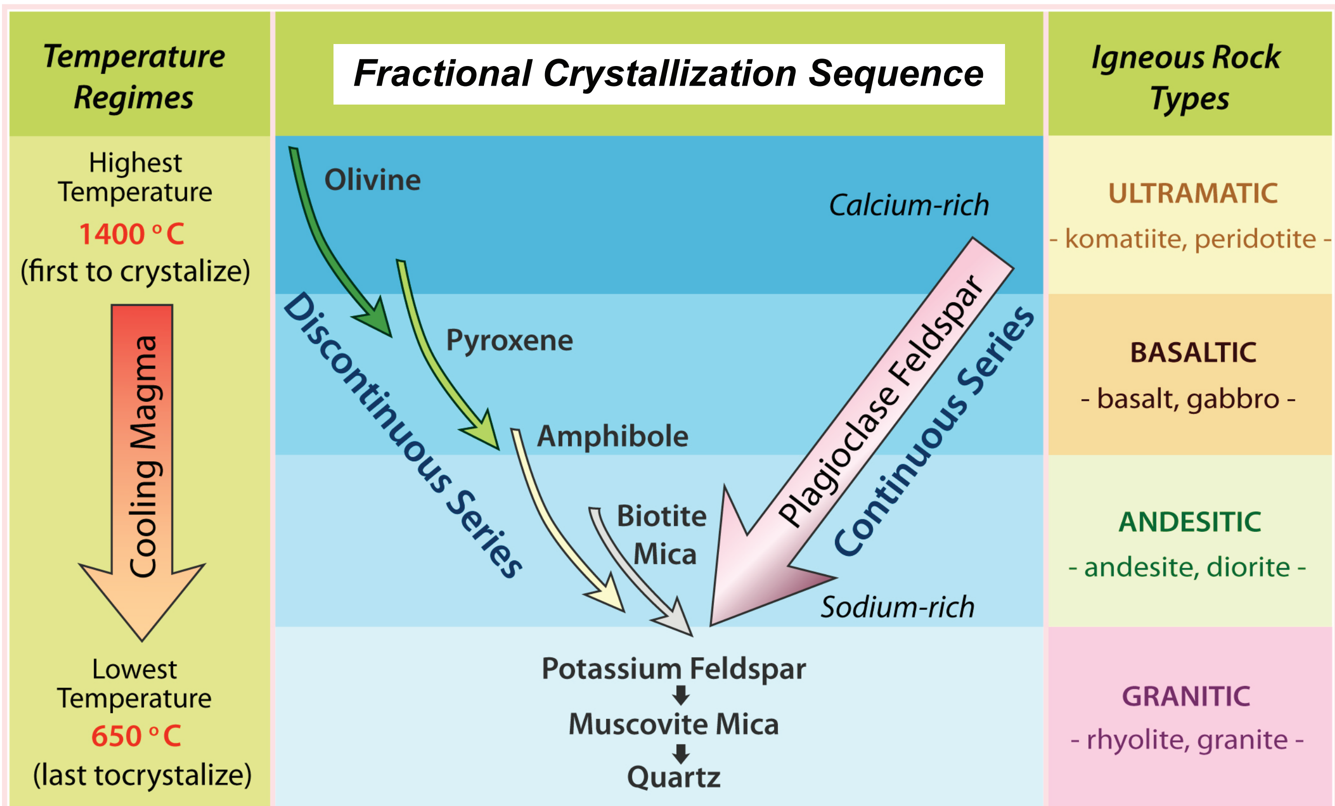
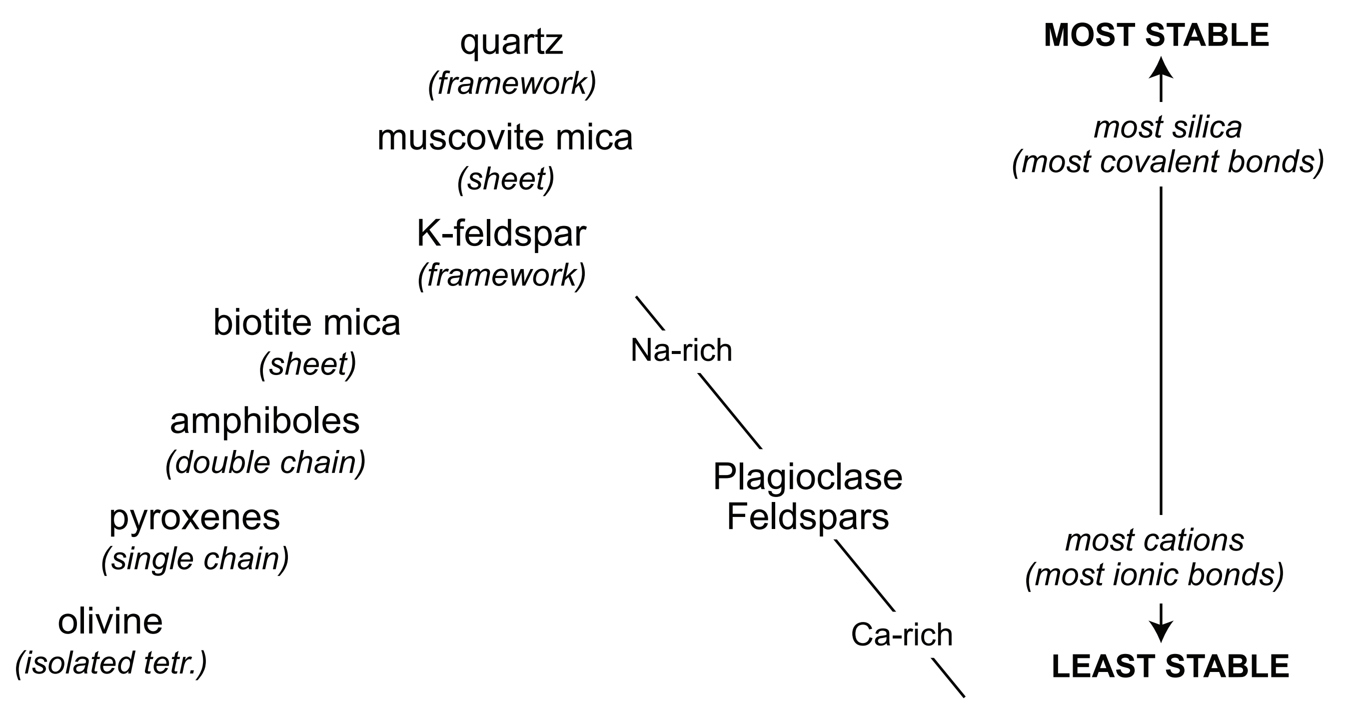
CHEMICAL WEATHERING



Goldich Stability Series
(resistance to chemical weathering)



CHEMICAL WEATHERING REACTIONS

all silicates are alumino-silicates, the source of the aluminum poses no problem and the hydrolysis reaction for K-feldspar can be written

$$\underset{\text{(microcline)}}{3\,KAlSi_3O_8} + 2\,H^+ + 12\,H_2O \longrightarrow \underset{\text{(muscovite)}}{KAl_3Si_3O_{10}(OH)_2} + \underset{\text{(dissolved silica)}}{6\,H_4SiO_4} + 2\,K^+$$

Based on field observations, it is generally believed that muscovite (and its clay mineral analog illite) is stable with respect to other clay minerals in cold to cool climates with lower than average precipitation. The natural variation in composition and structural characteristics of natural illites (see Sec. 8.5) makes it difficult to verify this belief thermodynamically.

Under temperate, humid conditions such as exist in southeastern United States, illite (or muscovite) is an unstable phase and undergoes incongruent dissolution to form kaolinite.

$$\underset{\text{(muscovite)}}{2\,KAl_3Si_3O_{10}(OH)_2} + 2\,H^+ + 3\,H_2O \longrightarrow \underset{\text{(kaolinite)}}{3\,Al_2Si_2O_5(OH)_4} + 2\,K^+$$

Under more severe weathering conditions, such as occur in humid tropical regions of central Africa, Brazil, or India, kaolinite is an unstable phase and decomposes to form free silica and a metastable hydrated aluminous residue that subsequently crystallizes to form either gibbsite or diaspore plus water. Available thermodynamic data are not precise enough to determine whether gibbsite or diaspore plus water is more stable under severe weathering conditions.

$$\underset{\text{(kaolinite)}}{Al_2Si_2O_5(OH)_4} + 5\,H_2O \longrightarrow \underset{\text{(gibbsite)}}{2\,Al(OH)_3} + 2\,H_4SiO_4$$

The preceding three equations are not the only possible reaction paths during weathering, for microcline may alter directly to kaolinite without the intervention of a muscovite or illite phase.

$$\underset{\text{(microcline)}}{2\,KAlSi_3O_8} + 2\,H^+ + 9\,H_2O \longrightarrow \underset{\text{(kaolinite)}}{Al_2Si_2O_5(OH)_4} + 2\,K^+ + 4\,H_4SiO_4$$

Also, muscovite (or illite) may alter directly to gibbsite (or diaspore plus water) without the appearance of kaolinite.

$$\underset{\text{(muscovite)}}{KAl_3Si_3O_{10}(OH)_2} + H^+ + 9\,H_2O \longrightarrow \underset{\text{(gibbsite)}}{3\,Al(OH)_3} + K^+ + 3\,H_4SiO_4$$

Stability Field of Each Mineral Phase

Based on field studies of modern sediments, as the climate changes from arid and either cold or hot to wet and hot, the mineral phase present during weathering changes from microcline to muscovite to kaolinite to gibbsite. This process occurs because, with increased water movement, the soluble products of each reaction in the weathering sequence of minerals in the K_2O—Al_2O_3—SiO_2—H_2O system are carried away more rapidly, and each reaction is forced to the right according to Le Chatelier's principle. As geologists, we are charged with the task of reconstructing earth history in as much detail as field evidence and laboratory data will allow, and so we must ask whether the presence of any of the minerals produced in our

Blatt, Middleton, and Murray (1980)

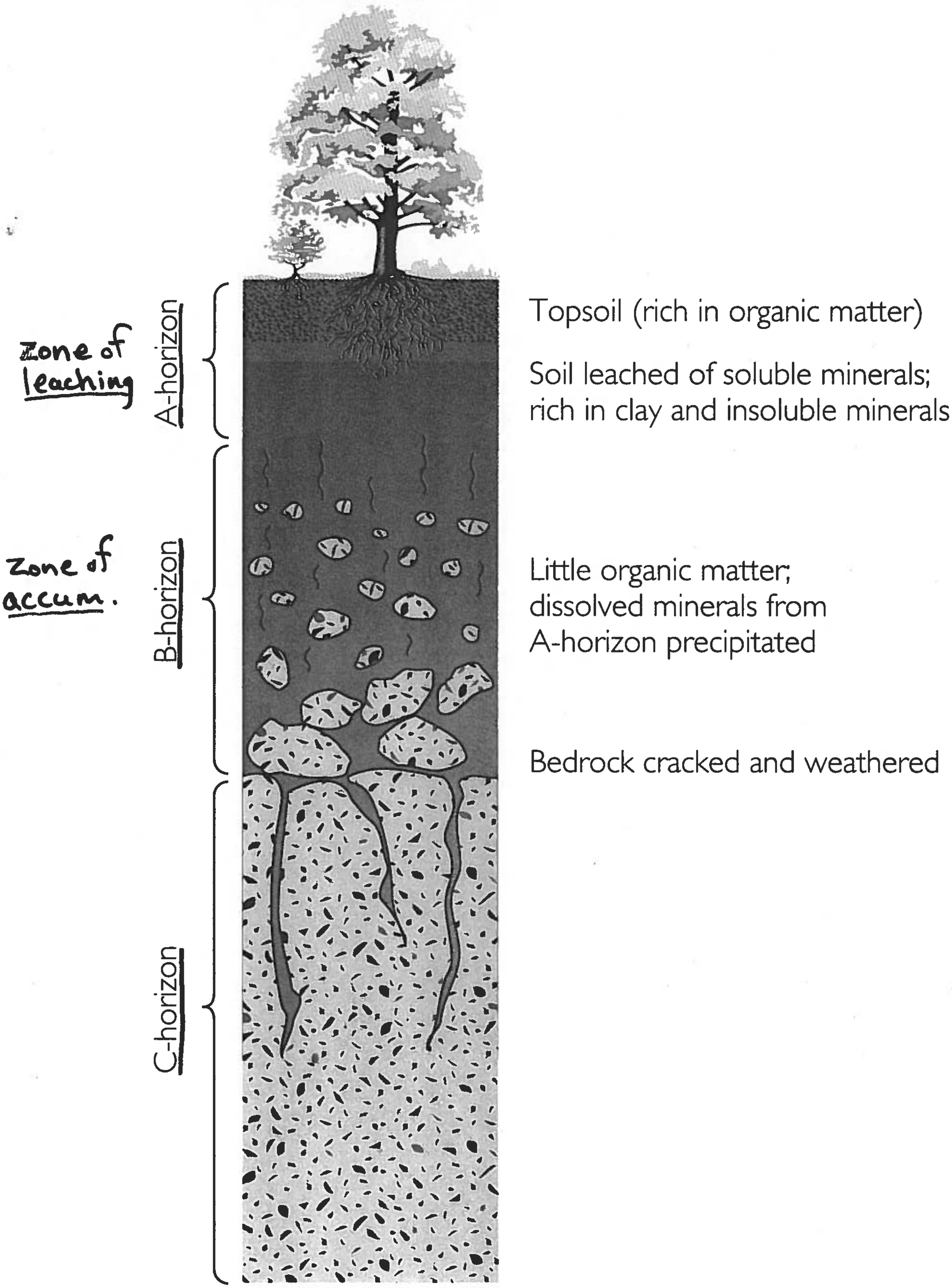


Figure 6.14
Press and Siever: ***Understanding Earth***

OHT 28

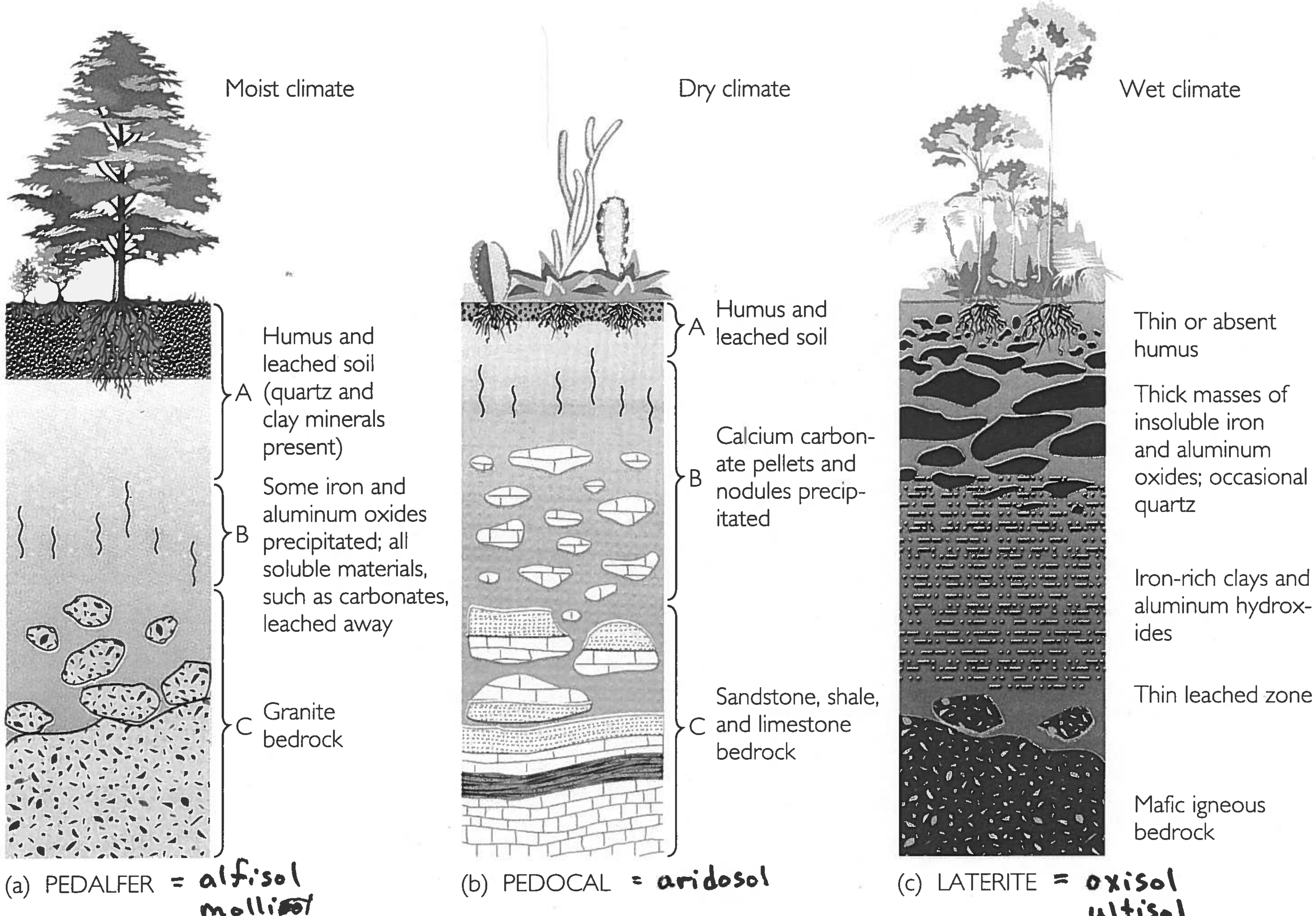


Figure 6.15
Press and Siever: ***Understanding Earth***

OHT 29

6.2 LIVING ON EARTH

Mapping Soil Types with a Newer Classification

Mapping of soils by the U.S. Soil Conservation Service and similar government agencies in other countries is a necessity for soil scientists. These scientists need accurate maps to understand soil formation better in order to reduce soil erosion and make optimum agricultural use of soils. In order to map soils, they need a good working classification. While the terms we have used, *pedalfer, pedocal,* and *laterite,* are useful and widely recognized as basic soil types, they are not easy to use in practical mapping, partly because they do not take sufficient account of the differences in bedrocks. Below is a list of the ten orders, as they are called in this classification, which is in official use in the United States and other countries.

SOIL ORDER	PROPERTIES	CORRELATION WITH MAJOR SOIL TYPES
Entisol	Soil formation only slightly advanced, soil profile rudimentary	—
Inceptisol	Weakly developed soils with definite A-horizon and poorly developed B-horizon	Pedalfer
Mollisol	High organic matter content in A-horizon	Pedalfer Pedocal
Alfisol	Some organic matter in A-horizon; A is thin and overlies clay-enriched B-horizon	Pedalfer
Spodosol	Organic-rich A-horizon overlies iron-enriched B-horizon	—
Ultisol	A-horizon overlies highly weathered B-horizon	Pedalfer Laterite
Oxisol	A-horizon overlies extremely weathered B-horizon	Laterite
Aridosol	Little organic matter in A-horizon and salt or silica accumulations at depth	Pedocal
Histosol	Peaty (abundant in preserved dead vegetation) soils	—
Vertisol	High content of clay minerals, which expand under wet conditions and contract in dry seasons	—

Andisol permafrost soils
Gelisol volcanic-ash soils

Soil types of North and South America. Alfisols and mollisols make the best farmland. (From William P. Cunningham and Barbara Saigo, *Environmental Science: A Global Concern* [Dubuque, Iowa: Wm. C. Brown, 1990], p. 188.)

Blatt, Middleton and Murray (1980)

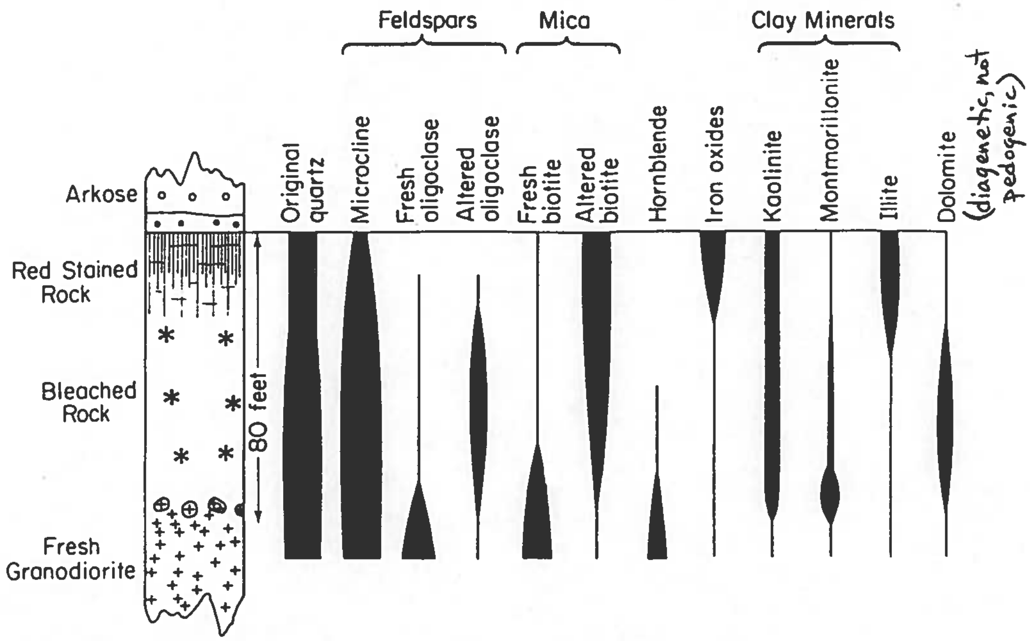


Fig. 7-2 Diagram showing persistence with depth of important minerals in pre-Fountain mantle (After E. E. Wahlstrom, 1948, *Geol. Soc. Amer. Bull.*, **59**,

TABLE 7-1 CHEMICAL ANALYSES OF THE PARENT GRANODIORITE AND THE SOIL PROFILE DEVELOPED ON IT DURING THE LATE PALEOZOIC (from Wahlstrom, E. E., 1948, *Geol. Soc. Amer. Bull.*, **59**, p. 1178).

Meters above base	*Granodiorite*	*1*	*10*	*18*	*22*	*24*	*25*	*26*
SiO_2	67.92	68.15	65.46	61.49	58.54	58.66	57.69	55.46
TiO_2	0.55	0.55	0.44	0.78	1.12	1.21	1.34	1.53
Al_2O_3	14.70	14.26	13.22	14.35	19.08	18.02	18.44	21.37
Fe_2O_3	0.91	2.24	2.79	4.65	6.46	6.55	6.85	8.65
FeO	2.61	1.03	0.74	0.78	0.44	0.82	1.04	0.37
CaO	2.94	1.17	2.04	1.75	0.83	0.58	0.76	0.38
MgO	0.98	1.19	1.31	2.18	2.01	1.69	2.71	0.56
Na_2O	3.31	1.95	0.53	0.42	0.61	0.57	0.54	0 49
K_2O	4.38	4.76	5.59	6.90	6.71	7.10	5.94	6.48
H_2O^+	0.80	3.54	5.64	5.81	3.25	3.32	4.03	3.58
H_2O^-	0.36	0.48	0.48	0.43	1.14	1.33	0.93	0.97
P_2O_5	0.18	0.12	0.13	0.24	0.38	0.29	0.32	0.20
CO_2	None	0.10	2.26	0.90	None	None	None	None
MnO	0.03	0.04	0.05	0.05	0.02	0.03	0.03	0 03
Total	99.67	99.58	100.68	100.73	100.59	100.17	100.62	100.07
Uncombined SiO_2	24	31	28	25	21	20	22	20

Increasing: during soil formation

- Al and K, conc. in clay minerals
- Ferric iron (Fe^{3+}), Fe_2O_3 is stable in oxidizing environment
- Ti, very stable

Decreasing:

- Na + Ca, due to destruction of oligoclase
- Ferrous iron (Fe^{2+}), due to alteration of biotite and magnetite
- Mg, due to destruction of hornblende
- some Si, due to loss of oligocl. + hbd