Geologic Map of the Gunsight Canyon 7 ½' quadrangle, Mohave County, Arizona

by

Lisa A. Thompson, Joseph P. Cook, and Victor H. Garcia

Arizona Geological Survey
Digital Geologic Map 191 (DGM-191)

February 2023

Arizona Geological Survey
University of Arizona
1955 East Sixth Street, Tucson, Arizona 85721

Includes 8 pages text and one 1:24,000 scale geologic map

Research funded in part by the U.S. Geological Survey National Cooperative Geologic Mapping Program under STATEMAP award G20AC00374, 2020. The views and conclusions obtained in this document are those of the authors and should not be interpreted as necessarily representing the official policies, either expressed or implied, of the U.S. Government.

Unit Descriptions

Quaternary Units

Big Sandy River Deposits

Qy3r – Modern channels and overbank deposits (Holocene) - Active river channel, bars, and overbank deposits. Unconsolidated, moderately to poorly sorted sand with some gravel. Clast lithologies consist of various granitoids, volcanics, schist and rare quartzite. Vegetation generally absent in active channels. Channel banks support mesquite, cottonwood, tamarisk, willow, ash and dense shrubs.

Qy2r – Low floodplain river terraces (Holocene, recent) – Unconsolidated gravel, sand, silt and some clay found adjacent to active river channel and floodplain deposits. Surfaces are about 2 to 3 m above the active channel and have well-developed bar and swale microtopography. Vegetation is light to moderate with commonly willow and juvenile mesquite and tamarisk. Soil is absent to weakly developed. Qy2r surfaces typically persist during flooding events, although can be eroded or abandoned, and in some areas of the floodplain Qy2r has at least two distinct topographic levels that were not differentiated; meandering scrolls recording former channel positions are outlined within Qy2r in some areas.

Qy1r – Low river terraces along modern floodplain margin (Holocene) – Low river terrace deposits consisting of unconsolidated gravel, sand, silt and some clay found 2 to 5 m above modern floodplain. More heavily vegetated than younger deposits; vegetation consists of a mix of cottonwood, mesquite, creosote, acacia, yucca, prickly pear, shrub, and grasses. Deposits consist of sand, moderately well sorted, micaceous and loamy, with slight undulating microtopography. Some salt encrustations where shallow groundwater is present. Gullies are common along Qy1r banks formed from headward erosion adjacent to the river floodplain. Qy1r deposits interfinger with Qy1 deposits, and Qy3 tributary deposits commonly form poorly developed alluvial fans on Qy1r surfaces.

Qi3r – Lowest-intermediate river terraces and alluvium (late Pleistocene) - Low-lying terraces along the modern Big Sandy River consisting of unconsolidated to lightly consolidated boulders, gravel, sand and silt with minor clay. Unit Qi3r terrace deposits form linear, flat terraces 5 to 10 m above the modern river, with minimal dissection, and are commonly capped by Qi3 piedmont deposits. Locally, this unit can be divided into similar landforms separated by 1 to 3 m elevation in the northeastern portion of the quadrangle. Qi3r deposits exhibit light to moderate argillic and calcic soil development and are up to 5 m thick. Locally, residences are developed on Qi3r surfaces along the river corridor and tributary mouths, and some deposits have been mined for aggregate.

Qi2r – Low to high intermediate river terraces and alluvium (Pleistocene) – Unconsolidated to weakly consolidated boulders, gravel, sand, silt and minor clay found in terrace deposits elevated 15 to 25 m above the modern Big Sandy River. Clasts consist of primarily Proterozoic crystalline lithologies and Cenozoic volcanics. Qi2r deposits are commonly capped by Qi2 piedmont deposits and are found up to 1.6 km (1 mile) west of the modern river. At least two

divisions of Qi2-age deposits are recognized, and earlier Qi2r deposits are thought to represent aggradational terrace fill deposits up to 15 to 18 m thick. Younger Qi2-age deposits and accompanying Qi2r deposits are commonly strath terrace deposits 2 to 5 meters thick positioned lower in the landscape relative to earlier Qi2 deposits. Clasts include diverse lithologies and are well-rounded relative to local piedmont alluvium.

Qi1r – High-intermediate river alluvium (Pleistocene) – Limited to one exposure immediately west of Hwy 93 (259,300 E, 3,853,700 N) approximately 35 m above the modern wash. Unconsolidated to weakly consolidated silt, sand, gravel and boulders, with minor clay. The deposit is generally light orange brown and clasts are moderately sorted, subrounded to rounded, with moderate sphericity. Clasts include diverse lithologies and are well-rounded relative to local piedmont alluvium.

Piedmont Deposits

Qy3 – Active channel, bar, and low terrace deposits (Holocene) – Moderately to poorly sorted, unconsolidated silt, sand and gravel deposits of active ephemeral washes and alluvial fans on the piedmont west of the Big Sandy River. This unit is characterized by fluvial channels, low terraces, and bars composed of locally derived alluvium. Terrace margins are typically elevated about 0.5 to 1 m above active washes and mantled with fine sand and silt. Soil development is absent to minor. Channel deposits are unvegetated to lightly vegetated but in-channel bars and adjacent terraces are vegetated by creosote, acacia, palo verde, and small shrubs. Juniper are present in the upper piedmont. Channels are prone to flooding during moderate to large precipitation events with scouring and bar deposition and lateral erosion of banks.

Qy2 – Low terrace deposits along larger active washes (Holocene) – Alluvial deposits and surfaces related to active ephemeral washes that are frequently active or relatively recently abandoned and not laterally extensive. Deposits are composed of poorly to moderately sorted and bedded coarse sand and gravel and commonly capped by silt and sand elevated from 1 to 2 m above active washes. Terraces may be paired or unpaired and well-preserved deposits exhibit bar and swale micro-topography. Rock varnish, clay accumulation, soil carbonate accumulation, and soil development is absent to minor. Vegetation includes creosote, acacia, cholla, mesquite, greythorn, and small shrubs.

Qy1 – Low terrace deposits along inactive portions of active channels (Holocene) – The youngest, likely fully abandoned alluvial deposits and surfaces elevated about 1 to 3 m above active washes and inset into extensive Pleistocene alluvial deposits. These deposits are unconsolidated and consist of poorly to moderately sorted sand and gravel reworked from older alluvium. Surfaces may or may not have relict depositional micro-topographic bars and channels. Laterally extensive deposits exhibit weakly integrated drainage networks of small distributary channels with thin splays of active sheetflood alluvium. Qy1 terraces in the upper piedmont are coarser and occasionally exhibit debris flow channel and levee morphology and mild rock varnish. Soil development is weak with incipient carbonate accumulation, very minor clay accumulation with light varnish on gravel and larger clasts. Vegetation consists of creosote,

desert broom, acacia, cholla, yucca, prickly pear, palo verde, mesquite, and small shrubs. Juniper and joshua tree are also present in the upper piedmont.

Qi3 – Low-intermediate piedmont deposits (late Pleistocene) – Broadly planar terrace and fan deposits elevated from 5 to 10 m above modern washes. Deposits consist of unconsolidated to weakly consolidated grus gravel, sand, and silt with minor clay. Qi3 deposits in the middle and lower piedmont are laterally extensive, overlie basin fill alluvium, and are inset below older, higher-standing alluvial deposits and often include reworked, calcium carbonate-coated clasts derived from older deposits. Near the mountain front and within narrow canyons, deposits include large cobbles and boulders in narrow terraces deposited atop bedrock or consolidated basin fill alluvium. Some Qi3 surfaces are characterized by a low relief (1 to 2 m), extensive rolling terrain of well-rounded elongate hills due to dissection along many small channels in a dendritic drainage network. Qi3 deposits range from 1 to 4 m thick and exhibit light to moderate, stage II to III- soil carbonate development with a mildly to moderately developed argillic horizon, moderate rock varnish and pavement formation. Vegetation includes ocotillo, palo verde, joshua tree, creosote, cholla, acacia, and small shrubs.

Qi2 – Low to high intermediate piedmont deposits (Pleistocene) – Broadly planar to moderately rounded terraces and fan deposits capping underlying basin fill alluvium. Qi2 deposits are elevated from 15 to 30 m above modern washes and are moderately to deeply dissected by internal drainage networks. Some Qi2 surfaces are characterized by a moderate relief (2 to 4 m), extensive rolling terrain of well-rounded elongate hills due to dissection along many small channels in a dendritic drainage network. Well-preserved planar surfaces are more extensive in the upper piedmont and are limited to isolated, high-standing, remnant abandoned fan surfaces in the lower piedmont. Deposits consist of grus cobbles, gravel, sand, and silt up to 15 to 18 m thick in some areas interpreted as fill terraces. Soil development includes moderately to strongly developed argillic horizons, stage III to IV calcic development, moderate to strong rock varnish and pavement formation. Qi2 deposits along the river corridor interfinger with and overlie Qi2r deposits and are up to 18 m thick in some areas. Vegetation includes ocotillo, creosote, greythorn, yucca, prickly pear, palo verde, joshua tree, juniper, and saguaro.

Qi1 – High-intermediate piedmont deposits (Pleistocene) – Unconsolidated to weakly consolidated boulders, grus gravel, sand and minor silt and clay, in well-rounded alluvial deposits elevated about 35 m above modern washes. Qi1 deposits are equivalent to Qi1r deposits and exhibit moderate to strong argillic and stage III to IV calcic soil development.

Other Surficial Deposits

d – Disturbed areas (recent) – Heavily disturbed ground due to extensive excavation, construction of earth dams and berms, road shoulders, and paved Highway 93.

Qtc – Talus and Colluvium (Quaternary) – Unconsolidated to moderately consolidated colluvium and talus hillslope deposits with varying degrees of soil development on moderate to steep slopes that typically overlie basin-fill and bedrock map units.

Basin Fill Units

Big Sandy Formation

Nbc– Conglomerate lithofacies (Miocene and Pliocene) – Tan to gray, poorly to moderately consolidated conglomerate, sand, and silt with minor clay, found generally adjacent to mountain ranges, deeply dissected by modern washes. Clasts consist of very poorly sorted, angular pebbles, cobbles and boulders derived from Proterozoic basement, primarily of granitic composition (Xg, Xu) and Cretaceous igneous rocks comprising Diamond Joe Peak (Kgd, Kpqm, Kqmp). Percent of gravel, cobbles, and boulders is highly variable in individual outcrops, but transition from conglomeratic sandstone to conglomerate to boulder conglomerate is predictable over 5-7 km from east to west towards the base of the Hualapai Mountains. Unit Nbc is matrix- and clast-supported and has bedding ranging from thin, crude to massive with multidirectional trough cross bedding common. Nbc erodes into well-rounded ridges capped with a gravel lag, where boulders can be up to several meters across. Maximum exposed thickness is at least 330 m (comprising high western fans).

Nbs – Sandy lithofacies (Miocene and Pliocene) – Tan, massive, well-sorted, unconsolidated to moderately consolidated sand and silt with subordinate mud and gravel located near the valley axis commonly exposed underneath Quaternary terrace deposits. Occasional bright white limestone marker beds up to 0.5 m thick are laterally continuous but not traceable between washes (e.g. northern Deluge Wash; indicated by marker bed line on map). Bedding is laterally continuous and planar-tabular with ripples, flutes occasional pea and pebble intraclasts. Primarily exposed in washes and in low-relief hills west of I-95. Type exposure at the mouth of Deluge Wash ~1.2 km west of I-95. Beds are locally tilted and/or deformed in the northern map area. Maximum exposed thickness is ~28 m. Unit Nbs is interbedded with unit Nbs to the west and grades into muddy facies to the east in the Tule Wash quadrangle.

Tule Wash Formation

Ntu – Tule Wash formation, undivided (Miocene) – Ranges from interbedded, poorly sorted, cobble and boulder conglomerate to conglomeratic sandstone, exposed under the Big Sandy conglomerate-dominated facies (Nbc) in the high piedmont or under dissected Quaternary fan deposits in the low piedmont. Cobble and boulder conglomerate are planar and trough-cross bedded and contain subround clasts of Cenozoic volcanic rocks and subangular to angular clasts Proterozoic and Cretaceous igneous rocks. Conglomeratic sandstone may be massive, low angle cross bedded, or planar bedded and includes may include coarse conglomerate lenses.

Ntc – Conglomerate lithofacies (Miocene) – Medium gray-brown, moderately consolidated, poorly sorted, matrix- and clast-supported, planar to trough cross bedded conglomerate found under dissected Quaternary fan deposits at the high/low piedmont interface in and the low piedmont north of Deluge Wash. Clasts consist of poorly sorted, angular to subangular pebbles and small cobbles, and trace small boulders of granite, metamorphic lithologies and trace vesicular basalt. Correlation to Tule Wash Formation beds is based on the overlying Big Sandy sediments and tilted Tule Wash beds east of Big Sandy River.

Nts – Sand-dominanted lithofacies (Miocene) – Tan, interlayered coarse, medium, and fine sand beds with minor conglomeratic lenses located north of Deluge Wash. Coarse beds are low-angle cross bedded. Medium to fine sand beds are massive. Sediments are coarser at the base and (exposed) top of section. Cobble clasts include quartz-phyric purple rhyolite.

Bedrock Units

Cenozoic to Cretaceous Intrusive Rocks

Czl – Lamprophyre dikes (Cenozoic) – Several north-west trending lamprophyre dikes are exposed in various portions of the Diamond Joe stock. Lamprophyre dikes are generally ~1 m thick and can be mapped up to a few hundreds of meters. Two major lamprophyre dikes (20 and 40 m thick and 1.3 km and 0.6 km long, respectively) were mapped and are easily seen on satellite imagery. Lamprophyre dikes occurred after emplacement and hydrothermal alteration of the Diamond Joe stock.

The lamprophyre dikes consist of 1-5 mm long euhedral hornblende phenocrysts in a grey to dark grey, fine-grained matrix. Rare rounded, 1 mm thick olivine grains are also visible with a hand lense. Petrographic examination of lamprophyre dikes revealed that the fine-grained groundmass is composed of subhedral to euhedral crystals of plagioclase with polysynthetic twinning. Minor magnetite, olivine, titanite, and apatite were also observed in thin section.

Chemical analyses and mineralogy by Gerla (1983) identified the lamprophyre dikes as minette or kersantite. Due to the lack of biotite phenocrysts in hand specimen and in thin section, we attribute the lamprophyre dikes specific to the spessartite composition of lamprophyres (i.e. hornblende and plagioclase dominant).

Kqmp – Diamond Joe quartz monzonite porphyry (Cretaceous) – The core of the Diamond Joe stock is a quartz monzonite porphyry (inner phase) that underlies most of the center 2 km radius of the stock (Gerla, 1983). In the Gunsight Canyon 7.5" quadrangle, the quartz monzonite porphyry covers an area approximately < 2 km^2 and thins out from ~ 1 km wide in the west portion of the mapping area to 0.20 km towards the east (near Deluge Wash). This phase of the Diamond Joe stock is generally less fractured, more resistant to erosion compared to other phases, and contains xenoliths of Proterozoic granite gneisses.

The Diamond Joe quartz monzonite porphyry contains abundant large euhedral K-feldspar phenocrysts that are up to 8 cm long and 3 cm wide. However, most K-feldspar phenocrysts range from 1-4 cm long and < 2 cm wide. The K-feldspar phenocrysts make up ~10%-20% of the mineralogic composition of this phase and are set in a subhedral to anhedral coarse-grained groundmass of quartz, plagioclase, orthoclase, and biotite. Hand sample observations were confirmed through thin section analyses.

Gerla (1983) identified and mapped three textural varieties of the inner phase quartz monzonite porphyry of the Diamond Joe stock. A fine-grained crystalline groundmass with K-feldspar phenocrysts, a coarser-grained groundmass with K-feldspar phenocrysts, and a phase composed

almost entirely of K-feldspar phenocrysts. In the Gunsight Canyon quadrangle, the fine-grained crystalline groundmass with K-feldspar phenocrysts was not observed. Only the coarse-grained phase with K-feldspar phenocrysts was identified. Minor outcrops of mainly K-feldspar phenocryst, with minimal groundmass, were identified but were lumped along with the coarse-grained phase in mapping. The K-feldspar dominant phase was locally associated with higher concentrations of hydrothermal veinlets. Hydrothermal veinlets are found throughout this phase and consist of quartz, quartz-sericite, sericite, and greisen veins that radiate away from the center of the stock. Most hydrothermal veins are <1 mm thick but 1-8 cm thick quartz, quartz-sericite, and greisen veins are found at some localities.

A K-Ar age (mineral unreported) of 68.9 ± 2.6 Ma is reported by Gerla (1983).

Kpqm – Diamond Joe porphyry quartz monzonite (Cretaceous) – The second phase, or intermediate phase, of the Diamond Joe stock is a porphyritic quartz monzonite covering an area of ~4 km^2 (within the Gunsight Canyon quadrangle) around the center of the stock. Contacts with the inner phase (quartz monzonite porphyry) and outer phase (granodiorite) are gradational.

The Diamond Joe porphyry quartz monzonite is distinguished in the field, from the quartz monzonite porphyry (inner phase), as having less than 10% euhedral, <~2 cm long K-feldspar phenocrysts in a medium- to coarse-grained groundmass of quartz, plagioclase, and biotite. Titanite and magnetite were observed in thin section. Biotite crystals have been slightly chloritized, some plagioclase crystals have been seritized, and some K-feldspar phenocrysts are perthitic (in thin section).

Hydrothermal veinlets are also found throughout this intermediate phase and consist of quartz, quartz-sericite, sericite, and rare quartz-sericite-hematite (after pyrite) veins that radiate away from the center of the stock. Most hydrothermal veins within this phase are <1 mm thick, specifically sericite veins, but others are up to 3 cm thick (i.e. quartz, quartz-sericite, and quartz-sericite-hematite (after pyrite) veins.

A K-Ar age (mineral unreported) of 71.9 ± 1.5 Ma is reported by Gerla (1983).

Kgd – Diamond Joe granodiorite (Cretaceous) – The third phase, or outer phase, of the Diamond Joe stock is an equigranular granodiorite covering an area of ~6 km^2 (within the Gunsight Canyon quadrangle). Near the gradational contact with the second phase of the Diamond Joe stock (i.e. porphyry quartz monzonite), this phase is relatively resistant to weathering but quickly grades into a friable phase forming small nubby-hills separated by alluvial Quaternary deposits. This is particularly common in the north and north-east sections of the Diamond Joe stock near the contact with basin-fill deposits (vast majority of dirt road heading south towards Crow Canyon is within this phase).

The granodiorite consists of twinned, regulary zoned euhedral plagioclase, orthoclase to perthitic microcline (observed myrmekite texture within one perthitic microcline grain in thin section), quartz, euhedral hornblende blades (only in the southern section of the Diamond Joe stock near the contact with the Proterozoic units), biotite, and minor magnetite and titanite. Xenoliths of Proterozoic granite gneiss and amphibolite are more common within this phase of the Diamond

Joe stock, compared to other phases, but are still rare. Contacts with the Proterozoic units are only observed in the southern section of the Diamond Joe stock within Deluge Wash.

Hydrothermal veinlets are also found throughout this outer phase and consist mainly of quartz, quartz-sericite, sericite, and rare quartz-sericite-hematite (after pyrite) veins. Most hydrothermal veins range from <1 mm thick for sericite veins to 3 cm thick for quartz, quartz-sericite, and rare quartz-sericite-hematite (after pyrite) veins.

The first reported age of the granodiorite phase of the Diamond Joe stock was a K-Ar age (mineral not reported) of 74.7 ± 2.7 Ma (Gerla, 1983). Recent LA-ICP-MS U-Pb zircon geochronology has resulted in three ages reported for the granodiorite phase: 72.8 ± 3.2 Ma, 72.1 ± 0.6 Ma, and 74.9 ± 1.2 Ma (Chapman et al., 2018; Greig, 2021; Marsh, 2022).

Proterozoic Igneous and Metamorphic Rocks

Yd– Diabase dikes (Proterozoic) – Diabase dikes occur as tabular, generally north-south trending bodies up to ~15-20 m in width, ~1 km in length, and intrude all other Proterozoic units. The diabase dikes have sharp contacts with the Proterozoic units and are easily mappable on the ground and through satellite imagery, except where they intrude similarly colored Proterozoic amphibolite units. Weathered surfaces range from dull black to brown, and in some cases, extreme weathering results in a terra rosa appearance. The diabase is composed dominantly of medium-grained plagioclase and pyroxene. A diabase dike sampled northwest of the Diamond Joe stock yielded a U-Pb date on baddeleyite of 1088 ± 3 Ma (Bright et al., 2011).

Xlg– Leucogranite and Pegmatite (Proterozoic) – Luecogranite and pegmatite dikes have sporadic orientations. Leucogranite dikes, generally 1 cm to 1 m thick, vary from fine- to medium grained granitic material composed mainly of feldspar, plagioclase, and quartz. Pegmatite dikes are commonly coarse to massively grained, 0.5 m to 2 m thick, and are composed of 3-10 cm long K-feldspar, similarly sized plagioclase, quartz, biotite, and muscovite.

Xbp– Burch Peak Batholith (Proterozoic) – The Burch Peak batholith was named by Loghry and Heinrichs (1980). The Burch Peak batholith is a medium- to coarse-grained, porphyritic biotite-rich quartz monzonite gneiss with distinctive blue-grey, crowded K-feldspar phenocrysts. Additionally, biotite content varies from outcrop to outcrop, producing lightly colored or darkly colored gneiss. All varieties were mapped as one single unit. In thin section, microcline, perthitic microcline, and lesser amounts of orthoclase were identified. Additionally, biotite, minor chloritized biotite, quartz, strained quartz, and minor plagioclase were also observed.

Xg– Granite & Granite Gneiss (Proterozoic) – Medium- to coarse-grained granite containing 2-7% biotite, and garnet-bearing granite gneiss with 5-20% biotite. Mylonitic granite "schist", biotite schist, and phyllite is present in some areas. Granite and granite gneiss is exposed in contact along the southern and south-eastern margins of the Diamond Joe stock in Deluge Wash and is mainly exposed towards the east in contact with basin-fill deposits.

This unit contains sporadic xenoliths of metasediments and is intruded by both pegmatite and diabase dikes. K-feldspar phenocrysts range in size from ~1 cm and up to ~6 cm in length, while

widths are typically less than 2 cm. At some localities (e.g. near the Diamond Joe stock and Xg contact), K-feldspars display characteristic large ovoidal megacrysts (i.e. augens). This has led to this unit being identified as an augen gneiss and/or megacrystic granite gneiss (Loghry and Heinrichs, 1980; Gerla, 1983). In some outcrops, the megacrystic augens are not single crystals but are concretions of multiple K-feldspar crystals, quartz, and plagioclase.

Xa– Amphibolite (Proterozoic) – This unit typically occurs as unmappable xenoliths within the Burch Peak batholith, but a few large outcrops are found within the undifferentiated Proterozoic unit. Amphibolites in the area are generally intruded by younger diabase dikes. The composition of the amphibolites varies between a medium- to coarse-grained plagioclase-amphibolite to a fine-grained plagioclase-amphibolite.

Xu– Undifferentiated Proterozoic Rocks (Proterozoic) – Identified rock units include migmatite, granite gneiss, garnet gneiss, phyllite, biotite schist, quartzite(?), and pegmatites. Migmatite is composed of strongly foliated, fine- to medium-grained gneiss consisting of quartz, K-feldspar, plagioclase, and biotite. Outcrops are generally less than 10 m wide, but a few larger outcrops were found. Granite gneiss tends to be a medium-grained gneiss with K-feldspar, quartz, plagioclase, and lesser amounts of biotite. Garnet gneiss is rarely encountered but tends to be found as <40 m wide xenolith outcrops in the Burch Peak batholith. The garnet gneiss is composed of mainly of alternating layers of amphibole and plagioclase with porphyroblasts of garnet in hand sample. Phyllite was only seen as <2 m wide outcrops and consists of fine-grained mica and quartz. Phyllite is generally found near larger (<10 m) outcrops of fine- to medium-grained biotite schist. Pegmatites intrude all Proterozoic units except for the diabase dike, which are the youngest Proterozoic unit.

References

Marsh, T. M., 2022, Poised for Discovery in a Land of Giants: Bell Copper Corporation presentation (https://www.bellcopper.net/_files/ugd/15e0cb_148cae7927a14e48927bc4dae0d163b9.pdf), accessed 20 January 2023.

Bright, R. M., Amato, J. M., Denyszyn, S. W., and Ernst, R. E., 2014, U-Pb geochronology of 1.1 Ga diabase in the southwestern United States: Testing models for the origin of a post-Grenville large igneous province: Lithosphere, v. 6, p. 135-156.

Chapman, J. B., Dafov, M. N., Gehrels, G., Ducea, M. N., Valley, J. W., and Ishida, A., 2018, Lithospheric architecture and tectonic evolution of the southwestern U.S. Cordillera: Constraints from zircon Hf and O isotopic data: GSA Bulletin, v. 130, p. 2031-2046.

Gerla, P. J., 1983, Structure and hydrothermal alteration of the Diamon Joe stock, Mohave County, Arizona: ProQuest Dissertations and Theses, The University of Arizona, p. 134.

Greig, R. E., 2021, Superposed magmatic and hydrothermal systems, and the evolution of the Laramide arc and porphyry copper province, southwestern North America: Unpublished Ph.D. dissertation, University of Arizona, Tucson, 346 p.

Loghry, J.D. and Heinrichs, Jr., W.E., 1980, Geologic evaluation of uranium in plutonic rocks, northwestern Arizona: National Uranium Resource Evaluation, Dept. of Energy, p. 260.