Chapter 9

Phosphorites and High Phosphate Sedimentary Rocks

Phosphorites and high phosphate rocks are rare sedimentary rocks. But, when they are discovered, they are in layers of high concentration. We can compare their present formation and distribution to Cenozoic distribution and use it as a guide toward finding the Flood/post-Flood boundary.

Phosphate Rocks Forming Today

Phosphorites are considered a marine biochemical sedimentary rock. Phosphorous (P) is added to the sediments today by coastal upwelling of P rich bottom water that is extracted by marine organisms. When these organisms die, P is accumulated in the organic-rich bottom mud.[1] Bacteria help to break down the organic matter leaving phosphate in the sediments.[2]

But the phosphate, mostly as P_2O_5, must become concentrated to above about 18% in the sediment to be called a phosphorite. Phorphorite formation continues to take place today, but it is rather rare and is believed to take thousands of years.[2] According to well-known sedimentologists Francis Pettijohn, if a sedimentary rock contains more than 19.5% phosphate, it is called a *phosphorite*.[3] If it contains more than 7.8%, but less than 19.5%, it is called a *phosphatic* sedimentary rock. These definitions are loose and most geologists would consider a rock as phosphatic if it contained 10 to 100 times or more phosphate than normal. There are small, local accumulations of high phosphate sediments, sedimentary rocks, pellets, and nodules, but this chapter will be concerned with large volume phosphate sedimentary rocks, generally called phosphorites.

Figure 9.1 shows ten areas along the coasts where current phosphogenesis is occurring, mainly because of upwelling of nutrients from the deep ocean that are utilized by organisms. Whether these concentrations reach greater than 18 to 19.5% is uncertain. There are also many more areas considered relict phosphogenic areas that were formed in the past and are not forming today.

High Phosphate Sedimentary Rocks

All sedimentary rocks on the continents contain phosphorus in small amounts. These deposits are thought to originate from the skeletons of organisms. Other sedimentary rocks contain extraordinary amounts of the phosphate ion $(PO_4)^{-3}$ in a variety of minerals. These would be phosphorites or high phosphate sedimentary rocks.

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[1] Nelson, G.J., Pufahl, P.K., and Hiatt, E.E., 2010. Paleoceanographic constraints on Precambrian phosphorite accumulations, Baraga Group, Michigan, USA. *Sedimentary Geology* 226:9–21.

[2] Föllmi, K.B., 1996. The phosphorus cycle, phosphogenesis and marine phosphate-rich deposits. *Earth-Science Reviews* 40:55–124.

[3] Pettijohn, F.J., 1975. *Sedimentary Rocks*, third edition, Harper and Row, New York, NY, pp. 427–434.

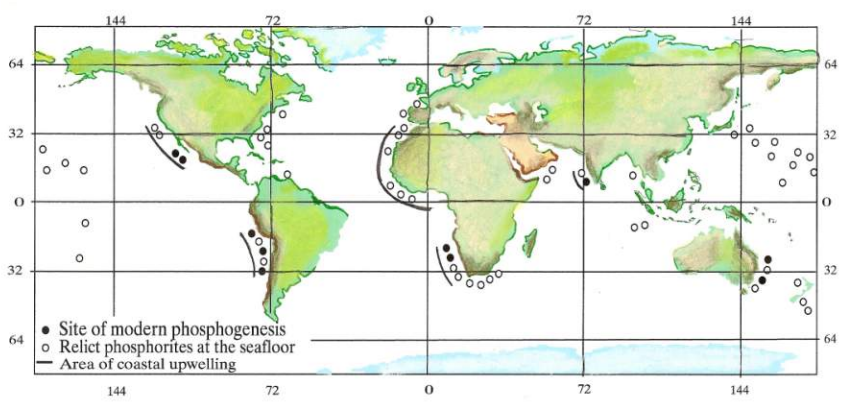

Figure 9.1. World map of sites of present day phosphorite formation, Cenozoic oceanic phosphorites at the sea floor (relict), and zones of coastal upwelling (redrawn by Mrs. Melanie Richard from Föllmi, 1996, p. 62).

High phosphate rocks are found in rocks of nearly all ages, including the Precambrian as old as about 2 billion years ago in the evolutionary/uniformitarian timescale.[1,4,5] Figure 9.2 shows a graph of the distribution of economic phosphorus resources according to evolutionary/uniformitarian earth history. There are two high concentrations of mineable phosphate in 1) the late Precambrian and early Paleozoic and in 2) the late Mesozoic and Cenozoic.[6]

One of the best known and most extensive high phosphate formations is the late Paleozoic Phosphoria Formation of southwest Montana, eastern Idaho, western Wyoming, and northern Utah[7,8] that covers an area of 135,000 mi^2 (225,650 km^2) (Figure 9.3). It is called the Park City Formation in Utah and in other states the Shedhorn Formation. The phosphate rock is mined at a number of locations, such as on the south side of the Uinta Mountains. The Phosphoria Formation has six times the concentration of P_2O_5 found in seawater and has high organic content.[9] It outcrops in 20 phosphate-rich beds and has an aggregate thickness of 73 feet (22 m) with the thickest bed 7 feet (2.1 m). Individual beds can contain up to 30% phosphate. The origin of the Phosphoria Formation is difficult to explain within uniformitarianism. Creationists have not yet worked on an explanation.

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[4] Papineau, D. 2010. Global biogeochemical changes at both ends of the Proterozoic: insights from phosphorites. *Astrobiology* 10(2):165–181.

[5] Lepland A., *et al.*, 2013. Potential influence of sulphur bacteria on Palaeoproterozoic phosphogenesis. *Nature Geoscience* 7:20–24.

[6] Kholodov, V.N and G. Yu Butuzova, 2001. Problems of iron and phosphorus geochemistry in the Precambrian. *Lithology and Mineral Resources* 36(4):291–302.

[7] McKelvey, V.E., Williams, J.S., Sheldon, R.P., Cressman, E.R., Cheney, T.M., and Swanson, R.W., 1956. Summary description of Phosphoria, Park City, and Shedhorn Formation in western phosphate field. *AAPG Bulletin* 40(12):2,826–2,863.

[8] Piper, D.Z., 2001. Marine chemistry of the Permian Phosphoria Formation and basin, Southeast Idaho. *Economic Geology* 96:599-620.

[9] Stephens, N.P. and Carroll, A.R., 1999. Salinity stratification in the Permian Phosphoria sea; a proposed paleoceanographic model. *Geology* 27(10):899-902.

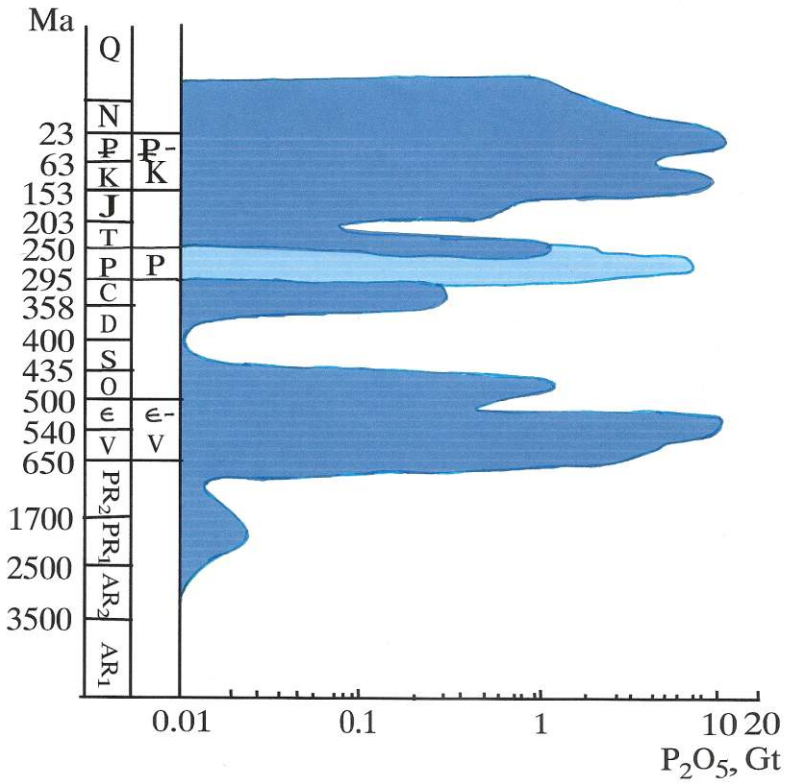

Figure 9.2. Distribution of economic phosphorus resources in earth history according to the evolutionary/uniformitarian timescale (modified by Mrs. Melanie Richard from Kholodov and Butuzova, 2001, p. 293).

Phosphorites are especially concentrated in the Cenozoic, including relict formations on the bottom of the ocean (Figures 9.1 and 9.2). There are a huge amount of phosphorites concentrated in the Miocene,[10] which is the early part of the late Cenozoic. For instance, phosphate-rich sedimentary rocks are found in Malta and southeast Sicily.[11]

The early Late Cenozoic Monterey Formation outcropping over numerous areas of the coastal section between Los Angeles and San Francisco, California, has high phosphate layers.[12] Some of these are thin, persistent laminae.[13] Catastrophic deposition is suggested:

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[10] Nelson *et al.*, Ref. 1, p. 17.

[11] Föllmi, K.B., B. Gertsch, J.-P. Renevey, E. De Kaenel, and P. Stille, 2008. Stratigraphy and sedimentology of phosphate-rich sediments in Malta and south-eastern Sicily (latest Oligocene to early Late Miocene). *Sedimentology* 55:1,029–1,051.

[12] Berndmeyer, C., D. Birgel, B. Brunner, L.M. Wehrmann, N. Jöns, W. Bach, E.T. Arning, K.B. Föllmi, and J. Peckmann, 2012. The influence of bacterial activity on phosphorite formation in the Miocene Monterey Formation, California. *Palaeogeography, Palaeoclimatology, Palaeoecology* 317–318:171–181.

[13] Föllmi, K.B. and R.E. Garrison, 1991. Phosphatic sediments, ordinary or extraordinary deposits? The example of the Miocene Monterey Formation (California); in: Miller, D.W., J.A. McKenzie, and H. Weissert (Eds.), *Controversies in Modern Geology: Evolution of Geological Theories in Sedimentology, Earth History and Tectonics*, Academic Press, New York, NY, pp. 55–84.

> The concept of local catastrophic burial as a favourable prerequisite for the triggering of phosphogenesis embodies a small-scale example of the importance of nonreversible, catastrophic events on geological and biological processes…[14]

It is not enough to simply bury an organism, the phosphate needs to be *concentrated* in layers by transport within the interstitial water of the sediments. That subsurface movement of phosphate in pore water must have occurred is provided by numerous examples of phosphatized fossils, coprolites (fossil dung), burrows, hardgrounds (hard cemented layers), etc.[2,11]

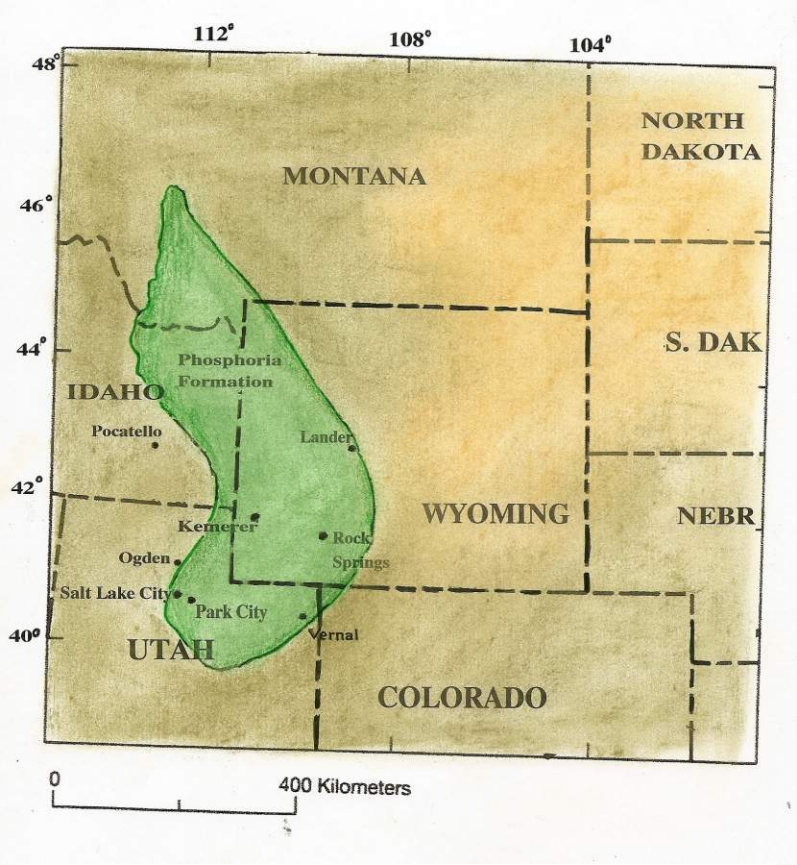

Figure 9.3. Area of the Phosphoria Formation in the western U.S. (drawn by Mrs. Melanie Richard).

The mechanism for the formation and concentration of phosphorites is poorly known, but within Biblical earth history it must be more rapid than what occurs today. Several suggested mechanisms are the rapid burial of organic remains with continental volcanism, especially apatite-bearing carbonatite volcanism, volcanism that exudes "lava" with greater than 50% carbonate minerals.[2]

Cenozoic Phosphate Beds Favor a Late Cenozoic Flood/Post-Flood Boundary

High phosphate beds are abundant in the Cenozoic, as well as within older periods in the evolutionary/uniformitarian geological timescale. Phosphate precipitation is taking place in some upwelling areas of the ocean, but it is fairly rare. Researchers had attempted to connect phosporites of the sea floor with areas of present-day upwelling but failed, until uranium series

[14] Föllmi and Garrrison, Ref. 13, p. 55.

dating suggested a "contemporary" origin for the deposits off Peru.[15] Most of these sea bed phosphorites are considered older than the Pleistocene.[2] Under present conditions it probably would take thousands of years to concentrate the phosphate.

Could post-Flood catastrophes cause high phosphate sedimentary beds? It seems rather doubtful that these catastrophes, whatever they may be, could bury enough organisms to result in much organic phosphate and then, concentrate the phosphate. Chances are these catastrophes would result in the phosphate being randomly disseminated within the sediment, making forming high phosphate layers, improbable.

Since there are such an abundance of phosphate beds in Cenozoic rocks, coupled with the fact that not much phosphate is expected to form in sediments after the Flood, the existence of abundant phosphate beds in the Cenozoic implies a Flood/post-Flood boundary in the late Cenozoic.

[15] Veeh, H.H., W.C, Burnett, and A. Soutar, 1973. Contemporary phosphorites on the continental margin of Peru. *Science* 181:844–845.