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Subsoil Wealth

H. Foster Bain, et al
Consulting Engineer, Bureau of Mines

The material on copper is the outcome of conversations with S. P. Hatchett and J. A. Grimes of the Internal Revenue Bureau and members of the Bureau of Mines and Geological Survey. The section on gold was prepared by F. M. Chace of the Geological Survey, and the introductory material by Mr. Bain. Estimates for bituminous coal were calculated in discussion with W. H. Young of the Bureau of Mines, Coal Economics Division. The figures on petroleum and natural gas were prepared by E. B. Swanson of the Oil and Gas Division, United States Department of the Interior. The iron ore estimates were based on talks with E. F. Burchard, formerly of the Federal Geological Survey, and engineers in the iron ore industry.

Mr. Bain died in March 1948. The Executive Committee of the Conference on Research in Income and Wealth wishes to thank E. W. Pehrson for reviewing the editorial changes in Mr. Bain's paper.

SUBSOIL MINERALS CONTRIBUTE SUBSTANTIALLY to the annual income of the United States, not only as sources of energy but also as raw materials of industry. In 1929 the approximate value of mineral output totaled $5,887,600,000. In 1939 it had fallen slightly—to $4,874,000,000—but in 1946 it reached a peak of $8,900,000,000. Through many years, the mineral industries have grown rapidly, even at an accelerating rate. Between 1899 and 1939 output from mines and quarries increased more than twice as much as that of agriculture and almost as much as manufacturing. Fuels and nonmetals increased most; but production of metals, though growing faster than agricultural output, fell behind manufacturing. The indexes of production, taking the output for 1899 as 100, were metals, 224; fuels, 430; other nonmetals, 382; total, 366; manufacturing, 374; agriculture, 159.[1]

Are we, as a nation, overproducing and exhausting our resources at a dangerous rate? The matter is vital because the mineral industries do not have a perennial base for operations, being dependent on irreplaceable mineral deposits. Thus mining, in contrast to manufacturing and agriculture, is a wasting asset industry. It is, then, all the more important to measure, if possible, total deposits and determine the place of subsurface minerals among the assets of the nation. Though, for many reasons treated in greater detail below, such an estimate is necessarily imperfect, it has been felt worth while to make such a start as may be possible at this time in full recognition of the difficulties of the problem and the incompleteness of any result likely to be attained.

The work falls naturally into two stages: first, estimating the amounts of the various minerals known to exist in the ground; second (for purposes of comparison and for fitting the results into a national balance sheet), evaluating these known reserves. Only the known reserves, or at most those reasonably to be expected to be produced within a period in which the present worth of the dollar is significant, can be covered. Probably

1 *The Mining Industries, 1899-1939,* Barger and Schurr (NBER, 1944), Table 1, p. 14.

there are large quantities of minerals in the ground that at some future time will come into use; but if knowledge concerning them is so indefinite that they cannot be measured, no tangible value can now be assigned to them. Moreover, if they cannot be produced and marketed within some reasonable period, say fifty years, their present worth is so small that their omission from the balance sheet will not materially invalidate the results. To see far into the future is as difficult as to see far into the ground, and any attempt to determine what may be true more than one generation or, at most, two ahead may well be as harmful as helpful. In the actual process of buying and selling, estimates of mineral reserves are usually based on supplies for 20 to 25 years or, at the highest, 50 years, not only because many unknown factors influence production and price but also because the present worth of future profits decreases as the years accumulate. The present value varies with the interest rates assumed; [2] at 5 percent compounded annually, a dollar that will not be received for 20 years has a present worth of only 38 cents. If payment is deferred 30 years, the present value decreases to 23 cents, if to 40 years, to 14 cents, and at 50 years it becomes as little as 9 cents. Since money that can earn 5 percent and be compounded at the same rate will double itself in 15 years and even if it earns only 3 percent will double in 24 years, to put one's money in a savings bank or insurance annuity may obviously be more profitable than to invest it in the risky business of mining.

The United States Department of the Interior has recently completed, through the joint activities of the Geological Survey and the Bureau of Mines, a general summary of estimates of the amounts of the various mineral resources in the ground, taking into account present standards of quality and methods of production. This has been presented to Congress and published as the appendix to a Congressional document.[3] Though

[2] See e.g., tables in *Mine Examination and Valuation,* Baxter and Parks (Michigan College of Mining and Technology, 1939).

[3] *Investigation of National Resources,* Hearings before a Subcommittee of the Committee on Public Lands of the United States Senate, 80th Cong., 1st Sess., May 1947.

the most comprehensive statement of ore reserves yet made, its limitations must be understood in order to avoid misinterpretation. Only ores and mineral deposits workable under conditions similar to the present were considered. If the cost of wages, supplies, and taxes rises and the price of the product is not raised correspondingly, known reserves may well become unworkable, as has already happened in the case of many gold mines, such as the great Alaska-Juneau. Technological progress will often narrow the gap between cost and price, though probably not in the instance cited, as both technology and the scale of operations seem to have already been pushed to the limit to reduce costs. Advances in technology have, however, so far proved the most effective safeguard for the future; many a mine after having been worked for years has shown a larger reserve than at the beginning, not only because more ore of the same grade has been found but also because better methods have made it possible to work ore of a grade previously deemed not workable. Notable illustrations abound in the so-called 'porphyry copper' deposits, where rock has been converted into ore by improvements in technology, administration, and financing on an enormous scale. Our country would be really starved for copper if only the grade of ore worked at the beginning of this century could now be mined at a profit. In the last decade of the 19th century, it was considered notable that ores containing as little as 5 percent copper could be profitably mined; but for some years much of the copper mined has been won from ores containing less than 1 percent. In large mines the 'cut-off point', or that below which the material mined is sent to the waste dumps rather than the mill, has been 0.4 percent copper. In some mines at certain times it has been even lower. The statement that our known reserves will supply us for only a certain number of years at present rates of production is a yellow warning, not a red, and the green light may not be as far away as even the next corner.

Sometimes for technical and at other times for financial reasons, it is not always advisable to develop ore reserves too far ahead of the market. The great Mother Lode of California has produced gold in quantity for almost a century, yet it is doubtful that measurement of the ore reserves in sight would often have shown more than a two years' supply ready for mining. The principal reason has been that, under conditions on the Mother Lode, it is frequently difficult and expensive to hold a drift for more than two years without retimbering. As this operation is expensive, opening ground too far ahead of actual mining is wasteful and is not done. Actually the operating companies have instead relied upon experience—they will be able to open more ground as rapidly as it becomes needed. Although there have been disappointments and some losses, the policy has on the whole proved wise. A small ore reserve therefore does not necessarily mean a short life for a mine. Only for special reasons, such as determining whether to invest large sums in reequipping a property, introducing a new method, or obtaining a larger position in some projected combination, is it customary to do more than a minimum of advance development. It is, though, not beyond a miner to dress up a mine for sale even if that does not conduce to maximum ultimate profit from the property.

Under other conditions, such as hard, firm walls or small pumping expense, it may well be that financial reasons, such as security for large investment, may make it sound to carry a larger ore reserve, measured in terms of the known life term of the mine. For example, in the Homestake, the largest American gold mine, physical conditions permit holding ground open at small expense; the occurrence of the ore is such that to be sure of reserves it is important to know in advance as much as possible about the ground to be opened up, and the heavy investment makes security important. So it has been the general policy of the Homestake Company to keep approximately ten years' ore supply developed ahead. The advantages in this case outweigh the disadvantages, such as the accumulating interest charge on the money spent on advance development and the risk of excessive taxation in a region where only a small fraction of the voting population is engaged in mining.

The danger of excessive taxation is one a prudent mine manager must constantly keep in mind in planning development. The sporadic distribution of ores, the general belief that ore deposits are treasure troves to the major part of which society as a whole is entitled, and the increasing pressure on tax authorities to produce additional revenue, render mines especially vulnerable from the taxation point of view, and many and diverse types of tax have come into being. It is not easy to determine a just tax on mines or on minerals in the ground, but the disposition of the authorities to tax everything in sight naturally leads mining companies to put as little ore in sight in advance of mining as possible. This, in turn, adds to the difficulty of determining how much national wealth is underground.

The experience of the Minnesota mining companies is probably as well documented as any. In this state lie the largest iron ore reserves of the United States, and records are available for more than thirty years. The mines are in a small section of a large state dominated by agriculture; the voting power of the miners is small compared with that of the wheat farmers. The Department of Taxation has wide authority and a competent staff of engineers and accountants who use accepted methods in calculating the ore reserves. Nonetheless, there are loud complaints against the amount of taxes collected, particularly those taken by county and local authorities, with charges of extravagance and waste in local government in consequence of the ease with which money can be raised by taxing the mines. The matter is of national interest, since little ore is used in Minnesota and any addition to the price due to taxation is borne by the people of the entire country who buy iron and steel products. The Department of Taxation collects both ad valorem and occupation taxes and collects from both the mining company and the royalty owner.

As of May 1, 1945 total ore in the ground was calculated to be 1,034,300,000 tons. The assessed valuation was placed at $129,306,000 or 12.5 cents per ton in the ground. On this there were collected in 1945 $20,600,432 in taxes, made up of $6,249,985 occupation tax, $1,762,134 royalty tax, and $12,-

588,313 ad valorem ($1,019,654 in state, $3,291,772 in county, and $8,276,887 in local taxes). The ore shipped totaled 62,830,-572 tons, and the tax collected came to $0.328 per ton *shipped,* not per ton *assessed.* The amount of taxes collected per year has remained fairly steady for twenty years; and, as shipments have varied greatly, the taxes paid per ton shipped have also varied, rising steeply in depression years when shipments were small. In 1932 the taxes collected amounted to $7.348 per ton; and the average sale price of Minnesota hematite ore, calculated back to the mine, was $2.79.[4] These figures would seem to be largely responsible for the fog that clouds the public mind with doubt concerning the adequacy or inadequacy of the Lake Superior iron ore reserves for the safety of the United States. Actually there are many excellent reasons for expecting a much longer life term for the Minnesota iron mines than that calculated by dividing the known reserves by the expected requirements each year.[5] The crucial factor is the ratio between the rate of use and the rate of discovery, including additions due to improvements in technology. These factors will be discussed in more detail in connection with the valuations proposed below. In a general way, it may be stated that many mining corporations, having once opened and equipped their mines, try to direct exploration so as to replace by discovery an amount of ore equal to that mined in each year or short period.

To place a dollar value on the subsoil resources of the continental United States for the purpose of drawing up any balance sheet of assets and liabilities, several assumptions must be made. It is, for example, assumed that what is desired is the fair market price at the date of the valuation; in this case 1929, 1939, and 1946. This can only be 'as is, where is', or in the ground, since any other price will necessarily include reimbursement for goods and services, to mention merely two items necessary to produce the goods and transport them to the point of sale. These are not to be regarded as part of the value of the

4 *Minerals Yearbook* (Bureau of Mines, 1932-33), p. 185.

5 See 'Iron Ore Supply for the Future', W. O. Hotchkiss, *Economic Geology,* May 1947; and 'The Iron We Need', C. B. Randall, *Atlantic Monthly,* June 1948.

resource itself. Because only an insignificant portion of any mineral resource is ever carried in stock as part of the live inventory of industry, the ore must be valued in the ground.

A fair price implies the usual assumption of a willing seller and a willing buyer, but in each instance the parties to the transaction review possible alternatives. The farmer, asked to sell the mineral rights in his land or to give a lease for purposes of mineral development, compares the amounts promised to or realized by other farmers for similar rights, while the would-be lessor will consider whether he can buy or lease equally good land elsewhere on better terms.

As the subsurface resources of the country, even those of significant minerals, are much too large for any single purchaser or syndicate to handle, their value can be estimated only by applying to the whole the values fixed by representative transactions or by indirect methods. The first method is based on royalties, the second on calculations of the margin of probable profit.

Mining engineers and mine valuers have developed a well founded system for working out the value of individual mines, deposits, or tracts of land. Since it is to be presumed that the purpose of a valuation is to fix a price for a transfer at a specific time and since in most instances that time is the present, most valuations are directed to finding the present value of the property, though for special purposes an earlier or later value may be taken. For tax purposes the value of the property at the time any specific law went into effect—such as March 1, 1913—is important, but in any event returns to be realized only in the future are discounted to find the equivalent present value. To do this, it is necessary to determine or estimate the quantity of recoverable ore in the ground, the rate of profit that may be made per unit, and then from considerations of market and of capital to be invested, the rate at which these profits may be realized. From these data the rate and amount of the annual returns can be determined. These are then discounted to present value, and the sum is taken as the value of the property. Obviously the crucial data are the profit per unit, the rate at which the profits accrue, and the number of years they will continue. This scheme for determining the present value of future profits or, more probably, the present value of expected future profits, is frankly based upon the profit motive, since we live and work in a profit economy.

The spread between the sale price of a product and the cost of production to that point must of course be enough to cover the value to the landowner of the material in the ground and the risk and use of money necessary to induce the investing public to finance the venture. When mineral properties are leased, the landowner accepts an agreement that either a certain proportionate share of the product as produced will be delivered to him, as is usual with petroleum or, as is more common with coal, iron, and other minerals, he will receive a cash price per ton or other unit as it is produced. Alternatively, the operator may buy outright either the fee to the land or to the mineral rights, the owner retaining the surface rights; or the landowner, having given a lease on a royalty basis, may sell his royalties to third parties. In the petroleum business there is a wide open market for royalties, which often sell for as much as or more than the lease itself. The landowner's one-eighth, not being burdened with costs of production, at times is estimated to be as valuable as the lessor's seven-eighths, which have to assume the costs of development and production for the whole. Incidentally, in mineral mining of various kinds it is not uncommon for the landowner's value to be estimated (as above) at one-half the expected net profit from the enterprise.

The time it takes to produce the mineral is important in determining its value. The sooner a placer miner can get the gold out of his ground and put it to work earning interest, the more valuable is it to him. Other things being equal, it is more profitable to equip the ground with a dredge that can work the area in ten years than with one that would take twenty; and, within limits, the same rule applies to equipping lode mines. In the late 'nineties one of our ablest mining engineers calculated that most profit could be made from a given area in the Rand (Africa) if the mine in it was equipped for a life of fourteen years than if for a longer or shorter time. Many factors enter such a calculation but in all, time is important. When a large amount of material is available, for example, limestone, sand, and gravel, the market mainly fixes the price, profit, and scale of output. There is no profit in opening mines or quarries with capacities exceeding the market for the product. Only the portion of the total reserve in the ground that can be marketed within the time that a dollar to be received in the future has an appreciable present worth is of any value—at least any value that can be stated in dollars. Such is the basis on which mineral properties are bought and sold.

That there are special risks inherent in the vagaries of deposits of ores and other minerals is generally accepted, and venture capital alone is attracted. To induce entrepreneurs to take these risks, the expected rate of return must be somewhat higher than in other fields of investment. Dry holes cost as much as producing wells, and the risks of unexpected changes in size, position, and grade of ore in a deposit are numerous and real, justifying the demand for a rate of return higher than that on a tax exempt bond or a public utility security in a growing industry. Through many prewar years mines were valued on a basis of an expected 8 to 12 percent on the investment plus return of capital, it being realized that, however large dividends might be, there was an offset to profit if a capital loss resulted. In 1929, one of the years chosen for this study, an ore deposit would have been valued on the basis of expectation of at least an 8 percent annual return on the capital, plus a sinking fund which, invested at 4 percent compound interest, would accumulate a reserve within the life of the mine that would equal the capital invested. In more recent years, interest rates have fallen, but it is doubtful that much money can be had for mining if less than an 8 percent return is expected, although sinking funds could hardly be set up at present on more than a 3 or 3.5 percent basis.

As has been indicated, engineers base valuations upon expected profits from exploitation. Admittedly, this is only one method of evaluation, and there may be other unrevealed values; but this is the accepted way to measure the present values of the known reserves at a particular time.

The profit, or value of a ton of ore in the ground, may be worth more under one management than another. If the attempt is made to measure the value of ore in the ground by royalty rates, these may, unless well established throughout an industry (as in the case of petroleum), reflect mainly the relative bargaining powers of the parties concerned. Finally, while the value is determined by the nearness of the date of production and that date may be so far off there is no present value that can usefully be expressed in figures, the existence of ore beyond that having a present worth gives an insurance value for continuity of operations. At least one large steel company bought iron ore lands years ago beyond the amount having at that time any reasonable present worth. It did, however, usefully ensure the company's future supply beyond the fifty years or so that might well have been taken as a basis of value, as well as its capacity to expand production beyond the point then appearing probable. Overbuying to some moderate extent, then, is justifiable to ensure future production, and has proved worth while in other instances too. But an owner of mineral lands can be as land-poor as a farmer. The carrying charges on the investment may and often do lead to losses rather than profits.

This situation has been true in the anthracite industry, where the cost of undeveloped reserve lands has hung like the proverbial millstone around the neck of the mining companies. In this instance, early buying was less for insurance than in the hope of creating a monopoly. Economic law brought penalties greater than any that might have been imposed by antitrust legislation; moreover, the economic law was self-enforcing and not subject to repeal.

Nations are expected to live longer than individuals or corporations, and to them security is of primary importance. Therefore, in setting up the value of subsoil mineral resources as an item in the balance sheet of national wealth, should some allowance not be made for their social value? Goodwill, which can seldom be measured in dollars and cents, is commonly entered in a balance sheet, if at only $1; why not some of these other items? How about underground water, so essential to life and industry but which, even when sold, is merely passed on at the cost of production? How about the water in our harbors and navigable rivers? They are useful; do they not have value?

At present it can be said only that there is no known system of valuing them although, if enough study is devoted to the subject, formulas may be worked out for some. However, as mining has learned to its cost, there is a reverse side to the picture. Many years ago hydraulic gold mining was stopped in central California because the discharge of tailings into the streams allegedly damaged lands, rivers, and harbors below the mines. Several hundred million dollars worth of gold was left locked in the unworked gravels. Had this gold been mined and put to work in industry, it would very possibly have made a contribution to national wealth that would have offset all the potential damage. In many places too smelters have been shut down, mines abandoned, and entire communities wiped out because of damage or alleged damage to plants and animals by smoke from the smelter stacks. Since action was taken against the smelters as 'nuisances', relative values did not enter into the matter. In other instances, smelting companies were able to buy out the 'smoke farmers' at less than the losses they would have incurred if the plants had been closed. These, and numerous stream-pollution cases, emphasize the values minerals have that may be called 'social' as distinct from 'profit' values. How should these be assessed?

It is extremely difficult to measure the value in the ground of the primary product, e.g., coal or iron ore, produced by captive mines belonging to integrated companies. Captive mines, apparently, will continue to be run as long as the parent industry needs their product to supply its manufacturing subsidiaries, whether or not they can show a profit. The overall cost of the final product sold outside the organization is the controlling factor, and products are passed on at cost from department to department or from subsidiary to subsidiary, so that finally the sales department alone shows a 'profit'. Unless a considerable outside market exists for the ore or intermediate product, there is no way to judge the fairness or unfairness of the price allowed at any given stage. For copper public quotations are usually for the finished product, the electrolytic or refined metal. Unless all the intermediate plant operations are considered merely facilities for production, how can anyone be sure of the worth of a ton of copper-bearing ore in the ground? As the petroleum industry has become more and more closely integrated, it has come pari passu to regard everything from oil well to filling station as a mere facility and not to expect a tangible profit from each step, such as a refinery or a pipe line. Pipe lines, it is true, occupy a rather special position, since their rates are in the province of the Interstate Commerce Commission and are largely influenced by the effect on actually, or potentially, competing railway rates.

For purposes of this paper we attempt to establish the value of the copper, gold, bituminous coal, petroleum, natural gas, and iron ore in the known reserves in the ground as of 1929, 1939, and 1946. Representative items, they include collectively the larger portion of the known subsoil mineral wealth of the country. But even they cannot be evaluated accurately. To cover the remaining minerals would require long and careful special studies, leading at best to approximations.

Published sources of many kinds have been consulted, and numerous discussions held with engineers within and outside the Department of the Interior. No figure given here is final or exact; all are first rough approximations and of possible use only in pointing the way to a more comprehensive and exact valuation if that is considered worth making. Two general conclusions stand out: The present value, in the ground, of the mineral resources of the United States is surprisingly small when the tonnages involved and the extent to which the minerals are essential to our national way of life and future security are considered. Mining as a whole, whatever may be true in specific instances, is not an especially profitable industry and subsists on a very narrow margin of profit. It is more what is put into a mine in the way of work and thought than what is taken out that determines profit or loss.

Two important conclusions follow from the above: The margin of profit being small, the present value may easily be wiped out by unsound public policy, such as overtaxation or any other action that may increase cost or narrow the margin between it and price. Even delaying action may operate to decrease present values notably. Technology is supreme, and the reserve that will most largely influence our future security is less in the ground than in the brains of the men concerned with the industry.

A COPPER

Copper is the largest nonferrous metal mining industry; its production gave rise to more than half of the dollar value of metal production in 1929. As data on it have been widely circulated, it may well be taken as typical of the group. Estimates of reserves covering ore in the ground became generally available when the porphyry coppers were being developed. Until then, nonferrous mining had been a small unit industry, and capital for it had come largely from within the industry. Mass production required large amounts of capital, for which the industry had to go to the public; to interest the latter in such investments, it became necessary and customary to supply data of the type used by promoters—carefully made engineers' reports on the ore in the ground available for treatment. Publication of ore reserves became common, except by such companies as Anaconda, which depended on vein deposits of a type for which estimating far ahead of production is expensive and uncertain. To this day, Anaconda does not publish ore reserve figures for its Butte properties, though freely doing so for other properties it controls where other conditions prevail. Since 1910 in the industry as a whole, ore reserve figures have been generally published and widely discussed.

Two summaries of these ore reserve figures have recently been published. One is a report on the Copper Industry by the Federal Trade Commission, of which a summary was published March 11, 1947. The other is a chapter by Ralph S. Cannon, Helena M. Meyer, and McHenry Mosier, in the *Mineral Position of the United States* (see note 3). In the first report the copper content of known ore reserves in the United States is estimated to be 29 million short tons. In the second, the recoverable copper under conditions and prices of 1944 was placed at 20 million tons. The second report states that in the 'thirties, estimates credited the reserves with a content of 25 million tons, but the decrease is not explained. On the face of it, this suggests a net rate of exhaustion of about one-third million tons per year. The Federal Trade Commission has not published its method, but the estimate is assumed to have been based mainly on a study of company reports and published engineer appraisals. The Interior Department experts state that to the 10 million tons of reserve reported by companies was added 5 million estimated to be recoverable from reserves that had been developed or indicated later by the same operators. A second 5 million tons was added for expected extensions of known ore bodies or mineralized areas of proved value. There was no allowance for future discoveries of ore in other areas or, apparently, for marginal ore that may be brought into production through technologic improvement or by any advancement in price not immediately absorbed by increases in costs of production or wages. All these factors may become important, and although the margin left for increased recovery through improvement of standard methods becomes progressively narrower with each step in accomplishment, there are distinct possibilities of a wholly new technology by virtue of which ore entirely outside the present field of possible production may and almost certainly will be mined whenever the need is keen enough. The effect of higher prices is less certain. The wartime plan of premium production brought out relatively little additional copper, but the recent increases in price to the public have brought a surprising amount of marginal ore from small producers to the custom smelters. On the whole, of the two estimates one is perhaps high and the other possibly a bit overconservative. If, for purposes of this paper, the reserve is taken to be 20 million tons of copper in ores that can be produced at the present margin of profit, the estimate will be at least of the correct magnitude.

Determination of the margin of profit, traced back to the pound of copper in the ore in the ground, is not easy. Quotations for copper are based on the metal after it has been mined, smelted, transported, and refined, so that the published price covers many items besides the cost of the metal itself. Moreover, the situation is complicated by the fact that copper is mined in conjunction with accessory metals. Lead, zinc, gold, silver, molybdenum, and other metals all come from copper mines in large amounts. Barger and Schurr (p. 369) found that only 93 percent of the copper produced originated in 'copper' mines, the remainder being supplied by mines of other metals. Conversely, 2.4 percent of the gold, 2.7 percent of the silver, nearly 1 percent of the zinc, and .5 percent of the lead were obtained from treatment of 'copper ores', to say nothing of the much larger amounts of lead and zinc ores mined as such but produced by copper mining companies. For many years Butte was the leading source of silver; now the Utah Copper Company is second in molybdenum production only to the Climax Molybdenum Company of Colorado, the world's largest producer. The copper refineries yield also most of such nickel and cobalt as are produced in the United States as well as most tellurium, selenium, and various other rare metals. Determining the cost of copper is indeed a problem in mixed costs.

It is also a problem to allocate earnings to various branches of the industry, from mining the ore to selling the fabricated products; there is no sharply marked dividing line save between refinery and fabrication plant. In practice, copper mining is considered to embrace only operation of the mines and beneficiation of the ores up to shipment to the smelters, where ownership often changes. The majority of the transfers are, however, intracompany affairs, and the terms rarely made public. Custom smelters generally pay New York quoted prices for 95 percent of the copper in the ore, minus certain service charges presumed to cover profit, costs, and losses in process. Charges are not uniform; and most of the ore treated, even in custom smelters, is company-owned or comes from subsidiary or affiliated companies, so that conclusions based on smelting rates would be inconclusive.

It is also impossible to get satisfactory figures on the basis of royalties as a measure of the land owners' value for ore in the ground, since nearly all copper mining companies own in fee the ground they work. Leasing in the copper and other nonferrous mining industries is common enough but is on a small scale—the lease of a particular stope or part of a mine or vein or even at times an entire mine. Since the lessor provides many facilities, and often services, the rates paid are not a fair measure of the value of the unmined ore. Mines and deposits are, it is true, frequently valued for sale or for purposes of combination or taxation; in these, the expected yield of metal is valued at the expected price when sold, minus the cost of production and selling, and credited with the gross amount to be won from accessory metals. Such valuations are calculated on the theory that the purpose of operating a mine is to get copper, and that any returns from other metals are incidental, as they are usually minor, and should be credited to the cost of producing the copper; moreover, any plant or operation involved is merely a facility to the general end and is not entitled to a separate profit. Analysis of a large number of valuation reports indicated that, from an expected price of 14 cents a pound, there was a residual value for the copper in the ground of about 1 cent, or about 7 percent of the sales price. Many of the big mines now operated were opened or equipped between 1910 and 1920; during that period a common figure for the expected future price of copper was 15 cents a pound. The actual average price, based on New York quotations for 1910-39 was about

14 cents. The average for 1910-20, which covered the years of World War I, was 18.32 cents. For the next decade, covering the period from the close of the war to the depression, the average was 16.09 cents. For the next decade, covering the depression and recovery up to World War II, the average was 9.76 cents. The general average for the 30 years, 14 cents, may well be accepted for the next period as a basis for the margin of profit, whatever the actual sales price per pound. Under normal conditions 1 cent a pound is believed to yield a sufficient margin. Economic forces, or, if necessary, government interference, will probably hold prices down to that level. It has evidently been high enough to attract to the industry adequate capital for expansion as the needs of the country have grown. A review of the histories of the companies that supply more than 80 percent of the product shows a profitable record.

There have been many important changes in the copper industry during the last quarter century. Consumption has increased, both by reason of the rise in population and the per capita advance in consumption. New uses for the metal have been found and old uses expanded. Scrap metal has become increasingly important in relation to newly mined ore. Exports, long an important feature of our metal market, have virtually ceased, and such American copper as now goes outside the country is largely in manufactured form. Imports have begun and in war years were large, about equaling the quantity needed to meet distinctly war needs. Contrary to common belief, we do not seem to have impoverished our copper resources to win the war, for the quantity produced apparently did not exceed much, if at all, that which would have been mined to supply the market for the same number of good business years.

Before World War II production of new copper from domestic mines was running about 800,000 tons a year. The average for 1925-29 was 885,826 tons, according to the *Minerals Yearbook*. Much lower during the depression, it rose to over a million tons a year during the war. It is now about 850,000 tons a year and, except for labor shortages, can be held at that figure without undue strain. The known and probable reserves in the ground can sustain an estimated future output of 900,000 tons for 20 years without any major reorganization of the industry, although several of the present big producers will have to curtail heavily or be eliminated in 10 to 15 years. If the past ratio of discovery to depletion holds, the net amount that will have to be taken from the present reserve will be only about one-third that estimated here, and the life of the mines will be lengthened correspondingly. Based on an annual output of 900,000 tons for the next 20 years and a profit, or return, for the value of the copper in the ground of 1 cent a pound, the present value of reserves may be estimated approximately as follows:

Nine hundred thousand tons a year at 1 cent a pound 'profit' is equivalent to an annuity of $18 million a year, which, for a 20-year life, would have a present value, if discounted at 3, 3.5, and 4 percent, of $26,800,000, $25,600,000, and $24,500,000. On these various assumptions therefore, the 1946 value of the copper in the ground was about $25 million. Many factors can alter this estimate, though probably not greatly. The life of the deposits may and probably will be lengthened by discovery and, as already noted, by changes in technology. The rate at which they will be worked may be accelerated by unexpected demand or retarded by substitution, by easing the difficulties in importing metal, or by other economic or political changes. Finally, the present value will always be influenced to some degree by the earning power of money. This value may be used for 1929 and 1939 since data on which significant changes could be based are unavailable.

B Gold Reserves

Because of the unique position gold occupies in the monetary system—serving as both a basis of exchange and a measure of value—determining the present value of the gold reserves of the United States is a somewhat different problem from valuing other metal and mineral resources. For gold no selling or marketing problem is involved; the United States Mint will buy, at a price fixed by law or by Executive Order, all the gold produced. In the long run, this has a stabilizing influence on the economy, but as far as the gold ore reserves are concerned, the effect on their foreseeable life is pronounced.

Unlike other mining operations, manufacturing, or agriculture, higher costs of operation in gold mining cannot be passed on to the consumer in the form of higher prices. Therefore, when costs are rising, the profit margin is narrowed appreciably, so that much of the rock in the ground that otherwise could be mined at a profit no longer has economic value; ore reserves are greatly reduced, and the life expectancy of those remaining becomes much less. On the other hand, when operating costs are decreasing, the spread between the fixed market price and charges for labor and materials becomes wider, and rock having a low gold content can be mined profitably; such gold reserves increase appreciably, and the life expectancy is greatly prolonged.

Because of these conditions, the gold mining industry runs counter to other industrial trends, tending to expand during depressions. It does not have the advantages or disadvantages of normal competition; its sole competitor is the general level of prices; this influence is reflected in its life expectancy and in drastic changes in the margin of profit.

The ultimate effect on gold output is not as drastic as on gold ore reserves, because a certain percentage of the gold mined (roughly 30 percent during the past 5 years) is obtained as a byproduct of copper, lead, and zinc mining. Thus, even when costs are extremely high—and even during World War II, when gold mining was actually prohibited by the War Production Board—a certain amount of gold is inevitably produced as a byproduct of the recovery of base metals.

The gold ore reserve figures used in this preliminary study came from two sources: the 15th International Geological

Congress publication on the gold resources of the world (1929), and the 1947 report on the Mineral Position of the United States by the Geological Survey and the Bureau of Mines.[6]

The figures on ore reserves, total gross value, rate of production, and estimated life are based on conditions known to exist in each year 1929, 1939, and 1947. For the purpose of determining present value, these seem to be the soundest assumptions that can be made, although, obviously, gold production will continue long after the period of 'estimated life' has expired.

The gold reserves of the United States for these years were evaluated from two points of view: that of the producer who operates solely for the profit that can be won from the exploitation of a gold-bearing ore deposit; that of the consumer or consuming public. The first, perhaps the only one of merit, is the usual approach to the valuation problem. The second, which may be termed the 'nationalistic' viewpoint, recognizes that mineral resources, including gold, have both a strategic and an economic value to the country as a whole that cannot readily be measured by the profit accruing to the producer in the course of the exploitation of a mineral deposit. The importance of mineral production to national defense, for example, cannot readily be expressed in dollars. Perhaps the only satisfactory way of determining present value from this point of view is to calculate the present value of the amount of 'new wealth' to be created by exploiting mineral resources. To measure 'new wealth created' is somewhat difficult, but, briefly stated, it may be considered to be the gross value of the mineral or metal produced after due allowance for the return to the operator of all capital and other invested wealth. The results are not altogether satisfactory for gold because of the peculiar nature of the industry. It is believed, however, that this method might be successfully applied to other metals and minerals.

[6] G. F. Loughlin and H. G. Ferguson, 'The Gold Reserves of the United States', *The Gold Resources of the World* (XVth International Geological Congress, South Africa, 1929); F. M. Chace, McHenry Mosier, and C. E. Needham, 'Gold', *Mineral Position of the United States.*

The conclusions concerning the present value of gold reserves in 1929, 1939, and 1947, examined from both points of view, are given in the accompanying summary.

Present Value of Gold Reserves, Summary

	1929	*1939*	*1947*
Estimated reserves, recoverable gold (oz.)	26,760,000	38,161,000	25,000,000
Total gross value	$553,129,200	$1,335,600,000	$875,000,000
An. rate of production (oz.)	1,682,000 or $34,700,000	3,950,000 or $138,250,000	1,500,000 or $52,500,000
Estimated life (years)	16	10	16.5
VALUATION			
Profit method			
1) Present value of profit on basis of av. profit for entire industry	0	0	0
2) Present value of profit assuming that $1 an oz. could be made	$10,000,000 (4% + 12%)	$21,500,000 (4% + 10%)	$10,590,000 (3% + 8%)
Nationalistic method			
1) Assuming no cost, no profit, & discounting total gross value to present value	$208,000,000	$479,000,000	$325,000,000
2) New wealth created, taking into consideration invested capital, costs, taxes, & profit	0	0	0

1 *Profit Method*

Inasmuch as the present value of an enterprise is the same as the present value of the profit it may be expected to yield during its lifetime, the present value of a natural resource may be expressed in terms of the present value of the profit that may be won from recovering and selling that resource. This principle may be applied, using the Hoskold formula, to various natural resources, such as coal, petroleum, and copper, when the average margin of profit is fairly well known or can be safely assumed. However, it cannot be applied successfully to the gold mining industry as a whole, although it can be applied to individual ore deposits and to individual mining companies, for the simple reason that a margin of profit cannot be assumed. In fact, probably more money is spent in the search for gold than is ever returned. It is difficult to substantiate this statement by statistics or direct evidence, but it is a view based on experience and common among mining men.

This abnormal situation arises from the fascination gold mining has for certain individuals. In many instances, the lure of possibly enormous profits encourages a share buyer to venture his money in the search for and exploitation of gold mines in the hope they will yield dividends commensurate with the risk. This venturesome practice results in a steady supply of newly mined gold, which may bring profit to certain companies or individuals but is not enough to return the invested capital plus a profit to the industry as a whole.

In view of this condition, it is doubtful that the gold mining industry has any present value when examined from the profit point of view, even though several individual mines may reap enormous profits. Even if one were to assume that gold mines could make a profit of $1 an ounce, the present value of the average annual production and of the known reserves is relatively small. For example, in 1947 it would be only $11,000,000 (see Sec. F).

2 *Nationalistic Method*

The consumer or 'nationalistic' viewpoint assumes that, regardless of profit or cost to the producer, the mining and recovery of gold over a period of years create a certain amount of new wealth for the benefit of the public at large. This new wealth is in the form of wages to employees, profits to supply and machinery merchants, taxes to local, state, and federal governments, profits to producers, and so on. In addition to these public benefits, gold is made available to be used as the basis of the credit system, for international exchange, and for the arts and sciences. Obviously, however, any estimate of the true amount of new wealth created *must* consider the cost to the producer of creating this wealth. Otherwise, the process simply represents the transfer of wealth from one group to another —a case of 'robbing Peter to pay Paul'.

Because more capital is spent in the search for and exploitation of gold deposits than is recovered, it is likely that no new wealth is created; its present value, therefore, is zero. This does not mean that the gold mining industry does not have considerable intangible value. It simply means that this value, from the nationalistic viewpoint, cannot be expressed in dollars.

If one entirely neglects the cost factor, the present value of the United States gold reserves can be determined by discounting the total gross value of these reserves to the present value, using as a discount rate the percentage depletion for each year of the reserve for its estimated life $\left(V_p = \frac{P}{(1 + r)n}\right)$. This, of course, is a fictitious figure which may be a measure of the magnitude of the turn-over of the industry rather than of the true value of the gold mined.

C Coal

Coal mining is our largest mining industry; and the known reserves, measured either in tons or in years of life at the present rate of consumption, occupy front rank. The occurrence of coal deposits is such that it is relatively easy to make fairly accurate estimates of the quantity in the ground because of the general persistence of beds. Disappointments have cropped up in the course of mining; but, in general, and far within the limits of accuracy demanded by this study, there are no grounds for large doubt concerning figures for estimated reserves. These are calculated by the Geological Survey and Bureau of Mines as sufficient to supply present demands for bituminous coal and lignite for considerably more than 1,000 years. The anthracite reserves are deemed adequate to last 187 years, but because of the special circumstances surrounding its production and consumption, this study will consider bituminous coal alone. Of this, the reserve is so large that no anxiety about supply is felt, except for certain kinds of coal in certain areas. There is of course a final limit, but it is far away; although coal is not as unlimited in quantity as the reserve supply of magnesium and salt, derived from both land mines and the sea, or nitrates, derived from the atmosphere, for all practical purposes it may be regarded as unlimited. In coal mining, the coal itself has always been the cheapest material the miner handled, hence it has been especially difficult to reach any high degree of efficiency from a conservation standpoint. To say that more than half the coal is left in the ground is an understatement, and its very abundance has led to much economic waste through overexpansion of mining whenever a temporary market shortage has produced an apparent scarcity of supply. After 1921, according to Treasury data, and until 1940 the coal industry of the United States ran at a loss, such profits as were made by a few companies being more than offset by deficits of the many.[7] Apparently it is only in war years, when the sudden increase in demand and the national shortage of labor and supplies temporarily prevent the opening and equipping of new mines, that coal mining yields a gain. A big war every generation or a big strike every year or so can hardly be considered nationally profitable even if one result does happen to be a temporary profit to our biggest mining industry. It is manifestly difficult to evaluate a business that for so much of the time operates at a loss, however necessary and beneficent it may be to the national economy and to defense.

The bituminous coal industry was equipped in 1946 to turn out 620 million net tons a year—far less than demand. Since 1915, however, there have been more years when the market called for less than 500 million tons than when it has called for more. At the depth of the depression demand totaled as little as 300 million tons. In the years since World War I coal has steadily lost markets to competing fuels and to hydro power; the higher price established during the recent war forced a greater efficiency in burning. With an overcapacity of 20-25 percent and widespread monetary losses from mining, the hope of profits and the desire of individual fuel-using industries for an assured supply induced a sufficient flow of capital into the industry to maintain production and provide for some expansion. Apparently the present expected rate of profit is

[7] *Minerals Yearbook, 1943,* p. 838.

sufficient to keep the industry functioning. Both costs of production and prices at the mine have risen, but the margin has been substantially the same for the last 40 years. It is this margin—the measure of the value of coal in the ground—that is crucial. The operator is little benefited by a higher sale price if his costs and taxes rise in the same ratio. Moreover, he cannot afford to pay more for additional tonnage in the ground, either in the form of royalty or by purchase in fee; these costs have apparently kept pace with increases in price and seem likely to continue to do so.

Of several reasons for the slim prospect of higher profits from coal mining, three are outstanding. First, since wages are still the largest element in production cost, higher rates of pay eat up the economies in other elements. Increased mechanization is transferring part of this cost from labor to capital, but the charge for the latter, despite falling interest rates, does not seem to decrease as rapidly as labor cost rises. The miners have succeeded in absorbing most of the profit from mechanization and may well press for more. Their standard of living has risen with their wages; though socially, and probably economically, a good thing, this is not conducive to lessening demand for higher pay. As opportunities have opened and wages have risen in other industries, fewer boys in miners' families have followed their fathers' trade—mining is not unique in this respect.

Second, the likelihood of higher taxes in the future, though less certain, is ominous. The progressive demands on government put cumulative pressure on legislative bodies and tax authorities to pounce on any possible source of revenue. The power to tax has been well said to be the power to destroy; but as long as an industry continues either to breed capital within or attract it from without, fear of killing the proverbial goose that lays the golden egg is unlikely to prevent tax authorities from making heavier assessments or raising rates.

The third factor is competition, not only with alternative sources of energy but within the industry itself. So much good coal land is available for development that competition is keen within the industry, nearly everywhere and always. Sellers' markets are rare in the coal industry, and selling agents and staffs are prone to cut prices to the limit. Even a small portion of the coal sold at too low a price may ruin the market for a large part of the output, and once reduced, prices are hard to restore.

For these and other less important reasons, the margin of profit, and hence the value of coal in the ground, is not likely to rise as long as an adequate tonnage comes to the market on the present basis. If profits become larger, it is more than probable that labor will demand a bigger share, that the taxing authorities will grab them, or that competing sales forces will dissipate them by cutting prices to get tonnage from competitors. Therefore it seems safe to predicate future earnings on the current margin of profit; in the absence of an elaborate study and many more data than are now available, this marginal profit per ton is the readiest measure of the value of the coal in the ground. It is the expectation of realizing such profit that induces coal production.

Unfortunately, no estimated figure for expected profit per ton can be accepted with full confidence. Some data may be obtained from examination of royalties, some from actual profits revealed or predicated in case of purchases of land or consolidation of companies, and some from studies of operations of particular companies, but the exact figure must be largely a matter of opinion. As such, rather than as an ascertained fact, it is believed that the amount left over after more immediate bills have been met and therefore available—or expected to be available—to pay for the coal itself, is of the order of 10 cents a ton. It is believed that, over a term of years and on the average for the whole industry, not more than this amount has been realized from mining itself, and that, on the expectation of such profit, adequate capital to maintain the industry at the present status is likely to continue to be forthcoming. This price would correspond to about $500 an acre for coal rights in undeveloped land containing a 5 foot bed of coal of good grade and fairly accessible. Government leases of coal land in the West generally call for 5 cents a ton; however, large mines have been opened and operated at twice this rate, although the coal, while thick, was lignitic rather than bituminous but so situated as to permit open-pit mining. Near centers of consumption, or with coal of superior grade, a higher price would be paid; however, as a general average, the figure is believed to be near enough the truth to serve.

The present value of the coal reserve depends on the number of tons that will be mined and the rate at which it will be brought to market as well as on the unit value. In view of the virtually unlimited amount available, the tonnage mined will depend upon market conditions, and the term of years through which production can be figured will be restricted only by the decreasing present value of the returns. Except for temporary heavier demand in war years and smaller demand in deep depression, output has been fairly stable since 1915—between 500 and 600 million tons a year. The long steady rise in demand from the beginning of the century was checked by the initial effects of World War I. Since then the trend has been generally about level, year after year, and 500 million would be approximately correct as the normal output. Assuming, as seems probable, that industrial growth will offset the effects of competition of other sources of energy plus any additional loss of market due to greater efficiency in the use of coal, only some extraordinary change could be expected to upset this assumption of future market.

Another war would do so. Failure of the supply of petroleum or natural gas would do so, at least temporarily. A shift in international demand might do so permanently, as it is now doing temporarily. Application of atomic energy to industry might in time ruin the coal industry, but it is hardly likely to do this within any short period. These various possibilities cannot be balanced with certainty, and we can only assume a future production rate of 500 million tons a year as a conservative estimate of average demand. Coal will be produced at present values for 40 or 50 years. Although coal to be produced in the years beyond has some present value, it cannot be reduced to a dollars and cents figure with any degree of assurance. The problem, then, becomes one of ascertaining the present value of the future output through 40 to 50 years of 500 million tons of coal at 10 cents expected profit a ton; in other words, the present value of an annuity of $50 million for the periods stated and at assumed discount rates. For reasons already given, these are calculated at 3, 3.5, and 4 percent, determined by the assumed rate at which depletion reserves could have been set to work in 1946, 1939, and 1929. For convenience, the results were calculated for both 40 and 50 year periods. To the objec-

	Discount, %	*40 years, $billions*	*50 years, $billions*
1929	4	0.990	1.074
1939	3.5	1.068	1.173
1946	3	1.156	1.286

tion that a billion and a fraction dollars is a very small sum to assign as the present value of 20-25 billion tons of coal, it may be pointed out that although the coal may be sold for $2 to $2.50 per ton at the mine and bring in $40-60 billion, these sums include not only what is paid for the coal but the cost of producing it, and the latter is by no means an asset to the land owner.

The instructive feature of these calculations is the small present cash value of an undeveloped resource, even though it is large in amount and essential to industry before it is put to work. The United States is rich not because of its natural resources but because of its people. With about 7 percent of the world's population, it produces half the world's goods because it puts its latent resources to work.

The foregoing value does not take into consideration the possible expansion of coal production if a synthetic liquid fuels industry is established in the United States. Such a development might well treble the demand for coal in two or three decades.

D PETROLEUM AND NATURAL GAS

Of the three years specified by the Conference on Research in Income and Wealth, the estimates of the current market value of the proved oil and gas reserves of the United States at the close of 1929 and 1939 present the most difficulty. At the close of 1929 the development of the oil industry was about midway between the discovery of the Oklahoma City field and the huge East Texas field. The oil states generally had not yet adopted the policy of regulating oil and gas production, and the more modern accomplishments of petroleum engineering were first appearing. Current data on the proved oil and gas reserves were not accessible to the public and values were still affected by price changes due to surges of excess supply. More data are available on the proved reserves at the close of 1939, but prices then were lower than in the preceding 3 years, and gasoline prices at the refineries were moving down. Accordingly, it is more difficult to determine the value of the proved oil and gas reserves at the close of 1929 and 1939, and any such determination is subject to more widely divergent viewpoints than is determination of the value of such reserves as of the end of 1946.

Within the limitations of the data and recognizing that the request is for approximate estimates only, the following values, in billions as of December 31, are suggested for the proved oil and gas reserves of the United States, producible through existing wells by methods currently in use: 1929, $6.5; 1939, $9; 1946, $15. These total values were obtained by multiplying the number of barrels or cubic feet of natural gas in the proved reserves by the value per barrel of oil or cubic foot of natural gas at which such oil or gas reserves were evaluated in the trades and transfers of oil and gas properties at the time. The calculation is based on average values and assumes that the values expressed in the transfer of individual properties are applicable to the entire reserves. The estimates are an expression of value that is not related to the corporate valuation of such assets or reflected generally in the purchase and sale of securities on the markets.

The 1946 figure was calculated by applying 50 cents a barrel to the approximately 24 billion barrels of crude oil and liquid hydrocarbons in the proved oil reserves and slightly less than 2 cents a thousand cubic feet to the 160 trillion cubic feet in the proved gas reserves, giving $12 billion for oil and $3 billion for natural gas. Fifty cents a barrel is a minimum, as transactions at higher prices were being made at the close of 1946 and subsequently.

Opinions of individual buyers concerning the future supply and price trend of oil are not identical, nor are their needs equal; so these differences can be expected to influence the values placed upon such reserves by individual buyers.

The oil reserve data used for 1929 and 1939 were those compiled for crude oil by the Petroleum Administration for War, plus an estimated quantity for other liquid hydrocarbons, natural gasoline, and condensates. The reserve data for natural gas were the estimates customarily in use—about 45 trillion feet in 1929 and about 70 trillion in 1939. The proved oil reserves, as estimated by the Petroleum Administration for War at the close of 1939, are higher than the American Petroleum Institute estimates for the close of 1946, but the average posted crude oil price at the end of 1946 was substantially higher than in 1939.

Opinions will of course vary concerning the value of the 1929 and 1939 reserves, and the figures suggested here represent an intermediate viewpoint between higher or lower estimates. Less difference of opinion can be expected about the value of the 1946 reserves. Undeveloped and undiscovered petroleum resources of the United States are not included in the foregoing estimates. The estimates are based on proved reserves, which have been drilled and are in production status. The value added by the drilling and equipping of the wells obviously accounts for the major portion of the total estimated value.

For the purposes of this study an evaluation exclusive of values added by drilling and equipping wells is desired. Such an appraisal of oil and gas resources in the ground can be approximated from royalty payments to land owners stipulated in leases taken prior to drilling. As previously stated, 12.5 percent is well established as the land owners' share of petroleum. Royalty rates for natural gas and liquefied products derived therefrom vary considerably, and are usually somewhat less than those for petroleum in recognition of the heavy capital investment required for liquefaction plants. It is assumed that they may average 10 percent. Applying these rates to the dollar value of oil and gas production in 1929, 1939, and 1946, and calculating the present worth of these annual royalty payments over the period indicated by known reserves and production rates in these three years, the value of oil and gas in the ground exclusive of value added by drilling and equipping wells is: 1929, $1,674 million; 1939, $1,971 million; 1946, $3,336 million. The present worth computations assume an 8 percent return on invested capital with sinking fund rates at 4 percent in 1929, 3.5 percent in 1939, and 3 percent in 1946. Petroleum reserves were calculated as equal to 13 years of production in 1929, 19 years in 1939, and 14 years in 1946. Those of natural gas were equal to 23, 29, and 39 years in the same years.

E Iron Ore

A large amount of data is available on the reserves and value of iron ore, particularly in the Lake Superior region, which supplies 80 to 85 percent of the annual production. In Minnesota the tax authorities have collected and published the essential figures on reserves and value since 1914. In other states the federal and state geological surveys have made fairly satisfactory if less complete estimates. Burchard, Johnson, and Melcher, of the Geological Survey and the Bureau of Mines, have summarized the estimates and allow 3,726 million gross tons for the measured and indicated ore, 1,755 million for the inferred ore, and 62,915 million for the potential ore. Of these amounts, the first corresponds most closely to estimates of known reserves of ore in the ground, as that term is generally used. Of this total, 1,306 million tons are credited to the Lake Superior region, 1,561 to the southeastern United States, and 536 to the northeastern region, including New York, New Jersey, and Pennsylvania. The estimate for the southeastern deposits is a little above other figures and for the northeastern a little below; but the ores of the southeast are perhaps most surely estimated in advance, and Burchard has long and intimate knowledge of them. The mode of occurrence of the ores in the northeastern region is such that it is much more difficult to make good estimates in advance of close drilling, which has been done in only a few districts. After many years during which the region had been only a minor producer, it has recently attracted renewed interest.

An excellent general summary of the whole iron ore problem has been made by C. M. White, President of the Republic Steel Corporation, which has carried on active exploration in the northeastern region as well as in other areas.[8] White thinks each of the three regions now contains reserves of approximately a billion tons. There is no doubt that the total iron in the crust of the earth is virtually unlimited, and if in all districts the means can be found to process and work ores of the low grade mined in other producing districts, there is virtually no limit to the ore reserves. It is a problem in technology to convert rock into ore, and the critical point is the ratio between rate of discovery plus technologic development and that of depletion by use. White's figures on experience in the Lake Superior region permit some rather comforting inferences. The reserves for the entire region for 1939 are given as 1,380,900,000 tons, and for 1946, 1,144,129,000, a decrease of 236,811,000 tons. But in the 7 years shipments totaled 526,923,000 tons, a difference of 290,112,000 tons, which could have come only from additional discoveries. In other words, while the mines shipped 75 million tons a year, 41 million came from discoveries that otherwise would have been added to the reserve. This indicates a ratio of discovery to production of 55 percent for the principal iron ore region of the United States during years of unusually heavy shipments and of curtailed exploration due to wartime shortages of labor and supplies, to say nothing of the deterring effect on exploration of

[8] 'Iron Ore and the Steel Industry', an address delivered before the American Institute of Mining and Metallurgical Engineers, March 1947.

the policy of taxing reserves in the ground for all the years after discovery and before production.

Recently concern has been voiced over the heavy draft on our iron ore reserves during the war; for example, by Hotchkiss in *Economic Geology,* May 1947. There can be little doubt that the big open pits in high grade ore on the Mesabi range, the shock absorbers for so many years, are rapidly nearing exhaustion. The Lake Superior iron ore reserves as a whole, however, are not being as seriously depleted as would appear at first glance. According to the present showing, a life of 27 years is indicated, even at wartime production rates and without further technologic developments that may reasonably be expected. About other ore producing regions less definite statements can be made. In the Northeast exploration is much less complete, and much heavier demands on it are to be expected to supply ore to the Atlantic coast steel plants reasonably certain to be built. In the Southeast, although there is no difficulty about total reserves, there is doubt about the continued availability of grades originally used to supply southern furnaces. The rich brown ores have been heavily drawn on, and the hard red hematite ore of the Birmingham district now being mined does not, on the average, contain as much iron as that mined in earlier years. In very general terms and for the country as a whole, it may be stated that whereas formerly 2 tons of iron ore yielded 1 ton of pig iron, now 2.5 tons are required. The southern companies are already hunting for richer ores that may be imported to improve the furnace charges. The conditions that once made the Birmingham district the cheapest large producer of pig iron have changed; in time, this will certainly be reflected in the value of ore in the ground, so that conservative figures must be taken in valuing the country's reserves. An independent appraisal on the basis of present royalties would probably put the value at 15 cents, or even more, per ton in the ground, but it seems wiser to use the 12.5 cents assessed by the Minnesota Tax Commission for the 1,034,300,000 known Minnesota reserve tonnage as of May 1, 1945.

This places, as of May 1945, a value of $129 million on the Minnesota reserves. State agencies estimated total reserves for the Lake Superior district to be 1,381 million tons in 1939 and 1,144 million in 1946. Applying the Minnesota assessment rate to the region as a whole, the total value of the Lake Superior ores in the ground may have been $173 million in 1939 and $143 million in 1946. All these figures are low, since the old range ore found in other parts of the Lake Superior district is of higher grade than the Mesabi, which dominates the Minnesota figures. Old range ore is also more expensive to produce, so that a more exact statement cannot be made with the data at hand. On the basis of the Department of the Interior estimates, the Lake Superior ore reserves may be considered to have a present value in the ground of about $163 million. If it is considered that the ore reserves of the entire country have a similar value per ton, the total would now be approximately $466 million. Although no attempt has been made to work out exact figures for 1929 and 1939, such data as are available seem to indicate that they would not differ from those for 1946 to any large degree.

One factor that may materially influence realization of this sum is change in practice. It is not iron or even iron ore consumption that fixes demand and prices, but steel consumption; the quantity (in tons) of iron ore used to produce 1 ton of steel fell from 1.47 in 1912 to 1.10 in 1937, rose to 1.45 in 1942 but fell to 1.13 in 1943.

Before World War I the ratio of iron to scrap in a steel furnace was of the order of 1.1. At the moment, owing to a shortage of scrap and an exceptional demand for steel, the blast furnaces are being called upon to furnish unusual amounts of iron; but this does not seem likely to continue, and the trend of more steel from less iron ore will probably be resumed, since the stock of steel in use and hence the amount potentially available as scrap is increasing. This may, in time, seriously affect the demand for iron ore and compensate, to a degree not easy to evaluate, for any scarcity that would otherwise develop from the exhaustion of ore reserves.

F Conclusions

On the basis of the five minerals studied, we may estimate the value of all subsoil mineral resources. In 1929 these commodi-

Reserves	*1929*	*1939*	*1946*
	MILLIONS OF DOLLARS		
Copper	25	25	25
Gold	10	22	11
Coal	1,074	1,173	1,286
Oil and gas	1,674	1,971	3,336
Iron ore	466	466	466
Total	3,249	3,657	5,124

ties contributed 67 percent of the value of all minerals produced in the United States as reported by the Bureau of Mines; in 1939, 74 percent, and in 1946, 75 percent. No attempt has been made to determine the values of the other resources that contribute the remaining 25-31 percent. Among these are anthracite and the nonmetallic minerals such as stone, sand, gravel, cement, and lime which are mined under conditions of royalty payments and unit-profit margins not greatly unlike those for coal and iron ore. Nonferrous metals other than copper and coal also contribute significantly to the nation's annual output and these are produced under conditions similar to those prevailing in copper and gold mining. Consequently, for the purposes of this study and in the absence of more specific data we may apply to all minerals the average ratio of resource value to the value of annual production as determined by our sample of five minerals. The order of magnitude is: 1929 and 1939, $5 billion; 1946, $9 billion.

In appraising the significance of these figures it should be clearly understood that the present value of the subsoil resources of the United States cannot be estimated precisely. Such tests as have been made in the course of this study have led to figures much smaller than those commonly published. The discrepancy is probably due to confusion between the sale price at the mine and the value in the ground. As already pointed out, the former includes the cost of production as well as the value in the ground. Oil and gas are an interesting illustration. Swanson's estimates give a present value to the reserves of these materials much higher than their value to fee owners, larger than any other rèserve studied here, and even larger than the total for all resources as computed above. To be sure, petroleum ranks first in gross sales ($2,093 million in 1945), and natural gas ($821 million in 1945) is well up toward the top. These are intrinsically high value materials and cost of discovery is one of the chief elements in production costs. Furthermore, the normally short interval between discovery and production has made the petroleum and gas industries unusually profitable. Nonetheless, it does not seem probable that the 15 years of known petroleum supply is worth 12 times as much as the 3,000 year supply of bituminous coal. Here in particular there should be some way of bridging the gap between the present value of the coal reserve as a source of profit and its value to the nation. The marked difference doubtless arises from the fact that petroleum companies refine and market petroleum products as well as produce crude petroleum, thereby retaining their hold on the major share of the profits of the industry, while the major profits of coal mining go to the railways, steel companies, or the marketing agencies. The major users of coal supply funds to keep coal mining active without too much regard to whether the mining operators make money or not as long as coal is shipped over the railways or supplies the coke ovens. In part, the same problem appears in the case of iron, where the larger mining operations are conducted by subsidiaries of steel companies. Just what would be the effect of a nicer adjustment of profits between parent and subsidiary companies or between department and department cannot be foretold with certainty; but, in justice to mining, it should be recognized that all too often mines are run at a loss in order that another industry may pay a 6 percent or larger dividend.

It should be remembered that the estimated values presented here are based upon quantities of known mineral in the ground or mineral believed, with good reason, to be there. Beyond this there are, in most categories, quantities of potential ore that can fairly be considered enormous and, in many instances, the technology necessary for bringing these 'potential' ores into the probable or even actual reserves has already been worked out or is not far from perfected. For various reasons, there is no economic incentive to apply these methods now, and usually it would be inadvisable to do so. The value of these resources to the national economy and security is of course very much greater but cannot be measured.

For reasons given above, the valuations made here concern the mineral in the ground, not at the mine shaft, and all are present values. It is as if an inventory were taken of the stock on the shelves of a store to fix a price for the sale of the business. Common experience has shown that such a sale yields a smaller sum than would be realized if the same goods were sold in the natural course of continuing trade. The larger value would be more satisfactory, but at present there is no accepted unit of measurement.

Another matter that should not be forgotten is this: The value of mineral resources is determined quite as often by market conditions as by quantities of ore in reserve. Were markets adequate, the present annual coal output of the United States could be multiplied many times, with profit to the national economy and without danger to our future safety. The difference between present and future values of a dollar to be received is so great that the time of production rather than the quantity in reserve determines the present value of many minerals.

Counting eggs before they are hatched is admittedly ill advised, but the fact that chickens are not yet born does not imply that our grandchildren will not have eggs for breakfast. It does, however, point to sound reasons for keeping our chickens well fed and healthy; and, if we are to enjoy continuing prosperity in the mineral industries, it is as essential to avoid public measures, such as taxation of developed reserves, that will retard growth as to stimulate technologic improvement in discovery and beneficiation. The vast quantities of basic metals in the ground have little or no value until dug out and put to work. From time to time it may be necessary to shift from the production of one mineral to that of another as scarcity approaches and substitution becomes advisable. Minerals are wasting assets, but mining need not be a diminishing industry. For all resources, the ratio of discovery to depletion is crucial.