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Contemporary Phosphorites on the Continental Margin of Peru

Abstract. *Phosphorite nodules occurring along the biologically productive continental margin of Peru have been dated by uranium-series methods. The radiometric ages range from late Pleistocene to Recent, indicating that phosphorites are currently forming in this area.*

Ever since Kazakov (*1*) linked the origin of marine phosphorite to coastal upwelling in the ocean, the association between these two has generally been considered as one of cause and effect (*2*). Until recently, however, attempts to demonstrate a contemporary age for phosphorites of the sea floor in areas of present-day upwelling proved unsuccessful. Many of the phosphorites studied contained pre-Pleistocene fossils, or showed other evidence of being reworked "lag deposits" (*3*), while absolute age determinations by uranium-series methods invariably yielded ages in excess of 800,000 years (*4, 5*). These results have hampered attempts to investigate the origin of marine phosphorite in greater detail, since an analysis of the present oceanographic conditions in these areas would not necessarily be relevant to the depositional environment of pre-Recent phosphorites.

So far, the only evidence suggesting contemporary formation of marine phosphorite was the exposed portion of a wooden log dredged from a depth of 410 m in the Gulf of Tehuantepec (*6*); unfortunately, the age of phosphorization could not be verified at the time by absolute dating. Baturin and co-workers (*7*) presented morphological evidence for authigenic marine phosphorite in Recent diatomaceous muds on the shelves off southwest Africa and Chile; the phosphorite occurred as semiconsolidated nodules, with no sign of transport or reworking. Using radiometric dating (*8*), they confirmed the contemporary formation of several of these phosphatic nodules.

We report here another extensive marine phosphorite deposit (Fig. 1), for which a contemporary origin is demonstrated by uranium-series age determinations. This deposit was discovered incidentally during an investigation of laminated anaerobic sediments associated with coastal upwelling off Peru and Chile (*9*). In this area of high organic productivity, a seasonal eastern boundary current maintains a well-developed oxygen minimum which intensifies toward the coast (*10*). A zone of anoxic sediments occurs between 100 and 400 m where the oxygen-deficient waters impinge on the continental margin. The phosphorite nodules are confined to two narrow bands roughly coinciding with the upper and lower boundaries of the oxygen minimum layer, as defined by hydrographic station data taken either at or in the immediate vicinity seaward of the dredging sites (*9*).

Electron microprobe analyses and x-ray diffraction data indicate that apatite rich in fluorine (2 to 4 percent fluorine)—most likely carbonate fluorapatite or francolite—is the major component of the phosphorites. The concentration of phosphorus, as P_2O_5, ranges from 17 to 35 percent, reflecting varying degrees of dilution by detrital minerals and biogenic debris. A few nodules are essentially pure cryptocrystalline apatite, or collophane, but more commonly the phosphatic material occurs as a matrix, cementing silt-size detrital minerals and biogenic components. A more complete discussion of the geochemistry and mineralogy of the phosphorite nodules and associated sediments will be presented separately (*11*).

To determine the age of formation of this deposit a number of representative phosphorite samples were selected and dated by uranium-series methods (*5*). Our results are shown in Table 1. If it is assumed that (i) uranium was incorporated into the phosphorites during their formation, (ii) the uranium was derived primarily from seawater, (iii) the $^{234}U/^{238}U$ ratio in seawater during the last few hundred thousand years has not significantly differed from its present accepted value of 1.15, and (iv) the phosphorites have remained a closed system with respect to uranium since the time of their formation, then the ages corresponding to the $^{234}U/^{238}U$ ratios range from about

Table 1. Isotopic data for uranium and thorium in marine phosphorites. The concentrations are in parts per million (ppm); ratios are activity ratios.

Sample	Depth (m)	Uranium (ppm)	Thorium (ppm)	$^{234}U/^{238}U$	$^{230}Th/^{234}U$	Age (× 10^3 years) ^{234}U	Age (× 10^3 years) ^{230}Th
				Off Peru			
KK 71-161							
Surface	320	103	6.7	1.09 ± 0.01	0.46 ± 0.02	180 ± 60	≤ 66
Core	320	9.6	6.1	1.10 ± 0.01	0.62 ± 0.03	140 ± 50	≤ 102
KK 71-96	450	6.7		1.06 ± 0.03		300 ± 100	
A-183							
Surface	446	140	2.3	1.11 ± 0.01	0.61 ± 0.03	110 ± 50	≤ 100
Core	446	117	1.8	1.10 ± 0.01	0.70 ± 0.03	140 ± 50	≤ 125
PD-12-05	345	168	2.4	1.15 ± 0.01	0.021 ± 0.001	Recent	≤ 2
PD-15-13	120	102	3.2	1.14 ± 0.02	0.06 ± 0.01	30 ± 50	≤ 7
				Other areas			
Sea off California [15 samples; (*5*)]	150–1100	36–149	5.5–43	0.95–1.02	1.00–1.12	> 800	> 200
Chatham Rise [7 samples; (*5*)]	285–420	117–524	4.5–12	0.96–1.01	0.99–1.25	> 800	> 200

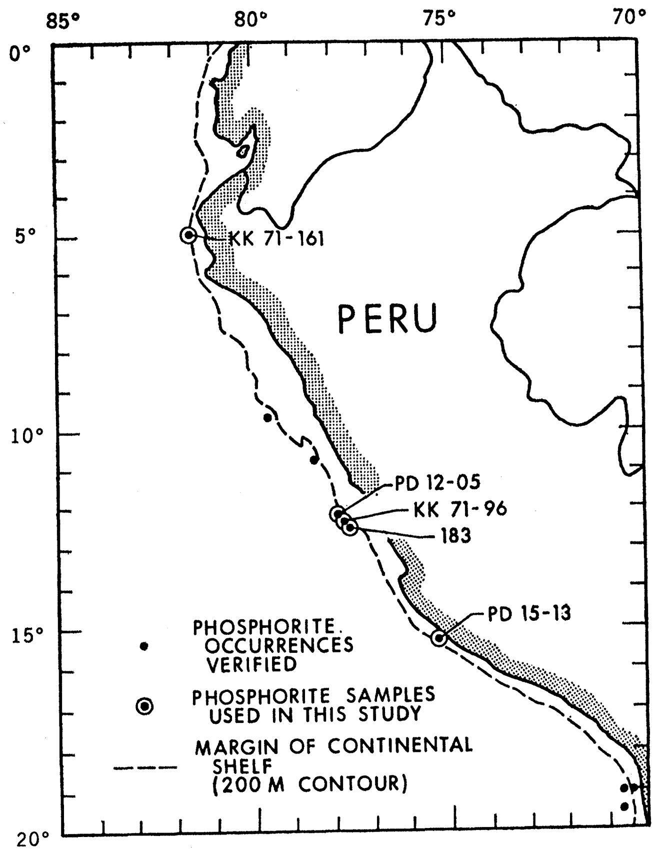

Fig. 1. Map showing phosphorite occurrences and sample locations on the continental margin of Peru.

300,000 years to Recent. This indicates that the phosphorite nodules off Peru are, at least in part, forming currently, in agreement with the results of Baturin *et al.* (*8*) for another location.

No absolute ages can be calculated from the $^{230}Th/^{234}U$ ratios because the ^{230}Th content in the phosphorites at the time of formation is not known. An upper limit can be placed on their ages, however, by assuming that all of the ^{230}Th measured is a decay product of the parent uranium in the nodules. These upper age limits range from 125,000 to 2000 years ago, which is further evidence for a late Pleistocene to Recent age for the phosphorites off Peru. The presence of measurable amounts of thorium in our samples (Table 1) suggests that some of the ^{230}Th found in the phosphorites could have an external origin, and hence the true ^{230}Th ages may be substantially lower than the upper limits.

It could be argued that the assumption of a closed system is invalid, and that the ages reported here are not real but apparent, due to secondary addition of uranium to the phosphorites. Secondary additions of uranium from seawater to pre-Pleistocene phosphorites with low initial uranium contents could result in $^{234}U/^{238}U$ ratios between 1.00 and 1.15 and $^{230}Th/^{234}Th$ ratios of less than 1.00. Such an interpretation is not plausible, however, since it then becomes difficult to explain why marine phosphorites from similar areas fail to exhibit similar evidence of secondary addition of uranium. More likely, the formation of phosphorites off Peru has been a more or less continuous process from at least late Pleistocene time to the present; thus, reworking and continued enrichment of older phosphorites would lead to a pre-Recent age bias in some of the nodules.

If phosphorites are currently forming off Peru, as our data indicate, a systematic study of the mode of occurrence of these deposits in relation to pertinent oceanographic parameters should lead to a better understanding of the processes of phosphorite genesis. Knowledge of the distribution pattern of the phosphorites with respect to the boundaries of the oxygen minimum layer where the latter impinges on the continental margin may hold an important clue to the mode of phosphorite formation and should serve as a guideline for future studies in this area.

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Human Chorionic Gonadotropin: Its Possible Role in Maternal Lymphocyte Suppression

Abstract. *Human chorionic gonadotropin completely inhibits the response of lymphocytes to phytohemagglutinin. The effect is both reversible and noncytotoxic. These observations support the theory that the fetus is accepted because human chorionic gonadotropin represents trophoblastic surface antigen and blocks the action of maternal lymphocytes.*

The fact that the mother accepts her fetus as an allograft when a large percentage of the potential antigenic sites of the fetus are different from those of the mother defies precise explanation by transplantation biologists (*1*). At the center of this enigma lies the question of how the fetal trophoblast can successfully engraft itself on the maternal endometrium while it is intimately and constantly exposed to presumably immunocompetent maternal lymphocytes.