

# Εφαρμοσμένη & Περιβαλλοντική Γεωχημεία

2023-24

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Διδάσκων

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Επίκουρος Καθηγητής

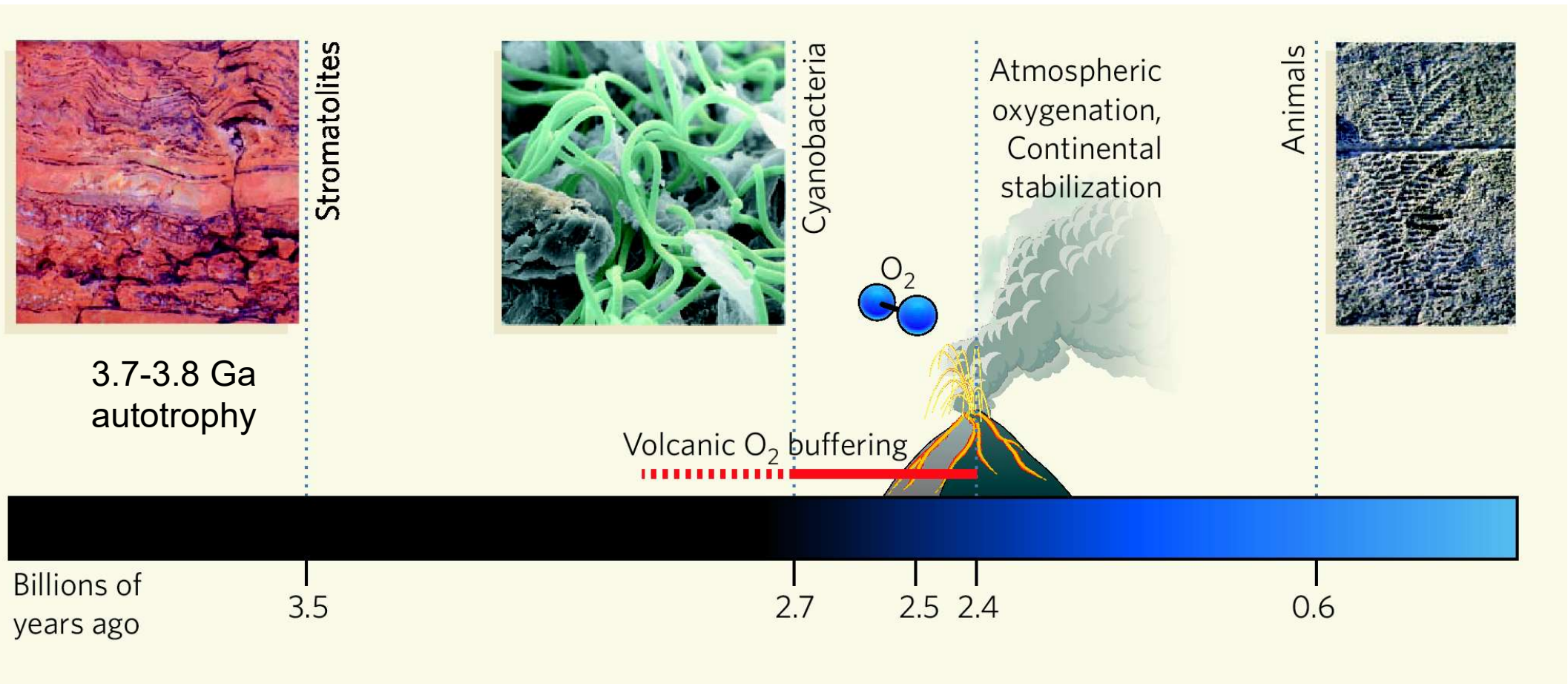
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ΠΑΤΡΩΝ  
UNIVERSITY OF PATRAS

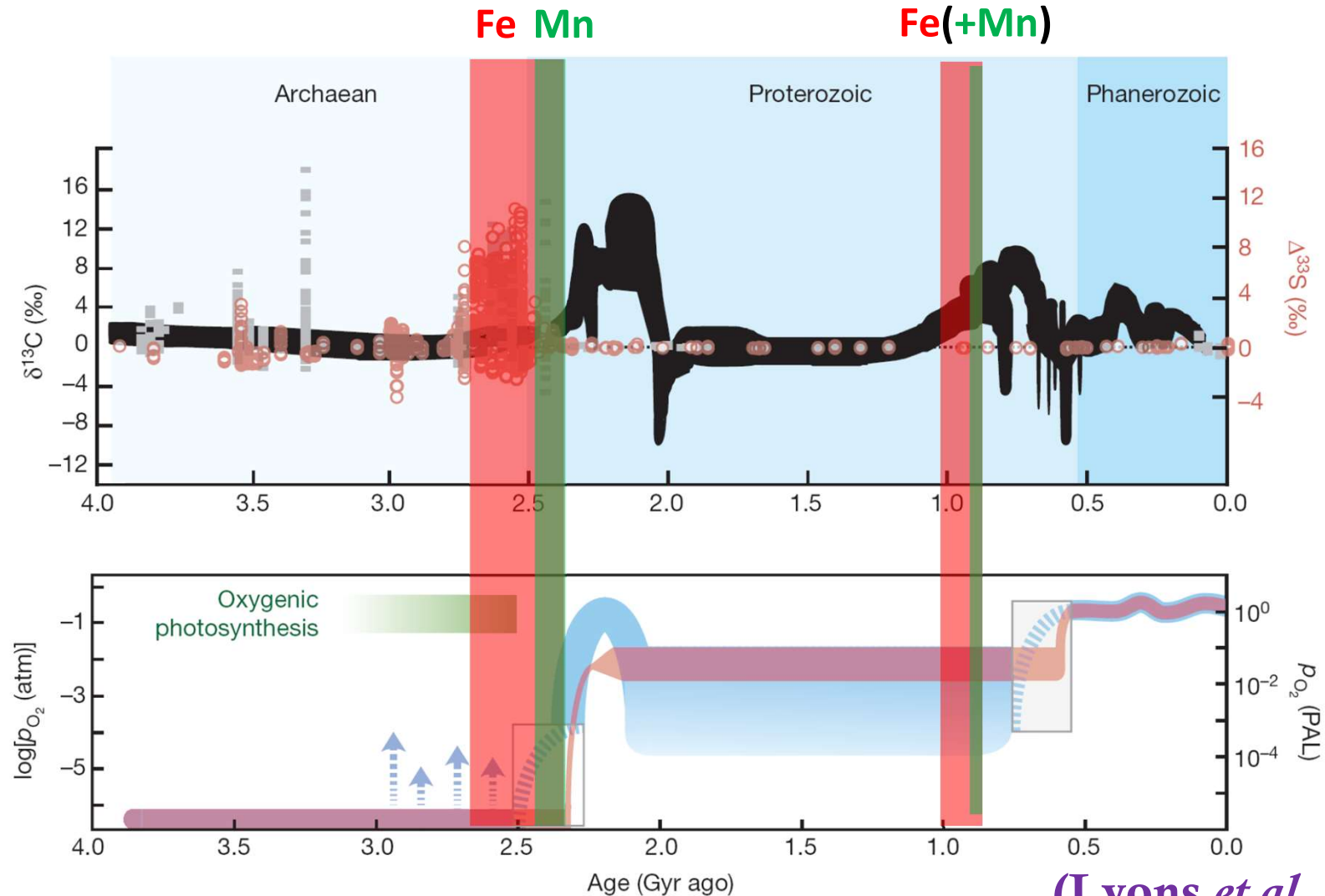


# Η ιστορία της πρώιμης Γης σε μία εικόνα



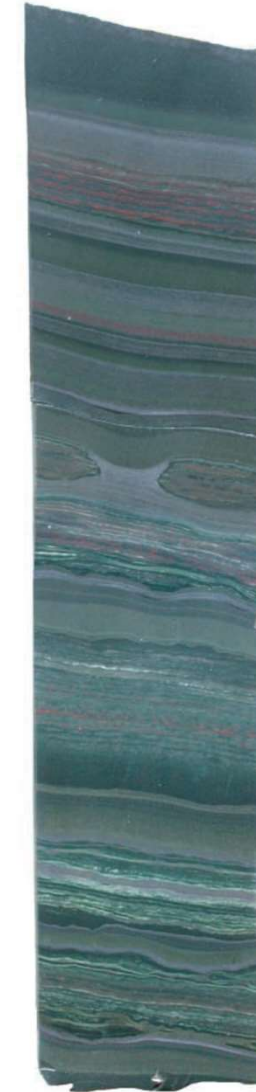
(Kump & Barley, 2007; Lyons, 2007)

## Η γεωχημική εξέλιξη Fe και Mn στο γεωλογικό χρόνο



(Lyons *et al.*, 2014)

**Οι ταινιώδεις σιδηρούχοι σχηματισμοί  
(Banded Iron Formations, BIF)  
και η παλαιοπεριβαλλοντική και  
βιογεωχημική τους σημασία**

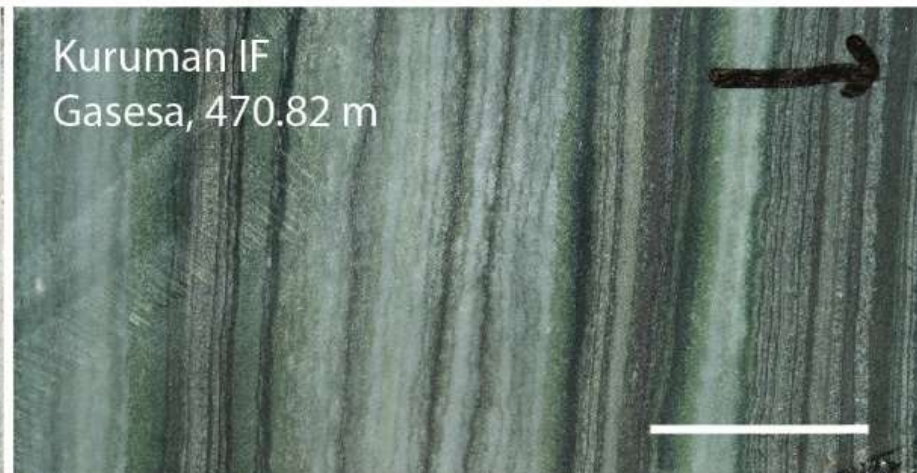
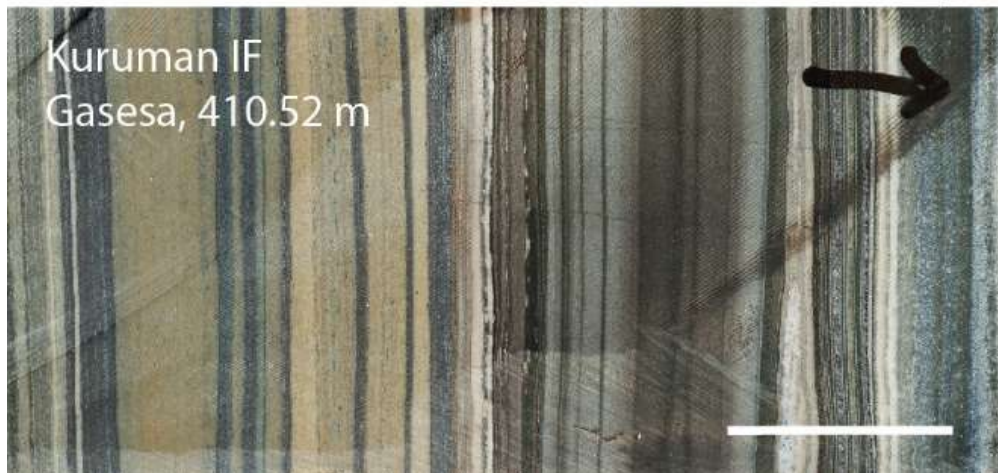


10cm

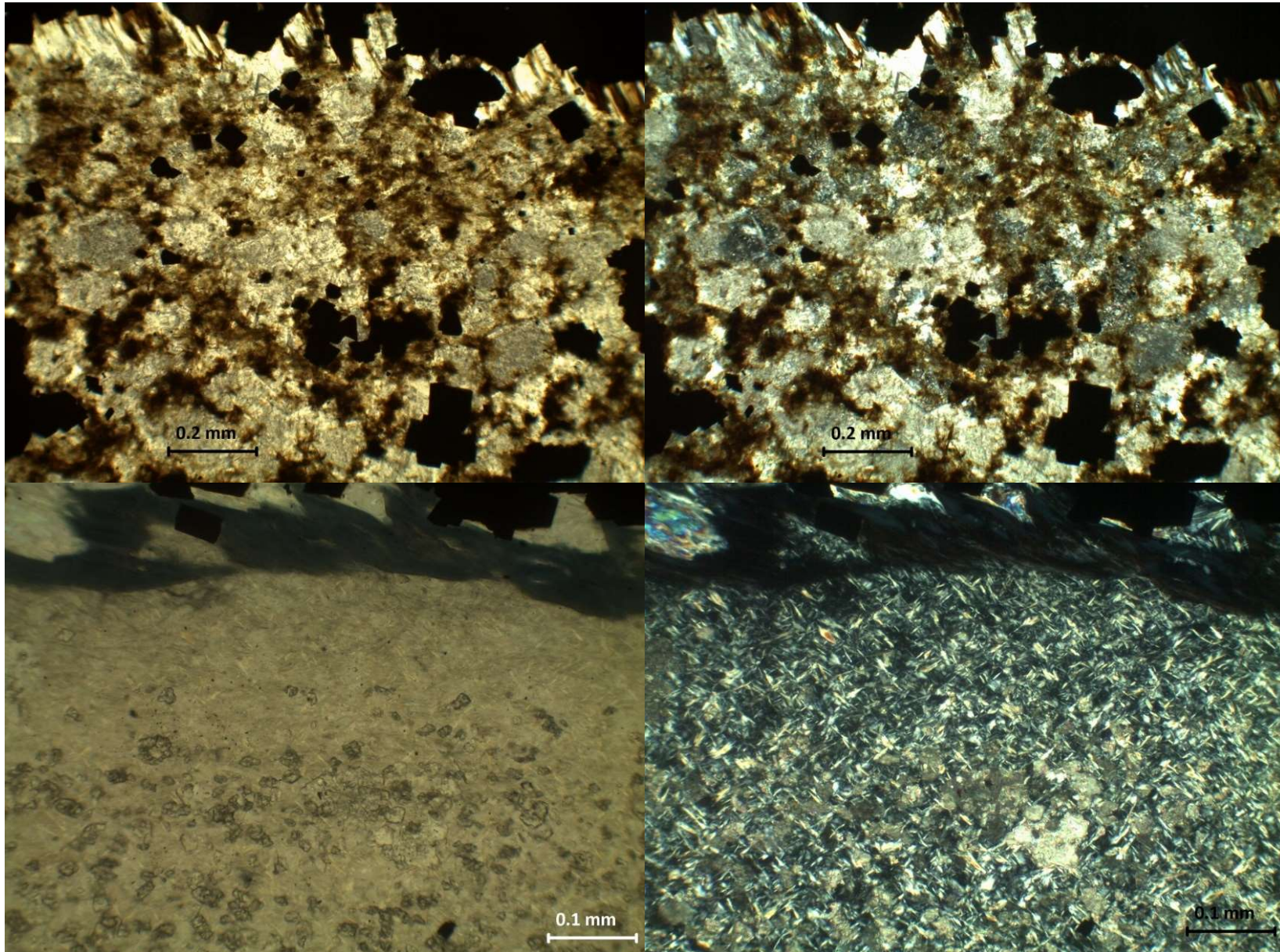
**Κοιτάσμα σιδήρου Sishen,  
Βόρειο Ακρωτήριο, Ν. Αφρική**



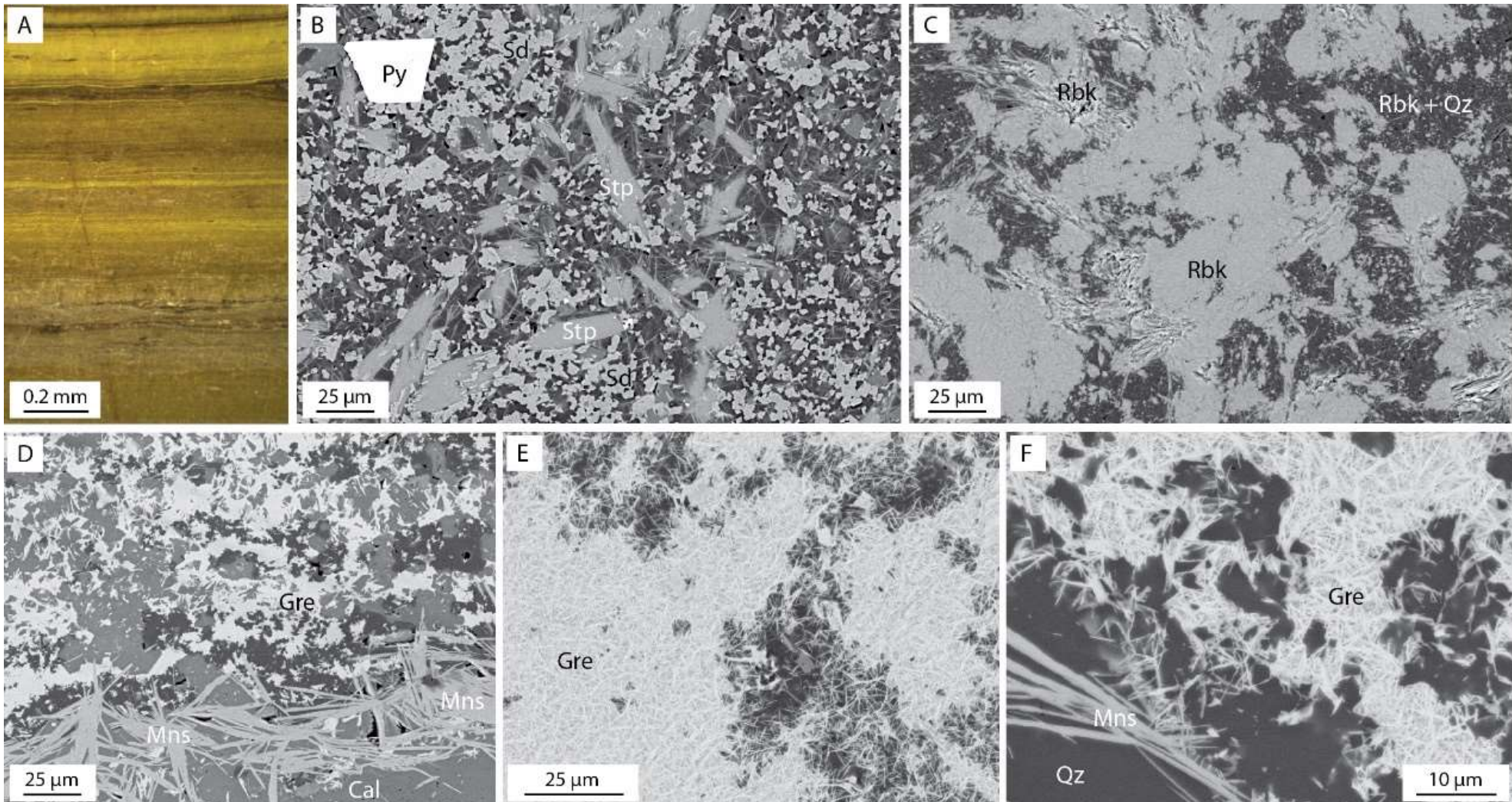
## Ιστολογική και ορυκτολογική ετερογένεια ενός BIF



## Το BIF στο μικροσκόπιο

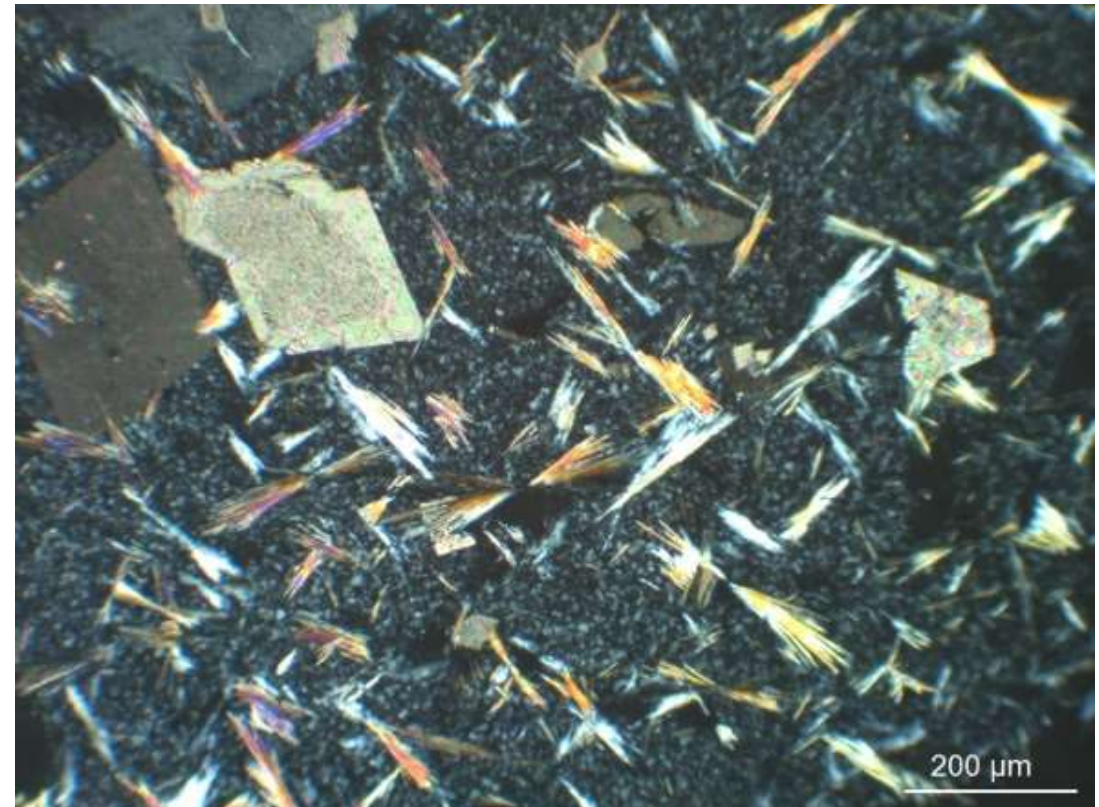
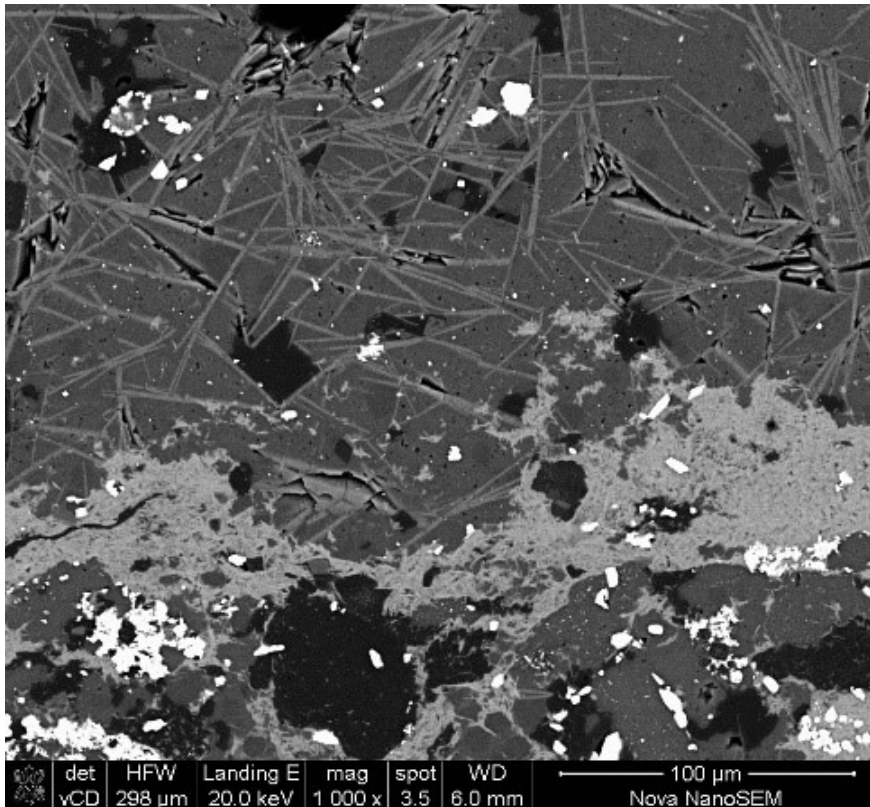


## Πυριτική ορυκτολογία των BIF

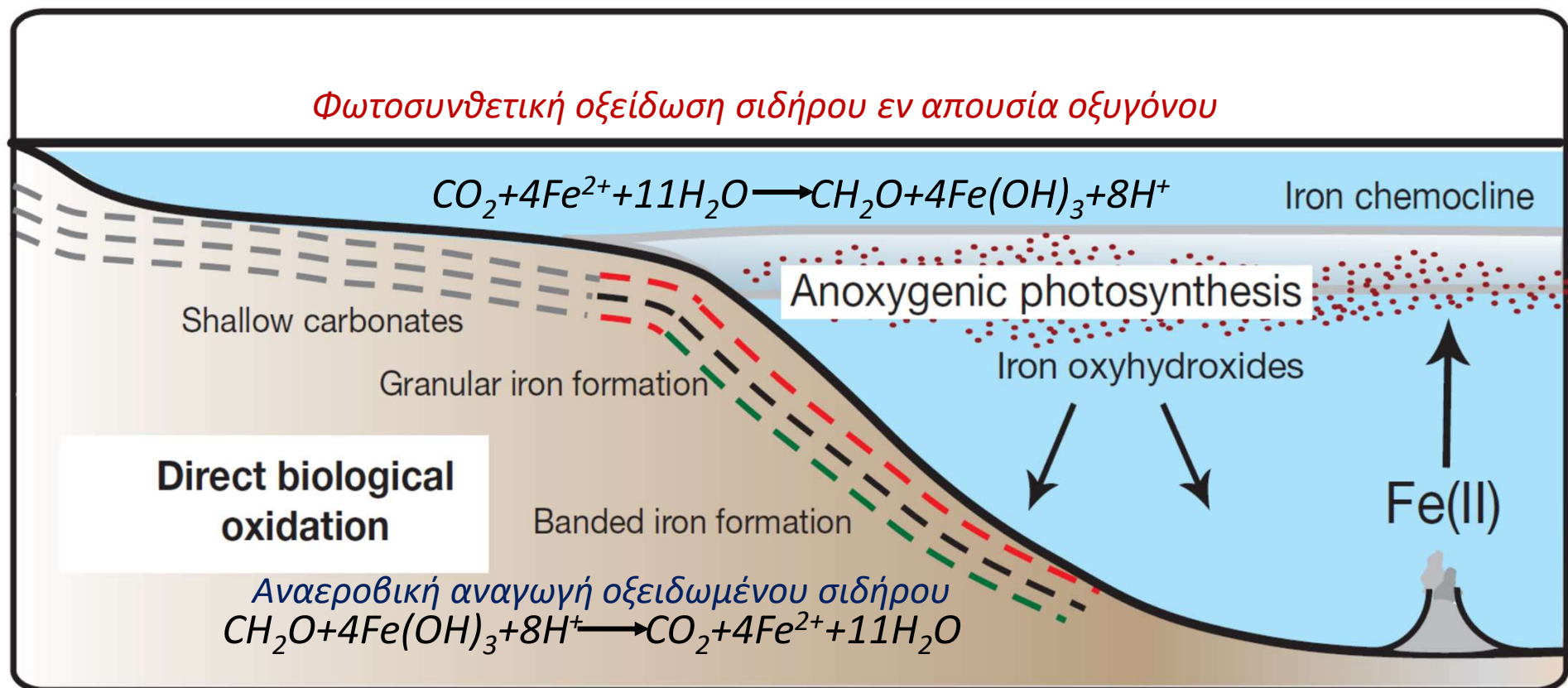




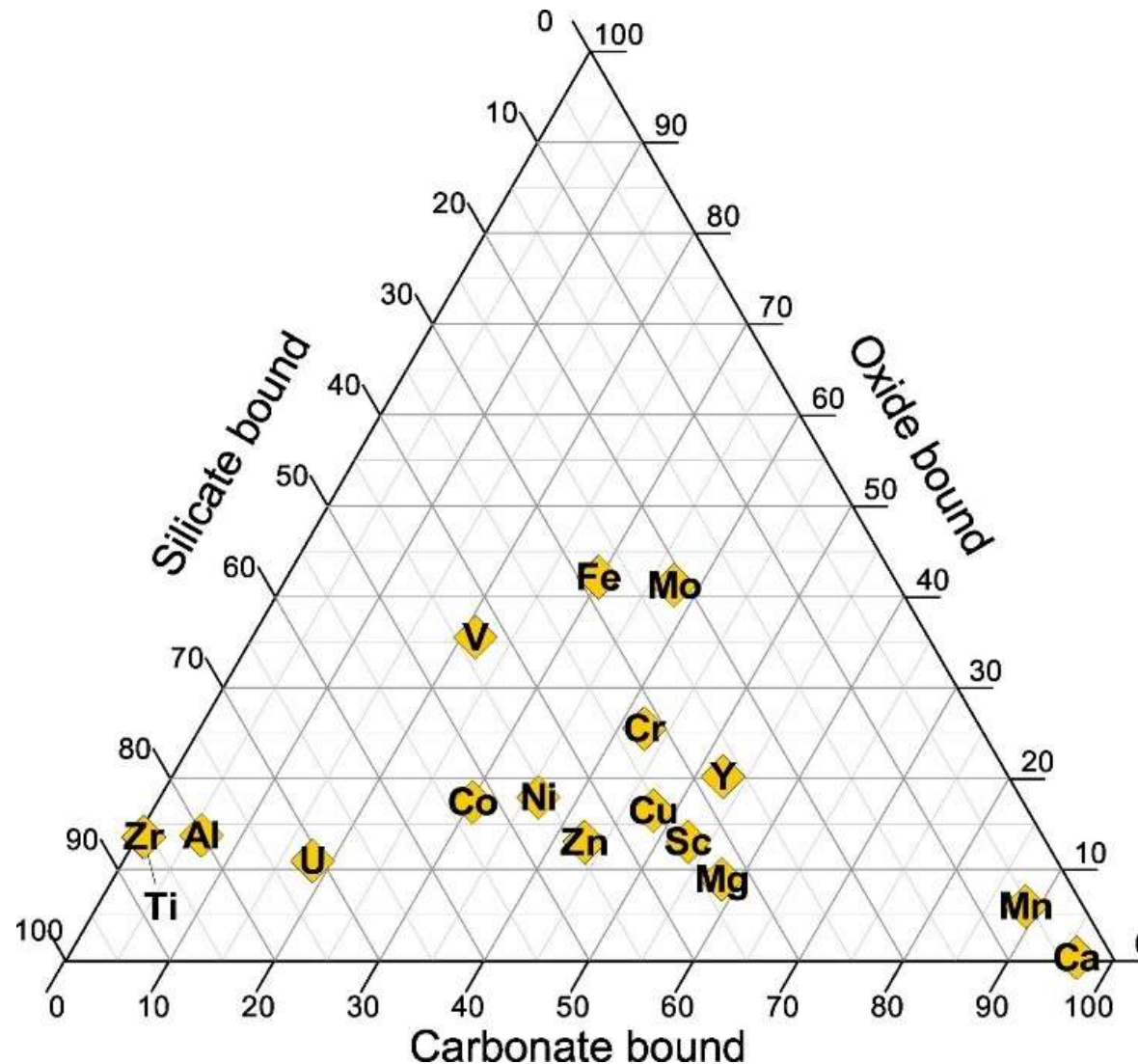
## Συσχετισμοί ανθρακικής και πυριτικής ορυκτολογίας



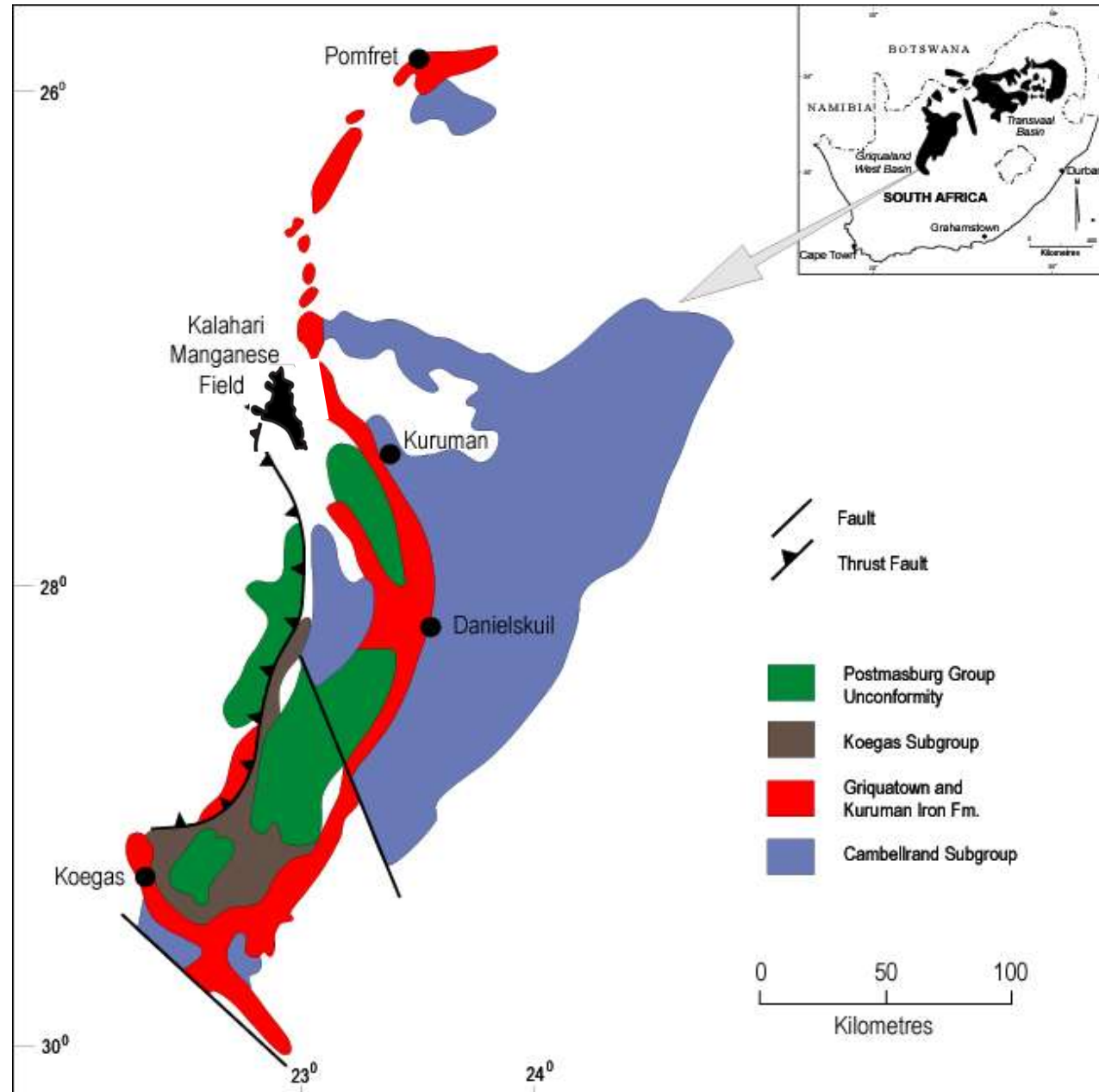
## Βιογεωχημικές διεργασίες σιδήρου στον ανοξικό και σιδηρο-πλούσιο ωκεανό του κατώτερου Προκαμβρίου



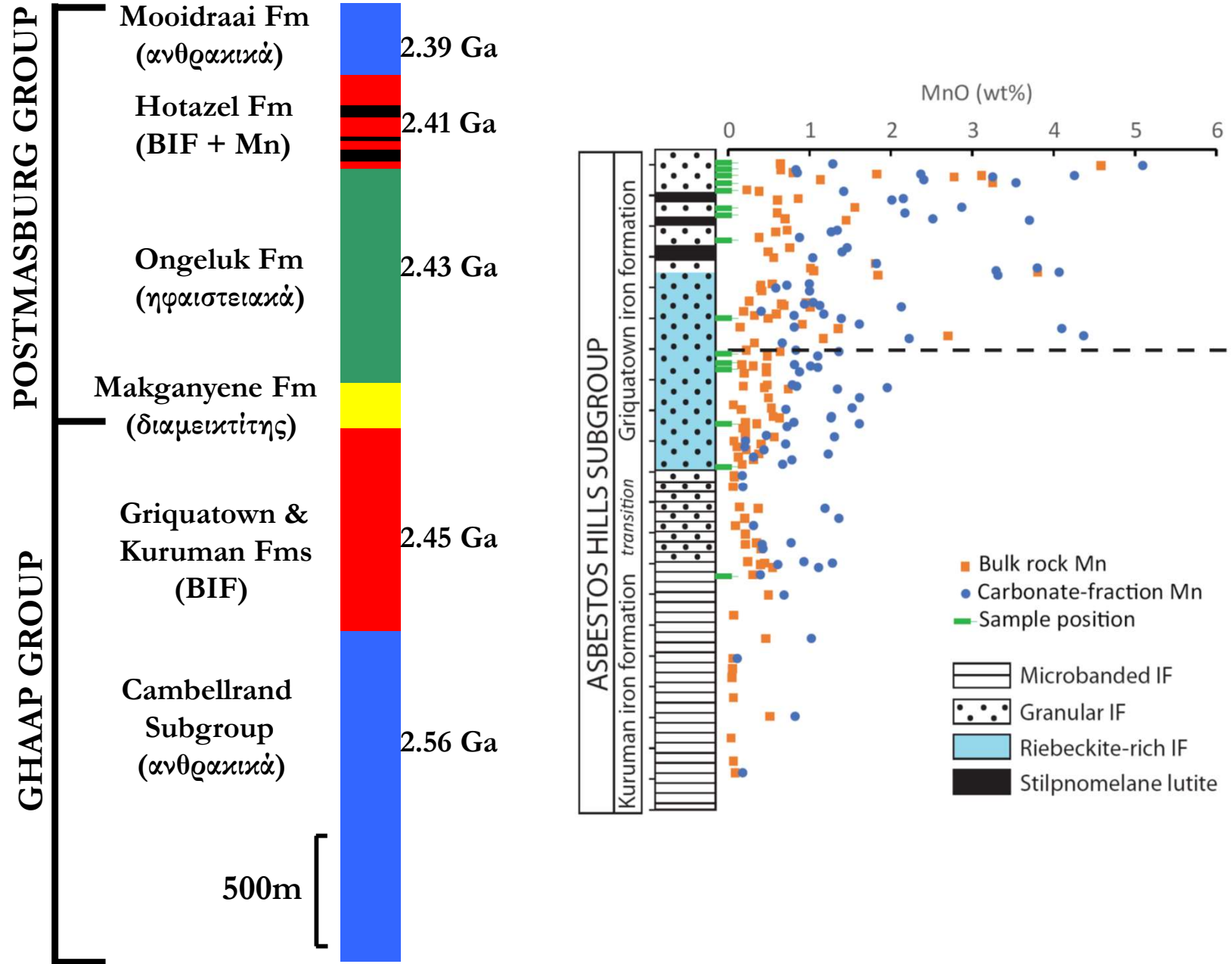
## Ορυκτολογική επιρροή στην χημική σύσταση ενός BIF



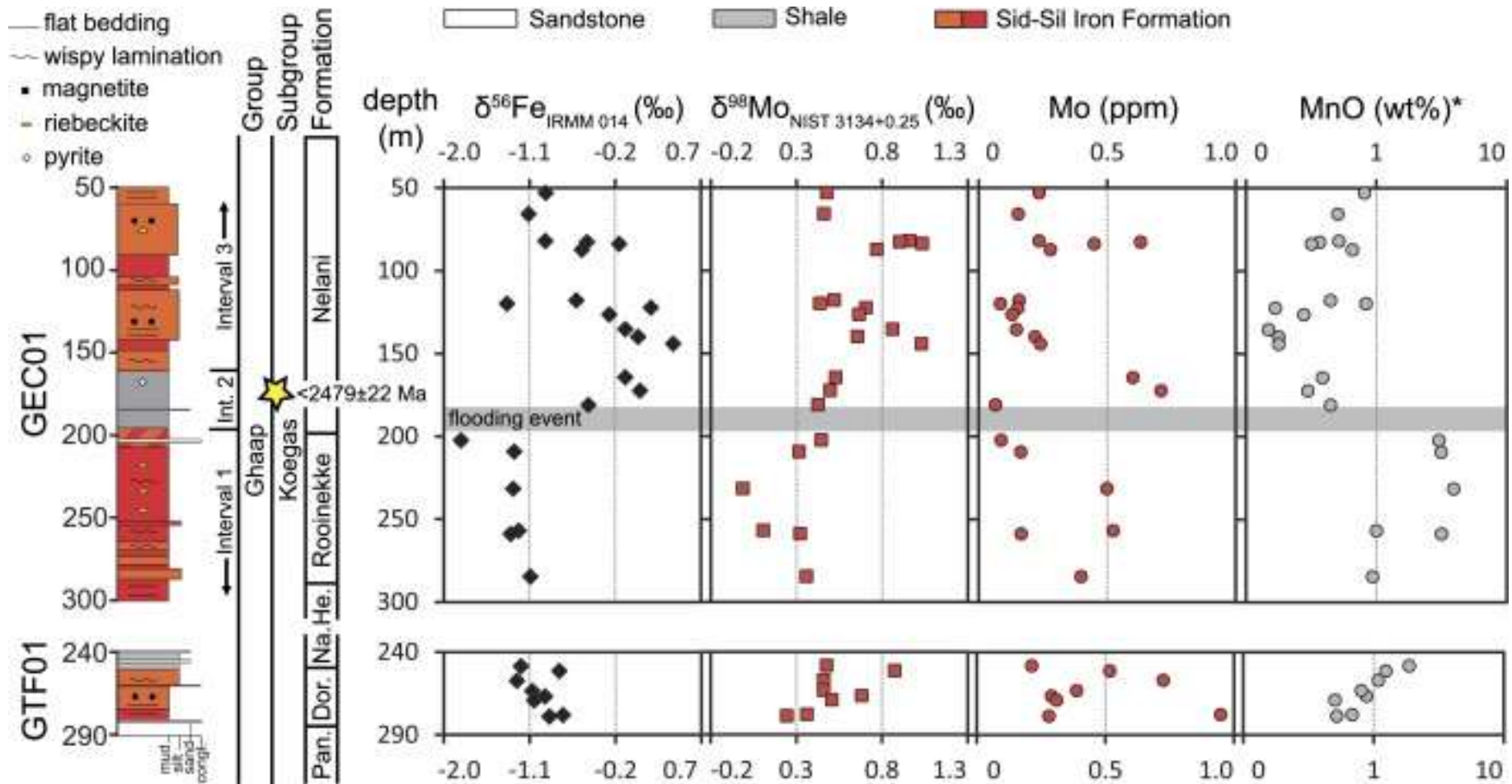
## Η λεκάνη Transvaal



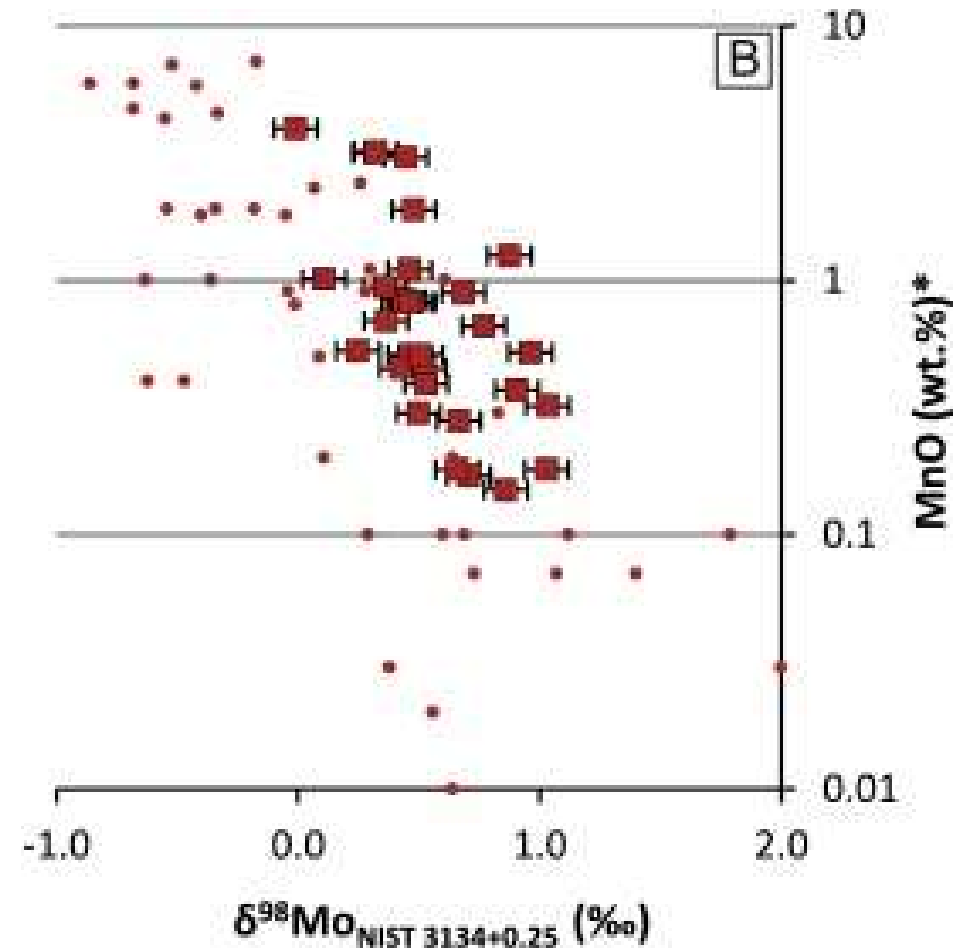
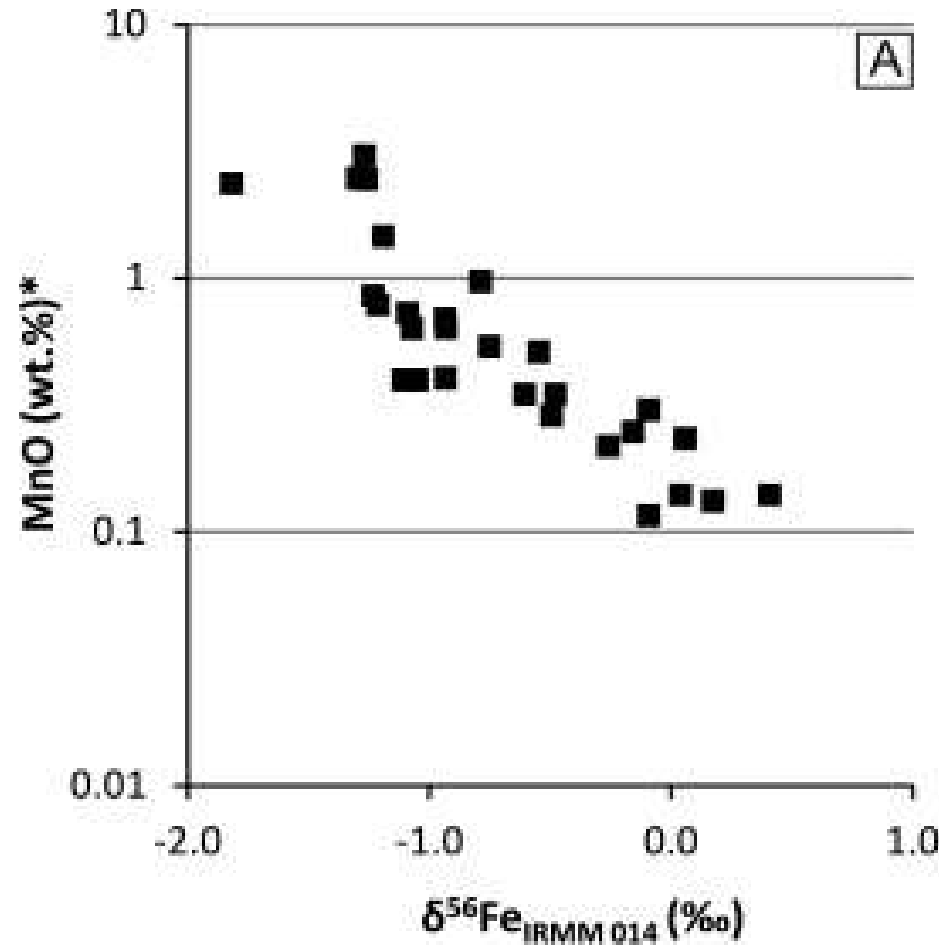
## Χημειοστρωματογραφία Mn σε BIF της λεκάνης Transvaal



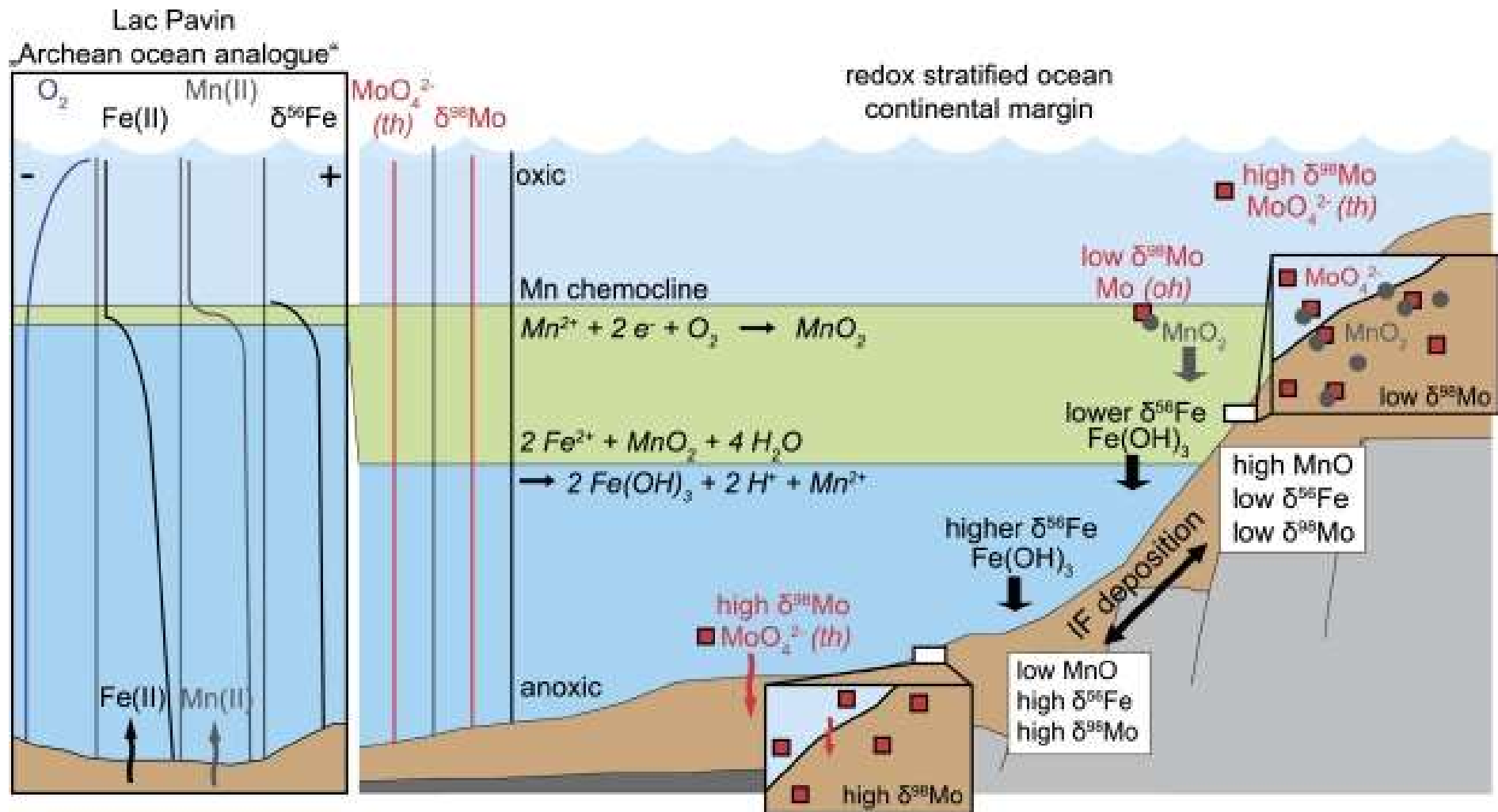
## Χημειοστρωματογραφία BIF σχηματισμού Koegas



## Ισοτοπικές συσχετίσεις με περιεκτικότητα σε Mn



## Ολιστικό μοντέλο απόθεσης BIF σχηματισμού Koegas



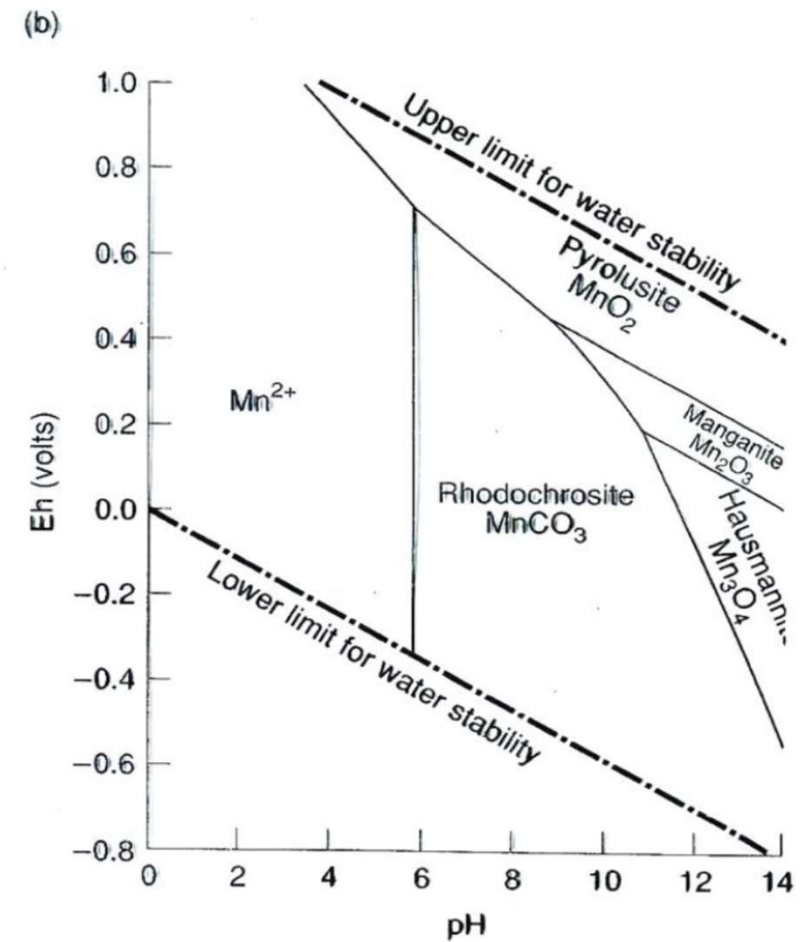
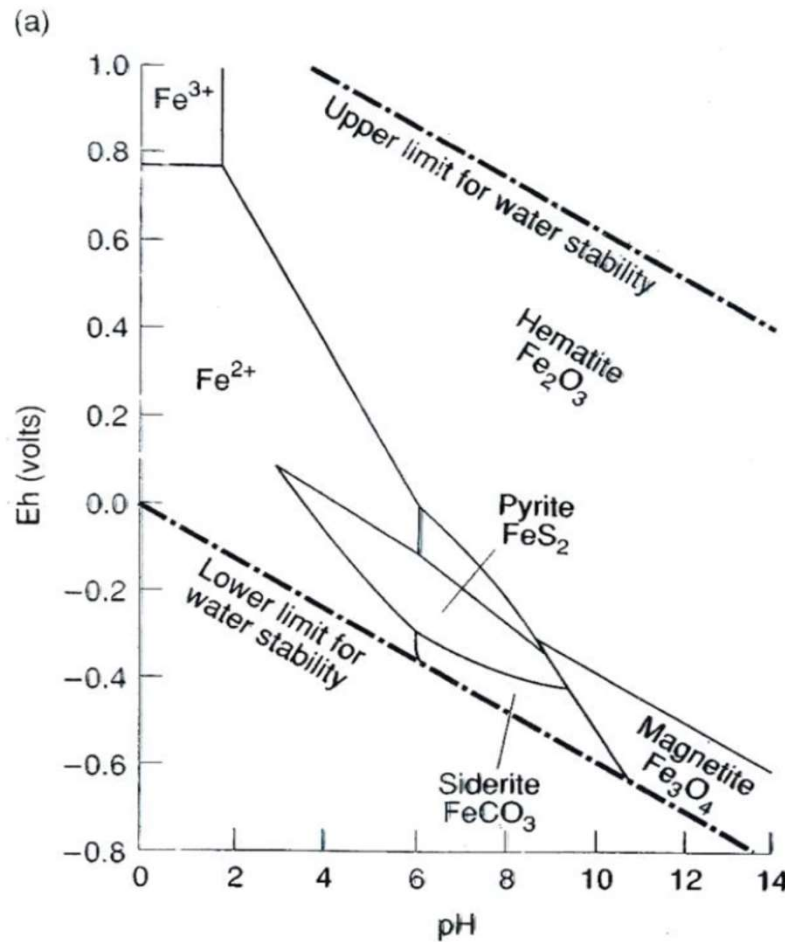




***Ο σχηματισμός Hotazel και  
η σημασία του σε σχέση  
με την οξειδοαναγωγική  
εξέλιξη της πρώιμης Γης***

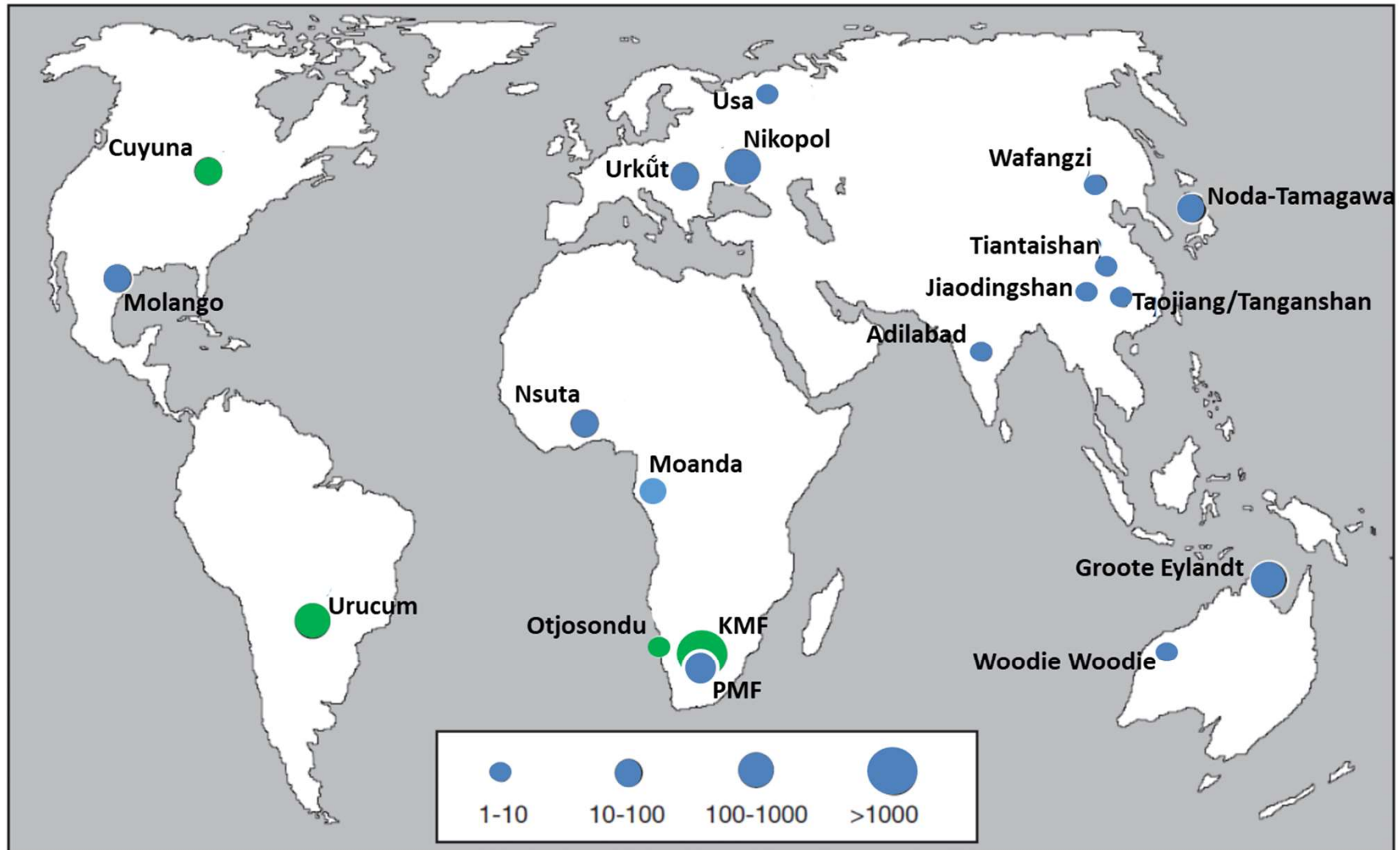
## Παράδειγμα διαγραμμάτων Eh-pH και πεδία σταθερότητας κοινών ορυκτών Fe και Mn σε υδάτινα διαλύματα (θερμοκρασία: 25°C)

Παρατηρήστε τις ομοιότητες των δύο στοιχείων σε συνάρτηση με τη γενική τους συμπεριφορά σε σχέση με Eh-pH, αλλά και το περιορισμένο πεδίο σταθερότητας οξειδίου του Mn σε σχέση με αυτό του Fe!



(Robb, 2005)

## Παγκόσμια γεωγραφική κατανομή κοιτασμάτων μαγγανίου

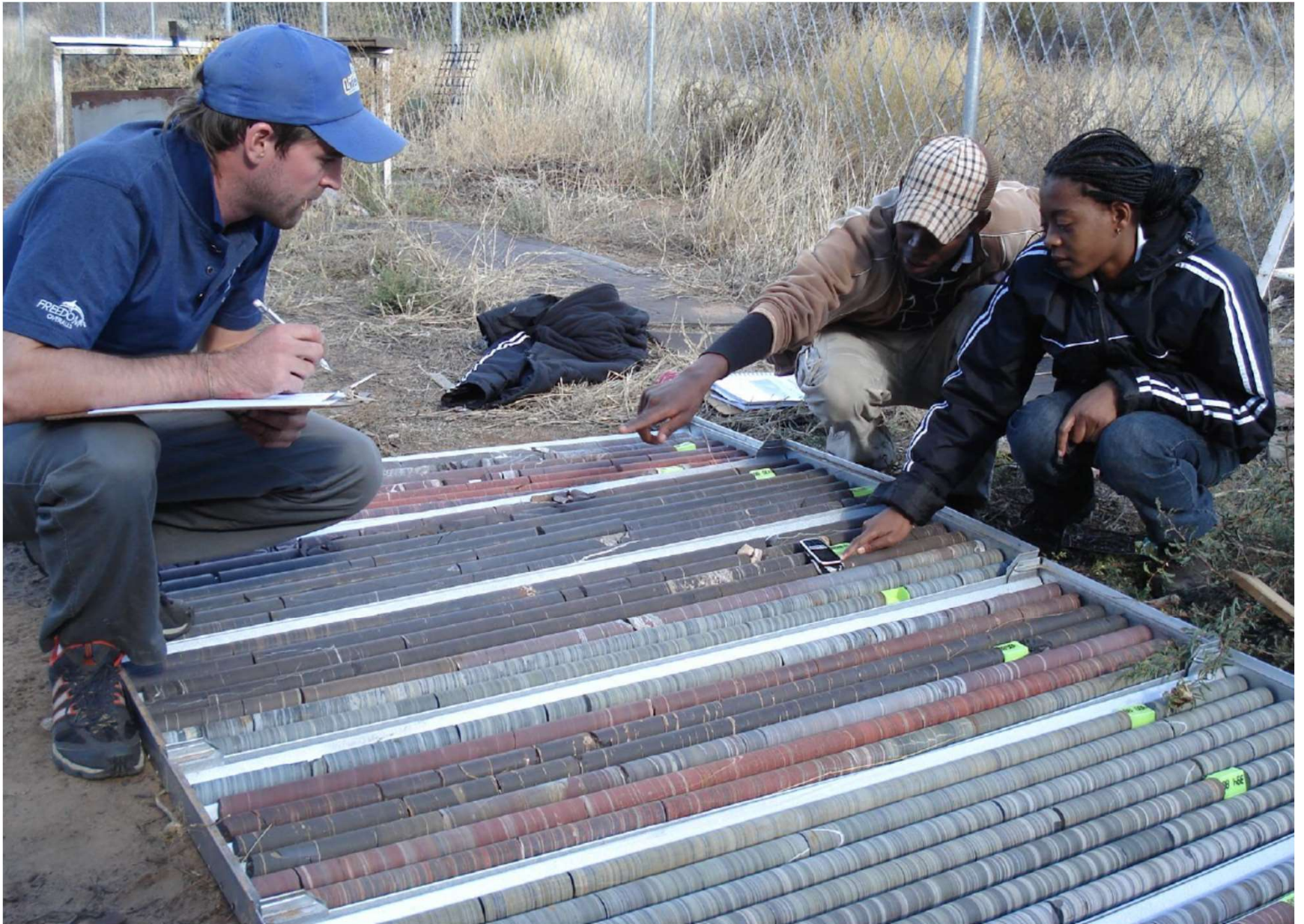


Green circles: BIF association; Blue circles: carbonate/black shale association

## Μεταλλείο Μαγγανίου Mamatwan (Northern Cape, RSA)



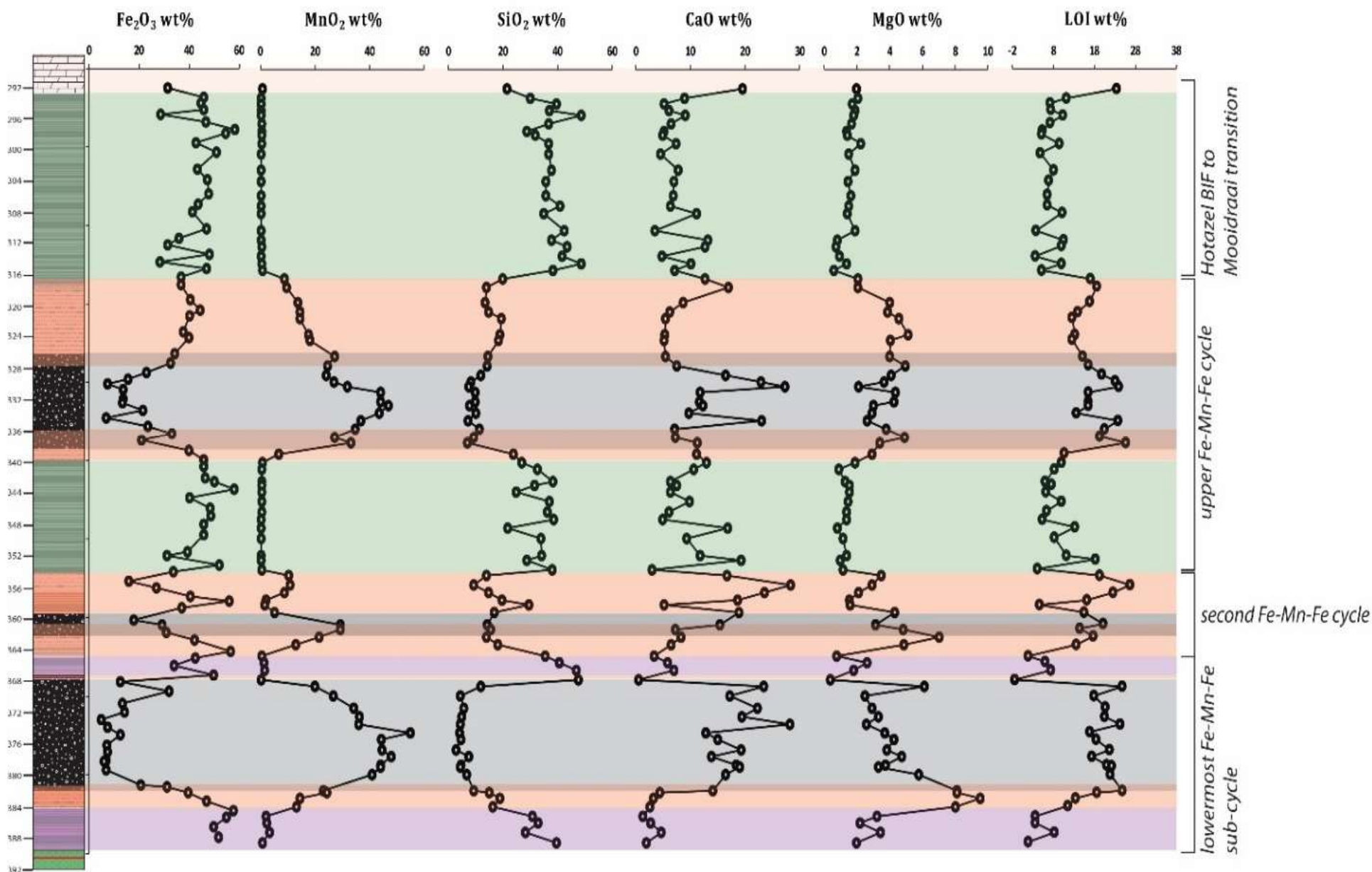
**Διαχωρισμός ιζημάτων Fe (γκριζωπό  
προς κόκκινωπό) και Mn (μαύρο)  
κατά τη διάρκεια του GOE, λόγω  
περιοδικών μεταβολών Eh-pH**



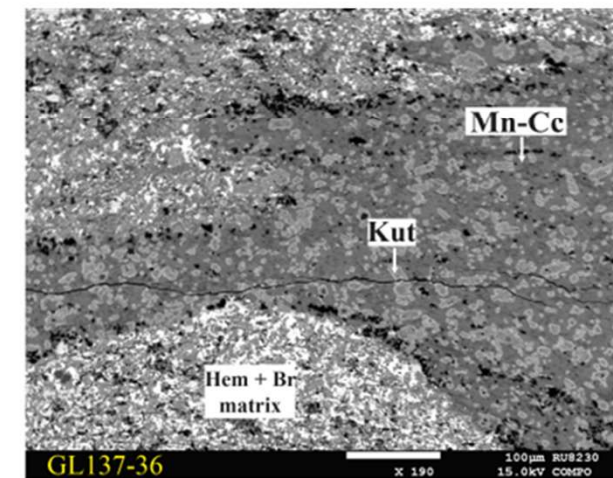
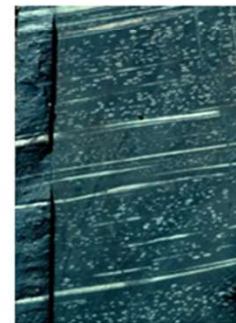
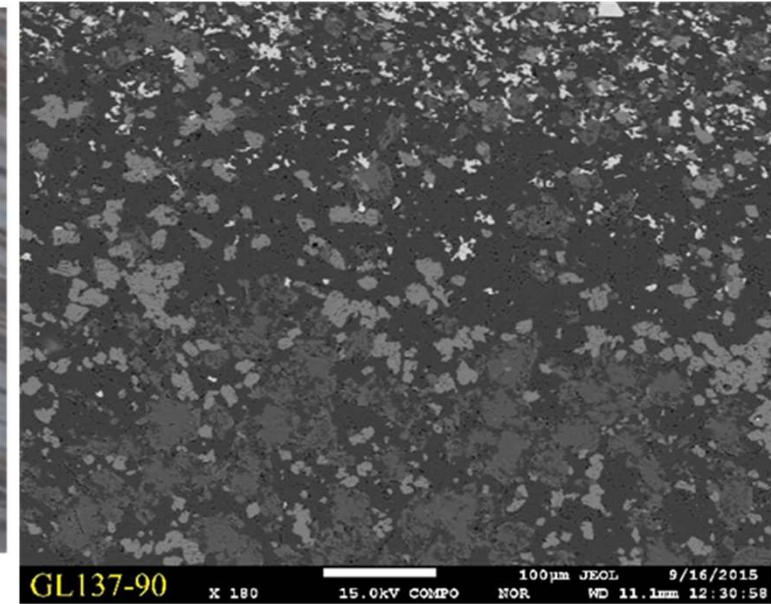
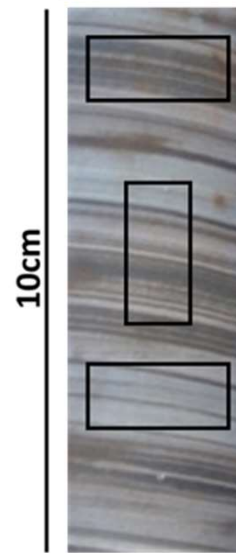
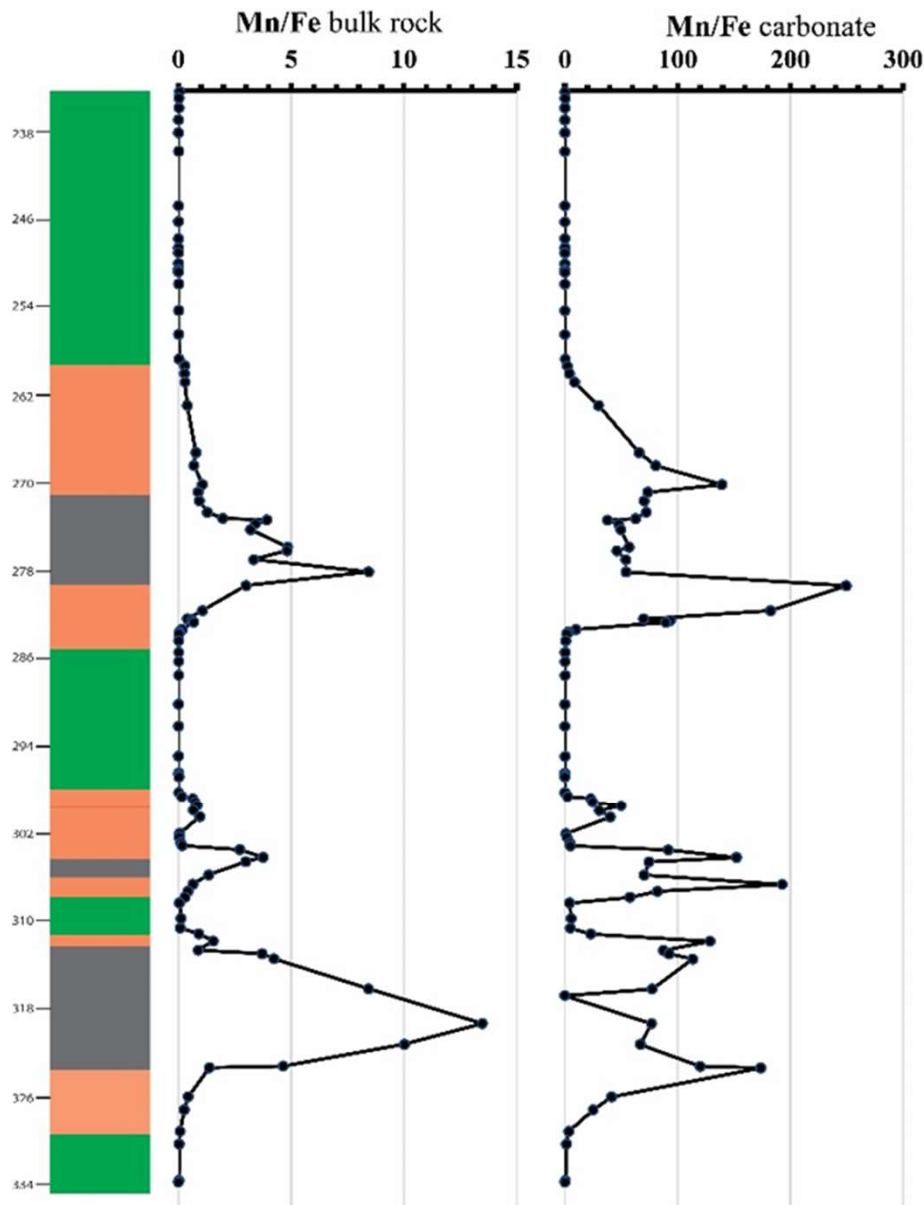
## Ο σχηματισμός Hotazel



## Ολική χημειοστρωματογραφία σχηματισμού Hotazel, Ν. Αφρική

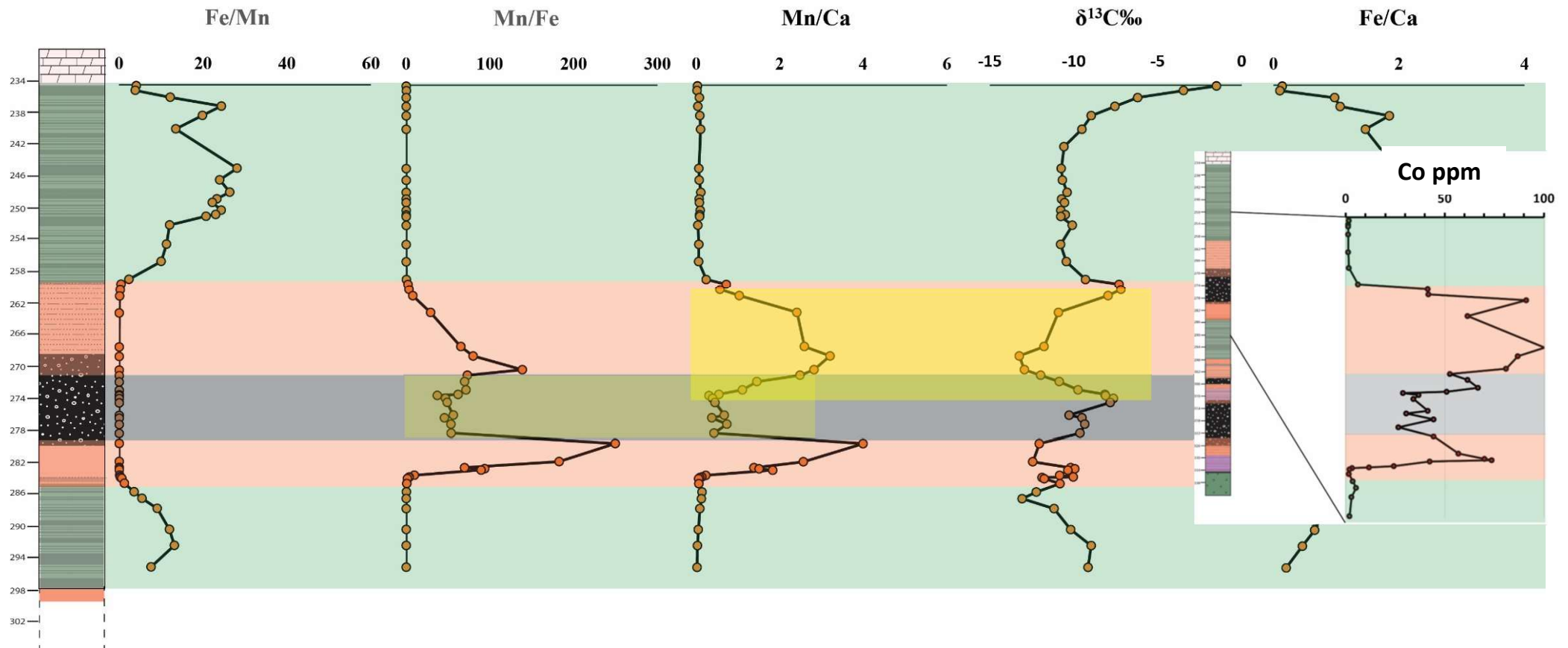


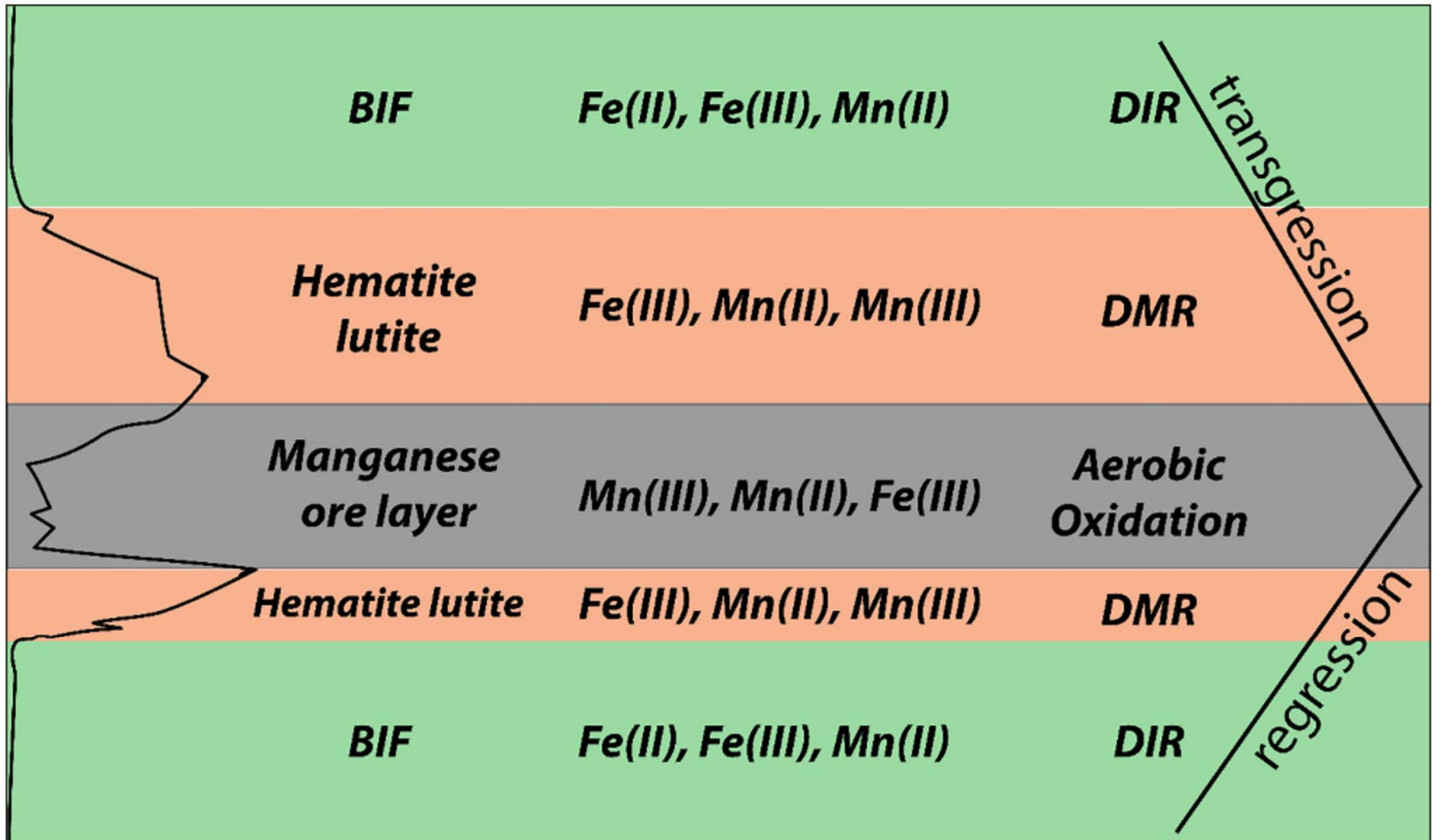
## Το πρόβλημα της δειγματοληψίας



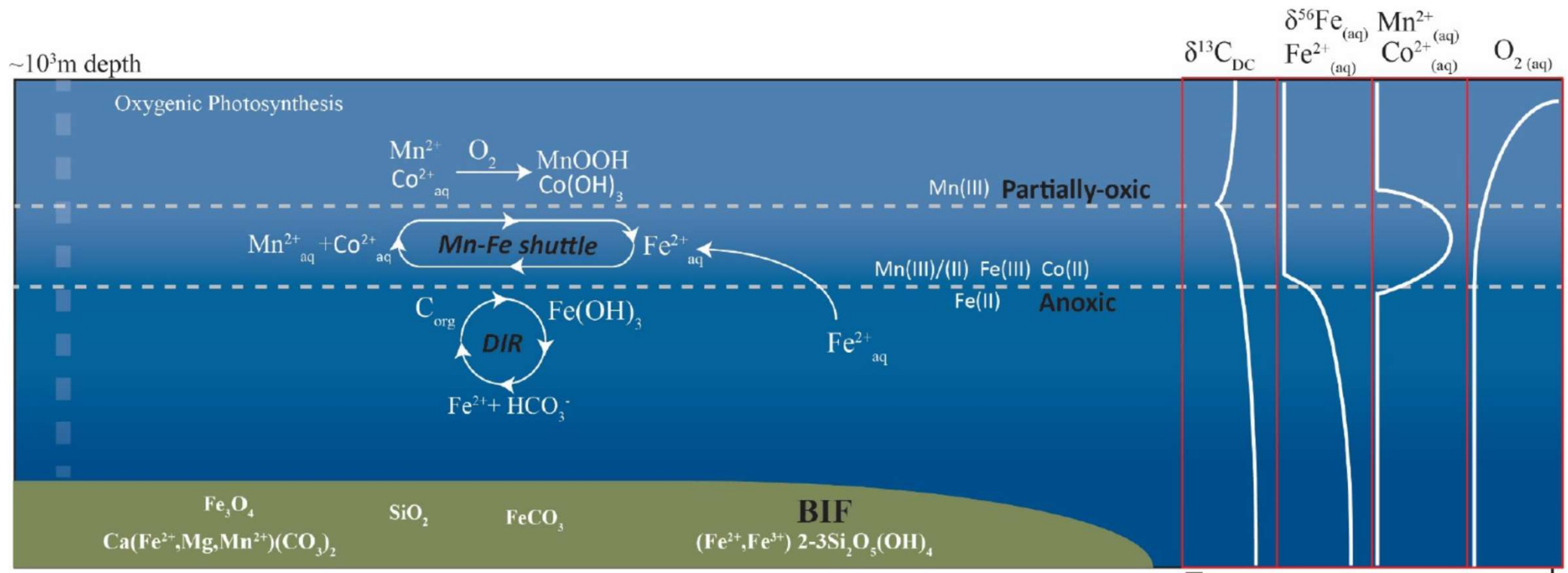


## Χημειοστροματογραφία ανθρακικού κλάσματος σχηματισμού Hotazel

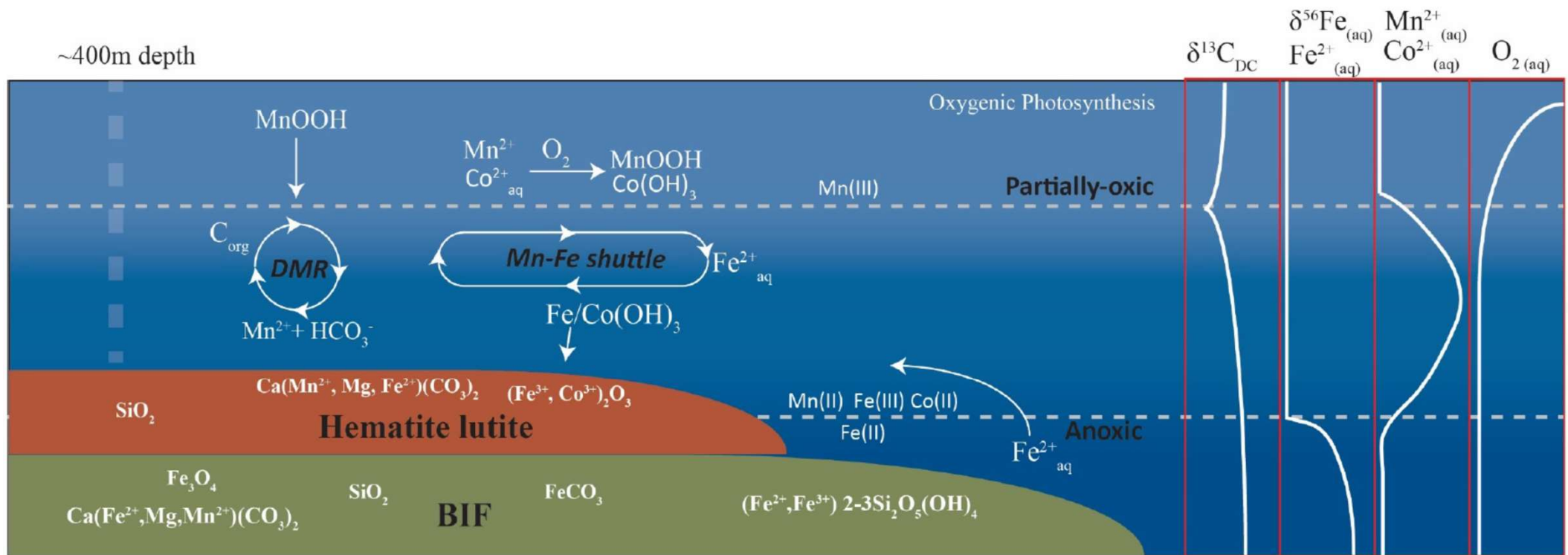




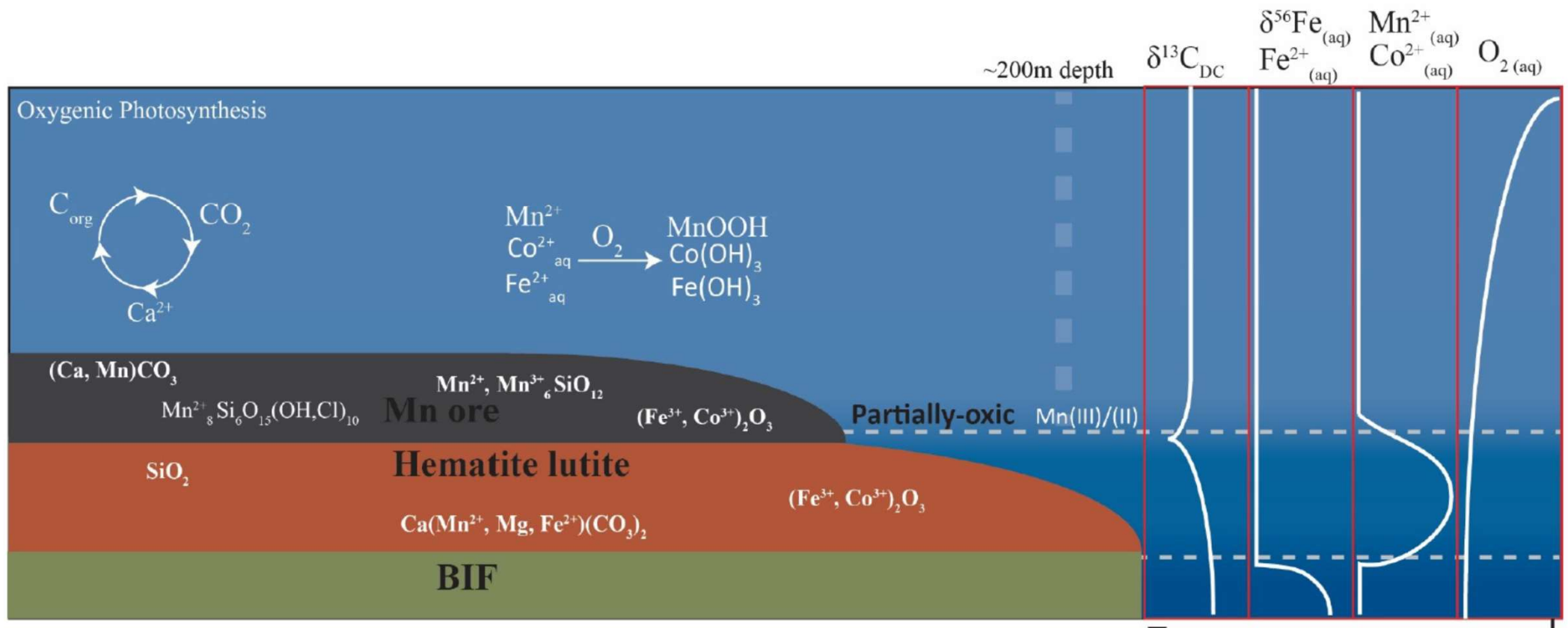
## Μοντέλο ιζηματογένεσης και οι επιπτώσεις στη κατανόηση του παλαιοπεριβάλλοντος απόθεσης - I



## Μοντέλο ιζηματογένεσης και οι επιπτώσεις στη κατανόηση του παλαιοπεριβάλλοντος απόθεσης - II



## Μοντέλο ιζηματογένεσης και οι επιπτώσεις στη κατανόηση του παλαιοπεριβάλλοντος απόθεσης - III



## BIBΛΙΟΓΡΑΦΙΑ

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- Konhauser KO, Planavsky NJ, Hardisty D, Robbins L, Warchola T, Hugaard R, Lalonde S, Partin C, Oonk PBH, Tsikos H, Lyons TW, Bekker A & Johnson C (2017) Iron Formations: A Record of Neoproterozoic to Paleoproterozoic Environmental History. *Earth Science Reviews* **172**, 140-177.
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- Siahi M, Tsikos H, Rafuza S, Oonk PBH, Mason PRD, Mhlanga XR, van Niekerk D, & Harris C (2020) Insights into the processes and controls for the absolute abundance and distribution of manganese in Precambrian iron formations. *Precambrian Research* **350**, 105878.
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- Wang C, Robbins LJ, Planavsky NJ, Beukes NJ, Patry LA, Lalonde SV, Lechte MA, Asael D, Reinhard CT, Zhang L & Konhauser KO (2022) Archean to early Paleoproterozoic iron formations document a transition in iron oxidation mechanisms. *Geochimica et Cosmochimica Acta* **343**, 286-303.

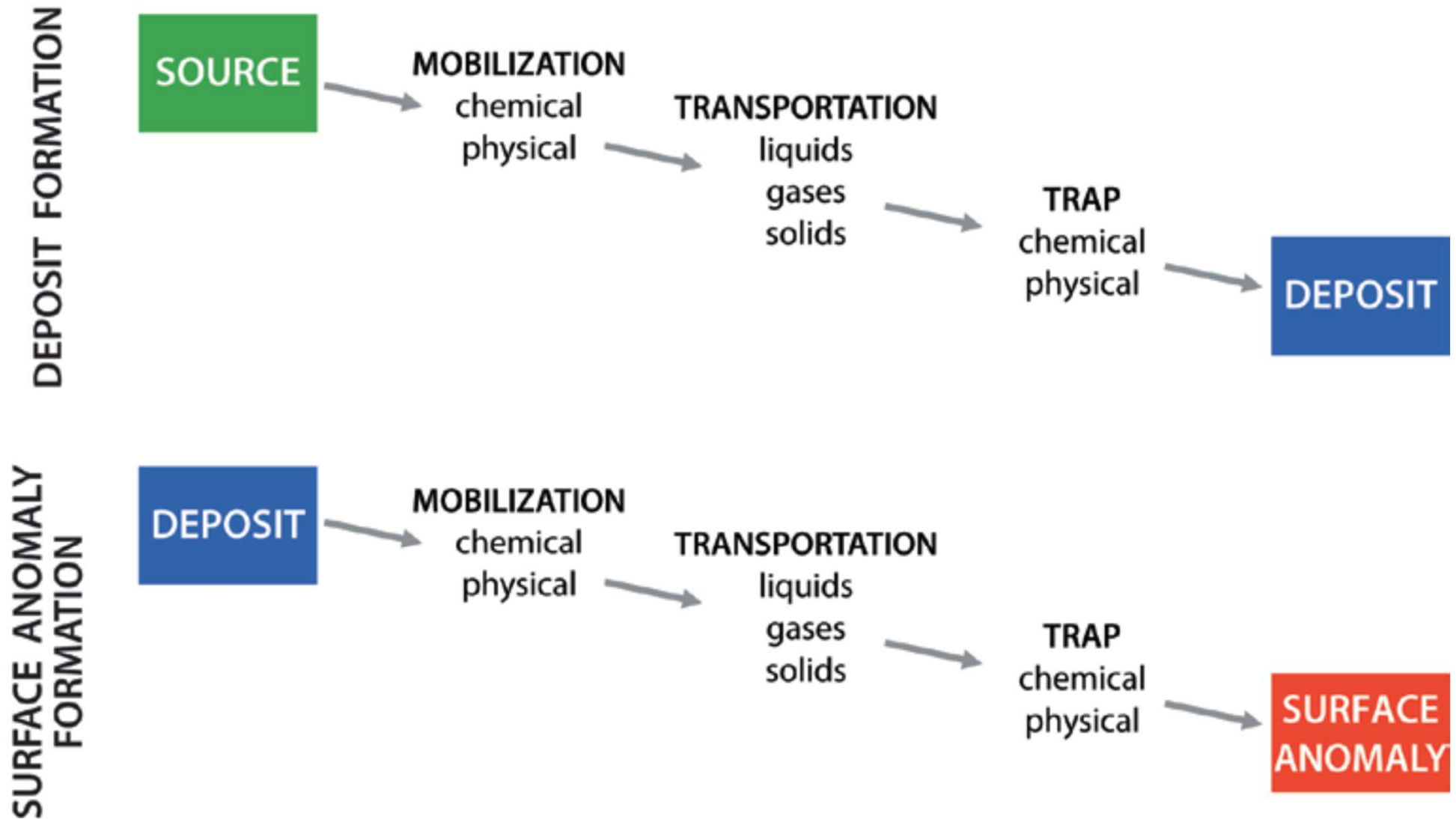


## Γεωχημικοί συσχετισμοί μιας επιλογής τύπων κοιτασμάτων

■ **Table 4.1** Examples of element associations for selected deposit types. It is noticeable that the elements that occur together share the same chemical characteristics and geochemical behaviour (e.g., compatible elements), as well as belonging to the same geochemical reservoir (e.g., chalcophile elements)

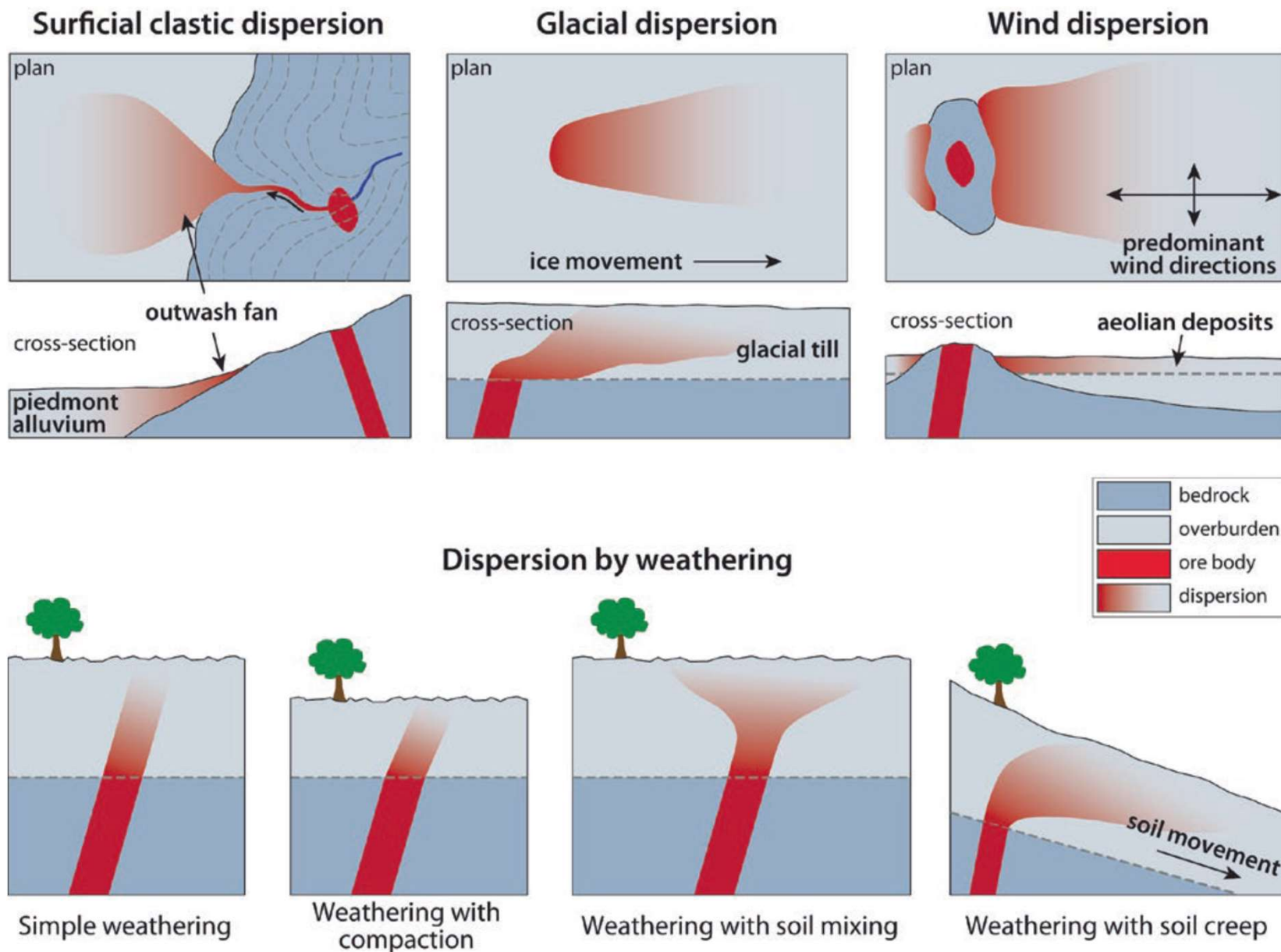
Deposit type	Main elements	Associated elements
<i>Magmatic deposits</i>		
Chromite ores (e.g., Bushveld)	Cr	Ni, Fe, Mg
Layered magnetite (e.g., Bushveld)	Fe	V, Ti, P
Immiscible Cu and Ni sulphides	Cu, Ni, S	Pt, Co, As, Au
Pt, Ni, and Cu in layered intrusion	Pt, Ni, Cu	Cr, Co, S
Immiscible Fe and Ti oxides	Fe, Ti	P
Nb-Ta carbonatite	Nb, Ta	Na, Zr, P
Rare-metal pegmatite	Be, Li, Cs, Rb	B, U, Th, REE
<i>Sedimentary deposits</i>		
Copper shale (Kupferschiefer)	Cu, S	Ag, Zn, Pb, Co, Ni, Cd
Copper sandstone	Cu, S	Ag, Co, Ni

<i>Hydrothermal deposits</i>		
Porphyry copper (e.g., Bingham)	Cu, S	Mo, Au, Ag, Re, As, Zn, K
Porphyry molybdenum (e.g., Climax)	Mo, S	W, Sn, F, Cu
Skarn—magnetite	Fe	Cu, Co, S
Skarn—Cu (e.g., Yerington)	Cu, Fe, S	Au, Ag
Skarn—Pb—Zn (Hanover)	Pb, Zn, S	Cu, Co
Skarn—W—Mo—Sn (e.g., Bishop)	W, Mo, Sn	F, S, Cu, Be, Bi
Base metal veins	Pb, Zn, Cu, S	Ag, Au, As, Sb, Mn
Sn—W greisens	Sn, W	Cu, Mo, Bi, Li, Rb, Si, Re, F, B
Sn sulphide veins	Sn, S	Cu, Pb, Zn, Ag, Sb
Co—Ni—As vein	Co, Ni, Ag, S	As, Sb, Bi, U
Epithermal precious metals	Au, Ag	Sb, As, Hg, Te, Se, S, U
Uranium vein	U	Mo, Pb, F
VMS—Cu	Cu, S	Zn, Au
VMS—Zn—Cu—Pb	Zn, Pb, Cu, S	Ag, Ba, Au, As
Au—As-rich iron formation	Au, As, S	Sb
Mississippi Valley Pb—Zn	Pb, Zn, S	Ba, F, Cd, Cu, Ni, Co
Sandstone U	U	Se, Mo, V, Cu, Pb
Red-bed Cu	Cu, S	Ag, Pb

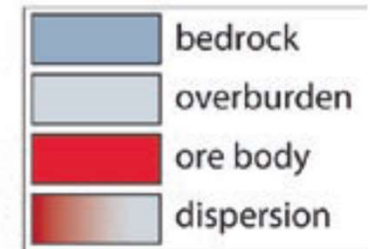
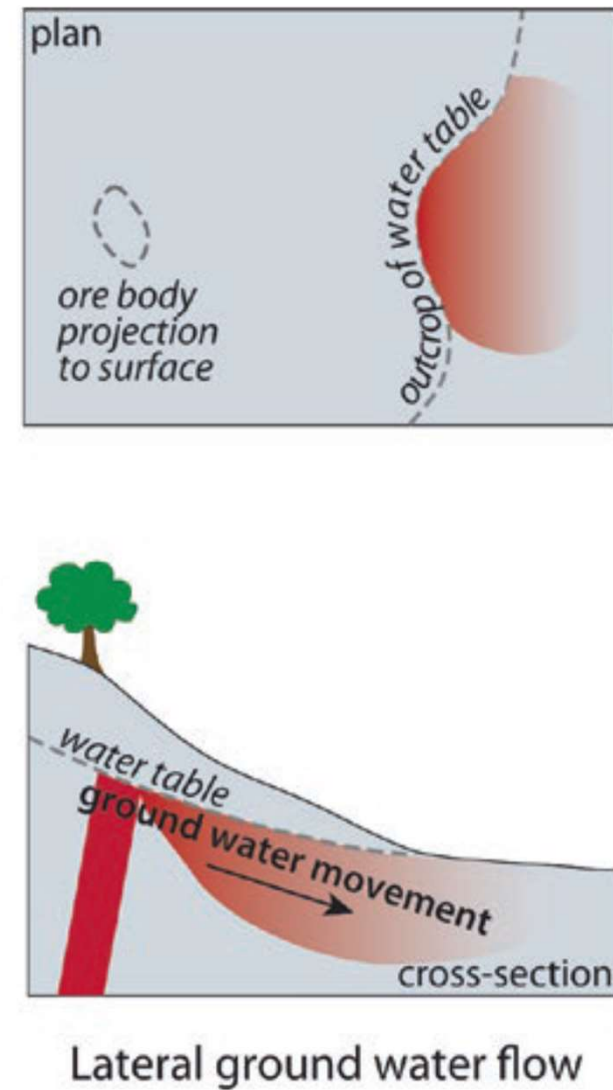
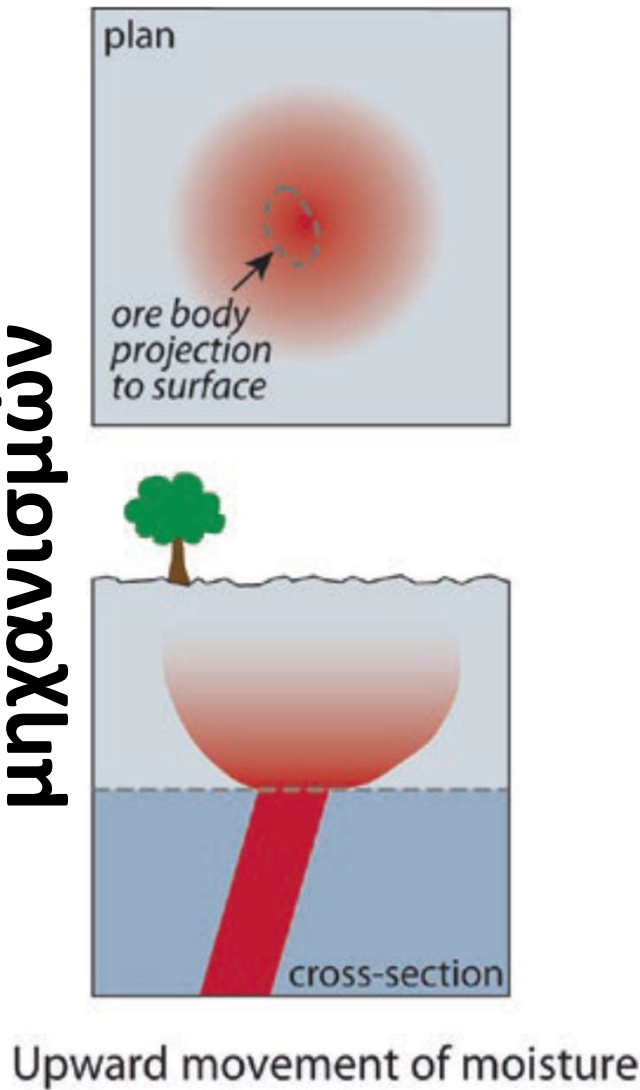




## Γεωχημική διασπορά μέσω φυσικών μηχανικών μηχανισμών



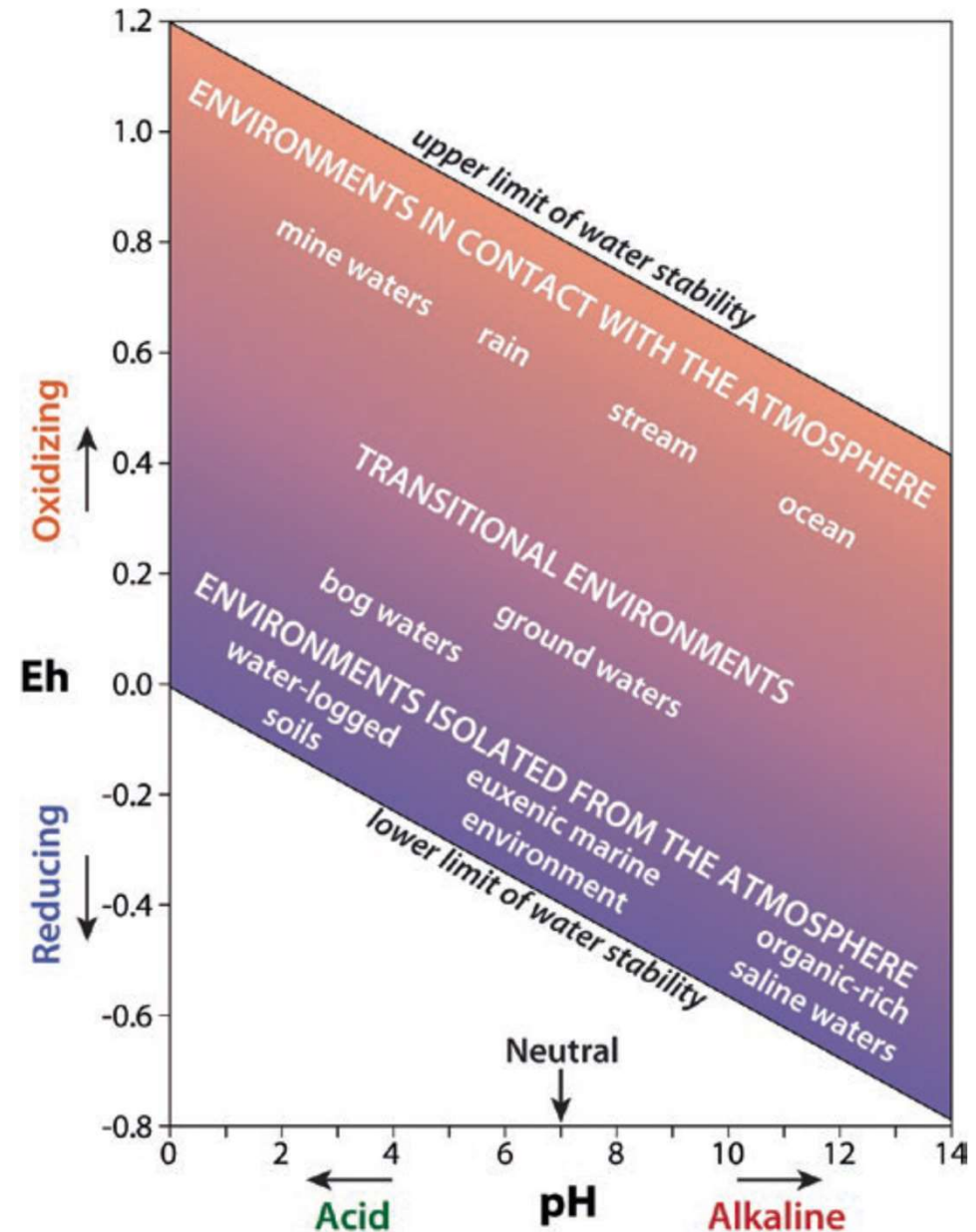
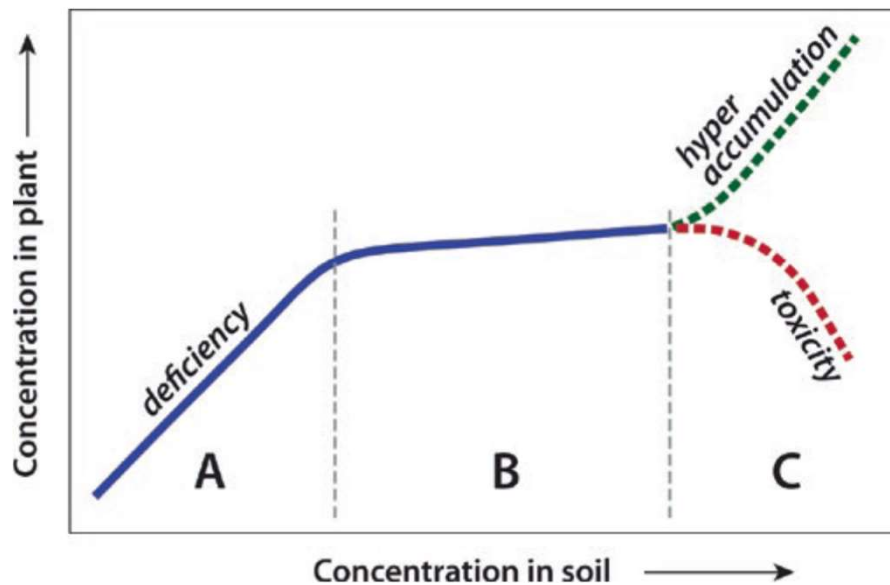
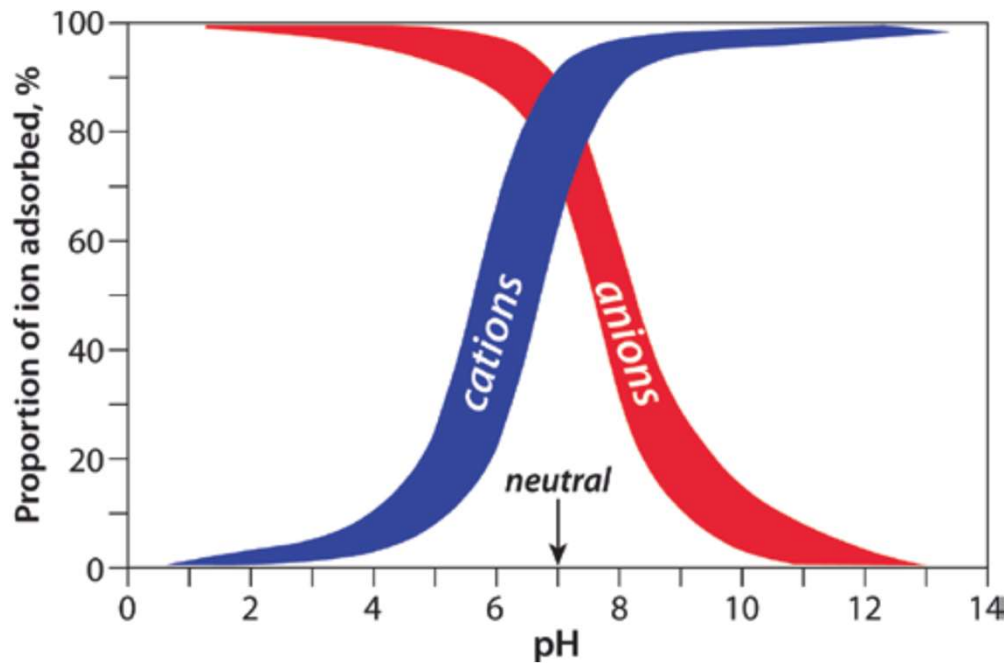
## Γεωχημική διασπορά μέσω φυσικών χημικών μηχανισμών



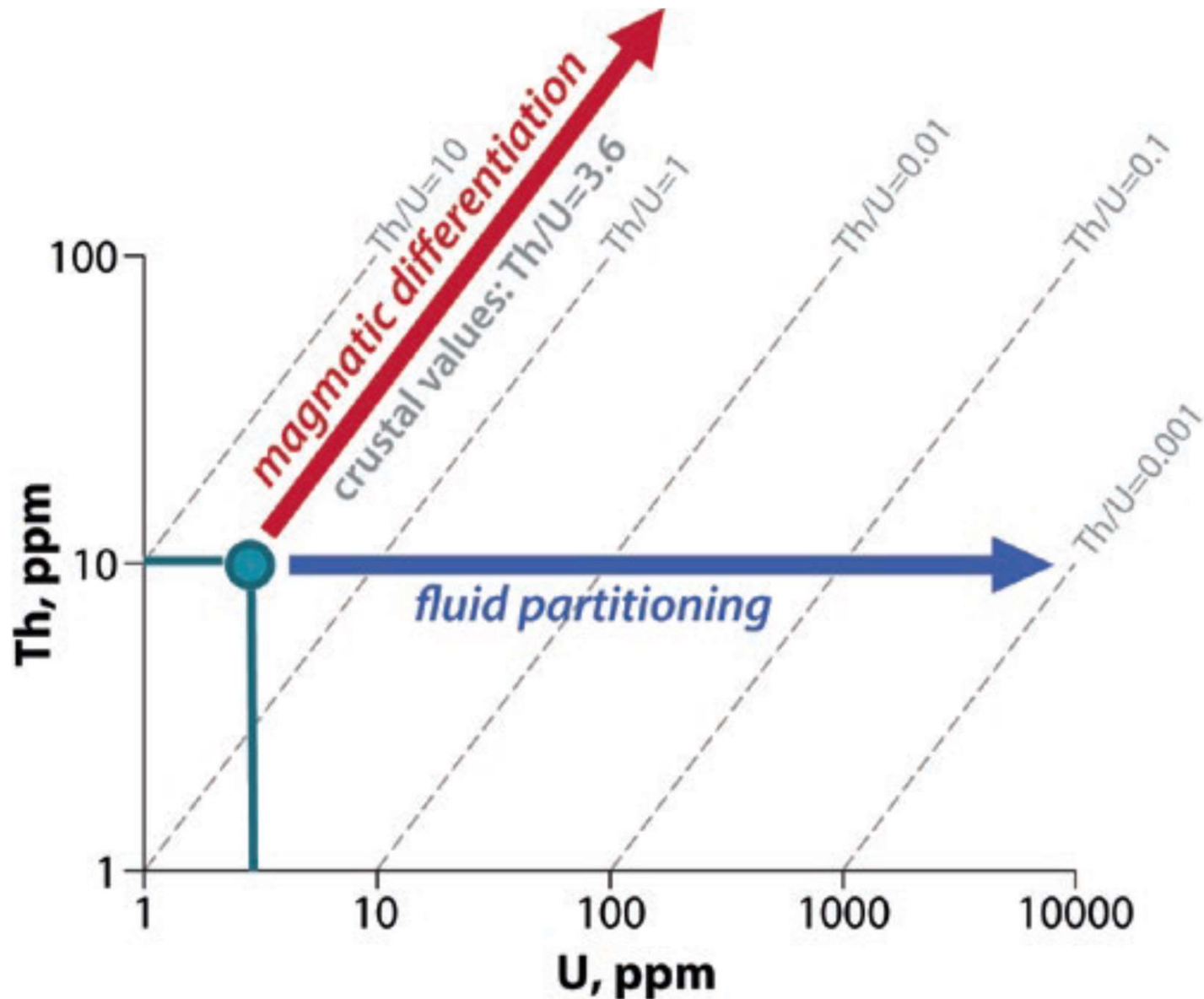
## Κινητικότητα στοιχείων σε συνάρτηση με το Eh και το pH

■ **Table 4.2** Mobility of elements as function of Eh and pH. Most cations tend to be more immobile in reducing alkaline conditions

Relative mobility	Conditions			
	Oxidizing	Reducing	Acid	Neutral to alkaline
Very high	B, Br, Cl, I, S	B, Cl, I	B, Br, Cl, I, S	B, Br, Cl, I, S, Mo, V, U, Se, Re
High	Mo, V, U, Se, Re, Ca, Na, Mg, F, Sr, Ra, Zn	Ca, Na, Mg, F, Sr, Ra	Mo, V, U, Se, Re, Ca, Na, Mg, F, Sr, Ra, Zn, Cu, Co, Ni, Hg, Ag, Au	Ca, Na, Mg, F, Sr, Ra
Medium	Cu, Co, Ni, Hg, Ag, Au, As, Cd		As, Cd	As, Cd
Low	Si, P, K, Pb, Li, Rb, Ba, Be, Bi, Sb, Ge, Cs, Tl	Si, P, K, Fe, Mn	Si, P, K, Pb, Li, Rb, Ba, Be, Bi, Sb, Ge, Cs, Tl, Fe, Mn	Si, P, K, Pb, Li, Rb, Ba, Be, Bi, Sb, Ge, Cs, Tl, Fe, Mn
Very low to immobile	Fe, Mn, Al, Ti, Sn, Te, W, Nb, Ta, Pt, Cr, Zr, Th, REE	Al, Ti, Sn, Te, W, Nb, Ta, Pt, Cr, Zr, Th, REE, S, B, Mo, V, U, Se, Re, Zn, Cu, Co, Ni, Hg, Ag, Au, As, Cd, Pb, Li, Rb, Ba, Be, Bi, Sb, Ge, Cs, Tl	Al, Ti, Sn, Te, W, Nb, Ta, Pt, Cr, Zr, Th, REE	Al, Ti, Sn, Te, W, Nb, Ta, Pt, Cr, Zr, Th, REE, Zn, Cu, Co, Ni, Hg, Ag, Au



## Γεωχημική συμπεριφορά U και Th μέσω μαγματικής διαφοροποίησης και κινητικότητας σε ρευστή φάση

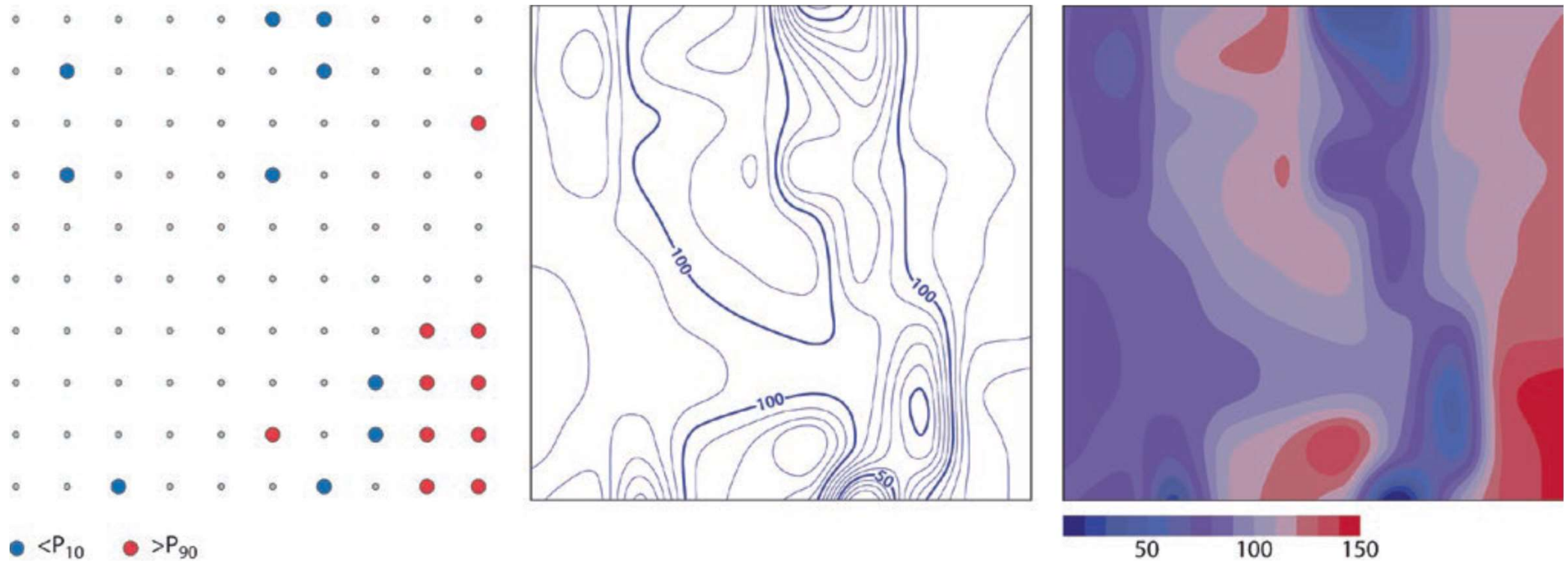


Horizon	Composition	Processes	Organic matter		Oxygen		CO <sub>2</sub>	
			less	more	less	more	less	more
<b>O</b>	fresh and partly decomposed organic matter	accumulation of organic matter		↑		↑		↓
<b>A</b>	dark decayed organic matter mixed with minerals	solution complexing		↑		↑		↓
	light, leached organic matter mixed with minerals	leaching maximum leaching		↑		↑		↓
<b>B</b>	organic matter, clay minerals, Fe and Mn oxides	accumulation of products leached from A horizon; precipitation of clay minerals and Fe and Mn oxides	↑		↑			↓
<b>C</b>	weathered bedrock (loose and partly decayed)	weathering of bedrock; removal of mobile ions to ground water	↑		↑			↓

■ **Table 4.3** Mobility and trapping mechanisms in soil at near neutral pH and high Eh, for a selection of elements. Both the mobility and the trapping mechanisms will vary extensively as function of the Eh and pH of the ground water (see ■ Table 4.1), as well as environmental factors such as mean annual temperature and precipitation. OM = organic matter

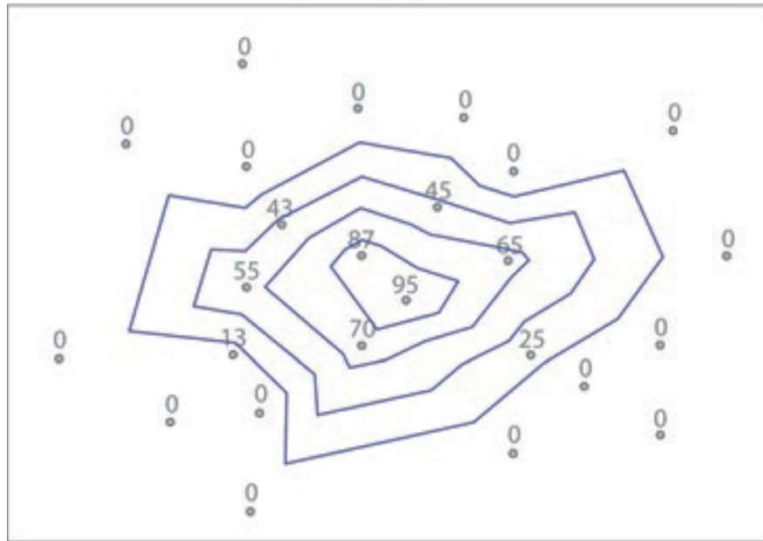
Element	Oxidation state in soil	Mobility in soil	Trapping mechanism in soil
As	As <sup>3+</sup> and As <sup>5+</sup>	Moderately mobile	Chemisorption on Fe and Al oxides at low pH
Ba	Ba <sup>2+</sup>	Mostly immobile	Precipitation with carbonates, adsorption on clays
Be	Be <sup>2+</sup>	Mobile	Chemisorption in the presence of OM
Cd	Cd <sup>2+</sup>	Highly mobile	Precipitation with carbonates
Co	Co <sup>2+</sup> and Co <sup>3+</sup>	Moderately immobile	Adsorption on Fe and Mn oxides
Cr	Cr <sup>3+</sup>	Immobile with organic matter	Substitution in Fe oxides, adsorption on clays
Cu	Cu <sup>2+</sup>	Moderately immobile	Adsorption on Fe, Mn, and Al oxides
Mn	Mn <sup>2+</sup> , Mn <sup>3+</sup> , Mn <sup>4+</sup>	Immobile	Forms its own insoluble oxides
Mo	Mo <sup>6+</sup>	Immobile, particularly at low pH	Adsorption on Fe and Al oxides and on OM
Ni	Ni <sup>2+</sup>	Immobile	OM complexes, precipitation with Fe and Mn oxides
Pb	Pb <sup>2+</sup>	Immobile, in particular at low Eh	Adsorbs on Mn oxides, binds strongly with OM
Sb	Sb <sup>3+</sup> and Sb <sup>5+</sup>	Immobile	Chemisorption on goethite
Se	Se <sup>0</sup> , Se <sup>2-</sup> , Se <sup>4+</sup> , Se <sup>6+</sup>	Highly mobile	Immobile as selenides
Ti	Ti <sup>1+</sup> and Ti <sup>3+</sup>	Ti <sup>1+</sup> highly mobile	Ti <sup>3+</sup> insoluble as Ti <sub>2</sub> O <sub>3</sub>
V	V <sup>4+</sup> and V <sup>5+</sup>	Highly mobile	Adsorption on or substitution in Fe oxides
Zn	Zn <sup>2+</sup>	Highly mobile	Chemisorbed on oxides

## Μορφές οπτικής παρουσίασης γεωχημικών ανωμαλιών σε εδάφη στο δισδιάστατο χώρο

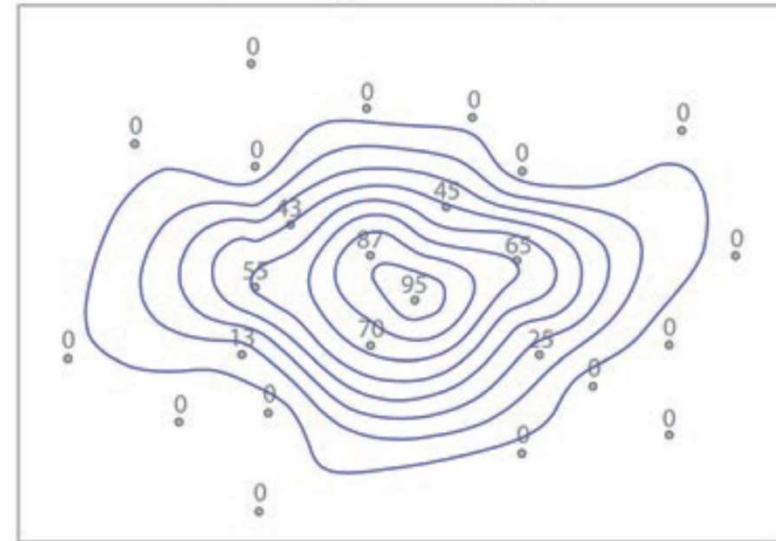




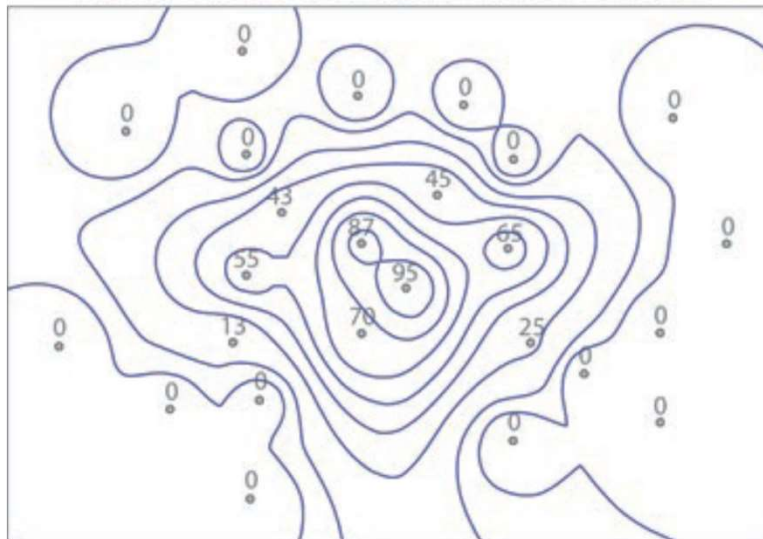
Linear interpolation



Natural neighbour interpolation



Inverse distance weighted interpolation



Kriging

