Overview: Biogeochemical Processes and Contaminant Fate in the Groundwater – Surface Water Interface

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Outline

- Definition of the groundwater-surface water interface (GWSWI)
- Physicochemical characteristics of the GWSWI environment
- Biogeochemical processes in the GWSWI
- Effects of biogeochemical processes on contaminant fate
- Conclusions

What is the GWSWI?

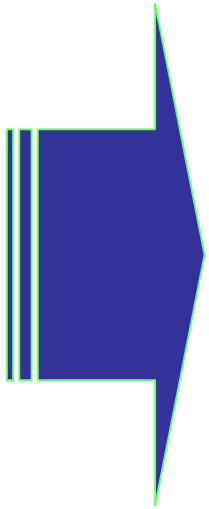
- Subsurface zone in which the water shares characteristics of both the groundwater and the surface water.

- These characteristics might be :
  - Redox
  - Water Chemistry
  - Biological Populations (microbes, benthic organisms)
  - Contaminant Profile

Characteristics of the GWSWI

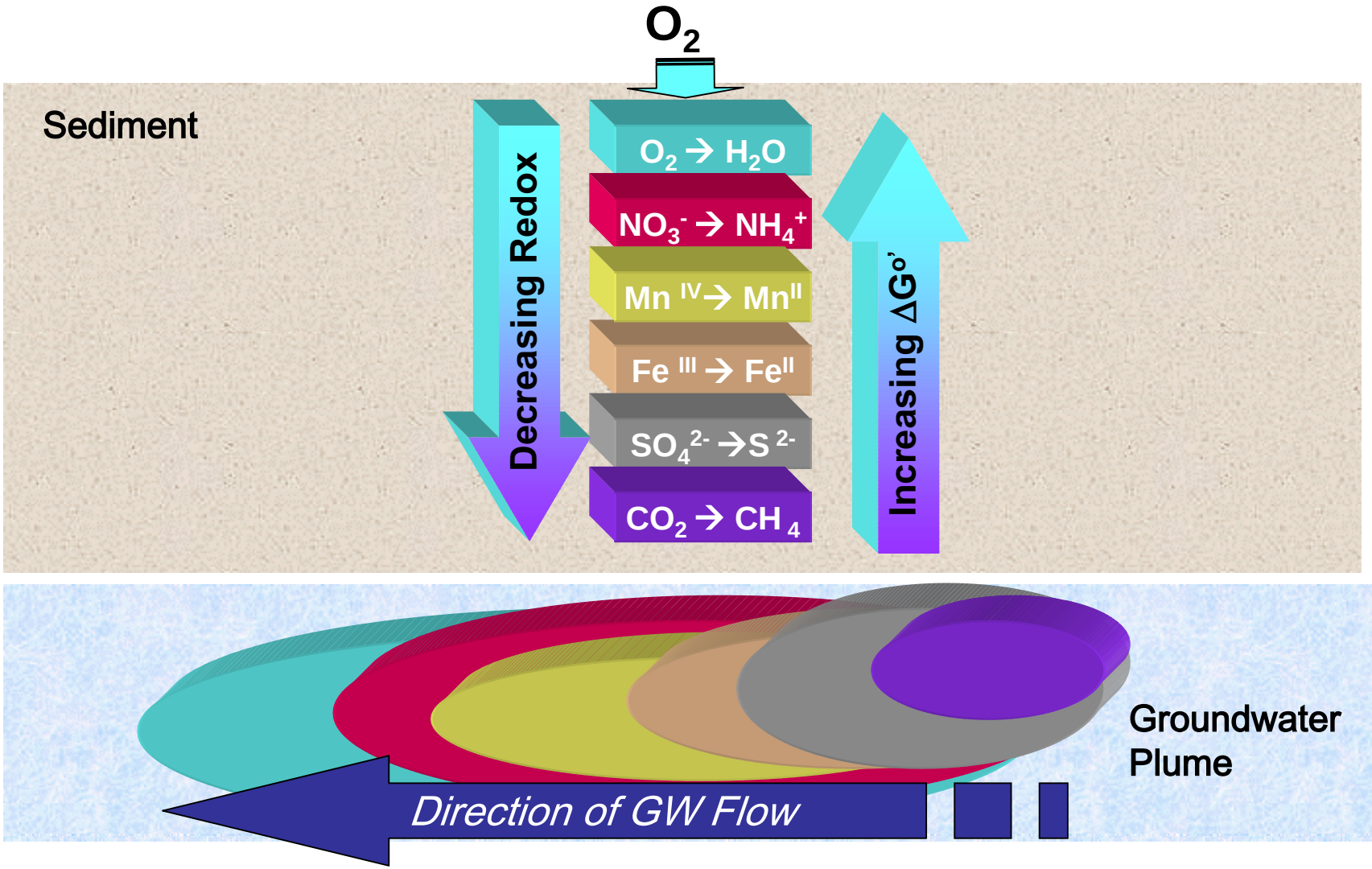
-Zone of Gradients and Transitions

- Gradients
  - Oxygen / redox
  - Organic content
  - Contaminant concentration / form



- Transitions
  - Hydraulic conductivity
  - Substrate (adsorption qualities)
  - Microbial community
    - Aqueous and surface chemistry
    - Environmental fate of contaminants

Redox Gradients in GW and Sediments



Contaminant Fate and Transport

Dependent upon:

- Physical-chemical characteristics of the contaminant
- Relative kinetics of the process vs. the discharge rate
- Depth and differences in surface water and groundwater chemistry
- Physiologies and competencies of the microbial population

Environmental Fates of Contaminants

Transformation:

Chemical changes in contaminant can result in new mobility or toxicity characteristics. Not always desirable.

Ex: PCE → TCE→cDCE→VC→Ethene

$Hg_{inorganic}$ → MethylHg

Nitrobenzene → aniline → covalent bonding to organic matter

Degradation:

Mineralization or transformation of contaminant to an innocuous compound.

Ex: Oxidation of BTEX compounds to CO_2

TCE +CH_4 +O_2→ CO_2

Retardation:

Contaminant transport is retarded through precipitation or sorption reactions within the GWSWI.

Ex: $Metal^{2+}$ + $Sulfide^{2-}$ → Metal-sulfide Precipitate

Abiotic Processes Affecting Contaminant Fate

- Hydrology – affects residence time in the different transition zones
- Precipitation – immobilization of metals through sulfide precipitation
- Sorption – retardation of contaminant mobility through association with organic phases
- Surface Chemistry – chemical transformation of contaminants mediated by surface associated reactive minerals

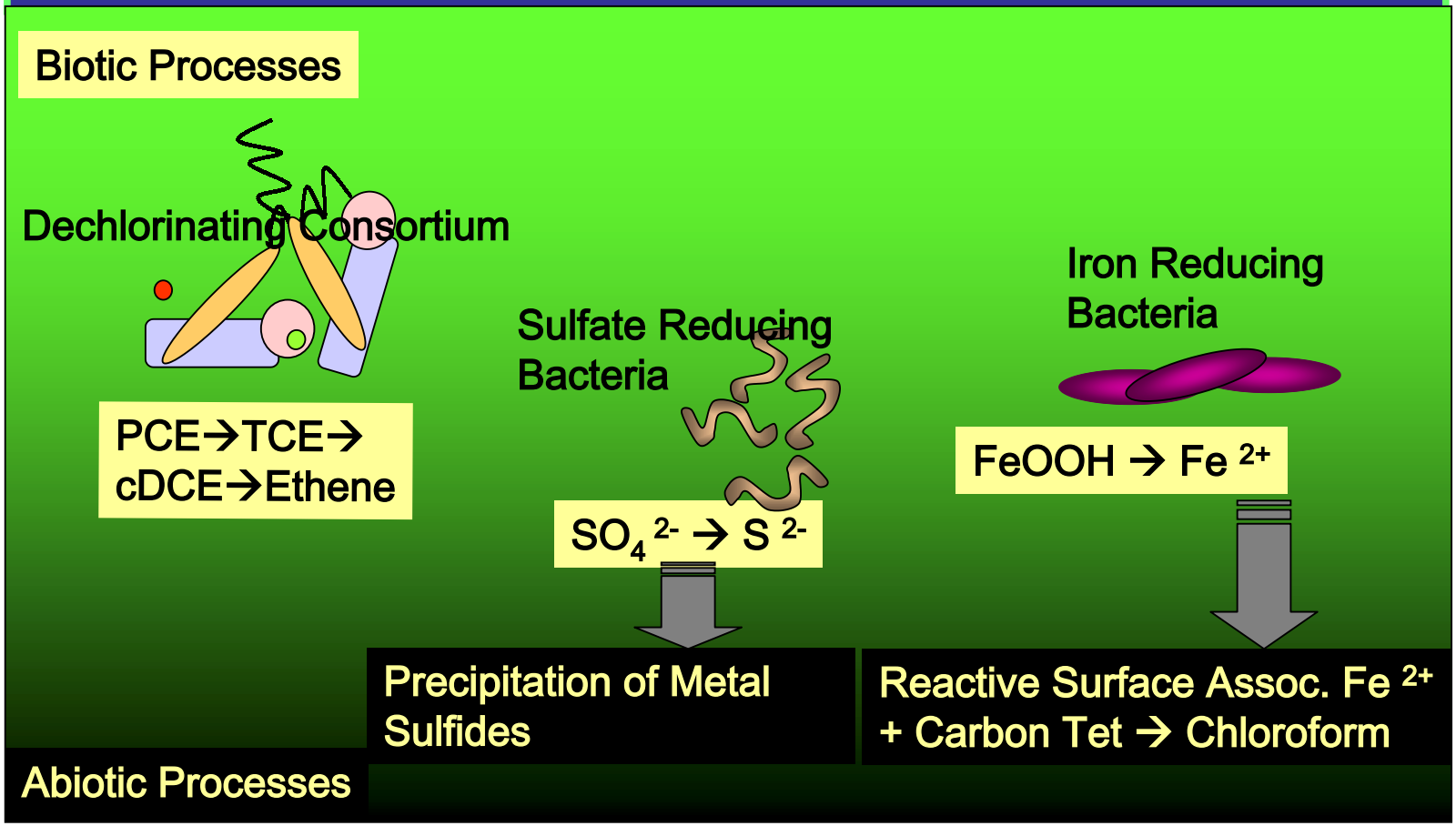
Biotic Processes Affecting Contaminant Fate

- Direct: Contaminant transformation is directly linked to physiological processes
    - Reductive Dechlorination of Halogenated solvents
    - Oxidation of BTEX Compounds
    - Co-metabolic Reactions

- Indirect: Organism produces an end-product that in turn transforms the contaminant
    - Reduction of nitroaromatics by surface associated reduced iron minerals
    - Precipitation of metallic contaminants by sulfide

Abiotic / Biotic Processes

- *Fundamentally Linked*

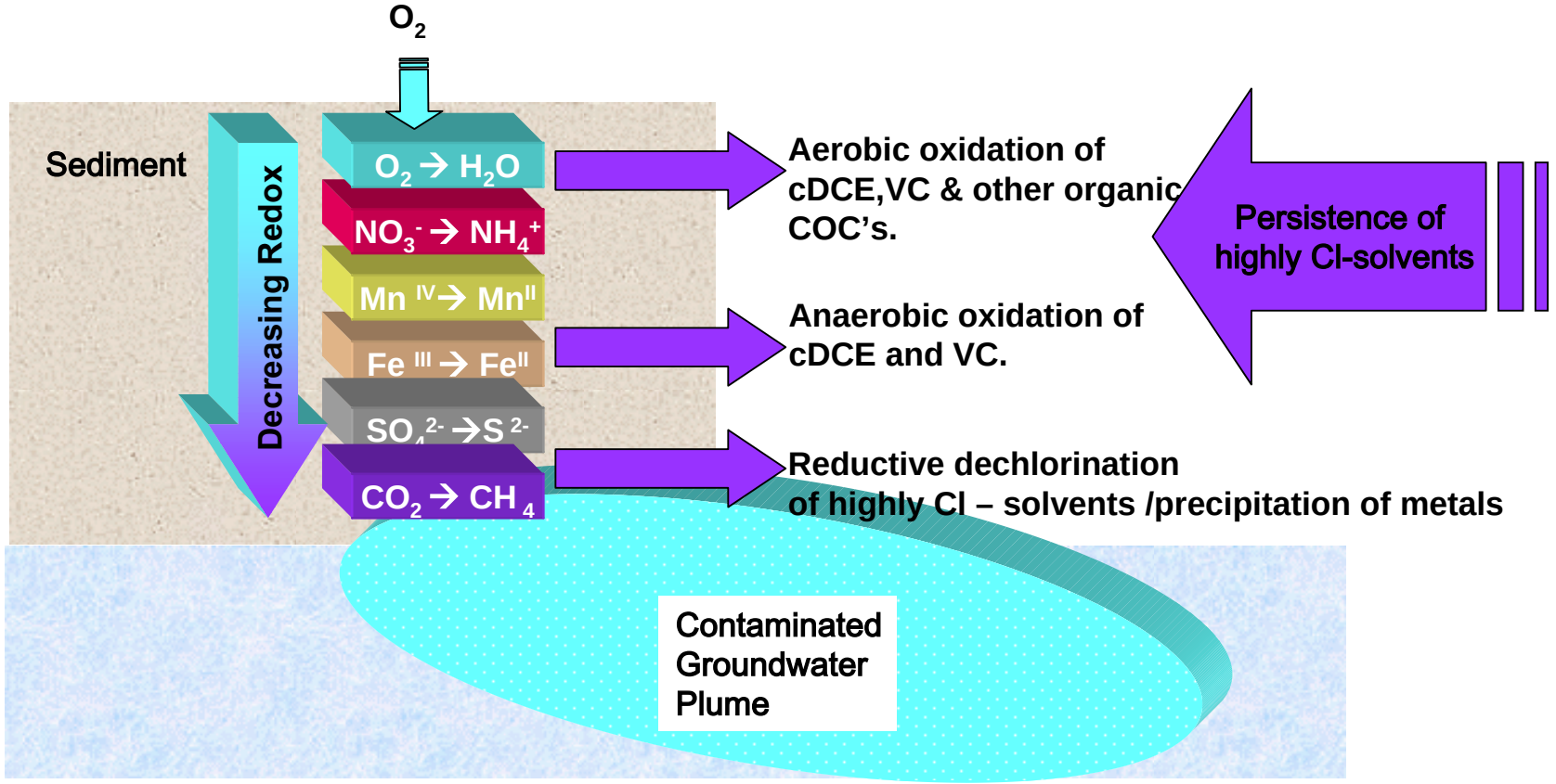


& Effects of hydrology, sorption and residence time…

Types of GWSWI's - 1

– High Redox Plume → Low Redox Interface

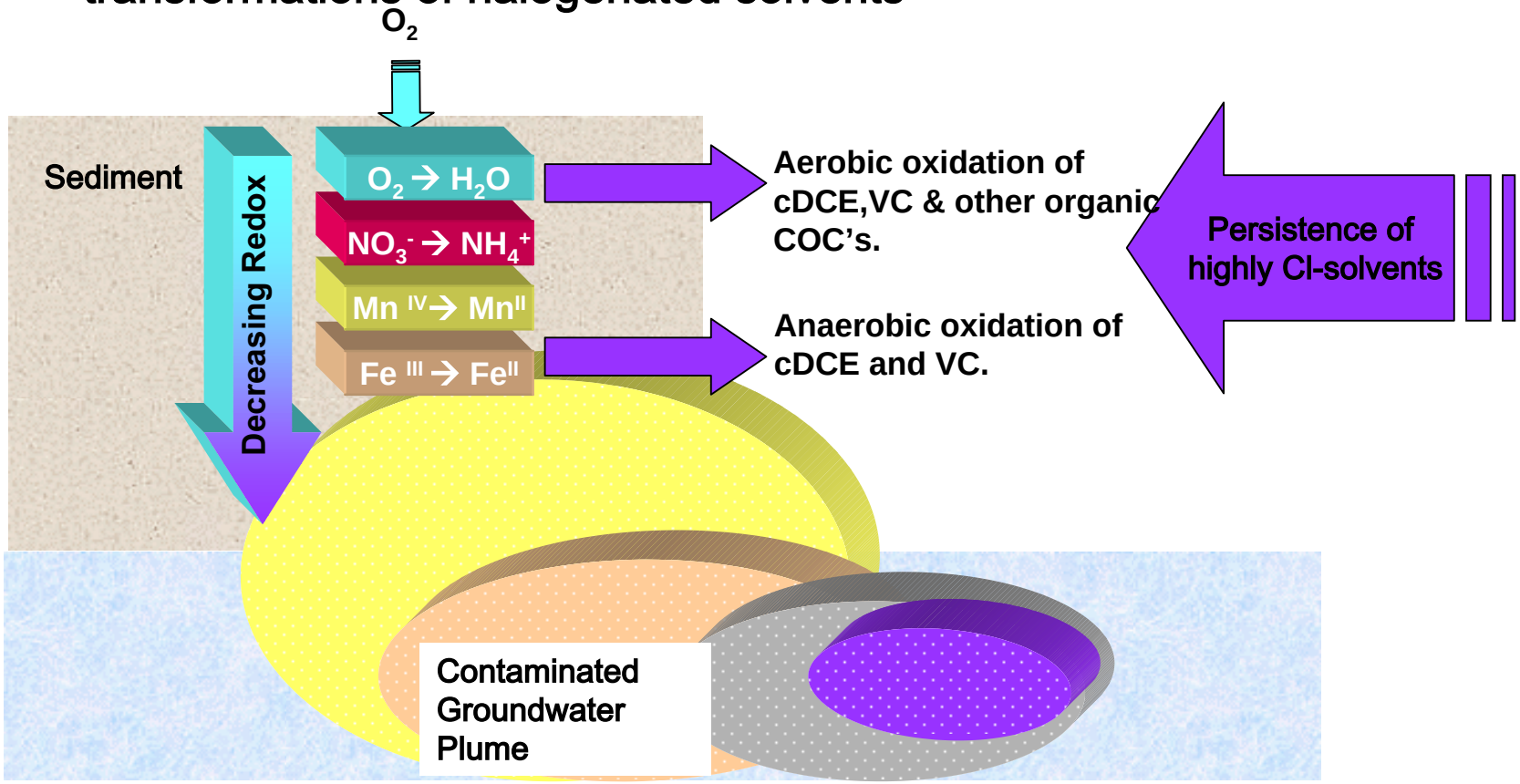
- High redox plume enters low redox GWSWI – zone of accelerated biodegradation for poly-halogenated solvents



Types of GWSWI's - 2

– Low Redox Plume → High Redox Interface

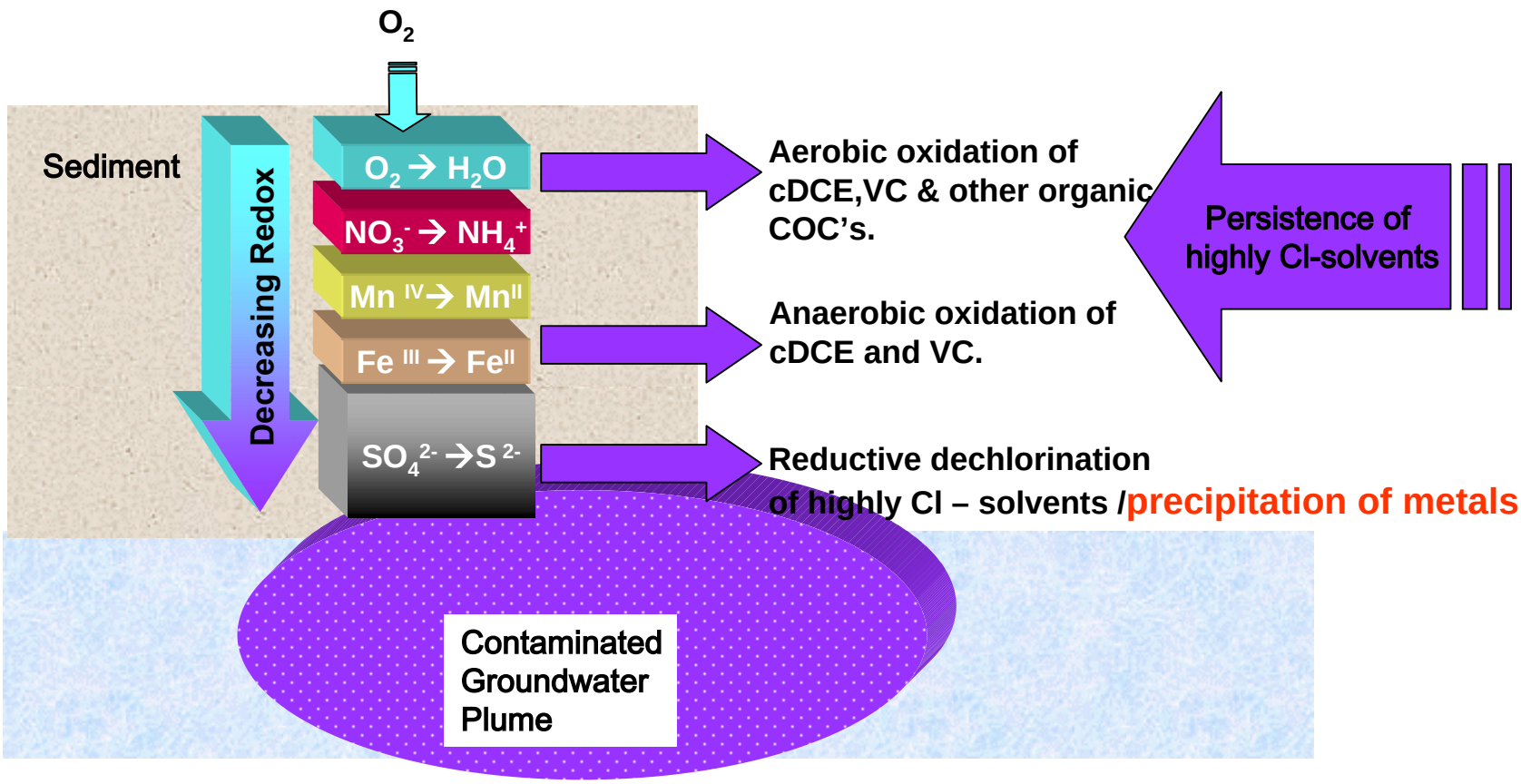
- Low redox plume enters high redox GWSWI – Respiration processes complete degradation of products of anaerobic transformations of halogenated solvents



Types of GWSWI's - 3

- *Low Redox Plume → Low Redox (Sulfate Reducing) Interface*

– Low redox plume enters zone of sulfate reduction in GWSWI (low redox) allowing precipitation of metal contaminants



Biogeochemical Processes in the GWSWI

Conclusion - 1

- Abiotic and biotic processes in the GWSWI environment may lead to significant changes in the chemistry, toxicity, and/or mobility of a contaminant.

- Discharge of groundwater from a contaminated plume into surface water *does not necessarily* mean discharge of plume contaminants.

Biogeochemical Processes in the GWSWI

Conclusion - 2

- Characterization of the GWSWI environment is necessary for accurate determination of risk to human and environmental health and selection of best strategies for management of GW contaminants.