Physicochemical characterization of galvanic anodes (GACP) released elements

Christelle Caplat, Université de Caen Normandie

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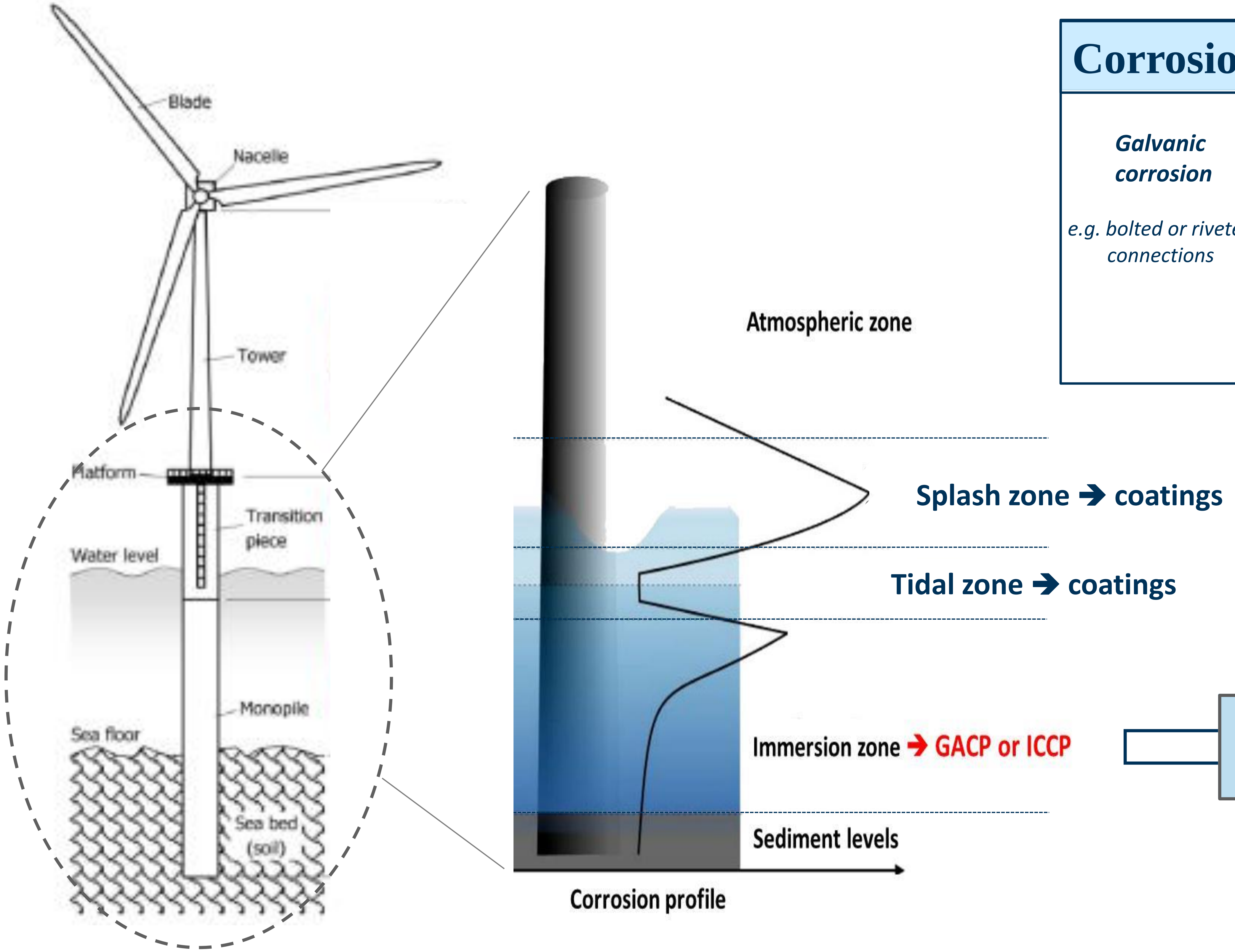

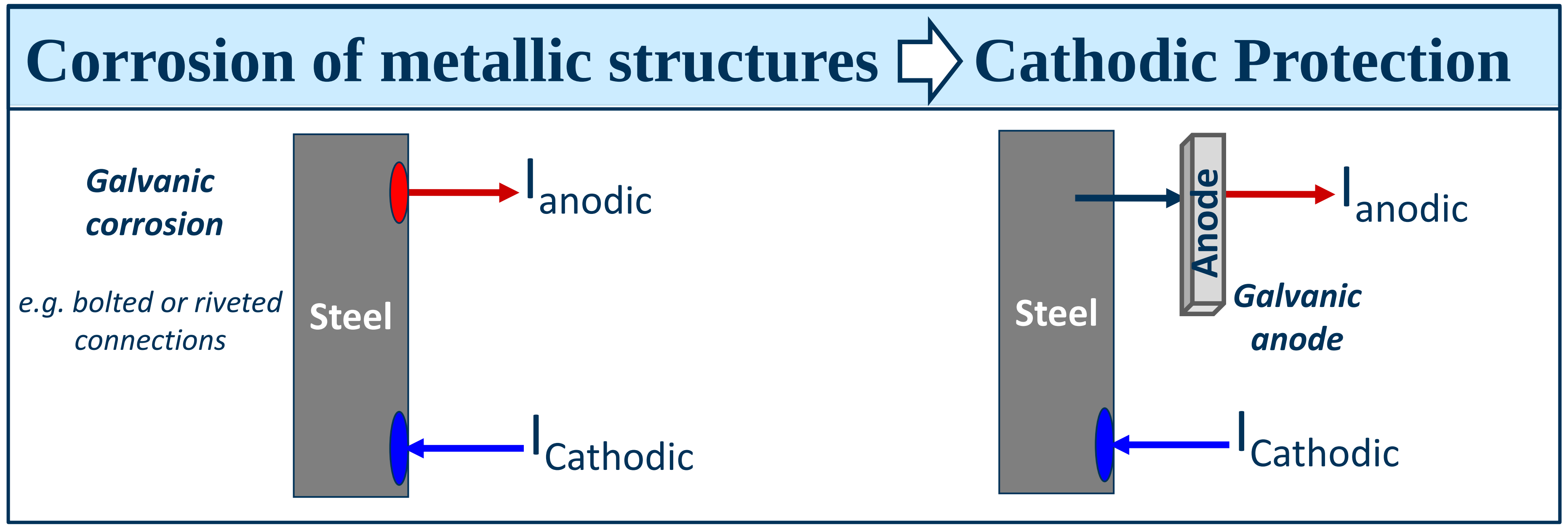

Cathodic Protection (CP)

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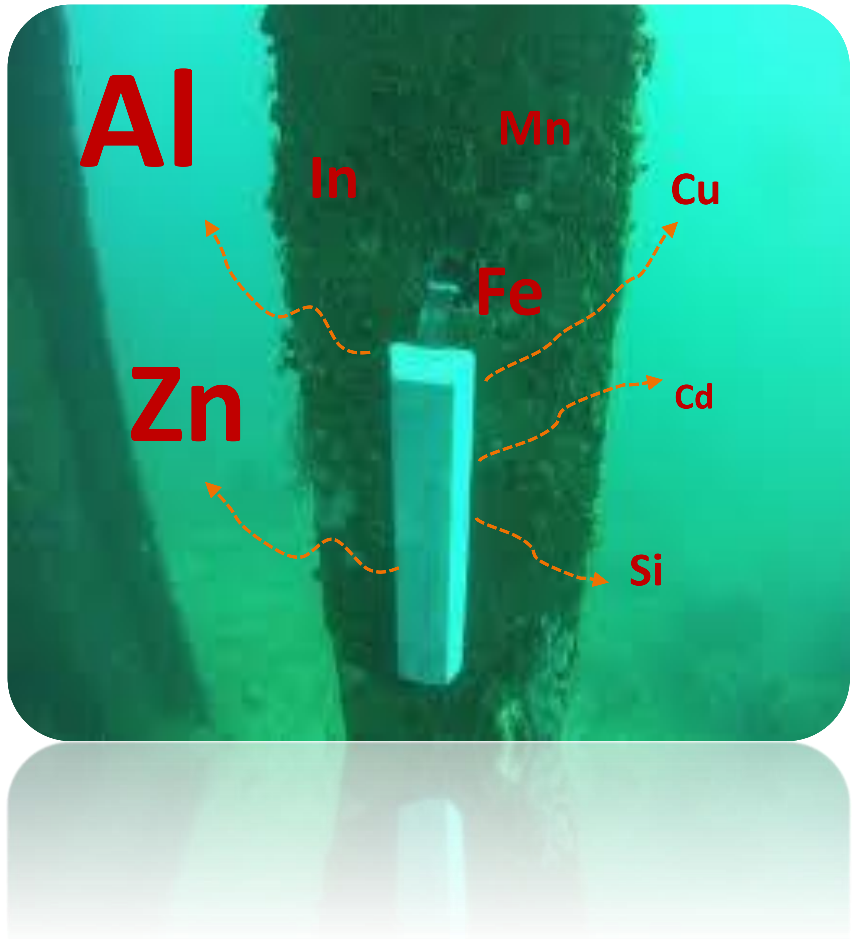
Element	Aluminium anode			
	Minimum [mg kg^{-1}]	Maximum [mg kg^{-1}]	median [mg kg^{-1}]	average [mg kg^{-1}]
Aluminium	944000 ± 37000	1010000 ± 50000	1015000	1001000
Zinc (Zn)	26200 ± 300	60700 ± 300	33200	38325
Iron (Fe)	526 ± 16	1670 ± 70	720.5	909.3
Bismuth (Bi)	<0.052 (LD)	665 ± 31	665	665
Manganese (Mn)	7.6 ± 0,3	2380 ± 80	9,3	601.6
Indium (In)	143.0 ± 2,0	231 ± 13	204.5	195.8
Vanadium (V)	97.6 ± 4,5	131 ± 2	118.0	116.2
Gallium (Ga)	78.5 ± 1,0	133 ± 6	100.4	103.1
Nickel (Ni)	30.1 ± 0,9	52.4 ± 0.9	35.4	38.3
Lead (Pb	6.7 ± 0,2	9.7 ± 0.1	8.9	8.5
Copper (Cu)	4.9 ± 0,1	17.4 ± 0.5	5.2	8.2
Magnesium (Mg)	<2 .5 (LQ)	7.2 ± 0.5	5.2	5.2
Chromium (Cr)	2.1 ± 0,1	5.6 ± 0.2	4.1	4.0
Cadmium (Cd)	0.2 ± 0,1	6.9 ± 0.1	1.4	2.5
Cobalt (Co)	1.8 ± 0,1	3.4 ± 0.1	2.1	2.4
Tin (Sn)	0.5 ± 0,4	3.4 ± 2.1	1.2	1.6
Lanthanum (La)	1.0 ± 0,1	1.3 ± 0.1	1.1	1.1
Uranium (U)	0.3 ± 0,0	1.8 ± 0.0	0.6	0.8
Cerium (Ce)	0,5 ± 0,0	1.2 ± 0.1	0.6	0.7
Silver (Ag)	<0.077 (LQ)	0.4 ± 0.0	0.4	0.4
Titanium (Ti)	<0.11 (LQ)	0.6 ± 0.0	0.2	0.3
Neodymium (Nd)	0.1 ± 0,0	0.3 ± 0.0	0.1	0.2
Gadolinium (Gd)	<0 .047 (LQ)	0.1 ± 0.0	0.1	0.1
Dysprosium (Dy)	< 0.044 (LQ)	0.1 ± 0.0	0.1	0.1
Samarium (Sm)	< 0.044 (LQ)	0.1 ± 0.0	0.1	0.1
Praseodymium (Pr)	< 0.041 (LQ)	0.1 ± 0.0	0.1	0.1

8/26 metallic elements: Al, Zn, Fe, Bi, Mn, In, V and Ga

Concentrations > 100 mg kg^{-1} of anode



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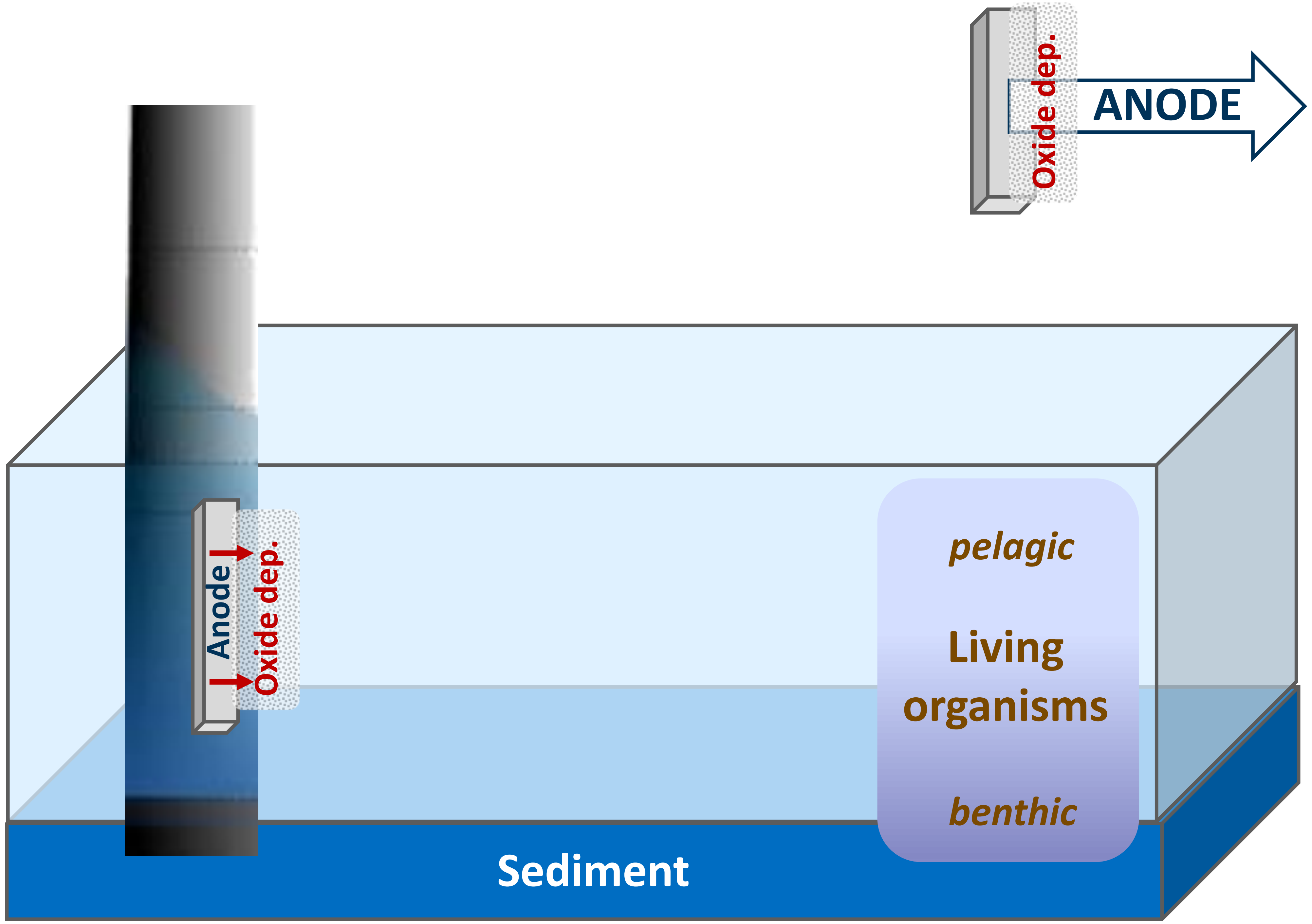
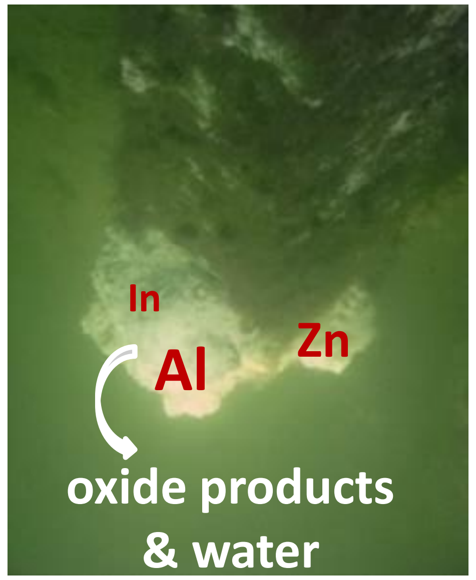


Diffusion of metals from GACP

1) Metallic elements change from a solid state (metallographic) to a crystallographic state (**metal oxides**) :

➔ **oxide products** (oxide deposit)



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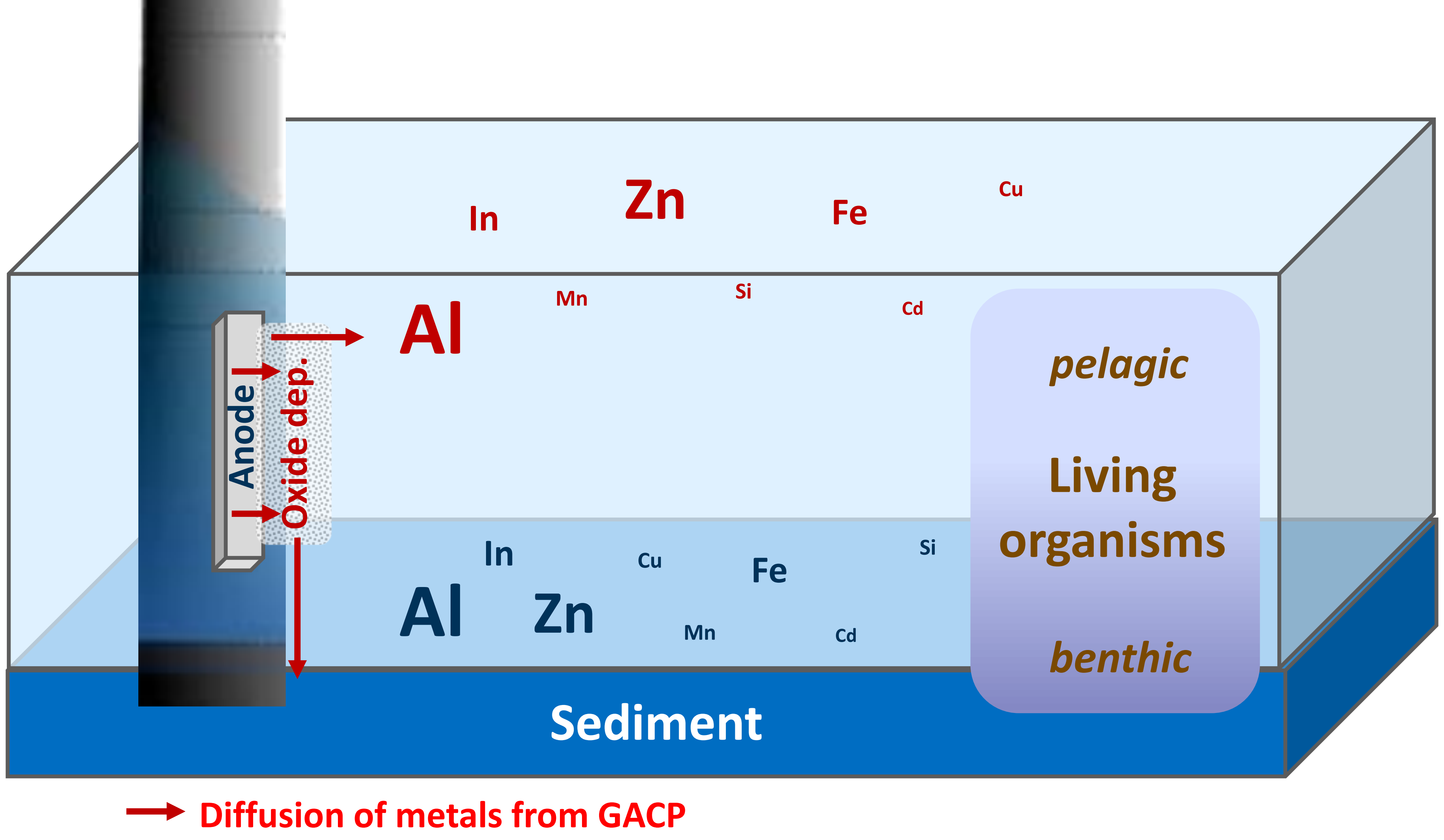
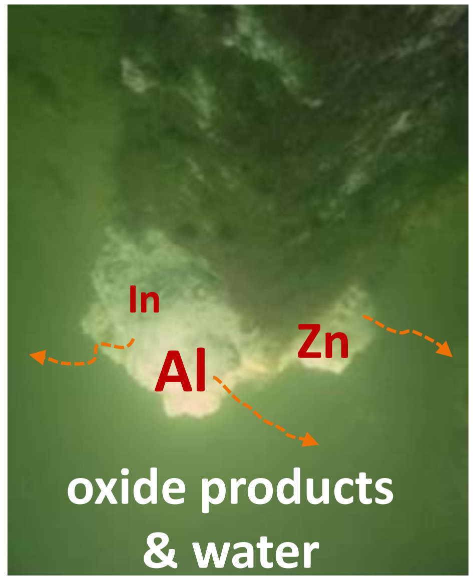
1) Metallic elements change from a solid state (metallographic) to a crystallographic state (**metal oxides**) :

➔ **oxide products** (oxide deposit)

➔ **dissolved state** in the pore water of the deposit and in the surrounding seawater





Physicochemical characterization of galvanic anodes (*GACP*) released elements

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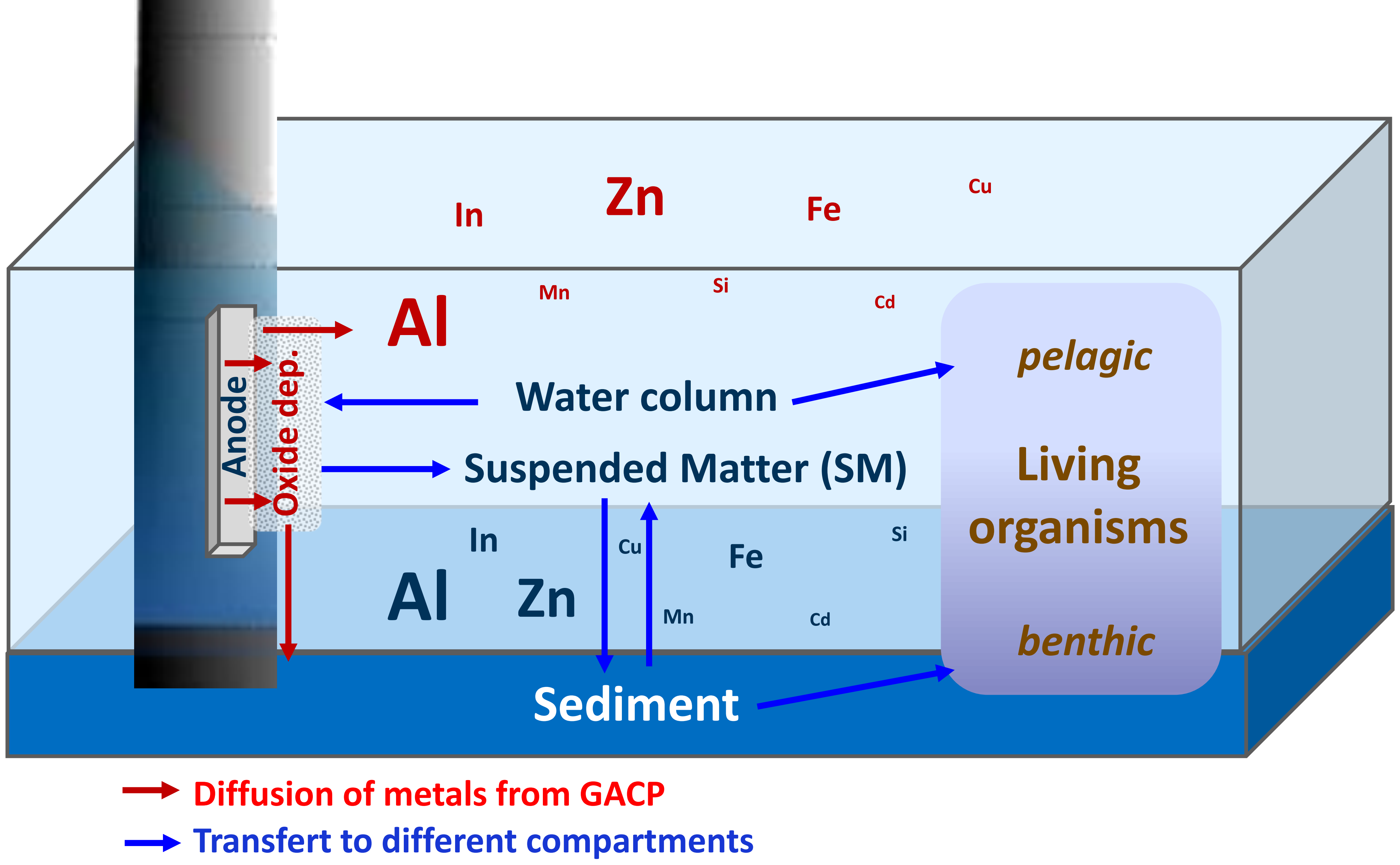
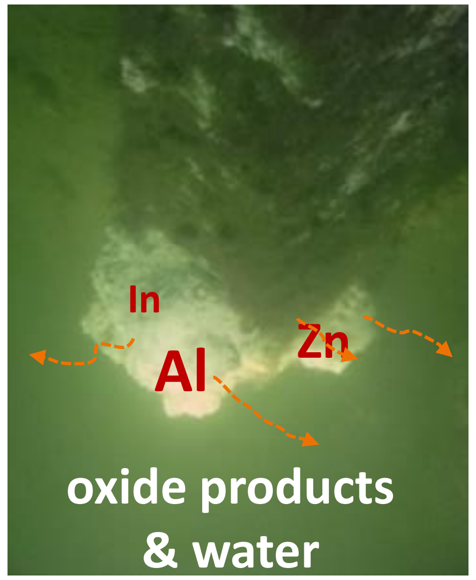
2) Released dissolved trace metals tend to interact with:

- living organisms (e.g. phytoplankton cells)
- dissolved organic matter (DOM)
- suspended Matter (SM)

↳ sediment ⇔ benthos





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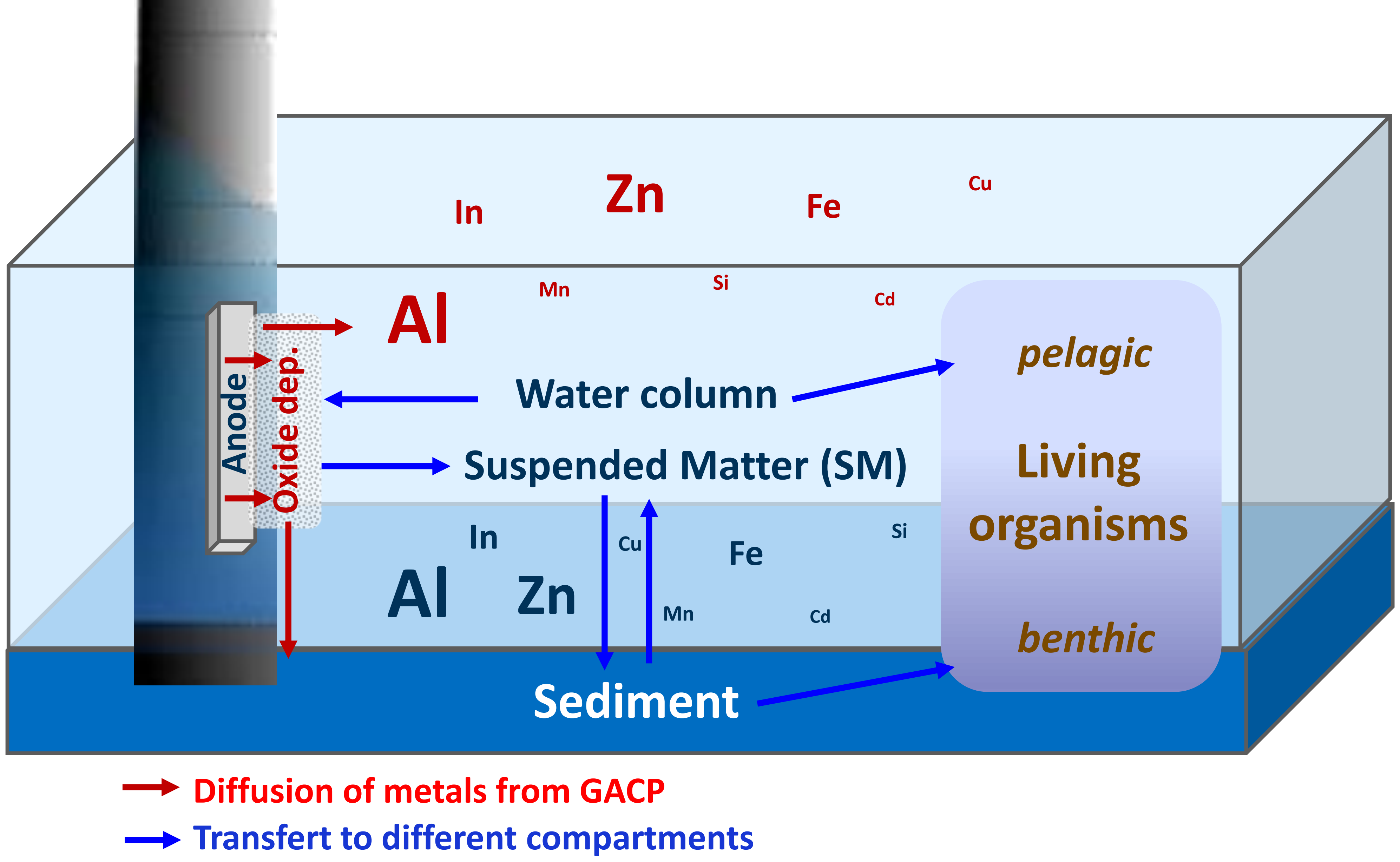

Transfer of trace metals to different compartments :

- water column
- sediment
- living organisms

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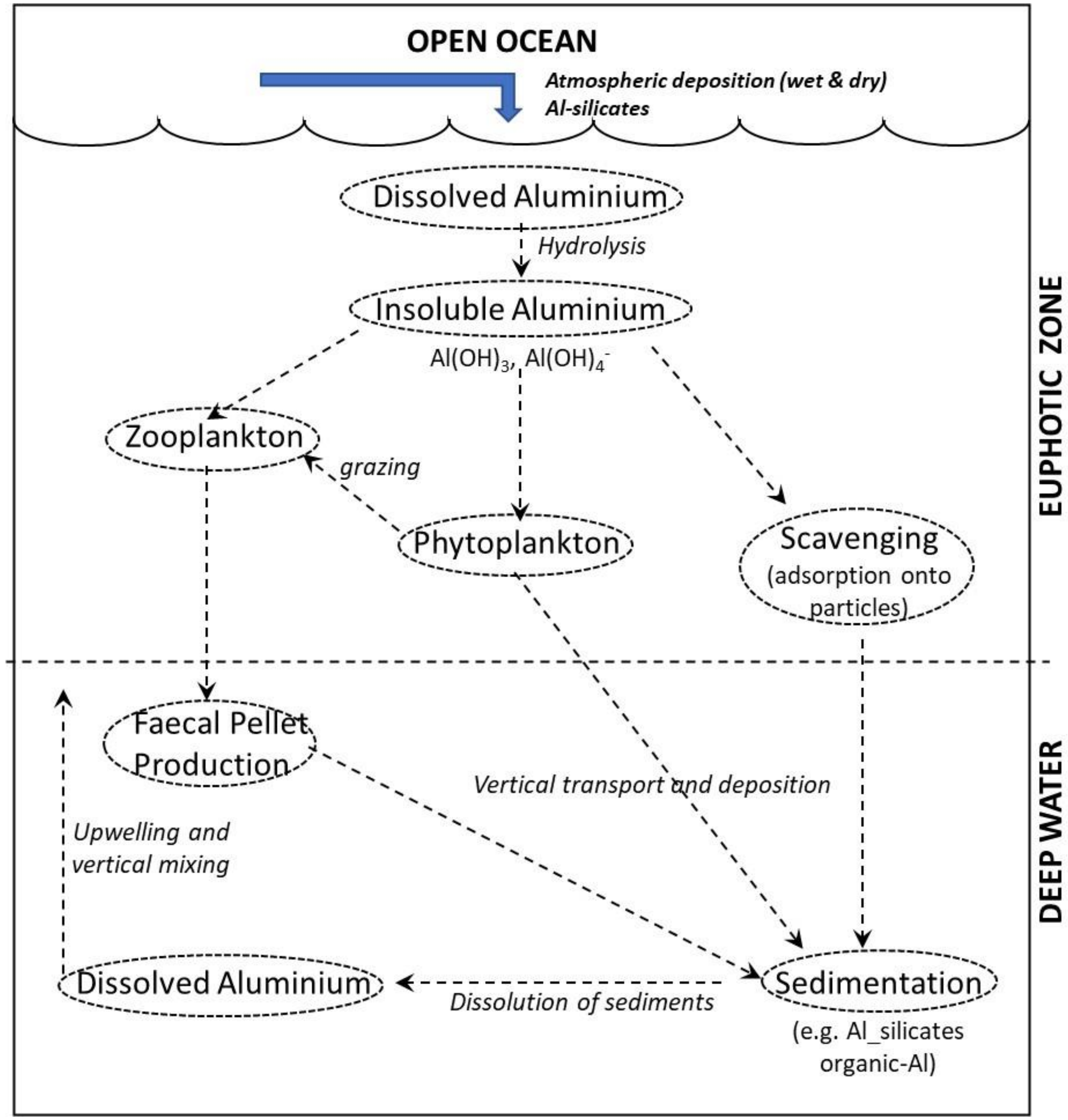

Biogeochemical cycle of aluminum according to Tria et al. (2007)

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Study the transfers of ETMs-GACP to different compartments (as described by Tria et al., 2005):

- water column
- sediment
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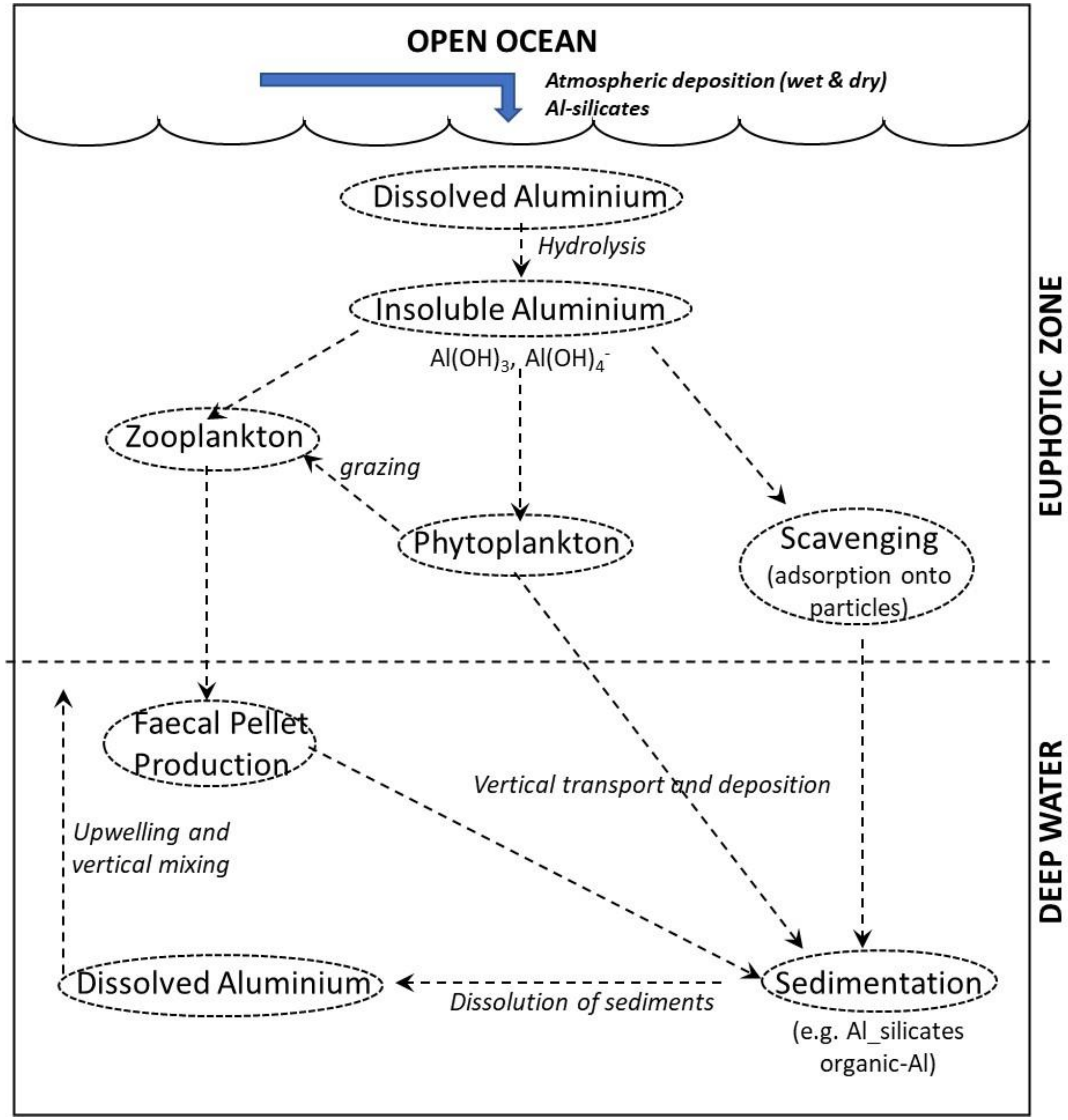

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ECOCAP

Transfer of Al (Al-salt vs Al-GACP)

Only ecotoxicological results on Al-salt will be presented …

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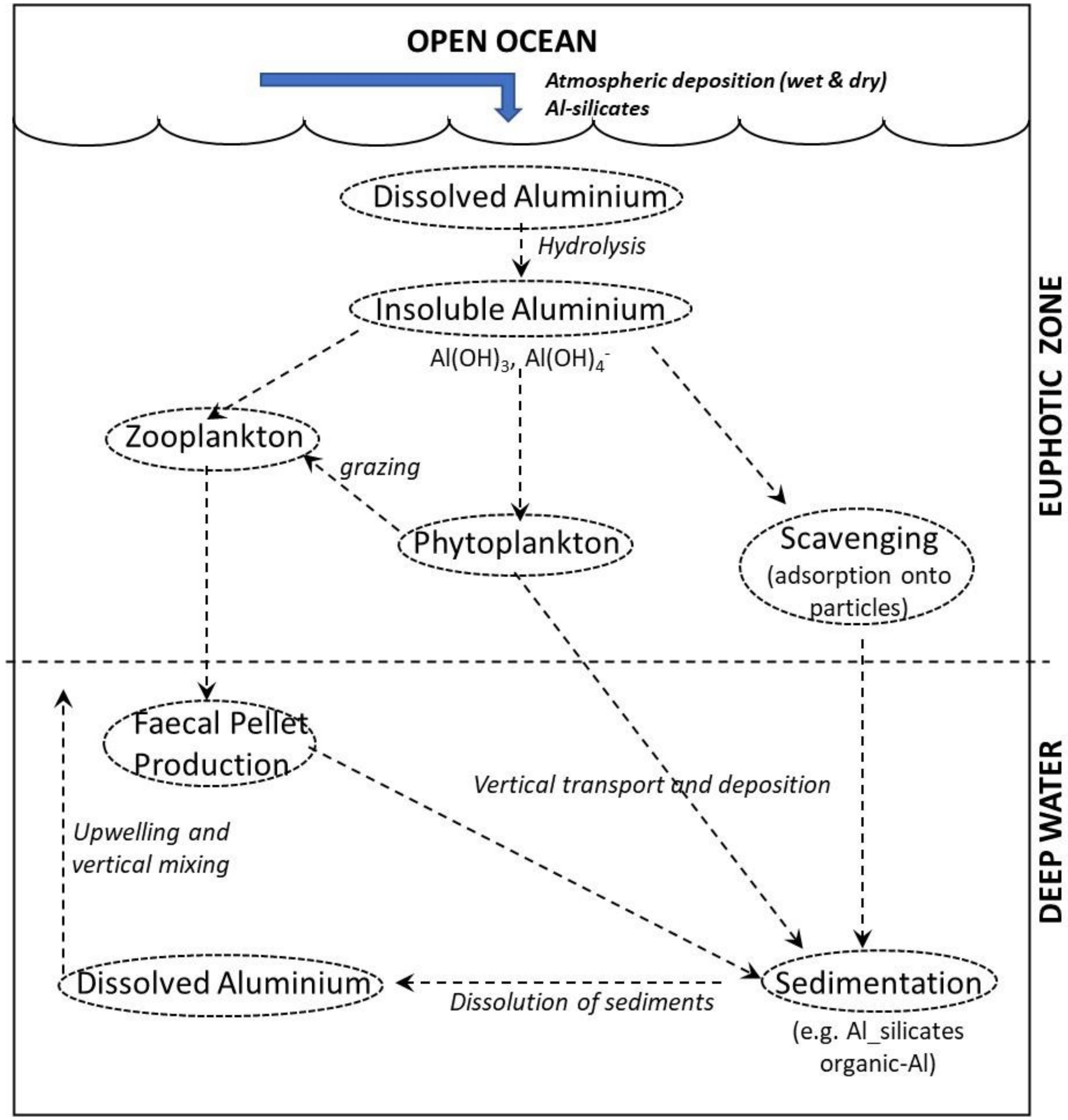

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The physicochemical parameters influence **speciation** of trace elements (e.g. Al): pH, S, $[Al]_m$, DOM, SM, organic ligands …

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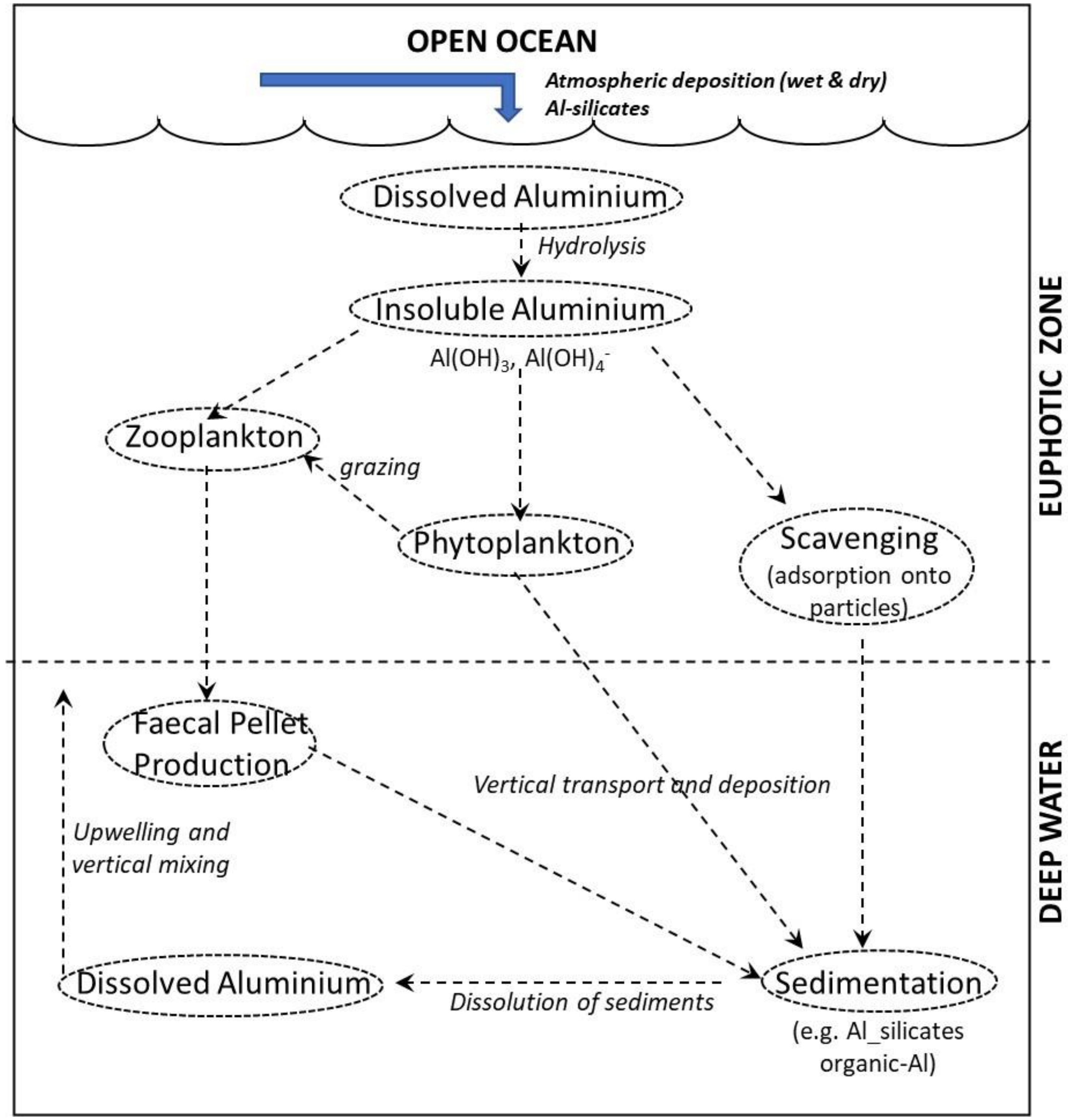

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The speciation of aluminium released in seawater column is complex and need more understanding

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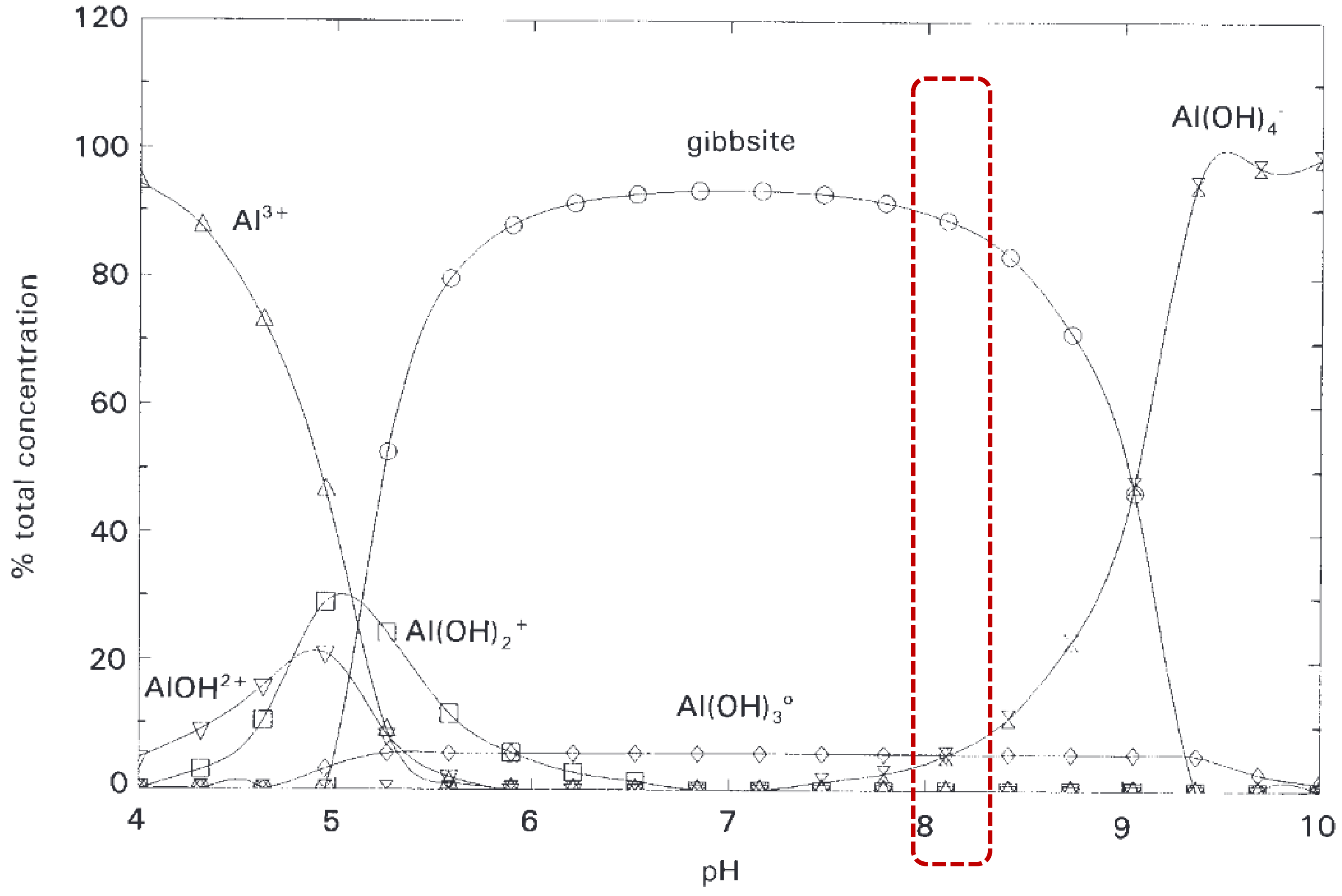
○ **Ecokinetic of Aluminium and Impact of abiotic parameters on its speciation in seawater**: REVIEW

The speciation of aluminium **in seawater** is very different from that in freshwater



Aluminium speciation depending on pH from Gensemer and Playle (1999)

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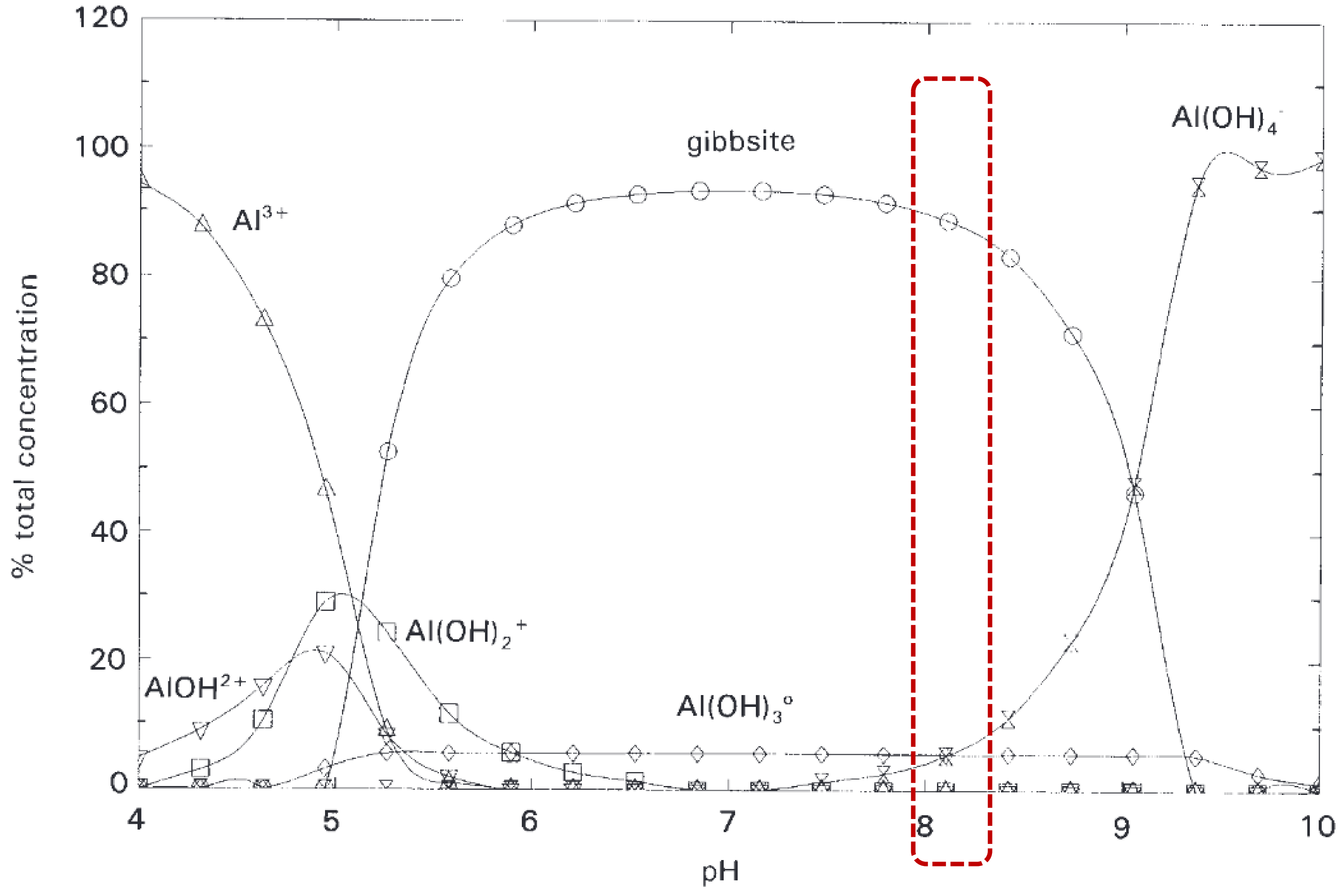
At **pH 8.2**, the dominant inorganic ligand that complexes it is **OH^-** (as well as for Fe(III) and In(III)) (Byrne *et al.*, 1988 ; Alberti *et al.*, 2005)



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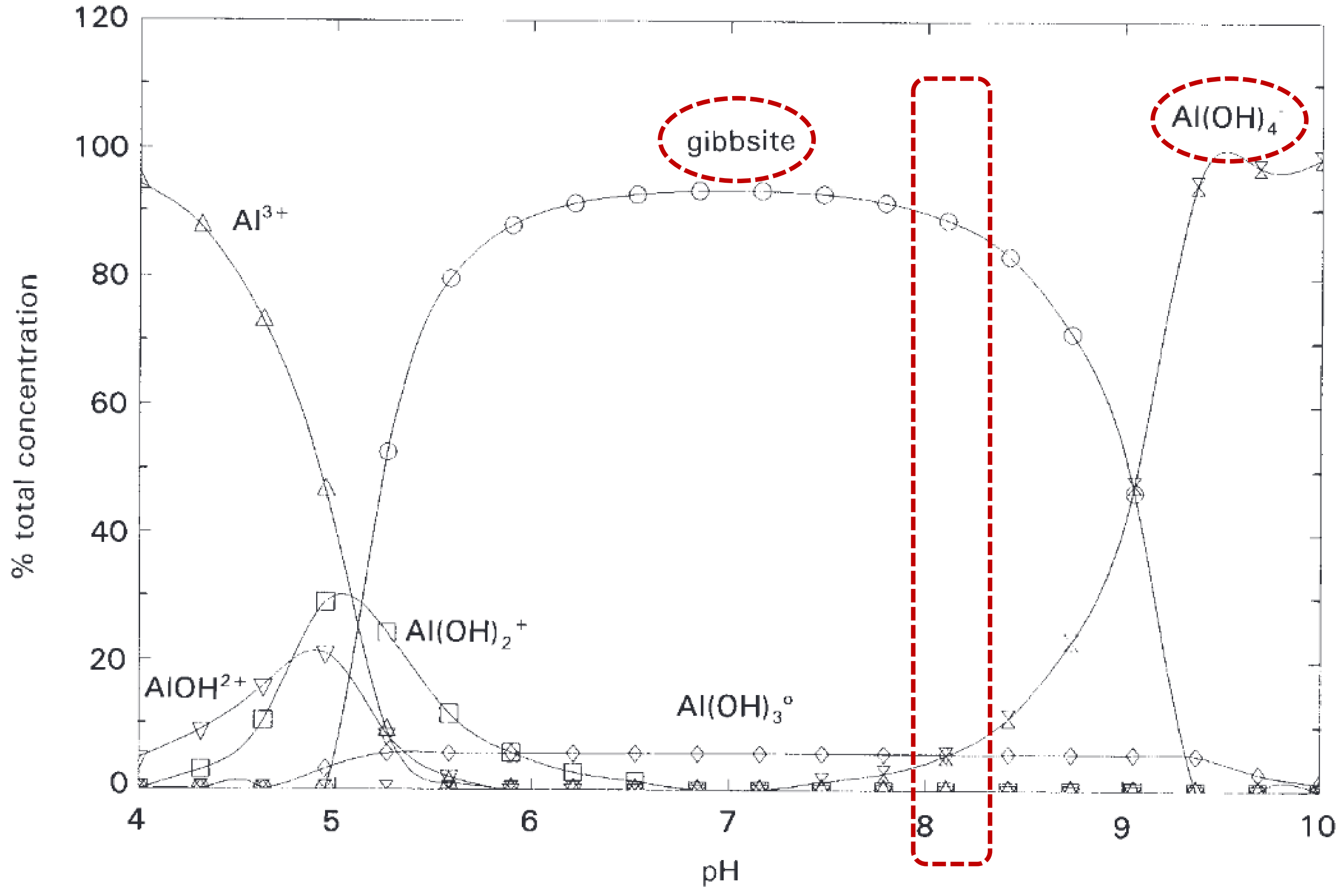
- 68 % aluminate $Al(OH)_4^-$
- 32 % colloidal neutral aluminium hydroxide $Al(OH)_3$



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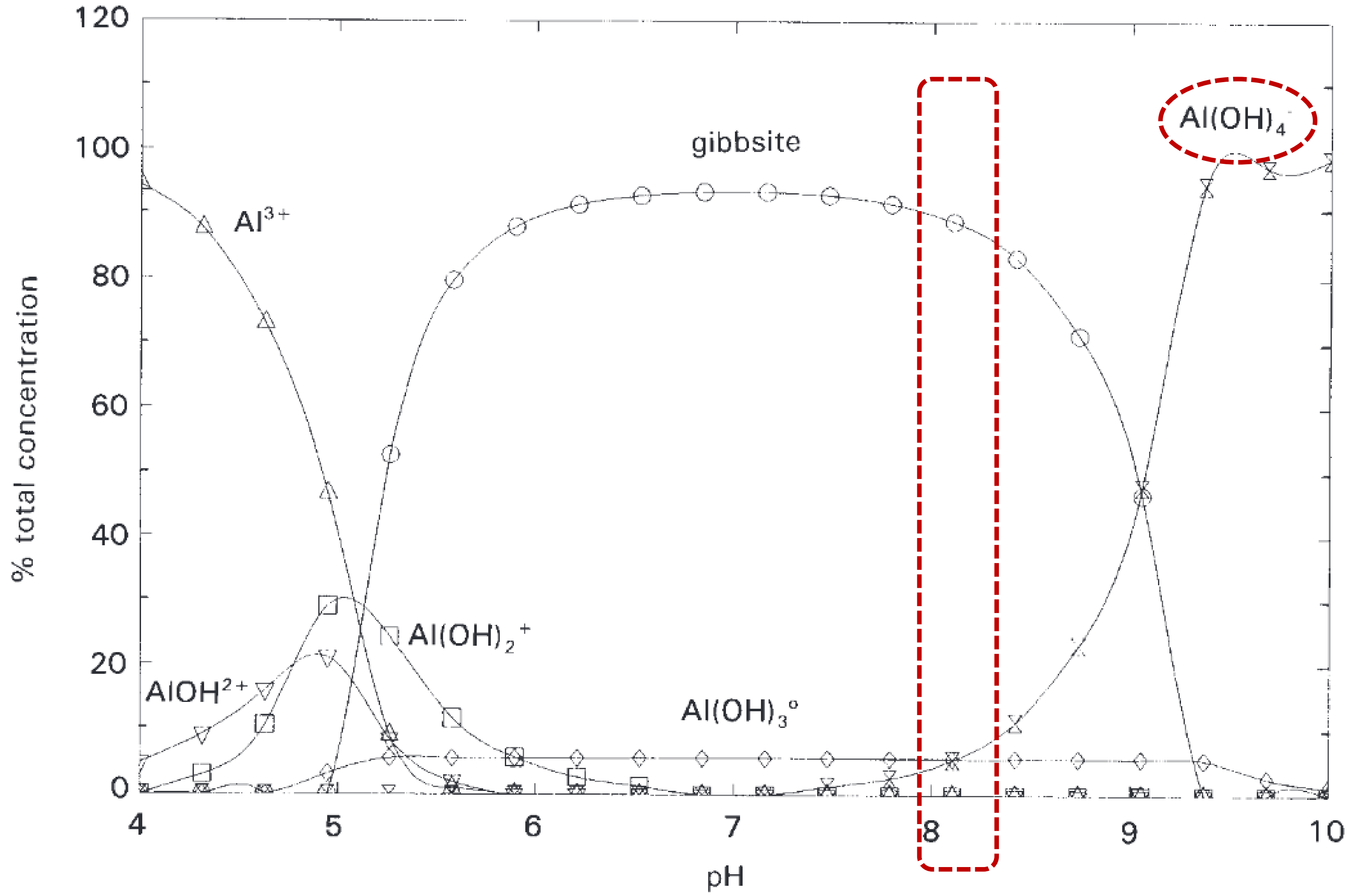
38.2% Mg-aluminate ion $MgAl(OH)_4^+$

11% following by Na-aluminate ion $NaAl(OH)_4^-$

3% Ca-aluminate ion $CaAl(OH)_4$

< 0.01% Al^{3+}



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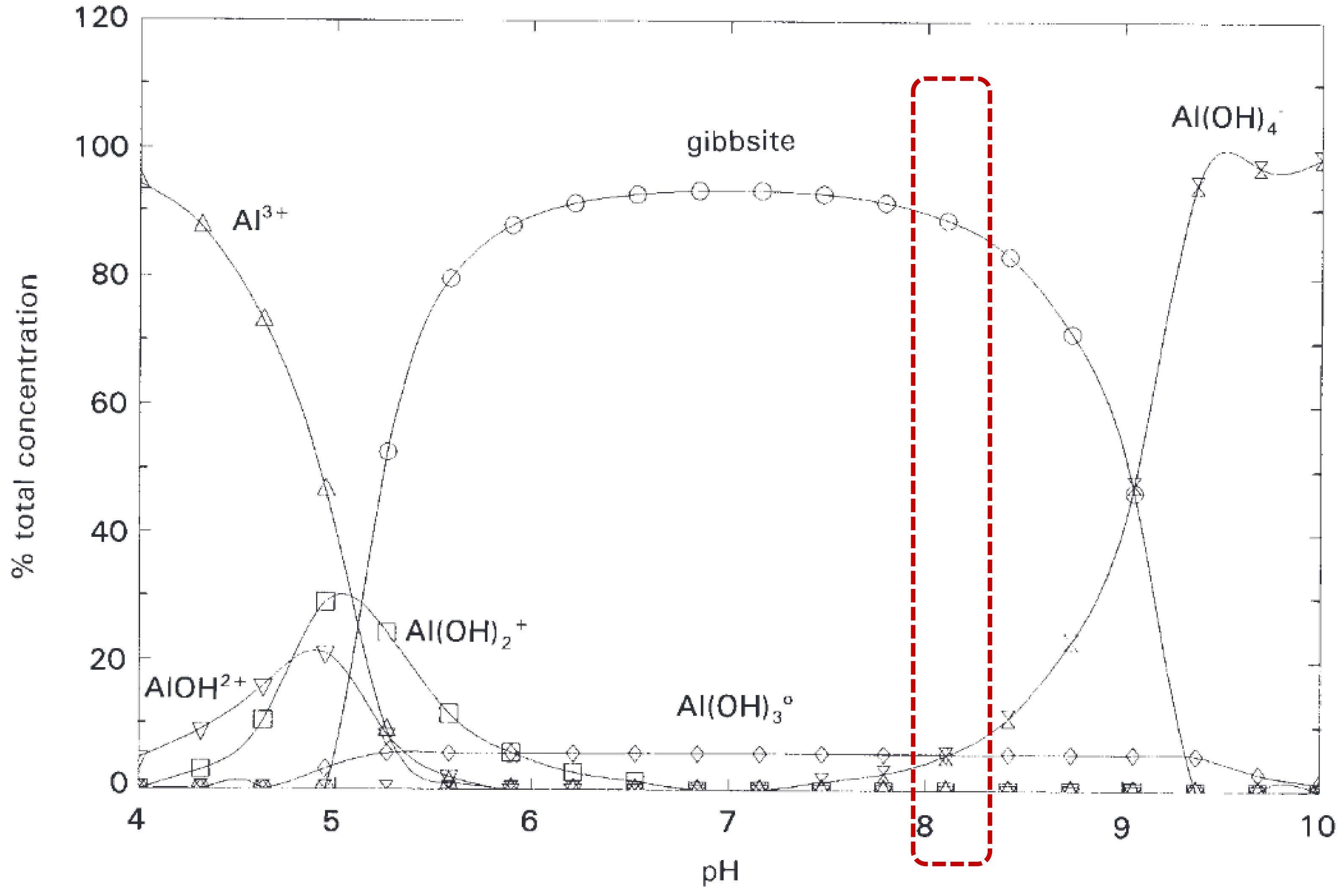

Aluminium speciation depending on pH from Gensemer and Playle (1999)

➔ need to better understand interactions between Al and the different compartiments

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○ Still to be done :

- Understand the interactions of Al-GACP elements with the suspended matters, organic matter and their bioavailability

- Necessary to develop integrative passive samplers for specific tracers of anode (e.g. In, Ga) and application in OWF

- Monitoring trace metals in SM and sediment in situ :
  - Improved knowledge of the interaction of GACP elements with the sediments
  - Define a $\textbf{PNEC}_{\textbf{sediment}}$ with adapted ecotoxicological tests (chronic)

- Because … :

$T\ y^{-1}$ (Watson *et al.*, 2025)	Europe today (30 GW OWF)	Europe in 2050
Al	3219	30 148 to 37 980
Zn	1148	10 756 to 13 550
In	1.2	10.9 to 13.7

(x9 to x12 GW OWF)

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Thank you for your attention


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