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ATLAS OF METAL AND NONMETAL MINERAL PROVINCES, CONTERMINOUS U.S.
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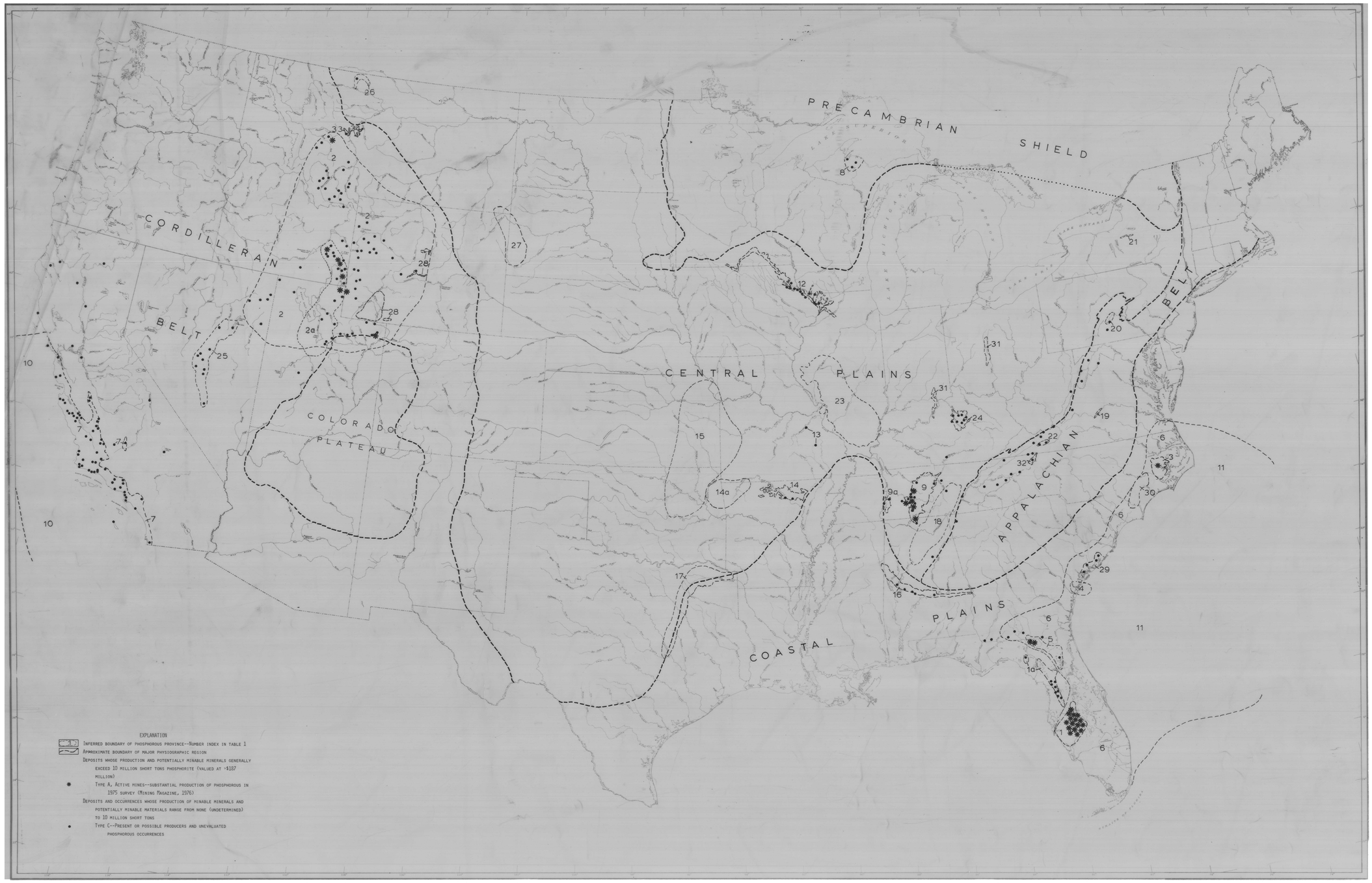
CATHCART AND TOOKER—PHOSPHOROUS



Planimetric base from National Atlas 1:7 500 000, 1970

SCALE 1:5 000 000

100 0 100 200 300 400 500 MILES

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PRELIMINARY MAP OF PHOSPHOROUS PROVINCES IN THE CONTERMINOUS UNITED STATES

BY

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Introduction

There are no substitutes for phosphorous, none is presently recycled, and most uses are dissipative, but shortages will be minimal because even when the present abundant supply of minable minerals in the conterminous United States is consumed, domestic potentially minable materials are available for development. Phosphorous is vital to plant growth, and almost 70 percent of total U.S. consumption is used in the fertilizer industry. The United States produced about 40 percent of world supplies in 1973; about 25 percent of the production that year was exported (U.S. Bureau of Mines, 1976). Demand for phosphate rock (containing an average of about 32 percent P_2O_5) in excess of 41 million short tons in 1975 (Mining Magazine, 1976) is expected to increase. Demand is expected to increase at an annual growth rate of 3 percent through the year 2000, according to Stowasser (1976), who discusses the economic availability of phosphate rock in detail. One important economic factor, concern for environmental protection, poses increasing problems for future production of phosphate rock, most of which is mined by open-pit methods. Severe, large-scale surface disruption and potential pollution of the environment will continue and may be accelerated when present subeconomic resources must be used.

The phosphorous province map locates district, mine, and unevaluated occurrences of rocks where phosphatic minerals are found, whether presently economic or not, and where will the best potential lies for the discovery of hypothetical deposits. Where appropriate, the map also shows the distribution of rock types and geologic structures that seem to be associated with the concentration of phosphorous.

The map was compiled from published reports (Barnes, 1970; British Sulphur Corporation, 1971; Brown, 1974; Clabaugh, 1964; Cannon and Klasner, 1976; Cobban and others, 1976; Gower and Nadeau, 1966; Gulbrandsen, 1966; King and Beikman, 1974; Love, 1964; Milton and others, 1968; Rogers and others, 1970; and Tourtelot and Cobban, 1968), and unpublished information from phosphate resource specialists. The assistance of R. A. Gulbrandsen, W. G. Gere, D. W. Hedge, and R. G. Roberts in identifying western phosphate regions is appreciated. The geologic data are from the Geologic Map of the United States (King and Beikman, 1974). The rationale for province maps and some of the technical terms used, which may be unfamiliar, are discussed and defined in a companion background report by Tooker (1979).

Characteristics of phosphate provinces

The map shows the distribution of known and potential phosphorous provinces and areas containing or expected to contain anomalous concentrations of phosphate rock. The boundaries may enclose areas of known deposits ranging from a single mine or occurrence to a broad regional mining district or belt, known presently subeconomic occurrences as well as evidence of anomalously high geochemical accumulations, and geologic environments favorable for phosphate rock depositions.

A large deposit, as defined here, is one that has produced a minimum of 10 million short tons, roughly one-third of a year's supply of primary phosphate rock. Type A are large mines that are active in 1975 and producing substantial amounts of phosphate, according to the international survey of mining (Mining Magazine, 1976). Type B, which would be the large inactive phosphate deposits in 1975 (considered mined out, temporarily shut down, deposits now producing at a much reduced level, or known but undeveloped future producers), cannot be shown owing to incomplete information. Small deposits and occurrences constitute the large type C group whose total production and minable mineral supplies range from none determined to 10 million short tons but for which additional resource development is possible. For some, no production data may be available, and these represent as yet unevaluated occurrences.

Minable concentrations of phosphate occur in sedimentary and igneous rocks. The main domestic source is in sedimentary phosphorite, a rock composed principally of pelletal apatite, which was deposited in a marine environment. The sedimentary accumulations of phosphorite, generally formed at low latitudes, are of three main types: (1) phosphorite beds deposited in shallow, subsiding geosynclinal basins and associated with black shale, dolomite, chert, and stratigraphically equivalent saline minerals; and (2) phosphorite beds deposited on broad, shallow continental shelves and associated with black shale or chert formed along the continental shelf or in coastal zones where submarine currents and leaching by weathering processes may rework and concentrate the phosphate; and (3) phosphate nodules in carbonate, shale, and sandstone that are deposited on stable shelves or in continental interior basins and commonly associated with glauconite. The three types of deposits range in age from Precambrian to Holocene (offshore). Only a part of the subeconomic deposits are listed on table 1, but the ones there serve to represent a vitally important future resource about which more information is needed.

A number of lesser sources of phosphorous include the following: Guano, the excrement of bats in caves or of birds, is negligible as a domestic source of phosphate. Phosphate also occurs as the mineral apatite in a variety of intrusive igneous rocks closely associated with iron (ilmenite and magnetite) deposits and peripheral to igneous bodies where hydrothermal solutions derived from late stages of the intrusion deposit apatite in veins and as disseminations in replaced host rocks. Igneous apatite deposits are of minor importance in the conterminous United States but provide a substantial source of phosphorous in Africa, South America, and the U.S.S.R. Detailed characteristics of the geologic habitats for phosphorous occurrences are discussed by Cathcart and Gulbrandsen (1973).

Phosphorous provinces

We identify 34 certain and possible phosphate provinces in the conterminous United States, but only the first few provinces listed in approximate order in table 1 are economically significant today. There may be additional occurrence types that are not included here. There are 32 type A deposits located in seven states (Mining Magazine, 1976); Florida continues to be the major producer of domestic phosphate rock.

The Coastal Plains region, which are the most favorable sites for the occurrence of Cenozoic phosphorites, contain nine provinces or potential province areas and a major province (9) embracing all the others in which phosphate is ubiquitously present and where many potentially economic deposits are already known. The Central Plains region, which includes the economic deposits of central Tennessee, also includes a number of subeconomic and poorly understood provinces related to phosphatic shale horizons that are of Paleozoic and Mesozoic age. Province 13 is of considerable interest because the tailings from the processing of the Pea Ridge, Mo., iron deposits are, in effect, an apatite concentrate. Moderate tonnages of apatite are also available as a byproduct of the iron mine.

The Cordilleran Belt is next in importance because of the phosphate deposits in the Phosphoria formation, but the region also includes a number of other future resource possibilities ranging in age from Precambrian to Cenozoic. Recent discoveries of possibly significant deposits in the Precambrain shield (province 7) indicate a moderate potential for future resources of phosphate. The Appalachian belt seems to have very limited potential as a source for future phosphorous resource, but along its western borders in the Southern and central part it does include a variety of types of possible deposits.

The offshore regions of the Pacific Ocean (province 10) appear to offer possibilities of extensions of coastal phosphatic shale deposits as well as more recently formed nodules. The Atlantic Ocean offshore deposits (province 11) are buried extensions of the land deposits (phosphatic limestone and sandstone) and also include modern phosphatic sediments, in which the phosphate has been reworked from older deposits.

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Table 1.--*Location, estimates of measure potential and status of measure information of phosphorous provinces in the conterminous United States*

Province No.	Province State	Province Area or rock unit	Geologic types of deposits	Preliminary estimates of resource potential High	Medium	Low	Status of geologic information for resource assessment Adequate	Inadequate	At present considered subeconomic
1	Florida	Lakeland	Land pebble phosphate.	X	--	--	X	--	X
1a			"Hardrock" phosphate	--	X	--	X	--	X
2	Idaho, Utah, Wyoming, and Montana	Phosphoria formation	Phosphorite.	X	--	--	X	--	---
2a	Idaho and Utah	Mississippian formations	Phosphorite.	--	--	X	--	X	X
3	North Carolina	Lee Creek	Phosphate.	X	--	--	--	X	--
4	South Carolina and Georgia		Sandy phosphorite.	X	--	--	--	X	X
5	Florida and Georgia	White Springs	Sandy phosphorite.	--	--	--	--	X	--
6	North Carolina, South Carolina, Georgia, and Alabama	Coastal Plain region	Hypothetical extensions of 1, 4, 5, 7, and 10.	X?	--	--	--	X	--
7	California	Southwest coast	Phosphatic shale.	X	X	--	--	X	X
8	Michigan	Bays of Ravenswood	Phosphatic shale and sandstone.	--	X	--	--	X	X
9	Tennessee	Central	Phosphatic limestone and sandstone and phosphate.	--	--	X	X	--	---
9a		West-central	Secondary phosphate.	--	--	X	--	X	X
10	Pacific Ocean	Undersea: Southern California coast	Phosphatic nodules.	---unknown---			--	X	X
11	Atlantic Ocean	Undersea: North Carolina to Southern Florida	Phosphatic limestone and sandstone.	---unknown---			--	X	X
12	Iowa, Minnesota, Missouri, and Illinois	Maquoketa Shale	Phosphatic shale and siltstone.	--	X	--	X	--	X
13	Missouri	Pea Ridge-Iron Mountain	Igneous apatite.	--	X	--	X	--	(byproduct)
14	Arkansas	Cason	Phosphatic shale.	--	X	--	--	X	X
14a		Fayetteville	Phosphatic shale.	unknown (large?)			--	X	X
15	Kansas, Oklahoma, and Missouri		Phosphatic nodules in shale and limestone.	unknown (medium?)			--	X	X
16	Alabama	Central	Phosphatic nodules in limestone or sandstone.						
17	Texas		Phosphatic nodules in limestone or sandstone.	--	--	X	--	X	X
18	Eastern Tennessee, Georgia, and northern Alabama	Chattanooga Shale	Phosphate in black shale.	X?	or X?	--	--	X	X
19	Virginia	Central	Nelsonite (apatite-ilmenite).	--	--	X	--	X	X
20	Pennsylvania	Central	Phosphatic nodules in sandstone, shale, and chert.	--	--	X	--	X	X
21	New York	Central	Phosphatic nodules.	--	--	X	--	X	X
22	Virginia	Western	Phosphatic nodules in shale, sandstone, quartzite, and limestone-cobble.	--	--	X	--	X	X
23	Illinois	Illinois Basin	Shale and limestone with phosphate.	--	X?	--	--	X	X
24	Kentucky	Cincinnati arch	Phosphatic limestone and residual phosphate.	--	--	X	--	X	X
25	Nevada	Central Great Basin	Phosphorite.	--	--	X	--	X	X
26	Montana	Sweetgrass arch		---unknown---			--	X	X
27	South Dakota, Nebraska, Wyoming, and Montana		Phosphorite	--	--	X	--	X	X
28	Wyoming		Transitrous phosphatic lakebeds.	--	--	X	--	X	X
29	South Carolina		Phosphate nodules.	--	--	X	--	X	X
30	North Carolina	Castle Hayne Formation	Phosphatic nodules in limestone.	--	--	X	--	X	X
31	Indiana and Ohio	New Albany Shale and Ohio Formations	Phosphatic shale.	--	--	X	--	X	X
32	Tennessee	Ocoee Supergroup	Phosphatic minerals in manganese mine, in shale, and in phosphatic-cobble limestone.	--	--	X	--	X	X
33	Montana	Belt Supergroup	Phosphorite in dolomite and siltstone.	---unknown---			--	X	X
34	Montana	Choteau 1° quadrangle	Phosphorite in Lower Mississippian siltstone.	---unknown---			--	X	X

Background information relating to this map and others in the Atlas of Metal and Nonmetal Provinces in the Conterminous United States is published as U.S. Geological Survey Circular 792 (Tooker, 1979), available free of charge from the U.S. Geological Survey, Reston, Va., 22092

This report is preliminary and has not been edited or reviewed for conformity with Geological Survey standards and nomenclature.