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RESEARCH PROGRAM

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File under DF-85

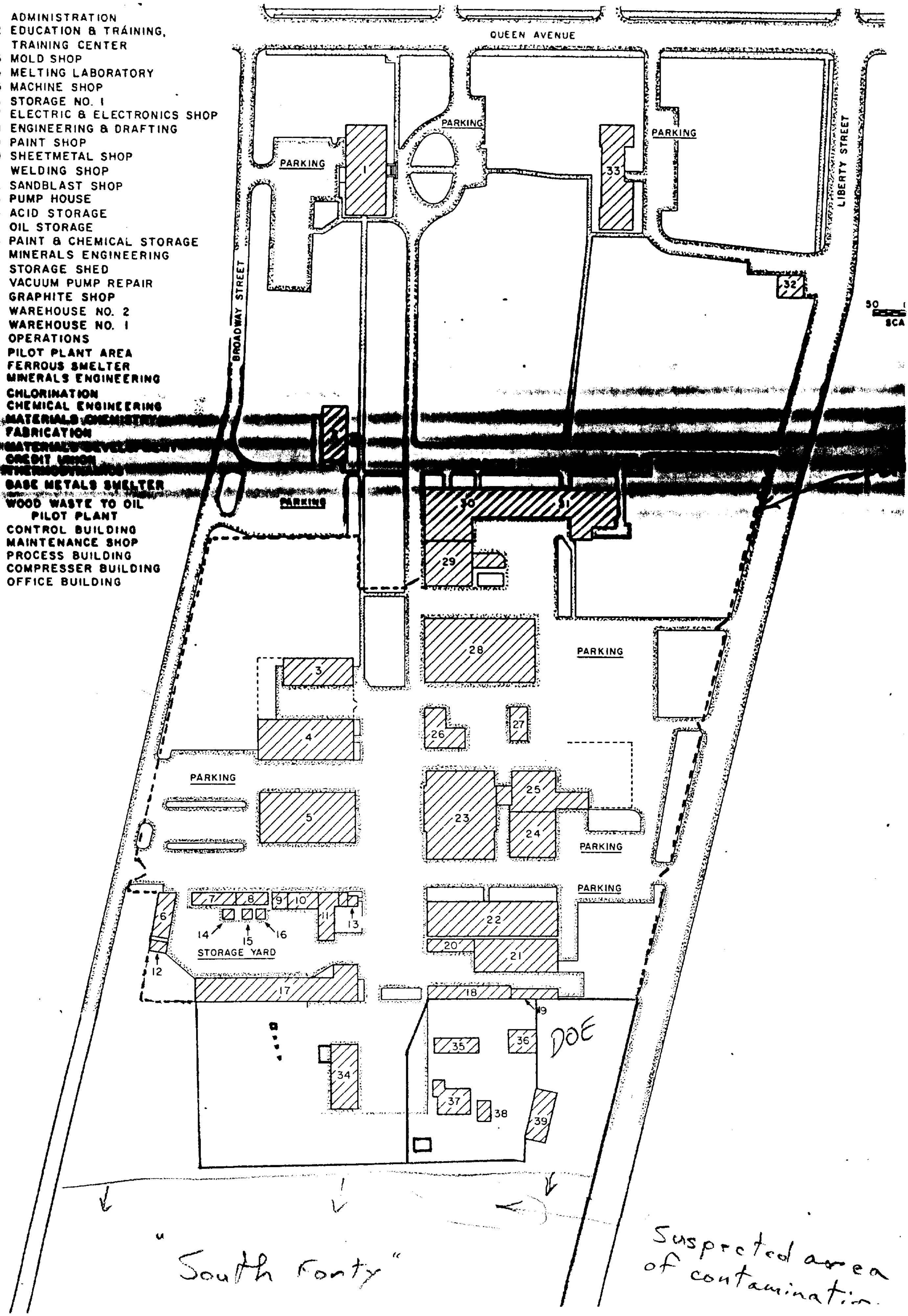
U.S. DEPARTMENT OF THE INTERIOR
SAFETY EFFICIENCY
MINERAL INDUSTRIES
BUREAU OF MINES

ALBANY RESEARCH CENTER

F. E. BLOCK, RESEARCH DIRECTOR

FOR OFFICIAL USE

1 ADMINISTRATION
2 EDUCATION & TRAINING, TRAINING CENTER
3 MOLD SHOP
4 MELTING LABORATORY
5 MACHINE SHOP
6 STORAGE NO. 1
7 ELECTRIC & ELECTRONICS SHOP
8 ENGINEERING & DRAFTING
9 PAINT SHOP
10 SHEETMETAL SHOP
11 WELDING SHOP
12 SANDBLAST SHOP
13 PUMP HOUSE
14 ACID STORAGE
15 OIL STORAGE
16 PAINT & CHEMICAL STORAGE
17 MINERALS ENGINEERING
18 STORAGE SHED
19 VACUUM PUMP REPAIR
20 GRAPHITE SHOP
21 WAREHOUSE NO. 2
22 WAREHOUSE NO. 1
23 OPERATIONS
24 PILOT PLANT AREA
25 FERROUS SMELTER
26 MINERALS ENGINEERING
27 CHLORINATION
28 CHEMICAL ENGINEERING
29 MATERIALS CHEMISTRY
30 FABRICATION
31 MATERIALS DEVELOPMENT
32 CREDIT UNION
33 THERMODYNAMICS
34 BASE METALS SMELTER
WOOD WASTE TO OIL PILOT PLANT
35 CONTROL BUILDING
36 MAINTENANCE SHOP
37 PROCESS BUILDING
38 COMPRESSER BUILDING
39 OFFICE BUILDING



"South Forty"

Suspected area of contamination

ALBANY RESEARCH CENTER

RESEARCH PROGRAM

Fiscal Year 1982

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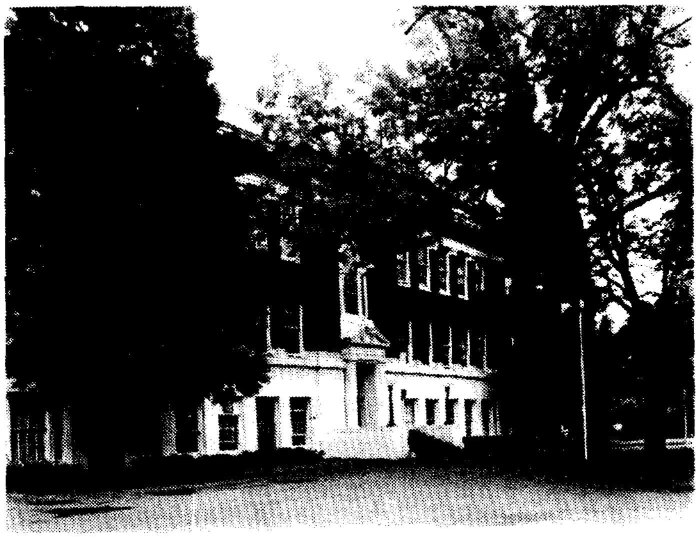


Albany Research Center

INTRODUCTION

The Albany Research Center was established by Congress in 1943 "to study the application of electrical energy to the processing of minerals," and within 10 years had become a nationally recognized center for metallurgy research on the newer metals. A noteworthy development during this early period was the development of the Kroll process for producing ductile, nuclear-grade zirconium.

In the ensuing four decades the Albany Center has continued to make contributions in much broader fields of metallurgy. Today the Center is unique among the Bureau's facilities in that its research program encompasses the entire spectrum of the minerals cycle. Its professional staff is experienced and well equipped to investigate all aspects of minerals beneficiation; hydrometallurgy including leaching, solvent extraction, and electrodeposition; pyrometallurgy including roasting, smelting, and melting and casting; and materials studies including alloy and hard materials development, wear research, and failure analysis. It also boasts a strong capability in minerals-related thermodynamics. Integral to all research efforts is a well-equipped analytical laboratory capable of providing state-of-the-art analytical services to all program areas.

The Center is staffed by 90 scientists and engineers, many with international reputations. The staff also is comprised of 42 highly-trained technicians, 18 skilled craftsmen, and 12 administrative and clerical employees. An active Equal Employment Opportunity program, including Hispanic and Federal Women's Programs, has been implemented to enhance employment and advancement opportunities for minorities and women.

Research programs at the Center are planned, executed, and coordinated by a Research Director and a Deputy Research Director, aided by six Research Supervisors, a Technical Assistant, and a Facility Manager.

STATISTICAL INFORMATION

ALBANY RESEARCH CENTER

Land Area 45 acres

Floor Space - 200,000 sq. ft.

Funding

		In-house	Contract FY 82	Contract FY 81
Mineral Resources Technology	-	$5,984,000	40,000	160,000
Minerals Health and Safety Technology	-	435,000	-0-	-0-
Miscellaneous	-	117,000		
		6,536,000	40,000	160,000

Employment

Full Time - - - - - - - - - - - - - - [illegible]

Research:

Professional [illegible]

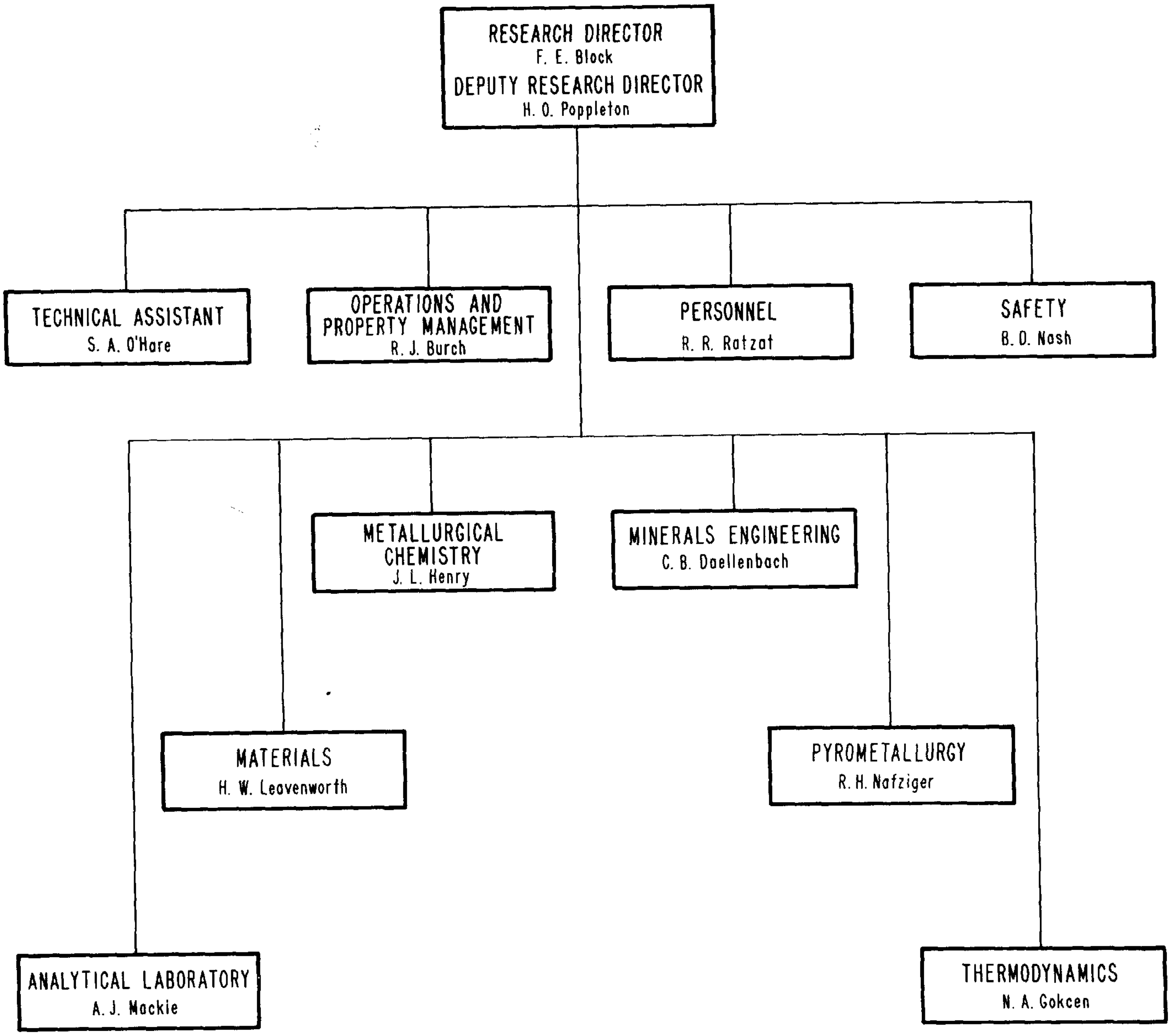
Technician [illegible]

Technical Support

Professional [illegible]

Technician [illegible]

ALBANY RESEARCH CENTER ORGANIZATIONAL CHART



RESEARCH DIRECTOR'S OFFICE

Block, F.E., Phy Sci Admin
Hice, F.N., Pers Mngt Spec (Act)
Jacobson, H.J., Secretary
Moyer, B.C., Info Receptionist
[1]Mrazek, R.V., Chem Engineer
Nelson, M.J., Clerk-Typist
O'Hare, S.A., Metallurgist
Poppleton, H.O., Phys Sci Admin
Ratzat, R.K., Pers Mngt Spec
Schrock, D.K., Clerk-Typist
Taylor, P.C., Personnel Clerk
[2]Wylie, L.J., Clerk-Typist

MANAGEMENT SERVICES

Abshire, E.F., Librarian
Anderson, S.T., Arts & Info
Barnes, T.V., Dup Eq Oper
Davis, L.J., Travel Clerk
Nash, B.D., Safety Manager

MATERIALS

Asai, G., Res Chemist
[3]Becker, M.J., Phy Sci Aid
Benz, J., Metallurgist
Blickensderfer, R., Metallurgist
Brooks, S.K., Eng Tech
Bullard, S.J., Chemist
Burrus, J.M., Phys Sci Tech
Doan, R.C., Phys Sci Tech
Dunning, J.S., Metallurgist
Forkner, B.L., Phys Sci Tech
Fortier, C.A., Eng Tech
Glenn, M.L., Metallurgist
[2]Gropp, R.H., Secretary
Kelley, J.E., Metallurgist
Koch, J.N., Phys Sci Tech
Koyto, P.J., Mech Eng Tech
Larson, D.E., Metallurgist
Larson, W.L., Eng Tech
Leavenworth, H.W., Supv Metal
Madsen, B.W., Metallurgist
Mai, T.T., Metallurgist
McDonald, G.L., Metallurgist
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Rhoads, S.C., Res Chemist
Rietmann, H.A., Secretary
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Singleton, D.J., Chemist
[3]Sizemore, J.C., Eng Aid
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Worthington, R.B., Metallurgist

[1]Faculty Member
[2]Part-time
[3]Student

OPERATIONS AND PROPERTY MANAGEMENT

Archer, R.E., Electronics Tech
Burch, R.J., Facility Manager
Farlee, M.L., Supv Gen Eng
Gibbs, R.E., Maint Worker
Kenagy, G.L., Mech & Maint Frm
Kyriss, J.R., Procurement Clerk
McKibben, E.D., Welder
McMackin, L.L., Supply Tech
Meuler, E.A., Purchacing Agent
Nuzum, L.T., Eng Tech
Partridge, G.L., Janitor Frm
Reynolds, J.L., Machinist
Roberts, K.E., Supply Clerk
Rust, M.E., Electrician
Scarborough, J.T., Wood Craftsm
Simon, F.W., Gardener
Tabler, L.D., Electrician
Unglesby, E.I., Toolmaker
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Wirowek, R.O., Maint Mech
Zilis, G.R., Electrical Eng

METALLURGICAL CHEMISTRY

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Esau, R.R., Phys Sci Tech
Galvan, G., Phys Sci Aid
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Hammond, S.W., Eng Tech
Henry J.L., Supv Res Chemist
Ko, H.C., Res Chemist
Koch, R.K., Res Chemist
Landsberg, A., Chemical Eng
Lincoln, R.L., Res Physicist
Maier, R.H., Chem Eng Tech
Mauser, J.E., Metallurgist
Olsen, R.S., Chemical Eng
Paige, J.I. Chemical Eng
Penner, L.R., Chemist
Slavens, G.J., Chemical Eng
Traut, D.E., Chemical Eng
White, J.C., Metallurgist
Wilson, R.D., Chemist
Yee, D.H., Res Chemist

THERMODYNAMICS

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Beyer, R.P., Chem Engineer
Brittain, S.L., Secretary
Brown, R.R., Res Chemist
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Ferrante, M.J., Res Chemist
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Stuve, J.M., Res Chemist

PYROMETALLURGY

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Calvert, E.D., Metallurgist
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Fulton, R.L., Eng Tech
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Holmes, W.T., Res Chemist
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Lowery, R.R., Metallurgist
Mitchell, T.F., Eng Aid (Stu)
Nafziger, R.H., Supv Metal
Oden, L.L., Supv Res Chemist
Sims, C.O., Phy Sci Tech
Soltau, G.F., Eng Tech
Tress, J.E., Chemical Eng
Wright, J.B., Chemical Eng

MINERALS ENGINEERING

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Brown, L.L., Geologist
Collins, D.G., Chemical Eng
Daellenbach, C.B., Supv Metal
Dahlin, D.C., Metallurgist
Dirrett, H.M., Secretary
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George, D.R., Eng Tech
Holmes, R.A. Chemist
Hundley, G.L., Chem Eng
Kinney, J.J., Geologist
Kirby, D.E., Metallurgist
Nilsen, D.N., Chemical Eng
[2]Noss, W.L., Phys Sci Tech
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Russell, J.H., Res Chemist
Siemens, R.E., Metallurgist
Wells, J.D., Phys Sci Tech
Williams, J.H., Phys Sci Tech

ANALYTICAL LABORATORY

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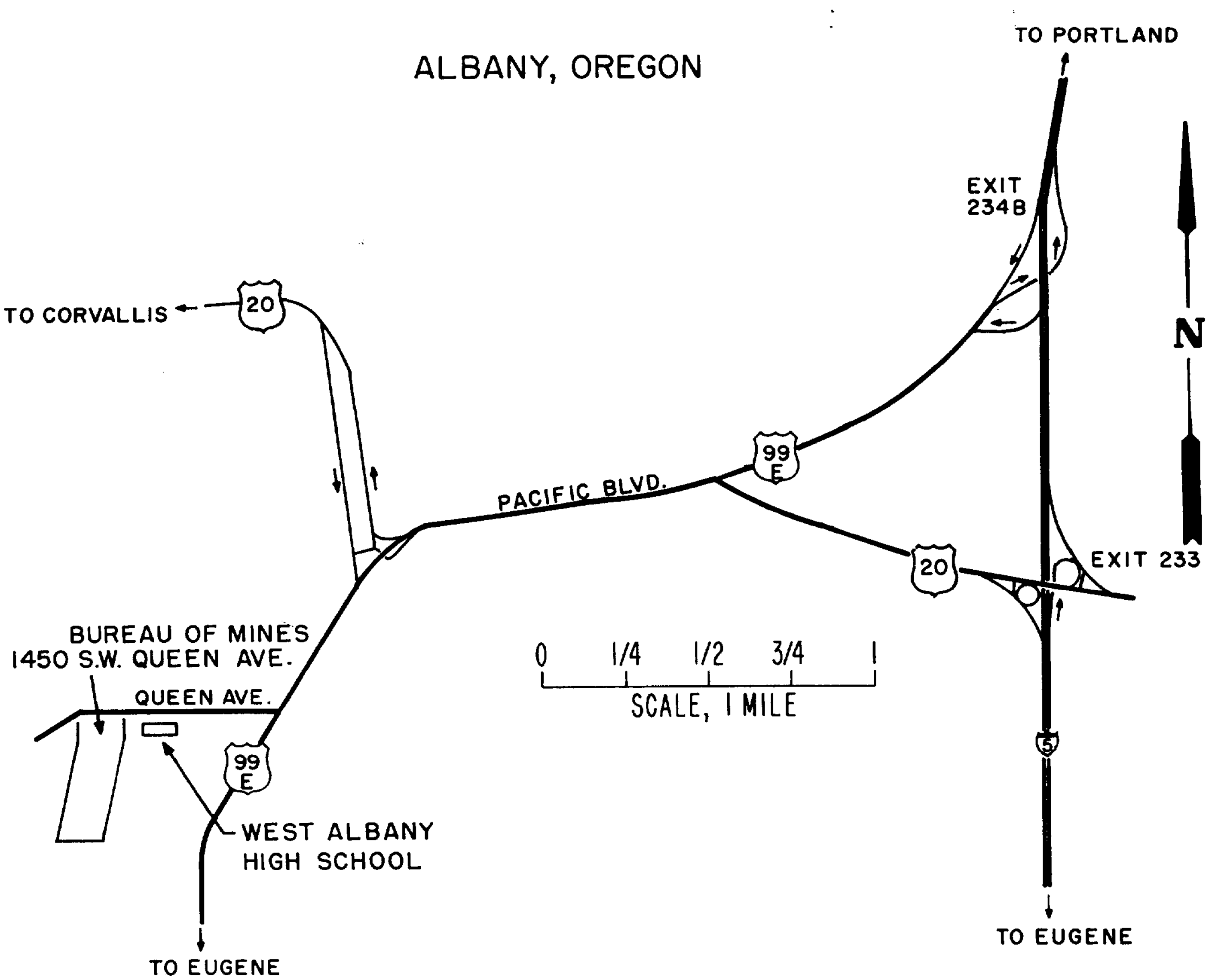
Bollman, D.H., Res Chemist
Farrell, R.F., Res Chemist
Hicks, B.L., Phy Sci Tech
Krug, V.D., Phy Sci Tech
Likaits, E.R., Chemist
Mackie, A.J., Supv Chemist
Matthes, S.A., Chemist
McCune, R.A., Res Chemist
Niebuhr, W.J., Res Physicist
Perry, J.A., Res Chemist
Romans, P.A., Res Physicist
Siple, J.W., Chemist
Standiford, C.J, Secretary
Uhde, R.R., Physicist
[3]Williamson, C.A., Phy Sci Aid


ALBANY, OREGON
TO PORTLAND
EXIT 234B
N
TO CORVALLIS
20
PACIFIC BLVD.
99 E
20
EXIT 233
BUREAU OF MINES
1450 S.W. QUEEN AVE.
QUEEN AVE.
0 1/4 1/2 3/4 1
SCALE, 1 MILE
5
99 E
WEST ALBANY
HIGH SCHOOL
TO EUGENE
TO EUGENE

1 ADMINISTRATION
2 MINE SAFETY & HEALTH ADMINISTRATION
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10 SHEETMETAL SHOP
11 WELDING SHOP
12 SANDBLAST SHOP
13 LUNCH ROOM
14 ACID STORAGE
15 OIL STORAGE
16 PAINT & CHEMICAL STORAGE
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18 STORAGE SHED
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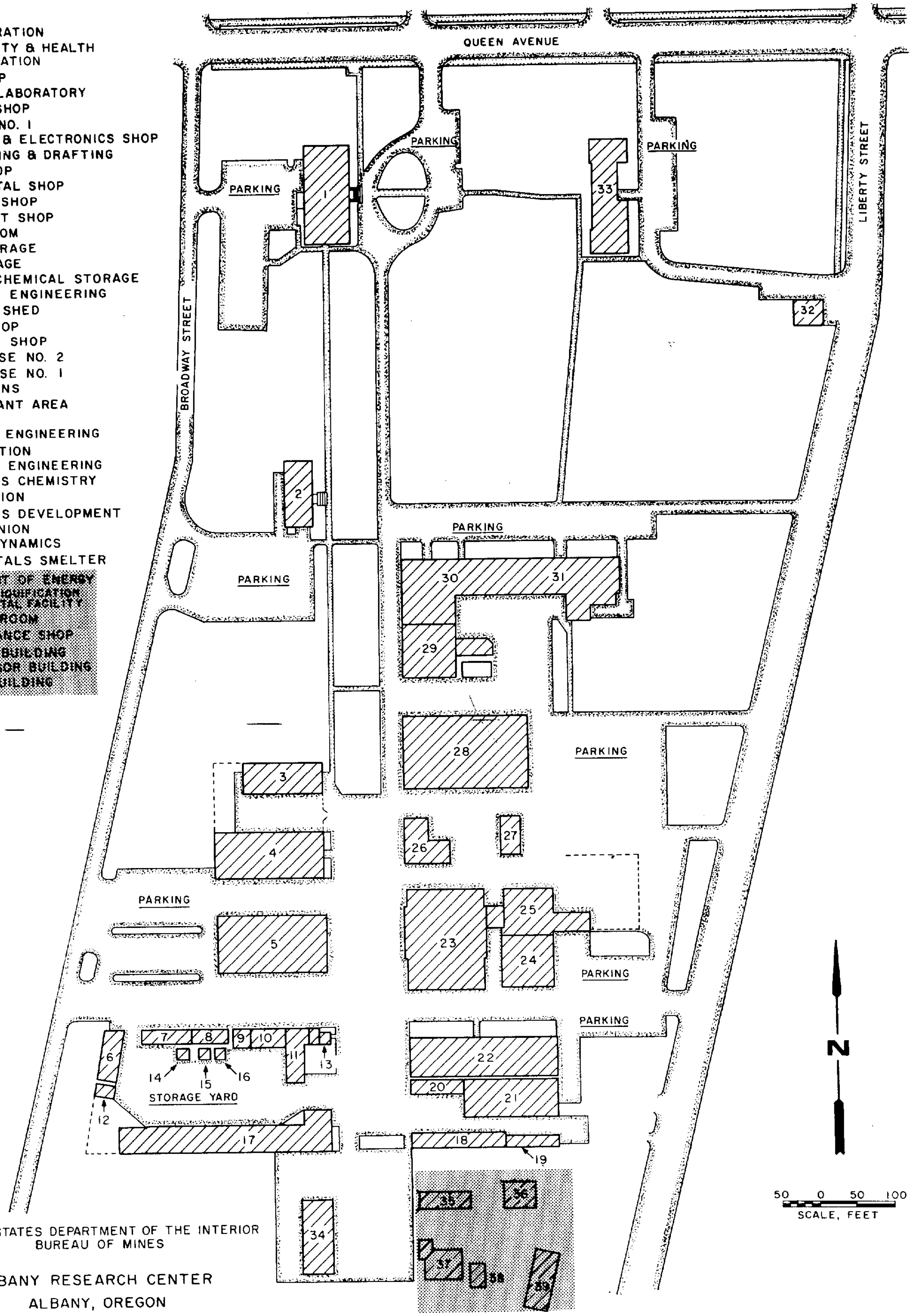
30 FABRICATION
31 MATERIALS DEVELOPMENT
32 CREDIT UNION
33 THERMODYNAMICS
34 BASE METALS SMELTER

DEPARTMENT OF ENERGY BIOMASS LIQUIFICATION EXPERIMENTAL FACILITY
35 CONTROL ROOM
36 MAINTENANCE SHOP
37 PROCESS BUILDING
38 COMPRESSOR BUILDING
39 OFFICE BUILDING



UNITED STATES DEPARTMENT OF THE INTERIOR
BUREAU OF MINES

ALBANY RESEARCH CENTER
ALBANY, OREGON

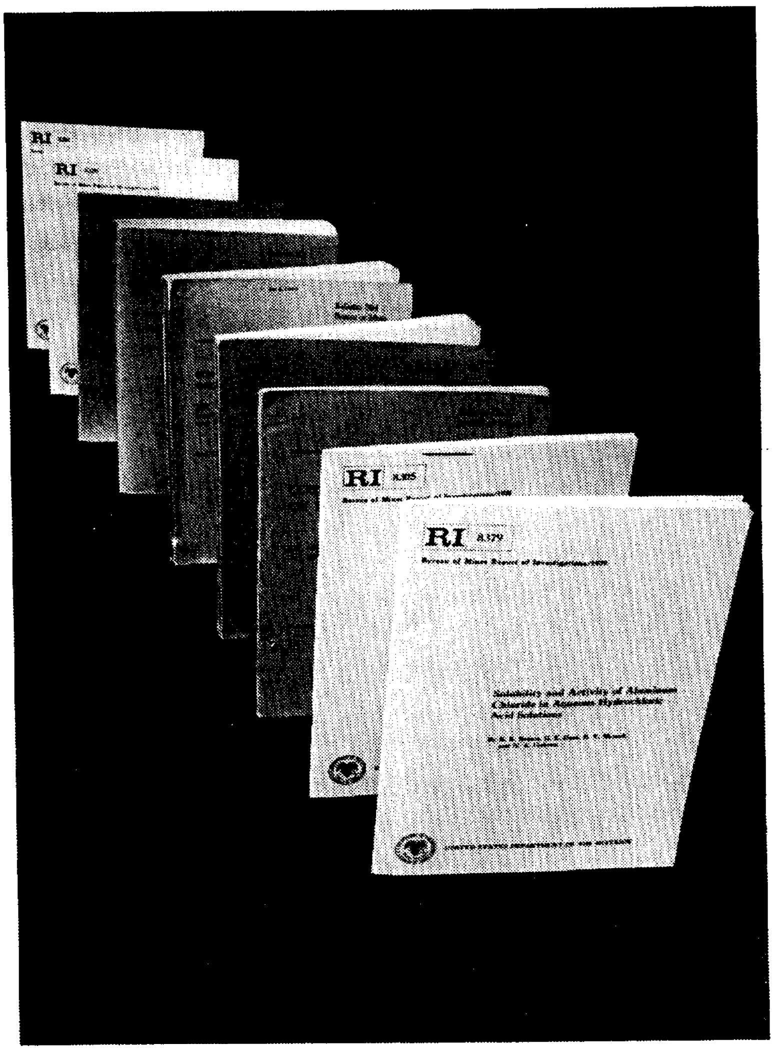
Research Program

Basic Research

Approximately 17 percent of the Center's budget supports basic research, principally in the area of minerals thermodynamics. Projects on minerals comminution, phase equilibria, and analytical methodology comprise the remainder of the basic research.

Thermodynamics

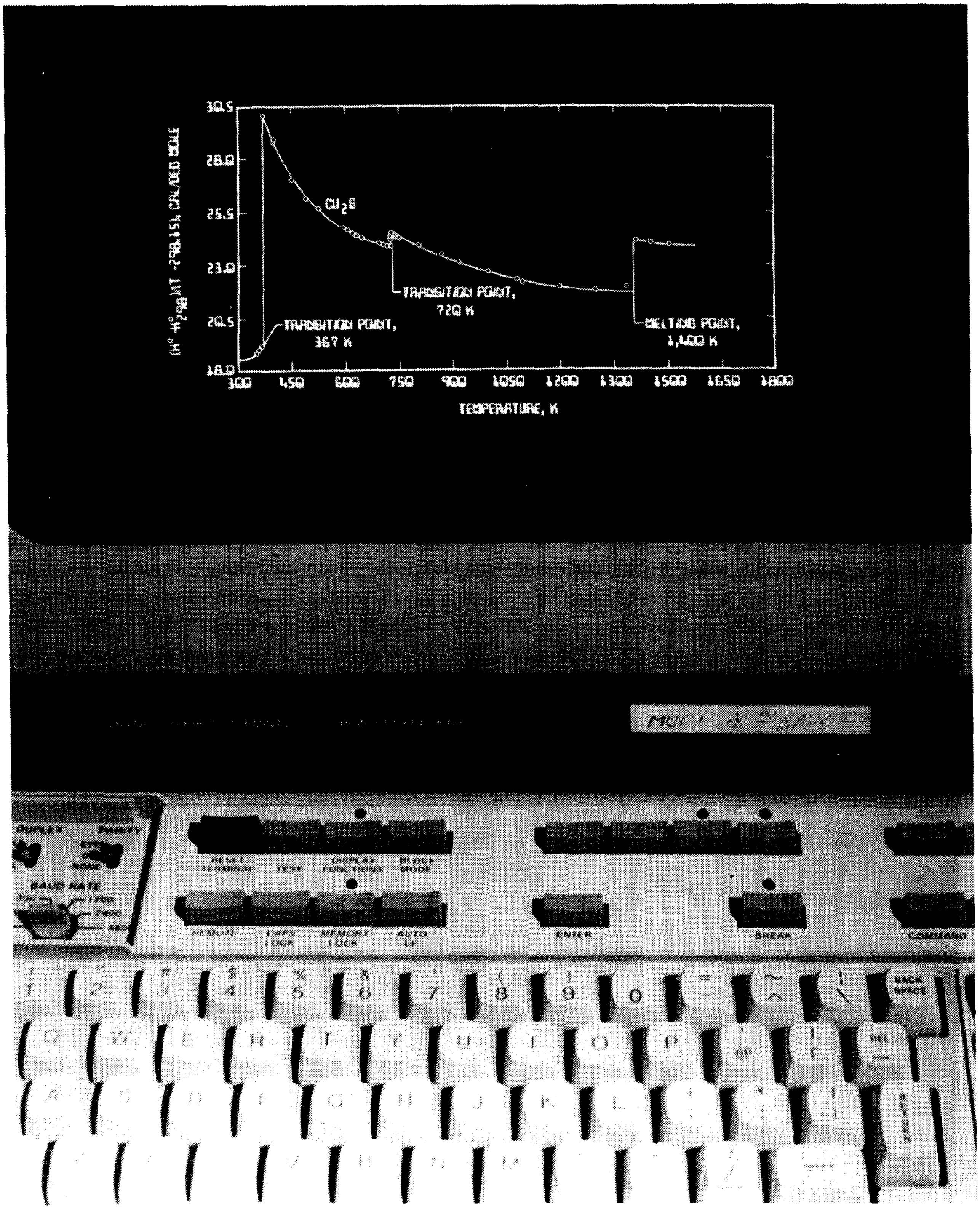
The Bureau of Mines has played a leadership role in minerals related thermodynamics from the time this research was pioneered by Dr. K. K. Kelley at the Bureau laboratory in Berkeley. This work was later transferred to Albany and has continued to the present. To provide the data base needed by the minerals community, thermochemical data are obtained by solution calorimetry, high- and low-temperature calorimetry, electromotive force measurements, and by determination of ionic activity.



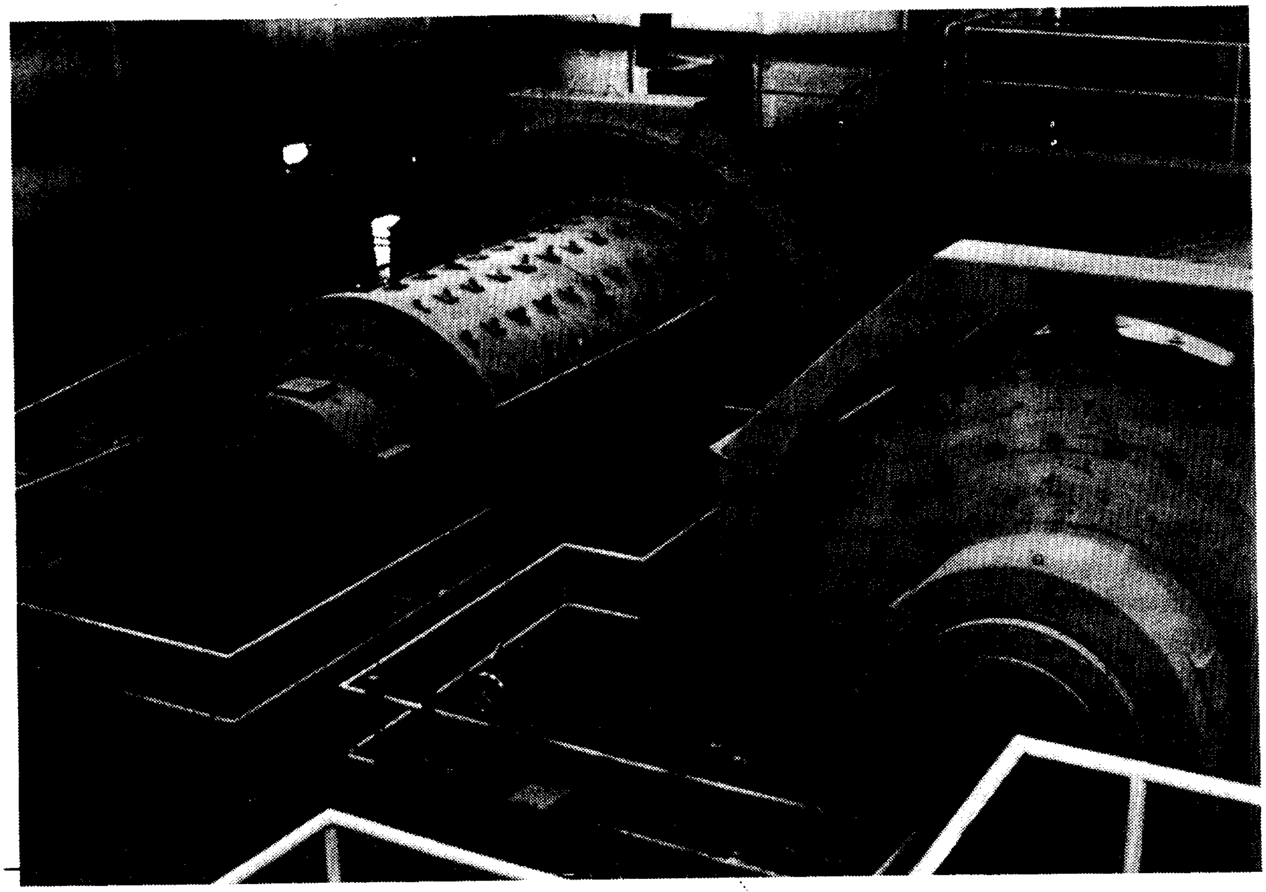
Bureau of Mines Bulletins are being prepared that compile the thermodynamic properties of oxides, and select halides and sulfides.

Beginning this fiscal year, studies will be made on the systems Al-Si-C and Al-Si-C-O to determine phase relationships and vapor-liquid equilibria at high temperatures. Reliable data are lacking for these systems which are of importance to studies on the carbothermic reduction of aluminum from domestic resources.

Because of the importance of thermodynamic data in assessing the feasibility of metallurgical processes without recourse to costly and time-consuming experimentation, the Bureau has a continuing program to critically evaluate thermodynamic data from all sources for publication as reliable, internally consistent compilations of data. Scheduled for publication this fiscal year is a bulletin covering the elements and oxides and another covering the halides.



Data from Bureau of Mines research and worldwide sources are compiled and evaluated to maintain a current data bank in thermodynamics.



Grinding ore to liberate the valuable minerals from the ore is the single most energy-intensive step in processing minerals. The ball mill illustrated above can use as much as 25.9 x 10^6 Btu in the production of one ton of copper.

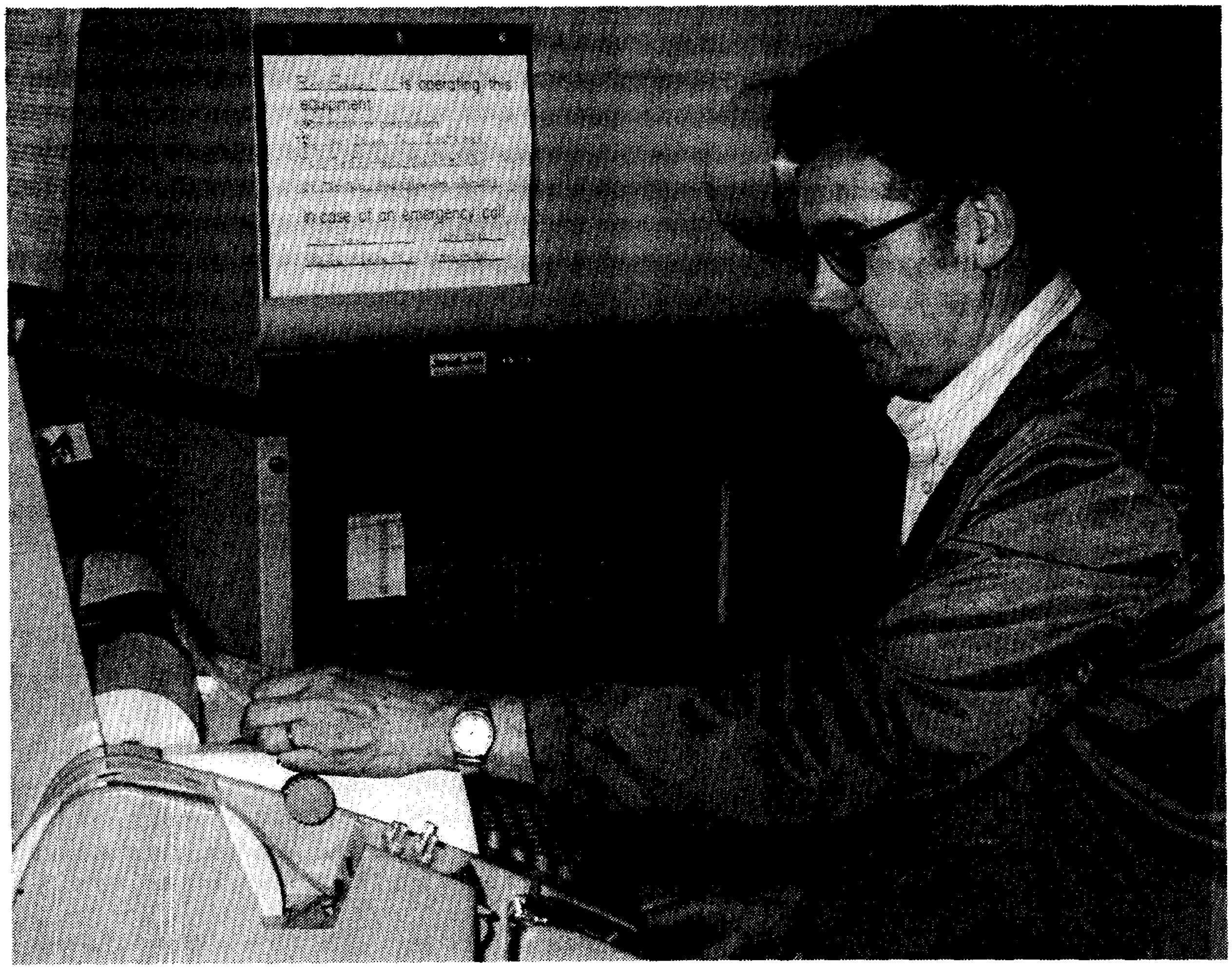
Comminution

Comminution, the grinding of an ore into fine particles, is the first step and, in many respects, the most important operation in metallurgy. It affects all subsequent processing steps by setting the size distribution of the ore, the extent of liberation, and the amount of unwanted fine material produced. It is usually the single most energy-consuming and costly step in the mineral processing cycle.

Fundamental data are being acquired to relate all variables and to gain an understanding of the controlling mechanisms. The ultimate goal of this research will be to reduce the energy consumed in grinding. During this fiscal year the role of chemical additives in the grinding process is being investigated.

Analytical Studies

Modern analytical techniques are imperative for providing rapid and reliable determinations of elemental compositions, especially in today's high technology where impurities are routinely measured in the parts per million range. In addition to developing and upgrading methods for the analytical support of the Center's ongoing research programs, the analytical laboratory is cooperating with the National Bureau of Standards (NBS) in certifying the precise level of impurities such as oxygen, nitrogen, hydrogen, and carbon in metals and alloys for use by NBS in providing standards that are available to the public.



Analyzing elements in cast iron samples using the direct reading spectrograph.

Extractive Metallurgy

The Albany Center, since its inception, has maintained a strong program in all areas of extractive metallurgy. Facilities are available for conducting re-search on a small, bench-top scale on up to 1-ton capacity, three-phase arc furnaces. Currently the program leans heavily toward research on new methods for recovering strategic and critical materials from domestic resources as one method for reducing our Nation's dependence on imports. Approximately 28 percent of the Center's budget is assigned to extractive metallurgy projects.

Laterites

Much of the Nation's nickel and cobalt resources occur in the laterite deposits that lie along the border between Oregon and California near the coast. Because the grade of these deposits is too low for economical recovery by conventional processing, new technology adapted specifically to these deposits is being studied. The process incorporates selective reduction with carbon monoxide followed by an oxidizing ammonia-ammonium sulfate leach. Solvent extraction followed by electrowinning recovers high-purity nickel and cobalt from the leach solution. This procedure has more potential economically than more conventional technology because metal recovery is higher, particularly with respect to cobalt.

Research during this fiscal year will focus on further improvements in methods for separating nickel and cobalt by solvent extraction. Extractants that are more selective for cobalt or that can be operated in an acidic circuit should offer further economies of operation, both in terms of material and energy consumption.

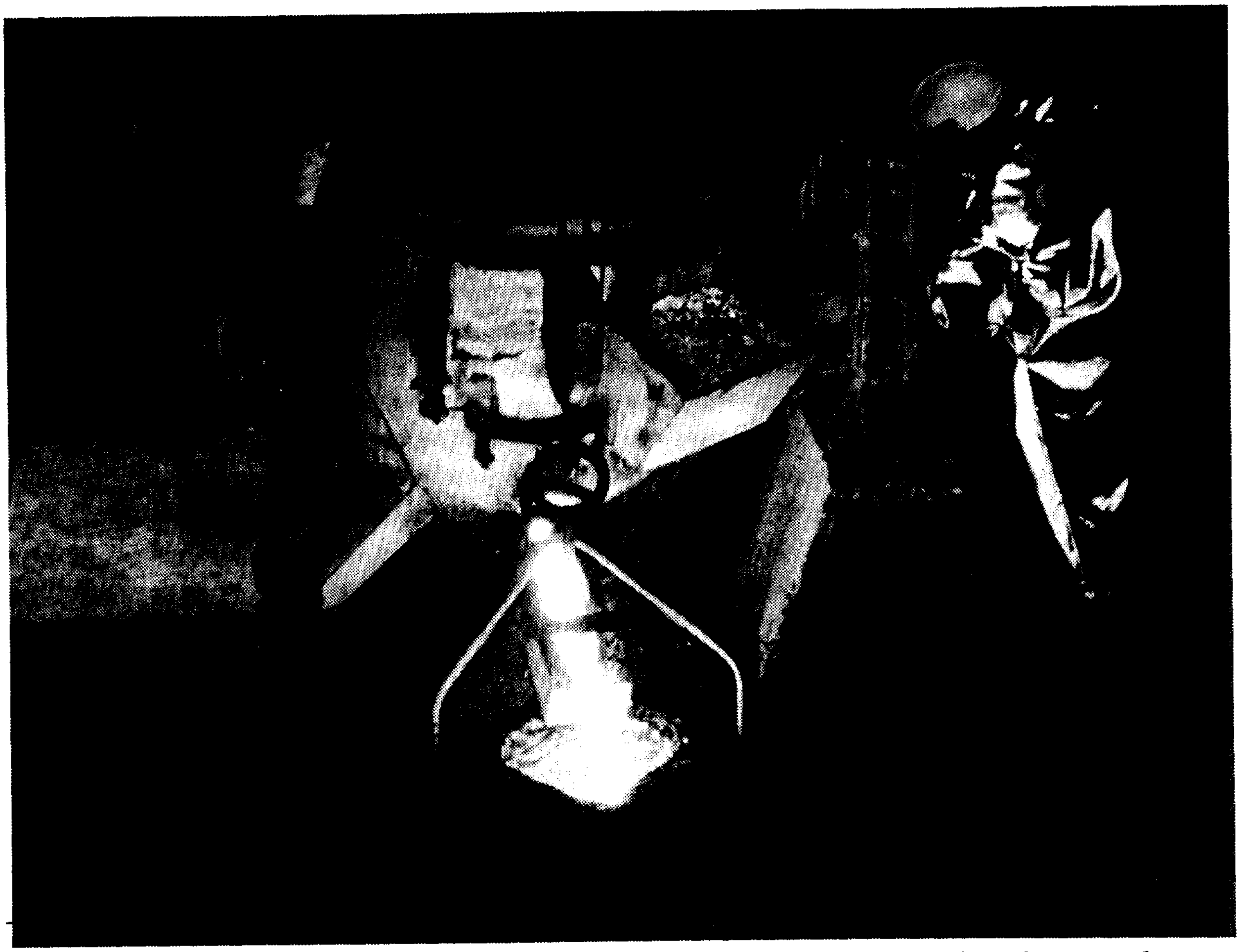
The Western laterites contain low grade chromites in addition to nickel and cobalt. Although the chromite grade is too low for economic recovery of chromite alone, the combined recovery of all three minerals could offer an economic advantage in the processing of these domestic laterites.

After the laterites have been processed for nickel and cobalt recovery, the chromites remaining in the residue will be upgraded by gravity concentration and subjected to a low-temperature soda roast which will render the chromium amenable to recovery by water leaching. After purification by solvent extraction, pure chromium will be produced by electrowinning. As an alternate to chemical processing and electrolysis to produce pure chromium, the low-grade concentrates will be smelted in an electric arc furnace to produce ferrochrome.

Ilmenite

High-grade titanium minerals are imported to satisfy the bulk of our Nation's needs for titanium, although we have abundant resources of low-grade ilmenite and titaniferous magnetites. These low-grade minerals are not amenable to processing by conventional carbochlorination to extract titanium because of the huge amount of chlorinated byproducts that would be formed and create operating as well as disposal problems.

Laterite deposits of the Western United States are our largest chromium, nickel, and cobalt resource. The valuable constitutents are low and only a simple, low cost technology is appropriate for its processing.



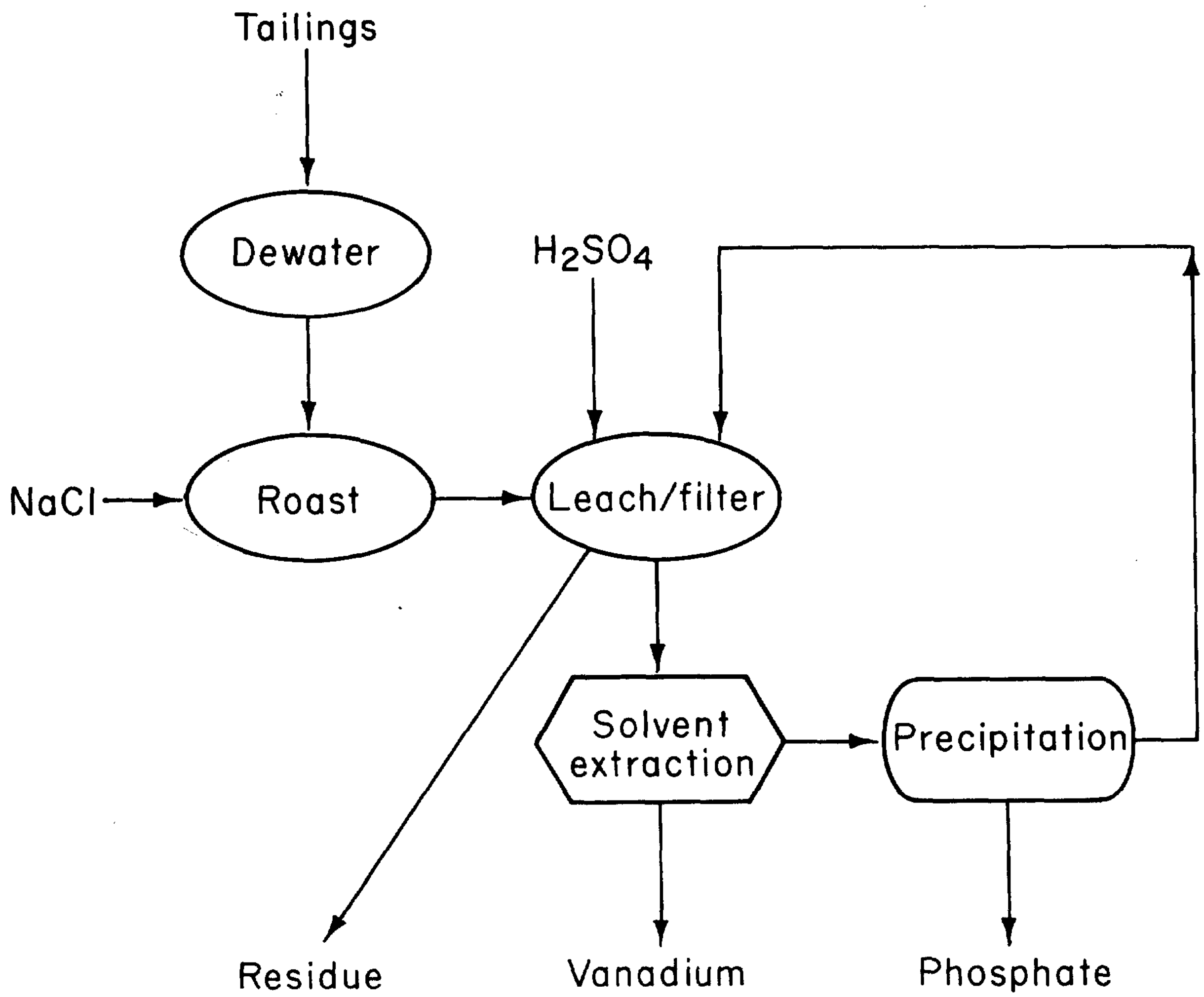
Processing ilmenite in an electric arc furnace with coke and sodium carbonate will produce pig iron and titania-enriched slags with low iron content. The slag is then processed to recovery titanium.

To overcome this problem, a method is being studied for upgrading domestic titanium minerals to provide an acceptable chlorination-grade feedstock. Ilmenite is smelted in an electric furnace to produce marketable pig iron and a titanium-rich slag. To render the slag suitable as a chlorination feedstock, it is further upgraded by sulfation leaching to remove calcium, magnesium, sodium, and manganese which interfere with operation of a chlorinator.

Higher grade domestic ilmenites can be chlorinated directly to extract titanium, but large amounts of iron chlorides are produced which consume chlorine and are difficult to dispose of in an acceptable manner. This problem could be overcome if a suitable method could be developed for recovering the chlorine from iron chlorides. In one approach being investigated, the iron chloride residue from ilmenite chlorination is reacted with oxygen in a fluidized bed to produce iron oxides and elemental chlorine which could be recycled back to a chlorinator. A major problem to be solved in this technology is how to overcome tendencies for the reactor charge to melt and cause plugging.

Phosphate

When western phosphate ores are processed to produce elemental phosphorus or phosphoric acid, large amounts of wastes are generated in the form of beneficiation tailings or furnace flue dusts. These wastes contain significant amounts of unrecovered phosphorus as well as vanadium, uranium, silver, and zinc. Both physical and chemical methods in various combinations are being studied for recovering these valuable constituents which now contribute to a waste disposal problem. By roasting the beneficiation tailings with salt, the phosphorus, vanadium, and uranium can be extracted. Cyanide leaching will extract silver from flue dusts.



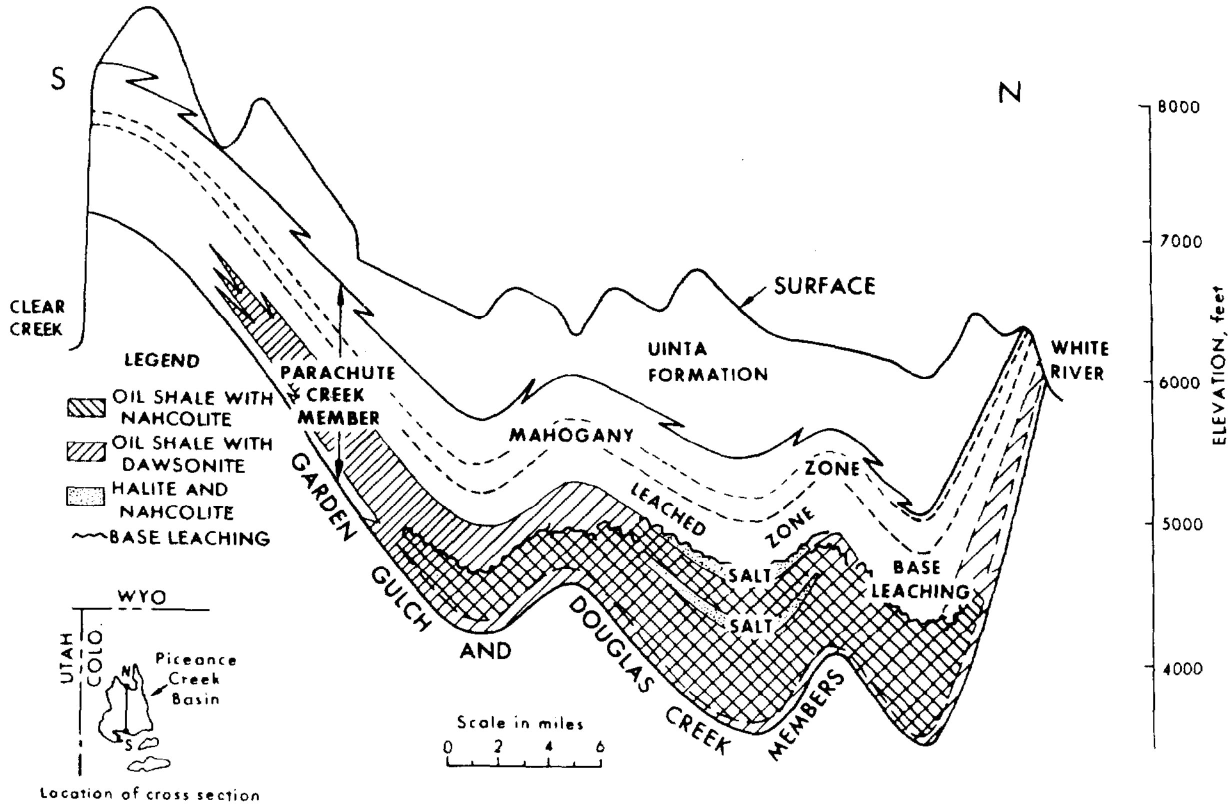
A proposed flow scheme to recover valuable materials that are currently discarded as tailing.

Aluminum

Despite our huge reserves of high-grade kaolin clays, over 90 percent of the feed material for our aluminum industry is derived from imported bauxite. Although there is no shortage of bauxite, our almost total dependence on overseas resources could be avoided by developing technology for economically extracting aluminum from clays. One approach that has been suggested involves the carbochlorination of clays to produce aluminum chloride which, in turn, could be either converted to alumina for feed to existing aluminum smelters or be used directly as feed to a chloride electrolyte cell. Research on this approach is oriented to the development of more basic information on factors that influence or control the reactions of clay with chlorine to produce aluminum chloride and chlorinated byproducts. Factors will be studied that may also influence or limit methods for purifying impure aluminum chloride to produce the necessary high-purity product required for feed to aluminum reduction cells.

The Nation's dependency on imported bauxite is not limited to primary aluminum production. All of the higher grade bauxites required for production of high-temperature furnace refractories are also imported, principally from Guyana. As a possible alternative to imports, should a supply disruption occur, a method is being studied for converting domestic clays into a product that could substitute for at least the lower grade, imported refractory-grade bauxite. Clay is subjected to a hot caustic leach at atmospheric pressure to dissolve silica. The desilicated product is given a mild acid treatment to remove any soda that remains. This processing sequence is being balanced to yield a product that is equivalent to refractory-grade bauxite in terms of chemical composition as well as pyrometric cone equivalent.

Another aluminum resource that may have potential for recovery is the dawsonite that occurs in some of the western oil shale deposits. If these oil shales are processed for recovery of hydrocarbon products, huge amounts of dawsonite and associated nahcolite will also be available for recovery from the residue that results after the oil has been extracted. To plan for this eventuality, methods for recovery of both alumina and sodium products are being investigated. Research is ongoing to delineate retorting temperatures that will maximize recovery of oil as well as the alumina and soda. Methods are under investigation for leaching the spent shale to recover a high-grade alumina product that is suitable as feed to an aluminum reduction cell and a marketable sodium product as well.



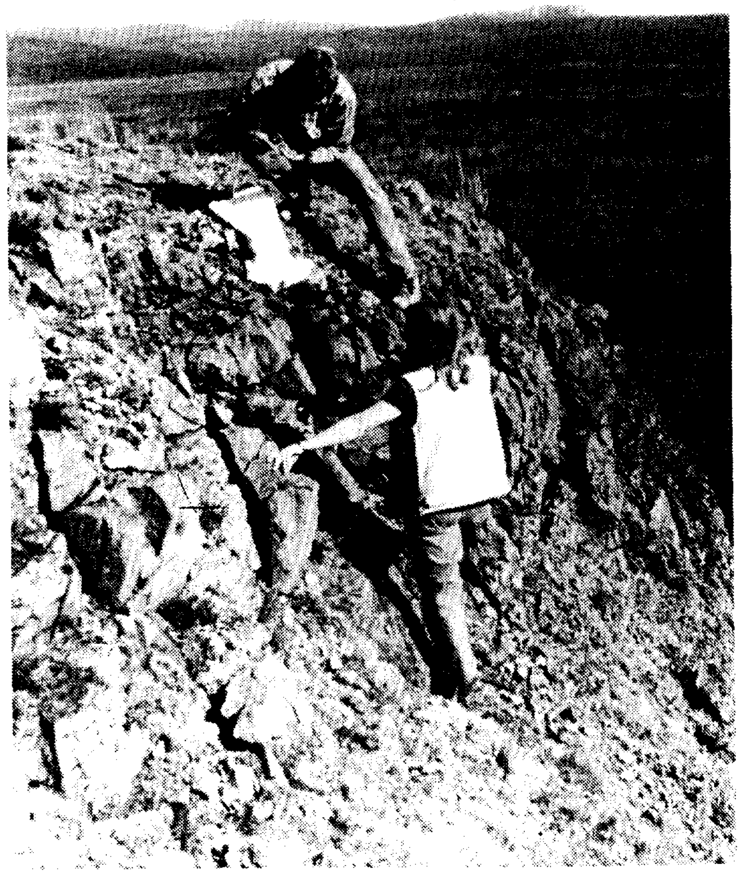
Diagrammatic cross section of dawsonite-bearing oil shale deposit in Colorado's Piceance Creek Basin.

Resource Appraisal

Much of the lands in Alaska and the northwestern states have not been thoroughly explored for their mineral potential. Should mineral occurrences exist that are considered strategic and critical, we could lessen our dependence on imports in the event of an emergency. In cooperation with the Alaska and Western Field Operations Centers of the Bureau of Mines, mineralized areas in these states are being explored to assess their potential as sources for platinum, chromite, cobalt, tin, and tantalum. Samples are being characterized for their mineral content, and beneficiation tests are being made to assess the potential for recovery of minerals that are present. This research will expand the data base for the resource potential of these areas of the country.

A secondary resource of unknown dimensions exists in the industries that employ catalysts to produce such products as hydrogenated oils or synthetic fibers. As these catalysts degrade and are discarded, metals such as nickel, cobalt, copper, zinc, and molybdenum that are contained in these catalysts are lost to our economy. Recovery and reuse of the metals in these spent catalysts would also lessen our dependence on imports.

To assess the magnitude of this problem, a contractor to the Bureau is surveying the industry to quantify the amounts and types of metals that are being wasted in these industries. Having determined which spent catalysts represent significant resources for recovery, processing schemes will be investigated in-house to devise possible flowsheets for recovery of the contained metals.



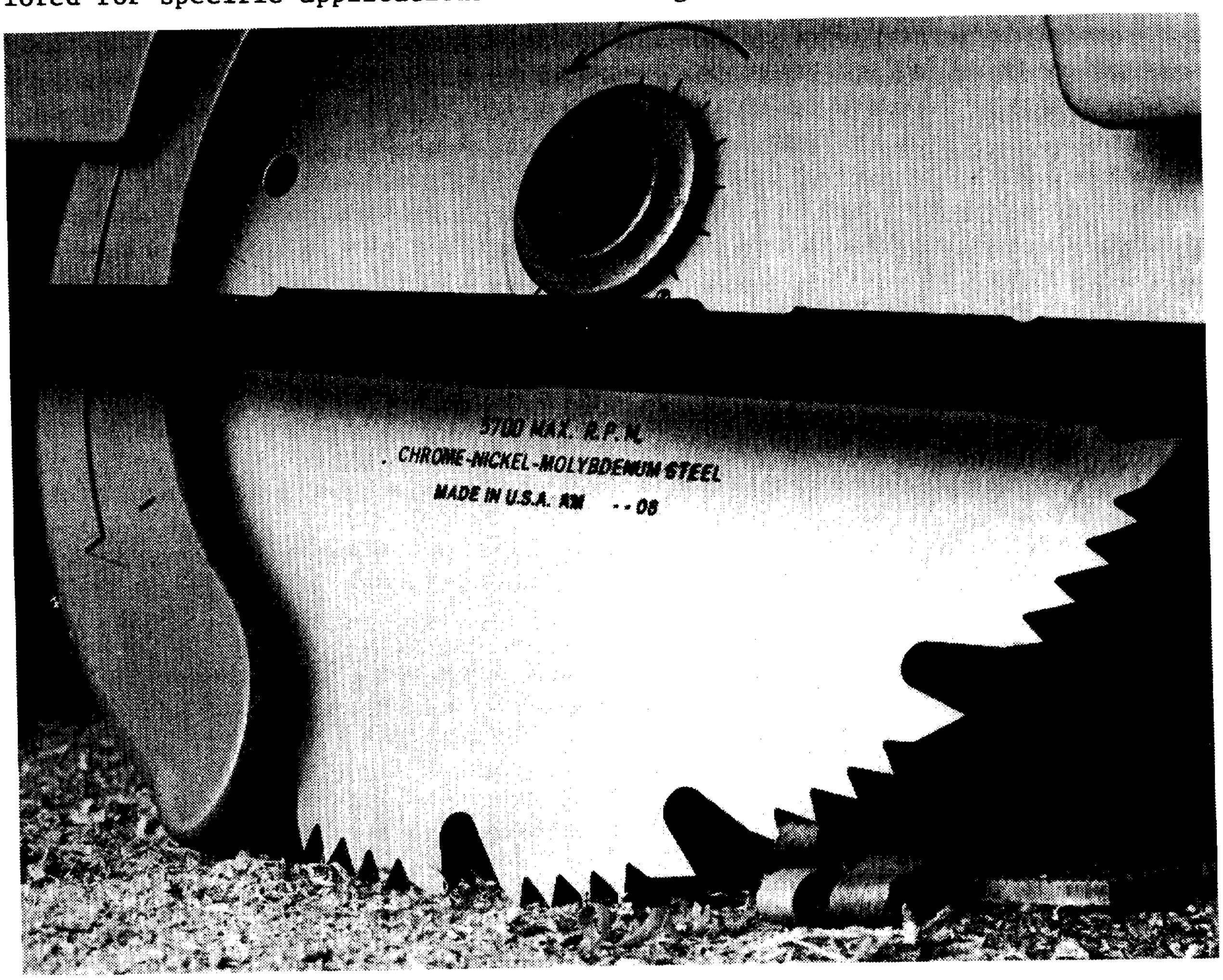
The photograph shows a geologist and a metallurgist collecting a chromite sample suspected to have associated platinum from an area near the Arctic Circle in Alaska. At the Albany Research Center, the sample will be characterized by techniques such as petrography, scanning electron microscopy, and microprobe analysis. Methods such as flotation, gravity, magnetic, and electrostatic separation are then used to devise procedures to concentrate the platinum values.

Material Research

Ever since the late 1940's, when the Albany Center became involved in the development of zirconium for use in nuclear reactors, the Center has maintained a program in materials research. This year the program constitutes 35 percent of the Center's budgeted funds and is primarily oriented toward the conservation or elimination of strategic and critical minerals through materials substitution. The Center's well equipped testing and fabrication facilities, together with its staff of experienced materials scientists, are unique among the Bureau's Research Centers.

Alloy Development

Most of the chromium consumed in our economy is for the production of stainless and heat resisting steels. In many cases the amount of chromium used in steels is much greater than necessary for the severity of the application. Research is underway to develop iron-base alloys that contain less chromium or no chromium but could be substituted for conventional chromium-containing alloys should the need arise for conservation. These alloys are being tailored for specific applications in which high-chromium alloys are now used.



Chromium is an important alloying element in tools, appliances, and industrial application.

To substitute for much of the stainless steels that are used for aqueous corrosion resistance, such as in the hydrometallurgical processing of ores or in the food processing industries, an iron-base alloy is being developed that contains only 9 percent chromium. Copper, molybdenum, and vanadium additions are being made to compensate for the lower chromium content. The alloy also contains 6 to 12 percent nickel and minor amounts of manganese. In addition to corrosion resistance, this alloy is being evaluated for its mechanical properties, weldability, and oxidation resistance.

For more severe environments where higher temperature strength and oxidation resistance are required, an iron-base alloy system is being investigated that contains at least 50 percent less chromium than the 25 percent chromium alloys it is designed to replace. The alloy contains a nickel-aluminum dispersion to compensate for the lower chromium content. Because of its excellent high-temperature strength and resistance to oxidation and sulfidation, this alloy shows promise of outperforming conventional alloys in applications where sulfur-containing ores or fuels are treated.

As a substitute for type 304 stainless steel, where high-temperature strength and oxidation resistance are required, but not aqueous corrosion resistance, a chromium free alloy is being developed that is strengthened by additions of up to 10 percent aluminum and up to 35 percent manganese.

Another heat-resistant alloy under study is an iron-base ferritic alloy containing 8 percent aluminum for oxidation resistance and 6 percent molybdenum and a dispersion of refractory metal carbides for high-temperature strength.

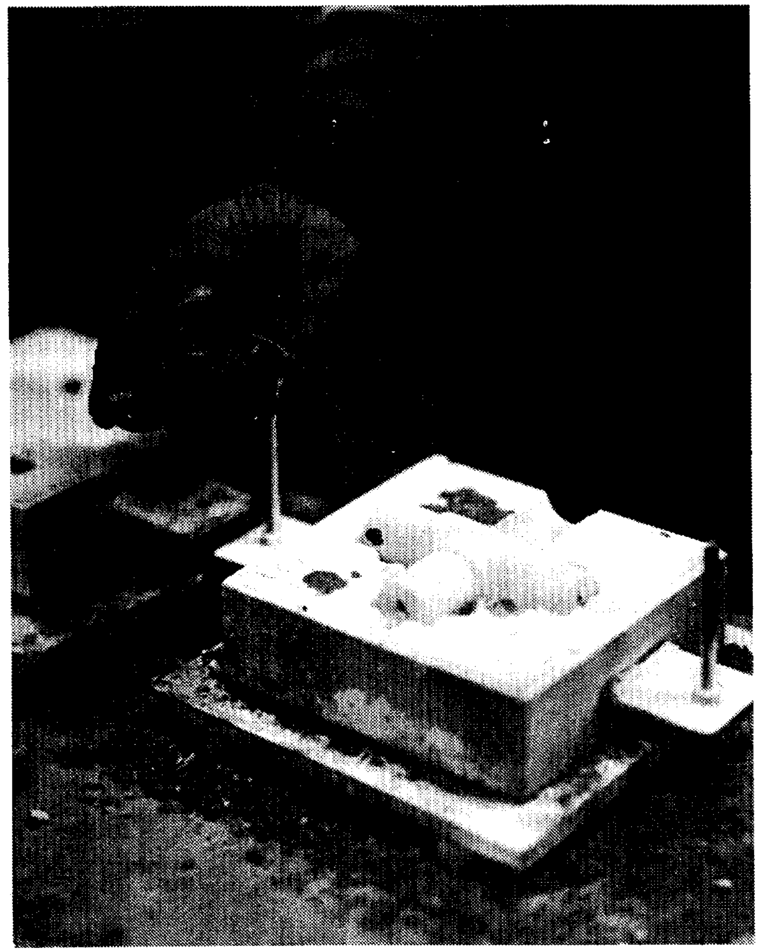
Hard Materials

Materials used for cutting and drilling contain cobalt as an alloy constituent or as a matrix to support dispersed hard carbides of tungsten, tantalum, or titanium. Because of cobalt's unique capability for cementing the dispersed hard particles and preventing their breakage in use, no adequate substitute is currently available. As these materials invariably wear out in service and are lost irretrievably, we have a continuing need for supplies of cobalt and other critical materials used in these tools. To lessen our dependence on these imported materials, new alloy systems and alternate methods for fabrication are being investigated.

Research is underway to decrease the requirements for cobalt by developing substitutes for the cobalt binders in cemented carbide cutting tools. Substitutes for the tungsten and tantalum carbides that are presently used in cutting tools also are under investigation. Titanium carbide is a possible substitute because it has higher hardness and lower thermal conductivity than carbides presently in use, as well as sufficiently high oxidation resistance. Casting methods are being investigated as alternatives to powder metallurgy in fabricating cermets containing substitutes for critical materials. Investment-type molds are being employed to make shapes that can be tailored to specialized mining applications, such as surface implanted hard particles cast to form tool shanks.

Casting Research

The Bureau of Mines has pioneered methods for melting and casting reactive metals such as titanium and zirconium. Research is now being oriented toward further refinements in casting technology to reduce operating costs and improve the integrity of castings. Casting into sand molds shows promise for yielding castings having much improved properties and with less labor than required for graphite molding methods now in use. By subjecting cast shapes to hot isostatic pressing, voids can be healed and mechanical properties improved further so that casting should approach the quality of forgings. Application of this new technology could reduce significantly the amount of expensive metal that is lost or must be recycled, thereby conserving critical metals such as titanium.



A titanium pipe tee produced by sand casting. Development of inexpensive titanium castings with improved properties could provide better corrosion resistant hardware.

The domestic foundry industry is becoming concerned with the quality of scrap being used to produce iron castings. Because alloy steel production is increasing steadily, it is reasonable to expect that alloying elements could find their way into cupola charges and seriously degrade the quality of castings.

The Bureau of Mines is cooperating with the American Foundrymen's Society in conducting a systematic sampling and characterization of cast irons being produced in domestic foundries. By sampling and analyzing a large assortment of cast irons over an extended period of time, any trends in the quality of these materials can be projected and measures can be planned to forestall anticipated problems.

Health and Safety Research

Prior to Fiscal Year 1979 the Albany Center was not regularly involved in research to improve the health and safety of miners and minerals industry workers. Upon reorganization of the Bureau of Mines into a multidisciplinary structure, opportunities arose to incorporate specialized expertise available at the Albany Center into this program area. During this fiscal year, 6 percent of the Center's funding addresses health and safety related problems.

Ignition Control

Methane seepage is a primary factor in coal mine explosions and fires. In most cases these explosions are caused when coal cutter bits strike rock surfaces and cause a hot spot that heats the methane to ignition. This problem is exacerbated as the cutter bits become worn and friction-induced hot spots develop.

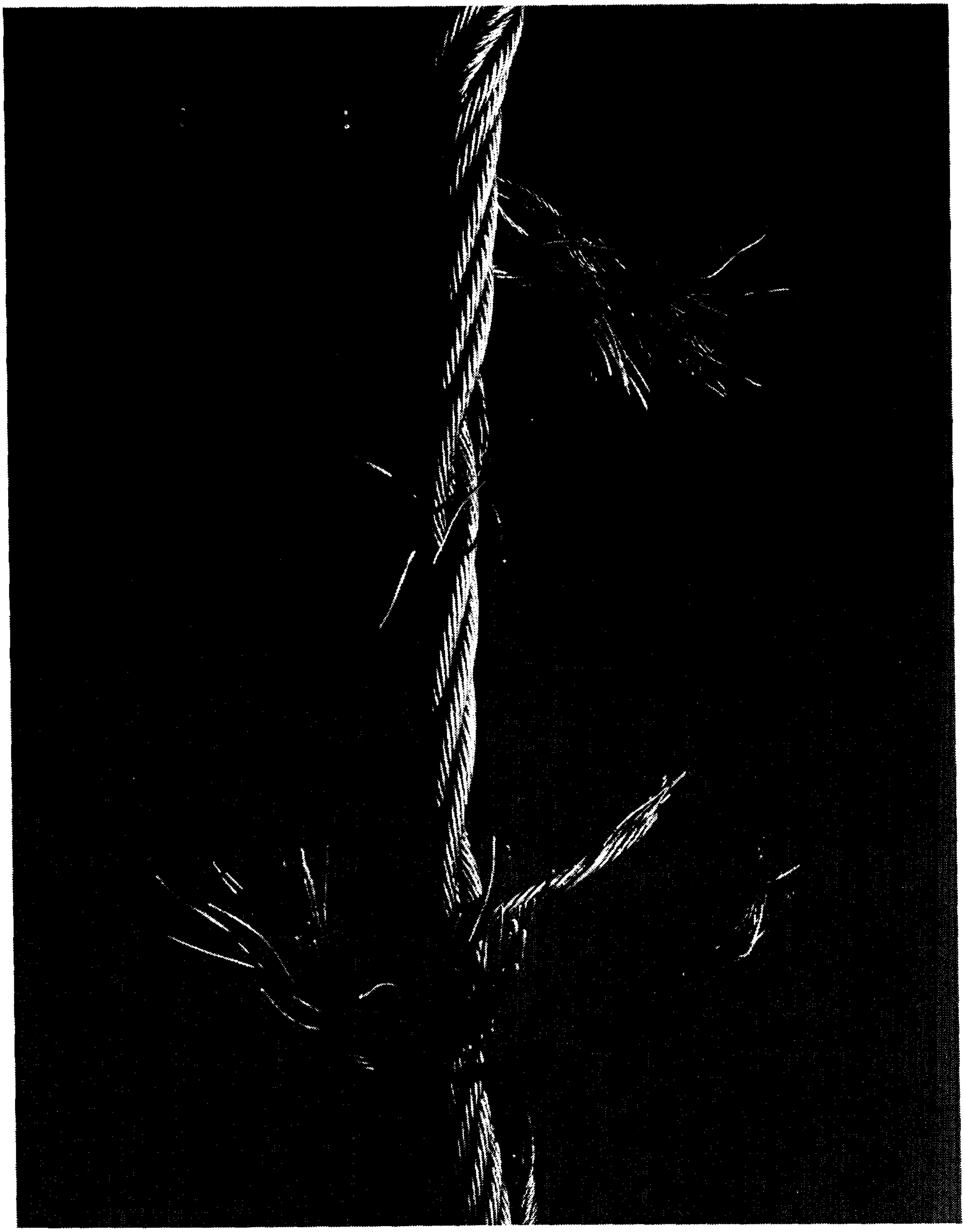
Research is in progress to study various compositions of cutter materials under different operating conditions and to relate these factors to the frequency with which an ignition occurs in an air-methane mixture when a cutter bit strikes a sandstone surface. Evidence shows that tool speed and bit composition play a major role in ignition probability. If the tool speed can be controlled and the bit composition modified, mine disasters from frictional ignition might be reduced.

Another source of ignition results when aluminum impacts rusty steel to yield a thermite-type reaction. The possibility for an explosion induced by this action may increase as aluminum is used in mining operations in greater amounts to take advantage of the reduced weight of aluminum for tools or roof supports.

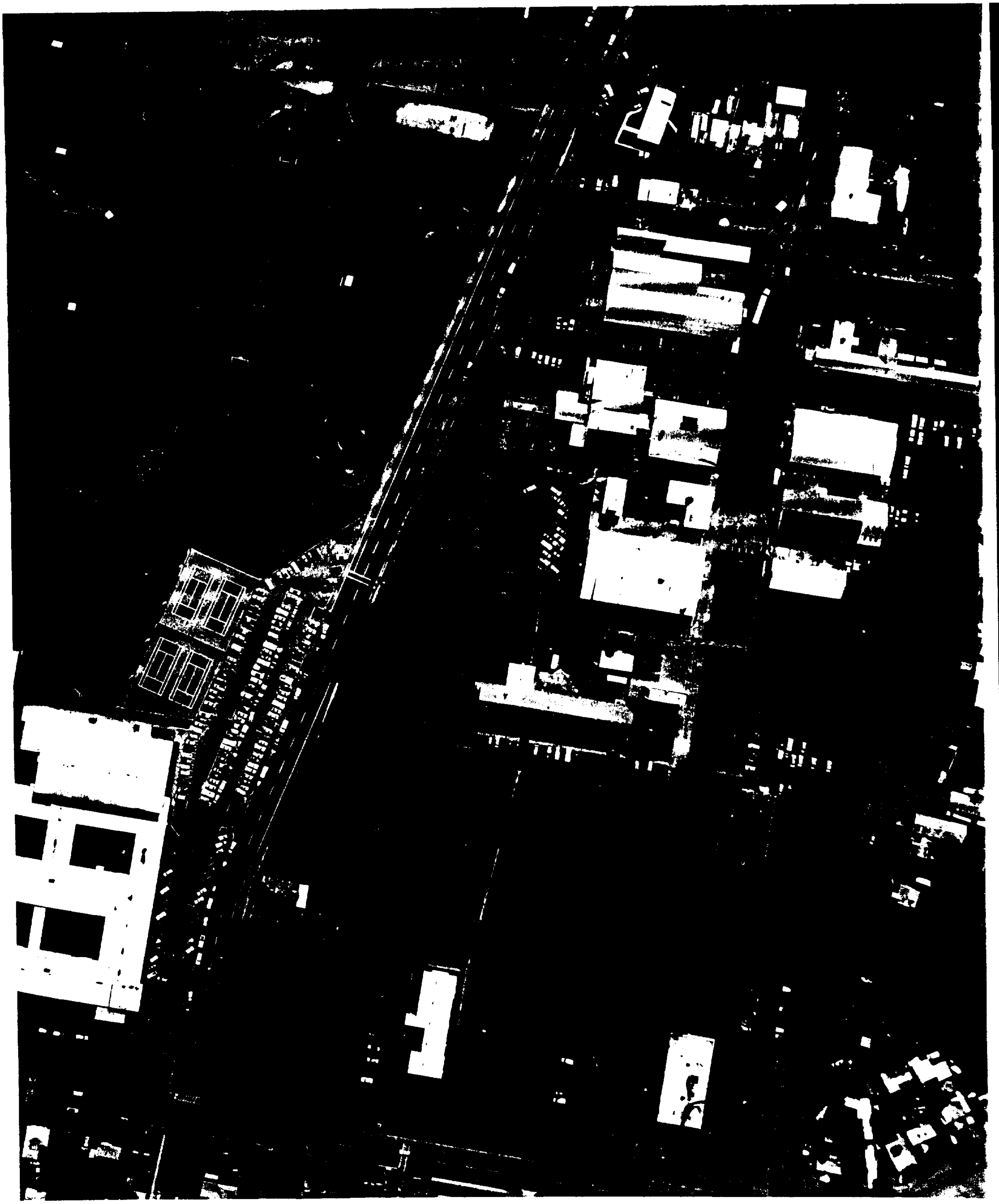
To gain a better understanding of this type of ignition, various aluminum alloys are being studied for susceptibility to ignition of air-methane mixtures when they impact rusted steel surfaces under controlled conditions. The goal of this research is to minimize or overcome the probability for ignition by selection or development of aluminum alloys that are less susceptible to frictional ignition. Another approach being evaluated is to coat or clad aluminum surfaces to overcome ignition susceptibility.

Wire Rope

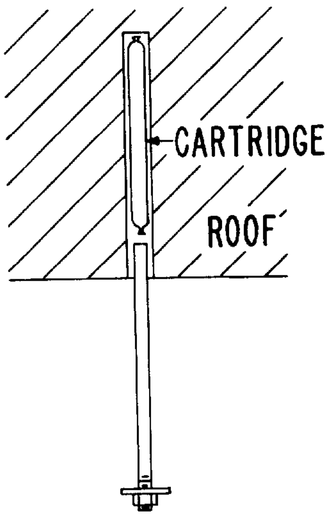
The wire rope used in vertical hoisting in mine shafts is a potential cause of mine disasters due to catastrophic rope failure. Satisfactory criteria are nonexistent for determining when a rope should be retired to insure against such a disaster without unduly sacrificing rope life. To set such criteria, the Albany Center is cooperating with other Bureau Centers in the evaluation of ropes from several sources. While other Centers research engineering aspects of rope usage, the Albany Center is concentrating on a detailed investigation of the metallurgical properties of both new and retired ropes. Individual strands of wire rope are being subjected to both chemical and physical analysis to relate these properties to failure.



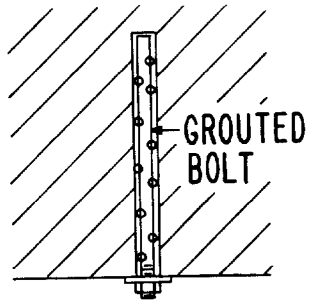
Wire rope is the underground miners direct link with the surface. The integrity of the rope must be maintained while maximizing the service life.



Roof Bolts



CARTRIDGE IS INSERTED IN HOLE. ROOF BOLT RUPTURES CARTRIDGE AND WATER CAPSULES



GROUT SETS IN 3 MINUTES TO PROVIDE EXCELLENT ROOF SUPPORT

Inorganic grouted roof bolts can be placed quickly and develop high strength rapidly providing improved ground control in mines.

The Bureau of Mines has pioneered the use of bonded roof bolts as a means to obtain higher roof holding capacity than the mechanical bolts now used in most mines. In the system now being studied a roof bolt is bonded in place with a fast-setting, inorganic grout. The grout is formed when the roof bolt is inserted into a hole and ruptures a plastic bag containing a mixture of plaster of paris and wax microcapsules containing water. By incorporating suitable accelerators into the mixture, gypsum is formed and rapidly bonds the roof bolt in place.

To prove the capability of this system and reduce the variability of properties, a systematic study is being made of all controlling variables. In addition to investigating the chemistry of the grouts, ultimate strength and creep properties will be determined. Simulated mine conditions, such as the effect of mine water seepage on grout strength, are being evaluated in this laboratory study.

Mercury

A unique mineral, corderoite, occurs in the McDermitt Mine in Nevada which is the major mercury producer in the United States. Because corderoite, unlike cinnabar, emits mercury vapor during the ambient processing procedure, a potential health hazard exists. To better understand the properties of corderoite so that mercury emissions might be controlled, a detailed characterization study is being performed. Both natural and synthetic corderoite are being subjected to petrographic, differential thermal, thermogravimetric, and other appropriate analytical methods. Decomposition products will be identified and the mechanism that results in the formation of free mercury will be ascertained.

Bibliography

Author and Title	Publication/Patent	Date
Anable, W. E., J. I. Paige, and D. L. Paulson. Copper Recovery From Primary Smelter Dusts.	BuMines RI 8554	1981
Barnard, P. G., W. M. Dressel, and M. M. Fine. Arc Furnace Recycling of Chromium-Nickel From Stainless Steel Wastes.	BuMines RI 8214	1977
Beall, R. A., R. B. Worthington, and R. Blickensderfer. Hot-Rolling Metals in Vacuum.	BuMines IC 8787	1979
Bennington, K. O., M. J. Ferrante, and J. M. Stuve. Thermodynamic Data on the Amphibole Asbestos Minerals Amosite and Crocidolite.	BuMines RI 8265	1978
Bennington, K. O., J. M. Stuve, and M. J. Ferrante. Thermodynamic Properties of Petalite ($Li_2Al_2Si_8O_{20}$).	BuMines RI 8451	1980
Beyer, R. P. An Algorithm for Determining Debeye Temperatures.	BuMines RI 8566	1981
Beyer, R. P., and G. E. Daut. Low-Temperature Heat Capacities of Potassium Disilicate.	J. Chem. and Eng. Data, v. 24, No. 3	July 1979
Beyer, R. P., M. J. Ferrante, and R. R. Brown. Thermodynamic Properties of $KAlO_2$.	J. of Chem. Therm., v. 12, No. 11	November 1980
Beyer, R. P., M. J. Ferrante, R. R. Brown, and G. E. Daut. Thermodynamic Properties of Potassium Metasilicate and Disilicate.	BuMines RI 8410	1980
Beyer, R. P., and H. C. Ko. Low-Temperature Heat Capacities and Enthalpy of Formation of Copper Difluoride (CuF_2).	BuMines RI 8329	1978
Blickensderfer, R. Cladding Metals by Continuous Strip Rolling in Vacuum.	BuMines RI 8495	1981
Blickensderfer, R. Bonding of Titanium and Molybdenum to Iron by Vacuum Rolling	Intern. Journ. Thin Solid Films	1978
Blickensderfer, R. Cladding of Metals to Iron by Vacuum Rolling	BuMines RI 8481	1981

Author and Title	Publication/Patent	Date
Blickensderfer, R. Sputtering Apparatus for Coating Elongated Tubes and Strips.	U.S. Pat. No. 4,290,877	Sept. 22,
Blickensderfer, R., D. K. Deardorff, and R. L. Lincoln. Normal Total Emittance at 400-850 K and Normal Spectral Reflectance at Room Temperature of Be, Hf, Nb, Ta, V, and Zr.	J. Less Common Metals, v. 51, No. 1	January 1977
Blickensderfer, R., D. K. Deardorff, and R. L. Lincoln. Spectral Reflectance of TiN_x and ZrN_x Films as Selective Solar Absorbers.	Solar Energy, v. 19, No. 4	1977
Brown, L. L., A. R. Rule, and C. B. Daellenbach. Characterization and Beneficiation of Phosphate-Bearing Rocks From Northern Michigan.	BuMines RI 8562	1981
Brown, R. R., G. E. Daut, N. A. Gokcen, and R. V. Mrazek. Solubility and Activity of Aluminum Chloride in Aqueous Solutions.	BuMines RI 8379	1979
Calvert, E. D. An Investment Mold for Titanium Casting.	BuMines RI 8541	1981
Chandra, D., R. E. Siemens, ~~and~~ C. Ruud. Electron-Optical Characterization of Laterites Treated with the Reduction Roast-Ammoniacal Leach System.	Pres. at AIME Meeting, Denver, Co. AIME Pub. TMSA 78-23	1978 1978
Chandra, D., Siemens, R. E., C. Ruud, and C. Barrett. Characterization of Laterites by X-ray Techniques.	Pres. 27th Ann. Con. on Application of X-ray Analysis, Denver, Co. Conf. Proc.	August 1978 1979
Clites, P. G. Cold Crucible.	U.S. Pat. 4,058,668	Nov. 15, 1977
Daellenbach, C. B., and W. Mahan. Method for Rapid Particle Size Analysis by Hydrosizing and Nuclear Sensing.	U.S. Pat. 4,010,369	Mar. 1, 1977
Dahlin, D. C., A. R. Rule, and L. L. Brown. Beneficiation of Potential Platinum Resources from Southeastern Alaska.	BuMines RI 8553	1981
Deardorff, D. K. Elimination of Reflection Errors in Emissometers by Using Alternate Apertures.	Rev. Sci. Instr., v. 47, No. 10	October 1976

Author and Title	Publication/Patent	Date
Deardorff, D. K., R. Lincoln, and R. Blickensderfer. Spectrally Selective Solar Absorbers.	U.S. Pat. 4,098,956	July 4, 1978
Dunning, J. S. Iron-Based Alloys Strengthened by Ternary Laves Phases.	BuMines RI 8411	1980
Dunning, J. S., M. L. Glenn, and W. L. O'Brien. Iron-Based Alloys Strengthened by Laves Phases as Substitutes for Stainless Steels.	BuMines RI 8470	1980
Dunning, J. S., M. L. Glenn, and W. L. O'Brien. Structure-Property Relationship in Laves Phase Strengthened Iron Alloys.	Annual Meeting, AIME, New Orleans, La.	Feb. 18-20, 1978
Elger, G. W., R. A. Holmes, and P. E. Sanker Process for Purifying a Titanium-Bearing Material and Upgrading Ilmenite to Synthetic Rutile with Sulfur Trioxide.	U.S. Pat. 4,120,694	Oct. 17, 1978
Elger, G. W., and D. E. Kirby. Synthesis of Rutile from Titaniferous Slags.	U.S. Pat. 3,996,332	Dec. 7, 1976
Elger, G. W., W. L. Hunter, and J. E. Mauser. Preparation and Chlorination of Titanium Carbide From Domestic Titaniferous Ores.	BuMines RI 8497	1980
Farrell, R. F., A. J. Mackie, and W. R. Lessick. Analysis of Steelmaking Slags by Atomic Absorption Spectrophotometry Using Pressure Dissolution.	BuMines RI 8336	1979
Farrell, R. F., S. A. Matthes, and A. J. Mackie. A Simple, Low-Cost Method for the Dissolution of Metal and Mineral Samples in Plastic Pressure Vessels.	BuMines RI 8480	1980
Farrell, R. F., W. J. Neibuhr, D. L. Paulson, W. Anable, and W. L. Hunter. Smelting Cement Copper in an Electric-Arc Furnace With an Appendix on Analytical Techniques.	BuMines RI 8284	1978
Ferrante, M. J., R. R. Brown, and G. E. Daut. Thermodynamic Properties of Potassium Metasilicate and Disilicate.	BuMines RI 8410	1980

Author and Title	Publication/Patent	Date
Kelley, J. E., and [illegible] Blickensderfer. Slower Speed, New Pick Metals May Reduce Ignition Hazards.	Coal Age, v. 82, No. 11	November 1977
Kelley, J. E., and [illegible] L. Forkner. Ignitions in Mixtures of Coal Dust, Air, and Methane From Abrasive Impacts of Hard Minerals with Pneumatic Pipeline Steel.	BuMines RI 8201	1977
Kelley, J. E., and [illegible] W. Leavenworth. Wear-Resistant Materials for Coal Conversion Components.	Proceedings of Fourth Annual Conf. on Materials for Coal Conversion and Utilization, Conf. 791014.	Oct. 9-11, 1979
Ko, H. C., and [illegible] Daut. Enthalpies of Formation of [illegible] and [illegible]-Magnesium Sulfate and Magnesium Sulfate Monohydrate.	BuMines RI 8409	1980
Ko, H. C., J. M. [illegible], and R. R. Brown. Low-Temperature Heat Capacities and Enthalpy of Formation of Aluminum Sulfide (Al_2S_3).	BuMines RI 8203	1977
Koch, R. K., and [illegible] M. Burrus. Bentonite-Bonded Rammed Olivine and Zircon Molds for Titanium Casting.	BuMines RI 8587	1981
Koch, R. K., and [illegible] M. Burrus. Shape Casting Titanium in Olivine, Garnet, Chromite, and Zircon Rammed and Shell Molds.	BuMines RI 8443	1980
Koch, R. K., [illegible] Hoffman, M. L. Transue, and R. A. [illegible]. Casting Titanium and [illegible] in [illegible] Sand Molds.	BuMines RI 8208	1977
Landsberg, A. Some Factors Affecting the Chlorination of Kaolinic Clay.	Met. Trans., v. 8B	September 1977
Landsberg, A., [illegible] Adams, and S. D. Hill. Vapor-Pressure Measurements by Effusion Methods.	BuMines RI 8207	1977
Landsberg, A., [illegible] Hauser, and J. L. [illegible]. Behavior of Arsenic in a Static Bed During Roasting of Copper Smelter Feed.	BuMines RI 8493	1980
[illegible], S. K., R. F. Farrell, and A. J. [illegible]. Determination of Arsenic in Smelter Copper and Flue Dust by Atomic Absorption Spectroscopy.	At. Absorpt. Newsl., v. 18, No. 2	March-April 1979

Author and Title	Publication/Patent	Date
Lincoln, R. L., and R. Blickensderfer. Adaption of Conventional Sputtering Equipment for Coating Long Tubes and Stripes.	J. Vac. Sci. Technol., v. 17, No. 5	September-October 1980
Madsen, B. W., and M. E. Wadsworth. A Mixed Kinetics Dump Leaching Model for Ores Containing a Variety of Copper Sulfide Minerals.	BuMines RI 8547	1980
Matthes, S. A. Rapid, Low-Cost Analysis of a Copper Slag for 13 Elements by Flame Atomic Absorption Spectoscopy.	BuMines RI 8484	1980
Moser, K. W., R. E. Siemens, and S. C. Rhoads. Recovery of Valuable Organic and Aqueous Phases from Metallurgical Solvent Extraction Emulsions.	U.S. Pat. 4,231,866	Feb. 2, 1981
Nafziger, R. H. Electric Furnace Smelting and Refining of Prereduced Titaniferous Materials.	Inst. Min. Met. Trans. Sect. C, v. 87	June 1978
Nafziger, R. H. Fluxes Used in Electroslag Melting and Welding.	Pres. at Spring Meeting, Electrochemical Soc., Seattle, Wash.	May 21-26, 1978
Nafziger, R. H., and C. E. Armantrout. Steelmaking by Electroslag Process Using Prereduced Iron Ore Pellets.	U.S. Pat. 3,997,332	Dec. 14, 1976
Nafziger, R. H., and H. E. Blake, Jr. Synthetic Fluorspar for Conditioning Electric Furnace Slags.	U.S. Pat. 4,053,302	Oct. 11, 1977
Nafziger, R. H., G. L. Hundley, and R. R. Jordan. Two-Stage Electric Arc-Electroslag Process and Apparatus for Continuous Steelmaking.	U.S. Pat. 4,133,967	Jan. 9, 1979
Nafziger, R. H., G. L. Hundley, and R. R. Jordan. A Two-Stage Electric Arc-Electroslag Process for Continuous Steelmaking.	Can. Min. and Met. Bull., v. 70, No. 785	September 1977
Nafziger, R. H., and R. R. Jordan. Ilmenite Reduction by a Carbon Injection Technique.	Pres. at 37th Electric Furnace Conf., Detroit, Mich.	Dec. 4-7, 1979
	Proc. 37th Electric Furnace Conf., v. 37	1980

Author and Title	Publication/Patent	Date
Nafziger, R. H., and R. R. Jordan. Prereduction and Melting of Titaniferous Materials.	Pres. at 100th AIME Annual Meeting, Chicago, Ill.	Feb. 22-26, 1981
Nafziger, R. H., and R. R. Jordan. Steelmaking From Prereduced Pellets by the Electroslag Process.	Ironmaking and Steelmaking, v. 14, No. 1	January 1977
Nafziger, R. H., R. R. Jordan, and W. L. Hunter. Electric-Arc Furnace Processing of Domestic Titaniferous Materials.	BuMines RI 8511	1981
Nafziger, R. H., and P. E. Sanker. Low-Sulfur Pressure Vessel Steels by the Electroslag and Electric-Arc-Furnace Processes.	BuMines RI 8385	1979
Nafziger, R. H., P. E. Sanker, J. E. Tress, and R. A. McCune. Prereduction and Melting of Domestic Chromites.	Pres. at 38th Electric Furnace Conf., Pittsburgh, Pa. Proc. 38th Electric Furnace Conf., v. 38	Dec. 9-12, 1980 1981
Nafziger, R. H., J. E. Tress, and J. I. Paige. Carbothermic Reduction of Domestic Chromites.	Pres. at AIME Nat. Meeting, Atlanta, Ga. Met. Trans. B, v. 10B	Mar. 7, 1977 March 1979
Nash, B. D., and H. E. Blake, Jr. Fluorine Recovery from Phosphate Rock Concentrates.	BuMines RI 8205	1977
Neumann, J. P. On the Occurrence of Substitution and Triple Defects in the Intermetallic Phases with the 2 Structure.	Acta Metallurgica, v. 28	1980
Nilsen, D. N., R. E. Siemens, and S. C. Rhoads. Solvent Extraction of Cobalt from Laterite-Ammoniacal Leach Liquors.	BuMines RI 8419	1980
Oden, L. L., and J. H. Russell. Methanation Activity of Raney Nickel Catalysts.	BuMines RI 8272	1978
Oden, L. L., and J. H. Russell. Self-Decrepitating Raney Nickel Alloys.	U.S. Pat. 4,175,954	Nov. 27, 1979
Oden, L. L., P. E. Sanker, and J. H. Russell. Method for Producing Supporting Raney-Nickel Catalysts.	U.S. Pat. 4,049,580	Sept. 20, 1977
O'Hare, S. A. Raney Nickel Catalytic Device.	U.S. Pat. 4,110,257	Aug. 29, 1978

Author and Title	Publication/Patent	Date
O'Hare, S. A., and J. E. Mauser. Melting and Casting of Raney Nickel Alloy.	BuMines RI 8210	1977
Olsen, R. S. Feed Preparation and Leaching of Aluminum From Kaolinitic Clay with Hydrochloric Acid.	Light Metals Book	1981
Paulson, D. L., and W. E. Anable. Smelting Prereduced Nickel Concentrate in an Electric-Arc Furnace.	BuMines RI 8196	1977
Paulson, D. L., W. E. Anable, and W. L. Hunter. Smelting Cement Copper in an Electric-Arc Furnace.	BuMines RI 8284	1978
Paulson, D. L., and W. L. Hunter. Process for Reducing Molten Furnace Slags by Carbon Injection.	U.S. Pat. 4,110,107	Aug. 29, 1978
Paulson, D. L., and W. L. Hunter. Recovering Iron From Copper Smelting Furnace Slags by Carbon Injection.	BuMines RI 8211	1977
Paulson, D. L., and R. B. Worthington. Method of Agglomerating Fine Powders.	U.S. Pat. 4,157,371	June 5, 1979
Perry, J. A., R. F. Farrell, and A. J. Mackie. Modification of a Commercial Atomic Absorption Spectrophotometer for Cold-Vapor Determination of Mercury.	BuMines RI 8573	1981
Poppleton, H. O., and D. L. Sawyer. Hydrochloric Acid Leaching of Calcined Kaolin to Produce Alumina.	Proc. 106th Ann. Meet., AIME, Atlanta, Ga. (pub. as Light Metals ed. by K. B. Higbie), v. 2	Mar. 1-10, 1977 1977
Rhoads, S. C., D. N. Nilsen, and R. E. Siemens. Solvent Extraction of Nickel, Cobalt, and Copper From Laterite-Ammoniacal Leach Liquors.	Proc. Intern. Solvent Extrac. Conf., CIM Sp. v. 21, The Can. Inst of Min. and Met.	1979
Rule, A. R., D. E. Kirby, and D. C. Dahlin. Recent Advances in Beneficiation of Western Phosphates.	Min. Eng., v. 30, No. 1	January 1978
Russell, J. H., L. L. Oden, and J. L. Henry. Effects of Additives on Methanation Activity of Raney Nickel Catalysts.	BuMines RI 8487	1980

Author and Title	Publication/Patent	Date
Russell, R. L., and R. Blickensderfer. Adapting Conventional Sputtering Equipment for Coating Long Tubes and Strips.	Journ. of Vacuum Sci. and Tech.	October 1980
Sanker, P. E., E. A. Johnson, L. L. Oden, and J. B. See. Copper Losses and the Distribution of Impurity Elements Between Matte and Silica-Saturated Iron Silicate Slags at 1,250° C.	Pres. at 100th AIME Annual Meeting Chicago, Ill.	Feb. 22-26, 1981
Sanker, P. E., R. H. Nafziger, and G. H. Reynolds. Preparation of Specialty Ferrochromium (9 Wt.% C) From a Domestic Chromite.	J. Metals, v. 32, No. 3	March 1980
Sanker, P. E., L. L. Oden, and J. H. Russell. Production of Supported Raney Nickel Catalysts by Reactive Diffusion.	U.S. Pat. 4,043,946	Aug. 23, 1977
Schaefer, S. C. Electrical Determination of Gibbs Energies of Formation of MnS and $Fe_{0.9}S$.	BuMines RI 8486	1980
Schaefer, S. C., and N. A. Gokcen. Thermodynamic Properties of Liquid Al-Ni and Al-Si Systems.	High Temp. Sci., v. 11, No. 1	March 1979
Schaefer, S. C., and N. A. Gokcen. Electro-Chemical Determination of Thermodynamic Properties of Molybdenite (MoS_2).	High Temp. Sci., v. 12,	1980
Siemens, R. E., and J. D. Corrick. Process for Recovery of Nickel from Domestic Laterites.	Min. Cong. J., v. 63, No. 1	January 1977
Siemens, R. E., and J. D. Corrick. Reduction of Laterite Ores.	U.S. Pat. 3,985,556	Oct. 12, 1976
Siemens, R. E., D. N. Nilsen, and S. C. Rhoads. Process for Recovering Ni (II), Cu (II), and Co (II) from an Ammoniacal-Ammonium Sulfate Leach Liquor.	U.S. Pat. 4,258,016	Mar. 24, 1981
Siemens, R. E., and S. C. Rhoads. Recovery of Organic and Aqueous Phases from Solvent Extraction Emulsions.	U.S. Pat. 4,231,866	Nov. 4, 1980

Author and Title	Publication/Patent	Date
Spironello, V. R., and R. H. Nafziger. An Evaluation of Used Aluminum Smelter Pot-lining as a Substitute for Fluorspar in Cupola Ironmelting.	BuMines RI 8530	1981
Stuve, J. M., G. E. Daut, and L. B. Pankratz. Low-Temperature Heat Capacities and High-Temperature Enthalpies of Cupreous and Cupric Sulfide.	BuMines RI 8305	1978
Stuve, J. M., and M. J. Ferrante. Low-Temperature Heat Capacities and High-Temperature Enthalpies of Chiolite ($Na_5Al_3F_{14}$).	BuMines RI 8442	1980
Stuve, J. M., and M. J. Ferrante. Thermodynamic Properties of Rhenium Oxides, 8 to 1,400 K.	BuMines RI 8199	1977
Stuve, J. M., M. J. Ferrante, D. W. Richardson, and R. R. Brown. Thermodynamic Properties of Ferric Oxychloride and Low-Temperature Heat Capacity of Ferric Trichloride.	BuMines RI 8420	1980
Stuve, J. M., H. C. Ko, and M. J. Ferrante. The Thermodynamic Properties of $NiBr_2$ and $NiSO_4$, 10 to 1,200 K.	BuMines RI 8271	1978
White, J. C., T. N. Goff, and P. C. Good. Continuous-Circuit Preparation of Phosphoric Acid From Florida Phosphate Matrix.	BuMines RI 8326	1978
White, J. C., and J. L. Henry. Removal of Organic Contamination From the Solvent Extraction Raffinate Stream of the Clay/HCl Process Miniplant by Use of a Skimming Tank-Coalescer-Carbon Adsorption Column System.	Topical Report USBM 1635	1977
Wood, F. W. Abstract: Vacuum Metallurgy and Critical Resources.	J. Vac. Sci. Technol., v. 14, No. 1	January/ February 1977
Wood, F. W., and R. Blickensderfer. Stabilization of Absorber Stacks Containing Zr or Ti Compounds on Ag.	J. Thin Solid Films, v. 39, No. 1	December 1976
Wood, F. W., and O. G. Paasche. Dubious Details of Nitrogen Diffusion in Nitrided Titanium.	J. Thin Solid Films, v. 40, No. 1	January 1977