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PHOSPHATIC PERMIAN ROCKS OF THE ADOBE RANGE, NEVADA, AND THEIR ENVIRONMENT OF DEPOSITION

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ABSTRACT

Permian sedimentary rocks in the Adobe range, northern Nevada, are phosphatic, and although the particles of phosphate are relatively more disseminated, they closely resemble the rocks of the Phosphoria Formation. In the northern Adobe Range, where the entire Permian sequence is approximately correlative with the Phosphoria Formation, it is 200 m thick and averages 1.7 percent P_2O_5. In the southern Adobe Range, the Permian sequence is more than 1,700 m thick, and the upper half which is roughly correlative with the Phosphoria Formation averages more than 2 percent P_2O_5. Some thin beds in rocks of Permian age contain more than 20 percent P_2O_5.

Phosphatic rocks of the Adobe Range were deposited in shallow water among islands in the western part of the epicontinental Phosphoria sea. The continental margin and the open ocean lay far to the west. At the same time, the Phosphoria Formation was being deposited in the eastern and central parts of the Phosphoria sea. Theories based on the work of Kasakov done in 1937 relating phosphate deposition directly to sites of upwelling oceanic waters are questioned. Nondeposition of diluent materials such as detritus and carbonate is probably of more importance in producing phosphate in economic concentrations than is geographic position with respect to upwelling waters.

INTRODUCTION

Permian rocks are widespread in central Elko County, Nevada, and have been described in several publications (Dott, 1955; Fails, 1960; Churkin and Kay, 1967; Coash, 1967; Ketner, 1970, 1973a, 1973b; Smith and Ketner, 1975; and Coats and Gordon, 1972), but heretofore little notice has been taken of their phosphate content. Close observation reveals that all of the younger Permian rocks of this area are remarkably phosphatic. This paper describes the Permian rocks of the Adobe Range and suggests that the emphasis on upwelling waters in current theories of phosphate deposition may be misplaced. Paleontological age determinations were made by Mackenzie Gordon, Jr., B. R. Wardlaw, N. J. Silberling, J. W. Huddle, John Pojeta, and E. L. Yochelson, all of the U.S. Geological Survey; and Bruce Runnegar, Visiting Research Associate at the U.S. National Museum.

NORTHERN ADOBE RANGE

Permian and Lower Triassic rocks of the northern Adobe Range (fig. 1) form a well exposed, well dated sedimentary sequence divisible into four distinctive lithologic units designated from the base upward as units A, B, C, and D. Formal names are avoided because lithologic correlation with established formations in other areas has not yet been achieved.

Permian beds in the northern Adobe Range lie unconformably on the Mississippian Chainman and Diamond Peak Formations and on unnamed eugeosynclinal rocks of early Paleozoic age (Ketner, 1973a). Their fauna indicate they are contemporaneous with the Phosphoria Formation.

The basal part of the Permian and Triassic sequence (unit A) is extremely varied in lithology and thickness and reflects sedimentation in a very nearshore environment. It differs from the overlying units in its coarse grain size and lateral variability. Principal lithologies are pebble conglomerate, gritstone, and sandstone. Individual particles in these detrital beds are composed of chert, shale, quartzite, quartz, or phosphate rock. With the exception of phosphate rock, these are the constituents of the underlying formations. Detrital beds commonly show effects of strong currents in the abundance of scours and crossbedding. In addition to the detrital rocks, beds of bioclastic limestone are fairly common. These are generally quartz-silty, quartz-sandy, and phosphatic, and locally they are partially replaced by secondary silica. They contain abundant brachiopods, molluscs, and bryozoan. The thickness of unit A ranges from 0 to about 50 m.

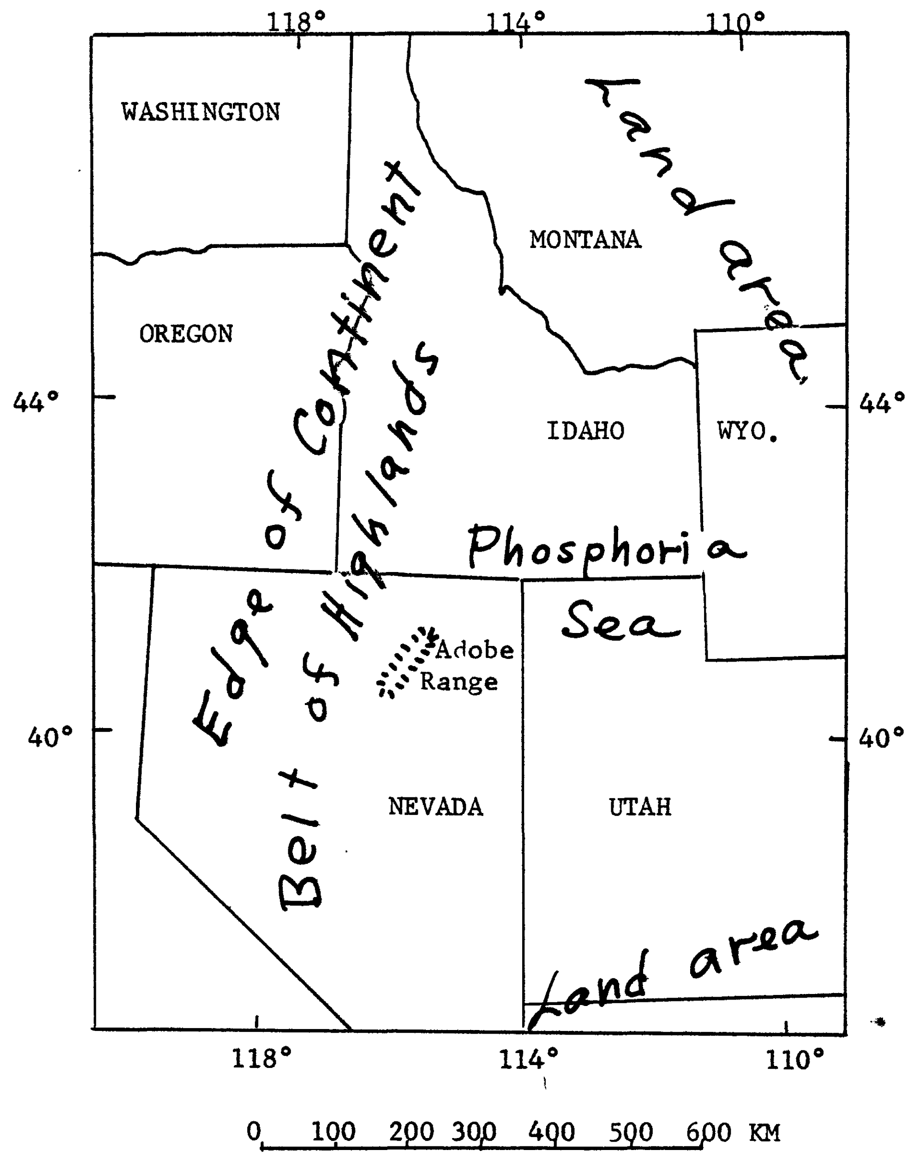

FIGURE 1.--Map showing the Adobe Range in relation to the Phosphoria Sea

Unit B lies conformably on unit A, and although it is rather thin and lithologically inconspicuous, it can be traced continuously for several kilometers. This unit is composed almost entirely of brown crossbedded phosphatic quartz siltstone cemented by carbonate and secondary chert. Invariably a moistened surface shows distinctive rounded silt-size grains of brown and tan phosphate. The unit contains a few thin lenses of grit composed of chert, quartz, and phosphate rock. The fauna of this unit is composed principally of the pelecypod Atomodesma. Unit B averages about 15 m in thickness.

Unit C lies conformably on unit B. It is composed almost entirely of dark-brown phosphatic quartz siltstone, mudstone, and shale which grade upward into limy siltstone and silty, platy limestone near the top of the unit. Less common constituents are lenses of sandstone and grit composed of chert and phosphate rock, crossbedded phosphatic siltstone resembling that of unit B, and thin phosphorite beds. One of the most distinctive features of the unit is the abundance of small dark-colored pelecypods that are clearly visible on weathered surfaces. Most of these are richly phosphatic internal casts about 0.5 cm in diameter. In addition to the abundant pelecypods, this unit contains a sparse brachiopod fauna. Its thickness is about 130 m in one place, but elsewhere it is much thinner.

Unit D lies conformably on unit C. It is composed almost entirely of platy, quartz-silty, argillaceous limestone, limy argillaceous siltstone, and soft clay shale. Minor constituents are thin beds of coarse bioclastic phosphatic limestone and small lenses of fine-grained limestone, distinctively chocolate brown when weathered. The coarse-grained limestones commonly contain large Permian brachiopods whereas the brown-weathering limestones higher in the sequence contain Triassic ammonoids. Sills and flows of intermediate composition form a small part of the middle and upper portions of unit D. The thickness of this unit is at least 600 m but only a small part is of Permian age.

SOUTHERN ADOBE RANGE

A thick sequence of Permian rocks is exposed in and near the southern end of the Adobe Range (Dott, 1958; Fails, 1960; Ketner, 1970, 1973b; Smith and Ketner, 1975). Its abundant fauna of conodonts, pelecypods, and brachiopods indicate the middle and upper beds are correlative with the Phosphoria Formation. These beds are composed mainly of quartz-silty and sandy calcarenite, quartz siltstone and fine-grained quartz sandstone, and chert. A minor constituent in the uppermost part of the exposed sequence is phosphate rock. The thickness of the entire Permian sequence is more than 1,700 m and of the beds correlative with the Phosphoria Formation about 800 m.

PHOSPHATE CONTENT

The phosphate content of Permian rocks in the Adobe Range was determined by arbitrarily selecting sample sites at regular intervals. Outcrops are relatively plentiful in the northern part of the Adobe Range but scarce in the southern part. Where outcrops could not be sampled, loose rock chips were collected along ridges and hilltops where soil is absent, and the possibility of contamination is minimal. Analyses for P_2O_5 were made volumetrically, and the richer samples were rechecked. The results clearly indicate that the entire sequence of Permian rocks is abnormally phosphatic, and the younger Permian beds are much more phosphatic than the older beds.

According to Turekian and Wedepohl (1961), the usual P_2O_5 content of sedimentary rocks similar to the Permian rocks under discussion is less than 0.2 percent. Most of the younger Permian rocks in the Adobe Range contain several times this amount (tables 1, 2).

Phosphate is visible in thin sections of every kind of rock in the Permian sequences of the Adobe Range, and microscopically it resembles the phosphate of the Phosphoria Formation as described by Cressman and Swanson (1964) and McKelvey and others (1953). It tends to be tan or brown and many of the smaller grains have lustrous surfaces. The principal forms of phosphate in the Adobe Range are as follows:

1) Round or ovoid pellets of relatively pure phosphate between 0.05 and 0.5 mm in diameter. Some of these are built up around nuclei of detrital quartz grains or carbonate grains.

2) Small irregularly shaped grains. These are common in siltstone where they conform to the spaces available between detrital quartz grains.

3) Large irregular nodules composed of homogeneous phosphate or aggregates of phosphatic pellets and other sedimentary debris. These grains which can be at least 4 cm in the longest dimension seem to be fragments of pre-existing beds of phosphorite that have been broken up and moved short distances.

4) Internal casts of small pelecypods about 0.5 to 1 cm in length.

5) Rod-like fillings of the axial canals of spicules. These range from 0.2 mm to 0.3 mm in diameter, and although they can be a few millimeters long they are usually broken into short segments.

Table 1.--*Percent P_2O_5 of samples chosen at arbitrary intervals across stratigraphic units, northern Adobe Range, Nevada*

[Analyst: G. D. Shipley, 1969]

Unit A	Unit B	Unit C	Unit D (lower part)
.66 top	1.34 top	1.33 top	0.45 top
.50	1.64	3.52	1.51 base
.24	1.45 base	1.54	
3.57		4.14	1.0 average
2.82	1.5 average	1.54	
1.66		1.36	
1.30		1.05	
1.76		2.89	
2.02		3.10	
2.97		.56	
4.26		1.54	
1.66		2.38	
1.02		1.59	
3.20		1.66	
.94		1.66	
2.35 base		1.48	
		1.13	
1.9 average		1.62	
		1.08	
		1.01	
		.66	
		1.35	
		.35	
		.58 base	
		1.6 average	

Table 2.--*Percent P_2O_5 of samples chosen at approximately equal intervals in the Permian beds exposed above the basal limestone, southern Adobe Range, Nevada*

[Analyst: G. D. Shipley, 1968]

Beds correlative with the Phosphoria Formation		Beds older than the Phosphoria Formation	
12.9	top of exposed	.24	
10.1	section	.28	
1.88		.43	
9.31		.41	
1.23		.33	
1.60		.39	
.94		.30	
.69		.37	
.62		.54	
1.54		.38	
.34		.99	
.63		.73	
.18		.63	
.41		.91	
.35		.89	
.43		.26	
.54		.41	
3.88		.36	
1.08		.32	
2.82		.56	
2.35		.32	
2.07		.17	
1.84		.32	
1.00		.49	
2.18		.29	
7.57		.20	
.52		.43	
.99		.37	
1.02		.58	
.89		.49	
.83		.33	
1.10		.41	
2.3	average	.38	
		1.75	
		.26	
		.53	
		.45	
		.33	
		.22	
		.39	
		.86	
		.70	
		.74	base of section
		.5	average

6) Concentrically laminated phosphatic oolites or the nuclear portion of carbonate oolites.

7) Colloform cavity fillings. These may be secondary deposits formed after consolidation of the sediments.

ENVIRONMENT OF DEPOSITION

Permian rocks of the Adobe Range were deposited in shallow water in the central part of the Phosphoria sea. The term Phosphoria sea in this report refers to the body of water in which the Phosphoria Formation and equivalent marine sediments were deposited in eastern parts of Nevada, Idaho, and British Columbia and in western parts of Utah, Wyoming, Montana, and Alberta. It lay partly in the Cordilleran miogeosyncline and partly on the edge of the craton. Regional relations indicate the Phosphoria sea was a partly enclosed epicontinental seaway screened, but not entirely cut off, from the open ocean to the west (Ketner, 1977).

The eastern boundary of the Phosphoria sea was formed by the stable continental interior which was the site, in Permian time, of extensive low lands that supplied a small amount of fine-grained detritus to adjacent areas; platforms on which continental sediments accumulated; partly enclosed basins in which evaporites were deposited; and shallow, ephemeral seaways (McKee and others, 1967a, figs. 3-6, pl. 9).

The southern boundary of the Phosphoria sea was an area of increasingly positive tendency throughout Permian time. This uplift apparently reduced circulation which resulted, successively, in evaporite deposits of probable Leonardian age (Brokaw, 1967; Brokaw and Borash, 1968; Hose and Repenning, 1959; Steele, 1960); in the deposition of nonmarine red beds and the nonmarine Permian Coconino Sandstone; and erosion or nondeposition of Upper Permian rocks as indicated by the disconformity between the Kaibab Limestone of Leonardian age and the Moenkopi Formation of Early and Middle(?) Triassic age (McKee and others, 1967a, b).

The western boundary of the Phosphoria sea was formed by a north-trending belt of highlands in western Nevada and central or western Idaho (Ketner, 1977). These highlands were formed in late Middle Pennsylvanian time and persisted through the Permian. The Phosphoria sea is interpreted to have been nearly enclosed by land at the time of phosphate deposition.

A theory that relates phosphate deposits to upwelling oceanic waters was proposed by Kazakov (1937) and applied specifically to the Phosphoria Formation by McKelvey and others (1953). According to this theory, phosphate is deposited in unusual abundance where cold deep ocean waters rich in phosphorus well up and are warmed on the continental shelf. Warming of these waters expels CO_2 causing a decline in acidity and consequent precipitation of carbonates and phosphates. The data of the present report do not adversely reflect on the validity of processes invoked by the Kazakov theory but raise a question concerning the closeness of the relationship between upwelling oceanic waters and the deposition of phosphate.

The data cited in the present report indicate that large amounts of phosphate were deposited simultaneously more widely in the Phosphoria Sea than was formerly recognized, and they locate the principal site of possible upwelling oceanic waters in a position well outside the Phosphoria Sea. If the data and interpretations of this report are correct, phosphate can be deposited widely over the continental margin at a great distance from the ocean. The principal factor governing the formation of a phosphate deposit of commercial grade is not so much proximity to upwelling waters as the absence of diluents. The commercial phosphate deposits of southeastern Idaho were formed far from the sources of detritus, whereas the deposits of the Adobe Range were close to tectonic highlands and were, therefore, diluted by large amounts of non-phosphatic detritus.

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