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ARIZONA GEOLOGICAL SURVEY

THE STATE AGENCY FOR GEOLOGIC INFORMATION

MISSION

To collect and archive information about the geologic character, processes, hazards, and mineral and energy resources of Arizona and to inform, advise, and assist the public in order to foster understanding and prudent development of the State's land, water, mineral, and energy resources.

GOALS

- Increase understanding of the geology of areas with potential population growth and economic develoment
- Improve effectiveness of administering Arizona's oil and gas statutes
- Expand the customer base of the Arizona Geological Survey
- Improve access to digital geologic information to all users

Arsenic in Ground Water

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Introduction

Arsenic is a naturally occurring chemical element in rock and soil and is present in trace amounts in ground water. Arsenic in drinking water is known to cause cancer in people if concentrations are above about 300 ppb (parts per billion). Extrapolation from exposures at these relatively high levels to low arsenic levels of 5 to 50 ppb, characteristic of U.S. groundwater in many areas, suggests to officials of the U.S. Environmental Protection Agency (EPA) that U.S. citizens are experiencing adverse health effects due to arsenic ingestion. The EPA recently proposed lowering the maximum allowable arsenic concentration in U.S. drinking water from 50 ppb to 5 ppb. Water from almost half of the 809 Arizona wells included in the U.S. Geological Survey's National Water Quality Assessment Program database exceeds 5 ppb arsenic (Figure 1). Furthermore, 247 of these 809 wells are used for drinking water, and almost half of these wells exceed 5 ppb arsenic (Figure 2). Continued use of many Arizona wells for drinking water will require implementation of expensive remediation technology if the maximum allowable arsenic concentration is reduced as proposed.

Arsenic as a poison

The toxicity of arsenic has been known at least since medieval times when smelting of arsenic-bearing sulfide minerals produced arsenic trioxide powder that

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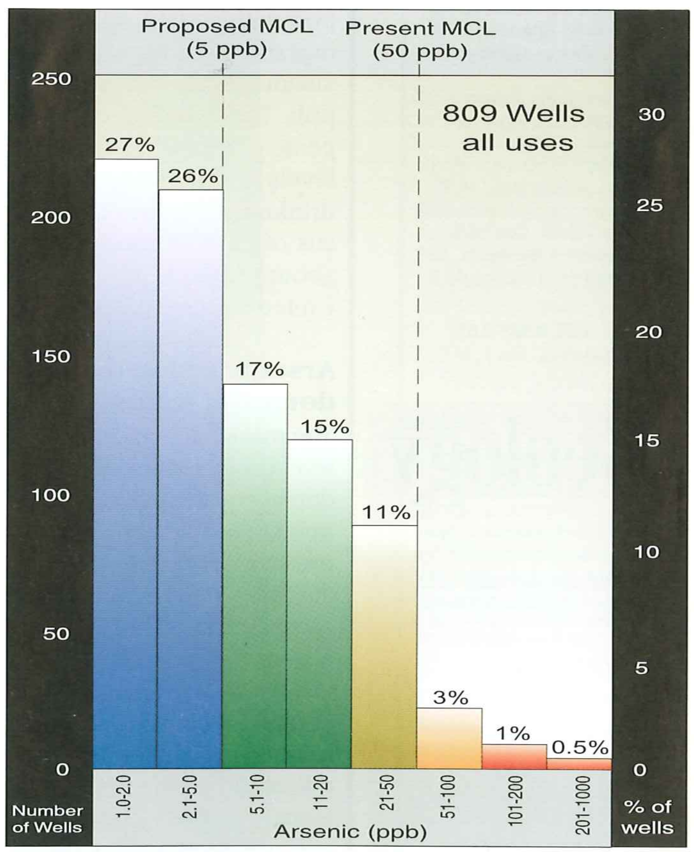

Figure 1. Arsenic levels in Arizona well water from 809 Arizona wells. MCL: maxium contaminant level. Data from U.S. Geological Survey National Water Information System (obtained from http://co.water.usgs.gov/trace/data/arsenic_may2000.txt).

Arsenic *(continued from page 1)*

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was identified and collected around primitive smelters. Arsenic trioxide is tasteless, odorless, and highly lethal. Arsenic trioxide poisoning became such a common method of homicide in central Europe in the fourteenth and fifteenth centuries that laws were passed specifically against such use.

Modern studies have established that ingestion of trace amounts of arsenic results in increased risk of skin, bladder, lung, kidney, and liver cancer, and possibly other cancers as well. Most of the studies that identified these associations were done in Taiwan where the affected populations had routinely ingested well water with arsenic levels above 300 ppb. The possible carcinogenic effects of arsenic at levels of 5 to 50 ppb in drinking water are the focus of current concerns about public health in the United States.

Arsenic regulation in domestic water

The maximum contaminant level (MCL) for arsenic in U.S. drinking water was set at 50 ppb in 1942. Based on new research, and prompted by the Safe Drinking Water Act Amendments of 1996, the EPA proposed in May 2000 that the MCL for arsenic in drinking water should be lowered to 5 ppb. A final rule must be promulgated by January 1, 2001. An MCL of 5 ppb will affect many wells in Arizona (Figures 1, 2, and 3) and expensive remediation techniques will be required to

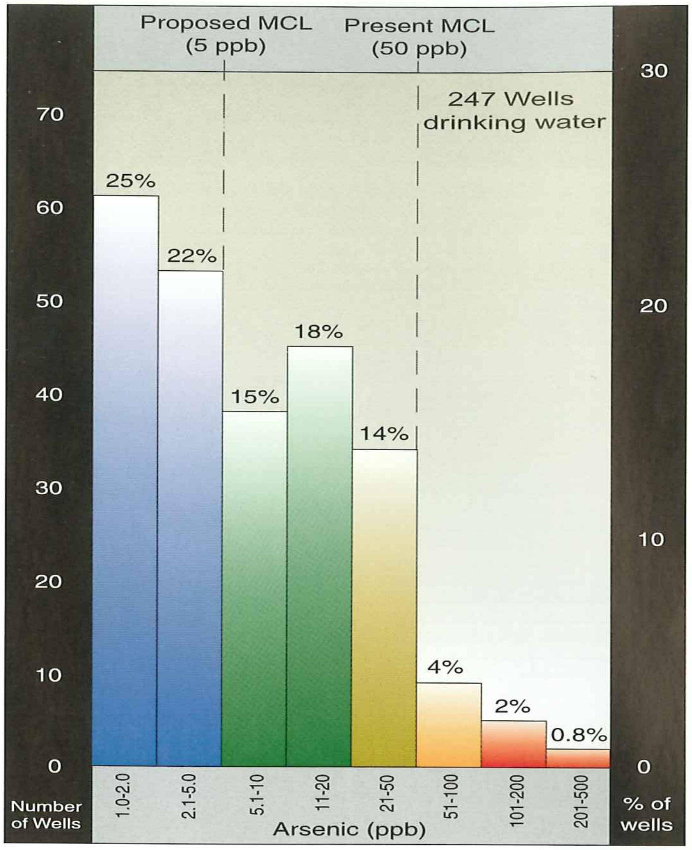


Figure 2. Histogram of arsenic levels in 247 Arizona wells that are used for drinking water. MCL: maxium contaminant level. Data from U.S. Geological Survey National Water Information System (obtained from http://co.water.usgs.gov/trace/data/arsenic_may2000.txt).

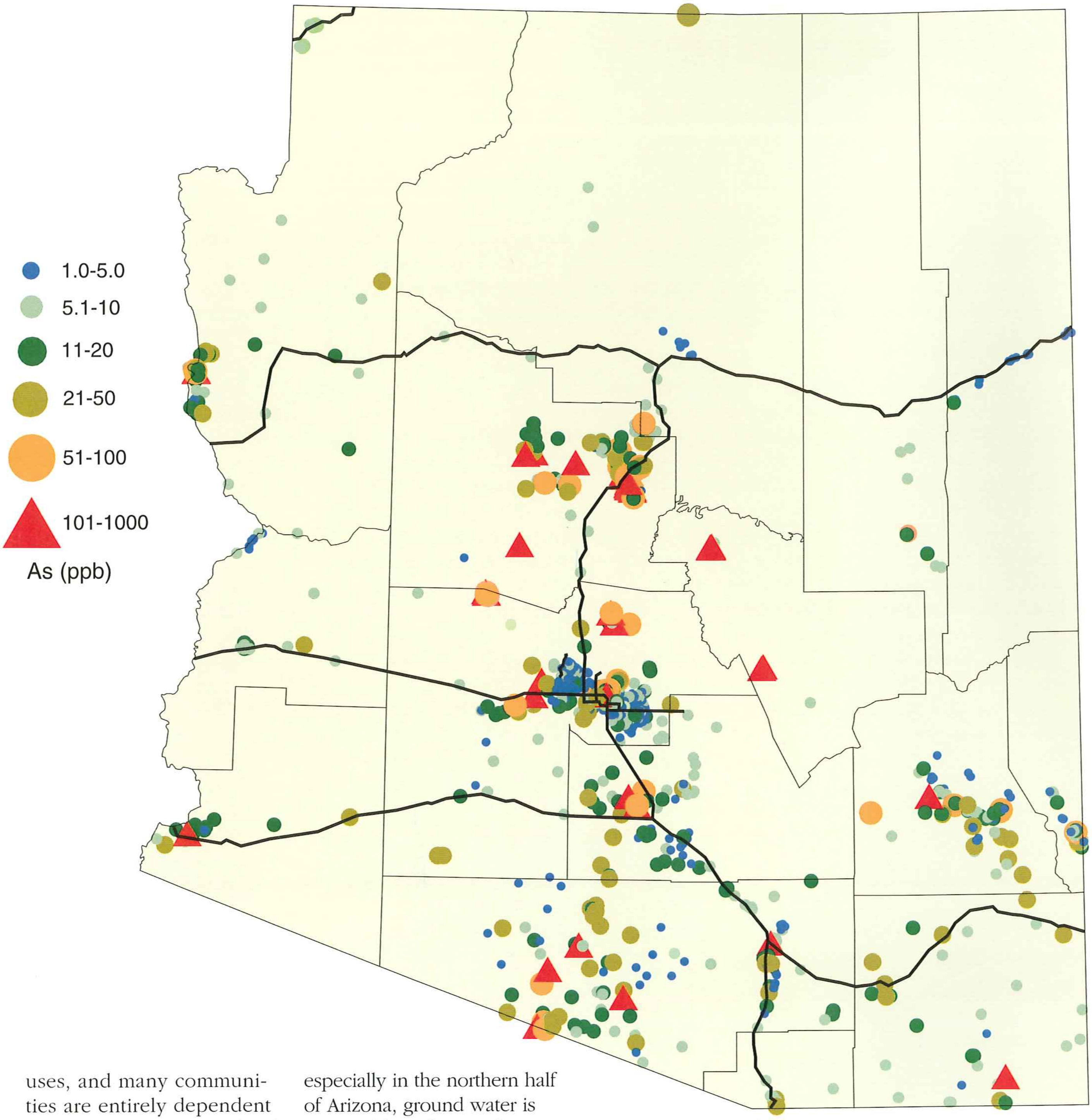
reduce arsenic levels in drinking water. Some wells will probably be closed.

Where does arsenic come from?

The average concentration of arsenic in the Earth's crust is about two parts per million by weight. In detail, however, concentrations in rock and soil are highly variable. Arsenic concentrations are highest in areas of hydrothermal sulfide mineralization where arsenic is concentrated in sulfide minerals. Arsenic is a major constituent of minerals such as arsenopyrite (FeAsS), realgar (AsS), orpiment (As_2S_3), and the copper minerals enargite (Cu_3AsS_4) and tennantite ($Cu_{12}As_4S_{13}$), and is a minor component of other sulfide minerals. The abundant, naturally occurring sulfide mineral deposits in Arizona may be a significant natural source of arsenic in basin-filling sediments. Arsenic is also present at very low concentrations in virtually all rock and soil and it is possibly this arsenic that is the dominant source of arsenic in ground water.

Arsenic in water

Nearly all communities in Arizona extract ground water for domestic water



uses, and many communities are entirely dependent on ground water. Much of southern Arizona is underlain by thick deposits of basin-filling sand and gravel that form large aquifers containing enormous quantities of high quality ground water. In other communities, especially in the northern half of Arizona, ground water is pumped from fractured or porous bedrock.

Arizona ground water generally contains arsenic in concentrations of 1 to 50 ppb. It is not well understood, however, where this

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Figure 3. Arsenic levels in selected water wells in Arizona (data provided by Xiaoling Qi of the Arizona Department of Environmental Quality). Arsenic is measured as parts per billion by weight, which is equivalent to micrograms per liter of water.

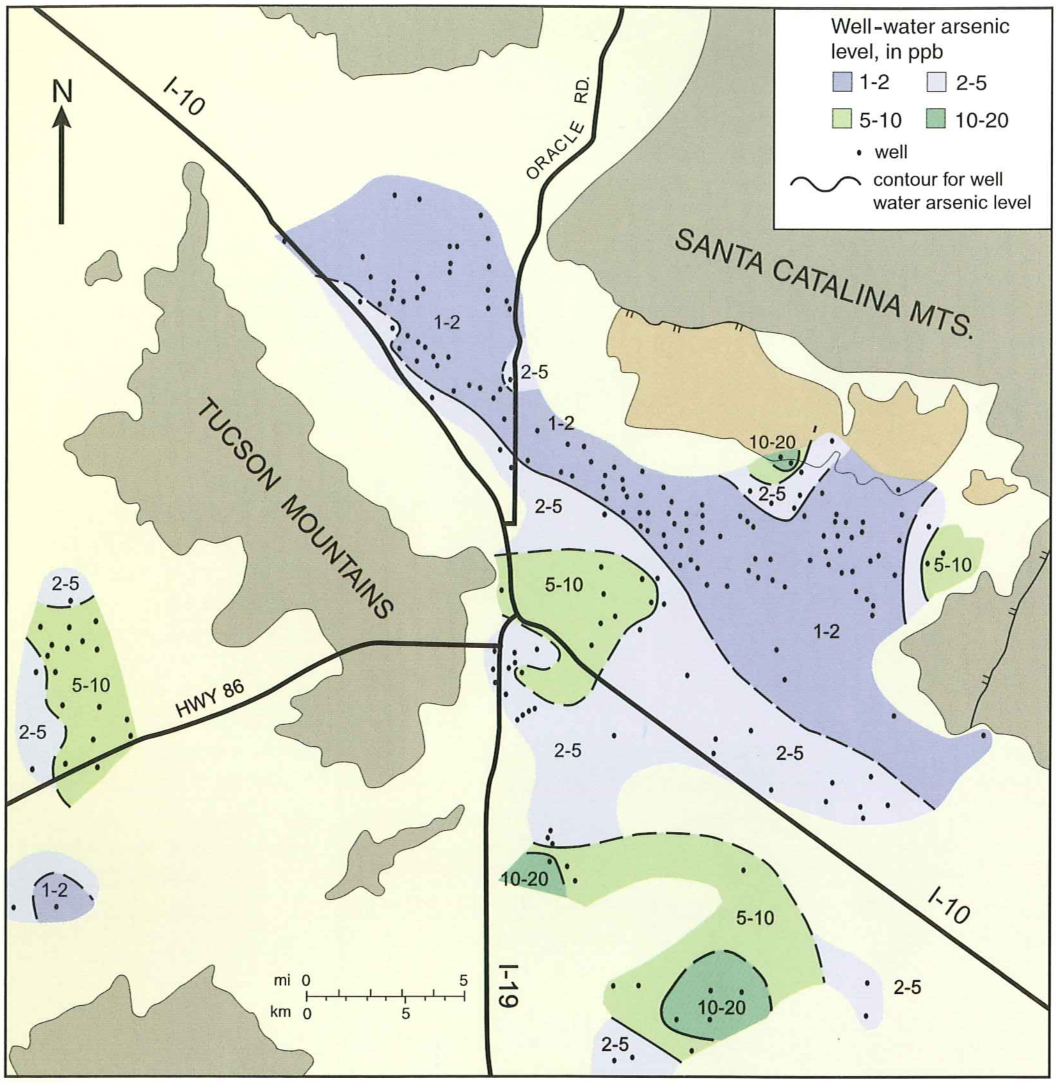


Figure 4. Map of the Tucson Basin and surrounding areas showing the distribution and arsenic levels in selected water wells. Greenish gray areas represent bedrock; tan areas south of the Santa Catalina Mountains in the Catalina foothills represent exposures of low-permeability, middle Tertiary sedimentary rocks; green areas contain wells that have >5 ppb arsenic. Data from Tucson Water, a division of the City of Tucson (obtained from http://www.ci.tucson.az.us/water/tsnwtr/quality/arsenic.htm) and Metropolitan Domestic Water Improvement District (provided by District Hydrologist Michael W. Block).

arsenic came from or how it was transported into aquifers. It seems likely that some of it was derived from Arizona's abundant sulfide mineral deposits, but it is not known if most arsenic in ground water was derived from sulfide mineral grains that were carried by streams from sulfide deposits to basins, or from the very low levels of arsenic present in virtually all sand and gravel. Some arsenic in ground water was likely leached from sulfide minerals within bedrock and transported to aquifers by surface or subsurface flow.

Arsenic concentrations in the Tucson Basin are possibly related to the composition of the sand and gravel that make up the underlying aquifer. Near the Santa Catalina and Rincon Mountains, arsenic levels are generally less than 2 ppb, whereas near the Tucson Mountains and in southwestern areas of the Tucson basin, arsenic levels are consistently greater than 2 ppb (Figure 4). The fairly straight dividing line between the two areas, defined by the 2 ppb arsenic-concentration contour for well water, extends for approximately 45 km (28 miles) southeastward across the Tucson basin (Figure 4). It is likely, but not known for certain, that this dividing line is a boundary between areas where aquifer sediments have different compositions. Northeastern aquifer sediments, with associated low arsenic levels, contain more debris derived from granitic rocks in the Santa Catalina and Rincon Mountains, whereas southwestern aquifer sediments contain more debris derived from volcanic rocks in the Tucson and Santa Rita Mountains, and from the porphyry copper deposits in the Sierrita Mountains.

Conclusion

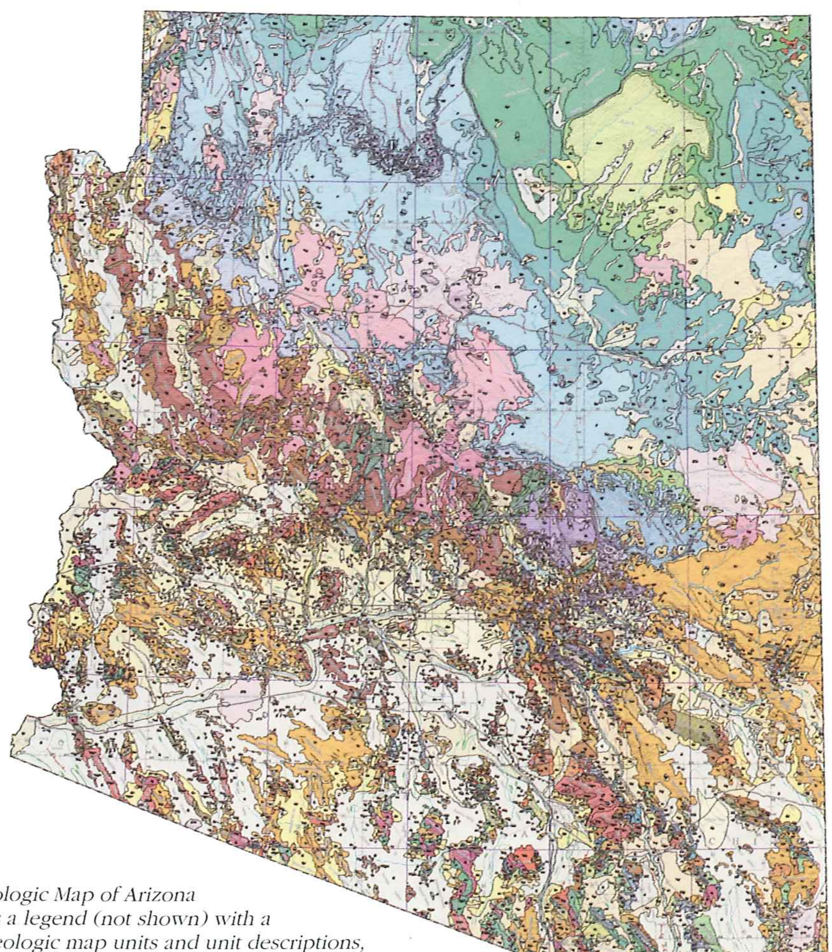
The geologic factors that determine concentrations of arsenic in Arizona ground water are only poorly understood. The EPA believes that arsenic toxicity at 5 to 50 ppb in water, a common level in Arizona well water, is significant and potentially hazardous. Reduction of the MCL for arsenic to 5 ppb will require remediation or result in closure of many Arizona wells, with likely significant increase in the cost of water to many consumers.

New Geologic Map of Arizona

Geologic Map of Arizona: S. M. Richard, S.J. Reynolds, J.E. Spencer, and P.A. Pearthree, compilers, 2000, Arizona Geological Survey Map 35 (Pub. number M 35), scale 1:1,000,000. $5.00 plus shipping and handling. Add $1.00 if you prefer an unfolded map.

This new version of the Geologic Map of Arizona replaces Map 26, which went out of print last year. Map 35 has been improved in several ways. The geology for about a quarter of the state has been updated based on new geologic mapping completed since the previous edition was compiled in 1987-1988. Map units are described in more detail on the new map and four new units have been added. The new map also shows depth to bedrock within major Tertiary basins. Finally, Map 35 has a simplified cultural base for better legibility and uses shaded relief to enhance the visualization of the geology with respect to landforms. Map 35, which measures 27 x 39 inches, is printed on 60-pound stock on one side only. Unfolded copies of Map 35 may be purchased for wall mounting.

Map 35 is significantly different from the *Geologic Highway Map of Arizona* (Map 33), which also features a 1:1,000,000-scale geologic map. Map 35 also complements Map 33. Produced cooperatively with the Arizona Geological Society, Map 33 is based on the geology depicted on Map 26. Map 33 includes stratigraphic columns, geologic cross sections, and supplementary maps and text about Arizona's geologic history, mineral resources, and geologic hazards. It is printed on both sides of a waterproof stock and is only available folded.



The Geologic Map of Arizona includes a legend (not shown) with a list of geologic map units and unit descriptions, a description of map symbols, and an introduction.

Ordering Information

You may purchase publications at the AZGS office or by mail. Address mail orders to AZGS Publications, 416 W. Congress St., Suite 100, Tucson, AZ 85701. Orders are shipped by UPS, which requires a street address for delivery. All mail orders must be prepaid by a check or money order payable in U.S. dollars to the Arizona Geological Survey or by Master Card or VISA. Do not send cash. Add 7% sales tax to the publication cost for orders purchased or mailed in Arizona. Order by publication number and add these shipping and handling charges to your total order:

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If you purchase Open-File Reports, Contributed Maps, or Contributed Reports at the AZGS office, please allow up to two days for photocopying.

New Releases

Permian salt in the Holbrook basin: S.L. Rauzi, 2000, Arizona Geological Survey Open-File Report 00-03 (Pub. number OFR 00-03), 20 p., 6 sheets, scale 1:250,000. $20.00 plus shipping and handling.

A 3,500-square-mile area south of Holbrook and Winslow in Apache and Navajo Counties is underlain by salt (sodium chloride). The maximum thickness of salt penetrated by drilling is 655 feet. Sylvite (potassium chloride) underlies a 600-square-mile area at the center of the basin. This report includes two maps and four cross sections that depict the distribution, thickness, correlation, and structure of the salt and other Permian rock units. One of the cross sections trends northwest across the basin; the other trends northeast. The author included information from 223 wells in this study.

Mid-Tertiary geology and geochronology of the Clifton-Morenci area: C.A. Ferguson, M. S. Enders, Lisa Peters, and W.C. McIntosh, 2000, Arizona Geological Survey Open-File Report 00-07 (Pub. number OFR 00-07), 69 p. $11.00 plus shipping and handling.

The authors conducted provenance studies of the conglomeratic rocks of the Gila Group, obtained $^{40}Ar/^{39}Ar$ dates of important volcanic units, and constructed a regional time-space diagram that integrates their work with previously published maps and reports. OFR 00-07 does not include a geologic map. Digital Geologic Map (DGM) 01, described on this page, includes OFR 00-07 in Adobe® PDF format and a digital geologic map all on a CD ROM.

Digital geologic map and cross sections of the Clifton-Morenci area, Greenlee County, Arizona: C.A. Ferguson and M.S. Enders, compilers, 2000, Arizona Geological Survey Digital Geologic Map 1 (Pub. number DGM 01), layout scale 1:24,000, 1 Adobe® PDF file (3 plates), and other files. 1 CD ROM. $15.00 plus shipping and handling.

DGM 01 includes OFR 00-07 in Adobe® PDF format. DGM 01 is also available with DI 18.

Summary of Tertiary stratigraphic and structural relationships, Camp Grant Wash–Antelope Peak area, Pinal County, Arizona: W.R. Dickinson, 2000, Arizona Geological Survey Contributed Map 00-B (Pub. number CM 00-B), 10 p., 1 sheet, scale 1:24,000. $4.00 plus shipping and handling DGM 01 is also available with DI 18.)

Geologic spatial data for the Clifton-Morenci area, Greenlee County, Arizona: C.A. Ferguson, M.S. Enders, and T.R. Orr, 2000, Arizona Geological Survey Digital Information 18 (Pub. number DI 18), 5 ARC/INFO export files, 26 ArcView shapefiles, and other files. 1 CD ROM. $30.00 plus shipping and handling

DI 18 includes DGM 01 and OFR 00-07 in Adobe® PDF format.

Detrital modes of selected sandstone samples from the McCoy Mountains Formation and correlative units in southwestern Arizona: W.R. Dickinson, 2000, Arizona Geological Survey Contributed Report 00-A (Pub. number CR 00-A), 18 p. $3.50 plus shipping and handling.

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