BUREAU OF ECONOMIC GEOLOGY

Geological Circular 65-2

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TEXAS MINERAL RESOURCES: PROBLEMS AND PREDICTIONS[1]

Peter T. Flawn

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The Today of Texas Mineral Resources

When a reference is made to the mineral resources of Texas, most people think of oil and gas, and some few also of sulfur. And, of course, it is true that of the whopping $4.4 billion dollars worth of minerals produced in Texas in 1963, 92% was oil, gas, and natural gas liquids. In 1963, for the 29th year, Texas led the Nation as a producer of minerals. Value of mineral products was twice the value of agricultural products, equal to the value of manufactured products, and equal to about one-half the value of all retail trade. It is clear that the State has a mineral-oriented economy; it is true also that the mineral industry is distributed broadly throughout the State and not concentrated in several giant oil fields or very large mines--241 of 254 counties reported mineral production in 1963.

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[1] Text of an address to the Governor's Conference on Natural Resource Management and Development in Texas, Dallas, Texas, October 16, 1964.

But in addition to oil and gas, Texas produced 22 other minerals last year valued at $361.7 million dollars. There are indeed many States which would happily settle for this 8 percent of Texas' mineral production. Significantly, this is the segment of Texas' mineral industry growing most rapidly (fig. 1) and it is the segment that will continue to grow. Let us look at it briefly.

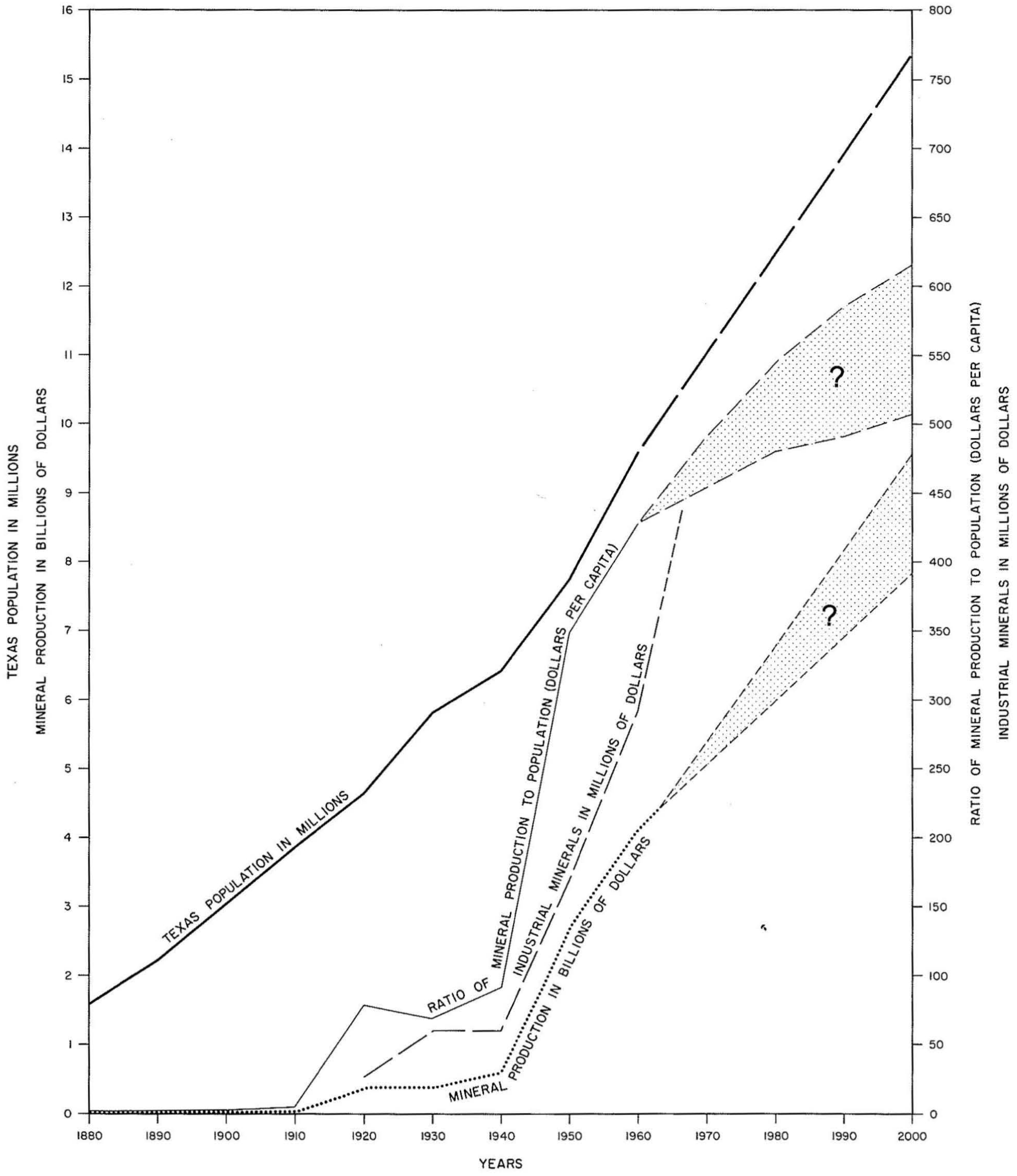
Seventeen non-metallic industrial minerals were valued at $307 million in 1963, according to preliminary figures. The other $55 million was accounted for by magnesium chloride (for magnesium metal), helium, iron ore, lignite, and uranium ore. Of the non-metallic industrial minerals, cement (portland and masonry) was first with $95.6 million, followed by stone ($54.0 million), sulfur (frasch, $50.1 million), sand and gravel ($36.3 million), salt ($22.4 million), lime ($13.0 million), clays ($6.9 million), gypsum ($4.0 million), talc and soapstone (less than $0.5 million), and gemstones ($0.15 million). Also in this category are commodities where the amount and value of production are concealed for business reasons. Asphalt, barite, bromine, graphite, magnesium compounds, pumice, and sodium sulfate together accounted for $24.2 million.

Texas owes its high rank among the States with metallurgical industries to numerous smelting and refining plants which do not process Texas ores (table 1). Ores and concentrates of aluminum, antimony, cadmium, copper, gold, lead, manganese, silver, tin, tungsten, and zinc are shipped to Texas metallurgical facilities from other foreign and domestic sources. However, the Texas steel industry is an exception and works on both Texas and foreign ores. Texas is a leading magnesium producer but the raw material is sea water. Metallurgical plants are located in Texas for a number of reasons, among which are access to tidewater, abundant fuel and power, effective transportation network, abundant sources of other raw materials used in metallurgical processes, and generally favorable business and labor climate.

The Yesterday of Texas Mineral Resources

The early settlers in Texas, red and white, depended on water and salt to sustain life and on a variety of minerals for tools and weapons. The Indians used flint. The white invader set up iron forges. He used first charcoal and then lignite and coal for fuel, and he made his powder and shot from local materials insofar as they were available. Nitrates were leached from deposits of bat guano in caves (to make potassium nitrate or saltpeter), and subsequently the guano was used locally as a fertilizer.

The first iron furnace in Texas was erected about 1855 in either Cass or Marion counties. By 1860, several additional small furnaces and bloomeries were operating. The industry grew rapidly during the Civil War to supply the needs of the Confederacy, and furnaces were operated in Anderson, Cherokee, Nacogdoches, Cass, and Marion counties. In the '80's and '90's, larger operations were planned and executed with construction of the famous Tassie Bell



TEXAS MINERAL INDUSTRY AND TEXAS POPULATION

FIGURE I

and Star and Crescent furnaces near Rusk and the Lone Star furnace at Jefferson. However, few operations survived many years into the 20th Century, and 1909 marked the last year of recorded pig iron produced from East Texas ores until the current Lone Star operations at Daingerfield and the Sheffield plant in Houston began production during World War II.

Early reports suggest that Texas lignite was utilized as early as 1819. By 1850, small-scale local production was well established. The industry grew until the early 1900's with mines located along the exposures of Eocene strata from East Texas southwest to the area south of San Antonio. In 1902, W. B. Phillips said: "The lignite industry is not at present in an encouraging situation. It has felt the competition of fuel oil much more rapidly and much more keenly than the bituminous coal. Many mines that were in operation last year are now idle, and those that are at work have had their output considerably reduced. In order to meet competition from oil, lignite is now offered for 50 cents a ton, f. o. b. mines, the lowest price ever reached in the history of the industry."

The bituminous coals of north-central Texas and the cannel coals of south Texas along the Rio Grande in Webb and Maverick counties were developed after the Civil War and were producing in the 1880's and '90's.

Production of coal and lignite rose steadily from less than 75,000 tons valued at $150,000 in 1887 to peak of more than $2\frac{1}{2}$ million tons valued at close to $5,000,000 in 1914. Production fell thereafter, although a marked price rise in 1920 sent the total value of production soaring to more than $6,500,000. After 1920, coal and lignite were hit hard in the market place by oil and gas, and production declined steadily. Significant production in north-central Texas ceased in the early 1940's and has not revived. Until construction of Alcoa's Rockdale plant, the last major fuel market for lignite was The University of Texas, and its power plant switched to natural gas in 1950. However, current lignite production from two mines is equal in value to past production from 80 mines.

Probably the most important mineral resource of the early frontier was salt. This was reflected in a general act passed in 1796, providing for the disposition of the newly acquired western lands, which reserved to the fledgling Federal government the "salt springs." In far western Texas, salt was mined by the Spanish as early as 1750 at Salt Flat in what is now Culberson County, and the 1877 salt wars attest to the importance of the resource. Of course, before any organized production by settlers, Indians produced salt from salt lakes and salt springs in Texas. Early explorers did the same. Spanish colonists in South Texas mined salt at El Sal del Rey and La Sal Vieja in Hidalgo and Willacy counties. In the Texas Republic, there is some question as to whether salt was first produced at Grand Saline in Van Zandt County or at the saline associated with the Palestine dome in Anderson County. According to The Handbook of Texas, General Nathaniel Smith began producing salt near Palestine in 1839, and his estate filed a claim against the Republic of Texas for $100 for salt used in the Trinity campaign. The first reliable statistic appears

TABLE 1. Texas Metals: Primary Extraction Plants.[1]

Product, Company, and Plant	Location, county	Material treated	Source of material
Aluminum			
Aluminum Co. of America			
Point Comfort (alumina)	Calhoun	Bauxite	Foreign
Point Comfort (reduction)	Calhoun	Alumina	Above
Rockdale (reduction)	Milam	Alumina	As above
Reynolds Metals Co.			
Sherwin, LaQuinta (alumina)	San Patricio	Bauxite	Foreign
San Patricio (reduction)	San Patricio	Alumina	Above
Antimony			
National Lead Co.			
Laredo (smelter)	Webb	Ore	Foreign
Cadmium			
American Smelting & Refining Co.			
Corpus Christi (electrolytic)	Nueces	Flue dust	Foreign
Copper			
American Smelting & Refining Co.			
El Paso (smelter)	El Paso	Ore & concs.	Foreign & domestic
Phelps-Dodge Refining Corporation			
El Paso (refinery)	El Paso	Blister & anode	Domestic
Iron			
Lone Star Steel Co.			
Daingerfield (integrated steelworks)	Morris	Ore & scrap	Domestic
Sheffield Division of Armco Steel Corporation			
Houston (integrated steelworks)	Harris	Ore & scrap	Domestic & foreign

TABLE 1 (continued)--

Product, Company, and Plant	Location, county	Material treated	Source of material
Lead			
American Smelting & Refining Co.			
El Paso (smelter)	El Paso	Ore & concs.	Foreign
Magnesium			
Dow Chemical Co.			
Brazosport (reduction)	Brazoria	Sea water	Domestic
Manganese			
Tenn-Tex Alloy & Chemical Co.			
Houston	Harris	Ore	Foreign
Tin & Tungsten			
Wah Chang Corporation			
Texas City (smelter)	Galveston	Concentrates	Foreign
Zinc			
American Smelting & Refining Co.			
Amarillo (retort smelter)	Potter	Ore & concs.	Domestic & foreign
Corpus Christi (electrolytic)	Nueces	Ore & concs.	Foreign
El Paso (fuming plant)	El Paso	Residues	Domestic
American Zinc Co. of Illinois			
Dumas (retort smelter)	Moore	Concs. & fumes	Foreign & domestic

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[1] Modified from E. H. Bucknall (1964) Texas Metals, Metal Industries and Metallurgy: Texas Business Review, Vol. XXXVIII, no. 8, p. 189.

for the year 1892 when 121,250 barrels of salt were valued at $99,500. During the Confederacy, production increased sharply through evaporation of surface salines associated with salt domes in Smith and Anderson counties. Underground mining of salt began in 1929 at the Kleer mine of the Morton Salt Company at Grand Saline in Van Zandt County. Large-scale salt production is a consequence of the growth of industries in the Texas region. Salt is an important chemical raw material in the manufacture of soda ash and in many other industrial uses in the areas of food, refrigeration, agriculture and livestock, metallurgy, and water treatment.

Although not now a producer of metals from its own ores (except for iron and magnesium), Texas has had its moments in the past. After the Civil War, there were attempts to promote and develop the small sporadic copper accumulations in redbeds of north Texas, and small shipments of copper ores were made. In the Trans-Pecos, mercury, silver, copper, lead, tin, and zinc have been produced sporadically from the post-Civil War period to the present. In Burnet and Llano counties in the Central Mineral Region, there are a number of prospects in which lead, copper, and tungsten mineralization can be demonstrated.

Beginning in the '80's with production of clays, lime, building stone, cement, gypsum, and salt valued annually at about $500,000, non-metallic industrial mineral products have grown more diverse and steadily increased in value.

The history of petroleum and sulfur has been treated separately in this conference.

One way to get a quick but comprehensive look at the past is to compare Texas' mineral production in 1882 with production in 1900, and again with production for the most recent year for which final figures are available, 1962 (table 2). The rise and fall of industries are recorded in these statistics, particularly if they are examined on a year-to-year basis. For example, mineral water was a big industry prior to the State-wide development of approved public water supplies. The boom and bust of metal mines in the west are reflected in these statistics, as is the fall of coal and lignite industries before oil and natural gas. But although individual commodities have had their day and passed from the scene, or have fluctuated widely, the overall mineral industry has grown in a great soaring curve like the Texas population curve (fig. 1).

The low unit value commodities, particularly the construction materials, do not move far in trade and their production reflects local conditions directly; production of higher value commodities which are transported long distances is geared to national and international markets.

The lesson we can learn from yesterday is that changing demand and changing cost structures due to technological and social changes affect individual commodities

TABLE 2. Comparison of Texas Mineral Production 1882-1886, 1900, and 1962.

TEXAS MINERAL PRODUCTION, 1882-1886 (five-year period) (Phillips, 1910, p. 22).

Clay products, estimated value	$1,500,000
Coal (including lignite), estimated, 500,000 tons	1,000,000
Iron ore, 33,100 tons	33,100
Pig iron, 12,400 tons, estimated value	248,000
Silver, 155,039 ounces, commercial value	154,263
All other products, including building stone, cement, gypsum, salt, etc., estimated	2,000,000
Total value for five years	$4,935,363

Note: This includes an extraordinary item of $1,000,000 for stone used in construction of the State Capitol.

TEXAS MINERAL PRODUCTION, 1900 (Phillips, 1910, p. 27)

Cement--hydraulic, 17,000 barrels, $28,900; portland, 26,000 barrels, $52,000	$ 80,900
Clay products--brick and tile, $1,083,553; pottery, $87,464	1,171,017
Coal and lignite, 968,373 short tons	1,581,914
Gold, 53 ounces	1,100
Granite	76,069
Gypsum, 50,000 short tons	100,000
Iron ore, 16,881 short tons	16,881
Limestone	124,728
Mineral waters, 5,438,700 gallons	209,991
Natural gas	20,000
Petroleum, 836,039 barrels	871,996
Pig iron, 10,150 long tons	203,000
Quicksilver, 1800 flasks	75,600
Salt, 320,000 barrels, estimated	210,000
Sandstone	37,038
Silver, 477,400 ounces, commercial value	295,988
All other products, estimated	400,000
Total	$5,316,222

TABLE 2 (continued)--

TEXAS MINERAL PRODUCTION, 1962[1] (U. S. Bureau Mines Minerals Yearbook)

Mineral	1961		1962	
	Quantity	Value (thousands)	Quantity	Value (thousands)
Cement:				
Portland, thousand 376-pound barrels	25,101	$ 80,808	26,204	$ 83,162
Masonry, thousand 280-pound barrels	851	2,529	926	2,774
Clays(2), thousand short tons	3,786	5,737	3,744	5,634
Gemstones	(3)	150	(3)	150
Gypsum, thousand short tons	1,074	(4) 3,832	1,120	3,956
Helium, thousand cubic feet	173,066	3,196	245,623	8,552
Lime, thousand short tons	(4) 790	(4) 8,703	1,047	11,999
Natural gas, million cubic feet	5,963,605	733,523	6,080,210	747,866
Natural gas liquids:				
Natural gasoline and cycle products, thousand gallons	3,111,427	214,279	3,205,517	233,345
LP gases, do	4,768,222	185,558	5,012,291	189,382
Petroleum (crude), thousand 42-gallon barrels	939,191	2,791,377	(5) 936,508	(5) 2,796,136
Salt, thousand short tons	4,695	17,682	5,553	19,485
Sand and gravel, do	27,398	30,691	30,076	33,097
Stone, do	38,316	45,874	38,067	48,988
Sulfur (Frasch-process), thousand long tons	2,730	62,720	2,655	57,297
Talc and soapstone, short tons	78,214	376	73,635	387
Value of items that cannot be disclosed: Asphalt (native), barite, bromine, clay (fuller's earth), coal (lignite), feldspar (1961), graphite, iron ore (usable), magnesium chloride (for metal), magnesium compounds (except for metal), pumice, sodium sulfate, and uranium ore	---	50,923	---	58,774
TOTAL		(4) $4,237,958		$4,300,984

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[1] Production as measured by mine shipments, sales, or marketable production (including consumption by producer).

[2] Excludes certain clays, value included with "Value of items that cannot be disclosed."

[3] Weight not recorded.

[4] Revised figure.

[5] Preliminary figure.

but that overall demand for minerals rises with population and with the march of our industrial society. The impact of the changes is, of course, less on regions or political units with broad-based mineral economies than on those with only one mineral crop. The economy of States or Nations which depend largely on one mineral, such as copper or iron, fluctuates with the health of that particular industry. Texas already knows this. When the petroleum industry (which accounts for 92% of the value of mineral products produced in the State) slumps, the State's mineral economy slumps and the State's tax revenue, geared in part to the petroleum industry, declines. Fortunately, the effect of the recent slump in petroleum production was in part offset by continued growth in natural gas and continued strength in other segments of the State's mineral industry. But the slogan for the future should be--broaden the base!

The Tomorrow of the Texas Mineral Industry

Rather than undertake a laborious commodity-by-commodity forecast, I propose to look at the future by discussing some of the major resource and conservation problems that will influence the mineral industry in the State. The past is interesting and we can learn from it. The present is soon past. The future is the real frontier. In discussions of mineral resources it is, I think, convenient and useful to consider three great groups of minerals--(1) minerals for materials, (2) minerals for energy, and (3) minerals to sustain life. Least critical in terms of eventual exhaustion are minerals for materials because as the limit is approached there are substitutions, such as ceramics, glass, and plastics for metals, although modern culture would certainly be drastically affected by a metal shortage. Energy minerals consist of fossil fuel minerals and nuclear energy minerals. The breeding process, wherein fertile isotopes are converted to fissile isotopes, makes available for use as nuclear fuels a very large reserve of uranium and thorium minerals. The ultimate substitute for energy minerals is continuous energy sources including solar, tidal, and geothermal energy, but a shortage of energy minerals would also profoundly change modern society. There is no practical substitute for the life-sustaining minerals, such as water, salt, and food-producing minerals (soils and fertilizers).

Our concern, therefore, is on several different levels. We can live with substitutes on the materials and energy levels but not on the life-sustaining level. Within our present social and economic structure, technology cannot create water economically on a large-volume basis. It can make potable water out of sea water, but if we were suddenly forced to turn to the sea for large volumes of water, the distribution systems required to move it to the continental interior would revolutionize living patterns.

Changes will come with changes in resource availability, both in terms of absolute availability and in terms of changes in cost structures. Those in industry and those in government concerned with exploration, development, exploitation, and management of mineral resources are responsible to see to it that the flow of resources into society continues in an orderly way sufficient to supply the needs, and that no disruptions occur due to uninformed political decisions and inadequate planning. In order that executive and legislative decisions can be informed decisions, and so that planning can be effective, we must have accurate information on reserves of mineral commodities.

It is customary among geologists and engineers to speak of reserves and resources in rather precise terms. Reserves, called measured, indicated and inferred depending on the degree of reliability of the data, are quantities of minerals that can be reasonably assumed to exist and are producible under existing economic conditions with present technology. Potential reserves include minerals which might become usable under future economic conditions and technology but which are not now usable because of high costs due to remote location or inaccessibility caused by other factors, difficult mining conditions resulting from depth of ore or nature of the ore or ground, small size of the ore body, impurities in the ore, or low grade of the ore. Resources are reserves plus potential reserves.

In order to meet the challenges of the future, it is necessary to weigh and understand two currently held concepts of mineral resources.

In the era of the high-grade ores, now drawing to a close, there developed the concept of an ore body as a finite volume of rock subject to physical exhaustion, and this ore-body concept was extended to the sum total of ore bodies, the mineral resource. High-grade ores are abnormally high concentrations of a mineral or minerals in the earth's crust, and in poking around on the present surface and in the rather limited third dimension accessible to exploration, it has been demonstrated that such high concentrations or high-grade ores are indeed finite in volume. I shall refer to this concept of finite mineral resources as the ore-body concept, but it applies equally well as the "oil-pool concept" or the "coal-bed concept."

Recently, there has been a shift away from the concept of a mineral resource as finite and exhaustible to a concept which views mineral resources solely as a function of cost or economics. This cost concept has been put forth mostly by economists (Gonzales, 1964; Brooks, 1964), and it seems well on the way to becoming a national viewpoint, despite a more balanced view recently put forth by the National Research Council (Frasché, 1962). I think the reason that this cost concept of resources has not been challenged by the engineer and geologist is because they react to it with mild surprise and a kind of "Well, of course" attitude, not realizing just how far the cost concept goes and the ramifications of it.

The economist, like all of us, is impressed by technology. Within a fluctuating price and cost structure, he has seen the mining industry move into ever leaner ground, on larger shift volumes. What was waste in 1900 was marginal ore in 1930 and is ore today. He has seen the cut-off grade on copper ores change from 2% Cu to 1% Cu to 0.8% Cu to 0.6% Cu. He has seen the design and implementation of mine, quarry, and mill equipment designed to handle ever-increasing volumes of ore at lower cost per unit volume.

At the same time, he has witnessed a seemingly endless parade of new discoveries of mineral deposits and the resulting development of fierce market competition. Some mineral commodities have been challenged in their traditional market place by substitutes. For example, in the early 1950's there was National concern over the adequacy of sulfur supplies, but by the mid-1950's, the price of sulfur was declining under pressure from new sources of Frasch sulfur and sulfur recovered from sour gas. Aluminum has taken some copper markets and comes out of its corner in a rush when the price of copper begins to rise. Tar sands and oil shale have spoken to the alarmists who predict the exhaustion of petroleum resources. I think the sanguine view of the economist is understandable. When immediately after World War II it was calculated that at the current rate of exploitation there remained to the Nation only 30 years' supply of copper, 13 years' supply of lead, and 26 years' supply of zinc, the Nation was alarmed.[2/] But now, nearly 20 years later with large proven domestic reserves of these metals, the wolf cry is not so alarming.

There is, however, danger in swallowing whole the panacea of "Technology will find a way," and it is the duty of the engineer and geologist to point out the limits of this dogma. As always, the truth lies between the extremes--between the "ore-body concept" and the "cost concept."

It is, of course, true that a rise in price, a decrease in freight rates, a decrease in costs, or a favorable change in taxes, subsidies, or tariffs can change the cut-off limits of mining and make more rock available as ore. Costs nowadays are lowered through technological advances rather than through cuts in wages. Technological advances are also responsible for making available, as ores, bodies of mineralized rock that were previously too deep for competitive mining or which were of such mineralogy and texture that they could not be competitively beneficiated.

There is, however, an ultimate limit which is reached when the total investment (of materials and energy) required to procure a commodity exceeds its value to society, that is, when a commodity becomes too expensive for its traditional uses. As the limit is approached, there will be a change and then a disruption in society, the magnitude depending on the importance of the commodity to society.

This discussion of ultimate limits would appear to support the cost concept of resources except that long before the limits are reached, the sources of minerals will continue to be ore bodies which are subject to exhaustion. We have to continue to explore for those parts of the crust where natural processes of

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[2/] Mineral resources of the United States: Public Affairs Press, 1948, pp. 98, 126, 212.

concentration have done part of the job and enriched a volume of rock in a particular constituent or constituents. These volumes of rock are finite and exhaustible. A comparison of the relative abundance of various elements in the earth's crust with the grade of ore currently being mined, shows that ores are natural concentrations anywhere from 4 to 2,500 times average concentration, depending on the commodity.

For the mineral producer working an ore body, oil pool, or coal bed, physical exhaustion of mineral resources is very real, and so it should be too for the planner concerned with State and National needs. Blithe references to "Technology will find the answer" or "We can tap the vast riches of the sea" do not take into account the disruptive effects that will accompany the strict application of the cost concept of mineral resources. Engineers and geologists do not seem to appreciate the possible repercussions of such a concept on the legal and political framework in which mineral exploration and development must take place. If the cost concept is adopted as National policy with accompanying changes in the tax structure of the mineral industry, exploration will be curtailed and the "temporary shortages" referred to by economists will turn into National crises. Our National policy must be one that encourages exploration and development, not one which merely allows it to occur. Ideally, there is an ore body for every economic situation. Practically, the problem is--where is that ore body? For example, if while we are exploiting copper ores which contain 0.8% copper, or 16 pounds per ton, we do not vigorously search for and measure bodies of rock containing 0.7% copper and 0.6% copper (14 and 12 pounds per ton), we are in trouble. When the 16-pound per ton ores are gone, technology will have no marginal material to work with, and the gap to be bridged will be a wide one.

Thus, there are practical limits to application of the cost concept of resources, because of the physical parameters of ore bodies or oil pools and coal beds. If the mineral industries do not operate efficiently by exploiting the highest natural concentrations of minerals, technology and society will be tested by the ultimate test of investment/return sooner rather than later.

Another requirement for a healthy mineral industry in the decades to come, and indeed a moral obligation to coming generations, is extension of the conservation concepts now well accepted in Texas in the oil and gas industry to other mineral commodities. Almost everyone agrees that conservation practices are necessary to protect our oil and gas industry, eliminate waste, and guarantee maximum recovery. However, the idea of extending conservation concepts to a commodity such as sand and gravel is commonly met with raised eyebrows. This is due to a failure to grasp the concept of "place value" applied to the mineral commodities that have a low unit value--the dollar-a-ton material--but which are used in large volumes.

Of paramount importance is the location of the resource with reference to the center of consumption--usually an urban area. If a commodity has a value of $1.00 per ton at the quarry, and if it costs $0.05 per ton-mile to transport it, one can easily see that at the end of a 20-mile haul, one-half the cost of the commodity is haulage cost; at 40 miles the cost of transport is twice the value of the commodity at the source. When multiplied by a factor of thousands of tons, the cost increment is substantial indeed. This is another way of saying that a large deposit of sand and gravel within the city limits is a valuable asset, whereas a similar deposit 100 miles away may be worthless.

Construction materials are already in short supply around many large cities and growing smaller cities. For example, in Texas in 1963 the total value of sand and gravel produced was over half a million dollars less than in 1962, while all other construction minerals showed increases. The decline was not due to a lessening of demand. In some areas, sand and gravel deposits have been depleted so that they are being replaced in their former markets by higher priced crushed stone.

Several years ago, leaders of the Denver, Colorado, metropolitan area became concerned about the decline of sand and gravel reserves in the area. A study was initiated by the Intercounty Regional Planning Commission. Its report showed: (1) Original reserves available to the city were 925 million tons. (2) Remaining were 244 million tons (24 years' supply at current rate of exploitation). (3) Since 1950, 50 million tons had been produced but because of new construction built on sand and gravel deposits, available reserves had diminished by 250 million tons. The Commission recommended that land use be regulated by zoning to protect and conserve sand and gravel reserves.

Construction materials are not as vital to a city as is water supply, and probably the same degree of control and supervision is not called for. Clearly, however, it is practical for a city government to be concerned with construction costs within its limits, and, therefore, it is practical for a city to look to its reserves of construction materials.

The planning group of a city that suddenly is concerned about depletion of sand and gravel or crushed stone sources cannot simply find the least desirable land in the city--the old swamp--and zone it for quarry sites. Resources are where they are and cannot be created by legislation. The sand and gravel resources are in the terraces along the river that are being sold to developers for $8,000 per acre. Politically, there is not a chance in the world that a prime real estate area will be zoned for quarry development. Ten years earlier it could have been done, but the city planners (1) did not have a geologic map so they did not know the sand and gravel were there; (2) did not know the total reserves then being exploited or the rate of consumption so they could not predict the shortage that was imminent. In fact, they did not and still do not know much about the resources of construction materials in and around the urban area. The same kind of advance planning used by city departments concerned with water, power, traffic, sewage, and parks must be applied to construction material resources. If sand and gravel are hauled in from distant points, the price of concrete will go up, construction costs will go up, and the bills will go up. Perhaps that school addition will not be built, perhaps the public education facilities will be rated as inadequate, perhaps the big plant will go elsewhere.

Demographers predict at least two giant cities or megalopoli in Texas: one along the Gulf Coast between Houston and Corpus Christi and one on the black prairies between San Antonio and Dallas-Fort Worth, including New Braunfels, San Marcos, Austin, Temple, and Waco. In the United States, about 1 million acres of land per year are being converted to home sites. Bear in mind that most of this land is in and around existing population centers where the mineral producer competes for land. Every mile of new Federal highway consumes 40 acres. The answer to the urban land shortage is multiple use. Mineral construction materials can be harvested, and then the land can be made available for construction sites.

Of course, there will always be resistance to planning--and it is true that exercise of eminent domain by a city can be reckless. The individual whose land is condemned by the city rarely feels that he has gotten a square deal. But in the future we will have to support planned urban complexes or live in chaotic urban jungles such as now exist around the old nuclei--Chicago and New York. It will be much cheaper to plan now. Los Angeles has attempted to bring mineral deposits into its plans for the future. The city surveyed sand and gravel deposits in the San Fernando Valley, evaluated them by drilling, and zoned a number of gravel-pit sites. After the deposits are quarried, the pits will first be used for refuse disposal and then restored for urban use. Mineral deposits must be protected and kept in the public realm until they are harvested. Thereafter, the land can be restored for other uses.

Commonly, there are conflicts between conservation and resource management groups because each group wants to conserve the area of its interest which, of course, seems of paramount importance. It would seem that conflicts might be resolved by determining the highest use. In dealing with specifics, however, it turns out that ordinary bookkeeping is complicated by the need to assign dollar values to intangibles. For example, what is the value of a pretty landscape used for picnics and other recreation as opposed to a crushed stone quarry? How is the value determined? If a premium is put on aesthetics and recreation, as is the trend, many taxpayers will absorb hidden costs as a result of increased general construction costs because the crushed rock must be hauled a long distance from another source. Thus, more is involved than the direct loss of jobs and tax revenue from the quarry industry. The only answer is that the various interests must come together fully informed to plan over the long term. What is needed in Texas is a council of State administrators concerned directly with natural resources. We are not trying to conserve trees or fish or oil for their own sake but rather as parts of a whole--we are trying to conserve a way-of-life, a culture.

I am closing with some predictions. Under sound conservation practices and disallowing extraordinary demand occasioned by National crises, oil and gas production in Texas will continue at about present levels until at least the year 2000. However, during this period, the value of oil and gas will increase and an ever larger percentage of the total production will be used as chemical raw materials. Lignite and coal production will grow slowly for both power and chemical raw materials, with facilities constructed at the resource site to eliminate or minimize transportation costs. Limestone will move to the industrial Texas coast in ever larger volumes both for use as cement raw material, chemical raw material, aggregate, and base material. In parts of the State where aggregate shortages already exist, plants will be constructed to manufacture aggregates from local materials. The State's ceramic industries will expand. High-alumina clays in East Texas will be used as aluminum ores. Exploration for uranium in the Texas Coastal Plain will turn up additional deposits, and the high-cost deposit in Duval County will be mined. Exploration for copper, mercury, molybdenum, silver and other metals in Trans-Pecos Texas will meet with some success and promote local mining industries. In the distant future, the tremendous low-grade iron reserves of the State will be developed. In central Texas, the low-grade near-surface hematitic ores will be concentrated and pelletized to make blast-furnace feed, and in East Texas the so-called greensands (glauconite) will yield to new metallurgical approaches. If I am only 50 percent correct in my optimism, the mineral industry of the State will remain strong. However, unless conservationists understand the role of mineral industries in our society and disabuse themselves of the idea that a woodlot is good but a quarry is bad--by definition--all bets are off!

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