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The Future of the United States Copper Industry:

Part One. The Production Side

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Is the U.S. losing its comparative advantage in copper metal production to other countries? A large and growing bibliography of studies and commentaries can be cited to support such a hypothesis (Sousa, 1981); Commodities Research, Ltd., 1976 and 1982; Consolidated Gold Fields, Ltd., 1979; Dresher, 1978; Harbridge House, Inc., 1977; Arthur D. Little, 1978; and Tomimatusu, 1980). In brief, these studies suggest U.S. copper producers have six disadvantages over the long term on the *supply* (production) side: (1) the depletion of high-grade domestic ores, (2) the rise in U.S. wage rates and other production costs, (3) the more recent applications of new technology outside the U.S. where metals-industry growth has been so much more rapid, (4) prejudicial U.S. government regulation of safety and the environment, (5) the mismanagement of federal lands and stockpiles, and (6) high levels of domestic taxation. On the *demand* (consumption) side, the studies suggest three additional problems for the copper industry: (1) cheaper and lighter weight materials developed in the communications, transportation, and construction markets offer competition to the copper industry, (2) government policies prevent the most agressive U.S. firms from capturing a growing share of their home or international markets, and (3) U.S. producers' prices have been deliberately depressed.

In Part One of this paper, I review the industry's problems on the supply side. In Part Two, which will appear in a future issue of *Fieldnotes,* I will analyze the more complex and generally neglected demand-side problems, relying on conventional commodity market analyses of short-term price fluctuations and long-term trends for insights into industry and government behavior. My conclusions lead to a somewhat different view of world copper's future, and the U.S. role, than conventional wisdom forecasts.

The domestic copper industry is apparently in serious trouble, and the problems, by all accounts, will not go away quickly. The most recent closures of mines and smelters during the current depressed market conditions, while net imports of metal and mill products continue to rise, give dramatic attention to short-run difficulties faced by industry. However, the long-term nature of U.S. comparative disadvantages is indicated by the decline of U.S. production over the past ten years, while the rest-of-the-world's markets and industry boomed. U.S. copper firms are not alone in their concerns. Because price trends signal the potential reduction of copper metal productive capacity and the attendant loss of domestic resource values, they raise strategic questions for major consumers of copper in the communication, transportation, and defense industries.

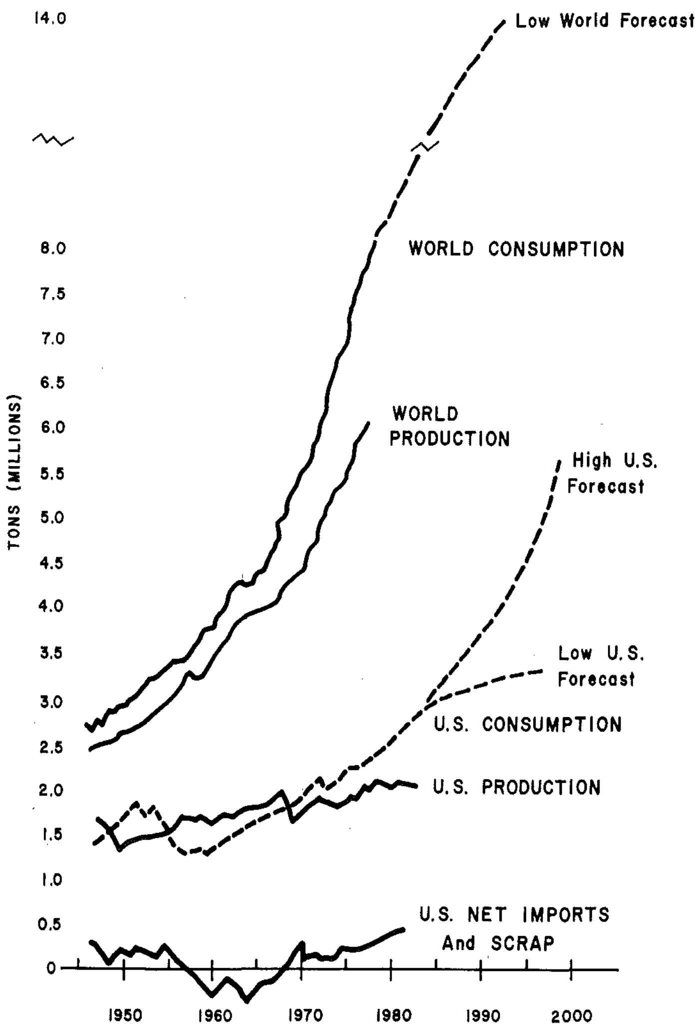
The U.S. copper industry consists of hundreds of firms. One-third of these firms, engaged in mining and smelting activities located largely in the western U.S., employ 90,000 persons and contribute $3-4 billion to the Gross National Product (GNP) annually. The remaining two-thirds of U.S. copper firms are brass and wire mills whose fabricating activities are concentrated in New England and the Middle Atlantic states. This paper focuses upon the future prospects of the twelve larger, integrated firms, their 26 mines and 16 smelters which produce almost all the country's primary metal, and their subsidiaries which supply a significant portion of the refined metal and semi-fabricated brass and wire products. These firms, by their activities, account for most of the copper resource values in the U.S. The fact that U.S. copper ore reserves are located in the states of Arizona, Montana, Utah, and New Mexico makes the industry of special interest to the Southwest.

U.S. DOMESTIC RESOURCES, DEPLETION, AND RISING COSTS

In the view of many, U.S. copper firms are casualties of high-grade ore depletion and rising costs of capital and labor. Both effects diminish the ability of U.S. firms to compete with producers abroad who are mining richer orebodies and experiencing lower labor and capital costs. This explanation is consistent with the observable trends in U.S. production of primary metal from 1945 to 1980 (Exhibit 1A). U.S. primary production has virtually stagnated at about two million tons while domestic consump-

EXHIBIT 1A

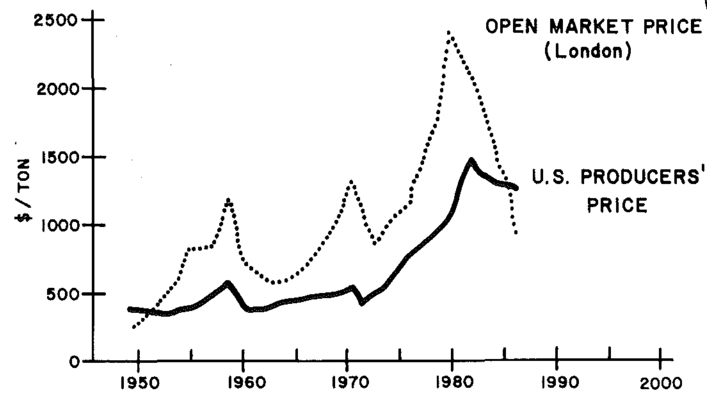
TRENDS IN WORLD AND U.S. REFINED COPPER PRODUCTION AND CONSUMPTION, 1945-2000



Source: U.S. Bureau of Mines, *Minerals Yearbook.*

EXHIBIT 1B

TRENDS IN WORLD AND U.S. REFINED COPPER PRICES 1954-1980 (in dollars per ton)



Source: U.S. Bureau of Mines, *Mineral Facts and Problems* and *Minerals Yearbook.*

tion has grown at most by about a million tons. The difference is imports and scrap. U.S. growth is much slower than consumption abroad. In contrast, demands outside the U.S. rose impressively from one million tons to almost five million tons, with the result that the U.S. share of world consumption declined from three-fourths in 1950 to one-fourth in 1974. Throughout the 30-year period world demands generally outpaced capacity growth. This forced open-market prices (Exhibit 1B) to rise in free metal exchanges, such as London's, far higher than the U.S. Producers' Prices, the price per pound charged by domestic producers, usually on longer contract terms. As a result, the U.S. was a net exporter of metal and scrap through the 1960's, although the quantities were small and few brass mill products were permitted by the major receiving countries. Since 1970 the excess of U.S. consumption over production has had to be met by imports and scrap.

The theory of competition suggests that the intersection of supply and demand determines both market prices and quantities of copper mined in producing regions and sold in consuming centers. Exhibits 2 and 3 illustrate the changes

EXHIBIT 2

PRINCIPAL WORLD SUPPLIES AND DEMANDS FOR COPPER BY MAJOR PRODUCING AND CONSUMING REGIONS, 1950

(in million tonnes)

Supply	Demand Regions	(NA)	(LA)	(PB)	(Af)	(So)	(Eu)	(Ot)	Total Supply
(NA) North America		**1.0**					**0.2**		**1.2**
(LA) Latin America		0.4							0.4
(PB) Pacific Basin									
(Af) Africa							0.5		0.5
(So) Soviet						0.1			0.1
(Eu) Europe									
(Ot) Other		0.3		0.1			0.1		0.5
Total Demand		**1.7**		0.1		0.1	0.8		**2.7**

Source: Derived from U.S. Bureau of Mines, *U.S. Mineral Yearbooks*

EXHIBIT 3

PRINCIPAL WORLD SUPPLIES AND DEMANDS FOR COPPER BY MAJOR PRODUCING AND CONSUMING REGIONS, 1974

(in million tonnes)

Supply	Demand (NA)	(LA)	(PB)	(Af)	(So)	(Eu)	(Ot)	Total Supply
(NA) North America								
U.S.	**1.7**							**1.7**
Can.	**.6**					**.3**		**.9**
(LA) Latin America	.2	.6			.2	.2		1.2
(PB) Pacific Basin			.8					.8
(Af) Africa	.3			.8		.4		1.5
(So) Soviet					1.1			1.1
(Eu) Europe								
(Ot) Other	.4					.3		.7
Total Demand	**3.2**	.6	.8	.8	1.3	1.2		**7.9**

Source: Derived from U.S. Bureau of Mines, *U.S. Mineral Yearbooks* and *Mineral Facts and Problems.*

in production and consumption volumes which determined the flows of trade in world copper from 1950 to 1974. Thirty years ago North America and Europe provided most of the consumption, and North and Latin America most of the production, in a total world use of 2.7 million tons. By 1974, the Pacific Basin, largely Japan encouraging production from Australia, New Guinea, and the Philippines, had become a growing and important copper mining and refining center. These and the expanding Common Market Community, largely Europe encouraging production from Latin America and Africa (Zambia, Zaire, and South Africa), accounted for most of the 5.2 million tons of increased copper use. In other words, the U.S. accounted for little of the world market growth to 7.9 million tons.

EXHIBIT 4

U.S. COPPER YIELDS, PRICES, AND LABOR EARNINGS PER HOUR, 1910-1979

Year	Ave. Cu. Yield %	Ave. Producers Price Current $	Ave. Producers Price Constant $ (1979)	Hourly Earnings Mining $	Hourly Earnings Other $	Total Earnings ($ millions) $	Total Earnings ($ millions) $ (1977)	Real Earnings $/ton (1967)
1910	**1.88**	.13	**100.0**	NA	NA	NA	NA	NA
1950	**.89**	.21	**64.8**	NA	NA	85	132	**145**
1960	**.73**	.32	**78.9**	NA	NA	137	160	**148**
1970	**.59**	.58	**108.0**	3.93	3.35	267	215	**125**
1979	**.49**	.93	**93.3**	9.53	6.69	537	205	**129**

Source: Sousa (1981), *The U.S. Copper Industry*

Ore-grade depletion is evidenced by the fall in average yields of U.S. mines (Exhibit 4). From 1910 to 1979 average grades dropped 75 percent, lowering yields from nearly two percent to one-half percent. Currently, the U.S. is mining ores containing less than 0.70 percent copper, although somewhat lower grades are minable in years when prices are high. These low grades must be compared to those in Africa, which are as high as 3.9 percent, or those in Latin America, which average above 1.0 percent (Exhibit 5). Most observers accept the claim that U.S. ore-grade depletion explains the observed shift of the copper industry's mining activities from the U.S. to other parts of the world in recent years. Real wages in the copper industry rose twice as fast as manufacturing wages, accompanying the decline in ore grades in the U.S. Since 1970, hourly earnings rose from $3.93 to over $9.53 (Exhibit 4). Present U.S. wage levels are five to fifteen times higher than those of competing countries. Energy and waste disposal problems also rose as ore grades fell, because of the added costs of mining and beneficiating increasing tonnages of ore to obtain a given metal output. The energy intensity of these activities in the U.S. rose 10 percent in mining and 20 percent in ore processing to a total of 52,000 Btu per pound of copper produced. Without extensive analysis, the implications of these data are that ore-grade depletion in the U.S. has reduced U.S. producers to mining reserves that cost more to develop than those of other regions. Exhibit 5 shows that in the last fully reported years U.S. production costs averaged 61 to 69 cents per pound. These must be compared to generally lower Canadian costs of 39 to 58 cents per pound, to African costs of 42 to 75 cents per pound, to Latin American costs of 43 to 56 cents per pound, and to Pacific Basin costs of 19 to 57 cents per pound.

EXHIBIT 5

CALCULATED AVERAGE GRADE OF COPPER RESERVES AND AVERAGE OPERATING REAL COSTS PER TON FOR MAJOR COPPER REGIONS, 1976-1978

	Percent grade 1977	Cents per pound (in 1977 dollars) 1976	1977	1978
NORTH AMERICA				
United States	.71	**61**	**69**	66
Canada	.70	**58**	40	**39**
LATIN AMERICA				
Chile	1.11	55	44	**43**
Peru	1.07	**56**	44	47
PACIFIC BASIN				
Australia	2.58	**57**	53	51
Philippines	.54	46	51	48
Papua New Guinea	.47	39	**19**	40
AFRICA				
Zaire	3.90	69	**75**	74
Zambia	3.06	66	69	69
South Africa	.71	**42**	48	44

Source: Sousa (1981), *The U.S. Copper Industry*

Exhibit 6 presents recent forecasts for the world and the U.S., based on the trends observed from 1950 to 1980. If the historic relationships between declining ore grades and rising energy costs were to continue through the year 2000, energy costs would double. U.S. wage rates are also expected to rise faster than those abroad, and U.S. ore grades are expected to fall further. Thus it has been surmised that U.S. producers will continue to smelt a declining share of total world output.

EXHIBIT 6

FORECAST WORLD SUPPLIES AND DEMANDS FOR COPPER IN 2000, ASSUMING OPTIMISTIC CONDITIONS

(in million tonnes, by major region)

Supply	Demand Regions (NA)	(LA)	(PB)	(Af)	(So)	(Eu)	Total Supply
(NA) North America	**3.9**					**1.5**	**5.4**
(LA) Latin America	0.2	2.0	2.9		2.2	0.9	8.2
(PB) Pacific Basin			1.5				1.5
(Af) Africa			1.0	1.3		3.3	5.6
(So) Soviet					2.7		2.7
(Eu) Europe						0.5	0.5
Total Demand	**4.1**	2.0	5.4	1.3	4.9	6.2	**23.9**

NA is Canada and U.S.
LA includes Mexico and North American Latin Republics.
PB includes Asia and Oceana (Australia and New Zealand).
AF includes Middle-East oil producers.
So includes Eastern European Soviet Bloc countries except Yugoslavia.
Eu includes United Kingdom and free Europe plus Yugoslavia.

Source: Leontief and others (1982), *Nonfuel Minerals Forecast.*

U.S. copper firms have also been alarmed at the manner in which the Environmental Protection Agency (EPA) has mandated improvements in mining and smelting operations for the control of sulfur oxide (SOx) emission. Exhibit 7, from Rieber (1982), lists the six major U.S. producers and their mining and smelting capacities, most of which are in five western states. The advanced ages of the furnaces, which average 57 years, are evident. Sousa (1981) estimates it has cost $724 million to date and will cost an additional $1.73 billion to meet ultimate EPA standards in 1988 (Exhibit 8). If so the cumulative costs may reach 10 cents per pound. The copper industry notes that the added costs of smelter control may well outweigh the

EXHIBIT 7

MAJOR U.S. FIRMS' MINE PRODUCTION, SMELTER CAPACITY AND AVERAGE SMELTER AGE

(in short tons of copper, 1979 and 1981)

Company	1979 Mine Output[1]	% U.S.	No. Mines	1981 Smelter RC[2]	% U.S.	No. Units	Ave. Age[3]
Kennecott	387,774	24	4	590,000	30	4	52
Phelps Dodge	342,900	22	4	654,000	34	4	35
Newmont	155,135	10	2	200,000	10	1	24
Anaconda	152,077	10	2	--	--	1	74
Duval	132,255	8	3	--	--	-	--
ASARCO	96,333	6	4	280,000	14	3	78
Subtotal	**1,266,474**	80	19	1,724,000	88	13	57
Others[4]	324,747	20	10	247,000	12	3	42
Total U.S.	**1,591,221**	100	29	1,971,000	100	16	**50**

[1] Short tons of metal annually.

[2] Rated Capacity in 1981; Anaconda's smelter closed in 1980.

[3] Unweighted by tonnage capacities. Includes one oxygen-process facility less than ten years old.

[4] Anamax, Cyprus, and Inspiration in the West; White Pine and Cities Service in the East.

Source: Rieber (1982), *Smelter Emission Controls.*

benefits of conversion to new standards at old facilities, forcing the replacement or relocation of some. Dorenfeld and others (1981) estimate that compliance may add 5-15 cents per pound to U.S. copper production costs. The implication is that, because of current disadvantages in ore grades and production costs, U.S. mines cannot possibly compete with new mines and smelters elsewhere in the world. Therefore, one can predict the closing of southwestern U.S. mines over time, and the increasing reliance of the eastern domestic copper industry on foreign ores or metal. As a matter of fact, such implications are not warranted from the economic analysis of the industry. On the contrary, despite continued declines in ore grades and rising production costs, U.S. domestic reserves will be competitive with ores mined abroad for many years in the future.

EXHIBIT 8

ACTUAL AND PROJECTED CAPITAL COSTS OF CONTROL, U.S. COPPER INDUSTRY

(in $ millions)

	Actual Costs 1973-78	Projected Costs 1979-88
Air Pollution Control	670	1,039
Worker Safety	27	225
Noise Abatement	--	150
Water Control	27	316
TOTAL	**724**	**1,730**

Source: Sousa (1981), *The U.S. Copper Industry*

TECHNOLOGICAL CHANGE

One reason for the economic viability of southwestern U.S. reserves is that technology and economic conditions do not stay constant, but change to offset ore-grade depletion effects, even to the extent of making geologically inferior ores more economic to mine than ores of higher grades. For example, in the 19th century, new U.S. underground mining and beneficiation equipment enabled the Calumet Mining Company of Michigan to compete successfully with other U.S. and European smelters despite lower average ore grades. Again, in the early 1900's, western firms developed porphyry copper deposits lower in grade than the type of deposits being mined elsewhere, such as in Michigan's "copper country." The switch to different deposit types of inferior ore grades was accompanied by the successful application of open-pit methods. Metallurgical innovations were also necessary and important; the effect of new techniques in this case offset ore-grade depletion. So great were the comparative advantages of Jackling's Butte, Montana operation that his integrated firm could ship metal much longer distances to its eastern brass and wire mills for refining and fabrication than could closer competitors. His mills could also undersell imports produced from ores of much higher grades. By 1950 the very high grade Michigan ores, which had achieved prominence in the 1890's, were facing extinction, yet the U.S. had become the dominant copper-producing region, accounting for two-thirds of the world's primary metal output. According to Sir Ronald Prain (1975), certain inferior-grade copper deposits in many parts of the world continue to be among the lowest cost producers of metal. It is noteworthy that some of the most recently established copper mines, such as in the Philippines and New Guinea, are mining copper with grades significantly below either American or African mines. Low-grade copper ores in Canada are produced by many mines that have low production costs; their comparative advantage lies in the production of high-valued by-products.

Innovations in equipment have increased the productivities of labor more than the rise in real wages. This has allowed some mines with low-grade ores to remain competitive. Thus, falling grades have not always meant lower recoveries of metal in ore per man-hour. Similarly, higher real wage rates do not always lead to higher wage costs per ton. More capital-intensive methods can offset higher wages when capital is substituted for labor. U.S. producers' copper prices showed no rise in real terms for over 30 years despite the rise in U.S. real wages. Again, while total labor earnings rose $73 million from 1950 to 1979, real labor earnings per ton fell from $145 to $129 per ton (Exhibit 4) simply because labor productivities rose so rapidly. This permitted U.S. metal prices to remain lower than world market prices notwithstanding rising wages and the increasing reliance on copper from lower-grade U.S. deposits. Even today, the capital costs of expanding U.S. mines are estimated to be half those of developing new mines abroad. Lower capital costs in the U.S. offset higher cutoff grades in new mines abroad, where new mines must force higher world prices. Thus technological changes, falling shares of labor in product value (Exhibit 4), and lower capital costs explain some of the observed differences between market prices on the London Metal Exchange (LME) and U.S. producers' prices since 1950 (Exhibit 1B). The latter have been significantly below the former over the past thirty years.

Infrastructure facilities, such as rail lines and docks, are another major contributor to higher incremental costs abroad than in the U.S. Considerable time is required for the variable factors of lower wages and better grades to offset high, fixed costs, making any direct correlation between observed grades and regional prices misleading. In the long run, ore-grade depletion triumphs over technical change in any extractive region, so that long-term industry expectations are always of rising prices. As copper prices rise, however, the substitution of more abundant materials will increase. Long before the physical exhaustion of reserves, demands for copper will cease to grow. This diminution in growth is most evident in the most highly developed countries. Thus, in the United States, aluminum and other materials are rapidly replacing much copper in electrical transmission systems or in automobile radiators, and polyvinyl chloride tubing is replacing some copper in construction. In Japan and Europe, such substitutions are less evident, while in under-developed regions, they are rare.

Innovations affecting the material costs of users are not limited by any means to extraction or processing. Changes in transportation technologies and the simple differential growth of demands in different locations also affect international market shares. In light of the above, recently expressed concerns about the disadvantages of "domestic" copper firms which compete with "foreign" companies can be seen as confused statements that fail to account for all factors influencing comparative advantages. Indeed, historically, U.S. copper firms have always been prominently involved in world copper trade. In the 1850's when the U.S. smelted virtually none of its own copper, Japan was a major producer and shipped metal to London as the mines of Cornwall, England became depleted. In the 1900's Japan became a copper metal importer. In 1982 Japan is again a major metal producer, but without any domestic production of copper ores. Recently, Japan began smelting western U.S. ores. "Domestic" U.S. firms have also been involved significantly in the foreign production of ores and in the international trade of copper products. The major U.S. firms, with their subsidiaries, helped develop many of the world's copper reserves in Canada, Mexico, Africa, and Latin America, including mines now operating in Chile, Peru, and Brazil. By 1900 the U.S. industry was a major exporter of copper products, and its importance grew as U.S. firms expanded abroad. Much of this international character would remain today were it not for the confiscations of U.S. facilities abroad in the 1970's, and the tendency for other countries to build national industries and shelter them from metal product imports. High tariff and non-tariff barriers were employed from 1950-1980 to protect European and Japanese copper industry expansions. Japan and European countries preferred reciprocal trade with less developed countries, even though U.S. mills were more efficient sources of brass mill products.

Changes in user technologies, because they affect regional demands, will also be factors in determining the pattern of world copper trade in the future. Leontief's study (1982) of copper production and consumption in the year 2000 (Exhibit 6) includes adjustments to reflect the expected increase of copper use in electrical-sector demands by 10 percent and in ordinance demands by 30 percent; but copper use is expected to decrease 10 percent in the construction, machinery, and transportation sectors (cf. below). The final effect of these changes on consumption of copper in a region depends on the differential rates of growth or decline maintained by the sectors using copper, and on the effects of changing trade patterns among countries. The net effect of all such changes can be computed as a coefficient giving the rate of copper consumption relative to the region's income. In the initial stages of development, a country's propensity to consume metals often increases, but after it reaches industrial maturity, this propensity often declines. Calculating propensities can be misleading when the metal in imported goods received is not counted in consumption, whereas the metal used in the region's manufacture of its export goods is counted in domestic consumption. For instance, the U.S. net propensity to consume copper is significantly understated by the fact that copper contained in the radiators of imported automobiles is excluded; in contrast, the German net propensity is overstated by the inclusion of exported automobile radiators as home metal consumption.

In addition to estimating future market shares, Exhibit 6 also estimates year-2000 world outputs and inter-regional trade patterns so these can be compared with those of 1950 (Exhibit 2) or 1974 (Exhibit 3). The results assume continued high growth in income per capita outside the U.S., but a slowing in world population increases. The forecasts also assume the maintenance of the current 50 percent recycling rate for copper in the U.S., as well as the continued decline of the U.S. share of industrial exports and the U.S. industrial consumption of raw materials. The consumption of other countries was adjusted on similarly gross bases. The world's copper consumption forecast is 23.9 million tons in the year 2000. This forecast compares only with the high U.S. Bureau of Mines projection of Exhibit 1A, which reaches 25.0 million tons in 2000, but maintains the 1974 distribution of trade in Exhibit 3. Given these "most favorable" assumptions, U.S. consumption is assumed to grow, at best, to 3.4 million tons and Canadian consumption to 0.4 million tons. The excess of North American production will be exported. These exports, largely from Canada, will follow present paths to European markets. Thus, the U.S. share of world output is expected to continue falling, hypothetically, from 25 percent to 15 percent, while world production and consumption will rise by 10 million tons. In Exhibit 6 projections, scrap use is maintained constant. Alternatively, if the U.S. scrap and imports are permitted to rise by 50 percent, all increased domestic consumption will be met from these sources, and no increase in the U.S. primary copper production will occur. Thus, the U.S. industry is not expected to contract in the future. In the second part of this paper, such predictions are shown to be overly pessimistic.

THE COSTS OF REGULATION

The relationships between rates of ore-grade depletion and technical change on one hand, and the externalities of production, such as safety and environmental problems on the other, are complex. An impressive increase in mining productivities occurred throughout the long period of output growth and ore-grade decline. The U.S. copper industry accomplished the increases largely by shifting to new, capital-intensive technologies, which greatly increased equipment and energy-use rates in mine operations and transportation. As the trend toward lower grades proceeded, it also became necessary to dispose of more waste. Ultimately, there was a shift to the massive open-pit mining and extensive processing which characterize U.S. operations today and require the movement and refining of large quantities of material. At the extraction stage, these technical changes had serious impacts on the hazards of fire, explosion, and machinery-related accidents. Simultaneously, hazards to mill workers in the work environment increased proportionately with the expanded size, complexity, and sophistication of the machinery involved in processing. At the smelter and refinery stages, waste disposal and emission controls became special problems.

The mining industry's successes in reducing the numbers of accidents per man-hour and accident rates per ton have, nonetheless, been dramatic in more recent years. Success is due, in part, to the use of more productive techniques which removed labor from the mining and processing activities. Lower accident rates also resulted from the cooperation between management, organized labor, and government, which increased regulations and inspection pressures on the industry. Most safety improvements have come about without raising the real costs per ton of metal recovered so that mining costs continued to fall even after the implementation of the Mine Safety and Health Act of 1970 and its Administration (MSHA).

The application of the Occupational Safety and Health Act of 1977 has been directed largely to smelters and refineries, regulating hazardous air pollution and solid waste disposal. Its impact on copper costs has been more controversial. Preliminary estimates by Arthur D. Little, Inc., and others, on the control costs of SO_x and other trace elements in emissions, prepared for the Council on Environmental Quality in 1972 led many to predict relatively low costs for reaching compliance. Actual costs have been considerably higher. The copper industry estimates that cumulative compliance costs, mostly for sulfur control at smelters, have reached $1 billion. Annually these costs to date represent 3-4 cents per pound. As EPA regulations have become more stringent, expenditures have risen, but the real problem is obsolete smelters. The average age of 85 percent of the smelters in use is 60 years. Modification of existing furnaces to date has not brought them up to the 90 or 98 percent SO_x removal standards required by 1988. Expert metallurgists doubt seriously that the industry can meet the 90-percent standard with the smelters built in the early 1900's, and certainly not without significant further increases in costs (Dresher, 1978). Compliance may require a total cost of 10 cents per pound annually, according to Dorenfeld and others (1981). When the 98-percent standard is met, the total compliance cost may reach 18 cents per pound. Comparable costs are anticipated in National Science Foundation-sponsored studies (1977) and later studies of Arthur D. Little, Inc. (1978). In light of this obsolescence and of rising costs for the factors of production such as wages, therefore, the ability of the major U.S. firms to comply with pollution controls competitively has been questioned. Can new technology offset these costs?

The technology to control SO_x is fully developed and operative in other parts of the world. Davenport (1980) examines the advantages and disadvantages of the 28 successfully operating new furnaces built from 1970-1980. Of these, the most numerous are Flash furnace installations (16), followed by electric furnaces (5), Noranda reactors (4), and all other systems (3). These are listed in Exhibit 9. This

EXHIBIT 9

COPPER SMELTING FACILITIES INSTALLED IN THE 1970's

Date	Location	Company	Hearth Size (m)
		FLASH FURNACES	
1970	Saganoseki, Japan	Nippon Mining Co. Ltd.	20 x 6-1/2
1971	Toyo, Japan	Sumitomo Metal Mining Co. Ltd.	20 x 7
1972	Ghatsila, India	Hindustan Copper Ltd.	17 x 6
1972	Mount Morgan, Queensland	Peko-Wallsend Metals Ltd	
1972	Tamano, Japan	Hibi Kyodo Seiren Co.	20 x 7
1972	Hamburg, Germany	Norddeutsche Affinerie	
1972	Hitachi, Japan	Nippon Mining Co.	18 x 7
1973	Samsun, Turkey	Karadeniz Bakir Isletmeleri, A.S.	
1973	Tennant Creek, Queensland	Peko-Wallsend Metals Ltd.	
1973	Saganoseki, Japan	Nippon Mining Co. Ltd.	20 x 7
1974	Khetri, India	Hindustan Copper Ltd.	17 x 6
1975	Huelva, Spain	Rio Tinto Patino S.A.	
1976	Hidalgo, New Mexico	Phelps Dodge Corporation	23 x 8
1977	Glogow, Poland	Kombinat Gorniczo-Hutniczy Miedzi, Lubin	
1980	Taihan, Korea	Onsan Copper Refinery Co. Ltd.	
1980	Salvador, Brazil	Caraiba Metals S.A.	
		ELECTRIC FURNACES	
1971	Mufulira, Zambia	Roan Consolidated Mines Ltd.	36000 KVA (dry concentrate)
1972	Copper Hill, Tennessee	Cities Service Co.	8000 KVA (calcine)
1974	Inspiration, Arizona	Inspiration Consolidated Copper Co.	51000 KVA (dry concentrate)
1976	Anaconda, Montana	The Anaconda Co.	36000 KVA (calcine)
1978	Falconbridge, Ontario	Falconbridge Nickel Mines Ltd	36000 KVA (two) (calcine)
		NORANDA PROCESS	
1973	Noranda, Quebec	Noranda Mines Ltd.	5m dia. x 21m long
1978	Garfield, Utah	Kennecott Copper Corp.	three 5m dia. x 21m long
		TBRC	
1978	Kamloops, B.C.	Afton Mines Ltd.	4 x dia. x 6-1/2 long
1978	Ronnskar, Sweden	Boliden Metall AB	30m³
		MITSUBISHI PROCESS	
1974	Naoshima, Japan	Mitsubishi Metal Corporation	7 x 10m smelting furnace
1979	Timmins, Ontario	Texasgulf Canada	11m diameter smelting furnace
		KIVCET PROCESS	
1973	Glubokoe, Kazakhstan	Irtysh Polymetal Combine	5 x 20m

Source: Davenport (1980), Copper Smelting to the Year 2000.

equipment meets standards higher than those to be imposed by the EPA in 1988. Japan has pollution problems which are more severe than the U.S., due to the location of its industry close to population centers, and relies on highly varied ores produced abroad. Japan's success in controlling emissions at high standards without losing trade is partially due to high tariffs on primary metal and products. New smelters also receive offsets by selling recovered sulfur. However it is now clear that these new technologies bring significant savings in energy and higher efficiencies, and these savings have offset the incremental costs of environmental control. Whereas U.S. firms, by and large, have elected to buy time through modification of older reverberatory furnaces, the high energy consumption rates and difficulties of removing SO_x from the dilute gases have made this older retrofitted technology quite costly to operate. The rising cost of electric energy since 1973 has also slowed the further expansion of electric furnaces. Thus, the largest increase in future capacity is expected to go the the Flash furnace type in which SO_2 is collected efficiently at high strength as a commercial by-product by combusting particles in an oxygen-enriched atmosphere above the metal bath, or to the Noranda type which injects offset high, fixed costs, making any direct correlation between observed grades and regional prices misleading. In the long run, ore-grade depletion triumphs over technical change in any extractive region, so that long-term industry expectations are always of rising prices. As copper prices rise, however, the substitution of more abundant materials will increase. Long before the physical exhaustion of reserves, demands for copper will cease to grow. This diminution in growth is most evident in the most highly developed countries. Thus, in the United States, aluminum and other materials are rapidly replacing much copper in electrical transmission systems or in automobile radiators, and polyvinyl chloride tubing is replacing some copper in construction. In Japan and Europe, such substitutions are less evident, while in under-developed regions, they are rare.

Innovations affecting the material costs of users are not limited by any means to extraction or processing. Changes in transportation technologies and the simple differential growth of demands in different locations also affect international market shares. In light of the above, recently expressed concerns about the disadvantages of "domestic" copper firms which compete with "foreign" companies can be seen as confused statements that fail to account for all factors influencing comparative advantages. Indeed, historically, U.S. copper firms have always been prominently involved in world copper trade. In the 1850's when the U.S. smelted virtually none of its own copper, Japan was a major producer and shipped metal to London as the mines of Cornwall, England became depleted. In the 1900's Japan became a copper metal importer. In 1982 Japan is again a major metal producer, but without any domestic production of copper ores. Recently, Japan began smelting western U.S. ores. "Domestic" U.S. firms have also been involved significantly in the foreign production of ores and in the international trade of copper products. The major U.S. firms, with their subsidiaries, helped develop many of the world's copper reserves in Canada, Mexico, Africa, and Latin America, including mines now operating in Chile, Peru, and Brazil. By 1900 the U.S. industry was a major exporter of copper products, and its importance grew as U.S. firms expanded abroad. Much of this international character would remain today were it not for the confiscations of U.S. facilities abroad in the 1970's, and the tendency for other countries to build national industries and shelter them from metal product imports. High tariff and non-tariff barriers were employed from 1950-1980 to protect European and Japanese copper industry expansions. Japan and European countries preferred reciprocal trade with less developed countries, even though U.S. mills were more efficient sources of brass mill products.

Changes in user technologies, because they affect regional demands, will also be factors in determining the pattern of world copper trade in the future. Leontief's study (1982) of copper production and consumption in the year 2000 (Exhibit 6) includes adjustments to reflect the expected increase of copper use in electrical-sector demands by 10 percent and in ordinance demands by 30 percent; but copper use is expected to decrease 10 percent in the construction, machinery, and transportation sectors (cf. below). The final effect of these changes on consumption of copper in a region depends on the differential rates of growth or decline maintained by the sectors using copper, and on the effects of changing trade patterns among countries. The net effect of all such changes can be computed as a coefficient giving the rate of copper consumption relative to the region's income. In the initial stages of development, a country's propensity to consume metals often increases, but after it reaches industrial maturity, this propensity often declines. Calculating propensities can be misleading when the metal in imported goods received is not counted in consumption, whereas the metal used in the region's manufacture of its export goods is counted in domestic consumption. For instance, the U.S. net propensity to consume copper is significantly understated by the fact that copper contained in the radiators of imported automobiles is excluded; in contrast, the German net propensity is overstated by the inclusion of exported automobile radiators as home metal consumption.

In addition to estimating future market shares, Exhibit 6 also estimates year-2000 world outputs and inter-regional trade patterns so these can be compared with those of 1950 (Exhibit 2) or 1974 (Exhibit 3). The results assume continued high growth in income per capita outside the U.S., but a slowing in world population increases. The forecasts also assume the maintenance of the current 50 percent recycling rate for copper in the U.S., as well as the continued decline of the U.S. share of industrial exports and the U.S. industrial consumption of raw materials. The consumption of other countries was adjusted on similarly gross bases. The world's copper consumption forecast is 23.9 million tons in the year 2000. This forecast compares only with the high U.S. Bureau of Mines projection of Exhibit 1A, which reaches 25.0 million tons in 2000, but maintains the 1974 distribution of trade in Exhibit 3. Given these "most favorable" assumptions, U.S. consumption is assumed to grow, at best, to 3.4 million tons and Canadian consumption to 0.4 million tons. The excess of North American production will be exported. These exports, largely from Canada, will follow present paths to European markets. Thus, the U.S. share of world output is expected to continue falling, hypothetically, from 25 percent to 15 percent, while world production and consumption will rise by 10 million tons. In Exhibit 6 projections, scrap use is maintained constant. Alternatively, if the U.S. scrap and imports are permitted to rise by 50 percent, all increased domestic consumption will be met from these sources, and no increase in the U.S. primary copper production will occur. Thus, the U.S. industry is not expected to contract in the future. In the second part of this paper, such predictions are shown to be overly pessimistic.

THE COSTS OF REGULATION

The relationships between rates of ore-grade depletion and technical change on one hand, and the externalities of production, such as safety and environmental problems on the other, are complex. An impressive increase in mining productivities occurred throughout the long period of output growth and ore-grade decline. The U.S. copper industry accomplished the increases largely by shifting to new, capital-intensive technologies, which greatly increased equipment and energy-use rates in mine operations and transportation. As the trend toward lower grades proceeded, it also became necessary to dispose of more waste. Ultimately, there was a shift to the massive open-pit mining and extensive processing which characterize U.S. operations today and require the movement and refining of large quantities of material. At the extraction stage, these technical changes had serious impacts on the hazards of fire, explosion, and machinery-related accidents. Simultaneously, hazards to mill workers in the work environment increased proportionately with the expanded size, complexity, and sophistication of the machinery involved in processing. At the smelter and refinery stages, waste disposal and emission controls became special problems.

The mining industry's successes in reducing the numbers of accidents per man-hour and accident rates per ton have, nonetheless, been dramatic in more recent years. Success is due, in part, to the use of more productive techniques which removed labor from the mining and processing activities. Lower accident rates also resulted from the cooperation between management, organized labor, and government, which increased regulations and inspection pressures on the industry. Most safety improvements have come about without raising the real costs per ton of metal recovered so that mining costs continued to fall even after the implementation of the Mine Safety and Health Act of 1970 and its Administration (MSHA).

The application of the Occupational Safety and Health Act of 1977 has been directed largely to smelters and refineries, regulating hazardous air pollution and solid waste disposal. Its impact on copper costs has been more controversial. Preliminary estimates by Arthur D. Little, Inc., and others, on the control costs of SO_x and other trace elements in emissions, prepared for the Council on Environmental Quality in 1972 led many to predict relatively low costs for reaching compliance. Actual costs have been considerably higher. The copper industry estimates that cumulative compliance costs, mostly for sulfur control at smelters, have reached $1 billion. Annually these costs to date represent 3-4 cents per pound. As EPA regulations have become more stringent, expenditures have risen, but the real problem is obsolete smelters. The average age of 85 percent of the smelters in use is 60 years. Modification of existing furnaces to date has not brought them up to the 90 or 98 percent SO_x removal standards required by 1988. Expert metallurgists doubt seriously that the industry can meet the 90-percent standard with the smelters built in the early 1900's, and certainly not without significant further increases in costs (Dresher, 1978). Compliance may require a total cost of 10 cents per pound annually, according to Dorenfeld and others (1981). When the 98-percent standard is met, the total compliance cost may reach 18 cents per pound. Comparable costs are anticipated in National Science Foundation-sponsored studies (1977) and later studies of Arthur D. Little, Inc. (1978). In light of this obsolescence and of rising costs for the factors of production such as wages, therefore, the ability of the major U.S. firms to comply with pollution controls competitively has been questioned. Can new technology offset these costs?

The technology to control SO_x is fully developed and operative in other parts of the world. Davenport (1980) examines the advantages and disadvantages of the 28 successfully operating new furnaces built from 1970-1980. Of these, the most numerous are Flash furnace installations (16), followed by electric furnaces (5), Noranda reactors (4), and all other systems (3). These are listed in Exhibit 9. This equipment meets standards higher than those to be imposed by the EPA in 1988. Japan has pollution problems which are more severe than the U.S., due to the location of its industry close to population centers, and relies on highly varied ores produced abroad. Japan's success in controlling emissions at high standards without losing trade is partially due to high tariffs on primary metal and products. New smelters also receive offsets by selling recovered sulfur. However it is now clear that these new technologies bring significant savings in energy and higher efficiencies, and these savings have offset the incremental costs of environmental control. Whereas U.S. firms, by and large, have elected to buy time through modification of older reverberatory furnaces, the high energy consumption rates and difficulties of removing SO_x from the dilute gases have made this older retrofitted technology quite costly to operate. The rising cost of electric energy since 1973 has also slowed the further expansion of electric furnaces. Thus, the largest increase in future capacity is expected to go the the Flash furnace type in which SO_2 is collected efficiently at high strength as a commercial by-product by combusting particles in an oxygen-enriched atmosphere above the metal bath, or to the Noranda type which injects

EXHIBIT 9

COPPER SMELTING FACILITIES INSTALLED IN THE 1970's

Date	Location	Company	Hearth Size (m)
		FLASH FURNACES	
1970	Saganoseki, Japan	Nippon Mining Co. Ltd.	20 x 6-1/2
1971	Toyo, Japan	Sumitomo Metal Mining Co. Ltd.	20 x 7
1972	Ghatsila, India	Hindustan Copper Ltd.	17 x 6
1972	Mount Morgan, Queensland	Peko-Wallsend Metals Ltd	
1972	Tamano, Japan	Hibi Kyodo Seiren Co.	20 x 7
1972	Hamburg, Germany	Norddeutsche Affinerie	
1972	Hitachi, Japan	Nippon Mining Co.	18 x 7
1973	Samsun, Turkey	Karadeniz Bakir Isletmeleri, A.S.	
1973	Tennant Creek, Queensland	Peko-Wallsend Metals Ltd.	
1973	Saganoseki, Japan	Nippon Mining Co. Ltd.	20 x 7
1974	Khetri, India	Hindustan Copper Ltd.	17 x 6
1975	Huelva, Spain	Rio Tinto Patino S.A.	
1976	Hidalgo, New Mexico	Phelps Dodge Corporation	23 x 8
1977	Glogow, Poland	Kombinat Gorniczo-Hutniczy Miedzi, Lubin	
1980	Taihan, Korea	Onsan Copper Refinery Co. Ltd.	
1980	Salvador, Brazil	Caraiba Metals S.A.	
		ELECTRIC FURNACES	
1971	Mufulira, Zambia	Roan Consolidated Mines Ltd.	36000 KVA (dry concentrate)
1972	Copper Hill, Tennessee	Cities Service Co.	8000 KVA (calcine)
1974	Inspiration, Arizona	Inspiration Consolidated Copper Co.	51000 KVA (dry concentrate)
1976	Anaconda, Montana	The Anaconda Co.	36000 KVA (calcine)
1978	Falconbridge, Ontario	Falconbridge Nickel Mines Ltd	36000 KVA (two) (calcine)
		NORANDA PROCESS	
1973	Noranda, Quebec	Noranda Mines Ltd.	5m dia. x 21m long
1978	Garfield, Utah	Kennecott Copper Corp.	three 5m dia. x 21m long
		TBRC	
1978	Kamloops, B.C.	Afton Mines Ltd.	4 x dia. x 6-1/2 long
1978	Ronnskar, Sweden	Boliden Metall AB	30m³
		MITSUBISHI PROCESS	
1974	Naoshima, Japan	Mitsubishi Metal Corporation	7 x 10m smelting furnace
1979	Timmins, Ontario	Texasgulf Canada	11m diameter smelting furnace
		KIVCET PROCESS	
1973	Glubokoe, Kazakhstan	Irtysh Polymetal Combine	5 x 20m

Source: Davenport (1980), Copper Smelting to the Year 2000.

pure oxygen into the metal bath. The amount of sulfur and iron oxidized in the smelting is determined by how much pure oxygen is used. Much more oxidation per unit of extraneous energy is applied because of the energy released by the process. This "self-generating" or autogenous operation accounts for efficient reduction of fuel consumption. The results are lower variable costs than are possible with either rehabilitated or new reverberatory furnaces, systems which have been rendered obsolete by new developments.

The switch from reverberatory to autogenous processes, such as the Flash furnace, has been assisted by a number of important developments, in particular (1) U.S. innovations drastically reducing the cost of pure oxygen during the 1950's, (2) the large incentives to reduce energy consumption in smelting since the four-fold increase in real energy costs during the 1970's, and (3) the development of sophisticated, computerized controls permitting high quality output from the faster autogenous metallurgical processes.

Latin American and African countries have encumbered their nationalized copper industries with few smelter regulations. On the other hand, they are eager to extend their value added during production by expanding domestic smelting. Clearly, it will also be cheaper for them to build a new industry based on Flash or Noranda furnace technology than to replicate the older furnace technology.

Does the quality of U.S. reserves warrant the expenditures required to replace the older smelting technology or will it be cheaper for the industry to export the problems of pollution by importing metal? Ore-grade declines in the U.S. will not control U.S. reinvestment decisions. North America has a larger reserve base of ore than Africa, Asia, or Latin America. The U.S. can reach the levels of production forecast through 2000 without significant declines in ore grade. Labor differentials will not be compelling factors in the reinvestment decision either. Capital costs, therefore, along with the other adoption costs of the new technologies, will hold the key.

The capital costs of opening new mines, smelters, and refineries are $9,000 per ton of annual capacity. These costs are very high, whether the installations are built in developed or underdeveloped countries. Exhibit 10, which employs the costs of Sousa's capital estimates in current (1981) dollars of 73 cents per pound and assumes present variable costs of 60 cents, shows that $1.33 per pound of copper is required to open new mines outside the United States. The capital costs of expanding existing U.S. mines, in contrast, are only 43 cents per pound. The variable costs for new U.S. facilities are comparable to those abroad. Therefore, to increase U.S. capacity to 3.7 million tons would require U.S. prices of only $1.03 per pound.

This incremental .7 million tons can be obtained at a cost quite competitive with the incremental costs of expansions abroad. Indeed, although estimates differ, almost all experts see the necessity for much higher copper prices around the world when expansion resumes. Metal prices are expected to rise to at least $1.40 per pound (in 1982 dollars). Certainly, under such price conditions, the U.S. industry will also prosper.

EXHIBIT 10

COMPARATIVE COSTS OF U.S. EXPANSION AND NEW WORLD CAPACITY IN COPPER
(in 1982 constant dollars)

	CAPITAL COSTS				FULL COSTS[3]	
	United States[1]		Rest of World[2]		United States	Rest of World
	$/ton of capacity	¢/lb	$/ton of capacity	¢/lb	¢/lb	¢/lb
Mines	$4,000		$5,900			
Smelters	700		2,500			
Refinery	NA		600			
Total	$4,700	**43¢**	$9,000	**73¢**	**$1.03**	**$1.33**

[1] Assumes domestic demand requires expansion of existing capacities by .5 million tons in mines and .7 million tons in smelters; no increase in refinery capacity. Capital costs updated to 1982 by applying factor of 1.4 to Sousa's 1977 estimates.

[2] Assumes world demand requires expansion by new facilities by 3.0 million tons in mines, smelters and refineries.

[3] Assumes present variable costs of 60¢ per pound with negligible capital costs on old facilities.

Source: Sousa (1981), *The U.S. Copper Industry*, and author's estimates for expansion scenario and inflation adjustments.

FEDERAL MANAGEMENT OF STRATEGIC MINERAL LAND AND TAX POLICIES

Anglo-American land and mineral policies have traditionally been based on a very different philosophy from those of other countries. Historically, much of the resource wealth of the U.S. consisted of public land, which was freely distributed among private-sector developers. In contrast, the other major copper-producing countries were developed under the Napoleonic code or earlier concepts in which natural resources belonged to the state. The nationalization of foreign copper concessions by host countries in Africa or Latin America have a precedent in such law. Similarly, there is long precedent in other major consuming countries, such as Japan and in Europe, to form state trading monopsonies for the purchase of materials and state monopolies for the development of sources. This practice has led to well-defined rents and high taxes on copper. The U.S. historically avoided the development of producer or consumer cartels. By giving away federal resources so energetically that excess demand and high prices were the exception rather than the rule, the U.S. neglected the collection of rents and royalties and emphasized the benefits of competition and cheap materials procurement. When problems in conservation and environmental control developed and became aggravated by excess supply, they were relegated to Congress. It is no accident that conservation became a significant political issue early in the 19th century as commodity prices declined. However, since 1960, environmental control acts of Congress have internalized most of these external costs and may have raised them above the level of benefits to consumers. Withdrawals of public land were the result of the Alaska Native Claims Settlement Act of 1971, the Alaska National Interest Lands Conservation Act of 1980, and the Federal Land Policy and Management Act of 1976. Together, these legislative acts have discouraged aggressive mineral exploration and development. At the same time, concerns over strategic material resources have led to some subsidies for domestic mineral industry expansion. Clearly, the decision in the 1950's to inventory copper in a national strategic stockpile encouraged the opening of new copper mines. Thus, recent legislative history has had mixed impacts on the copper industry.

For decades the concentration of U.S. firms mining and smelting copper has been diluted due to vigorous antitrust actions which discouraged domestic growth of the major companies and continually constrained their operations. Later, the strategic stockpile became a federal instrument to control inflation and stabilize prices, and growth was further discouraged. U.S. policies can be shown to have discouraged the expansion of U.S. firms abroad, in contrast to the policies of other developed nations. At best, therefore, U.S. government policies have been both confused and conflicting. The Department of Interior and other branches of federal administration have been urged by economists to make timely and much needed reforms. Current review of nonfuel minerals policy is especially welcomed by industry, in light of the above.

Some observers argue that federal environmental policies compel a basic choice between domestic or foreign sources of copper; however, these arguments are not convincing. The projected growth of U.S. firms through the year 2000 (if growth does indeed occur) is supported by ample competitive U.S. copper reserves in private hands. These reserves are almost all cheaper to mine than the proved, indicated, or estimated reserves on federal lands. Finally, the state and federal taxation of copper is lower than that of other metal resource industries in the U.S. or abroad. Many producing countries have taxed all gains by nationalizing copper production. For profitable U.S. companies, a depletion allowance of 15 percent of value of copper refined shelters revenues from income taxes. Finally, tax credits are available for capital improvements.

While this analysis fails to confirm significant U.S. disadvantages on the supply side and supports the ability of domestic brass and mill-product producers to compete in the world markets when world demands resume their growth, it does not necessarily assure that U.S. firms will prosper or survive in the future. Concerns arise on the demand side because technical change and substitution may continue to erode world markets and because other countries, which export commodities to the U.S., refuse to permit U.S. firms to trade freely in their own markets. The ability of the U.S. industry to survive, therefore, depends on more than low-cost production. It also depends very much on access to growing consumption in the markets outside the United States. These problems and their solutions on the demand side will be described in the concluding part of this article.

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EXPANDED BLM MINERALS PROGRAM

By Secretarial Order, dated December 3, 1982, the Bureau of Land Management (BLM) assumed all onshore minerals management functions including oil and gas, geothermal, and solid leasable minerals on both Federal and Indian lands. These functions, which were formerly the responsibility of the U.S. Geological Survey (USGS), include mineral resource evaluations, fair-market-value determinations, approval or rejection of drilling permits and mining or production plans, and on-site inspection and enforcement of mineral-lease operations. These expanded BLM mineral responsibilities will be in addition to the historical BLM mineral role with respect to mining claims, saleable minerals, and issuance of leases. The BLM will also now provide assistance to the Bureau of Indian Affairs in the supervision of mineral operations on Indian lands.

The consolidation of onshore minerals management activities should provide greater emphasis on opportunities for energy and mineral development on Federal and Indian lands, strengthen mineral resource expertise in the BLM, streamline mineral leasing procedures, and enhance mineral considerations in multiple resource management and land-use decisions. The BLM Director has also set forth a minerals policy that encourages the development of mineral resources.

The BLM Arizona State Office has established a position of Deputy State Director, Mineral Resources, and an expanded staff to provide greater focus to the Federal and Indian land minerals program in Arizona. Mr. Ray A. Brady, who was selected as the Deputy State Director, is a graduate of the University of Arizona (1970) with a degree in Geology and is returning to his home state of Arizona. His professional experience includes work with hardrock minerals, oil shale, coal, uranium, and potash in Arizona, Colorado, and New Mexico. Mr. Brady was Deputy Manager of Mining, in the Albuquerque, New Mexico office of the USGS prior to his reassignment to the BLM Arizona State Office in Phoenix.

pure oxygen into the metal bath. The amount of sulfur and iron oxidized in the smelting is determined by how much pure oxygen is used. Much more oxidation per unit of extraneous energy is applied because of the energy released by the process. This "self-generating" or autogenous operation accounts for efficient reduction of fuel consumption. The results are lower variable costs than are possible with either rehabilitated or new reverberatory furnaces, systems which have been rendered obsolete by new developments.

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For decades the concentration of U.S. firms mining and smelting copper has been diluted due to vigorous antitrust actions which discouraged domestic growth of the major companies and continually constrained their operations. Later, the strategic stockpile became a federal instrument to control inflation and stabilize prices, and growth was further discouraged. U.S. policies can be shown to have discouraged the expansion of U.S. firms abroad, in contrast to the policies of other developed nations. At best, therefore, U.S. government policies have been both confused and conflicting. The Department of Interior and other branches of federal administration have been urged by economists to make timely and much needed reforms. Current review of nonfuel minerals policy is especially welcomed by industry, in light of the above.

Some observers argue that federal environmental policies compel a basic choice between domestic or foreign sources of copper; however, these arguments are not convincing. The projected growth of U.S. firms through the year 2000 (if growth does indeed occur) is supported by ample competitive U.S. copper reserves in private hands. These reserves are almost all cheaper to mine than the proved, indicated, or estimated reserves on federal lands. Finally, the state and federal taxation of copper is lower than that of other metal resource industries in the U.S. or abroad. Many producing countries have taxed all gains by nationalizing copper production. For profitable U.S. companies, a depletion allowance of 15 percent of value of copper refined shelters revenues from income taxes. Finally, tax credits are available for capital improvements.

While this analysis fails to confirm significant U.S. disadvantages on the supply side and supports the ability of domestic brass and mill-product producers to compete in the world markets when world demands resume their growth, it does not necessarily assure that U.S. firms will prosper or survive in the future. Concerns arise on the demand side because technical change and substitution may continue to erode world markets and because other countries, which export commodities to the U.S., refuse to permit U.S. firms to trade freely in their own markets. The ability of the U.S. industry to survive, therefore, depends on more than low-cost production. It also depends very much on access to growing consumption in the markets outside the United States. These problems and their solutions on the demand side will be described in the concluding part of this article.

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EXPANDED BLM MINERALS PROGRAM

By Secretarial Order, dated December 3, 1982, the Bureau of Land Management (BLM) assumed all onshore minerals management functions including oil and gas, geothermal, and solid leasable minerals on both Federal and Indian lands. These functions, which were formerly the responsibility of the U.S. Geological Survey (USGS), include mineral resource evaluations, fair-market-value determinations, approval or rejection of drilling permits and mining or production plans, and on-site inspection and enforcement of mineral-lease operations. These expanded BLM mineral responsibilities will be in addition to the historical BLM mineral role with respect to mining claims, saleable minerals, and issuance of leases. The BLM will also now provide assistance to the Bureau of Indian Affairs in the supervision of mineral operations on Indian lands.

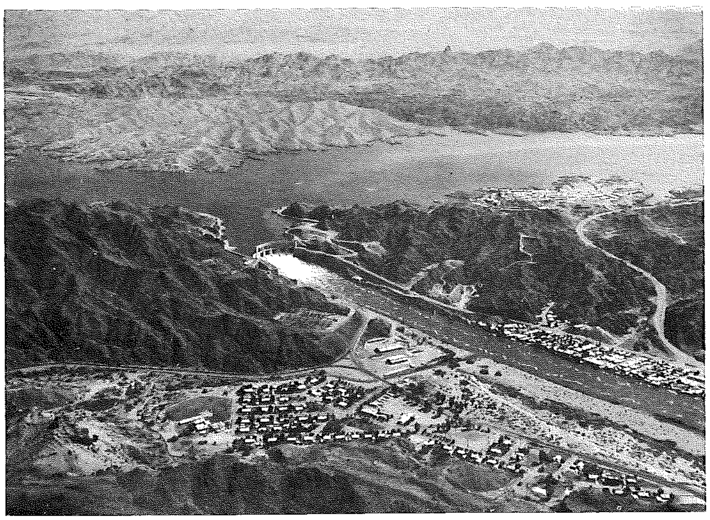
The consolidation of onshore minerals management activities should provide greater emphasis on opportunities for energy and mineral development on Federal and Indian lands, strengthen mineral resource expertise in the BLM, streamline mineral leasing procedures, and enhance mineral considerations in multiple resource management and land-use decisions. The BLM Director has also set forth a minerals policy that encourages the development of mineral resources.

The BLM Arizona State Office has established a position of Deputy State Director, Mineral Resources, and an expanded staff to provide greater focus to the Federal and Indian land minerals program in Arizona. Mr. Ray A. Brady, who was selected as the Deputy State Director, is a graduate of the University of Arizona (1970) with a degree in Geology and is returning to his home state of Arizona. His professional experience includes work with hardrock minerals, oil shale, coal, uranium, and potash in Arizona, Colorado, and New Mexico. Mr. Brady was Deputy Manager of Mining, in the Albuquerque, New Mexico office of the USGS prior to his reassignment to the BLM Arizona State Office in Phoenix.

Colorado River in Flood Stage

View is north across the southern Cibola Valley, south of Blythe. Flooded trailer court is Gilmore's Camp, located north of Walker Lake and across the river from Cibola Lake. Barely visible in the upper left is another partially flooded development, Walter's Camp, also known as Paymaster Landing. The river here divides Imperial County, California (left) and Yuma County, Arizona (right). Photo by Peter L. Kresan.

View is east along the Colorado River, confined by levees, just east of Yuma. Highway I-8 is seen in the lower right and the Gila River joins the Colorado where the main channel bends to the north (to the left). Photo by Peter L. Kresan.



Parker Dam and the Bill Williams River Embayment of Lake Havasu is shown in this view northeast. Aubrey Hills are above the lake. Arizona Highway 95 curves through hills above the Parker Strip on the far right. Photo by Peter L. Kresan.

Photographs were taken on the morning of July 8, 1983.

Flooding of buildings is shown in this view southeast across Topoc Marsh. The development is just north of Goose Lake on the Fort Mojave Indian Reservation, Arizona. Needles, California is due east across the main channel of the Colorado River. Photo by Peter L. Kresan.

LEST WE FORGET (Of Oil Gluts and Gas Bubbles, and Cabbages and Kings)

A Guest Editorial
by
Howard Bucknell*

Following a year or so of rhetoric in the national press concerning the demise of the energy crisis, we were then treated to an impassioned analysis as to the imminent collapse of OPEC (Organization of Petroleum Exporting Countries) or some dramatic restructuring of world oil pricing procedures. The short-term prospects of such events seemed fairly evident: lower oil prices. However, the longer-term prospects appeared more complex. The purpose of this short essay is to point out, lest we forget, that these longer-term prospects should be kept in mind. They include the alternatives of prosperity and poverty, and peace and war — probably within the present decade.

Today an "oil glut" certainly continues to exist. It is the product of gross overpricing, and resultant unemployment and recession, the beginnings of conservation efforts, and some use of alternative fuels (coal). Despite brightening conditions in our own country, more than 25 million skilled workers are still unemployed in the 24 OECD (Organization for Economic Cooperation and Development) countries. People without jobs don't drive to work in big *or* small cars. Gasoline is "saved". Closed factories are marvelously energy efficient. Shutdown assembly lines do wonders for the energy budget. Thus depressed economic conditions are one answer to the energy crisis — which some now claim never occurred.

Substantial economic recovery cannot occur in the OECD (or the United States itself) without a concomitant increase in energy use — particularly of oil. Thus, a further significant drop in the price of oil, say $15 per barrel, would undoubtedly assist in economic recovery. A significant drop in the price of oil would also see the almost complete curtailment of drilling activity in this country (drilling starts are significantly down already, with an attendant slide toward greater foreign dependence), the cessation of synthetic fuel development (note the current curtailment of oil shale projects), and the complete abandonment of both the Canadian tar-sand venture and the development of the Venezuelan heavy-oil deposits. A drastic lowering of oil prices would force the disruption of Mexican oil production and the cessation of production from the North Sea oil fields. Venezuela, Mexico, and Nigeria would probably face economic collapse while dissolving simultaneously into political chaos. Ultimately a similar fate could await Great Britain and other friendly countries. To reckon that the United States could proceed unscathed amidst such chaos is to be extremely naive.

We should consider the impact on the average American. After all, gasoline prices, heating bills, and electric bills would go down. Money would be usefully released into the private and corporate spheres. The main impact on the average American, however, would come *after* the price drop had been achieved.

Those countries able to produce and distribute oil profitably at the lower price would have eliminated all sources of competition. As the oil-consuming world benefited from the price drop, the surviving oil-producing counties would control the market. These countries, by and large, rim the Persian Gulf and comprise the Organization of Arab Petroleum Exporting nations (OAPEC) and the so-called Gulf Corporation Council. These nations, controlling one-third of the world's proven oil reserves and led by Saudi Arabia, have long dominated OPEC. They expend on the average $2 to lift a barrel of oil from the ground. By comparison, North Sea oil is produced at a cost of about $9 per barrel.

At the present time the United States produces about 8.7 mbpd (million barrels per day) of oil (plus 1.5 mbpd of natural gas liquids) and imports about 5 million barrels each day to meet basic needs. In 1973 the U.S. imported about 6 mbpd, approximately 12 percent of which was from Arab sources. Of the 5 mbpd *currently* imported by the U.S. in a still austere economy, 41 percent comes from Arab sources. In 1974, when the Arab producers imposed an oil embargo shutting off less than a million barrels per day, about 500,000 Americans immediately lost their jobs. But those were very prosperous times. Today, with about 9 million Americans already (still) out of work, a similar embargo would deprive us of over 2 million barrels per day — or about 15% of our *total* (reduced) oil consumption. Nor has our Strategic Reserve been given much attention. Sadly enough, after years of talk, legislation, and political propaganda, our oil vulnerability and our dependence on Persian Gulf supply has become greater, not less.

Yet our vulnerability and dependency pales into insignificance when compared to that of Europe. Of the 10 million barrels of oil imported daily into Western Europe, fully 60 percent comes from the Persian Gulf. In spite of the output of the North Sea fields and imports of oil and gas from the Soviet Union, it is unlikely that Western Europe, recession or no, could survive in its present industrial, social, or political likeness if denied Persian Gulf oil.

Control of Persian Gulf oil then implies in every way *de facto* control of Europe. The movement of the Soviet Union toward the Gulf is understandable in this context alone. However, it can be additionally argued that the Soviet Union will one day require foreign oil to meet its own needs. In the same context, it is also understandable that the United States regards the Persian Gulf as an area of extraordinary strategic importance. The ability of the U.S. to safeguard this precious area is, however, limited.

The European nations whose welfare is so individually and collectively affected by Persian Gulf oil understand full well that no war of major proportions can be fought in the Middle East without interrupting the flow of oil to Europe. Regardless of who is to be the victor or the vanquished in such a contest, Europe can only be the loser. Therefore Europe, predictably, would not support the United States in a war against Soviet or Soviet-sponsored encroachments in the Middle East unless the United States were in a position of being able to replace the lost Persian Gulf oil in the fashion of the Suez Crisis of the 1950s. To underscore this point one must also remember that the Soviet Union is already a substantial supplier of oil and gas to Western Europe and that growing bonds of trade are being forged between these entities.

The only hope of increasing Western Hemispheric oil supplies to the point where they could substantially reduce

European dependence on Persian Gulf sources would be to fully develop our synthetic fuel resources, the Canadian tar sands, and the Orinoco River Heavy Oil Belt in Venezuela. In the face of any seeming OPEC breakup and a further sharp drop in oil prices, it is clear that these steps will not be taken until too late.

Thus further drastic drops in oil prices which many hope for, while promising short-term relief to our economy, could ultimately lead us into a quagmire where our neighbors are beggared, many of our great banks are broken, and breadlines are formed. In reaction to all this we could find ourselves in a war which would maim our children and destroy our friends, but not solve our problem. Lest we forget—the energy crisis has not yet been overcome.

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*Howard Bucknell, a 1944 graduate of the U.S. Naval Academy, retired from the U.S. Navy as Captain, received a Ph.D. in Political Science from the University of Georgia, and taught at The Ohio State University, where he directed the Energy and National Security Project. Dr. Bucknell formed John Addison Cobb Associates, a consortium of energy analysts, in 1980.

SO WHAT'S THE WORTH OF A GEOLOGIC REPORT

By Arthur A. Socolow

Recently a highly dedicated watchdog of space and dollars suggested we dispose of our stock of published geologic reports because many of them are more than two years old. People who publish are supposed to know that it's all over for a book after a year and a half. I tried to explain that while Pennsylvania has undergone numerous geologic upheavals over the millions of years, our geological reports would still be valid and useful after several decades. Our efficiency experts didn't give up. How come, said he, most of the geologic reports we have issued only sell 20 to 50 copies a year - how important can they be?

Good question: How important is a geologic report? How much is the report worth if it enables the highway department to pick a route that saves millions of dollars in construction costs? What's the value if the report identifies the location of mineral deposits needed to provide lime for the farmers, clay for the brickmakers, or coal for the steel industry? To justify its existence, how many copies of a geologic map must be sold which shows the location of geologic faults hazardous to nuclear power plants, and the location of sinkholes hazardous to schools and dams? How do you assess the value of a geologic report which identifies the location of groundwater needed to locate a new glass factory employing hundreds, or a sprawling, new multimillion dollar bottling operation? If our reports lead to natural gas occurrences that heat our homes, and dam sites that keep them from being flooded, must we sell as many copies as *Gone With the Wind* to justify their existence? Among those who tunneled the Turnpike, designed routes 80 and 81, engineered the renewal of Philadelphia, developed water wells for thirsty Lehigh, Bucks, and Chester Counties, rehabilitated the stripped lands of Western Pennsylvania, none of those eager users of our geologic reports were less thankful because the reports were done 10 years ago and the sale of the publications did not make the *Times'* best seller list.

To those who concern themselves over cost benefit ratios, turnover, and timeliness, we who issue geologic reports say: Rest easy. Be assured the value of the report is not measured by its $4.75 price (plus tax); nor does its 1962 date relegate it to the uselessness of a vintage phone book; nor does its annual sale of 47 copies measure real need. Whether they provide mineral raw materials for our industries, locate the waters needed for our survival, identify the geologic hazards that can ruin us, or assist the road builders, farmers, and recreation planners, our geologic reports measure up well to the test of time and value.

Editor's note: We thank Mr. Socolow, State Geologist of Pennsylvania, for giving us permission to reprint this article, which originally appeared in Pennsylvania Geology, v. 13, no. 5, October 1982.

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RIVERS IN THE DESERT — OCTOBER 1983

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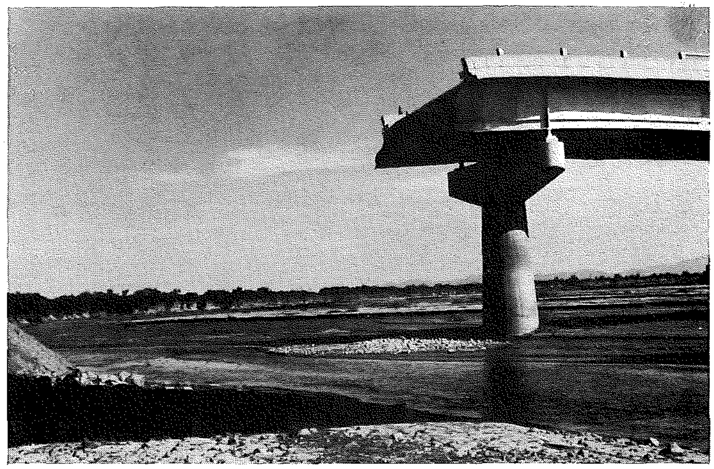

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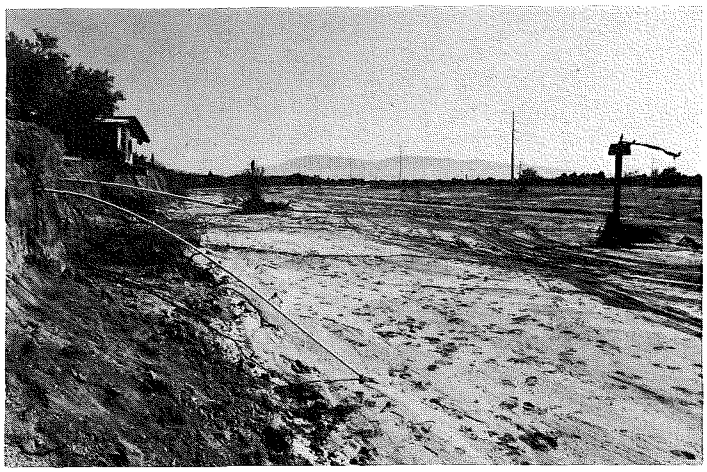

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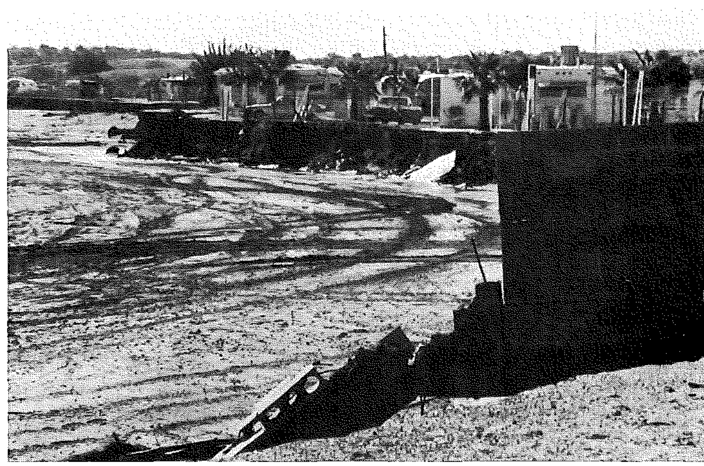

D.

A. Rillito river near 1st Avenue looking downstream. Post in river marks former bank. Erosion removed about five acres and undercut building. (Tucson)

B. Santa Cruz river at I-19 bridge crossing south of Tucson. Bank erosion out of picture to left destabilized bridge support allowing a span to collapse.

C. Rillito river near north Columbus looking upstream. Well casing left high and "dry" by more than one hundred feet of bank erosion. (Tucson)

D. Pantano Wash looking upstream. Bank erosion encroached upon trailer park washing away some and threatening others. (Tucson)

Watch for further developments of this and related subjects in a future issue of *Fieldnotes*.

Fieldnotes

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