# Brief Overview of the Geology and Mineral Resources of the Tonto Basin, Gila County, Arizona

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# INTRODUCTION

This report is a brief summary of the geology and mineral resources of the Tonto Basin, prepared in conjunction with a mineral potential report for a proposed land withdrawal in the Theodore Roosevelt Lake area, requested by the Bureau of Reclamation (Federal Register, v.62, No. 232, p63957, Dec. 3, 1997). This report is based on available published literature and recent mapping by geologists from the Arizona Geological Survey.

# DESCRIPTION OF GEOLOGY

## Physiography

The Tonto Basin is located in the Transition zone province of Arizona, between the southern Mazatzal Mountains and Two Bar Ridge on the west and the Sierra Ancha on the east (Figure 1). A ridge of bedrock in the vicinity of Jakes Corner separates the Tonto Basin from the Payson Basin located to the north. The physiography of the Tonto Basin consists of broad terraces dissected by wide arroyos eroded by the active drainages. The terraces grade into variably dissected alluvial fans near the mountain fronts. Hills underlain by bedrock are present in a north-south zone that crosses the basin in the Windy Hill area. Elevation of the subject lands ranges from the current water level in Theodore Roosevelt Lake (about 2050 feet above sea level in January, 1999) to about 2700 feet in the highest parts of the parcels northeast of Theodore Roosevelt Lake.

## Rock Units

Mountain ranges surrounding the Tonto Basin consist of Early to Middle Proterozoic granitic and metamorphic rocks, overlain by Middle Proterozoic strata of the Apache Group and lower Paleozoic clastic and carbonate strata (Figure 3). Tertiary volcanic rocks crop out around the southeastern part of the basin. The Tonto Basin contains about 1700 feet of sandstone, mudstone, and conglomerate in its central part [Nations, 1987, 1988; Anderson et al., 1987; Richard, 1999]. These basin-fill deposits range in age from Early Miocene to Quaternary.

### Precambrian and Paleozoic rocks

The southern Mazatzal Mountains consist mostly of a variety of Early and Middle Proterozoic granitic rocks. Starting about 4 miles NW of Theodore Roosevelt Dam, and southward onto Two Bar Ridge, these granitic rocks are overlain by sandstone, mudstone, quartzite, and limestone of the Apache Group, and intruded by diabase sills [Spencer and Richard, 1999]. The Sierra Ancha, which lies on the northeast side of the basin, consists mostly of sandstone, mudstone, quartzite, and limestone of the Apache Group and Troy Quartzite [Shride, 1967]. Very thick diabase sills have intruded these strata and now crop out over large parts of the mountain range. Northeast of the northern end of Theodore Roosevelt Lake, Middle or Early Proterozoic granitic rocks that underlie the Apache Group are exposed along the southwestern front of the Sierra Ancha [Bergquist et al., 1981].

Devonian and Mississippian sandstone, limestone and dolomite are preserved on the southwest side of the basin in the area immediately north and south of the Theodore Roosevelt Dam, and on the northeast side of the basin in the area just west of Armer Gulch. Thin Cambrian(?) sandstones are preserved in channels locally cut into the underlying Apache Group in these areas. Devonian rocks are the most widely distributed Paleozoic strata in this area, and typically include a basal sandstone member locally mapped as the Becker's Butte Member [Teichert, 1965]. The stratigraphy of overlying interbedded dolomite, marl, shale, and sandstone is variable between outcrops. Mississippian strata are mostly limestone with sparse sandstone, correlated with the Redwall Limestone [Purves, 1978]. Conodont alteration index numbers of 1-2 from Mississippian limestones [Wardlaw and Harris, 1984] indicate that these strata have never been deeply buried (sample locations show on Figure 2).

The unconformity at the base of Devonian strata transects stratigraphy in the underlying formations. In lower Mills Canyon, about 3 km north of the Salt River, the Devonian is deposited on diabase that forms a thick sill regionally intruded into the upper part of the Pioneer Formation. Just south of Theodore Roosevelt Dam, basalt and the upper argillite member of the Mescal Formation are present, as well as a thin sandstone unit interpreted to be the Troy quartzite [Spencer and Richard, 1999]. About 3 km southeast of the dam, Cambrian(?) sandstone and Devonian strata are preserved in a paleovalley cut into the Dripping Spring Quartzite. On the northeast side of the Tonto Basin, Devonian strata overly upper Dripping Spring Quartzite or lower Mescal Limestone in the hills north of Windy Hill, and Dripping Spring Quartzite in the southeastern Sierra Ancha.

## Tertiary rocks

Tertiary basin fill strata consist of conglomerate, sandstone, and mudstone, with minor evaporite and carbonate beds. Nations [1987, 1988, 1990] identified two facies within this sequence, which he informally named the Tonto Basin formation. These are a basal and basin margin conglomerate facies and an upper and basin center fine-grained facies. The conglomerate facies consists of poorly stratified, very poorly sorted conglomerate. Clasts are locally derived and reflect the rock types present in nearby bedrock exposures. The conglomerate facies in the southern part of the basin contains abundant cobbles and boulders derived from Tertiary volcanic rocks, particularly the Apache Leap Tuff, which crop out around the south side of the Tonto Basin. The basin fill strata are younger than Apache Leap Tuff (18.6 Ma, McIntosh et al., 1998) in the southern part of the basin. The lower age limit is presently bracketed by the presence of a late Miocene or Pliocene vertebrate fossil in the mudstone member in the northern part of the basin. A K-Ar date of 18.6 Ma from a tuff interbedded near the top of the section in the northern part of the basin [Nations, 1987] suggests that much of the basin fill sequence in the Punkin Center area is older than the lower conglomerate in the southern part of the basin, and may in fact be correlative with strata referred to as Whitetail conglomerate in the southern part of the basin.

Much of the central part of the Tonto Basin is underlain by a red-brown to tannish-gray mudstone and very fine-grained sandstone facies of the Tonto Basin formation. Lance et al. [1962] measured 3 stratigraphic sections in the area around Punkin Center and proposed a stratigraphic sequence as follows: 1) a sequence of red beds, consisting of sandstone and mudstone; 2) a zone up to 300 feet thick of red beds containing abundant gypsum; and 3) a few tens of feet of light colored beds of clay, silt, tuff, and marl, which contains the fossiliferous beds. The gypsiferous zone thins northward, and the red-brown mudstone is overlain by conglomerate, and grades northward into conglomerate exposed around the northern margins of the basin (Tsy and Tcp of Ferguson et al., 1998). The mudstone overlies Rock Island conglomerate facies of the Tonto Basin Formation in the area between Rock Island and Pinto creek, but the details of the relationship between facies in the Tonto Basin formation have not been described in the literature.

Reports on the mineralogy of 6 mudstone samples from the Tonto Basin formation are included in Appendices D and E in Nations [1987] (locations on Figure 2, data summarized in Table 1). The two reports describe the same samples, one dealing with the bulk sample, and one with the detailed clay mineralogy. The mudstone samples in this study consist of 55- 70% clay, 5-15% quartz, 5-10% feldspar, 5-15% calcite with minor dolomite, 0-10% zeolite minerals (identified as heulandite), trace to 5% chlorite, 5% iron oxides (mostly amorphous $FeO_x$), and 5% trace minerals. The clay analyses from the two sources are not consistent; the N. Arizona University results (Appendix D in Nations [1987]) are considered more reliable because the focus was on clay analysis. Smectite is chiefly calcium montmorillonite [Monk, in Nations, 1987, Appendix E]. The NAU clay analyses report that clay from mudstone in the Punkin center area is mostly illite, with some chlorite and mixed layer clay, consistent with clay derivation from degradation of feldspar in adjacent granitic rock. Three samples from the central part of Roosevelt Lake contain 85-90% smectite with sparse chlorite and illite. The abundance of smectite is consistent with derivation from degradation of diabase that intrudes the Apache Group, as suggested by Nations [1987]. The diabase is abundant both north and south of the lake in this area. Samples from adjacent to the northern and southern part of Theodore Roosevelt Lake consist of smectite, mixed layer clay, and illite in subequal amounts, consistent from derivation from a mixed plutonic and diabase-rich source. Monk (in Nations, 1987) reports small amount of analcite from two samples on the north side of Roosevelt Lake. The clay mineralogy data, although sparse, suggests that clay mineralogy in the mudstone member reflects bedrock lithology along the adjacent basin margin.

### Quaternary deposits

Quaternary alluvial deposits blanket much of the Tonto Basin; these consist of non-indurated to moderately indurated, poorly stratified, moderately to poorly sorted conglomerate with scattered sandy lenses. The deposits form thin veneers (2-10 m) on pediment-terraces [Royce and Barsch, 1971; Anderson et. al, 1987] that are cut into fine-grained basin fill deposits, and form terraces along major drainages incised into the basin fill sequence. Alluvial deposits in the terrace deposits may be more than 20 m thick in places. Near the basin margins, it becomes quite difficult to distinguish Quaternary pediment-veneer deposits (units Qm, Qo) from the younger conglomerate facies of the basin fill sequence (unit Tsy where differentiated). Deposits in the active flood plains of major drainages (Units Qycr, Qyr on Figure 3) contain rounded to well rounded clasts from a wide variety of sources. Terrace deposits representing accumulations of older floodplain deposits (units Qlr, Qmlr, Qmr, and Qor) also contain a wide variety of clast types and well rounded to rounded clasts. Old alluvium that forms pediment veneers and alluvial fans (Ql, Qml, Qm, Qo) generally contains more angular clasts (rounded to sub-angular), and an assemblage of clasts that represent rocks in the local drainage basin. Anderson et al. [1987] report that the older Qm and Qo deposits are commonly blanked by 2-25 cm of 'fine grained deposits' that may be loess. North of Theodore Roosevelt Lake, older locally derived deposits (Qm, Qo) contain angular to sub rounded, locally derived clasts southwest of Tonto Creek, but on the northeast side of Tonto Creek these deposits are mantled by sub-rounded to rounded clasts derived from the Sierra Ancha [Ferguson et al., 1998].

## Geologic History and Tectonics

Rocks in the Tonto Basin area record the effects of Proterozoic, Laramide(?) and middle Tertiary deformation events. Early or Middle Proterozoic granitic rocks form most of the basement throughout the Mazatzal Mountains and Sierra Ancha adjacent to the study area. These granites are intruded into a poorly understood boundary zone that separates the Mazatzal block on the north from the Pinal block on the south [Karlstrom and Bowring, 1991]. Contrasting assemblages of Early Proterozoic metasedimentary and metavolcanic rocks characterize the Mazatzal and Pinal terranes [Anderson, 1989]. Rocks of the Pinal block are some 20 Ma younger than those of the Mazatzal block. The granitic plutons in this boundary zone locally contain weakly developed, steeply dipping and northeast-trending (about 030°) foliation, and a few northeast-trending mylonite zones [Spencer and Richard, 1999]. These plutons have commonly been interpreted to be Middle Proterozoic [Reynolds, 1988; Anderson, 1989; Karlstrom and Bowring, 1991], but new U-Pb data from similar granitic rocks in the Usery Mountains [Isacson et al., 1999] suggests that some of the locally foliated granites in the boundary zone may be Early Proterozoic.

Clastic rocks of the Middle Proterozoic Apache Group and the Troy Quartzite were deposited on deeply eroded Early Proterozoic crystalline rocks [Shride, 1967; Wrucke, 1989]. These sedimentary rocks were intruded by large volumes of diabase at about 1100 Ma [Wrucke, 1989]. The diabase intruded as thick sills, and forms a significant part of the stratigraphic section in the preserved Apache group. High angle faulting must have accompanied intrusion of the sills, as indicated by abrupt changes in sill thickness and stratigraphic position across high-angle faults.

After a long (>500 Ma) period of inactivity, Paleozoic strata were deposited on Apache Group on an erosional surface of low relief. Some faulting and gentle tilting also predated deposition of the Paleozoic section, indicated by regional pinch out of Upper Apache group strata beneath the Paleozoic section [Shride, 1965; Wrucke, 1989].

Laramide structures are difficult to identify because of the absence of Late Cretaceous to early Tertiary rocks that would allow distinction of Mesozoic and Tertiary structures. Laramide monoclines and thrust faults have been identified north [Reynolds, 1998], east [Davis et al., 1981], and south [Richard and Spencer, 1998] of the Tonto Basin. One fault located south of Theodore Roosevelt Dam has been identified as a possible Laramide monocline [Spencer and Richard, 1999]. Other faults in the Sierra Ancha and Mazatzal Mountains may have Laramide movement as well.

Erosional removal of Paleozoic strata from the Sierra Ancha and in the Superstition Mountains predates eruption of early Miocene volcanic rocks, and is probably due to uplift and erosion in Late Cretaceous-Early Tertiary time. A major northeast-flowing drainage followed the present course of the Salt River Canyon northeast from the Tonto Basin in early Miocene time [Faulds, 1988, 1989; Potochnik, 1989; Potochnik and Faulds, 1998], and probably drained a Laramide orogenic highland (Mazatzal highlands) [Peirce et al., 1979]. The Apache Leap tuff (18.6 ±0.1 Ma [McIntosh and Ferguson, 1998]) flowed northeastward in this paleocanyon from a source to the southwest [Faulds, 1986; Potochnik and Faulds, 1998].

Available data on the age of basin fill suggest that mudstone and conglomerate in the basin east of Windy Hill may be younger than similar strata in the northwestern part of the basin, and southeast of the basin along the Salt River. Accumulation of sediment in the northern Tonto Basin began before eruption of the Apache Leap Tuff, based on a K-Ar date of 18.6±0.6 Ma from tuff in the upper part of the mudrock facies of the Tonto Basin formation (sample TB20 [Nations, 1987]). At the southeastern end of the basin, Apache Leap Tuff overlies conglomerate correlated with Whitetail conglomerate [Faulds, 1986; Potochnik and Faults, 1998]. This conglomerate apparently accumulated in the paleocanyon described above, because it thickens dramatically in the central part of the paleocanyon, and pinches out to the north and south (see cross section A-A', Potochnik and Faulds, 1998, p. 154). On the southwestern margin of the basin, the Rock Island Conglomerate facies of the Tonto Basin formation overlies Apache Leap Tuff [Nations, 1987], and conglomerate of this unit contains clasts of Apache Leap Tuff. Cuttings from an oil exploration well drilled in the south central part of the basin suggest the presence of Apache Leap Tuff at a depth of about 1700 feet beneath the surface (Sanchez-O'Brien Federal 1-4 [Richard, 1999]).

The youngest faults in the map area cut mudstone and conglomerate units that are interpreted to be Middle or Late Miocene in age [Nations, 1987]. These faults bound the southwestern side of the Tonto Basin [Royse and Barsch, 1971; Anderson et al., 1987; Ferguson et al., 1998; Spencer and Richard, 1999]. Gentle southwestward tilting of basin-fill strata is interpreted to be the result of displacement on these faults [Ferguson et al., 1998]. The faults are overlapped by conglomerate deposited in alluvial fans along the basin margins and in the flood plain along the ancestral Salt River and Tonto Creek. Geomorphic analysis by Anderson et al. [1987] suggests that the oldest of these conglomerate units are capped by geomorphic surfaces of probably Pliocene age.

Cessation of tectonic activity occurred before integration of the Salt River into the regional drainage system, which immediately predates the formation of the highest preserved geomorphic surfaces. The history of the basin subsequent to the integration of the Salt River has been one of progressive erosion of basin fill deposits. This erosion has been episodic, resulting in the formation of 10 or more geomorphic surfaces within the basin [Royse and Barsch, 1971; Anderson et al., 1987]. These surfaces record climate variations and possible tectonically induced base level changes, but the detailed chronology of surface formation, and the dynamics of the geomorphic processes that form the surfaces are uncertain.

## MINERAL DEPOSITS AND MINERALIZATION IN THE TONTO BASIN AREA

Mineralized sites are shown on Figure 2, and available published information is summarized in Table 2.

Several zeolite prospects are reported in the USGS Mineral Resource data system (MRDS) [Mason and Arndt, 1996; Richard, 1996] and U.S. Bureau of Mines Mineral Locator system (MILS) [Causey, 1998]. These are apparently in altered tuff beds within the Tonto Basin formation. The age of the tuffs and stratigraphic position within the Tonto Basin formation are unknown.

The Arizona Department of Transportation Materials Inventory [Arizona Highway Department, 1961] shows a number of aggregate pits in the southeastern part of the study area, mostly on the southwestern side of the Tonto Basin. Two clay prospects are reported in Tertiary mudstone (Tonto Basin formation?) just north of the study area. One of these is described as "fine bedded and variable colored clay beds in lake deposit" [Phillips, 1987; Mason and Arndt, 1996].

Several small mines and mineral occurrences in the Sierra Ancha contain copper or uranium mineralization. Regionally, anomalous quantities of uranium are known to occur in the middle part of the Dripping Spring Quartzite [Granger and Raup, 1969]. Some production has been recorded from mines in the Sierra Ancha from steeply dipping uraninite veins and some stratiform zones in Dripping Spring Quartzite near contacts with diabase [Granger and Raup, 1969]. The closest mine that reported production of more than 2000 tons of ore is the Red Bluff, located near the Globe-Young road about 3 km northeast of its junction with the A-Cross road.

A uranium and a thorium prospect (#26, north part of Figure 2, #17, south part of Figure 2 respectively) are reported in the MRDS database to be located in Tertiary basin fill deposits (Tonto Basin formation?), but no other information is available on these sites. Scarborough [1981] reports slightly anomalous radioactivity (3X background) from thin shale beds interbedded in quartzite (Bolsa, Troy or Dripping Spring?) on Roundup Hill, just northeast of location #17 on Figure 2, and also reports detrital magnetite, illmenite and wolframite in the adjacent wash. Radioactive lignite and mudstone beds are reported in Tonto Basin formation adjacent to Proterozoic granite at the eastern margin of the Tonto Basin north of the study area near Haystack Butte (Giger Claims, Scarborough [1981]).

Manganese, iron and tungsten mineralization are reported from the Sunset Mine and Armer Wash properties located along the northeastern edge of the study area (Figure 2) [Mason and Arndt, 1996]. The mineralization is reported to consist of psilomelane ($MnO_x$) in shears and veins in Dripping Spring Quartzite, but except for the Sunset Mine (#23, Figure 2), the sites plot in an area mapped as Tertiary conglomerate by Bergquist et al. [1981]. Mineralized Dripping Spring Quartzite may be exposed in canyon bottoms. Some production is reported from these sites [Causey, 1998; Mason and Arndt, 1996].

The Christmas Gift mine, located about 2 miles southwest of Theodore Roosevelt Dam on the north side of the Salt River (#2, Figure 2), produced a small amount (<100 oz) of gold [Keith et al., 1983; AZGS files]. The mine is located in Early Proterozoic granitic rocks [Spencer and Richard, 1999], but no other information is available about the character of mineralization. No unusual alteration or mineralization was noted in nearby areas during fieldwork on the Theodore Roosevelt Dam quadrangle map by the author.

# POTENTIAL FOR THE OCCURRENCE OF MINERAL RESOURCES

## Coal

The potential for occurrence of coal is low, with high confidence. There are no known coal occurrences in the Tonto Basin; the red color and abundance of evaporitic minerals in the fine-grained basin fill is suggestive of deposition in a semi-arid environment not conducive to generating the plant biomass necessary to form coal. Bedrock formations around the basin are either too old to contain coal (Pre-Mississippian), or were deposited in a marine environment.

## Oil and Gas

The potential for occurrence of oil and gas is low, with high confidence. Although some organic matter is present in the Martin Formation, the volume of potential source rock is small due to Tertiary erosion, and the highly faulted nature of the Paleozoic rocks makes the existence of any but very small traps unlikely. The area is shown as not prospectively valuable on Stipp and Dockter [1987]

## Geothermal

The map of Geothermal Resources of Arizona [Witcher et al., 1982] shows the Roosevelt Hot Springs located at Roosevelt Dam. The temperature of the water in the spring is reported to be 48° C. More in depth information about the springs could not be located. The spring is mentioned once in Stone and Witcher [1983], where it is included in a group of springs located just downstream of dams, with the implication of a relationship between the dam, a constriction at the outlet of a groundwater basin, and the hot spring. In view of the absence of any other data indicating significant geothermal activity in the Tonto basin, the potential for occurrence of geothermal resources in the described areas is considered low with moderate confidence.

## Sodium and Potassium

The potential for occurrence of sodium and potassium is low with high confidence. No halite or sylvite has been reported from the Tonto Basin. The area is shown as not prospectively valuable on Haigler et al. [1978].

## Metallic Minerals

The potential for occurrence of metallic minerals is low with high confidence. Few of the parcels include outcrop of pre late Tertiary bedrock that might host metallic mineralization. There is no recorded placer production from gravels in the Tonto Basin, and the few known lode deposits in the adjacent mountain ranges are unlikely provide a source for placer gold.

## Uranium and Thorium

The regional occurrence of anomalous quantities of uranium in the Dripping Spring Quartzite indicates that uranium mineralization is possible [Granger and Raup, 1969]. The upper Dripping Spring Quartzite crops out in the eastern part of parcel 26 [J.E. Spencer and S.M. Richard, in preparation]. Otton and others [1981] indicate a zone of uranium resource potential in the southwestern part of the Sierra Ancha (MR-9 on their map). They interpret that the uranium occurrence in this area is not related to the upper Dripping Spring Quartzite, but do not suggest an alternative. Scarborough [1981] reported the presence of radioactive lignite in Tonto Basin formation just north of the study area, and it is possible that some uranium may be concentrated in other organic-rich parts of the formation.

## Nonmetallic Minerals/ Industrial Minerals

There is some potential for small-scale production of aggregate for construction from many of the alluvial deposits in the area.

There is low potential for zeolite occurrence in fine-grained Tertiary basin fill units (Tmt, Ts) on the northeast side of the Tonto Basin. Reported zeolite occurrences are concentrated in a linear east-trending zone near the boundary between townships 4 and 5 north. The structure in the basin fill deposits (Tonto Basin formation) has not been mapped, and the zeolite-bearing horizon may crop out in other areas beneath thin pediment veneer deposits.

There is moderate potential with moderate confidence for production of crushed rock, dimension stone or rip rap from Dripping Spring Quartzite and Martin Formation, particularly near the highway in the vicinity of Theodore Roosevelt Dam (Figure 2,3)

# REFERENCES AND SELECTED BIBLIOGRAPHY


Anderson, L.W., Piety, L.A., and LaForge, R.C., 1987, Seismotectonic investigation, Theodore Roosevelt Dam, Salt River Project, Arizona: U.S. Bureau of Reclamation Seismotectonic Report no. 87-5, 95 p., 3 sheets, scales 1:48,000, 1:14,400, 1:6,200.

Anderson, P., 1989, Stratigraphic framework, volcanic-plutonic evolution, and vertical deformation of the Proterozoic volcanic belts of central Arizona, *in* Jenney, J. P., and Reynolds, S. J., eds, Geologic Evolution of Arizona, Arizona Geological Society Digest 17, p. 57-148.

Arizona Highway Department, 1961, Aggregate sources and geology of Gila County, Arizona Materials Inventory: Phoenix, 49 pages.

Bergquist, J. R., Shride, A. F., and Wrucke, C. T., 1981, Geologic map of the Sierra Ancha Wilderness and Salome Study Area, Gila County, Arizona: U. S. Geological Survey MF MF-1162-A, 1 sheet 1:48,000.

Causey, J. D., 1998, MAS/MILS Arc/Info point coverage for the western U. S. (excluding Hawaii), U. S. Geological Survey Open-file Report 98-512, 24 pages, numerous files.

Davis, G.H., Showalter, S.R., Benson, G.S., McCalmont, L.S., and Cropp, F.W., III, 1981, Guide to the geology of the Salt River Canyon region, Arizona: Arizona Geological Society Digest, v. 13, p. 45-97, scale 1:32,000.

Duval, J.S., and Pitkin, J.A., 1980, An aerial radiometric and magnetic survey of the Sierra Ancha Wilderness, Salome Study Area, Gila County, Arizona: U.S. Geological Survey Open-File Report 80-2004, 4 p., 8 sheets, scale 1:48,000.

Faulds, J. E., 1986, Tertiary geologic history of the Salt River Canyon region, Gila County, Arizona, [M.S. Thesis]: Tucson, University of Arizona, 319 p.

Faulds, J. E., 1988, Cenozoic structural and geomorphic evolution of part of the Transition Zone, Salt River Canyon region, east-central Arizona Field Trip Guidebook to the Tonto Basin: Denver, CO, U. S. Bureau of Reclamation, no. p. 109-128.

Faulds, J. E., 1989, Geologic Map of the Salt River Region, Rockinstraw Mountain Quadrangle, Gila County, Arizona: Arizona Geological Survey Contributed map CM-89-B, 3 sheets 1:24000.

Ferguson, C. A., Skotnicki, S. J., and Gilbert, W. G., 1998, Geologic map of the Tonto Basin 7.5' quadrangle, Gila and Maricopa counties, Arizona: Tucson, Arizona Geological Survey Open-file Report 98-16, 15 pages 2 sheets, 1:24000.

Granger, H. C., and Raup, R. B., 1969, Geology of uranium deposits in the Dripping Spring Quartzite, Gila County, Arizona, U. S. Geological Survey Professional Paper: Washington, D.C., 108 pages, 4 plates.

Haigler, L., Miller, S., and Cook, A., 1978, Lands classified prospectively valuable for sodium and potassium: Phoenix, U. S. Dept. of the Interior, Bureau of Land Management, Arizona State Office, 1 sheet, 1:500,000.

Isachsen, C., Gehrels, G., Ferguson, C., Skotnicki, S., Richard, S. M., and Spencer, J. E., 1999, U-Pb zircon dates from nine granitic rocks in central and western Arizona: Tucson, Arizona Geological Survey Open-file Report 99-5, 35 pages.

Karlstrom, K. E., and Bowring, S. A., 1991, Styles and timing of Early Proterozoic deformation in Arizona: constraints on tectonic models, *in* Karlstrom, K. E., ed, Proterozoic Geology and Ore Deposits of Arizona: Tucson, Arizona Geological Society Digest 19, p. 1-10.

Karlstrom, K.E., Doe, M.F., Wessels, R.L., Bowring, S.A., Dann, J.C., and Williams, M.L., 1990, Juxtaposition of Proterozoic crustal blocks: 1.65 - 1.60 Ga Mazatzal orogeny, Arizona Geological Survey Special Paper 7, p. 114-123.

Keith, S. B., Gest, D. E., DeWitt, E., Toll, N. W., and Everson, B. A., 1983, Metallic Mineral districts and production in Arizona: Tucson, Arizona Bureau of Geology and Mineral Technology Bulletin 194, 58 pages.

Lance, J. F., Downey, J. S., and Alford, M., 1962, Cenozoic Sedimentary Rocks of the Tonto Basin, *in* Weber, R. H., and Peirce, H. W., eds., Guidebook of the Mogollon Rim region, east-central Arizona: New Mexico Geological Society Field Conference Guidebook, New Mexico Geological Society, p. 98-99.

McIntosh, W. C., and Ferguson, C. A., 1998, Sanidine, single crystal, laser-fusion $^{40}Ar/^{39}Ar$ geochronology database for the Superstition Volcanic Field, central Arizona: Tucson, Arizona Geological Survey Open-file Report 98-27, 74.

Mineral Resources Data System (MRDS) (CD-ROM), 1996, Mason Jr., George T., and Arndt, Raymond E., U. S. Geological Survey Digital Data Series no. 20: Denver, Colorado, U. S. Geological Survey compact disc.

Nations, J. D., 1987, Report on the Tertiary stratigraphy of the Tonto Basin, central Arizona, *in* Seismotectonic Investigation for Theodore Roosevelt Dam, Salt River Project, Arizona: Denver, Colorado, Seismotectonic Report 87-5.

Nations, J. D, 1988, Stratigraphy and tectonic significance of Cenozoic basin-fill sediments, Tonto Basin, Arizona Anderson, Larry W., and Piety, Lucy A., Field Trip Guidebook to the Tonto Basin: Denver, CO, U. S. Bureau of Reclamation, p. 165-177.

Nations, J. D., 1990, Late Cenozoic stratigraphy and tectonics of the Tonto Basin, Central Arizona, *in* Gehrels, G. E., ed., Geologic excursions through the Sonoran Desert region, Arizona and Sonora: Tucson, Arizona Geological Survey Special Paper 7, p. 24-27.

Otton, J. K., Light, T. D., Shride, A. F., Bergquist, J. R., Wrucke, C. T., Theobald, P. K., Duval, J. S., and Wilson, D. M., 1981, Mineral Resources of the Sierra Ancha Wilderness and Salome Study Area, Gila County, Arizona: U. S. Geological Survey Miscellaneous Field studies map 1162-H, 1 sheet, 6 pages, 1:48,000.

Pearthree, P. A., Skotnicki, S. J., and Demsey, K. A., 1997, Surficial geologic map of the Theodore Roosevelt Lake 30' X 60' Quadrangle, Arizona: Tucson, Arizona Geological Survey Open-file Report 97-17, 1 sheet, 1:100000.

Peirce, H. W., Damon, P. E., and Shafiqullah, M., 1979, An Oligocene(?) Colorado Plateau edge in Arizona: Tectonophysics, v. 61, pp. 1-24.

Phillips, K. A., 1987, Arizona Industrial Minerals: Phoenix, Arizona Department of Mines and Mineral Resources Mineral Report 4, 185 pages, 5-page addendum.

Potochnik, A. R., 1989, Depositional style and tectonic implications of the Mogollon Rim Formation (Eocene), east-central Arizona Southeastern Colorado Plateau: New Mexico Geological Society Guidebook, p. 107-118.

Potochnik, A. R., and Faulds, J. E., 1998, A tale of two rivers: mid-Tertiary structural inversion and drainage reversal across the southern boundary of the Colorado Plateau, *in* Duebendorfer, E. M., ed, Geologic Excursions in Northern and Central Arizona, Field Trip Guidebook for Geological Society of America Rocky Mountain Section meeting, Flagstaff, AZ: Flagstaff, Northern Arizona University, p. 149-174.

Purves, W. J., 1978, Paleoenvironmental evaluation of Mississippian age carbonate rocks in central and southeastern Arizona [Ph.D. Dissertation]: Tucson, University of Arizona, 672 p.

Reynolds, S. J., 1988, Geologic map of Arizona: Tucson, Arizona Geological Survey Map 26, 1 sheet, 1:1000000.

Reynolds, Stephen J., 1998, Tertiary reactivation of Laramide monoclines north of the Sierra Ancha, central Arizona: Boulder, CO, Geological Society of America Abstracts with program, v. 30, no. 6, p. 34.

Richard, S. M. and Spencer, J. E., 1998, Compilation of geology of the Ray-Superior area, Pinal County, Arizona: Tucson, Arizona Geological Survey Open-file Report 98-13, 1 sheet, 1:24000.

Richard, S. M., 1996, *Data structure design and data editing*, Database files describing mineralized sites in the State of Arizona, ver. 1.0: Tucson, Arizona Geological Survey Digital Information DI-3: Tucson, Arizona Geological Survey, 21 pages, 3 floppy disks.

Richard, S. M., 1999, Subsurface information from three wells in the Tonto Basin, Gila County, Arizona: Tucson, Arizona Geological Survey Open-file Report 99-07, 9 pages.

Royse Jr., C. F., and Barsch, D. B., 1971, Terraces and pediment-terraces in the southwest: An interpretation: Geological Society of America Bulletin, v. 82, pp. 3177-3182.

Scarborough, R. B., 1981, Radioactive Occurrences and uranium production in Arizona: Tucson, Arizona Bureau of Geology and Mineral Technology Open-file Report 81-1, 297 pages, 21 sheets.

Shride, A. F., 1967, Younger Precambrian geology in southern Arizona, U. S. Geological Survey Professional Paper 566, 89 pages.

Spencer, J. E., Pearthree, P. A., and Richard, S. M., Kneale, S. M., 1998, Geologic map of portions of the Theodore Roosevelt Lake 30' X 60' Quadrangle, Arizona: Tucson, Arizona Geological Survey Digital Information Series DI-11, 15 pages, 3 3.25" disks, Arc/Info Export file, 1:100,000.

Spencer, J. E. and Richard, S. M., 1999, Geologic Map and report for the Theodore Roosevelt Dam Area, Gila and Maricopa Counties, Arizona: Tucson, Arizona Geological Survey Open-file Report 99-6, 28 pages, 1 sheet, 1:24000.

Spencer, J. E., Richard, S. M., Ferguson, C. A., and Gilbert, W. G., 1999b, Preliminary bedrock geologic map and cross sections of the Windy Hill 7 1/2' Quadrangle, Gila County, Arizona: Tucson, Arizona Geological Survey Open-file Report 99-12, 1 sheet, 1:24000.

Stipp, T. F. and Dockter, R., 1987, Lands classified known to be valuable and prospectively valuable for oil and gas: Phoenix, AZ, U. S. Dept. Interior, Bureau of Land Management, Arizona State Office, 1 sheet, 1:500,000.

Stone, C., and Witcher, J. C., 1983, Geothermal Energy in Arizona, Final contract report: Tucson, Arizona Geological Survey Open-file Report 83-12, 397 pages.

Teichert, C., 1965, Devonian rocks and paleography of central Arizona: Washington, D.C., U. S. Geological Survey Professional Paper 464, 181 pages, 11 sheets.

Wardlaw, B. R., and Harris, A. G., 1984, Conodont-based thermal maturation of Paleozoic rocks in Arizona: American Association of Petroleum Geologists Bulletin, v. 68, no. 9, pp. 1101-1106.

Witcher, J. C., Stone, C., and Hahman Sr., W. R., 1982, Geothermal Resources of Arizona: Tucson, Arizona Geological Survey Map 15, 1 sheet, 1:500,000.

Wrucke, C. T., 1989, The Middle Proterozoic Apache Group, Troy Quartzite, and associated diabase of Arizona, *in* Jenney, J. P., and Reynolds, S. J., Geologic Evolution of Arizona: Tucson, Arizona Geological Society Digest 17, p. 239-258.

# TABLES

Table 1--clay mineralogy of samples from Tonto Basin formation. Data from Nations [1987]. Approximate sample locations shown in Figure 4.

| | | fraction of rock | | | | | fraction of total clay | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| sample | location | smectite | chlorite | kaolinite | illite | total clay | smectite | chlorite | mixed layer | kaolinite | illite | total |
| TB-1 | N side of lake, near Salome Creek, m. Section#1 | 47% | 0% | 2% | 10% | 59% | 80% | 0% | | 3% | 17% | 100% |
| TB-4 | E. side Salt Gulch base m. sec. 2 | 50% | 0% | 5% | 10% | 65% | 77% | 0% | | 8% | 15% | 100% |
| TB-7 | 3 mi S of Punkin center, base m sec. 6 | 47% | 0% | 7% | 10% | 64% | 73% | 0% | | 11% | 16% | 100% |
| TB-9 | 1st Canyon N of Mills Canyon, in roadcut | 37% | 5% | 7% | 10% | 59% | 63% | 8% | | 12% | 17% | 100% |
| TB-10 | 1st point E of Grapevine point, lakeshore | 52% | 2% | 5% | 10% | 69% | 75% | 3% | | 7% | 14% | 100% |
| TB-11 | E. Side Rock Island, 50' S of Graben fault, ibdd w/ Rock Island conglomerate | 52% | 0% | 2% | 10% | 64% | 81% | 0% | | 3% | 16% | 100% |

analyses by E.F. Monk, Bureau of Reclamation, 1986 — mixed layer clay not reported

| sample | | | | | | | smectite | chlorite | mixed layer | kaolinite | illite | total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| TB-1 | see above | Results reported only for clay minerals | | | | | **86%** | **3%** | | | 11% | 100% |
| TB-4 | " | | | | | | 15% | 4% | 42% | | 39% | 100% |
| TB-7 | " | | | | | | | 14% | 22% | 4% | 63% | 103% |
| TB-9 | " | | | | | | **89%** | **4%** | | 2% | 5% | 100% |
| TB-10 | " | | | | | | 29% | 4% | 43% | | 24% | 100% |
| TB-11 | " | | | | | | **90%** | **2%** | | | 7% | 99% |

analyses by D. Zuber, N. Arizona University Clay Laboratory, 1987

Table 2. Data for mineralized sites shown in Figure 2. Mils_id and Mrdsrec are record numbers from the MILS and MRDS databases respectively.

| ID | Mils_id | Mrdsrec | Name | Notes | Commodity |
|---|---|---|---|---|---|
| 2 | 40070234 | | CHRISTMAS GIFT | Not located during field mapping (Spencer & Richard, 1999); no unusual alteration observed in area; small gold production reported. | gold |
| 4 | 40070279 | TC35487 | DAGER RANCH CHABAZITE DEPOSIT | No production; Phillips 1987: Chabazite bed in brownish-white altered vitric tuff | zeolites |
| 8 | 40070390 | | GRIFFIN WASH MAGNETITE | Probable detrital magnetite in basin fill or Quaternary deposits | iron |
| 9 | 40070433 | | JACKIE 1-4 | In Apache Group (Yds?) in the high part southern Sierra Ancha; no geologic data found. | copper, uranium |
| 10 | 40070548 | | PINNACLE CLAIMS | Location plots in alluvium lower Mills Canyon near old highway NE of bedrock edge; is not a lode deposit, or the location is wrong. | copper |
| 11 | 40070589 | TC35482 | ROOSEVELT LAKE CHABAZITE DEPOSIT | No production; Phillips 1987: chabazite in altered vitric tuff ashy mudstone altered ashy tuff | zeolites |
| 12 | 40070590 | TC35481 | ROOSEVELT LAKE PHILLIPSITE | No production; Phillips1987: phillipsite in altered vitric ash | zeolites |
| 13 | 40070643 | | SUME URANIUM | In Apache group Sierra Ancha, Armer Mtn. quad; location not reported by Scarborough [1981] or by Granger and Raup [1969] | uranium |
| 15 | 40070658 | TC35488 | TONTO BASIN EAST DEPOSIT | No production; Phillips1987: Chabazite in pinkish-white altered vitric tuff | zeolites |
| 17 | 0 | M800275 | IDA A CLAIMS | CLASTIC SEDIMENTARY ROCK; placer?; no production | thorium |
| 21 | 0 | M800285 | BLACK DIAMOND CLAIMS | VEIN (U); no production | Asbestos, uranium |
| 22 | 0 | TC35486 | DRIPPING SPRING VALLEY CHABAZITE | LACUSTRINE SEDIMENTARY ROCK; no production | Zeolites, clay |
| 23 | 40070646 | M241201 | SUNSET MINE, SUNSET | VEIN/SHEAR ZONE (TERT) in DRIPPING SPRINGS QUARTZITE; small production; Dripping Spring Quartzite is very dark gray on air photos in this area; mineralization appears related to northwest-trending normal-separation fault. | manganese, iron |
| 24 | 0 | D000760 | ARMER WASH | PSILOMELANE VEIN; no production | Tungsten, manganese |
| 25 | 40070018 | M003009 | SUNSET MINE | SEAMS, VEINLETS, (Early TERT); small production; Relationship to site reported in MRDS record M241201 is not clear, may be same site. | manganese |
| 26 | 0 | M800284 | GIGER CLAIMS | Scarborough [1981] reports radioactive lignite and mudstone at this site; lignite yielded 0.5% $U_3O_8$. | uranium |
| 29 | 0 | | Mineralized site [Spencer & Richard, 1999] | granite cut by zones of strong fracturing that contain coarse calcite | |
| 30 | 0 | | Mineralized site [Spencer & Richard, 1999] | swarm of quartz veinlets up to 1 cm thick, some drusy quartz, trace red hematite in center of veins | |

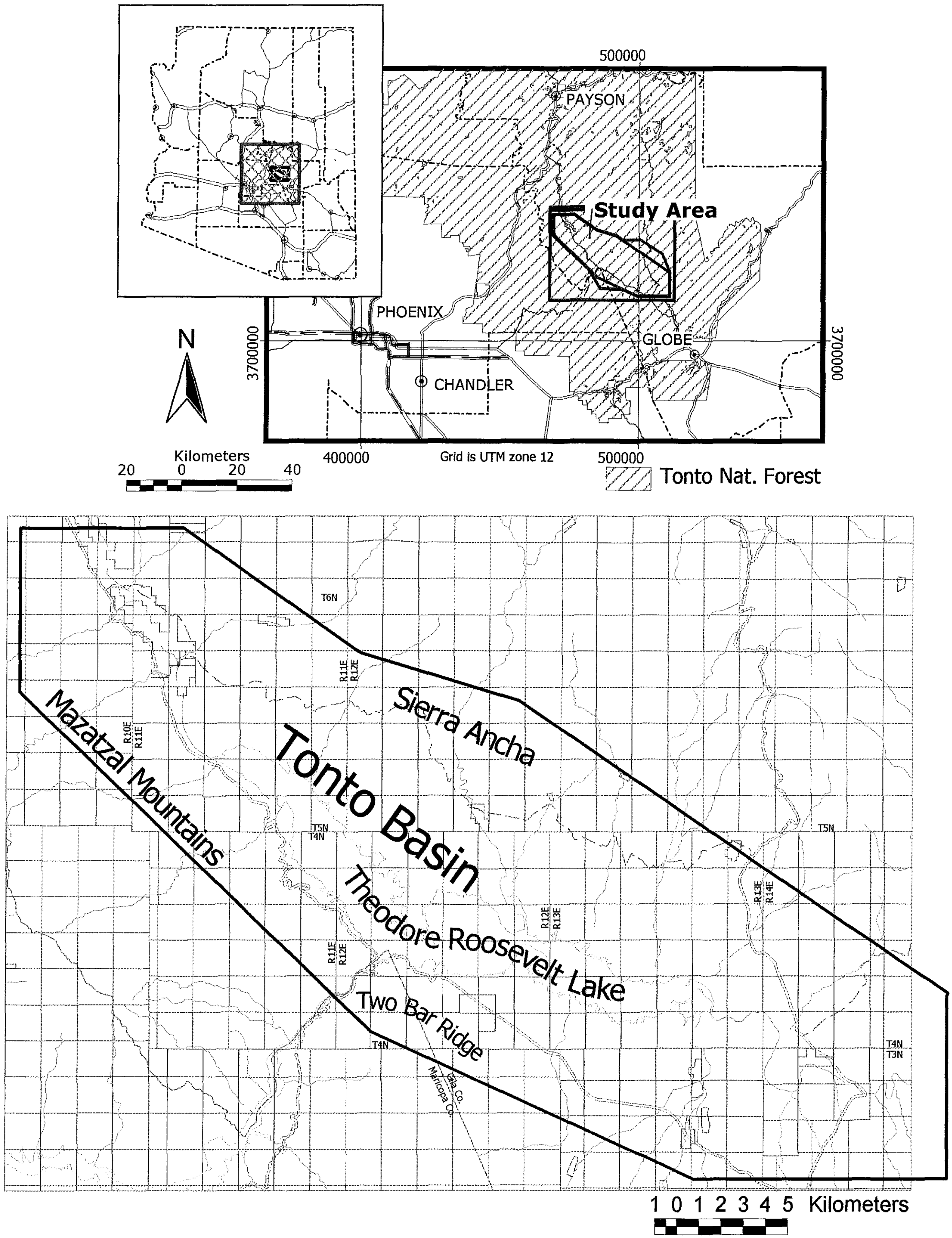


Figure 1. Location of study area within Arizona and Tonto National Forest.

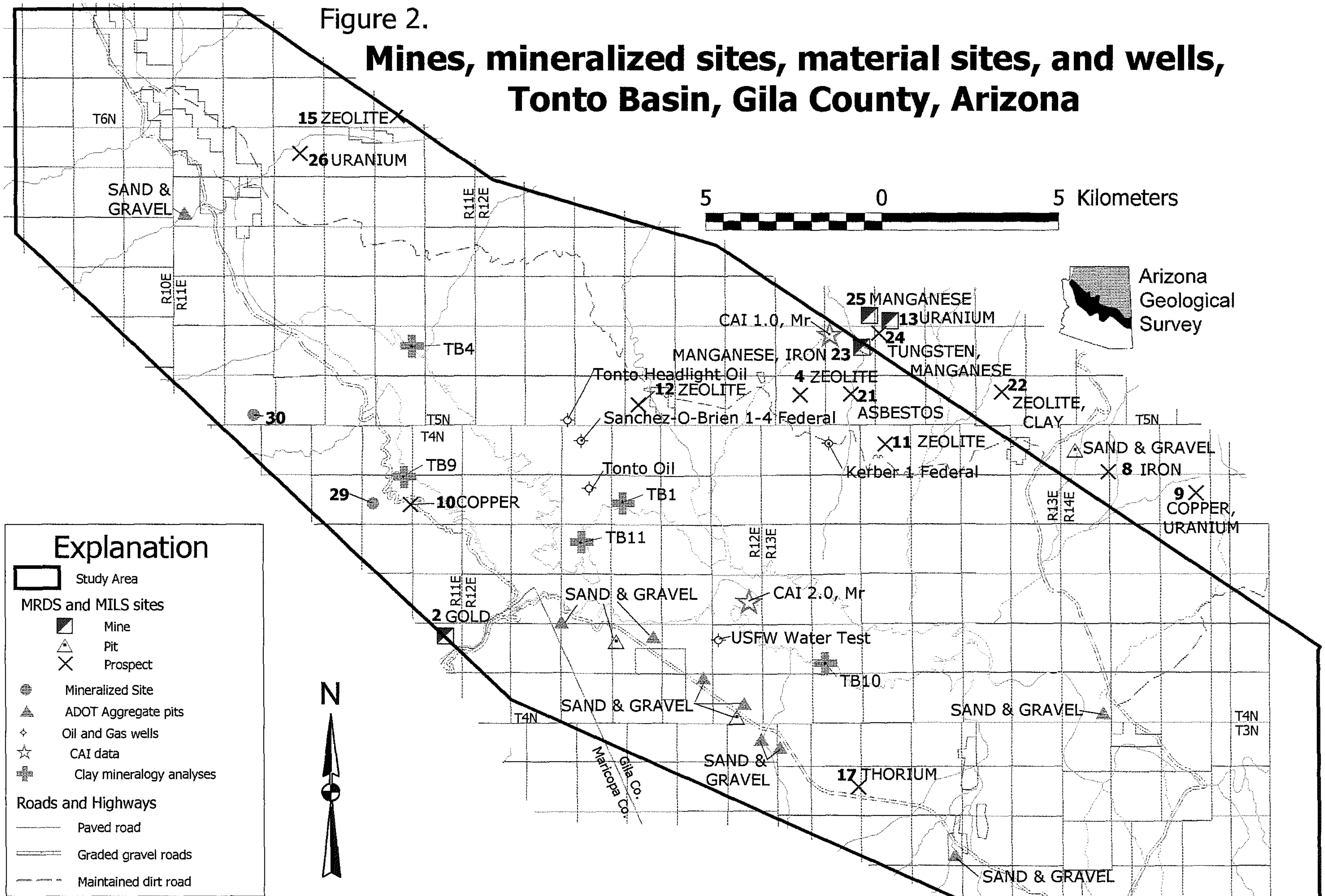


Figure 2.

**Mines, mineralized sites, material sites, and wells, Tonto Basin, Gila County, Arizona**