Applied & Environmental Geochemistry

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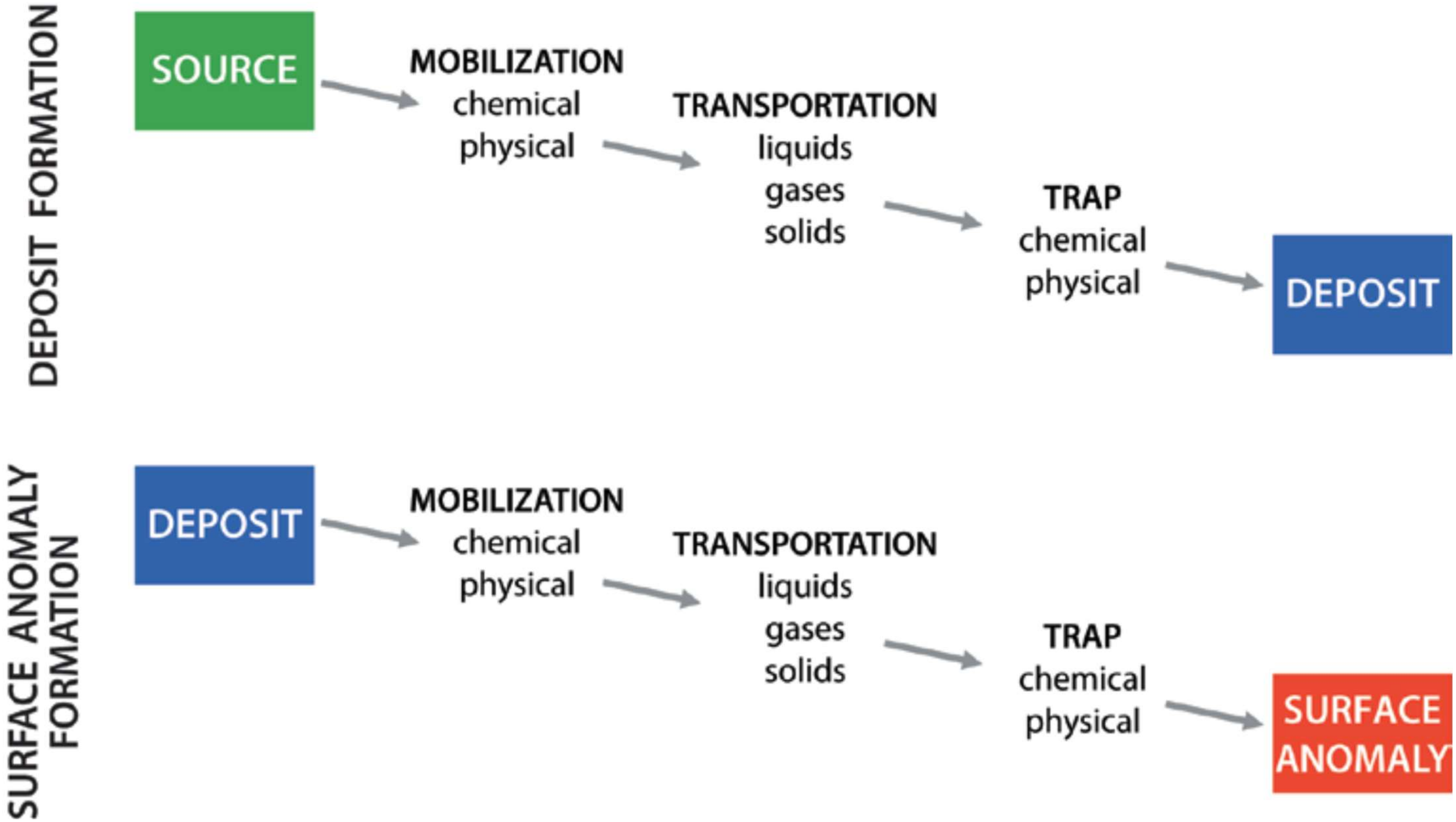
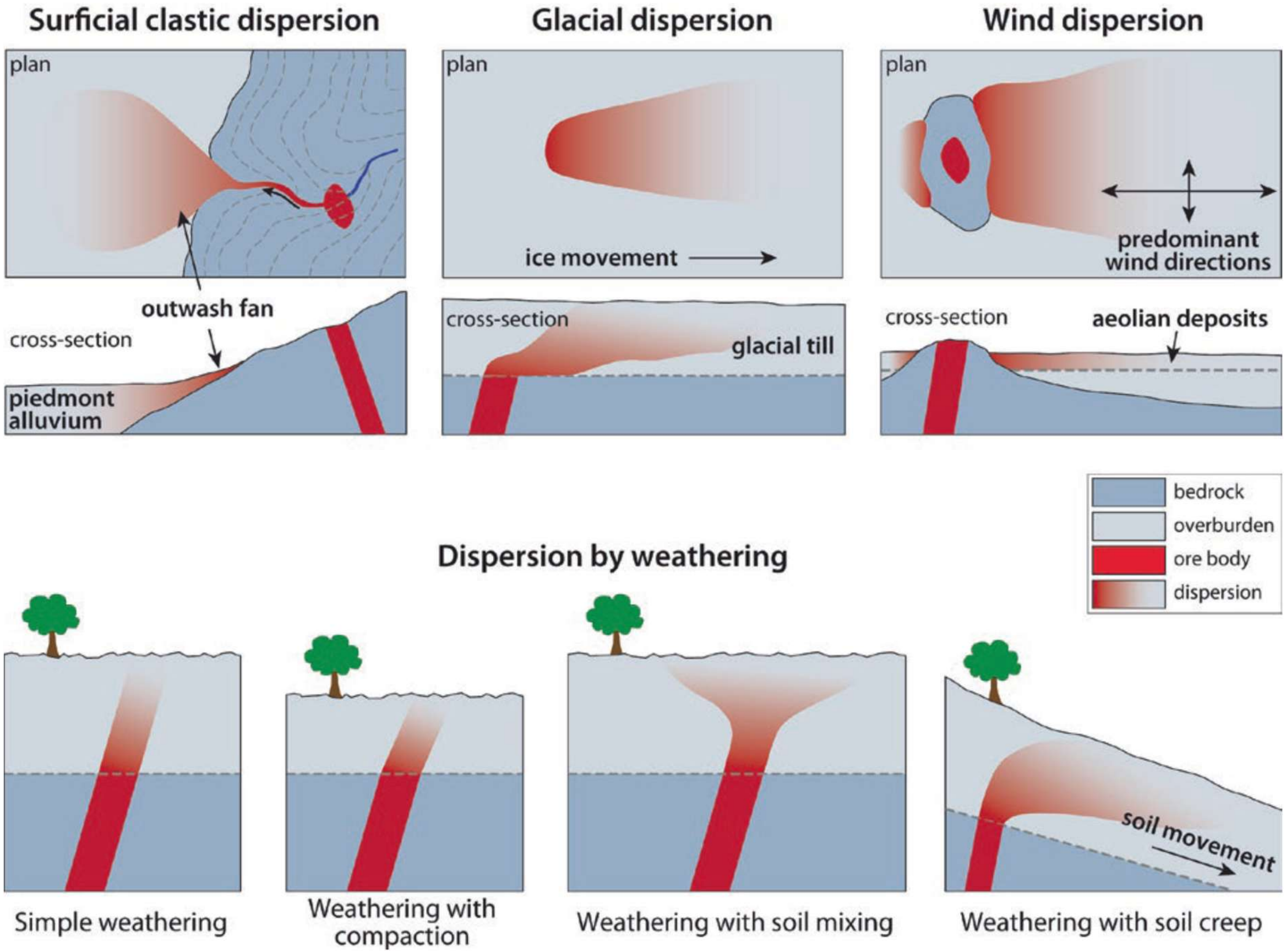
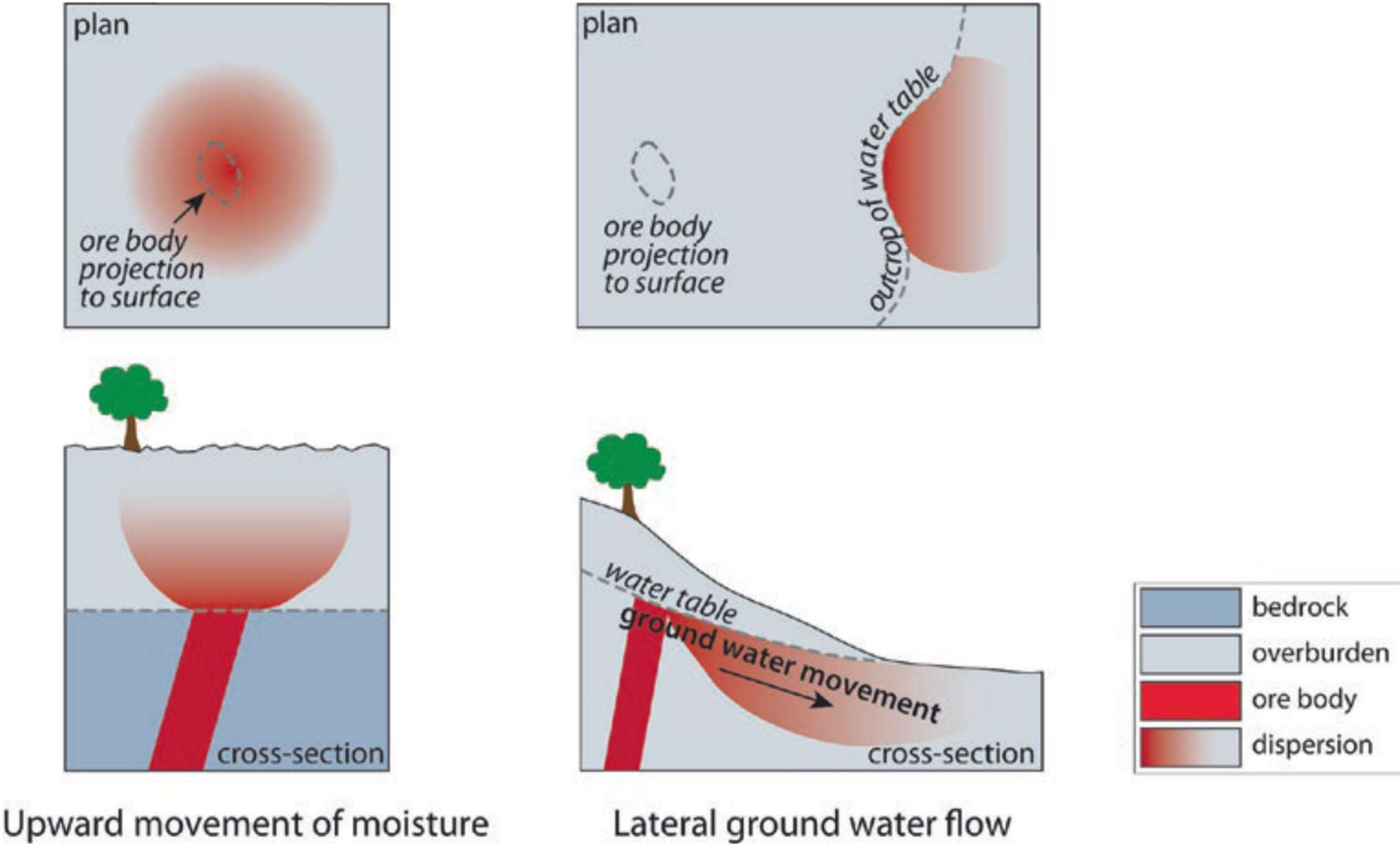
Table 4.1 Examples of element associations for selected deposit types. It is noticeable that the elements that occur together share the same chemical characteristics and geochemical behaviour (e.g., compatible elements), as well as belonging to the same geochemical reservoir (e.g., chalcophile elements)

Deposit type	Main elements	Associated elements
Magmatic deposits		
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
Sedimentary deposits		
Copper shale (Kupferschiefer)	Cu, S	Ag, Zn, Pb, Co, Ni, Cd
Copper sandstone	Cu, S	Ag, Co, Ni
Hydrothermal deposits		
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


DEPOSIT FORMATION
SOURCE
MOBILIZATION
chemical
physical
TRANSPORTATION
liquids
gases
solids
TRAP
chemical
physical
DEPOSIT
SURFACE ANOMALY FORMATION
DEPOSIT
MOBILIZATION
chemical
physical
TRANSPORTATION
liquids
gases
solids
TRAP
chemical
physical
SURFACE ANOMALY


Surficial clastic dispersion
plan
outwash fan
cross-section
piedmont alluvium
Glacial dispersion
plan
ice movement
cross-section
glacial till
Wind dispersion
plan
predominant wind directions
cross-section
aeolian deposits
bedrock
overburden
ore body
dispersion
Dispersion by weathering
soil movement
Simple weathering
Weathering with compaction
Weathering with soil mixing
Weathering with soil creep

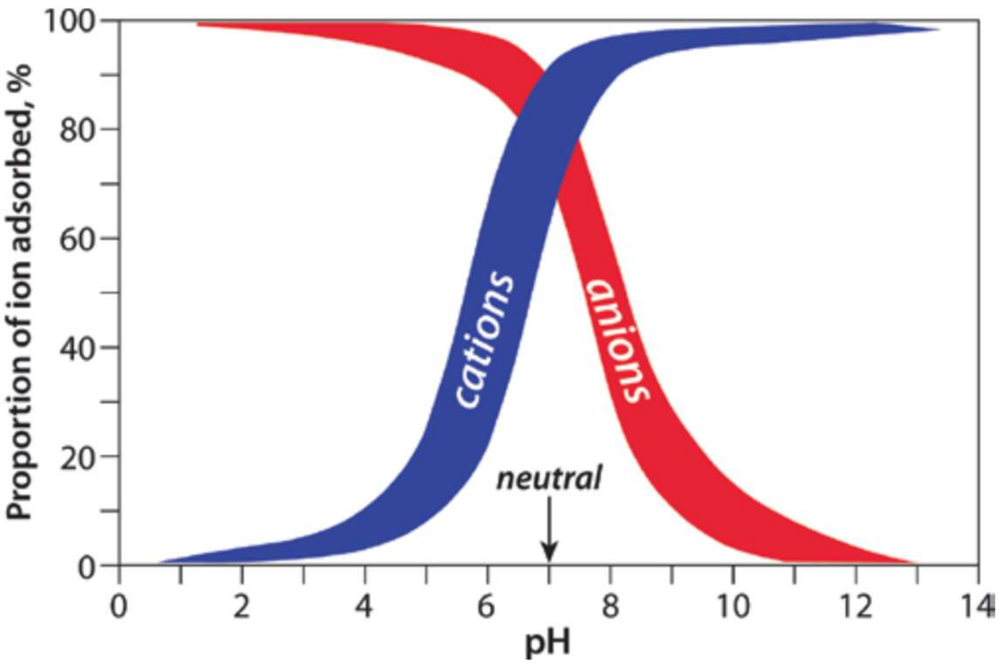


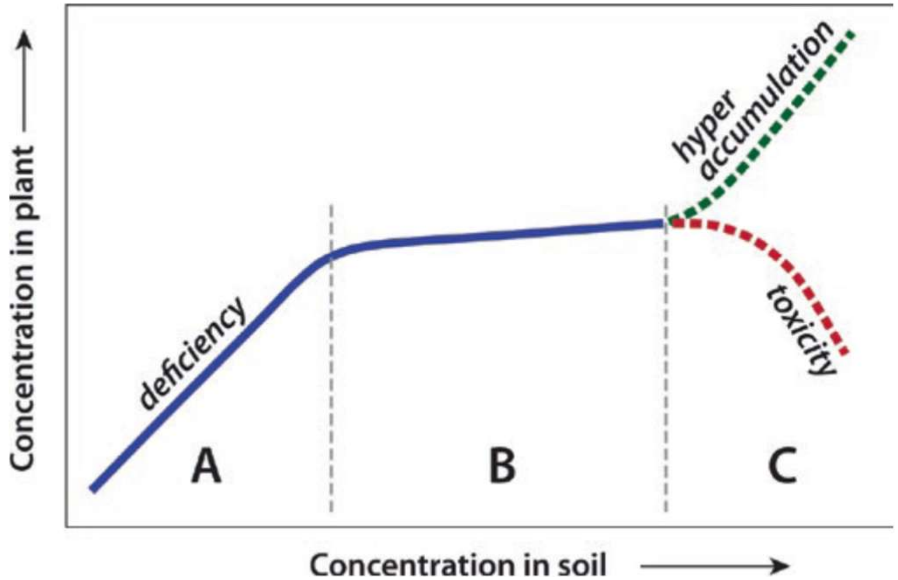
(Kump & Barley, 2007; Lyons, 2007)

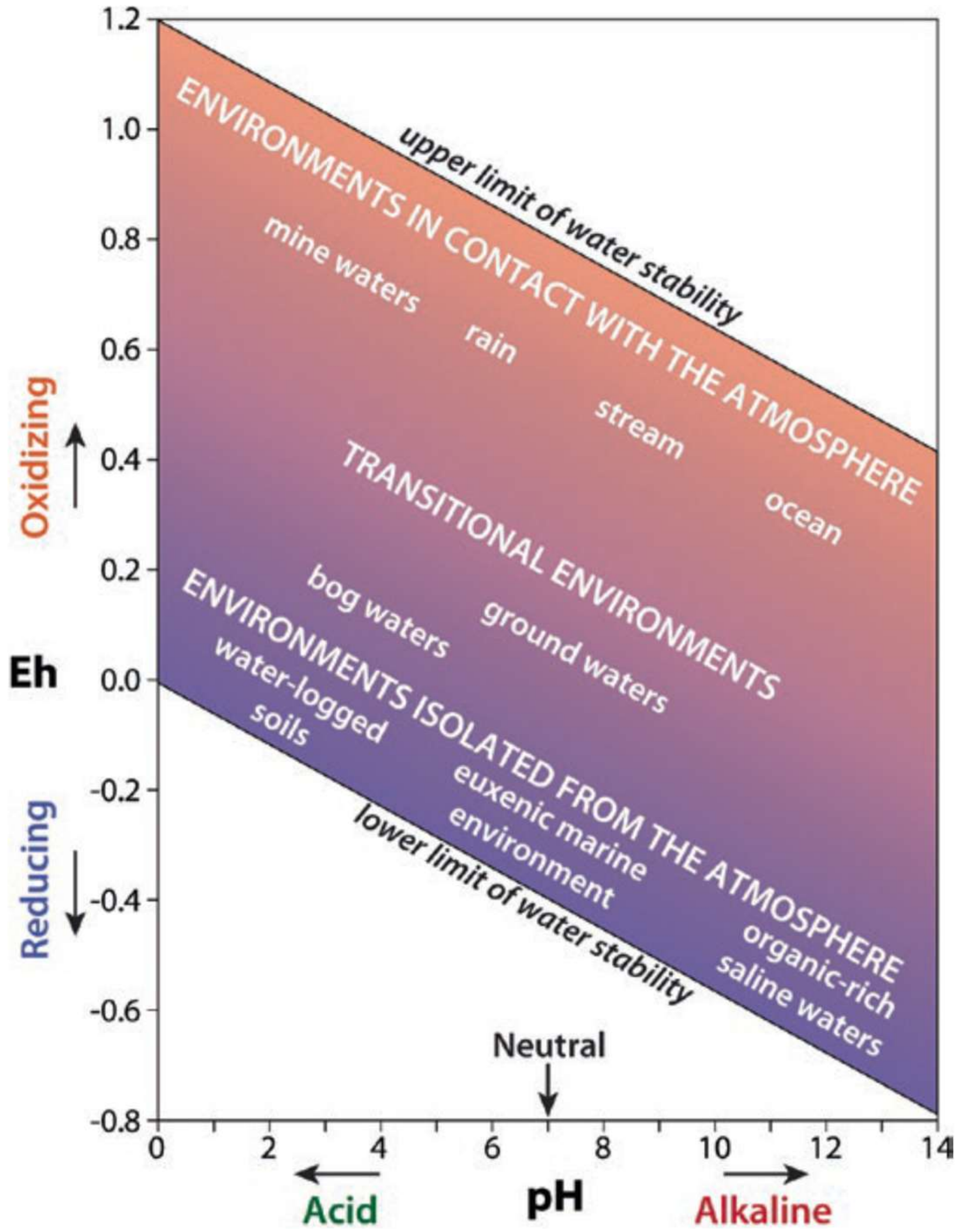
Element mobility as a function of pH and Eh

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

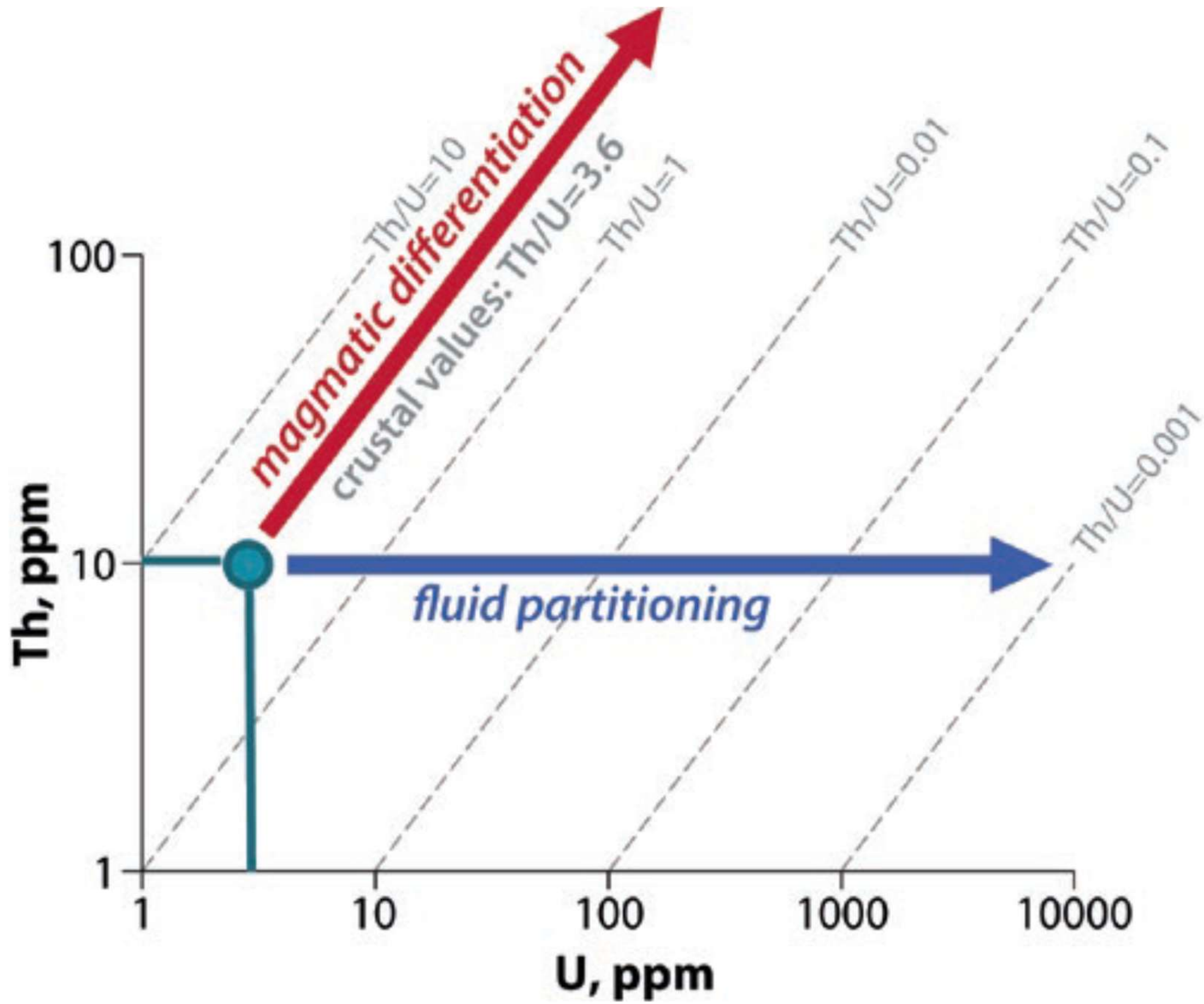
Relative mobility	Conditions			
	Oxidizing	**Reducing**	**Acid**	**Neutral to alkaline**
Very high	B, Br, Cl, I, S	B, Cl, I	B, Br, Cl, I, S	B, Br, Cl, I, S, Mo, V, U, Se, Re
High	Mo, V, U, Se, Re, Ca, Na, Mg, F, Sr, Ra, Zn	Ca, Na, Mg, F, Sr, Ra	Mo, V, U, Se, Re, Ca, Na, Mg, F, Sr, Ra, Zn, Cu, Co, Ni, 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


Proportion of ion adsorbed, %
100
80
60
40
20
0
cations
anions
neutral
0
2
4
6
8
10
12
14
pH


Concentration in plant
Concentration in soil
deficiency
hyper accumulation
toxicity
A
B
C


Eh
Oxidizing
Reducing
1.2
1.0
0.8
0.6
0.4
0.2
0.0
-0.2
-0.4
-0.6
-0.8
upper limit of water stability
ENVIRONMENTS IN CONTACT WITH THE ATMOSPHERE
mine waters
rain
stream
ocean
TRANSITIONAL ENVIRONMENTS
bog waters
ground waters
ENVIRONMENTS ISOLATED FROM THE ATMOSPHERE
water-logged soils
euxenic marine environment
organic-rich saline waters
lower limit of water stability
Neutral
0
2
4
6
8
10
12
14
Acid
pH
Alkaline

Magmatic differentiation *versus* fluid-induced mobilization; the example of U and Th



Horizon	Composition	Processes
O	fresh and partly decomposed organic matter	accumilation of organic matter
A	dark decayed organic matter mixed with minerals	solution complexing leaching
	light, leached organic matter mixed with minerals	maximum leaching
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
C	weathered bedrock (loose and partly decayed)	weathering of bedrock; removal of mobile ions to ground water

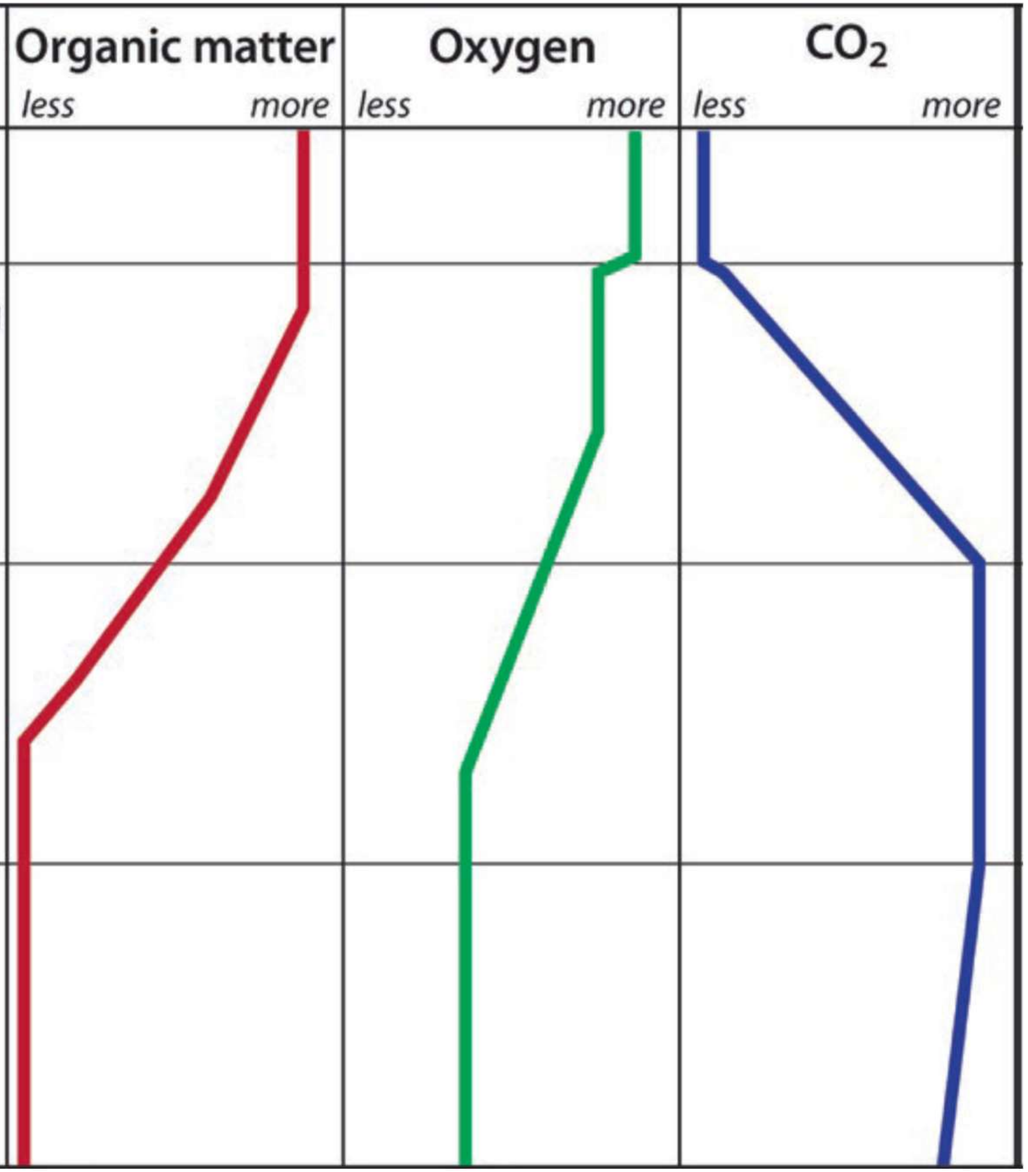
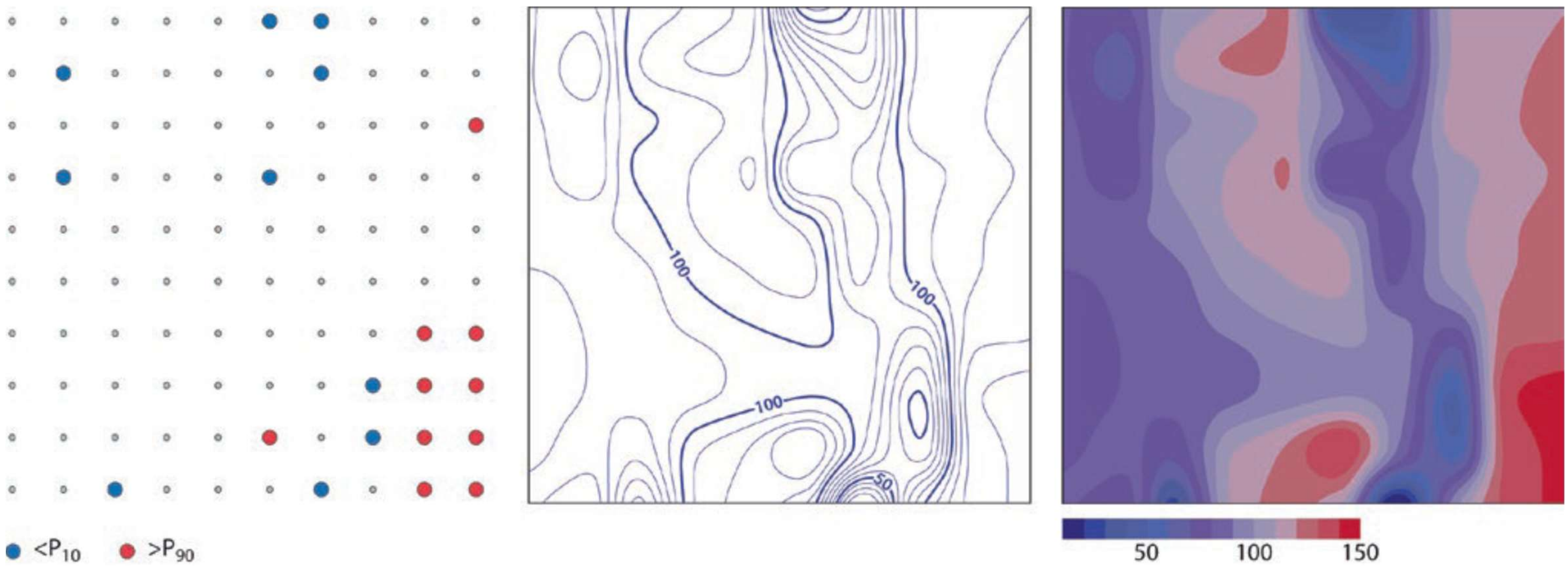
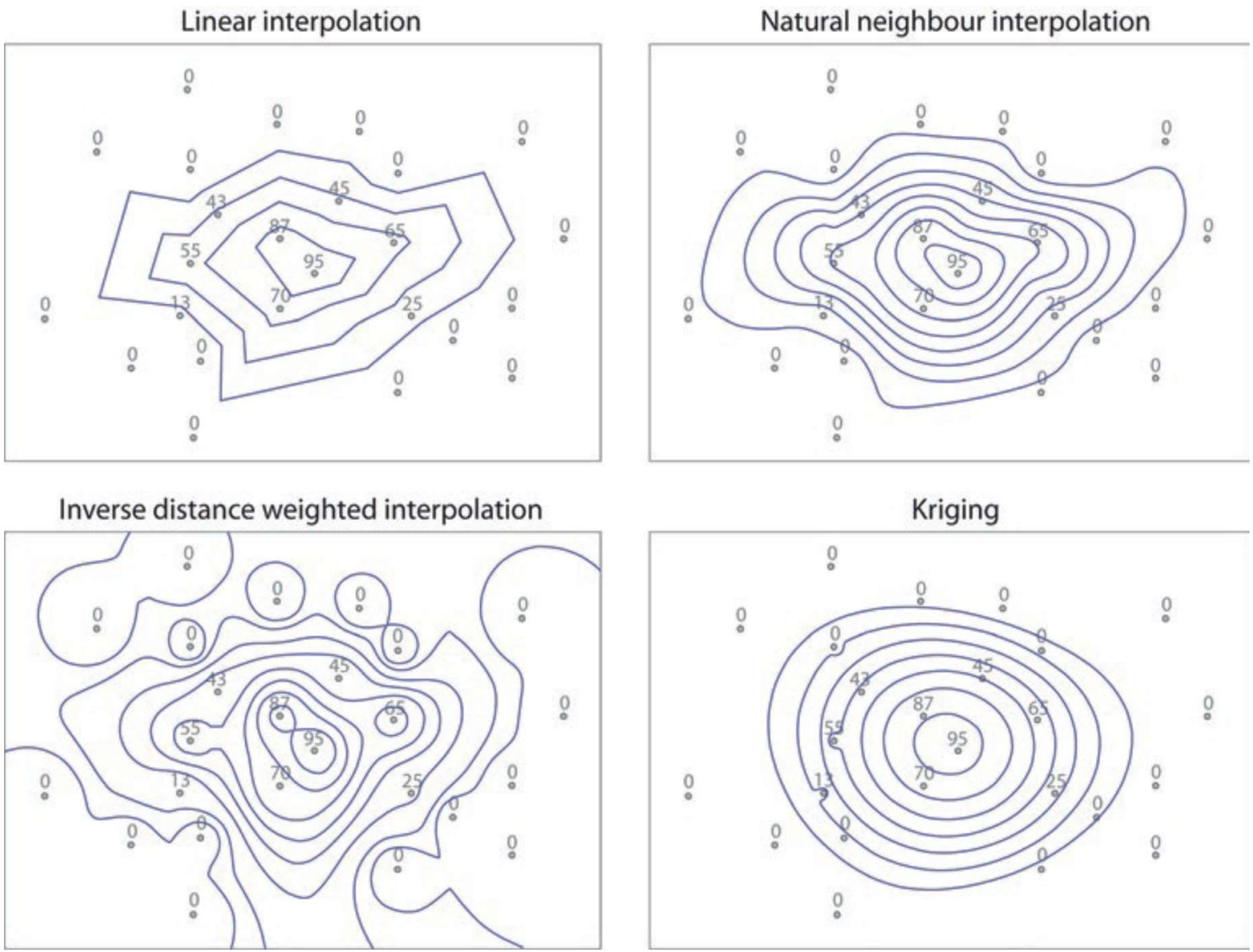


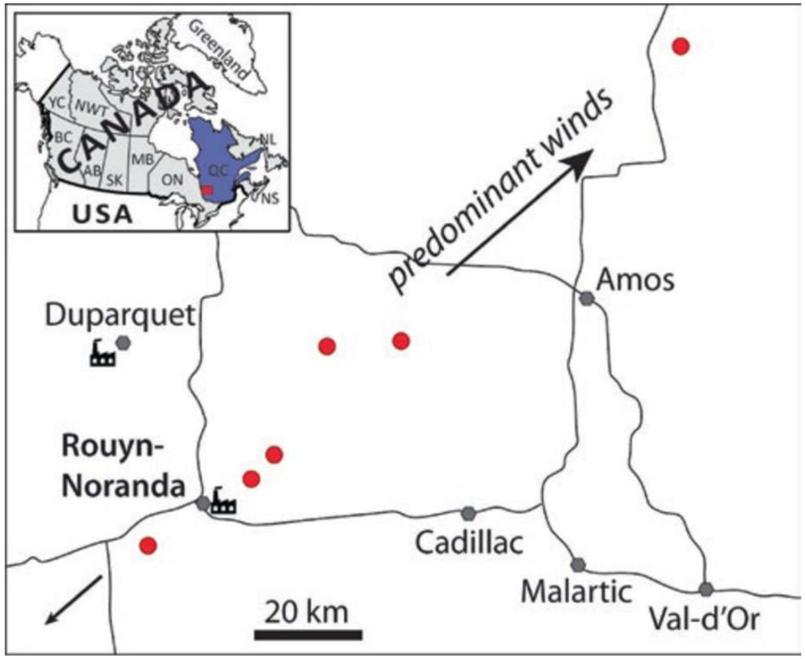
Table 4.3 Mobility and trapping mechanisms in soil at near neutral pH and high Eh, for a selection of elements. Both the mobility and the trapping mechanisms will vary extensively as function of the Eh and pH of the ground water (see Table 4.1), as well as environmental factors such as mean annual temperature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

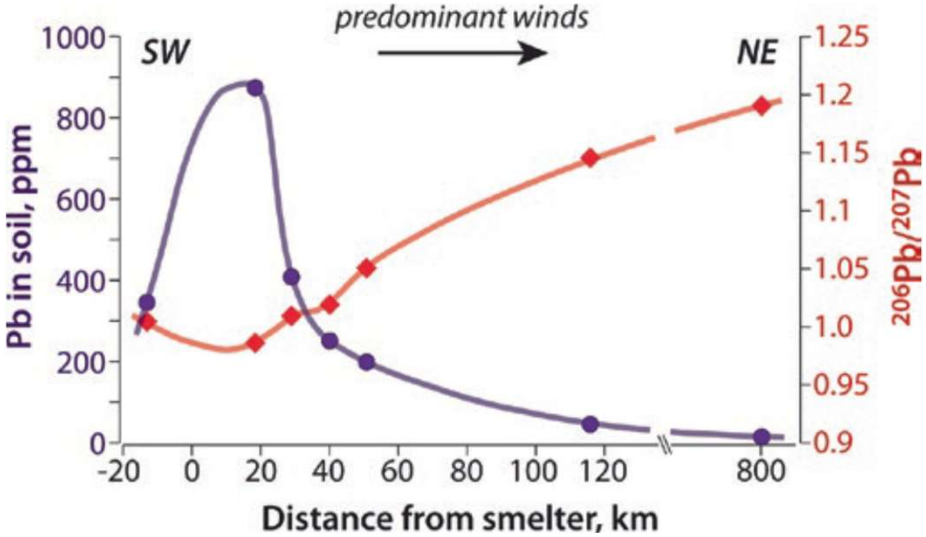
Element	Oxidation state in soil	Mobility in soil	Trapping mechanism in soil
As	As^{3+} and As^{5+}	Moderately mobile	Chemisorption on Fe and Al oxides at low pH
Ba	Ba^{2+}	Mostly immobile	Precipitation with carbonates, adsorption on clays
Be	Be^{2+}	Mobile	Chemisorption in the presence of OM
Cd	Cd^{2+}	Highly mobile	Precipitation with carbonates
Co	Co^{2+} and Co^{3+}	Moderately immobile	Adsorption on Fe and Mn oxides
Cr	Cr^{3+}	Immobile with organic matter	Substitution in Fe oxides, adsorption on clays
Cu	Cu^{2+}	Moderately immobile	Adsorption on Fe, Mn, and Al oxides
Mn	Mn^{2+}, Mn^{3+}, Mn^{4+}	Immobile	Forms its own insoluble oxides
Mo	Mo^{6+}	Immobile, particularly at low pH	Adsorption on Fe and Al oxides and on OM
Ni	Ni^{2+}	Immobile	OM complexes, precipitation with Fe and Mn oxides
Pb	Pb^{2+}	Immobile, in particular at low Eh	Adsorbs on Mn oxides, binds strongly with OM
Sb	Sb^{3+} and Sb^{5+}	Immobile	Chemisorption on goethite
Se	Se^{0}, Se^{2-}, Se^{4+}, Se^{6+}	Highly mobile	Immobile as selenides
Ti	Ti^{1+} and Ti^{3+}	Ti^{1+} highly mobile	Ti^{3+} insoluble as Ti_2O_3
V	V^{4+} and V^{5+}	Highly mobile	Adsorption on or substitution in Fe oxides
Zn	Zn^{2+}	Highly mobile	Chemisorbed on oxides

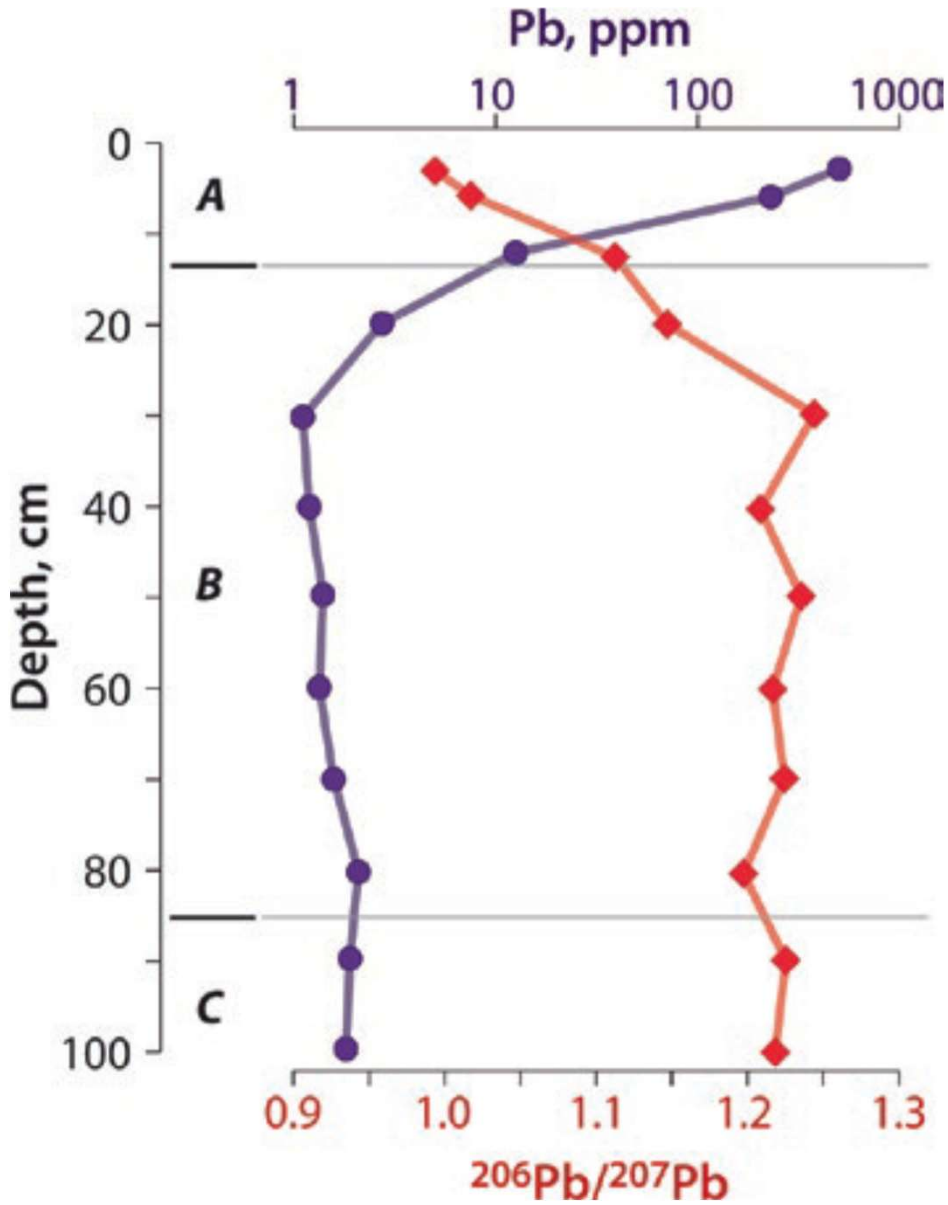
Μορφές οπτικής παρουσίασης γεωχημικών ανωμαλιών σε εδάφη στο δισδιάστατο χώρο




Linear interpolation
Natural neighbour interpolation
Inverse distance weighted interpolation
Kriging


Greenland
CANADA
YC
NWT
BC
AB
SK
MB
ON
QC
NL
NS
USA
predominant winds
Amos
Duparquet
Rouyn-
Noranda
Cadillac
Malartic
Val-d'Or
20 km


predominant winds
SW
NE
Pb in soil, ppm
206Pb/207Pb
1000
800
600
400
200
0
1.25
1.2
1.15
1.1
1.05
1.0
0.95
0.9
-20
0
20
40
60
80
100
120
800
Distance from smelter, km


Pb, ppm
1
10
100
1000
Depth, cm
0
20
40
60
80
100
A
B
C
0.9
1.0
1.1
1.2
1.3
206Pb/207Pb