GEOLOGICAL SURVEY CIRCULAR 882

Sedimentary Phosphate Resource Classification System of the U.S. Bureau of Mines and the U.S. Geological Survey

Sedimentary Phosphate Resource Classification System of the U.S. Bureau of Mines and the U.S. Geological Survey

GEOLOGICAL SURVEY CIRCULAR 882

1982

United States Department of the Interior
JAMES G. WATT, *Secretary*

Geological Survey
Dallas L. Peck, *Director*

Library of Congress catalog-card No. 82-600634

Free on application to Distribution Branch, Text Products Section,
U. S. Geological Survey, 604 South Pickett Street, Alexandria, VA 22304

CONTENTS

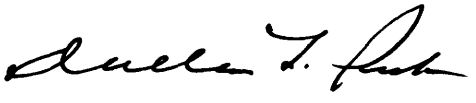
ILLUSTRATIONS

FOREWORD

In order to use mineral resource terms with precision and common understanding and to compare resource data effectively, a joint U.S. Bureau of Mines and U.S. Geological Survey working group developed a standardized, definitive, broadly applicable classification system to derive uniform, coordinated resource estimates. The *principles* of the system are given in U.S. Geological Survey Circular 831, and this supplementary report presents the criteria for classification of phosphate resources. The subcommittee preparing this report consisted of William B. Hall, Cochairman, William F. Stowasser, and Gary A. Kingston of the U.S. Bureau of Mines, and Richard P. Sheldon, Cochairman, David F. Davidson, and Thomas Leshendok of the U.S. Geological Survey. Many other geologists and engineers participated in the work, and particularly helpful were James B. Cathcart and Robert A. Gulbrandsen.

Approved:

Director, Bureau of Mines



Director, Geological Survey

Sedimentary Phosphate Resource Classification System of the U.S. Bureau of Mines and the U.S. Geological Survey

INTRODUCTION

The availability of phosphate resources to support domestic phosphate fertilizer supply and the U.S. phosphate export industry has been questioned for a number of years. Discussion of this problem has tended to center mistakenly around "optimistic" and "pessimistic" resource estimates. However, on detailed analysis of the various estimates of phosphate, the differences between estimates are commonly due more to differences in what is being estimated than in how much is there. One resource scientist/engineer may give a large figure but include rock that is only potentially available along with the rock currently available, while another scientist/engineer may limit his estimate to only the currently available rock. Differences in estimates may relate to differences in areas treated, differences in price assumptions or mining technology assumptions, differences in quality of phosphate rock for use in different ore processing or fertilizer manufacturing technology, differences in geologic assurance of existence or measurement, differences between the sets of data used in making the estimates, and finally differences in the methodology of assessing the resource.

Difficulties in producing compatible phosphate resource estimates occur because of imprecise technical language, which has been confusing to the specialist as well as the nonspecialist. A sedimentary phosphate resource classification system is presented here to provide a pathway out of the jungle of confused terminology and to permit real differences between scientific/engineering estimates to be identified and analyzed.

The principles of this classification system have been presented in U.S. Geological Survey Circular 831, published in 1980 and jointly prepared by the U.S. Bureau of Mines and the U.S. Geological Survey. It should be made clear that the purpose of this sedimentary phosphate resource classification system is to facilitate the assessing of national phosphate rock resources.

The phosphate reserve and inferred reserve on federally owned lands must be assessed and evaluated by the U.S. Department of the Interior for the purpose of leasing to private developers. This activity may seem to be similar to the activity of assessing the national phosphate rock resource, but it is much more restrictive. First, only federally owned lands are studied for the leasing program; phosphate rock resources on other lands are ignored. Second, the evaluation of federally owned lands requires establishing the reserves to at least an inferred level. Thus, an economic analysis of the lease tracts must be made. National phosphate resource assessment, on the other hand, requires an estimate of the reserve base and inferred reserve base, that is, the physically determined body of rock from which reserves and inferred reserves are calculated. Thus, the reserve base must always be larger than the reserve, and the inferred reserve base must always be larger than the inferred reserve. Therefore, this set of resource definitions, which deals with the national phosphate rock resources, is largely irrelevant to the lease tract evaluation of phosphate lands.

In the following section, resource/reserve definitions relative to phosphate rock are presented, along with criteria for each resource class. The criteria were made to relate to current industrial practice as much as possible. It should be emphasized that the criteria for the resource classes are arrived at by using parameter limits currently in use by industry. However, industry practices vary somewhat from mine to mine and from district to district. Also, trade-offs between parameters are possible; for example, richer ore may sometimes be mined in thinner beds than stipulated in the criteria, or blending of two ores, each with one parameter below the criteria, may give a mixture that is within the criteria. Thus, these criteria are only guidelines that may be replaced for specific

deposits by parameter limits reached through detailed studies. As the high-grade phosphate rock is depleted, technology will change to allow the mining and processing of lower quality rock, if favorable economics permit. This would result in changing the classification criteria for the resource classes.

The two main phosphate provinces in the United States are the southeastern province, from Florida to North Carolina, and the northwest province of southeastern Idaho and the adjacent States of Montana, Wyoming, and Utah. These two provinces accounted for 97 percent of the U.S. 1980 phosphate rock production and contain the overwhelming share of U.S. phosphate resources. Only these two provinces have been treated in this study. Due to differences in the physical characteristics of the deposits, somewhat different technologies of mining and processing have been developed for the two districts, making it necessary to establish different sets of classification criteria for the respective districts. Also, the criteria for identification of resource classes are made considering only major industry economics and technology. Thus, small mining operations that operate on different criteria are excluded.

RESERVE/RESOURCE DEFINITIONS

The classification system is based on two fundamental aspects of mineral resources (fig. 1; McKelvey, 1972): first, how well known and well measured the deposit is (degree of geologic assurance), and, second, how feasibly a deposit can be brought into production with existing mining and processing technology at existing prices (feasibility of economic recovery). The criteria for classifying resources according to those two aspects, of course, differ and are treated below, with reference to figures 2*A* and 2*B*. Summary diagrams showing the resource class criteria for the southeast and northwest provinces are given in figures 3 through 5.

DEGREE OF GEOLOGIC ASSURANCE

Phosphate resources are broken into two groups, identified and undiscovered.

Phosphate Identified Resources.—Phosphate resources whose location, grade, quality, and quantity are known or estimated from specific geologic evidence. To reflect varying degrees of geologic certainty, phosphate identified resources can be subdivided into demonstrated and inferred resources.

(Phosphate Identified Resources—Continued)

Phosphate Demonstrated Resources.—A term for the sum of measured plus indicated resources.

Phosphate Measured Resources.—Quantity is computed from dimensions revealed by outcrops, trenches, workings, or drill holes; grade and (or) quality are computed from the results of detailed sampling. The sites for inspection, sampling, and measurement are spaced so closely and the geologic character is so well defined that size, shape, depth, and phosphate content of the resource are well established.

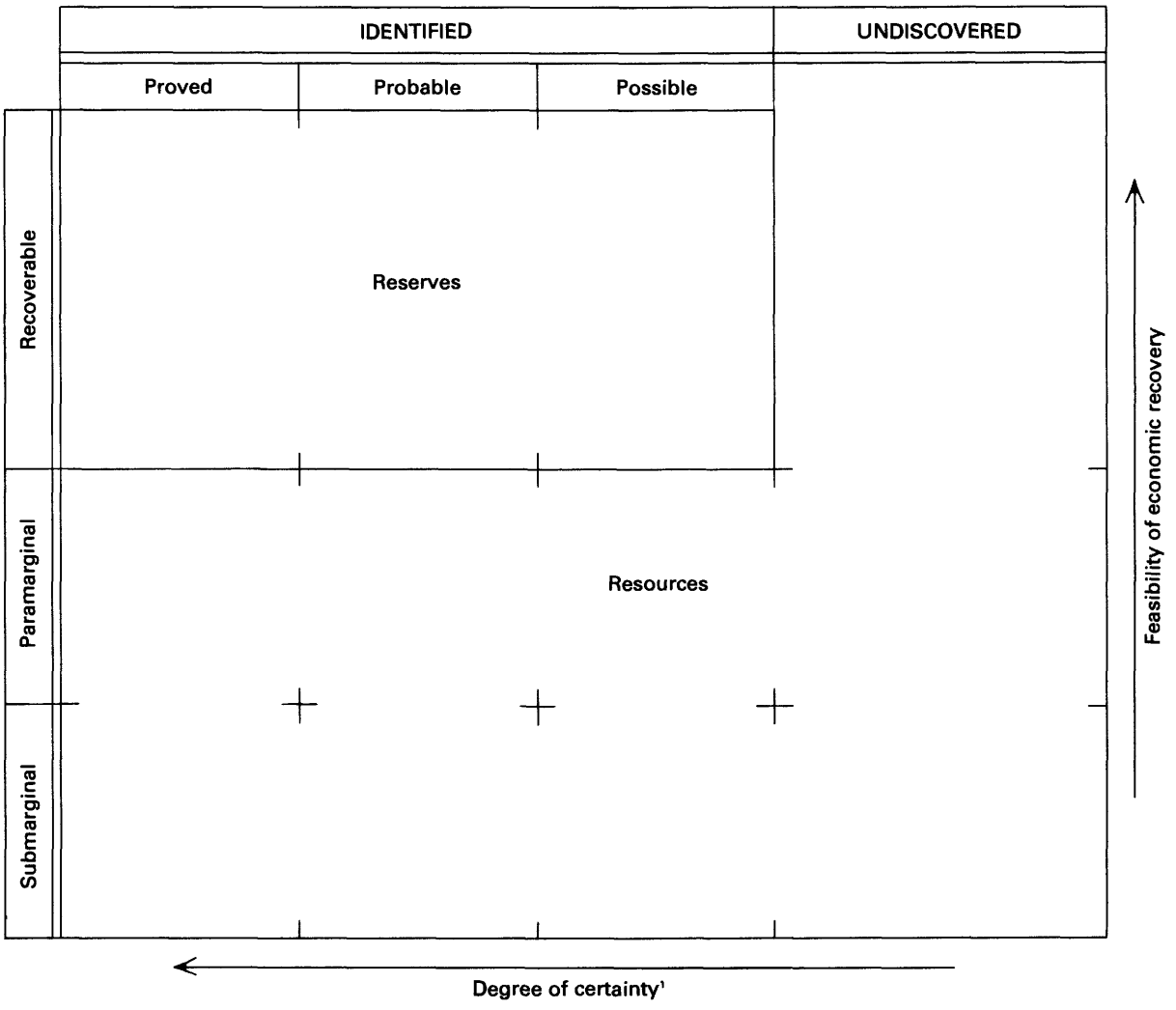
Criteria for classification: The delineation of measured resources is the function of industry and often is proprietary. No criteria have been set in this paper for this resource class. The criteria generally used in industry are a sampling density of more than 64 boreholes per square mile.

Phosphate Indicated Resources.—Quantity and grade and (or) quality are computed from information similar to that used for measured resources, but the sites for inspection, sampling, and measurement are farther apart or are otherwise less adequately spaced. The degree of assurance, although lower than that for measured resources, is high enough to assume continuity between points of observation.

Criteria for classification: At least four boreholes or measured stratigraphic sections per square mile or no more than 0.5 mile between holes.

Phosphate Inferred Resources.—Estimates are based on an assumed continuity beyond measured and (or) indicated resources for which there is geologic evidence. Inferred resources may or may not be supported by samples or measurements.

Criteria for classification: At least one hole or measured stratigraphic section per square mile or no more than 1 mile between boreholes. A greater distance between holes may be used if, in the considered judgment of the resource geologist, geologic inference allows.



[1]The "degree of uncertainty" was replaced by "degree of geologic assurance" in USGS Circular 831.

FIGURE 1.—Classification of mineral reserves and resources. Degree of uncertainty increases from right to left, and feasibility of economic recovery increases from bottom to top. From McKelvey, 1972.

Phosphate Undiscovered Resources.—Phosphate resources whose existence is only postulated. Two categories of phosphate undiscovered resources exist, hypothetical and speculative.

Phosphate Hypothetical Resources.—Phosphate undiscovered resources that are similar to and may be hypothesized extensions of known phosphate bodies and that may be reasonably expected to exist in the same producing district or region under analogous geologic conditions. If exploration confirms their existence and reveals enough information about their quality, grade, and quantity, they will be reclassified as identified resources.

Criteria for classification: That part of a deposit more than 1 mile away from a bore-

(Phosphate Undiscovered Resources—Continued)
(Phosphate Hypothetical Resources—Continued)
hole or a measured stratigraphic section of that deposit, or a farther distance away from such a point source if, in the considered judgment of the resource geologist, geologic inference allows.

Phosphate Speculative Resources.—Undiscovered phosphate resources that may occur either in known types of deposits in favorable geologic settings where phosphate discoveries have not been made or in types of deposits as yet unrecognized for their economic potential. If exploration confirms their existence and reveals enough information about their quantity,

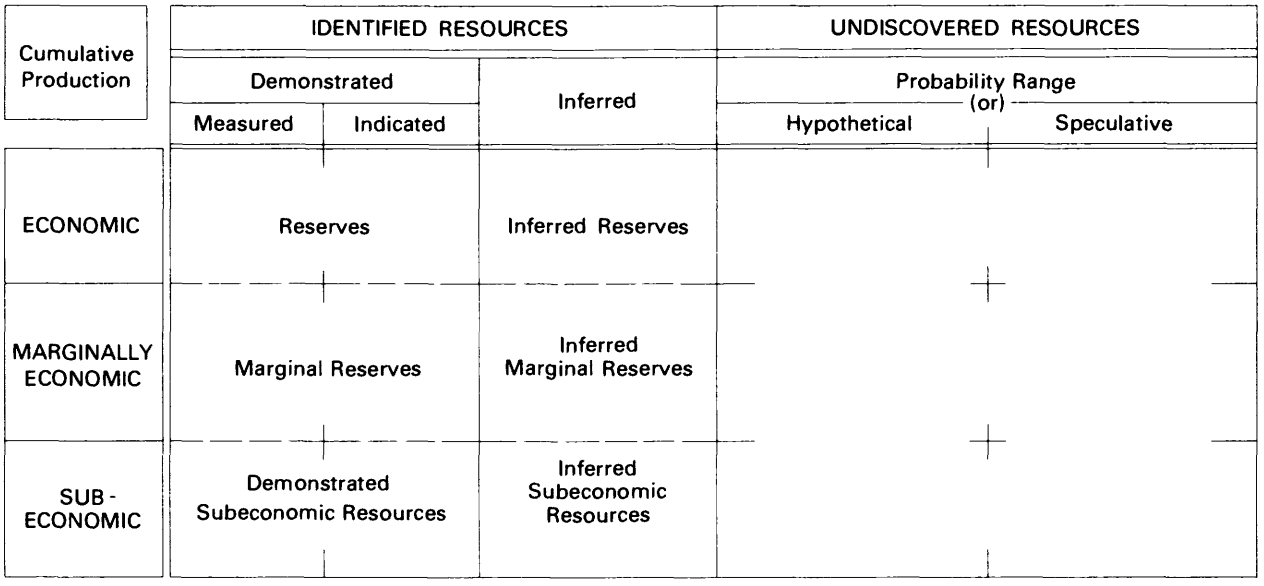


FIGURE 24.—Major elements of mineral-resource classification, excluding reserve base and inferred reserve base. From U.S. Geological Survey Circular 831.

(Phosphate Undiscovered Resources—Continued)
(Phosphate Speculative Resources—Continued)
grade, and quality, they will be reclassified as identified resources.

Criteria for classification: No identification by borehole or surface outcrop.

Phosphate Restricted Resources/Reserves.—That part of any resource/reserve category that is restricted from extraction by laws or regulations. For example, *restricted reserves* meet all the criteria for reserves except that they are restricted from extraction by laws or regulations.

DEGREE OF ECONOMIC FEASIBILITY OF USE

Resources can be broken down into three classes according to their degree of economic feasibility of use. These classes include economic, marginally economic, and subeconomic resources, which are discussed below. The criteria for identifying economic and marginally economic resources are deposit and time specific and are not based on physical parameters alone. Thus, they lie outside the scope of this report.

Phosphate Economic Resources.—Those phosphate resources for which profitable extraction or production under defined investment assumptions have been established, analytically demonstrated, or assumed with reasonable certainty. Economic resources include reserves, inferred reserves, and economic undiscovered resources discussed below.

(Phosphate Economic Resources—Continued)

Phosphate Reserves.—That part of the demonstrated resources that can be economically extracted or produced at the time of determination. The term "reserves" need not signify that the extraction facilities are in place and operative. Reserves include only recoverable materials.

Phosphate Inferred Reserves.—That part of the inferred resources that can be economically extracted or produced at the time of determination. Otherwise similar to phosphate reserves.

Phosphate Economic Undiscovered Resources.—In general, it is not possible to subdivide undiscovered resources into classes based on feasibility of economic recovery because of lack of information on the physical characteristics to do so. However, it is possible to make statistical estimates of such classes by analogy with identified deposits.

Phosphate Marginally Economic Resources.—Those phosphate resources that, at the time of determination, border on being economically producible. Their essential characteristic is

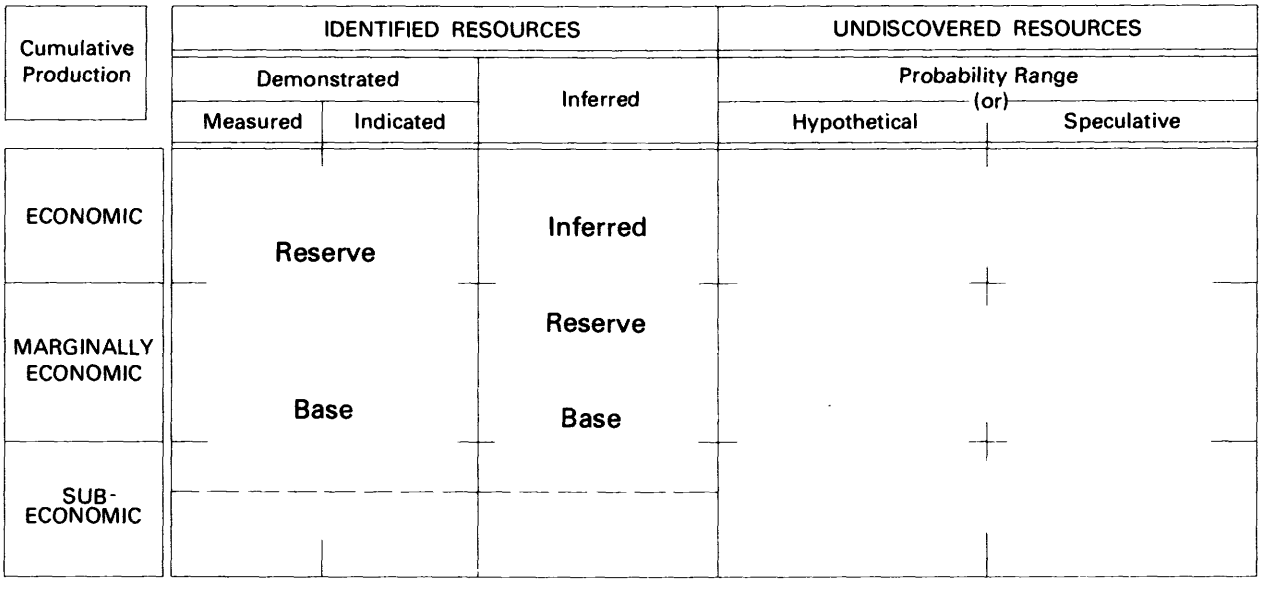


FIGURE 2*B*.—Reserve base and inferred reserve base classification categories. From U.S. Geological Survey Circular 831.

(Phosphate Marginally Economic Resources— Continued)

economic uncertainty. Included are phosphate resources that would be producible given postulated changes in economic or technologic factors. Marginally economic resources include marginal reserves, inferred marginal reserves, and marginal undiscovered resources.

Phosphate Marginal Reserves.—That part of demonstrated resources that, at the time of determination, borders on being economically producible. Its essential characteristic is economic uncertainty. Included are resources that would be producible given postulated changes in economic or technologic factors.

Phosphate Inferred Marginal Reserves.—That part of inferred resources that, at the time of determination, borders on being economically producible. Its essential characteristic is economic uncertainty. Included are resources that would be producible given postulated changes in economic or technologic factors.

Phosphate Reserve Base.—That part of an identified phosphate resource that meets specified minimum physical and chemical criteria related to current mining and production practices, including those for grade, quality, thickness, and depth. The *reserve base* is the *in-place* demonstrated (measured plus indicated) resource from which reserves are estimated. It

(Phosphate Reserve Base— Continued)

may encompass those parts of the resources that have a reasonable potential for becoming economically available *within planning horizons beyond those that assume proven technology and current economics.* The reserve base includes those resources that are currently economic (reserves), marginally economic (marginal reserves), and some of those that are currently subeconomic (subeconomic resources), but the latter is included only if it is the unrecoverable part of an economic or marginally economic resource and should not be included if it is a separate deposit. The purpose of distinguishing between the reserve base and the combined reserves and marginal reserves (defined above) is that the reserve base is a body of rock identified by its physical parameters (thickness, grade, quality, depth) alone, whereas reserves and marginal reserves are identified by economic factors in addition to the physical parameters. Thus, the reserve base is independent of short-term variations of price or other short-term economic factors and changes only by losses from production and increases from discovery and technologic improvements.

Criteria for classification: At the present time, only strippable phosphate rock is economic or marginally economic. An exception to this is an underground mine in Montana in the northwestern phosphate province. This mine is a part of an integrated Canadian opera-

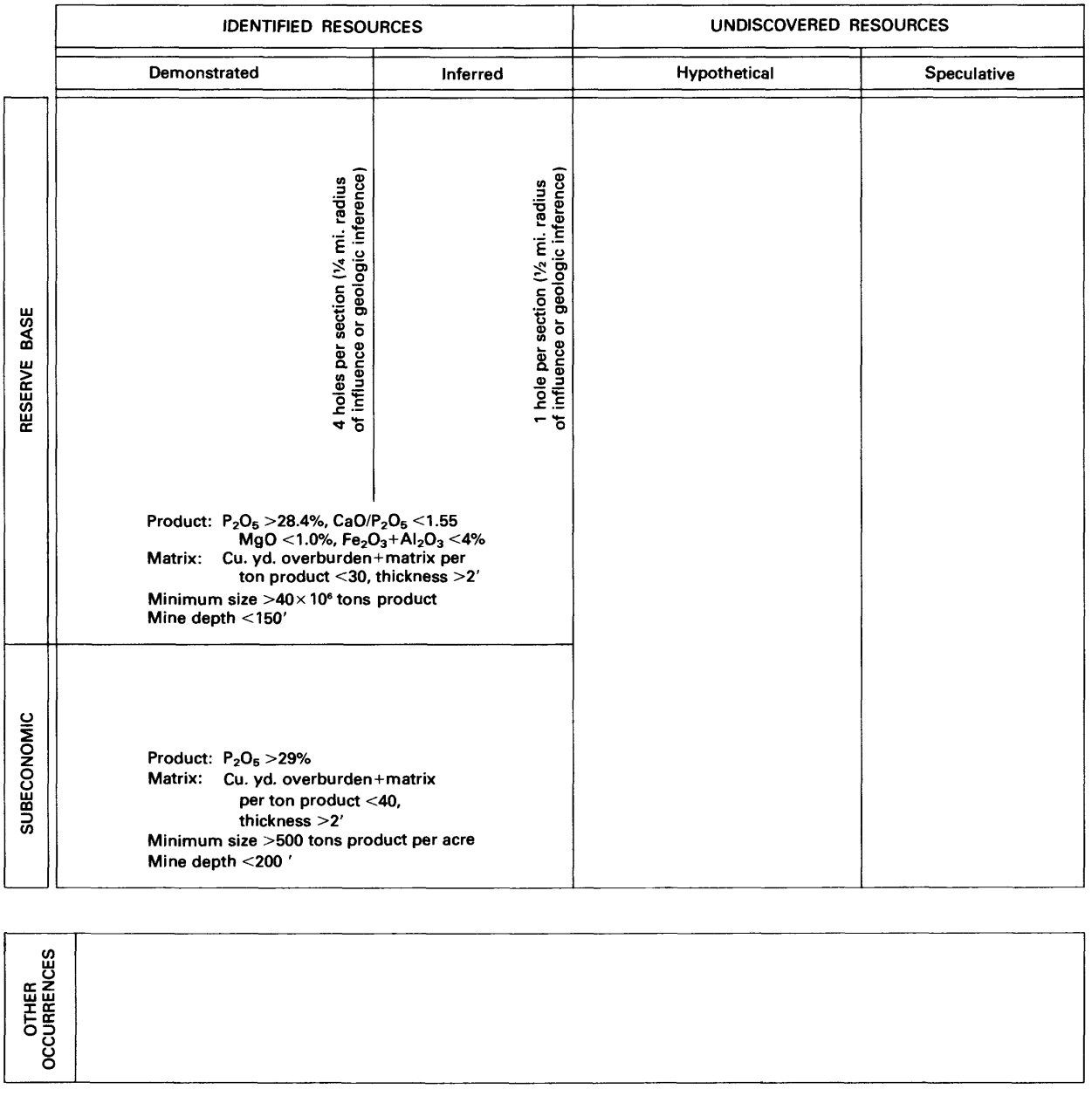


FIGURE 3.—Southeastern phosphate resource category definitions: strippable resources, present major industry economics and technology.

(Phosphate Reserve Base—Continued)

tion producing sulfuric acid from metallic sulfide deposits with overall acceptable economics. Mining and processing practices differ between the southeastern and northwestern fields, and the minimum criteria for the resource differ. These two provinces are dealt with separately below.

Southeastern Phosphate Province.—The product[1] must have more than 28.4 per-

[1] Product is "pebble" or concentrate, which is made of the fraction greater than 1 mm in diameter and the concentrate between 0.1 and 1.0 mm, unless one of these fractions is below acceptable grade.

(Phosphate Reserve Base—Continued)

(Southeastern Phosphate Province—Continued)

cent P_2O_5 [62.0 percent BPL (bone phosphate of lime)], a ratio of CaO to P_2O_5 of less than 1.55, an MgO content of less than 1.0 percent, and a combined Fe_2O_3 and Al_2O_3 analysis of less than 4 percent. The matrix (phosphate ore bed) must have a thickness of more than 2 feet and a stripping ratio of cubic yards of overburden and matrix per ton of product of less than 30. The minimum size of the deposit must be greater than 40 million tons of recoverable

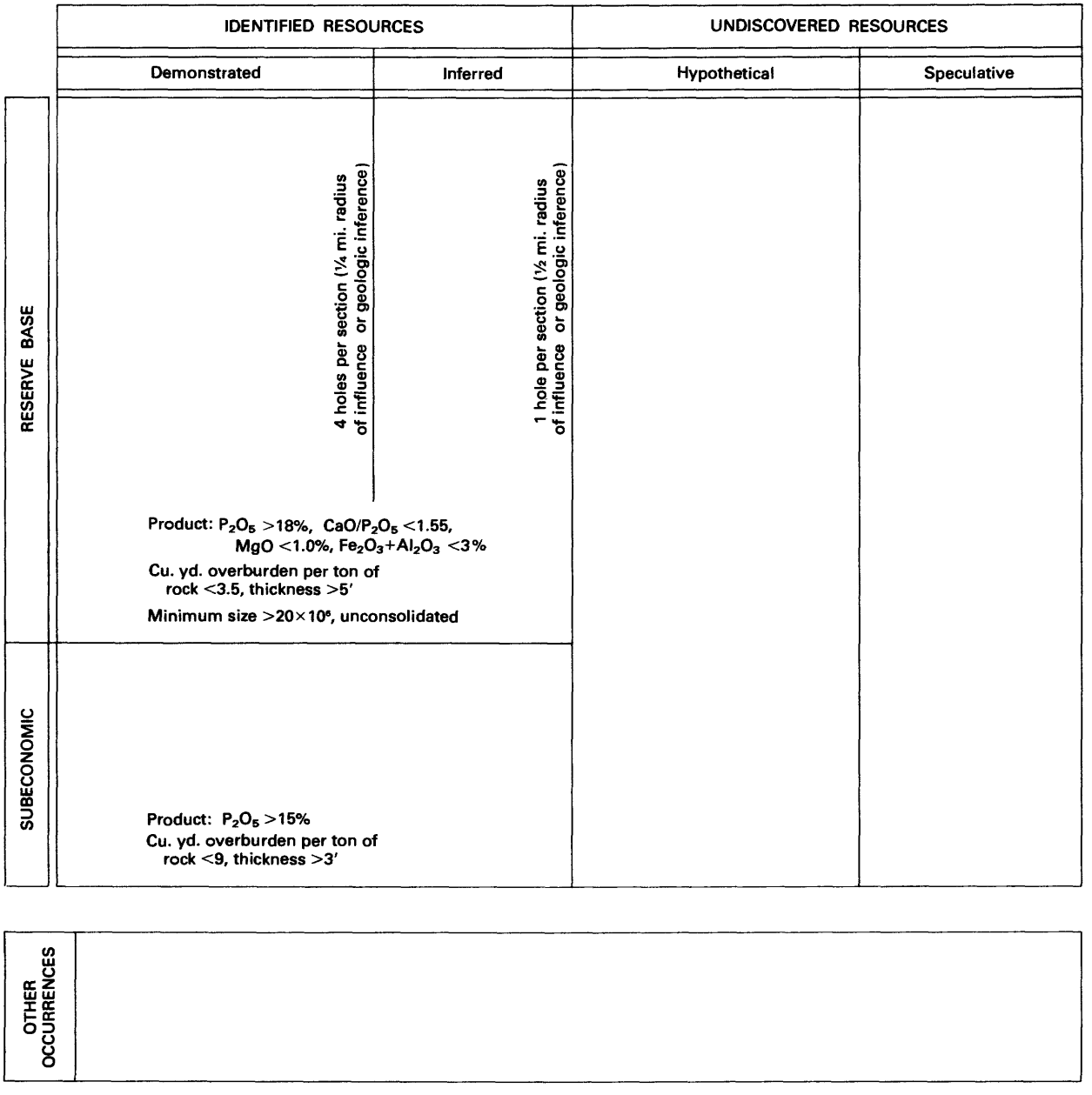


FIGURE 4.—Northwestern phosphate resource category definitions: strippable resources, present major industry economics and technology.

(Phosphate Reserve Base—Continued)

(*Southeastern Phosphate Province* – Continued) product, and the maximum mine depth must be less than 150 feet.

Northwestern Phosphate Province.—The minable unit of phosphate rock must be weathered or oxidized and must average greater than 18 percent P_2O_5; the rock must have a ratio of CaO to P_2O_5 of less than 1.55, an MgO content of less than 1.0 percent, and a combined Fe_2O_3 and Al_2O_3 analysis of less than 3 percent; the thickness of the bed must be more than 5 feet; the stripping ratio of cubic yards of overburden per ton of phosphate rock must be less than 3.5; and the size of the deposit must be greater than 20 million tons of rock.

(Phosphate Reserve Base—Continued)

(*Northwestern Phosphate Province*—Continued)

Phosphate Inferred Reserve Base.—The in-place part of an identified resource from which inferred reserves are estimated. Quantitative estimates are based largely on knowledge of the geologic character of a deposit, for which there may be no samples or measurements.

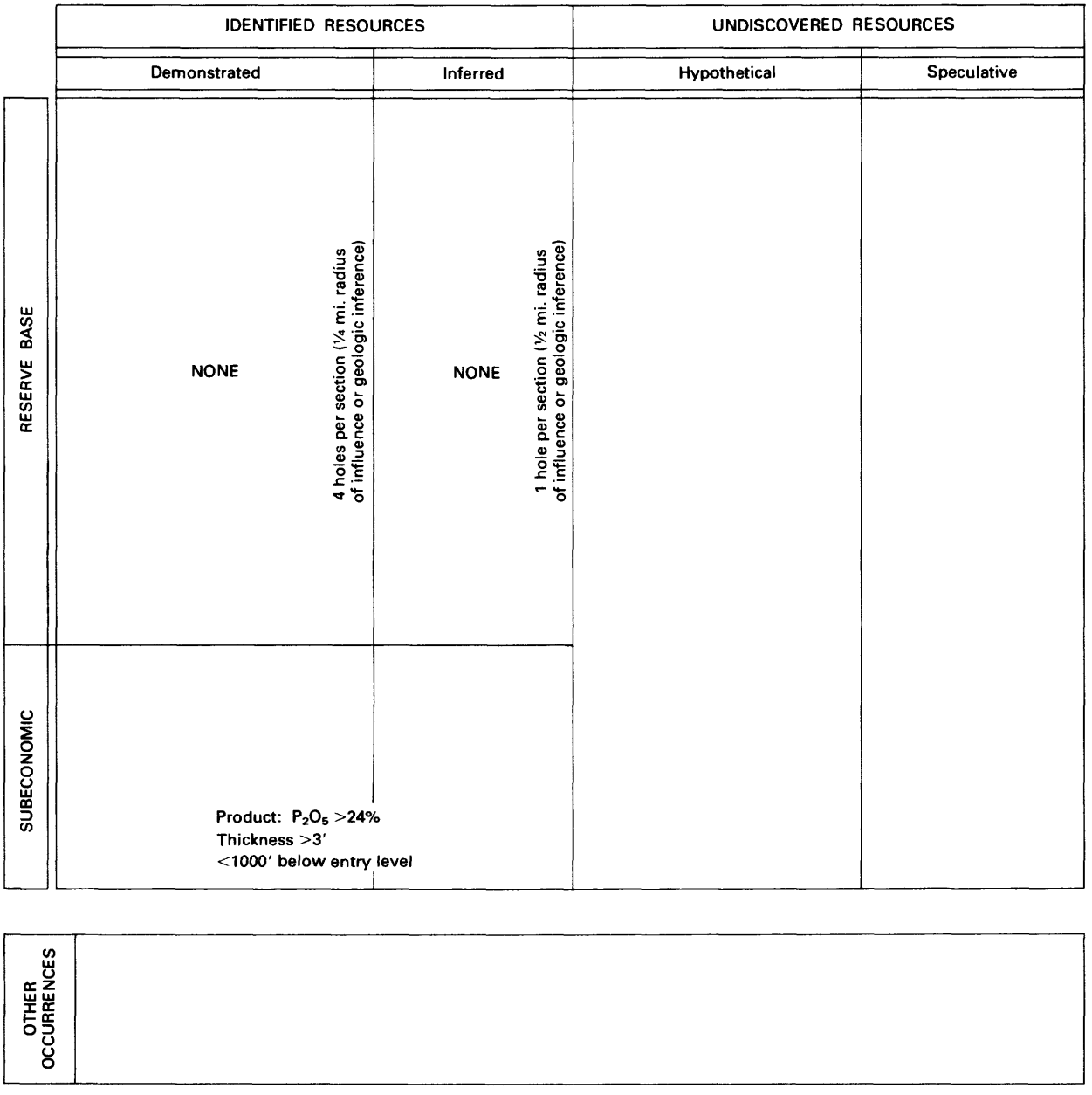


FIGURE 5.–Northwestern phosphate resource category definitions: underground resources.

(Phosphate Inferred Reserve Base–Continued) The estimates are based on an assumed continuity beyond the reserve base for which there is geologic evidence.

Criteria for classification: Same as minimum criteria for Reserve Base.

Phosphate Subeconomic Resources.–That part of identified resources that does not meet the economic criteria of reserves and marginal reserves. In practice this class includes the resources that do not meet the physical criteria of the reserve base and marginal reserve base and excludes those parts of the reserve base that are not economically recoverable to assure that no rock is double counted as a resource.

(Phosphate Subeconomic Resources–Continued)

Criteria for classification:

Southeastern Phosphate Province.–The product must have a phosphate grade

(Phosphate Subeconomic Resources – Continued)
(*Southeastern Phosphate Province* – Continued) greater than 28.4 percent P_2O_5 (62.0 percent BPL). The matrix must have a thickness of more than 2 feet, a stripping ratio of cubic yards of overburden and matrix per ton of product of less than 40, and a mine depth of less than 200 feet. The deposit must have the potential of greater than 500 tons of product per acre. Only strippable deposits are considered in this classification.

Northwestern Phosphate Province. – Subeconomic resources include both strippable deposits and underground deposits. Strippable subeconomic resources must be made up of a phosphate bed greater than 3 feet thick, contain greater than 15 percent P_2O_5, and have a stripping ratio of cubic yards of overburden per ton of phosphate rock less than 9. Underground subeconomic resources must be made up of a phosphate bed greater than 3 feet thick, contain greater than 24 percent P_2O_5, and occur in beds not more than 1,000 feet below entry level.

Other Occurrences. – Materials not meeting the criteria for any of the resource/reserve classes but having sufficient magnitude of occurrence to indicate possible future interest can be recognized by this classification.

Criteria for classification: The general basis is characteristics below the minimum criteria of the subeconomic resources class. Also, the criterion of not having current or potential feasibility of economic production is applicable.

DYNAMICS OF PHOSPHATE RESOURCES

An assessment of any mineral resource is valid only at the time when the assessment is made, because all the factors that influence the magnitude of resources of the various classes are time dependent.

Changing economics has a clear effect on the magnitude of reserves, inferred reserves, marginal reserves, and inferred marginal reserves. A rise in price as other factors remain the same will cause some marginal resources to become economic and subeconomic resources to become marginal. On the other hand, falling prices will have the opposite effect. The reserve base class was created to deal with fluctuation in price. The resources categorized by their physical parameters alone would remain stable in spite of short-term variations in price.

Governmental policies can affect the economics of mineral production and have a profound effect on resource classifications. Examples of these changing policies are policies on taxation, depletion allowance, railroad and shipping freight rates, environmental cost, and price controls.

The effects of changing mining and processing technology also can be profound and have the effect in extreme cases of making economic resources subeconomic by replacing them with what had been subeconomic resources. This happened, for example, when low-grade taconite was processed into high-quality pellets, replacing high-grade direct shipping iron ore and reducing the cost of hot metal from the blast furnace. Changes in technology of fertilizer manufacture can affect the quality specifications of phosphate rock, which in turn will affect the resource class boundaries.

The generation of geologic and engineering data relating to the assurance of existence of resources has the effect of moving resources to the left in the classification diagram. Basic research allows conception of speculative resources. Resource assessment activities create hypothetical resources from speculative resources; exploration creates inferred resources from the undiscovered classes; and development drilling creates demonstrated resources out of inferred resources.

We conclude that resource estimates are in a constant state of change, as basic science, resource assessment, exploration, development drilling, and research on mining and processing technology increase the availability of resources. It is necessary to continually update resource estimates of all classes. Resource estimates should be framed in precise technical terms and the dates of each estimate recorded.

REFERENCES CITED

McKelvey, V. E., 1972, Mineral resources estimates and public policy: American Scientist, v. 60, no. 1, p. 32–40.

U.S. Bureau of Mines and U.S. Geological Survey, 1980, Principles of a resource/reserve classification for minerals: U.S. Geological Survey Circular 831, 5 p.