

TABLE 1. Ten stages of mineral evolution of terrestrial planets, with possible timing on Earth, examples of minerals, and estimates of the cumulative number of different mineral species

Stage	Age (Ga)	Examples of minerals	~ Cumulative no. species
The era of planetary accretion (>4.55 Ga)			
1. Primary chondrite minerals	>4.56 Ga	Mg-olivine/pyroxene, Fe-Ni metal, FeS, CAIs	60
2. Planetesimal alteration/differentiation	>4.56 to 4.55 Ga		250
a) aqueous alteration		phyllosilicates, hydroxides, sulfates, carbonates, halite	
b) thermal alteration		albite, feldspathoids, biopyriboles	
c) shock phases		ringwoodite, majorite, akimotoite, wadsleyite	
d) achondrites		quartz, K-feldspar, titanite, zircon	
e) iron meteorites		many transition metal sulfides and phosphates	
The era of crust and mantle reworking (4.55 to 2.5 Ga)			
3. Igneous rock evolution	4.55 to 4.0 Ga		350 to 500
a) fractionation		feldspathoids, biopyriboles (volatile-poor planets)	350
b) volcanism, outgassing, surface hydration		hydroxides, clay minerals (volatile-rich planets)	500
4. Granite formation	4.0 to 3.5 Ga		1000
a) granitoids		quartz, alkali feldspar (perthite), hornblende, micas, zircon	
b) pegmatites		beryl, tourmaline, spodumene, pollucite, many others	
5. Plate tectonics	>> 3.0 Ga		1500
a) hydrothermal ores		sulfides, selenides, arsenides, antimonides, tellurides, sulfosalts	
b) metamorphic minerals		kyanite, sillimanite, cordierite, chloritoid, jadeite, staurolite	
6. Anoxic biological world	3.9 to 2.5 Ga		1500
a) metal precipitates		banded iron formations (Fe and Mn)	
b) carbonates		ferroan carbonates, dolostones, limestones	
c) sulfates		barite, gypsum	
d) evaporites		halides, borates	
e) carbonate skarns		diopside, tremolite, grossularite, wollastonite, scapolite	
The era of bio-mediated mineralogy (>2.5 Ga to present)			
7. Paleoproterozoic atmospheric changes surface oxidation	2.5 to 1.9 Ga	>2000 new oxide/hydroxide species, especially ore minerals	>4000
8. Intermediate ocean	1.9 to 1.0 Ga	minimal mineralogical innovation	>4000
9. Neoproterozoic biogeochemical changes a) glaciation b) post-glacial oxidation	1.0 to 0.542 Ga	extensive ice deposition, but few new minerals extensive oxidative weathering of all surface rocks	>4000
10. Phanerozoic Era a) biomineralization b) bio-weathering	0.542 Ga to present	extensive skeletal biomineralization of calcite, aragonite, dolomite, hydroxylapatite, and opal increased production of clay minerals, soils	4300+

Note: The timings of some of these stages overlap and several stages continue to the present.