FIELD NOTES FROM THE ARIZONA BUREAU OF MINES

Vol. 2 No. 3 Earth Science and Mineral Resources in Arizona *Sept. 1972*

GEOLOGIC HAZARDS AND LAND-USE PLANNING

by
H. Wesley Peirce

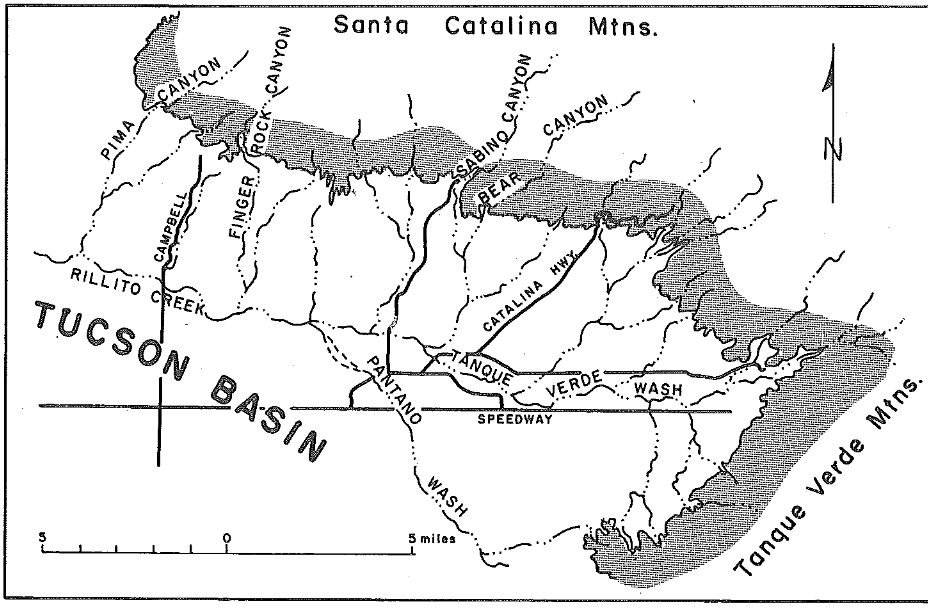


Fig. 1 Generalized drainage map of northern Tucson Basin, Arizona.

INTRODUCTION

The Arizona Bureau of Mines, being the principal State agency that assembles and distributes basic geologic information to Arizona residents, is interested in the ramifying relationships between Society, the geologic condition, and "land use". "Land use" is an infinitely complex subject and most likely will provide a focus for future articles in FIELDNOTES. For this report we are introducing the subject of geologic hazards in the Tucson region, with emphasis on general conditions that should warrant consideration when choosing a residential setting.

A "hazard" is a special condition that threatens damage to life and/or property. The "geologic condition" includes the physical-chemical characteristics of the earth as well as its processes. The geologic condition might or might not be a threat to man because it is the local geologic setting that controls the kinds and magnitudes of the active processes. Earthquakes (faulting), volcanic activity, water movement, landslides, mudflows, land subsidence, rock falls, etc., are processes that operate unequally around the earth. Each locality or community has its own sets of conditions that can be evaluated for hazardous or threatening characteristics. It is a wise man or animal that renders more than a cursory evaluation before settling down in one place for an extended stay.

Construction and destruction are judgmental words because, when viewed in the larger context, natural processes are, in the long run, constructive. They are nature's way of balancing forces; they are mechanisms to restore equilibrium to a complex system of action and reaction. The evolution of the surface of the earth is incessant, unrelenting, and guaranteed to continue for a time. The biosphere is the newcomer and is required to adapt in order to survive. Adaptation means playing by the rules of the game and learning these rules is experience. Tragedy is commonplace among those who do not or cannot heed the collective experience. At this point, we are not concerned with "Acts of God" but rather the predictable, the repetitive, the avoidable.

Continued page 2

A NOTE FROM THE DIRECTOR:

NEW USGS PROGRAM PROPOSED TO HELP PLANNERS

Complex problems stemming from the interaction of population and economic growth, land use, resource depletion and environmental pollution are accelerating in degree and in number throughout the nation. Resolution of these serious problems is often difficult because key information on the land and other natural resources is either not available or is not in a form usable by or available to decision makers.

The United States Geological Survey has proposed a program, to begin in FY 1974, titled "The Resource and Land Information (RALI) Program". The program is designed to provide: (a) a broad data aquisition capability, encompassing both conventional techniques and sophisticated remote-sensing from satellites and high altitude aircraft; (b) interpretation, analysis, and translation of the data into products that are applicable to the user of the problem, and (c) a national information system network capable of delivering stored data and using them to solve new problems.

The State of Arizona is involved in a precursor of this program through an agreement between NASA, the USGS and the State's Arizona Resources Information Service (ARIS). The purpose of the program is to photo-map the entire State for land use planning purposes. Thus, detailed information concerning land form, vegetation and state of development will be obtained for the State of Arizona before similar information is obtained for any other state in the nation. In addition to the ARIS activity, the Office of Arid Lands Studies at The University of Arizona is participating in the Arizona Regional Ecological Test Site (ARETS) program sponsored by NASA and the USGS for the utilization of data received from the Earth Resources Technology Satellite (ERTS). This program was described in FIELDNOTES last month. Data from both the ARIS and the ERTS activities will become part of the RALI program's data assemblage.

The RALI program is planned to incrementally provide new high priority data through FY 1978 with additional details provided through FY 1988. The data acquired will be available to State and local agencies on a fee basis once the Regional Centers are made operational in FY 1975. The data will provide State and

Continued page 2

DIRECTOR *Continued*

local planners and decision-makers with data heretofore unavailable. The existence of such data will be of great assistance in analyzing effectively the alternatives in land use and in evaluating the tradeoffs between resource development and environmental protection concerns.

ANNOUNCEMENT

Arizona Bureau of Mines Bulletin No. 185 entitled ARIZONA WELL INFORMATION is expected to become available by the end of September, 1972. This publication was assembled by Dr. H. Wesley Peirce of the Arizona Bureau of Mines and James R. Scurlock of the Arizona Oil and Gas Conservation Commission. It records both geologic and engineering data from oil, natural gas, helium and various mineral exploration tests drilled in Arizona through 1971. The geologic data includes depths to the tops of widely recognized stratagraphic units. Information about 735 wells is recorded on 195 pages.

GEOLOGIC HAZARDS AND LAND-USE PLANNING

Continued

The following treatment is very general and incomplete. The examples largely are restricted to the Tucson region because of ready access. It is hoped that this brief venture into "geologic hazards" will stimulate some awareness so that more persons will be encouraged to make use of their own powers of observation. Adequate management of our conduct in the environment in which we live requires, besides money, interest, wisdom, and knowledge as well.

TUCSON AREA

The Tucson metropolitan area occupies the Tucson Basin, a valley surrounded by mountain masses. The basin is within the Colorado River drainage system which means that all surface drainage is connected by an integrated network that terminates at the Gulf of California below Yuma. The valley is drained by intermittent drainages, the: (1) Santa Cruz River to the west flows to the north from Mexico, (2) Pantano Wash to the east flows northwest from near Vail, (3) Tanque Verde Wash to the east flows west to a junction with Pantano Wash to become Rillito Creek that, in turn, flows north-northwest along the junction of the main valley with the foothills of the Catalina Mountains. Numerous washes transect the foothills, some draining large canyons incised sharply into the bedrock of the Catalina-Tanque Verde-Rincon mountain block (Fig. 1).

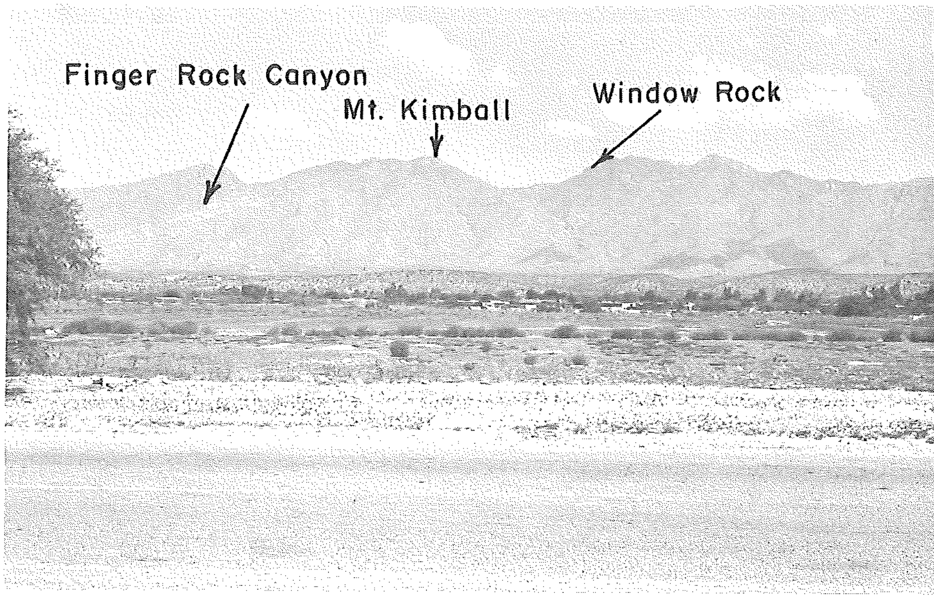


Fig. 2. Some land form characteristics of northern part of the Tucson Basin. Catalina Mountain block in distance, Catalina foothills in middle distance, and Pantano Wash floodplain in foreground. Houses are built on the floodplain near Pantano Wash. Looking north from E. Grant Road.

This mountain block reaches an elevation in excess of 9,000 feet above sea level (over 6,000 feet above the valley floor), is over 40 miles in length, and averages 15 miles in width. Anyone who has seen its winter snow pack reach a depth of over twenty feet (1967-68), or the beautiful cumulus cloud buildup in the summer, should recognize that this mass has the potential to transfer large volumes of water to the valleys below.

An assessment of the Tucson geologic setting suggests that the most hazardous of the operating geologic processes is related to water movement along canyons, washes, and rivers (also city streets!). Rockfall near the mountain margins is a likely hazard for some (more in the future). Differential subsidence of the Tucson Basin might constitute an approaching property hazard if it is not already a factor in the extensive cracking of residences.

DRAINAGE HAZARDS

At the outset, it is necessary to recall that the large drainages in the Tucson area are unfettered by dams or other means to capture and distribute periodic and erratic flow—they are, largely, as nature made them. Normally dry, the experienced will recognize that they can be, at unpredictable times, raging torrents. Churning, debris ladened waters rip into and chew away soft banks wherever the water is forced by confining banks to change its direction. A moving object or substance tends to continue in a straight line and will do so if

PLATE 1 ⟶

Floodplain (lowlands) - Development

A. Looking west down East Speedway—foreground is terrace level before the road descends onto the Pantano Wash floodplain in middleground. Higher ground to west is terrace level again. Tucson mountains in distant background.

B. Looking west from Pantano Road on terrace level to the Pantano Wash floodplain level on which housing has been clustered.

C. Aerial view of development shown in 1B which is located beside and entirely on the floodplain of Pantano Wash. The right side of this cluster appears vulnerable to the erosional processes associated with channel straightening that occurs on the outside edges of directional changes. (See dashed lined.) The bridge to the south (Broadway) crosses the main channel and not the floodplain, which extends to the east edge of the picture.

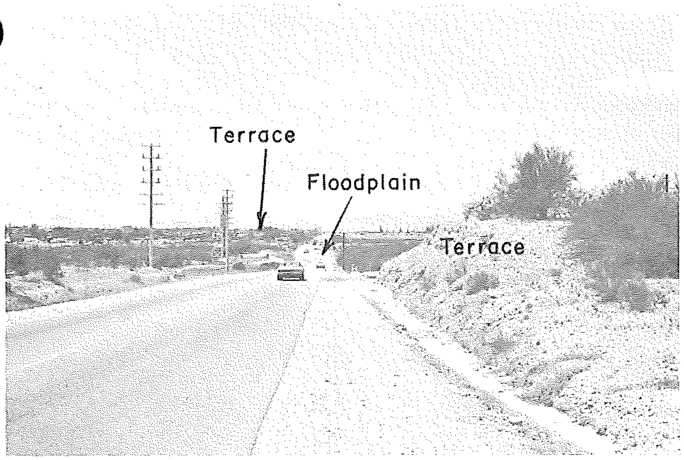
D. Same as 1C looking northerly toward the 9,000 feet high Catalina Mountains. Reinforcing along the channel bank is inadequate.

E. Aerial view looking northwest along meandering Pantano Wash. The residential areas at center left (trailers and houses) are developed entirely on the floodplain level. The nearer site is in the line of channel migration (see dashed line) and both are within the zone of flooding potential. Golf Links Road is near center of picture. White cluster in center distance development shown in 1 C and D.

F. Looking northwest from Pantano Road across Pantano floodplain being cleared for development. Homes in distance are "high", being on the terrace level above Pantano Wash, which follows growth line. Such level open space encourages development.

Floodplain (lowlands) — Development

PLATE 1



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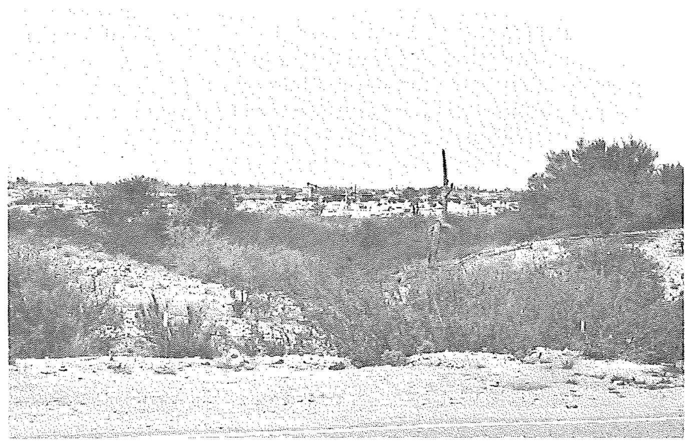

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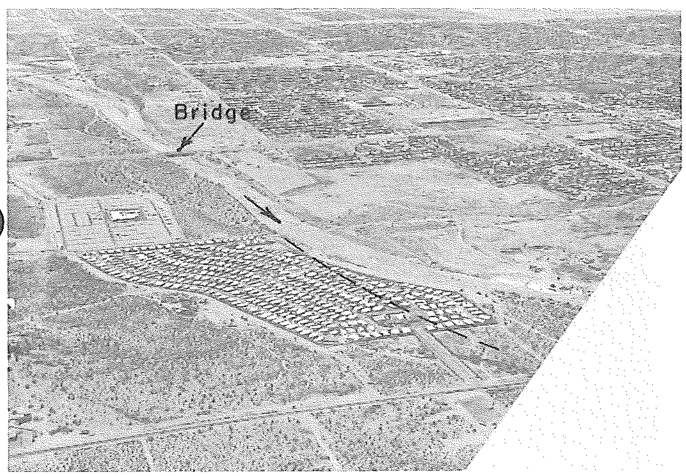

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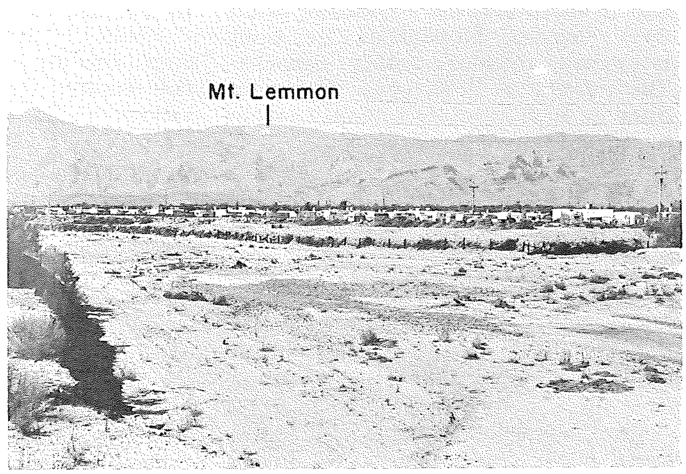

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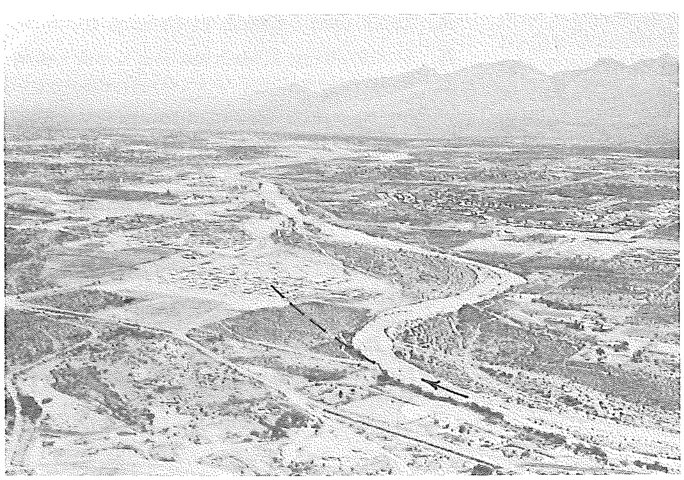

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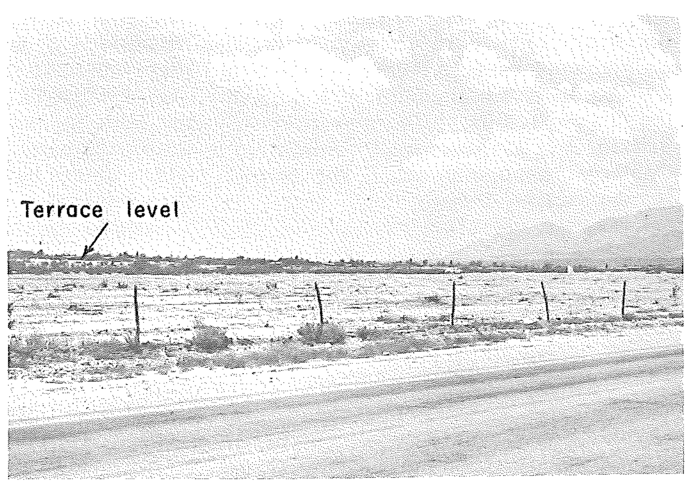

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unrestrained. Thus, channel migration at unreinforced turns is a process as relentless as an oncoming bulldozer. It is this latter process that does so much violence to man-made features. It is to be emphasized that this destructive (only if man is in the way) potential operates whenever there is enough water to erode banks. It does not require overbank (flooding) flow, therefore occurs more often than flooding because of decreased flow requirements.

As the basin population increases, encroachment into the domains of these drainages increases. The larger drainages (Santa Cruz, Pantano Wash, Rillito Creek, and Tanque Verde Wash) have created extensive relatively flat surface features, the floodplains, adjacent to main channels (Plate 1). Floodplains are depositional in origin and result from slack water sedimentation at times of overbank flow. They are *absolute* testimony of high water activity independent of the records kept by man. An important aspect of a floodplain is that it constitutes the playground of the main channel. Floodplains are easily recognized, therefore readily mappable. There should be little excuse for anyone living on such a feature without knowing it. Perhaps the degree of risk is thought to be so minimal that it isn't worth a worry. On the other hand, it is likely that many occupants of high density developments on floodplains do not recognize the fact because of poor perspective (can't see the forest for the trees). All of Tucson's major drainages have *living* floodplains; that is, they are subject to flooding during unusually high water stages. However, as emphasized here, they are subject to severe erosional destruction at *lesser* water stages. Living floodplains should not constitute a place for lengthy investment in permanent habitation for the *discreet!*

The magnitude of possible damage to property on floodplains is a function of: (1) volume of water in transit, (2) the duration of flow, and (3) position on the floodplain relative to the dynamics of main channel erosion. Points one and two are variable and unpredictable. Runoff in the basin results from a variety of possible climatological conditions. Contrary to popular belief, the normal summer storm, though locally severe, is not usually of sufficient duration and extent to cause widespread filling of main channels for any length of time. The heaviest flows have been in September in response to tropical storms and during the winter-spring snow melt season. The summer cloud burst, if placed in a strategic spot, can effect much damage, especially to dwellers of lowlands associated with washes fed by large canyons incised into the high mountain blocks. Too, damage is done within the city by locally heavy downpours. Runoff rates are increased by continued development so that present accommodations might not satisfy future drainage requirements.

It has become popular to talk of the 50 or 100-year floodplain. This involves a statistical concept that attempts to delineate those areas in a floodplain system that might be flooded once in fifty or one hundred years. Flow records have not been kept for one hundred years; therefore, actual records are not in hand. It is necessary to make many assumptions in order to arrive at some idea as to flood possibilities over a long time span. Can anyone predict when a 100, 200 or 1000-year, etc., hydrological event will baptize the Tucson area, or what it will be like? The answer is no! Again, anyone interested in protecting an investment in land and housing for one or two generations should be shy of floodplains, or lowlands in general. An axiom just as sound for homeowners as it is for soaring pilots suggests that it is well to "*get high and stay high!*"

Plates 1 and 2 are designed to emphasize the fact that development in the Tucson area does take place on various lowlands, including floodplains. Pictures B, C, D and E of Plate 1 are examples of floodplain living. Pictures 1 C and E show developments, portions of which appear vulnerable to floodplain destruction by progressive bank erosion. (See dashed lines.) The C development is located outside of the projected 100-year flood zone, according to the local office of the U.S. Geological Survey, Groundwater Branch, whereas the E area is included within such a zone. However, both are vulnerable to eventual erosion damage as contrasted with flooding, perhaps C before E, the opposite of the flooding potential! The bridge in C is an example of spanning a channel and not the floodplain.

Pictures B, D and E of Plate 2 and picture D of Plate 4 are examples of habitation along lowlands associated with tributary washes in the Catalina foothills that connect the mountain block with the axial stream (Rillito Creek) that drains the nothern part of the valley. Plate 2A shows an earth dam in a wash below which houses have been placed at or near the wash bottom as shown in 2B.

All the canyon drainages shown in 2C eventually coalesce to pass through the low points shown in 2 D and E (See caption for 2E).

ROCK FALLS

As population increase tends to fill out the living area, encroachment along the bedrock front of the Catalina and other mountains is taking place. The often rugged topography at mountain-valley interfaces presents hazards of a different type—moving (falling-rolling) rocks and/or water. Plate 3 depicts dwellings within the zone along which boulder migration has occurred before. The frontal cliffs of the Catalinas continue to evolve, largely by failure along a fraction system that traverses these rocks. Is the past a key to what might happen in the future? To a geologist, the answer is, "yes!" See the more detailed explanations that go with Plate 3, A, B and C.

EARTH CRACKING AND MISCELLANEA

Plate 4 contains examples of miscellaneous phenomena. Picture 4A is a portion of the earth fissure (crack) system along the west side of the Pichacho Mountain in Pinal County. Interstate 10 east of Eloy is intersected by this system. Both the highway and the paralleling railroad require periodic maintenance where this fracture crosses each. These are believed to be subsidence cracks and are often attributed to groundwater withdrawal in the extensive agricultural area to the west. Measurements indicate ground level subsidence of as much as seven (7) feet near Eloy. Extensive cracking has been noted elsewhere in Arizona. In one case, cracking has occurred near a housing development.

Again, as Arizona grows and population spreads out, it is likely that fissuring of this sort will overlap with construction projects. It is probable that new fissuring will occur in areas of large volume pumpage of groundwater where the subsurface conditions are favorable for their development. "Land use" studies would be deficient if they did not address the question of subsidence causes and effects. Houses and other structures in the Tucson area crack with regularity,

PLATE 2 ⟶

Wash (lowlands) Development - Catalina Foothills

A. Earth dam on wash in Catalina foothills.

B. Development in wash lowland ¼ mile below dam. Arrow points to wash bottom.

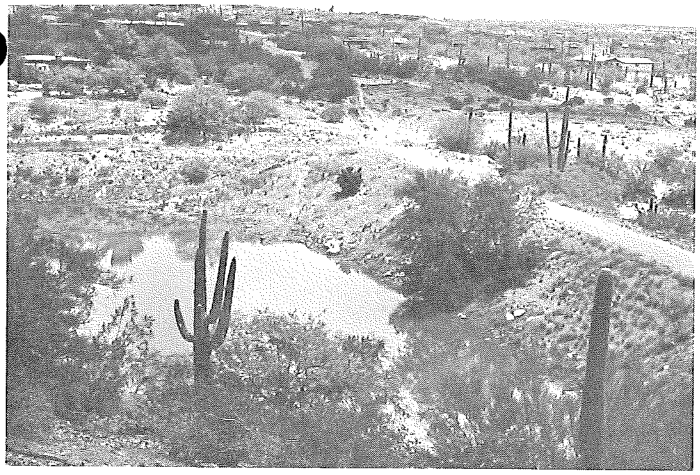
C. South face of Catalinas. Entire visible area drains into one wash (see 2 E and F and also Fig. 1). Finger Rock (arrow) is at left skyline. Finger Rock canyon is below. Looking north.

D. House in Finger Rock wash lowland. Boulders are easily accessible because of position in the zone of high energy flow along wash. Looking west.

E. Finger Rock wash lowlands development. Note also hidden roof top at center. The Finger Rock drainage is deceptive because the canyon mouth is just off the left edge of the picture. From there the drainage hooks back to the east before flowing south to the Rillito (see Fig. 1). Looking northwest.

Wash (lowlands) Development — Catalina Foothills

PLATE 2



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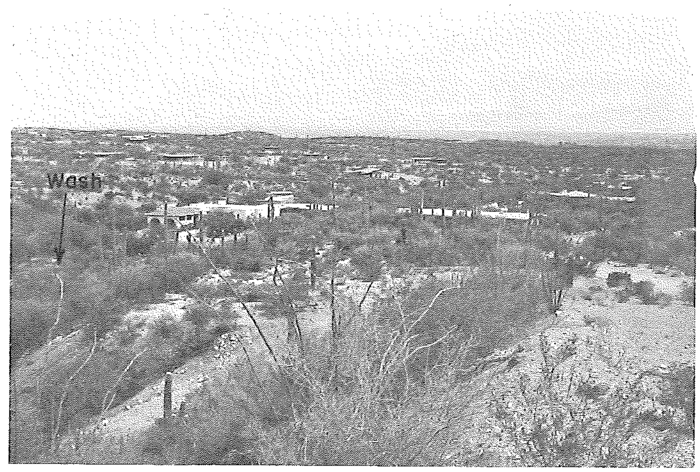

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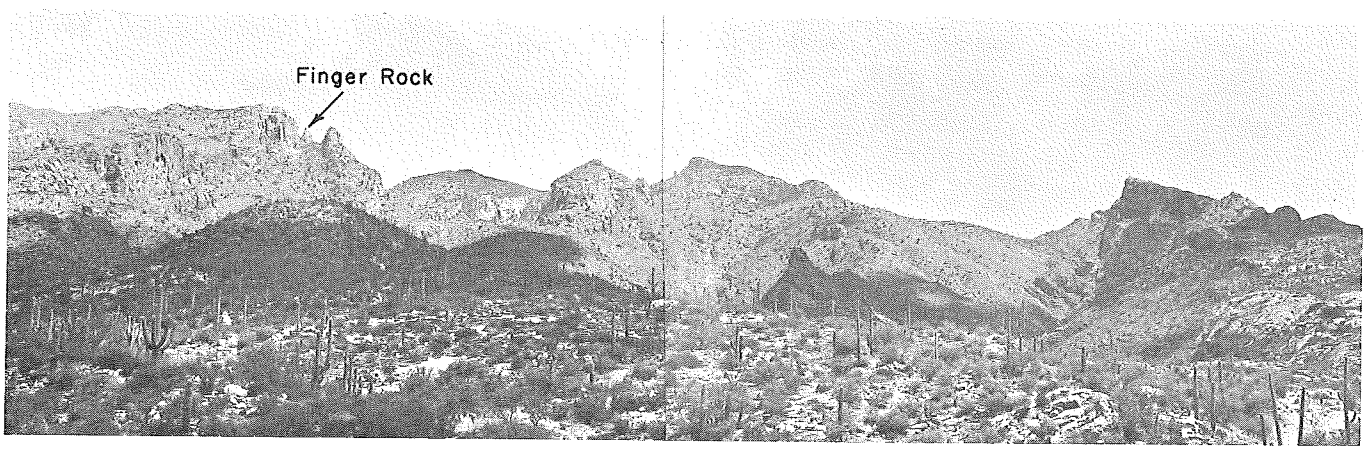

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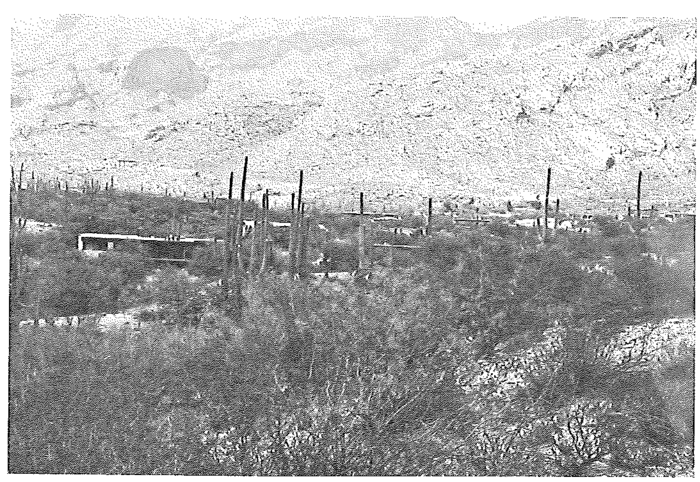

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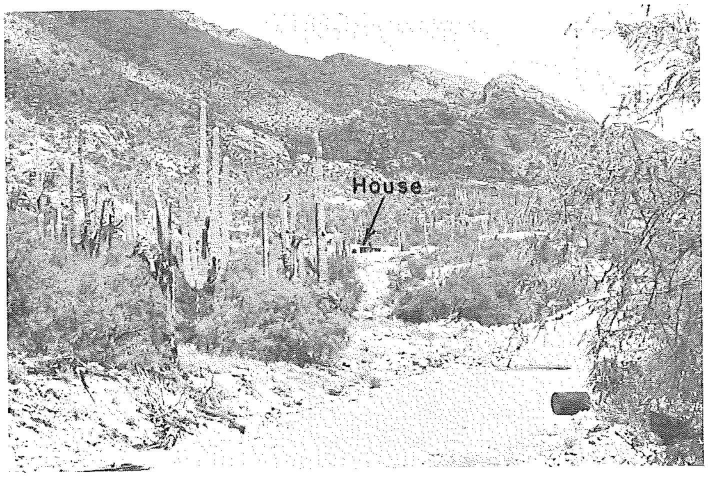
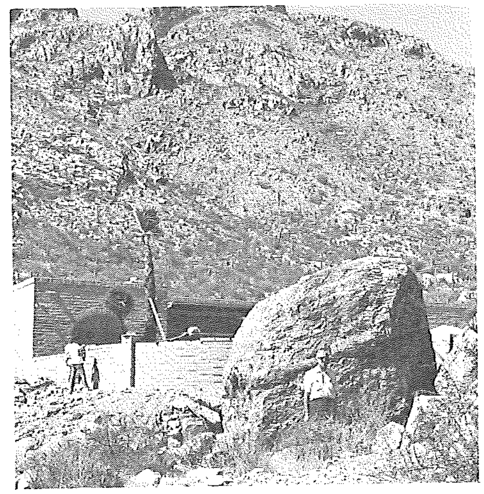
PLATE 3

Mountain Fronts and Boulders (A,B,C)





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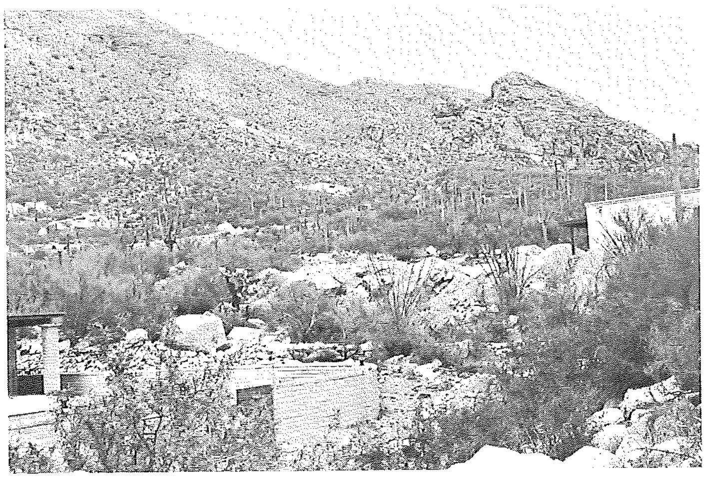
Urban Drainage (D,E,F)



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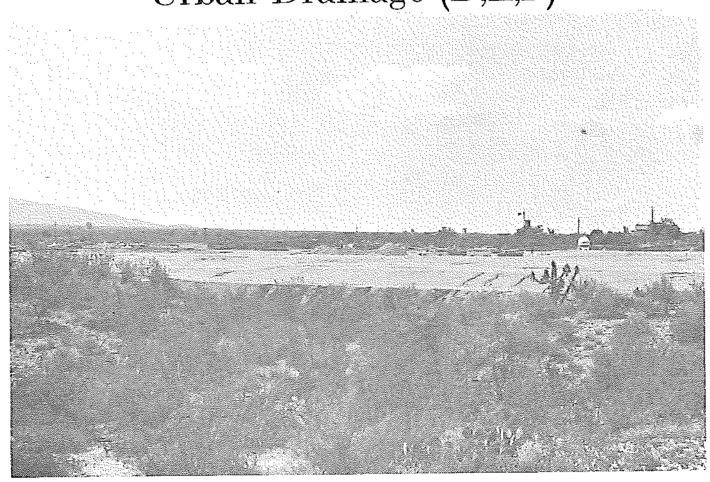

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but absolute causes largely are not yet documented. All of Tucson's water supply is groundwater; therefore, the question of possible subsidence effects must be raised. To the best of our knowledge, there isn't a survey program in the Tucson region designed to monitor detailed changes in land surface elevations. Land level adjustments might be taking place in areas of principal pumpage near the major waterways but we will not know for sure until a systematic surveying program is set up and adequately financed and maintained. Residents of Tucson and elsewhere have a need to know what is going on, and so do the people who must design and build in this setting. It is this writer's personal suspicion that some of the settling attributed to local watering habits, especially on the older soils, is actually subsidence adjustment associated with water table decline. If so, the problem is not likely to diminish, but to increase with time.

Pictures 4 B and C illustrate a land development project in which a network of dirt roads is intertwined with a complex of washes. It would appear that a creditable attempt was made to construct many interior roads parallel to wash trends so as to avoid the maintenance costs associated with numerous wash crossings. Picture 4C shows what happens when roads are built "against the grain" and not properly protected. Buyers of acreage in raw developments should consider the stability of ingress and egress routes, and wonder who ultimately will bear the responsibility for proper road maintenance and its associated costs.

Picture 4F is a culvert that passes drainage from Pima Wash (4D) beneath Ina Road. Pima Wash drains Pima Canyon in the Catalinas (Fig. 1). Although this crossing is apparently calculated to wash out occasionally, the tendency is for restrictions such as culverts to become fouled and plugged with debris. As can be seen, a debris buildup has already started. If allowed to continue, the culvert might become prematurely plugged and Ina Road topped and washed out sooner than may have been calculated. Picture 4E is a smaller scale example of what can happen.

The handling of urban drainage is a difficult and costly matter. Overall planning is made difficult by uneven development in both time and space. Tampering with the natural system leads to a long chain of reaction effects—the solving of a local situation creates new situations elsewhere (This is a repetitious story in the natural world!). Pictures 3 D, E, and F are in the urbanized setting. They illustrate interference with a natural drainage (D), the creation of an artificial channel (E) and how an unappreciated side drainage compromises the handling of a major wash at a street crossing (Glenn east of Swan-Alamo Wash).

← PLATE 3

Mountain Fronts and Boulders (A,B,C)
Urban Drainage (D,E,F)

A. House in center encroaching upon steep mountain front. Looking northeast.

B. Same as 3A but closer look. Question: where did the large boulder come from and by what natural process was it positioned? Is the answer of any potential significance to anyone?

C. Same area as 3B. Houses are among a boulder field that reaches out from the mountain front.

D. New development covers up natural drainage way.

E. Concrete lined channel that shunts drainage through development. Such unnatural channels rapidly deliver large volumes of water to lower areas, thus transfering problems elsewhere. Major drainages, by the time such channels are placed end to end, are asked to carry more water than would naturally be the case.

F. A quarter of a million dollar project along a major wash and street crossing is breached by an unappreciated side drainage. This is not to find fault but rather to emphasize the monstrous and costly problem of urban drainage control and maintenance.

CONCLUSIONS

These few examples of living with potentially and actually hazardous as well as nuisance conditions can be multiplied many times within the Tucson metropolitan region. Many of them represent a flirtation with forceful natural processes that have been active in recent times and that again will be active in the future. The valley population will

Continued page 9

WHAT MINING MEANS TO THE UNITED STATES

(From the Earth, a Better Life)

Note: The following is an abridgement of a 1972 publication by the American Mining Congress. Copies of the 22-page booklet may be obtained by writing AMC Headquarters, 1100 Ring Building, Washington, D.C. 20036.

WHAT MINING MEANS TO EACH OF US

Mining is the extraction of any mineral matter from the earth for the benefit of mankind. The term "earth" includes the atmosphere surrounding the earth, the surface of the earth and formations underlying the surface, and the oceans.

Mineral matter may be solid (coal or ore), liquid (petroleum or mineral-bearing brines), or gas (natural gas or helium). This booklet presents U.S. production and consumption data for the 91 solids, liquids, and gases listed by the U.S. Bureau of Mines as essential mineral materials extracted from the earth.

Two basic industries have enabled man to progress through the Stone Age, Bronze Age, Iron Age, Industrial Age, and now the Age of Technology: Agriculture and Mining. These two supply the food, fiber, fuel and materials to feed, clothe and house us and to sustain nearly all productive industry. Without them we would have to return to the life of primitive man.

A large part of agriculture is dependent upon mining. For example, the three major fertilizer minerals come from mines. In fact, mining replaces essential elements that plants extract from the soil and prevents the deterioration of soils so common in areas where mineral fertilizers are not employed. Also, during the period 1955 to 1968, farm output increased 38 percent but farm employment decreased 43 percent. This was possible because of tractors, trucks, harvesters and other machinery made of steel and other metals, plus the petroleum products mined from the earth. Note also the importance of aluminum, stainless steel, nickel, copper, and silver in modern food preparation, storage, and utilization.

Clean water, essential to health, cleanliness and comfort and indispensible for the production of power and processing industries comes to us through or by use of materials extracted from the earth by the mining industry.

Clothing, housing, transportation, communications; all are based on the utilization of metals and minerals from the earth.

A look at hospitals, or a doctor's or dentist's office must convince anyone of the importance of metals and alloys to prevent and cure disease and to add to national health levels. Safety in our rail, highway, air, and water transportation systems is provided by signal systems, the basic components of which are metals.

All communication systems use copper, aluminum and other metals. Even the paper products of the publishing industry utilize earth minerals extensively and press room installations are huge masses of moving metal.

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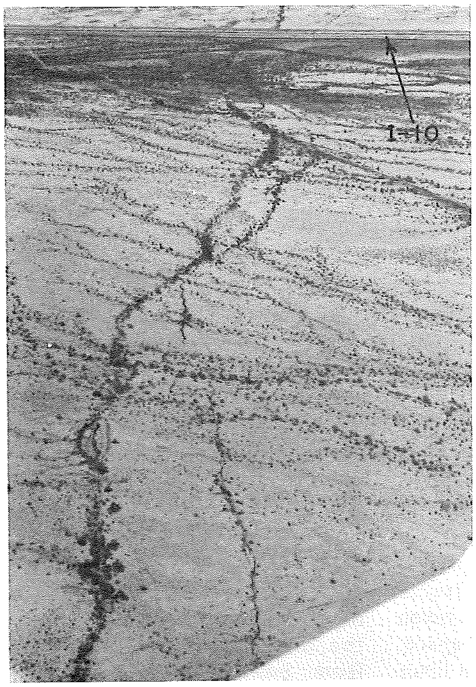
Miscellaneous

PLATE 4



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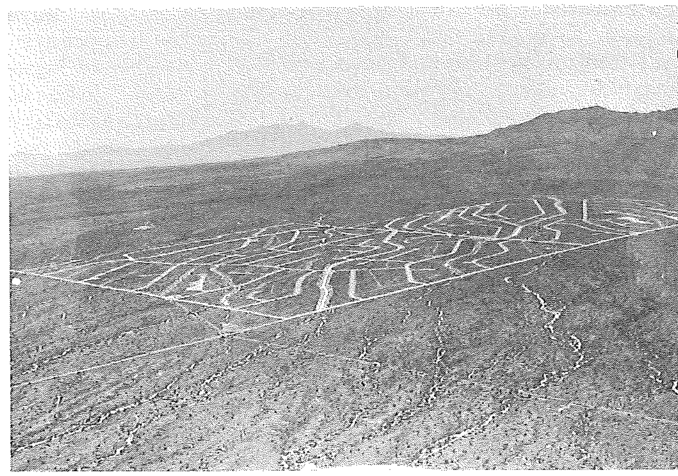

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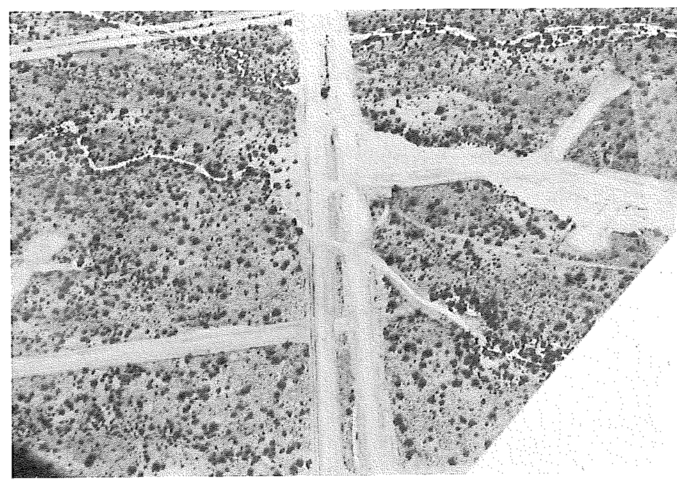

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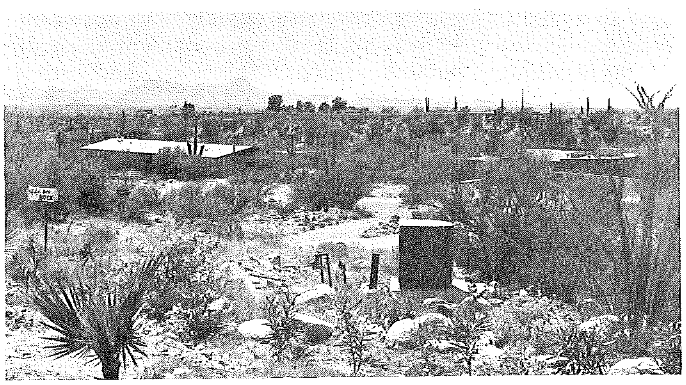

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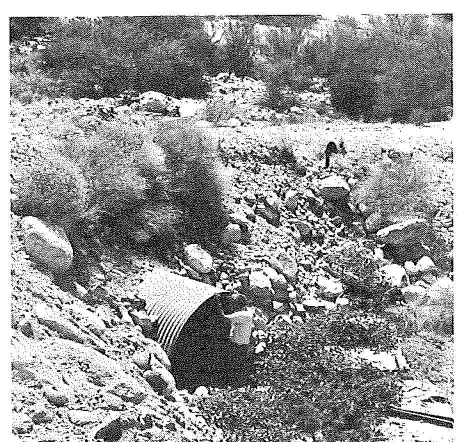

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GEOLOGIC HAZARDS *Continued*

continue to grow, which means that "hazardous" acreage will tend to be pressured into development. The responsibility for picking and choosing building sites is left to the discretion of individuals as laws regarding lowland development are apparently nonexistent. In the absence of protective zoning laws, it is essential that individuals become aware of the hazards that do exist, and that they can be minimized by proper sensitivity and selectivity.

Constrasting philosophies exist regarding floodplain management. Much riverbottom and floodplain property is privately held, which complicates overall management. Development leads to demands for protection after the problem is belatedly perceived. In these times of environmental awareness, it might be possible to find merit in the discouragement of development along lowlands and to open these lands to recreational pursuits. For some, it would be an asset to develop drainage easements that would allow the public to move without encountering barbed wire fences in river and wash bottoms, etc. Too, there might be merit in protecting future sources of that which is so vital to all communities–sand and gravel (especially gravel) for construction purposes. "Planning" and "Land use" are terms that have become commonplace. Neither will be meaningful unless the larger community can muster the will, the wisdom and the knowledge to do it well.

←—— PLATE 4
Miscellaneous

A. Earth fissure (crack) zone trending southeast across Interstate 10 near top of picture (arrow). Both the highway and the adjacent railroad require periodic maintenance along this zone of rupture. Location is just west of Picacho Mountains.

B. Aerial view looking southeast toward Sierrita Mountains with Santa Rita Mountains in distance. Network of dirt roads is interlaced with a drainage complex that traverses a broad gentle slope. Activity is associated with a development.

C. Aerial view within 4B showing conflicts between washes and roads.

D. Lowland development along Pima Wash which drains Pima Canyon in western Catalina Mountains.

E. Culverts filling with sand. Drainage now overflows and spills across highway to become another problem source.

F. Culvert passes flow from Pima Wash beneath Ina Road. If debris clogs pipe, premature overflow and damage to Ina Road might occur.

MINING MEANS *Continued*

The surge in power demand for air conditioning has required increased production of gas, oil, coal, and uranium. Heating and lighting have improved so much in recent years that we take them for granted. Such factors, important to health and vital comfort, depend on metals and fuels supplied by the mining industry. Other activities such as Man's use of his leisure hours and the exploration of space depend on minerals produced from the earth.

THE U.S. NEEDS A HEALTHY MINING INDUSTRY

Most people know very little about the mining industry because mining employs only 0.9 percent of the U.S. working force, occupies less than 0.3 percent of the surface area of this country (primarily in remote areas), and produces only 3 percent of the Gross National Product. Further, few mined products are purchased or used by the public in a form that can be identified with mining.

Though mining may not appear to be a giant industry the living standards in the United States today are based on its minerals. With only 5 percent of the world's population and 7 percent of the land area, we use 30 percent of the world's mineral production and must import varying amounts of many mineral products. Changing competition for world mineral supplies dictates we can no longer assume that foreign mineral products will flow to our nation as freely as they have in the past. The United States must build up a stronger domestic mining industry at home. This can be done only if people outside the mining industry understand how vital minerals are to their existence.

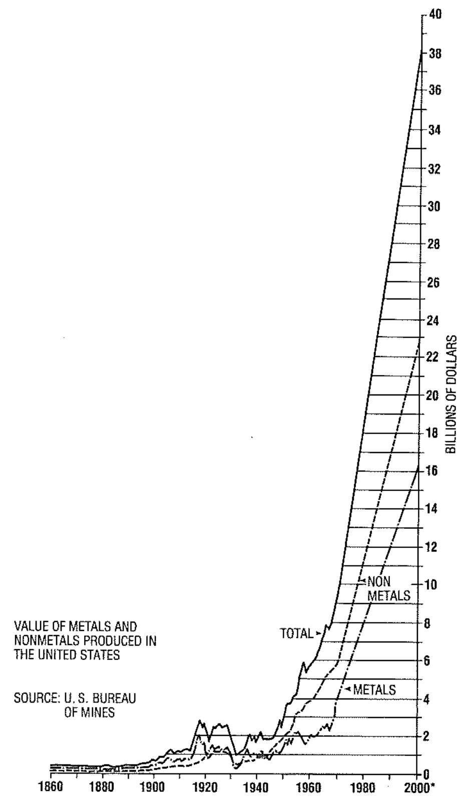
The fuel, metals, and nonmetals produced in the United States have a direct impact on 40 percent of the economy and an indirect impact on an additional 35 percent. No nation can enjoy prosperity without a reliable source of minerals which, in turn, supports its industries. Further, it is evident that metals are vital to national security. Minerals are like money in the bank–without them a nation will decay and its people face a more austere, lower standard of living.

HOW MUCH DO WE USE – HOW MUCH DO WE NEED

The U.S. Bureau of Mines and the U.S. Geological Survey keep records on how much we use and how much we will need in the future, and make estimations of current reserves. An abbreviated listing of U.S. mineral production follows:

VALUE OF MINERAL PRODUCTION IN UNITED STATES
(in billions of dollars)

	Metals	Nonmetals	Subtotal	Fuels	Total
1940	0.8	0.8	1.6	2.7	4.3
1950	1.4	1.8	3.2	8.7	11.9
1960	2.0	3.9	5.9	12.1	18.0
1970	3.9	5.7	9.6	20.2	29.8
2000	16.0	24.0	40.0	70.0	110.0



These numbers do not include materials recovered from scrap (secondary) or imported materials. In the future large quantities of materials from secondary sources will have to be produced. With any lesser amount than the total quantity estimated for the year 2000, the standard of living of the nation would decline seriously.

A large portion of the minerals of the future are yet to be discovered. The brief listing in this booklet of some of the metals or minerals and their common uses does not really convey the scope of the contribution that metals and mineral products make to everyday life, nor their significance.

However, at least two important dimensions are missing: first, the incalculable scope of human inventiveness for which these minerals provide raw material and second, the enormous changes in the character and quality of life that minerals have wrought under

Continued page 10

MINING MEANS *Continued*

human control. We do know that mining companies must find at least one pound of new metal for every pound they mine simply to stay in business. And to accomplish this task, they expend many millions of dollars in searching for and developing new ore bodies.

IN MEMORIAM

Our Bureau has received word of the untimely passing of Undersecretary of the Interior William T. Pecora in July. Dr. Pecora spent many years as a geologist for the U.S. Geological Survey, and in 1965 was promoted to Director. President Nixon nominated Pecora as Undersecretary on April 20, 1971, and the Senate confirmed the post the following month. Secretary of the Interior Rogers C.B. Morton stated that "Few men possessed the leadership qualities which Dr. Pecora showed in the quest for balance and harmony in resource development and conservation."

EMPLOYMENT AND PERSONAL INCOME GROWTH IN THE ARIZONA MINING INDUSTRY

by
George F. Leaming

EMPLOYMENT

Employment in the mineral industries has grown markedly in Arizona since the years immediately following World War II. From a level of about 13,000 in 1947, employment in the state's mining activities dropped to a low of about 11,000 in 1950. With the start of the Korean War, however, there was a sharp climb in mining employment as the demand for copper rose. Arizona mining employed a high of nearly 17,000 persons in 1957. The recession of 1958 and the prolonged copper strike of 1959 subsequently dropped the average annual employment in Arizona mining to about 13,000 in 1959. With the advent of expanded military activity in Vietnam in the early 1960's, a period of rather steady growth in copper demand began and Arizona mining employment again increased, approaching 17,000 by 1966. In 1967 and 1968, however, an almost industry-wide work stoppage in the nation's copper industry had a severe and adverse effect upon average mining employment in Arizona. The termination of the strike came early in 1968, and since that time, average employment in Arizona mining has rebounded sharply, climbing above 20,000 in 1970 and remaining at that level despite a month-long strike in 1971.[1]

Over the entire period from 1947 to 1971, average employment in the Arizona mining industry increased at an average rate of 340 persons per year. This rate has been far from uniform, however, and has been acutely affected by times of national recession and variations in copper prices. Variations above and below the trend have often been as much as 3,000 persons. In those months when work stoppages resulting from labor disputes have been in effect, employment in the state's mining activities has dropped even further below the trend defined by the annual averages.

If the conditions that have influenced employment in the Arizona mineral industries should continue to exist over the next 13 years as they have over the past 25, then by 1985 Arizona's mining firms should employ between 19,000 and 26,000 persons. Cyclical variation over the period to 1985 is likely to be relatively large, however. By 1975, it is expected that average annual mining employment in the state will not drop below 15,000. Neither can it be expected, however, to rise much above 22,000 for any sustained period during the early 1970's.

PERSONAL INCOME FROM MINERAL PRODUCTION

Annual personal income derived from current effort in mineral production in Arizona has climbed much more sharply than has total employment in the state's mining industry. Since World War II the mineral industry has been persistently one of the highest paying industries in Arizona, and the growth in mining wage rates has been much more rapid than in most other industries within the state. From less than $50 million in 1947, personal income derived from all mineral production in Arizona rose to more than $80 million annually in the late 1950's, but then dropped as a result of the recession of 1958 and the prolonged copper industry strike of 1959. In the early 1960's, however, there was a substantial rise in mineral-derived income, reaching a high of more than $140 million annually in 1966. The copper strike of 1967-68, however, caused another decline. In 1967, personal income from all mining in Arizona dropped to less than $110 million. Since the strike of 1967-68, however, personal income derived from mining activity in the state has rebounded sharply, reaching $168 million in 1969 and $210 million in 1971.[2]

Throughout the period from 1947 to 1971, annual personal income derived from mining activity in Arizona climbed at an average rate of almost $6 million per year, with considerably less year-to-year variation about the average trend than in total mining employment. If conditions persist over the next 15 years, as they have over the past 25 in the Arizona mining industry, personal income derived from mining activity in the state in 1985 could exceed $270 million and will probably not be less than $200 million. The $250 million per year level could, in fact, be reached as early as the late 1970's. It is not likely, even within the next few years, that personal income from mining in Arizona will fall as low as $150 million, even in the event of serious recession or labor disputes.

Because copper mining and the production of construction minerals dominate the mineral industry of Arizona, personal income derived from the output of nonfuel minerals alone has followed a pattern similar to that for total mining activity. The major types of mineral activity in the state, in addition to nonferrous metal and molybdenum mining, include sand and gravel and cement production. The activity in these latter commodities in many respects is closely related to other mineral industry activity although it is undoubtedly more closely related to construction activity in the state's largest metropolitan areas. Changes in the construction industry have caused some variations in personal income and employment derived from sand and gravel output, but the variation has been slight compared to that caused by fluctuations in copper mining activity. The production of fuel minerals in Arizona over the last 25 years has been relatively unimportant in the state's total employment and personal income picture. With the advent of coal mining in Northern Arizona, however, this is expected to change. Over the next decade and a half, fuel minerals could become as important in providing jobs and personal income as industrial minerals are now.

LOCAL CHANGES

Although total mining employment in Arizona has grown sharply in the last years, the overall trend in such employment since the end of World War II has been only moderately upward. Developments in several of the state's regions, however, indicate that there are some fundamental changes taking place.

Since the mid-1950's the sharpest gains in Arizona mineral industry employment have been made in the Northwestern and Southeastern regions of the state. The substantial gains made in both of these areas have been caused by the development of major copper mining operations in comparatively new districts. In the state's more traditional mining areas of the Eastern Region, mineral industry employment has actually shown a tendency to decline somewhat since the mid-1950's. New developments in these historical copper mining areas presage a reversal of that trend, however, making the simple projection of past data inadequate as a forecast of local mining employment.

Elsewhere in the state, types of mineral activity other than copper mining have not shown any significant tendencies to increase their employment on any long-term basis. Even in the Maricopa Region, which includes the rapidly growing Phoenix Metropolitan Area, there has been no rise in mineral industry activity corresponding to the rise in population. The major exception to this generalization, of course, is coal mining in Northeastern Arizona.

Future growth in employment and personal income in Arizona's mineral industries will probably be more widespread throughout the state than it has in the past. The development of additional fuel mineral resources, the greater importance of industrial minerals, a greater degree of vertical integration in the copper industry, and the opening up of significant new metal mining districts should all contribute to the future expansion.

[1]U.S. Bureau of Labor Statistics, *Employment and Earnings, States and Areas, 1939-70,* Washington, D.C., U.S. Department of Labor, 1971, p. 16; and *Arizona's Current Employment Developments,* Phoenix: Employment Security Commission of Arizona, various issues, January-December 1971.

[2]Office of Business Economics, *Survey of Current Business,* Washington, D.C., U.S. Department of Commerce, various issues, 1948-1971; and Employment Security Commission of Arizona, unpublished personal income estimates, summaries, 1969-1971.

MINING AND THE ENVIRONMENT

by
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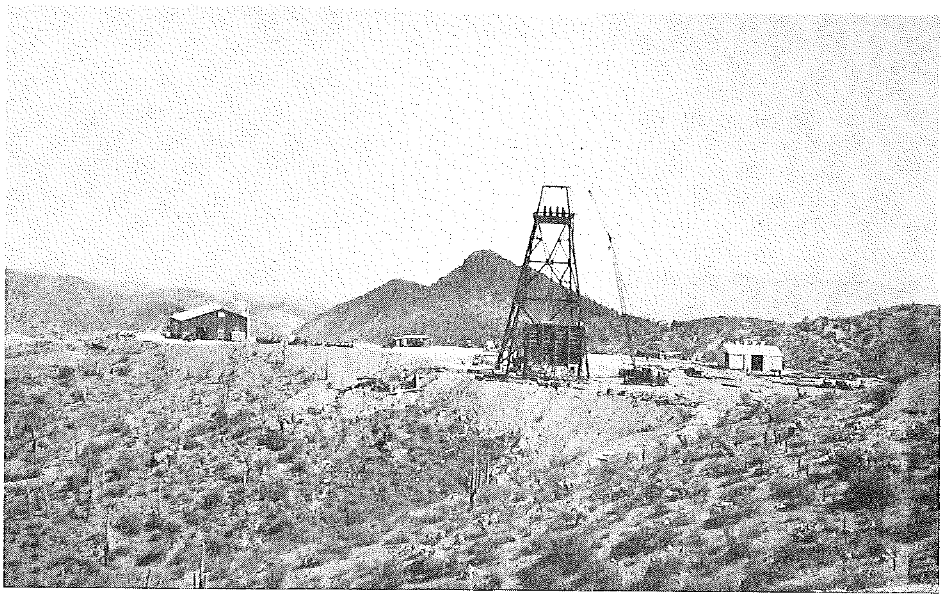
In a ceaseless effort not only to secure the "better things in life" for himself and his progeny, but more often in order to merely exist, man *must* make use of resources in the world around him.

In doing so, he frequently initiates undesirable changes in the environment. In truth, *anything* that man does makes some change in the environment. For every benefit received, there must be some penalty paid. The problem is how to minimize the penalty and maximize the benefit! There is growing concern over society's misuse of irreplaceable resources and industry's impact on the environment in utilizing these resources. Yet, without such resource utilization, the quality of our life must suffer.



Early development at San Manuel (Arizona) showing mine dumps and surface leveling at No. 1 shaft.

Mining (and its related processing) has traditionally been an initiator of environmental change, scarring the landscape, and polluting streams and the atmosphere. Frequently, there is no single effect, but rather a host of ancillary related spin-offs resulting from one activity. An extreme example of adverse environmental impact is illustrated in the chain of events which followed the building of the Aswan High Dam. Although the purpose of the dam was simply to provide irrigation, water and electric power, the impact has been something else! Constant irrigation has provoked the spread of disease, caused dramatic depletion and salinization in the soil, and brought about a disaster in important fisheries of the eastern Mediterranean.

Another historical example of complex impact is seen in the rise of the coal and steel industries in Britain. The initiating action was a 17th-Century conservation measure to save the threatened oak forests of southern England for strategic use in shipbuilding rather than allow their destruction for charcoal for iron-making. Iron-makers were expected to move to other forests in the north and west; they took another option, however, and experimented with coal. When the advantages of using coal were learned, the industry expanded as a leading force in the Industrial Revolution. The impact on the economy and the engendering of new conservation problems outstripped any earlier intentions by far. In a way, the delightful woodlands of the Sussex Weald were saved for the 20th Century by coal mining and by steel ships but at the price of grim industrial landscapes in the coal fields of South Wales.

Environmental impact and land-use compatability can be more clearly defined. In applying these data to a potential mine or to an ore body, the life cycle begins with the first accumulation of geologic and economic data and progresses through the stages of exploration, preproduction development, active mining, decline and abandonment. The life cycle may be relatively simple, but more often it is complicated by superimposed cycles of expansion projects, new engineering directions, rejuvenation and economic or geologic resurrection.

During the exploration stage the impact on the surroundings is relatively light. Pits, access tracks, and drillsites need not create much disturbance if properly done and if account is taken of the sensitivity of the tundra, desert, or forest environment. At least several major mining companies have spelled-out rules for their exploration teams to preserve the environment.

Information gathered at this stage will have an effect on the future development and use of the entire area. Ground-water hydrologic data is, for example, of value outside of the mining operation, as has been reported from Saxony where subsurface stratigraphic water-related data gathered during coal exploration was used in the design of a groundwater recharge system with the strip mine itself as a component of the system. There are many possibilities for compatability in the exploration stage. If the orebody is held as a reserve for extraction at a later time, compatable uses include forestry, grazing, agriculture, and outdoor recreation right up to the time when the mineral at a particular place must be extracted. For example, green areas in the Ruhr are actually coal reserves; park areas in California are sometimes set aside from urban sprawl because they are gravel reserves. In contrast, incompatable land uses would be those involving permanent industrial installations or urban development.

The pre-production stage, or the renewal and expansion of a former mining operation, is much more intense in its impact on the environment. At this time, priority is given to mine and plant development. Provisions for water, power, transportation, and townsites have a large impact on the environment. If the site is an older industrial area, the inherited condition may be cleaned up as was done by Meggen in West Germany where, as part of a new plant installation, accumulated polluted conditions of 100 years were eliminated.

Compatability is, of course, dependent upon the method of mining. With all underground mining (no open-pit), development can be compatable with recreational use; example, the deep potash deposits beneath Britain's North York Moors National Park.

In the productive stages of mining, the environmental impact is at its widest while compatability at its most restricted level. In the youthful phase of production, the pattern of urbanization is stable in comparison to the prior phase of development, and there is a considerable infusion of tax money for urban amenities. As the operation reaches a mature stage, the active mining or industrialized area grows while some beginnings may be made in waste utilization, backfilling of workings, and re-cycling of materials.

In the declining stage of a mining operation, the emphasis commonly changes from the orebody to other fields of profitability and to other potential mining sites. At this stage, compatability with other land uses again becomes important; e.g., farming, afforestation, use of the Mine workings for waste disposal, and the use of transportation and power for other industry become factors and goals.

With abandonment of the mining operation, the entire scene changes to high compatability. The area is not a primitive area because it *has* produced wealth and has become an industrial site. New industry with large-scale fixed installations can make use of the now barren unused site. Or, if conditions are favorable, there may be the start of considerable urban development.

The life cycle of an orebody passes through several degrees of environmental impact and compatability ranging from low impact and varied compatability at the beginning to the most active stage of extraction where mining is dominant and relatively incompatable. Then at the ending of the mining cycle, there is low impact on the environment and frequently an adaptation to other uses.

For the realization of maximum benefit to society, an orebody requires protection at an early stage, priority at its most active stage, and well-planned replacement by other activities when it has served its purpose. An orebody is nothing without a mine, and a mine has an impact which extends over a period of time. Compatability with other needs for the land *must* change in every stage in the cycle. Most of all, a mine is not merely a single activity; you can never do merely one thing without many side-effects. Careful planning will minimize the bruising impact on man's environment and allow the maximum benefits from resources essential to our health and well being.

FIELD NOTES

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