# Geologic Map of the Fortuna 7.5' Quadrangle, Yuma County, Arizona

by

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Arizona Geological Survey Digital Geologic Map 55 (DGM-55)

January 2007

Scale 1:24,000 (1 sheet)

with 13 page text and one oversized figure

Arizona Geological Survey

416 W. Congress St., #100, Tucson, Arizona 85701

www.azgs.az.gov

Research supported by the U.S. Geological Survey, National Cooperative Geologic Mapping Program, under USGS award number #05HQAG0078. The views and conclusions contained 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.

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## INTRODUCTION

This map depicts the geology of the Fortuna 7 ½' Quadrangle and about 2.5 square miles of the northern end of the Gila Mountains that is in the adjacent Laguna Dam, Dome, and Ligurta 7 ½' Quadrangles. The map area encompasses the northwestern Gila Mountains and the broad Gila River valley between the northern Gila Mountains and Yuma, in the southwestern corner of Arizona. The quadrangle covers bedrock in the northwestern Gila Mountains, much of the western piedmont at the foot of the northwestern Gila Mountains, and alluvial sediments deposited by the Gila and Colorado Rivers. Large, active gravel quarries, and the historic Dome placer gold district, are within the map area at the foot of the Gila Mountains. This mapping was completed under the joint State-Federal STATEMAP program, as specified in the National Geologic Mapping Act of 1992.

## Mapping Methods

Surficial deposits that cover most of the quadrangle were mapped using stereo pairs of 1:24,000-scale color aerial photos taken in 1979, georeferenced digital color orthophotos taken in 1996 and 1992, and topographic information from USGS 7.5' topographic quadrangle maps. Mapping was verified by field observations during the spring and summer of 2006, and unit boundaries were spot-checked in the field. The bedrock in the eastern quarter of the quadrangle were mapped and structural measurements obtained in the spring of 2006. The mapped area is rapidly developing and out pacing the most recent aerial photos. Developed surfaces were mapped using the 1996 orthoquad photos and their deposits were interpreted by field checking their lateral undisturbed equivalent. Map data was compiled digitally using the ARCMAP program and the final line work for the map was generated from the digital data.

Characteristics evident on aerial photographs and on the ground were used to differentiate and map various alluvial surfaces. The color of alluvial surfaces depicted on aerial photographs is primarily controlled by soil or deposit color, vegetation type and density, and locally by rock varnish on surface gravel clasts. Significant soil development begins on an alluvial surface after it becomes isolated from active flooding and depositional processes (Gile et al., 1981, Birkeland, 1999). Alluvial fans shedding off the Gila Mountains have well-developed desert pavements, which were visible on the aerial photographs and were used to designate like surfaces. Hummocky surfaces on some fans can be distinguished from the aerial photos and were used to for mapping. Topographic relief between adjacent alluvial surfaces and the depth of entrenchment of channels can be determined using stereo-paired aerial photographs and topographic maps. Young surfaces appear nearly flat on aerial photographs and are less than 1 m above channel bottoms. Active channels are typically entrenched 2 to 30 m below older surfaces.

Bedrock geology was mapped by traditional field methods with use of portable global positioning (GPS) units that were used to recorded station locations. Bedrock field maps were scanned, georeferenced, and used for map compilation in an ESRI™ ArcMap geodatabase. Point data, such as structure measurements (e.g., strike and dip), were entered into the geodatabase and located using GPS field measurements. The map is a graphical representation of the digitial geodatabase.

## RECENT GEOLOGIC EVOLUTION OF THE FORTUNA AREA

### Flooding

Present day flooding hazards exists near the Fortuna Wash, which drains the west side of the Gila Mountains. This floodplain has been developed with residential properties, with some engineering of the drainage to mitigate flooding. There is no historic flooding along this tributary; however it has recently been developed for residential with houses developed on areas with flooding potential.

The Gila River flows across the northern portion of the quadrangle and its present day floodplain is entrenched and narrow. Flooding is controlled by the Painted Rock Dam, which came into existence in 1959. The Painted Rock Dam was constructed to control the flood in the Lower Gila and Lower Colorado River. A lake was created behind the dam during the flood in 1978. A major flood in 1993 caused the dam to open up its spillway and created some flooding down stream (Tellman, 1997, 97-108).

Most of the agricultural lands in the northern part of the mapped area are located on the former floodplain of the Gila River. This abandoned floodplain has not been flooded since completion of the Painted Rock Dam in 1959. During the floods in 1993 the Painted Rock Reservoir filled to its capacity and the spillways released approximately 30,000 cfs. However, even during this event flood waters did not over-top the banks of the Gila River. Although there was no flooding, the Gila shifted laterally consuming some of the developed floodplain. Pre-dam, the agricultural zone had been flooded regularly (Tellman, 1997, 97-108; Murphy, 1906).

### Remnant River Alluvial deposits

Qi1r "Yuma Mesa" is composed of fine grained alluvial deposits associated deposition from the Colorado/Gila Rivers, 200 ft in elevation. Similar deposits, same in elevation as the Yuma Mesa, lap onto the southeastern side of the Laguna Hills, north of the Gila River. Deposits interpreted to be related to Yuma Mesa have been dated as 40 to 70 ka using luminescence, (non published data).

QTcg "Upper Mesa" are composed of alluvial deposits with gravel lenses through out the unit. The landscape is spotted with mounds which are composed of these gravel lenses that armor the surface preventing erosion. This surface is older than the "Yuma Mesa" surface and has been associated with older Colorado River deposits. Much of the landscape has mound shaped outcrops of gravel dominated conglomerate, these outcrops have been mined for their gravel material.

## BEDROCK GEOLOGY

Bedrock in the Gila Mountains consists of a Cretaceous composite granitic suite that intrudes a sequence of foliated meta-igneous and meta-sedimentary rocks in the north and older gneissic rocks in the south. In addition, weakly consolidated conglomerates and debris flows of the Oligo-Miocene Kinter Formation are exposed at the north foot of the range and are separated from the crystalline rocks of the range by the steep Grey Fox fault zone. The historic gold placers of the Dome district were mined from the base of Quaternary sediments where they overlie the Kinter Formation. Both the Kinter Formation and Pliocene(?)-Pleistocene fan gravels were being very actively quarried for aggregate in 2006.

An impressive south-dipping shear zone is exposed at the northern end of the Gila Mountains in the northeast corner of the Fortuna Quadrangle and in the immediately adjacent part of the Ligurta Quadrangle. This zone is referred to here as the northern Gila Mountains shear zone. Foliated intrusive rocks, layered gneisses and probable Paleozoic-protolith metasedimentary rocks are interleaved in this zone. The biotite granodiorite phase of the granitic rocks of Blaisdell intrudes and truncates this zone on the south, and various mafic border phases of the granitic pluton of Blaisdell intrude within the zone. The northern boundary of the northern Gila Mountains shear zone is the steeply dipping Grey Fox fault zone. This fault juxtaposes the deformed crystalline rocks against Tertiary sandstone and conglomerate. The fault is characterized by a brittle deformation zone, and consists of several apparently en-echelon segments that step to the right from west to east across the northern end of the range. Although the Gray Fox fault zone is broadly parallel to the northern Gila Mountains Shear Zone, there is no indication that the two structures are genetically related.

The northern Gila Mountains shear zone is intruded by diorite (map unit Kd – dioritic phase of the granitic rocks of Blaisdell) that is foliated and lineated in some areas and undeformed in others. A sample of the diorite was collected for U-Pb geochronologic analysis at one location where foliation and lineation are particularly clearly developed, and lineation in the diorite is parallel to lineation in the intruded metamorphic rocks of the northern Gila Mountains shear zone (see oversized Figure 4A). Twenty-nine zircon crystals separated from this sample each yielded a $^{206}Pb/^{238}U$ date when analyzed by laser microprobe ICP-MS at the University of Arizona in a laboratory supervised by professor George Gehrels (Figure 1). The weighted mean of these dates is 73.4 ± 0.6 Ma (2σ). A sample of the unfoliated biotite granodiorite phase (map unit Kg) of the granitic rocks of Blaisdell that intruded the foliated rock units yielded a date of 74.4 ± 0.7 Ma (2σ) using the same techniques (Figure 1). The older rock unit yielded the younger date, but the 2σ uncertainties encompass a 1.5-million-year period from 73.1 to 74.6 Ma. We interpret these geochronologic analyses to indicate that both granitoid samples crystallized, and much of the penetrative deformation occurred, during this time period (73.85 ± 0.6 Ma). Deformation is weaker in the diorite than in the most strongly deformed metamorphic rocks, which probably means that the penetrative deformation began earlier.

At its southern margin, the granitic pluton of Blaisdell intrudes an assemblage of granitic gneisses. The general style of deformation in these gneisses is similar to that observed in the northern Gila Mountains Shear Zone, but the rocks are lithologically distinct. A relatively small area of these rocks was mapped in the study area, insufficient to draw conclusions as to their relationship to the gneissic rocks in the shear zone at the northern end of the range. They are considered to have a Proterozoic protolith based on their lithology and available dates from other similar gneisses in southwest Arizona. A Mesozoic metamorphic/deformation overprint seems likely given their proximity to the northern Gila Mountains Shear zone.

The non-foliated, coarse-grained granite of McPhaul Bridge is lithologically identical to granitic rocks in the southern and western Laguna Mountains, mapped as map unit qmo by Olmstead (1972), and to granite west of Laguna Dam in the southeastern California Chocolate Mountains. These rocks are reported to by dated ‘near Yuma’ by U-Pb zircon at 1440 Ma (Olmstead et al., 1973 p. 32, written communication from L.T. Silver, 1968; R. Powell, personal communication, 2006), and certainly bear a lithologic resemblance to Middle Proterozoic porphyritic granites throughout the region. These granitic rocks are overlain depositionally by coarse-grained Tertiary clastic rocks of the Kinter Formation (correlative with Tc and Tdf on this map; Olmstead, 1972; Richard, 1993b, Lombard, 1993), and are reported by Olmstead (1972) to intrude gneissic rocks of the eastern Laguna Mountains. Granitic rocks that intrude the gneisses of the Laguna Mountains, included in the same granite unit (qmo) by Olmstead (1972), are reported to be foliated to gneissic. It is possible that the weakly to strongly foliated porphyritic rocks intruding gneisses in the Laguna Mountains are correlative with the biotite augen gneiss unit (KYgn) in the northern Gila Mountains shear zone. These foliated porphyritic granitoids are interpreted here as a different granitic unit, not a deformed and metamorphosed equivalent of the granite of McPhaul Bridge. Relationships between the granite of McPhaul Bridge and other crystalline rocks in the northern Gila and Laguna Mountains are thus unclear.

## Northern Gila Mountains Shear zone

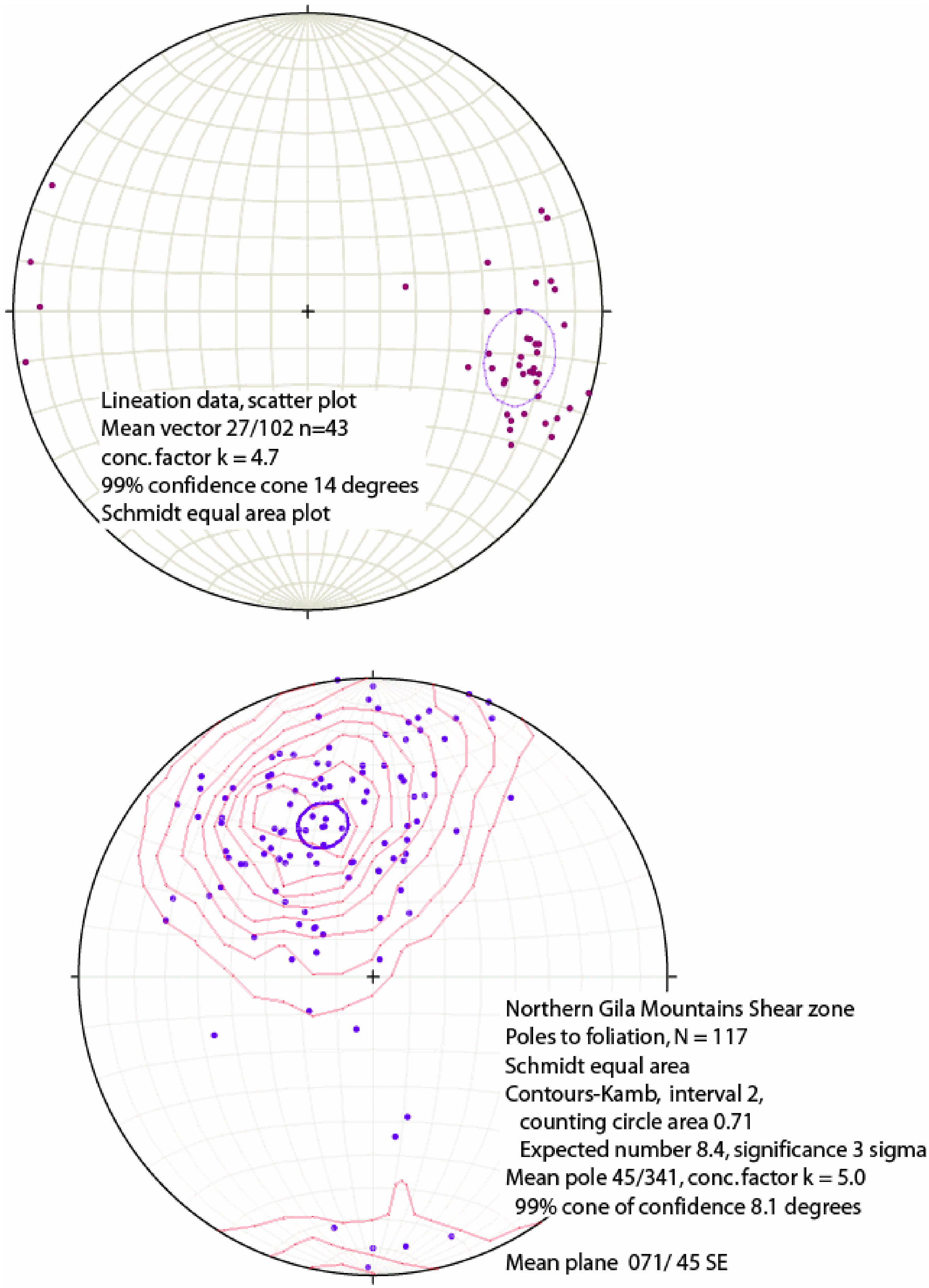
Four main assemblages of rocks are interleaved in the shear zone at the northern end of the Gila Mountains. These include: (1) biotite augen gneiss (KXgn) and associated diorite to granodiorite (KXdd); (2) grey gneiss (JXgg); (3) mafic gneiss (JXmg); and (4) Paleozoic-protolith metasedimentary rocks (Pzs and associated sub-units). The biotite augen gneiss is a rock type that has possible correlative protolith types of Early or Middle Proterozoic and Jurassic age. Isotopic data are necessary to determine the age of this unit. Contacts with structurally underlying gray gneiss and overlying gray gneiss are high strain zones characterized by some of the most strongly developed mylonitic foliation seen in the deformation zone. The contact with structurally overlying lenses of foliated diorite-granodiorite (KXdd) is always within this high strain zone. Locally the contact appears gradational (e.g., near UTM 743700E, 3624875 N), or can be observed transecting foliation, suggesting that these rocks may be related phases of a single igneous suite. Although they are not mapped, slivers of the foliated diorite-granodiorite are ubiquitous along the boundary between the biotite augen gneiss and mafic gneiss all along the central part of the shear zone.

The gray gneiss unit appears in the structurally lowest and highest position in the shear zone, and is interpreted to represent a more felsic metavolcanic assemblage with abundant associated clastic sediment and hypabyssal to plutonic granitic intrusive components. Interleaving with the mafic gneiss along their contact suggests that the felsic volcanic protolith of the gray gneiss may have been associated with the mafic volcanic protolith of the mafic gneiss. Contact at the base of the biotite augen gneiss unit with the gray gneiss is a high strain zone. Dike-like layers of fine grained granitoid similar to granitic phases in the gray gneiss are observed to cut across foliation at a low angle in the biotite augen gneiss; if these granitic rocks are related to the felsic volcanic protolith of the gray gneiss this would indicate the gray gneiss is younger. Alternatively, the fine-grained granitic intrusive rocks may post date both units.

Carbonate and quartzite metasedimentary rocks include lithologic assemblages that strongly resemble metamorphosed Bolsa (Tapeats) Quartzite, Abrigo Formation, Devonian, Mississippian or Permian carbonate rocks (e.g. Martin Formation, Escabrosa or Redwall Limestone, Naco Group, Kaibab Limestone), Supai Formation, and Coconino Quartzite that have been mapped in the Maria fold and thrust belt of west-central Arizona and adjacent California (Reynolds et al., 1986; Richard et al., 1994). Although the lithologic assemblages are typical of metamorphosed Paleozoic strata in the region, the sequencing of units is only locally consistent with that expected in a metamorphosed Paleozoic section. The complex sequencing of the lithologic facies in these metasedimentary rocks is interpreted to be the result of deformation before and during development of the northern Gila Mountains shear zone (see oversized Figure 4B). The similarity of the lithologic assemblage to Paleozoic strata in the region, and absence of any known Proterozoic or Mesozoic package of rocks that might be the protolith outweigh the inconsistent stratigraphic sequencing.

The Paleozoic-protolith rocks are consistently associated with mafic gneisses that have textures and composition suggestive of deformed, metamorphosed, mafic metavolcanic rocks. If the interpretation of supracrustal protolith for these gneissic rocks is correct, they may be Proterozoic rocks that were the substrate for Paleozoic strata when they were deposited, or represent a Mesozoic arc-related volcanic package that overlie the Paleozoic section, or be a stratigraphically unrelated assemblage juxtaposed by faulting. The degree of interleaving of the two units suggests to the author that the two units were in juxtaposition before deformation in the Northern Gila Mountains Shear Zone, but the depositional or tectonic nature of this older juxtaposition is not constrained.

The maximum exposed thickness of the shear zone is about 900 m (3000 feet) assuming an average dip for the zone of 45° (average foliation orientation is 071/45 SE, see Figure 2). Stretching lineations are prominently developed in tectonitic rocks in the shear zone, with an average orientation (n = 43) of 27/102. In some rocks, particularly the gray gneiss unit (JXgg), the 'l' fabric is the predominant fabric. Sense of shear indicators are sparse. Asymmetric augen observed in the biotite augen gneiss unit suggest top to the east sense of shear, which would make the shear zone a left normal displacement zone in its present orientation. The northern Gila Mountains shear zone is probably part of a larger zone that has been mapped and described to the west in the Cargo Muchacho Mountains of SE California and to the east in the Muggins Mountains (Smith et al.1989; Tosdal, 1990).




Foliation and lineation, Northern Gila Mountains Shear Zone

Figure 2.

## Grey Fox fault zone

The exposed bedrock of the Gila Mountains is bounded at the north end of the range by an east-northeast striking fault zone, herein named the Grey Fox fault zone (Figure 3). This fault zone is represented by one fault or two sub-parallel faults that juxtapose a variety of granitic and metamorphic rock on the south with latest Oligocene to early Miocene debris flows and related clastic rocks of the Kinter Formation on the north. Fault dip, measured at four locations, varies from 49° north to 60° south. Fault rocks are crushed over a distance of a few decimeters to a few meters, as is typical for middle to late Cenozoic high-angle faults in Arizona, and show no evidence of hydrothermal alteration or mineralization.

Coarse clastic rocks of the Kinter Formation in the northern Gila Mountains consist largely of massive to very poorly bedded, extremely poorly sorted conglomerate. Sub-angular to subrounded clasts are typically 1-100 cm in diameter and locally are as large as 3 m. Most of these deposits are interpreted as debris flows because of their massive, unsorted, and matrix-rich character. Rarely visible beds dip generally and fairly consistently to the northwest at about 20°-30° (Figure 3), with all dips in the range of 10°-40°. Weakly bedded conglomerate is more common up-section at the northernmost exposures in the Gila Mountains. Similar tilting has affected the Kinter Formation and basal sandstone and conglomerate to the northwest in the Laguna Mountains (Figure 3; Olmstead, 1972; Lombard, 1993) whereas Kinter Formation in the nearby Muggins Mountains generally dips 10°-30° to the southwest (Smith et al., 1989). The northwest-dipping Kinter Formation is not highly disrupted as would be expected for strata displaced above a low-angle normal fault, but the massive character of much of the unit could conceal significant deformation.

The age of the Grey Fox fault zone is constrained by the ages of adjacent Cenozoic sedimentary rock units. Faulting is older than the age of Pliocene(?) – Pleistocene fanglomerates that overly the west end of the fault zone. Clast types in the Kinter Formation are primarily banded, medium- to fine-grained gneiss, with less abundant granitoids and high-grade metamorphic rocks. The granitoid clasts do not contain fresh biotite books that characterize the granite that makes up the northern Gila Mountains bedrock, and are typically finer grained. Other Kinter Formation clast types are also dissimilar to bedrock exposed in the northern Gila Mountains. If the Gray Fox fault zone had been active at the time the Kinter Formation was deposited, it is likely that clasts derived from the uplifted northern Gila Mountains would be abundant in the adjacent part of the Kinter Formation. The fact that they are completely absent suggests to us that the Gray Fox fault zone was active after the Kinter Formation was deposited, not during deposition. The Kinter Formation contains a tuff bed dated at 23.6 ± 0.06 Ma (unpublished data from W. McIntosh, 1997, New Mexico Bureau of Geology and Mineral Resources, sample 4-15-94-7), which is approximately at the age of the Oligocene-Miocene boundary. We conclude that the Gray Fox fault zone was active after latest Oligocene to earliest Miocene deposition of much or all of the Kinter Formation, and is pre-Pleistocene and probably pre-late Pliocene.

The relationship between tilting of the Kinter Formation and movement on the Grey Fox fault is not known. If tilting occurred after fault movement, then the fault zone was originally sub-vertical to moderately northwest dipping, as might be expected for a steep north-side-down normal fault that was active before northwestward tilting. If tilting occurred before faulting, then the current sub-vertical character of the fault would be most consistent with a strike-slip fault origin. Furthermore, the east-northeast strike of such a strike-slip fault is suggestive of a left-lateral strike-slip fault that accommodated clockwise rotation during distributed transform motion along the Miocene continental margin of southwestern North America (e.g., Richard, 1993a; Dickinson, 1996).

## ECONOMIC GEOLOGY

### Aggregate deposits

Two incised Pleistocene to Pliocene(?) alluvial fans are present at the foot of the west side of the northern Gila Mountains (map unit QTs). The southern of these two fans contains a much greater proportion of locally derived leucogranite (map unit Kgl), whereas the northern of these two contains primarily biotite granite (map unit Kg). A large quarry operation was active at each alluvial fan in early 2006. The southern fan is here judged to contain superior material because of the reduced mica content of its granite clasts and therefore greater hardness and resistance to chemical degradation (however, we do not actually know what material properties have been identified by quarry operators as most desirable for the end users of each quarry's products). Two smaller quarries are present within the Miocene Kinter Formation along the north flank of the range, and the eastern one of these was inactive in early 2006. We suspect that the greater content of fine grain sizes, resulting in greater processing costs and waste sand and silt, make the Kinter Formation a less economically favorable aggregate source than the Pliocene(?)-Pleistocene alluvial fan deposits on the west side of the range. Land-use planning intended to preserve access to aggregate, an essential building material, could conceivable preserve these fan deposits for future aggregate production.

### Grey Fox placer deposits

The Grey Fox placer mines are within the historic Dome placer district in the northern Gila Mountains. This district was most heavily mined during 1858-1865 and has seen intermittent activity since then (Wilson, 1933). A single, 160 acre placer claim at the Grey Fox mines was being worked at the time of this investigation (Bob "The Claim Jumper," oral communication, 2006). A metal detector was being used to locate buried gold nuggets. Holes dug to recover the nuggets were generally 1-3 m deep, primarily in a bouldery wash bottom. It appeared that the recovered gold was located at the interface between the underlying Kinter Formation and overlying Quaternary fan gravels derived from the northern Gila Mountains bedrock. The only identified rock-avalanche breccia in the Kinter Formation in the northern Gila Mountains, derived from quartz-rich (~80%) metapsammite, underlies part of the Grey Fox placer mines. It is a distinct possibility that the rock-avalanche breccia formed a more resistant and consistently irregular surface for trapping placer gold from overlying stream flow than did surrounding, less resistant Kinter Formation debris flows and fanglomerates, and for this reason the Grey Fox placers are concentrated above the breccia.

## Hydrothermal mineralization

Rocks in the map area are generally devoid of apparent hydrothermal mineralization. Some chloritization and weak silicification was observed in bedrock south of the Grey Fox fault. Sites where mineralization was observed are summarized in Table 1.

Table 1. Mineralized sites

| Station | Location (UTM, zone 11, NAD 83) | Notes |
|---|---|---|
| 184 | 744976E, 3625709N | trace copper oxide minerals (chrysocolla?), on fractures in quartzite |
| 294 | 743068E, 3624802N | mine shaft, collared in fresh hornblende-biotite diorite transitional to border zone. Brittle crush zone about 40 cm thick in cut west of collar has minor brown FeOx stain, some brown Iron oxide minerals stained quartz vein material in waste around collar. Estimate shaft 50feet deep, has water in bottom. Vein material is glassy quartz with disseminated red brown hematite(?), some has interesting reddish rosy color possibly due to hematite flakes? |
| 737 | 745086E, 3620260N | about 10 cm thick silicified red brown FeOx stained biotite granodiorite; black MnOx? on fratures, muscovite on fracture surfaces in aplite. |
| 743 | 745926E, 3620972N | quartz-black calcite veins are associated with minor fault zone that here forms the boundary of the banded granitoid and aplite zone. Sparse float of 1-2 cm gobs of dark brown limonite after pyrite, appear to be related to vein. |
| 852 | 745613E, 3625736N | adit, about 50' long, cuts high angle vein. Massive bull quartz, highly fractured with black MnOx? and red brown iron oxide minerals on fractures, vein steepens upward, forms 'dike' on hill side; To south of vein is mafic gneiss with white marble and brown feldspathic quartzite lenses, with abundant blobs of diorite of Blaisdell. |
| 853 | 745641E, 3625736N | Prospect pit has dark spots of sulfide stockwork (chalcopyrite??) with chrysocolla>>malachite halos, in main vein. |

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