GEOLOGIC MAP OF THE McGREW SPRING 7½' QUADRANGLE, COCHISE COUNTY, ARIZONA

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INTRODUCTION

The McGrew Spring 7½' quadrangle is located in northwestern Cochise County about 45 miles southeast of Tucson, Arizona and lies south of the town of Benson. The western portion of the map encompasses a portion of the eastern flank of the Whetstone Mountains, which is part of the Coronado National Forest. Kartchner Caverns State Park is located in the northeast corner of the map. The majority of the map area is covered by Quaternary fan and Tertiary basin fill deposits. Bedrock and surficial geology in the study area were mapped between October 2002 and June 2003 as part of a multiyear mapping program directed at producing geologic map coverage for the Karchner Caverns State Park and surrounding areas. The primary product resulting from new mapping in the study area is a 1:24,000-scale geologic map describing rock units and other geologic features. Quaternary and late Tertiary deposits in the McGrew Spring 7½' quadrangle were partially mapped by Gray (1965) however Quaternary deposits were not separated from each other. Multiple phases of Quaternary alluvial fans top late Tertiary valley fill. Large outcrops of valley fill are exposed in the southeastern portion of the map which could be related to structure, however, there was no direct evidence for this structure in the mapped deposits. Paleozoic rocks in the Kartchner Cavern block are preserved in a keystone graben that narrows to the south. The block is bounded on the west by the McGrew Spring fault which accommodates at least 2 km of down-to-the-east motion. The block is bounded to the east by a normal fault with at least 200 m of down-to-the-west motion. A range-bounding, down-to-the-east normal fault probably exists farther to the east, but no evidence for such a structure is apparent at the surface.

Structure within the Kartchner Cavern block is very complex. The Paleozoic rocks are cut by a myriad of faults (Thomson, 1990; Jagnow, 1990; 1991), many of which are associated with silicified breccia zones and extensive quartz-calcite veins up to 2 m wide. Only faults that offset stratigraphic contacts more than ~15 m are shown on our map. Many of these faults are probably extensional and/or possibly transtensional structures related to formation of the keystone graben, but some of the structures, particularly the east-west striking faults directly north of the caverns, may be reactivated contractional structures related to a series of open, east-west striking folds. Folds of this orientation are found throughout the northern Whetstone Mountains deforming strata as young as the Lower Cretaceous Bisbee Group (Creasy, 1967; Skotnicki, 2001), and are probably the result of a regional north-directed Laramide (Late Cretaceous) compressional event.

GEOLOGIC UNIT DESCRIPTIONS

QUATERNARY

d — **Disturbed areas (<100 years)** — Areas where human activity has obscured the underlying geology, primarily by excavation of earthen water tanks for cattle ranching. A large area near the western portion of the map was mined for road metal and is currently not active.

Qyc — **Late Holocene active channel deposits (<100 years)** — Unit Qyc consists of deposits in braided and meandering active channels. Qyc deposits are composed of coarse to medium sands, pebbles, cobbles, and occasional boulders. Clasts are typically sub-angular to rounded with metasediment and limestone lithologies. Incised meandering channels are high order streams with low order braided channels. Soil formation is minimal to absent for these active channel surfaces. Qyc is primarily vegetated by opportunistic grasses, shrubs, and flood damaged trees.

Qyt — **Late Holocene deposits affected by the development of the train track (<100 years)** — Unit Qyt is composed of <1 m thick organic rich deposits that have accumulated most likely due to the blockage of the drainage by the construction of the train track.

Qy2 — **Late Holocene alluvium (<2 ka)** — Unit Qy2 consists of recent alluvium on floodplain and low terraces that shows evidence of intermittent inundation during large flood events. Qy2 deposits are composed of siltstone with pockets of conglomerate lag. Qy2 deposits are located along active channels less than 2 m above the active channels. Surfaces are commonly planar. Qy2 soils are weakly developed, 10 YR 5/3 brown to light brown, with no ped development or secondary carbonate. Qy2 is primarily vegetated by opportunistic grasses.

Qy1 — **Middle to older Holocene alluvium (~2 to 10 ka)** — Unit Qy1 consists of low terraces and mid-channel island deposits composed of sand, silt and clay, with a dominance of cobbles. Qy1 deposits are located along active channels less than 4 m above the active channels. Surfaces are commonly planar. Qy1 soils are weakly developed, 10 YR 6/4 brown to light brown, with some ped formation. There is minimal clay accumulation and filament secondary carbonate build-up. Desert pavement is sparse and immature. Qy1 is primarily vegetated by small mesquite and acacia trees with some opportunistic grasses.

Qy — **Undifferentiated Holocene alluvium (~100 years to 10 ka)**

Qyd — **Dissected Qy (~100 years to 10 ka)** — Unit Qyd represents the eroded surface of the Qi3, and covers a large area in the southern part of the map.

Qi4 — **Late Pleistocene alluvium (~10 to 130 ka)** — Unit Qi4 consists of weakly dissected alluvial fan deposits which commonly flank active channel valley walls near the mountain front and formed narrow fans in the basin. Qi4 deposits are composed of sandy-silt with clay and some cobble size conglomerates composed of limestone, quartzite, and granite. Granite is the primary parent material for Qi4. Qi4 surfaces are lower than Qi2 surfaces and planar with more dissection and beveling near their eroded edges. Qi4 soils are weak to moderately developed, 7.5 YR 5/6 yellowish red, no carbonate present in the profile, with moderate clay accumulation. Qi4 has a weak desert pavement with no interlocking clasts. Qi4 represents an alluvial fan aggradation which sourced its sediment from exposed granite. Qi4 is primarily vegetated by sparse acacia and mesquite trees, barrel cactus, and catclaw.

Qi3 — **Late Pleistocene alluvium (~10 to 130 ka)** — Unit Qi3 consists of weakly to moderately dissected alluvial fan deposits. Qi3 deposits are composed of clay loam mudstone. Qi3 surfaces mantel Qi1 and Qo surfaces usually as broad distributed fans. Qi3 surfaces are patchy and planar sloping toward the valley that is broadly dissected. Qi3 source primarily limestone material. Qi3 soils are weak to moderately developed, 10 YR 6/4 light brown, stage I to II secondary nodular carbonate (Machette, 1985) present in the profile, with columnar peds. Qi3 has no desert pavement. Qi3 represents a broad alluvial fan deposit across the moderately dissected fan surface. Qi3 is primarily vegetated by creosote and sparse acacia.

Qi2 — **Middle Pleistocene alluvium (~130 to 750 ka)** — Unit Qi2 consists of moderately dissected alluvial fan deposits. These fan deposits dominate the western half of the map and have been buried and dissected in the southern portion. Qi2 deposits are composed of grüss with isolated conglomerate lenses composed of metasediments, limestones, and granite cobbles. Qi2 is beveled with moderate dissection across the entire surface. Qi2 deposits commonly mantle isolated dissected valley interfluves in the eastern portion of the map. Qi2 soils are moderately to strongly developed, 10 R 4/6 orangish red, no carbonate in the profile, well developed clay coated medium blocky peds. Qi2 represents a major aggradation event that seems to source from the northern portion of the map. Qi2 is primarily vegetated by sparse catclaw, mesquite trees, and barrel cactus.

Qi1 — **Middle and early Pleistocene alluvium (~500 ka to ~1 Ma)** — Unit Qi1 consists of deeply incised alluvial fan deposits. Qi1 deposits are composed of carbonate-cemented conglomerate with metasediment, limestone, and sandstone cobbles that have a 0.5 m thick clay horizon mantling top of the surface. Qi1 is beveled and highly dissected by deeply incised slot channels. Qi1 soils are well developed, 10 R 4/8 reddish brown, stage IV secondary carbonate development, large prismatic peds with well develop clay coats. Qi1 represents a major fan complex that developed along the mountain front. Qi1 is primarily vegetated by junipers, ocotillo, green torn bush, and prickly pear.

Qo — **Early Pleistocene alluvium (~750 ka to 2 Ma)** — Qo unit consists of deeply incised and degraded alluvial fan deposits. Qo deposits are composed of matrix-supported carbonate cemented conglomerate with metasediment, limestone, and sandstone cobbles. Qo is highly degraded and dissected by deeply incised slot channels, the surface is covered with carbonate chips and cobbles that have pendent secondary carbonate. Qo soils are well developed stage V to VI secondary carbonate with 7.5 YR 7/3 light brownish white. Qo represents a major nested alluvial fan complex which is the oldest fan complex in the mapped area. Qo is primarily vegetated by ocotillo and creosote.

Qog — **Early Pleistocene alluvium (~750 ka to 2 Ma)** — Qog is similar to Qo, however it has a granitic parent material.

QTcg — **Early Pleistocene to Miocene alluvium (Quaternary to late Tertiary)** — QTcg unit consists of tabular bedded carbonated cemented matrix supported conglomerate with limestone, metasediments, and granite cobbles. Root casts are abundant throughout the tabular bedding. QTcg lies unconformably on top of unit Tsd. QTcg surfaces are highly degraded with chips of carbonate littering the erosive hill slopes. QTcg is laterally discontinuous and represents the incision and valley fill on top of the Tsd.

Qc — **Colluvium and talus (<2 Ma)** — Unconsolidated to moderately consolidated colluvium and talus hill slope deposits. This units typically includes subangular to angular, poorly sorted, sand to boulder sized clasts. Adjacent bedrock lithologies dominate the clast compositions. These deposits range in age from Holocene to Pleistocene.

QTbf — **Early Pleistocene fine-grained alluvium (~1 to 2 Ma)** — Unit QTbf consists of very old relict basin floor deposits forming an undissected surface that dips gently to the northeast in the southeastern part of the map area. The QTbf surface is brown in color, with abundant carbonate litter derived from the underlying petrocalcic horizon. Surface deposits are primarily sand and silt, with little or no gravel. Exposures around the margins of the plateau reveal the existence of a ~1 to 2 m thick carbonate cemented layer that is probably a petrocalcic horizon. Small, incised swales evidently convey surface runoff across this surface, and deposits ranging in age from Holocene to middle Pleistocene appear to lap onto the QTbf surface from the Whetstone piedmont. QTbf deposits in this area sit immediately above basin-fill deposits, probably the middle St. David Formation.

Tsdm — **Middle member of the St. David Formation (Pliocene)** — Middle St. David Formation consists of red and green mudstone, marl, tuff, and fine to medium grained sandstones.

Tsdl — **Lower member of the St. David Formation (Pliocene)** — Lower St. David Formation consists of red mudstones and fine grained sandstones with nodular and fibrous gypsum located in the mudstones.

Tsd — **Undifferentiated Pliocene** — St. David Formation which includes the lower and middle members.

CRETACEOUS-TERTIARY

TKd — **Mafic dikes (Cretaceous-Tertiary)** — Fine-grained diorite dikes. Dikes are generally east-west striking, moderately to steeply north-dipping and most abundant north of Guindani Canyon where they are typically associated with quartz veins and hydrothermal alteration.

KJm — **Monzosyenite (Cretaceous-Jurassic)** — Fine- to medium-grained, equigranular pinkish gray monzosyenite to quartz monzonite with approximately 10-20% biotite and hornblende. The monzosyenite contains 1-5% 1-30cm rounded inclusions of fine-grained diorite or monzodiorite. The unit occurs as a pair of sills; the lower one (up to 400 m thick) intruded between the Bolsa Quartzite and Abrigo Formation, and the upper one (2-20 m thick) intruded within the lower Escabrosa Limestone. The upper sill, mapped by Creasy (1967) as rhyodacite (his map unit Kr), has a fine-grained phaneritic texture similar to the lower sill, but does not have fine-grained diorite inclusions. The upper sill is light brown in color which is probably due to alteration of its mafics. Creasy (1967) describes the lower sill as a fine-grained granodiorite (his map unit Kgs) and reports a K/Ar biotite and hornblende age of 74 Ma from a related stock (his map unit Kg) located approximately 10 km to the southwest.

PALEOZOIC

Ph — **Horquilla Limestone (Pennsylvanian)** — A sequence of mostly recrystallized, medium gray carbonate consisting of medium- to thick-bedded, tabular-planar units, with local preservation of skeletal packstone and wackstone texture, and sparse grainstone. The sequence is interbedded with 5-20%, thin- to medium-bedded fine-grained, dark gray, recrystallized micritic carbonate and/or silty, tan to peach-colored, laminated to cross-laminated limestone. Bed-parallel bands of ribbon chert up to 20 cm thick ranges between 0-10% in the thicker units.

Me — **Escabrosa Limestone (Mississippian)** — A sequence of medium- to thick-bedded, massive to amalgamated, recrystallized medium gray carbonate. Preserved primary textures are dominated by skeletal packstone and grainstone. Bed-parallel bands of ribbon chert (1-20 cm thick), and lenses of bread loaf chert up to 40 cm thick range between 0-20%. Thin, discontinuous lenses of quartz sandstone are present in the lower third of the unit in the Kartchner Caverns area. The top of the unit is defined by a zone of discontinuous lenses and pockets of dark red silty mudstone interpreted as siliciclastic infilling of paleokarst cavities. To the north, in the Kartchner Caverns area, this interval is represented by lenses and pockets of specular hematite altered siliciclastic nodules. This upper interval, mapped as the Black Prince Limestone by Creasy (1967), was not differentiated.

Dm — **Martin Formation (Devonian)** — A sequence of fine-grained, recrystallized, micritic, medium to dark gray carbonate (dolostone and limestone). The unit is thin and poorly exposed.

C — **Abrigo Formation (Cambrian)** — Thin- to medium-bedded, cross-stratified, ripple-laminated, purple to dark gray calcareous quartz sandstone and quartz sandy carbonate, mostly limestone.

Cb — **Bolsa Quartzite (Cambrian)** — A sequence of medium- to thick-bedded pebbly quartz sandstone that grades up into quartz sandstone. The pebbly sandstone typically occurs in tabular-planar sets that grade up into tabular-planar and wedge-planar cross-stratified quartz sandstone beds with very sparse silty mudstone interbeds. A distinctive, medium-bedded, tabular-planar interval with abundant *Skolithos* burrows occurs in the middle of the unit.

MESOPROTEROZOIC-TERTIARY

TYq — **Vein quartz (Mesoproterozoic-Tertiary)** — Individual dikes and zones of east-west striking, steeply north-dipping quartz veins that intrude Mesoproterozoic granitic rocks west of McGrew Spring. The unit also includes significant areas of highly silicified and consequently unidentifiable country rock adjacent to the veins. The most prominent zone occurs at and to the west of Ricketts Mine. The quartz veins in this area may be associated with a similarly oriented set of quartz veins and highly fractured Paleozoic rocks along east-west striking faults in the Kartchner Caverns block. Veins in the Guidani Canyon area include wolframite (AZGS file data, courtesy of Russell Corn).

MESOPROTEROZOIC

Ygm — **Muscovite leucogranite (Mesoproterozoic)** — Medium-grained equigranular, but locally coarse-grained and sparse potassium feldspar porphyritic leucogranite containing 5-20% muscovite. In a 500-ft deep drill hole in Guindani Canyon, the granite contains on average 20-25 ppm U_3O_8. The upper 50 feet of the hole is leached, with values averaging < 5 ppm, but in a supergene enriched zone between 50 and 100 feet, U_3O_8 values average 70 ppm with some 5-foot thick zones in excess of 200 ppm (AZGS file data, courtesy of Russell Corn).

Yg — **Granite (Mesoproterozoic)** — Medium- to coarse-grained, potassium feldspar porphyritic granite with between 5-12% biotite.

Xp — **Pinal Schist (Paleoproterozoic)** — Thin-banded to massive, fine- to medium-grained biotite and sericite schist with 0-10% <5 cm thick quartz veins. Quartz veins are oriented parallel to prominent schistosity. Locally the schistosity is kink folded and/or crenulated. The schist is hornfelsed near intrusive contacts with abundant recrystallized (fine-grained aggregates of quartz and mica) rectangular porphyroblasts up to 2 cm.

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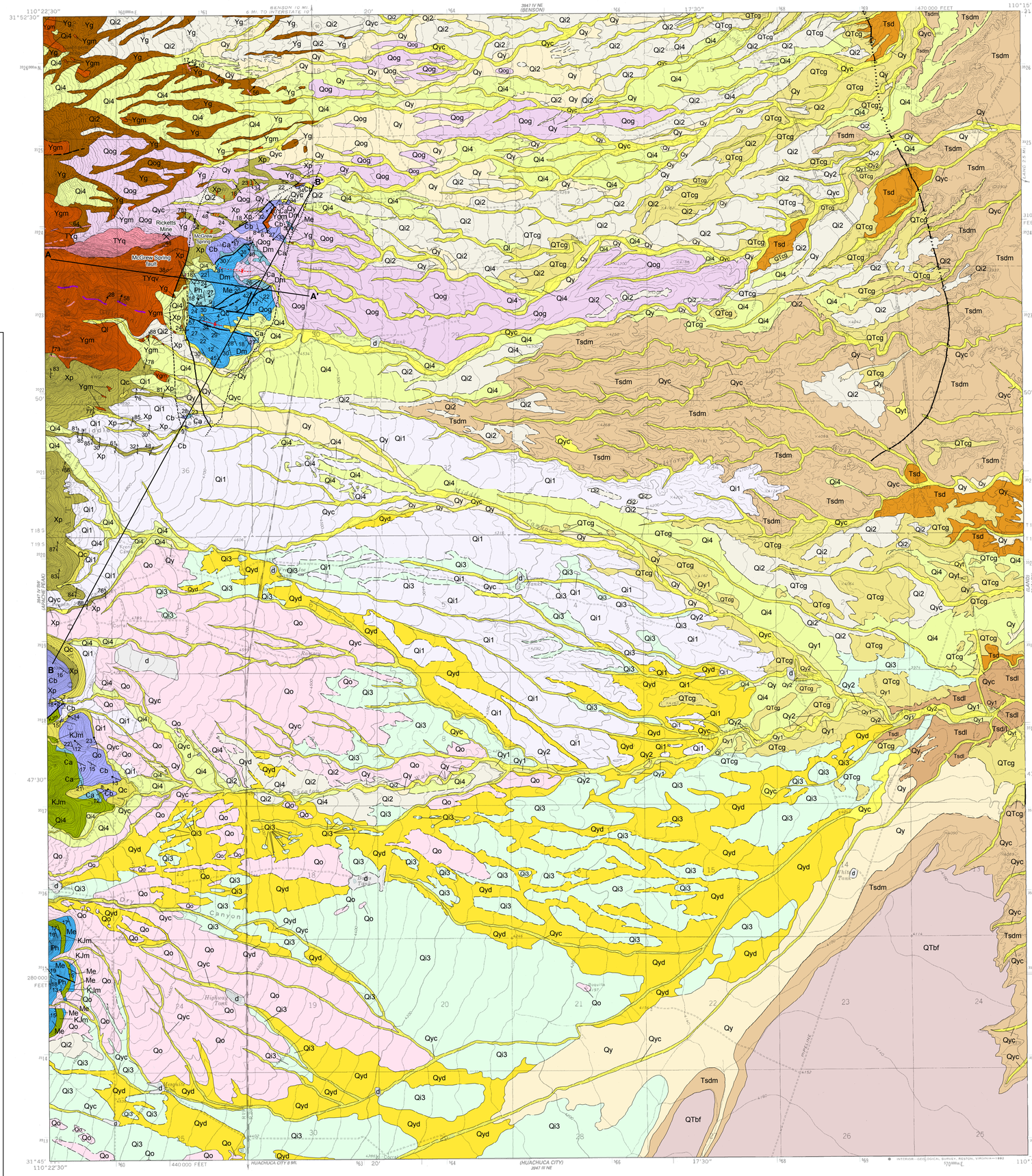


Topographic base from USGS 7½-minute McGrew Spring quadrangle, Arizona. Transverse Mercator Projection, UTM grid, zone 12; 1929 North American Datum; Clarke 1866 Spheroid.

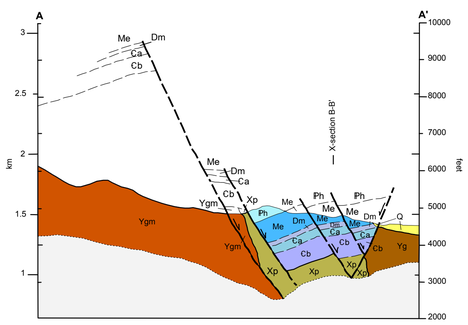
GEOLOGIC MAP SYMBOLS

Bedding and fault symbols

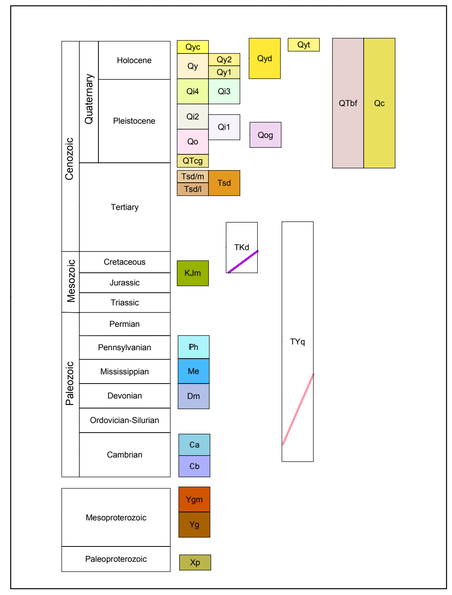
- Bedding
- Bedding with stratigraphic top known
- Vertical joint
- Slaty cleavage
- Eutaxitic foliation
- Flow foliation
- Minor fault showing dip

Contact, fault and dike symbols

- **Depositional or intrusive contact** — Dashed where approximately located, dotted where concealed, queried where location uncertain
- **Fault, showing dip** — Dashed where approximately located, dotted where concealed, queried where location uncertain
- Dikes of unit Ygm



STRATIGRAPHIC CORRELATION DIAGRAM

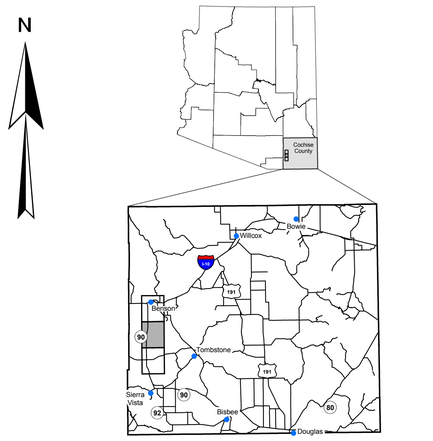


SCALE 1:24,000

1 0 1 MILE
1,000 0 1,000 2,000 3,000 4,000 5,000 6,000 7,000 FEET
1 0.5 0 1 KILOMETER
1000 500 0 1000 METERS

CONTOUR INTERVAL 20 FEET

INDEX MAP OF ARIZONA



McGrew Spring quadrangle (shown as gray box, above) is one of three quadrangles mapped in 2003 in San Pedro River Valley. The other maps are Benson 7½' quadrangle (DGM-34) and Huachuca City 7½' quadrangle (DGM-36).