Economic Geology, v. 100, pp. 1489–1509

100th Anniversary Special Paper:

Sedimentary Mineral Deposits and the Evolution of Earth's Near-Surface Environments

HEINRICH D. HOLLAND†

Department of Earth and Planetary Sciences, Harvard University, 20 Oxford Street, Cambridge, Massachusetts 02138

Abstract

The nature of sedimentary mineral deposits has evolved during Earth's history in concert with changes in the oxidation (redox) state of the ocean-atmosphere system, biological evolution, and the growing importance of geologically young accumulations of ore-grade material. There is now strong evidence that the atmosphere and the oceans were anoxic, or essentially anoxic, before 2.4 Ga. Banded iron formations (BIF) and the detrital uranium ores formed prior to 2.4 Ga are consistent with such a state.

The period between 2.4 and 2.0 Ga is called the Great Oxidation Event by some. Its ores bear unmistakable marks of the presence of atmospheric O_2. Shallow-water BIF from this period tend to be oxidized, hydrothermal uranium ores took the place of the earlier detrital uranium ores, the concentration of the redox-sensitive elements in carbonaceous shales began to increase, and phosphorites made their first appearance.

Between 1.8 and 0.8 Ga the Earth system seems to have been remarkably stable. Sedimentary ore deposits of this period were influenced by the presence of O_2. BIF, sedimentary manganese, and phosphorites disappeared ca. 1.8 Ga, but sedimentary exhalative (SEDEX) deposits and unconformity-type uranium deposits flourished, and nonsulfide zinc deposits put in an appearance.

The period between 0.8 Ga and the end of the Proterozoic at 0.54 Ga was as turbulent or more so than the Paleoproterozoic. BIF returned, as did sedimentary manganese deposits and phosphorites. A further rise in the O_2 content of the atmosphere and an increase in the sulfate concentration of seawater during this period brought the composition of the atmosphere and of seawater close to their present redox state.

The last 540 m.y. of Earth's history have seen the system pass through two supercycles of roughly equal length. Climate, the redox stratification of the oceans, ocean mixing, and the nature of sedimentary ores were influenced by tectonically and volcanically driven changes during these supercycles. The evolution of the higher land plants gave rise to coal deposits and sandstone-type uranium ores and was important for the formation of bauxites, even on iron-rich rocks. During the Cenozoic, bauxites, nickel laterites, and secondary enrichment zones of sulfide orebodies took on greater importance, because these ores tend to be destroyed rather than preserved in the geologic record. The preponderance of Cenozoic porphyry copper and other ore deposits that were emplaced at a high level in the crust may be related to the erosion of their earlier counterparts.

† E-mail, Holland@eps.harvard.edu

0361-0128/05/3554/1489-21 $6.00