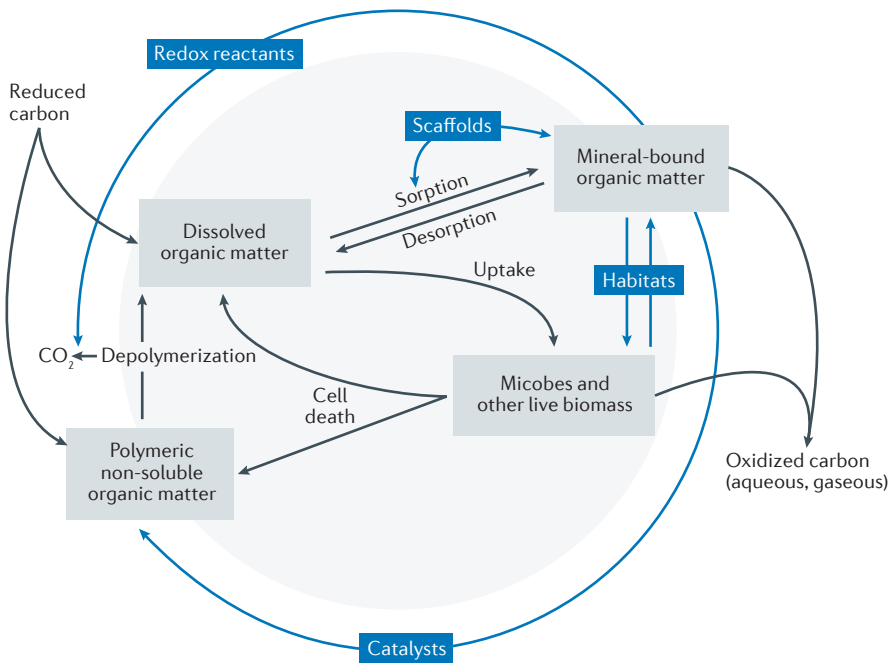


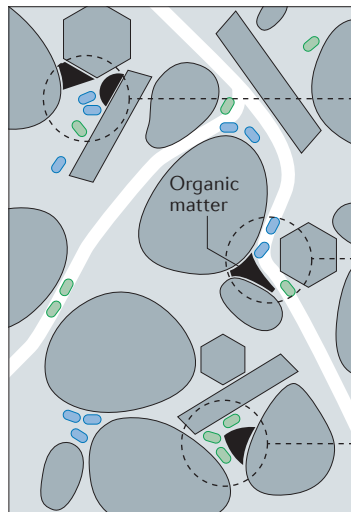


Fig 1

a Minerals may modulate the phase, transformation, and turnover of organic matter by acting as scaffolds, catalysts, redox reactants, and habitats.



b Tier 1 Compartmentalization



Tier 2 Physiochemical constraints

Substrate localization

- Sorptive fixation
- Substrate dilution

Mobility filter

Preferential diffusion and transport pathways

Habitat definition

Constraining decomposer size composition and metabolism

Tier 3 Molecular-level processes

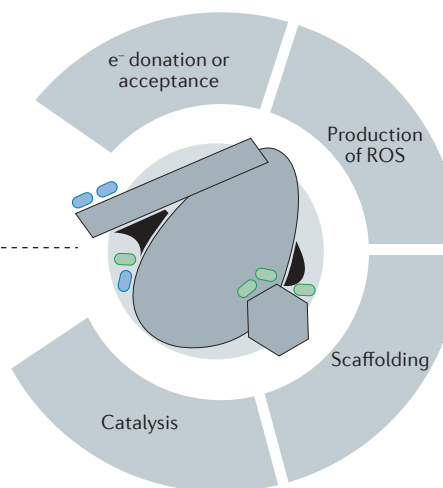


Fig 2


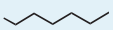

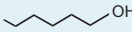
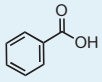
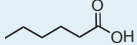
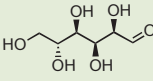
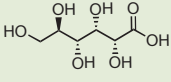
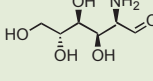
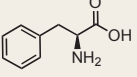
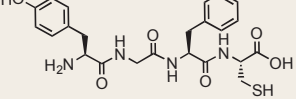
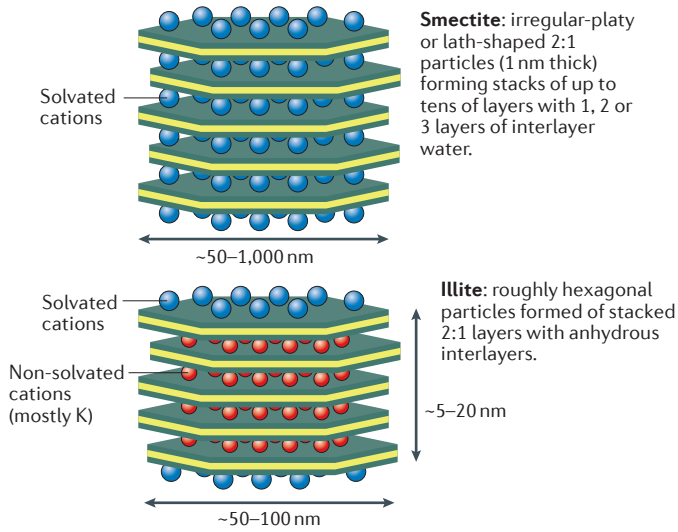
	Sensitivity to pH:	pH independent		pH dependant		Ability to unfold
		Functionality:	Nonpolar	Polar but neutral	(-) charge	
	Mechanism of attachment:	Hydrophobic exclusion	H-bonding	Coulombic attraction	Coulombic attraction	Entropy gain
Aliphatic/aromatic moiety with minor functionalization						
Napthalene		×				
Hexane						
<hr/>						
Catechol		×	×			
Hexanol						
<hr/>						
Benzoic acid		×		×		
Hexanoic acid						
<hr/>						
Inherently polar moieties with additional functionalization						
Glucose			×			
Gluconic acid			×	×		
Glucosamine			×		×	
<hr/>						
Compounds equipped with all major functionalities (usually N-containing)						
Phenylalanine		×		×	×	
Polypeptide/protein		×	×	×	×	×

Fig 3

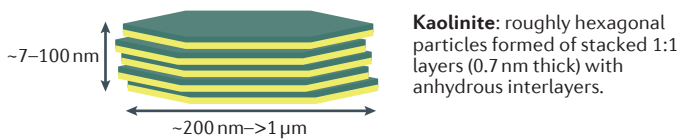
Mineral type	Crystal structure	Charge (σ , mmol _c g ⁻¹)	Area (a _s , m ² g ⁻¹)
Phyllosilicates			
2:1 layer type Illite ≥ Smectite ≥ Vermiculite ≥		Smectite: -0.7 to -1.2	Smectite: 740 to 780
1:1 layer type Kaolinite		Illite: -0.16 to -0.22	Illite: 20 to 200
Modulated phyllosilicates Imogolite, Allophane		Kaolinite: 0 to -0.02	Kaolinite: 7 to 80
		Imogolite: 0.1 to 0.5	Imogolite: 600 to 900
		Allophane: 0 to -1.0	Allophane: 700 to 900
Metal oxides			
Fe oxides Goethite > Hematite ≥ Ferrihydrite > ...	<p>Goethite (FeOOH) Chains of edge-sharing octahedra linked by corner-sharing</p> <p>Hematite (Fe₂O₃) Pairs of face-sharing octahedra linked by corner and edge-sharing</p> <p>Ferrihydrite (Fe₁₀O₁₄(OH₂)) Tetrahedra and clusters of edge-sharing octahedra linked by corner-sharing</p>	Goethite: 0 to 0.15	Goethite: 40 to 90
		Hematite: 0 to 0.02	Hematite: 10 to 35
		Ferrihydrite: 0 to 1.3	Ferrihydrite: 200 to 800
Mn oxides Birnessite > Todorokite > ...	<p>Birnessite (MnO₂) Sheet of edge-sharing octahedra</p> <p>Todorokite (MnO₂) Chains of edge-sharing octahedra linked by corner-sharing</p>	Birnessite: -1.3 to -2.8	Birnessite: 1200
		Todorokite: -0.15	Todorokite: ~1200
Al oxides Gibbsite > Boehmite, Al oxide gels	<p>Gibbsite (Al(OH)₃) Sheet of edge-sharing octahedra</p> <p>Al-hydroxide gel Amorphous</p>	Gibbsite: 0 to 0.02	Gibbsite: 1 to 100
		Al(OH) ₃ gel: 0 to 0.4	Al(OH) ₃ gel: >200

Fig 4

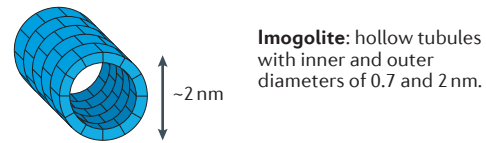
2:1 Layer type phyllosilicates



1:1 Layer type phyllosilicates

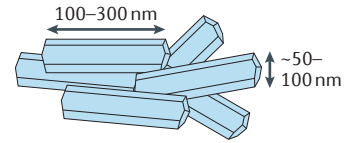


Modulated phyllosilicates

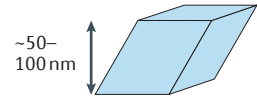


Fe oxides

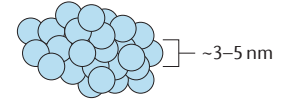
Goethite: rod-shaped crystals in roughly ordered clusters (also observed as oblong particles 3–5 nm in diameter, possibly stabilized by Al impurities).



Hematite: roughly rhombohedral crystals (tending towards a platy shape with increasing Al impurities).

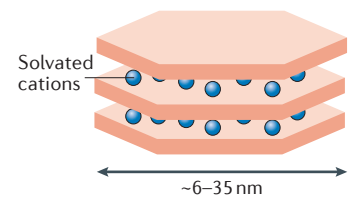


Ferrihydrite: aggregates composed of nanoparticles 3–5 nm diameter.



Mn oxides

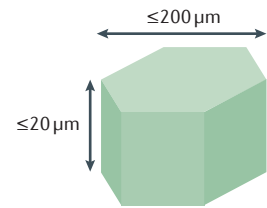
Birnessite: flake-shaped particles (0.7 nm thick) forming weakly ordered stacks with 0 or 1 layer of interlayer water.



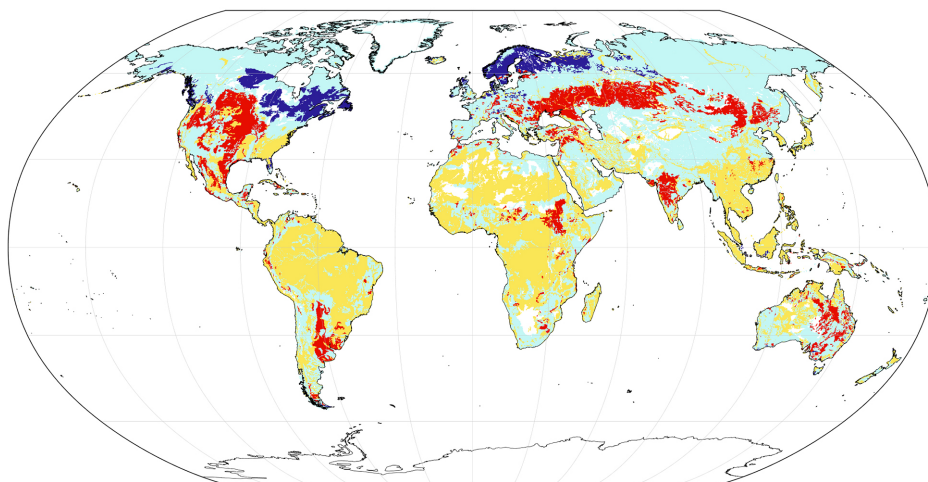
Todorokite: platy or fibrous particles formed of intergrown hollow needles.

Al oxides

Gibbsite: rectangular crystals 50 to 100 nm long; larger crystals form pseudo-hexagonal plates or rods with dimensions up to ~200 μm.



Al-oxide gels: amorphous polymeric network forming ~2 μm particles with internal porosity on lengths scales of ~20 nm to sub-nm.



Mineral	Abundance
Illite/mica	25%
Smectite	15%
Vermiculite	8%
Chlorite	5%
Kaolinite	28%
Gibbsite	4%
Fe-oxides	3%
SRO phases (mostly allophane)	0.5%
Other (mostly framework silicates, such as quartz, feldspar)	11%

Fig 5

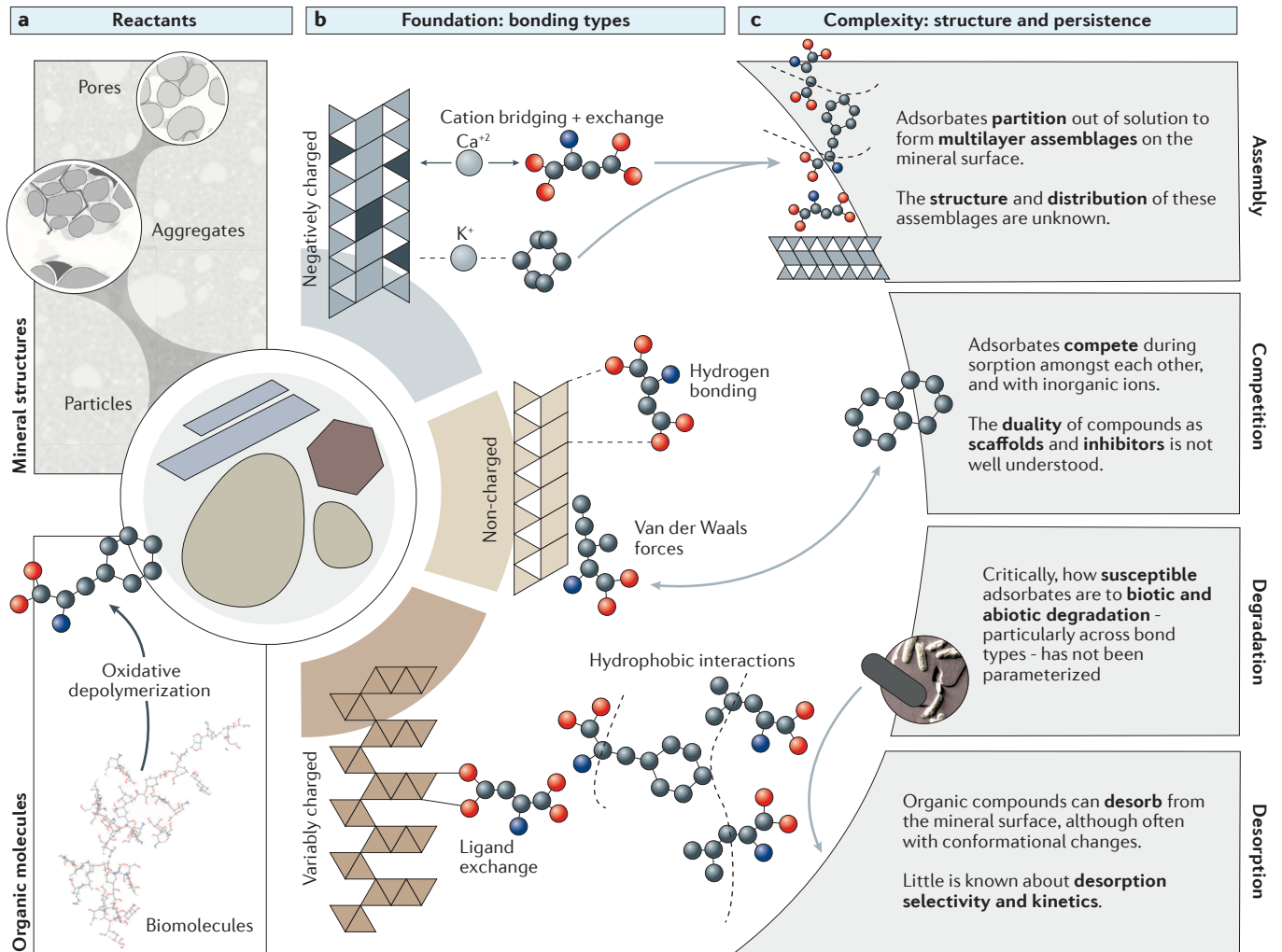


Fig 6

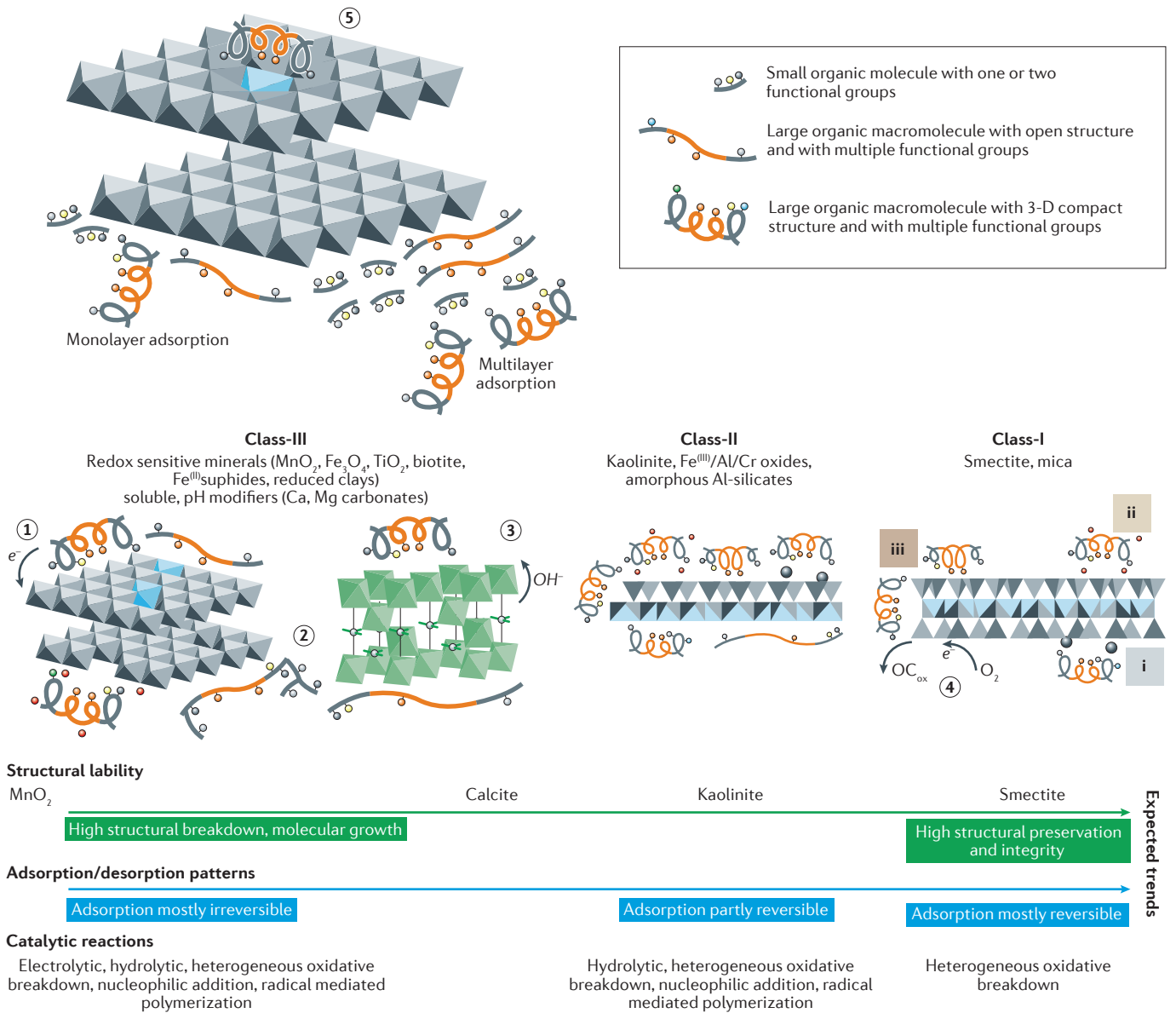
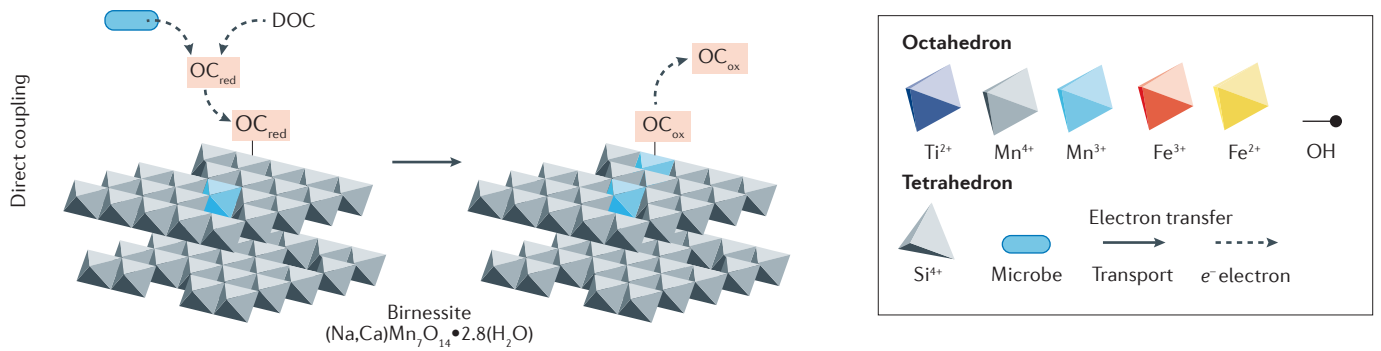
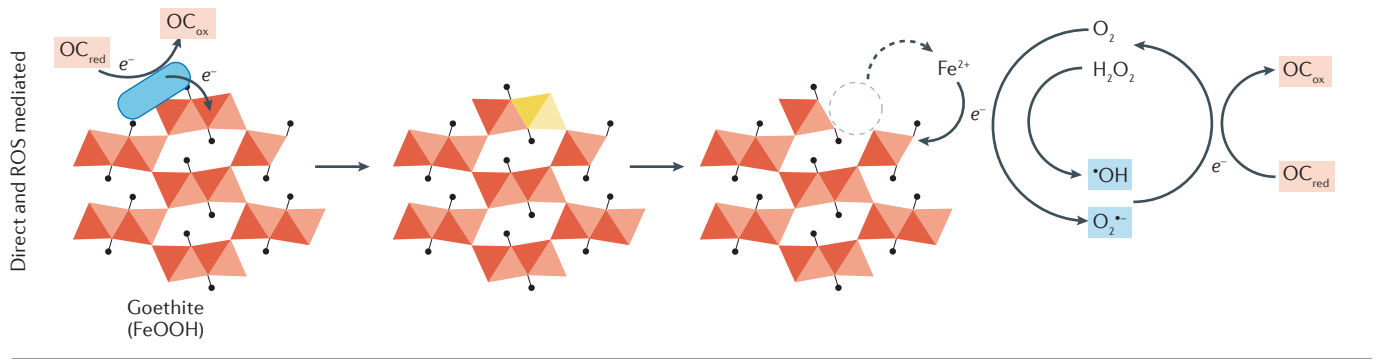


Fig 7

a Mineral-induced oxidation



b Mineral-derived aqueous Fe²⁺



c Mineral-hosted Fe(II)

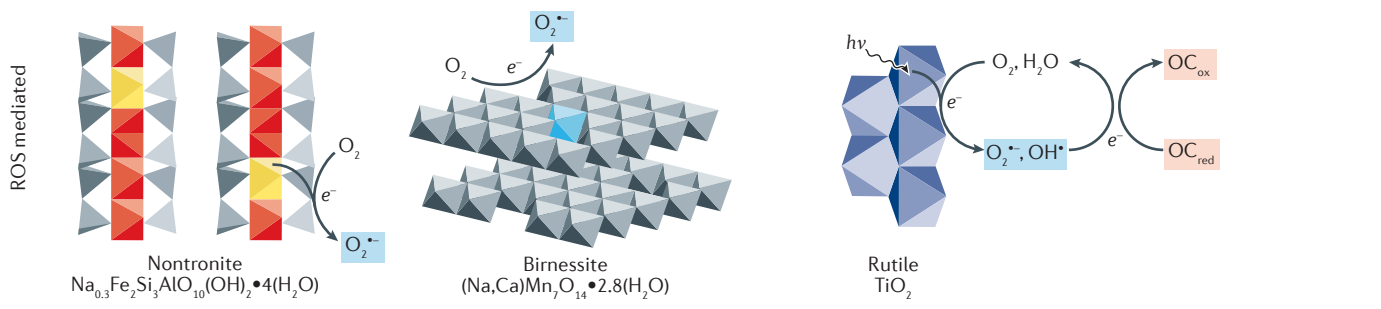


Fig 8

