FIELD NOTES FROM THE ARIZONA BUREAU OF MINES

Vol. 2, No. 2 Earth Science and Mineral Resources in Arizona *June, 1972*

THE EARTH RESOURCES TECHNOLOGY SATELLITE OVER ARIZONA

Larry K. Lepley
Kennith E. Foster

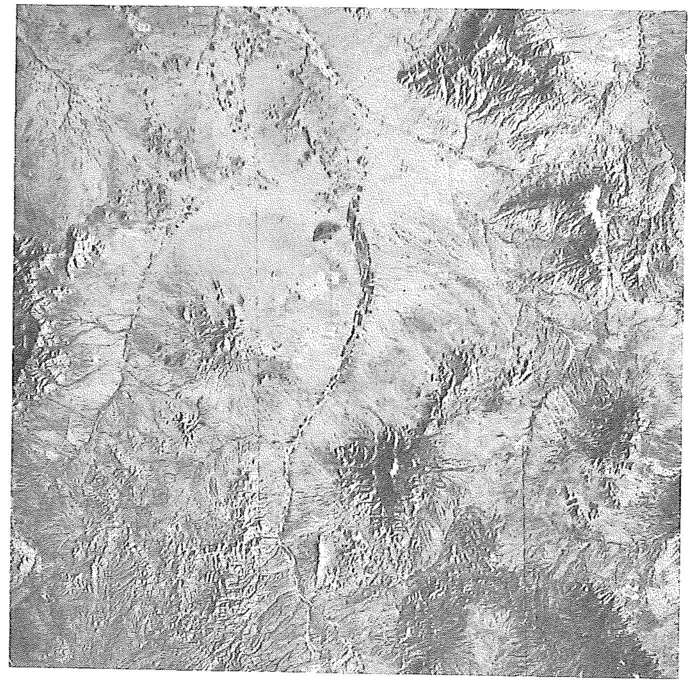
Research Associates, Office of Arid Lands Studies, University of Arizona.

In June of this year the earth resources test satellite (ERTS) will be launched by NASA from Vandenberg Air Force Base, California. This unmanned satellite will obtain pictures of the earth's surface in 100-mile-square overlapping frames, covering the entire United States and certain other regions of the globe, every 18 days for at least one year.

The satellite payload will include an array of three vidicon cameras which will telemeter signals from which color infrared and spectrazonal color (similar in appearance to color photography) photographs will be constructed at Goddard Space Flight Center in Maryland. Also aboard will be a multispectral scanner, from which will be produced magnetic tapes especially suited for image processing and analysis by digital computer.

The purpose of the ERTS project is to produce data remotely sensed from a satellite which can be analyzed to determine the feasibility of using automated satellites to monitor the earth's environment and to conduct an inventory of the earth's resources. It is expected that the results of many of these multidisciplinary experiments will not only produce answers to the feasibility of the various applications, but will also produce economically valuable resource information.

The Arizona Regional Ecological Test Site was initiated in October of 1970 by the United States Geological Survey's Earth Resources Observation System (EROS), at the request of NASA, to consolidate research efforts designed to test and evaluate spaceborne remote sensoring techniques and applications to environmental and resource problems in a semi-arid area.



The area between Tucson and Nogales, Arizona, as it appears from an altitude of approximately 120 miles. The white squares in the center of the picture are tailing pond dams. Photo taken during Apollo 6 overflight.

ARETS is headquartered in the Office of Arid Lands Studies, University of Arizona, and serves as a NASA data center and coordination center for the ERTS experiments. The ARETS project is open to any organization, federal, state or local that is willing to freely exchange information and contribute their findings to comprehensive project reports.

To simulate the data that will be acquired by the ERTS, repetitive small scale multiband photography for most of Arizona has been acquired by NASA's U-2's and RB-57 aircraft from 60,000 - 65,000 ft. altitude. This data is available for public use at the ARETS headquarters and at the U.S. Geological Survey Offices in the Federal Building in Phoenix. Other NASA imagery of this area includes 9-inch metric color and color infrared photography and a collection of Apollo and Gemini photography and radar imagery.

Some of the unique characteristics of space photography that makes it particularly valuable to geologists are:

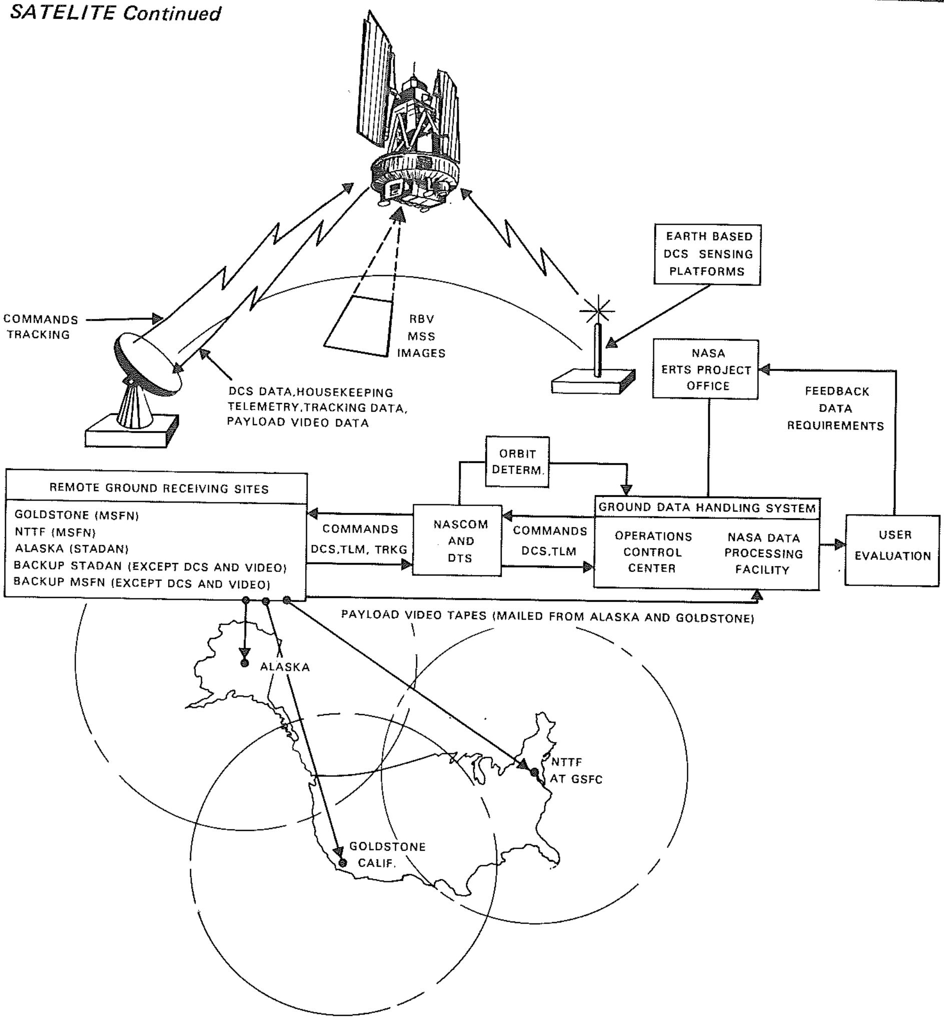
1) the large synoptic view of ground combined with the narrowing of view made possible by the use of telephoto lenses at orbital altitudes. The resulting images can be projected to a map scale with no topographic distortions and will show large synoptic views of the ground, which will thus facilitate detection of lineations and patterns too large and diffuse to have been perceived from aircraft altitudes;
2) the repetitive 18-day cycle of complete coverage of the entire United States of America and other parts of the globe increases the probability of acquiring at least one set of imagery which was made under optimum conditions of cloud cover, snow cover, moisture, vegetation and sun angle.

The experimenters who will be analyzing this satellite data and the accompanying high-altitude aircraft data include scientists from universities, federal agencies, local agencies, and private industry. There are three experiments being conducted at sites in Arizona that should be particularly interesting to the readers of FIELD NOTES. An experiment by the ERTS Satellite Corporation will evaluate the mineral exploration potential of ERTS-A data taken in south-central Arizona. The research objectives are the identification of structural features, lithologic boundaries, vegetation indicators, and drainage patterns. Some ideas and facts pertinent to these objectives are: (a) the spatial relations between ore deposits and particular types of igneous rocks as related to the regional tectonic framework; (b) ore deposits as associated with transform or strike slip faults that are related to global ridge and rift systems; (c) igneous activity in mineral deposits in relation to rejuvenated lines of weakness along strongly established foliation and fracture trends; (d) younger plutons and zones of fracture rejuvenation are concentrated in regions bordering stable crustal blocks. All of these items involve large scale phenomena that should be amiable to identification and study from the superior vantage point provided by orbital imagery.

Members of Jet Propulsion Laboratory, California Institute of Technology, and

Continued page 2

SATELITE Continued



Flow sheet of data-processing system for a typical EROS mission.

the Center of Astrogeology at Flagstaff will study the application of ERTS images to the geologic structure of the basin and range Colorado plateau boundary in north-central and northwestern Arizona. The focal geological problem of this investigation is the origin and late cenozoic history of the basin and range structural province. The record of the geomorphological evolution of the development of the Colorado drainage system is important evidence on the development of the basin range province. This geomorphological evolution is preserved in a series of ancient disrupted drainage channels, partly filled with sediments and volcanic rocks and in other more widespread fluvatile and lacustrine deposits and lava flow. The principal techniques in this investigation will be the computer processing of the ERTS magnetic tape data to obtain enhancement of color contrast, structural patterns, and changes of vegetation in time. Thus this study will attempt to use computer image processing to produce data not accessible through conventional photo interpretation. One of the particularly interesting problems in this study is to trace the former path of the Colorado River which apparently has not always discharged into the Gulf of California.

A study of the U.S. Geologic Survey will attempt an inventory of the post-1890 A.D. episode of accelerated erosion and to monitor future erosional changes. A study of ERTS imagery will determine: (1) which spectral bands provide optimum geologic, pedologic, and plant ecologic information to determine the present erosion cycle of arroyo-cutting, sheet erosion and sand dune development, and (2) monitor changes which further endanger the desert grassland of southern Arizona. The geologic results from vegetation changes which accelerate erosion are practically irreversible. It is essential to understand the interrelated regional problems,so that proper management can be instituted to help prevent further degradation. Surficial geology, soils, geomorphic, and and vegetation maps produced from this experiment should be of immediate value not only to land management and planning organizations but to soils engineers and construction engineers.

Copies of the satellite and aircraft imagery for most of the State of Arizona and bordering regions and the use of optical and electronic image enhancement equipment is available at the ARETS headquarters. Two of the prime user groups of our high altitude color and multispectral photography have been the Arizona copper industry and graduate students from the University of Arizona.

ARIZONA GEOLOGICAL SOCIETY

The Arizona Geological Society publishes Guidebooks, Digests, and an Arizona Highway Geologic Map for the purpose of presenting an up-to-date record of geological research carried on by members of the Society as well as by other workers in earth science in Arizona and adjacent areas of the Southwest.

The Guidebooks are published in connection with major scientific meetings held in Tucson and consist of general articles by professional geologists on many aspects of Arizona geology as well as road logs of several field trips in southern Arizona and neighboring areas. They serve as very useful references for anyone working in or interested in the geologic features of southwestern United States. Three Guidebooks have been published but only Guidebook III, 1968 is still in print.

The Digests consist of numerous articles of general interest on Arizona geology and are published on an irregular basis. Only a few copies of Volume 4, 1961 and copies of Volume 7, 1964 (published in 1966) and Volume 8, 1966 are still available for purchase. Volume 9 has just been published. This latest edition, consisting of 265 pages, contains the following articles:

Sturgul, J.B. and Irwin, T.D., Earthquake History of Arizona and New Mexico 1850-1966

Mayo, E.B., Defense of "Volcanic Orogeny"

Schmidt, E.A., Belts of Laramide-Age Intrusive Rocks and Fissure Veins in South Central Arizona

Butler, W.C., Permian Sedimentary Environments in Southeastern Arizona

Graybeal, F.T., Atomic Absorption Whole Rock Analysis Using a Lithium Metaborate Fusion Technique and Some Possible Applications to Ore Finding

Davis, R.W., An Analysis of Gravity Data from the Tucson Basin, Arizona

Sauck, W.A., Sumner, J.S., and Christensen, J.P., Aeromagnetic Map of the Northern Part of the Tucson Basin, Pima County, Arizona

Mayo, E.C., Feeders of an Ash Flow Sequence on Bren Mountain, Tucson Mountain Park, Arizona

Handverger, P.A., and Marsh, B.D. Reconnaissance Geology of Isla Mejia: Gulf of California, Mexico Part I

Marsh, B.D., Geologic Reconnaissance Geology of Isla Mejia: Gulf of California, Mexico Part II Magnetic Survey

Nevin, A.E., An Alternate Hypothesis on the Structure of the Dragoon Pass Area, Cochise County, Arizona

Weaver, R.R., Uplift and Gravitational Adjustment Ruby Star Ranch Area, Pima Mining District, Arizona

Denney, P.P., Relation of Fossil Landslides to Geologic Structure, Canelo Hills, Arizona

Barsch, D., and Updike, R.G., Late Pleistocene Periglacial Geomorphology (Rock Glaciers and Blockfields) at Kendrick Peak, Northern Arizona

Luepke, G., A Re-Examination of the Type Section of the Scherrer Formation (Permian) in Cochise County, Arizona.

Shakel, D.W., and Harris, K.M., Age of Cerro Colorado Crater, Pinacate Volcanic Field, Northwestern Sonora

The Arizona Highway Geologic Map (in color), at a scale of 1:1,000,000, has been very popular and the available copies have been nearly exhausted. Consideration is being given to reprinting this map after checking for any necessary corrections and revisions. Notice will be made if and when a second edition is available.

Below is a list of the presently available publications. They may be ordered from the Arizona Geological Society, P.O. Box 4489, University Station, Tucson, Arizona 85717. To save on bookkeeping, the Society requests that the proper remittance accompany all orders.

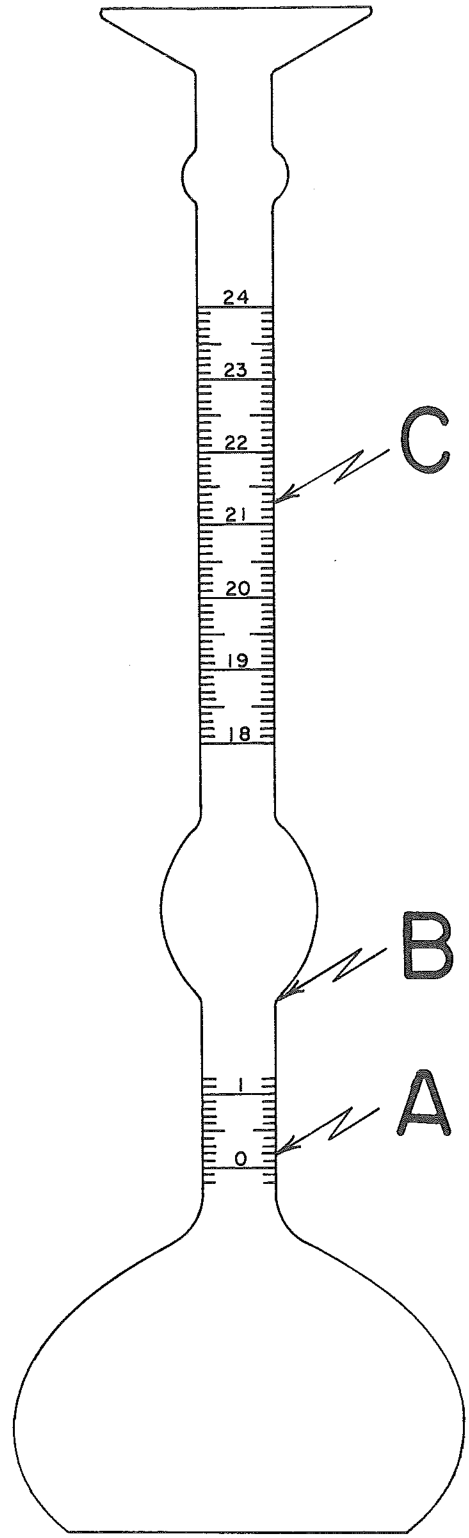
Digests in print
- Vol. 4, 1961 (very limited supply) ———————— $ 3.50
- Vol. 7, 1964 (Publ. in 1966) —2.50
- Vol. 8, 1966 ——————— 3.50
- Vol. 9, 1971 ——————— 4.00

Arizona Highway Geologic Map, 1967 (very limited supply)
Folded ———————— $ 1.75

Guidebook III, 1968 ——— $10.00

DETERMINATION OF SPECIFIC GRAVITY

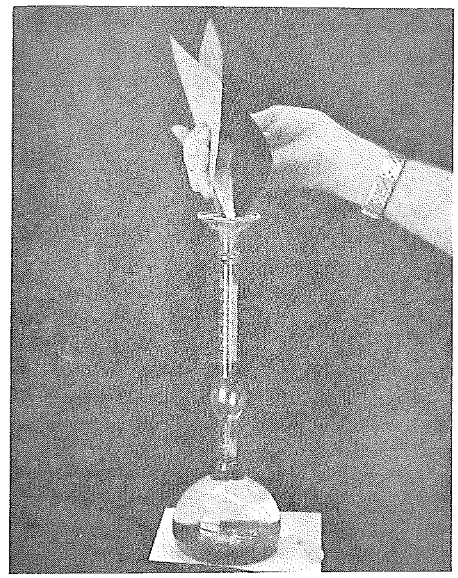
A fast and accurate method of determining the specific gravity of sand or any finely divided material is to use a Le Chatelier flask. See Figure 1. Kerosene is used as the liquid media in place of water because it will wet the material,



Le Chatelier (specific gravity bottle).

especially a flotation product, much better than water. The weight of sample to be tested will vary from 60 to 90 grams depending upon the specific gravity of the material.

After reading the height of the solution in the lower part of the tube at point "A", a sample is weighed out and slowly poured into the flask. See Figure 2. The material may tend to clog at the lower restriction at point "B". It may take some gentle tapping or shaking to get the solid to move down to the bottom of the flask. After all the sample is shaken down to the bottom, the flask is rotated slowly by hand until all air bubbles are out of the sample. Then another reading is taken of the liquid level in the tube at approximately near point "C". This final reading may be rechecked after a few minutes. Then first reading, if somewhere above 0.0, is subtracted from the last reading. The weight of the material in grams is then divided by the displacement



Charging powder to specific gravity bottle.

of solution (in cubic centimeters) to obtain the specific gravity. Duplicate determinations should check or be reproducible to within 00.04 or less specific gravity points.

The kerosene is then decanted off to about "0" or slightly above preparatory for any subsequent determination. After 4 or 5 sample determinations, it may be necessary to dump the accumulated material, clean the flask and refill afresh with kerosene.

The La Chatelier flasks are manufactured in strict accordance with the specification of circular No. 9 National Bureau of Standards and may be purchased through a Chemical glassware supply house.

WOMEN UNDERGROUND

Typical of those who labor or travel alone in areas of danger, miners tend to be superstitious. The dead darkness in which the miner's lamp serves only to distort every shape, the uncanny noises of restless rocks whose support has been disturbed, the approach of danger and death without warning, the sudden vanishing or discovery of good fortune-all yield a thousand corroborations to superstitious minds. *Continued page 4*

WOMEN Continued

Traditionally, miners believe underground mines are inhabited by supernatural little beings. Not all are classified as bad, some are gentle unless ridiculed or aroused.

The presence of gnomes or demons was a general belief in Eastern Europe before Agricola's time, circa 1500 AD, and has continued through the centuries. German-Austrian miners in the seven mine cities of the Hartz and Joachimisthal were not alone. Note the Tommyknockers of the Cornishmen and the very strong persistence to this day of a belief in "diablolitos" and "muquis de otro mundo" in the mines of Mexico and South America, instilled by the early Spaniards.

Some believe these little people work with or for Santa Barbara, the Patron Saint of all miners. After lightning struck the high tower where her father had her confined, she was adopted as La Patrona of all those exposed to violent and quick death.

Saint Barbara, however, is not kindly and loving but rather is jealous, vindictive, and cruel. She resents intrusions by rivals and when a woman trespasses her domain, dire things happen.

So strong is this feeling (that the presence of women attract gnomes, demons, and devils from the infernal regions, and bring a curse and bad luck) that entire crews have walked off the job when a woman entered the mine. And if she dons coveralls, pants or trousers, the Saint Barbara is really irritated.

From a purely practical point of view women are not physically suited for mining. Also their clothing does not (or did not in the past) lend itself to climbing up and down ladders and in and out of dark damp holes. There are no conveniences for women underground and sometimes the art work and/or graffitte might offend.

When men are engaged in purely male action, they feel the presence of women distracts, engenders accidents, and generally causes trouble.

INSTITUTE OF DESERT ECOLOGY

The Tucson Audubon Society's second annual Institute of Desert Ecology was held at the Tanque Verde Guest Ranch April 21-30. The Institute accepts 60 registrants from around the country. This year 12 states were represented. The purpose of the program is to stimulate insight into relationships between living things and interactions of living things with the physical surroundings. This year a staff of five representing insects, birds, plants, mammals, and physical factors (geology – soils, etc.), conducted field studies in the Ranch area. Dr. H. Wesley Peirce, Arizona Bureau of Mines Geologist, joined the staff to provide instruction and guidance in the physical factors domain.

Tanque Verde Guest Ranch is located at the end of East Speedway Blvd. at the foot of the Tanque Verde mountains. Local geologists will recall that the present Catalina – Tanque Verde – Rincon Mountain block is bounded by a fault on the Tucson basin side. Dr. Peirce traced this fault in the area of the Ranch and pointed out that the Ranch is built on both sides of as well as over this complex structure. The influence of this and other structures on the water habit and water quality in the Ranch area was emphasized. Many of the waters originating along this mountain front are high in fluorides and sulphates.

The existing washes provide excellent examples of the erosional – depositional processes that are responsible for various habitats (flood plains, terraces). One flood plain exposure contains a pressure spray can buried six inches by fluviatile sediments which suggests rather recent (last ten years?) flooding. This observation quite naturally leads to a consideration of man's use of such geologic features in desert regions, including Tucson!

Dr. Peirce claims that he learned more than anyone else and expresses his gratitude to the local Audubon leaders who afforded him this opportunity to demonstrate the relevance of the inherited condition on the activities of living things, including Man.

IN MEMORIAM

George R. Fansett, 87, who retired in 1955 after serving 39 years as mining engineer in the Arizona Bureau of Mines, died March 21 in Tucson.

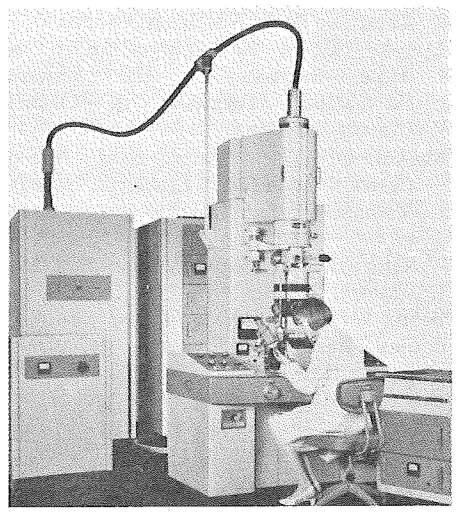
Fansett's FIELD TESTS FOR THE COMMON METALS, for decades one of the most frequently requested publications produced by the University, was first produced to spur the search for "rare minerals" such as tungsten, vanadium and molybdenum during World War I.

His other activities included demonstrating gold placering methods to Arizonans during the early years of the depression; championing thin-walled copper tubing against iron pipe in 1938, making a strong case for the lower cost and greater durability of copper pipe as compared to iron pipe when the price of copper fell to five cents a pound and the mines curtailed operations in Arizona, and demonstrating Geiger counters to a new generation of prospectors anticipating the boom for radioactive minerals.

Mr. Fansett, whose wife Flora died in 1969, is survived by a nephew, Elmer Fansett of Waldport, Ore.

Electron Microscope Services Available

The Electron Microscopy Group of the Department of Metallurgical Engineering offers a service to the industry of the state in the form of analyses employing the Hitachi HU-200E electron microscope acquired three years ago. This instrument is capable of 200 KV accelerating voltage. It is the only such instrument with this magnitude of accelerating voltage between the state of California and the Mississippi River.



Electron Microscope

Examination of specimens with this instrument can be carried out using either surface replicas or direct transmission methods. Specimens too thick to be penetrated by an electron beam of 200 KV (> 3000 Å) can be examined directly by preparing replicas of the specimen surface. With suitable techniques, resolution approaching 20 Å for the surface details can be achieved.

Samples thin enough for direct-transmission microscopy can be prepared by a variety of methods. By far the most useful of these involve the mechanical, and chemical or electrolytic thinning of bulk specimens. The tremendous advantage of the transmission technique over the replica technique of electron microscopy is that the evidence in regard to the internal structure with the former is visual, and therefore convincing. In addition, it is possible to interpret electron micrographs of crystals by using the theory of electron diffraction. Diffraction patterns can be made of the identical areas that are observed through electron microscopy thus adding additional valuable information concerning internal structure.

Electron micrograph made on the HU-200E instrument from a two-stage plastic replica of a polished and etched surface of a Plains Specimen meteorite from Canyon Diablo, Arizona belonging to the private collection of Dr. W. W. Walker. Shown are Neumann bands within, and boundaries separating grains in the Kamasite (ferrite) phase. Etchant: nital. Total magnification, 72,000 X. Microscopist: William J. Mitchell, U/A, 1971.

Most electron microscopes for use in transmission work operate at 100 KV. With higher accelerating voltage, the thickness of sample penetrable by the electron beam is correspondingly increased. With higher accelerating voltage, the thicker regions of specimens which may be examined provide a much greater assurance that conditions observed in the thinned sample are representative of actual conditions within the bulk material.

The instrument in the Department of Metallurgical Engineering is capable of a resolution of better than 6 Å, and of direct magnification over the range of 1,000 X to 200,000 X. With optical enlargement of 10 X, total magnifications on the order of 2,000,000 X may be realized.

Accessories available with the electron microscope provide for tilting the specimen under examination and for heating the specimen to 1000°C. The tilting feature allows for the determination of crystal orientation and the geometry of crystal defects. It also provides for the preparation of stereoscopic pairs of electron micrographs. Stereoscopic viewing spatially separates overlapping details and reveals three-dimensional relationships in the structure.

Replica studies which have been performed in the Electron Microscope Laboratory have been concerned with the examination of fractured metal parts in order to establish the initiation site, cause, and mode of fracture. In the direct transmission mode of examination of thin metal film specimens, studies are concerned with the nature and distribution of dislocations and other lattice defects, as well as fine-scale precipitates and the nature of grain boundaries. The mechanical and chemical properties of metals largely depend on these features which, in turn, are determined by alloy composition, heat treatment, and processing.

The Electron Microscopy Group includes Dr. L. J. Demer, in charge of the laboratory and Mr. Craig Shevlin, a Ph.D. candidate in Metallurgy, as Chief Microscopist. These individuals may be contacted for discussion of problems which may require the capabilities of electron microscopy for their solution.

PLATINUM-GROUP METALS

Platinum is a relatively rare metal and one of a group of such metals that usually occur intimately mixed together. Thus the name "platinum-group" is applied to these metals. Recently platinum has been in the news both in respect to its possible use in controlling automobile exhaust emissions and also to its alleged occurrence in Arizona. Although many people are aware of its use in high price jewelry and as an important catalyst in chemical processes, few are knowledgeable concerning its occurrence in nature and the difficulties involved in its detection.

The other metals of the platinum-group are palladium, indium, osmium, rhodium and ruthenium. Platinum and palladium are the most common members of the group, occurring as alloys and compounds, usually with varying but small amounts of two or more of the other members. Chemical and physical characteristics of these combinations vary considerably and small amounts of other metals, such as iron, copper, gold, nickel, and chrome are often present. As a group, the metals are relatively heavy, relatively hard, somewhat malleable and ductile, sometimes slightly magnetic, and practically infusible. In appearance they are whitish steel-gray to dark gray with a metallic luster and are opaque. Pure platinum can only be dissolved in aqua regia, a mixture of hydrochloric and nitric acid. Palladium can also be dissolved in hot nitric or sulphuric acid. The other metals of the group are not appreciably affected by any acid.

The chemical and physical properties of the group make their positive identification difficult. On occasion, "chilled" bird shot (a lead-arsenic alloy), lead fragments, flakes of specular hematite, old amalgam, and particles of metallic iron, have been mistakenly identified as Platinum group metals. Even reliable and experienced investigators and assayers have learned to use extreme caution and care in determining its presence in a sample. However, if platinum-group metals are present, even in trace amounts, they can be detected by reliable methods. There is no foundation for the sometimes alleged concept that some precious metals such as platinum, gold, and silver can occur in a chemical state which defies detection by well-established, reliable assay methods.

Whether occurring in nature as alloys or as chemical compounds, the platinum-group metals are usually in small grains or scales. The alloys occur most frequently in certain placer deposits derived from basic or ultrabasic rocks while the compounds are found associated with other metals in such rocks. Russia produces about 60 per cent of the current primary world supply of some 3.8 million troy ounces. South Africa is second with about 30 per cent and Canada contributes most of the balance. The U.S. primary production of some 15,000 troy ounces a year comes mainly from platinum recovery from gold and copper refinery sludges and from one gold dredging operation in Alaska. The platinum content in the original gold or copper ore is so minute that it can seldom be detected and only shows up in the combined sludges derived from hundreds of thousands of tons of ore. The major domestic source of platinum is from

Continued page 6

PLATINUM Continued

secondary recovery from platinum bearing scrap, such as discarded electronic equipment, and amounts to some 300,000 troy ounces per year. The demand and use of platinum has been increasing in recent years but with adequate production and reserves in Russia and South Africa and the high recovery from scrap, there should not be any shortage for many years to come. Presently there is actually a surplus in the world market.

The occurrence of platinum in Arizona has been reported from time to time but no such occurrence has been substantiated except for a trace found in copper assay buttons produced from ore mined at Jerome. Sometimes traces of platinum and palladium may be found in copper anodes in some smelters but the source can be traced to electronic scrap that has been introduced into the smelting process. In the December 1943 issue of the Engineering and Mining Journal, p. 106, U.S. Geological Survey personnel reported the occurrence of platinum in a sample taken from Sugarloaf Peak in Yuma County. Due to the very unlikely geologic setting for platinum mineralization in that locality, the Arizona Bureau of Mines requested the Survey to recheck that reported occurrence. In a letter to Engineering and Mining Journal, April 1972, page 4, the Survey stated that a careful re-analysis of the same sample showed no detectable platinum or palladium to be present.

The Arizona Bureau of Mines has found that fire assay methods and spectrographic analyses of the precious metal bullion button can give accurate results in determining the presence of platinum in any detectable amounts. The use of atomic absorption equipment, often termed "AA", can give reliable results for palladium but due to a number of interfering elements, the method is unreliable for platinum. An excellent article on "Determination of palladium, platinum and rhodium in geologic materials by fire assay and emission spectrography" by Joseph Haffty and L.B. Riley was published in Talanta, v. 15, p. 111-117, Pergamon Press, New York. In summary it is emphasized again that if platinum-group metals are present in a sample they can be detected by reliable fire assay and spectrographic methods and if not so detected, no amount of mysterious treatment will magically produce platinum in the material.

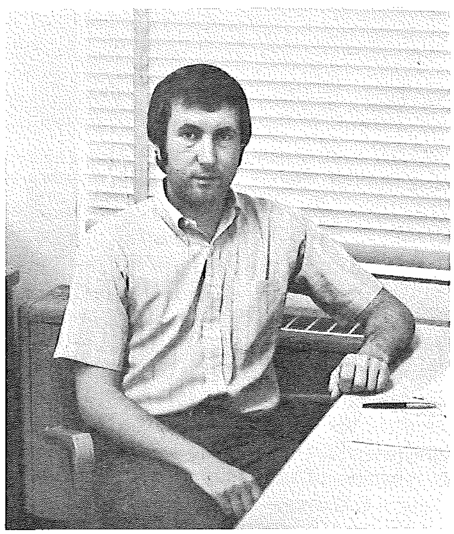
Although traces of platinum-group metals may be found in Arizona in association with certain gold placers and copper deposits, the scarcity of favorable geologic formations such as ultrabasic rocks in the state is an unfavorable factor for their occurrence in anything approaching commercial amounts. For those who may wish to learn more of the occurrences and use of platinum-group metals, the following selected references are suggested.

Mertie, J.B., 1969, Economic geology of the Platinum metals; U.S. Geological Survey Professional Paper 630, 120p.

Ageton, R.W. and Ryan, J.P., 1970, Platinum-group metals in Mineral Facts and Problems; U.S. Bureau of Mines Bulletin 650 p. 653-669.

Hoyt, C.D. and Ryan, J.P., 1971, Platinum-group metals in U.S. Bureau of Mines Minerals Yearbook, Vol. I-II, p. 921-931.

NEW GEOLOGIST AT THE BUREAU



Mr. John Vuich recently appointed assistant geologist on the Bureau staff.

On February 1, 1972 John S. Vuich was appointed Assistant Geologist for the Arizona Bureau of Mines. He received a B.S. Degree in Geological Engineering from the University of Arizona in 1968 and is presently a M.S. candidate in the same field.

Prior to college, John served three years in the U.S. Marine Corps and then was employed by Reynolds Metals at their metallurgical testing laboratory, McCook, Illinois. Subsequent to his undergraduate work, he was a geological engineer for two years with the Duval Corporation exploration office, Tucson.

For the past two years, while an M.S. candidate he was variously employed as a field geologist with the Tucson Exploration Offices of Cerro Corporation and Humble Oil Company.

John's work experience has been primarily mineral property exploration and evaluation. He is a member of AIME and the Arizona Geological Society.

The Bureau is pleased to welcome John to its staff.

ARIZONA PHOSPHATIC MATERIALS

H. Wesley Peirce

Manufacturers of sulfuric acid produced as a by-product from the smelting of sulfide ores have long been interested in developing consumptive uses for excess acid. As more smelters construct acid plants, the incentive to find useful disposal methods increases. Elsewhere, one use has been in the manufacture of phosphorous-bearing fertilizers from phosphate rock.

Although the question of phosphatic material resources in Arizona is not new, there has been little, if any, progress regarding recognition of occurrences. Stan Keith (1969) of the Bureau staff reported that "Marine sedimentary conditions in Arizona during the geologic past evidently were not favorable for phosphate deposition. Trace to a few tenths of a percent phosphate have been detected in Permian and some other Paleozoic marine shales and fossiliferous limestones but there is no evidence that either original deposition or weathering has produced any concentrations that could be considered of economic interest. Apatite crystals have been noted in some igneous rocks of the State (Galbraith and Brennan, 1959, p. 72) but not in commercial amounts."[1]

Recently, during the course of routine field studies of some (of) Arizona rocks, the curiosity of a Bureau geologist was aroused by linear-shaped pores in a float specimen of Cambrian Bolsa Quartzite. Back in the laboratory the specimen was sliced on a diamond saw and a thin-section made for microscopic inspection. Figure 1 is a microphotograph taken of this thin-section. The laminated, wavy platelets are amorphous under X-nicols. A spectroscopic test revealed calcium fluoride bands and a standard qualitative phosphate test using nitric acid and ammonium molybdate produced the canary yellow precipitate diagnostic of phosphorous content. The substance is believed to be collophane (a fluorapatite).

The outcrop area in the Mescal Mountains was revisited. It happens that the "discovery" site is shown in Plate 6 of Arizona Bureau of Mines Bulletin 176, "Geologic Guidebook 2 – Highways of Arizona – Arizona Highways 77 and 177", where it is labeled "B". Figure 2 is a closeup showing exterior porosity developed in the quartzite.

A brief reconnaissance in the immediate region indicates that phosphatic meterial occurs from the

Figure 1. Photomicrograph of phosphatic (collophane?) platelets among quartz grains of the Cambrian Bolsa Quartzite. Platelets are elongated in direction of stratification. Magnification 60 X.

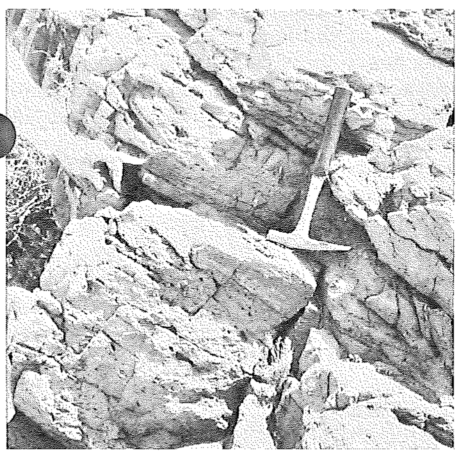


Figure 2. Tilted outcrop of upper part of the bolsa Quartzite showing porosity development in a phosphatic horizon. Mescal mountains looking easterly.

upper contact with the Devonian Martin Formation down section for about sixty feet until a noticeable lithologic change takes place. Phosphatic material is not evenly dispersed throughout the 60-foot section. Although no attempt yet has been made to systematically sample or prospect the zone laterally, one fist-sized grab sample contains 5 percent P_2O_5. According to our information, this is the highest phosphorous content yet reported to occur in an Arizona rock.

The physical nature of the phosphatic substance is of interest. Phosphatic materials are frequently nodular, pelletal, or ovoid. Although brachiopods with phosphatic shells have been reported from Cambrian strata in Arizona, it is not clear that the majority of the platelets are either shells or shell fragments even though platelets tend to be parallel to bedding and pre-lithification in age. Whether or not excess precipitated phosphate is present over and above that originally accumulated in shells is a question. Too, the response of phosphatic shells to the processes leading to silicification of the original sandstone has yet to be studied.

Regionally, Cambrian strata thin northward towards Salt River Canyon. Although the paleogeography is not completely known, it is possible that there was a northward shelving that might have been a favorable environment for marine waters relatively enriched in phosphorous.

Whether or not phosphatic occurrences of economic significance occur in these Cambrian strata is both an economic and a geologic question. It is possible that the economic equation normally applied to the manufacture of phosphorous-bearing products will not be applicable in Arizona. Where sulfuric acid is a vital component in an economic formula it will be necessary to consider the acid factor in the light of possible surpluses in the near future.

Geologically, it seems clear that there is more to learn about phosphatic materials in Arizona. The Arizona Bureau of Mines plans to continue an investigation to ascertain the regional aspects and the nature of the occurrences of these seemingly unusual phosphatic materials. Not only is a useful product involved but there is the added consideration that 2 tons of acid are required to process each ton of phosphatic mineral (apatite type) into superphosphate.

[1]Keith. S.B., "Guano, Nitrate, and Phosphate", in Arizona Bureau of Mines Bulletin 180, MINERAL AND WATER RESOURCES OF ARIZONA, p. 370.

LAND ACQUISITION BY THE NONFUEL MINERAL INDUSTRIES

by
George F. Leaming

Since the presentation to the Congress of the report of the Public Land Law Review Commission in 1970,[1] several proposals have been made, both by members of the Congress and the Executive Branch, to change the legislation under which the public domain may be used for mineral purposes. Most of these have been concerned primarily with replacing the mineral location system established under the Mining Act of 1872 with a type of leasing system similar to those already established for the fuel minerals and certain industrial minerals.[2] In examining and evaluating these proposals, the relative importance of the various mineral land systems, both public and private, in providing land for mineral resource development becomes a significant consideration. Has the Mining Act of 1872 been a major factor in making land available for nonfuel minerals production in the United States?

By the end of the 1960's the lands used in the production of the nation's nonfuel mineral commodities had been acquired by their existing users in a variety of ways. As indicated by a survey of a representative sample of both large and small producers of nonfuel minerals conducted in 1968, the single most important method had been by direct location on public lands under the provisions of the Mining Act of 1872 and related state legislation. Approximately 30 percent of the mineral land area held by those producers surveyed had been obtained by direct location on federal lands. Almost 11 percent had been obtained by the purchase of patented mining claims, and a little more than eight percent through the purchase of unpatented mining claims on public lands. Thus, nearly half of the land in use by mineral producers in the late 1960's had been acquired through the mineral location system. State land leases accounted for less than eight percent of the land in use, while federal land leases provided less than 12 percent, and private land leases were used in obtaining another 12 percent. A significant share (10 percent) of the land had been acquired from other firms through merger or partnership, and it is assumed that a portion of this was also originally acquired under the provisions of the Mining Act of 1872. Leases on Indian lands and land exchanges had provided relatively insignificant proportions of the nation's nonfuel mineral lands.[3]

In obtaining land for purposes other than those directly involved in mining operations other methods of land acquisition had been used by mineral producers. By 1968, almost one-quarter of the total acreage used for such auxiliary purposes had been acquired from private land owners by purchase. Another 17 percent had been obtained by leasing state owned land. Less than 12 percent was acquired through federal land leases and a little more than nine percent was acquired through federal land leases leases and a little more than nine percent through land exchanges. Approximately eight percent of the land acquired by existing mineral producers for auxiliary purposes had been acquired by direct location on public lands. This is an indication of the relative importance (or unimportance) of the "mill site" claim as a provider of land for auxiliary mineral purposes.

Continued page 8

LAND ACQUISITION Continued

Specific Purpose Land Acquisition

Nonfuel minerals producers operating in the United States at the end of the 1960's had obtained control of lands that were either directly over valuable mineral deposits or immediately adjacent to the deposits and necessary to the mining operations in several ways. More than 55 percent of the land situated directly over nonfuel-mineral ore deposits had been acquired through the location system, while only about 15 percent had been acquired through the federal leasing system. Private lease land and state lease land combined accounted for about 20 percent of all such mineral property. A somewhat smaller proportion (16 percent) of the land directly peripheral to the ore bodies and needed for mining operations had been acquired under federal, state, or private leases. Other means of land acquisition, including outright purchase, land exchanges, and other arrangements, accounted for more than 18 percent of the peripheral mining land. More than 56 percent, however, had been claimed under the Mining Act of 1872.

Public land acquired under the mineral location system had also provided for more than half of the surface area used for waste storage and dump leaching sites by nonfuel minerals producers in the United States by 1968. More than one-fourth of all land so used, however, had been acquired by agreements made outside of either the federal or state land systems. The sizeable proportion of specific waste storage land acquired through the mineral location system can be explained in large part by the widespread practice of using old excavations for the storage of waste materials created by current mining operations, and, unfortunately for some operators, the not uncommon practice of storing waste on land later found to overlay additional ore.

The mineral location system apparently has not been a substantial factor in the acquisition of land by minerals producers for surface plant sites. Despite the mill site provision of the Mining Act of 1872, by the late 1960's only eight percent of the land so used by existing mineral producers had been obtained under the mineral location system developed by that law. Private lease land accounted for almost three-fourths of all land area in use in the late 1960's for the construction of beneficiation and advanced processing plants as well as necessary mine surface facilities such as shops and offices. Curiously enough, a somewhat different situation existed with respect to that land acquired by existing mineral producers for company owned, mining-related, residential and commercial structures. Almost one-third of the land used in this manner was on patented mining claims. The importance of patented claim land in this use has apparently arisen from the practice followed in many early mining districts of placing residential and commercial structures (and in a few cases entire towns) on inactive waste storage dumps. The traditional practice followed by miners of placing their homes as close as possible to the mine in which they work has also been a factor.

Environmental buffer zones, although not in widespread use in the mineral industry, have been acquired largely through the mineral location system. In fact, by 1968 almost 90 percent of the land used for environmental buffer zones was on patented or unpatented mining claims. The various leasing systems, on the other hand, had provided only 1.5 percent of the land used for this purpose. This heavy imbalance is undoubtedly the result of the fact that much of the land used as environmental buffer zones in realty is land that is considered potentially valuable for mineral uses, and has therefore been acquired, but has not yet been developed for mining. This accounts for the relatively high percentage of such "buffer" land (more than 58 percent) that had been obtained as unpatented claims. The small amount of lease land so used was undoubtedly the result of the much higher cost of such land compared to its relatively unproductive use as an environmental buffer zone.

Table 1*

MEANS OF ACQUISITION OF LAND FOR MINERAL RESOURCE UTILIZATION IN THE UNITED STATES

Acquired by:	Percentage
1. Direct location on federal lands	30.5
2. Federal leases	11.8
3. Purchase of patented claims	10.6
4. Merger or partnership	10.1
5. Private land leases	10.0
6. Purchase of unpatented claims	8.3
7. State land leases	7.9
8. Private lease with option to buy	1.7
9. Indian land leases	0.4
10. Land exchange	0.1
11. Other means	6.5
12. Unknown	2.1
TOTAL	100.0

Table 2*

MEANS OF ACQUISITION OF LAND FOR AUXILIARY OR NONMINERAL PURPOSES BY ACTIVE MINERAL PRODUCERS IN THE UNITED STATES

Acquired by:	Percentage
1. Purchase of private land	24.7
2. State lease	16.9
3. Federal lease	11.6
4. Land exchange	9.2
5. Direct location on federal land	8.1
6. Purchase of state land	7.4
7. Private lease with option to buy	6.7
8. Purchase of federal land	3.5
9. Indian lease land	2.9
10. Private land leases	1.2
11. Direct location on state land	0.2
12. Merger on partnership	0.0
13. Other	7.6
TOTAL	100.0

* Data from a representative sample of large and small metallic and non-metallic mineral producers in the United States surveyed in 1968 by the Division of Economic and Business Research, The University of Arizona.

Summary

The mineral location system established by the Mining Act of 1872 is now a century old. On that basis alone, some have maintained that it is antiquated and should be replaced. But mining is an activity with typically distant time horizons. While many nonfuel mineral producing districts in the United States have blossomed and died during the last 100 years, many of those actively producing today had their beginnings in the late 1800's.

Almost half of all land used by nonfuel mineral producers in the United States in the late 1960's had been acquired prior to 1930. More than one-fifth of the land used by mineral producers, however, had been obtained since 1961. This included land acquired as unpatented mining claims as well as land acquired through the patenting of

Table 3 *

CURRENT STATUS OF MINERAL LAND CONTROLLED BY NONFUEL MINERALS PRODUCERS IN THE UNITED STATES

Status	Land Actually Over the Orebody or Mineable Mineral Percentage	Land Peripheral to the Orebody but Needed for Mining Percentage
Patented claims	20.5	33.9
Unpatented claims	35.6	32.5
State lease land	7.5	7.8
Federal lease land	15.2	4.6
Private lease land	12.2	3.0
Other	9.0	18.2
TOTALS	100.0	100.0

Table 4 *

CURRENT STATUS OF NON-MINERAL LAND USED FOR SPECIFIC PURPOSES BY NONFUEL MINERALS PRODUCERS IN THE UNITED STATES

Status	Land Used for: Surface Plant Sites	Waste Storage	Producer-owned Residential and Commercial Buildings	Environmental Buffer Zones
Patented claims	6.7	46.6	32.7	30.0
Unpatented claims	1.1	7.7	0.7	58.2
State lease land	0.2	2.6	0	0
Federal lease land	0	12.9	0	0
Private lease land	72.8	1.8	0.4	1.5
Other	19.2	28.4	66.2	10.3
TOTALS	100.0	100.0	100.0	100.0

* Data from a representative sample of large and small metallic and nonmetallic mineral producers in the United States surveyed in 1968 by the Division of Economic and Business Research, The University of Arizona.

claims and through public, state, and private land leases. Thus, the mineral location system has been and remains an important means of land acquisition by mineral producers in the United States.

REFERENCES

[1]United States Public Land Law Review Commission, One-Third of the Nation's Land, Washington, D.C., United States Government Printing Office, 1970, 342 pp.

[2]See, for example, Senate Bill 921, Title II, amended, "Federal Hardrock Mineral Leasing Act of 1971," 92nd Congress of the United States, First Session, September 1971. For more detail on the various federal nonfuel mineral land systems, see Howard A. Twitty and George S. Reeves, Legal Study of the Nonfuel Minerals, Phoenix: Twitty, Sievwright, and Mills for the Public Land Law Review Commission, 1969.

[3]George F. Leaming and Willard C. Lacy, Nonfuel Mineral Resources and the Public Lands, Tucson: Division of Economic and Business Research, The University of Arizona, for the United States Public Land Law Review Commission, 1969, 1050 pp.

OVERVIEW OF GEOTHERMAL RESOURCES POTENTIAL IN ARIZONA

by

John W. Harshbarger
Professor of Geosciences and Hydrology
University of Arizona, Tucson

INTRODUCTION

During 1971, specific attention on potential geothermal resources in Arizona has captivated the interest of private organizations, state and federal agencies, utility companies and academic researchers. Intensive geological, geophysical, exploration surveys, and studies are actively underway, and one group has uncovered sufficient information to warrant the beginning of an exploration drilling program within the next 60 days. Although surface emanations of steam are excellent indicators of leakage from geothermal reservoirs, the absence of such activity at land surface does not provide evidence that this potential resource is not present. In the Bagnore, Italy area, about 40 miles southeast of the Larderello thermal area, the only surface indications were several thermal springs ranging from 68° to 122°F and several gas vents prior to exploration. Active intense studies and drilling proved successful and, in 1964, the production capacity for electric power was 9,500 kilowatts (McNitt, 1963, p. 39, 40; 1965, p. 242).

There are sparse data indicating a possibility that latent geothermal energy may be present at depth at several areas in southern Arizona. Data on springs and wells have been compiled on Table 1, which is a listing of localities where thermal waters of 100°F or greater are known. The locations of these occurrences, shown on Figure 1, are relatively close to population centers which could possibly utilize thermal energy. There are no known geothermal resources areas which produce geothermal steam in Arizona and no known boreholes have been drilled to explore the potential of geothermal energy. *Continued page 10*

TABLE 1 – SELECTED THERMAL SPRINGS AND WELLS IN ARIZONA

Locality No. on Fig. 1	County and Location	Maximum Temperature (°F) Reported	Discharge in Gallons Per Minute	Depth (feet)	Gradient (feet/ 1°F
	Cochise				
1	Hookers Hot Spring Sec 6, T 13 S, R 21 E	130	40	–	–
2	San Simon Valley-wells	103	–	920	26
	Gila				
3	Spring Sec 1, T 3 S, R 16 E	99	90	–	–
4	Well, Sec 29, T 3 S, R 15 E	110	–	150	–
	Graham				
5	Indian Hot Springs Sec 17, T 5 S, R 24 E	118	200-300	–	–
6	Wells in Safford Area	99+	–	1095	30
7	Safford Golf Course Well	100	–	2180-2420	30
	Greenlee				
8	Clifton Hot Springs Sec 30, T 4 S, R 30 E	160	–	–	–
9	Spring, Eagle Creek Sec 26, T 4 S, R 28 E	120	–	–	–
10	Gillard Hot Springs Sec 27, T 5 S, R 29 E	184	100-400	–	–
11	Well, Clifton	130		220-498	31
	Well, Clifton	143	–	140-500	33
	Maricopa				
12	Agua Caliente Spring Sec 19, T 5 S, R 10 W	104	–	–	–
13	Buckhorn Area Wells	107	–	325	8
14	Well Sec 16, T 5 S, R 10 W	114	–	884-1268	–
	Mohave				
15	Pakoon Spring Sec 24, T 35 N, R 16 W	100	200-400	–	–
	Pima				
16	Wells near Ajo	99	–	1021	39
17	Wells, SE Tucson	126+	–	2500	42
	Pinal				
18	Well, near Redrock	108	–	1950	49
19	Hana Well Sec 6, T 6 S, R 8 E	161	500-600	2700	–
	Yavapai				
20	Castle Hot Springs Sec 3, T 7 N, R 1 W	122	280	–	–
21	Verde Hot Springs Sec 3, T 11 N, R 6 E	106	10	–	–
	Yuma				
22	Radium Hot Springs Sec 12, T 8 S, R 18 W	140	–	–	–
23	Wells in Sections 2, 5, 11, T 4 S, R 11W	105	–	280-585	–
24	Wells in Palomas Plain	108	–	443	13
25	Oil Test Well	125	–	6015	120

Data tabulated from: Haigler (1969) and Wright (1971) in Selected References

GEOTHERMAL Continued

RESUME OF CONDITIONS RELATED TO POTENTIAL GEOTHERMAL RESOURCES

It has been established that, when natural resources are not known by accidental discovery, an intensive program encompassing geological and geophysical investigations followed by adequate borehole exploration commonly yields fruitful results. A cursory review of the geological features associated with known geothermal areas indicates that such conditions are plentiful in southern Arizona. These geological features have undoubtedly provided a stimulus for several active detailed mapping and geophysical surveys to be followed with borehole exploration. A brief examination of the broad geological characteristics of Arizona is given herein to provide a capsule sketch of Arizona geology as related to potential occurrence of geothermal resources.

Arizona contains parts of two distinct physiographic provinces, the Colorado Plateaus and the Basin and Range which are shown on Figures 1 and 2. The Basin and Range province is characterized by northerly and northwesterly trending ranges separated by desert plains. The Colorado Plateaus comprise mesa and canyon topography and lofty mountainous areas formed by the extrusion of late Cenozoic lava flows, cinders, and intrusive rocks. In both provinces, rocks of nearly all the geological ages and types are known to be present. Their distribution, lithologic and petrologic characteristics are widely reported, as well as the various tectonic disturbances, followed by the emplacement of intrusive and extrusive rock sequences.

The rocks of Arizona have been faulted and folded many times throughout geologic time. The faulting and folding occurred during short episodes, and concurrent periods of igneous activity were common. The entire area had the most intense deformation during the late Cretaceous and early Tertiary periods. In the Basin and Range province, these structural features were disrupted by later structural features which, in turn, have been followed by late Cenozoic volcanism.

In the middle Tertiary, about 30 million years ago, the first phase of block faulting began which developed the Basin and Range structural features, and many of these uplifted blocks cut across previous structures. Large amounts of volcanic material were emplaced in the basins which, in places, dammed the drainage systems. These structural troughs have been filled with heterogeneous mixtures of clastic materials ranging from fine-grained lake-bed deposits to boulder-cobble conglomerate interbedded with lava flows. During this phase, several intrusive bodies were emplaced in the southeastern part of the state. Some volcanic activity continued to about 1,000 years ago, such as in the Flagstaff area.

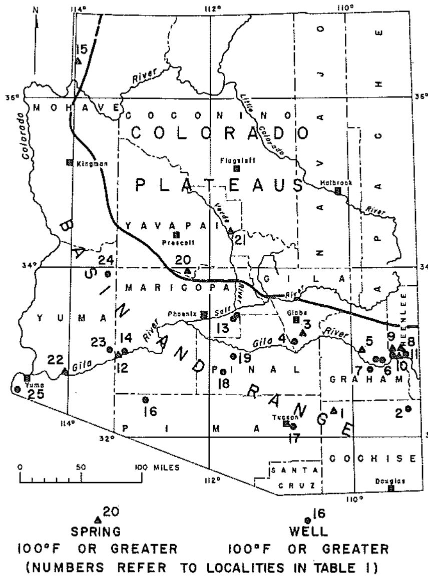


FIGURE I.--THERMAL SPRINGS AND WELLS IN ARIZONA.

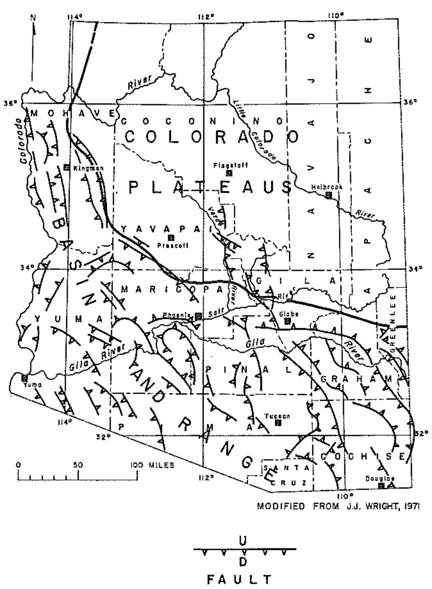


FIGURE 2.--FAULT TRENDS IN SOUTHERN ARIZONA.

Arizona has been divided into three water provinces: Basin and Range Lowlands, the Central Highlands, and the Plateau Uplands. Large amounts of groundwater occur in the alluvial basins in the Lowlands which have been filled to depths of several thousands of feet of sand and gravel interbedded with very low permeable silt and clay bodies. In many places, the aquifers are a single hydraulic system, whereas, in other basins aquifers are separated by impervious clay and silt sequences which function as a confining layer on the lower artesian aquifer system. Large amounts of groundwater are in storage in the sandstone and limestone aquifers in the Uplands area, but the lesser permeability of the sandstones constrain well yields. Both areas receive recharge from the Highlands area which occurs across the central part of the state. This area is also the source of the state's surface water supplies, which are impounded by dams along the base of the Highlands area.

The quality of water resources ranges widely throughout the state. The groundwater quality ranges from less than 200 to more than 100,000 ppm (parts per million). The streams and rivers carry variable amounts of dissolved salts. The rivers entering the Lowlands have salt loads ranging from 110,000 to more than 400,000 tons per year. A large percentage of the salt in some of these drainages is from springs which contribute saline water to the streamflow. The U.S. Geological Survey has collected copious records of chemical analyses on the quality of both surface and groundwaters.

An examination of the available thermal data in Table 1 in relation to the tectonic fabric and occurrence of Tertiary igneous rocks reveals several interesting suggestions. Nearly all the occurrences are in the Basin and Range Lowlands; most of the springs and some of the wells appear to be related to fault structures and/or Cenozoic igneous rocks; the highest temperatures occur in Greenlee County; and the geothermal gradient observed in wells by Wright (1971) is about 30 feet per 1°F in southeastern Arizona. These data and geological features appear to indicate that most of southern Arizona comprises a target area to conduct studies and exploration for potential geothermal resources, particularly in the southeastern quadrant and western section. The Plateau Uplands area is not necessarily ruled out, as reservoir rocks may be deeply buried and the overlying extensive groundwater system could have a cooling effect on any leakage through the thick blanket of fine-grained sediments. The youngest volcanism activity occurs in this area and a geothermal reservoir area could be enclosed by fine-grained rock sequences.

Selected references are included to provide a cursory sample of available reports. In recent years, considerable geological works have been reported on the age determinations of the igneous rocks by geochemical techniques; geophysical surveys which indicate the configuration of the basement rocks and their magnetic characteristics; detailed studies on the structural fabric as related to occurrence of mineral deposits; and the extent and character of the materials which contain groundwater in the alluvial basins.

The Arizona Regional Ecological Test

Site, University of Arizona, has a library of color aerial photos, high altitude (U-2) photos and other material obtained in co-operation with NASA. Logs and samples of oil test wells and many deep ground-water wells are available for study at the Oil and Gas Commission of Arizona and Arizona Bureau of Mines. The U.S. Geological Survey offices in Tucson, Phoenix, and Flagstaff have extensive files of geologic and water data on the State of Arizona.

Regulation

At present, the regulation of geothermal development, including drilling, production and disposal of waste products is under surveillance by the Oil and Gas Conservation Commission, State of Arizona. The office is located at 4515 North Seventh Avenue, Phoenix, Arizona 85013, telephone (602) 271-5161. Mr. John Bannister is the Executive Secretary and persons wishing additional information on these matters pertaining to geothermal resources should contact this state agency.

Power Supply and Demand

The total power consumed in Arizona is derived from supplies generated within the state and supplemented with supplies transported from external sources. The total sales of electric power in Arizona in 1970 was 15,605 million KWH (kilowatt hours). In the first ten months of 1971, the total sales amounted to 14,916 million KWH. This amount compared to the first 10 months in 1970 (13,319 million KWH) indicates a 12 percent growth for 1971. A growth rate of about 10 percent is currently projected by several utility companies as manifested by plans to meet the demands in the next 5 years.

The major power utility companies in Arizona have agreements to obtain additional power from the Navajo Project now under construction at Page, Arizona. It is scheduled for completion in 1976 and the net output is expected to exceed 2,310 megawatts.

CONCLUSIONS

1. There are no known Geothermal Resources Areas in Arizona.
2. There are several investigations on geothermal resources being conducted by private enterprise which indicate a potential occurrence. Exploration borehole drilling is reported to start within the next 60 days.
3. In southern Arizona, there are many geologic structural and rock characteristics similar to known geothermal reservoirs.
4. There are no surface indications of steam leakage, but the occurrence of thermal water nearby favorable geologic features suggests the potential occurrence of geothermal energy.
5. There are several favorable target areas in southern Arizona; the application of skillful study, creative imagination, and data from borehole drilling programs could lead to successful geothermal development.

SELECTED REFERENCES

Arizona Bureau of Mines and University of Arizona, 1962, Folio of geologic and mineral maps of Arizona: University of Arizona Press, Tucson.

Arizona Bureau of Mines, 1969, Mineral and water resources of Arizona: Univ. of Ariz. Bull. 180.

Conley, J.N., June 1971, Index of samples of drill-bit cuttings and/or cores of wells drilled in Arizona: Oil & Gas Conserv. Comm. State of Ariz.

Damon, P.E., 1959, Geochemical dating of igneous and metamorphic rocks in Arizona: Ariz. Geol. Soc., Guidebook II, p. 16-20.

_____,1967, Potassium-Argon dating of igneous and metamorphic rocks with applications to the Basin Ranges of Arizona and Sonora: Radiometric Dating for Geologists, Intersci. Pub.

Damon, P.E. and Bikerman, Michael, November 1964, K-AR Dating of post-laramide plutonic and volcanic rocks within the Basin and Range Province of southeastern Arizona and adjacent areas: Ariz. Geol. Soc. Digest, vol. VII, p. 63-78.

Damon, P.E., and Giletti, B.J., 1961, The age of the basement rocks of the Colorado Plateau and adjacent areas: N.Y. Acad. Sci., Annals vol. 91, art. 2, p. 443-453.

Damon, P.E., Mauger, R.L. and Bikerman, Michael, 1964, K-AR Dating of laramide plutonic and volcanic rocks within the Basin and Range Province of Arizona and Sonora: Proceedings, XXII Inter. Geol. Cong., New Delhi, India, p.45-55.

Damon, Paul E. and Mauger, R.L., 1966, Epeirogeny-Orogeny viewed from the Basin and Range Province: Soc. of Min. Engrs. Trans., vol. 235, p. 99-112.

Darton, N.H., 1920, Geothermal data on the U.S.: U.S. Geol. Sur. Bull. 70.

Erickson, Rolfe, Welded intrusive volcanic breccia in the Dos Cabezas Mountains, Arizona: Submitted to Bulletin Volcanologique.

Gilluly, James, 1949, Distribution of mountain building in geologic times: Geol. Soc. Am. Bull., v. 60, p. 561-590.

_____,1963, The tectonic evolution of the western United States: Quart. Jour. Geol. Soc. London, p. 113-174.

Haigler, L.B., 1969, Geothermal resources in mineral and water resources of Arizona: Ariz. Bur. Mines Bull. 180.

Harshbarger, J.W., 1958, Use of ground water in Arizona: *in* Climate and man in the Southwest - a symposium: Univ. Ariz. Bull., v. 28, no. 4, p. 51-68

_____,1960, (Contributor to section on water); *in* Arizona-its people and resources: Univ. Ariz. Press, Tucson.

Harshbarger, J.W., Lewis, D.D., Skibitzke, H.E., Heckler, W.L., and Kister, L.R. (revised by H.L. Baldwin), 1966, Arizona water: U.S. Geol. Survey, Water-Supply Paper 1648.

Hunt, C.B., 1956, Cenozoic geology of the Colorado Plateau: U.S. Geol. Survey, Prof. Paper 279.

Jahns, R.H., 1959, Collapse depressions of the Pinacate volcanic field, Sonora, Mexico: Ariz. Geol. Soc., Guidebook II, p. 165-184.

Johnson, P.W., 1959, Test holes in southern Arizona valleys: Ariz. Geol. Soc., Guidebook II, p. 62-65.

Kuhn, T.H., 1941, Pipe deposits of the Copper Creek area, Arizona: Econ. Geol., v. 36., p. 512-538.

Lasky, S.G., and Webber, B.N., 1949, Manganese resources of the Artillery Mountains region, Mohave County, Arizona: U.S. Geol. Survey Bull. 961.

Lindgren, Waldemar, 1905, Description of the Clifton quadrangle: U.S. Geol. Survey Geol. Atlas, Folio 129, 13 p.

Longwell, C.R., 1926, Structural studies in southern Nevada and western Arizona: Geol. Soc. Am. Bull., v. 37, p. 551-583; (absts): p. 165 (1926); Pan-Am. Geol., v. 45, p. 164.

_____, 1950, Tectonic theory viewed from the Basin Ranges: Geol. Soc. Am. Bull., v. 61, p. 413-433.

Lovering, T.S., 1948, Geothermal gradients, recent climatic changes, and rate of sulphide oxidation in the San Manuel District, Arizona: Economic Geol. Bull, v. 43, No. 1, p. 1-20.

McKee, E.D., 1951, Sedimentary basins of Arizona and adjoining areas: Geol. Soc. America, Bull. vol. 62, p. 481-506.

McNitt, J.R., 1963, Exploration and development of geothermal power in California: Calif. Div. Mines and Geol., Spec. Rept. 75, 45 p.

______,1965, Review of geothermal resources in Terrestrial heat flow: Am. Geophys. Un. Geophys. Mon. ser. no. 8, p. 240-266.

Mayo, E.B., 1958, Lineament tectonics and some ore districts of the southwest: Min. Engr. v. 10, no. 11, p. 1169-1175.

______,1959, Volcanic geology of the northern Chiricahua Mountains: Ariz. Geol. Soc., Guidebook II, p. 135-138.

Peirce, H.W., Keith, S.B., and Wilt, J.C., 1970, Coal, oil, natural gas, helium and uranium in Arizona: Ariz. Bur. of Mines, Bull. 182.

Continued page 12

GEOTHERMAL Continued

Richard, K.E., and Courtright, J.H., 1960, Some Cretaceous-Tertiary relationships in southeastern Arizona and New Mexico: Ariz. Geol. Soc., Digest vol. III, p. 1-7.

Robinson, H.H., The San Franciscan volcanic field, Arizona: U.S. Geol. Survey, Prof. Paper 76.

Titley, S.R., 1959, Igneous rocks of the Basin and Range Province in Arizona: Ariz. Geol. Soc., Guidebook II, p. 85-88.

Waring, G.A., 1915, Thermal springs of the U.S. and other countries of the world-a summary: U.S. Geol. Survey Prof. Paper 492.

Wilson, E.D., 1931, New mountains in the Yuma Desert, Arizona: Geog. Rev., v. 21, p. 221-228.

______,1933, Geology and mineral deposits of southern Yuma County, Arizona: Ariz. Bur. Mines Bull. 134, 236 p.

Wilson, E.D. and Moore, R.T., 1959, Structure of Basin and Range Province in Arizona: Ariz. Geol. Soc., Guidebook II, p. 89-105.

Wright, J.J., 1971, The occurrence of thermal ground-water in the Basin and Range Province of Arizona: *in* Hydrology and Water Resources in the Southwest, Proceedings, Ariz. Sec. Am. Water Resources Assoc. and Ariz. Acad. Sci., Tempe.

HUMBLE GIFT TO UA

The University of Arizona has received a $3,000 grant from the Humble Companies Foundation, Houston, Texas, for the academic year.

Funds are equally divided between the UA Departments of Geology, Chemical Engineering and Mechanical Engineering and the use of the money is determined by the individual departments.

Douglas G. Garrott, exploration manager, Humber Oil & Refining Co., Southwest Division, Midland, Tex., and D. I. Bolding, Humble Oil public relations manager, Los Angeles, presented the check to UA President John P. Schaefer.

Humble Oil & Refining Co., Humble Pipe Line Co. and Esso Production Research Co. are the participating companies of the foundation.

SPRAY DRYER DONATED TO COLLEGE OF MINES

A new item of metallurgical test equipment has been added to the University of Arizona College of Mines laboratories. A portable stainless-steel NICHOLS-NIRO spray dryer was given to the College by the NICHOLS Engineering and Research Corporation, 150 Williams Street, New York City.

This compact, self-contained unit can dry a wide diversity of wet sludge or slurries and provides a reproducible and meaningful evaporation capability over a range of temperatures, e.g.,

Drying Air		Temperature °C		Evaporation Capacity lb/hr
lb/hr	SCFM	Inlet	Outlet	
185	41	150	80	3.
175	38	200	90	5.5
163	36	350	90	15

This small centrifugal atomizing dryer is a perfectly scaled-down model of the large commercial spray dryer that NICHOLS Engineering has operating in a number of plants.

The College of Mines welcomes this portable dryer as a valuable research tool which enhances its capability to provide up-to-date useful research for Arizona industry and to keep pace with technological advances.

FIELD NOTES
Volume 2, No. 2 *June, 1972*
State of Arizona
Governor ....Hon. Jack Williams
University of Arizona
President ....John P. Schaefer
Arizona Bureau of Mines
Director ....William H. Dresher
Editor ....F. Catherine Cate
ARIZONA BUREAU OF MINES
THE UNIVERSITY OF ARIZONA
TUCSON, ARIZONA 85721