GEOLOGICAL SURVEY CIRCULAR 746

Phosphorite and Other Apatite-Bearing Sedimentary Rocks in the Precambrian of Northern Michigan

Report prepared in cooperation with

Geological Survey Division,

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Phosphorite and other apatite-bearing sedimentary rocks in the Precambrian of northern Michigan

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ABSTRACT

Phosphatic pebbles are widespread in basal units of the Marquette Range Supergroup (Precambrian X) in the central part of the Upper Peninsula of Michigan. At one locality, a conglomeratic bed about 15 m thick averages about 15 percent P_2O_5, and many thinner beds are of comparable grade. This occurrence is believed to be the richest sedimentary phosphate deposit known in the Precambrian of the United States, as well as one of the oldest. Although outcrops are generally scarce, similar material has been found at four other localities in the Upper Peninsula of Michigan.

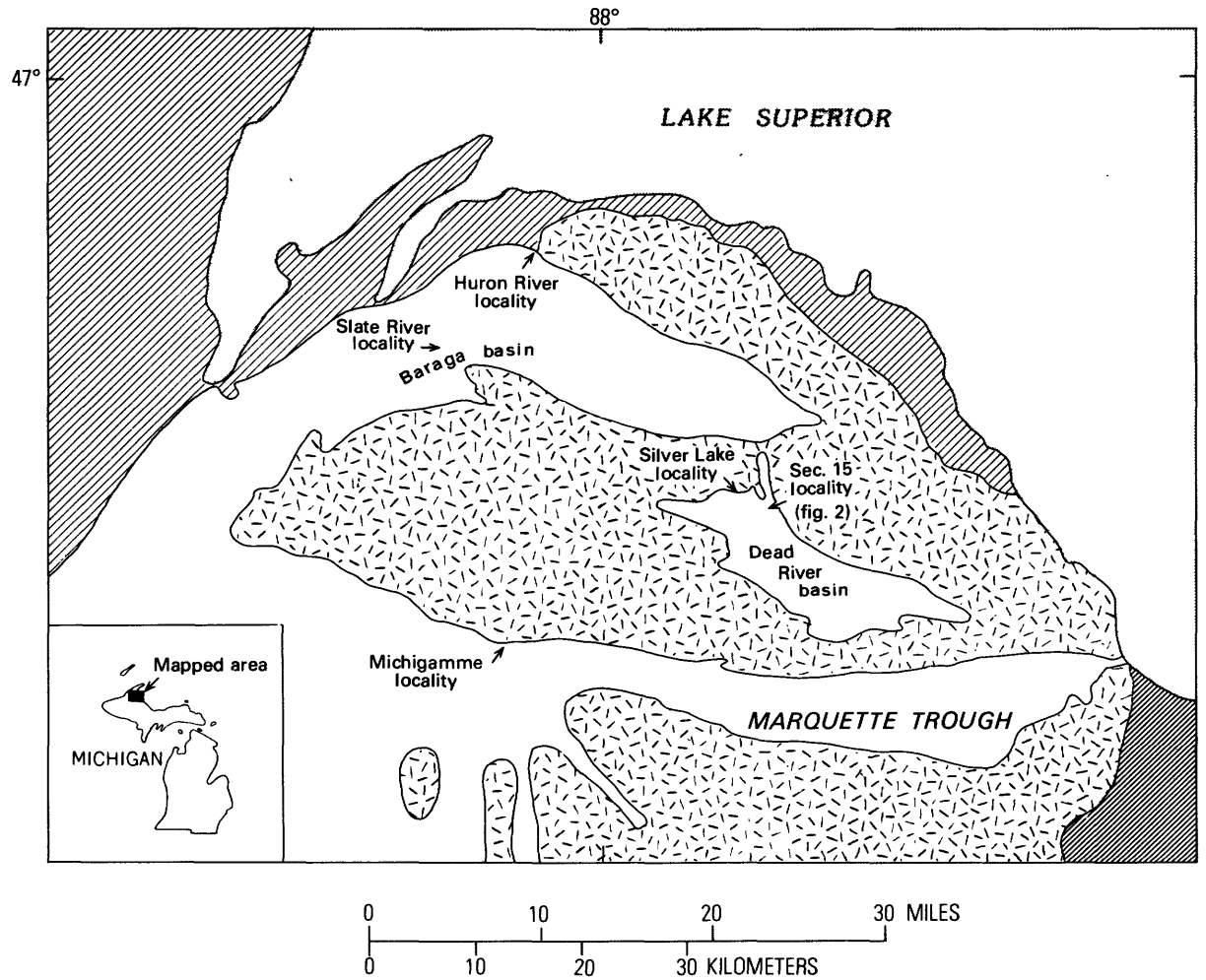
INTRODUCTION

Although phosphate-rich sedimentary rocks of commercial grade are known at many places in the United States and throughout the world, phosphate-bearing sedimentary rocks in the Precambrian of the United States are rare; none that approach economic grade have been known previously. We have recently discovered that pebbles of apatite are relatively widespread in basal units of the middle Precambrian (Precambrian X) Marquette Range Supergroup in the central part of the Upper Peninsula of Michigan (fig. 1) and have found one locality (Sec 15 locality) where a bed about 15 m thick averages about 15 percent P_2O_5 and where many other thinner beds are of comparable grade. This occurrence is believed to be the richest sedimentary phosphate deposit known in the Precambrian of the United States, as well as one of the oldest. Mancuso, Lougheed, and Shaw (1975) reported beds of carbonate-apatite in carbonate iron-formation at about the same stratigraphic horizon in nearby areas.

The purpose of this paper is to call these occurrences to the attention of those interested in the geology and mineral exploration of the area and to provide information to assist them in the further field examination of the phosphate-bearing rocks. Our research on these deposits is continuing.

GEOLOGIC NATURE AND SETTING OF THE DEPOSITS

All known occurrences of phosphate-bearing rocks reported here are in metasedimentary rocks of the Marquette Range Supergroup, about 2 billion years old, and stratigraphically near the basal unconformity with lower Precambrian (Precambrian W) gneiss and greenstone. The two occurrences reported previously (Mancuso and others, 1975) are beds of carbonate-apatite in lean carbonate iron-formation near the base of the Baraga Group in the Baraga basin (Huron River and Slate River localities, fig. 1). The three new localities reported here differ from these earlier known beds in that most phosphate is in well-rounded pebbles commonly 1 to 3 cm long in beds of conglomerate. At the Silver Lake and Michigamme localities, the pebbles are in a basal conglomerate within a meter or two of the unconformity with Precambrian W gneiss and are only a minor component of the rock. At the Section 15 locality, the pebbles of phosphate are the major component of conglomeratic zones throughout the lowermost 100 m of the sedimentary section; one bed is as much as 15 m thick. The pebbles are black and very fine grained. On fresh surfaces, they are difficult to distinguish from fragments of black slate. On weathered surfaces, the phosphatic pebbles weather into negative relief and have a characteristic light-



EXPLANATION

LOWER PALEOZOIC SEDIMENTARY ROCKS—Mostly flat-lying sandstone

JACOBSVILLE SANDSTONE—Flat-lying sandstone and shale, probably of Keweenawan age (Precambrian Y)

MARQUETTE RANGE SUPERGROUP (PRECAMBRIAN X)—Metasedimentary and metavolcanic rocks. Phosphate deposits are near base

GRANITIC GNEISS AND GREENSTONE (PRECAMBRIAN W)

Contact

FIGURE 1.—Geologic sketch map of the central part of the northern peninsula of Michigan showing the location of five occurrences of phosphate-bearing rocks.

gray to white chalky coating. In this respect, they resemble limestone or dolomite and were originally mistaken for carbonate pebbles by us.

The Michigamme locality is in the Ajibik Quartzite, the basal unit of the Menominee Group. All other occurrences are near the base of the Baraga Group, which unconformably overlies the Menominee Group, although the Menominee Group is not present in the areas of the Baraga Group phosphate localities.

DESCRIPTION OF OUTCROPS

SECTION 15 LOCALITY

The Section 15 locality is in the NE¼, sec. 15, T. 49 N., R. 28 W. There, on a low topographic knob, outcrops of rock in the lowest 200 m of the Baraga Group are relatively abundant, and phosphate-bearing beds of some economic potential are abundant in a stratigraphic unit 90 to 100 m thick. The unit is underlain by massive to thick-bedded dolomitic quartzite (fig. 2), which is the basal unit of the Baraga Group; the unit is overlain by greenish-black thinly laminated argillite. Bedding strikes about N. 70° W. and dips 70°–80° SW. Phosphate beds contain well-rounded flat pebbles of black aphanitic apatite. Diameter:height ratios of pebbles are mostly 3:1 to 5:1, and the largest pebbles are about 10 cm long. The pebbles are in a matrix of fine-grained quartz sand, which in the richest beds also includes abundant apatite. Muscovite and pyrite are common in small amounts, generally a percent or two. The apatite pebbles weather into negative relief and are coated with a grayish-white-weathering residue. Interbedded with the phosphate-rich beds is black to light-gray chert and less commonly argillite and arkosic quartzite.

The richest beds contain 40 to 60 percent apatite and about 15 percent P_2O_5. In spite of relatively abundant outcrops (fig. 2), thin soil cover obscures much of the bedrock, and our data do not completely characterize the P_2O_5 content of the entire unit. What follows is a general appraisal of the unit based on field observations and limited assays.

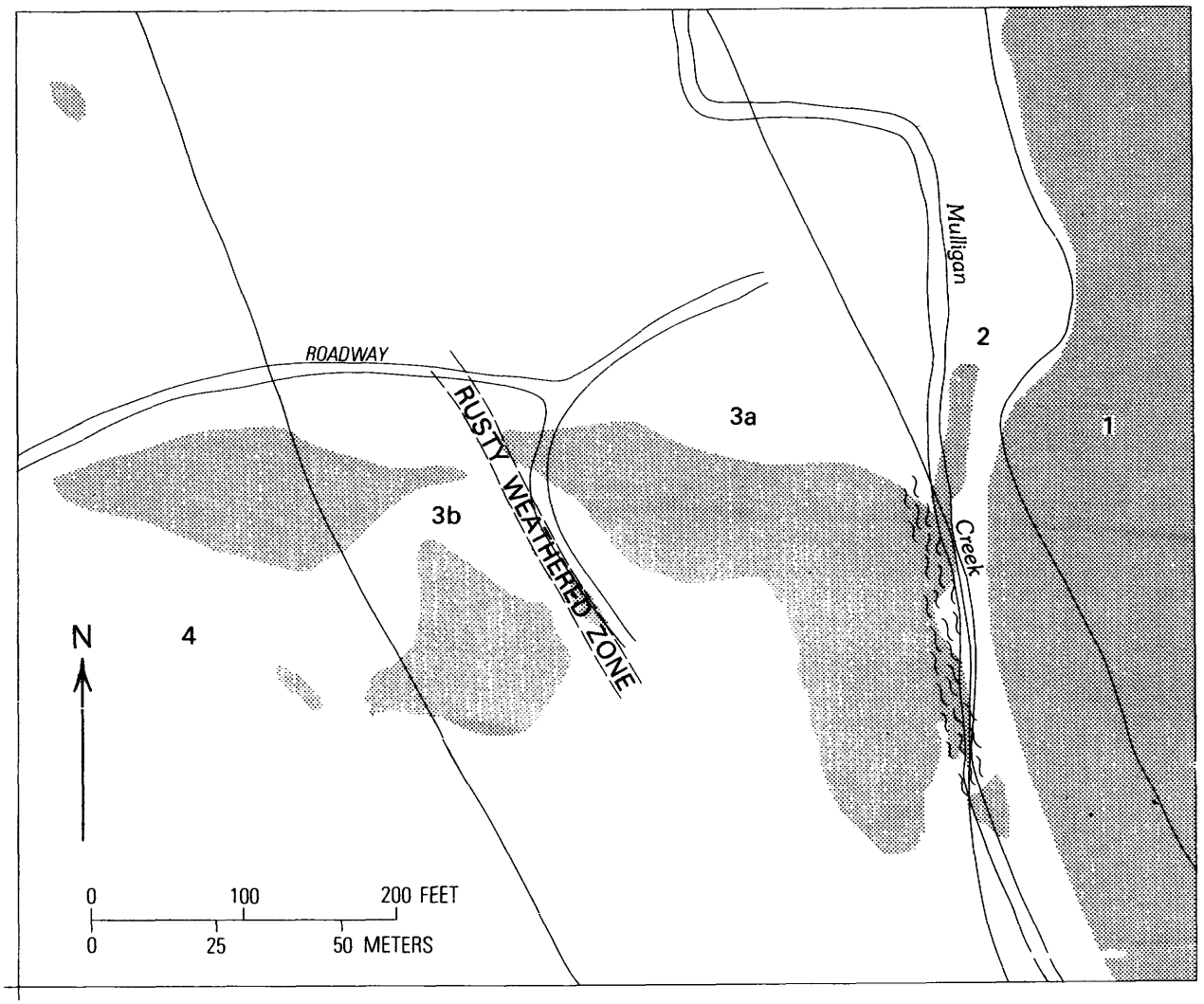
The lowest 45 m of the unit (lower part of unit 3a in fig. 2) contains many rich beds of phosphatic rock about 0.1 to 2 m thick, which, by comparison with other assayed beds, contain as much as 15 percent P_2O_5; however, they are widely interspersed in cherty beds. Two composite chip samples, representing about 20 of the 45 m, contain 4 to 5 percent P_2O_5.

Stratigraphically above this unit is a unit 25 to 30 m thick (upper part of unit 3a) that in outcrops is very poor in apatite pebbles and was not assayed. It is overlain by a rusty-weathering unit about 5 m thick which contains abundant carbonate rhombs and pyrite and for which a composite chip sample indicates about 9 percent P_2O_5.

The richest unit (lower part of unit 3b) is immediately above the rusty zone. A composite chip sample representing about the lowest 15 m of unit 3b contains slightly more than 15 percent P_2O_5. The uppermost part of the unit (upper part of 3b), about 30 m thick, is known from field examination to contain many phosphate-rich beds, but it has not been adequately sampled. Two composites of two and three grab samples contain only about 0.5 percent P_2O_5, which, from field observations, we believe is not representative of this part of the section; the P_2O_5 content is probably considerably higher. High scintillometer readings, typically produced by apatite-rich beds, were measured over parts of the uppermost 30 m of section, and a scintillometer profile measured across the outcrop indicates that this uppermost part of the section also contains considerable apatite.

The limited sampling indicates that the P_2O_5 content of the entire 100-m-thick unit is 5 to 10 percent but that individual beds, the thickest being at least 15 m, contain about 15 percent. The outcrops are somewhat weathered, and apatite has been preferentially dissolved out of the siliceous matrix. Although we attempted to avoid the most deeply weathered material in our sampling, this preferential solution may have resulted in lower assays than would be characteristic of unweathered rock.

Samples were also analyzed for 65 elements by a semiquantitative spectrographic technique. The richest apatite unit contains about 120 ppm cerium and about 200 ppm yttrium, but no other anomalous values were detected. The apatite-rich beds are radioactive, generally producing readings of two to three times background, measured on the outcrop, and show a slight trend toward being more radioactive in strati-



Approximately 180 m south and 240 m west to center of sec. 15, T. 49 N., R. 28 W.

EXPLANATION

PRECAMBRIAN

X

4 — Thinly laminated gray-green argillite

3 — Phosphate-bearing unit—a, gray to black banded chert containing beds 0.1–2 m thick of pebbly phosphate rock. b, mostly pebbly phosphate rock containing some cherty beds

2 — Rusty-weathering dolomitic quartzite

W

1 — Greenstone and granitic gneiss

Contact

Sheared zone

Area having abundant outcrops

FIGURE 2.—Sketch map of the Section 15 locality showing the distribution of outcrop areas and contacts between lithologic units.

graphically higher units. No uranium was detected in the semiquantitative analyses, but the method is very insensitive to uranium, the limit of detection being 320 ppm.

SILVER LAKE LOCALITY

Along the north shore of Silver Lake in the NW¼, sec. 8, T. 49 N., R. 28 W., are many exposures of the basal units of the Baraga Group and of the Precambrian W gneisses, on which the Baraga Group rests unconformably. The roughly planar unconformity dips southeastward toward the lake, so that only the lowermost meter or two of the Baraga Group is exposed above lake level. The sedimentary rocks are mostly poorly sorted conglomerate, mostly of local derivation, containing clasts of gneiss and vein quartz, but shaly beds are also present. Phosphate occurs in rare, well-rounded pebbles composed of very fine grained apatite. The pebbles are as much as 2 cm long and etch away selectively, leaving a characteristic chalky-white-weathering coating. No concentrations approaching commercial grade have been found, but only the lowermost beds of the section are exposed; richer beds might be found higher in the section beneath the lake.

MICHIGAMME LOCALITY

At the Michigamme locality in the NW¼, sec. 24, T. 48 N., R. 31 W., phosphate is mostly in well-rounded apatite pebbles, but thin (~1 cm) beds of apatite have also been recognized. Outcrops can be reached from a gravel road leading from U.S. 41 to Keewaydin Lake. About 1.1 km north of U.S. 41, steep south-facing bluffs of Precambrian W granitic gneiss rise abruptly from nearly featureless lowlands of glacial outwash. The lowlands are underlain by Ajibik Quartzite and Siamo Slate of the Menominee Group, but outcrops are extremely sparse (Klasner and Cannon, 1974). Within about 200 m east and west of the road, the basal conglomerate of the Ajibik Quartzite can be seen along the base of the bluffs. This conglomerate lies on gray-green sericitic rock, probably a regolith, which grades downward into granitic gneiss. The conglomerate is very crudely bedded, dipping about 60° S., and contains clasts of vein quartz, gneiss, older quartz-pebble conglomerate, and apatite. The matrix is quartzose and contains disseminated pyrite and magnetite grains. Apatite in both pebbles and beds is extremely fine grained and difficult to identify, even with a microscope, but nowhere does it appear to compose more than about 1 percent of the rock. Only the basal 1 to 2 m of the sedimentary section is exposed here, and because of the lack of outcrops, neither the lateral extent of the conglomerate along strike nor the possibility that it becomes more phosphate-rich up section can be determined.

HURON RIVER AND SLATE RIVER LOCALITIES

The Huron River locality is in the bed of the Huron River in the NW¼, sec. 35, T. 52 N., R. 30 W. The Slate River locality is west of the Slate River near the center of sec. 28, T. 51 N., R. 31 W. These two occurrences were described by Mancuso, Lougheed, and Shaw (1975). Carbonate apatite occurs as laminated brownish-black beds in a cherty carbonate iron-formation about 20 m thick near the base of the Baraga Group. The apatite beds contain traces of calcite and variable amounts of pyrite (0–25 percent).

POSSIBILITY OF ADDITIONAL DEPOSITS

All presently known phosphate-bearing localities, which are roughly within a circle 40 km in diameter, were found "accidentally" during reexamination of field notes and hand specimens in the laboratory or office. None were identified initially in the field. The fact that five localities have been found through such a cursory examination and that outcrops are very sparse suggests that phosphate-bearing rocks may be fairly common and widespread in the area. On the basis of the exposed rocks, only one locality seems to have economic potential; however, so little is known of the rocks beneath the glacial cover that at present the potential cannot be fully determined. At both the Silver Lake and Michigamme localities, outcrops are restricted to the lowest 1–2 m of the sedimentary section, and the nature of the overlying sediments is unknown. Because at the Section 15 locality, the richest beds are well above the basal unconformity, similar rich beds might be present at these other localities.

The stratigraphic horizons of interest, the lower 100–200 m of the Precambrian X section, are so poorly exposed throughout the region (only a very small fraction of 1 percent of these rocks crops out) that the Section 15 locality is unlikely to be the only rich deposit or the best deposit in the region, especially because the phosphate-rich rocks tend to weather rapidly. We suggest, therefore, that other phosphate-rich units may well be present beneath the glacial cover in this area.

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