Geologic Map of the Pilgrim Wash 7 ½' Quadrangle, Mohave County, Arizona

by

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Unit Descriptions

BIG SANDY RIVER, KNIGHT CREEK AND TROUT CREEK DEPOSITS

Qy3r – Active river floodplain and bar deposits (Holocene) – Active river channel and low-lying bars with numerous active channels. Unconsolidated, moderately to poorly sorted medium to coarse sand with some subangular to rounded gravel and rounded cobbles. Clasts consist of, but are not limited to, basalt, schists, granitoids, quartzites, and acicular porphyry. Bars are elevated up to 1 m above channel bottom and have sparse vegetation consisting of shrubs and rarely cottonwood. Bars commonly have flotsam and distinct gravel to cobble deposits. Little to no vegetation in active channel.

Qy2r – **Low river terraces along active floodplain (Holocene)** – Low river terraces along active channel, elevated approximately 1 to 2 m above active floodplain. Unconsolidated, moderately to poorly sorted sand and gravel with some gravel and cobble bars. Clast types are similar to those found in Qy3r and subangular to rounded. Surface commonly has microtopography comprised of small channels, gullies, and swales. Extreme flow events can cause surface to erode and channels and gullies to flow. Moderately dense to dense vegetation comprised of mature desert broom, willow, and other shrubs, young to juvenile mesquite and creosote, and occasional mature cottonwood. Younger surfaces may have flotsam. Older surfaces can have weak biocrust formation. Remnant meander scrolls are common and outlined.

Qy1r – **Low abandoned river terraces along active floodplain (Holocene)** – The youngest, likely abandoned river terraces elevated approximately 2 to 5 m above the active floodplain. Consist of unconsolidated silt and sand with occasional remnants of cobble bars. Organics and silt give surface darker appearance than Qy2r and Qy1r deposits. Vegetation is dense and comprised of mature creosote, acacia, mesquite, and some juvenile to mature tamarisk, palo verde, yucca, cholla, and desert broom. Vegetation density increases in canyons. Surface generally planar with minor microtopography. Gullies common from headward erosion at the active floodplain. Surface can have weak to moderately developed biocrust and weakly developed soils. Qy1 deposits interfinger with Qy1r deposits. Qy3 and Qy2 deposits commonly incise through, or form alluvial fans on, Qy1r surfaces. Remnant meander scrolls are fairly common and are outlined.

Qi3r – Lowest-intermediate river terraces and alluvium (latest Pleistocene) – Low-lying terraces along modern Big Sandy River, Trout Creek and Knight Creek consisting of unconsolidated to lightly consolidated boulders, cobbles, gravel, sand and silt with minor clay. Unit Qi3r terrace deposits form linear, planar terraces elevated 4 to 10 m above the modern river, commonly capped by Qi3 deposits. Locally, this unit can be divided into terraces inset 1 to 3 m within Qi3r. Clast composition is similar to older river deposits, varying greatly in percent between each river/creek, and consist of various coarse-grained and porphyritic granites, gneiss and schist, felsic, intermediate and mafic aphanitic and porphyritic volcanics, vein quartz and

less common purple and tan quartzite. Clasts have a very thin, sub-millimeter weathering rind. Qi3r deposits exhibit light to moderate argillic (5YR 4/4) and light calcic soil development (stage I) with light to moderate pavement and are up to 5 m thick. Locally, residences are developed on Qi3r surfaces along the river corridor and tributary mouths, and deposits have been locally mined for aggregate. Vegetation consists of creosote, cholla, ocotillo, palo verde and small shrubs.

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 12 to 25 m above the modern river and creeks, and about 20 to 30 m below Qi1r deposits. Clasts consist of primarily Proterozoic crystalline granites, gneiss, and orthogneiss and felsic, intermediate and mafic aphanitic and porphyritic volcanics, similar to Qi3r. Clasts are generally subrounded to well-rounded with moderate sphericity. Qi2r deposits are commonly capped by Qi2 piedmont deposits and are typically found along the main river corridor, and up to 1.6 km (1 mile) west of the modern river in the southernmost portion of the quadrangle. At least two divisions of Qi2-age deposits are recognized although not differentiated, with older Qi2r deposits representing aggradational terrace fill deposits up to 15 to 18 m thick, and commonly fill older paleotopographic tributaries at and below the modern wash/river level. 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. Argillic and calcic soil development is poorly preserved, though well-developed (stage II-III).

Qi1r – High-intermediate river alluvium (Pleistocene) – Unconsolidated to weakly consolidated boulders, gravel, sand, silt and minor clay found in terrace deposits elevated 45 to 65 m above the modern river/creek, typically 4 to 6 m thick. Deposits are generally light orange brown and clasts are moderately sorted, subrounded to rounded, with moderate sphericity. Clast lithology consists of varied granites, pegmatitic and vein quartz, some metamorphic rocks, and felsic and mafic volcanic rocks. Qi1r remnant planar surfaces are rarely preserved and have well-rounded margins and landforms, thus desert pavement and varnish are not well preserved, and a cobble-boulder lag is characteristic when not capped by Qi1 deposits. Weathering rinds are typically 1 to 3 mm and up to 1 cm thick. Tributary or colluvial Qi1 deposits commonly cap Qi1r. Soil development poorly preserved although locally stage III+ to IV+ based on Qi1 piedmont deposits. Vegetation consists of palo verde and creosote.

PIEDMONT DEPOSITS

Qy3 – **Active channel and bar deposits (Holocene)** – Active channels, bars, and floodplain of ephemeral tributaries on the piedmont east and west of the modern river and major creeks. Deposits consist of unconsolidated, moderately to poorly sorted sand and gravel with common gravel and cobble bars. In larger tributaries such as Moss Wash and Cane Springs Wash, bars can contain clasts up to medium boulders, particularly within the upper piedmont. Clasts are subangular to rounded. Active channels typically have little to no vegetation, while the bars and floodplain can have minor grasses, desert broom, and other small shrubs. Qy3 often cuts through Qy2r and Qy1r at tributary-river confluences, but in some instances, Qy3 can form alluvial fans on Qy2r, Qy1r, and Qy surfaces. This is more common with smaller tributaries.

Qy2 – **Low terraces along active tributaries (Holocene)** – Low terraces and alluvial deposits along active ephemeral tributaries that are typically only active during moderate to large flooding events. Unconsolidated, moderately to poorly sorted silt and fine to coarse sand with common gravel and cobble bars. Surfaces are typically elevated 1 to 2 m above active channels with microtopography consisting of swales and overflow channels. Moderately dense vegetation on these surfaces includes juvenile to mature creosote, desert broom, acacia, and prickly pear. Qy2 can form alluvial fans on, or incise through, Qy2r, Qy1r, and Qy surfaces.

Qy1 – **Low abandoned terraces along active tributaries (Holocene)** – The youngest, likely abandoned tributary terraces elevated approximately 1.5 to 3.5 m above active ephemeral tributaries. Unconsolidated silt to fine sand with some remnant cobbles. Clasts are angular to rounded. Colluvium from adjacent slopes commonly merge with Qy1 surfaces. Qy1 surfaces are commonly planar with remnant paleo-microtopography. Headward-eroding gullies are present on margins adjacent to active washes. Soil development is weak to absent with very light argillic development and slight reaction to HCl. Moderately dense to dense vegetation consists of mature acacia, creosote, mesquite, cholla, yucca, and prickly pear. Qy1 deposits often interfinger with Qy1r deposits along modern creeks and Big Sandy River.

Qy – **Low intermittent tributary deposits, undifferentiated (Holocene)** – Intermittent tributary deposits that often form planar surfaces with some swale microtopography. Deposits are most common in tributaries on shallow-relief regions of the piedmont, and can form broad surfaces that interfinger with Qy3, Qy2, Qy1, and Qy1r deposits at the confluence of tributaries and major creeks and the Big Sandy River. Argillic development is absent to minor. Sheetwash and minor channelized flow can occur on these surfaces. Vegetation consists of creosote and other small shrubs and ranges from sparse to moderately dense.

Qi3 – Low-intermediate piedmont deposits (latest Pleistocene) – Unconsolidated to weakly consolidated gravel, sand and silt with minor clay, forming generally wide, planar surfaces about 3 to 10 m above modern washes. Surfaces are commonly inset below older surficial deposits, broad when overlying basin fill and some Qi2 planar fan remnants, and relatively narrow in bedrock canyons where debris flows are locally well-developed. Qi3 deposits are about 1 to 4 m thick and exhibit light to moderate, stage II to III-soil development with a light to moderate argillic horizon with moderate varnish and light pavement and exhibit minimal dissection except along the margin of active washes. Vegetation includes cholla, acacia, creosote, and dwarf mesquite. In the southernmost mapping area at 255355E, 3862507N, Qi3 appears to be faulted down to the east less than 1.5 to 2 m.

Qi2 – Low to high intermediate piedmont deposits (middle (?) Pleistocene) – Unconsolidated to weakly consolidated gravel, sand and silt found 15 to 30 m above modern washes as broad, moderate to deeply dissected remnant planar alluvial surfaces. Qi2 deposits can be up to 15 to 18 m thick in places, which are thought to represent fill terraces, followed by Qi2 and Qi3 deposits inset into older Qi2 fill deposits. Soil development on surface remnants exhibit moderate to strong argillic accumulation and stage III to IV calcic development. Along the river corridor Qi2 interfingers with Qi2r. Qi2 surfaces are faulted in the southern half of the mapping area west of the river along a fault scarp that can be traced for about 4 miles. The scarp is well

exhibited and accessible along Cane Springs Road at 254,236 E, 3,867,358N with an estimated 3 to 5 m down to the east. A second Quaternary fault is located at on the south side of the confluence of Moss and Left Hand washes at 252,528E, 3,875,145N. The scarp is not well defined but is traceable to the south. Offset along this fault in Qi2 deposits is an estimated 2 to 3 m down to the east.

Qi1 – High-intermediate piedmont deposits (early (?) Pleistocene) – Unconsolidated to weakly consolidated boulders, gravels, sand and minor silt and clay, forming well-rounded, linear alluvial deposits elevated 35 to 70 m above modern washes representing former alluvial fans. Qi1 deposits are equivalent to Qi1r deposits and exhibit moderate to strong argillic and calcic soil development, stage III to IV. Qi1 deposits are faulted in the southern fault, similar to Qi2 and Qi3 surfaces, though with greater offset estimated 7 to 20 m down to the east near 254,850E, 3,865,173N.

Qi – Intermediate piedmont deposits, undivided (Pleistocene) – Unconsolidated to weakly consolidated deposits of silt, sand, and gravel with rare boulders. Deposits comprise abandoned terraces and alluvial fan remnants of uncertain age formed on bedrock, basin fill and older river deposits.

OTHER DEPOSITS

d – **Disturbed (modern)** – Significant human disturbed surfaces such as along Highway 93 as pavement, berms and culverts. This unit is also used for gravel quarries and earthen dams.

Qtc – **Talus and Colluvium (Quaternary)** – Talus and colluvium below steep slopes graded to modern washes, Holocene surfaces and Pleistocene terraces. Consists of locally derived unconsolidated sand and gravel with variable, locally thick argillic and calcic development. Qtc deposits are abundant locally, especially within coarse-grained basin fill, although mapped where distinct or when underlying map units are too concealed to show.

BASIN FILL UNITS

Big Sandy Formation

The Big Sandy Formation was formally described by Sheppard and Gude (1972) as consisting chiefly of lacustrine deposits occupying an area of approximately 70 km^2 in southern Big Sandy Valley. Sheppard and Gude (1972) defined the Big Sandy Formation as a lacustrine facies consisting of mudstone, with silt and sand components found primarily in the Wikieup quadrangle, and in the southern part of the Tule Wash quadrangle. They recognized a marginal conglomerate lithofacies that laterally grades into the lacustrine facies, but did not include the coarse-grained facies as part of the formation definition or extent. Other researchers made similar observations that lacustrine facies graded into marginal sandy and conglomeratic facies (Morrison, 1940; Dickinson, 2008), although their distribution and extent was not mapped. Our mapping delineates two distinct lithofacies in the Pilgrim Wash quadrangle as part of the redefined Big Sandy Formation, which can be continuously traced north and south of this map area.

Nbc – Big Sandy Formation, conglomerate lithofacies (Miocene – Pliocene) – Tan to light gray, poorly to moderately consolidated, very poor to poorly sorted conglomeratic sandstone, conglomerate, and boulder conglomerate with minor clay, found generally adjacent to mountain ranges, deeply dissected by modern washes. Clasts consist of very poorly sorted pebbles, cobbles and boulders derived from Proterozoic basement, primarily of granitic composition, and include Cretaceous igneous rocks, mid-Cenozoic volcanic rocks and likely older Tule Wash basin fill deposits. Some specific clasts include hornblende-biotite porphyry, granite, granodiorite, diorite, diabase, gneiss, and quartz-kspar-muscovite/biotite pegmatite, aphanitic non-vesicular basalt, plagioclase-hornblende phyric andesite, aphyric dacite, and pink-purple rhyolite. Unit Nbc is matrix- and clast-supported and has sub-horizontal bedding ranging from thin, crude to massive with multidirectional trough and low-angle cross bedding common. Nbc erodes into well-rounded ridges capped with a gravel lag. Gullybed carbonate cementation is common near its base in contact with older basin sediments. Nbc is everywhere unconformable with older, weathered basin fill and bedrock, indicating a period of erosion preceding deposition of Big Sandy alluvium. Nbc grades laterally into sandy lithofacies, in some places gradually over several miles. Basal beds in this unit fill erosional paleotopography in older bedrock and basin fill deposits, locally several 10's of meters. The base of unit Nbc can be traced from high elevations in the Aquarius and Hualapai Mountains down to the valley floor, and in most places below the modern river corridor in the subsurface. Along Knight Creek however, the Big Sandy units are not present, nor do they appear to have occupied this space. Paleocurrents in the mapping area are consistently to the east, southeast and south, although in the northern mapping area paleocurrents are to the northeast, indicating a paleo-depositional divide occupied by an alluvial fan system emanating from the Hualapai Mountains. The maximum exposed thickness is at least 300 m (comprising high western fans).

Units Nbc and Nbs are generally nondeformed, although a Quaternary fault in the southwestern portion of the mapping area does offset Big Sandy units. East of this fault, the base of Big Sandy deposits in the hanging wall is not exposed, indicating offset is at least 25 m of stratigraphic throw down to the east.

Nbs – Sandy lithofacies (Miocene and Pliocene) – Tan, light orange-tan, and light gray, massive, well-sorted, unconsolidated to moderately consolidated quartz and feldspathic sand and silt with subordinate mud and gravel located lower in the valley floor. This facies grades laterally with coarser-grained Nbc west towards the Hualapai Mountains. Bedding is laterally continuous, sub-horizontal and planar-tabular, generally thin to medium-bedded and crude to massive bedding. Poor to moderate sorting with pebble and fine gravel clasts are common. Primarily exposed in washes and in low-relief hills, commonly exposed underneath Quaternary terrace deposits where weathering and soil development are common within Nbs as carbonate stringers along bedding fabric are common. Unit Nbs commonly erodes into gentle to moderate hillslopes mantled in colluvium. The base of unit Nbs is not exposed.

Tule Wash formation

Worley (1979) assigned tilted Miocene strata of the eastern Big Sandy Valley to three formations: Bull Canyon, Tule Wash, and Burro Wash. Doing so facilitated description and sedimentological interpretation of the strata, and Worley noted that stratigraphic relationships

between the three units were uncertain. Gootee and Johnson (2023) abandoned two of those unit names and assigned all the tilted Miocene units to the Tule Wash formation. We follow that nomenclature here. Some stratigraphic relationships remain uncertain, therefore our map units within the Tule Wash formation are based on lithofacies rather than interpretation of stratigraphic position. There are several representative sections of this formation and its lithofacies located in the Tule Wash quadrangle (Scarborough and Wilt, 1979; Worley, 1979).

Ntc – Tule Wash formation, conglomerate lithofacies (Miocene) – Light olive-gray, dominantly clast supported, massive to planar-bedded, cobble-boulder conglomerate composed of angular, hornblende-biotite porphyry (Kw), granite varieties (Xg), granodiorite, diorite, plagioclase-phyric non-vesicular andesite, diabase, gneiss, and quartz-Kspar-muscovite/biotite pegmatite, and rare clasts of monolithologic rock-avalanche breccia. Dominant clast types vary locally, and clast composition can be up to 90% monolithologic. Slopes tend to form 1-2 m thick orange-red colluvial deposits.

Nts – Tule Wash formation, sandstone lithofacies (Miocene) – Light tan to light orange-brown, poorly- to well-sorted planar to low-angle cross-bedded, and as thin, medium, occasionally thick and commonly massive tan sandstone located primarily in the northwestern part of the mapping area. Poorly sorted, low-angle cross-bedded sandstone is conglomeratic. Well-sorted massive medium to fine sandstone locally has mud laminae stringers and convolute bedding. Coarser beds are moderate to well-indurated and trough cross-bedded with angular to subrounded, locally-derived clasts similar to unit Ntc. Sandstone packages are interbedded with Tule Wash conglomerate facies (Ntc). Nts erodes into soft hillslopes commonly mantled by colluvium and talus. Unit Nts is commonly tilted 10 to 20 degrees and locally exhibits abundant fractures, joints and occasion faults.

Ntr – Tule Wash formation, redbed lithofacies (Miocene) – Light to medium reddish-brown, angular to subangular to occasionally subrounded, sand-supported pebble and cobble conglomerate cemented by hematite. Clasts are predominantly granite with some granodiorite, gneiss, quartz-K-feldspar-muscovite/biotite pegmatite and hornblende-biotite porphyry, supported by a grus-dominated coarse sand. This unit was mostly sourced from the Hualapai Mountains, although some clasts of megacrystic granite were sourced from the Aquarius Mountains and some mixed volcanic clasts from upper Trout Creek area, although these subfacies are not unique to this map unit. The clasts and matrix in this map unit are commonly coated with hematite and other oxide minerals.

Ntx – Breccia lithofacies (Miocene) – Monolithologically zoned breccia derived from various bedrock units (gneiss, granite, quartz-kspar-biotite/muscovite pegmatite, granodiorite, diorite), hornblende-biotite porphyry or andesite. Boundaries between individual lithologic zones are generally undulatory and irregular, although locally some homogenous zones of diorite or andesite breccia display fluidal (stringer) shapes. Clast size ranges from a few mm to ~80 cm. Clasts can be jigsaw fit or rotated. Granite breccia fracture surfaces are typically oxidized and hematite coated. Internal fabric, where present, aligns with regional dip of Ntc. Bed thickness ranges from two m to tens of meters and some individual deposits can be traced laterally several hundred meters. Poorly exposed outcrops are identified through monomictic surface lag gravel.

Ntx generally forms resistant ridges and is immediately overlain by monomictic, massive colluvial wedges lumped with unit Ntc.

Ntu – Tule Wash formation, undivided (Miocene) – Basin-fill sediments of the Tule Wash formation typically concealed beneath talus and colluvium that prevent identification of its lithofacies.

BEDROCK UNITS

Late Cretaceous - Paleogene rocks

PEKp – Biotite-feldspar porphyry (Late Cretaceous - Paleogene) – Dikes containing >20% pink feldspar phenocrysts (2-4 mm, mostly plagioclase but may include minor K-feldspar) and 1-2% biotite (1-2 mm) in a light-gray aphanitic to fine-grained groundmass.

Proterozoic rocks

Xg – Aquarius pluton (Paleoproterozoic) – Medium- to coarse-grained monzogranite to quartz monzonite containing K-feldspar megacrysts up to 5 cm long in a groundmass of plagioclase, K-feldspar, quartz, biotite, and hornblende. The granite in this map area typically has 5-35% K-feldspar megacrysts 1-3 cm long and contains 8-15% mafic minerals. Fine- to medium-grained biotite is the predominant mafic mineral in most parts of the pluton, forming aggregates with variably epidotized hornblende that increases in abundance with increasing overall mafic content. The megacrystic granite locally contains screens of gneiss, and the map unit locally includes minor dioritic and medium-grained granitic rocks.

Xgn – Heterogeneous gneiss (Paleoproterozoic) – Mesocratic to leucocratic biotite granitoid gneiss interlayered with foliated pegmatite, amphibolite, dioritic gneiss, quartzofeldspathic paragneiss, and biotite schist. Intruded by abundant, discordant, fine-grained leucogranite and pegmatite dikes that are probably of Mesoproterozoic age.

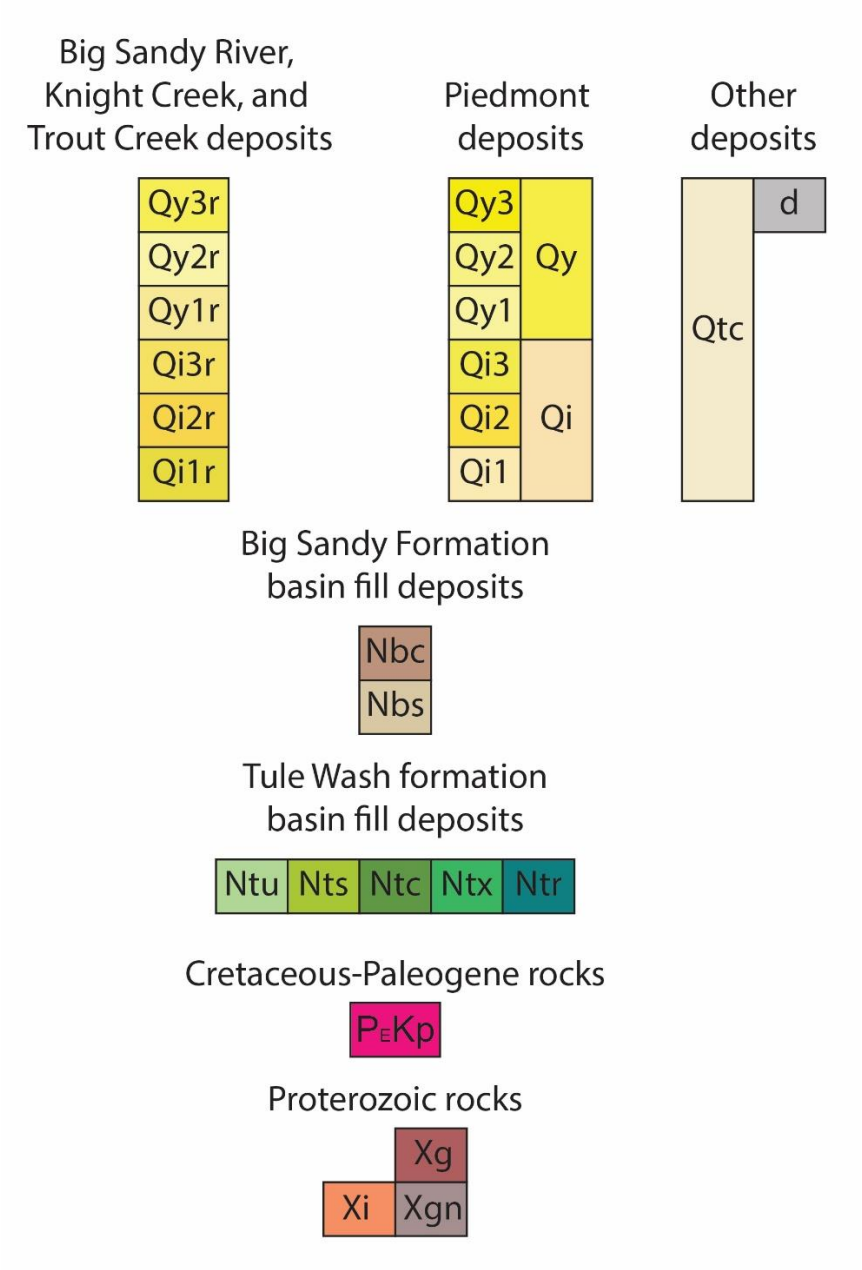
The predominant components of igneous protolith are fine-grained biotite-quartz-feldspar granitoid gneiss, fine-grained leucogranitic gneiss, and foliated pegmatite. The biotite granitoid gneiss is typically light gray with 10% biotite, but there are relatively uncommon dark-gray layers with 20% biotite and some dioritic layers that may be transposed dikes. Other local components of igneous origin include fine- to medium-grained amphibolite, weakly foliated to nonfoliated medium-grained granite with 10% biotite, and rare K-feldspar-megacrystic granite that resembles the Aquarius pluton (unit Xg). The megacrystic granite locally exhibits recrystallized mylonitic fabric with K-feldspar porphyroclasts.

Rocks of sedimentary protolith include fine-grained psammitic paragneiss and biotite schist. The paragneiss is quartz-rich, feldspathic, and some layers contain small amounts of biotite and garnet.

Xi – Iron formation and paragneiss (Paleoproterozoic) – Hematitic iron formation forms an interval or intervals up to at least 5-6 m thick, with layers and lenses of metachert <1 to 4 cm

thick. Interlayered with psammitic feldspar-quartz paragneiss, fine-grained garnet-biotite schist, dark-gray biotite-feldspar-quartz schist and gneiss, and fine-grained amphibolite. Some layers in the paragneiss contain fine-grained biotite and 1-mm garnet. In some sections this unit is represented by ferruginous biotite schist with metachert layers 1-2 cm thick.

Figure 1. Correlation of map units diagram.



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