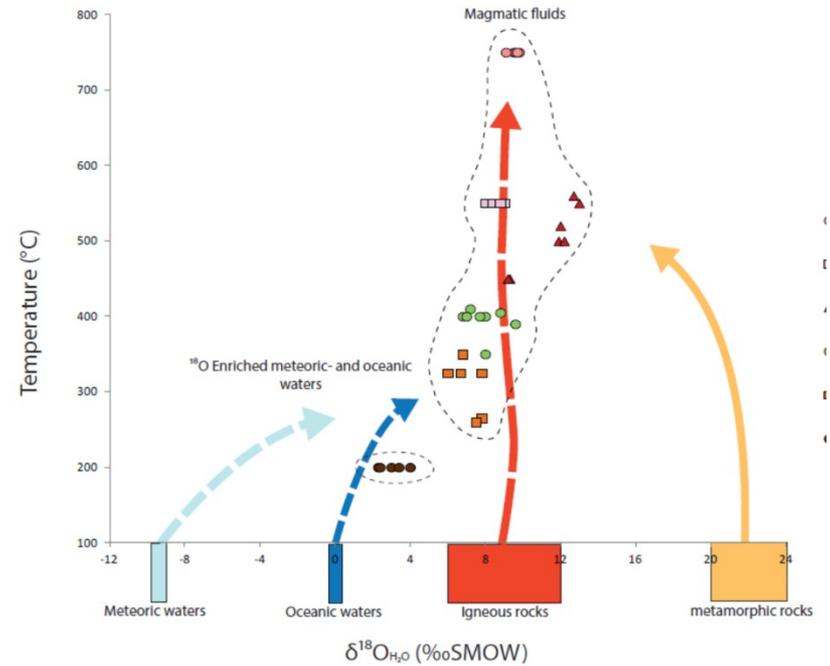
Altération des skarns



hématite-pyrite-chlorite-calcite-(épidote-chalcopyrite)

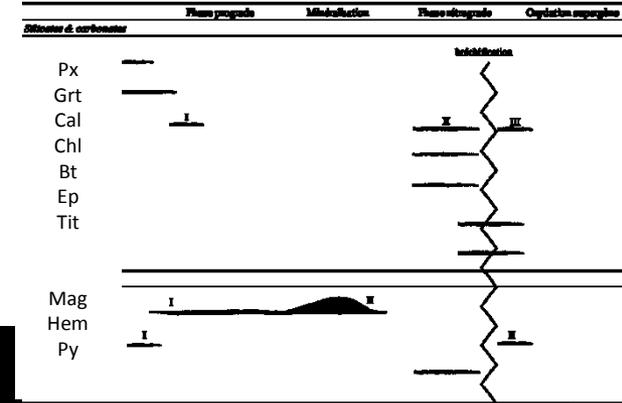
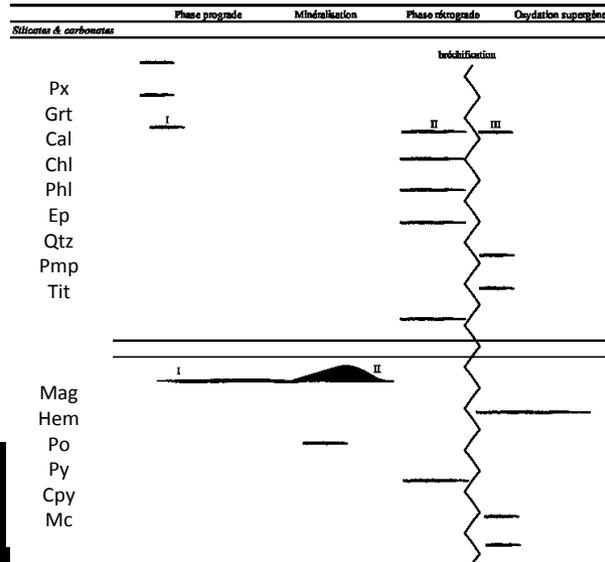
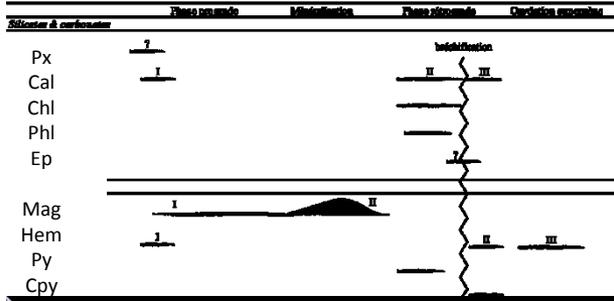


Vegas peladas



Serifos

Séquences paragénétiques caractéristiques des skarns à magnétite (ici Nador)



Phase prograde

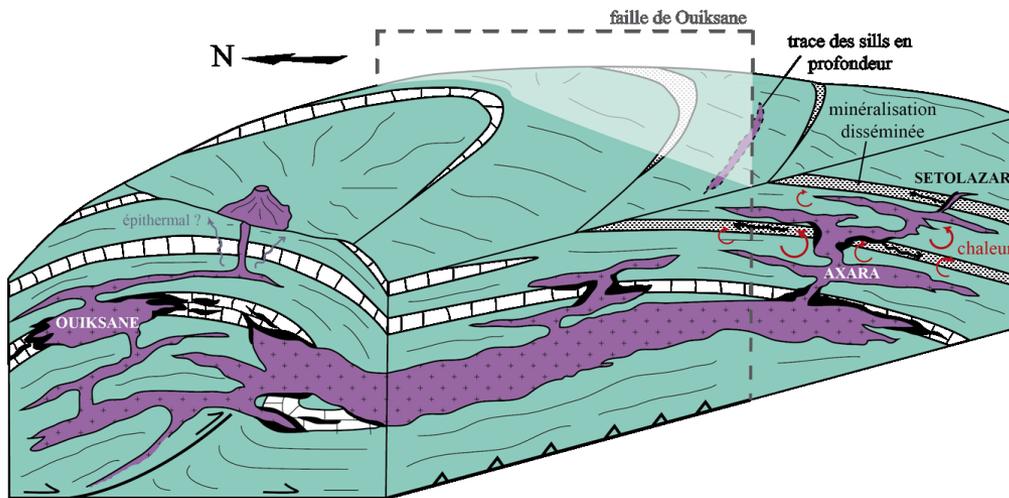
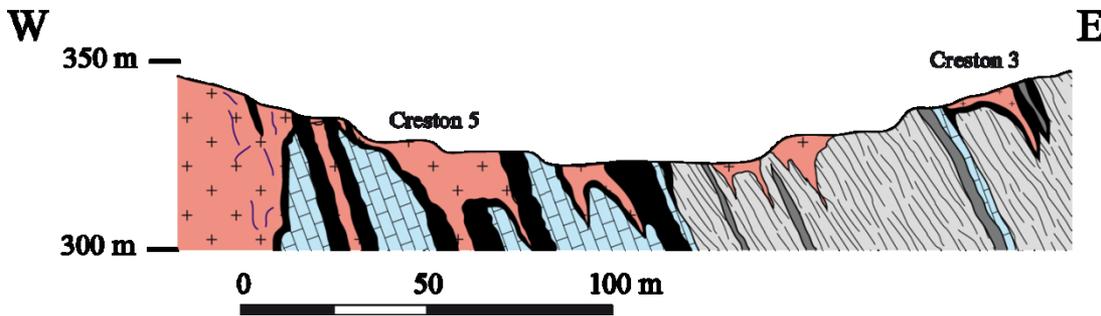


Minéralisation

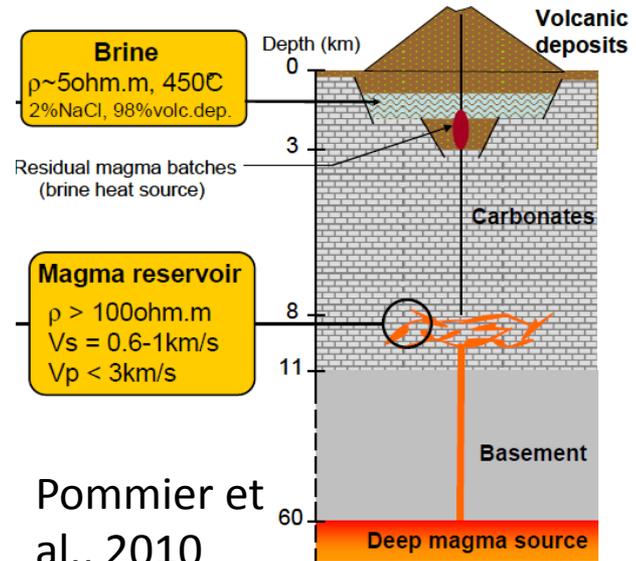


Phase rétrograde

Synthèse: chambre hypo-volcanique très digitée dans carbonates (e.g Vésuve)



Hyp.2: Crystal-poor deep magma interconnected within carbonates

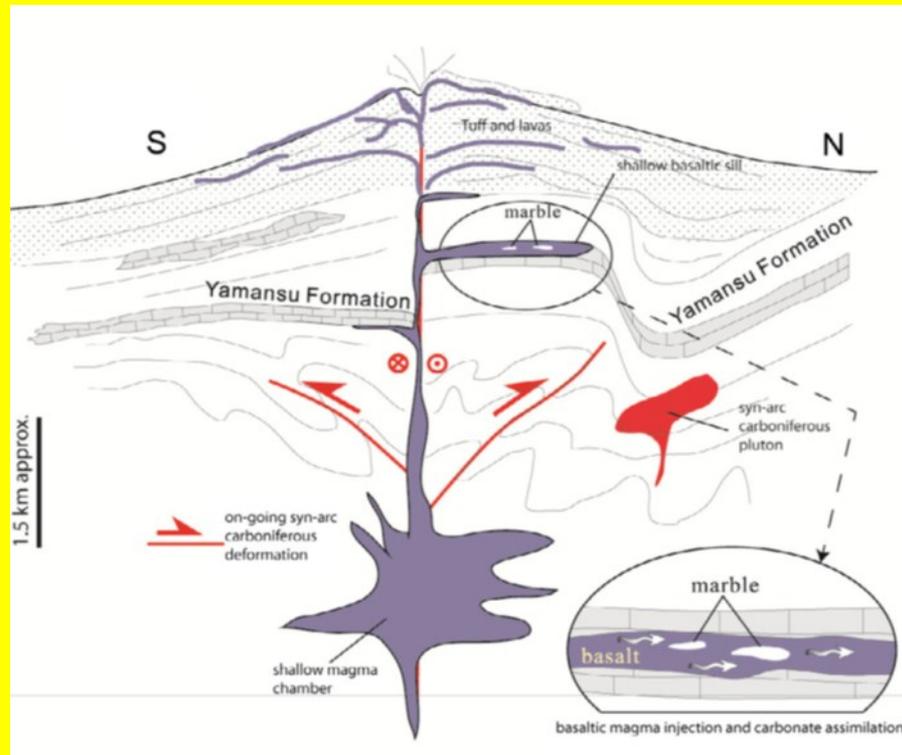


Pommier et al., 2010

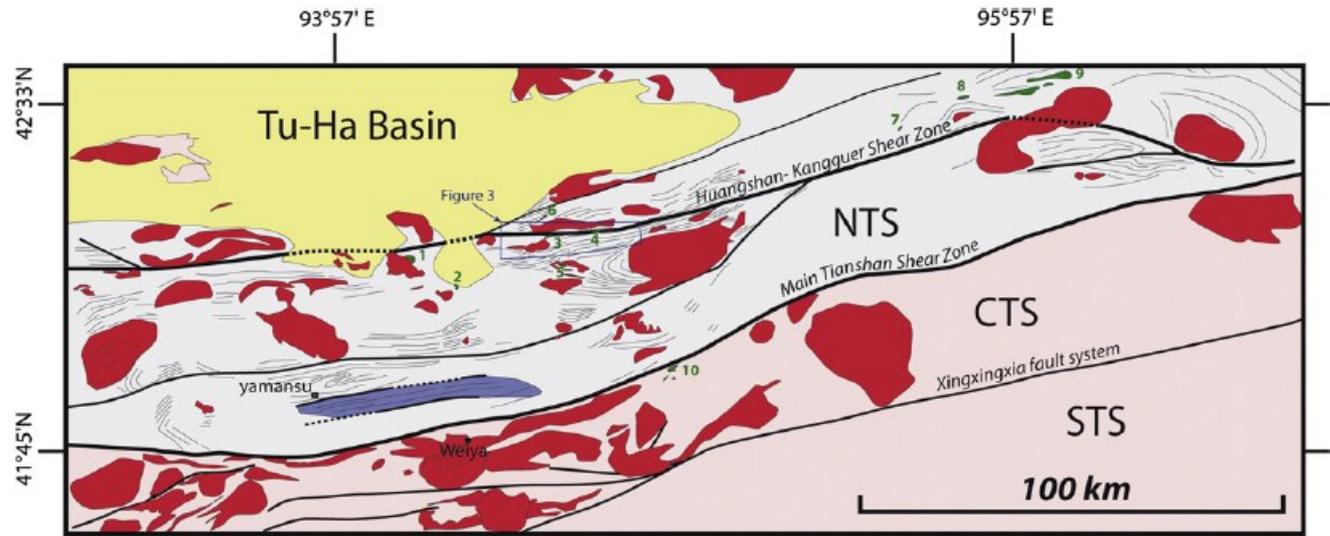
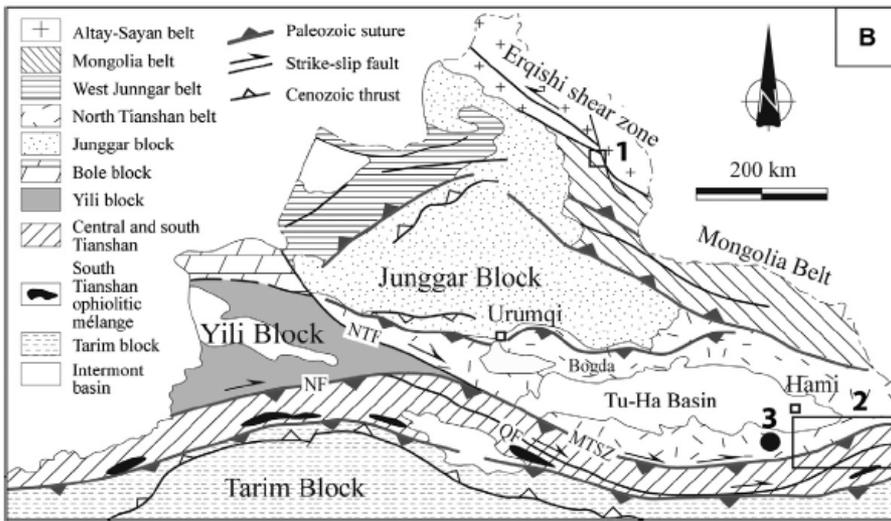
Melt inclusion record of immiscibility between silicate, hydrosaline, and carbonate melts: Applications to skarn genesis at Mount Vesuvius

Paolo Fulignati* Dipartimento di Scienze della Terra, Università degli Studi di Pisa, via Santa Maria 53, 56126 Pisa, Italy
 Vadim S. Kamenetsky* School of Earth Sciences and Centre for Ore Deposit Research, University of Tasmania, GPO Box 252-79, Hobart, Tasmania 7001, Australia
 Paola Marianelli* } Dipartimento di Scienze della Terra, Università degli Studi di Pisa, via Santa Maria 53, 56126 Pisa, Italy
 Alessandro Sbrana* } Italy
 Terrence P. Mernagh* Australian Geological Survey Organisation, GPO Box 378, Canberra, ACT 2601, Australia

Gisements de magnétite associés à des skarns encaissés au sein de séries volcano-sédimentaires sans relation directe avec une intrusion plutonique



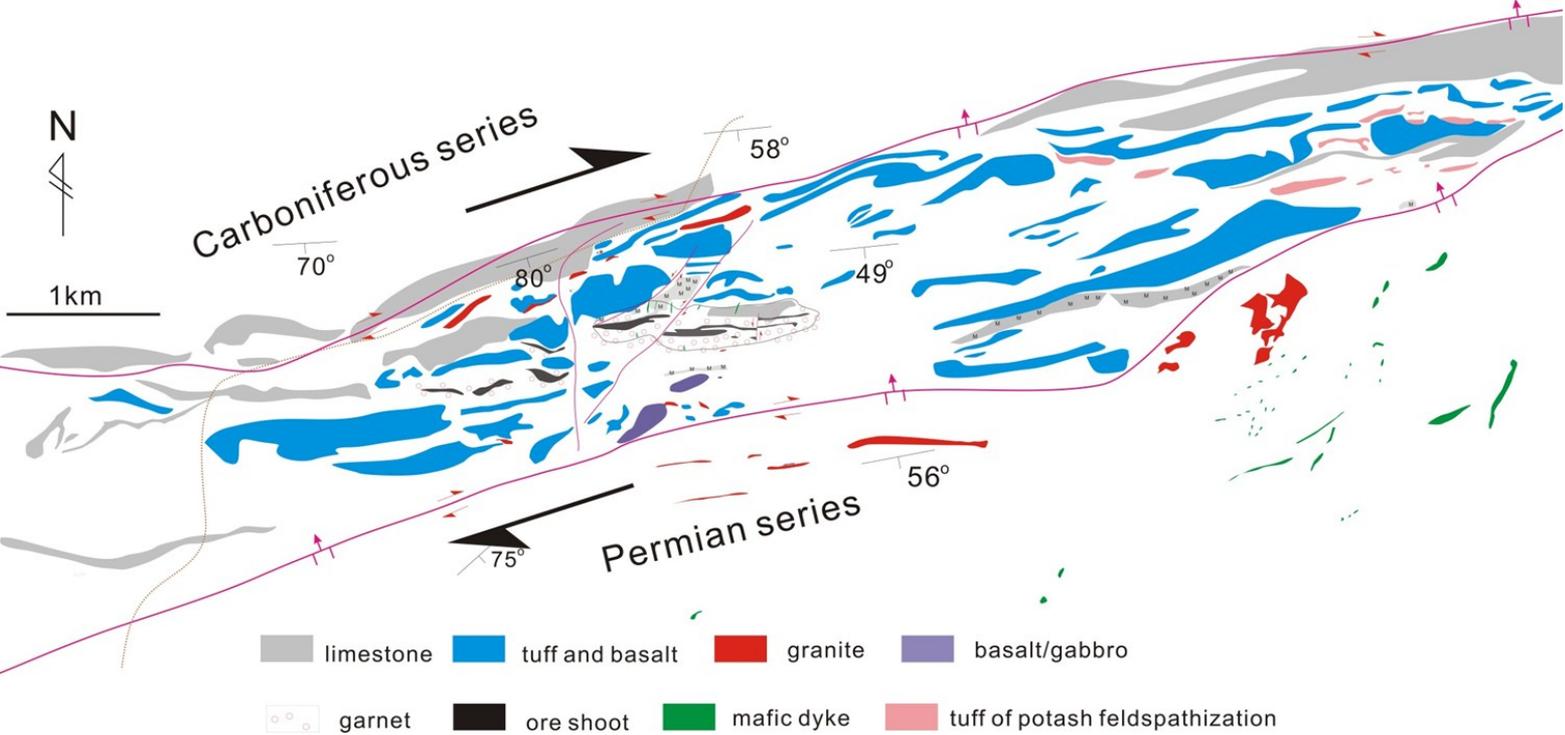
Contexte géologique des gisements de Yamansu et Cihai, Tianshan, Chine

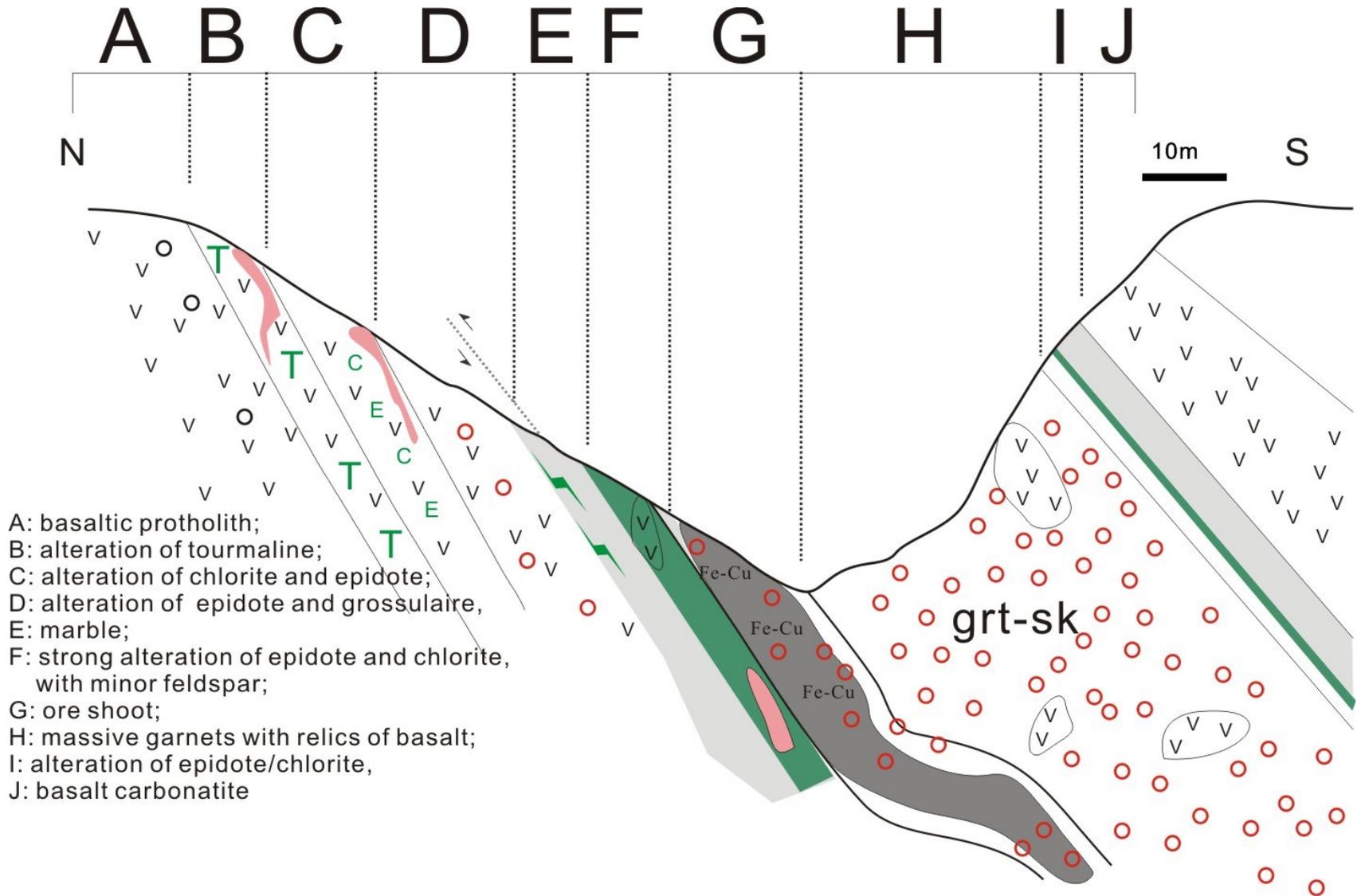


- Lower Paleozoic and Proterozoic rocks (undifferentiated)
- Post-Permian sediments of the Tu-Ha basin (Quaternary not figured in the NTS, CTS and STS)
- Permian sediments
- Bedding/foliation trace in NTS
- Carboniferous volcanics and sedimentary rocks (arc formations)
- Mafic/ultramafic Permian intrusives bearing Cu-Ni sulphides deposits
- Orthogneiss and intrusions (Carboniferous and Permian in the NTS)

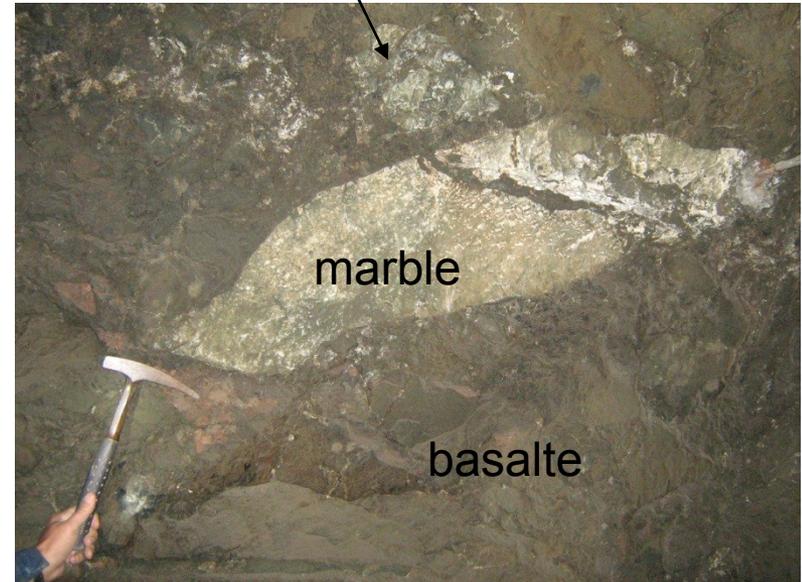
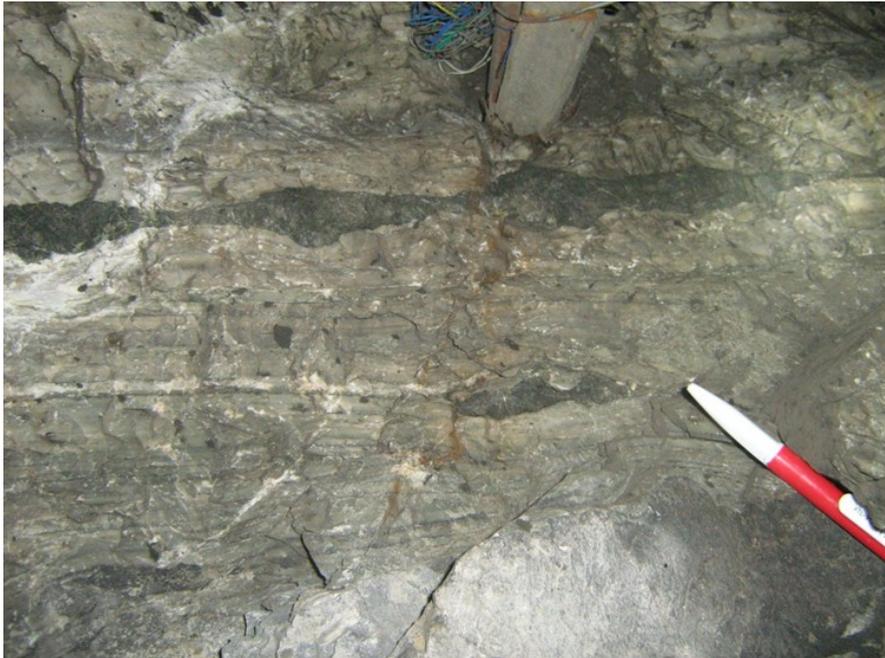
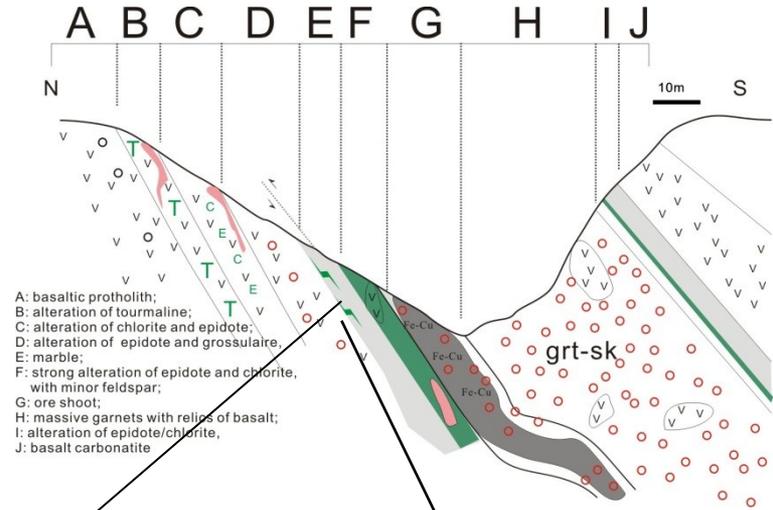
Branquet et al., 2012

Gisement de Yamansu: syn-arc, 328 Ma

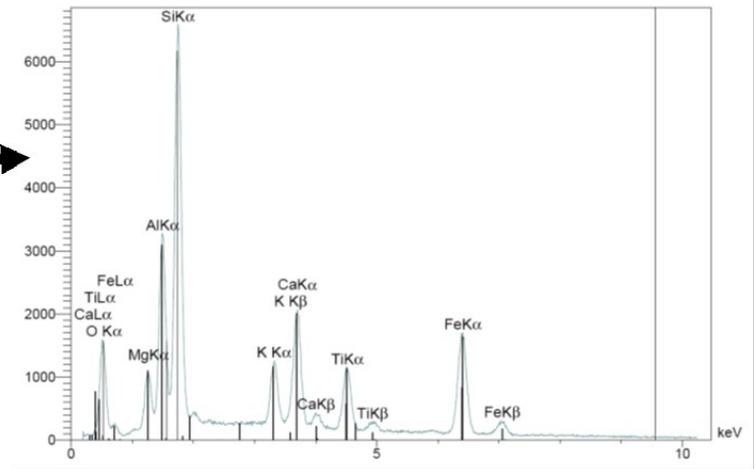
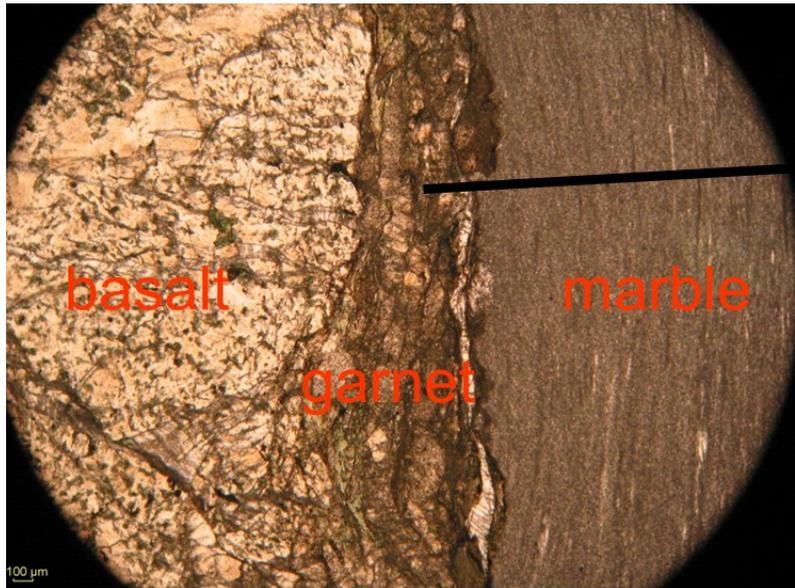




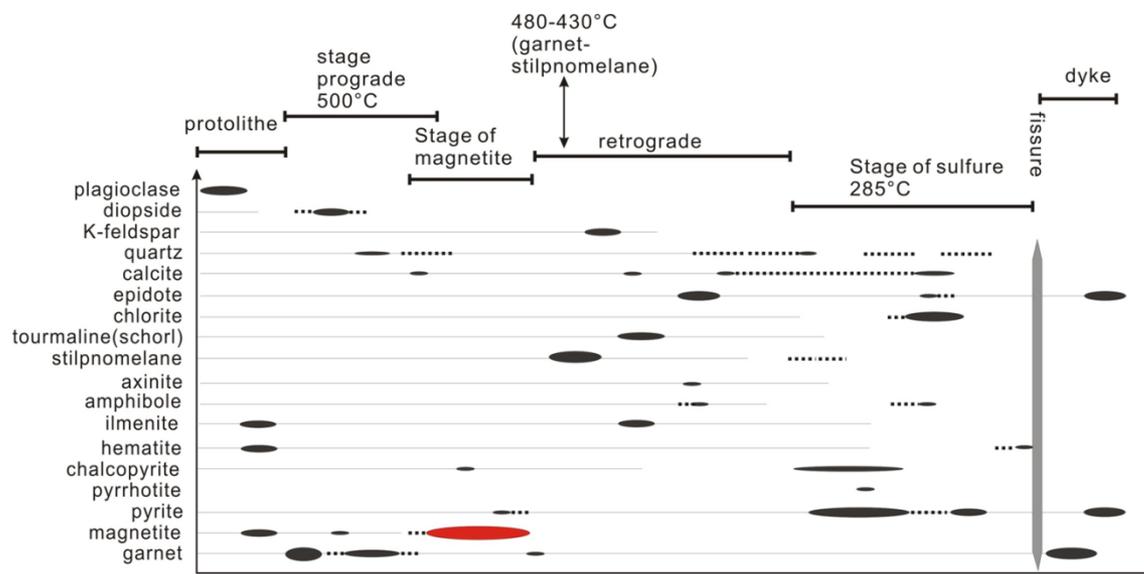
Nombreuses évidences
d'assimilation de carbonates
par les basaltes



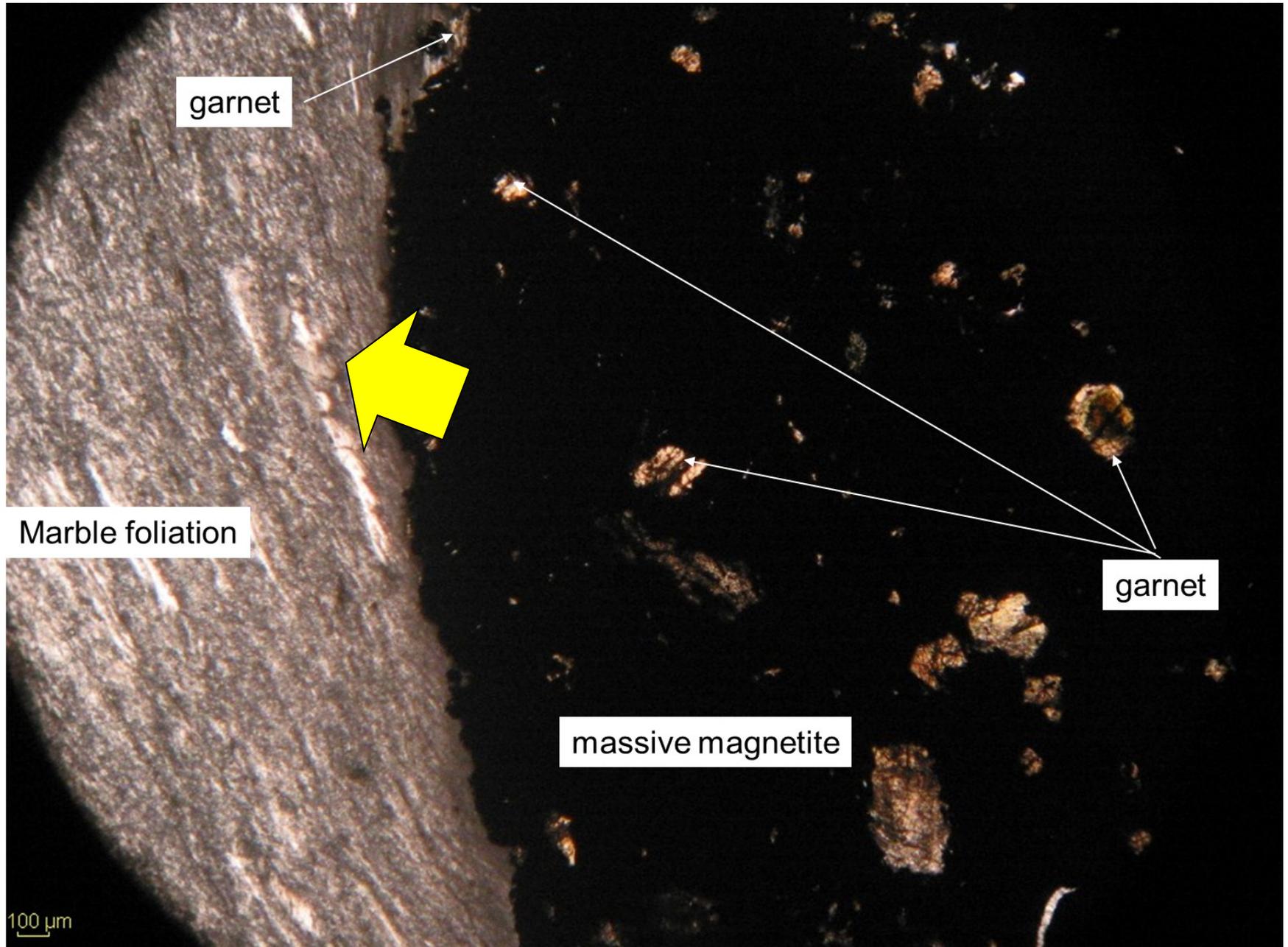
Skarns de contact basaltes/marbres



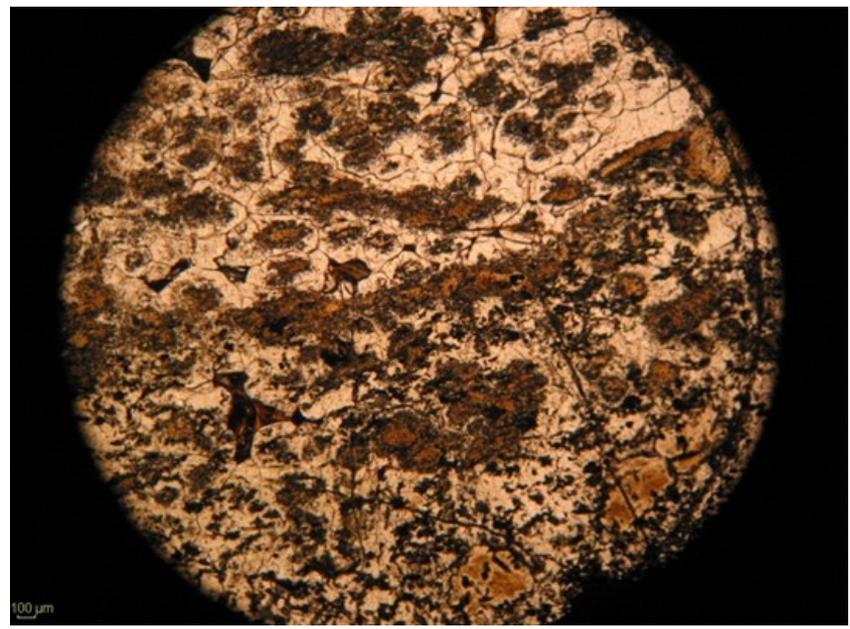
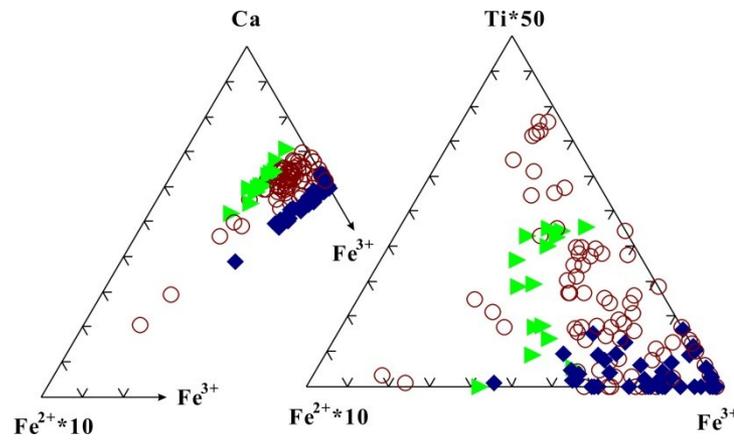
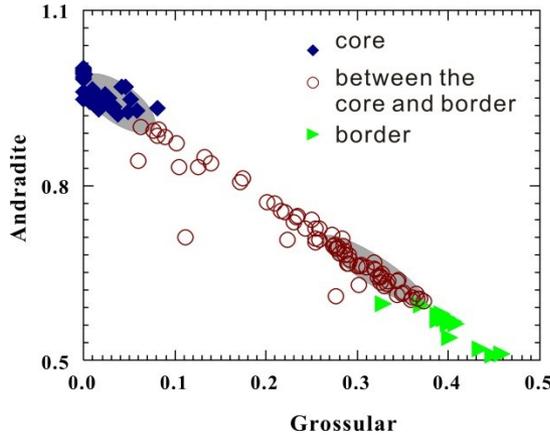
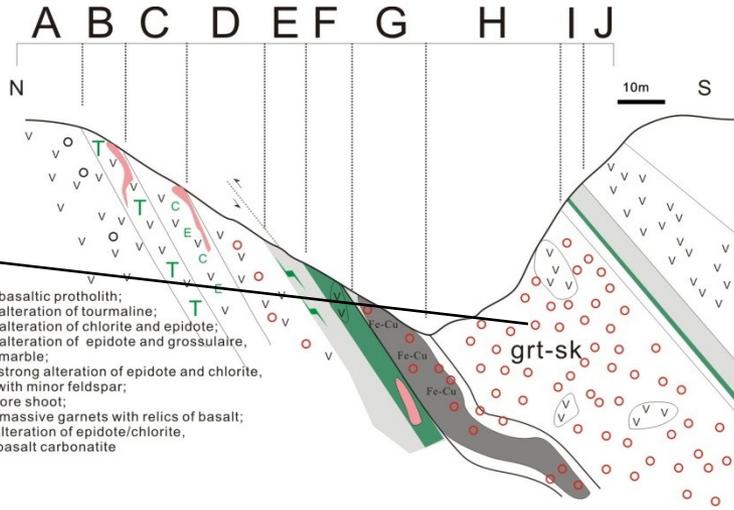
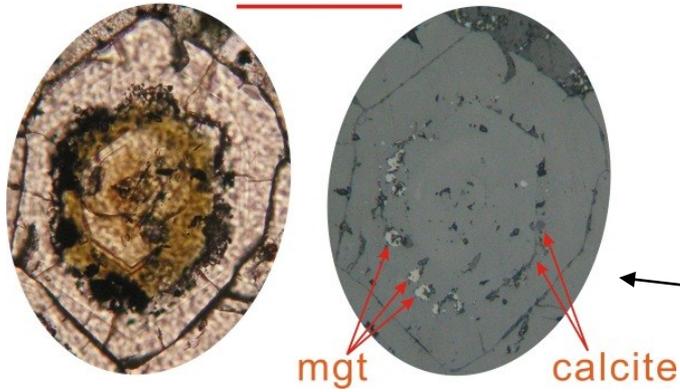
Minerai à magnétite puis chalcopryrite (Cu exploité il y a 10 ans)



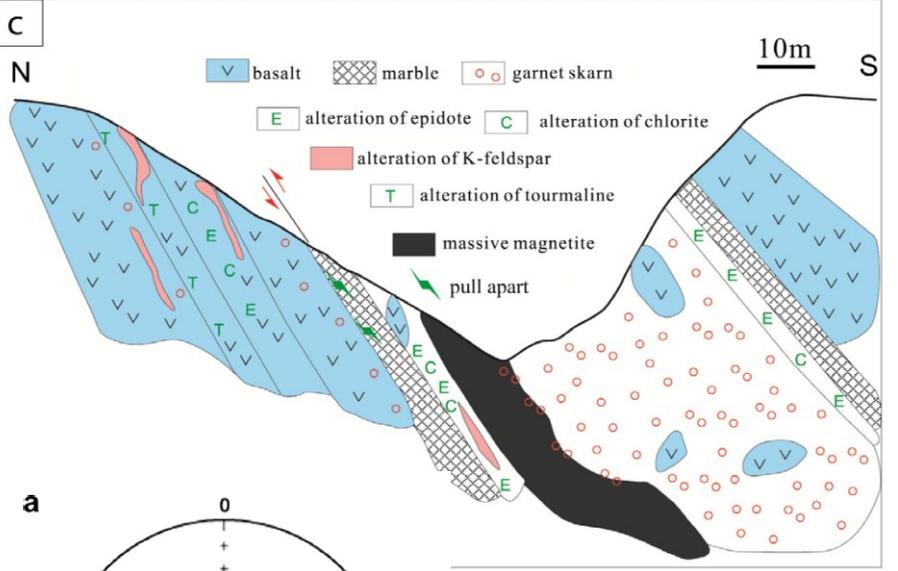
Magnetite chemical front within marble



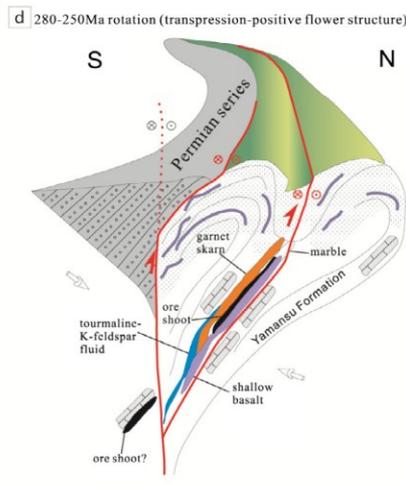
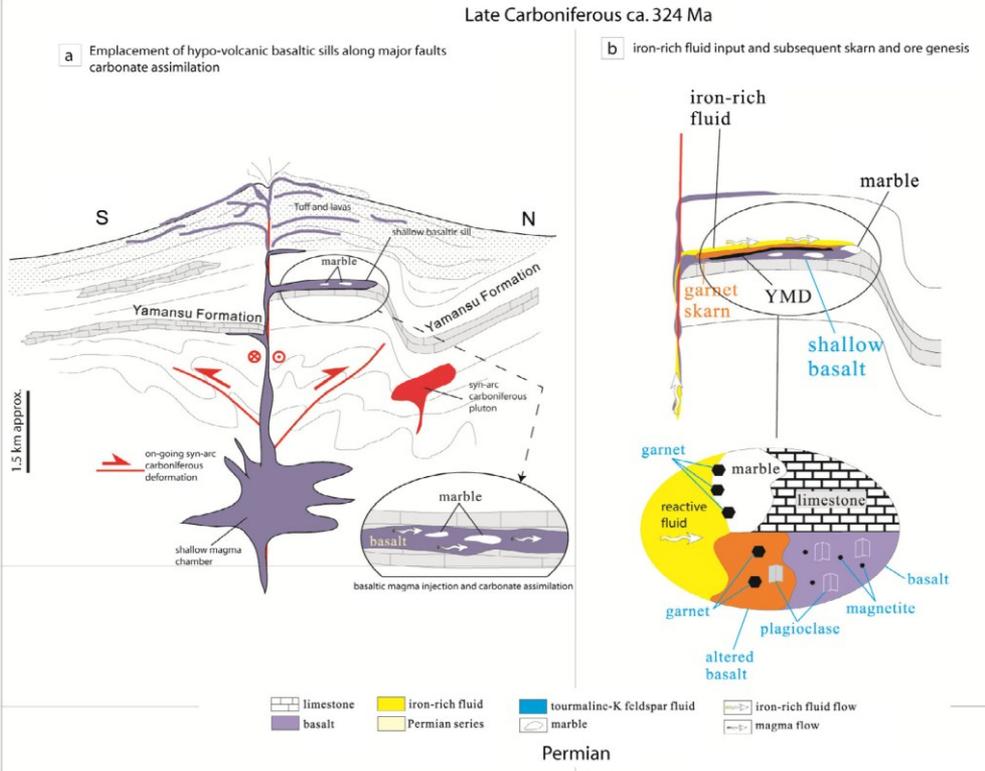
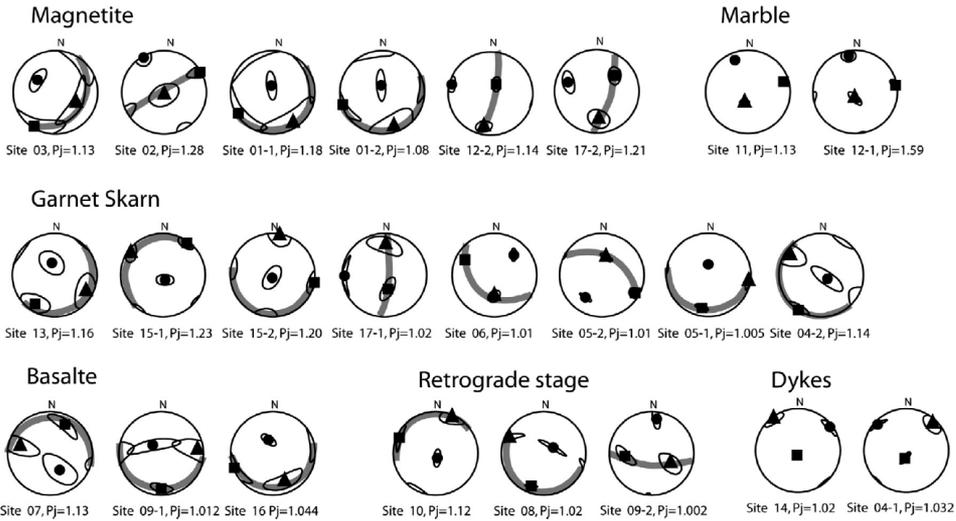
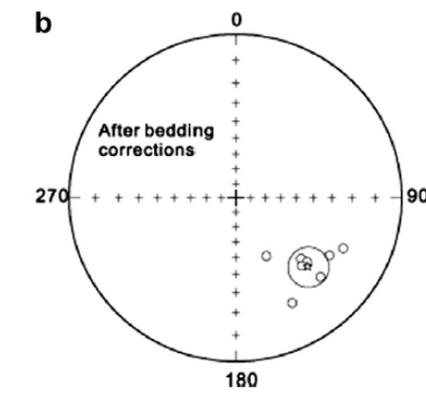
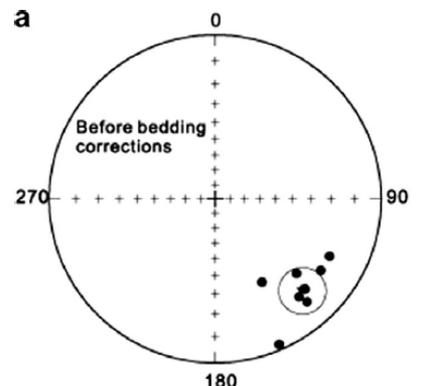
100µm



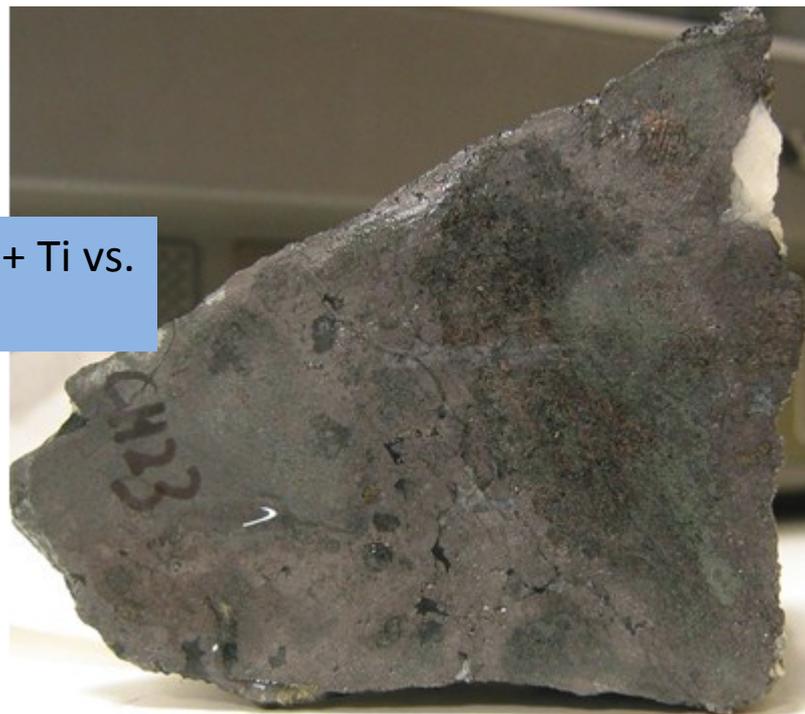
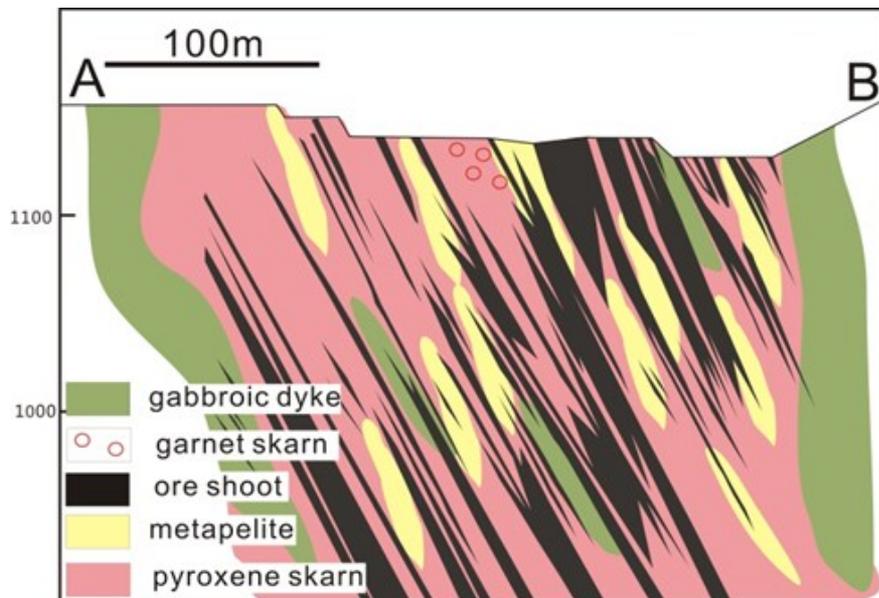
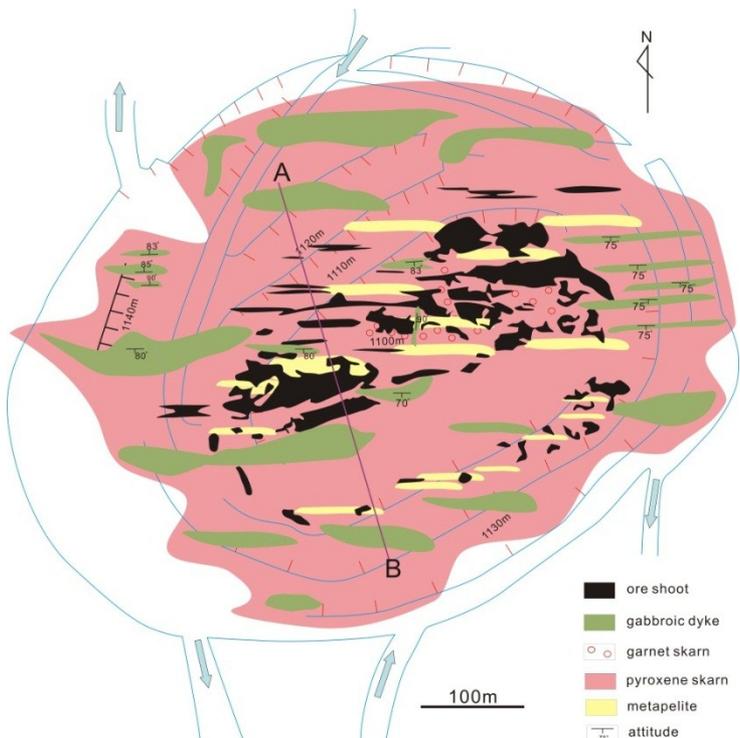
Synthèse: contexte subvolcanique associé à des sills de basaltes, beaucoup de caractères communs aux Fe skarns décrits dans les IOCG



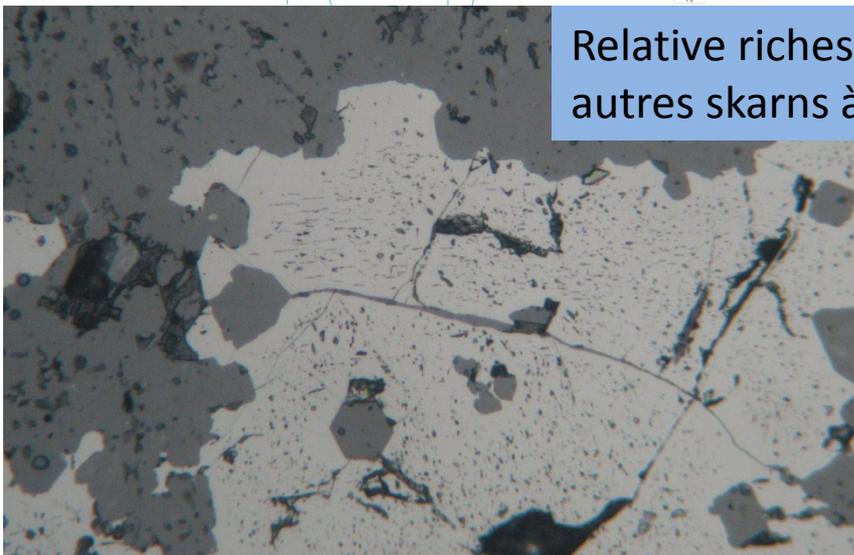
Gisement de Fer associé à des skarns de Yamansu, Tianshan, Chine, Li et al. (2014)

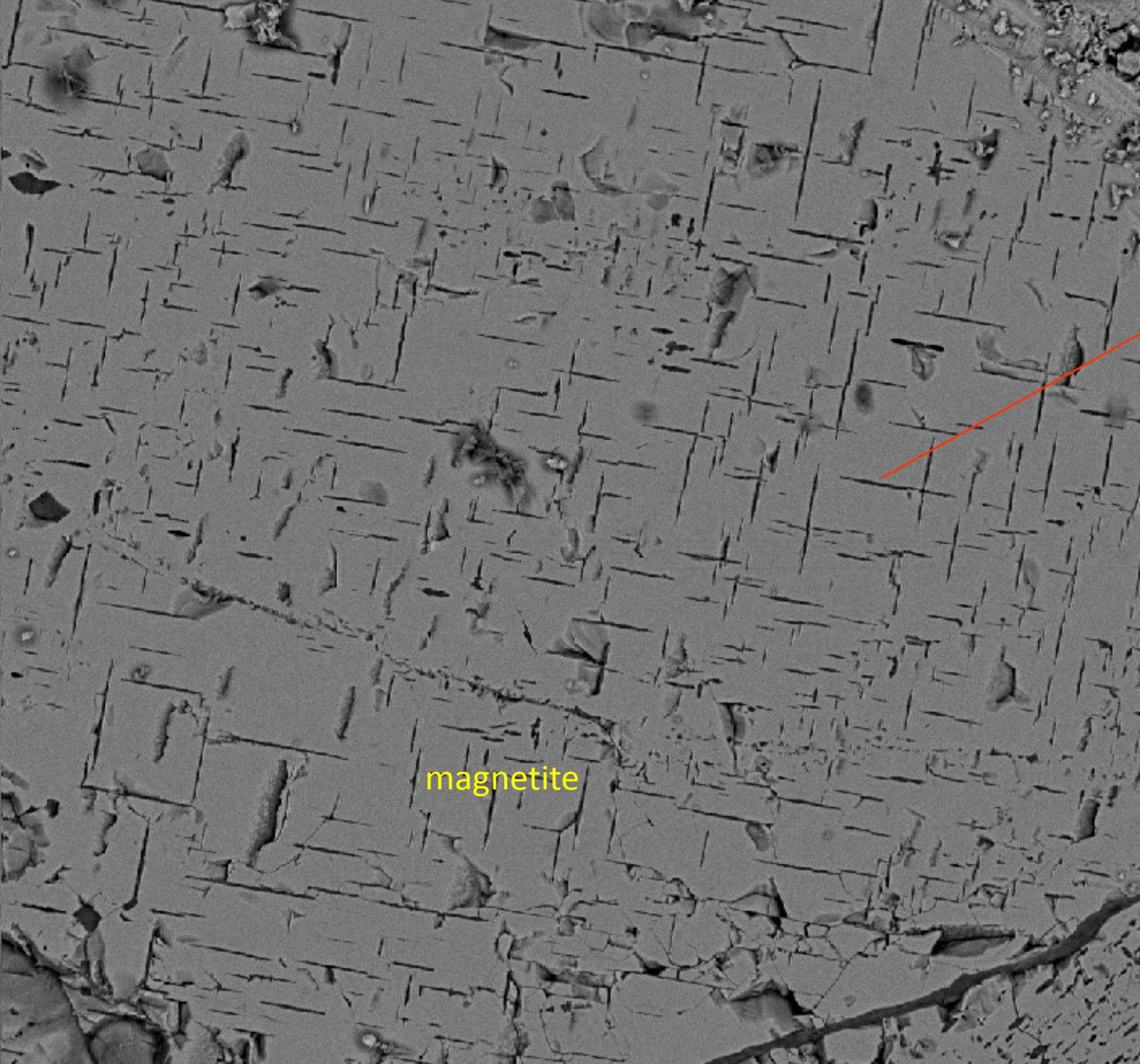


Gisement de Cihai (280 Ma)

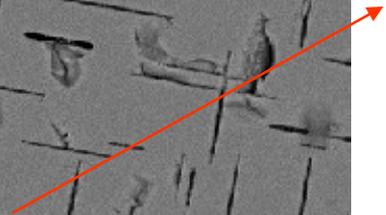


Relative richesse en P + Ti vs. autres skarns à Mgt





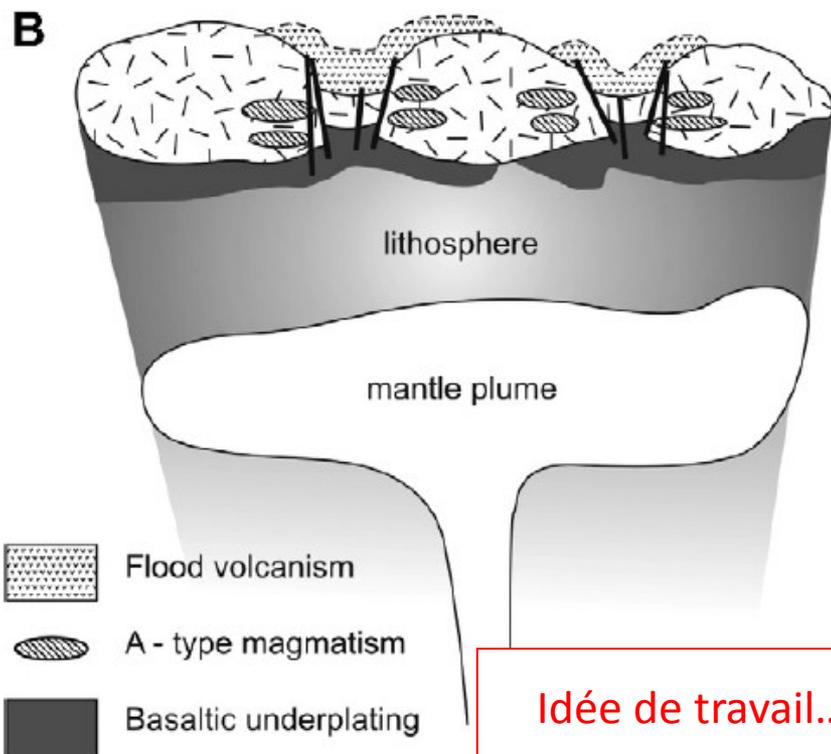
Spinel sub-solidus exsolution



magnetite

Synthèse/contexte????????

Le Tianshan au Permien inf.....



Pirajno et al., 2008

-> magmatisme mafique/ultramafique

Et associé

-> pic minéralisateur à Ni/Cu sulfures magmatiques + Fe/Ti/V magmatiques

Idée de travail.....

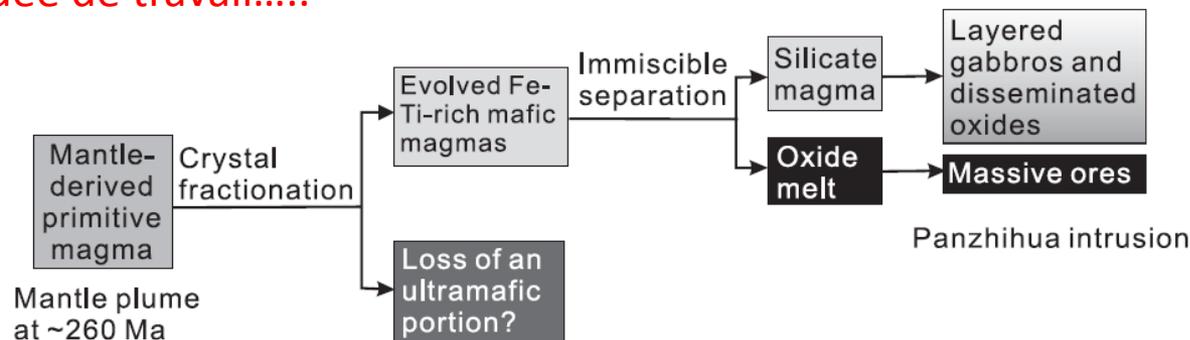


Fig. 14. A schematic model for magma evolution and the formation of the oxide ore deposits in the Panzhihua gabbroic intrusion, SW China.

Zhou et al., 2005

Perspectives: source et processus de concentration du Fer -> travailler plus sur l'assimilation des carbonates

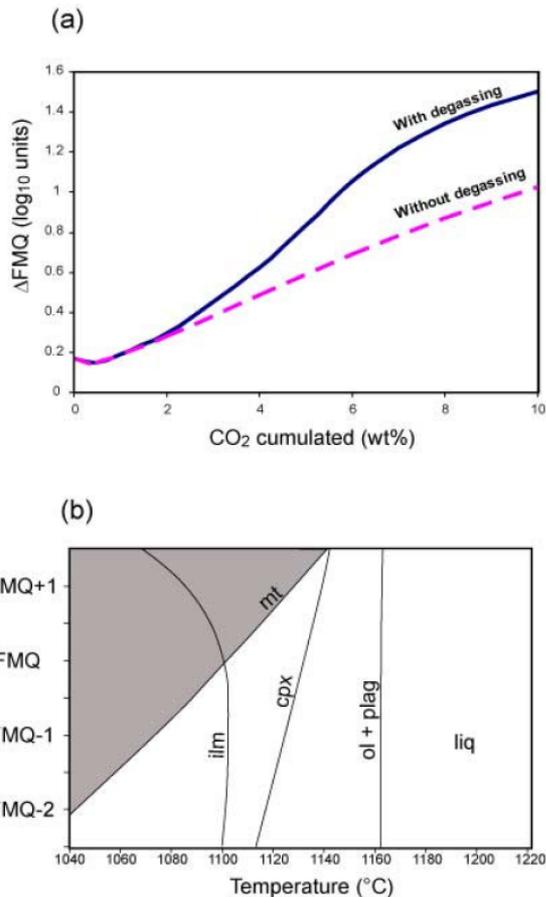
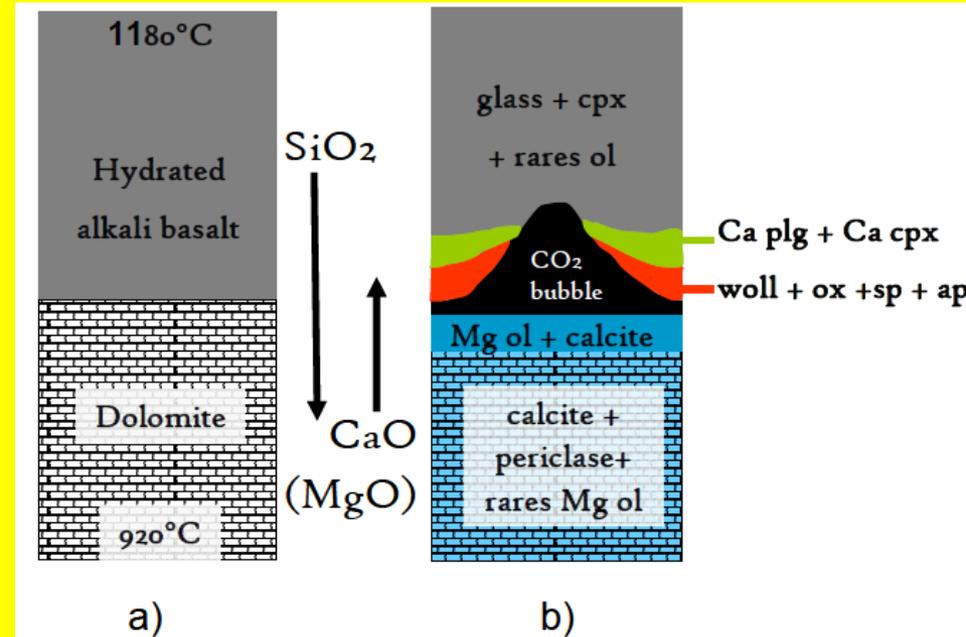


Figure 10 (a) Diagram illustrating the effect on the oxygen fugacity, expressed as ΔFMQ , of interaction between a CO_2 -rich fluid and basaltic magma. Results from x equilibrium computation in the system Fe, C, O, H, S. (b) Experimentally determined phase equilibria as a function of oxygen fugacity (modified from Toplis Carroll (1995)).

Ganino et al., 2008



Giada Iacono, ISTO
(en cours)

MERCI!

