FIELDNOTES
From The State Of Arizona
Bureau Of Geology And Mineral Technology

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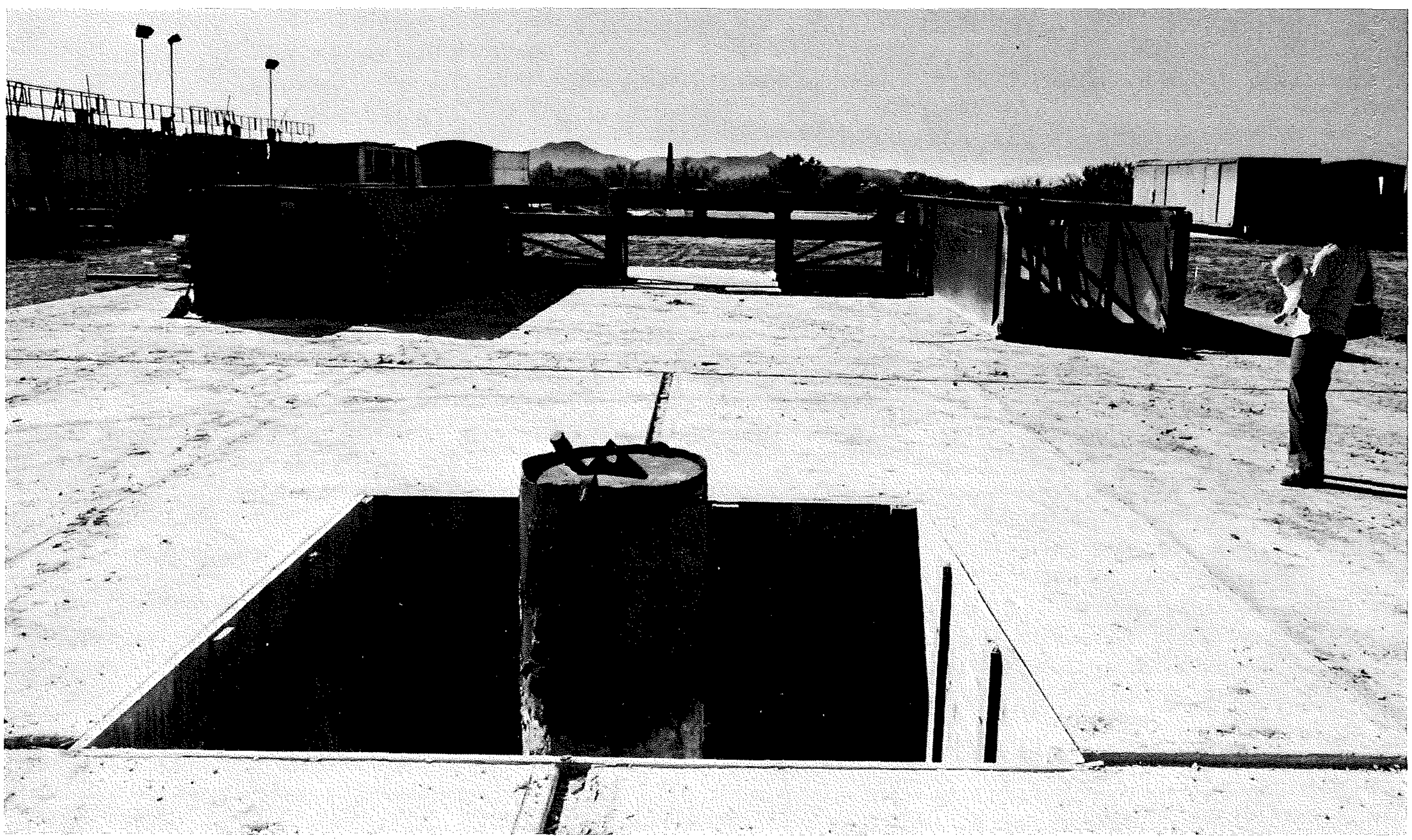
THE GREAT SOUTHWESTERN ARIZONA OVERTHRUST OIL AND GAS PLAY

Drilling Commences

by Stanley B. Keith



Anschutz-Texoma drill site as of February 23, 1980. View west toward northern Picacho Mountains. In the foreground is the previously-drilled three-foot diameter pilot hole with casing. **Photo: S.B. Keith**

Fifteen miles south of Florence, Arizona, preparations for a unique drillhole were completed in late February. The drillhole is unprecedented in its physical dimensions. It will likely smash the Arizona depth record of 12,500 feet set in 1972 by Exxon, 15 miles southeast of Tucson. The geologic reasoning behind the placement of the well is also unprecedented in its vision of a thrust fault complex of heretofore undreamed-of size and displacement that hides oil-bearing rocks under a veneer of barren crystalline granite and metamorphic rocks.

In late February, 1980, Anschutz Corporation of Denver, in conjunction with its partner, Texoma Production Co., an exploration subsidiary of Peoples Gas Company of Chicago, began drilling their historic and long-awaited oil test. After two years of exploration, Anschutz-Texoma have located their wildcat well in Section 2 T. 7 S, R. 10 E. of Pinal County, between Tucson and Florence (Figure 1). In January, over 100 truckloads of equipment were scheduled to arrive at the Anschutz-operated site from a former drilling site in Wyoming. A smaller hole has been drilled on the site to supply water for the parent rig. In order to reach the drilling depths expected to be favorable for oil and/or gas, the initial hole diameter at the surface is about three feet in diameter. The initial three foot penetration was drilled by a smaller rig. This "pilot" rig has now been replaced by a much larger rig from Wyoming owned by Parker Drilling Company and capable of a 25,000 foot test if needed. Anschutz-Texoma officials expect to reach favorable rocks in 8-10,000 feet and are prepared to drill to 20,000 feet, and spend twelve million dollars if necessary. Anschutz officials have indicated that a second hole will be started (spudded) while the first drillhole is still in progress. The first hole will take 240 to 300 days to drill. In drillers' parlance, the drillhole is "well engineered" to handle almost any eventuality, such as blow-outs, and corrosive agents, like salt and hydrogen sulfide.

Of particular interest to geologists is a provision for spot-coring which will allow collection of solid rock core samples at short intervals, greatly facilitating rock identification and interpretation. Certainly, some of these rock cores will be the most expensive and most scrutinized rock samples ever collected in Arizona.

The final location of the site came after two years of intense seismic exploration within Arizona. To date about 3,000 line miles of seismic cross section have been completed. Anschutz-Peoples Gas have spent about 6.2 million dollars and are currently spending about $500,000 a month mostly obtaining seismic lines. Figure 1 shows the approximate location of one of these lines (AZ-18), which was used in conjunction with other nearby seismic data to locate the Anschutz-Texoma Hole, named Anschutz-Texoma State No. 1-10-2. The upper part of Figure 3 shows an uninterpreted 35-mile long "raw data" segment of AZ-18 in the vicinity of Anschutz-Texoma State No. 1-10-2. Until line AZ-18 became available in June of 1979, the Anschutz-Texoma oil and gas quest was without a largescale prospect or play. The lower part of Figure 2 shows the Anschutz interpretation of AZ-18 that led to their decision to drill Arizona's potentially deepest oil test.

The Anschutz interpretation of AZ-18 is consistent with their regional geologic concept that central Pinal County is part of a vast regional overthrust belt that runs from the northwest to southeast corner of Arizona. More regionally, this belt is interpreted by Anschutz to extend the length of the Cordillera from Northeastern British Columbia, Canada to south of Vera Cruz, Mexico (see Keith, 1979, and Anschutz, 1980, for overviews of the overthrust belt). Some idealized styles of overthrust faulting known to be present in the Cordilleran overthrust belt were described by Keith, 1979 (see Fieldnotes v. 9, no. 1, p. 11). More specifically, the Anschutz interpretation of AZ-18 bears a resemblance to their interpretation of seismic reflection profiles of similar appearance at Anschutz Ranch, Utah (compare Figure 3 with Figure 2), a known natural gas producer. The gas field at Anschutz Ranch, like many other such occurrences in the Idaho-Wyoming-Utah segment of the Cordilleran overthrust belt, consists of an accumulation of gas within the Twin Creek-Nugget sandstone horizon of Figure 3. Furthermore, this gas accumulation occurs in the Twin Creek-Nugget sandstone horizon where it crosses the crest of an anticlinal fold (archlike flexure in figure 3). The Jurassic age (190-180 m.y. old) Twin Creek-Nugget sandstone horizon is a reservoir for petroleum fluids that migrated there from hydrocarbon-rich source rocks of Cretaceous age (110 m.y. to 80 m.y. old), thought to be below and to the right of the Twin Creek-Navajo horizon in Figure 3. These source rocks are separated from the reservoir rocks by the Tunp and Absaroka thrust faults.

One interpretation is that petroleum formation began when the leading edge of the Tunp and Absaroka thrusts came to rest (following their arrival from the west) on the hydrocarbon-bearing Cretaceous rocks. During the emplacement of these thrusts, hydrocarbon materials in the Cretaceous rocks were converted or matured into a petroleum condensate by increased heat and pressure associated with burial of the Cretaceous rocks underneath the Absaroka and Tunp thrusts. The petroleum condensate then migrated from the high pressure regions to structural traps in areas of lower pressure. In the overthrust belt, petroleum "traps" (as they are called in the trade) are classically associated with the hinges of anticlines (refer again to the arch-like structures in Figure 3 and Figure 2). The interested reader may refer to Ver Ploeg (1979) and Anschutz (1980) for a summary of the geologic setting and review of the recently discovered oil and gas fields in the Utah-Wyoming sector of the Cordilleran overthrust belt.

By comparing Figures 2 and 3, it is apparent that the Anschutz interpretation of seismic line AZ-18 is similar to the proven petroleum-productive analog in Wyoming. Anschutz believes that the prominent sub-horizontal seismic layering or 'reflectors', conspicuous in the lower two-thirds of AZ-18, represents sedimentary rocks of Mesozoic and Paleozoic age. The

EXPLANATION

ROCKS

- Late Miocene valley fill alluvium; includes minor intercalations and cones of basalt.
- Middle Oligocene through middle Miocene volcanic and sedimentary rocks. 'V' pattern shows volcanic-dominant facies. Stipple pattern shows clastic-sedimentary dominant facies.
- Middle Oligocene through early Miocene intrusions.
- Late Cretaceous through Paleocene (Laramide) intrusions.
- Late Cretaceous volcanic and sedimentary rocks.
- Mid-to-late Mesozoic (post-160 m.y. and pre-90 m.y. B.P.) clastic sedimentary rocks.
- Younger Precambrian (1.4 to 1.2 b.y. B.P.) clastic-dominant sedimentary rocks, 1.2 to 1.1 b.y. B.P. diabase. Paleozoic sedimentary rocks.
- Older Precambrian granitic rocks. Predominantly 1.45 to 1.4 b.y. porphyritic granitic rocks; includes a minor amount of older 1.7 b.y. (?) granodiorite rocks and a minor amount of younger muscovite granites.
- Pinal Schist (1.7 b.y. +). Predominantly green schist grade metasedimentary rocks; includes a minor amount metavolcanics.

STRUCTURE

- High angle fault; bar and ball on downthrown side; dashed or dotted where hidden or concealed
- Low-angle normal fault; hashures on downthrown side; dashed or dotted where hidden or concealed.
- Low-angle reverse fault (thrust); barbs in upper plate; dashed or dotted where concealed.

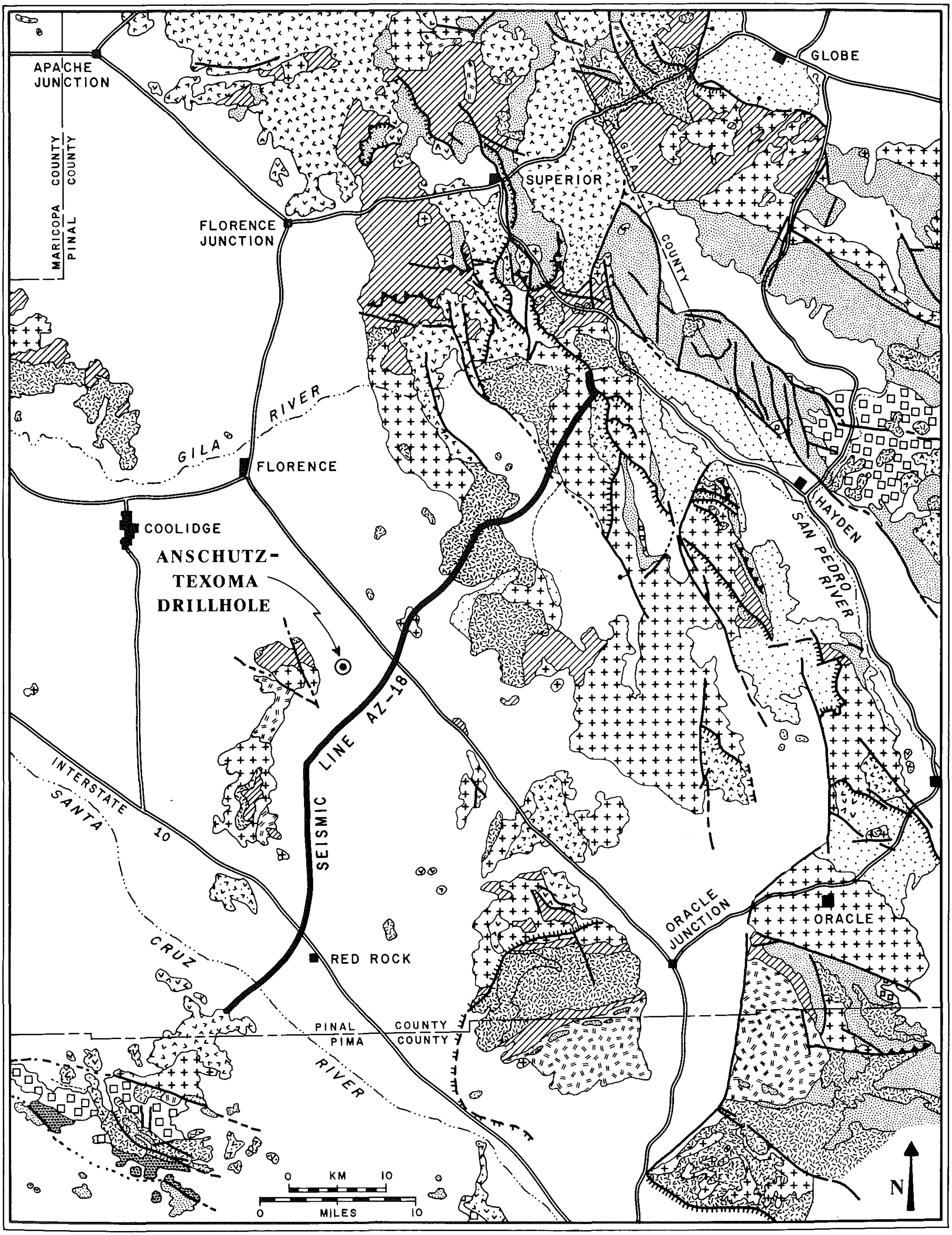


Figure 1: Geologic map of a portion of central Arizona showing location of seismic time cross-section AZ 18 and Anschutz-Texoma drillhole. Geology is modified from Wilson and others (1969).

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Mineral Resources Policy

The members of the American Institute of Professional Geologists are practicing geologists in government, educational, industrial and consulting organizations. APIG is the sole national geological organization concerned with certification of professional geologists, based on education, experience, competence, and ethics. The institute is vitally interested in the nature and quality of geological work and its impact on society. These comments are excerpted from the AIPG Mineral Resource Position Statement printed in *Geotimes* (November 1979), and prepared by Robert L. Bates, Ohio State University; James R. Dunn, Dunn Geoscience Corp., Latham, N.Y. (chairman); Fredrick F. Mellen, Jackson, Miss.; and John A. Taylor, Oklahoma City.

Depletion of mineral resources: Mineral policy must be based on a realistic assessment of the status of mineral reserves and mineral resources. The history of the use of minerals shows that the world is *not* running out of most usable mineral materials. Both the number of minerals used and the total mineral reserves have expanded enormously with technological change. In a real sense, technology creates mineral reserves. Traditionally, valuable ore deposits have been depleted first. However, technology has made it possible to recover low-quality ores (often those left behind in earlier mining) and to extract ore from former waste piles . . . how minerals are viewed and handled by society has far more influence on mineral availability than the actual amount in the ground or in the ocean. For virtually all countries, the total mineral reserves are less related to the quantity of minerals in the ground than to the state of technology and to the degree to which mineral production is encouraged or allowed by their government. For example, many of the less developed nations of the world have enormous mineral potential, but their sociologic processes are not conducive to mineral development for export. Moreover, their technology cannot use the minerals, so the deposits lie dormant.

Recommendations: The American Institute of Professional Geologists urges that:

1. Government policy should encourage the exploration for and development of domestic sources of mineral supply.
   a. Mineral materials contained on federal lands should be made more available to individual prospectors and to companies.
   b. Designation of federal lands as single-use wilderness, without adequate provision for development of mineral resources which they may contain, should be discontinued.
   c. All existing wilderness areas should be reviewed by Congress every 10 years to determine whether multiple uses would be more beneficial to the national interest.
   d. A model zoning ordinance that would encourage the development of mineral resources within a framework of sound environmental constraints should be drafted and its use throughout the United States be encouraged by the federal government.
   e. The federal government should work with state and local governments to develop a uniform and equitable form of financial compensation for communities that are adversely affected by mineral production, in some manner commensurate with the value of the minerals produced. This might take the form of tax relief or other benefits.
   f. The public-hearing process, which is often required before mineral deposits can be developed, should be revised so that the long-term interests of the whole nation are more clearly represented.
   g. Depletion allowances, rapid amortization, or similar tax incentives should be continued as mechanisms for encouraging the discovery and development of new reserves of mineral materials.
2. National policy should encourage those methods of mineral extraction that are environmentally acceptable and economically realistic.
   a. The concept of multiple land use for mineral lands should be encouraged.
   b. Improvement of mined land by sound reclamation practices should be encouraged by a favorable tax structure. These improvements should be taxed only after the reclaimed land has become economically productive.
   c. The production of such mineral materials as crushed stone and similar bulk products from underground should be encouraged, particularly where the underground space so created can be put to other uses once mining is completed.
   d. New methods of transporting processed mineral products should be studied to determine how minerals might be moved by techniques that are environmentally more acceptable than those in current use.
   e. National policy should dictate that costs of alleviating significant environmental problems created by mining activities should be borne by the producers creating such problems. However, the concept of 'environmental significance' needs to be reviewed.
3. Recycling of mineral-derived waste materials should be greatly encouraged.
   a. Research in this area should be vigorously pursued with adequate incentives, through tax relief or other means, to encourage private initiative.
   b. Recycling of waste materials should be encouraged by allowing freight rates that are similar to those available for production and shipment of virgin materials.
   c. Mechanisms for making waste recycling more acceptable to the communities in which it is done should be studied.
   d. A community compensation system such as that suggested in 1(e) above should be considered.
4. Stockpiling of essential mineral materials—including petroleum products—should continue or be expanded. However, stockpiles should not be used to the detriment of domestic mineral production.
5. A vigorous information program, by both public and private sectors, should be instituted to make people aware that mineral recovery properly done is a critical component of both environmental and resource conservation.
   a. National policy should encourage gathering specific quantified data about the economic, military,

environmental, and conservation importance of our mineral production, and disseminating it to the general public.

b. Our school systems should be encouraged to give adequate courses showing the interrelationship of mineral production, national defense, economics, environmental improvements and conservation, and the overall impact of our mineral materials on our standard of living.

6. All mineral-resource policy should be made consistently, within the framework of a mineral-resource conservation ethic that acknowledges the overriding importance of mineral policy to the future well-being of the United States.

   a. The federal government should sponsor and finance, as soon as possible, a conference for the purpose of defining a mineral-resource-management policy leading to a consistent rationale for the development of our minerals.

Copies of the full-length or condensed versions of the AIPG Statement may be obtained from AIPG Headquarters, P.O. Box 957, Golden, CO. 80401.

Geothermal Reconnaissance

During 1979, the Bureau of Geology and Mineral Technology's Geothermal Group conducted detailed exploration in the State of Arizona. This work was funded by the U.S. Department of Energy, Division of Geothermal Energy and the U.S. Department of the Interior, Water and Power Resources Service (formerly the Bureau of Reclamation). These programs complemented each other and were implemented in a manner to avoid duplication of effort. The areas of investigation were Yuma, Willcox, Safford-San Simon, Hyder, Harquahala-Tonopah, Big Sandy (Kingman), Verde Valley, Tucson, Springerville, Clifton-Morenci, San Francisco River and Williams Air Force Base.

The following are brief summary statements concerning the areas of investigation.

Yuma: Shallow to deep, sediment-filled basins created by extreme topographic relief in nearly-buried bedrock, and a deep sediment-filled structural trough that is part of the northwest-trending Salton Trough. The Yuma area possibly possesses a significant geothermal resource, on the basis of electrical surveys and favorable geologic features.

Willcox: The Willcox Palya area is a deep, Tertiary sedimentary basin formed by the down-dropping of a central graben with subsequent filling of the lower unit with sediments from the topographically higher surrounding blocks. Three anomalous areas were defined where temperatures of 150°C could be encountered at depths of 3km or less.

Safford-San Simon: Deep, sediment-filled Cenozoic structural basin (graben) with a probable granitic basement. Sediment fill is probably underlain by Mid-Tertiary volcanics interbedded with well-indurated continental sediments. A 180°C reservoir may exist at depths greater than 3 km. Permeability of the immediately-underlying rocks is unknown; however, favorable permeability of the target zone has been found to the north.

Hyder: The north to northwest-trending basin (graben) is filled with a mixture of fine to medium-grained clastics, sand lenses and conglomerates. Eighty-eight wells and springs are known to have surface discharge temperatures in excess of 30°C. Abnormal temperature gradients are observed, and temperatures in excess of 150°C could be encountered at depths of less than 2.5km, if the gradients hold.

Harquahala-Tonopah: The basins (graben structures) underlying the Harquahala Plain and Tonopah Desert are deep and filled with Tertiary continental deposits. One hundred twelve wells have recorded discharge temperatures in excess of 30°C. Four areas may have temperatures of 150°C at depths of 3km or less.

Big Sandy Area (Kingman): The graben structure basin is filled with a mixture of conglomerate, gravel, sand, silt and clay. At least 2,000 meters of sediments have accumulated in the northern part of the basin. Direct use temperatures are indicated by both well discharge temperature measurements and chemical geothermometers. Higher temperatures may be encountered in the deeper portions of the basin or along the basin-bounding faults.

Lower Verde Valley including Paradise Valley: A north trending graben containing more than 1,300 meters of semi-consolidated alluvium and Tertiary continental clastic sediments. Direct use temperatures of 90°C or less are indicated by chemical geothermometers.

Tucson: The Tucson basin, a complex graben, is filled with poorly consolidated to well-indurated Tertiary continental sediments. The basin is situated in an area of high regional heat flow, <2.0 HFU. Numerous shallow wells less than 300 meters deep encounter water ranging from 28°C to 40°C. Hot water, 50°C to 100°C, is probably within drilling depths of 762 to 1,524 meters in areas with anomalous subsurface temperature gradients. Temperatures of 150°C may be expected to depths of 3km.

Northern Hassayampa Plain: The northern Hassayampa Plain is a broad, sediment filled basin with a complex, faulted basement. The three distinct structural trends (NE, NNW and NW) identified from air photo interpretation, Landsat lineaments, and geochemical trends are interpreted as fault traces. The measured geothermal gradients define a single discrete area of hydrologic discharge that is about $30km^2$ and can best be explained as being fault controlled. The maximum reported water temperature is 53°C from a well with an anomalous chemical analysis and a geothermal gradient of 140°C/km.

Springerville: Geologically, the Springerville area is comprised of relatively flat-lying sedimentary rocks of Tertiary to Paleozoic age overlying granitic basement rocks. The sedimentary rocks are only locally exposed, being covered by extrusive igneous rocks of the White Mountain volcanic field dated 32 m.y. to about 10,000 years ago. Geochemical evidence, that is, locally anomalous silica concentrations in the groundwater indicative of high heat flow, supports the probability of a geothermal resource in the Springerville area. Geophysical evidence in the form of measured heat flow of 115 mWm^{-2} (above the Colorado Plateau average of 49 mWm^{-2}), as well as a zone of low resistivity and anomalous gravity and magnetic lows further support the probability of a geothermal resource. The conclusion drawn to date is that a geothermal resource of uncertain magnitude exists in the Springerville area.

Clifton-Morenci: Numerous hot springs discharging sodium chloride water occur in two different geologic settings in the Clifton area. Gillard Hot Springs, with temperatures to 82°C, occur along the Gila River south of Clifton at the northwestern end of the sediment-filled Duncan Basin. Clifton Hot Springs, with temperatures to 66°C, discharge from numerous seeps and springs along a two mile zone in the thin fluvial sediment filling the bottom of the San Francisco River canyon, which is cut through mid-Tertiary volcanic rocks, Paleozoic clastic and carbonate rocks and Precambrian granitic rocks. Geothermometer temperatures range up to 180°C for both silica and Na-K-Ca calculation when mixing models are applied. Gravity data shows a closed low anomaly in the Duncan basin. Several magnetic lows, excluding the ore deposits, may be the result of hydrothermal alteration associated with a geothermal reservoir. Available geologic, geochemical and geophysical data point toward a high temperature geothermal resource.

San Francisco River: Physiographically, the San Francisco River between Clifton, Arizona and Pleasanton, New Mexico, lies in the transition zone between the Colorado Plateau and the Basin and Range Province. The river cuts through a sequence of nearly flat-lying Tertiary volcanics and does not expose pre-Tertiary rocks except immediately north of Clifton. The purpose of this study is to provide timely information on the geothermal resource potential on this segment of the San Francisco River which is a proposed Wild and Scenic River and Wilderness Area. The results of this reconnaissance study and of previous studies at Clifton Hot Springs, Arizona, and the lower San Francisco Hot Springs, New Mexico, show very high potential for significant geothermal energy resources in this area.

Williams Air Force Base: Williams AFB is situated in the southwestern half of the Higley basin, a small northwest trending basin approximately 30 miles long and 15 miles wide. The straitigraphic sequence beneath the present valley surface is divided into two parts: an upper basin fill section and a lower pre-basin volcanic section. Geothermal Kinetics, Inc. has drilled two wells just southwest of the base, the deepest being 3,186m. Temperature data from these wells indicate temperatures in excess of 100°C below depths of 2,134 meters and temperatures in excess of 150°C below 2,743 meters. The reservoir would be in the volcanic rock in fracture zones and porous pyroclastic zones. Whether the reservoir will sustain production is not known. The geothermal energy potential is excellent.

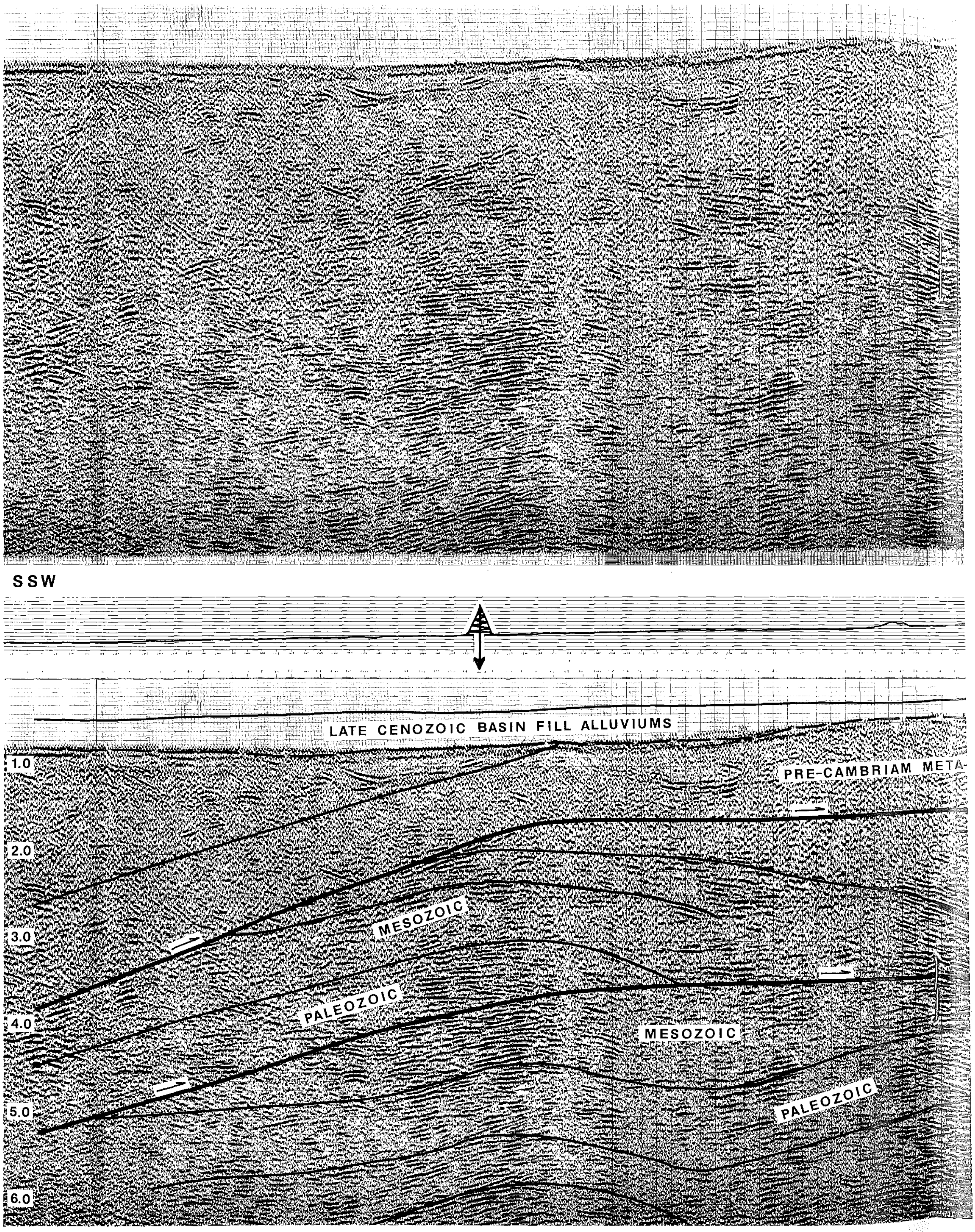
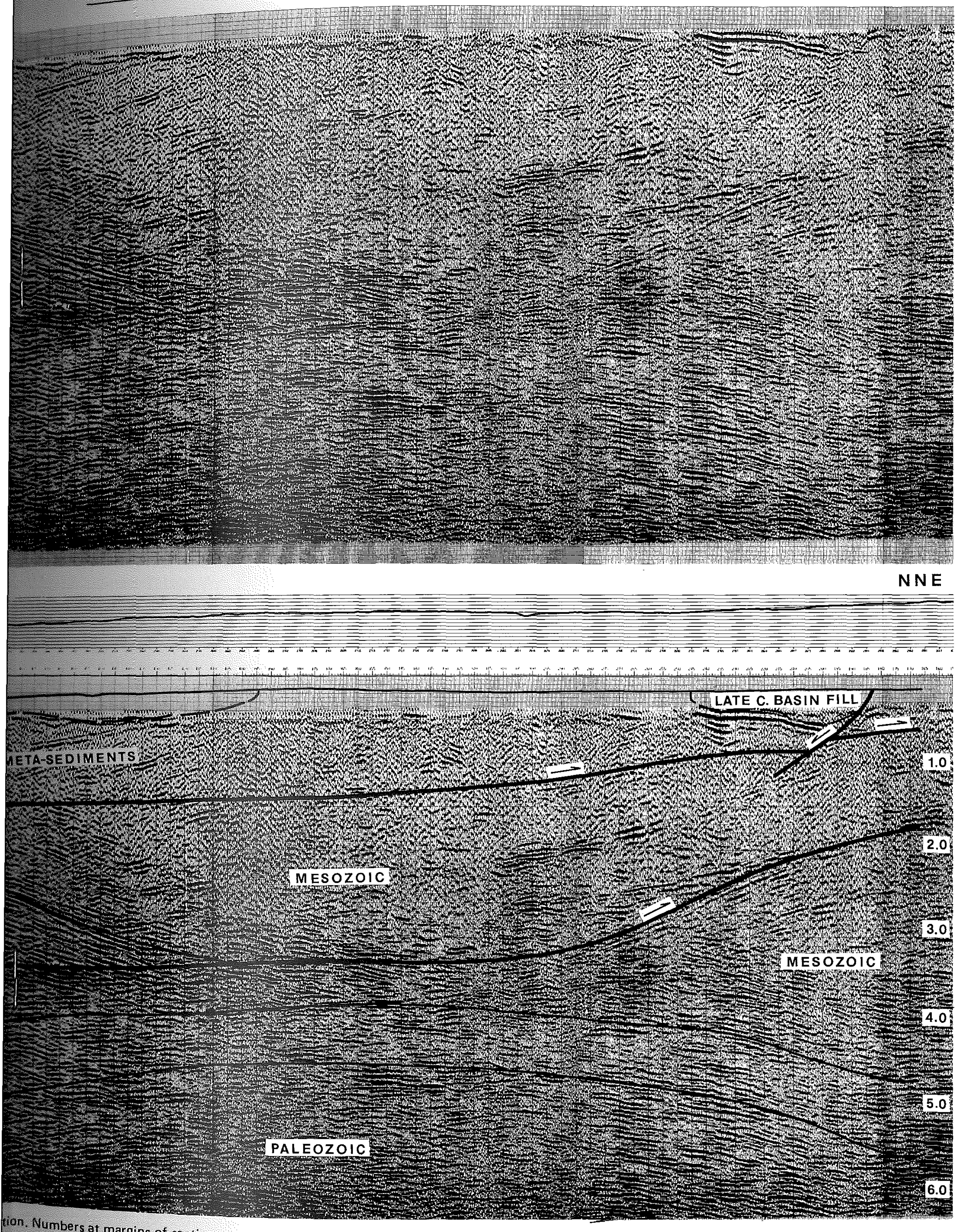


Figure 2: AZ 18 seismic time cross section. Upper panel is uninterpreted "raw data". Lower panel is Anschutz interpretation. Nu
Seismic data courtesy of Pacific West Exploration Company, Denver, Colorado.



tion. Numbers at margins of sections represent time in seconds. Anschutz-Texoma drillhole has been projected on to the section.

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Oil & Gas continued

sedimentary rocks occur beneath an upper plate of Pre-Cambrian age metasedimentary rocks which are represented by an area that contains few seismic reflectors in the upper third of the seismic section. For Anschutz, all of the Precambrian crystalline rocks shown on the geologic map in figure 1 are part of the upper plate. Anschutz would also suggest that the late Cretaceous-early Tertiary igneous rocks are part of the upper plate. Further, this entire upper plate package of crystalline rocks has been transported to the central portion of Pinal County from an original position some 60 to 120 miles to the SW, according to Anschutz. In a broad sense, then, many of the southern Arizona Laramide porphyry copper deposits which have yielded the great proportion of Arizona's copper production are, for Anschutz, structurally rootless.

Anschutz has located the Anschutz-Texoma wildcat well near the hinge of a broad arch-like seismic structure, toward the left of Figure 3a. The model is based on the assumption (similar to the Utah-Wyoming presumed analog), that petroleum condensate might have migrated to structural traps in this arch from possible source regions in nearby Mesozoic and Paleozoic sediments buried underneath the thrust. Anschutz expects to drill through a veneer of about 3,000 feet of late Cenozoic valley fill sedimentary rock 0 to 15 m.y. old, penetrate Precambrian metasedimentary rocks in the upper plate, and encounter potential petroleum resources at 8 to 10,000 feet in structural traps near the hinge of the arch-like structure. In oil industry parlance, Anschutz is hoping to encounter the top of a petroleum column or pay zone at depths of 8 to 10,000 feet.

The seismic work commissioned by Anschutz et al during the great southwestern Arizona oil and gas play has excited the imagination of every geologist-geophysicist who has seen the data. Naturally, the data have provoked interpretations other than the Anschutz model previously outlined. Some would suggest that the prominent seismic reflectors represent buried, layered crystalline gneisses of the kind found in the forerange of the Santa Catalina Mountains, in canyons like Sabino Canyon. The conventional view would be that the seismic reflectors mirror slight changes in seismic velocities and densities of an otherwise entirely Precambrian crystalline basement, like the one exposed at the surface in central Pinal County. An outrageous speculation tossed in with a big grain of salt by myself is that the seismic reflectors represent sedimentary rocks of Franciscan vintage normally present along the western coast of California. The proposition is that these rocks have been shoved some 300 miles eastward underneath Arizona's Precambrian crust (underthrust rather than overthrust from the southwest) during low-angle subduction beneath North America 55 to 45 million years ago. In any case, discovery of the enigmatic reflectors represents a totally new, unexpected and provocative twist for Arizona-based geologists. The reflected anomalies may mean petroleum. They may not. But Anschutz should be credited for its determination to take a crack at what they do mean.

In closing, it is interesting to note that one of the deepest of the few wildcat oil tests in southern Arizona was drilled in 1953, eight miles northwest of the Anschutz-Texoma site. It is said that the well was promoted after a Texas oilman's wife's arthritis flared-up when the couple were driving through Pinal County, like it had when she was near several producing well fields in Texas. Western Oil Fields #1 Federal bottomed at 5,142 feet in what was interpreted to be a dry Precambrian granite. Wouldn't it be something if they didn't drill deep enough. We can't wait to find out.

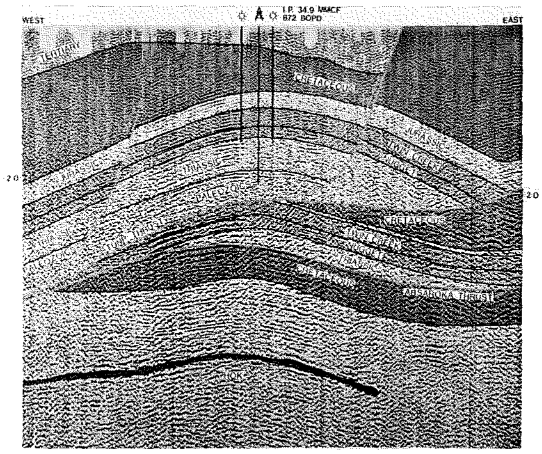

Figure 3: Seismic time cross section through Anschutz Ranch Field, North Pineview area, Wyoming.

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THE WILLCOX "OIL FIELD"

By Edgar B. Heylmun

The Southern Pacific Railroad drilled a 650-foot water well across the tracks from the Willcox depot in the late 1800's. The well produced clear, cool water until the 1920's, when the well started to produce 42.3° A.P.I. (American Petroleum Institute) high gravity, low-sulfur oil along with water. The ice plant water well, two blocks to the north, also started to produce oil, and a portion of the town's water supply became contaminated with oil. Fourteen hand-dug postholes in the chicken yard of the Lundquist residence, near the railroad, produced over 10,000 gallons of oil, and several additional wells drilled within two or three blocks of the Southern Pacific well encountered oil. The U.S. Bureau of Mines tested the oil in 1937 and reported it to be "natural crude".

Several hundred barrels of high-gravity oil were produced from the Willcox "oil field" in the 1920's and 1930's, and were sold locally, unprocessed, for 10-12 cents a gallon, for use in stoves, lanterns, farm machinery, and even in automobiles. The occurrence of oil in the town of Willcox brought on a flurry of promotional activity by speculators, and a number of wells were drilled for oil and gas in southeastern Arizona between 1930 and 1963. Some of the reported oil and gas shows were probably legitimate, but a number of the reported oil shows cannot be confirmed by a study of well-cuttings kept on file by the State of Arizona.

How can the "oil field" at Willcox be explained? Did an oil field suddenly migrate into the area and cause high-gravity oil to seep into wells that had been producing clear, clean water? The writer went to Willcox to get at the heart of the matter. Old records and town plats were examined and longtime residents were quizzed. The answer to the problem appears to be obvious. Following World War I, storage tanks for oil were constructed along the railroad. Some of the tanks were masonry cisterns which apparently leaked like a sieve, and some of the underground piping also leaked. In the late 1930's, the storage tanks were replaced. Upon replacement of the tanks, all *oil production* ceased within a few weeks. There appears to be little question that the oil was leaking from the storage tanks and entering the groundwater system, affecting an area of six to eight blocks in downtown Willcox. The Willcox oil was not "natural crude," and the mystery of the Willcox oil field appears to have been solved. This is not to say, though, that good, bona fide oil and gas possibilities do not exist in parts of southeastern Arizona.

NATIONAL/REGIONAL EVENTS

The Bureau of Geology welcomes announcements from the community on geologically-related activities, especially pertinent to the western United States. Listed below are some of the conferences, conventions, exhibits, meetings and symposia scheduled during 1980.

Geological Society of America—Annual Meetings:
Cordilleran Section, Corvallis, Or., March 19-21, 1980
Rocky Mountain Section, Ogden, Ut., May 16-17, 1980

Geology of Rocky Mountain Coal-Symposium and Field Trip: **School of Mines Research Institute**, Golden, Co., April 28-29, 1980

American Association of Petroleum Geologists and Society of Economic Paleontologists and Mineralogists—Annual Meeting, Denver, Co., June 8-11, 1980

Society of Economic Paleontologists and Mineralogists—Special Research Conference, Wisconsin, August 11-16, 1980

Wyoming Geological Association—Annual Meeting and Field Trip, Teton Village, Wy., September 6-10, 1980

American Mining Congress Mining Convention, San Francisco, September 21-24, 1980

Geological Society of America and associated societies—Annual Meeting, Atlanta, Ga., November 17-20, 1980

LOCAL EVENTS

The eighth annual Geoscience Daze, organized by the graduate students of the **Department of Geosciences at the University of Arizona,** will be held on March 5-7, 1980. The presentation of 42 papers will take place at 1:00 p.m. on Wednesday, March 5, and at 9:00 a.m. on Thursday and Friday. These sessions will be conducted in the Senior Ballroom of the Student Union on the U of A campus.

Geoscience Daze is a unique opportunity for faculty, students and those sharing an interest in current research. Graduate and undergraduate students will be presenting results of research undertaken for graduate degrees or independent studies.

Here is a brief preview of the topics: Two papers on geophysics will deal with stress measurements along the San Andreas fault and the residual seismic activity following the 1887 Sonoran earthquake. A late Pleistocene mastodon in southeastern Arizona will be a dominant paleontological topic. Talks on structure and tectonics will include a study of the Klamath Mountains in California and Oregon, and a structural and petrologic analysis of a pematite-quartzite tectonite in the Coyote Mountains of Arizona. Reports on economic geology will cover a massive sulfide deposit in Alaska, mineralization at Mineral Park and Tungsten distribution in limestone contact environments.

A photographic slide exhibition and competition on geologic phenomena will be held on Friday, March 7 at 4:30 p.m. The Evans B. Mayo Undergraduate Award for Outstanding Performance in Field Geology and awards for the Geoscience Daze presentations will be given following the slides.

A field trip to the Silver Bell Mine, northwest of Tucson, will be conducted on Saturday, March 8. Details will be discussed during the conference.

If you would like to attend or obtain further information, please contact Marie Slezak at the Department of Geosciences, U of A.

A chapter of the **Association of Women Geoscientists** has been established to provide a forum for career advancement and communication among women professionals in Tucson. The AWG is affiliated with the national organization based in San Francisco. Meetings will be held monthly and will be announced in **Gaea,** AWG's periodic newsletter. Additional information may be obtained by contacting Jan Wilt, 3035 S. Shiela Ave., Tucson, Az. 85706 (883-6669) or Susan DuBois at the Arizona Bureau of Geology, 845 N. Park Ave., Tucson 85719 (626-2733).

Just a reminder. The **Arizona Geological Society** is soliciting manuscripts on Arizona geology for its 13th Digest, to be published in the fall (1980). Papers must be in by March 15, 1980.

MINING EXHIBIT SPANS FOUR CENTURIES

Photo: Ken Matesich

More than $12 billion in ore has been mined since 1860.

The Arizona Historical Society's *Mining Hall* is billed as the largest, most comprehensive mining exhibit in the southwest. Opened in November 1979 after eight years of research and planning, the million dollar exhibit contains authentic artifacts—tools, machinery, mineral products and household paraphernalia—all dating from the turn of the century. Virtually all mining materials and equipment in the exhibit were at one time in operation at Arizona mines and/or were donated by mining companies.

A mine tunnel, typical of southwestern mines in the early 1900's, leads visitors along an 85-foot-shored tunnel, with savvy dialog provided by lifesize figures of miners. The tunnel, which illustrates underground mining techniques, ends at a simulated concentrating plant, with an immense two-story stamp mill and other milling equipment.

A mining *town*, composed of a reassembled blacksmith shed, an assayer's office and a prospector's makeshift wood and canvas cabin, has been recreated.

Photographs, murals and displays express the miners' evolving lifestyles, providing a visual history of mines and miners, and the growth of their boom towns, cities and laws.

Dioramas depict mining practices of the earliest miners—the Spanish, Mexicans and Indians—at the shallow ore deposits discovered in the 1540's.

Handheld receivers with taped messages give supportive interpretation at strategic points of the entire exhibit. Visitors concur that the exhibit succeeds in expressing its overall theme that Arizona's development as a territory and state has been inextricably tied to the economic and social consequences of its mines.

NATIONAL GSA MEETING
bureau contributes

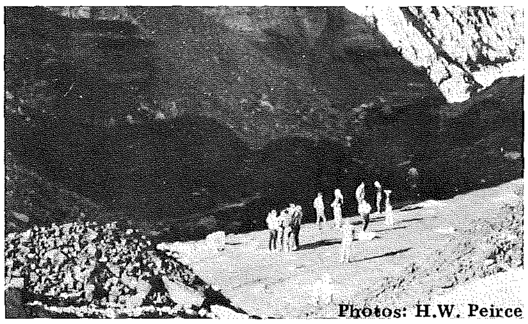
by H. Wesley Peirce

The 92nd annual meeting of the Geological Society of America was held November 5-8, 1979 in San Diego, CA. Personnel from the Geological Survey Branch were involved in the presentation of three scientific papers, one poster session, and the organization and conduct of a pre-meeting field trip in Arizona. Following is a brief summary of these activities.

BLACK MESA FIELD TRIP

Several pre-meeting GSA field trips were offered in various parts of the southwestern U.S. The Coal Geology Division of the Geological Society of America engaged the volunteer services of H. Wesley Peirce of the Bureau to set up and lead a field trip to include Arizona's remote Black Mesa coal-mining operations. Wes, with the aid of his wife, Maxine, assembled a guidebook with over 300 miles of road logs.

One bus load of participants, representing 13 states and Canada, left Phoenix in the early morn of November 3, 1979.



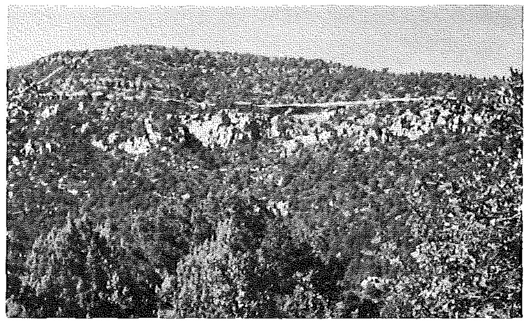
Photos: H.W. Peirce

Figure 1, *Black Mesa:* Explaining a coal seam on Black Mesa.

After traversing the Transition Zone and ascending onto the Plateau, we stopped for refreshments at the Museum of Northern Arizona, Flagstaff. Here we picked up Bill Breed, head of the Museum's geology department, who joined me as co-trip leader. From the piney woods of Flagstaff we descended to lower slopes of the San Francisco Mountains edifice and the fascinating wide-open, austere country of the Navajo Indian Reservation. An occasional windmill marked the few and far between sources of one of nature's most important geologically controlled fluids – water. Over much of the Reservation the geological link to life is the 160 million-year old Navajo Sandstone which underlies the surface and contains groundwater that can be tapped by wells. This formation also forms the Great White Throne in Utah's Zion National Park and the walls of Glen Canyon near Page, Arizona.

After stopping for a box lunch beside topographic features known as the Elephant's Feet, we ascended the north edge of Black Mesa. On Black Mesa, Gardar G. Dahl, Jr., of the Peabody Coal Company, discussed both coal geology and exploitation reclamation practices and procedures. By coincidence, we watched a crop duster plane spray grass seeds onto a large segment of recontoured and otherwise prepared land that previously had been mined out. The company let us explore and "pound" on a coal seam (Fig. 1).

Black Mesa coal is used almost exclusively to fuel two electrical generating plants. The Mohave plant is located on the Nevada side of the Colorado River near Bullhead City, Az, and the Navajo plant is near Page, Az. Transport to the Mohave plant is by a 273-mile slurry pipeline, the only pipeline of its kind in the U.S. Mr. Paul V. Flindt of the Black Mesa Pipeline kindly showed us the coal handling and preparation facilities at the pipeline.



AGS Trip: Diamond Rim. Prominent ledge is sandstone at the base of the Paleozoic System above Precambrian granitic rocks.

After a pleasant repast and evening at Page, we started off the morning of Nov. 4 with a visit to Glen Canyon Dam and Lake Powell. Mr. Jewel Beckwith of the Bureau of Reclamation graciously showed us the inner workings. He told us that the dam is operated remotely from Colorado, although a couple of men are always on duty in the control room should anything unusual arise. The cold water emitting from the dam supports one of the best rainbow trout fisheries in the U.S. Bill Breed told us about environmental changes down stream in the Grand Canyon caused by the present control of flood waters upstream (riparian takeover).

AGS Trip: Annan Cook explains scintillator.

Following a box lunch on the shores of Lake Powell, we toured the grounds of the Navajo generating station near Page. This is the other plant fueled by Black Mesa coal. Here, coal is hauled by an automated electric railroad (a man is aboard just in case a Navajo sheep strays onto the tracks!). Mr. Jerry Jones of the Salt River Project, capably led us around the facility and answered our numerous questions.

Later that afternoon we headed for the Page airport where

AGS Trip: Dog oversees search for plant fossils at Promontory Butte uranium prospect.

most of us boarded one of six small crafts that flew us back to Phoenix. We flew right by the beautiful snowcapped San Francisco Peaks and close to the route that we had traversed the day before by bus. All arrived in Phoenix safely and, hopefully, satisfied.

AGS FALL FIELD TRIP

About forty hardy souls gathered in Payson, Arizona early on November 17, 1979. The Arizona Geological Society Fall Field Trip was devoted to geologic aspects of the famous central portion of the Mogollon Rim. The trip, led by Bureau geologist Wes Peirce, included stops to: (1) discuss the origin of the Mogollon Rim, (2) pick up clear quartz crystals near the Diamond Rim, (3) examine features, including plant fossils, associated with the Promontory Butte uranium prospect and (4) observe the relationship between modern canyon cutting and the older Mogollon Rim that in places remains buried beneath thick sequences of lava flows, most notably at Fossil Creek Canyon.

It was indeed a pleasure to have geology student representation from both Northern Arizona University (Flagstaff) and Arizona State University (Tempe), as well as the University of Arizona.

THE 1887 SONORAN EARTHQUAKE

Susan M. DuBois, in collaboration with Marc Sbar of the University of Arizona, Geosciences Department, presented a stimulating and pertinent talk on *The Northern Sonoran Earthquake of 1887: Hazard Implications for Arizona.*

The 1887 earthquake (estimated magnitude, 7.2), originated in the San Bernardino Valley, south of the Arizona-Mexico border, and was felt throughout most of Arizona, with major damage occurring in the southeastern part of the state.

The principal message of Susan's presentation is that Arizona's large population centers, notably Phoenix and Tucson, would be significantly vulnerable should a similar seismic event recur in the same place. As a consequence, it seems obvious that the State of Arizona has a legitimate, practical interest in the geologic nature of this close, but isolated region south of the border. If the 1887 epicenter does indeed fall in a continuous zone of seismicity trending NW across Arizona, then it is possible that a magnitude 7 earthquake could occur further north.

With the aid of grants from the U.S. Geological Survey and the Nuclear Regulatory Commission, Susan is continuing research that promises to lead to a better understanding of Arizona seismicity than presently exists. She is also currently preparing a Bureau publication on the 1887 seismic event.

CENOZOIC SEDIMENTS AND STRUCTURE

Robert B. Scarborough, in collaboration with M. Shafiqullah of the Geosciences Department, University of Arizona, presented selected preliminary results of a recent geologic study done under a grant from the U.S. Geological Survey. The original 101-page report, relating to uranium favorability of pre-basin fill Cenozoic sediments in the Basin and Range Province of Arizona, is available from the Bureau as open file report #79-1429. Twenty-five new K-Ar age determinations on volcanic rocks provide a valuable tool with which to begin to organize widely scattered outcrops of variously, but systematically deformed Cenozoic sedimentary materials that are preserved in many of the range blocks of the Basin and Range Province.

Three broadly defined "stratotectonic" groups are recognized on the basis of age, sedimentology, and degree of deformation: (1) deformed pre-22 m.y. (million years) Oligocene redbeds, megabreccias and varicolored shales and mudstones, (2) less deformed early to mid-Miocene redbeds and tuffaceous stream and lake deposits with silicic to intermediate volcanic rocks and (3) least deformed late-Miocene and younger basin-fill. Hopefully, these new data eventually will be more thoroughly synthesized and the results published.

PLATE TECTONICS AND METAL DEPOSITS

Stanley B. Keith delivered a provocative paper entitled, *Possible Magmatic and Metallogenic Products of 120 m.y. to 10 m.y. Subduction in Southwestern North America.* Stan has developed an empirical explanation, reflected in this title, for the general distribution of types (chemistries) of igneous rocks (granitic and volcanic) and their associated metals. After accumulating, organizing and plotting massive amounts of published data about the chemistry, age and position of mineralized igneous rocks, he recognizes systematic regional patterns that beg for explanation. The large scale of occurrence patterns quite naturally requires a commensurate genetic process.

Stan finds a satisfying plate tectonics-related explanation in the process known as "subduction." In this case, subduction alludes to the "diving" or underthrusting of the Pacific oceanic plate beneath the overriding North American continental plate. Deep seated processes led to magma generation and, when the plumbing system of fractures permitted it, magma and associated products (metals) escaped upward into the continental plate. Stan believes that with time the subducting slab angle changed, which, in turn, caused a change in the location of igneous activity in the continental marginal zone. Furthermore, he sees an affinity of certain metal ratios for certain igneous rock chemistries. Because the position of igneous activity varied with time, so did the position of associated metal deposit types.

Arizona has an unusual concentration of copper. Stan would suggest that the explanation for this is to be found in being in the right place at the right time regarding processes related to a subducting Pacific plate.

POPULAR POSTER SESSION

Stanley B. Keith and William R. Dickinson of the U of A Department of Geosciences, enthusiastically conspired to conduct a poster session that was notable for the long line of people emanating therefrom. The formal title of the session, *Transition From Subduction to Transform Tectonics in Southwestern North America (22-8 M.Y.B.P.),* might be intimidating to some. This is the language of plate tectonics and seems destined to be with us for a while.

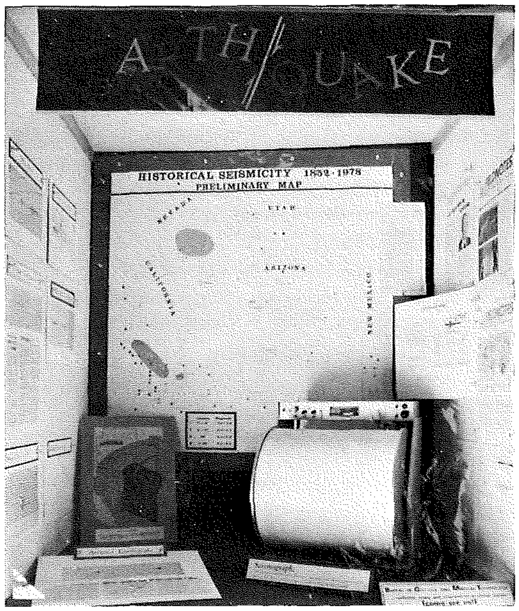
As indicated in Stan's paper, subduction results when two plates butt heads and the loser (Pacific Plate) is pushed under the winner (Continental Plate). However, this is not the process that is going on today along the coast of the southwestern U.S. Instead of colliding, the plates are now sliding by each other along a steep fault (the San Andreas), a so-called transform fault. Obviously, there has been a fundamental change in the plate boundary condition. As a consequence, processes have changed which, in turn, have led to unique and contrasting geologic results.

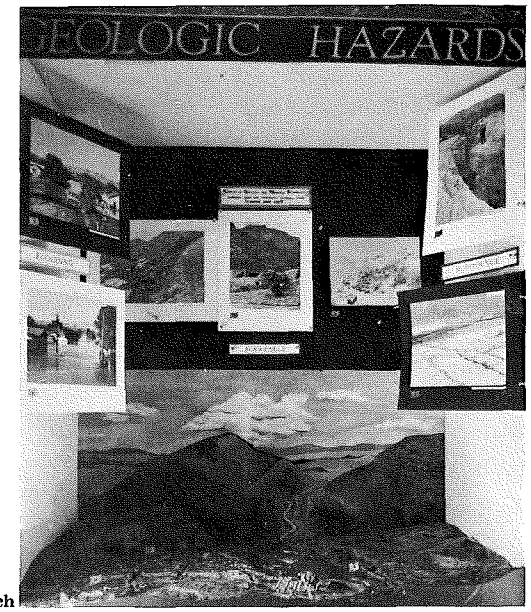
ASBESTOS

Arizona asbestos has recently been projected into the national news. The subject under discussion is a trailer park in Globe, Arizona, that occupies land adjacent to an abandoned asbestos mill. Here, a technical, mineralogical matter has been drawn into the political arena. Questions of relative health risk and alternative courses of action have been asked. Respondents represent high levels of technical authority in the U.S. Some say that "asbestos" is bad, while others discriminate between the various mineral species embraced by the nontechnical term, "asbestos".

Arizona asbestos is chrysotile. Indeed, only the chrysotile variety is mined and milled in North America. In future issues of *Fieldnotes,* we plan to report on significant developments in the asbestos controversy.

Bureau Displays Model and Map





Photos: Ken Matesich

Two new displays have been placed in the Bureau's windows facing Park Avenue.

A *Seismograph Recorder* has been operating at the Bureau since November 1979; it steadily records seismic and/or atmospheric disturbances on a roll of glossy paper. Each 24-hour sheet (seismogram) registers time by minute and hourly intervals. Finely-inked, notched lines travel the length of the sheet every 7½ minutes.

Seismograms, patterns (graphic signatures) of various recorded events, are illustrated so the viewer may compare a mine blast, a nuclear test blast, a sonic boom, a distant earthquake (Columbia), an earthquake in California and an earthquake occurring in Arizona.

An *Historical Seismicity Map* (preliminary) on Arizona serves as a backdrop for this display, pinpointing earthquake epicenters from 1850 to 1978, with accompanying intensity or magnitude.

Another window exhibits a model landscape representing some of the geologic hazards found in many southwestern communities. These hazards are directly related to the way we live — our shelter, food and water supply, transportation — and include the following: Water runoff (urban floodplain development and flash flooding in arroyos); diversion of water supply (dams); river bank erosion; mass movement along unstable slopes (rockfalls, rockslides, slumping); alteration on and below the land surface (subsidence, faults, earthcracks); and damage to materials and property (walls, foundations and buildings, roads and bridges).

Photographs surrounding the model illustrate some of the hazards present in urban and rural areas of Arizona.

New Publication

A Special Paper entitled, *The 1887 Earthquake in San Bernardino Valley, Sonora: Historical Accounts and Intensity Patterns in Arizona*, authored by Susan M. DuBois and Ann W. Smith, is currently in press. This publication will be available for purchase in March 1980.

Fieldnotes

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