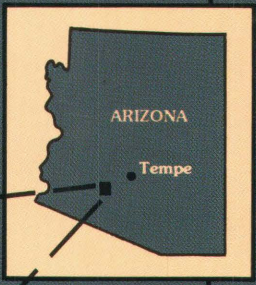
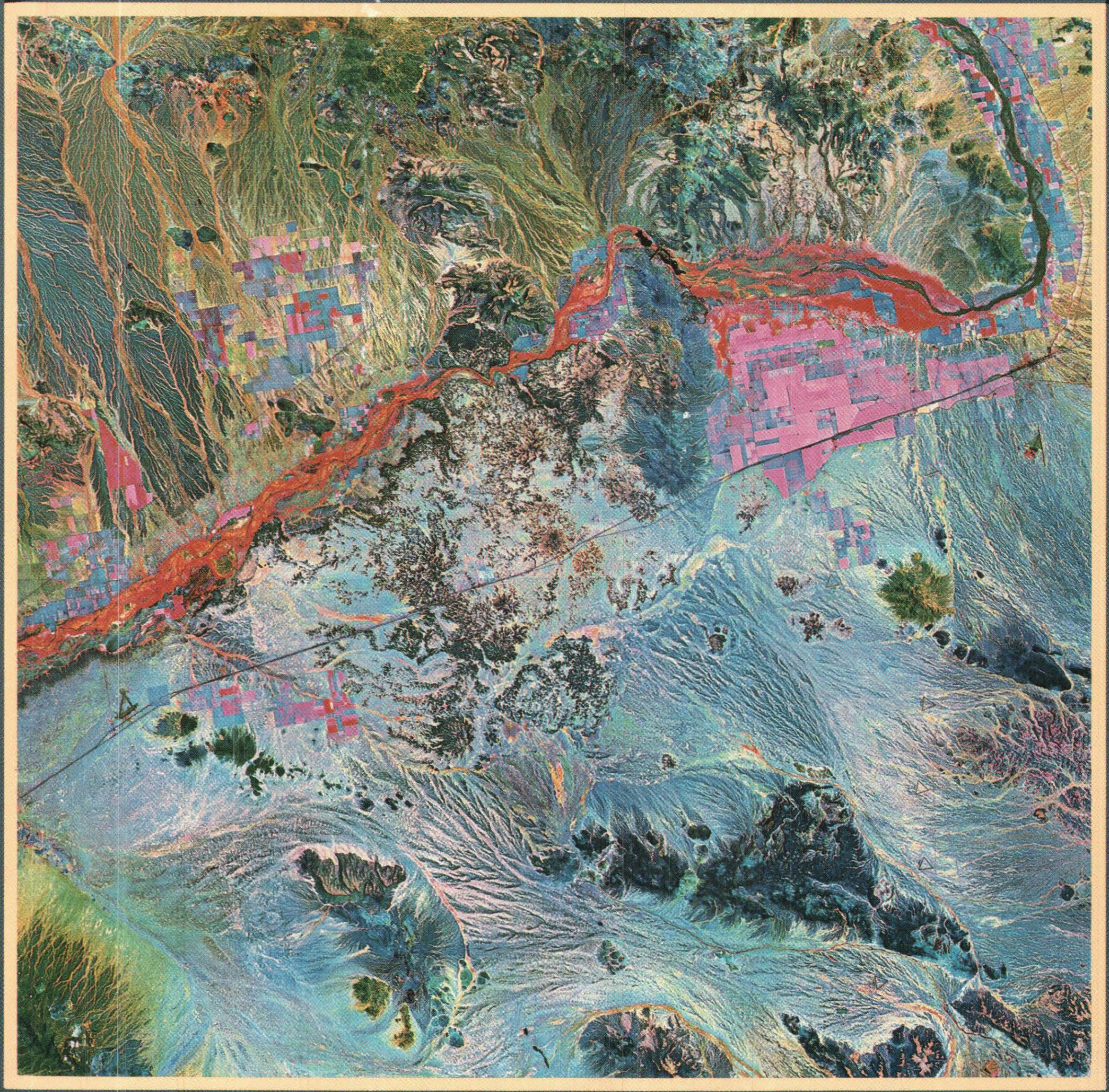
Arizona's Industrial Rock and Mineral Resources—Workshop Proceedings

Prepared in cooperation with the Arizona Geological Survey





U.S. GEOLOGICAL SURVEY BULLETIN 1905

WORKSHOP PARTICIPANTS

Glenn H. Allcott, Chief
Office of Mineral Resources
U.S. Geological Survey
Reston, Va.

Kenneth G. Arne, Consultant
Western Gold Exploration and Mining Co.
Golden, Colo.

William C. Bagby, Geologist
Deputy Chief, Office of Mineral Resources
U.S. Geological Survey
Reston, Va.

Aldo Barsotti, Chief
Branch of Minerals Availability
U.S. Bureau of Mines
Washington, D.C.

Larry Bauer, Deputy State Director, Minerals
U.S. Bureau of Land Management
Phoenix, Ariz.

James D. Bliss, Geologist
Branch of Resource Analysis
U.S. Geological Survey
Tucson, Ariz.

Kenneth G. Broadhead, Resource Supervisor
U.S. Bureau of Mines
Reno, Nev.

James K. Crowley, Geophysicist
U.S. Geological Survey
Reston, Va.

James Crowther, Mining Engineer
U.S. Bureau of Indian Affairs
Phoenix, Ariz.

Debra Daniel, Hydrologist
Hydrology Section
Arizona Department of Environmental Quality
Phoenix, Ariz.

Walter E. Dean, Chief
Branch of Sedimentary Processes
U.S. Geological Survey
Denver, Colo.

John C. Dohrenwend, Geologist
Branch of Western Mineral Resources
U.S. Geological Survey
Menlo Park, Calif.

Daniel F. Eyde, Consultant
GSA Resources, Inc.
Cortaro, Ariz.

Ted H. Eyde, Consultant
GSA Resources, Inc.
Cortaro, Ariz.

Larry D. Fellows, Director and State Geologist
Arizona Geological Survey
Tucson, Ariz.

Michael P. Foose, Geologist
Deputy Chief, Office of Mineral Resources
U.S. Geological Survey
Reston, Va.

John Gutierrez, Mining Engineer
U.S. Forest Service
Phoenix, Ariz.

J. Dale Nations, Professor of Geology
University of Northern Arizona
Flagstaff, Ariz.

Nyal Niemuth, Mining Engineer
Arizona Department of Mines and Mineral Resources
Phoenix, Ariz.

Greta J. Orris, Geologist
Branch of Resource Analysis
U.S. Geological Survey
Tucson, Ariz.

Phillip A. Pearthree, Research Geologist
Arizona Geological Survey
Tucson, Ariz.

H. Wesley Peirce, Principal Geologist Emeritus
Arizona Geological Survey
Tucson, Ariz.

James R. Perry, Urban and Regional Planner
The Planning Consultants
Phoenix, Ariz.

Ken A. Phillips, Chief Engineer
Arizona Department of Mines and Mineral Resources
Phoenix, Ariz.

Stephen J. Reynold, Research Geologist
Arizona Geological Survey
Tucson, Ariz.

Michael J. Rice, Geologist
Nonrenewable Resources and Minerals Section
Arizona State Land Department
Phoenix, Ariz.

Michael F. Sheridan, Professor of Geology
Arizona State University
Tempe, Ariz.

Gary D. Slusher, Natural Resources Manager
Arizona State Land Department
Nonrenewable Resources and Minerals Section
Phoenix, Ariz.

Paul K. Theobald, Jr., Geologist
Branch of Exploration Geochemistry
U.S. Geological Survey
Denver, Colo.

Senator Doug Todd
Arizona Senate
Phoenix, Ariz.

Edwin W. Tooker, Geologist
Workshop Coordinator
Branch of Western Mineral Resources
U.S. Geological Survey
Menlo Park, CA

Barry N. Watson, Regional Exploration Manager
U.S. Borax
Tucson, AZ

COVER

An enhanced Landsat Thematic Mapper Satellite image of the Gila Bend, Arizona, area on June 2, 1984. The image enhancement, sponsored by the National Aeronautics and Space Administration, was processed at the Jet Propulsion Laboratory, California Institute of Technology, using the direct band ratioing technique of Crippen, Blom, and Heyada (1988). Rocks in blue are relatively high in ferric iron, those in green are generally high in ferrous iron. Red denotes high clays and (or) carbonate in rocks. Vegetation is also red. The image is about 90 × 90 km.

Arizona's Industrial Rock and Mineral Resources—Workshop Proceedings

E.W. TOOKER, Compiler-Editor

Prepared in cooperation with the Arizona Geological Survey

Presentations and discussions at a workshop
held May 17–18, 1988, in Tempe, Ariz.,
on problems encountered in, and recommendations
for improving, current and potential industrial
rock and mineral resource availability in Arizona

U.S. GEOLOGICAL SURVEY BULLETIN 1905

DEPARTMENT OF THE INTERIOR

MANUEL LUJAN, Jr., Secretary

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CONTENTS

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ABBREVIATIONS AND ACRONYMS

ACEC	area of critical environmental concern
ADEQ	Arizona Department of Environmental Quality
ASLD	Arizona State Land Department
ADMMR	Arizona Department of Mines and Mineral Resources
ADT	Arizona Department of Transportation
ADWR	Arizona Department of Water Resources
AEG	Association of Engineering Geologists
AGIS	Arizona Geographic Information System
AICP	American Institute of Certified Planners
AMT	audiomagnetotelluric
ASTM	American Society for Testing and Materials
ASU	Arizona State University
AZ MILS	Arizona Mineral Industry Information Location System (ADMMR)
AZGS	Arizona Geological Survey
BIA	U.S. Bureau of Indian Affairs (Department of the Interior)
BLM	U.S. Bureau of Land Management (Department of the Interior)
CAD	computer-aided design
CD ROM	compact-disc read-only memory
CUSMAP	Conterminous United States Mineral Assessment Program (USGS)
DOT	U.S. Department of Transportation
EDAX	energy-dispersive analysis, X-ray
EIS	environmental-impact statement
EM	electromagnetic
EPA	U.S. Environmental Protection Agency
FEMA	Federal Emergency Management Agency
FIA	Federal Insurance Administration
FOB	free on board
GIS	Geographic Information System
MILS	Mineral Industry Information Location Systems (USBM)
MIO	Minerals Information Office
MRDS	Mineral Resource Data System (USGS)
NSF	U.S. National Science Foundation
OSHA	Occupational Safety and Health Administration
PC	personal computer
RMP	resource-management plan
SEM	scanning electron microscope
TM	thematic mapping (Landsat)
T/R/S	township, range, section
UNA	University of Northern Arizona
USBM	U.S. Bureau of Mines
USDA	U.S. Department of Agriculture
USFS	U.S. Forest Service
USGS	U.S. Geological Survey
VLF	very low frequency (EM)
WSA	wilderness study area (BLM)
XRD	X-ray diffraction

Introduction

By E.W. Tooker

Industrial rocks and minerals are an often-overlooked, but nevertheless economically important, part of the resource base in Arizona. This volume presents information and recommendations from a May 17–18, 1988, workshop for improving public and private understanding of this resource base; the workshop was held in Tempe, Ariz., jointly sponsored by the USGS and AZGS. This workshop was partly an outgrowth of recommendations made during a 1987 Tucson, Ariz., workshop on unconventional metallic-mineral resources (Theobald and others, 1987).

Several recent publications highlight industrial-mineral issues, including those by the Northwest Mining Association (1986), Coope (1987), and Peirce (1987b). The consensus is that industrial rock and mineral resources historically have had a low commodity profile and that their economic and utilitarian importance has not been fully recognized. In Arizona, these resources are of vital interest because access to present resources and the development of new resources are hampered by restrictions on for land use, owing to Government land withdrawals, pollution controls, and urban zoning.

A precise, all-inclusive definition for industrial rocks and minerals is difficult because of the many unrelated types, sometimes involving materials with specialized properties or performance characteristics, and their broad and diverse range of uses (fig. 1); thus, the grouping of these resources must be marked by flexibility in contrast with sharply defined metallic-mineral resources. The World Bank (Noestaller, 1987) defines them as all nonmetallic, nonfuel minerals extracted and processed for industry end uses, some metallic-mineral materials consumed in nonmetallurgic applications, and consolidated and unconsolidated rock materials (for example, sand, gravel, crushed rock, and dimension stone) and manufactured products (for example, cement and refractories). The Mining Journal (1988) classifies these materials into three economic groups: (1) low-price, large-volume commodities, such as sand, gravel, and construction materials; (2) medium- to high-price, large-volume commodities, such as chemical and fertilizer minerals (for example, salt, sulfur, and potash); and (3) high-price, small-volume commodities, such as feldspar, fluorspar, talc, and barite. The low-price, large-volume materials are mainly used in areas close to their source, and generally achieve maximum use during the population growth and economic development of an area. The high-value-added, small-volume materials are used in the more industrialized nations and often are traded internationally. A measure of industrial maturity, according to the Mining Journal (1988), is achieved when the value of nonmetallic-mineral resources materials exceeds that of metallic-mineral resources. (For example, this point was reached in the United States early in the 20th century, but has just been reached in Australia.)

Industrial rock and mineral materials represented 72 percent of the world's nonfuel-resource production in 1987 and 40 percent of its value (Mining Journal, 1988). The nonfuel-mineral production of the United States in 1987 totaled $25.5 billion, of which $18.0 billion was from the industrial minerals, in contrast to $7.5 billion for metals, on the basis of U.S. Bureau of Mines data reported in the Skillings Mining Review (1988). The value of nonfuel mineral resources in Arizona in 1987 was $1.8 billion, or 7 percent of the national production of these materials. However, metals output in Arizona accounted for 84 percent ($1.5 billion) of this total value; copper accounted for more than 75 percent, and gold production increased sharply over previous years (Skillings Mining Review, 1988). In a region of rapidly expanding population such as Arizona, the production of industrial rocks and minerals can be expected to increase in the direction observed elsewhere in the Nation. Anticipating this need, the Tempe workshop was convened to consider (1) what these resources include and the status of their availability, (2) the problems impeding expansion of the resource base in Arizona and adjoining States, and (3) what role State and Federal efforts should play in the research on these resources.

This workshop provided a summary of industrial rocks and minerals currently being produced in Arizona and the potential for expanding the industrial-mineral

PRODUCTS \ USES	ADHESIVES	BITUMEN & ROOFING	BRAKE & FRICTION	CARPET BACKING	CATTLE FOOD	CERAMICS, COARSE	CERAMICS, FINE	CERAMICS, HOBBY	CHEMICALS & FERTILIZERS	CONSTRUCTION	COSMETIC & PHARM.	DENTAL PRODUCTS	DRILLING MEDIA	FERRITES	FILTER MEDIA	FOOD	FOUNDRY & MOULDING	GLASS, GLAZES & ENAMELS	INSECTICIDES, HERBI/FUNGI	PAINT, COATINGS, VARNISH, POLYM.	PAPER	PLASTICS & RUBBER	MINERALS PROCESSING	REFRACTORIES	SCOURING & POLISHING MEDIA	SURFACE TREATMENT	WELDING ELECTRODES
ASBESTOS	●	●	●			●			●											●							
ANDALUSITE																								●			
ANORTHOSITE							●											●							●		
BARIUM CARBONATE						●			●					●				●									
BARYTE	●		●	●					●		●							●		●		●					
BENTONITE						●	●		●				●		●		●	●		●				●			●
BLASTING GRIT																										●	
BORON MINERAL									●									●		●							●
CALCINED BAUXITE																								●			●
CALCINED CLAYS																	●							●			
CALCINED DIASPORE																	●							●			
CALCINED SAND										●										●							
CALCIUM CARBONATE	●	●		●		●	●		●		●							●	●	●	●	●			●		●
CALCIUM SULPHATE						●	●		●									●									
CALUMITE																		●									
CERAMIC GLAZES & PAINTS						●	●	●																			
CERAMIC KILNS & TOOLS							●	●																			
CHROMITE						●	●		●									●						●			
CHROMITE SAND																	●										
COLOURED SAND										●										●							
CRISTOBALITE FLOUR							●			●		●						●		●					●		
CRISTOBALITE FLOUR FINE							●			●		●						●		●							
CRISTOBALITE SAND							●			●		●								●							
DIATOMACEOUS EARTHS									●		●				●	●			●	●							●
DOLOMITE							●		●									●		●		●			●		●
FELDSPAR							●											●									
FILTER SAND										●					●												
FLINT PEBBLES							●													●			●				
FLUORSPAR									●								●	●				●					●
FUSED SILICA FLOUR							●										●			●							
FUSED SILICA FLOUR FINE							●													●							
FUSED SILICA SAND																	●							●			
GRAPHITE			●						●								●			●		●		●			●
IRON OXIDE						●								●				●									
KAOLIN	●				●	●	●	●	●		●			●				●	●	●	●	●		●	●		●
KYANITE						●	●																	●			●
LITHIUM-ALUMINIUM SILICATE							●											●						●			●
LITHIUM CARBONATE							●		●		●							●									
MANGANESE DIOXIDE						●	●		●					●				●									●
MANGANESE SULPHATE					●				●												●						
MICA	●	●				●			●		●									●		●					●
MULLITE																								●			
OLIVINE																	●							●			
PREPARED BODY CLAYS						●	●	●																			
PUMICE					●				●											●					●		
PYROPHILLITE	●				●		●		●								●		●	●		●		●			●
RUTILE							●											●		●	●	●					●
SEPIOLITE									●				●														
SILEX LINING BLOCKS																							●				
SILICA FLOUR	●						●		●	●			●				●	●		●				●	●		●
SILICA FLOUR FINE	●						●		●	●								●		●		●		●			
SILICA GRAVEL										●					●												
SILICA SAND		●				●			●	●			●		●		●	●						●	●		
SILICEOUS EARTH	●								●													●			●		●
SILLIMANITE																								●			
SLATE POWDER		●	●						●											●							
SURFACE TREATED CRISTOBALITE										●		●								●							
SURFACE TREATED FUSED SILICA												●								●							
SURFACE TREATED MINERALS									●											●							
SURFACE TREATED SILICA									●			●								●							
TALCUM	●	●		●	●		●		●		●					●			●	●	●	●		●	●		●
WOLLASTONITE							●											●									●
ZIRCON							●		●								●	●		●				●			●

Figure 1. Some industrial rock and mineral products and their uses (from Coope, 1987).

resource base, followed by extended discussions of (1) current and emerging problems for the search and evaluation of these resources; (2) recent geotechnical research that may assist the search, evaluation, and development of the resource base; (3) political realities of the resource climate in Arizona; and (4) recommendations for State and Federal basic and applied research to meet the needs of users of Arizona resource information. An important objective of the workshop was to open lines of communication among the originators and users of industrial rock and mineral resource information so as to develop a better and more readily available data base. This report is intended to so inform users, to initiate a continuing dialog, and, where possible, to stimulate active collaboration among academia, industry, the Indian Nations, and Federal, State, and local Government agencies with respect to the recognition, assessment, exploration, development, and use of Arizona's industrial rock and mineral resources.

An organizing committee developed the workshop agenda (see app. 1) and selected participants to represent constituencies that are connected with the issues selected for informal open discussion. This report documents the substance and tenor of the workshop proceedings.

Acknowledgments.—The workshop committee gratefully acknowledges the encouragement, participation, and support of the USGS and AZGS in developing the meeting program and selection of the participants. Members of the organizing committee who materially contributed to the planning and conduct of the workshop include: H. Wesley Peirce, AZGS, retired (Tucson, Ariz.); Ted H. Eyde, GSA Resources (Cortaro, Ariz.); Barry N. Watson, U.S. Borax (Tucson, Ariz.); Paul K. Theobald, Jr., USGS (Denver, Colo.); Michael P. Foose, USGS (Reston, Va.); L.D. Fellows, AZGS (Tucson, Ariz.); and E.W. Tooker, USGS (Menlo Park, Calif.). The committee, in turn, greatly appreciates the interest and spirited involvement of the participants, whose insights and contributions are represented in the following pages, and the technical assistance of Susan Garcia (USGS, Menlo Park, Calif.) and Pamela Detra (USGS, Denver, Colo.) in making arrangements and conducting the workshop.

Industry Overview

By H.W. Peirce

Introduction

Instead of thinking that the expression "stone age" is an artifact of the past, Bates and Jackson (1982) admonish us to acknowledge that modern civilizations are largely products of a modern stone age. Indeed, in Arizona we have been using basic nonmetallic materials at a rate of approximately 13 tons per person per year. We do this without fanfare as a matter of everyday business. The average citizen knows little about the basic material factors that are an essential part of its physical growth and the maintenance of civilization. Among cities in the United States of more than 1 million population, Phoenix has been the fastest growing. If we think of Phoenix or any other large city as an organism, it can be likened to an octopus with a great many tentacles of varying lengths, each of which has a function; together they serve the central body with its material needs. Indeed, the whole system is so complex that few persons, if any, can comprehend how it works in detail. To further complicate matters, resource-seeking tentacles from other States extend into Arizona; these are exports. Commodities exported from Arizona range from basic raw materials, such as special sands, clays, or zeolites, to fabricated or processed materials, such as vitrified sewer pipe and salt.

The nonmetallic-minerals industry in the State traditionally has assumed a low profile because it is overshadowed by a very large metal-mining industry, which is dominated by a single commodity, copper. The value of nonfuel-mineral production in 1985 exceeded $1.5 billion (Burgin, 1985), about 84 percent of which was derived from the metallic-mineral production and about 16 percent from nonmetallic-mineral resources. The value of the nonmetallic-mineral component of this production is estimated at about $250 million, an amount that would place Arizona in the bottom third of the 25 most important producers of industrial minerals (by value) in the United States. In terms of all nonfuel-mineral production in Arizona, the value of sand and gravel is second only to copper. Within the nonmetallic-mineral group itself, sand and gravel, cement, and lime made up more than 90 percent of the dollar value in 1985. The remaining $25 million is attributed mainly to gypsum, clays, salt, zeolites, volcanic-rock products such as cinder, pumice, and perlite, stone (other than that used in making cement), and miscellaneous other mineral materials.

Arizona is one of the Sun Belt States, the sixth largest in area and the sixth least populated. Since 1980, however, population has increased steadily, with a concomitantly increasing demand for many of the industrial-mineral resources produced in or imported into Arizona. The continuity, or discontinuity, in the production of several nonmetallic-mineral commodities is shown in figure 2.

Geologic Occurrence

No two places on Earth are geologically identical, whether in the United States, in Arizona, or in any of its 15 counties. Geologic diversity generates a broad spectrum of geologic habitats that, in turn, potentially harbor a diversity of useful earth materials, including nonmetallic-mineral resources. Geologic maps of the State constitute the basic tools for evaluating geologic environments that prevailed in the past, with which all resources are necessarily associated. Although these maps are two-dimensional, it is essential to interpret the nature of the third, or "downward," dimension to evaluate the potential for hidden resources.

Arizona can be subdivided into three basic physiographic-geologic provinces or regions, each with its own contrasting geology: (1) the Colorado Plateaus, (2) the transition zone, and (3) the Basin and Range province. These three provinces, each with its own unique geologic attributes, may be expected to contain contrasting suites of resources. Figure 3 depicts the geographic-geologic distribution of selected industrial minerals in

Arizona. More than 90 percent of the State's population reside in the Basin and Range province, where the large and growing urban areas (Phoenix and Tucson) are located. Tentacles from these growth centers reach out to many localities to secure various of nonmetallic raw-material supplies.

Highlights of some of the industrial rock and mineral resources found in Arizona are considered in the following sections. The occurrence of useful Arizona rocks and minerals by geologic age and geologic province is summarized in figure 4.

Cement and Lime

High-calcium limestones are a fundamental ingredient in the manufacture of cement and lime. The more important limestone resources in Arizona are associated with carbonate rocks of Mississippian age. Though buried in the Colorado Plateaus, the Redwall Limestone rises to the southwest and crops out along a northwest-trending belt in the transition zone. This formation constitutes an important source of both lime and cement and contains abundant resources for future use. It supports Arizona's largest lime plant near Peach Springs, in northwestern Arizona (fig. 3). This plant serves the copper industry, which uses the lime to control the chemistry in copper-mill flotation circuits. Much of this lime, however, is exported to California. One of Arizona's two cement plants is located on this outcrop belt at the north end of the Verde Valley, near Clarkdale (fig. 3). Originally, the plant was constructed to supply cement for the Glen Canyon Dam. The plant is now owned by a consortium of Indian interests from the Phoenix area.

The State's largest cement plant is in the Basin and Range province, near Tucson, in southern Arizona (fig. 3). Again, high-calcium limestones of Mississippian age provide important resources of carbonate rock. Remnants in fault blocks contain exposures of the Escabrosa Limestone. These exposures are nearly exhausted, and most of the reserves are buried below the adjacent desert surface, where they are being mined by open-pit methods. The Central Arizona Project (CAP), designed to transport Colorado River water into southern Arizona, is utilizing large volumes of cement made from these important limestone formations.

Clay

Clay, a complex group of minerals, has long been of direct use to man. Its versatility continues to result in new products. One of the newer industries in Arizona is the manufacture of vitrified sewer pipe of widely ranging sizes. For many years, this pipe was imported from California. After an exhaustive search and many trial-and-error attempts, materials were located that, when blended, make a high-quality pipe. High plasticity and refractoriness are provided by kaolinitic shales from the Upper Cretaceous strata along the edge of the Colorado

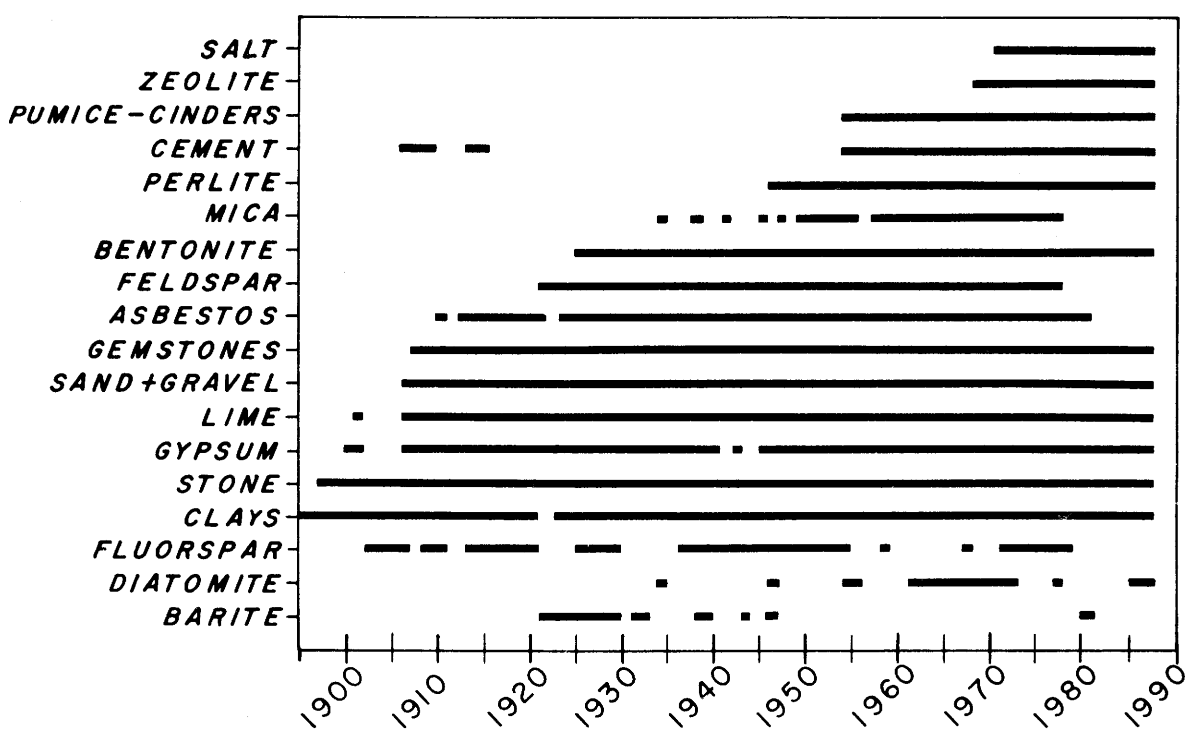


Figure 2. Production history of nonmetallic minerals in Arizona, 1895–1988 (modified from Reynolds and Peirce, 1988).

Plateaus in east-central Arizona (fig. 3). Material is trucked to the plant near Phoenix during the summer months, after the snows at 7,000-ft elevation are gone and the product has dried out. Another component is clay of Quaternary(?) age near Dewey, in the transition zone (fig. 2). This product, blended with more refractory clay, fuses at a low temperature, forming an impervious glasslike binder (Morris, 1987).

Clay in the form of relatively pure calcium montmorillonite known as the Cheto bentonite deposit is mined on the Colorado Plateaus in east-central Arizona, near Gallup, N.Mex. (fig. 3). These deposits of Pliocene age have been mined continuously since 1924. Currently, the raw product is exported for processing into high-value-added desiccants, acid-activated bentonites, thickeners, and gellants (Eyde and Eyde, 1987b).

Gypsum

Although gypsum is of comparatively low dollar value, it nevertheless is essential in the manufacture

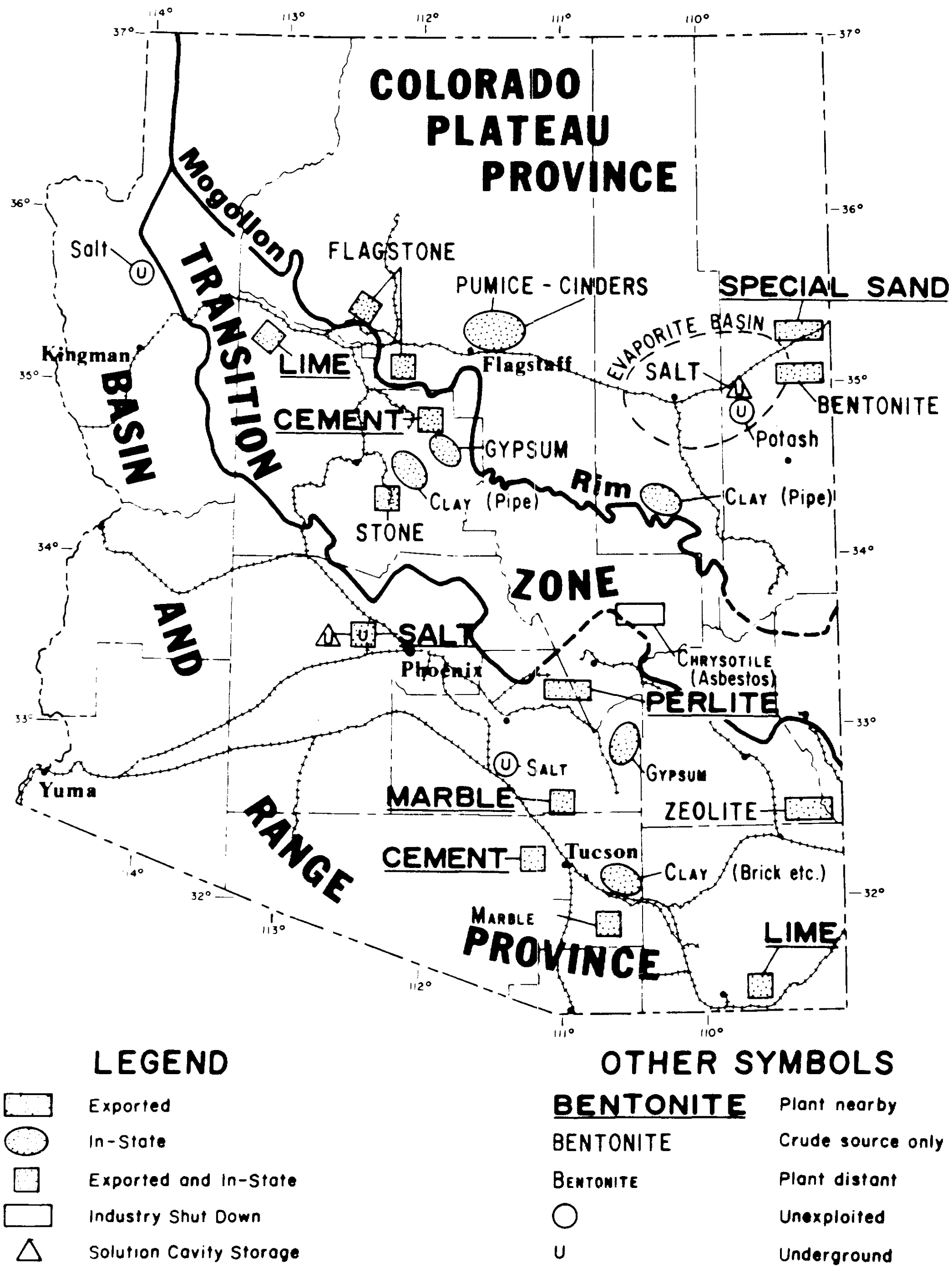


Figure 3. Arizona, showing geologic provinces and locations of major industrial-mineral operations and some undeveloped deposits (from Peirce, 1987).

<table>
<tr><th colspan="3" rowspan="2">GEOLOGIC TIME</th><th colspan="5">ARIZONA PROVINCES</th></tr>
<tr><th colspan="2">Basin & Range</th><th>Transition</th><th colspan="2">Colorado Plateau</th></tr>
<tr><td></td><td colspan="2">Quaternary</td><td colspan="2">Sand and Gravel</td><td>Sand and Gravel</td><td></td><td rowspan="3">Volcanics: Pumice, Cinder, Rock, S&G</td></tr>
<tr><td rowspan="5">TERTIARY</td><td colspan="2">Pliocene</td><td>Peridot</td><td rowspan="2">Gypsum Zeolite</td><td rowspan="2">Clay (vitrified pipe)
Zeolite
Gypsum
Rock</td><td>Special clay
Special sand</td></tr>
<tr><td colspan="2">Miocene</td><td>Halite, Perlite, Cinder, Pumice, Zeolite, Rock</td><td></td></tr>
<tr><td colspan="2">Oligocene</td><td colspan="2">Clay, Gravel</td><td>Gravel</td><td colspan="2"></td></tr>
<tr><td colspan="2">Eocene</td><td colspan="2"></td><td></td><td colspan="2">Gravel</td></tr>
<tr><td colspan="2">Paleocene</td><td rowspan="3">Formation of kyanite etc. and marble by mtamorphism</td><td rowspan="2"></td><td rowspan="5">Not
Present</td><td colspan="2"></td></tr>
<tr><td rowspan="4">MESOZOIC</td><td rowspan="2">Cretaceous</td><td>Up</td><td colspan="2">Clay (vitrified pipe)</td></tr>
<tr><td>Low</td><td>Lime</td><td colspan="2">Not recognized</td></tr>
<tr><td colspan="2">Jurassic</td><td colspan="2">Kyanite etc.
protolith</td><td colspan="2">Sandstones</td></tr>
<tr><td colspan="2">Triassic</td><td colspan="2">Gypsum occurrences in western Arizona</td><td colspan="2">Rock, Gypsum, Petrified wood, Clay (bentonitic)</td></tr>
<tr><td rowspan="6">PALEOZOIC</td><td colspan="2">Permian</td><td>Gypsum</td><td rowspan="4">Marble protolith</td><td>Gypsum</td><td colspan="2">Flagstone, Gypsum, Halite, Potash</td></tr>
<tr><td colspan="2">Pennsylvanian</td><td rowspan="3">Cement
Lime</td><td>Limestone and Shale</td><td colspan="2" rowspan="4">Not generally
exposed</td></tr>
<tr><td colspan="2">Mississippian</td><td rowspan="2">Rock,
Cement, Lime</td></tr>
<tr><td colspan="2">Devonian</td></tr>
<tr><td colspan="2">Cambrian</td><td colspan="2">Quartzite (flux), Locally Phosphatic (Abrigo)</td><td></td></tr>
<tr><td rowspan="2">PЄ</td><td colspan="2">Younger</td><td colspan="2">Quartzite (rock & flux)</td><td>Asbestos (chrysotile)
Quartzite (rock)</td><td colspan="2">Asbestos (chrysotile)</td></tr>
<tr><td colspan="2">Older</td><td colspan="2">Silica, Granite, Feldspar</td><td>Granite, Pegmatite, Stone (schist)</td><td colspan="2">Granite (rock)</td></tr>
</table>

Figure 4. Distribution of nonmetallic rock types and minerals in Arizona by age and physiographic-geologic subdivision (after Reynolds and Peirce, 1987).

of wallboard and portland cement in Arizona. Additionally, gypsum is used in the State as an agricultural product to assist in minimizing the accumulation of sodium in arid soils. The center of gypsum mining currently is in the Basin and Range province, northeast of Tucson, in the San Pedro Valley. The resource occurs in strata of Pliocene age (fig. 3); the gypsum-bearing sequence is about 300 ft thick. Although significant gypsum occurrences are numerous elsewhere in Arizona, many are in areas relatively remote from development centers.

Volcanic Minerals

Products of volcanism in Arizona, largely Cenozoic in age, include perlite, cinders, pumice, and various basaltic to rhyolitic rocks. Perlite is mined, ground, and dried at plants in Superior, east of Phoenix, in the Basin and Range province (fig. 3), and shipped out of the State. Cinders are abundant in numerous cinder cones associated with volcanic fields along the southern margin of the Colorado Plateaus (fig. 3). The cinders are used in landscaping, road covering, and the manufacture of cinder block. The more durable volcanic rocks commonly are crushed and used as aggregate in highway construction. Interest has been shown in the use of pumiceous rhyolite in the making of lightweight, portland-cement concrete (Bryan, 1987).

Saline Deposits

Large deposits of bedded salt are widely distributed in Arizona's subsurface strata. Deposits of Permian age occur in the Holbrook Basin in the Colorado Plateaus of east-central Arizona (fig. 3). These deposits were first penetrated during petroleum exploration in the 1920's, and later drilling and core logging demonstrated the existence of sylvite (potassium chloride) within the larger salt basin. Several hundred exploration holes failed to outline an economically viable potash deposit. If, however, the USBM's prediction (Searls, 1985) of future restrictions on the availability of potash supplies is borne out, this Arizona occurrence could again attract attention. Presently, solution cavities in the nearly horizontal salt beds are being utilized to store propane and butane along the Santa Fe Railroad (fig. 3).

Since 1950, large salt bodies have been discovered by drilling. These occurrences, once controversial as to their origin, are now generally believed to represent evaporites indigenous to the sedimentary basins in which they occur. Both drilling and geophysical data indicate that anhydrite and halite sequences are thousands of feet thick. In 1968, drilling in the Luke salt body near Phoenix, which was located at the center of a gravity anomaly identified on a USGS geophysical map (Peterson, 1968), penetrated halite at a depth of 880 ft beneath a cotton field (fig. 3). This salt deposit, exploited by solution mining and solar evaporation since 1970, was acquired by Morton Salt in 1985. An adjacent operation stores propane and butane liquids in solution cavities in the halite.

The search for cheap underground storage in halite, as well as the possible occurrence of rarer evaporite minerals, should stimulate ongoing interest in Arizona's closed basins of Cenozoic age. The presently known deposits may represent the thickest, youngest bedded evaporite deposits in the world.

Stone Products

Rock materials, other than those used for common rip-rap and aggregate, find beneficial use in Arizona. These include decorative facing stone, flagstone, grass substitutes in landscape design, and white marble sand. Precambrian foliated rocks from the transition zone are used as decorative facing stone, whereas decomposed porphyritic granitic rocks of similar age are finding increasing use in landscaping, in place of grass. The Capitol Building grounds in Phoenix are a good example of this application. Nearer Tucson, the Precambrian Oracle Granite of Peterson (1938) is a popular landscaping amenity after light crushing, screening, and sorting by color. Recently, the fines have been used in making red clay tennis-court surfaces at various localities in the southwest. White marble, near Tucson (fig. 3), is crushed and screened for use in white swimming-pool plaster, and as an animal food. The famous Permian Coconino Sandstone of the Grand Canyon region (fig. 3) is of eolian origin, and its large-scale foreset strata make an excellent flagstone that is exported, as well as widely used within the State.

Sand and Gravel

Arizona's sand and gravel production is second only to copper in total annual dollar value. Most of the sand and aggregate essential in making concrete for the large metropolitan regions, such as Phoenix and Tucson, comes from modern riverbeds. Although this is the cheapest and generally closest source for these essential materials, pressures are mounting to restrict the locations of sand and gravel operations. Construction on flood plains, building of large bridges, and channel-stabilization projects combine to restrict the locations of sand and gravel mining. Governmental-policy development regarding this resource should begin to recognize (1) the necessity of an active sand and gravel industry and (2) the need to locate and protect those resources needed for the future.

Other Industrial-Mineral Resources

Arizona's storehouse of useful industrial rocks and minerals includes other products, some of which are currently being produced and some that once were produced. Zeolite, special sands, diatomaceous earth, and gem stones are being produced, whereas barite, beryllium, fluorspar, quartz (for abrasives), mica, feldspar, and chrysotile asbestos are not currently being produced. At any given time, economic and (or) political conditions may influence the production of any particular commodity.

The Bowie chabazite (a zeolite) deposit in southeastern Arizona (fig. 3), which is an alteration product of a late Cenozoic vitric ash, has yielded the most tonnage of any natural zeolite deposit in the United States (Eyde and Eyde, 1987a). Crude chabazite is exported and made into a high-price activated molecular-sieve product. On the Colorado Plateaus in east-central Arizona, special sands used as a propping agent in oil and gas wells are produced from the Miocene and Pliocene Bidahochi Formation (fig. 3). A diatomaceous-earth deposit in San Pedro Valley, northeast of Tucson, is being processed for use as a filler product, which is exported. Finally, Arizona leads the States in the production of such gem stones as turquoise, petrified wood, chalcedony, agate, jasper, amethyst, clear quartz crystal, peridot, pyrope garnet, marekanite (Apache tears), and onyx marble.

Conclusions

Even though about 13 tons of nonmetallic-mineral materials is produced yearly per Arizona resident, the importance of these resources remains generally unappreciated, in contrast to those of the metallic-mineral commodities. Many nonmetallic-mineral products are relatively cheap, dollarwise, but they have high utilitarian value. Although we no longer make many of our tools out of stone, a sophisticated civilization relies heavily on a continuous flow of an increasing array of useful nonmetallic-mineral materials.

The size and scope of Arizona's heritage of useful nonmetallic rocks and minerals are directly related to the diversity of geologic habitats found in the Colorado Plateaus, transition zone, and Basin and Range province. For reasons that are basically geologic, both people and mineral resources are unequally distributed within this framework. Though constituting about half of the State, more than 90 percent of both the population and value of all mineral production are associated with the geologically diverse Basin and Range province.

Because growth and maintenance in urban areas require consumption of large amounts of earth resources, and most growth is associated with the octopus-like, resource-devouring urban regions, there is active competition for use of the land in and peripheral to the urban regions to satisfy the demands for useful nonmetallic rocks and minerals, and for environmentally preserved growth space. Transportation costs for mineral materials are an important marketability factor that inevitably is linked to the proximity of these resources to urban centers, which, in turn, often leads to conflicts in the form of pleas to restrict the associated bothersome environmental intrusions. Zoning, often promoted to restrict obtrusive land use, needs to be applied to all the legitimate but conflicting interests involved. Responsible zoning, therefore, should include provisions for protecting resources for the future.

This zoning, in turn, leads to the ongoing need to acquire information about where important reserves of these earth materials might be located. It should be the task of natural-resource-related agencies, both State and Federal, to gather and disseminate the appropriate information. Resource discovery and development opportunities must be identified if the State and Nation are to be continuously supplied with the mineral-rock ingredients that form the foundation of modern civilization.

Potential Growth for the Industry

By T.H. Eyde

Introduction

Nationwide, as Wes Peirce has pointed out, industrial minerals contribute $18 billion to the U.S. economy, in contrast to $7 billion for the metallic-minerals industry. The reverse is true in Arizona, which produces about $1.5 billion in metals and only about $0.3 billion in industrial materials. One of the curious aspects of USBM statistics is that materials like clay are valued as crude materials without any value added, whereas for copper, gold, silver, and other metals, value added is the basis for the market price of the metal. If we consider the market price of industrial minerals, particularly for the performance or specialty minerals, they are probably worth two or three times the value of the crude material.

Expanding the use of industrial-mineral resources is based on three factors: (1) the marketplace, (2) the specifications of the materials, and (3) the political and environmental scene. Most performance or high-value-added minerals are relatively insensitive to transportation costs. Geology actually plays a subordinate role in the economic development of these resources. Arizona is a rapidly growing State, with a population now passing the 3 million mark. It is adjacent to California, a huge State that has the sixth largest economy in the world. California also has the most stringent environmental laws of any State in the West. This location may mean that Arizona will be a prime area for developing the industrial materials which now cannot be produced in California. In the following sections, I present some examples of the response of industrial-minerals production to marketing (production of high value from formerly common minerals and rocks), specifications (requirements for special product response), and the political/environmental climate, and the effect of these factors on the future of industrial-mineral operations in the State. As you will soon note, however, these factors are not mutually exclusive, and considerable overlap remains.

The Marketing Factor

Arizona bentonites are produced principally in the northeast corner of the State. They have become performance clay materials used for clay desiccants, selling from $650 to $1,000 per ton. Bentonites are also used as acid-activated bleaching clays to clarify nearly all edible oils, including olive oil, safflower oil, and corn oil. These processed clays sell in the range $200–400 per ton. The bentonite bed is in the Tertiary Bidahochi Formation. This is the same bentonite on which the military specifications for desiccants are based—approximately 18.5 weight percent water adsorbed at 40-percent humidity.

Another clay produced in Arizona is hectorite. Production is small, but there are only three productive deposits of this clay mineral in the United States. Hector, Calif., produces approximately 12,000 tons per year. The deposit at Lathrop Wells, Nev., produces from 400 to 500 tons per year, and the Kirkland Junction, Ariz., deposit about 150 tons per year. These specialty clay products have a high value added as a final washed product, which at Hector, Calif., sells for $1.50 per pound or about $3,000 per ton, FOB at the plant. The air-float material, which sells for about $0.75 per pound, translates into about $1,500 per ton. The plant at Hector is a $40-million-per-year operation. These specialty clay products are used as thickeners and viscosifiers in a whole range of products, such as paints, greases, cream rinses, shampoos, rouge, eye shadow, mascara, and lipstick, in which they form a stable gel.

Gypsum has been produced in Arizona for many years for wallboard, cement retarder, and soil conditioning. At present, the Nevada and New Mexico producers can satisfy the demand beyond Arizona's productive capacity. Mexico fills much of the additional demand for gypsum raw materials along the west coast in California.

Zeolites are used mainly in ion-exchange applications and as adsorbents. The Bowie chabazite deposit in

Cochise and Graham Counties may be the best known deposit and the largest producer in the United States on a sales basis. Because of its specialty applications, the price of the processed products are in the range \$2.50–7.50 per pound. The deposit is mined by eight people, usually Apache Indians, who mine the chabazite with one front-end loader after the surface waste material is stripped. In 1988, more than 4,000 tons was produced, equaling 8 million lb sold at a composite price of \$2.00 per pound, and generating \$16 million in sales.

Resource Specifications

One surprising fact is that some ordinary industrial materials are becoming performance minerals as the specifications for them are made more stringent. For example, the common material aggregate has been produced in Arizona mainly from streambeds of the Salt River at Phoenix and the Santa Cruz River and Pantano Wash in Tucson. In outlying areas, much sand and gravel production comes from alluvial fans and dry streambeds. But for some uses, sand and gravel is no longer a common material. For example, prudency audit at the Palo Verde nuclear powerplant questioned the \$178 million cost of aggregate that was shipped from the San Gabriel Mountains to the reactor site. Why was this source of aggregate used? The Salt River gravels contain Cenozoic volcanic rocks with inclusions of opaline silica and other minerals, which because of their reactivity would not be appropriate for use in a containment vessel at the reactor. An inspection by an intervenor would have required the structure to be replaced.

A new magazine, *Materials Edge*, published by the Metals Bulletin (London), notes that one of the most serious construction problems today is reactive concrete. A good example can be seen in the deterioration of the railings and the structural cracking and crazing of the Tempe Bridge across the Salt River. Since the introduction of such materials as calcium chloride into aggregate, the development of structural cracks have been so serious in Great Britain and Europe that many structures have had to be torn down. Thus, aggregate is becoming a performance material with stringent standards set by the ASTM, the DOT, and even local Governments. Aggregate must bond well, so that the filler materials in asphalt and cement lend strength to the final road mix. Architectural aggregates have also become a high-value-added material. In California, where they are used widely in terrazzo, precast concrete, ground cover, and roof granules, the price ranges from \$25 to \$45 per ton, FOB at the plant. Stricter performance standards have increased the price and quality of these materials.

Several years ago, I was an expert witness in court where the ASDL contended that the brick clays of the Pantano deposit were a common mineral material. Nevertheless, the ASDL's expert witness conceded that these clays represented the widest range of colors he had ever seen. Moreover, he said that it was the only high-alumina clay deposit in the State suited to making good-quality facing brick. It *is* a performance material that is mixed with clay filler from the Talleson deposit, west of Phoenix. The Pantano specialty clay is hauled from Pantano to Phoenix, a distance of 140 mi. Are there other high-quality clays like the Pantano to be found?

Environmental and Political Factors

A feldspar deposit was operated near Kingman for many years. The feldspar came from pegmatite dikes. The operation was closed when the feldspar deposit was mined out. Later, the operators attempted to produce a finely ground quartz for scouring compounds. This operation could not meet emission standards and was closed. The old White Picacho district may be reactivated for feldspar production and processed in a milling facility near Wickenburg. There may yet be a future for the production of Arizona feldspar.

Of the two perlite producers in the State, one, Silflow, has recently been purchased by Nord Resources to add perlite to their existing extender-filler product line. Not only is perlite a good extender-filler, but also the industry has by attrition milling been able to make acicular particles that have high aspect ratios (fiberlike structure) greater than 10–20 to 1. These crystals are used in engineering plastics. There is another reason why perlite is a valuable material. In August 1987, the International Association for Research on Cancer, in its monograph volume 42, determined that it is no longer safe to go to the beach. The mineral quartz, SiO_2, has been placed on the list of potential carcinogens! Because perlite may be substituted for diatomite, which is composed entirely of SiO_2, in filtration media and filler applications, demand for perlite may increase. This circumstance is particularly important because Arizona perlite is remarkably white, after processing, and is an excellent filler-extender.

Salt is generally considered a common mineral, but this is not true of all salt. Luke salt differs from the bedded salt deposits elsewhere in the United States and from the salt evaporated from seawater. A unique characteristic of the salt from the Luke deposit is that it is low in magnesium and calcium, which means that it meets certain purity and environmental specifications. For example, Georgia Pacific manufactures chlorine from salt. Any excess magnesium or calcium ends up in their spent brine. Disposal of this brine in a hazardous-waste site costs more than production of the salt entering the plant. Southwest Salt washes all the sand, dust, or clay that blows into the evaporation ponds, and disposes of the waste products in injection wells. This procedure saves Georgia Pacific the cost of disposing of the spent brines that would have been derived from using sea salt. Luke salt can also be used effectively in steam flooding in the heavy-oil fields in California, because salt containing magnesium and calcium ions tend to block the permeability and transmissivity of the producing horizon. Such a salt commands a premium price of $40 per ton, FOB at the plant, in contrast to about $8.00 per ton for most solar salt.

Bowie chabazite, which has a 5-μm size, also has a high silica-to-alumina ratio. Chemists have not been able to synthesize this zeolite mineral, which has applications in the treatment of sour gas (gas with a high hydrogen sulfide content). These sour gases have a low pH; chabazite can absorb all the moisture, hydrogen sulfide, and carbon dioxide to produce a pipeline-quality gas. The most profitable application however, is in ion-exchange products: Bowie chabazite ion-exchanges and removes cesium-137. The activated extrudates produced from the chabazite have been described as a sandlike product. They were used to fill the canisters used in the submersible ion-exchange system at the damaged Three Mile Island nuclear reactor; the chabazite removed strontium-90 and cesium-137 from the liquid-reactor effluent. Such hazardous-waste applications make natural zeolites an important and useful industrial mineral of the future.

Conclusions

The ever-changing needs of an industrial society will demand new mineral raw materials. Thus, we may soon be leaving the metals age and entering the ceramics age. The raw materials needed for these new and exciting products are not yet known or recognized, but the specifications for mineral raw materials certainly will be increasingly stringent, and so the minerals may also command a premium price. If we continue the present practice of withdrawing access to public and private lands and restricting the development of natural resources, we will greatly increase the possibility of inadvertently overlooking important and valuable resources. No nation can afford to depend on foreign sources of strategic raw materials.

Therefore, the transition from the common materials of greatest need in today's economy will inevitably be to small-volume, high-value-added, specialized, high-technology industrial-mineral resources. Arizona is known to have some of these resources, but the availability of many more remains to be determined. Therein lie the future challenges for explorationists.

Critical Problem Areas

E.W. Tooker, *Moderator*

Three of the many factors that may inhibit industrial rock and mineral resource search, discovery, and development in Arizona were chosen as a focus for the workshop: (1) data availability, access, and effective management; (2) availability and comparability of chemical, petrographic, and mineralogic analyses and materials-specification testing; and (3) State and Federal land availability, access, and permitting.

Effective Data Access and Management

Access to resource information and its management have become serious problems. The amounts of data are staggering when broadly defined to include geologic, geochemical, and geophysical information, as well as drill-core records—or even the skeletonized drill cores themselves. What kinds of data are available, and where? What valuable data are unavailable, and how can they be captured? What kind of data format and management system will best meet the needs of most users? The discussion leaders, who represent the main available sources of data from the State and Federal geological surveys and bureaus of mines, provided some answers to the first question; the other questions were considered by the workshop participants in the discussions that follow.

ARIZONA GEOLOGICAL SURVEY AND U.S. GEOLOGICAL SURVEY

By S.J. Reynolds

Let's begin by listing some of the sources of Arizona industrial rock and mineral resource data available through the AZGS and USGS. Several published indexes list sources of geologic-map coverage and book publications by the AZGS and USGS. The AZGS also has an index of unpublished maps by survey and industry geologists. These maps, which were used in the compilation of the 1969 State geologic map, are available for inspection. A new State map (1:1,000,000 scale) is available from the AZGS. Geology in 1° by 2° quadrangles (1:250,000 scale) is being compiled jointly with the USGS; the Tucson quadrangle, one of this series, is currently in review. AZGS and USGS staffs currently are mapping bedrock and Quaternary terranes in some of the less well known areas in the State that are considered important potential resource areas. The AZGS has a library in Tucson (which contains USGS and USBM maps and reports), and USGS libraries are in Menlo Park, Calif., Denver, Colo., and Reston, Va.; all are available for public use. A summary compilation of Arizona resource information was prepared jointly with the USGS in 1969 as a Senate Document and reprinted by the AZGS as *Water and Mineral Resources of Arizona*.

The AZGS is commissioned as a repository for well logs, cuttings, and cores. Cuttings from every oil well drilled in the State and from some water wells are available. Some cores are also preserved, and electrical logs and chip descriptions from these wells provide a wealth of subsurface information.

Presently, data on the geology of Arizona mineral deposits are being computerized. These data include a computer listing of AZGS library records, well cuttings, a bibliography of sources of information about metallic-mineral districts, and radiometric-age determinations (AZGS Bulletin 197). The AZGS has printouts for inspection of the USBM's MILS file and the USGS' MRDS file (formerly the CRIB system). These files provide a large variety of information on the geology, resources, production, reserves, and mineral-resource development in the State.

U.S. BUREAU OF MINES

By A.F. Barsotti

The USBM's Information and Analysis Directorate includes statistical and commodity specialists who deal with about 90 commodities, 40 of which are industrial minerals. Commodities like titanium, commonly considered a nonferrous metal, are really industrial minerals. Mineral-commodity specialists provide information and statistical data on both domestic and international production and consumption. USBM publications include the annual *Minerals Yearbook* and *Mineral Commodity Summaries*, and the periodic *Mineral Industry Survey, Mineral Facts and Problems Bulletins*, and *Information Circulars*.

The Resource Evaluation Division's Mineral Land Assessment program, in collaboration with the USGS, is directed toward resources on Federal lands managed by the USFS, BLM, and BIA. Commodity geologists, mining engineers, and economists located in three field centers focus on resources. In Arizona, there are 26 published reports and 14 open-file reports on USFS lands, 32 open-file reports on BLM lands, and 13 administrative reports on 19 Indian reservations for the BIA. These reports provide information, maps, and data on known mineral lands and those considered favorable for the occurrence of resources.

The Mineral Availability Program is responsible for the minerals-availability data base, part of which is the MILS. The MILS file consists of about 200,000 data records, mostly in the United States, that include information on the identity and location of plant sites, ownership, status and type of operation, principal and other commodities present, and their marketability. For 10,000 of the 200,000 records, additional data exist on geology, mineralogy, and resource-quantity estimation. For 5,000 of the 10,000 records, additional data exist on mining, processing, and capital and operating costs.

The USBM field center responsible for Arizona activities is the Denver Intermountain Operations Field Center, where information is gathered and entered into the data base. These data are available to the public on request in reports, electronic printouts, and overlays. There are approximately 8,000 records on Arizona in the MILS. The BLM is currently working with the State of Arizona to add an additional 3,000 records to the MILS and to update the dynamic data in each record. The Minerals Availability System also provides data on mining costs and on capabilities to measure the economic potential of known mineral resources. Capital- and operating-cost models and feasibility-analysis models (discounted cash-flow rate of return) for mines are available, in addition to the base data that permit estimating cost of production. Program products include availability appraisals (worldwide) for 34 mineral commodities, including 12 industrial minerals.

ARIZONA DEPARTMENT OF MINES AND MINERAL RESOURCES

By K.A. Phillips

The ADMMR is charged with aiding in the promotion and development of the State's mineral resources, primarily by educational seminars, collection of data from all available sources, visits to mining properties, advice to prospectors, and information to potential mineral-resource consumers. Offices are in Phoenix (headquarters) and Tucson. The Arizona Mineral Museum is located in Phoenix at the State Fair Grounds. The staff consists of mining and geologic engineers who have industry experience ranging from claim staking to financial management and money raising for major mining corporations. The ADMMR publishes directories of current industry activity, industry consultants, and combined statistical analysis/discussion reports on industries, particularly the copper industry, and has published a book on the industrial-mineral occurrences in the State (1,400 occurrences, still incomplete).

Three groups of data bases are available through the ADMMR. (1) The AZ MILS, an adaptation of the USBM's MILS file for Arizona, organizes and indexes 11,000 mineral properties and occurrence sites. These data are on a PC. Included are map plots of the occurrences, maps at a scale of ½ in. per mile, and a set of indexes that provide the primary name(s) of properties, latitude and longitude, T/R/S, commodities present, and a bibliography. (2) A set of mine files covers more than 4,000 properties in the State. Files may range from a one-line rumor to voluminous data, including consultant's reports, underground and surface assays and geologic maps, historical-operational data, information from technical journals and newspapers, and field contacts with operators, prospectors, and promoters. (3) The museum's mineral collection, which contains about 12,000 mineral specimens, many of which are on display, ranges from choice specimens to common rock types. The ADMMR can supply examples of mineral materials to metallic- and industrial-mineral prospectors from this collection.

PARTICIPANTS' DISCUSSIONS OF THE DATA PROBLEM

Unified Computer Data System

• State and Federal agencies have made disparate, yet not unrelated, efforts to collect resource data and make them available to the user community. Some obvious redundancy exists, and possibly some gaps in these efforts. Is there any attempt to develop a unified information system in Arizona, a single place where a user can go rather than to four (or more) separate agencies?

Replies and comments: The AZGS endorses a unified data concept, agrees that it would be a logical site for such a beneficial unified data system, and offers the following suggestions. This system should have access to the MILS, MRDS, ADMMR, and AZGS files of collective knowledge. The difficulty is that these files will take a big computer system, and more time and manpower than are now available to the AZGS, to enter these data into a central file and to manage that system efficiently. Could this be accomplished as a cooperative program located in the AZGS or nearby, and funded by those who contribute to and use these data?

The USGS and USBM recently announced the opening of a Minerals Information Office (MIO) in Washington, D.C. (Interior Building), that will have access to all Federal data bases. The intention is to expand that office in the Western States. One of these expansions will be a small branch in Tucson, in collaboration with the AZGS and whoever else is interested. Part of that effort will be devoted to dissemination of minerals data by a USGS Public Information Office, selling topographic maps and all the book products of the USGS and USBM. The hope is to network this office with Arizona water-resource data (State and Federal), the USGS' geochemical and MRDS data, and the USBM's MILS data. The Tucson MIO may be a step in the direction of a one-stop resource-information center. It will be a growing effort to better meet local user needs.

Industry makes effective use of resource data files. These data provide information about locations, as well as about commodities of interest. The major disadvantage at present is the cost of acquiring these data, sorting them by hand, and locating the separate commodity occurrences of interest on the topographic base. In spite of this disadvantage, these files are most useful, and the probability of exploration success is enhanced.

One of the new mechanisms for communicating ideas is by PC's and modems in a laboratory linked to data bases. Some data handlers require a minimum level of data, and it would be most useful to obtain specific data without getting the whole data set. Electronic mail, which has been used by volcanologists to obtain petrographic and analytical data, may be a vehicle to obtain specific amounts of information from a data base. MRDS data are already available in this form, and other data systems could be made available in this format, if needed.

The goal of a national resource data base on industrial minerals will require the establishment of a compatible unified data system in all of the States. This project has begun in a several States that have adopted the MRDS and MILS. The interstate exchange of information and technologic expertise will be useful to industry, as well as to Federal, State, and local users, both in avoiding costly duplications of effort and in meeting the requirements for more effective regional and national resource planning.

Other Available Sources of Resource Data

• *University theses*, both completed and in progress, are a useful source of data. Are indexes of theses available and kept current?

Reply: The AZGS tries to keep an index listing of theses concerned with Arizona geology. The reliability of that index is fair for the Arizona universities, but records of theses from out-of-state universities is quite spotty. Efforts to fill this gap are encouraged.

• *Computerized mining-claims data* are being completed by the BLM because such data are too expensive to be developed independently, over and over again, on maps.

• *Well-drilling data* are required by the Arizona Oil and Gas Commission; any wells drilled for oil, gas, or geothermal energy must have information on file. Do any other State agencies have similar requirements for filing well data?

Replies and comments: Holes drilled on State trust lands must be recorded by industry operators, and the ADWR requires some information that may not always be of a type needed for industrial-minerals exploration. Most company drilling, however, is done on Federal lands, and many of the managing agencies do not have such requirements.

Filings are required on Federal (BLM, USFS) and Indian (BIA) lands for leasable minerals, oil and gas, and coal. Copies of logs and some samples are required. Oil and gas data are open to public view unless specifically requested to be held proprietary by the company. Nearly all leasable data are assumed to be proprietary. On a few acquired lands, all minerals are leasable. Hard-rock, locatable, or salable mineral products are not regulated. The location of these data varies; some data are in State, some in district, offices. The BLM is now seeking to resolve the location problem.

The ASLD requires filings of drill logs by legislation passed in 1974–75 but specifically excludes things like assays and interpretative data. This information is largely useless because some companies regard everything as proprietary information, even formational breaks or notations on mineralogy.

In contrast, the Midcontinental States require filing of core records of non-ore intercepts. Thus, core data can be effectively used in making broad, regional geochemical studies.

Until the ADMMR can obtain the legislation making mandatory the filing of drill-core information from leases, voluntary donation of such information to that office is urged and encouraged after the confidentiality period has expired. The State Geologist has a statutory obligation to maintain a core-cuttings library. The ADMMR is required to maintain the prospect and mineral-occurrence information used by the BLM. The BLM and other land-management agencies also draw on the satellite AZ MILS. Whereas many people may consider the MILS a somewhat static information file made 10 years ago, the ADMMR has continued to add to and update the individual property files in that system. The ADMMR has a small computerized system operating and would like to obtain data, even in abstract form, to add into this information file.

If a company or a Federal Government project on private property or mining-claim groups can't turn data back to the public sector, the data can be turned back to the owner. Encourage the owner to turn it in to the ADMMR. The Canadians are accustomed to doing this, and when they work down here, they follow through and file their data with the ADMMR.

The USBM once had a core repository, but it was transferred it to the University of Minnesota. The core library, which lists the core samples, currently makes the list available to each State, as well as any cores they may want. The list for the Eastern United States is complete, and that for the Western States is in preparation. The ADMMR may be interested in these records and cores; I'm not sure how many files or cores are from Arizona.

• *Industry data acquisition* is problematic because what is discovered today may not be economic, although it may become economic at some future time. Most companies have extensive files on what has been drilled, and they consider these data to be proprietary.

Replies and comments: An exploration manager who misses something that someone else later recognizes as an overlooked resource, after the data are released, understandably will be reluctant to give out such important information the next time around. But the owner of private land can, and commonly does, require that the data be made available to him.

Mandated release of data on lands that continue to be of interest to a company may not be in the best interests of that company. Yet if lands are abandoned by a company, there should be an obligation to release any geologic information collected, including core-drilling and assay data, to a State or Federal data-base repository. However, the interpretations derived therefrom need not be turned over! This idea may not be acceptable to old-line companies, but opinions in the mining industry are changing. For example, the oil industry has long held this philosophy.

Upgrading Existing Data

From time to time, the contents of existing data systems need to be examined and upgraded. Many industrial minerals have unique properties, and their uses are driven by those properties. Some minerals are important only in the area where they are consumed. A few years ago, sand and gravel deposits were in that category, but no longer. The city of Houston, Tex., for example, imports crushed stone aggregate from Scotland; it is cheaper to buy crushed stone from Scotland than to get it from San Antonio, 300 mi away! Here, one critical piece of information about marketability is the cost of transportation. Costs for rail transport in the United States are highly unfavorable for the movement of resource materials from mine to user. This kind of information is absent in the MILS data at present.

Summary

There is a general consensus that resource data are a significant problem for which some kind of unified solution is overdue. Exploration data are expensive to obtain and should be preserved and available, if possible, to forestall having to rediscover them again and again—as often happens. A one-stop, unified, State-wide data storage and management system is desirable; such a system also should be compatible with those in adjoining States and the Nation. Active collaboration in preserving resource data between State and Federal agencies, universities, research institutes, and industry (where possible, as when a company leaves an area) is necessary to assure continuing support of resource development in the State and Nation.

Analytical-Laboratory and Industrial Testing Capability and Availability

Chemical and petrographic analyses and testing facilities for the physical properties of industrial materials are relatively scarce, and these services are generally expensive. Marketability of a mineral product depends heavily on these data, for which few published standards and nonproprietary specifications are available to the resource entrepreneur. What types of analytical services are needed to meet identification needs and industrial specifications, and what are their availability from public or private facilities?

INDUSTRY VIEWPOINT

By D.T. Eyde

Industrial minerals can be divided into two types: chemical minerals and physical materials. Each type has a fairly specific analytical requirement. Examples of chemical minerals include borate, salt, trona, limestone, and, possibly, silica sand (in some applications). These minerals have fairly standard analytical chemical tests to characterize their composition and determine their specific uses. For example, the arsenic level in a borate may limit its applications. In contrast, many physical-mineral products are aggregates or mixtures of minerals. The analytical report from a laboratory is commonly a semiquantitative XRD analysis used to determine mineralogy. Indirect tests of properties may be used, including ion-exchange capacity, pore size, and adsorption, as well as physical tests of the mineral grains or crystals. Each material of interest may have some specific properties requiring extensive evaluation.

A serious problem is the expense of these tests. A one-sample XRD mineral analysis by a private laboratory may cost $120, with a turnaround time, if it's a well-organized laboratory, of 2 to 3 weeks. If a large company has its own analytical facilities and many samples are submitted, the costs are unknown, but the turnaround time may be as much as 6 months. An even more serious problem is that there are relatively few independent testing laboratories. Owens Corning has one; the Ontario Research Foundation of Canada also provides such services, and Miles Industrial Minerals Research is also available (see app. 2).

Considering the useful applications for these minerals, there is another problem. Each customer for a given mineral has a different set of test specifications, and sometimes these tests are considered proprietary. Usually, the customer will not reveal the analyses used to characterize a clay—for example, the evaluation tests. A fundamental problem is the absence of standard tests; each laboratory has its own methods for testing. For natural zeolites, there are at least five types of ion-exchange or cation-exchange analyses. Generally, each company uses the test that gives it some competitive advantage. If a company uses their test, their product appears better than their competitors' because of the way the material tested reacts under the specific conditions of the test. The test itself then becomes a marketing tool.

One example of indirect analyses is the Bowie chabazite deposit. Union Carbide used the measurement of oxygen absorption as the basis for their estimates of the chabazite content. They compared the Bowie material with a chabazite standard from the Reese River, Nev. Because the Bowie material absorbs about 80 percent of the oxygen absorbed by the standard, the Bowie chabazite content was assumed to be 80 percent of that of the Reese River standard. Though technically accurate, this test had inherent limitations because the rate of adsorption was not considered. A test of the cation-exchange capacity found that some of the material, running 70 percent chabazite by the oxygen-absorption test, had twice the cation-exchange capacity of material that had an oxygen absorption of 110 percent of the Reese River standard. This result was obtained because the oxygen-absorption test failed to account for the different exchangeable cations in the mineral sieve that blocked the sites for oxygen absorption. Although the test was reproducible, it did not accurately characterize the samples.

There are no accepted XRD industrial-mineral standards. We use Cheto clay as a standard for calcium montmorillonite. The Mud Hills clinoptilolite, Union Pass mordenite, and Bowie chabazite are good zeolite standards. Instruments are calibrated for these materials to give semiquantitative results. Materials with different crystal sizes, or distributions of crystal sizes, may have different data sets, and so they cannot be compared directly. Commonly, results from different laboratories cannot be compared; each data set is unique. Although the data are a useful guide to the objective of the survey, comparison of data from different laboratories can be misleading.

Other physical analyses, such as size distributions, are helpful; however, there are no standards for size distributions. A geologic engineer will set up distribution curves one way, but a sedimentologist's curves will trend in a different direction, and a user of mineral products may require a different size distribution. Hardness, density, and color also may be useful and important factors. One tendency that must be avoided is to collect a single sample, believing that it accurately characterizes the whole deposit. It may not even be close! Surface samples generally differ from those collected beneath the surface. A drill core back away from the outcrop may not be affected by chemical modifications from surface weathering.

U.S. BUREAU OF MINES CAPABILITIES

By K.G. Broadhead

The USBM does not have a publicly available testing service. We can analyze samples, but our capacity is quite limited because the USBM is forbidden to make commercial assays. If an employee member of the USBM is involved in a cooperative research program, a Memorandum of Understanding (MOU) may be prepared to consider the problem of mutual interest.

There is no central USBM laboratory facility. Each regional installation has good, but only limited, analytical facilities—for example, in Reno, we have XRD, fluorescence, inductively coupled plasma, atomic-absorption, emission, electrochemical, and microprobe instrumentation.

U.S. GEOLOGICAL SURVEY CAPABILITIES

By P.K. Theobald, Jr.

Standardization has long been a problem for chemical analysis. About 30 years ago, Mike Fleischer (USGS) obtained two standard rock samples, W–1 and G–1. He split them carefully and sent samples to laboratories all over the world for standard rock analysis, using 99.9 percent as a total. He then compared the results from these laboratories. There was an extraordinarily large variation in silica, to say nothing of the minor components. You cannot establish absolute standards. You have to accept the fact that different laboratories produce different results, even when using the same techniques.

In USGS analytical laboratories, we have a mission to supply chemical information necessary to the programs across the USGS' Geologic Division. We do not do materials testing. We have just produced Bulletin 1770, which details the analytical methods currently used in USGS laboratories for the more precise chemical analyses needed for geochemistry. These analyses are relatively expensive, ranging from neutron-activation to colorimetric methods. USGS Circular 948 describes the simpler exploration-geochemical procedures, mostly semiquantitative, which produce large numbers of data at a lower cost and are useful for most applied geochemical problems.

A second part of the USGS program includes a whole series of custom analyses that require a research chemist to do the work. Some of these analyses are also standardized—for example, coal analysis, which differs from conventional rock analysis. There are a series of analytical techniques for *available* metals; these techniques are used mainly by environmental geochemists to identify elements that are in the soluble part of the soil environment. A whole series of partial-dissolution techniques are also available—not total metals but, for example, the exchangeable arsenic in clays. Is that arsenic available when the clay is used to make dishware for use in the home, or is it locked up and will not contaminate food in the dish? These tests were designed primarily for exploration geochemistry for metals—for example, which metal is tied up with iron oxide, manganese oxide, sulfides, or in a silicate lattice (and thus not of exploration significance). These techniques also have strong application in environmental geochemistry, where its a matter of availability of metals rather than absolute amount of metal.

A third area of USGS research is the development of new analytical techniques and the testing of new instrumentation. For example, infrared analysis is based on determination of the molecular bonds between atoms rather than of actual atoms. Extensive tests over a 15-year period provided few applications for this technique in mineral exploration; it is being replaced now by Raman spectroscopy, which does a similar type of analysis but promises to be more useful. Another research area concerns how a metal gets into the system, that is, the geochemical cycle. Deposit modeling is a research area that depends heavily on stable- and radiogenic-isotope analyses and fluid-inclusion petrography and analysis. This technique is not of great interest to the nonmetallic-mineral industry at present, but there is a potential for future applications. Finally, paleohydrologic studies of ore-fluid movement are being done. In the Midcontinental States, an area from the Ozark uplift in the south northward into Illinois is being studied. Similar studies are being done for the low-temperature precious-metal systems. A nonmetallic-minerals program involving basins in the Basin and Range province could use this sort of study.

PARTICIPANTS' DISCUSSIONS OF THE ANALYSIS AND TESTING PROBLEM

Availability of Analysis or Testing Services

• The ASTM continues to set up mineral standards for analysis. Their testing procedures are identified, and the tests are discussed and modified at the time the standards are established. The type samples used in testing are available from the ASTM. Other commercial sources of prepared mineral standards are listed in most scientific journals.

• Chemical and mineralogic properties of industrial-mineral materials generally are readily agreed on, but such physical properties as density or durability are difficult to determine, commonly because of the absence of specific tests. For example, the density of pumice, which is less than 1, has no ASTM test.

• There is a continuing need to identify rock or mineral species. Generally, commercial laboratories are not available for that purpose. The State geological surveys provided that service for many years; there was a State Mineralogist whose primary job was to identify rocks and minerals. The current AZGS geologic staff may do this for the public, and the ADMMR engineering and museum staffs try to help. Is there a place where such materials can be identified?

Reply: The geologic publication *Geotimes* lists some of the commercial laboratories that provide petrographic and mineralogic information (see app. 2). The USGS and AZGS do it occasionally as a courtesy, but their facilities are mainly for internal use. The USBM will also do this, but as a Federal organization, it is not supposed to be in competition with the private laboratories.

• Industrial-mineral development, as seen from the perspective of the ADMMR, depends on the availability of numerous persistent prospectors and the technical wherewithal for effective prospecting. Right now, there is no geologic model, and there are no stain tests to identify the wide range of materials in the field and to find markets for them. The ADMMR tries to help by indicating where resources were found in the past, provides samples of materials, suggests appropriate field methods and field tests, and so on.

• The modified and altered marketed material may include only a small fraction of a specific industrial-mineral material. For special-purpose clays, sometimes only 30 percent of the clay is recovered from the mined ore as a salable product; the rest is discarded as waste magnesite, dolomite, or calcite impurities, which are regarded as contaminants. Wollastonite ore at the mine may include 30 percent silica and 20 percent garnet, both of which must be removed. These impurities provide the industrial-mineral entrepreneur with a serious analysis problem for evaluation and marketing.

Setting Standards and Specifications

• There needs to be some sort of taxonomy for industrial-mineral materials from the perspective of the end user rather than just the mineral-processing user. What are the specifications and needs? This problem should be worked on, so that we know when we have a deposit and whether it meets the requirements of any user out there.

• In consideration of standards, we are often comparing apples and oranges. A distinction should be made between mineral properties and marketing properties. Whereas the former are usually well documented, the latter—for example, ion exchange—are the more persistent unanswered problems. Ordinarily, marketing properties are not considered in the USGS-USBM resource-assessment exercise. Do not compare what industry uses as a product with what is being looked for to mine; they are two different things. For zeolite, a standard test could be proposed; but for a mineral like talc, which is used by a competitive cosmetics industry, the specific properties or tests used by industry as a basis for the marketability of talc are proprietary and would never be released.

• The USBM publication *Minerals Fact and Problems* has a section on specifications for every commodity. This report provides a good-quality basic guide for each commodity. Analysis is the basis of composition, and specifications may include tests for anything from composition to behavior. There are fields in the MILS data base for marketability—for example, the phosphate rock description says that the presence of manganese or magnesium affects marketability. There are things that could and should be done to improve the MILS information, so that when you look at an industrial-mineral resource, you get a ballpark idea of whether that material has potential marketability. The *Raw Materials Index* also gives a good idea as to the color, particle size, water absorption, and so on, for filler and extender minerals. To standardize specifications and make the assessment of industrial minerals by the Department of the Interior more responsive to present and future needs, it is recommended that industry and Government surveys (under the lead of the USBM) jointly prepare improved, consolidated guidelines for the evaluation of industrial-mineral materials and establish procedures for testing them.

The USBM's widely recognized research on gold extraction is a prime example of the type of research that ought to be focused on industrial-mineral materials. USBM research also is underway for borehole mining and secondary recovery of high-technology materials from Florida phosphate deposits, and there may be other industrial-mineral research underway. These types of activities ought to be reported in one place on a regular basis, as a public service.

• It may be time to stop writing off the standards problem by saying that the definitive tests are all proprietary. There are published analytical procedures, such as those established by the ASTM, to evaluate the direct and indirect properties of materials.

Reply: The proprietariness of the tests used for industrial source or product materials is a serious and complex problem. Producers of mineral-based products will not divulge the test information that they use to evaluate raw materials. They may use a specific product and a specific test to make their product, which is sold for a profit. In trying to sell industrial minerals, you may have difficulty trying to break into the supply system because the producer usually has a source of material that works for him. A mineral like talc is used in a dozen products by different industries, all of which have different tests that are specific for the product—whether as a filler for tires or for use in cosmetics. In spite of this apparent standoff, Government land and resource agencies are responsible for evaluating resources, and so an evaluation method must be developed, including definitive tests of source materials.

• An example of the problems in developing specifications for a resource material is the coatings industry. Coatings (or paint) made for aluminum house sidings must meet stringent exposure requirements because the siding is guaranteed for as long as 20 years. Thus, because of liability, before any batch of paint is made up, samples of the raw materials to be used, including titanium dioxide, chrome, iron oxide, and other mineral-derived pigments, as well as calcium carbonate, talc, and barium sulfate fillers or extenders, along with the appropriate resin polymers and solvents, are tested in laboratory-size batch mixes to see whether the desired characteristics can be achieved. Standards would include color, gloss, viscosity, adhesion, curing rate and time, film hardness, and impact resistance. If the laboratory-batch characteristics meet the standards, the paint batch is made up, and the paint product is delivered to the siding manufacturer. Even then, sample panels coated with material from the plant batch are prepared, coded, and set out for exposure at "paint farms," where they are checked periodically. This provides a backup to the batch integrity, should there be surface problems with aluminum siding during the warranty years.

On one occasion, the backup panels from a batch of paint that had met quality-control standards gave evidence of chalking or rapid loss of gloss retention after only a 6-month exposure. Because of the tremendous liability involved, an array of laboratory test batches were made, varying both the raw-material sources and the processing and application techniques, to identify the cause of the poor gloss stability. After considerable investigation, it was determined that at a certain ratio of iron oxide yellow (a mineral material) to titanium dioxide

(TiO_2 from ilmenite and anatase minerals) pigments, an incompatibility developed between the two pigments during the grinding and dispersion stages of the processing. In addition, it was discovered that this incompatibility occurred only when the iron oxide yellow from one supplier was used with the TiO_2 from another supplier. Both pigments individually met the quality-assurance specifications, but it could not be determined which of the two pigments contained the unknown characteristics that caused the failure. Suffice it to say that both suppliers were rejected as sources for the particular coating product. Such cases occur frequently, and so for many raw materials, including industrial minerals, it is almost impossible to know all the characteristics to test for, much less to look for, in seeking out economic deposits. The ultimate acceptance test will most likely be its performance in the final product.

• The USFS' Coronado Forest zone office has published a document that defines how they plan to dispose of such mineral materials as petrified wood, common varieties of sand, gravel, stone, pumice, pumicite, cinders, clays, and other similar materials. This proposed rule making would clarify which mineral materials or common varieties are subject to disposal by the Secretary of Agriculture under the Mineral Materials Act of 1947 (see app. 6).

• Production of industrial minerals is a market-driven, not a resource-driven, business. Product standards vary from place to place. Not all wollastonite deposits, for example, are the same. A New York deposit is composed of highly acicular, beautiful long pinkish-white crystals of a purity such that it requires no processing; it is particularly well suited for ceramics and paint. The Willsboro deposit contains garnet, calcium carbonate, and silica, and so it has to go through a flotation process, and generally the fibers do not have the characteristics suitable for ceramics and paint. Nonetheless, the material is competitive in the plastics industry. Any producer who starts out in the West, where there is a market for as much as 20,000 tons of wollastonite per year, is going to have to be able to make a product acceptable to the ceramic, paint, and plastics formulators, that is, comparable in quality and color to the deposits in the East.

You can start a gold mine, once you locate the deposit, and get the financing. The deposit can be put into production because there is a ready market for the product, and you can sell all you want. Usually, it's just a matter of price. That's also true for copper, lead, zinc, molybdenum, and many other metals. When you get to industrial minerals, that's no longer true—a market has to be developed. That factor has its limitations, but the good news for the specialty products is that the producer sets the price rather than the buyer. Also, because there are many consumers who use relatively small amounts of product, the industrial-minerals business is not so vulnerable to depressions.

• The changeover of technology to advanced ceramics is going to revolutionize the material needs of the United States. If any of these so-called new materials or wonder materials come into the mass market, higher and higher purity materials will be needed. It will become a chemical-processing problem to get the raw material in the grain size needed, particularly for extremely high purity materials. Specialty minerals with low contaminants will become a valuable part of the industrial-minerals group. As raw-material needs change from metals to extremely strong cast ceramics, as in jet-engine turbines and advanced fibers and reinforcements, materials needs are going to change. We have no way of assessing these needs at present. It is uncertain who is going to look ahead to identify these presently high purity common resources, such as silica or alumina.

• Sometimes, the testing procedure fails to recognize the existence of a resource. For example, an industry representative recently took USGS evaluators into the field and pointed out a saponite deposit, which is a rare and unique resource—possibly the most valuable material in the area being evaluated. The material was tested for its refractory characteristics in a USBM laboratory. The clay was not refractory, it failed the test, and the deposit received a two-line mention in the WSA report. Clearly, the management system was not adequately addressing the industrial-mineral-potential problem, in spite of the fact that an effort was made to test the material. The problem of selecting the proper test for a material should be resolved as soon as possible.

• Research on the surface activity of fibrous or acicular minerals is something which the State and Federal geological surveys and the universities may be equipped to study and for which they may have the required mineralogic expertise. From an environmental standpoint, it is important to know why some of these materials may not be carcinogenic and perfectly safe to mine, because so many of the metallic- and nonmetallic-mineral industries have to deal with particulate-material problems.

Recognition of "Future" Resource Materials

• The standards problem has hindered examination of WSA's for industrial-mineral potential by the USGS and USBM. Potentially marketable industrial-mineral resources are difficult to define and recognize. The Nation has gone from the metals age into the new stone age of ceramics, composites, and advanced materials, yet resources are being locked up whose uses are not yet recognized. Once legally unavailable, it will be difficult, if not impossible, to unlock such resources in (low or no resource potential) land classification. A resource can't be recognized and assessed unless there's a way of evaluating it.

• How do the USGS and USBM deal with the industrial-minerals-assessment problem to make sure that materials are not placed in some classification whereby they will be unavailable 20 years from now? These agencies have been less than confident in their assessments of materials like sand and gravel. A statement in a report may say that there is a resource present, but there is a lot more of that material available in many other places. So, they write it off in the report, and the BLM rates it as having a very low potential.

Reply: The materials should be tested in appropriate laboratories or evaluated as to the type and quality of the aggregate.

• The Government must evaluate the resources on Federal lands by 1991 (congressional mandate); the USGS and USBM cannot ignore this mandate. The Government needs to have help from industry and academia in resolving issues concerning resource identification, particularly for the potential future types. Recommendations are needed for what industrial-minerals producers feel would be responsive actions by the Federal agencies in their consideration of industrial-mineral-resource potentials on Federal lands. The land-managing agencies (USFS, BLM) would welcome such information that is generated in a positive sense, and they would use it positively. What are some criteria we all can agree on that would identify a material as a potentially valuable resource?

• Resistance to the discovery and development of new industrial-mineral deposits may result from a reluctance of consumers to change suppliers. There was a recent failed effort to assist a local plant processing vermiculite for potting soil. They should have bought 1,500 tons per year in Arizona at a low rate, instead of importing vermiculite from Virginia at $160 per ton in freight cost alone. The marketer was an expert in processing and selling soil, but not in mining industrial minerals. Furthermore, he had no concept of land-acquisition problems or mining methodology for mineral development. Consumers prefer to go to a purchasing agent for a trademark product that meets their needs. They resist moving capital plants from one part of the country to another, even though markets are developing there.

• In the opinion of one participant, a significant deterrent to industrial-mineral development in Arizona is that land-management agencies seem to favor land preservation over mineral development. The classification of many industrial minerals as common varieties under the mining laws makes it more difficult to obtain rights to them.

Improved Testing and Specification Procedures

• One problem is that "weighting standards" are used by land managers in determining whether a deposit is valuable or not. Mineral potential has a lower "weight" in the EIS than many other, more readily quantifiable values, such as like recreation, esthetics, or animal habitats. The argument commonly used is, "Yes, this is an occurrence of talc, but there are deposits of talc elsewhere. Therefore, this particular one is not needed." In truth, it cannot be argued that any one talc occurrence is more valuable than another, because each deposit is unique. The argument that a deposit in a WSA has unique and specific properties which make it valuable for an as-yet-unknown application is not considered valid. However, if this deposit has characteristics that are definable and for which there is value attached, it no longer is a common material. It is inexpensive to prove that a resource material is not valuable on the basis of a resource survey, when there is little or no information about the third dimension or grade of the occurrence, but it's very expensive to prove that it is valuable.

• Those making Government resource assessments need to know how to best represent industry's interests (in the national interest), so as to ensure that companies are not abused by a management system that doesn't recognize their special needs. Clearly, resource-assessment methods must be improved or developed to properly represent industrial-mineral producers. Industry seems to have the choice of helping to develop usable assessment tools for the industrial minerals, or saying that such tools can't be developed. In that case, industry will continue to be underrepresented in resource assessments.

Replies and comments: Returning to the diopside example mentioned earlier, the material certainly has or will have some value. Proving that value to a land classifier is not easy because there is no comparable massive diopside deposit in the United States. In the last analysis, it will be necessary (but impossible in the time frame available) to build a market for the product from scratch. Nevertheless, from an industry perspective, the occurrence should not be included in a WSA. What practical steps will be useful to prove the uniqueness of the deposit? Why not divide industrial materials into two groups—one that is so specialized that it presents unique problems which must be dealt with individually, and a second, broad group comprising the bulk materials, those that have common associated specifications? Then, a set of widely recognized basic parameters associated with the second group, permitting their routine testing and examination, can be defined. These materials can be said to meet certain basic criteria that, while not proving ultimate value, minimally ensure their recognition as known or potential resources. This procedure may facilitate assessment and solve a part of the recognition problem. Participation in the classification procedure will require close collaboration between industry, resource assessors, and land managers.

Under current regulations, the prudent-man test must be met in some acceptable way. Few productive operations of industrial materials function at maximum capacity. Changes or fluctuations in the market may also affect the operation. Is a 2-ton supply in a celestite deposit worth preserving, when the world market is only about 12,000 tons? Value is difficult to prove unless a producer can make a useful product out of the material at a profit. In a sense, it may be a resource of the future. Nonetheless, does it make sense to leave such a material out of a WSA report when the technology to make use of it does not exist at the present time and the potential resource cannot be produced at a profit?

Another way to look at this classification problem is to segregate those materials that require strict quality controls from those that have lesser quality-control requirements. Some materials will require more attention from applied geologic research and chemical analysis. Will the end user pay for the effort of quality control?

Some industries have quality-assurance programs, in which the company sets the standard, and the suppliers agree to meet those standards. Thus, you can go through the array of industrial minerals and categorize them. Which ones call for more stringent quality than is justified by usage in the market? Some of these materials, such as fluorine, titanium dioxide, or iron oxides, have fairly standard specifications for some industries.

• Assessment of WSA's could be improved by having the evaluators go to the local producers of industrial-mineral materials and discuss the resource potential of an area. For example, if a WSA area that is partly in a basin is evaluated and the evaluator anticipates the presence of borates, then the evaluator should consult a borate producer to determine the resource potential for borates in that area. It should be recognized, however, that the company will not be required to divulge its trade secrets or specific exploration models. An obvious ancillary problem is the fairness issue—if there is more than one company operating in the area that could be approached, which one do you choose to contact? That may be difficult, but there are a lot of industry experts who could provide input to the assessment of the resource potential of an area. A meeting between industry and Government resource experts is recommended to consider these problems, to propose possible mechanisms and eliminate possible conflicts of interest.

Conclusions

Consideration of the analysis and testing problems facing industry lead to concern for their effect on resource assessments by Federal agencies. Although no definitive answers were derived, some suggestions were made that merit more detailed consideration. The main problem for industrial rock and mineral resources, which depend heavily on their marketability, is the absence of accepted standards by which many of these materials can be compared. For individual pure minerals, the problem is not as serious as determining the specifications of components in aggregates or commercially prepared materials, for which standards are generally proprietary.

Even if tests and specifications were established, only a few commercial testing laboratories are available (see app. 2), and as has been noted, the analytical results on the same materials by competing service laboratories are generally not comparable. The USGS, USBM, and State survey laboratories do not provide public testing services. The USGS has published the standards and rapid chemical-analysis methods it uses.

Government agencies (USGS, USBM) need help from industry and academia in developing a useful and acceptable resource-evaluation methodology to identify industrial-mineral materials in WSA's, so that nonmetallic-mineral materials receive equal treatment with metallic-mineral resources. If such advances in assessment technology can be attained, land managers will be more able and willing to "weigh" resource values equally with competing environmental values in Federal and State land-use classifications. In particular, the term "common materials" needs to be reexamined.

Land Access and Availability

Access to available Federal, State, Indian, and privately owned lands is a subject area of tangled and often poorly known or understood regulations and constraints for those conducting exploration and development for industrial resources. Session leaders from the BIA, BLM, and ASLD describe their mission objectives and methods for classification of public-land resources, and review the methods for obtaining access to explore, evaluate, and produce minerals. A discussion and clarification session by the workshop participants follows.

U.S. BUREAU OF INDIAN AFFAIRS

By James Crowther

Before considering access to the resources on Indian lands, it seems appropriate to explain the organizational structure of the BIA. The Phoenix area office covers a three-state area—Arizona, Nevada, and Utah, as well as parts of California, Idaho, and Oregon. A total of 13 agencies, or field offices, are located on reservations within that region, 9 in Arizona (see app. 3). A total of 19 tribes in the State are under BIA jurisdiction, exclusive of the Navajo Tribe, which has its own area office and is not served by the Phoenix area office. Because these Indian lands, as well as the resources on them, are owned by the tribes, access to the reservations is through the tribes; they control access to the land and its minerals. It is hard to consider the BIA a land-managing agency in the usual sense because the tribes have so much responsibility in dealing with their resources. However, because the Federal Government is trustee for the Indians, the BIA approves any contracts made between the tribes and mining companies. The BIA's role is to determine whether the contract is in the best interest of the Indians and to go through the environmental- and cultural-resources procedures.

As far as access is concerned, it starts with the tribes (see app. 4). Any companies wanting to do business on Indian lands to develop minerals (or anything else) must deal with the tribes and their attorneys. In many cases, a BIA specialist may be called in to assist in negotiations. The main BIA role is to give technical assistance to the tribes, to evaluate, and to approve or disapprove contracts between the tribes and the mining companies. BIA relations vary from tribe to tribe, just as the tribes differ one from another. All the tribes are interested in having companies come in and develop their resources. It may not appear that way, in some cases, because any opposition reported in the press is taken as general opposition to mineral development. This is simply not true. A fair and equitable mining proposal is rarely, if ever, turned down. Similarly, because Indian land is not Federal land, although the Federal Government does have legal title to it, the economic aspect of a mineral operation is of utmost importance and carries a heavy weight in negotiations. A contract price for a mineral commodity on public or fee lands might not be acceptable to the Indians.

Since 1975, the BIA has been involved in a mineral-inventory program, now called the Indian Mineral Assessment Program, covering all the Indian reservations in the United States. Through contracts with the USBM and USGS, the BIA has performed studies on all reservations. These studies are divided into phases. A phase 1 study inventories existing resource information, which is cataloged in an administrative report that is available to anyone who wants copies. Phase 2 consists of field studies to gather new information; this information is confidential to the tribes and is available to the public by tribal permission only. A few phase 3 studies have been implemented on reservations where drilling was done to verify geologic information; the drilling is not to make a discovery or to block out an ore deposit.

U.S. BUREAU OF LAND MANAGEMENT

By L.P. Bauer

The BLM is probably the largest landlord in the Nation, managing some 300 million acres (fig. 5). In Arizona, the BLM manages 12 million acres plus an additional 12 million acres of mineral estate managed jointly with the USFS. Access to minerals on Federal mineral lands may be obtained in one of three ways: (1) leasing, (2) locating, or (3) buying under the Mineral Materials Act. Leasing applies to minerals not usually considered industrial materials—oil and gas, coal, oil shale, tar sand, and sodium. Locatable minerals include everything else except for those handled under the Mineral Materials Act, such as sand and gravel and the "common varieties" of materials (see app. 5). The leasing is done by application and is strictly a discretionary act on the part of the Secretary of the Interior. Under the 1872 mining law, primary access to locatable minerals is by staking and filing a mining claim with the appropriate county recorder and the BLM within 90 days (fig. 6). There is a requirement for an annual filing of assessment work or intention to hold the claim. Under the Mineral Materials Act, the BLM sells the material on application. The BLM's policy is that unless the land is withdrawn from mineral entry in consideration of other values, it will be available for mineral development. Recently, a decision by Judge Pratt in a National Wildlife Federation suit placed a cloud over many withdrawal revocations made since January 1981. The Judge said that the Reagan administration had moved too precipitously in making withdrawal revocations, and the Judge moved the time clock back, so that all withdrawal revocations since January 1981 have been reversed and the withdrawals put back into place. The impact of the decision, retroactively, is unclear on those claims and leases already issued. The BLM is presently taking many actions right up to the final decision point and placing them on the shelf until a final settlement of the suit.

WSA's in BLM lands are an outgrowth of the 1976 Federal Land Policy and Management Act, in which the BLM was directed to inventory its lands for consideration of their inclusion into the wilderness system, under the Wilderness Act. The wilderness land characteristics specified in the act, which include natural beauty, opportunities for recreation, and solitude untrammeled by man, were required to be assessed in the evaluation by the BLM. The converse is that land areas meeting these criteria have not been extensively explored, mined, or developed for agriculture. Almost by definition, all the areas that have not been developed were studied for designation as wilderness areas. About 70 WSA's are still under consideration in Arizona. The BLM has made decisions and is recommending that many of these WSA's be dropped from further consideration; many others are being recommended for modification. Where there is reasonable information, the BLM is adjusting boundaries. The point has nearly been reached where final recommendations will be submitted to the Congress and final negotiations will take place at the congressional level. The BLM's Phoenix office has prepared maps and charts of each of the WSA's for use by congressional delegations in making the final decisions. Draft WSA reports, available for public inspection in the BLM's State office, contain these maps and charts.

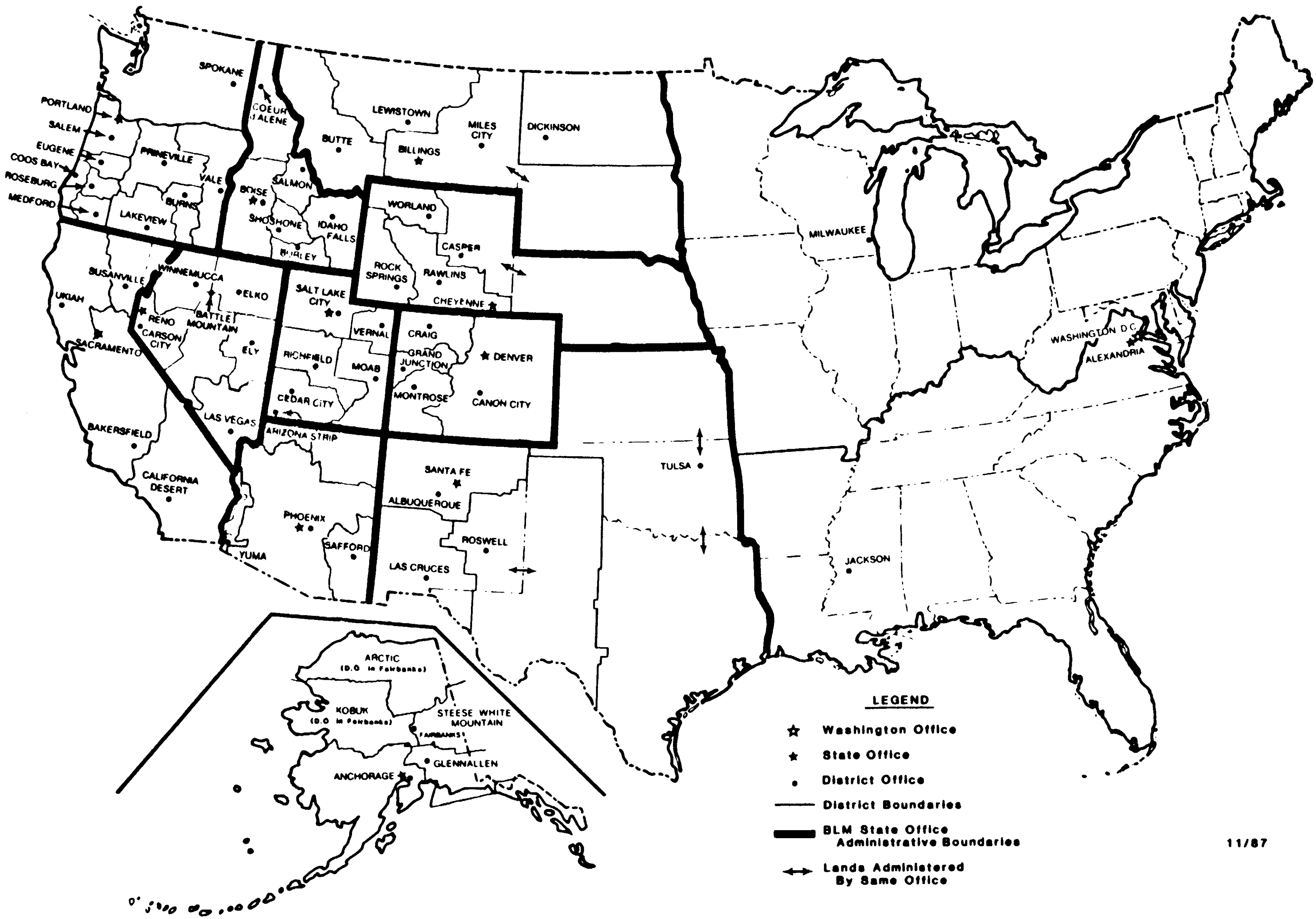


Figure 5. U.S. Bureau of Land Management areas in the conterminous United States.

For many years, mining-claim information has been available at BLM offices on microfiche (see app. 5). The microfiches are organized by Arizona Mining Claim (AMC) serial number, the name of the claim, the name of the claimant, or the geographic location by T/R/S. This record is updated several times per year. There are about 286,000 mining claims in Arizona (fig. 6), of which approximately 148,000 are active. Current information on mining-claim activity is commonly required to make decisions involving land title and resource uses.

Land and mineral information are being automated in the BLM in the Automated Land and Mineral Record System (ALMRS). The Mining Claim Recordation System can now provide current information on mining claims (see app. 5). A serial page can be printed by a specific AMC number; it includes information on the name of the claim, the name of the claimant, the location of the claim, and any actions that have happened on that specific case. A report is also available by T/R/S that includes information on all claims in the specified area and includes the name of the claim, the name of the claimant, the status of the claim (active/closed), the type of claim (placer/lode/millsite), the date of location, and the date of latest assessment. These computer reports, which are current to the previous day's activity, are available at all BLM offices in Arizona.

ARIZONA STATE LAND DEPARTMENT

By G.D. Slusher

State-trust lands cover about 9 million acres, approximately 13 percent of the total acreage within Arizona. The ASLD was established to administer these trust lands and given the responsibility to manage them in a manner that protects the best interests of the trust and its beneficiaries.

One of the primary responsibilities of ASLD is to generate revenues for the trust beneficiaries (primarily schools), through a multiple-land-use policy that involves leasing State-trust lands for mineral, agricultural, grazing, and commercial uses. Sales of State-trust lands through public auction are also an important part of the revenue-generating process.

The ASLD's minerals section is responsible for issuing and administering mineral and mineral-materials leases and sales. Natural resources in Arizona are divided into two categories, locatable and salable. Separate procedures exist for dealing with each group; distinctions are based on the commodity, as well as on its intended use.

Rights to locatable minerals (for example, gold, silver, copper) are mostly obtained through prospecting permits, which give an applicant the right to enter upon State-trust lands and conduct approved exploration activities so as to establish the potential for discovering economic-mineral deposits. Prospecting permits are good for as long as 5 years but are subject to annual renewal. Within this 5-year period, prospecting permits can be converted to mineral leases if substantial evidence supports the potential for economic-mineral discovery.

Mineral materials (common minerals, for example, sand, gravel, clay) fall into the salable category. Rights to these commodities are obtained through the filing of a mineral-materials application. Application can be made for a lease term of as long as 10 years. During the evaluation process, minimum royalties, surface rents, and production guarantees are set. Once the application is approved and its terms accepted by the applicant, a notice of public auction/sale is advertised in two newspapers for 10 consecutive weeks. The highest bidder at the auction is awarded the sales agreement, which confers the right to remove, process, and sell the material products.

Geothermal, energy, timber, and oil and gas resources are another part of the ASLD's natural-resource program.

PARTICIPANTS' DISCUSSIONS OF LAND PROBLEMS

Federal Lands

• How long is it possible to comment on or object to the BLM's land classifications, particularly with respect to potential resources in a WSA?

Reply: Intervention is possible at several points during WSA consideration with the BLM, USGS, and USBM staffs, as well as the congressional delegations. These agencies can also help if it is believed that the future of industrial minerals is being compromised. In addition to BLM/USFS lands (32 million acres, or 44 percent of State acreage), Indian lands make up about 18 million acres, or 25 percent of the State; large additional

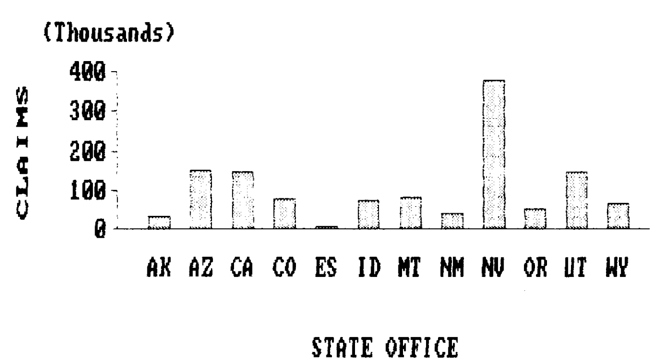


Figure 6. Number of active mining claims in the United States. AK, Alaska; AZ, Arizona; CA, California; CO, Colorado; ES, Eastern States; ID, Idaho; MT, Montana; NM, New Mexico; NV, Nevada; OR, Oregon; UT, Utah; WY, Wyoming.

acreages are devoted to fish and wildlife areas, national parks, and military reservations.

• If someone should ask where the 148,000 claims in the State are located, how they relate to BLM lands, and whether they are associated with industrial minerals or precious metals, how could the question be answered?

Reply: BLM claims records are sorted by T/R/S on microfiche, as well as being stored in the Mining Claims Records data system. This system is interactive: Data can be retrieved by the public. However, the claims are not sorted by mineral-material content. There is no comparable retrieval system for State or Indian lands.

• How can someone get an overview of what are tied up, withdrawn, or allocated to the BLM, national parks, or to military reservations?

Reply: The USBM has a publication that gives this information, but it is a one-shot, dated report. For an up-to-date search, you would have to go to the ASLD, BLM, or BIA individually to find this information.

• How many patents were issued on the 148,000 claims last year?

Reply: Since June 1987, the BLM has granted at least one, but the agency doesn't have many patent applications to consider.

• It is extremely difficult to bring an industrial-mineral deposit to patent because of the need to demonstrate marketability or to show a contract for sales, and so on.

Reply: We recognize that this is a problem, but the BLM has to follow its classification guidelines.

• There was a program for the BLM and ASLD to join their split surface and subsurface estates. Is this program still going on, or is it complete?

Reply: It is still going on. Three-quarters of a million acres of Federal land in the State has been transferred to the ASLD, and the BLM has acquired about 940,000 acres from the State. Land-use planning is being completed in some areas to facilitate the exchange program. It is anticipated that the program will take 2 more years to complete. The BLM also has been negotiating with the Santa Fe Railroad to clean up some of the private minerals under Federal surface, and with the State, so that Federal minerals under the State will become private minerals under the State.

• How are these exchanges made, and what information is used when no data base exists?

Reply: It is difficult to manage a split estate. In spite of the risk of inequality, it is worth the effort to consolidate. From the industry point of view, it is probably better to deal with only one Government land-management agency. Each decision is made on the basis of available information. In the absence of drilling or geochemical data, a decision has to be based on a best professional estimate. The decision is made. There have been no exchanges of lands on which there are mining claims.

• Government agencies have to recognize that a long time may elapse from drilling to production of an industrial-minerals product. This is true for an existing company with marketing know-how and the laboratories to do the required work. For example, in the case of paint pigments, the time is measured in years.

State Lands

• How many lease applications under the State system are awarded to small companies?

Reply: If we consider all the applications received by the ASLD, small companies would account for approximately 15 percent. Only a few large, major producers account for 10 percent of the total applications; the ADT accounts for the other 75 percent.

• Does anyone have the right to go in and test a deposit before it goes to auction?

Reply: We issue rights-of-entry or special-use permits for testing purposes. Most materials testing is for aggregate (sand and gravel). There has not been a lot of interest or demand for other materials, such as building stone, decorative rock, boulders, and so on.

• If a highway is being built somewhere, does the ADT make application for borrow-pit materials for the road?

Reply: They file applications based on an ongoing program to test and identify material resources around the State.

• Does the ADT have an active exploration program for these materials?

Reply: Yes, but major highway projects are contracted out and require the contractor to assure that the materials used meet the prescribed job specifications. The ADT used to specify the material sites to be used. As a result of some litigation, they no longer dictate material sites; however, they continue to acquire material leases.

• Is it true that most industrial minerals on State lands are classified as salable—for example, barite or bentonite, which are not usually considered salable?

Reply: Again, the ASLD determines the appropriate lease for the commodity of interest on the basis of its intended use. For example, a marble used for its chemical properties (cement) would fall under a mineral lease (locatable). However, if the marble is intended to be used for decorative purposes or as decorative stone, it comes under the category of salable materials. So, two opposing, overlapping leases based on the same natural product but with divergent uses are possible.

Geotechnical Research Applications

M.P. Foose, *Moderator*

As was the case for WSA's on Federal lands, the assessment of industrial rock and mineral resources by the USGS in the 1° by 2° quadrangles of the Conterminous United States and Alaska mineral-resource program (CUSMAP, AMRAP) has been a mixed success (Richter and others, 1975; Goldsmith and others, 1986). In part, the unevenness of assessment for industrial minerals was due to the problems peculiar to these commodities. Some of these problems have been considered previously during this workshop. However, some new, developing, and in some cases not fully tested geoscience technology offers methods for improving the resource assessment of industrial materials. The following presentations led to discussion by workshop participants.

Applications of Geophysical Research

By J.K. Crowley

Several advanced geophysical techniques may have applications for industrial-mineral-exploration problems, including gamma-ray spectroscopy, EM systems, and spectral reflectance.

GAMMA-RAY SPECTROSCOPY

Gamma-ray spectroscopy measures the natural radiation emitted by potassium, uranium, and thorium as those atoms decay. A contour map showing gamma-ray emission in Arizona is being compiled by the USGS; it should contain important information. Because the gamma radiation does not penetrate much soil cover, only emissions by surficial deposits are detectable. Contours of K, U, and Th may be displayed singly or in combination. One possible link to industrial minerals might be in detecting rocks that contain zeolites, which commonly concentrate uranium.

ELECTROMAGNETIC SYSTEMS

EM systems include various geophysical techniques that can be either ground based or airborne. In the simplest system, electrodes are placed in the ground, and electrical current is run into the ground through electrodes. Response is measured and recorded from other electrodes at several different spacings to obtain an idea of the resistivity of rock and soil units beneath the surface. *Sounding* looks at the vertical layering beneath the measuring point, whereas *profiling* looks for contrasts along a traverse. *Audiomagnetotellurics* (AMT) is one of the best sounding methods; it is a ground-based system that uses a natural "controlled" source (for example, lightning strikes in the Tropics). These strikes generate low-frequency EM waves. Waves of different frequencies penetrate to varying depths along different paths. These measurements give depth information and indicate areas of differing resistivities. In the Basin and Range province, alluvium is relatively conductive; it generally overlies a more consolidated, less conductive bedrock. Because of this contrast in resistivity, AMT soundings can be used to determine the depth of alluvial cover. One important profiling method uses very low frequency (VLF) EM waves broadcast by powerful radio transmitters. For example, a series of VLF traverses might be used to delineate a clay body surrounded by gravel, where the clay is more conductive than the enclosing material.

SPECTRAL REFLECTANCE

Spectral reflectance of minerals in rocks can be measured with a portable field spectrometer that measures detailed reflectance spectra in the visible and near-infrared wavelength range. Many different minerals can be identified by their reflectance spectra. Calcite and dolomite, for example, can be readily distinguished, and the method is also sensitive to ferric and ferrous iron. Thus, iron impurities in industrial minerals could be detected and, possibly, quantified. Several other industrial minerals have distinctive spectral bands that could be useful in exploration. Many clay minerals are easily distinguished.

Remote-sensing applications of this technique are now available that permit detailed spectra to be obtained from an aircraft scanner. For example, talc-rich soil areas in Montana could be distinguished by using remotely sensed data. Field or airborne measurements can be used to determine mineral distributions and to make rapid estimates of certain impurities. Minerals that are concentrated in soils may provide surface clues to buried deposits.

PARTICIPANTS' DISCUSSIONS OF GEOPHYSICAL RESEARCH

• A Chinese-Russian exploration technique combines EM and conventional geochemical exploration. If you pump electricity into the ground through electrodes, metallic ions migrate to a collector electrode. Metallic ions like zinc and copper, which occur in the rocks between the input and output electrodes, can be moved and collected on the electrodes. The Russians have used large energy input to penetrate hundreds of meters. The Chinese, with smaller portable sources of energy, have been able to replicate the process on a smaller scale. Depending on the polarity of the electrodes, cations or anions can be moved and collected. Sodium, potassium, and lithium should be amenable to this technique. We may need to get geophysicists and geochemists together to look at this method in the Basin and Range province.

• What is the cost per mile for airborne spectral reflectance?

Reply: A commercial airborne high-resolution spectral system, Geophysical Environmental Research, Inc., in New York, charges about $200 per flight kilometer and provides images that cover about a 6-km width. A 1:62,500-scale quadrangle would cost about $34,000. These costs may be coming down.

• Have Landsat TM data (see cover) been used for exploration of industrial minerals?

Reply: Not to my knowledge, but they certainly could be. For hydrothermally altered rocks and associated metallic-mineral deposits, considerable research using TM data has already been done.

• Have geophysical techniques been used for industrial-mineral exploration by industry?

Reply: Yes, seismic techniques have been used with limited success for borates, and gravity and aeromagnetics have been used for determining structures.

• Concerning the possible value of gamma-ray data, K-metasomatism may occur in altered tuff units where high potassium concentrations may be detected. One aspect of the metasomatism is the creation of adularia and the displacement of other elements, such as strontium. During this process, what is lost, and where do they go? Is a strontium deposit the distal product of K-metasomatism whose potential could be predicted from analysis of the potassium gamma-ray map?

• It is sometimes not known beforehand how an EM technique will work in a particular situation. A good approach is just to try several EM methods—for example, to trace a known unit in the subsurface. Clearly, much could be done to test the use of various geophysical methods for industrial-mineral exploration and assessment.

• How much exploration for industrial minerals is going on in Arizona?

Reply: Probably very little at the moment, although there's a bit of secrecy involved in the exploration business. To give an idea of exploration costs, since 1981 one consultant probably has spent or overseen the expenditure of nearly $1 million on clays in Arizona, equivalent to about $150,000 per year for an exploration budget—sufficient for one person plus drilling expenses.

• Regarding the need for improved analytical techniques, spectral-reflectance measurements are excellent for differentiating clay species. At least 100 spectra per day can be recorded without difficulty, making reflectance much faster than X-rays for distinguishing clays. However, spectral reflectance will not measure cation-exchange capacity. I understand that oil companies have used spectral reflectance to study drill cores, probably to assess the type of cement and clay content.

• Could you use low-altitude spectral images to go on a "fishing" expedition over WSA's?

Reply: Possibly, but it would cost money and manpower. Also, deposits sometimes can't be picked up, particularly where there is moderate to heavy vegetation cover. Arizona would be a good place to test the feasibility of spectral data for wilderness assessments, if there were money available to support it.

• The overall conclusion of this discussion was that geophysical exploration technology is mostly only a potential. Applied research to develop and field-test specific methods and to verify their applicability is essential for advancing the exploration state of the art for many industrial minerals, particularly for the large WSA's whose industrial materials heretofore may not been have been adequately assessed. Once these methods are perfected, routine operational costs may not be prohibitive.

Applications of Geochemical Research

GEOCHEMICAL EXPLORATION TECHNOLOGY

By W.E. Dean

I suggest that an understanding of chemical processes in sedimentary environments of ore deposition can enable us to evaluate the resource potential of geologic terranes. This is one of the goals of the USGS Branch of Sedimentary Processes, with which I am associated. In particular, this branch is interested in how various chemical resources accumulate in sedimentary environments. In addressing these issues, we use models of processes and occurrences to attempt to locate where new deposits might be found. The following are some examples of the types of information that can be used in developing geochemical exploration models for some industrial-mineral chemical deposits.

Anoxic basins are my first example. These are of personal interest to me, and I've just spent 3 weeks looking at this environment in the Black Sea. One type of deposit that forms in anoxic basins is bedded phosphates. These deposits develop when phosphorus dissolves in anoxic water and then precipitates where that phosphorus-rich water mixes with overlying or underlying oxygenated waters. Chemically, manganese should behave similarly and thus should also accumulate as bedded deposits near the margins of anoxic zones. Waters in the oxygen-poor zones may be enriched in both phosphate and manganese, and deposits of manganese and phosphorus may form where these waters impinge on overlying or underlying oxygen-rich water. The continental margin of Peru is one area where bedded phosphate deposits of this type occur. Other areas include the Santa Barbara Basin, the Guaymas Basin, the Gulf of California, and the Black Sea.

We decided to test this model in the Black Sea, where the boundary between the oxygenated surface water and anoxic bottom water occurs at about 180 m below sea level. We took a series of core samples along the margin of the Black Sea to find out what happened as the zone of anoxic water migrated upward during postglacial times. Below the surface laminated sedimentary rocks, a zone was observed in which the sediment is enriched in both phosphate and manganese. Manganese appears to be replacing the sediment nearly parallel to stratification, thus forming an incipient bedded manganese deposit. These observations support the model of bedded-manganese-deposit formation.

This model may also partly apply to another type of deposit that is found in modern marine sediment. Bedded barite in organic-carbon-rich, hemipelagic, deep-sea sediment is commonly associated with unconformities on the sea floor and thus seems to be deposited during times of slow sedimentation. Barite also is associated with organic matter and commonly occurs immediately below a black shale. This type of barite seems to be deposited at the contact between a suboxic zone and an anoxic black shale zone within the sediment. Many questions remain about these deposits, such as where the barium source is.

Some of the major resources of Arizona are zeolites, used mainly in pollution control and for agricultural applications. Zeolite minerals form in lacustrine deposits that are rich in volcanic ash. Commonly, these deposits are part of a chemical zonation in this ash. For example, the Jurassic Brushy Basin Shale Member of the Morrison Formation in the Four Corners region contains distinctive zonation of the zeolites clinoptilolite and analcime that are associated with a chemical gradient imposed on the sediment of this formation as it was deposited in a Jurassic lake. Another example is in Lake Tocoba, Calif., where lacustrine tuff deposits contain phillipsite and clinoptilolite formed by chemical zonation within a closed basin in an arid environment. These deposits can be quite thick. The large chabazite deposit at Bowie, in southeastern Arizona, is one of the most economically important zeolite deposits in the United States.

Alteration in arid, closed lacustrine basins may also form lithium minerals. Although spodumene in pegmatites has long been a main source of lithium, the clay mineral hectorite may also be considered a source. It forms in sedimentary, tuffaceous, lacustrine rocks that have been altered by lithium-bearing ground water in a closed basin.

Finally, another geochemical exploration tool for industrial minerals is the use of bromine in an evaporite deposit. This element can be used to locate potash accumulations because the bromine content indicates the salinity of the water that formed a rock-salt deposit. Bromine concentrations in evaporite minerals increase with increasing salinity in the original basin, and thereby point in the direction of possible potash-salt accumulation.

DIRECT GEOCHEMICAL TOOLS FOR INDUSTRIAL-MINERAL EXPLORATION

By P.K. Theobald, Jr.

Over the past 30 years of metallic-mineral exploration, using exploration geochemistry, serendipity has caught up with me enough times that I can make some suggestions for direct exploration possibilities for nonmetallic-mineral materials. One direct geochemical approach is the analysis of near-surface materials, such as rocks, soils, stream sediments, and vegetation, for ore elements or ore-associated elements. A stream collects materials from the soils throughout its drainage basin. The soils are weathered components of bedrock; thus, the stream sediment represents a whole drainage area, whereas the rock sample represents just one spot. If you are examining a large area, it is not possible or economical to collect enough rock samples to represent the whole area. Stream-sediment samples integrate a somewhat larger area and provide an ideal direct chemical measure of what is in that drainage basin. An anomalous stream sediment, for example, may be composed largely of white, angular rhyolitic pebbles in a matrix of coarse wulfenite sand, and may contain as much as 20 weight percent Pb and 7 weight percent Mo.

Barium provides an example of the application of these methods to industrial minerals. Stream sediments from Sonora, Mexico, have a single mode for barium at about 500 ppm. Almost all of that barium is a minor component of a major mineral in the rock system, such as barium in feldspar. In heavy-mineral concentrates from stream sediment, there is one mode at about 1,000 ppm, probably as barium in a mineral like apatite. A second mode is greater than 1 weight percent Ba. The high mode is for barite. White, clean barite occurs in veins and as gangue peripheral to the porphyry systems in northern Sonora. By comparing the barium in stream-sediment samples with the barium in heavy-mineral concentrates, you can distinguish the barium in an economic mineral from the barium in a rock-forming mineral.

In a similar data set from the National Petroleum Reserve in Alaska, the stream sediment has a mode at 500 to 700 ppm Ba that is tied up in feldspars in the clastic sediment. The frequency distribution for stream sediment makes a second mode in the range 1–2 weight percent Ba. Here, heavy-mineral concentrates contain so much barium that the data are of little use. The upper mode in stream-sediment samples, or the barium in heavy-mineral concentrates, is derived from black, fetid (full of organic debris) barite, which smells like an anoxic sediment. There is so much barium that the upper mode is easily seen in the sediment. It has to be derived from a massive source like bedded barite. This is the bedded barite associated with massive sulfide deposits in the Brooks Range. At least for barite, there is a direct geochemical method to distinguish a small amount in hydrothermal veins from the large accumulation that might be an economic barite deposit.

Here in Arizona, using similar techniques, there seems to be a constant association of barium and strontium, although the ratio of the two varies. Among the areas studied in the Ajo 2° sheet is a celestite deposit south of Gila Bend. The same geochemical pattern as seen in Alaska exists, except that it's for strontium. Heavy-mineral concentrates are almost wholly celestite, the strontium analog of barite. At the deposit south of Gila Bend, from descriptions made when the pits were still open, the celestite is associated with gypsum. I've seen this same association, high-celestite concentrates associated with the gypsum in deposits, south of Winkelman, in the San Pedro Valley. As far as I know, no one has found any celestite in these occurrences. In at least two other areas in Arizona, the same association is found in stream sediment. Although there may be only a limited market for celestite, there is a good way to find it.

Biogeochemistry provides another direct geochemical exploration method in an arid environment, such as Arizona. In this environment, ground water is not easily obtained. There is a group of plants called phreatophytes, of which mesquite is the best known. They always have their deep roots tapping ground water directly or the capillary fringe above ground water. In the metallic-minerals area, the Sol deposit (porphyry copper), east of Safford, was discovered on the basis of mesquite through approximately 100 m of transported gravel cover. These methods have not been tested for industrial minerals, but mesquite in Arizona also collects both boron and lithium and gives a direct indication of a source for these elements in the root systems of the plant. If these elements are present in the mesquite but not in the soils or shallow-rooted plants, for example, greasewood, then you know the source has to be at depth. These are only three examples of direct geochemical exploration technology in the search for chemical resources. More examples could be generated if the necessary research were directed toward exploration geochemistry for nonmetallic minerals.

PARTICIPANTS' DISCUSSIONS OF GEOCHEMICAL RESEARCH

• If we look at where we are today and then project 5 to 10 years into the future, what should we be doing to improve our ability to use geochemical and geophysical techniques, to improve our ability to assess industrial mineral resources, and to discover new deposits?

Reply: Both geophysical and geochemical techniques are anomaly generators. An anomaly does not mean that there is a deposit. One in a hundred or one in a thousand anomalies, depending on where you are and what commodity is being looked for, is going to result in something economic. I think we need to develop a better understanding of what anomalies are and what causes them. This may reduce the odds to 1 in 10.

• In that context, do you see a systematic Statewide program of data collection to focus on this assessment?

Reply: In part, yes. There is a larger geochemical data base that is being put on CD ROM. A geochemical atlas of Arizona would be most useful; however, to date we don't have the data base to make one. The existing data base has all of the available geochemical data from Arizona in the USGS system and will be computer accessible. However, you should be careful not to attempt using these data without going to the individuals who collected and entered them. This caution is necessary to find out exactly what the data represent. Each data set must be checked because it was collected for a specific purpose, almost all of which are different (for example, a quadrangle, a wilderness report, or a 2° sheet) The National Uranium Resource Evaluation (NURE) aerorad data were pretty good for a 2° sheet, but there are problems when trying to put these data together for the whole State. Therefore, a geochemical atlas cannot come from the existing raw-data base; there will have to be an interpretative intermediate version.

• One problem with collecting geochemical data on most industrial-mineral commodities is that their chemical breakdown is not readily distinguishable from a normal soil profile. For example, an analysis of silicates and carbonates (unless it's a strontium carbonate) is not going to show many differences. The minerals of economic interest for their physical properties are mostly used because they are inert, nonreactive, and don't contain anything unusual. Maps showing zoning of materials like lithium might be useful as guides to exploration, such as looking for hectorite clays, and mineralogic zoning patterns appear to work better than chemical patterns. Lithium, for example, is not an abundant chemical species. If we can find lithium at all, then we can worry about whether it's in clay or in brine.

A second problem is one of scale. A good-size specialty clay operation might produce 2,500 tons of product per year; a good size limestone operation might produce 15,000 to 20,000 tons per year, or even 250,000 tons per year from a really big one. So, the same cost margins do not exist in these operations as in a 200,000-ton-per-year copper operation.

• Are there any inexpensive techniques that could be used to actually identify the minerals in heavy-mineral, heavy-metal concentrates in stream sediments? For example, in a study of a granite in western Arizona, it was discovered that mineral separates from the rock contained zircon needed for the dating, but the rock also contained twice as much scheelite. This was a new find, in a mountain range in which there is a WSA. It would have been an important contribution if the heavy-mineral samples could have been run through a spectral-analysis system and every 100th grain discovered to be scheelite. Of course, black light would identify the scheelite, but what about other interesting minerals, like kyanite? Would it be possible to automate the procedure, so that kyanite in a USGS stream-sediment sample would be detected?

Reply: If the kyanite is present in an abundance of about 10 percent or more, it can be detected; if only about 1 percent, probably not.

• If we can identify these minerals from space, we ought to be able to do it on the Earth.

Reply: In the USGS laboratory in Denver, we are examining the spectra of a large variety of materials, and we believe that within the not-too-distant future, we will be able to sit across a canyon and shoot the other side and tell not only what is there but also what the grain sizes are. These methods are called inplace measurements. Lots of other techniques are available that we have tested in geochemistry, but we don't use them because they are too costly. For example, much phase chemistry is available, and it is used in such cases as biogeochemical exploration using mesquite, where we do not use standard geochemistry. Such expensive, nonstandard methods also are probably useful for some of the industrial materials, but we have not seen a great demand for such work.

• Part of the answer to the mineralogic problem is that the USGS has only a few persons who know how to analyze minerals routinely. We need to develop a rapid technique for mineralogic analysis, and we can do so if we specify the element to look for. For example, tin in cassiterite can be identified by a spot test after chemical treatment of the grains. By simple solution chemistry of stream-sediment samples, some mineralogic analyses may be possible.

• It might be well to clarify the USGS and USBM roles in resource assessment, particularly with respect to the use of geochemical and geophysical techniques. In previous discussions, a large strontium anomaly would not be considered a resource because no use for it the strontium had been identified. This nomenclature highlights both the role of geochemical exploration and the primary mission of the USGS, which is to search for undiscovered resources. We can define undiscovered resources in many ways, but one way is to call them a geochemical anomaly. One of the things done in land-assessment programs is to find geochemical anomalies and then to consider what they might be caused by and whether or not they may indicate a potential resource. In so doing, the attempt is to shift what is an undiscovered resource into categories that become progressively better identified, first as an inferred resource and ultimately as an identified resource. By the time a resource has become "identified," it is the responsibility of the USBM. Even though we might not know whether something will be useful as a filler or purifier, if it can be identified as an anomalous commodity, we can then begin to consider it a resource. The USBM ultimately will evaluate such factors as minability, processing, quality control, resource specifications, and marketability.

Applications of Geologic Research

Several developments in geologic research provide new tools to help predict regional resource-forming domains and resource distribution in surface and subsurface sediment and igneous rocks. J.C. Dohrenwend describes his studies of basin characteristics in the Great Basin in Nevada, which should lead to a better understanding of potential for concealed deposits. M.F. Sheridan discusses some of the new geologic methods developing at ASU.

CONCEALED RESOURCES IN THE BASIN AND RANGE PROVINCE

By J.C. Dohrenwend

The current emphasis of USGS regional mineral-resource assessment in the Basin and Range province is focused on metallic-mineral resources exposed in the mountain ranges and concealed within the intervening basins of Nevada, but the methodology is equally applicable for use in the assessment of industrial minerals in southern and western Arizona. Two examples of recent research in Nevada include the identification of neotectonic domains and the use of TM.

Neotectonic Domains

Few, if any, areas here or elsewhere in the world are the same geologically, and the various areas of the Basin and Range province in Nevada, southeastern California, and southwestern Arizona illustrate this point rather well. This province can be divided into subregions or areas that I will refer to as neotectonic domains. These domains have histories of basin-and-range development that differ in timing, style, and level of tectonic activity. To demonstrate these differences more formally, regionally consistent geologic mapping of young faults in central and southern Nevada shows that both the density and orientation of these faults vary significantly from one neotectonic domain to another. Also, the timing and level of activity of these faults appear to vary substantially from one domain to another. Not too surprisingly, young-fault density and activity seem to be fundamental determinants of the region's geomorphology. Among the several neotectonic domains, significant correlations exist between young-fault density and various general morphometric parameters (for example, ratios of range relief to total relief, range area to total area, topographic closure of basins). The present configuration of the region probably is largely determined by the high-angle, deeply penetrating style of normal-fault extension and by how active or inactive, how recent, or how ancient this style of deformation has been.

Another neotectonically significant characteristic of the Basin and Range province in Nevada is the distribution of pediments and areas of thin alluvial cover. Mapping at 1:250,000 scale shows significant differences in the size, continuity, distribution, and density of these areas among the various neotectonic domains.

Experimental maps show the general subsurface configuration of the basins throughout this region: These maps combine surficial geologic data about young faults, pediments, and areas of thin alluvial cover with available geophysical and subsurface geologic data, including gravity data (interpreted by a four-layer density gravity model), aeromagnetic data, some limited seismic-reflection-profile data, and well data (oil and gas, geothermal, and water). Using these maps, we can begin to define the three-dimensional subsurface geometry of these basins. We can estimate approximately how deep and continuous they are, and we can now begin to identify the neotectonic and geologic controls on this geometry and thus develop predictive models of basin geometry for other areas.

A typical example of these maps, showing the central and northeastern part of the Tonopah 1° by 2° quadrangle, is figure 7, which shows three large intermountain basins. The westernmost basin, Big Smoky Valley, is a typical asymmetric graben, bounded on the west by the high, young-fault-bounded front of the Toiyabe Range and on the east by the relatively gently west dipping flank of the Toquima Range. The subsurface geometry of this basin reflects these relations: It is deepest near its western margin and progressively shallows toward an area of pediments and thin alluvial cover along its eastern margin. In contrast, the next basin to the east, Monitor Valley, is more of a true graben: Both sides are flanked by high-angle faults. Resources concealed here could lie at considerable depth and would be less accessible than those in the eastern part of Big Smoky Valley. The next basin to the east, Little Fish Lake Valley, is intermediate in style between its two neighbors; its subsurface configuration includes a major fault along its western margin and lesser faults along its eastern margin that are separated by an asymmetric graben. These differences in subsurface geometry are highly significant to mineral-exploration activities in basin areas.

Preliminary results of this work include the observations that: (1) the size, depth, and continuity of the basins decrease markedly toward the margins of individual neotectonic domains; (2) basins within or adjacent to "transverse accommodation zones" (generally east-west trending zones where the overall Tertiary dips of the range blocks systematically change orientation) are generally small, discontinuous, and shallow, even though many basins appear on the surface as broad, continuous alluvial plains; (3) in these broad areas, middle Tertiary volcanic rocks, which are part of the basin fill, commonly lie within a few hundred meters of the surface; and (4) basins within the various domains of the Walker Lane also are generally small, discontinuous, and shallow in the subsurface. All of these shallow-basin areas seem to have considerable promise for concealed mineral resources.

In summary, combination of regional neotectonic and surficial geologic data with available geophysical and subsurface data can provide a first-order approximation of what to expect below the surface of the alluviated basins of the Basin and Range province. Although this type of basin analysis does not apply directly to industrial minerals, it does provide a useful geometric and stratigraphic context for those situations where large volumes of such minerals occurs as basin-fill materials. The three-dimensional geometry and stratigraphy of such basins must be at least approximately defined if we are to have a basis for assessing the resource potential of such commodities as lithium, zeolites, or evaporite deposits.

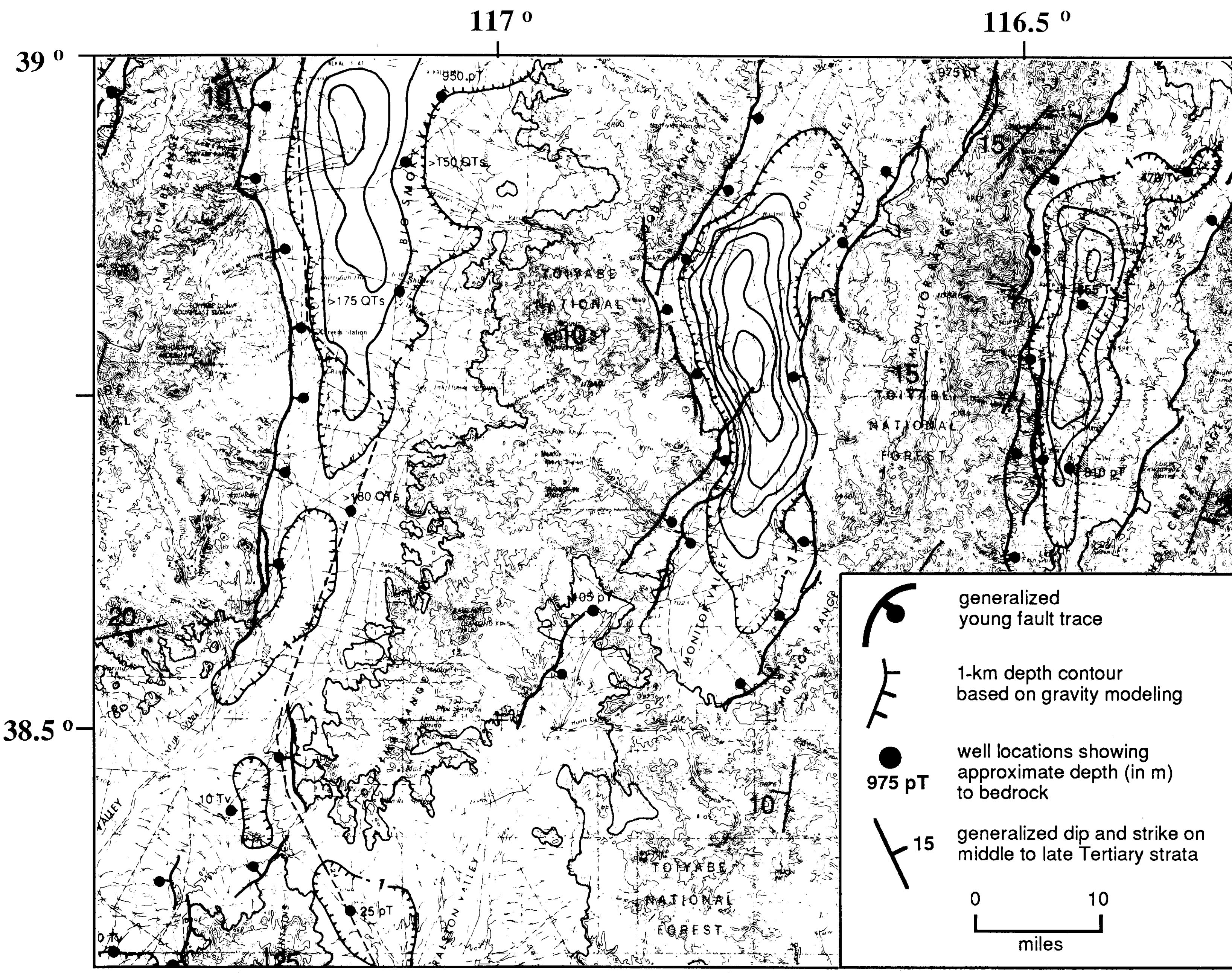


Figure 7. Part of the Tonopah 1° by 2° quadrangle, Nev., showing structural configuration of Big Smoky, Monitor, and Little Fish Lake Valleys.

In Arizona, the AZGS has already developed preliminary regional maps for young faulting and gravity data and a similar type of basin analysis could be conducted for basin-and-range areas in the southwestern part of the State.

Thematic Mapping

Another new technique useful for regional studies of basin and other surficial deposits is the interactive digital analysis of Landsat TM imagery and other similar multispectral-image data (Taranik, 1988). Band-ratioed images (see cover) provide geologists with a new tool to facilitate geologic interpretation and to enhance the mapping process. The potential of such imagery for resource assessment and (or) exploration in piedmont and basin areas should be readily apparent. In the cover, for example, compositionally distinct plumes of surface deposits derived from different source areas can be distinguished within the ranges. This ability provides a means for quickly estimating the general compositions and grain-size characteristics of aggregate materials on piedmont surfaces and thus provides a basis for designing geochemical surveys in basin areas. The image also shows extensive areas with discontinuous pink to violet to light-blue coloration immediately south and southeast of the Gila River flood plain (dark-orange-red area). These areas are veneered by accumulations of eolian dust and calcium carbonate; in this particular image, the more dust, the lighter, and the more calcium carbonate, the bluer the surface appears. Such color variations are common on band-ratioed TM images of arid regions, and they can be used to estimate both the general surficial characteristics and the relative ages of basin and piedmont surfaces. This highly detailed imagery, which is produced from digital data that can be transferred directly to maps without going through any intervening manual manipulations, conjures up all sorts of possibilities for resource research and assessment applications.

NEW SCIENTIFIC AND TECHNICAL DATA USEFUL IN THE DEVELOPMENT OF RESOURCE MATERIALS

By M.F. Sheridan

Improved exploration and development of industrial materials in Arizona must advance on three fronts: (1) improved access to data, (2) use of modern equipment, and (3) development of new theoretical models. Before examining the potential use of new technology in the exploration of volcanic materials, we should consider our present use of existing technology. High technology is currently underused in the exploration of nonmetallic minerals in Arizona, partly because industrial-mineral deposits are very small features on a regional scale. It is doubtful that some of the smaller deposits could be detectable using such standard remote-sensing techniques as Landsat images. Furthermore, the value of industrial materials depends on the use(s) to which they are applied. Because it is difficult to predict which materials will be valuable in the future, exploration and development of resources based on current uses and demands will be flawed. Technology has not been a major factor in the location and development of industrial materials in the past. Given these reservations, let's examine the most useful technologic resources for Arizona in the future.

Centralized Data Base

The highest priority technology for the largest number of people in Arizona will be a uniform data base that is available for easy public use. This data base will require a physical facility for data manipulation and a technical staff to administer it. The compilation of dispersed data sets into a centralized data bank will require a tremendous amount of work and money. Automatic entry and update of spatial data would be preferable to manual entry. An optimum data system for mineral exploration could accept and overlay land and airborne (including spacecraft) geophysical, geochemical, and geologic data.

After the type and format of the data have been selected, the next step will be to choose a system for interrelating and overlaying the various data elements. A good system for the manipulation of this type of data is a GIS. Researchers at ASU have begun development of a GIS termed the AGIS that covers the entire State. Spatial data, such as spacecraft images, can be indexed into the AGIS and combined with other types of geographic data from municipality and county sources, as well as with numerical and tabular data. Using the AGIS, you could draw polygons to query the system for information of various types from specific areas, such as mining districts, river channels, or entire basins. The data could include the types of materials mined, quantity of products, or any other pertinent information. Many of the data that we have discussed thus far in this workshop could be incorporated into the AGIS data base. The AGIS requires a dedicated mainframe-size computer and technical-support personnel. Thus, financial support at the State level will be required to establish a GIS for mineral exploration.

Thematic Mapping

Landsat TM data are especially valuable for mineral exploration. Although hardcopy images are useful, the maximum potential of TM data sets is in conjunction with image-processing facilities, to enhance various bands of the digital data. A few image-processing systems exist at universities, but these systems are expensive (about $100,000) and are currently used to their capacity for funded research projects. An image-processing system should be available at the State level, along with appropriate data sets, for use by the mineral industry. The most important data set for the State to obtain is complete coverage of Arizona by Landsat TM images. These images should be available for viewing by the public and for image processing with the assistance of a technician on a fee basis. This TM data base could be computer-linked to other types of geographic data through a system like the AGIS. Models also could be incorporated into such systems. These data should be brought up to date periodically and archived.

Establishing Resource Criteria

My experience as a consultant on industrial materials (principally volcanic rocks) in Arizona has made me aware of a general misunderstanding of the quality of volcanic materials while they are still in the ground. Legal suits commonly arise over the use of "bad" materials that were bidded on as good materials on the basis of Government-provided specifications. These could be multi-million-dollar suits concerned with an outcrop-level decision. The legal question may be as simple as whether or not the outcrop is a common lava flow or a lava with special industrial characteristics.

We must establish criteria for specifying the quality of volcanic materials. For sand and gravel and similar industrial materials, the deposits and use specifications are adequate, and so "prospectors" can identify good areas to develop. This is not so for volcanic materials. Generally, developers or potential users are unclear what constitutes a "good" lava, a "good" cinder deposit, or a "good" pumice before to removal from its natural environment. We need to establish acceptable criteria for common volcanic materials, so that we can keep the geologist out of court and on the outcrop. A publication that compiles the various types of volcanic materials in Arizona, their physical properties, and their uses would be a step toward solving this problem.

Expanding the Application of Existing Technology

We should also try to find other forms of existing technology that could be useful for exploration of nonmetallic-mineral deposits in Arizona. The most applicable techniques should be rapid and inexpensive. One example of an underutilized technique is SEM. This instrument could be a powerful tool for rapid analysis of industrial materials in the form of grain concentrates or rock slabs. When an object is examined by backscatter electrons, the brightness of the viewed image is proportional to the mean atomic number of the material present. For example, barite would appear bright relative to anhydrite. A heavy-mineral concentrate mounted in epoxy and subjected to backscatter electrons could be analyzed by using a computer program that conducts a modal analysis based on grain brightness (atomic number). This type of analysis could result in an assay, using an appropriate computation. The method is highly reliable, and the costs are comparable to those of assays by other methods. An SEM analysis could also use EDAX in combination with the backscatter data for quantitative chemical analyses of single grains. This technique can be adjusted to determine the proportion of grains with different properties in a sample. Thus, we can obtain an excellent chemical analysis of individual grains, as well as a modal analysis of the minerals present in the entire sample, in a few minutes by the use of this technique.

Exploration Models

Besides new data and new instruments, we must also develop new exploration models. An example of a new model for volcanogenic mineral deposits is the scheme of Burt and Sheridan (1986) for the distribution of lithium, beryllium, uranium, and thorium in relation to fluorine-rich rhyolites. The association of lithium deposits with certain pegmatites is well known, but the close relation of topaz rhyolites, rich in fluorine, with lithophile elements (such as Be, Li, Th, and U) was established only a few years ago. Two localities in Arizona where topaz-bearing rhyolites occur are at Burro Creek and at the south end of the Chiricahua Mountains. Basins adjacent to these mountains have lithium deposits. It is easy to imagine the glass of fluorine-rich rhyolites weathering and devitrifying to release lithium, which migrates to clay zones in the basin. Thus, identifying a specific type of host rock—here, topaz rhyolite—could be used to locate mineral deposits (Be, Li, U, and Th) in various environments near to the source. This study serves as an example of the type of new exploration models that we need to develop and test for other mineral commodities so as to develop new resources in Arizona.

PARTICIPANTS' DISCUSSIONS OF GEOLOGIC RESEARCH

Neotectonic Domains

• How are the maximum depths of basins determined?

Reply: Gravity data indicate depth to well-consolidated basement rocks, which in most places underlies any Tertiary basin fill. In Arizona, we commonly find an upper posttectonic basin fill, which is essentially undeformed, and a lower syntectonic fill and associated volcanic rocks, which typically are well deformed. The same general sequence is observed in

Nevada, and so it is not altogether clear how, quickly and easily, we can come up with closely constrained depths for late Tertiary basins. What we are seeing with the gravity data is the depths of the late Tertiary basins plus something else.

• Are the drill holes superficial?

Reply: Some are, but some of the drill holes go all the way to basement. In areas where we have some control, the basin depths range from less than 1 to as much as 6–7 km. In central Nevada, more than half of the basin fill may be pre-upper Miocene volcanic and sedimentary rocks, and the upper Miocene to Holocene fill may represent less than 30 to 40 percent of the total.

• In seismic profiles, can you distinguish volcanic materials from sedimentary materials that might contain industrial minerals.?

Reply: If you've looked carefully at seismic-reflection profiles, particularly published profiles, there's a good chance you'd agree that this is probably not possible, except, possibly, in situations where reliable logs of wells data are abundant. Without reliable core or well-log data, interpretation of seismic-reflection profiles usually is highly subjective.

Thematic Mapping

• Use of Landsat photos and interpretation of TM data is one of the most positive exploration methods now used by private industry for both industrial minerals and metals.

Comments: We in the USGS wish that we could afford to use TM data more than we currently are able. Since the formation of launching of Eosat, TM data have become too expensive for many research projects. Each pixel in the resolution of TM data represents an area 30 by 30 m. The French SPOT satellite data have a resolution of 10 by 10 m. Planned systems have much higher resolutions that will probably make the TM system obsolete. Let's hope we can afford to use these data as they become available.

• What targets does industry particularly look for in TM data?

Reply: We use TM data to identify a particular type of mineralogy in basins. If you get the right ratio, for example, a pattern for gypsum distribution comes out. If you look at the images from different angles, different structures emerge, and so structural interpretation becomes very useful. On an image-processing machine with an experienced operator, you can flip through ratios rapidly. A combination of ratioed data may bring something out—a rock type, a certain mineral in a formation, or a structure. TM data may be applied to any mineral you might want to look for; it's a matter of experimenting with the ratios of images. The search may not be direct, but indirectly through a combination of structures or rock types. Part of the power of the image-processing technique is the capability for interactive image viewing.

Research activity on remote sensing should place more emphasis on the identification of aggregate resources, particularly those that occur in or near urban areas.

• Can the color variations in volcanic rocks be quantified relative to age?

Reply: Quantification is possible, provided you have good information on the ground. However, a single image covers many thousands of square kilometers, and so collecting ground data can be time consuming and labor intensive.

• What about distinguishing soils?

Reply: This particular type of imagery would have to be modified to enhance more relevant band ratios. With appropriate modifications, useful soil data would be generated.

• Some Landsat processing needs to be taken out of the hands of specialists closely wedded to technology and put in the hands of field geologists. The field persons should be the ones flipping through the imagery and making interpretations. Some of these techniques are no longer state-of-the-art, "black box"-type technology. There is no reason why much of this work can't be done by the exploration geologist with a little orientation training. Indeed, right now it's possible to take subscenes on a PC or other computer and develop a workstation for $12,000 to $15,000 instead of $100,000. Five years from now, it will surely be even less costly. The real problem is the size of the data base. On a big TM image, the user needs 200 to 300 megabytes of storage capacity; however, you can use the subscene technique with present computer capacity. Programs are currently being developed that will vastly streamline computer processing of TM data.

Geographic Information Systems

• The USGS is spending a lot of effort developing GIS technology for such purposes as the National Census and mineral exploration. Techniques are available for overlaying geochemical, geophysical, and geologic data for the Western States and for integrating these data with Landsat TM imagery. Some of this technology ultimately will be available to the Arizona user community in the form of a cooperative facility at the USGS' Tucson office.

• The shortfall in a multidisciplinary interpretation has been the fact that the geologic map is not in digital format. The USGS intends to have all State geologic maps of the Western States on tape, disk, or otherwise within the next 2 years. For example, the geologic map of Arizona (Beikman, 1986) will be completely digitized shortly. In the future, we will take the best available maps, scan them, and store them in digital form, available on request. This capability will be accomplished by 1990, assuming that the necessary level of funding continues.

• We have heard of the anticipated population explosion in Arizona and the increasing demands for industrial minerals expected in the next 5 to 10 years. If this workshop group were to reassemble 5 to 10 years hence, what would we conclude needed to have been done here to anticipate the future demand? First, the USGS, AZGS, USBM, ADMMR, BLM, USFS, and ASLD will need information in a reliable data system. We have already discussed this proposal in several ways, but we may not have addressed both whether we would need to put an integrated data system together and how actually to do it. It seems that at some point we need to start looking at what it takes to put together the data for user groups ranging from land-use planners to geologists and people who are managing specific plots of land. That range touches a GIS, and how to make it work. This project should have a high priority, possibly the subject of another workshop by a similarly representative group of participants.

Conclusions

• Clearly, having a trained person with a professional geologic background included in data analyses adds important additional information and experience to data interpretation and avoids reliance solely on rote data manipulation. Thus, the USGS' role in mineral exploration should include more than finding geochemical anomalies. Professional geologic experience must be involved in evaluating what resources that an anomaly may indicate to be present.

• Industry uses geophysical and geochemical methods, satellite imagery, and data bases. These are exploration tools, but they cannot of themselves find mineral deposits. Such tools help to put the explorationist into the right area, but it still takes trained professionals to make discoveries. The human mind must be involved.

Application of Resource-Occurrence Models

Resource-occurrence models have long been recognized and used informally by geoscientists to categorize and compare ore deposits. The economic-geology literature is replete with models of individual deposits or classes of deposits, such as those by Lindgren (1932), Dolbear (1949), and Ridge (1968). Cox and Singer's (1986) *Mineral Deposit Models* provides a more formal, systematic summary of the various descriptive and grade-tonnage models of ore deposits. Descriptions of two types of current deposit models are included here that may bring the model concept into focus for industrial minerals. Such models may be useful for resource assessment and exploration for industrial rocks and minerals. First, Orris and Bliss' descriptive/statistical model is useful in the systematic characterization of deposits and the resource assessment of larger areas. Second, Nations and Ranney's analysis of the geologic environment of a basin is particularly useful in the exploration for sedimentary-rock types of industrial minerals.

INDUSTRIAL-ROCK- AND MINERAL-RESOURCE-OCCURRENCE MODELS

By G.J. Orris and J.D. Bliss

Introduction

Government-sponsored studies have been evaluating the probable future availability of mineral resources for many decades. Early studies were based on the opinions and experiences of expert economic geologists; more recent studies, especially in the past 20 to 30 years, have become increasingly structured (that is, based on standardized data and rules) and quantitative. Major advances in methodologies to quantitatively assess fuel and metallic-mineral resources have been made, but industrial minerals have been largely ignored in developing these methodologies, and regional assessments have commonly failed to evaluate industrial minerals beyond a few scattered passing comments. For many areas in the United States, the value of industrial-mineral production far exceeds that of metals or fuels, and urbanization has lead to increasing demand and inadequate supplies of so-called common industrial minerals. This situation points to the need and appropriateness for assessment methods in evaluating industrial minerals. This discussion summarizes the current status of some assessment methodologies used in the USGS's Branch of Resource Analysis and the efforts to incorporate an evaluation of industrial minerals into this framework.

Resource Assessments

Mineral-resource assessments are conducted to meet a broad range of needs, including managing of public lands, determining the probable future availability of mineral resources, and planning exploration for undiscovered mineral resources. Mineral-resource assessment involves the overlapping of geology and economics, and it requires an understanding of both. The beginning of and continuing interest in mineral-resource assessment is based on Government requests for guidance on land disposition, particularly in areas of limited exploration and, commonly, those areas in dispute. The U.S. Government requested that the mineral resources in the Boulder Dam area be evaluated (Hewett and others, 1938). Similarly, Allais (1957) was requested by the French Government to evaluate the French Sahara. One of the earliest assignments was in 1846 by the Canadian

Government for William E. Logan to assess the mineral potential of Upper Canada as part of a general geologic survey. This assignment became a foundation for the Geological Survey of Canada (Cargill and Green, 1986).

The beginning of *quantitative* mineral-resource assessment is rooted in the evaluation of petroleum resources (Rice, 1986), an area of study much advanced in comparison with the assessment of methodologies for most nonfuel minerals. A quantitative assessment by Drew and others (1984) gave the undiscovered metallic endowments of Cr_2O_3, Cu, Au, Pb, Mn, Hg, Mo, Ni, Ag, WO_3, and Zn at the 90-, 50-, and 10-percent-confidence levels for undiscovered deposits in USFS wilderness areas in the Pacific Mountain system. Methods of assessing metallic-mineral resources are numerous (Harris and Agterberg, 1981; Singer and Mosier, 1981), reflecting both the range of techniques and the desired end products.

It may be helpful, at the outset, to define some of the underlying terms and concepts used in the following discussion of models. A *model* may be a facsimile in three dimensions (Thrush and others, 1968), a word representation to help visualize what may not be directly observable, or a mathematical description. Models consist of generally applicable, representative, non-site-specific features (Barton, 1986). As modified from Cox and Singer (1986), a *mineral occurrence* is considered to be an unusual concentration of minerals or commodities of economic or scientific interest, without regard to economic potential. A *mineral deposit* is a mineral occurrence of sufficient size, grade, and ore characteristics to have economic potential. An *ore deposit* is a mineral deposit that has been tested and has suitable ore characteristics and accessibility for profitable production.

The Three-Part Method

Models for industrial rocks and minerals are compatible with and based on the three-part assessment method of Singer (1975). Examples of the use of this method are by Richter and others (1975), Eberlein and Menzie (1978), Grybeck and DeYoung (1978), Hudson and DeYoung (1978), Mackevett and others (1978), Hodges and others (1984), and the U.S. Geological Survey and others (1987). In simplified terms, the three-part method includes the following considerations: (1) Areas are delineated according to the type of deposits permitted by the geology, (2) the amount of metals and some ore characteristics are estimated by means of grade-tonnage models (to be defined later), and (3) the number of undiscovered deposits of each type within delineated area(s) is estimated.

Models Applicable to Industrial Minerals

A key concept in the three-part assessment method is definition of the mineral-deposit type. In their summary of deposit models, Cox and Singer (1986) defined "deposit type" as consisting of several deposits "sharing a relative wide variety and large number of attributes." The systematically arranged shared attributes that represent a deposit type compose the *descriptive model* (Barton, 1986). An important contribution provided by a well-tailored descriptive model is the distinction of essential shared features from incidental accessory features that may not be present in all such deposits (Barton, 1986). Cox and Singer (1986) also noted that these models should highlight the more descriptive aspects of deposits to help users to recognize the deposit types.

The format of a descriptive model consists of two parts (Cox and Singer, 1986), the regional geologic environment of the deposit and the deposit characteristics. Subheadings of the geologic environment include rock type, texture, age range, depositional environment, tectonic setting, and associated deposit types. The deposit description includes mineralogy, texture, structure, ore control, weathering, geochemical signature, and examples of typical deposits. Information in descriptive models for industrial-mineral deposits is largely identical to that for metallic-mineral-deposit types. Of the 85 descriptive models presented by Cox and Singer (1986), 12 are for deposits of nonmetallic- and (or) industrial-mineral commodities, as defined by Harben and Bates (1984), including bedded barite (Orris, 1986a), diamond placers (Cox, 1986b), carbonate-hosted asbestos (Wrucke and Shride, 1986), serpentine-hosted asbestos (Page, 1986), laterite-type bauxite deposits (Patterson, 1986b), karst-type bauxite deposits (Patterson, 1986a), shoreline Ti (Force, 1986), warm-current-type phosphate deposits (Mosier, 1986a), upwelling-type phosphate deposits (Mosier, 1986b), diamond pipes (Cox, 1986a), and podiform chromite (Albers, 1986). Mosier and Page (1988) recently modified an older descriptive model for volcanogenic Mn (Koski, 1986), expanding it to include the Franciscan, Cuban, Olympic Peninsulan, and Cyprian deposit types. An example of a descriptive model for bedded barite is shown in figure 8. Current developments of descriptive models for industrial materials attempt to identify differences in the chemical and (or) physical properties of a commodity from one deposit to the next, which materially affect its application. Economic limitations play a larger role in industrial minerals and are part of the descriptive models.

For metals, *grade-tonnage models* are used to describe the economic characteristics of the ores. Ideally, the data used in grade-tonnage models should be premining grade and tonnage (Cox and Singer, 1986); tonnages are associated with the lowest cutoff grade used.

The models are displayed graphically, with grade or tonnage plotted against cumulative proportion of deposits. These models show the frequency distribution of grade and tonnage. Individual values are shown as points, or as a number if deposits overlap. Curves are plotted through the points, and the intercepts of the 90-, 50-, and 10-percent-confidence levels are given. The total number of deposits is given in the upper right corner of the diagram (in our examples). Correlations among grades and between grade and tonnage are reported only when significant at the 1-percent-confidence level (Cox and Singer, 1986). Each grade-tonnage model is applicable to the population of deposits defined by the descriptive model. Examples of a grade-tonnage model for bedded barite are shown in figure 9. Grades and tonnages can commonly be described by using a statistical distribution—most often, a log-normal distribution, although a small percentage of grade-tonnage models do not exhibit a log-normal distribution. Of the 60 grade-tonnage models presented by Cox and Singer (1986), 10 are for deposit types that represent nonmetallic-mineral commodities. These models accompany the descriptive deposits listed earlier, except that no grade-tonnage models were published for diamond placers, diamond pipes, and carbonate-hosted asbestos.

Most grade-tonnage models with log-normal distributions exhibit a characteristic inverted-S-shaped curve. The curves for commodities with grades approaching 100 percent may be truncated concave to the left, such as for

Model 31b

DESCRIPTIVE MODEL OF BEDDED BARITE

By Greta J. Orris

APPROXIMATE SYNONYM Stratiform barite.

DESCRIPTION Stratiform deposits of barite interbedded with dark-colored cherty and calcareous sedimentary rocks.

GEOLOGICAL ENVIRONMENT

Rock Types Generally dark-colored chert, shale, mudstone, limestone, or dolostone. Also with quartzite, argillite, and greenstone.

Age Range Proterozoic and Paleozoic.

Depositional Environment Epicratonic marine basins or embayments (often with smaller local restricted basins).

Tectonic Setting(s) Some deposits associated with hinge zones controlled by synsedimentary faults.

Associated Deposit Types Sedimentary exhalative Zn-Pb (see fig. 158).

DEPOSIT DESCRIPTION

Mineralogy Barite ± minor witherite ± minor pyrite, galena, or sphalerite. Barite typically contains several percent organic matter plus some H_2S in fluid inclusions.

Texture/Structure Stratiform, commonly lensoid to poddy; ore laminated to massive with associated layers of barite nodules or rosettes; barite may exhibit primary sedimentary features. Small country rock inclusions may show partial replacement by barite.

Alteration Secondary barite veining; weak to moderate sericitization has been reported in or near some deposits in Nevada.

Ore Controls Deposits are localized in second- and third-order basins.

Weathering Indistinct, generally resembling limestone or dolostone; occasionally weathered-out rosettes or nodules.

Geochemical Signature Ba; where peripheral to sediment-hosted Zn-Pb, may have lateral (Cu)-Pb-Zn-Ba zoning or regional manganese haloes. High organic C content.

EXAMPLES

Meggen, GRMY	(Krebs, 1981)
Magnet Cove, USAR	(Scull, 1958)
Northumberland, USNV	(Shawe and others, 1969)

Figure 8. Descriptive model for bedded barite deposits (from Orris, 1986a).

barite (fig. 9) and glass sand, as well as for other industrial commodities that commonly occur in high-grade (more than 90 percent) deposits. Grade-tonnage models prove useful for some, but not all, industrial commodities.

Grade-tonnage models are useful in differentiating two graphite deposit types (figs. 10*A*, 10*B*), disseminated-flake graphite and amorphous graphite (J.D. Bliss and D.M. Sutphin, unpub. data, 1989). Although the grades of these two deposit types differ, the tonnages are

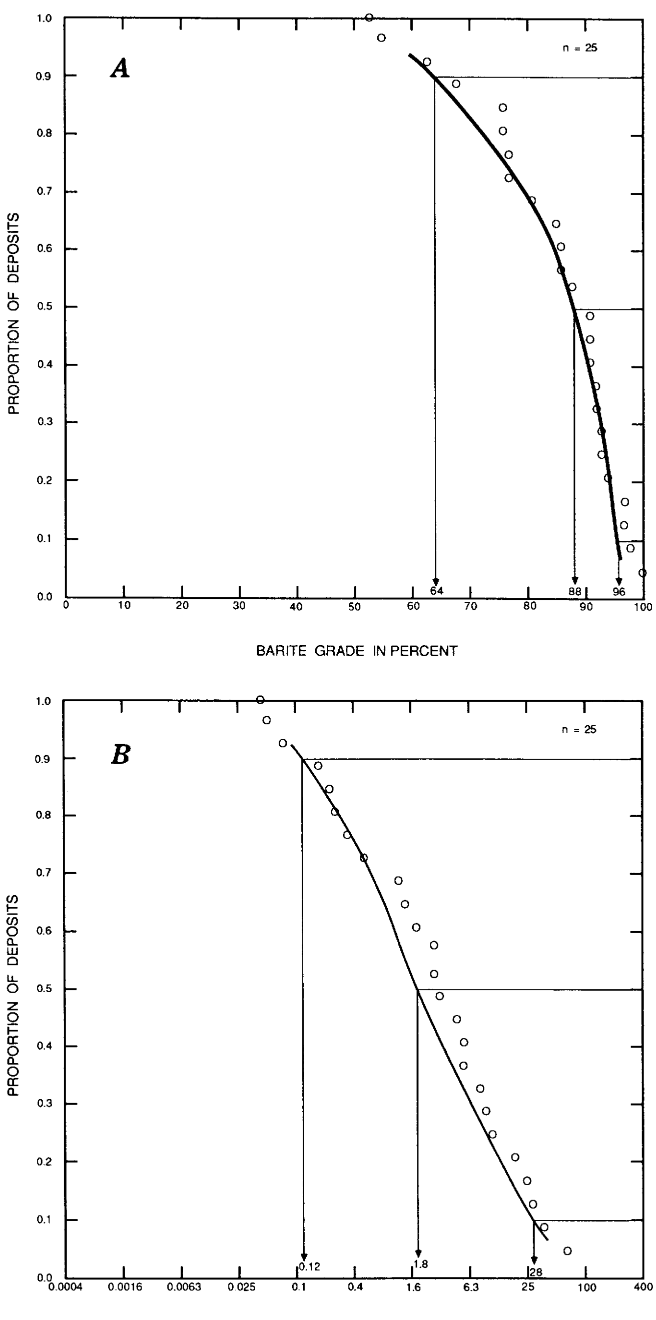


Figure 9. Grade (*A*)-tonnage (*B*) model for bedded barite deposits (from Orris, 1986a).

similar, and their carbon contents are essentially the same (fig. 10*C*).

For some industrial minerals, grades are not applicable; the only requirement is that the material meet some minimum level of purity. These types of industrial-mineral deposits can be best modeled by using their material contents. Two *contained-materials models* developed to date include one for feldspar in pegmatites (fig. 11) and one for travertine deposits along streams in Virginia (fig. 12). Contained-materials models will probably be developed for several industrial minerals. Even diamonds in placers are best modeled by using such a model (fig. 13).

For materials that are required to be of high purity, the distribution of impurities becomes critically important. These minor constituents can be modeled in the same way as in a grade-tonnage model, except that here it is an *impurity model.* These types of models describe such impurities as iron or aluminum distributed in glass-sand deposits in Canada that may affect utilization of the commodity.

Although various model types are available to describe the quality of materials from industrial-mineral deposits, model development can be complex and is not always successful. One example of a particularly difficult problem involves diamond kimberlites. Diamonds mined from these deposits are always a mixture of two commodities—industrial diamonds and gem stones. The value of the gem stones is potentially orders of magnitude higher than that of the industrial diamonds. Here, *deposit-specific models* need to be developed to determine the proportions of diamonds that consist of gem stone, the average size of the stones, and the distribution of diamonds within the deposit.

Model development is plagued by several problems, including size biasing (that is, only larger deposits are used), which can be due to several causes, including incomplete reporting or truncation due to economics. Reliable models are more likely if based on data from more deposits. To meet the need to develop these models, a data base describing grade, tonnage, and other attributes in 2,000 and 3,000 industrial-mineral deposits is under development. In addition to the models already published, about 50 grade-tonnage, descriptive, and related models have been or are in preparation for about 29 industrial commodities.

Spatial Models

All the model types identified up to this point have been concerned, in the broadest sense, with the characteristics of the ore. To make a mineral-resource assessment, however, an estimate of the number of undiscovered deposits is needed (see preceding section). This is one of the most difficult tasks for the economic geologist. To provide assistance in this area, *spatial models* need to be available. Both the development and use of spatial models need to be consistent with deposit type (as described by a descriptive model) and with ore characteristics (as described by a grade-tonnage model, contained-materials model, impurity model, and (or) deposit-specific model). Spatial models are just beginning to be developed for metallic-mineral deposits. To develop this type of model, first, well-explored areas that contain a specific deposit type need to be identified; it must be assumed that all deposits have been found. Second, the area must be delineated, using rules based on geologic and other criteria that can be applied elsewhere. Such criteria might include lithology, stratigraphy, metamorphic grade, and intrusive-rock types, among others. Given the number of deposits and the size of the permissible area, a mineral-deposit density can be computed (expressed in number of deposits per square kilometer). Example calculations are in Bliss and others (1987) and Mosier and Page (1988). Given deposits within a well-explored area, not only can deposit density be calculated, but also discrete distributions can be fitted. To date, most distributions seem to be best described by a Poisson or negative-binomial distribution. For bedded barite deposits in Nevada, the Devonian Slaven Chert has a density of 74 $\times$ 10^{-3} deposits/km^2, best described by a Poisson distribution (fig. 14).

Spatial models are sensitive to both the scale and level of reporting in a target area. With better information, several spatial models may be applicable to the same deposit type where areas are nested. An example of a *nested spatial model* is for magnesite deposits in California. Soil maps developed by the USDA for an area in two counties in central California allow an additional 90-percent reduction in the area defined as permissible for magnesite on the basis of host geology—a substantial decrease in the area to be searched!

Summary

Work is underway to develop models for industrial-mineral deposits for use in the three-part method of

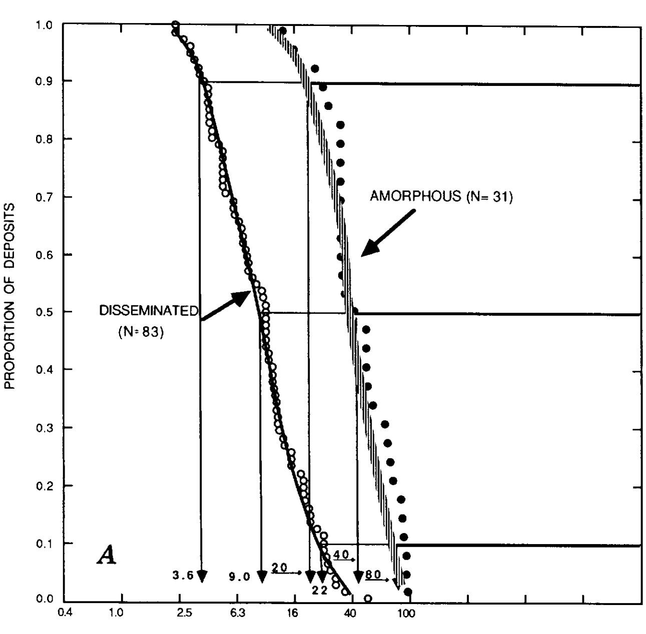
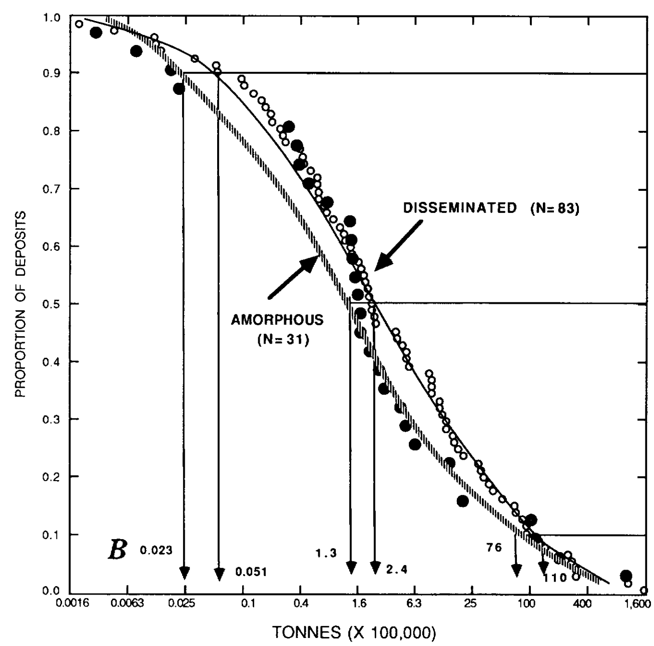


Figure 10. Grade and tonnage models. *A*, Grades in disseminated and amorphous graphite deposits. *B*, Tonnages in disseminated and amorphous graphite deposits. *C*, Tonnages of contained carbon in disseminated and amorphous graphite deposits (from J.D. Bliss and D.M. Sutphin, unpub. data, 1988).



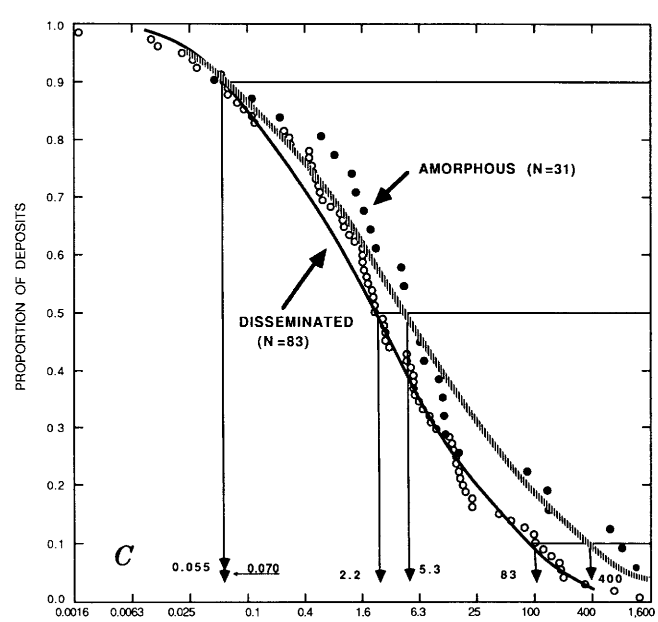


Figure 10.—Continued.

mineral-resource assessment. Descriptive models are needed for step 1; grade-tonnage, contained-materials, impurity, and deposit-specific models for step 2; and spatial models for step 3. Although we have focused on the models used in assessment, we recognize a continuing need to conduct research in deposit genetics, as well as the role the exploration model plays in the successful search for undiscovered deposits of industrial minerals. Nevertheless, we expect that the models we already have and hope to develop will contribute to the needs of those making quantitative mineral-resource assessments, as well as to our understanding of deposit genetics, as they already have for some metallic-mineral-deposit types.

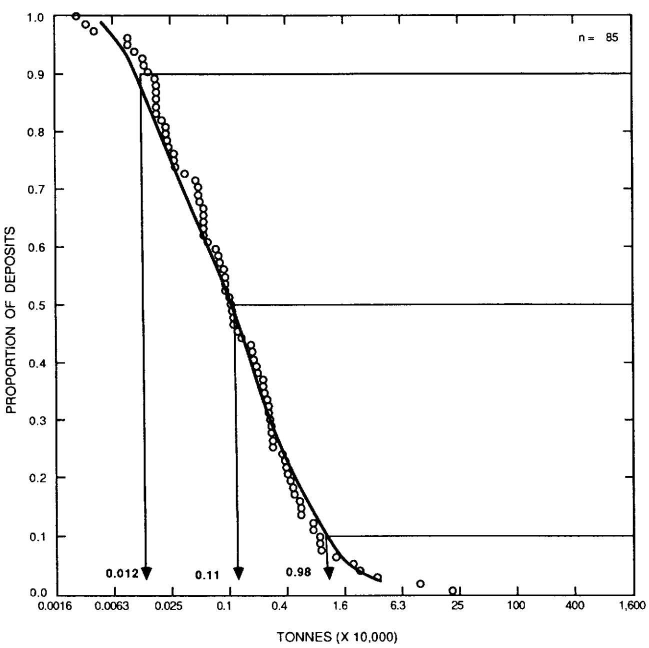


Figure 11. Contained-materials model for feldspar in pegmatite deposits.

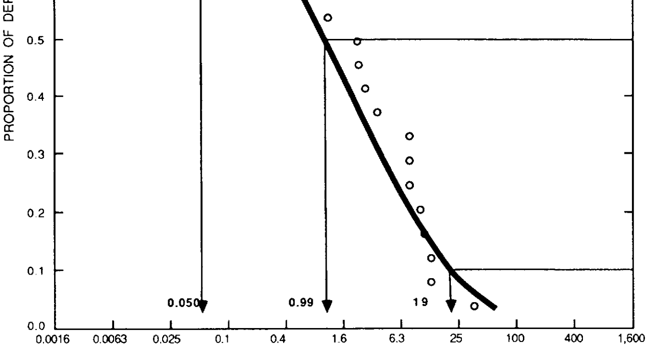


Figure 12. Contained-materials model for travertine-marl in deposits along streams in Virginia.

GEOLOGIC MODEL OF A CENOZOIC BASIN IN ARIZONA

By J.D. Nations and W.D.R. Ranney

The Cenozoic basins of Arizona are the sites for various industrial minerals. One of these basins, the Verde Basin, illustrates of the geometry and facies relations that help to explain and predict the occurrence of

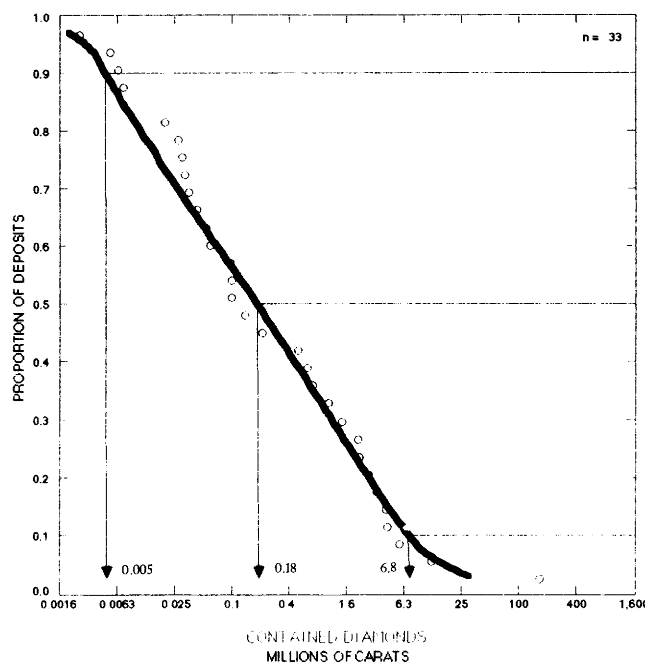


Figure 13. Contained-materials model for carats of diamonds in diamond placers.

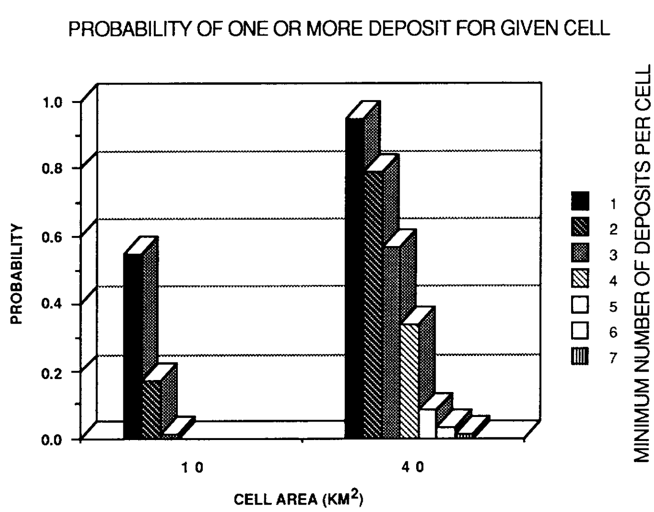


Figure 14. Spatial model for bedded barite in the Slaven Chert, given tracts (cells) of 10 and 40 km^2.

industrial minerals. Geologists familiar with the distribution of Cenozoic rocks in Arizona will recognize that most Cenozoic rocks occur mostly in present-day topographic basins. Earlier, Tertiary rocks deposited on the Colorado Plateaus, at the base of the Mogollon Rim in the transition zone, and in the Basin and Range province do not conform to present-day topography. This occurrence reflects their deposition before basin-and-range disturbance, which is responsible for most of the modern topographic features on the landscape. These topographic basins are visible on a physiographic map (fig. 15). Most of the Cenozoic stratigraphic units occur in the Basin and Range province, some in the transition zone, and a few on the Colorado Plateaus. In cross section, the age distribution of the rocks illustrates a pattern that is controlled by the tectonic evolution of Arizona. The earliest Tertiary sedimentary rocks on the Colorado Plateaus are of Eocene age. Most of the Cenozoic deposits in the Basin and Range province young from southeast to northwest and into the transition zone (fig. 16). The ages are based on radiometric and paleontologic data or stratigraphic correlations for various Tertiary sedimentary rocks in basins.

The Verde and Tonto Basins (fig. 15) are mid-Tertiary extensional basins that contain diverse types of basin-fill sedimentary rocks. Exposure of the sedimentary rocks in these basins by dissection allows stratigraphic and paleoecologic analysis and the construction of depositional models that may be useful for predicting the composition of poorly dissected basins in the rest of the Basin and Range province. The erosional dissection of basins in the transition zone was a response to lowering of the base level, probably by the opening of the Gulf of California, about 5 to 6 Ma. Headward erosion, after this event, eventually caused the dissection of the Tertiary basins at higher elevations in the transition zone. During and after basin-and-range extension, the Verde Basin was filled by sediment of the Verde Formation, which ranges in age from about 8 Ma (Lewis, 1983) to about 2 Ma (Lindsay and others, 1975).

The long axis of the Verde Basin trends northwest-southeast, parallel to the structural grain developed during the basin-and-range disturbance in the Western United States (fig. 17). Protolithic sediment of the Verde Formation filled this basin to about 4,600 ft above sea level, on the basis of their present elevation. Much of the Verde Formation is exposed along the Verde River, where it has been eroded to a depth of about 1,600 ft. Erosion probably began in the early Pleistocene, because the youngest lacustrine sedimentary rocks are of Blancan age, on the basis of fossils of land mammals (Lindsay and others, 1975). Volcanic rocks in the south end of the basin are part of the Hackberry Mountain volcanic field, which functioned, to some extent, as a dam at the south end of the basin because volcanism coincided with subsidence and sedimentation. The bounding surfaces along the eastern margin of the basin, where the Verde Formation overlaps the base of the Mogollon Rim, are primarily topographic. In the vicinity of Sedona, the Verde Formation apparently was deposited on an extensive pediment eroded down to the Permian red beds during the development of the Colorado Plateaus escarpment. The Verde also overlaps remnants of earlier Tertiary sedimentary and volcanic rocks. The western margin of the basin is formed by the Black Hills. North of Jerome, the Verde Formation overlaps folded Pennsylvanian to Permian red beds, and to the southeast, in the vicinity of Camp Verde, Ariz., it has a fault contact and exhibits drag folding, dipping as much as 45° into the basin. The basin margins are structurally controlled on the west. The rocks beneath the Verde Formation range in age throughout the Basin and Range province from Proterozoic to Miocene, depending on the amount of erosion that had occurred before subsidence.

The timing of subsidence is known because the youngest volcanic rocks of the Hackberry Mountain volcanic field and the Hickey Formation, which underlie much of the basin, are about 10 Ma old. They have been displaced downward by the Verde fault from the top of the Black Hills to the bottom of the valley—a throw of as much as 6,000 ft between Jerome and Cottonwood. Movement on this fault was apparently intermittent during deposition of the Verde Formation.

Along the eastern margin of the basin, fine clastic and carbonate sediment was deposited against Permian red beds on the plateau escarpment. Generally, the facies relations in the Verde Basin are typical of those of an internally drained basin, with coarse clastic materials near the margins, finer clastic materials toward the center, and mudstones and carbonates in the center of the basin (fig. 17). Evaporites are concentrated in the southeast end of the basin near the Verde fault and the Hackberry Mountain volcanic center. Carbonate content generally increases in the upper (Pliocene) part of the Verde Formation.

Coarse-grained clastic near-shore facies are interbedded with lacustrine facies in many places but are most abundant along the western margin of the basin. Vertical variation in the coarseness of the clastic materials suggests that movement along the Verde fault was episodic. The Verde Formation is thickest near the faulted western margin and fines upward in the section. Carbonate content generally increases upward through interbedded red sand, silt, and limestone, and culminates in thick lacustrine limestone in the upper third of the basin fill. Near the northwest end of the Verde Basin, a 4.5-Ma lava flow is interbedded with Verde Formation near the base of an 800-ft-thick section. A vertebrate locality at the top of this section indicates a Blancan age of approximately 2 Ma. These and other dated interbedded lava flows and fossil occurrences provide a reasonably well documented chronology within the Verde Basin.

Distally from the shoreline, silt- and sand-size fluvial and lacustrine sedimentary deposits increase in abundance. Carbonate sedimentary rocks increase in abundance toward the center of the basin, where they form massive limestone deposits. Massive carbonates toward the center of the basin are commonly composed of highly porous travertine or tufa. South of Camp Verde, Ariz., a thick mudstone sequence was deposited; these

Figure 15. Physiographic diagram of Arizona, showing Miocene to Holocene topographic features, major drainages, and locations of major cities (modified from Smiley and others, 1984).

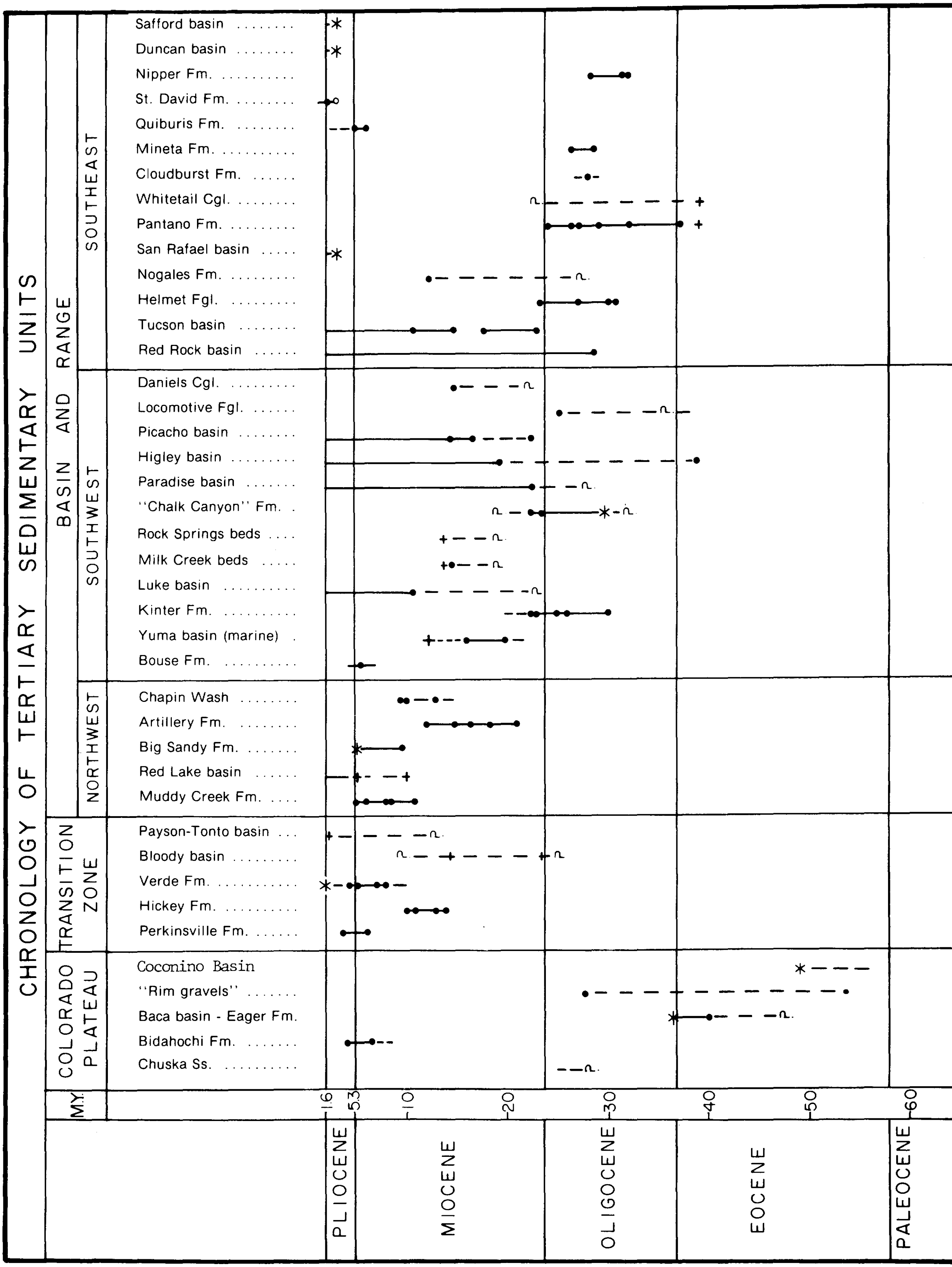


Figure 16. Chronology of Tertiary rocks in Arizona. •, K-Ar ages; *, fossil correlations (ages); +, lithologic correlations (after Nations, 1984).

clay beds are contorted by slumping, and scour-and-fill structures are common.

Environmental indicators in the Verde Formation signify a dominantly lacustrine environment, but fossils of aquatic plant and elephant tracks are also found, probably indicating a marshy area rather than a deep lake. Farther to the south, near the Hackberry Mountain volcanic center, the mudstones are interbedded with gypsum and halite. South of Camp Verde, the gypsum currently is being mined, and halite was mined by the prehistoric inhabitants of Verde Valley. Thick deposits of halite and other more exotic evaporite minerals have also been identified—thenardite, glauberite, and others. The localization of evaporites in the southeast end of the basin suggests that it was the topographically lowest area during deposition and that evaporation occurred there during times of low water level. Common deformation of these mudstones and evaporites adjacent to the Verde fault indicates that movement on the fault system continued after they were deposited during the late Miocene.

A model based on measured sections and subsurface data indicates that the Verde Formation rests on Paleozoic strata and Tertiary volcanic rocks and has a total thickness of approximately 3,000 ft. Fossil occurrences and radiometric ages on interbedded lava flows provide chronologic control for a stratigraphic analysis of the Verde Formation. Interbedded lavas near the eastern margin of the Verde Basin are dated at about 5 Ma, which is the boundary between the Miocene and Pliocene. Restoration of the Verde Formation indicates that the uppermost beds were deposited about 4,600 ft above sea level, on the basis of their present elevation, and included lacustrine sedimentary deposits (carbonates and fine-grained clastic materials), coarse-grained marginal facies, evaporites, and interbedded volcanic rocks. The Verde sedimentary rocks overlap the Paleozoic erosional surface to the north, abut the Verde fault to the west, and are interbedded with volcanic rocks to the south. A generalized axial cross section shows the lithofacies within the basin (fig. 18). A cross section normal to the axis shows the distribution of these facies across the basin (fig. 19).

In contrast, the Tonto Basin, 60 mi southeast of the Verde Basin (fig. 15), is filled primarily with mud. Coarse-grained debris flows preceded deposition of much in the basin center and are laterally equivalent along its margins (fig. 20). Only minor amounts of carbonate rocks or evaporites are present. Basin subsidence also occurred earlier than in the Verde Basin, with initiation of basin filling about 19 Ma.

To use such models for mineral-resource prediction, the explorationist needs to understand the facies distributions in greater detail. Nevertheless, this brief analysis demonstrates that such basin models can be constructed and used for the prediction of the occurrence of some types of sedimentary resources.

PARTICIPANTS' DISCUSSIONS OF RESOURCE MODELS

Resource-Occurrence Models

• Both academic and USGS constituencies recognize the importance of ore-deposit models and model development for resource assessment. Does industry recognize this technology as an important part of their exploration program? More to the point, is this an area of interest in which more communication between industry, academia, and the USGS could provide constructive criticism and collaboration?

Reply: Models are important tools for the minerals industry, and they are avidly examined as they are published. Industry, however, is not likely to contribute their own ideas on the subject because of proprietary interests.Somehow, in the near future, there should be an attempt to correct this unfortunate situation.

• How are models used (if at all) by other Government agencies or industry exploration groups?

Reply: Models are useful in that they can be tested!

• The USGS and USBM have a program of resource assessment and appraisal mandated by their organic acts. To accomplish this program, they need some mechanism by which information from a piece of geography can be put together with information from

Index of Measured Sections Shown in Figures 17, 18, 19

Section Number	
1.	House Mountain. Section measured by Twenter and Metzger (1962); and Nations (1974); NE 1/4, sec.. 4, T. 15 N., R. 5 E. to NE 1/4, sec. 29, T. 16 N., R. 5 E. Fossil localities: NAU 42, 71, 43, 44, 45.
2.	Sedona Interchange. Section measured by Nations and others (1981); NW1/4, sec. 20, T. 15 N., R. 6 E. Fossil locality: NAU 30.
3.	Hog Canyon. Section measured by Nations and others (1981); SE 1/4, T. 15 N., R. 5 E.
4.	Wet Beaver Creek. Section measured by Twenter and Metzger (1962); SE 1/4, sec. 17, T. 14 N., R. 5 E.
5.	Camp Verde north. Section measured by Twenter and Metzger (1962); NE 1/4, sec. 32, to NE 1/4, sec. 32, to NE 1/4, sec. 28, T. 14 N., R. 5 E.
6.	Camp Verde south. Section measured by Twenter and Metzger (1962); SE 1/4, sec. 1, to NW 1/4, sec. 1, T. 13 N., R. 5 E.
7.	Clear Creek. Section measured by Bressler and Butler (1978); sec. 12, T. 13 N., R. 5 E.
8.	Arizona Verde #1 oil test. NW 1/4, sec. 14, T. 13 N., R. 5 E. Lithologic data based on generalized sample log in Arizona Oil and Gas Conservation Commission files.
9.	Wingfield Mesa. Section measured by Twenter and Metzger (1962); NW 1/4 sec. 1, T. 12 N., R. 5 E. to SW 1/4, sec. 25, T. 13 N., R. 5 E.
10.	Hackberry Mountain-Verde River composite section. Section measured by McKee and Elston (1980), from Cottonwood Wash to Hackberry Mountain, approximately from SW 1/4, sec. 36, T. 13 N., RF. 5 E. to sec. 18, T. 12 N., R. 6 E.
11.	Minter Wash. Section measured by Twenter and Metzger (1962); SW 1/4; sec. 2, T. 14 N., R. 4 E.
12.	Arizona Verde #72-3 stratigraphic test hole; sec. 9, T. 15 N., R. 3 E.
13.	Clarkdale. Section measured by Cassell (1980); SE 1/4 to NE 1/4, sec. 7, T. 16 N., R. 3 E. Fossil localities: NAU 75 (=MNA 181).
14.	Buckboard Wash. Section measured by Nations and others (1981); SW 1/4, sec. 25, T. 17 N., R. 3 E., to NW 1/4, sec. 9, T. 16 N., R. 3 E. Fossil localities: NAU 28, 74, 33, 34, 35, 36, 37 73, 40, 38, 39, 41.
15.	Anderson Butte. Section measured by Twenter and Metzger (1962); NW 1/4, sec. 17, T. 17 N., R. 4 E.

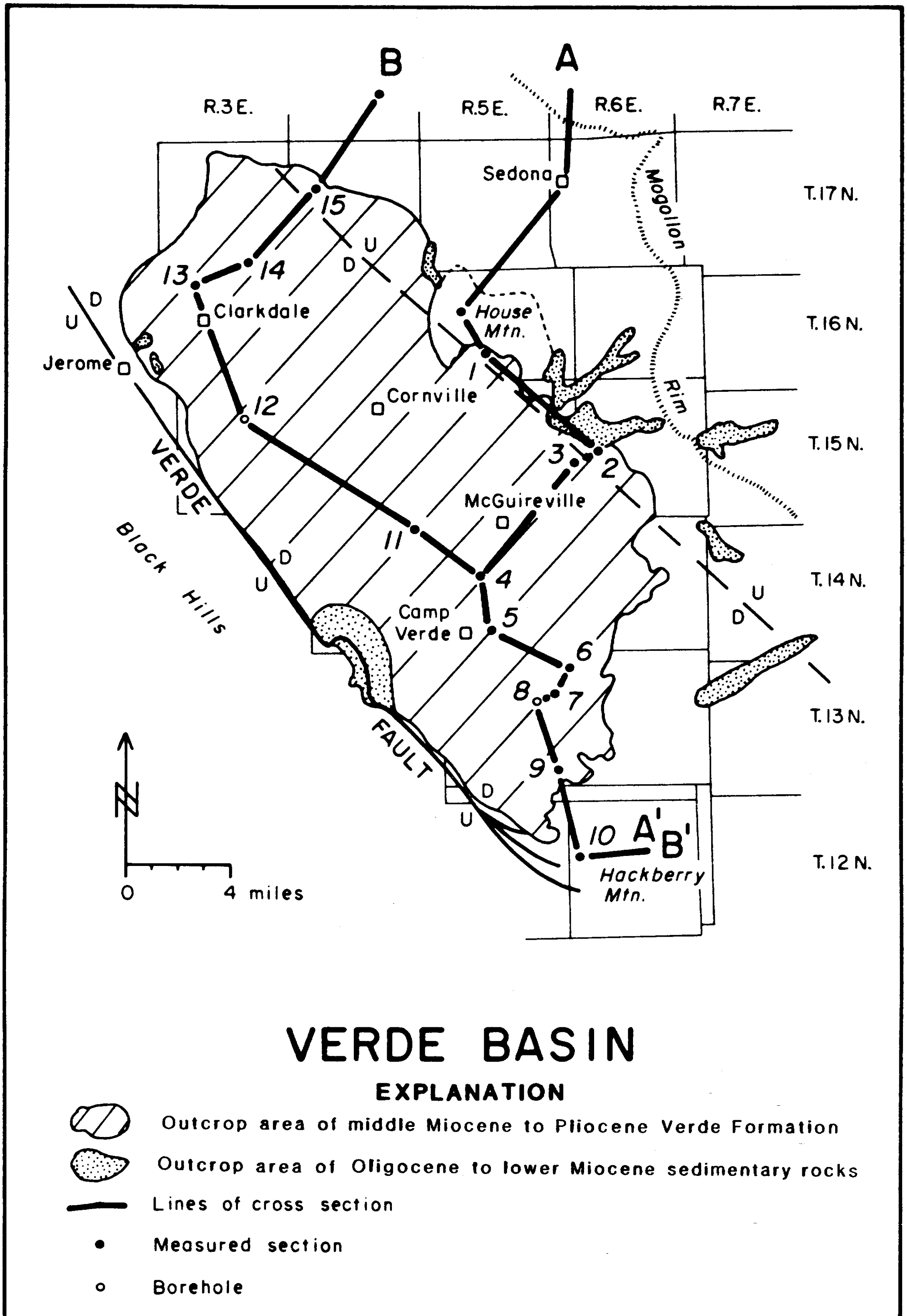


Figure 17. Generalized geologic map of Verde Valley, showing outcrop limits of the Miocene to Pliocene Verde Formation and Tertiary sedimentary rocks older than the Verde, and lines of cross sections *A–A′* (fig. 19) and *B–B′* (fig. 18).

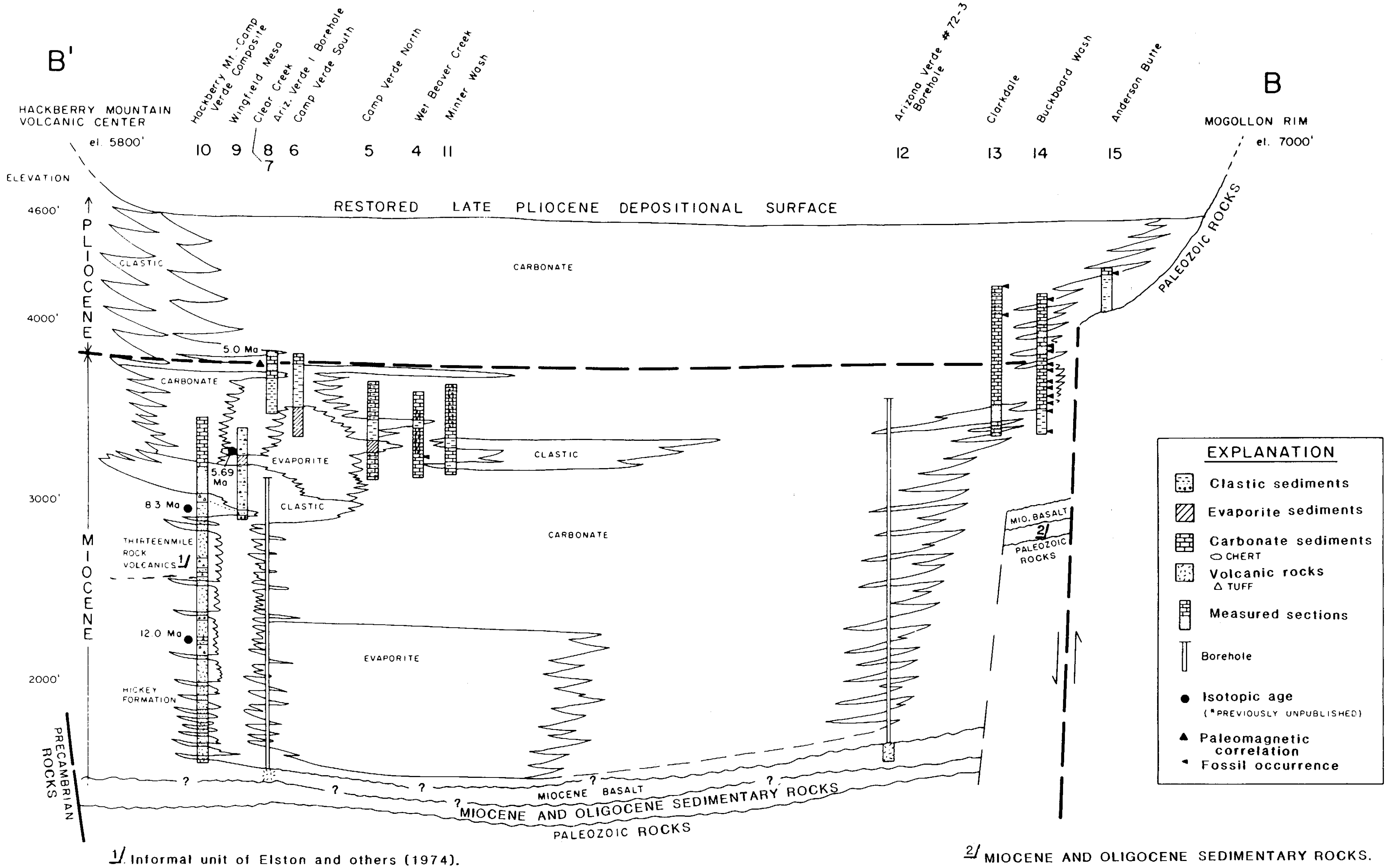


Figure 18. Stratigraphic cross section along northwest-southeast axis of the Verde Basin, showing facies relations in the Verde Formation.

other pieces of geography to make a national assessment. The only way to do it is probabilistically.

Geologic Models

• Do you have any information on the ground water in the basins?

Reply: Yes, there have been some good studies of the ground-water system in the Verde Basin, most notably by Twenter and Metzger (1963). The data for the Tonto Basin are uncertain. Ground water in the Verde Basin is mostly fresh, very low in salinity, and certainly not a brine.

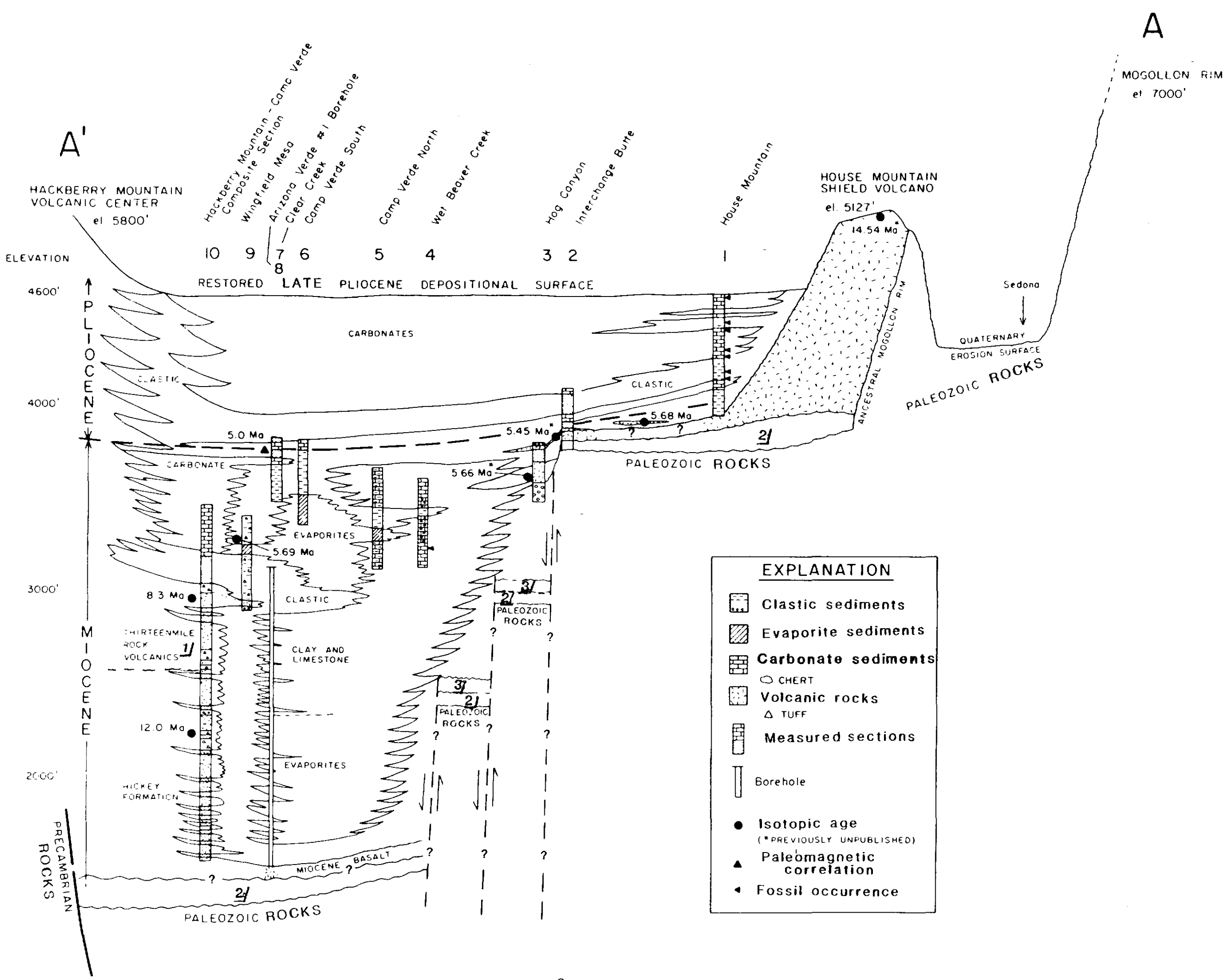
• How did rates of deposition change over time in the Verde Basin?

Reply: Basin filling was much more rapid in the Miocene than later in the Pliocene. About the beginning of the Pleistocene, the area was subjected to erosion.

• Were the Tonto and Verde Basins once connected by a river system?

Reply: The basins were part of a single drainage system, but not since basin-and-range faulting. Previously, after the Laramide orogeny and until middle Tertiary time, the drainage from the Colorado Plateaus might have crossed these basin areas.

• There was commercial production of sodium sulfate in the early days in the halite area; it was also an aboriginal source. The asymmetry of the location of the halite deposits is interesting. They are not far from the Verde fault, and they are not centrally located. We shouldn't think that all industrial minerals in Arizona occur in basins. There are many potentially important, recently discovered types of industrial-mineral deposits that have not been addressed here. In the past 5 to 6 years, USGS-AZGS projects in the Kofa area have found about 10 exposures of massive quartz-kyanite rocks



1/ Informal unit of Elston and others (1974).

2/ Miocene and Oligocene sedimentary rocks.

3/ Miocene basalt.

Figure 19. Stratigraphic cross section across southeast end of the Verde Basin, showing facies relations in the Verde Formation.

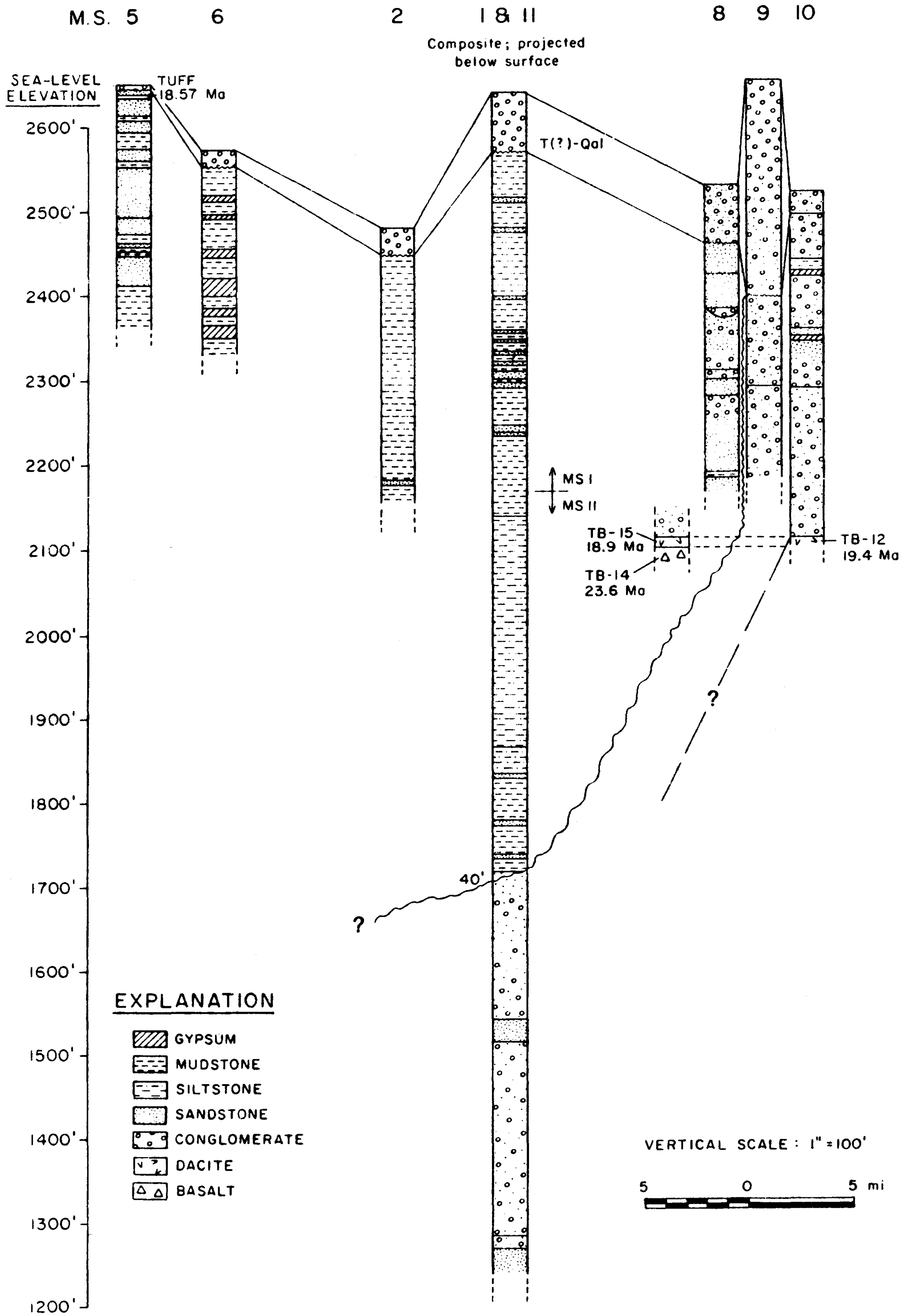


Figure 20. Stratigraphic cross section along axis of the Tonto Basin, showing basin-fill and facies relations of Cenozoic rocks (from Nations, 1988).

containing 70 to 80 percent kyanite. Other bedrock units contain dumortierite, rutile, and other minerals. These are massive pyrite-andalusite schists and massive deposits of pyrophyllite, aggregating hundreds of millions of tons in beds several hundred feet thick. There are many possibilities besides those in the basins. In the Kofa area, these deposits are associated with Jurassic hydrothermal events or Cretaceous metamorphism. The kyanite-rich rocks, for example, were probably an advanced argillic-alteration zone before metamorphism.

Meeting Information Needs

L.D. Fellows, *Moderator*

The users of resource information range widely, from those concerned with governmental processes involving the legislative, legal, or administrative disposition of public lands that contain these resources, to private industry exploration and the development of the resources therein. Although the particular needs of each of these constituencies may vary in considerable detail, there also is a strong overlapping interest. Identification of these needs is an important first step to assure that specific aspects of the needs are not overlooked and that users become more appreciative of the requirements placed on the others—whether by law or economic survival. In the following sections, the specific concerns and requirements of legislators, the mining industry, State and Federal Government land managers, the Indian Nations, and local communities are considered.

A Legislative Point of View

The resource industry operates in a political world, and the legislative system needs to be well informed about resource issues to foster industrial growth in Arizona, while, at the same time, it is protecting the environment. Senator Doug Todd represents Tempe district No. 27 in the Arizona Legislature.

CURRENT POLITICAL REALITIES FOR THE RESOURCE INDUSTRY

By Senator Doug Todd

Introduction

As you may know, I was a farmer in the Tempe area, dealing with the earth and related problems for many years before I entered politics. Not too long ago, I didn't know the difference between mass wasting and a Precambrian outcrop. I now have been from the Coconino Sandstone, all the way through the Tapeats Sandstone and Redwall Limestone, down to the Vishnu Schist. My association in the legislature with the natural-resources constituency has been most enjoyable.

I'm going to address some of the current political realities for industrial rock and mineral resources in Arizona. In particular, I'd like to share with you my perspective after having served 10 sessions in the Arizona House and Senate.

My legislative involvement with geology and geologists began with a discussion of the licensing of geologists and assayers in the State. Most recently, I've sponsored a bill that makes petrified wood the official State fossil. It's important, however, to recognize that I'm only 1 of 90 legislators—there are 89 others. Contrary to what you might want to believe, most of them don't give a rap about what happens to geologists or anything geologic. Part of the reason for this is the poor communication between the geologic profession and the legislature.

Impact of Legislation on Resources

Many legislative items go on daily that may have a bearing on you as geologists and producers of industrial minerals. Currently, the legislature is facing many problems in addition to balancing the budget. We're looking at ways to address these problems—raising taxes, revenue enhancement, or plugging loopholes. Some of the things that happen in this process let the legislature know that there's something going on in the world of geology.I think that we're mostly aware that the Superconducting Super Collider project proposal for Arizona has seen a high level of cooperation between our two universities, ASU and the University of Arizona. It has been good to see the two geology departments working together on this project. If my information is right, the potential of the Maricopa Mountains site was first pointed out by a member of the AZGS in a review of the initial screening. More legislators are now aware that the million or million and half dollars which they authorized to advance this cause was specifically allocated for geologic surveying of the project site. Increasingly, all of us have become more aware of the significance of geology in the past few years.

Tomorrow, we will discuss a sand and gravel bill. Briefly, it's regulatory, but it addresses something that exists out there. We have a State mine inspector who doesn't have many mines to inspect, and now sand and gravel fall into the mine category. Therefore, these deposits are exempt from certain zoning regulations outside city limits. We now will address this problem, which has great economic impact.

Let me briefly touch on another example of a problem that we've looked at in the past couple of years. Up in Verde Valley, one sand and gravel mining operation created a disturbance in the bank downstream. It caused local concern, and so the people went to their legislator to see whether something could be done about the problem. As a result, someone started checking into the old statutes and the Constitution, and found that ownership of some of these mines, some of which had been family businesses for years, possibly was questionable. It was called a problem of navigable streams. In the process of becoming a State, ownership of the land under those streams was uncertain. The legislature passed a bill that is now being tested in the courts to resolve the ownership question. Again, there is great economic impact that may have a direct relation to your ability as geologists to work in the real world.

Impact of Voters on Legislators

If there's anything that I'd like to leave with you, it is that you cannot afford to remain above the legislative process. I've enjoyed my association with geology and geologists, largely because of my personal involvement with friends in this particular arena. Thus, I've been or become an advocate for those things connected with your profession and professional interests. But what about the 89 other legislators? They also need your support for input to the legislative process. And that's not all. It's not an easy process to try to get a few more votes out of a committee or enough to make sure that there are 16 votes to pass Senate legislation which you feel is conducive or good for Arizona. Thus, I'll leave some ideas for your consideration.

Whether you live in Arizona or in another State, you have a responsibility to become a voter. A citizen who has registered as a voter hopefully knows who his or her senator and representatives are. As taxpayers, you should want to follow issues before the legislature and to search out your legislators to be advocates for you, so as to foster getting something passed that's good for the State. Those of you in Arizona have three people representing you in the State legislature, in whatever district you may live.

The Political Facts

How does it work in the real world? Let's say there's a bill going through the State legislature. Your legislator may not have heard about that bill. A taxpayer calls up and says, "I'd like you to support this bill—it's a good bill." The legislator might say, "Is that right, what did you say your name was, where do you live, have we ever met? OK, I'll take a look at the bill." What I'm telling you is that if you want an advocate in the State legislature for support of a bill, remember that you're represented by one senator and two representatives from your legislative district. If you want them to do something for you at the State capital, have you ever thought what you might be able to do for them?[1]

This spring, between now and June, everyone who's up for election or reelection has to have petitions filled out with the signatures of registered voters who support their candidacy. You live in a neighborhood and have neighbors, most of whom are registered. About 51 or 52 percent of those eligible to vote in Arizona are registered. A petition has 25 blank lines on it. You and your wife can provide two names. Hopefully, you are registered in the party of the person you want to support for the legislature. Go out in your neighborhood and complete a petition for him or her. When you do this, your name, address, and phone number go into the candidate's computer, and the candidate writes you a letter thanking you for carrying the petition. Next year, when someone comes around with a geological bill, you call up the person you supported and say, "This is J. Smith, I'm for bill number such-and-such." The legislator will know who you are and will respond very positively. If you want to really blow your legislator away, volunteer to put up road signs for him. You'll impress him, and next year when you ask for his support, he'll really know who you are. You don't need to spend money or go to meetings. Money is important, but your personal involvement in his or her campaign is primary. And whether it's a sand and gravel bill or the petrified-wood State fossil bill or an increase in the budget for the AZGS, you'll have a friend in Phoenix. When you call your legislators, they'll know who you are and what issues are of concern to you. Thus, if you become involved, it will make you an acceptable and effective participant in the legislative process. This is the only realistic way to go.

Industry Need for Data and the Results of Applied Research

By B.N. Watson

Several industry persons were polled in an attempt to obtain a broadened industry point of view. Although these comments concern industrial-minerals exploration primarily, many of the points made are equally applicable for metallic-minerals exploration. These observations are

[1]Editors note—Federal and State Government employees' permitted political involvement should be considered.

divided into three parts: (1) data needs, (2) applied research needs, and (3) legislative needs.

DATA NEEDS

Industry has long depended on several types of resource data supplied by Government agencies, academic institutions, and other private sources. The main types and sources of these data are as follows.

• Geologic mapping is the main continuing need of industry from Government . We are aware of the outstanding history of the USGS throughout the decades for producing geologic maps of the United States and its territories. Those of us in industry will be happy to see continuing emphasis on geologic mapping by the USGS, and we hope that current budget cuts will not affect that aspect of their program. Quick publication of geologic maps and reports by open-file release is also helpful.

There is a need for mapping and geophysical studies of the basins in the Western States. Throughout past decades, the USGS and others have concentrated on the more interesting rocks in mountainous areas of outcrop. Many industrial-mineral commodities occur in basins, as we have seen in the talks and discussions here. These basins have been lightly passed over in the past as being Quaternary alluvium, Quaternary gravel, or Tertiary to Quaternary sedimentary rocks. There is a lot more out there in those basins than these generalized geologic units. We need better geologic and geophysical evaluation of what really is in the basinal areas. Another program element of the USGS that helps industry is map compilation, based on university theses or other studies, with fill-in mapping of the intervening areas. We also need reinterpretation of old mapping, as well as remapping of areas that were mapped long ago on a gross scale or with the use of now-outdated geologic models. An example, accomplished recently by the USGS, is the work by Lipman and Sawyer (1985) in compiling information on some of the old porphyry copper districts in the mountain ranges of southeastern Arizona.

I have collected some minor complaints that are probably not original but should be mentioned anyway. We know that the USGS was inundated by WSA's that they had to evaluate. This program must have put a strain on personnel. Nevertheless, when we are talking about areas that may be locked up for a long period of time, we would like to have the areas evaluated properly. In our opinion, some of the WSA evaluators simply lacked the experience and capability to know how to evaluate the areas assigned. Another problem is that certain USGS topographic maps, particularly some of the more recent 7.5-minute quadrangles, lack road, prospect, and mine symbols in places where those roads, prospects, and mines are known to exist. We hope that this sometime practice is reversed and that these important location symbols for assessment and exploration are always included on these maps.With respect to the AZGS, we are encouraged to see that their staff has been strengthened, particularly in the areas of tectonic mapping and Quaternary studies. We also encourage the AZGS to do more mapping.

• Age determination of materials is becoming an important tool in putting the explorationist in the right geologic environment to find the type of deposit being sought. We use ages extensively, and we are fortunate to have the Geochronology Laboratory of the University of Arizona in this area. We need a clearing house for new ages, and we would like to make sure that ages are not held back for a final formal publication. This preliminary release could be in the form of a column in the AZGS' *Arizona Field Notes*, published four times a year. Each issue ought to carry a listing of new ages for the State. For the rest of the Western United States, the magazine *Isochron West*, which is still in print, could be a clearing house for ages for the broader region.

• A core and drill-hole data repository is needed by industry because we have an exploration-duplication problem. All too often, at present, holes must be redrilled because we cannot find out what was discovered in earlier drilling programs. This is an environmentally and financially unsound practice. It should be mandatory for terminated projects that, when a company is finished in an area and is walking away and letting claims lapse, they deposit information with some governmental group. Such information should include who drilled the holes, to what depth they were drilled, a brief geologic log, some representative core and chips (skeletonized), and any other information that would be useful. The information is going to be imperfect, some good, some poor; nevertheless, something is better than nothing. Conservative industry objections to a core repository is lessening as time goes on. Such a repository is currently in use in Canada. The Texas repository charges $2.00 for examination of a box of core, and the response has been exceptional. Originally, I thought that this would be a good function for the ADMMR, but the AZGS has some of this information already. It is immaterial to me who might administer such a service, but it would be good to have it in one place. The storage costs might well become a problem, eventually.

• Analytical data of three principal types are of interest to industry. *Water analyses* are important for some types of industrial-mineral exploration, such as for borates and lithium. We are struggling to understand what water analyses really mean, but we do use them as a tool. Our problem is that we need a broad and consistent spectrum of ground-water analyses. Too often, water analyses omit certain important elements, such as boron. For example, you would think that it would be critical to know what the boron content is in agricultural areas, because more than 1 ppm B can be toxic; however, many water analyses from such agricultural areas omit boron. We also encourage reporting such anions as bicarbonate, carbonate, and sulfate in these analyses, so that we can know what type of water we are dealing with. It lets us know what types of bedrock might be below or up drainage. *Soil and streambed chemistry* is not considered as important in Arizona as it would be in Montana or Canada, but because we are dealing with industrial minerals and they sometimes do occur in basins, I think that soil and streambed geochemistry can be important. Finally, there are *outcrop analyses*. Some of the industry persons polled felt that the Government should not be in the assay business. There is a risk that information will get out prematurely and may unduly benefit certain companies. But there are people in the USGS and AZGS who understand what altered and mineralized outcrops are, and I believe that these people should sample outcrops and publish the results.

Another complaint involves the Federal Government's Paperwork Reduction Act. People commented that this act requires data destruction by some Government agencies for space reasons. Old publications of the USGS and analytical data of some organizations have not been given away or put in a repository somewhere, but destroyed. In one case, the U.S. Bureau of Reclamation destroyed analytical data from the Lake Meade area that we could have used. If nothing else, Government agencies ought to donate old data that they don't want to keep and give it to an institution like the University of Wyoming's Heritage Center, which has been set up to house old company files and other forms of data of potential use to explorationists.

• Industrial-minerals demand and known mineral-occurrence data are often provided by the major companies themselves, but there are times when State geologists run across specific needs for specific minerals in specific areas. It would be useful if there were some system whereby such information could be regularly released to the public. Mineral occurrences are being cataloged in Arizona, and I would like to call attention to the excellent publication mentioned earlier—the ADMMR's 1987 publication on Arizona's industrial minerals. It should be updated periodically.

• Land-availability data in the USBM's 1986 *Availability of Federally-Owned Minerals for Exploration and Development in the Western United States: Arizona* has been helpful; this is also a publication that needs updating periodically. The ADMMR has a publication by Clark and Verity (1986), *Laws and Regulations Governing Mineral Rights in Arizona*, which also has been most useful. One complaint under land-availability data concerns the BLM's delays in posting data on claims staked and claim-assessment work. It seems that the BLM is often behind in posting such data, which causes industry problems in trying to keep up to date or in obtaining rights for land on short notice. The BLM has been 4 or more months behind in such States as Nevada, California, and Arizona, where the current gold rush is occurring. Somehow, the county courthouses are keeping up; why is the BLM so far behind?

• Permitting information is needed because industry is often hampered by duplicate needs for permitting from various agencies that all seem to require much of the same information. We are also hampered by the time involved in the permitting process. Nevertheless, if we must go through these items, it would be nice to have all the permitting information for the State in one place. In Arizona, I'm told, it's pretty well scattered about. One State, Colorado, is trying to put it all in one place. The Colorado Department of Natural Resources publishes the *Colorado Permit Directory for Energy and Mineral Resource Development*, of which this is the third (1983) update prepared by the Colorado Joint Review Process Program; it contains all the permitting information, all the needed forms, all the names of important persons and their phone numbers, and so on.

• Academic information and liaison with the university system is important to industry to obtain information about student availability for mapping theses. Industry has supported numerous theses and can use students for summer work and part-time work during the rest of the year. University libraries contain good geologic information from student theses in areas where we have interest. Universities should advertise student project areas and their theses subjects. The University of Arizona attempts to do this with a special meeting, a geosciences symposium, each spring. They allow students and others to give presentations on work that they are conducting. Apparently, UNA does not have such a program, and I don't know whether ASU does or not. It would be helpful to industry to know where the students are working, and, where mutually beneficial, they might receive some funding from industry that they were not aware was available. If there are going to be geosciences symposia held by the universities, then the sessions need backing and attendance by industry. I'd also like to see a list of these in progress, as well as theses published on some sort of a regular basis. Again, a regular column in *Arizona Field Notes* would be a good place to have this reported. These data should not be difficult to obtain from the Arizona universities, and information about theses on Arizona geology by students from out-of-State institutions could also be obtained and published in *Arizona Field Notes*.

APPLIED-RESEARCH NEEDS

The mining industry is interested in new exploration technology and the development of new scientific concepts of ore deposition.

• Introduction of new techniques is viewed by many industry folk as best met by academia and the private sector. However I'm sure that there are important areas of applied research suitable for Government input, including introduction of new techniques in geochemistry, geophysics, age determination, computer data and digital systems, and satellite imagery. Industry will use these new methods once their practicality is demonstrated.

• Development of new concepts is a second way in which Government and academia can contribute to industry exploration programs. Such ideas as the connection between geologic processes and ore formation, and between plate tectonics and certain ores, have been most useful.

LEGISLATIVE NEEDS

Industry needs support from Government, such as avowed and stable policies with respect to land availability, permitting, and access. We need legislative stability; constant change hampers and discourages industry. A classic example is Mexican mining law, which seems to change after every election. This instability has hindered mineral development in Mexico.

Finally, some industry persons are quite concerned about the politicization of such Government agencies as the USGS, USBM, BIA, BLM, and USFS. Their strength and contributions to society have been based on the fact that their loyalty is to the Nation and meeting its needs.

PARTICIPANTS' DISCUSSION OF INDUSTRY NEEDS

• The AZGS has statutory responsibility for a cuttings and core repository in Arizona, which has several thousand wells represented, mainly water wells. The AZGS also gets oil and gas well data and cuttings. Not much has been done with respect to cores, mainly because of space, time, and funding limitations. Those records that have been maintained are open to the public. This is an area that the AZGS believes should be improved. Other State geological surveys also have such facilities, and they are used extensively.

• The BLM was unaware of the lag in recording of Arizona mining claims. A company is allowed 90 days after staking a claim before they have to record it with the BLM. The BLM is now putting these data into an automated system and can check on how long it takes, after a claim is staked, before it appears on the system. The BLM is going more and more to an automated land-record system, and at some point in the future, when the paper records are shipped to an archive, there will be a total dependence on computer files—CD ROM technology for record keeping. We now have 148 thousand active mining claims in the State, and many patents have been granted over the years. All of these data are accessible through the BLM's automated land-record system.

• Patenting of claims is a problem for the industry. We see that many metallic-mineral claims, particularly those for copper at Safford, are allowed to go to patent. Many of these metallic-mineral deposits may never have been in production. When industrial-mineral claims—specifically, the Bowie zeolite deposit, which is adjacent to the productive Union Carbide deposits—came to be considered, the smaller Bowie group was turned down on the basis of no demonstrated marketability. There seems to industry to be a bias against patenting industrial-mineral deposits because contracts for these materials are expected.

Reply: The same criteria for metallic- and nonmetallic-mineral deposits are used by the BLM, regardless of the commodity. If you believe that the decision by the authorizing officer is invalid, please take it up with your field office and get a judicial decision on it. The problem for industry producers is that they are faced with the position that if they do not withdraw the application for patent and the BLM finds that the claims cannot be taken to patent, the operator is faced with possible invalidation of the claims because the material is not marketable.

• Regarding a core repository, if industry kept requests coming in to the USBM, there is a chance that the USBM would create a repository. The last time this matter was considered by the USBM, it was dropped, not from outside pressure but from internal USBM policy; the funds appropriated were cut off and diverted elsewhere. Had there been sustained industry pressure, such a repository might have been created.

Replies and comments: It seems doubtful that industry pressure to create a core repository will be forthcoming. Such pressure will have to come from the governmental end. Nonetheless, I think that industry is now at the point where it would accept rather than rebel against the concept. There is a difference between accepting and saying that industry wants it.

There is a USGS core repository in Denver that is available for anyone to examine. They charge a user fee because it is very expensive to create and maintain such a repository. The USGS gets many offers of core, but the problem is that such a program has a relatively low funding priority relative to all other programs. The program started out mainly with oil-well cores, but lately mineral cores—the first are from Creede, Colo.—have been made available. The Geologic Division is encouraging this venture. In the future, there undoubtedly will be pressure for accessions from other States.

• Information is a much-needed commodity by industry. Like vegetables, it becomes less valuable the longer it sits around. In the case of the USGS, the time interval between the acquisition of information and its availability in a report may be several years. If there could be some way of getting the critical information out more rapidly, that would help. It may not be as important to have the information released in good form as to get it out where it can be used.

Replies and comments: Recently, the USGS has been conducting open meetings to review CUSMAP studies, or meetings of a program-review type. Are such meetings before publication of sufficient interest to gain industry support? Is this a good way to get information out without the laborious publication route?

From an industry point of view, these open meetings were a good effort, and appreciated. The problem is to find a time when most industry folks are in town and available to attend. USGS Open-File Reports also are being used increasingly to speed release of data and interpretations. These reports are now listed in the USGS' *Monthly List of Publications*.

State and Federal Government Needs

STATE LANDS-MANAGEMENT NEEDS

By M.J. Rice

Before discussing the ASLD's various needs for resource information, I believe it is appropriate first to explain how State lands are leased. Like the Federal Government, we classify minerals as locatable, leasable, and salable. Industrial minerals are classed as either locatable or salable. Locatable minerals are leased under a mineral lease, and salable minerals under a mineral-materials lease. As required under Federal law, the type of lease depends on a determination whether the mineral commodity is a common variety. Because Arizona statutes further define common mineral materials as those that are used for similar purposes, we must also consider any proposed marketing of the mineral. With these distinctions in mind, I will first address our resource-information needs relative to issuance of a mineral lease for locatable minerals.

In applying for a mineral lease, the applicant is required to submit documentation in support of his discovery of a valuable mineral deposit. Upon review of that documentation, which usually includes laboratory analyses, drill-hole logs, geologic reports, and reserve estimates, the ASLD must make a determination as to the value of the deposit. At this point in the evaluation, we find a serious absence of information about commodity prices and other market conditions, such as product demand. If we could obtain this type of information in greater detail, I believe our economic evaluation of the property and projection of royalty income would be greatly enhanced.

For a mineral-materials lease of salable minerals, we do not have most of the detailed information that is available under the mineral lease. Thus, we must rely on the available literature, geologic maps, and fundamental exploration guides. Here, the ASLD is in a position like that of any exploration company, and so we would find such specific geologic information as drill-hole information or depositional-basin studies most valuable. Efficient management of State lands requires that this information be made available in a timely manner, and we encourage development of an avenue of exchange, such as a library or computer file. This information could also be used in evaluating mineral properties for the purposes of commercial leasing, our Federal land-exchange program, and the sale of State land, as well as for advising other ASLD divisions. In conclusion, I would identify technical data, drill-hole information, depositional-environment studies, and market-related information as most essential to the leasing of industrial minerals. Because we also have a great deal of information to share, I believe the key to using that information effectively is to identify an efficient avenue of data exchange.

PARTICIPANTS' DISCUSSIONS OF STATE LAND-MANAGEMENT NEEDS

• Are we correct in saying that there are there are basically two ways to acquire industrial minerals: (1) through a regular State mineral lease for such commodities as clay, bentonite, and zeolites, which customarily are 20-year leases, starting from a prospecting permit, or staking 20-acre parcels; or (2) through a materials-purchase contract for common clays, sand, cinders, and other aggregates, where that commodity must be submitted to public bidding, after a statutory time interval?

Reply: Yes, that's correct, but the issuance of a 20-year lease requires that the commodity be distinguished from common types. Therefore, the technical information and (or) product use must support that requirement. The whole question of royalties is up in the air right now, but otherwise you're correct.

• One problem we have with industrial minerals is that the product has value at several points. Value at the mine generally bears very little resemblance to the value of the end products; there are many steps in between. If the value is set too high at the mine, the commodity has no value; it's basically a crude raw material that has to be processed to a final product. It's important not to confuse the mine and product values. For a bentonite that has a mine value of $35 per ton, the end values come after $300 of processing.

• Major problems for industry are public auctions and royalties. If someone is going to risk accepting the cost to make the discovery, that person will be reluctant to have the information made public, so that a competitor could step in and buy the claim by making a higher bid. There would be little incentive to explore, because there is no assurance of title if a discovery were made.

STATE ENVIRONMENTAL-QUALITY NEEDS

By Debra Daniel

Unlike the other agencies represented here, the Hydrology Section of the ADEQ does not control any lands, and so we do not zone land or specify which lands are or are not available for special uses. However, we do regulate how activities are conducted on lands. Activities that may affect water or air quality need to obtain permits. Mining is a regulated activity. Many of the environmental permits required for an activity are issued by the ADEQ, although the EPA also issues some permits in Arizona. The ADEQ rules are necessarily based on geologic, hydrologic, and geochemical information. Thus, the ADEQ is a user of resource information and also produces and maintains such information.

The rules of most concern to this group would be those governing air-quality permits, which are given by either the county or the ADEQ, and aquifer-protection permits, presently called ground-water-protection permits until the new regulations are finalized. The aquifer-protection-permit program, which is being developed, is more rigorous than the existing ground-water-protection program. The aquifer-protection-permit program will require permits for any facility that discharges to ground water, including surface impoundments, discharges to dry washes, leach operations, and so on. The proposed rules for this new program are out for public comment at this time. Copies can be obtained from the ADEQ (telephone, (602) 257–6897).

Under the new rules, most people will be required to obtain an individual permit for each discharge. The applicant has to perform studies to demonstrate that the standards for the aquifer will be met. There is also a requirement to use BADCP (Best Available Demonstrated Control Technology). In addition to individual permits, there is a provision for a general permit, a permit-by-rule, that would not require an applicant to come to the ADEQ to obtain an individual permit. Institution of a general permit is something that the ADEQ is looking at for sand and gravel operations that meet certain criteria and that do not use chemicals in processing. Another type of permit that may be required is the NPDES (National Pollution Discharge Elimination System) permit. This permit is still given by the EPA in Arizona, but the ADEQ does most of the administrative processing, and so you have to come to the ADEQ for it. The non-point-source program will cover discharges to surface water from dispersed sources. The EPA is also working on regulations for non-point-source discharges. Most of the mining activities that have been discussed will fall under this non-point-source program. Operations involving underground injection are presently required to have a UIC (Underground Injection Control) permit, which is issued by the EPA. These activities would also require an aquifer-protection permit issued by the ADEQ.

With respect to resource information, the ADEQ is working to produce DRASTIC maps for the whole State. ("DRASTIC" is an acronym for a system of mapping that gives an indication of aquifer vulnerability to contamination, as developed by the National Water Well Association under contract to the EPA.) We have completed maps for Yuma and La Paz Counties; the Maricopa County map is about to be released, and Pima County is in line to be done. These maps can be used by a wide variety of Government agencies for planning. They might be useful for developing the well head-protection program, which is still in a formative stage. The well head-protection program will likely affect mining activities near urban areas and around public water wells, where certain activities would be limited or prohibited. As presently conceived, individual cities and counties will be developing their own well head-protection programs, probably in conjunction with the ADEQ and EPA.

The ADEQ is developing computerized data bases for the chemical quality of water and soil. These data bases were authorized by statute in 1986, and we are still getting them on line. We are looking at eventually developing a GIS, in conjunction with the ASLD, so that the well data located and can be overlaid with other data in the GIS. One application, for example, would be to help identify sources in an area of ground-water contamination.

At present, the ADEQ compiles numerous data on water quality and receives additional data from regulated facilities. Drinking-water systems, some ground-water-permitted facilities, and RCRA (Resource Conservation and Recovery Act)-permitted facilities have to monitor ground-water quality and submit the data to the ADEQ. Presently, it is difficult to access that information when studying an area unless the particular facilities and permit programs are known in advance. The ADEQ hopes to enter all the water-quality data into one data base, which can be accessed by any interested person. The ADEQ generally requires data for standard inorganic materials, as well as any contaminants of concern.

PARTICIPANTS' DISCUSSIONS OF ENVIRONMENTAL-QUALITY NEEDS

- Airborne particulate discharges generated by mining activities are of great interest to industrial-mineral operators. Decisions by the State have been held in abeyance for at least a year, pending the outcome of a lawsuit by a mining company against OSHA regarding generic asbestiform minerals—minerals that really are not asbestos but have the morphologic characteristics of asbestos. How is the air-quality-standards program being handled?

Reply: I am unfamiliar with air-quality permitting and with how those standards are set; you should ask the Air Quality Section of the ADEQ.

• Some areas of mutually beneficial cooperation have been identified. The ADEQ's water-quality data base might be a good exploration source because many toxic substances are also indicators used in geochemical exploration.

• Not only should volcanic rocks be looked at as marketable sources in themselves, but they also may be source rocks for such elements as boron and lithium, and thus serve as geochemical indicators of nearly deposits.

• Mitigation of environmental hazards, such as the protection of ground water from acid rain and the disposal of refuse in landfill, will require large additional supplies of industrial materials like limestone and clays. The sources of these materials will have to be near the place of use. The location and type of these material requirements should be addressed in some way.

FEDERAL LAND-MANAGEMENT NEEDS

By L.P. Bauer

I'd like to start with a description of the BLM's land-planning process, which we call "developing the resource-management plan" (RMP), as required by the BLM's 1976 organic act, the Federal Land Policy and Management Act. The BLM had always done some planning on an as-needed basis, but comprehensive planning is now required. The BLM is managed at a State office (which considers one or more States), at district offices, and at the resource-area (field) office. An RMP generally covers a resource area; it examines how the BLM wants to manage a given resource area. All aspects of the BLM's program are considered in the search, and minerals are one important area examined in the planning effort.

Planning starts with a "scoping process," whereby the BLM publishes an announcement in the *Federal Register* that a plan is going to be developed. Public meetings provide input on what resources are important and need special consideration. Do we need a plan for mineral development in some areas? Is recreation a big issue in some areas? What about wildlife preservation or range management? There may be a series of scoping meetings to determine the issues to be addressed in developing a plan.

The BLM then prepares a "management-situation analysis," which summarizes what is known about the area at present and what currently is being done. It is a basic working document to be modified or from which alternatives are developed, if a new direction is indicated. Among the alternatives considered is no action, the current management alternative. In such a case, a survey is made of how many mines are operating there today, how many mineral leases are there, and, if we make no changes in mineral priorities, the effects of allowing the current level of activity to continue. How many head of deer are out there, and what will be the effect of no change on management of the deer population? We also look at other resource-protection alternatives; for example, to maximize the number of wildlife the land can carry, what changes in mining activity will have to occur? We consider the problem with the view of setting up special management areas, such as ACEC's, natural-maintenance research areas, or special recreation management areas. Another alternative considers commodity production; that is, we examine the decisions necessary to maximize mineral production, timber cutting, and cattle grazing. After looking at those alternatives, the BLM develops the "preferred alternative," which generally is a common meeting ground.

It is important for industry to be involved in the scoping process as early as possible, so as to identify their concerns for present and future mineral development. On a practical level, each alternative is developed because of the special interests of people. The wildlife specialist is going to make his best case for protecting the resource he knows best. The range manager is going to be working with his client. The geologist is going to use his data to encourage mineral development. The BLM needs *data* for this purpose, not entreaties for no more wildernesses.

The BLM makes use of information from USGS and AZGS publications. The BLM also has some of its own specialists who go out into the field to determine what is happening at mineral-development sites. It has its own data base, which contains notices and plans of people operating mining claims, and records what is going on in the area and for what commodity, but that's about it. The BLM needs public contributions to expand that data base, and knowledge of the area to prepare these reports.

In the final development of a "preferred alternative," each specialist makes his case before an authorized officer, in most cases, the resource-area manager or district manager. This is basically a highly personal type of political process. The more data in hand, the better the case that can be made for a particular resource area. In counting deer or trees, you obtain good, hard numbers to build a case. It's a little harder to develop a comparable mineral-resource data base. The preferred alternative is produced and published as a draft RMP.

The types of geologic data needed to build a good case include mineral-occurrence information, particularly in the broad areas between the mountain ranges where the BLM has no data. These areas get proposed for wilderness status because they haven't been much affected by man. When these areas are identified in public notices, anyone in industry who knows about any available data or exploration activity going on in the area probably knows more about that area than the BLM does.

The planning process is nearly complete in Arizona. We are preparing new RMP's for the Safford district and the Arizona strip. Where we know about mineral development, we have to factor in such information. In some of our WSA's there are cherry-stemmed roads into known mineral developments. If we don't know about them, we can't make a case for development.

When the draft is published, there is further opportunity for people to provide their input or to challenge the draft. The BLM has to consider every comment that comes in and show that it either adopts the comment, adopts it as modified, or rejects it, giving the reasons for rejection. That is part of the process in producing the final RMP. There is still another chance to protest the decision. If the BLM sets up a mineral-withdrawal area or an ACEC that excludes mineral development, there is the opportunity to protest to the Director of the BLM when the final plan is published. A protester must have been part of the planning process at some point—either by attending a public meeting or making a comment—to have any recognized standing. A protest can be lodged by a company, an individual, or a trade association. If there are no protests to the final RMP, it is set in place. If there are any protests, they are resolved by the Director.

Amendments to RMP's can also be made. Assume that an RMP is in place and someone wants to exchange some large blocks of lands covered by the RMP but not considered suitable for exchange in the RMP. The planning process is reopened to consider that amendment. Anyone can come in and ask for certain amendments to the plan. If they are considered important—for example, discovery of a new gold deposit that wasn't known before—this new piece of information would be sufficient to reopen the plan. The plan is designed for a 5- to 10-year life. Thus, as the BLM is completing its first go-around, it's time to begin the process all over again.

PARTICIPANTS' DISCUSSIONS OF FEDERAL LAND-MANAGEMENT NEEDS

• What is the process for introducing recommendations of areas of "critical mineral potential," as discussed in the Wilderness Act?

Reply: When the BLM has asked for nominations for areas of critical mineral potential, it has obtained mostly unusable suggestions. Nothing has been received that pinpoints special areas, and generally the information is for too broad an area. If a new piece of information indicates that an area contains important mineral resources, that area can be proposed for exclusion according to the act, and the process will resume with public hearings. If the proposal is valid, the area can be set aside and managed as an area of critical mineral potential.

• As the process has been described, there are several points of input. Can you describe the early stages of the process when the BLM staffs are starting to prepare the report? You come to the AZGS, USBM, and USGS and make use of their available information. There may be a lot of data that are irrelevant or meaningless. Could you elaborate further on what the BLM finds most useful from these surveys, with regard to geologic information, to help get a better RMP that will minimize protests?

Reply: The most useful data are those that the BLM is least likely to get—site identification and reserve tonnages. Regional information is generally available in the BLM's files; it consists of site locations and reserve data that interact with the quantifiable data of the proponents of nonmineral-resource development.

• One thing we discovered on winding up an industry project, in which we had identified several specific types of mineral deposit, was the vast number of occurrences for which we had data. Plots of these occurrences were spread over the Southwestern United States, covering a very large area, sparsely. This type of deposit could never be pinned down to a specific area. What could be done with these interesting data?

Reply: One service that USGS, AZGS, and ADMMR data-collecting facilities provide is to collect data that industry people may be reluctant or unwilling to put their name on, for whatever reason. The collection of fundamental site and locality data is not particularly interesting, but it is as important for any future industry exploration as it is for BLM planning. In Arizona, the BLM is getting more involved in land information and geographic information; they are beginning to build coordinate data and computer-overlay site-specific data, and then overlay various other resource themes. You can now ask a computer to show you all the mineral sites and to overlay the critical wildlife habitats on them. The computer can calculate all kinds of areal relations. The Arizona strip RMP is being done in this mode, which helps make better comparisons and formulate better alternatives.

• An often-heard comment is that we've been looking for a material in this area for a long time, and so we must already have found all that can be found. This simply isn't true, because the science is dynamic. With changes in occurrence models and increases in the number and type of data, old conclusions become outdated.

• In one case of critical mineral potential, mining claims were located in an area that adjoined a wilderness. A letter had been filed indicating this information, but its argument was essentially dismissed. Can the process be reopened under the act? This is the case for a saponite deposit, which is composed of a unique magnesium clay, although it is not a strategic material at the moment.

Reply: Yes, the case can be reopened if new information is made available. The saponite deposit you refer to is an interesting case: It's also the site of an endangered plant species. This is a typical example of a management problem for the BLM. Which use should take presidence?

• If you think that the BLM is dealing with an ocean of ignorance in site-specific mineral data, you should realize that most mining companies also are dealing with these same types of problems; they are in the same ocean. You can't put hard reserve numbers or economic potential on a little bit of outcrop, some chip samples, or even a few diamond-drill holes, and make a case that the company should go ahead with mining. The explorers at that juncture are fairly ignorant, and so the BLM shouldn't expect too much in the way of hard data. The sources of hard data are from the producing mines. Exploration targets in a wilderness area have the least amount of information available. However, the discovery of the Copperstone mine was based on three mineralized outcrops, each about the size of a table.

Reply: It may be that the best solution is for direct industry interaction with the land-management agency, to become personally acquainted with the people involved in making the BLM's decisions. In the final analysis, it's a personal decision for the decisionmaker.

• There doesn't seem to be much consistency between the decisionmakers in different BLM offices within or between States—one is a biologist, another may be interested in mineral development and understands it. Each decisionmaker is more sympathetic with his or her own field of competence; usually, that situation provides an opening for a lawsuit, but it doesn't get the job done for exploration or for planning.

Reply: If someone feels excessively put upon by an individual in the BLM, he should contact the next higher level. Overzealousness can result in problems, and the BLM needs to become aware of such problems. All too often, geologists and mining engineers are good people who want to deal with hard data, but they forget about dealing with other people who must deal with other types of data.

• Such forums as this are the first real opportunity to get all of these constituencies into one room and to be able to interact on a nonthreatening, frank, and informal basis. In a public forum, such interaction usually is not possible because people with violently different persuasions become argumentative, and the proceedings are not productive. If a regional exploration manager takes the time to write a letter, does it have the same weight as 16 letters from the Sierra Club? The manager may present data and a professional analysis worth thousands of dollars, in contrast with a blast from a person who just *believes* that an area should be a wilderness. The BLM has a difficult problem to read and evaluate such letters.

• Exploration for industrial minerals entails problems very different from those for metallic minerals. For example, consider the hectorite deposit at Kirkland Junction. A clay producer needed a clay resource that was high in lithium. Drilling began in 1982. Preliminary testing indicated that the clay in this deposit was a satisfactory viscosifier with the proper amount of lithium. Several chemical problems were successfully overcome during 1982. In 1983, additional drilling confirmed the amount of the resource needed. Next, a large bulk sample was taken to determine whether a product could be developed for sale under their trade name; it would be a substitute for the Hector, Calif., materials currently being used. The Kirkland Junction material passed these tests. Next, in 1986–87, 137 tons of the material was shipped for bulk testing and processing. The product was prepared, and sold under the buyers' trade name, and they waited for acceptance of the product. The waiting process will take another year or two. This development process will extend well into 1989 to 1990, a span of 8 years just to find out whether the material is marketable. Expenses of the mine operator are not nearly as high as those of the buyer; it takes time and money to develop a resource.

• What kinds of information can Government surveys provide to the land-management agencies?

Reply: From BLM experience, while working in the lower Gila and Kingman areas, the most useful pieces of information for resource assessment were the published regional studies. Core complexes had just been recognized at that time, and the regional mapping by the AZGS was essential in interpreting the depositional environments in the basin. The value of a certain tract of land could be predicted, albeit somewhat crudely. Although it was not a definitive prediction, it was good enough, in this case, to forestall inclusion of areas into a wilderness classification. You know what has already been discovered from MILS data and survey publications; what is not known is where those undiscovered resources are going to be located. The way you obtain real clues is by looking at regional studies, as we've been talking about, developing predictive models, and interpreting depositional environments, volcanogenic history, the timing of basin subsidence, and so on. Such models are essential for making management-plan decisions.

• The USGS is setting up regional offices in Tucson, Ariz., Reno, Nev., and Spokane, Wash., to assist in mineral-resource activities. Each office will have a full-time person whose job it is to visit the USFS and BLM district and State offices. A senior manager will be able to talk with senior managers of industry and the Federal and State agencies. There also will be an information system, locally, that has plotting capability and other support equipment that will be available to the user public. This will be a joint USGS-AZGS effort in Arizona. The USGS also is trying to approach this problem through better intra-Government communication and coordination. We are proposing to develop a program that would increase the USBM's and USGS's efforts to provide more useful mineral data to our clients like the BLM, and whoever else wishes to use it.

Geologic Data and Research Needs of the Indian Tribes

By James Crowther

The invited representatives of the Indian tribes apparently were unable to be present during this workshop, so I will do my best to represent what I think they might want to tell us from my experiences working with the tribes. It is difficult to speak on their behalf, and I would like to qualify my statements by saying that I am not speaking for them. I learned a long time ago that you cannot do this. There are some needs that the Indian tribes in Arizona have in relation to mineral resources, but these needs are not necessarily for hard data. I look upon their needs as more social than technical. I have tried to suppress basic idealism from creeping into my discussion. Nonetheless, it was encouraging to hear Larry Bauer say pretty much the same thing about industry striving to build a closer relationship with the regulatory agencies.

I think that what the Indians need, first, is the confidence to be able to deal with mining companies on an equal footing, and to receive the same kind of respect that other mineral owners receive. Currently, the Indians rely on tribal attorneys to negotiate mineral contracts for them. There are many competent attorneys out there, but there are also many who are unfamiliar with the mineral industry. This unfamiliarity creates a burden. The Indians need education in that respect; they need members of their own tribes willing to become familiar with resource matters. They also need companies and local, State, and Federal agencies willing to spend time with the tribal governments to form trusting relationship and to get to know the Indian's side of the story. It takes a lot of commitment and patience to do this sort of thing; this task up to now has been relegated solely to the BIA. Other interested parties need to take a hand in it.

Some of the people in companies that are interested in minerals on Indian reservations look upon the reservations and their inhabitants as targets of opportunity that are available to be exploited by any available means. This predatory approach is no longer viable. Instead, companies need to consider forming partnerships with the tribes for mineral development. There has been more of this activity in the past few years, and I hope companies are losing their fear of dealing with the Indians. This sense of partnership can come about by fostering personal relationships, so that the true aspect of the situation is recognized.

Federal agencies, including the BIA, need to recognize the importance of mineral development to the tribes. Mineral income to Indian tribes far exceeds all other revenues, yet the BIA is geared more toward crop production, forestry, and grazing resources. Paul Theobald, who is involved with Indian tribes, understands that the solution to this problem is education of both the tribes and those dealing with them, to get to know the situation and to bring the Indians up to a level of competence whereby they can give proper attention to mineral issues.

As far as basic technical data are concerned, I think the tribes have received quite a bit from various Federal programs and from private industry. Companies are required to give copies of their exploration data to the tribes. Thus, as I view it, the problem is more one of education than of technical information.

PARTICIPANTS' DISCUSSIONS OF INDIAN TRIBAL NEEDS

• There seems to be a substantial difference between attempting to do mineral exploration with the Alaskan Native corporations and attempting to do so with the tribes in the conterminous States. Is this difference because of the legal setup of the Native corporations?

Replies and comments: The Alaskan tribes are, in fact, corporations, approaching, in a few years, the ability to sell off the lands that were distributed to them. It is a different management system. There are only two Indian reservations in Alaska in the same situation as those in the lower 48 States. The Alaskan Indians were never put upon in the same way as those in the conterminous States, that is, violated treaties, constant reduction in reservation boundaries, and so on. That sort of thing did not occur in Alaska, and so there seems to be more trust of non-Indians. As Jim Crowther said, you have to build trust between the two parties before you can work effectively.

The BIA does not have responsibility for the Alaskan corporations. They are independent corporate organizations; there is no Federal oversight of their programs, except that there would be some response if a corporation failed. As a result of this independence, you can get rapid turnaround. In the lower 48, the BIA has to sign off on contracts.

Local Government Needs for Urban Land-Use, Planning, and Zoning

By J.R. Perry

Because I am not an earth scientist, I should give you some idea of my background as a preface to my comments on urban land-use planning and zoning. I am an urban planner and real estate consultant. I have an undergraduate degree in political science and am a member of the National Political Science Honorary Fraternity. My Master of Science degree is in urban planning, and I am a member of the AICP. I have had some experience in remote-sensing applications to land planning in Arizona, and I have worked at several local Government levels as an urban planner.

On the basis of my training and experience, I have developed some theoretical observations on the subject at hand. The first is that Federal assistance to local Government comprehensive planning has become virtually extinct; the HUD 701 program is dead, and with it went planning grants to local Governments. Linkage to Federal programs has become functionally integrated into regulatory programs on a vertically insulated basis throughout Government. This was not always the case. At one time, there was a movement, the comprehensive-planning movement, that focused on the local and regional Government planning process as an integrative mechanism in a democratic planning process. This comprehensive-planning focus at the local level has lost its place in the mainstream of Government. Regulation and management of individual Federal programs by different agencies with various goals over different time horizons, without comprehensive budget integration and goal setting by a professional planning body, has become the conventional wisdom.

My second observation is that the de facto planning theory in American Government has been "muddling through," rather than attempting to achieve a rational-calculative ideal. Systems maintenance through regulation, rather than institutionalization of the planning function within Government, has been the pattern since World War II. This policy has deteriorated to the point where the judicial system becomes planning through the "back door" by punishing the wrong moves in the increasingly cumbersome regulatory process. Wrong and inefficient directions are, of course, inevitable without comprehensive planning in a regulatory system. The cost of such wandering may be to the detriment of our children's quality of life and many aspects of their environment.

Not since the National Resources Planning Board was abolished in the 1940's has there been any comprehensive Federal commitment to resource planning. Since F.D. Roosevelt, no president has been committed to the concept of planning for optimization of our national resources. The situation has deteriorated further since the Nixon administration axed the HUD 701 Comprehensive Planning Assistance Program. Even that level of Federal support was very low; however, it supported thousands of planning jobs and idealistic careers that no longer exist at the city, county, and State levels. A third observation is that history demonstrates that although a depression scenario was required to elevate planning to a level beyond ad hoc, disjointed incrementalism, we can rediscover that experience to advantage without another depression. Now that the "cold war" is truly thawing, we may find ourselves within a new, more rational political atmosphere than existed before the nuclear age. In fact, we may be near the dawn of a positive political environment favorable for considering a major national resource-planning effort that is integrated at all levels of Government and tied directly to budget planning.

Such a commitment, for example, would facilitate data storage and the use of highly improved data-gathering techniques at all levels of Government. I perceive a small improvement in data coordination within the past few years among various agencies, mostly as a natural result of computerization. This progress, I feel, is the precursor to more efficient and realistic government through planning; the planning would involve a new degree of professionalism at all levels and require the highest educational and retraining commitments.

There is still very little planning coordination between the private and public sectors, both because Government regulation and judicial punishment inhibit the free flow of information, and because of justifiable fears that competitors will obtain proprietary knowledge. Even this consideration could be addressed within a rational planning framework in a democratic system. The corporate long-range planning efforts should be directly involved in a national effort to optimize the total costs and benefits to our society within the constraints of its democratic, republic, and capitalistic framework. The ultimate synthesis of my ideal future for planning may be embodied in the constitutional amendments developed by Rexford Guy Tugwell, one of F.D.R.'s "brain trust," now available through the Center for the Study of Democratic Institutions in Santa Barbara, Calif.

On a practical level, there have been some good examples of Federal assistance in local planning, and I think the two most outstanding were USGS programs. The flood-plain-mapping program is a good example. The USGS flood-hazard-boundary maps were the basis for the first flood-plain-zoning ordinances in Arizona. Also, in the ground-water-management area, passage of the USGS program to the State level helped to facilitate what has become the Nation's most comprehensive ground-water-management and ground-water-planning program.

As with the Depression-driven NRPB, CCC, and WPA Federal programs, it took negative, disastrous environmental problems (flooding and drought) involving land-use conflicts at the local level to implement the Federal programs. A good recent example, developed as part of an earthquake-hazard-reduction program, has been the seismic-risk data provided for use at the local planning level. In California, this facilitated major changes in their State Planning Act, which requires that local Governments develop hazard-reduction and seismic-risk elements in their comprehensive plan in concert with land-use plans.

Unfortunately, when the problems are economic and esthetic, rather than oriented to immediate safety and survival, Government priorities are much more difficult to define without a formal and professional goal-setting process. Spectacular events precipitate legislative action, but the more mundane, positive, and nonstrategic (nonmilitary) aspects of our natural environment, such as planning for nonmetallic minerals, hardly make for headlines, media attention, and the legislative votes that we seem to need to obtain planning action. This is hardly a rational planning situation; it is the epitome of ad hoc incrementalism, but it is our present political climate.

An example of the planning situation at the local level is the media attention and court action that has recently precipitated a complete change in Arizona law and better enabling legislation for local planning of gravel lands. Until 1988, the sand and gravel mines claimed constitutional exemption from planning and zoning authority, then settled for land-use self-regulation after litigation. Lack of data at the Government level has led to allowing the local operators to proclaim themselves the only experts and to prepare the maps to zone their own lands as SG (sand and gravel zone). Certainly, State and local Governments have recognized the importance of this resource, but they are uncertain where it is, do not have the geologic expertise to plan for such lands, and have begun to allow private landowners to delineate the zones without any realistic geologic interpretations, drilling, data gathering, or planning effort by State or Federal Government agencies. Lack of such data does not facilitate proper use of one of the most effective planning tools, the police power over land use. A similar course of events was experienced with flood-plain planning before the USGS, FEMA, and FIA got into the act, and provided some scientific basis for use of the police power in land-use planning and zoning.

The economic consequences of mining this resource are not trivial. Within the next 15 years, about 715 million tons of sand and gravel are going to be needed to meet projected construction demands in Arizona, largely in areas of urban growth. The total payroll for Arizona workers in sand and gravel mining and various affiliated construction industries was more than \$2.39 billion in 1985. In that year, output per worker in sand and gravel mining was \$80,908, which was slightly higher than that of the exalted electronics worker, who accounted for \$80,490. The presently planned freeway system for Maricopa County will create a future demand for 8,760,000 yd^3 of concrete and 14,496,000 tons of sand and gravel for its construction.

In addition to the availability of the resource itself, the weight of rock products and the perishability of mixed concrete lead to increased transportation costs. As sand and gravel production sites are moved farther and farther away from construction sites, the total urban economic costs rise dramatically. Studies show that if production sites were moved only 10 mi from delivery sites, this would add more than \$1.3 billion to Arizona construction costs over the next 15 years; and at a distance of 40 mi, the cost would increase to more than \$5.2 billion in added construction costs to Arizona consumers. This increase does not account for other external diseconomies, such as torn-up urban streets, traffic congestion from trucks, air pollution, and so on.

Certainly, sand and gravel lands should be available as close as possible to the place of use. However, considerable local opposition has become a reality as urban residential land uses have pushed onto the bajadas, flood fringes, and alluvial fans. Zoning is a tool being utilized to restrict the use of resources in some urban places. This situation has become more critical as the flood-plain program itself has made it difficult to mine in floodways.

The nonmetallic minerals may be so varied and discrete that different data programs and mapping techniques are necessary for each, and the interface with local Government land-use planning programs will be different for each one. Each mineral may require different scales of data. I have focused only on sand and gravel because of their importance to the future of urban areas, and their sensitivity to good urban land-use planning.

In summary, the future of integrated, intergovernmental, comprehensive natural-resource and land planning in America should be positively affected by a continuing thaw of the cold-war philosophy and its concomitant antiplanning political rhetoric. This change may foretell a virtual renaissance in planning during the 1990's, further accommodated by major improvements in computers and such planning tools as remote sensing. Despite the lack of commitment and coordination of land planning, there have been good examples of Federal assistance to local planning, but not nearly enough to stem the rising costs of growth. Among these examples are the flood-plain, ground-water, and seismic-risk programs. A specific example of how geologic-resource information could be beneficially used now is the scientific identification of sand and gravel deposits for local Government planning and zoning agencies. The economic benefits could be very high. A mapping program would be required, in combination with flood-plain-mapping efforts on the same base maps. To be useful at the local level, a scale of 1 in. to 200 ft would be required; help in transposing the data to zoning maps would be much appreciated by local planning directors. Identifying the deposits in urban areas, ranking their value (size and composition) on a rough scale, and printing the results on Flood Insurance Rate Maps would be a major contribution.

PARTICIPANTS' DISCUSSIONS OF LOCAL-PLANNING NEEDS

• The total mineral output in Arizona of copper and everything else was about $1.7 billion. That gives us a scale to work from. The additional cost of moving the gravel to the consumer caused by zoning gravel pits out to areas beyond a 30-mi radius from the use site is going to add $4.5 billion in direct cost. That's more than the output of the entire mineral industry of the State!

• Even though Phoenix is the largest city in Arizona and the ninth largest in the United States, it's still a pretty small spot on the map. Planners are not worried about 1:1,000,000-, 1:250,000-, or even 1:24,000-scale maps; they often are thinking about data at a some fairly tight scale.

Reply: When you have discrete data—let's say, the location and description of one of the zeolite mines—those data are at a pretty large scale. As for maps, I've never seen a map that wasn't useful to a land planner. There are 15 county planners; some counties have a lot of private land, and some don't. In addition, the State is trading off its land with the Federal Government, and so we can't depend on the pattern remaining unchanged. Some lands will be urbanized if a 50- or 100-year time scale is used. Once these data are available, we can start saying that subdivisions will not be put on an area because it has mineral potential. All an urban planner can tell is that urbanization is increasing all across the State. Phoenix isn't the only town that's growing: Tucson is big, but the Yuma, Flagstaff, Camp Verde, and Parker areas are also expanding. Some of the counties where traditional mines are located are not developing significant urban areas, for example, Greenleaf and Cochise. So, as to scale of practicality on the geological-survey level, whatever scale is economic is acceptable because the next wave of urbanization will take up any slack.

• If there were an opportunity for the Arizona State Geologist to hold a meeting of county land planners or city county planners to discuss minerals, is there anyone out there to invite?

Reply: The AICP at the State level is one possibility. There was a remote-sensing committee within it, and there are GIS subgroups at the national and local levels. There are planners interested in information, some involved in transportation as well as land-use planning, some involved in environmental planning. But they come from the private land-planning tradition. There are mailing lists and contacts for such persons.

• Is there some way the AZGS could support a group meeting with planners that would focus their attention on minerals?

Reply: A talk could be scheduled at an annual meeting of the AICP, or you could schedule a meeting and invite the society. It would be more economical to ask to be put on the annual-meeting program.

• Can we have more elaboration and clarification about the data requirements for planners? There is a clear picture of explosive growth in Arizona over the next several decades, and an increasing use of industrial minerals. We have heard that the data necessary to work on this problem, using the analogy of the flood plain, were needed but weren't available early enough. What types of industrial-mineral information will be necessary at the local planning level, and how should it be put together and made available?

Reply: That's a big question deserving some theoretical work by resource experts over a period of time; it's not something that can be answered specifically. For example, there are 14 counties that don't have maps of sand and gravel potential to use for overlays. Data for use in compliance with a pending State act, if passed, would be a sand and gravel resource map for each county for use by the planning department and zoning agencies. For discrete mines, the scale changes, and data within a very small area are needed. Unless the deposits occur within an urban area, they would never cause a major conflict. There are other mines that create incredible hazards from tailings, which that can result in disastrous floods. I've surveyed some disaster areas where tailings have become involved in urban water supplies. Obviously, the environmental departments have been created to help regulate water pollution, and the health agencies may have an interface with them. That's another level of data use for environmental-planning purposes, but communication has to be kept up over time. As for maps, the use of remote-sensing data opens up another level of data whereby improved technology permits identification of resources as well as tectonic features. Geomorphologic data that may be useful in the scientific community are not always useful at the local planning level; they have to be interpreted.

• This workshop has been principally a meeting of geologists, so I'd like to speak from the viewpoint of a manager and operator of a local industrial-minerals operation, as opposed to an academic looking at rocks. I've worked in the minerals industry all my life in oil and gas, coal, uranium, and metallic minerals, as well as industrial minerals. Each of these commodities is somewhat different, but they all have a common base. From an economic standpoint, you realize that there are different areas of expertise which will be required to be successful. For example, in the early (pre-1902) oil and gas industry, the only thing necessary to be a successful company was to be a smart geologist, that is, a smart finder of the resource; you could have total idiots running the rest of the business. In Eastern coal, a different set of skills were required for success. Geologic skills were not particularly important, but very strong local managerial presence, to keep costs down, and some moderate sense of market trends were important for success. In Western nonferrous metals, copper-lead-zinc, similar competence—

more geologic input, but strong cost control of the operation—was needed, as well as a high level of technology in the mineral-processing field. Marketing ability was not required.

Industrial minerals are different, in that you need some competence in all three areas, as well as very strong ability in the marketing area. The geologic input is needed to discover and delineate competitive deposits—not perfect deposits, but competitive deposits, that is, something that will be useful for the market being defined. The mineral technology and processing skills are needed so that the mine will not operate at a substantial cost disadvantage to its competitors. It's a pretty rough-and-ready process in most cases. The real key for success, in my experience, is to be a darn good marketer, or you've lost the ball game. The geologic input, the resource assessment, and the mineral technology are all important, but the creation of a market product that meets specifications which can beat out competitive substitutes is more important. That's where you obtain leverage.

If I were going to attempt to encourage industrial minerals in Arizona, or anywhere else for that matter, I think I'd be looking at this problem differently. Rather than hiring more geologists, I'd be looking at hiring some mineral economists and (or) market-development persons to see if some of these common materials can be made into a silk purse. For example, most of northern Arizona is covered with volcanic cinders. You can take those cinders and make dandy roadstone or driveway gravel when it's mixed with asphalt. Their value is about $2.00 to $4.00 per ton. It's a low-value, common-variety resource. How about taking those same cinders and putting research-and-development money into seeing if you could create a medium for making hot tubs to sell in California? In this form, the cinder resource becomes a high-value, specialty resource. The same is true with specialty clays and diatomaceous earth in Arizona; these materials take technology at the market end that probably is as important as the resource identification and delineation. Again, I think we as professionals need to encourage and apply as great an effort on the marketing side as on the resource-assessment side, to stimulate the industrial-minerals industry in the State.

• There seems to be a philosophical difficulty and a frustration that we must defend minerals development and exploration, as if these activities were the enemy of the environment. There should be no reason for minerals to compete with the deer for priority. We have to make the case at the lower level that ore deposits are necessities for living and cannot be taken for granted. There also seems to be a momentum or mindset at present that the long-range national objectives are the biotic values, which take precedence over the abiotic resources. How can we reset the current priorities of public and governmental planners to the reasonable perspective that resources are also necessary?

Replies and comments: We can start off with the term "benign ignorance." But beyond that, the history of the BLM may illustrate the root of the problem. The USGS' Conservation Division dealt with minerals management in the Federal domain. This responsibility was transferred to the Minerals Management Service, and subsequently to the BLM. Over the period of USGS tenure, from 1925 to 1982, the BLM was called the General Land Office. In 1936, the Grazing Service was formed. These agencies were combined in 1946, becoming the Bureau of Land Management. At that time, its entire focus had been on the surface estate—grazing and land disposal. With the addition of the Minerals Management Service, the BLM underwent large expansion and responsibility for the overview of the surface and the subsurface—two entirely different, mostly competing perspectives of the world. The competition between surface and subsurface values continues today within the BLM. In answer to the question, there may be a lot of people who recognize this area of conflict and try to compensate. The BLM's job, before 1982, was almost entirely surface protection; minerals development was handled by a different agency. I don't think that we can expect to turn around attitudes of that magnitude in a short period of time. It's something that requires much effort in education. It may be a never-ending process.

Outside of Government, the answer is probably the same, local education of lay persons. It will never end, but we have to continue trying to develop that clear, long-range vision of reasonable and proper priorities.

As Senator Todd said, perhaps 1 out of 90 persons in the legislature is interested in natural resources, but let's hope that there are more than that 1. Even among geologists in and outside of academia, how many are really concerned about resources? All too often, we're interested in our own research, and we can communicate effectively with others of a like persuasion. That's important, of course. We tend to get specialized in this society, and sometimes we look at the world differently; that may not be what the real world needs.

We have to do a better job of talking to the public about these concerns, rather than just to ourselves. We must move in that direction in any way possible, to let the public know what the issues are and their significance in national priorities. Let's not forget to talk to the Optimist Clubs.

Summary Comments and Recommendations

T.H. Eyde, *Moderator*

Introduction

Several resource-availability issues have been examined during the workshop: (1) the current status of industrial rock and mineral resources in Arizona and the future prospects for enhancing them; (2) some of the critical problem areas that complicate the search for and evaluation of these materials; (3) several encouraging current geotechnical research programs that can be expected to assist in the evaluation, exploration, and discovery of resources; and (4) examination of the perceived needs of resource information by a widely divergent user constituency, including Federal, State, and local Governments, the Indian Nations, academia, and the resource industry.The objective in the final workshop session is to develop participant recommendations for sharpening the focus of resource programs and products of the AZGS, USGS, and other resource-directed organizations. A summary statement by a panel representing the user community is followed by a compilation of the specific recommendations.

Industry Comments

By B.N. Watson

Exploration for industrial minerals differs vastly from exploration for metallic minerals. Development of both metallic- and nonmetallic-mineral materials is market driven, but industrial minerals have to be handled on a much more individual basis. Material specifications are critical, and a marketing strategy may be crucial. A serious problem for many explorationists—those who are not affiliated with a large company—is to get material identified, analyzed, and tested. We've also seen that sand and gravel is another world, which needs to be considered separately from all the other industrial minerals.

There probably is a lot more industrial-mineral exploration and development going on in Arizona than you might think. It's a type of business that's out of the limelight, in comparison with gold and silver. As Ted Eyde pointed out, the industrial-minerals business accounts for something like $18 billion per year, in comparison with only $7 billion for the metallic minerals, mostly copper. Note that domestic supplies meet most U.S. needs for industrial rock and mineral materials.

I think that this workshop has considerable potential value, an important part of which has been the opportunity to clear the air and to make some suggestions for program enhancement. It bothers me that I've felt inclined to make such recommendations as the core repository and upgrading BLM claims-data posting, which would require increased Government personnel and money. I view the USGS and AZGS as service organizations, each with strong research components. But as service organizations, I stress that the industry has a continuing need for their traditional geologic mapping. That's probably the number 1 need of industry from both surveys. Age determinations and analytical data also are continuing basic needs. I'm happy with the general directions of the USGS resource programs, as far as I know them. I would deplore any deemphasis on mapping. I'm also happy with what I see of the AZGS programs, but I'd like to see that activity scaled up and their publications increased.

Finally, I guess I'd agree that better communication is definitely needed between industry and the Federal and State regulatory agencies. My own land agent and geologists are working on this problem with the BLM in California and Nevada. I think, perforce, if not for other reasons, that communications between industry and the regulatory agencies will increase. I don't have a list of items that I wish the Government would provide at the present time; I'd like more to emphasize the things we like that they're already doing and that we'd like to see continued.

Federal Land-Management Agency Comments

By L.P. Bauer

This has been an extremely useful workshop for me in calling attention to the special problems of the industrial-minerals industry, because my background has been in leasable minerals—oil, gas, and coal. The need for increased communications is especially important, and I'll see if a one-day conference with industry persons and the Federal land regulators can be scheduled—to explain our administrative positions on new policies, to develop ways of handling legal requirements and data, and to gain advice from industry. The BLM has done this on almost a yearly basis for the oil and gas industry in the "OPEC" States of New Mexico, Colorado, Wyoming, and Montana. We should do that for the industrial-mineral industry in Arizona.

State Land-Management Agency Comments

By M.J. Rice

The current mapping being done by the AZGS and the possibility of completing depositional-environment studies are information that we would find useful, particularly in evaluation for an inventory of potential mineral properties in Arizona.

As far as industry's needs are concerned, we can provide access to the lithologic and electric logs that are in our files, and can assist in land-status determinations. Because our need for information is quite extensive, I'd like to see the ASLD involved in a focused exchange of information with all the agencies represented here, as well as with industry representatives. I believe that these workshops are helpful in identifying the framework for better communication.

Academia Comments

By M.F. Sheridan

The three main functions of a university are teaching, research, and service. Some suggestions are presented here for improvement in education related to nonmetallic-mineral deposits, provision of resources necessary for training and research in these areas, and development of services that they could provide to the resource community.

Improvement in education requires better resource information regarding nonmetallic minerals. At present, the State lacks a uniform coverage of geologic and spectral data. Landsat TM imagery is one of the best available sources for such data. A complete set of TM images for Arizona would greatly improve the availability of geologic and other information to the public. Its dissemination would be facilitated by the use of a centralized image-processing laboratory. The estimated cost for complete coverage of the State by TM imagery in digital format is approximately $40,000. The presence of an image-processing facility for geologic data at an academic institution, at the new USGS office, or at the AZGS office in Tucson would be important for evaluation of industrial-mineral resources.

Closer cooperation between academia and industry would be of great benefit for resource assessment and exploration. University students constitute a tremendous asset for on-the-job training because they are technically well trained and strongly motivated. The students need both moral and financial support from industry and Government agencies. Students are constantly looking for research problems; however, it is difficult to convince them to choose research problems that appear to have a poor chance of being funded. Although research projects range from theoretical to practical, funding from Government agencies, such as the NSF, is generally directed toward the more theoretical; research projects with strongly practical objectives generally go unfunded. Because specific target commodities change over time, an early connection with a company could focus a student toward an area of research that is interesting to industry and also beneficial to the general public.

Close contacts among all the groups represented at this workshop would help achieve the academic goals of research and service. Better communication among universities, Government agencies, and industry could help promote the development of natural resources. Joint research projects with common goals would be of great benefit to the State. Identification of specific commodities to be studied by industry, Government, and academia is needed. One example of a topic that could be studied is volcanic materials—lavas, pumice, pumicite, and cinders. A study of these products could determine possible markets, the available resource base, and field specifications for exploration. Such a study would form the basis for a source document for decisions by land-management agencies. At present, each site for these materials is generally considered unique.

The universities are the ideal environment in which to foster advances in the techniques of resource assessment and exploration. One potential research theme is the development of a prototype GIS for mineral resources. A GIS would be useful because it not only contains a CAD component with geographic layers but also has an integrated data-base system with linkages between both modes. Changes in one part of the system have an immediate and visible effect on the rest. Thus, a GIS is dynamic and well suited to testing various economic and geographic models. A GIS should be invaluable for considering projected markets for commodities. In many other ways, a GIS would be extremely useful for resource assessment.

Development of a GIS will require a large team of researchers to cover different aspects of the project. Because of the great investment of time and effort in acquiring the GIS data base, we must start developing a prototype system as soon as possible. The ultimate form of data structure and display cannot be assembled without developing and testing a prototype. We also need to create resource models for analysis of the data. Both of these projects (data acquisition and resource models) are areas in which academia can be helpful in the establishment of an Arizona GIS (AGIS).

The university faculty could synthesize models for resource assessment, using data from student theses and their own projects. An example of a project well suited to data synthesis is the type of basin analysis that Dale Nations and Wayne Ranney reported on at this workshop. Every basin in Arizona is probably unique, and we need to know more about the resources they contain. This also is an area where better coordination between industry and academia could produce positive results. Students will be much more interested in practical problems if their faculty advisors are also involved.

Finally, there is a need for developing new analytical techniques that are specific for different types of industrial-mineral products. The universities have the facilities and faculty to provide the diverse research capabilities needed for this type of investigation. Most faculty members in the geosciences, however, are unaware of the types of problems facing industry, in terms of identifying the quality and quantity of various industrial minerals. Projects must be proposed and research funds made available for development of the new technology.

Recommendations of the Participants

E.W. Tooker, *Compiler*

Before setting forth specific workshop recommendations, it seems worthwhile to place them in the context of the main conference findings. It was recognized that there will be a continuing and increasing pressure to expand the Arizona economy so as to accommodate an explosive increase in population, which, in turn, will require accelerated use of industrial rock and mineral materials. At the same time, the known available industrial rock and mineral resource base is being depleted, and the sources of potential materials are being subjected to increasing land-use competition. How can earth scientists, land managers, planners, and the mineral industry begin to help alleviate this apparent impasse? First, accurate, up-to-date, retrievable resource information, together with new earth-science search technology, will aid resource-assessment, discovery, and economic-development activities. Second and no less important is the need promote congenial, mutual understanding of the ground rules for, and the motivation of, the individual parts of the resource constituency in Arizona. Reduction of adversarial working relationships among the diverse users of industrial-mineral resources should help provide the climate for more equitable and environmentally safe future resource decisions.

This workshop produced a beginning response to these determinations. The recommendations that follow illuminate some of the specific paths toward resolving the apparent resource dilemma facing the State. Ways to increase the effectiveness of the resource programs of the USGS and AZGS are also considered. The recommendations are grouped in the order in which they were considered during the workshop. Starred (*) recommendations indicate that their significance warrants prompt attention; unstarred recommendations represent desirable, longer term goals.

DATA ACQUISITION AND MANAGEMENT

*1a. The AZGS and USGS should continue and, where possible, expand their joint and individual resources-directed geologic-mapping programs.

*1b. The AZGS and USGS should continue their joint efforts to acquire a broad spectrum of computer-based resource information and to provide data-retrieval systems accessible by a wide range of users.

*1c. The computer systems of the AZGS and USGS should be compatible with each other and with those in other States, ultimately to develop a uniform system of national industrial-mineral-resource information.

*1d. The operation of the AZGS and USGS data centers should be more closely coordinated with and tied to related systems or sources of additional data in other Government agencies, academia, and industry.

*1e. The existing AZGS well-cutting and core-storage library obtained from public and private industry sources should be expanded.

*1f. The AZGS and USGS computer systems should be periodically evaluated by representatives of the user community to assure that the systems meet existing and anticipated data needs.

1g. A "one stop" computer center for Arizona resource information may provide users with the most efficient and economical data source.

*2. An interagency and academic inventory of available Arizona resource information should be undertaken, and a plan developed to share such information on request.

3. Upon completion or abandonment of any industry activity on State, Federal, and, ideally, private lands in Arizona, the files of raw data from drilling and geologic exploration should be made available to AZGS data systems, so as to improve the data base, forestall or reduce present costly duplicative exploration efforts, and assist in resource assessments.

4. A complete set of Landsat TM images for Arizona and the equipment necessary to use the data should be made available.

5. As research on and development of a GIS proceeds, such capabilities should be applied to the State's resource-data system, along with the technical backup required.

6. The capability to digitize and manipulate geologic, geophysical, and geochemical map data should be made routinely available to meet needs for quick release of map data, and for update and compilation. The State geologic map (1:500,000 scale) should be digitized first; this would be the core data for a GIS and for regional interpretation.

7. A centralized repository for the systematic collection and quick release of the rock ages that become available each year in the State should be undertaken by the AZGS.

8. Completed and inprogress dissertations on Arizona geology and resource-related subjects by Arizona and out-of-State universities should be compiled, indexed by title, and published annually by the AZGS.

9. Industry and Government agencies should make better use of the technical support available from academia by the use of strongly motivated, well-trained, and faculty-guided students. The University of Arizona's geoscience symposium program for the review of student research activities should be expanded to the other universities in the State.

10. Public apathy or ignorance of the fragility of the industrial-mineral-resource market and the tenuous availability of these resources highlights the need for increased education in the schools, the legislature, at public and service-club meetings, and in the printed and video media.

RESOURCE ANALYSIS AND TESTING

1. Although industry depends on commercial laboratories for analyses and materials testing, these laboratory facilities and services often are not well known. Therefore, an unofficial listing of volunteered information about available laboratories, their services, and charges, but without warranty as to the quality or speed of the services, should be kept on file as a useful service to explorationists who may lack access to such services.

2. Industrial minerals are unlike metallic minerals in terms of their occurrence, specifications, testing, production, and marketing characteristics. Thus, most of the land-management and resource-assessment methodology has been modeled on metallic-mineral-resource characteristics, whereas the classification, development of specifications, and production of industrial-mineral resources lie more in the area of marketing than of geologic availability:

a. Agreement on standard physical and chemical properties of industrial minerals should be considered by a broadly based committee representing industry, academia, and Government agencies. The composition of many individual minerals has been established by ASTM, AEG, and State and Federal resource agencies, but generic and specific attributes for aggregated materials and for many of the specialized or performance-oriented industrial minerals have not been established systematically.

b. The USGS, AZGS, USBM, ADMMR, and academia together should harmonize economic factors and mineral technology to provide correct, more equitable formulas in determining resource values in land-management decisions.

3. A broader range of materials testing should be implemented to improve the accuracy of resource assessments for industrial minerals in WSA's, particularly to enable changing certain "common variety" materials into specialized, performance-oriented materials, where applicable, and thereby increase their weight in the assessment process.

4. Additional academic research is needed on fibrous or acicular minerals in determining their surface-activity properties to use to counter the current shape-of-the-silicate-minerals criteria for separating those industrial minerals that may be carcinogenic from those that are safe to mine and use.

5. Periodic updating of information in such publications as the ADMMR's report on Arizona industrial minerals and the USBM's publication on the status of and need for specific industrial-mineral commodities in the State should be continued.

LAND-AVAILABILITY AND PERMITTING INFORMATION

*1. Completion of the computerization of mining-claim location, staking, and assessment records by the BLM should receive priority; a similar file should be started for State-owned lands by the ASLD, and for Indian lands by the BIA.

*2. Duplicative permitting requirements by State and Federal agencies that oversee exploration activity and resource development should be eliminated; the essential permitting requirement should be placed in one agency, available to all. Colorado, for example, has a permit directory for energy-and mineral-resource development that contains all the forms, names of contacts, and pertinent telephone numbers. A similar directory for Arizona would be desirable.

3. Existing publications, such as the USBM's report on the availability of Federally owned minerals in national parks and on military reservations in Arizona, and the ADMMR's report on the laws and regulations governing mineral rights on State lands, are invaluable sources of information that need to be regularly updated to reflect changes in minerals availability and policy.

4. Regularly scheduled meetings that include industry, land managers, and resource evaluators should be initiated to discuss problems, clarify controversial actions, foster development of acceptable weighting standards for resource values, and propose revisions of outdated or handicapping BLM or ASLD guidelines, many of which currently may provide only minimal recognition of known or potential industrial-mineral-resource values.

GEOTECHNICAL RESEARCH

*1. Periodic scientific/technical meetings of personnel from academia, State and Federal agencies, and industry who are directly involved with Arizona resource problems and challenges should be established. Such meetings will provide the incentive for closer liaison and mutual support, sharing of expertise and facilities, expansion of research opportunities (particularly in the areas noted below), and the development of new concepts to stimulate the industrial-minerals activity.

2. Research in geophysical technology, which has not been fully tested, is needed to expand the capability for assessing the potential for and the exploration of industrial minerals. This research should include gamma-ray-spectroscopy, EM, spectral-reflectance, and other techniques.

3. Research is needed to provide a stronger base for evaluation of geochemical anomalies and to distinguish those anomalies having resource potential from those that may be of scientific interest but do not have resource potential.

4. Existing regional geochemical data, originally collected for special purposes, should be screened and edited before being released into regional digitized geochemical data base.

5. Research is needed leading to rapid and quantifiable mineral technology, using simple chemical or instrumental methods for field and laboratory use in the detection of industrial-mineral materials.

6. Promising new assessment and exploration methods, such as remote sensing and neotectonic-domains research, should be developed and expanded to aid in identifying new terranes permissive for the discovery of industrial-mineral resources.

7. The focus of ASU's and USGS' prototype resource programs in their respective GIS's should be specifically broadened to include industrial rock and mineral materials.

8. Resource-occurrence models, such as the mineral, geochemical, and geologic basin types, which assist exploration, and the statistical models needed for resource assessment require continuing research and testing.

MEETING THE NEEDS FOR RESOURCE INFORMATION

*1. Arizona and the Nation need committed, coordinated, and well-informed land planning from Federal, State, and local land-management and protection agencies to assure availability and wise use of resources, while maintaining environmental and health values.

*2. Government agencies should strive to maintain open communication with industry representatives, who depend on prompt, sympathetic, and equitable actions. A wide range of management alternatives is needed to assure that future resource development is not forestalled or precluded in an adversarial climate or by overzealous use of the regulation.

3. Creating sound legislation in the public interest depends on resource scientists and professionals to provide their best, unbiased information and advice to the legislatures, and on industry support for those legislators who are responsive to meeting the State's continuing need for industrial-mineral resources.

4. The Indian tribes will benefit from the development of greater inhouse tribal expertise and confidence in handling their own mineral-resource matters with the outside resource community.

a. Companies should form mutually beneficial partnerships with the tribes through the development of personal relationships with tribal representatives, technology transfer, and training of Indians in developing their resource base.

b. Special programs should be developed by academia in which useful university-extension programs are jointly planned and held on tribal lands.

c. Expertise in the form of land management, geologic and mining technology, and resource-assessment methods should be available from the Federal Government.

5. Public meetings are encouraged, such as those of the USGS' CUSMAP, at which the results of an organization's resource information, management actions, or research results can be presented and discussed informally by users before release of formal, usually delayed, publications.

6. Informal discussions of resource-related problems, which may involve a diverse group of producers and users, such as those participating in this workshop, are

more productive for developing solutions than are formal adversarial hearings. Therefore, the workshop participants recommend that this session be followed at some regular interval by followup sessions to evaluate what has been accomplished toward meeting these recommendations, to consider further strategies for moving forward, and to consider any problems that have arisen in the interim.

7. Future industrial-mineral-resource requirements in Arizona undoubtedly will move toward a search for those resources required for high-technology applications, such as superconductivity, structural ceramics, and organic polymers, that meet as-yet-undefined, stringent user specifications and require long and complex processing. These small-volume, high-cost materials for "tomorrow's necessities" (London Mining Journal, 1988) will require technology advances to locate and develop them, and the modification of land management and planning regulations to make them available. Thus, high-technology research by Government, academia, and industry must be anticipated and planned.

Closing Comments

By G.H. Allcott

The AZGS and USGS greatly appreciate the time and serious effort by the workshop participants in their considerations of the problems faced by the industrial rock and mineral resource community, and their purposeful recommendations to reduce or solve these problems. Our industrial-mineral-resource programs should benefit from a better appreciation of the ways in which the information we develop can be used, how it can be delivered successfully in a timely fashion, and even more significantly, what the gaps are that our users find. Your opinions have been helpful to us, and we hope that you have gained a better understanding of what we are doing and where our interests lie. I concur with you that such meetings as these need to be conducted regularly. We will make significant progress toward meeting Arizona's resource needs only if we approach them constructively—together.

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APPENDIXES 1–6

APPENDIX 1.—Program for the 1988 Industrial Rock and Mineral Resources Workshop

INDUSTRIAL ROCK AND MINERAL RESOURCES OF ARIZONA: PROBLEMS, OPPORTUNITIES, AND RECOMMENDATIONS

A workshop sponsored by the Arizona Geological Survey (AZGS) and the Office of Mineral Resources, U.S. Geological Survey (USGS)

Sheraton Tempe Mission Palms Hotel
Tempe, Ariz.
May 17–18, 1988

Registration and coffee (May 17) 8:00–9:00 a.m.

• **SESSION 1 (May 17)** 9:00 a.m.

Welcome and introductory remarks: Goals, acknowledgments, and organizational plan for the workshop
Larry Fellows, *AZGS, Co-convenor/Co-host*

Overview of the current geologic and economic availability of industrial rock and mineral resources in Arizona
Wesley Peirce, *AZGS (retired)*

Potential for expanding the industrial rock and mineral resource base in Arizona
Ted Eyde, *GSA Resources, Inc.*

Coffee Break 10:00–10:15 a.m.

DISCUSSION—Current and emerging critical problem areas for the search and evaluation of Arizona industrial rock and mineral resources
E.W. Tooker, *Moderator* 10:15 a.m.

1. Data acquisition and management—what types of data (that is, written or drill cores) are available, where, and stored in what retrievable computer format or facility from Government, academic, industry, or consultant sources?
[Leaders: **S.J. Reynolds,** *AZGS*; **A. Barsotti,** *USBM*; and **K.A. Phillips,** *ADMMR*]
2. Analytical and laboratory and industrial testing capability—what types are needed to meet mineral-identification, chemical, and industrial specifications, and what is their availability from public or private facilities?
[Leaders: **D. Eyde,** *GSA Resources*; and **K. Broadhead,** *USBM*]

Lunch 11:45 a.m.–1:00 p.m.

• **SESSION 2 (May 17)** 1:00 p.m.

3. Land access and availability—what are constraints, regulations, and methods of obtaining access to Indian, State, Federal, and privately owned lands for evaluation, exploration, and production?
[Leaders: **M. Rice,** *ASLD*; **J. Crowther,** *BIA*; and **L. Bauer,** *BLM*]

DISCUSSION—Geotechnical and research capabilities to stimulate understanding and facilitate discovery of industrial rock and mineral resources

M.P. Foose, *Moderator* 1:45 p.m.

1. Application of geophysical technology in discovery and assessment
   [Leader: **J. Crowley,** *USGS*]
2. Geochemical exploration technology using solid and fluid materials to locate and assess resources
   [Leaders: **W. Dean,** *USGS*; and **P.K. Theobald,** *USGS*]

Coffee Break 3:15–3:30 p.m.

3. Regional geologic—use of new scientific and technical data to predict resource-forming processes and resource distribution in surface and subsurface sediments and igneous rocks
   [Leaders: **J.C. Dohrenwend,** *USGS*; and **M.F. Sheridan,** *ASU*]
4. Deposit models—methodology for deriving models to codify deposit-type characteristics and identify critical base data required; examples of USGS resource assessment models presented
   [Leaders: **G. Orris,** *USGS*; and **J.D. Nations,** *UNA*]

• SESSION 3 (May 17, evening)

Social Hour and Dinner 6:00 p.m.

INVITED SPEAKER: Senator Doug Todd, Arizona Senate, Introduction by Larry Fellows, State Geologist of Arizona

Topic: The legislative point of view, current political realities for the industrial rock and mineral resources industry in Arizona 8:00 p.m

• SESSION 4 (May 18, morning)

PANEL/DISCUSSION—Meeting the needs of the users of resource information. What are viable applied research components and products that may be expected from the mineral resource programs of AZGS and USGS?

L.D. Fellows, *Moderator* 9:00 a.m.

1. Industry needs for data and applied research to assess resources, assist exploration, and development
   [Leader: **B.N. Watson,** *U.S. Borax*]
2. State and Federal government needs for efficient land management
   [Leaders: **M. Rice,** *ASLD*; and **L. Bauer,** *BLM*]

Coffee Break 10:00–10:15 a.m.

3. Indian Nation's needs for effective development of their resource base
   [Leaders: **G. Anton,** *Salt River-Pima-Maricopa Committee*; and **R. Edwards,** *San Carlos Apache Tribe*]
4. Local government needs for resource information to assure broadening the resource base consistent with effective urban land-use planning and zoning regulations
   [Leader: **J.R. Perry,** *AICP*]

Comments from the floor—other user needs

Lunch 11:30 a.m.–1:00 p.m.

• **SESSION 5 (May 18, afternoon)** 1:00 p.m.

SUMMARY SESSION—What are the main conclusions developed during this workshop by the prime user groups (for example, Federal, State, and local Governments, Indian Nations, academia, and industry) regarding types and availability of resource information, advances in resource assessment and exploration research, and land access and use? What recommendations can the users make to improve the resource services of the State and Federal geologic and mining programs?

PANEL: **T. Eyde**, *Moderator*
B.N. Watson: Industry
L. Bauer: Federal Government
M. Rice: State Land Department
Debra Daniel: State Environmental Quality
M.F. Sheridan: Academia

WRAPUP—Evaluation of the workshop and appreciation of the participant's contributions; encouragement for continuing communication with AZGS and USGS
Glenn Allcott, *USGS, Co-convenor/Co-host*

ADJOURN

Appendix 2. Partial List of Analytical and Testing Laboratories

The following are some of the firms that advertise their capabilities to analyze and test industrial rock and mineral materials. This list is not complete, and no warranty of service quality is implied by the U.S. Geological Survey or the Arizona Geological Survey. This is only a starting point for interested users.

Chemex Labs, Inc.
103 N. Parkmont
Butte, MT 59702

C.S.M.R.I.-Analytica, Inc.
5930 McIntyre
Golden, CO 80403
(303) 279–2581

Corning Engineering Laboratory Services
Corning, NY 14830
(607) 974–6360

Charles H. Kline & Co., Inc.
330 Passaic Avenue
Fairfield, NJ 07006
(201) 227–6262

Global Geochemistry Corp.
6919 Eaton Avenue
Canoga Park, CA 91303
(818) 992–4103

Metallurgical Laboratories, Inc.
1142 Howard Street
San Francisco, CA 94103
(415) 863–8575

Ontario Research Foundation
Sheridan Park Research Community
Mississauga, Ontario, Canada L5K 1B3
(416) 822–4111

Explore (the Association of Exploration Geochemists Newsletter) contains advertisements for analytical services. A more extensive listing, indexed as (1) chemical analyzing and assaying, (2) mineral determinations, and (3) testing, other than 1 or 2 above, may be found in the 1988 Buyer Guide, Engineering and Mining Journal, v. 189, no. 9, p. 103–104.

Appendix 3. Indian Agency and Tribal Council Officials, Phoenix Area

ARIZONA

Colorado River Agency	C. L. Henson, Superintendent	Rt. 1 Box 9-C, Parker, AZ 85344	(602) 669-6121
Chemehuevi Tribal Council	Richard Alvarez, Chairman	P.O. Box 1976, Chemehuevi Valley, CA 92363	(619) 858-4531
Colorado River Tribal Council	Anthony Drennan, Sr., Chairman	Rt. 1 Box 23-B, Parker, AZ 85344	(602) 669-9211
Fort Mojave Tribal Council	Nora Garcia, Chairperson	500 Merriman Avenue, Needles, CA 92363	(619) 326-4591
Fort Apache Agency	(Vacant) Superintendent	P.O. Box 560, Whiteriver, AZ 85941	(602) 338-4364
White Mountain Apache Tribal Council	Reno Johnson, Sr., Chairman	P.O. Box 700, Whiteriver, AZ 85941	(602) 338-4346
Fort Yuma Agency	Felix Montague, Superintendent	P.O. Box 1591, Yuma, AZ 85364	(619) 572-0243
Cocopah Tribal Council	Fred Miller, Sr., Chairman	Bin G, Somerton, AZ 85350	(602) 627-2102
Quechan Tribal Council	Lorraine White, President	P.O. Box 1352, Yuma, AZ 85364	(619) 572-0213
Hopi Agency	Alph Secakuku, Superintendent	P.O. Box 158, Keams Canyon, AZ 86034	(602) 738-2228
Hopi Tribal Council	Ivan Sidney, Chairman	P.O. Box 123, Kykotsmovi, AZ 86039	(602) 734-2445
Papago Agency	James Barber, Superintendent	P.O. Box 578, Sells, AZ 85634	(602) 383-7286 (8-261-7286)
Tohono O'odham Council	Enos Francisco, Chairman	P.O. Box 837, Sells, AZ 85634	(602) 383-2221
Pima Agency	Denise Homer, Superintendent	P.O. Box 8, Sacaton, AZ 85247	(602) 562-3326 (963-7673)**
Ak Chin Indian Community Council	* Delia Antone, Chairperson	Rt. 2, Box 27, Maricopa, AZ 85239	(602) 568-2227
Gila River Indian Community Council	* Thomas R. White, Governor	P.O. Box 97, Sacaton, AZ 85247	(602) 562-3311 (963-4323)**
Salt River Agency	(Vacant) Superintendent	Rt. 1 Box 117, Scottsdale, AZ 85256	(602) 241-2842
Mohave-Apache Community Council	Clinton Pattea, President	P.O. Box 17779, Fountain Hills, AZ 85268	(602) 990-0995
Pascua Yaqui Tribal Council	David Ramirez, Chairman	7474 S. Camino De Oeste, Tucson, AZ 85746	(602) 883-2838
Salt River Pima-Maricopa Indian Community Council	Gerald Anton, President	Rt. 1 Box 216, Scottsdale, AZ 85256	(602) 941-7277
San Carlos Agency	Allen J. Anspach, Superintendent	P.O. Box 209, San Carlos, AZ 85550	(602) 475-2321
San Carlos Council	Buck Kitcheyan, Chairman	P.O. Box 0, San Carlos, AZ 85550	(602) 475-2361
Truxton Canon Agency	George Keller, Superintendent	Valentine, AZ 86437	(602) 769-2286
Havasupai Tribal Council	* Delmer Uqualla, Chairman	P.O. Box 10, Supai, AZ 86435	(602) 448-2961
Hualapai Tribal Council	Edgar Walema, Chairman	P.O. Box 168, Peach Springs, AZ 86434	(602) 769-2216
Tonto Apache Tribal Council	Jeri Johnson, Chairperson	Tonto Reservation #30, Payson, AZ 85541	(602) 474-5000
Yavapai-Apache Community Council	Theodore Smith, Sr., Chairman	P.O. Box 1188, Camp Verde, AZ 86322	(602) 567-3649
Yavapai-Prescott Board of Directors	Patricia McGee, President	P.O. Box 348, Prescott, AZ 86301	(602) 445-8790
San Carlos Irrigation Project*	Ralph Esquerra, Project Engineer	P.O. Box 250, Coolidge, AZ 85228	(602) 723-5439 (963-6902)**
Phoenix Hopi Partitioned Lands Office	Ray Smith, Natural Resource Manager	P.O. Box 10, Phoenix, AZ 85001	(602) 241-5190

*Denotes changes & **Phoenix numbers 9 + seven digit number)

Appendix 4. General Requirements for Indian Mineral-Resource Development

A. Proposal Stage

1. Proposals (written or oral) must be submitted to the tribal governing body (tribe) having authority over the lands in which the proposer is interested.

2. The BIA may offer procedural and other information to proposers.

B. Negotiations Stage

1. Negotiations are conducted by the tribes. The BIA is available to provide technical assistance to tribes, if requested.

C. Contract Stage

1. Contracts should be submitted by proposers and reflect the following basic principles:

a. Prospecting/exploration contracts, and mining contracts are executed by the tribes, and approved by the BIA.

b. Prospecting/exploration plans, and mining plans, are approved by the BLM after consultation with the BIA. Current policy requires concurrence by the tribes.

c. Absolute options for mining cannot be conferred in a prospecting/exploration contract because of the requirement for National Environmental Policy Act of 1969 (NEPA) compliance.

2. Contracts under the authority of the Indian Mineral Leasing Act of 1938 must conform to the regulations contained in 25 CFR 211, 212, and 216 (regulations existing as of 5/15/88).

3. Contracts under the authority of the Indian Mineral Development Act of 1982 must conform to specific provisions of the Act in the absence of regulations, (no regulations as of 5/15/88). Leases issued under this authority must also conform to the procedures contained in 25 CFR 216.

4. Proposed regulations apply to the following authorities:
   a. 25 CFR 211
      (1) Subpart A - 1982 Act
      (2) Subpart B - 1938 Act
      (3) Subpart C - Applicable to all contracts
   b. 25 CFR 212
      Removed and reserved. Currently this number applies to mineral leasing of allotted Indian lands.
   c. 25 CFR 225
      (1) Subpart A - 1982 Act Oil & Gas Agreements
      (2) Subpart B - 1938 Act Oil & Gas Agreements
      (3) Subpart C - Applicable to all contracts

Appendix 5. U.S. Bureau of Land Management Mining-Claim Reports

For many years, mining claim information has been available at BLM Offices on microfiche by Arizona Mining Claim (AMC) serial number, the name of claim, the name of claimant, or geographic location (Township/Range/Section). This microfiche is updated several times a year.

Arizona has about 286,000 mining claims, of which approximately 148,000 are active. Current information on mining claim activity is often required to make decisions involving land title. Land and mineral information is being automated in accordance with the Automated Land and Mineral Record System (ALMRS). The Mining Claim Recordation System can now provide current information on mining claims. A serial page can be printed by a specific AMC number. The serial page includes information on the name of the claim, the name of the claimant, location of the claim, and actions that have happened on that specific case. A report is also available by Township/Range/Section. This report includes information on all claims in the specified location and includes the name of the claim, name of the claimant, status of the claim (active/closed), type of claim (placer/lode/millsite), date of location, and date of latest assessment.

The AMC Serial Page generally prints within a few minutes. However, the Township/Range/Section Report may take some time to generate the requested information and print (usually within the same day as requested). These computer reports are current to the day before's activity and are available in all Arizona BLM Offices.

Arizona State Office
Bureau of Land Management

May 23, 1988

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TRANS: LTSRP1T  FUNCTION: R  SERIAL NO: AMC134413
CASE TYPE: 384201  CLAIM NAME: SANDS OF TIME          COMMODITY CODE:
NAME(PEOPER/CORP/AGY)  MAILING ADDRESS        CITY              ST   ZIP
 GARRITY G W              PO BOX 1483           WICKENBURG        AZ  85358
              INT-REL: 03              PCT-INT: 00000000
 GARRITY DANI             PO BOX 1483           WICKENBURG        AZ  85358
              INT-REL: 03              PCT-INT: 00000000

              INT-REL:                 PCT-INT:

              INT-REL:                 PCT-INT:
MERIDIAN  TOWNSHIP  RANGE   SECTION    NE-NW-SW-SE     COUNTY  GEO-ST  DISTR
14         0080N    0050W    012           X             025      AZ      02


ACTION-DATE(MDY) ACTION-CODE  ACTION-TAKEN              ACTION-REMARKS
 05  05  1981         403       LOCATION DATE
 07  22  1981         395       RECORDATION NOTICE RECD
 05  26  1981         404       COUNTY RECORDATION        0;1383;743


 SUCCESSFUL RETRIEVE. ALL DATA PRESENTED.
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REPORT DATE:04/15/88

PCN:LT993

UNITED STATES DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT
LIST OF MINING CLAIMS BY SECTION

MERIDIAN = 14 TOWNSHIP = 0080N RANGE = 0050W SECTION = 012

QUADRANT NE	QUADRANT NW	QUADRANT SW	QUADRANT SE	SERIAL NUMBER	CLAIM NAME	CLAIMANT	CASE TYPE	STATUS	LOC DATE	LAST ASMT
X				AMC134413	SANDS OF TIME	GARRITY DANI	384201	CLOSED	05/05/1981	0000
						GARRITY G W				
			X	AMC134414	GARRITY'S MLST #1	GARRITY DANI	384401	CLOSED	05/19/1981	0000
						GARRITY G W				
			X	AMC134415	GARRITY'S MLST #2	GARRITY DANI	384401	CLOSED	05/19/1981	0000
						GARRITY G W				
			X	AMC17753	TOLLEY MILLSITE NO 1	TOLLEY CLARK	384401	CLOSED	10/25/1977	0000
			X	AMC17754	TOLLEY MILLSITE NO 2	TOLLEY CLARK	384401	CLOSED	10/25/1977	0000
		X	X	AMC194264	TIP #5	FEHR GEORGE	384201	ACTIVE	04/13/1983	1987
						GROSS DARRELL				
						WINDERS BUD				
		X	X	AMC194852	C G S I #7	FEHR GEORGE	384201	ACTIVE	04/13/1983	1987
						GROSS DARRELL				
						WINDERS BUD				
			X	AMC195380	MISTAKE MINE #1	BURRIS BRUCE	384101	CLOSED	04/14/1983	1985
			X	AMC195381	MISTAKE #2	BURRIS BRUCE	384101	CLOSED	04/14/1983	1985
			X	AMC195382	MISTAKE #3	BURRIS BRUCE	384101	CLOSED	04/14/1983	1985
			X	AMC199458	MOONSHINE	BEAVER JIM	384201	CLOSED	04/14/1983	1985
			X	AMC200174	MOONSHINE	BEAVER JIM	384101	CLOSED	05/15/1983	1984
X				AMC200175	MOONSHINE #2	BEAVER JIM	384101	CLOSED	05/15/1983	1984
X				AMC235741	MISTAKE	JONES HENRY	384101	ACTIVE	04/09/1985	1987
X				AMC235742	MISTAKE #1	JONES HENRY	384101	ACTIVE	04/09/1985	1987
X				AMC235743	MISTAKE #2	JONES HENRY	384101	ACTIVE	04/09/1985	1987
X				AMC275364	SANDS OF TIME #1	GARRITY DANI	384201	CLOSED	08/01/1987	0000
						GARRITY GW				
						KIRKLAND JOHN				
						KIRKLAND LLOYDA				
			X	AMC275365	SANDS OF TIME #2	GARRITY DANI	384201	CLOSED	08/01/1987	0000
						GARRITY GW				
						KIRKLAND JOHN				
						KIRKLAND LLOYDA				
X				AMC275366	SANDS MILLSITE	GARRITY GW	384401	ACTIVE	08/01/1987	0000
						KIRKLAND JOHN				
			X	AMC281212	SANDS MILLSITE #1	GARRITY DANI	384401	ACTIVE	12/30/1987	0000
						GARRITY G W				
						KIRKLAND JOHN				
						KIRKLAND LLOYDA				
			X	AMC281213	SANDS MILLSITE #2	GARRITY DANI	384401	ACTIVE	12/30/1987	0000
						GARRITY G W				
						KIRKLAND JOHN				
						KIRKLAND LLOYDA				

REPORT DATE:04/15/88 PCN:LT993

UNITED STATES DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT
LIST OF MINING CLAIMS BY SECTION

MERIDIAN = 14 TOWNSHIP = 0080N RANGE = 0050W SECTION = 012

QUADRANT NE	NW	SW	SE	SERIAL NUMBER	CLAIM NAME	CLAIMANT	CASE TYPE	STATUS	LOC DATE	LAST ASMT
X				AMC281215	SANDS OF TIME #1	GARRITY DANI	384201	ACTIVE	12/30/1987	0000
						GARRITY G W				
						KIRKLAND JOHN				
						KIRKLAND LLOYDA				
			X	AMC281216	SANDS OF TIME #2	GARRITY DANI	384201	ACTIVE	12/30/1987	0000
						GARRITY G W				
						KIRKLAND JOHN				
						KIRKLAND LLOYDA				
			X	AMC36142	TOLLEY MILL SITE #1	TOLLEY CLARK	384401	CLOSED	01/30/1975	1979
			X	AMC36143	TOLLEY MILL SITE #2	TOLLEY CLARK	384401	CLOSED	01/30/1975	1979
			X	AMC56585	TOLLEY MILL SITE #1	KIRKLAND JOHN	384401	ACTIVE	07/11/1979	1986
			X	AMC56586	TOLLEY MILL SITE #2	KIRKLAND JOHN	384401	ACTIVE	07/11/1979	1986
X				AMC56588	SANDS OF TIME	BARNES RON	384201	CLOSED	07/11/1979	1986
		X	X	AMC84710	COPPER LODE NO 1	AROS JOE	384101	ACTIVE	02/10/1956	1987
						JONES LOIS				
						STANSBERRY KARL				
		X	X	AMC84713	VISTA NO 2	AROS JOE	384101	ACTIVE	04/24/1956	1987
						STANSBERRY KARL				
X			X	AMC84715	BLACK TOP	AROS JOE	384101	ACTIVE	11/22/1954	1987
						JONES HENRY				
						JONES LOIS				
						STANSBERRY KARL				
X	X	X	X	AMC84716	BLACK TOP NUMBER ONE	AROS JOE	384101	ACTIVE	11/22/1954	1987
						JONES HENRY				
						JONES LOIS				
						STANSBERRY KARL				
			X	AMC84717	MISTAKE	AROS JOE	384101	ACTIVE	11/22/1954	1987
						JONES HENRY				
						JONES LOIS				
						STANSBERRY KARL				
			X	AMC84719	MISTAKE NO ONE	AROS JOE	384101	ACTIVE	11/22/1954	1987
						BAKER C D				
						STANSBERRY KARL				
		X	X	AMC84720	MISTAKE NO 2	AROS JOE	384101	ACTIVE	11/22/1954	1987
						BAKER C D				
						STANSBERRY KARL				

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Appendix 6. U.S. Forest Service's Proposed Resource Classification

[3410-11]

DEPARTMENT OF AGRICULTURE

Forest Service

36 CFR Part 228, Subpart C

Disposal of Mineral Materials

AGENCY: Forest Service, USDA.

ACTION: Proposed rule.

SUMMARY: Existing regulations at 36 CFR 228, Subpart C, authorize the disposal of mineral materials. These materials include petrified wood and common varieties of sand, gravel, stone, pumice, pumicite, cinders, clay and other similar materials. This proposed rulemaking would clarify which mineral materials are those common varieties subject to disposal by the Secretary of Agriculture under the Mineral Materials Act of 1947.

DATE: Comments must be received by June 27, 1988

ADDRESSES: Send written comments to F. Dale Robertson, Chief (2850), Forest Service, USDA, P. O. Box 96090, Washington, D. C. 20090-6090. The public may inspect comments received on this proposed rule in the office of the Director, Minerals and Geology Staff, Room 606, 1621 North Kent Street, Arlington, VA, during regular business hours (8:00 a.m. to 4:00 p.m.), Monday through Friday.

FOR FURTHER INFORMATION CONTACT: Steve Marshall, Minerals and Geology Staff, (703) 235-3142.

SUPPLEMENTARY INFORMATION: The Materials Act of July 31, 1947 [30 U.S.C. 601 et seq.], as amended by the Act of July 23, 1955 [30 U.S.C. 601, 603 et seq.] allows the Secretary of Agriculture, under such rules and regulations as he may prescribe, to dispose of mineral materials including, but not limited to, common varieties of sand, stone, gravel, pumice, pumicite, cinders, and clay. Existing regulations at 36 CFR 228, Subpart C, covering disposal of mineral materials do not specify what materials are common varieties. This lack of specificity makes it difficult for operators and the agency to know what materials may be disposed of under 36 CFR 228, Subpart C, versus those materials that are subject to exploration, prospecting, and claim under the U.S. Mining Laws. Consequently, operators have staked numerous mining claims under the provisions of the 1872 Mining Law for materials on National Forest System lands that are actually subject to sale and disposal by the Secretary of Agriculture through Subpart C provisions.

The lack of an explicit description of common varieties in the 1955 Act and in subsequent regulations has led to several hundred mining claim contests dealing with common variety issues. These contests have resulted in a series of administrative and judicial interpretations variously defining common variety characteristics. The result of these precedents is a complex set of criteria making it difficult for the Forest Service and operators alike to know whether or not a material is a common variety. The time and cost of resolving such questions is an imposition on both parties.

The overall objectives of the 1955 Act were to allow for the multiple use of public land resources and to prevent fraudulent location of mining claims under the mining laws. Towards these ends, this proposed rule would establish five categories of common variety mineral materials to guide authorized agency personnel in determining whether a material should be sold under the rules at Subpart C. These categories reflect both the legislative history prior to the passage of Public Law 167 and the judicial and administrative interpretations since then. The proposed categories and representative examples of uses within each category are as follows:

1. Common Varieties.

A. Agricultural Supply and Animal Husbandry Materials. This category includes, but is not limited to, materials used as or for: soil conditioners or amendments, fertilizers or other direct applications to the soil such as carbonate rocks, animal feed supplements, and other animal care products.

B. Building Materials. This category includes, but is not limited to, materials used as or for: flagstone, ashlar, rubble, mortar, brick, tile, and terrazzo used for floors, walls, roofs, fireplaces, and similar building construction uses.

C. Cleaning and Abrasive Materials. This category includes, but is not limited to, materials used as or for: filters, absorbents, filing, scouring, polishing, sanding, and sandblasting.

D. Construction Materials. This category includes, but is not limited to, materials used as or for: fill, borrow, rip-rap, ballast, road base or surfacing, crushed rock, concrete aggregate, and clay sealants.

E. Decorative and Ornamental Arts Materials. This category includes, but is not limited to, materials used as or for: sculpture, lapidary, furniture, and natural art objects. This category does not include precious gems.

F. Landscaping Materials. This category includes, but is not limited to: chips, granules, sand, pebbles, cobbles, boulders, or slabs used for retaining walls, walkways, patios, yards, gardens, and the like.

2. Uncommon Varieties. The following types of uncommon materials are not subject to disposal under this Subpart:

A. Limestone suitable and used for cement manufacture, metallurgy, production of quicklime, sugar refining, whiting, fillers, paper manufacture, and desulfurization of stack gases;

B. Silica suitable and used for glass manufacture, production cf metallic silicon, and rock wool;

C. Alumino-silicates or clays suitable and used for production of aluminum, ceramics, drilling mud, taconite binder, and foundry castings;

D. Gypsum suitable and used for wallboard, plaster, or cement;

E. Precious gems (gem quality diamond, jade, opal, sapphire, star garnet, turquoise, and tourmaline); and

F. Block pumice which occurs in nature in pieces having one dimension of two inches or more.

Based on both past experience and environmental analysis, this proposed rule will have no significant effect on the human environment, individually or cumulatively. Therefore, it is categorically excluded from documentation in an environmental assessment or an environmental impact statement (40 CFR 1508.4).

This rule has been reviewed under Executive Order 12291 and USDA procedures and it has been determined that this rule is not a major rule. Additionally, it will not have a significant economic effect on a substantial number of small entities as defined under the Regulatory Flexibility Act (5 U.S.C. 601 et seq.).

The proposed rulemaking contains no information collection requirements needing the approval of the Office of Management and Budget under 44 U.S.C. 3501 et. seq.

List of subjects in Part 228

Administrative practice and procedure; Environmental protection; Mines; National forests; Public lands--Mineral resources; Rights of way; Reporting and recordkeeping requirements; Surety bonds; Wilderness areas.

Therefore, for the reasons set forth in the preamble, it is proposed to amend Subpart C of Part 228 of Title 36 of the Code of Federal Regulations as follows:

PART 228

Subpart C

1. The authority citation for Part 228 continues to read as follows:

AUTHORITY: 30 Stat. 35 and 36, as amended (16 U.S.C. 478, 551), and 94 Stat. 2400.

2. Revise {228.41 by adding new paragraphs (c) and (d) to read as follows:

{228.41 Scope.

* * * * *

(c) Materials to which this subpart applies. This subpart applies to mineral materials which consist of petrified wood and common varieties of sand, gravel, stone, pumice, pumicite, cinders, clay, and other similar materials. Such common variety mineral materials include deposits which, although they have economic value, are used for agriculture, animal husbandry, building, cleaning and abrasion, construction, decorative and ornamental arts, landscaping, and similar uses. Representative examples of these materials are:

(1) Agricultural Supply and Animal Husbandry Materials. This category includes, but is not limited to, materials used as or for: soil conditioners or amendments, fertilizers or other direct applications to the soil, such as carbonate rocks, animal feed supplements, and other animal care products.

(2) Building Materials. This category includes, but is not limited to, materials used as or for: flagstone, ashlar, rubble, mortar, brick, tile, and terrazzo used for floors, walls, roofs, fireplaces, and similar building construction uses.

(3) Cleaning and Abrasive Materials. This category includes, but is not limited to, materials used as or for: filters, absorbents, filing, scouring, polishing, sanding, and sandblasting.

(4) Construction Materials. This category includes, but is not limited to, materials used as or for: fill, borrow, rip-rap, ballast, road base or surfacing, crushed rock, concrete aggregate, and clay sealants.

(5) Decorative and Ornamental Arts Materials. This category includes, but is not limited to, materials used as or for: sculpture, lapidary, furniture, and natural art objects. This category does not include precious gems.

(6) Landscaping Materials. This category includes, but is not limited to: chips, granules, sand, pebbles, cobbles, boulders or slabs used for retaining walls, walkways, patios, yards, gardens and the like.

(d) Materials not covered by this subpart. Common variety mineral materials do not include materials used in manufacturing, industrial processing, or chemical operations for which no other mineral material can be substituted due to properties giving it distinct and special value; nor do they include block pumice which in nature occurs in pieces having one dimension of two inches or more. Disposal of these latter varieties of mineral materials is subject to the terms of the United States Mining Laws of May 10, 1872, as amended (30 U.S.C. 22 et seq.), on those portions of the National Forest System where these laws apply. They include:

(1) Limestone suitable and used for cement manufacture, metallurgy, production of quicklime, sugar refining, whiting, fillers, paper manufacture, and desulfurization of stack gases.

(2) Silica suitable and used for glass manufacture, production of metallic silicon, and rock wool.

(3) Alumino-silicates or clays suitable and used for production of aluminum, ceramics, drilling mud, taconite binder, and foundry castings.

(4) Gypsum suitable and used for wallboard, plaster, or cement.

(5) Precious gems (gem quality diamond, jade, opal, sapphire, star garnet, turquoise, and tourmaline).

(6) Block pumice which occurs in nature in pieces having one dimension of two inches or more.

3. Revise {228.42 by removing the term and definition of "mineral materials."

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(date)