FLOOD CONTROL DISTRICT OF MARICOPA COUNTY

Contract FCD2003C061

Lower Centennial Wash Watershed
Zone A Delineation Study
Low Level Geomorphic Assessment
Earth Consultants International
Project #2407

Earth Consultants International

May 2, 2005
ECI Project No. 2407.01

To: **Flood Control District of Maricopa County**
2801 West Durango Street
Phoenix, Arizona 85009
Attention: **Mr. Richard Harris & Ms. Kathryne Gross**

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To: **RBF Consulting**
16605 North 28th Avenue, Suite 100
Phoenix, Arizona 85053
Attention: **Mr. Scott Larson & Mr. Paul Sclafani**

Subject: **Final Report, Lower Centennial Wash Watershed Zone A Delineation Study – Contract FCD2003C061, Task 7 – Low Level Geomorphic Assessment**

INTRODUCTION

Earth Consultants International, Inc. (ECI) has completed the Low Level Geomorphic Assessment of the Lower Centennial Wash and its tributaries, as required by Task 7 of the general scope of work contract FCD2003C061. The purpose of this low level geomorphic assessment was to analyze and document landforms in the Lower Centennial Wash study area, and to identify locations where surface geomorphology may effect channel networking and result in distributary flow. Specific tools used to map and delineate landforms include: 1) digital and stereoscopic aerial photography, 2) 7.5-minute USGS topographic quadrangle maps and 10-foot-contour elevation datasets provided by the County through RBF Consulting, 3) the NRCS soil maps for Maricopa County, 4) published geologic and alluvium maps of the area, and 5) limited field work. This report describes the methodology and criteria used to discriminate the various landforms, and how the GIS layers were constructed to compile the final maps.

Geologic and alluvium maps from the Arizona Geological Survey (AZGS) (Demsey, 1988a, 1988b, 1989; Spencer, 1995, 1990; Reynolds and Skotnicki, 1993) were scanned and rectified to coordinate system NAD 83 and used as a basis for the GIS dataset. We also imported rectified color and black-and-white aerial photography, the NRCS soil map for the study area, and several contour data sets, all supplied by the Flood Control District, for digital cross-correlation of different datasets with landform mapping. GIS polygon-shape files were completed for landforms that delineate areas of active fans, inactive fans, relict fans, pediments, alluvial terraces and alluvial plains.

Specific exhibits included with this memorandum include:

- Exhibit 1: Landform Delineation Map (11 x 17 format);
- Exhibit 2: Landform Delineation May superposed on an aerial photography background;
- Exhibit 3: Landform Delineation Map superposed on the NRCS soil maps;
- Exhibit 4: Soils with Active Fans and Channels;

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- Exhibit 5: Landform Delineation Map superposed on the geologic maps;
- Exhibit 6: Index Map to Selected Landforms;
- Exhibit 7: Geomorphology of the northern Eagle Tail Mountains;
- Exhibit 8: Geomorphology of the central Eagle Tail Mountains;
- Exhibit 9: Geomorphology of the southern Eagle Tail Mountains;
- Exhibit 10: Southwestern Distributary Flow Area;
- Exhibit 11: Northern Saddle Mountain Piedmonts – Example of Relict Fans and Pediments;
- Exhibit 12: Geomorphology of the western Saddle Mountains area; and
- Exhibit 13: Geomorphology of the western Saddle Mountains area with topographic expression.

METHODOLOGY

The Lower Centennial Wash study area incorporates a region that includes areas of riverine flooding, sheet flooding in areas of alluvial plains, alluvial fan deposition, and stable areas that are underlain by pediments and relict fans (see **Exhibits 1 - 5**). In general, the areas occupied by the alluvial plains and areas where active alluvial fan sedimentation is ongoing are defined as unstable, whereas areas of relict alluvial fans and pediments underlain by Pleistocene soils are considered stable. The stable areas are those with essentially no deposition or erosion, although most surfaces may have localized areas of distinct channelized flow (washes). Two general types of stable areas were observed: those with channelized flow in washes incised 1 to 4 m below a pediment or relict fan surface, and those with areas of channelized flow that are very close to the average elevation of the surrounding fan or pediment. In all cases where field checks were conducted, the pediments and relict fans are underlain by stage IV calcic horizons and/or well-formed argillic horizons (Typic Paleargids and Petrocalcic Paleargids), capped by well-developed desert pavements. The strength of aridisol development indicates no deposition since at least the middle Pleistocene, along with very low rates of denudation. Although sheet flooding may occur in these areas, it does not result in either deposition or widespread erosion. In contrast, the unstable areas are underlain by deposits with little or no soil development (Torrifluvents and, for early Holocene deposits, Calciorthids and Camborthids) and have sustained Holocene deposition. For more specific soil designations, see http://www.nrcs.usda.gov/ and **Exhibit 3**. Because of the scale of the mapping area, the NRCS soil codes are not printed directly on the figures. Please refer to the GIS database for complete soil code designations.

General Mapping Units

Six general mapping units were delineated on the Landform Delineation Map (**Exhibits 1 - 5**), five of which are outlined in the Maricopa County Manual on "Piedmont Flood Hazard Assessment For Flood Plain Management." The sixth mapping unit, riverine, is mapped as "Channel Deposits." Riverine systems have well-defined stream terraces that confine flood flows within their tributary drainage networks. There are some riverine areas between and within mapped units on the piedmont itself. There are places where piedmont surfaces are dissected with shallow channels, which have straight to anastomozing networks. These areas are labeled as unstable distributary flow surfaces. See the Index Map (**Exhibit 6**) for the location of specific study areas.

To distinguish the various landforms for this study, we used channel network morphology, piedmont surface texture, relative degrees of surface coloration due to desert pavement and varnish development (patina development), relative differences in vegetation density, and limited field

observations on soil characteristics. NRCS soil maps (see the appendices for specific soil unit codes and descriptions) and AZGS surficial geology maps were utilized and incorporated (see the appendices for the full AZGS report). Each of the mapped units is further defined below, as each unit relates to the specific landforms encountered in our mapping. It should be stated that the transition from one particular landform to another, such as the transition from an alluvial fan to an alluvial plain, varies both temporally and spatially; therefore, the mapped separation between such landforms as shown here should be considered transitional, and locally somewhat arbitrary. A more definite characterization of these contacts would have necessitated higher resolution mapping than that requested for this study. Each of the mapped units is described in more detail below.

Alluvial Plains (AP). Alluvial plains are defined as the very low gradient transitional areas between the piedmonts and the riverine flood areas associated with Lower Centennial Wash. They do not show evidence of distinct channelization, but rather have broad areas of distributary flow and recent sedimentation. They typically have torrifluvent soil profiles (essentially young or no soil development) and they are expected to periodically sustain future sheet flooding during periods of concentrated flow on the piedmont.

Soils on alluvial plains, as designated by the Soil Conservation Service (NRCS), generally consist of sandy loams with none to little clay content (**Exhibits 1- 4**).

Potentially Active Fans (AF). Alluvial fans are depositional landforms that typically have distributary flow that splays out from a hydrographic apex, where confined flow transitions to unconfined flow (**Exhibits 1** and **7-10** and **12-13**). Alluvial fans are topographically expressed as concave upslope contours (**Exhibit 13**), with a concave longitudinal (radial) profile and a convex transverse profile, which gives them their fan-like shape. Active fans are those that have sustained recent flooding and deposition, and are therefore underlain by young deposits with weak to absent soil development. We primarily distinguished these in the aerial photographs by their drainage patterns, their topographic expression and their lack of surface patina. All of the landforms in our study area, including alluvial fans, were identified by using low-level geomorphic assessment techniques. More detailed application of the Piedmont Assessment Manual will be necessary in the future to more accurately distinguish the types and characteristics of the landforms within the study area.

Several active alluvial fans (AF) were identified on the western flank of Saddle Mountain (**Exhibits 1** and **6** and **12-13**). They were distinguished from relict fans and pediments based on their fan-shaped topographic expression, the underlying soil types, and lack of desert pavement and channel networks. Soils underlying the fans on the western flank of Saddle Mountain are composed of sandy loams of the Anthro-Carrizo complex (AGB) with interfluves of older Gunsight-Rillito complex (**Exhibit 4).** The geologic mapping compiled by Spencer (revised in 1997) does not show active fan deposits, but depicts older middle to late Pleistocene alluvium (see **Exhibit 5**). This difference could be a result of different mapping scales and the more cautious approach implemented in this study in identifying potential non-riverine flood hazards.

Alluvial fans on the eastern flank of the Eagle Tail Mountains were mainly identified by their distributary channel network and slightly lighter surface color (**Exhibits 6** and **7-10**). The soils in this area are mostly assigned to the Anthro-Valencia association (**Exhibit 3**). The surfaces in this area may be transitional alluvial fan to alluvial plain landforms, but additional mapping is required to more precisely delineate their boundaries.

Relict Alluvial Fans (RF). Relict alluvial fans are fan remnants that are now undergoing erosion and denudation, and may no longer retain a fan shape. These deposits are fundamentally composed of ancient alluvium that, in cross-section, may still express primary sedimentary structures. For surfaces preserved on these fan remnants, they typically have well-formed soils (Petrocalcic Paleargids) that are capped by varnished, well-formed desert pavements. However, extensive portions of the relict fans may be undergoing erosion such that the original surface soils are lost (eroded) and the washes may incise into the carbonate-cemented lower portions of the soil profile. Drainages on these deposits are mostly tributary in nature, and drainage densities tend to be moderate to high, as they are undergoing active erosion and denudation.

Relict fans were identified in the aerial photographic mapping by their relative topographic position, the extent of pavement and varnish development where surfaces were preserved, their drainage densities, their contour crenulations, and their extent of soil development as mapped by the NRCS and from our limited field examinations. Given the scale of this mapping project, it was difficult to discern relict fans from extensive pediments. Many of the relict fans can be classified as fan pediments due to their well-indurated surfaces, shallow channel incision and potential for sheet flooding (**Exhibits 1 - 5**). Relict fan examples can be observed around the northern flanks of Saddle Mountain (**Exhibit 11**).

Inactive Alluvial Fans (IAF). Inactive alluvial fans are those that retain their original fan morphology with distributary flow networks. They commonly have incised through-flow channels that separate broad surfaces underlain by well-formed soils (Petrocalcic Paleargids) that are capped by varnished, well-formed desert pavements. Channels on some inactive fans appear to deepen (be more incised) towards the paleo-fanhead, whereas towards the distal portions of the fan remnants, the washes may barely be below the average fan elevation.

The inactive fans were distinguished by their fan shape with generally distributary drainage patterns, the presence of well-formed, varnished surfaces with intervening through-flow channels, and by the presence of well-developed soils as mapped by the NRCS and in our field visits. Soils underlying relict fans are mostly Harqua-Gunsight and Gunsight-Pinal complexes.

Several inactive alluvial fans (IAF) are mapped throughout the study area. For example, on the western flanks of Saddle Mountain (**Exhibit 12**), inactive alluvial fans exhibit a fan-shaped topographic expression, are generally proximal to younger active fans, but have a more moderately to well-developed desert pavement and varnish. These inactive fans often show a mottled texture in aerial photographs. Inactive fans on the western flanks of Saddle Mountain show deeper channel incision than the adjacent active fans, especially near the fan/plain transition.

Pediments (Ped, PAT, AT). Pediments are erosional landforms that develop in regions of little or no base level fall by sheet flood erosion, lateral planation from stream flow, and from stripping of old weathering regoliths. They are essentially very low energy mass transit systems that accommodate very low rates of denudation. Classic pediments are thin veneers (up to a few meters) of rubble that overlie bedrock, and they express well-developed soils that indicate their relative landscape stability. Drainage networks developed on pediments are tributary (erosional) in nature, and most are a network of washes that barely incise the pediment surface.

We distinguished pediments in the study area based on their proximity to degraded mountain fronts, their typically poorly formed tributary drainage patterns with few contour crenulations, their overall topographic expression and relatively steeper relief relative to the fans, and the presence of

inselbergs. We also used the mapped NRCS soil types as a guide in some cases. The major flood hazard associated with pediments is from sheet flooding, where very well-developed petrocalcic horizons do not allow rapid infiltration, which leads in turn to rapid surface runoff. This phenomenon is exacerbated in pediment areas where washes are shallow or non-existent. Much of the study area may be mapped as "fan pediments," consisting of ancient alluvial fan deposits that are very well indurated and therefore inhibit scouring. These surfaces are labeled as relict fans, alluvial terraces or paleoalluvial terraces (**Exhibit 1**), and are considered stable unless indicated as distributary flow areas (**Exhibit 10**).

Channel Deposits (CD). Relatively young channel deposits were identified by their channel morphology, light-colored, loose sediment, and vegetation. Many of the channels on older surfaces, such as older pediments and relict fans, are generally shallow because these older deposits have well-developed petrocalcic horizons that inhibit channel scour. In the southwestern portion of the study area (**Exhibit 10**), channels are anastomosing and appear to be shallow. This area has distributary flow and is therefore not stable.

CONCLUSIONS

This technical memorandum summarizes the Low Level Geomorphic Assessment of the Lower Centennial Wash and its tributaries, as required by Task 7 of the general scope of work contract FCD2003C061. The purpose of this work was to identify areas within the study area where riverine delineation methods should not be applied. And, depending on the landform, non-riverine analysis methods such as the Piedmont Flood Hazard Assessment Manual or the State Standard for Sheet flow may be more appropriate, specifically for active fans, alluvial plains, and other areas of distributary flow.

We used digital and stereoscopic aerial photography, 7.5-minute USGS topographic quadrangle maps and 10-foot-contour elevation datasets provided by the County through RBF Consulting, the NRCS (previously referred to as the Soil Conservation Service, SCS) soil maps for Maricopa County, published geologic and alluvium maps of the area, and limited field work to discriminate and map the various landforms, and placed the mapping into GIS layers (GIS polygon-shape files were completed for landforms that delineate areas of active fans, inactive fans, relict fans, pediments, alluvial terraces and alluvial plains) that we used to construct and compile the final exhibits.

Specific exhibits (Exhibits 1-13, respectively) included with this memorandum are: 1) a landform delineation map; 2) landform delineation superposed onto an aerial photographic background; 3) the landform delineation map superposed on the NRCS soil maps; 4) the landform delineation map of potentially active fans and active channels superposed on the NRCS soil maps; 5) the landform delineation map superposed on the geologic maps; 6) index map to selected areas; 7) landform delineation map of the northern Eagle Tail Mountains piedmont; 8) landform delineation map of the central Eagle Tail Mountains piedmont; 9) landform delineation map of the southern Eagle Tail Mountains piedmont; 10) map of distributary flow area south of the Eagle Tail Mountains; 11) landform delineation map of the northern Saddle Mountains piedmont; 12) landform delineation map of the western Saddle Mountains piedmont; and 13) map of the western Saddle Mountain piedmont with topographic expression.

We thank you for the opportunity to have worked on this project. If there are any questions regarding the content of this report or exhibits, please do not hesitate to call.

Respectfully submitted for
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Appendices:
Appendix 1: Soil Conservation Service Unit Codes and General Descriptions
Appendix 2: Open File Report 97-5 from the Arizona Geological Survey

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Demsey, K. A., 1988a, Quaternary Geologic Map of the Salome 30 X 60 Minute Quadrangle, West-Central Arizona, Arizona Geological Survey Open File Report – 88-4.

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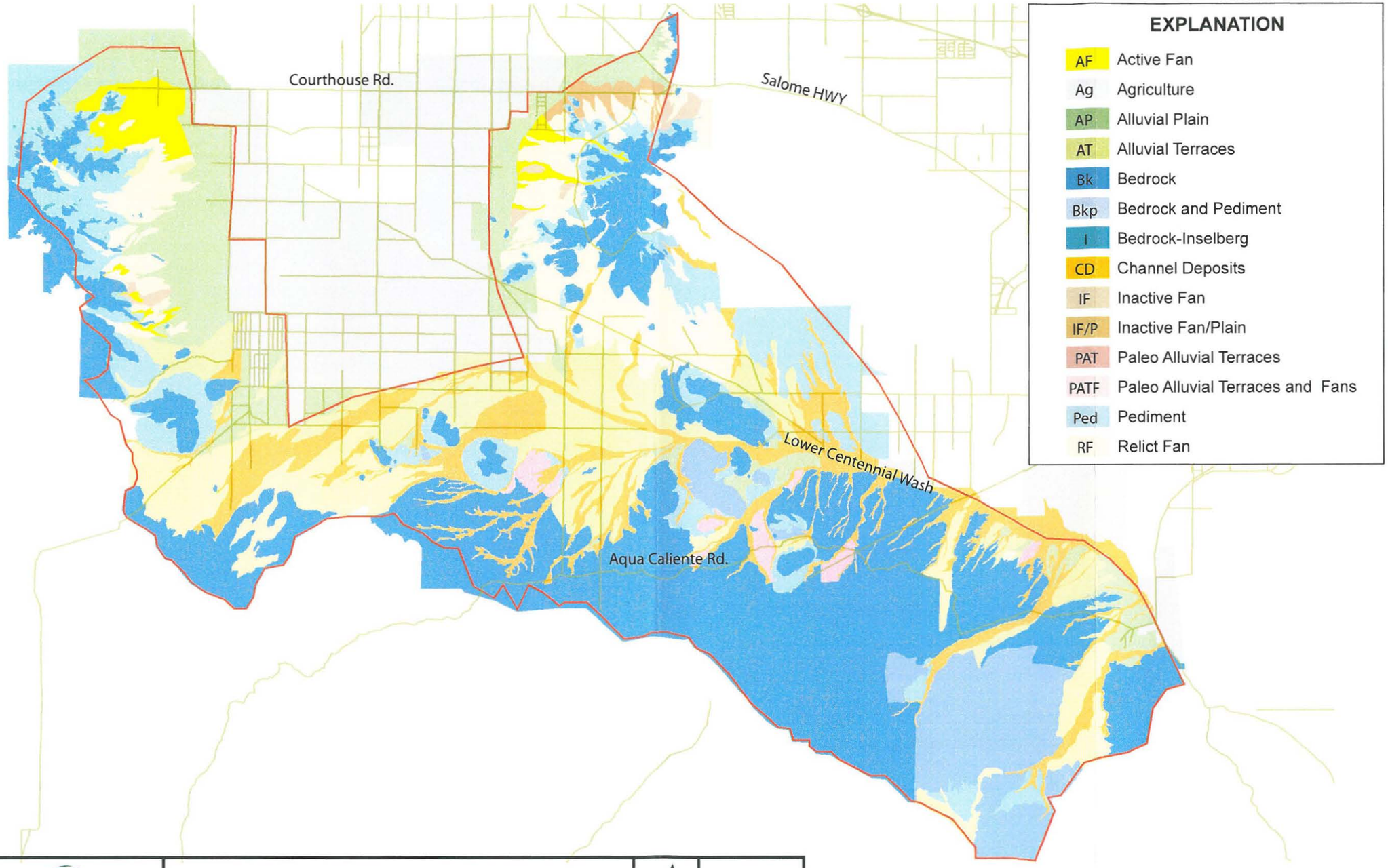
Hjalmarson, H.W., Pearthree, P.A., and Lehman, T., 2003, Peidmont Flood Hazard Assessment for Flood Plain Management, for Maricopa County, Arizona, User's Manual.

Reynolds, S. J. and Skotnicki, S. J., 1993, Geologic Map of the Phoenix South 30′ X 60′ Quadrangle, central Arizona, Arizona Geological Survey Open-File Report 93-18.

Spencer, J. E., 1995, Geologic Map of the Little Horn Mountains, 30′ X 60′ Quadrangle, southwestern Arizona, Arizona Geological Survey Open File Report 95-1.

Geographical Information Systems Soil Coverage for Aguila-Carefree Area, Parts of Maricopa and Pinal Counties, Arizona, Soil Conservation Service, SCS, http://www.nrcs.usda.gov/



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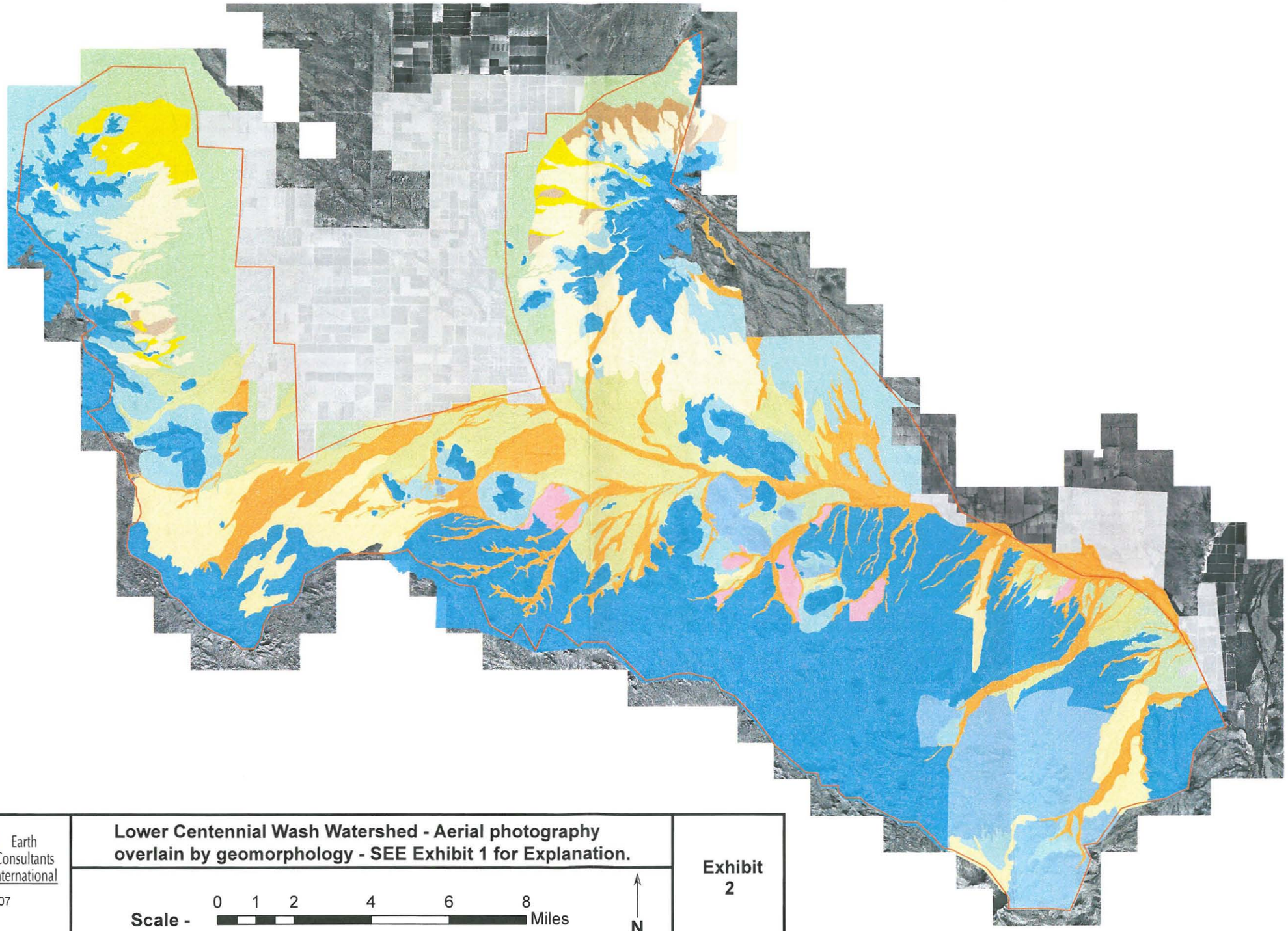
Lower Centennial Wash Watershed Geomorphology Overview & Roadways.

N

Exhibit 1



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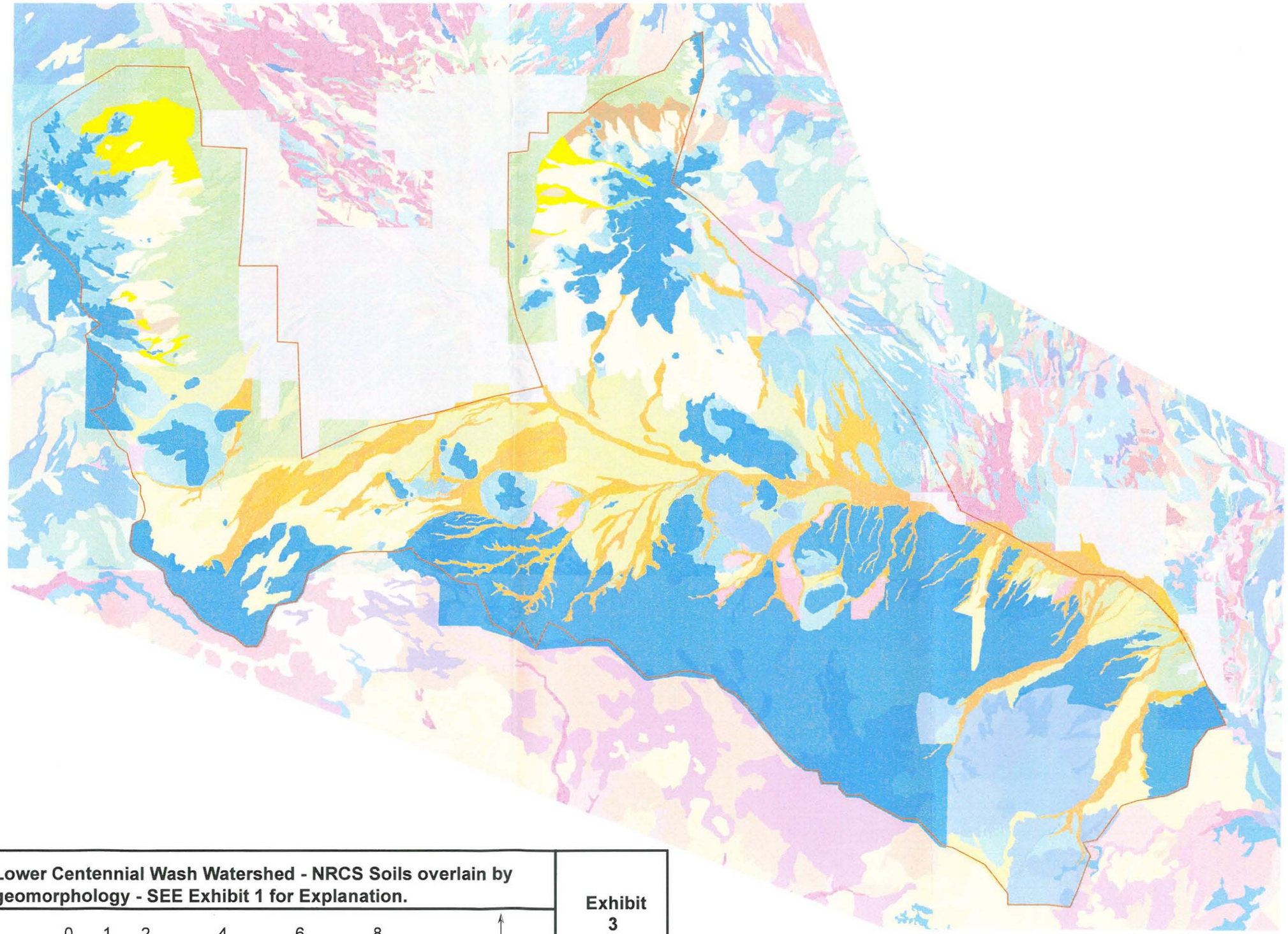
Lower Centennial Wash Watershed - Aerial photography overlain by geomorphology - SEE Exhibit 1 for Explanation.

Scale - 0 1 2 4 6 8 Miles

N

Exhibit 2



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Lower Centennial Wash Watershed - NRCS Soils overlain by geomorphology - SEE Exhibit 1 for Explanation.

Scale 0 1 2 4 6 8 Miles

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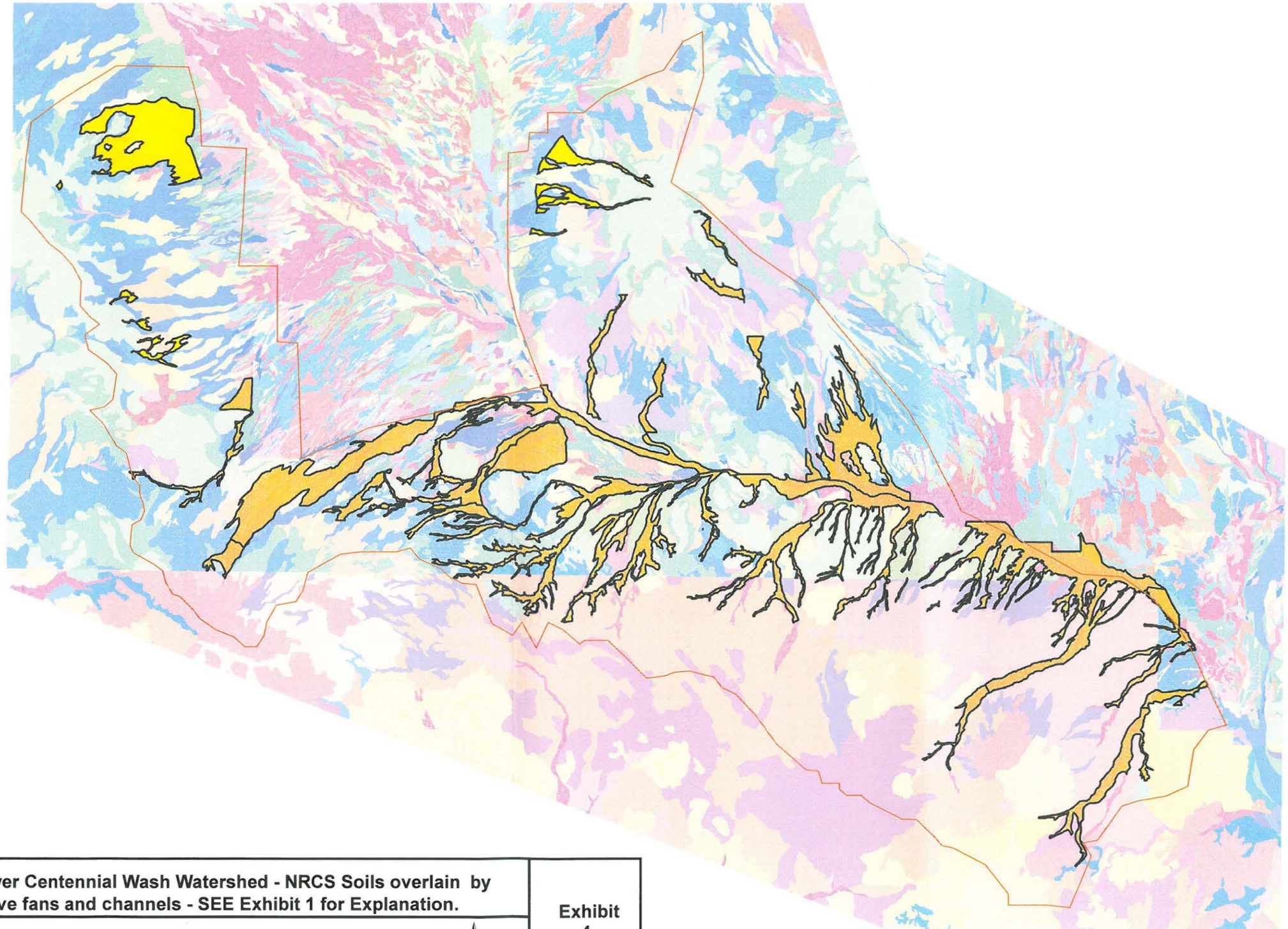
Exhibit 3



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Lower Centennial Wash Watershed - NRCS Soils overlain by active fans and channels - SEE Exhibit 1 for Explanation.

Scale 0 1 2 4 6 8 Miles

N

Exhibit 4

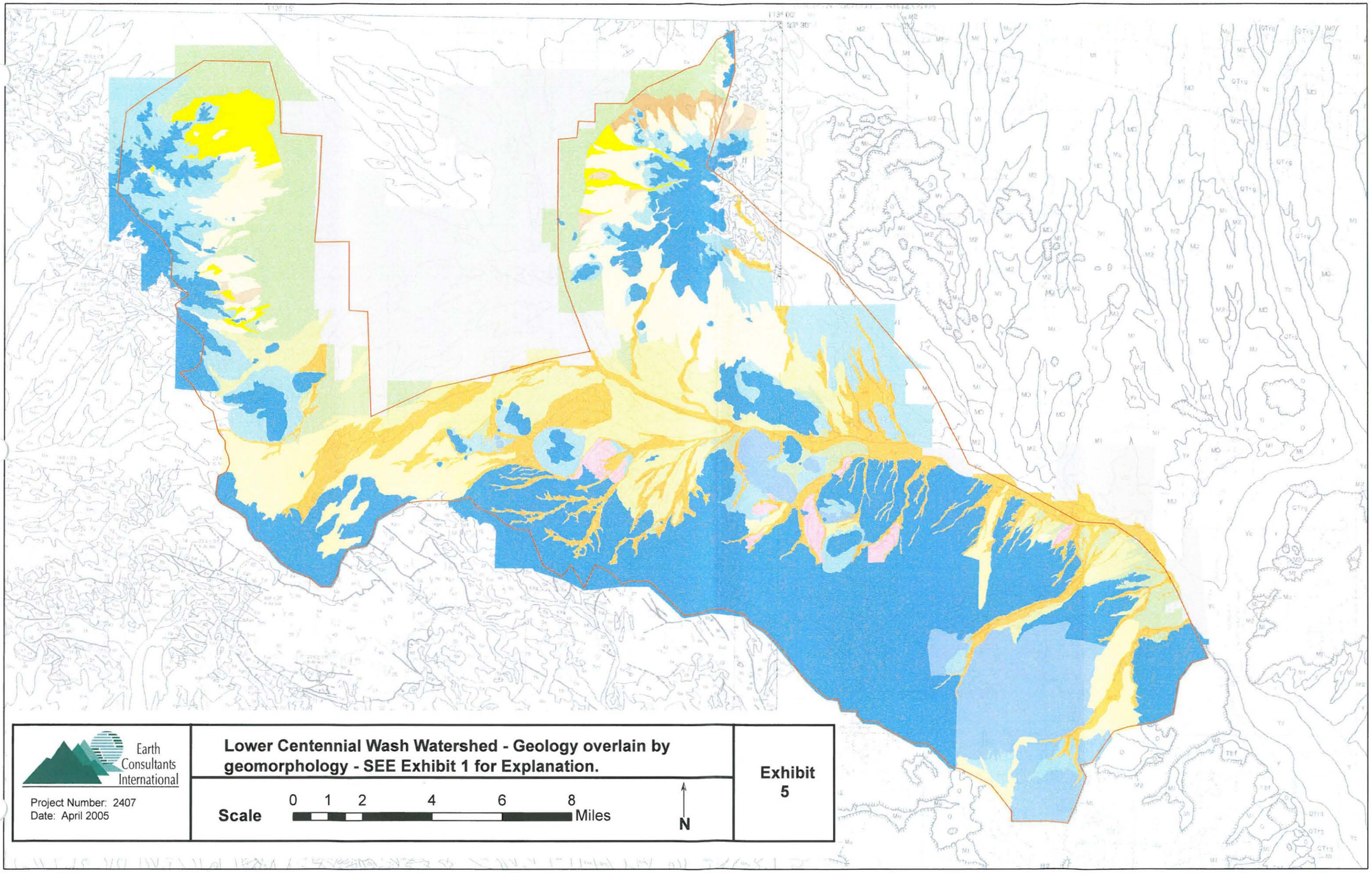
113° 15'
113° 00'
93° 30'
Earth Consultants International
Project Number: 2407
Date: April 2005
Lower Centennial Wash Watershed - Geology overlain by geomorphology - SEE Exhibit 1 for Explanation.
Scale
0 1 2 4 6 8 Miles
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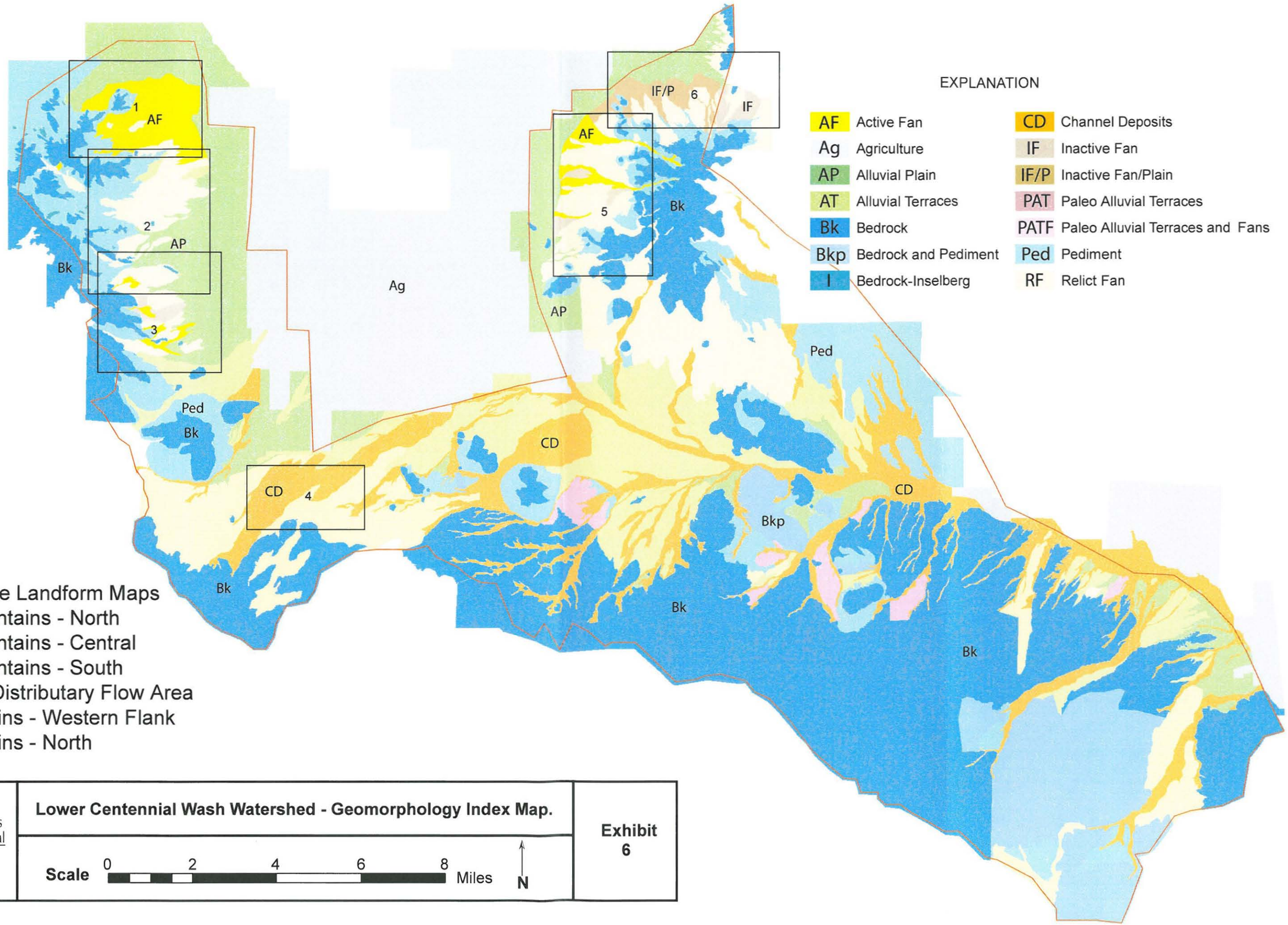
Exhibit 5



Non-Riverine Landform Maps

1. Eagle Tail Mountains - North
2. Eagel Tail Mountains - Central
3. Eagle Tail Mountains - South
4. Southwestern Distributary Flow Area
5. Saddle Mountains - Western Flank
6. Saddle Mountains - North

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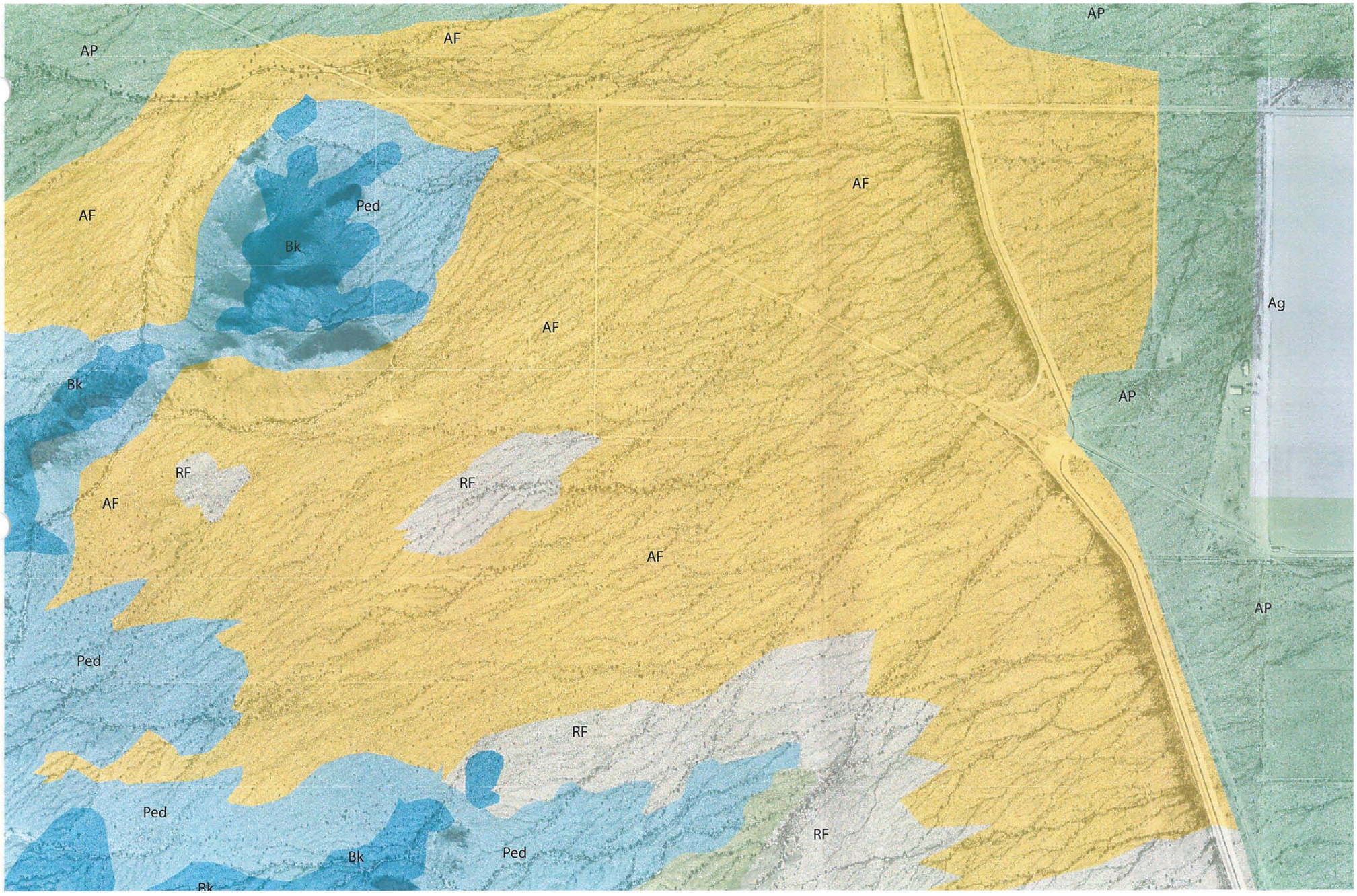
Lower Centennial Wash Watershed - Geomorphology Index Map.

Scale 0 2 4 6 8 Miles N

Exhibit 6



EXPLANATION

AF	Active Fan
Ag	Agriculture
AP	Alluvial Plain
AT	Alluvial Terraces
Bk	Bedrock
Bkp	Bedrock and Pediment
I	Bedrock-Inselberg
CD	Channel Deposits
IF	Inactive Fan
IF/P	Inactive Fan/Plain
PAT	Paleo Alluvial Terraces
PATF	Paleo Alluvial Terraces and Fans
Ped	Pediment
RF	Relict Fan

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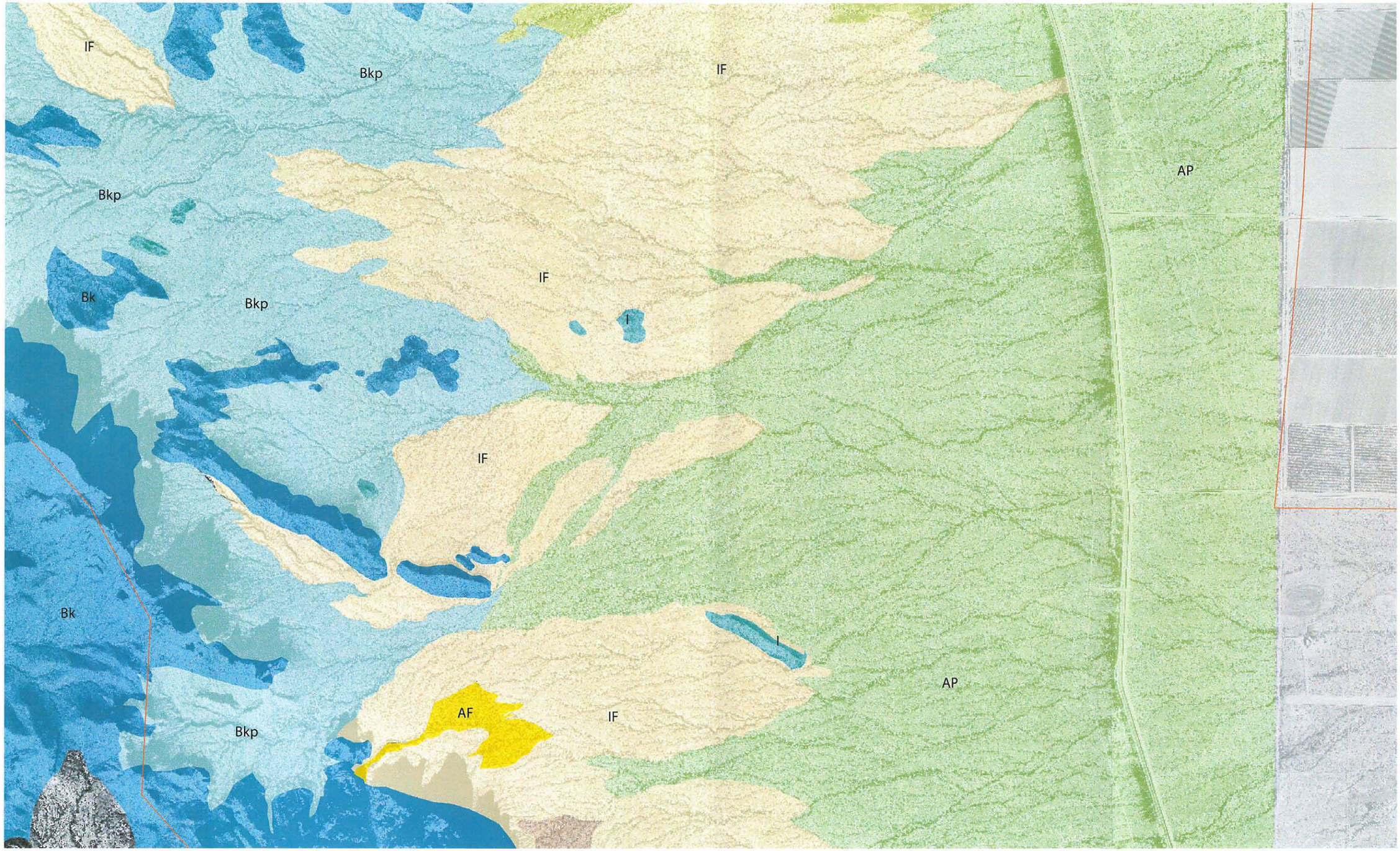
Lower Centennial Wash Watershed - Northern Eagle Tail Mountains geomorphology.

Scale 0 0.25 0.5 0.75 1 Mile

N

Exhibit 7



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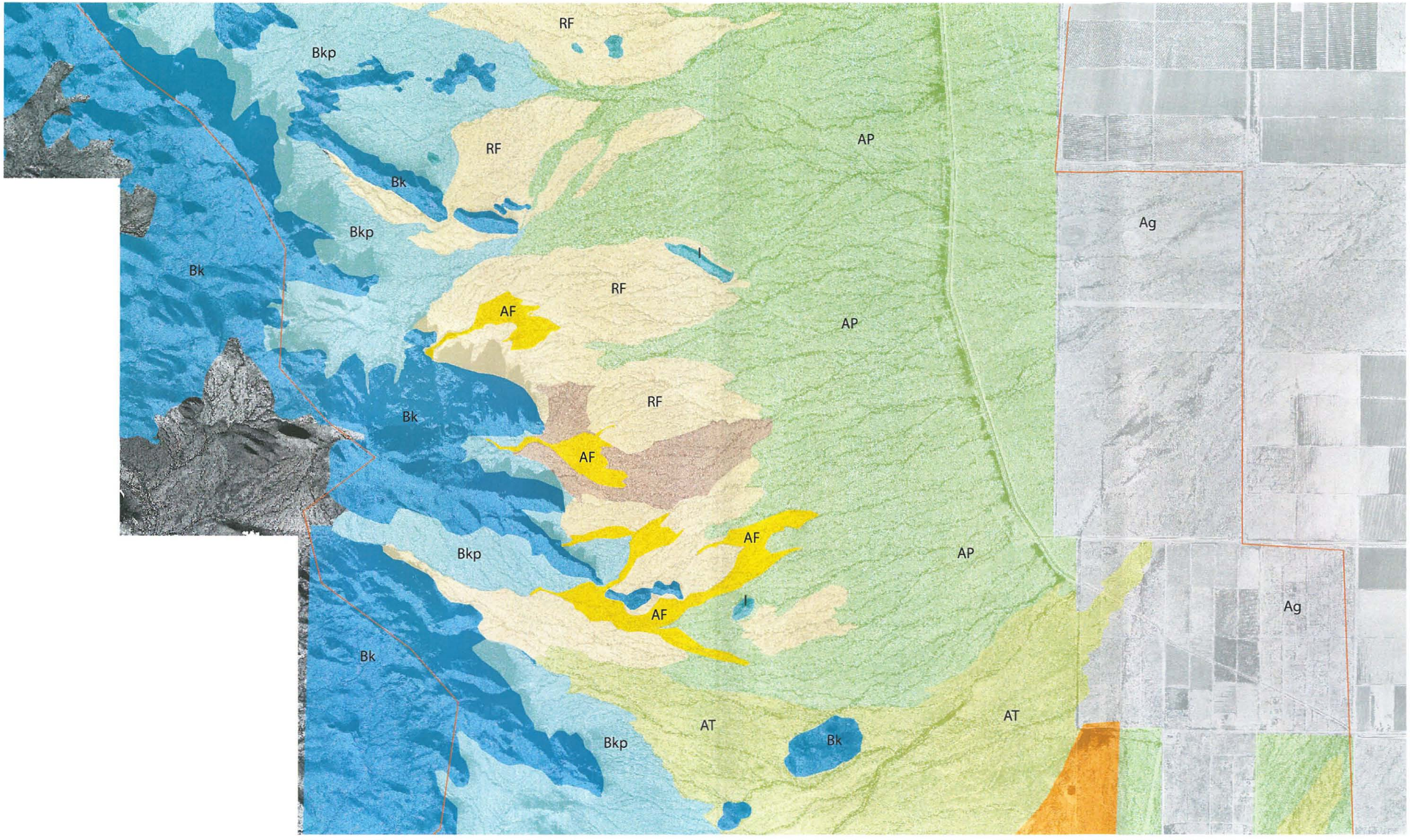
Lower Centennial Wash Watershed - Central Eagle Tail Mtns. geomorphology - SEE Exhibits 1 or 7 for Explanation.

Scale 0 0.5 1

N

Exhibit 8



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Lower Centennial Wash Watershed - Southern Eagle Tail Mtns geomorphology - SEE Exhibit 1 for Explanation.

Scale 0 — 1 Mile

N

Exhibit 9

EXPLANATION

AF	Active Fan	CD	Channel Deposits
Ag	Agriculture	IF	Inactive Fan
AP	Alluvial Plain	IF/P	Inactive Fan/Plain
AT	Alluvial Terraces	PAT	Paleo Alluvial Terraces
Bk	Bedrock	PATF	Paleo Alluvial Terraces and Fans
Bkp	Bedrock and Pediment	Ped	Pediment
I	Bedrock-Inselberg	RF	Relict Fan

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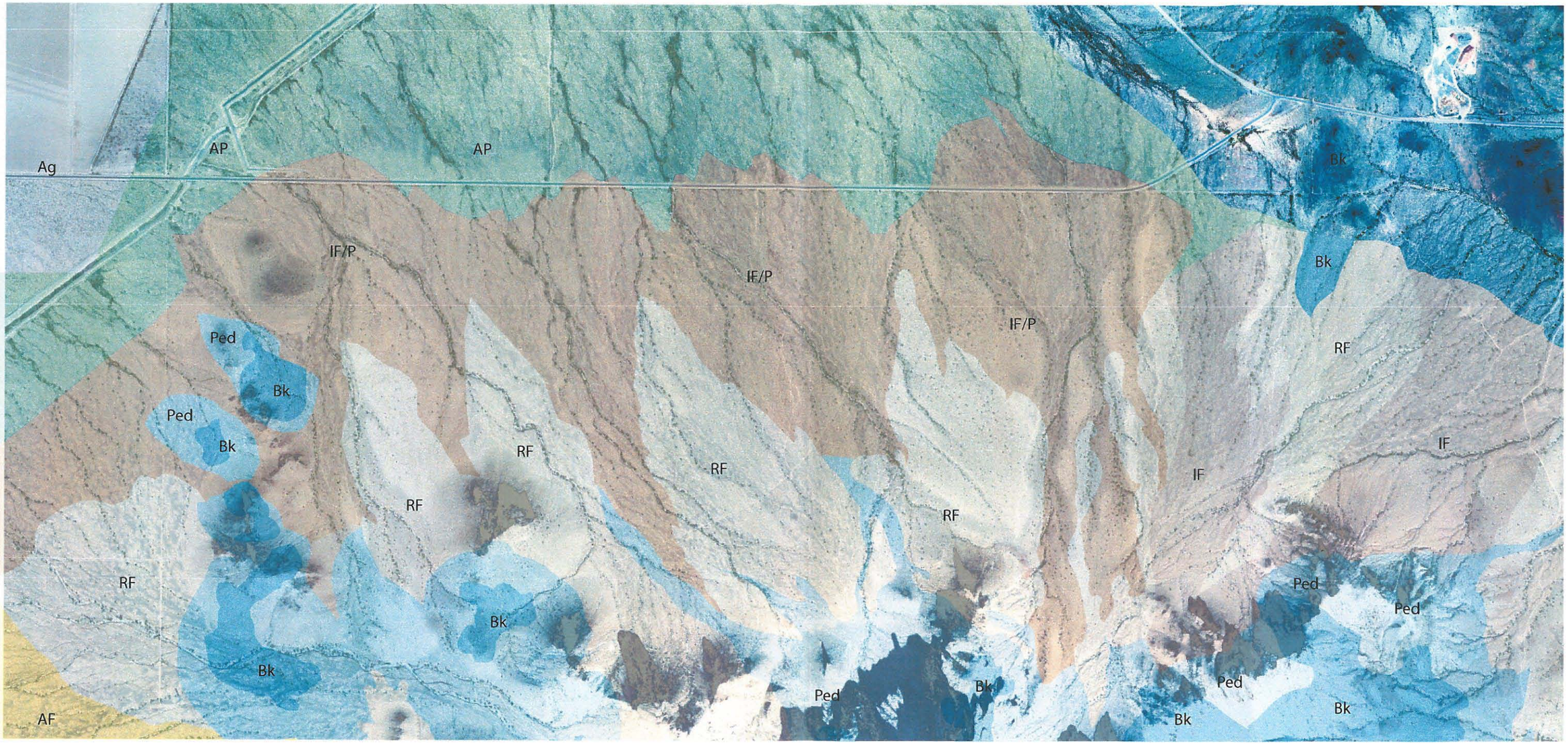
Lower Centennial Wash Watershed - Distributary flow channels, south of the Eagle Tail Mtns.

0 0.125 0.25 0.5 0.75 1 Mile

Scale

N

Exhibit 10



EXPLANATION

AF	Active Fan	CD	Channel Deposits
Ag	Agriculture	IF	Inactive Fan
AP	Alluvial Plain	IF/P	Inactive Fan/Plain
AT	Alluvial Terraces	PAT	Paleo Alluvial Terraces
Bk	Bedrock	PATF	Paleo Alluvial Terraces and Fans
Bkp	Bedrock and Pediment	Ped	Pediment
I	Bedrock-Inselberg	RF	Relict Fan

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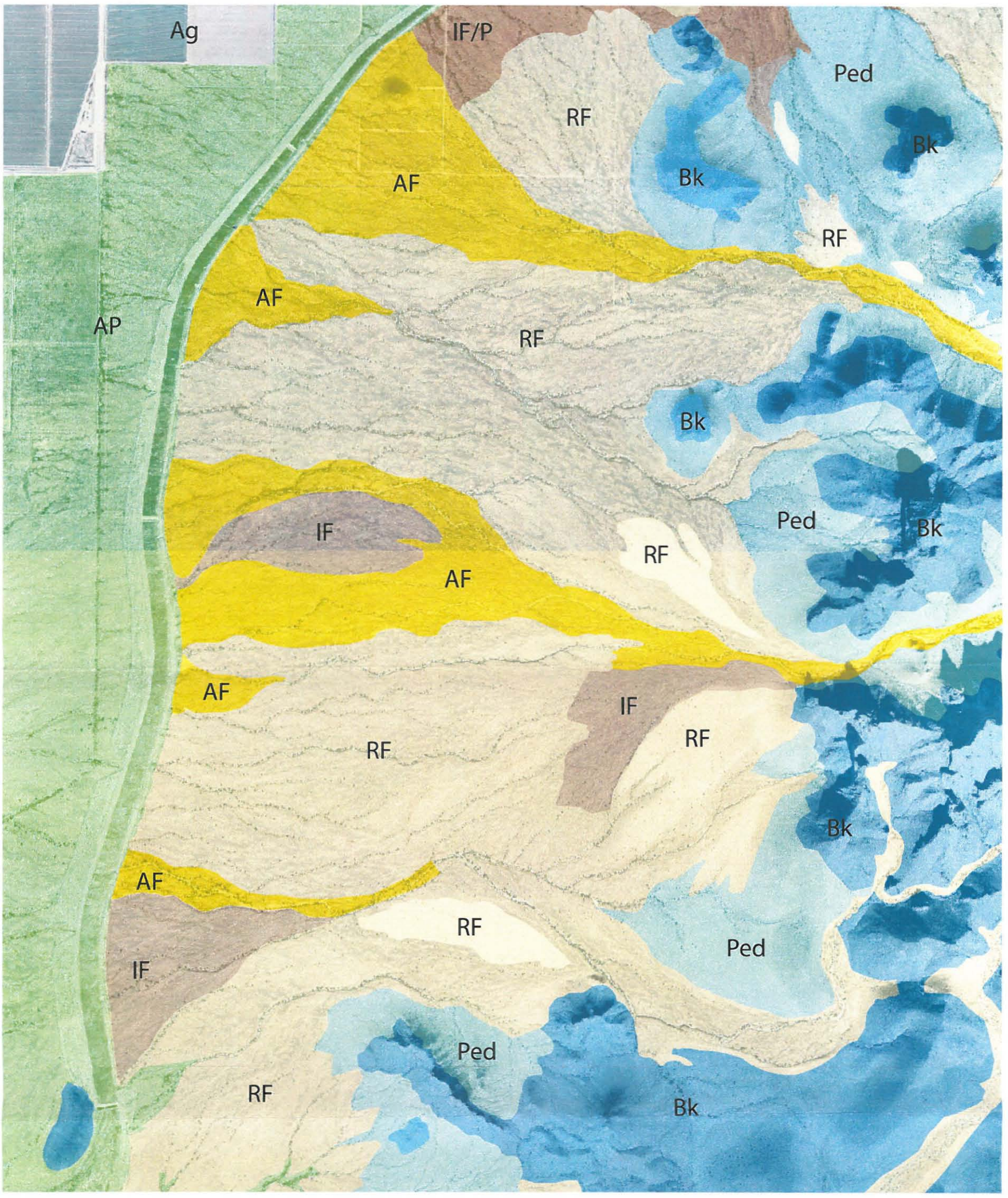
Lower Centennial Wash Watershed - Northern Saddle Mtns. geomorphology.

Scale 0 0.25 0.5 1 Mile

N

Exhibit 11



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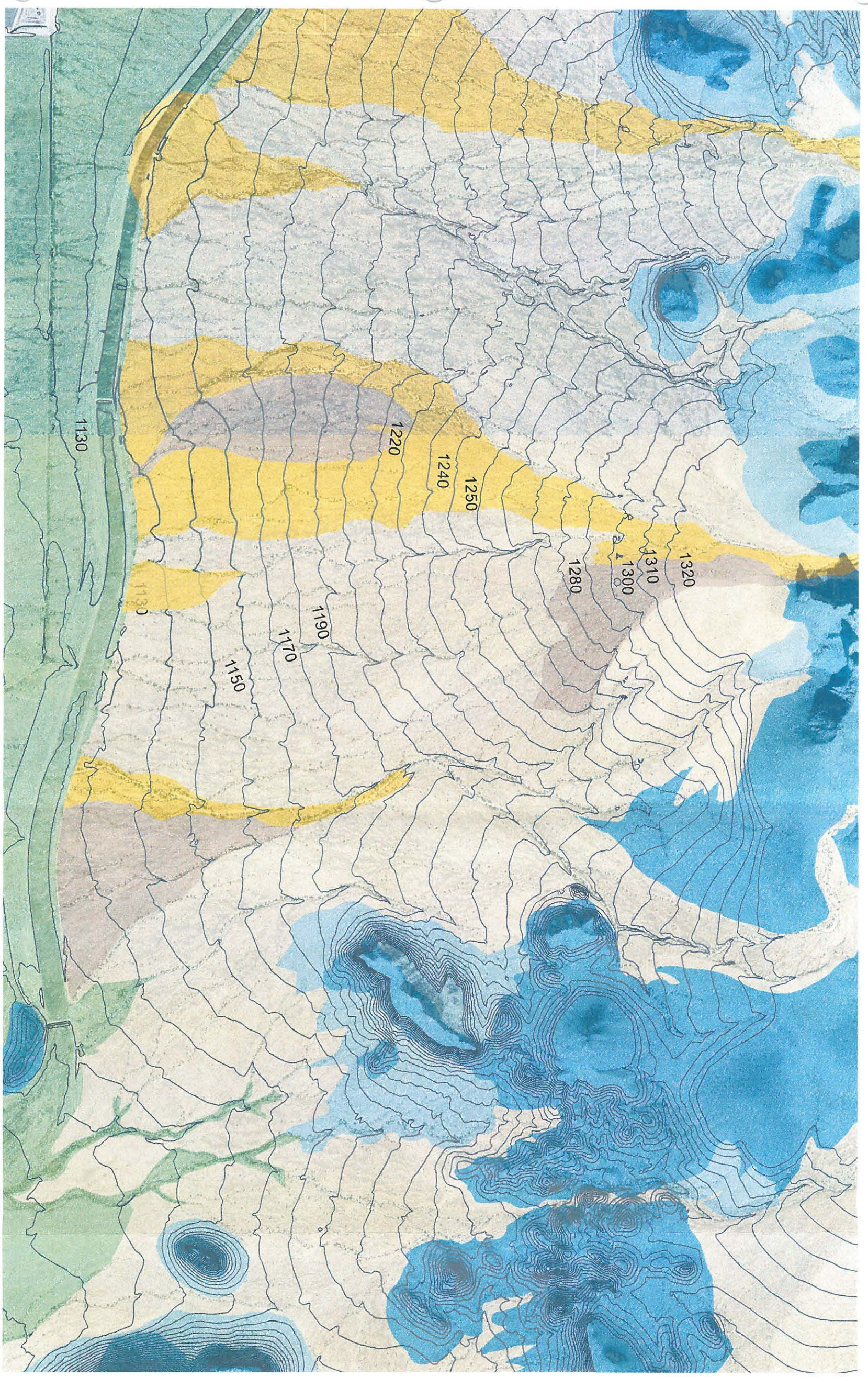
Lower Centennial Wash Watershed - Western Saddle Mtns. geomorphology - SEE Exhibit 1 for Explanation.

Scale 1 0.5 0 1 mile

N

Exhibit 12



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Lower Centennial Wash Watershed - Western Saddle Mtns. geomorphology with 10 ft contours - SEE Exhibit 1 for Explanation.

Scale 0 0.5 1 Mile

N

Exhibit 13

Appendix 1:
Soil Conservation Service Unit Codes and General Descriptions

SOIL_COD	SOIL_DFN	SOIL_COD	SOIL_DFN
	Antho sandy loams	Ap	Avondale clay loam, saline-alkali
1	Agualt and Ripley soils	BPI	Borrow pit
2	Antho gravelly sandy loams	Br	Brios loamy sand
4	Antho-Carrizo-Maripo complex, low precipitation	Bs	Brios sandy loam
6	Carrizo-Momoli complex, 0 to 3 percent slopes	Bt	Brios loam
7	Cherioni very cobbly fine sandy loam, 3 to 10 percent slopes	CA2	Calciorthids and Torriorthents, eroded
8	Cherioni-Coolidge complex, 1 to 15 percent slopes	Cb	Carrizo gravelly sandy loam
9	Cipriano-Hyder-Rock outcrop complex, 15 to 65 percent slopes	CF	Carrizo and Brios soils
10	Brios-Carrizo complex, 1 to 5 percent slopes	Cg	Casa Grande Sandy loam
11	Brios-Carrizo complex, low precipitation, 1 to 5 percent slopes	Ch	Casa Grande loam
14	Dateland-Cuerda complex, 0 to 3 percent slopes	Ck	Casa Grande complex
15	Dateland-Denure fine sandy loams, saline-sodic, 0 to 3 percent slopes	Cm	Casa Grande-Leveen complex, alkali
16	Cellar-Rock outcrop complex, 10 to 70 percent slopes	Cn	Cashion clay, saline-alkali
17	Cellar-Rock outcrop complex, low precipitation, 10 to 70 percent slopes	CO	Cheriono-Rock outcrop complex
18	Cheriono-Rock outcrop complex, 5 to 60 percent slopes	Cp	Coolidge sandy loam
19	Chuckawalla-Gunsight complex, 1 to 8 percent slopes	CrB	Coolidge gravelly sandy loam, 1 to 3 percent slopes
20	Chuckawalla-Gunsight complex, low precipitation, 1 to 8 percent slopes	CV	Coolidge-Laveen association
20	Denure-Coolidge complex, 1 to 3 percent slopes	Dn	Dune land
21	Cipriano very gravelly loam	EPD	Ebon-Pinamt complex, 0 to 10 percent slopes
21	Denure-Rillito-Why complex, 1 to 5 percent slopes	Es	Estrella loam
27	Gilman very fine sandy loam	Et	Estrella loam, saline-alkali
29	Denure-Momoli-Carrizo complex	GA	Gachado-Rock outcrop complex
30	Denure-Momoli-Carrizo complex, low precipitation	Gb	Gadsden clay loam
34	Gunsight-Chuckawalla complex, 1 to 15 percent slopes	Gd	Gadsden clay, saline-alkali
35	Gunsight-Cipriano complex, 1 to 15 percent slopes	Ge	Gilman fine sandy loam
36	Gunsight-Pinamt complex, 1 to 15 percent slopes	Gf	Gilman fine sandy loam, saline-alkali
37	Gunsight-Rillito-Carrizo complex, 1 to 15 percent slopes	GgA	Gilman loam, 0 to 1 percent slopes
40	Hyder-Gachado-Gunsight extremely gravelly sandy loams, 1 to 25 percent slopes	Gh	Gilman loam, saline-alkali
41	Indio silt loam	GL	Gilman complex, saline-alkali
42	Indio silt loam, saline-sodic	GM	Gilman-Antho association
43	Lagunita-Vint complex	GN	Gilman-Laveen association
46	Ebon-Contine complex, 1 to 8 percent	Gp	Gilman loam, clayey subsoil variant, moderately saline
47	Ebon-Gunsight-Cipriano association, 3 to 25	Gr	Glenbar loam

SOIL_COD	SOIL_DFN	SOIL_COD	SOIL_DFN
	percent slopes		
49	Ebon-Pinamt complex, 20 to 40 percent slopes	Gs	Glenbar loam, saline-alkali
49	Momoli-Carrizo extremely gravelly sandy loams, 1 to 10 percent slopes	Gt	Glenbar clay loam
50	Estrella loams	Gu	Glenbar clay loam, saline-alkali
51	Gachado-Lomitas complex, 8 to 25 percent slopes	Gv	Glenbar clay
52	Gachado-Lomitas-Rock outcrop complex, 7 to 55 percent slopes	GWD	Gunsight-Pinal complex, 1 to 10 percent slopes
53	Quilotosa-Momoli-Carrizo complex, 1 to 15 percent slopes	GxA	Gunsight-Rillito complex, 0 to 1 percent slopes
54	Quilotosa-Rock outcrop complex, 15 to 55 percent slopes	GxB	Gunsight-Rillito complex, 1 to 3 percent slopes
55	Riverwash	GYD	Gunsight-Rillito complex, 0 to 10 percent slopes
56	Gilman loams, low precipitation	HAB	Harqua complex, 0 to 3 percent slopes
56	Rock outcrop-Hyder complex. 25 to 65 percent slopes	HAC	Harqua complex, 3 to 8 percent slopes
58	Schenco-Laposa-Rock outcrop complex, 10 to 55 percent slopes	HLC	Harqua-Gunsight complex, 0 to 5 percent slopes
59	Gilman-Momoli-Denure complex, low precipitation	HM	Harqua-Laveen complex
61	Vaiva-Quilotosa extremely gravelly sandy loams, 3 to 25 percent slopes	HrB	Harqua-Rillito complex, 1 to 3 percent slopes
65	Greyeagle-Continental-Nickel association, 1 to 40 percent slopes	La	La Palma very fine sandy loam
66	Why gravelly fine sandy loam	Lb	Laveen sandy loam
67	Why-Carrizo complex, 0 to 3 percent slopes	LcA	Laveen loam, 0 to 1 percent slopes
68	Gunsight-Cipriano complex, 1 to 7 percent slopes	Ld	Laveen loam, saline-alkali
69	Gunsight-Cipriano complex, low precipitation, 1 to 7 percent slopes	Lf	Laveen-Antho complex, saline-alkali
70	Gunsight-Rillito complex, 1 to 25 percent slopes	Ma	Maripo sandy loam
71	Gunsight-Rillito complex, low precipitation, 1 to 40 percent slopes	Mo	Mohall sandy loam
75	Mohall loam	Mp	Mohall loam
91	Momoli-Carrizo complex	Mr	Mohall clay loam
92	Momoli-Carrizo complex, low precipitation	Pa	Perryville sandy loam
98	Pinamt-Tremant complex, 1 to 10 percent slopes	Pb	Perryville loam, saline-alkali
99	Pinamt-Tremant complex, low precipitation, 1 to 10 percent slopes	PeA	Perryville gravelly loam, 0 to 1 percent slopes
100	Quilotosa-Vaiva-Rock outcrop complex, 20 to 65 percent slopes	PeB	Perryville gravelly loam, 1 to 3 percent slopes
102	Rillito gravelly loam, 1 to 8 percent slopes	PsA	Pinal loam, 0 to 1 percent slopes
103	Rock outcrop-Gachado complex, 5 to 55 percent slopes	PsB	Pinal loam, 1 to 3 percent slopes
106	Sal-Cipriano complex, 1 to 10 percent slopes	PT	Pinal gravelly loam
107	Sal-Cipriano complex, low precipitation, 1 to 10 percent slopes	PWB	Pinal-Suncity complex, 0 to 3 percent slopes
108	Schenco-Rock outcrop complex, 3 to 25 percent slopes	PYD	Pinamt-Tremant complex, 1 to 10 percent slopes
109	Schenco-Rock outcrop complex, 25 to 60 percent slopes	RaA	Rillito sandy loam, 0 to 1 percent slopes
110	Suncity-Cipriano complex, 1 to 7 percent slopes	RbA	Rillito loam, 0 to 1 percent slopes
112	Tremant gravelly sandy loams	RhB	Rillito-Harqua complex, 1 to 3 percent slopes
114	Tremant gravelly loams, low precipitation	RS	Rock outcrop-Cherioni complex

SOIL_COD	SOIL_DFN	SOIL_COD	SOIL_DFN
115	Tremant-Antho complex, 1 to 5 percent slopes	TB	Torrifluvents
116	Tremant-Gunsight-Rillito complex, 1 to 5 percent slopes	TD	Torripsamments and Torrifluvents, frequently flooded
123	Vaiva very gravelly loam, 1 to 20 percent slopes	Te	Tremant loam
126		TfA	Tremant gravelly loam, 0 to 1 percent slopes
Aa	Agualt loam	Tg	Tremant clay loam
AbA	Anthosandy loam, 0 to 1 percent slopes	Th	Tremant gravelly clay loam
AbB	Antho sandy loam, 1 to 3 percent slopes	TrA	Tremant-Rillito complex, 0 to 1 percent slopes
Ac	Antho sandy loam, saline-alkali	TSC	Tremant-Rillito complex, 0 to 5 percent slopes
AdA	Antho gravelly sandy loam, 0 to 1 percent slopes	Tu	Tucson loam
AdB	Antho gravelly sandy loam, 1 to 3 percent slopes	Tw	Tucson clay loam
Ae	Antho-Brios sandy loams	Va	Valencia sandy loam
AfA	Antho-Carrizo complex, 0 to 1 percent slopes	Vb	Valencia sandy loam, saline-alkali
AfB	Antho-Carrizo complex, 1 to 3 percent slopes	Vc	Valencia gravelly sandy loam
AGB	Antho-Carrizo complex, 0 to 3 percent slopes	Ve	Vecont loam
AHC	Antho-Tremant complex, 1 to 5 percent slopes	Vf	Vecont clay
AL	Antho association	Vg	Vint loamy fine sand
AM	Antho-Valencia association	Vh	Vint fine sandy loam
An	Avonda clay loam	Vk	Vint loam
Ao	Avondale clay loam	Vr	Vint-Carrizo complex

Appendix 2:
Data Structure for Arizona Geological Survey Digital Geologic Maps

by
Stephen M. Richard and Jennifer P. Thieme
Open-File Report 97-5
Version 1.3

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Introduction

This document describes the database structure for Arizona Geological Survey digital geologic maps. The database structure was designed using a proposed standard format from the U.S. Geological Survey [USGS, 1995] as a guide. Similarities and differences between our data structure and the proposed standard are described throughout the text. This document is a working document. As new maps are digitized and problems or deficiencies with this system are recognized, modifications will be made. It is anticipated that the most common modification will be the addition of descriptor codes in Tables 2, 3 and 5. It is assumed that the reader is familiar with the basics of Arc/Info data organization.

Digitizing Procedures

The 1:100000 scale maps have been digitized using PC Arc/Info 3.4.2 and a Calcomp Drawingboard II table digitizer. The source of the line work and structural data was the mylar originals compiled for published 1:100000-scale geologic maps. The map projection of the coverages is Universal Transverse Mercator (UTM), zone 12; map units are meters, with a -3.2×10^6 yshift. Arcs are digitized in the Arcedit module using stream mode with the weed tolerance set at 5.08 meters. Lines are later smoothed with the Arcedit spline command with the grain tolerance set at 40 meters. Ornamented arcs (lines with attached symbols indicating slip, separation, or dip of fault) are digitized such that as the arc is transversed from the start to end node, the ornamentation is on the right side. After the linework is complete, the file is generalized with a 5 meter weed tolerance to reduce the number of vertices in the straighter arcs.

Coverages

The following table summarizes the coverages and shapefiles possibly included with each geologic map, and the user-defined features included in their feature attribute tables. Field definitions are in parenthesis. I is an integer field, C is a character field, and the number indicates the width.

Table 1. Summary of coverages or shapefiles and their associated database tables

Coverage	Type	PAT	AAT	Related tables	Notes
Geology (included for all digital maps)	Poly & Arc	unit (C,6)	Type (I,4), Accuracy (I,1), Descriptor (I,3), Identifier (C,10), LinkTable (I,3)	Units.dbf (related with "unit" field)	Coverage includes all faults and contacts. Related table, units, includes formation and age data as well as links to additional tables with suggested color and pattern data.
Lines (included if applicable)	Arc		Type (I,4), Accuracy (I,1), Descriptor (I,3), Identifier (C,10), LinkTable (I,3)		Includes all lines except contacts and faults.
Structur (included if applicable)	Point	Type (I,4), Mod1(C,1), Strike (I,3), Dip (I,2), Mod2 (C,2), Loc_ID (C, 6)			Includes point structure data with associated numerical measurements to the nearest degree; may include coincident points if several measurements made at same outcrop, linked by Loc_ID.
OthrArea (included if applicable)	Poly & Arc	Type (I,4), Identifier (C,10), LinkTable (I,3)	Accuracy (I,1)		Includes linework to define areas not based on map units (alteration, metamorphism, geomorphic features).
Location (included if applicable)	Point	Type (I,4), Identifier (C,10), LinkTable (I,3)			Includes points defining locations of sample collection, mines, wells, etc.
Label (included if applicable)	Point	Type (I, 4)			Includes point locations of graphical elements for map composition; not linked to actual geographic locations.
Shapefile					
Index (included if citation information is available)	Poly	unique_id		sources.dbf (related with "unique_id" field)	Shapefile includes polygons delineating extent of source maps used to compile the generalized map. Related table, source.dbf, contains citations information for the sources.

Geology Coverage

One polygon and arc coverage will include contacts and faults that define the boundaries between map units.

Polygon features

The PAT for this coverage will contain one feature.

- UNIT: A character field. Character strings are equivalent to unit labels on maps. See the coverage's metadata, field 5.2.1, and related table, units.dbf, for a list of unit labels and their explanations.

Arc features

The AAT will contain 5 fields, see Table 2 for a complete list of AAT codes.

- TYPE: An integer field with 4 digits.

  First (leftmost) digit describes the general feature the line represents:

4: Line on the surface of the Earth (e.g. crater outline, lava pond outline, foot of lava flow lobe, landslide scarp, crest line glacial moraine, fluvial terrace scarp, shoreline, top of fault scarp)

5: Line projected to surface of the Earth (e.g. isopachs, structure contours)

6: Line representing intersection of geologic surface with surface of the Earth (contacts, faults, shear zones)

7: Line representing intersection of two geologic surfaces projected to the surface of the Earth. (marker bed cutoff at fault)

8: Line, degenerate area represented by line (dike trace, vein trace)

Last 3 digits describe the specific feature. Codes for this come from first minor code described in USGS [1995]. e.g. 6010 is a fault.

- ACCURACY: An integer with 1 digit.

  Digit defines accuracy. Codes are minor codes from USGS [1995], with addition of code for solid (accurate) line.

  5: Accurate to line width (.2 mm) at scale of map. Default value

  1: Approximately located

  2: Inferred

  3: Concealed

  4: Gradational or mixed

  6: Undefined

- DESCRIPTOR: An integer with 3 digits.

  Digits are minor codes in USGS [1995]. Additional codes have been added for features not listed in the USGS report. Meaning varies according to TYPE.

- IDENTIFIER: A character string used to relate to associated table of additional information (e.g. name of fold or marker bed)

- LINKTABLE: An integer with 3 digits used to lookup file name of table containing related data.

Examples of attribute codes for arc features in the *geology* coverage:
approximate normal fault—Type: 6010, Accuracy: 1, Descriptor: 010;
accurate thrust fault—Type: 6010, Accuracy: 5, Descriptor: 020

Related tables

Related table, *units.dbf*, will contain 4 fields

- UNIT: A character string with the abbreviation of the formation name. This is the field used to join with the geology.pat.
- FORMATION: A character string with a short formation description for the map unit.
- SORT CODE: An integer field with numbers assigned to age, used to sort the list in reverse chronological order.
- AGE: A character string with the geologic age of the map unit.

Lines Coverage

One coverage, named 'lines' for all linear features not representing contacts and faults. This coverage includes all linear geologic features that do not bound rock units, including fold hinge-surface traces, degenerate areas like dikes, marker beds, etc.

Arc features

The AAT will contain 5 fields equivalent to the items in the *Geology* coverage. See Table 2 for a complete list of AAT codes.

Table 2. AAT codes currently in use for Geology and Lines coverages:

Type: (I, 4) [geotype.dbf]

code	feature
6001	Contact
6010	Fault
6020	Fold Trace
8001	Dikes & Veins
8002	Marker Beds
3333	Border

Accuracy: (I, 1) [geoaccu.dbf]

code	feature
5	Accurate to line width (0.2 mm) at scale of map
1	Approximately located
2	Inferred
3	Concealed
4	Gradational
6	Undefined

Descriptors (I, 3)

Faults (6010) [geofault.dbf]

code	descriptor
010	Unclassified
011	*Sub vertical**
012	*Normal**
013	Generic high angle w/
014	Reverse
016	*Strike slip**
017	Right lateral strike slip
018	Left lateral strike slip
019	Oblique slip
020	Thrust
024	Overturned thrust
025	Low angle normal
026	Detachment
027	Generic low angle
028	High angle normal
033	Right normal oblique slip
034	Left normal oblique slip
035	Right reverse oblique slip
036	Left reverse oblique slip
037	Shear zone

**italic numbers and descriptors are no longer used.*

Fold Traces (6020) [linefold.dbf]

code	descriptor
001	Antiform
002	Synform
003	Monocline unspecified
004	(not assigned)
005	Anticline upright
006	Anticline overturned
007	Anticline Inverted
008	(not assigned)
009	(not assigned)
010	Syncline upright
011	Syncline overturned
012	Syncline inverted
013	(not assigned)
014	(not assigned)
015	Monocline anticlinal bend
016	Monocline synclinal bend

Dikes & Veins (8001) [linedike.dbf]

code	descriptor
001	mafic
002	intermediate
003	felsic
004	pegmatite
005	old mafic

Marker Beds (8002) [linembed.dbf]

code	descriptor
001	Ferruginous quartzite
002	Conglomerate

Structure Coverage

Coverage of point features associated with structural orientation data.

Point features

The PAT will contain six items.

- TYPE: An integer with 4 digits. Derived from the USGS OFR major code 600 series. The codes are listed in Table 3.
- MODIFIER1: A character, width 1, describing the method or certainty of structural data. The default for this field is 's'. Modifiers listed in Table 4.
- STRIKE: An integer with 3 digits for strike or trend, user right-hand rule to define dip direction.
- DIP: An integer with 2 digits for dip.
- MODIFIER2: A character with 2 digits. Modifier from Table 5; meaning varies according to TYPE. Default value is '1'.
- LOC_ID: A character field, width 6. It is a unique identifier for linking data. May be used to link structural data acquired in the same location, e.g. when more than one foliation or lineation is measured in a given outcrop, or for linking measured orientations of faults and contacts with the lines representing the trace of those surfaces. If the first character is a number, reference is to Loc_ID in Structur\pat.dbf; if G, reference is to User_ID in Geology\aat.dbf; if L, reference is to user_ID in lines\aat.dbf. Default value is '0'.

Table 3. AZGS attribute codes for structure data [strutype.dbf]

PLANAR STRUCTURES	
Primary foliations	
Type code (0NNN)	*Feature*
1	strike and dip of bedding
2	massive igneous rock
3	igneous flow foliation (includes flow banding in lava)
4	eutaxitic foliation in welded tuff
5	cumulate foliation in igneous rocks
6	
7	
8	
9	
Tectonic foliations	
generic	
Type code (0NNN)	*Feature*
10	generic foliation
11	generic crystalloblastic foliation
12	generic cleavage
13	generic shape (mylonitic) fabric
14	
15	
16	
17	
18	
19	

differentiated foliations

20	gneissic layering (compositional banding)
21	laminated differentiated foliations
22	layering derived from bedding (transposed)
23	layering derived from bedding w/ tops
24	

mineral alignment foliations

25	schistosity
26	
27	
28	
29	

disjunct foliations

30	joints
31	spaced disjunct cleavage/close joints
32	close disjunct cleavage ('fracture cleavage')
33	
34	

mylonite series (TRIG/shape foliations)

35	weak shape fabric
36	well developed s-tectonite
37	protomylonite
38	mylonite
39	ultramylonite

composite fabrics

40	cleavage parallel to bedding
41	
42	
43	
44	

geometrical fabrics

45	continuous crenulation
46	axial surface to fold (no associated foliation)
47	
48	
49	

other discontinuities

50	*faults**
51	vein
52	minor faults
53	
54	

LINEAR STRUCTURES

Primary lineations

Type code (0NNN)	*Feature*
55	generic
56	tool marks
57	flute casts
58	flow feature in igneous flow foliation
59	

Tectonic lineations

Type code (0NNN)	*Feature*
60	generic lineation
61	groove or striae in surface
62	stretch/shape lineation (mylonitic)
63	mineral lineation (mod2 to indicate mineral and generation)

	64	intersection lineation; bedding/cleavage
	65	intersection lineation; Sn/Sn+1
	66	
	67	
	68	
	69	
Folds		
	70	fold hinge orientation, associated with map-scale fold
	71	generic minor fold hinge orientation
	72	minor fold hinge orientation, antiform
	73	minor fold hinge orientation, anticline
	74	minor fold hinge orientation, synform
	75	minor fold hinge orientation, syncline
	76	cascade folds, hinge orientation, no asymmetry
	77	asymmetric minor fold hinge orientation
	78	
	79	
	80	
	Other	
	81	apparent dip
	90	contact orientation (dip direction & dip)
	91	fault orientation (dip direction & dip)
	92	other line feature orientation (i.e. veins & dikes)

**italic numbers and descriptors are no longer used.*

Table 4. Modifier 1 codes [strumod1.dbf]

code	meaning
s	standard, on-site measurement of planar foliation
a	approximate measurement
I	contorted or irregular orientation, generalized
p	photogeologic determination

Table 5. Modifier 2 codes [strumod2.dbf]

Table 5a. Facing direction: use with any primary foliation symbol (1-4):

code	meaning
u	upright
ut	upright, tops indicator seen
o	overturned
ot	overturned, tops indicator seen
d	doubly overturned
dt	doubly overturned, tops indicator seen

Table 5b. Generation: use with any tectonic foliation or lineation: number indicates generation of structural feature--either in given outcrop or regionally

code	meaning
1	Oldest structure recognized
2	Younger than generation 1, older than generation 3
3	Younger than generation 2, older than generation 4
etc.	

Table 5c. Veins and mineral lineations (51, 63), code indicates mineral defining the feature.

code	meaning
q(n)	quartz; number in second place indicates generation of vein
h(n)	amphibole; number in second place indicates generation
s(n)	sillimanite; ditto
c(n)	calcite; ditto

Table 5d. Kinematic a-lineation (61 and 62), with sense of shear; code indicates vergence and generation of structure

code	meaning
u(n)	top up plunge; number in second place is generation
d(n)	top down plunge; number in second place is generation

Table 5e. Intersection lineations and asymmetric folds (64, 65, 76); code indicates vergence and generation of structure

code	meaning
d(n)	dextral vergence viewed down plunge; number is generation
s(n)	sinistral vergence viewed down plunge; number is generation

OthrArea Coverage

A polygon coverage for areas not based on map unit contacts, e.g. alteration zones, mylonite zones, metamorphic zones (other area types listed in USGS [1995]).

Polygon features

The PAT for this coverage will contains three user defined fields.

- TYPE: An integer with 3 digit minor code in the 690 or 630 series for areas and degenerate areas in USGS [1995]. Codes beginning with 0 were created for situations not covered in the USGS [1995] publication.
- IDENTIFIER: A character string used to relate to a separate table with character strings for named areas.
- LINKTABLE: An integer with 3 digits used to lookup file name of table containing related data.

Arc features

The AAT will contain 1 field to define the accuracy of the boundaries of the area.

- ACCURACY: An integer, width 1, coding identical to ACCURACY field in 'Geology' & 'Lines' coverages. See Table 2 for a complete list of accuracy codes.

Table 6. Type codes for OthrArea coverages [othrtype.dbf]

code	meaning
320	vent
003	Tertiary mylonitic fabric
020	Mesozoic to early Tertiary metamorphic fabric
3nn	
9nn	

Location Coverage

Location of sample collection, fossil localities, age dates, wells, etc. Also includes degenerate areas as defined in USGS [1995]—mines, breccia pipes etc. Each type of locality is related to a table specified by the LINKTABLE field using IDENTIFIER as the relate field. The table LinkTabs associates integers from the LINKTABLE field with path names for the external tables.

Point features

There will be three items in the PAT.

- TYPE: An integer with 4 digits using minor code associated with major code 630 in USGS [1995]. A table will be generated with a list of codes used by the Arizona Geological Survey. Additional codes will be added for geochronological locations, water and oil wells.
- IDENTIFIER: A character string used to relate to ID# in separate table (specified by the LINKTABLE field) containing any useful data pertaining to site.

- LINKTABLE: An integer with 3 digits used to lookup file name of table containing related data

Label Coverage

Location of decoration (graphics features) on maps to provide additional information for presentation. The Arizona Geological Survey will not be creating this coverage until generation of paper maps for publication.

Point features

The PAT will contain one item.

- TYPE: An integer with 4 digits. The minor codes associated with major code 611 in USGS [1995]. A table will be generated with a list of codes used by the Arizona Geological Survey.

Index Shapefile

Polygons delineating extent of source maps used to compile the generalized digital geologic map. This is an ArcView shapefile which can be accessed directly with ArcView or converted into an Arc/Info coverage. If converted into an Arc/Info coverage, the overlapping polygons must be treated as regions.

Polygon features

The polygon shapefile's associated feature table will contain one field.

- UNIQUE_ID: An integer assigned to one data source. Multiple polygons may have the same number. Coincidental polygons will have different unique_ids.

Related tables

Related table, *sources.dbf*, will contain 5 fields.

- UNIQUE_ID: An integer assigned to one data source. This is the field used to join with the shapefile's associated feature table.
- AUTHORS: A character string with a list of the source's authors.
- PUBDATE: An integer field with the year of publication.
- TITLE: A character string with the source's title.
- CITATION: A character string with the source's citation information.

Other Tables

These tables apply to all of the digital maps available in the AZGS Digital Information series. They are not map specific and therefore will have more information than necessarily needed for any one digital map product.

linktabs

If features in the geology, lines, othrarea, or location coverages contain links to external tables, then a table named 'linktabs' must be present to define the names of the linked tables (full path names) and the 3 digit integer associated with that table in other database files, to be used in the 'LINKTABLE' fields.
The database will contain 2 items.

- TableID: A unique integer identifier with 3 digits for each external table.
- Table Name: A character field with the full path name string for external table, to allow automatic joining in scripts.

Areasymb.dbf

Provides a suggested color and symbol reference for the map units.
The database will contain 3 fields:

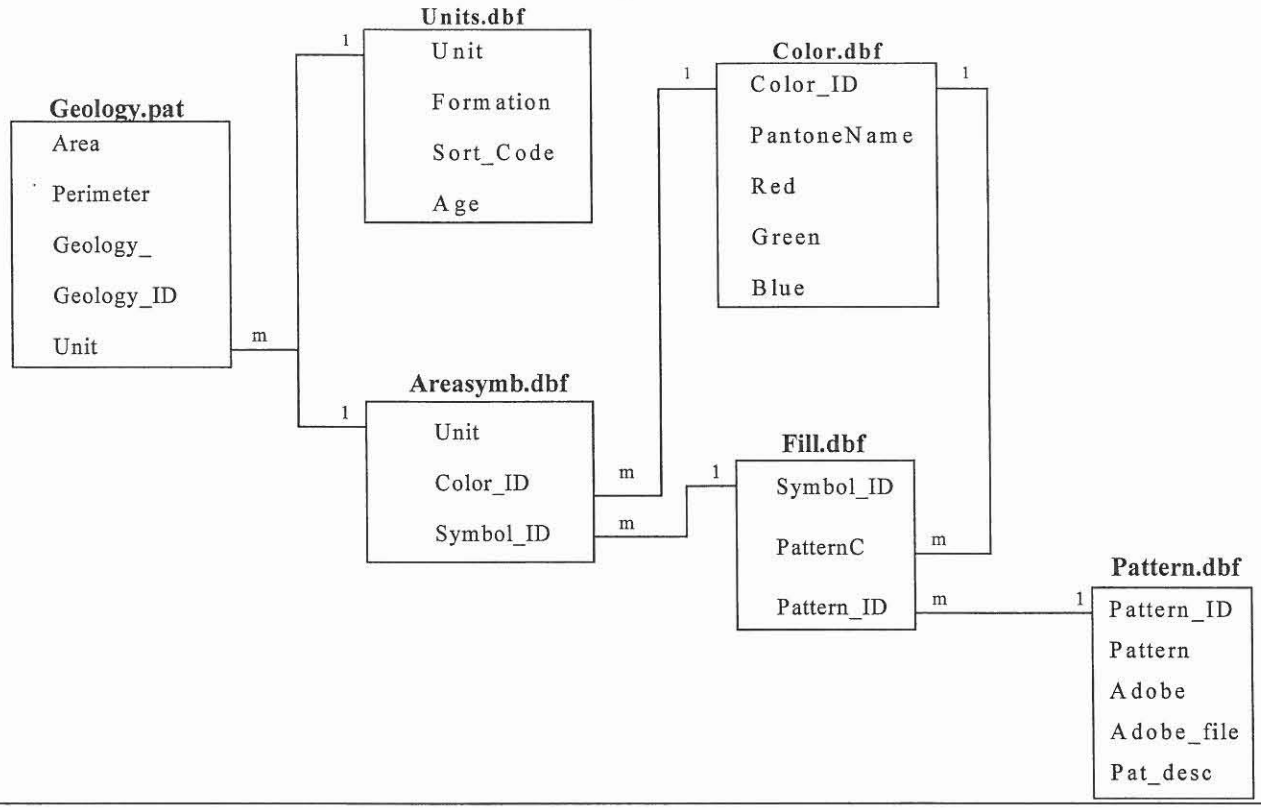
- UNIT: A character field with a unique map unit. This field is joined with the 'unit' field in the geology.pat table.
- COLOR_ID: A integer used to join with the 'Color_ID' field in the color.dbf table referencing a suggested background color for the map unit.
- SYMBOL_ID: A integer used to join with the 'Symbol_ID' field in the fill.dbf table referencing a pattern and pattern color. The default for map units without a pattern is '-1'.

Color.dbf

Includes colors from Pantone® color formula guide 1000 (Pantone®, Inc., 1991) and approximate red, green, and blue values for onscreen viewing. Values range from 0 to 255 (as used in ArcView).
The database will contain 5 fields:

- COLOR_ID: An integer field with a unique color identifier. This is the field used to join with Areasymb.dbf table on the 'Color_ID' field and with fill.dbf table on the 'PatternC'.
- PANTONENAME: A text field with the name of a Pantone® color.
- RED: An integer from 0 to 255 with the red color intensity for screen display of the map unit.
- GREEN: An integer from 0 to 255 with the green color intensity for screen display of the map unit.
- BLUE: An integer from 0 to 255 with the blue color intensity for screen display of the map unit.

Figure 1. Table Relationship for symbolizing Map Units



Fill.dbf

Provides references for a pattern design and pattern color if a map unit requires more complicated symbolization than a solid color.
The database will contain 3 fields:

- SYMBOL_ID: An integer field used to join with the Areasymb.dbf table on the 'Symbol_ID'.
- PATTERNC: An integer used to join with the 'Color_ID' field in the color.dbf table. This color is the suggested pattern color for the unit.
- PATTERN_ID: An integer used to join with the 'Pattern_ID' field in the pattern.dbf table.

Pattern.dbf

References USGS and Adobe Illustrator patterns.
The database will contain 6 fields:

- PATTERN_ID: An integer field with a unique identifier. This is the field used to join with the fill.dbf table's 'PatternID'.
- PATTERN: An integer referring to a standard USGS pattern number in the USGS [1995] report. These patterns can be downloaded from the following web site in encapsulated postscript format: http://greenwood.cr.usgs.gov/maps/software.html

- ADOBE: An integer referring to an Adobe illustrator pattern created at the USGS. These patterns can be downloaded at the site listed above for pattern.
- ADOBE_FILE: A character field with the downloaded Adobe file name.
- PAT_DESC: A character field with pattern descriptions.

Figure 2. Copy of USGS [1995] patterns

Please see Printed Readme File included with distribution disks.

Lookups

This report contains codes used in the coverages distributed for the Arizona Geological Survey's digital geologic maps. These tables have been converted to lookup tables to be used with the database. The figure below shows the relationship between the lookup file, coverage, and table in OFR 97-5.

Figure 3. Lookup files

lookup file	coverage-feature attribute table - item - type	OFR 97-5 table
geotype.dbf	geology/lines - aat - type	part of Table 2
geoaccu.dbf	geology/lines - aat - accuracy	part of Table 2
geofault.dbf	geology - aat - descriptor - faults	part of Table 2
linefold.dbf	lines - aat - descriptor - folds	part of Table 2
linedike.dbf	lines - aat - descriptor - dikes and veins	part of Table 2
linembed.dbf	lines - aat - descriptor - markerbeds	part of Table 2
strutype.dbf	structur - pat - type	Table 3
strumod.dbf	structur - pat - modifier1	Table 4
strumod2.dbf	structur - pat - modifier2	Table 5a and 5b
othrtype.dbf	othrarea - pat - type	Table 6

References:

USGS, 1995, Cartographic and digital standard for geologic map information (Draft): U. S. Geological Survey, Open-File Report 95-525, unpaginated.

Appenix 3
Open File Reports

1. Open-File Report 92-30
2. Open-File Report 92-50
4. Open-File Report 93-60
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Open-File REPORT

GEOLOGIC MAP OF THE EASTERN EAGLETAIL MOUNTAINS, MARICOPA, LA PAZ, AND YUMA COUNTIES, ARIZONA

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Arizona Geological Survey
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Includes map, scale 1:24,000, and 13 page text.

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This report is preliminary and has not been edited or reviewed for conformity with Arizona Geological Survey standards

INTRODUCTION

The area described in this study includes the eastern Eagletail Mountains, Maricopa, La Paz, and Yuma counties, Arizona. The srudy area encompasses all of the Eagletail Mountains East Quadrangle (1:24,000) and is partially within the Eagletail Mountains Wilderness Area (Figure 1). Bedrock in this area consists largely of pre-Tertiary granitoid rocks of probable Jurassic age that are intruded by numerous Tertiary dikes and overlain by an extensive sequence of Miocene silicic volcanic rocks and subordinate mafic and intermediate volcanic units (Plate 1). Sources of data are shown in Figure 2, rock-unit correlations and relative ages are shown in Figure 3, and map symbols are shown in Table 1.

The area was mapped in part with funds provided to the Arizona Geological Survey by the U.S. Geological Survey COGEOMAP program, contract #14-08-0001-A0872. Field work was carried out by the authors in February, 1992. 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.

PREVIOUS INVESTIGATIONS

Previous geologic studies of the area include reconnaissance studies incorporated into State geologic maps by Wilson and others (1969) and Reynolds (1988), and reconnaissance mapping by Miller and others (1989). The area directly to the south and southwest of the study area was mapped by Gilbert and others (1992) and Gilbert and Spencer (1992), and the area directly to the west was mapped by Grubensky and Demsey (1991). Mineral deposits in the eastern Eagletail Mountains were described by Lane (1986) and Miller and others (1989). The upper Cenozoic surficial deposits were mapped and described by Demsey (1990).

GEOLOGIC SETTING

The study area is within the Basin and Range physiographic and tectonic province, much of which underwent severe Tertiary extension and magmatism (Spencer and Reynolds, 1989). The region around the study area is characterized by northwest-trending normal faults and fault blocks and the northwest trend of the Eagletail Mountains is probably due to Tertiary normal faulting. Pre-Tertiary rocks in the Eagletail Mountains consist of Jurassic to Proterozoic granitoid rocks. Early Miocene magmatism produced a thick sequence of ash-flow tuffs that form the backbone of the range and numerous northwest-trending dikes within pre-Tertiary rocks. Felsic magmatism was followed by early to middle Miocene basaltic magmatism.

STRUCTURE

Pre-Tertiary shear zones and fabrics

Pre-Tertiary plutonic bodies along the northeastern flank of the Eagletail Mountains are separated by northeasterly trending zones of mylonitic gneiss. The contact zone between the diorite phase of the Frenchman Mine pluton (unit JXfd) and porphyritic granodiorite (unit JXg) is the best exposed. Gneissic rocks separating the Frenchman Mine pluton from the porphyritic granodiorite are interpreted to be high-temperature mylonites formed along an intrusive contact. Formation of fine-grained, thinly layered gneiss by deformation-induced grain size reduction and recrystallization is recorded in the gradational contacts between the largely undeformed main body of the porphyritic granodiorite and the gneiss zone on the west side of Granite Mountain. The mixed, gradational contact between the diorite phase of the

Frenchman Mine pluton and the gneiss zone, which has less pervasive and more complexly contorted gneissic foliation than the western contact of the gneiss, suggests that this is an older intrusive contact. Thus, the porphyritic granodiorite is interpreted to be the younger plutonic body.

Similar, but more poorly exposed, gneissic zones are present on the southeast side of the Frenchman Mine pluton at its contact with the metasedimentary gneiss and pegmatite (unit JXms), and on the northwest side of the porphyritic granodiorite at its contact with the Sore Fingers monzogranite (unit JXmg). The presence of mylonitic gneisses derived from Frenchman Mine granodiorite interleaved in the metasedimentary gneiss and quartzo-feldspathic gneiss of uncertain origin suggests that the Frenchman Mine pluton intruded the metasedimentary gneiss during or before formation of the high-strain zone. The contact zone between the porphyritic granodiorite and Sore Fingers monzogranite is very poorly exposed, but the presence of similar feldspar-quartz-biotite gneisses apparently derived in part from the adjacent plutonic rocks suggests a similar high strain zone between the plutons. The porphyritic granodiorite has a weakly developed linear fabric in most outcrops, defined by alignment of the long axis of feldspar phenocrysts and of recrystallized clots of biotite or hornblende. The Sore Fingers monzogranite has no fabric. On this basis, the porphyritic monzogranite is considered older than the Sore Fingers monzogranite.

To summarize, the Frenchman Mine pluton is interpreted to be the oldest plutonic body, and intruded the metasediment, muscovite granite, and pegmatite unit (JXms). A neodymium-samarium isotope analysis of the granodiorite phase of the Frenchman Mine pluton indicated that this pluton is Phanerozoic and not Proterozoic in age (S.J. Reynolds, oral communication, 1992, analysis by M. Felix Lerch). The porphyritic granodiorite intruded the Frenchman pluton on the northeast, and the Sore Fingers monzogranite intruded the porphyritic granodiorite on the northeast. Before or during intrusion of the Sore Fingers monzogranite, the contacts between these units became high strain zones within which the mylonitic gneisses formed. The shear zones between the porphyritic granodiorite and Frenchman Mine pluton dips moderately to steeply southeast, and the other two shear zones dip gently to moderately northwest. Mineral elongation lineations, where observed in the shear zones and present as weak 'l' fabrics in the Frenchman Mine pluton and porphyritic granodiorite, all consistently trend between about 020° and 050°. The lithologic similarity of the porphyritic granodiorite and Sore Fingers monzogranite suggests that they are part of the same plutonic suite. The Sore Fingers monzogranite is believed to be Jurassic in age in the Little Harquahala Mountains (Richard, unpublished U-Pb data from correlative monzodiorite in the northern Little Harquahala Mountains). If the correlation of these rock units is correct, the deformation of these rocks is Jurassic in age.

Other Faults

The contact between the Tertiary and pre-Tertiary rocks along the range front southwest of Granite Mountain is a moderately to steeply southwest-dipping fault zone. Where well exposed, the fault zone contains indurated, foliated cataclasite. The foliation is defined by irregular lenses of comminuted granitoid rock, volcanic rock, and red hematitic gouge. Weak striations in this foliation observed in one outcrop plunge down the dip of this fault. Tertiary hypabyssal intrusions at the base of Eagletail Mountain apparently intrude this fault zone; other intrusions along the range front to the north probably intrude this zone as well. No depositional contacts between the Tertiary and pre-Tertiary rocks along the northeast front of the range have been observed except at the southeastern edge of the map area where a Tertiary conglomerate forms the base of the Tertiary stratigraphic sequence.

Dikes

The Tertiary dikes intruding the pre-Tertiary rocks along the northeastern front of the range trend

northwest and generally dip steeply northeast to vertical. The density of dikes increases towards the range front to form composite intrusions elongated in a northeasterly direction. Courthouse Rock is formed by one such intrusion; it is no larger than several of the other intrusions and is formed by similar dike rock. Its greater resistance to erosion may be due to deuteric alteration.

MINERAL DEPOSITS

Minor mineralization and alteration affected crystalline rocks along the northeast flank of the Eagletail Mountains. These areas are not, however, within a metallic mineral district as recognized by Keith and others (1983). Some mineral deposits in the map area are associated with brittle shear zones or mafic dikes and contain hematite, specular hematite, malachite, and chrysocolla, commonly with open-space filling textures (Lane, 1986; this report). These deposits resemble other deposits in west-central Arizona that are associated with shallow-level brittle shear zones and/or mafic dikes (Spencer and Welty, 1989), and all of these deposits are almost certainly middle Tertiary in age. Other deposits are quartz veins that contain hematite and locally manganese oxides and calcite. These deposits are possibly of pre-Tertiary age.

DESCRIPTION OF MAP UNITS

Qs **Surficial deposits (Quaternary)**--Unconsolidated alluvium and colluvium, including talus, sand and gravel in modern washes, and unconsolidated to poorly consolidated gravel, sandy gravel, and sand, locally with silt or boulders, that typically forms flat, locally incised surfaces up to 5 meters above modern drainages.

QTc **Pedogenic carbonate (Quaternary and Pliocene?)**--Caliche-cemented gravel and sedimentary breccia (talus deposits?).

QTs **Older surficial deposits (Quaternary to Miocene?)**--Poorly to moderately consolidated fanglomerate with subangular clasts, typically 1 to 10 cm, of mafic schist, granitoids, and Tertiary basalt.

Tb **Basalt (middle to early Miocene)**--Black to medium gray, fine-grained, locally porphyritic, olivine basalt. Typically occurs as mesa-capping flows. Textures consist of massive, vesicular to nonvesicular, platy, scoriaceous, and agglomeratic facies. Includes local red scoria. Generally very resistant to weathering and weathers into resistant blocks.

Tmu **Upper mafic volcanic rocks (early Miocene to late Oligocene)**--Gray, brown, and purple weathering, fine- to medium-grained, mafic to intermediate volcanic flows. Commonly contains plagioclase (altered) and hornblende phenocrysts. Massive to highly fractured or brecciated and locally amygdaloidal. Rocks of this unit are cut by locally abundant silica and calcite veins and veinlets. Red to purple liesegang banding is present locally.

Tt **Bedded to massive, variably welded tuffs (early Miocene to late Oligocene)**--Generally pale yellow weathering, weakly bedded tuff and lapilli tuff. Commonly white or pale red or tan on fresh surfaces. Unit is moderately consolidated and typically forms cliffs or steep slopes. Weathering of cliff faces may produce cavities (tafone) up to several meters diameter. Commonly contains biotite phenocrysts up to 3 mm diameter and locally contains hornblende and feldspar phenocrysts up to 3 mm long. Locally grades into welded tuff and contains minor amounts of tuffaceous sandstone. Locally contains low-angle cross stratification.

Tf **Felsic volcanic rocks (early Miocene to late Oligocene)**--Generally massive, cliff forming, and brown weathering, with fractures perpendicular to bedding that crudely resemble columnar jointing. Interpreted as welded tuffs and, possibly, rheomorphic tuffs, and flows. May contain fresh biotite phenocrysts up to 3 mm diameter and slightly altered hornblende up to

4 mm long. Weathering color varies; may be tan or light gray.

In SW1/4, sec. 34, T. 1 N., R. 10 W., includes reddish tan, aphyric rhyolite(?) with highly flattened, gray pumice fragments. High-temperature slip surfaces(?) in this area are lineated and have undulations with axes parallel to lineations. Both are perpendicular to tension gashes.

Tfv **Vitrophyre (early Miocene to late Oligocene)**--Dark gray to black vitrophyre flows and breccia. Up to 30% of the rock consists of phenocrysts of hornblende, biotite, and plagioclase set in a glassy groundmass. Commonly light grey where partially devitrified. Locally grades into partially devitrified vitrophyre and then into map unit Tf.

Tfvt **Vitrophyre and tuff (early Miocene to late Oligocene)**--Heterogeneous unit characterized by dark gray to black vitrophyre and vitrophyre breccia interbedded with lapilli-crystal tuff as in unit Tt and crystal-vitric welded tuff as in unit Tf.

Tfts **Felsic tuff and sandstone (early Miocene to late Oligocene)**--Felsic tuff interbedded with medium-grained pebbly sandstone and conglomerate.

Tap **Andesite Porphyry (early Miocene to late Oligocene)**--Brown weathering, light-tan, porphyritic, intermediate intrusion. Typically contains 30% to 40% phenocrysts of plagioclase up to 2 cm long and of biotite and hornblende up to 1 cm long set in a light tan aphanitic groundmass. Probably hypabyssal equivalent of Tm.

Tfd **Felsic dike rocks (early Miocene to late Oligocene)**--Light-gray to pinkish grey dikes intruding pre-Tertiary rocks. Rocks of this map unit typically contain phenocrysts of quartz, feldspar, and chloritized biotite in an aphanitic groundmass, and are generally distinguished from rocks of map unit Tid by the presence of quartz.

Tid **Intermediate to felsic dike rocks (early Miocene to late Oligocene)**--Includes white, gray, greenish gray, tan, and brown aphanitic dikes, locally with 1 to 3 mm phenocrysts of quartz, feldspar, biotite, and hornblende. Rocks of this unit generally do not contain quartz.

Some thick dikes are composite, with fine-grained, equigranular, dark-grey basaltic or andesitic margins, and a more felsic interior zone. Many of the andesitic dikes contain rounded inclusions of mafic dike rock interpreted to result from magma mixing.

These dikes locally form lensoid and irregular (in map view), resistant silicic intrusions that form steep cliffs and resistant rock spires, such as at Courthouse Rock in the northwestern part of the map area. Steep flow foliation and steeply plunging lineation characterize this rock unit near its intrusive margins. Wall rocks and rocks of this unit may be brecciated along contact zones and in some areas are mixed.

Tmd **Mafic dikes (early Miocene to late Oligocene)**--Dark greenish grey to black, fine-grained basaltic or andesitic dikes. Generally equigranular, but some dikes contain 1 mm hornblende or plagioclase crystals.

Tml **Lower mafic volcanic rocks (early Miocene to late Oligocene)**--Brown-weathering, medium gray, intermediate to mafic volcanic flows with fine-grained plagioclase and pyroxene(?) phenocrysts. Locally contains quartz (unsurveyed NE1/4, sec. 33, T. 1 N., R. 10 W.).

In one area (north-facing cliff face 1.3 miles N7°W from Anvil Mountain) this unit is shattered, appears to be a debris avalanche deposit, and locally contains 5- to 50-cm-thick dikes of granitoid-clast conglomerate that were apparently intruded as a slurry from beneath at the time of avalanche emplacement. The lower 20 meters of overlying tuff (map unit Tt) contain numerous basalt clasts. Tuff is draped over irregular top of brecciated basalt and contact is locally interdigitated. Possibly basalt breccia was locally mechanically fluidized and intruded into tuff at the time of tuff emplacement.

Tfu **Bedded to massive, variably welded tuffs, rheomorphic tuffs, and flows, undivided (early Miocene to late Oligocene)**--Rocks of map units Tf and Tt, undivided. May locally include

hypabyssal intrusions. Commonly consists of red to purplish tan, flow-banded rhyolite that is generally brecciated. Includes flow-banded rhyolite(?) with local disharmonic folds with 10 to 100 cm long limbs. Locally grades into dark gray vitrophyre (map unit Tfv).

The spectacular cliff-forming outcrops along the range front in the area approximately 1 to 2 miles southeast of Eagletail Peak include massive, pale gray, pale red, or tan, aphyric rhyolite(?) breccia with fragments typically 1 to 10 cm diameter. Brecciation was not tectonic as throughgoing fractures are generally absent. The brecciated rocks were not produced by catastrophic debris avalanches as they do not contain a crushed-rock matrix and are not porous. Brecciation is interpreted as either high-temperature volcanogenic or diagenetic.

Ts **Sedimentary rocks, undivided (early Miocene to late Oligocene)**--Conglomerate and sandstone. Light tan to red, medium- to coarse-grained, moderately to poorly sorted, feldspatholithic pebbly sandstone and granule to pebble conglomerate interbedded with volcanic rocks. Approximately 2.7 miles northwest of Eagletail Peak, near range crest, rocks of this unit consist of pebble to cobble conglomerate with clasts of Tertiary volcanic rocks and pre-Tertiary crystalline rocks.

Tbx **Debris avalanche deposits (early Miocene to late Oligocene)**--Light colored, angular to subangular, gneissic and granitoid rock fragments in an unsorted matrix.

TJqp **Silicic dikes (early Miocene to Jurassic)**--Very fine-grained, light gray or greenish gray groundmass with about 10-20% 3-6 mm diameter quartz phenocrysts, 5-10% subhedral K-feldspar and 1-3% chloritized biotite. These intrude pre-Tertiary crystalline rocks. Intermediate to felsic dikes (unit Tid) intrude these silicic dikes.

TXg **Granite to granodiorite (early Miocene to early Proterozoic)**--Reddish-brown weathering, medium to fine-grained leucocratic granitoids, equigranular, nonfoliated to moderately foliated. Mafic minerals are altered to iron oxides except locally where some biotite is preserved. Mineral grains are sutured, rock weathers into angular fragments. Quartz content is possibly low enough that this unit is a quartz monzonite.

JXfgn **Feldspathic gneiss (Jurassic to early Proterozoic)**--Generally reddish weathering, fine-grained, light gray, microcline gneiss with approximately 1% apatite and laminations of chlorite, epidote and opaques.

JXmg **Sore Fingers monzogranite (Jurassic to early Proterozoic)**--Medium- to coarse-grained monzogranite, with 20-50% K-feldspar in phenocrysts up to 7 cm in diameter, 20-25% quartz in anhedral grains up to 8 mm diameter, 30-35% plagioclase in 2-5 mm subhedral crystals, and 5-10% biotite generally greatly in excess of hornblende. Biotite is variably recrystallized to very fine-grained aggregates. K-feldspar phenocrysts are irregularly distributed in rock body; locally they occur packed together in cumulate zones which may consist of >50% phenocrysts. Sparse aplite dikes intrude the monzogranite. Correlated with the Sore Fingers Monzogranite (Spencer and others, 1985) of the southern Little Harquahala Mountains based on lithologic similarity. A sample of this rock in the southern Little Harquahala Mountains yielded a K-Ar minimum age of 140 Ma (Rehrig and Reynolds, 1980). U-Pb data from a probably correlative monzodiorite in the northern Little Harquahala Mountains indicates an age of near 160 Ma (S. M. Richard and N. R. Riggs, unpublished data).

JXg **Porphyritic granodiorite (Jurassic to early Proterozoic)**--Medium- to fine-grained biotite and hornblende-biotite granodiorite to monzogranite with gray potassium feldspar phenocrysts up to 4 cm long. Large K-feldspar phenocrysts may be rounded with long axes subparallel to local tectonic lineation. Local foliation and lineation are not obviously mylonitic, and are crosscut by younger quartz veins up to 5 cm thick. Locally includes medium- to fine-grained hornblende diorite(?) with up to 40% mafic minerals in bodies ranging from enclaves with diameters <1 m to pendants up to several 10's of m long. In more highly deformed zones

near the margins of the body, the large K-feldspar phenocrysts are commonly recrystallized to rounded quartz-feldspar aggregates, which appear granitic; hornblende is typically moderately to completely replaced by biotite in these zones as well. Contacts on both the northwest and southeast are gneissic shear zones (shown as unit JXgn).

JXgg **Granodiorite gneiss (Jurassic to early Proterozoic)**--Feldspar-quartz-biotite gneiss; medium gray, fine grained, and very thinly layered. Interpreted to be derived from granodiorite unit.

Frenchman Mine pluton

JXfg **Hornblende biotite granodiorite (Jurassic to early Proterozoic)**--Medium grained, equigranular hornblende to hornblende-biotite granodiorite. Consists of approximately 3-10% hornblende in stubby prismatic crystals 3-7 mm long; 1-5% biotite in 1-2 mm variably recrystallized crystals; 10% 3-5 mm subhedral potassium feldspar; 50-60% plagioclase; 10-20% quartz in anhedral grains 1-3 mm in diameter, some of which contain plagioclase inclusions; 2-4% secondary(?) epidote in aggregates of anhedral .5-1 mm grains. Sphene is a common accessory mineral. Hornblende crystals give the rock a slightly speckled look. Granodiorite is cut by sparse aplite dikes; these are fine-grained, equigranular and consist of quartz and feldspar with rare muscovite. The aplite locally grades into medium- to coarse-grained quartz-rich pegmatite irregularly distributed within the dike.

JXfd **Diorite (Jurassic to early Proterozoic)**--Texturally variable hornblende diorite to hornblendite. Diorite is typically fine-grained, equigranular, and unfoliated, but grades to medium-grained hornblende gabbro, with local pods of coarse-grained hornblendite. All of these varieties are locally gneissic. Contact with the gneiss (unit JXgn) is gradational over 10-20 m, with mixing of gneiss and massive to gneissic diorite; the contact is placed where diorite becomes the predominant rock. Contact with hornblende granodiorite (unit JXfg) is gradational over about 10 m.

JXlg **Fine-grained, equigranular, leucocratic granite (Jurassic to early Proterozoic)**--In some areas contains up to 2 to 3 percent biotite. Commonly contains pegmatite dikes.

JXms **Metasedimentary gneiss, muscovite granite, and pegmatite (Jurassic to early Proterozoic)**--Schist and gneiss abundantly intruded by pegmatite. Metamorphic rocks contain variable proportions of quartz, feldspar, muscovite, biotite and garnet, and are typically fine grained and gneissic. The protolith was apparently mostly sandstone. These are abundantly intruded by medium- to fine-grained equigranular muscovite granite, containing up to about 10% 1-2 mm muscovite grains, and by quartz-feldspar-muscovite pegmatites.

JXgn **Gneiss (Jurassic to early Proterozoic)**--Fine-grained feldspar-quartz-biotite (±hornblende) gneiss. Typically very thinly layered (2-5 cm), with layering defined by compositional variations. Unit includes irregular small intrusions of medium- to fine-grained equigranular leucogranite, granodiorite and diorite. These are sub-concordant to cross-cutting. The contact between gneiss and granodiorite at the northeast end of Granite Mountain is an irregular mixed zone with 5-15 cm diameter, partially resorbed, rounded inclusions of gneiss in texturally highly variable granodiorite. Granodiorite layers are interleaved in the gneiss near the contact, and are concordant to subconcordant.

Gneiss zones along the boundaries of the porphyritic granodiorite (unit JXg) locally include muscovite-rich gneiss (similar to unit JXms), diorite and diorite gneiss lenses. Contacts with the porphyritic granodiorite are typically gradational over 1-5 m; phenocrysts are deformed and recrystallized into thin quartzo-feldspathic layers and then obliterated across this boundary.

DESCRIPTION OF MINERAL DEPOSITS--Descriptions correspond to numbered locations on Plate 1.

1. Quartz-hematite vein with minor calcite. Approximately 30 cm thick with silicified border zone. Veinlets of reddish brown and orange iron oxides cut the quartz. Locally abundant pits containing iron oxides are interpreted as oxidized pyrite or chalcopyrite(?). Sparse malachite and dioptase(?) are present.
2. Quartz-hematite-manganese oxide vein. Drusy quartz with black spongy manganese oxides and dark brown to orange iron oxides. Vein strikes 146°, dips 62°SE, and forms margin of fine-grained andesite dike. The vein and associated alteration zone in the dike and adjacent wall rock thickens down hill to east. Sericite-silica alteration zone up to 1 to 2 m thick contains a network of quartz-iron oxide veinlets and local hematite after octahedral mineral (fluorite?, magnetite?). No copper minerals or relict sulfides were seen.
3. Mineralized shear zones. Shear zones containing fault gouge trend northwest, dip steeply to the southwest, and cut dacite(?) intrusion (composite dike). Thin mafic dikes intrude along shear zones. Hydrothermal minerals in shear zones include earthy iron and manganese oxides, cuprite(?), minor malachite and trace barite. Chlorite and sparse sericite form alteration zones around shear zones. Mafic dikes locally contains specular hematite-epidote alteration. Prospect is 20 foot deep pit.
4. Mine shaft in mafic dike. Fifteen-foot-thick chloritically altered mafic dike with veins of variably silicified earthy hematite along sheared contacts with porphyritic granodiorite. Drusy quartz and sparse malachite are present in open spaces, and disseminated malachite and chrysocolla are present in the hematite. Waste heap contains silicified and iron-stained dike and porphyritic granodiorite. Dike trends 141°, dips 70°NE. Shaft is approximately 50 feet deep. Numerous bulldozer cuts have been made along dike to southwest of shaft. Shaft shown on map about 300 feet northeast of this mine is unmineralized and is probably a water well.
5. Frenchman Mine. No mineralization recognized.
6. Many dikes in this area (more than shown on map). Weak to moderate sericitic alteration with numerous thin quartz-hematite veins characterizes porphyritic granodiorite in this area. Mine shaft not visited.

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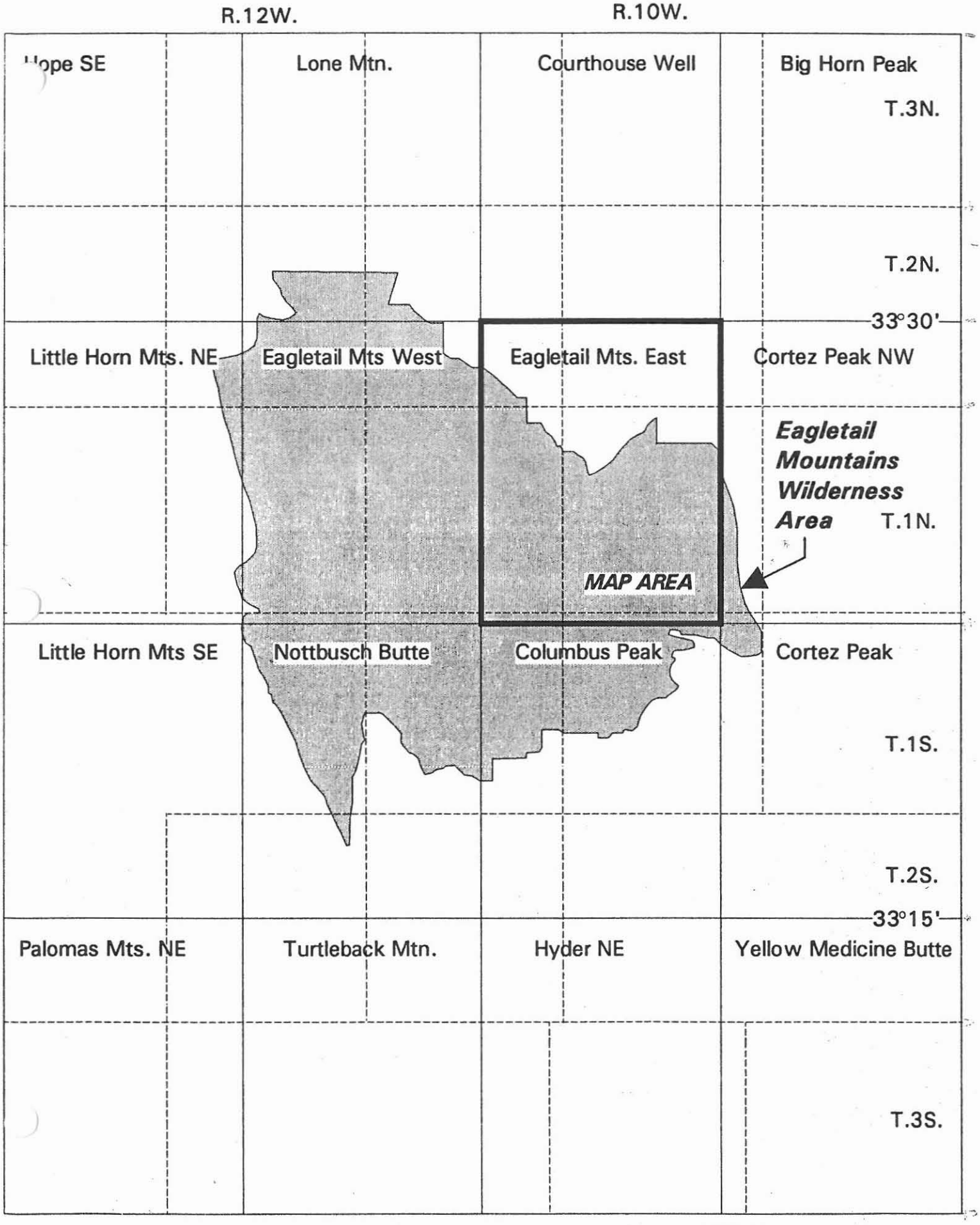


Figure 1. Location of map area.

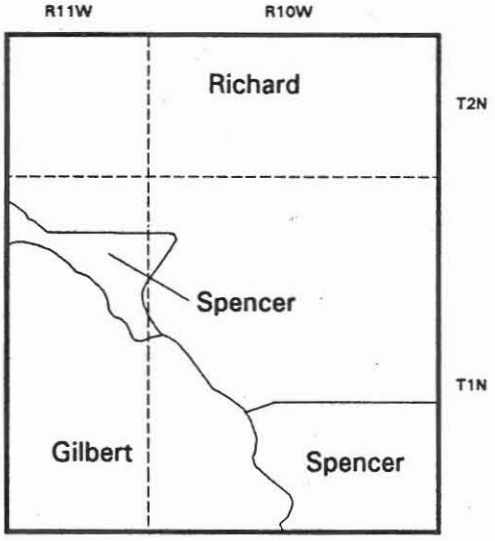


Figure 2. Respective areas mapped by authors

Figure 3
Correlation of Map Units

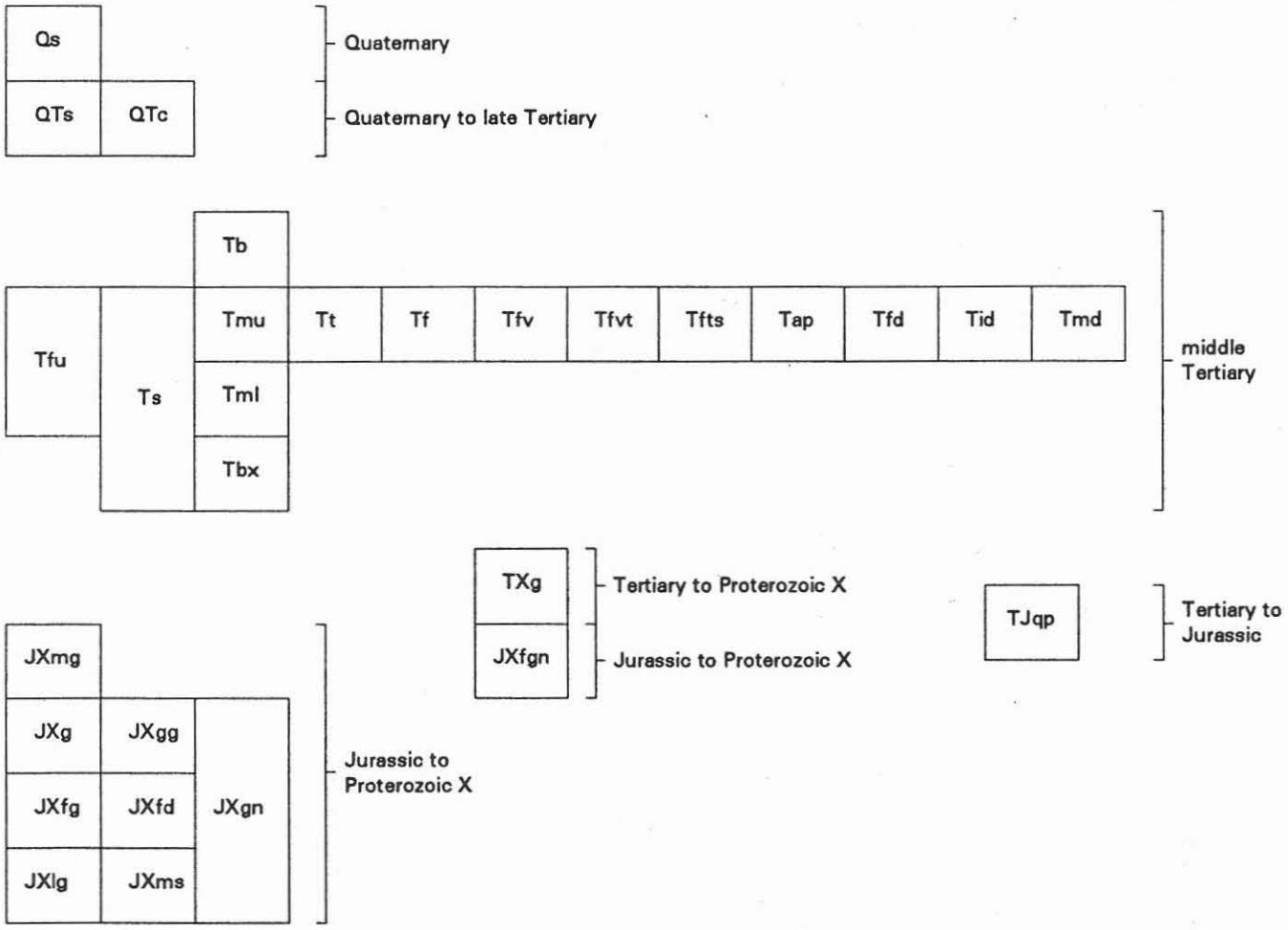


Table 1

MAP SYMBOLS

14 INTRUSIVE OR SEDIMENTARY CONTACT -- Arrow represents dip. Dashed where approximately located.

INTRA-UNIT CONTACT OR MARKER BED

65 FAULT -- Arrow represents dip. Dashed where approximately located, dotted where concealed.

ORIENTATION OF BEDDING, GNEISSIC LAYERING, AND FOLIATION -- Broken lines indicate approximate orientation. Wavy lines indicate curviplanar orientation.

BEDDING

HORIZONTAL BEDDING

GNEISSIC LAYERING

VERTICAL GNEISSIC LAYERING

VERY THIN GNEISSIC LAYERING -- Not clearly related to original mineralogical layering in protolith

FRACTURE CLEAVAGE

VERY WEAK MYLONITIC FOLIATION AND LINEATION

WEAK MYLONITIC FOLIATION AND LINEATION

MODERATE TO STRONG MYLONITIC FOLIATION -- Grain size reduction associated with fabric development

SECOND GENERATION WEAK MYLONITIC FOLIATION

LINEATION

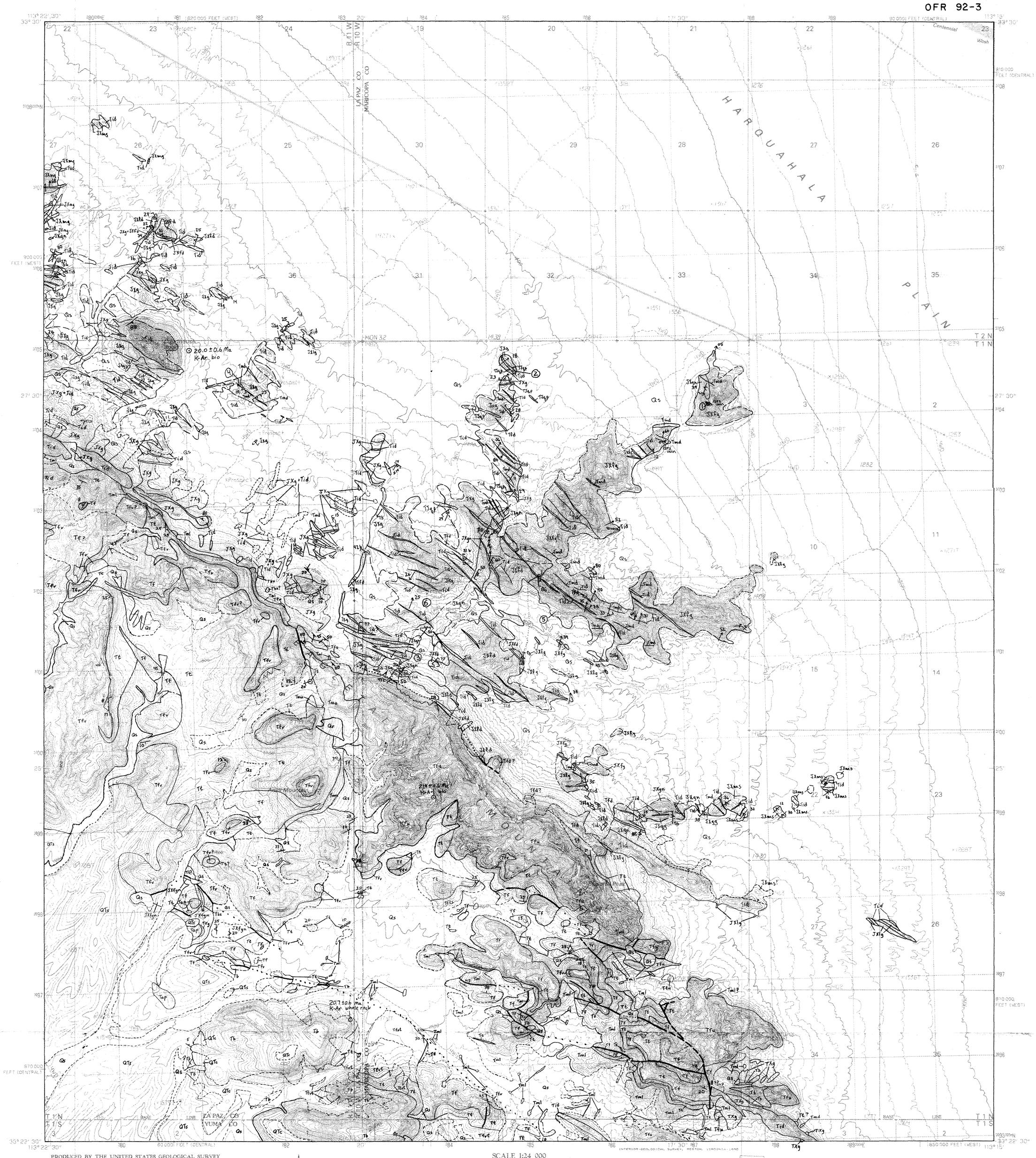
FLOW OR FLATTENING FOLIATION AND LINEATION IN VOLCANIC ROCKS

VEINS AND ALTERATION

QUARTZ VEIN

PEGMATITE VEIN

HEMATITE STAINING AND SERICITIC ALTERATION



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COMPILED FROM AERIAL PHOTOGRAPHS TAKEN . . . . . 1956 AND 1960
FIELD CHECKED 1962
LIMITED REVISION FROM AERIAL PHOTOGRAPHS TAKEN 1984
FIELD CHECKED . . . . . 1986 MAP EDITED 1990
PROJECTION . . . . . TRANSVERSE MERCATOR
GRID: 1000-METER UNIVERSAL TRANSVERSE MERCATOR . . . . . ZONE 12
10,000-FOOT STATE GRID TICKS . . . . . ARIZONA, CENTRAL ZONE
ARIZONA, WEST ZONE
UTM GRID DECLINATION . . . . . 1°16' WEST
1990 MAGNETIC NORTH DECLINATION . . . . . 12°30' EAST
VERTICAL DATUM . . . . . NATIONAL GEODETIC VERTICAL DATUM OF 1929
HORIZONTAL DATUM . . . . . 1927 NORTH AMERICAN DATUM
To place on the predicted North American Datum of 1983, move the projection lines as shown by dashed corner ticks (2 meters south and 69 meters east)
There may be private inholdings within the boundaries of any Federal and State Reservations shown on this map
Where omitted, land lines have not been established
Public Land Survey System is shown as published in 1962 and verified or supplemented in 1986

NORTH

PROVISIONAL MAP
Produced from original manuscript drawings. Information shown as of date of field check. T

SCALE 1:24 000

KILOMETERS
METERS
MILES
FEET

CONTOUR INTERVAL 20 FEET
To convert feet to meters multiply by .3048
To convert meters to feet multiply by 3.2808

THIS MAP COMPLIES WITH NATIONAL MAP ACCURACY STANDARDS
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OR RESTON, VIRGINIA 22092

ARIZONA

QUADRANGLE LOCATION

1	2	3
4		5
6	7	8

1 Lone Mountain
2 Courthouse Well
3 Big Horn Peak
4 Eagletail Mountains West
5 Cortez Peak NW
6 Northwatch Butte
7 Columbus Peak
8 Cortez Peak

ADJOINING 7.5' QUADRANGLE NAMES

ROAD LEGEND
Improved Road . . . . . .
Unimproved Road . . . . . .
Trail . . . . . .
Interstate Route U.S. Route State Route

EAGLETAIL MOUNTAINS EAST, ARIZ.
PROVISIONAL EDITION 1990
33113-D3-TF-024

GEOLOGIC MAP OF EASTERN EAGLETAIL MOUNTAINS, MARICOPA, LA PAZ, AND YUMA COUNTIES, ARIZONA

Jon E. Spencer, Wyatt G. Gilbert, and Stephen M. Richard

1992

Scale 1:24,000

Jointly funded by the Arizona Geological Survey and the U.S. Geological Survey COGEOMAP Program. Contract No. 14-08-0001-A0872.

Open-File

REPORT

GEOLOGIC MAP OF THE WESTERN GILA BEND AND SOUTHERN EAGLETAIL MOUNTAINS, MARICOPA AND YUMA COUNTIES, ARIZONA

by

Wyatt G. Gilbert [1], Daniel P. Laux [2],
Jon E. Spencer and Stephen M. Richard [1]

Arizona Geological Survey
Open-File Report 92-5

May, 1992

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Contract #14-08-0001-AO872,

Includes map, scale 1:24,000, and 17 page text,

This report is preliminary and has not been edited
or reviewed for conformity with Arizona Geological Survey standards

INTRODUCTION

The area described in this study includes the western Gila Bend and the southern Eagletail mountains, Maricopa and La Paz counties, Arizona. The study area encompasses all of the Columbus Peak Quadrangle (1:24,000) and the northern part of the Hyder Northeast Quadrangle (1:24,000), and is partially within the Eagletail Mountains Wilderness Area (Fig. 1). Bedrock in this area consists largely of scattered, limited exposures of Proterozoic to Jurassic metamorphic and igneous rocks intruded by a Miocene granitoid pluton and overlain by an extensive sequence of Miocene silicic volcanic rocks and subordinate mafic and intermediate volcanic units and continental clastic rocks (Plate 1). Sources of data are shown in Figure 2, rock-unit correlations and relative ages are shown in Figure 3, and map symbols are shown in Table 1.

The area was mapped with funds provided to the Arizona Geological Survey by the U.S. Geological Survey COGEOMAP program, contract #14-08-0001-A0872. 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.

PREVIOUS INVESTIGATIONS

Previous geologic studies of the area include reconnaissance studies incorporated into State geologic maps by Wilson and others (1969) and Reynolds (1988), and reconnaissance mapping by Miller and others (1989) in the Eagletail Mountains. The area directly to the west of the study area was mapped by Gilbert and Spencer (1992) and the area directly to the north was mapped by Spencer and others (1992). Stratigraphic studies just east of the map area are presented by Scarborough and Wilt (1979). Some of the mineral deposits in the Gila Bend Mountains were described by Wilson (1933) and those in the southeastern Eagletail Mountains were described by Lane (1986) and Miller and others (1989). The upper Cenozoic surficial deposits were mapped and described by Demsey (1990).

GEOLOGIC SETTING

The study area is within the Basin and Range physiographic and tectonic province which underwent moderate to severe Tertiary extension and magmatism in west-central Arizona (Spencer and Reynolds, 1989). The study area and surrounding areas are characterized by northwest-trending normal faults and fault blocks.

Pre-Tertiary rocks consist of granitoid and amphibolite-grade crystalline rocks of probable Proterozoic age, and sparse, greenschist- to amphibolite(?)-grade metamorphosed Paleozoic and Mesozoic sedimentary and volcanic rocks. Sparse Paleozoic and Mesozoic strata were apparently metamorphosed and preserved from erosional destruction by regional Cretaceous thrusting and thrust burial (Reynolds and others, 1986; Spencer and Reynolds, 1990). Voluminous magmatism and normal faulting occurred in the early Miocene and were followed by middle Miocene basaltic magmatism.

STRUCTURE

Numerous northwest-trending high-angle faults cut all pre-Quaternary rock units in the map area. Displacements along these faults generally range from a few tens to a few hundred meters. In the western Gila Bend Mountains faults blocks generally dip moderately or steeply northeast to northwest. Vitrophyric and tuffaceous units, however, that cap the Picacho Hills are gently dipping, locally to the southwest. Rarely observed fault surfaces are characterized by up to a few meters of gouge and/or fault breccia.

A moderate- to low-angle fault juxtaposes mid-Tertiary granite (Tg) and mid-Tertiary volcanic units in the central part of the map area. Along this fault both upper- and lower-plate rocks are generally shattered for a few meters adjacent to the fault. The moderate to steep north and northeast dips of bedding in fault blocks above this fault suggests that displacement was top to the south or southwest. Normal faulting occurred largely before eruption of gently dipping vitrophyre (Tfv units) and gently southwest-dipping basalt (Tb).

Repetition of gently southwest-dipping basalt (Tb) capping the older mid-Tertiary volcanic rocks indicates the presence of one or more buried northwest-trending faults between the Eagletail Mountains and Cemetery Ridge.

MINERAL DEPOSITS

Several small mines are located within the southeastern Eagletail Mountains in the northeastern corner of the map area. This area is not within any of the mineral districts designated by Keith and others (1983). Two types of mineral deposit are present in this area. One type consists of fracture-filling specular hematite and chrysocolla with pervasive iron-oxide staining along steep, northwest-trending fractures and shear zones. Calcite, fluorite, chlorite, and relict sulfides are also present, and some shear zones host altered mafic dikes of probable Tertiary age (Lane, 1986). Galena and sphalerite are associated with fluorite at the Double Eagle Mine. Open-space-filling textures suggest a Tertiary age. These deposits resemble other middle Tertiary mineral deposits in western Arizona that are associated with mafic dikes (Spencer and Welty, 1989). The other type of deposit is represented by bull quartz veins in pre-Tertiary rocks. Some contain specular hematite and calcite, whereas others are not obviously associated with any other minerals.

Mineral deposits in the western Gila Bend Mountains form part of the Gila Bend Mountains mineral district, which has no reported production (Keith and others, 1983; see also Wilson, 1933). The deposits are characterized by open-space filling textures and typically contain pervasive iron-oxide staining and quartz with less abundant calcite and copper minerals (chrysocolla, malachite, relict chalcopyrite, and native copper). Open-space filling textures indicate a probable Tertiary age for the deposits. Two prospects are within or at the margin of the Miocene Columbus Wash pluton. Prospects discussed by Wilson (1933) in the western part of the map were not identified with certainty, but two prospects examined during this study (nos. 4 and 5 in *Description of Mineral Deposits*) probably are described by Wilson (1933).

A mid-Tertiary age for mineralization in the map area is indicated by four separate lines of evidence: (1) open-space filling textures, (2) occurrences of mineralization within the Columbus Wash pluton, (3) occurrences of mineralization within the Miocene-Oligocene(?) Ts map unit, and (4) association with Tertiary mafic dikes.

ACKNOWLEDGEMENTS

Assistance in the field by Thomas McGarvin (Arizona Geological Survey) and helpful discussions about the area's geology with Steve Reynolds (Arizona Geological Survey) are gratefully acknowledged. Financial support for Laux from Stanley B. Keith (Magmachem Exploration) is sincerely appreciated.

DESCRIPTION OF ROCK UNITS

Qs **Surficial deposits (Quaternary)**--Unconsolidated alluvium and colluvium, including talus, sand and gravel in modern washes, and unconsolidated to poorly consolidated gravel, sandy gravel, and sand, locally with silt or boulders, that typically forms flat, locally incised surfaces up to 5 meters above modern drainages.

QTc **Pedogenic carbonate (Quaternary and Pliocene?)**--Caliche-cemented gravel and sedimentary breccia (talus deposits?).

QTs **Older surficial deposits (Quaternary to Miocene?)**--Poorly to moderately consolidated fanglomerate with subangular clasts, typically 1 to 10 cm, of mafic schist, granitoids, and Tertiary basalt. Possibly in part correlative with Tsb.

Tb **Basalt (middle to early Miocene)**--Black to medium gray, fine-grained, locally porphyritic, olivine basalt. Groundmass is locally trachytic. Typically occurs as mesa-capping flows. Textural varieties include massive, vesicular to nonvesicular, platy, scoriaceous (red and black), and agglomeratic. Generally very resistant to weathering and weathers into resistant blocks. Major-element oxide chemistry of two samples (sample locations G and N) from this unit is reported in Table 2 and Figure 4.

Tbs **Sandstone (early Miocene to late Oligocene)**--Sandstone that underlies or is interbedded with map unit Tb. Includes buff, medium- to coarse-grained, subangular to subrounded feldspatholithic sandstone with lenses of map unit Tsb up to 15 cm thick, and fine-grained, well-sorted, eolian, lithofeldspathic sandstone.

Tnrt **Rhyolite tuff of Nottbusch Valley (early Miocene to late Oligocene)**--Tan to cream to yellow lapilli crystal tuff and tuffaceous sandstone. Resembles map units Tft and Tst, and conformably underlies map unit Tb. This unit is correlated with the Rhyolite of Nottbusch Valley as mapped and named by Grubensky and Demsy (1991).

Tsb **Sedimentary breccia (early Miocene to late Oligocene)**--Light tan, crudely stratified, sedimentary breccia (fanglomerate) with subangular cobbles of granodiorite (Tgd) and foliated diorite (Jmi; 60-90%), felsic volcanic rocks (Tf; 10-40%), and minor basalt. At and near the top of the unit it is locally interbedded with sandstone of overlying map unit Tbs.

Tdf **Felsic dikes (early Miocene to late Oligocene)**--Gray, resistant, intermediate to felsic dikes and hypabyssal intrusions with approximately 1% biotite and sparse plagioclase in a microcrystalline to aphanitic groundmass. Ridges underlain by Tdf in the western part of the map area consist predominantly of porphyritic hypabyssal rocks overlain by welded tuff.

Tdm **Mafic dikes (early Miocene to late Oligocene)**--Aphanitic, porphyro-aphanitic, and fine-grained mafic and intermediate dikes and small intrusions.

Tfu **Felsite (early Miocene to late Oligocene)**--Brick-red to light-pink, flow-banded felsite and felsite crystal tuff. Commonly contains fragments or phenocrysts of Plagioclase, biotite, and hornblende. Resembles Tf, but probably the youngest felsic volcanic unit.

Tfvt **Vitrophyre and tuff (early Miocene to late Oligocene)**--Heterogeneous unit characterized by dark gray to black vitrophyre and vitrophyre breccia interbedded with lapilli-crystal tuff as in unit Tft and crystal-vitric welded tuff as in unit Tf.

Tfvx **Vitrophyre breccia (early Miocene to late Oligocene)**--Buff weathering, light gray, partially devitrified vitrophyre breccia and subordinate dark gray vitrophyre in Picacho Hills.

Tfv **Vitrophyre (early Miocene to late Oligocene)**--Dark gray to black vitrophyre flows and breccia. Up to 30% of the rock consists of phenocrysts of hornblende, biotite, plagioclase, iron oxides, +/- quartz set in a glassy groundmass. Commonly light gray where partially devitrified. Locally grades into partially devitrified vitrophyre and then into map unit Tf. Major element oxide chemistry of these rocks (sample I from this map area) suggests that they

are cogenetic with felsic flows and tuff of map unit Tf (Table 2; Fig. 4).

Tft **Felsic tuffs, undivided (early Miocene to late Oligocene)**--White to light-tan to yellow, fine-grained felsic crystal tuff and lapilli crystal tuff. Moderately consolidated and commonly bedded. Locally contains approximately 1% 1- to 2-mm euhedral biotite crystals. Locally grades into welded tuff and contains minor amounts of tuffaceous sandstone.

Tf **Felsic volcanic rocks, undivided (early Miocene to late Oligocene)**--Lavender to light pinkish tan to buff felsic flows, pyroclastic rocks, and probable hypabyssal intrusions. In the northeastern part of the map area this unit consists predominantly of red to purplish tan, flow-banded rhyolite that is generally brecciated. In this area Tf commonly displays red and gray bands 5 to 20 m long and 10 to 50 mm thick. Locally interbedded with and grades into dark gray vitrophyre. Major element oxide chemistry of unit Tf (includes sample O from this map area) indicates that the composition of the unit ranges from dacite to trachydacite (Table 2; Fig. 4).

Tfx **Felsic volcanic breccia (early Miocene to late Oligocene)**--Brown weathering felsic breccia composed of 30% to 90% felsite fragments up to 10 cm long set in a groundmass of pale gray aphyric rhyolite. Interbedded with Tm in eastern part of the map area, and forms spectacular cliffs along the eastern front of the Eagletail Mountains in the northeastern part of the map. Is found as a minor component of Tf throughout the map area.

Tst **Tuffaceous sandstone and tuff (early Miocene to late Oligocene)**--Yellow, medium- to coarse-grained tuffaceous sandstone and crystal lapilli tuff. Resembles rocks of map units Tnrt and Tft, but generally interbedded with units Tc and Tm.

Tm **Mafic and intermediate volcanic rocks (early Miocene to late Oligocene)**--Gray-, brown-, and purple-weathering, fine- to medium-grained, mafic to intermediate volcanic rocks. Commonly contains plagioclase (altered), clinopyroxene, and hornblende phenocrysts. Locally displays secondary epidote. Massive to highly fractured and locally amygdaloidal. Commonly weathers into 1 to 10 cm diameter pieces. In the eastern part of the map area, this unit can be subdivided into lower and upper members separated by the Tfx and Tst map units. The lower member locally contains small, corroded quartz phenocrysts. Thin beds of volcaniclastic (arkosic) sediments are also intercalated with the lower member. The upper member commonly displays a mottled texture. In northeast part of the map area the unit is generally an andesitic volcanic breccia. The unit is cut by locally abundant silica and calcite veins and veinlets. Red to purple liesegang banding is present locally. Chemical classification of these rocks (samples H, P, Q, and R from this map) ranges from basalt to trachyandesite (Table 2, Fig. 4).

Tap **Andesite porphyry (early Miocene to late Oligocene)**--Brown-weathering, light-tan, porphyritic, intermediate intrusion. Typically contains 30% to 40% phenocrysts of plagioclase up to 2 cm long and of biotite and hornblende up to 1 cm long set in a light tan, plagioclase-dominated, aphanitic to fine-grained groundmass. Probably hypabyssal equivalent of map unit Tm.

Tc **Conglomerate (early Miocene to late Oligocene)**--Red, gray, and green granule to boulder conglomerate. Clasts are well rounded and average approximately 7 to 10 cm across; maximum clast size ranges up to a meter across. The conglomerate displays crude stratigraphic layering and was possibly deposited as matrix-supported debris flows. In the central and eastern part of the map area, imbrication of tabular clasts generally indicates that the unit was derived from a source to the north. In the western part of the map area clasts were derived from granitic and metamorphic rocks, with about 30% of the clasts derived from megacrystic biotite granite (Proterozoic?). In the central part of the map area, units bearing up to 30% volcanic clasts are present (Tcv), and in the eastern part of the map area clasts in

the conglomerate are of highly variable lithology, consisting of numerous plutonic, metamorphic, and volcanic rock types, including Jurassic(?) quartz porphyry and related volcaniclastic rock types. Includes local, thin, light-gray to pink, interbedded lapilli tuff.

Ts **Sedimentary rocks, undivided (early Miocene to late Oligocene)**--Conglomerate, sandstone, mudstone, and limestone. This unit is generally brick red, medium- to coarse-grained, moderately sorted to poorly sorted, subangular, feldspatholithic, pebbly sandstone with subordinate granule to pebble conglomerate layers up to 25 cm thick. The unit grades upward into the conglomerate unit (Tc). In the southeastern Eagletail Mountains pebbles and cobbles in this unit consist primarily of subrounded to subangular bull quartz up to 10 cm long with less abundant granitoids and Proterozoic metamorphic rocks. In eastern areas this unit consists of interbedded red mudstone, red to gray arkose, light to dark gray, commonly cherty limestone, and purple to gray shale. Based on the presence of charophyte fossils in the limestone, the unit formed in a lacustrine (freshwater) environment. Similar sedimentary rocks are present along the Arlington-Agua Caleinte Road to the southeast. An interbedded tuff in this section has yielded an age of 23.7 Ma (Scarborough and Wilt, 1979). The contact between this unit and the overlying conglomerate is an angular unconformity.

Tmd **Microdiorite (early Miocene to late Oligocene)**--Green, fine-grained microdiorite forms WNW-trending elongate intrusions within Tgd. The microdiorite is composed of subequal amounts of plagioclase and hornblende. The hornblende displays both equigranular and wispy, acicular textures; the plagioclase is equigranular. Major element oxide chemistry of these rocks suggests that they are more likely to be cogenetic with older mafic and intermediate volcanic rocks (Tm) than with younger basalts (Tb) (Table 2; Fig. 4).

Tga **Altered granodiorite (early Miocene to late Oligocene)**--The southeast part of the Columbus Wash granodiorite contains a zone of pervasive propylitic alteration (Tga) along the fault contact with amphibolite (YXa).

Tg **Columbus Wash granodiorite (early Miocene to late Oligocene)**--White, medium-grained, equigranular, hornblende-biotite granodiorite that locally grades into quartz monzonite. Generally comprises approximately 35-40% plagioclase, 20-25% quartz, 20-25% pink sanidine, 15% biotite, 2-4% hornblende, and accessory magnetite and sphene. The presence of sanidine is uncommon in plutonic rocks and indicates that the pluton cooled rapidly. Pink to white aplite dikes and sills are common. The aplite contains abundant miarolitic cavities lined with euhedral quartz, feldspar, and epidote. The aplite also contains accessory sphene. All younger bounding units are in fault contact with the pluton. The pluton locally grades into unit TXg. Major element oxide chemistry of three samples (J, K, and M) from the Columbus Wash Granodiorite is reported in Table 2 and Figure. 4. A sample of the Columbus Wash granodiorite yielded a biotite K-Ar date of 22.9 ± 0.5 Ma (M. Shafiqullah, written communication, 1992).

TXq **Quartz vein (Miocene to Proterozoic)**--A prominent quartz vein cuts TXq in the southern Eagletail Mountains (SE 1/4, Sec. 9, T. 1 S., R. 10 W.).

TXg **Granite to Granodiorite (Miocene to Proterozoic)**-- Reddish-brown weathering, medium to fine-grained leucocratic granitoids, equigranular, nonfoliated to moderately foliated, and commonly strongly fractured. Feldspars and mafic minerals are commonly altered to sericite, chlorite, and epidote. Mafic minerals are altered to iron oxides except locally where some biotite is preserved. Sparse 1- to 10-cm-thick bull-quartz veins are characteristic in the southern Eagletail Mountains and indicate that this unit is probably pre-Tertiary in age.

In the southern Eagletail Mountains this unit includes local, small, irregular intrusions of dark-green hypabyssal mafic rock (map unit Jmi) that contain little or no quartz. Both rock types may have a strong fracture cleavage. Intrusions of Jmi are not obviously associated

with any mineral deposits, in contrast to younger, northwest-trending mafic dikes (map unit Tmd) that do not have strong fracture foliation and are mineralized (see deposit #2 in *Description of Mineral Deposits*, and Lane, 1986).

Jvs **Schist derived from Jurassic volcanic and volcaniclastic rocks (Jurassic)**--Light green, purple, or light gray sericite-feldspar schist and phyllite. Contains porphyroclasts of quartz and feldspar. Probably derived from a mixture of tuffaceous and pelitic sediments. Lithologic variations are interpreted as reflecting original compositional variations in Jurassic volcaniclastic rocks and minor interbedded nonvolcaniclastic sedimentary rocks.

Jmi **Mafic and intermediate metaigneous rocks (Jurassic)**--Dark-green, medium- to fine-grained, foliated, actinolitic diorite and dark-green, fine-grained, foliated actinolitic metabasite. This unit contains minor amounts of light-gray, lavender and green phyllite and banded quartzite. In the southwestern part of the map area this unit grades over several tens of meters into schist (map unit Jvs).

JTrs **Schist, undivided (Jurassic to Triassic)**--Green, quartz-poor schist and light gray sericite-quartz schist. Locally includes phyllite and minor iron-stained calc-schist and layers of black quartzite up to 1m thick. Commonly displays crenulations and S2 cleavage. May vary over distance of as little as a few meters from blocky and mica-poor to sericitic or chloritic and very platy.

Pc **Coconino Sandstone (Permian)**--Pure white quartzite, pink to black weathering.

PPc **Supai Group (Permian and Pennsylvanian)**--Impure and possibly calcareous quartzite with 1 to 5 cm thick limestone interbeds.

MDm **Dolomite and calcite marble (Mississippian and Devonian)**--Largely pale-tan to pale-gray dolomitic marble correlative with the Devonian Martin Formation and the Mississippian Redwall Limestone. Locally contains siliceous laminations that are revealed by differential weathering and color (siliceous laminations form brown protruding layers).

JDl **Limestone (Jurassic to Devonian)**--A ten meter thick gray limestone bounds quartzite of JCq on the northwest in NE 1/4, sec. 15, and SE 1/4, sec. 10, T. 2 S., R. 11 W. The limestone generally contains silty partings up to 1 cm thick but is locally massive.

JCq **Quartzite (Jurassic to Cambrian)**--Brown to lavender weathering, gray, banded quartzite (with minor feldspar) in the southwest edge of the map (NE 1/4, sec. 15, and SE 1/4, sec. 10, T. 2 S., R. 11 W.). This unit includes iron-stained, white and gray, medium to coarse-grained schistose quartzose sandstone.

YXgn **Gneiss (middle to early Proterozoic)**--Undivided, highly variable, hornblende-biotite quartzofeldspathic gneiss. Probably derived from both igneous and sedimentary protoliths. Cut by common magnetite-bearing pegmatite dikes. Also contains local amphibolitic gneiss bands. Although the contact with amphibolite unit (YXa) is not well exposed, it is probably gradational. In the southern part of the map area the unit is predominantly a foliated, biotite granodiorite. Major-element oxide chemistry of one sample (sample S) from foliated granodiorite is reported in Table 2 and Figure 4.

YXa **Amphibolite (middle to early Proterozoic)**--Mostly dark-green, coarse- to fine-grained, foliated amphibolite consisting dominantly of hornblende and plagioclase. Hornblende porphyroblasts are present locally. Calc-silicate alteration (epidote and garnet?) is widespread but minor volumetrically. The amphibolite is intruded by common, generally concordant, foliated felsic dikes. A prominent NNE-trending ferruginous chert (exhalite?) occurs within this unit in the eastern area of exposure.

YXps **Pelitic schist (middle to early Proterozoic)**--Biotite-feldspar schist with porphyroblasts of garnet and staurolite. Small amounts of quartz and kyanite(?) are also present.

DESCRIPTION OF MINERAL DEPOSITS (The following descriptions correspond to numbered locations on the geologic map.)

Southern Eagletail Mountains

(1) White and black calcite veins and bull quartz veins, 2 to 10 cm thick. Iron oxide staining is common.
(2) Fracture-filling specular hematite and chrysocolla and pervasive iron-oxide staining on fracture surfaces that tend to be steep and northwest striking. Sparse relict pyrite that formed crystals up to 1 cm across are represented by amorphous iron oxides. This type of mineral deposit is present at many prospects in this general area (see also Lane, 1986). At this specific location mineralization was pervasive and resultant deposits are associated with a highly altered, northwest-trending (N50°W 80°SW) mafic dike up to 1 m thick. Bull quartz veins were also mined in this area but are not directly associated with fracture-filling iron-oxide bearing deposits. It appears that two types of deposit are coincidentally present in the same area here.
(3) Double Eagle Mine. Mine shaft in Quaternary surficial deposits adjacent to hill of Paleozoic dolomite marble. Mine dump contains abundant fragments of silvery gray, fine-grained schist that is just slightly more recrystallized than a phyllite. Protolith was probably Mesozoic tuffaceous or fine-grained sedimentary rocks. Dump samples contain fracture-filling clear fluorite up to 15 mm diameter and sparse fracture-filling malachite and relict pyrite (now iron oxides) up to 1 cm diameter. Open-space filling textures and local vugs are present.

Gila Bend Mountains

(4) Outlaw mine. Highly fractured bull quartz veins, 10 to 100 cm thick, contain pervasive fracture-coating iron oxides. Host rocks are Cortez Peak granite and metamorphic rocks intruded by the granite. Veins are broadly associated with intrusive margin of granite.
Wilson (1933) describes the Bill Taft Group, Belle Mackeever Group, and Yellow Breast Prospect in the Gila Bend Mountains. Localities 4 and 5 probably correlate with one or more of these claim groups. The U.S. Bureau of Land Management (1987) identifies the Outlaw Mine as the Taft group.
(5) Stardust mine. Large mine dump indicates many hundreds of feet of mine workings. Dump consists of pre-Cretaceous mafic gneisses with fracture-coating iron oxides. Sparse bull quartz is highly fractured and contains iron oxides and local manganese oxides on fracture surfaces. Local open-space filling textures associated with vein quartz and very sparse chrysocolla. Probably the Camp Creek Prospect discussed by Wilson (1933).
(6) Black Silver mine. A 10-m-deep, inclined adit is driven on a 1-m-thick vein trending N10°E and dipping 28°W. The hanging wall of the vein consists of highly shattered Columbus Wash pluton with a matrix of brown calcite and quartz. The vein consists of white, medium-grained quartz and irregular zones of brown calcite. Both the vein and brecciated granite are cut by dark gray to black, coarse-grained calcite (2-20 mm). Material observed on the adit dump includes banded and colloform chalcedonic quartz veins, copper oxides (chrysocolla and malachite), and hematite. North of the inclined adit is a caved-in shaft; the upper 10 m of the shaft is within alluvium. Common copper oxides and brecciated granite are present on the dump adjacent to the shaft.
(7) Copper Camp area (GF claims). Copper and iron deposits are present within highly fractured, pervasively limonitized amphibolite and gneiss, and are predominantly localized by moderate- to high-angle, W to WSW-trending, south-dipping shear zones. Copper deposits are generally confined to relatively narrow (< 1 m thick) zones within strongly limonitized host rock. The deposits consist predominantly of chrysocolla with lesser malachite. Rare chalcopyrite and native copper are locally present. Mineral deposits are commonly associated with limonitized, silicified breccia, open-space

quartz (locally amethystine) filings, chalcedonic quartz, and specular hematite. White, coarsely crystalline barite veins are also common and widespread. Local, irregular, bleached, highly-altered dikes are associated with mineralization. Geochemically, mineral deposits are characterized by strongly anomalous copper, moderately to strongly anomalous zinc, lead, and barium, and weakly to moderately anomalous silver, manganese, bismuth, boron, and gold. Generally Ag:Au ratios tend to be high, and arsenic, antimony, and mercury values are typically not anomalous. Older NNE-trending ferruginous chert zones (exhalite?) are also present within the amphibolite unit (YXa) in the area.

(8) A steep, 2- to 5-cm-thick, chrysocolla vein cuts the Ts map unit at this locality. Economically this mineralization is insignificant, but it does provide important geologic constraints. Charophyte microfossils present within limestone strata of this unit range from the Middle Eocene to the present, precluding a Laramide age for copper mineralization. Local, minor copper deposits are also present in other outcrops of map unit Ts and in the Tc and Tm map units.

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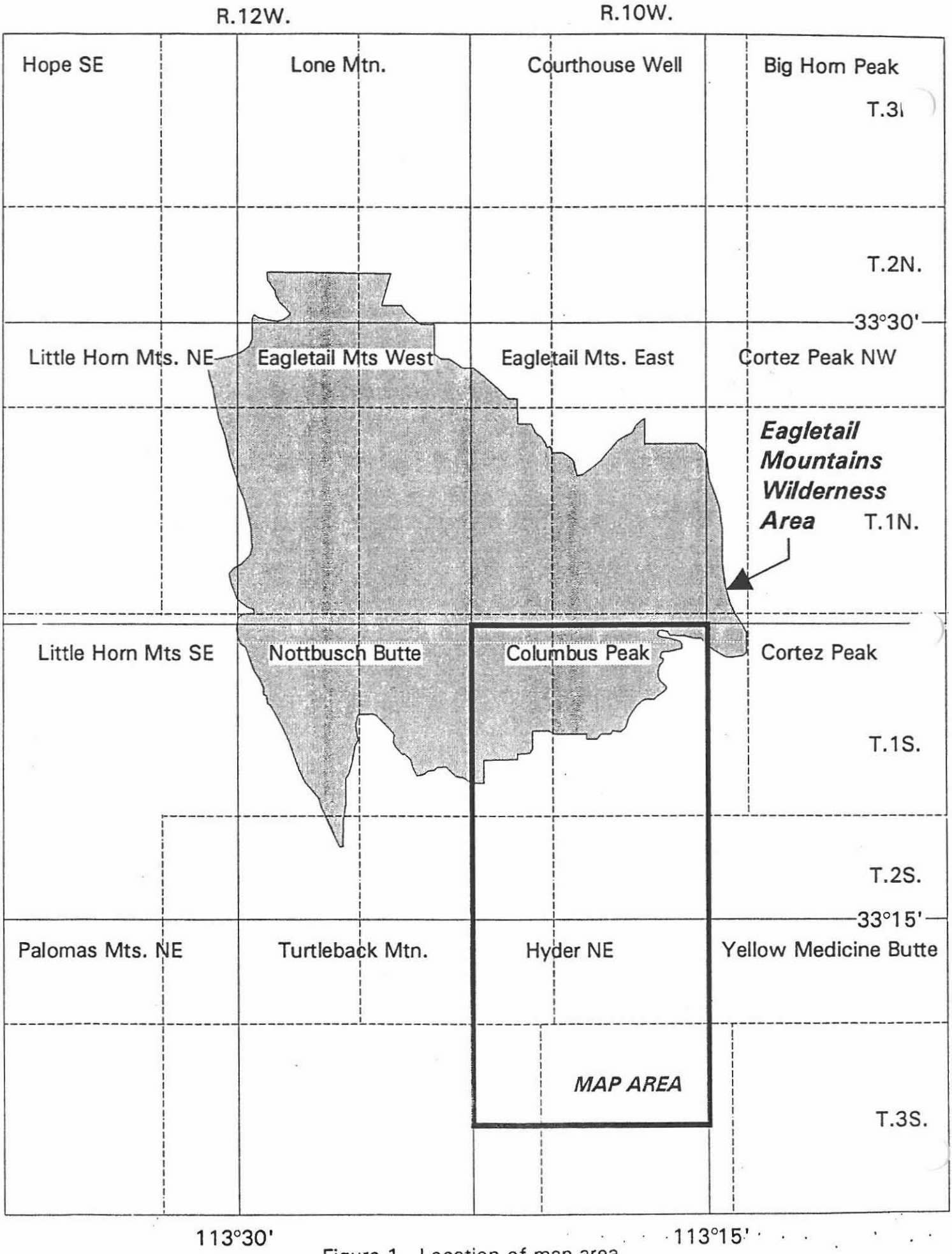


Figure 1. Location of map area.

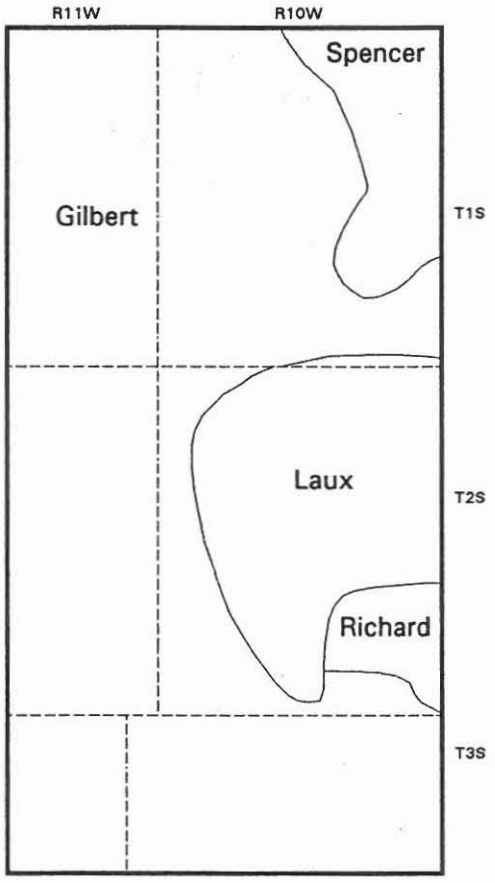
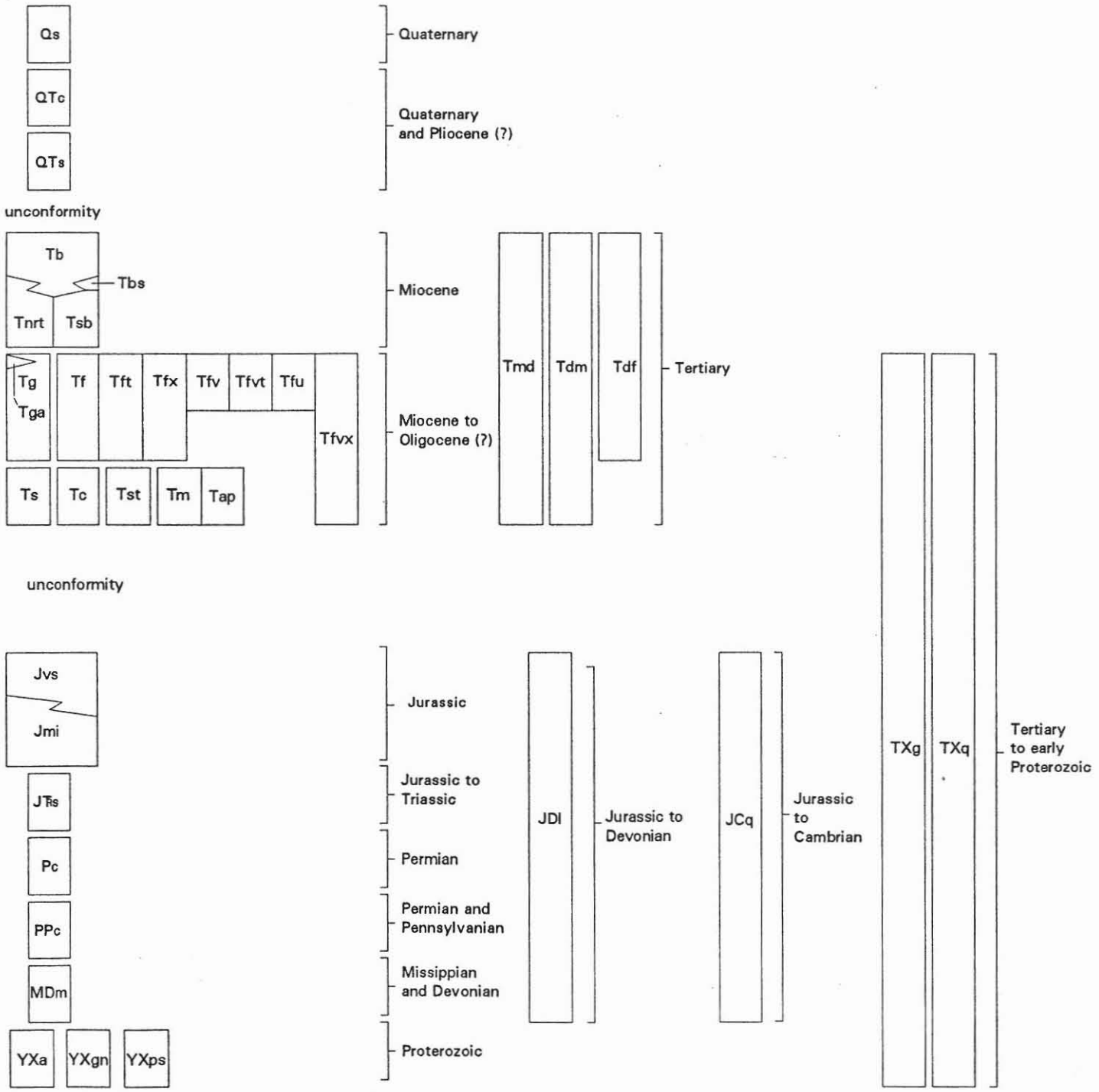


Figure 2. Respective areas mapped by authors

Figure 3. Correlation of Map Units



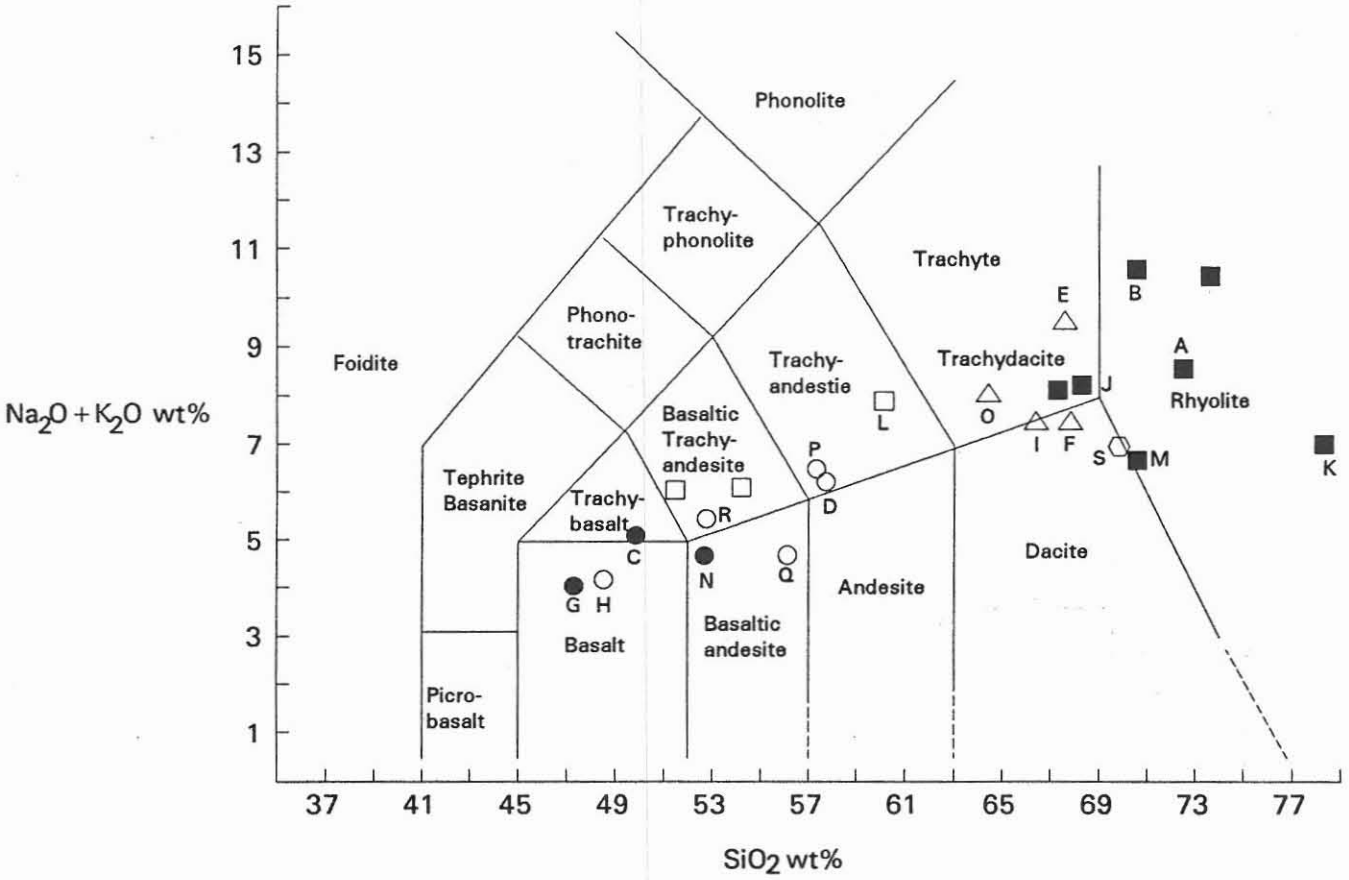


Figure 4. Total alkalies vs. SiO_2 for rocks from western Gila Bend and southern Eagletail Mountains, Maricopa and Yuma Counties, Arizona. ● - unit Tb; ○ - unit Tm; △ - felsic volcanic rocks (Tf, Tfv); ■ - unit Tg; □ - unit Tmd; ⬡ - unit YXgn. Classification scheme for volcanic rocks from Le Bas and others (1986). Map symbols A-F reported in Gilbert and Spencer (1992), symbols G-S in this report.

Table 1

MAP SYMBOLS

Contact, dashed where approximate

Fault, dashed where approximate, queried where inferred, dotted where concealed

Strike and Dip of Bedding

inclined

horizontal

vertical

Strike and Dip of Foliation

inclined

Mineral deposit locality

Major-element oxide sample locality

Locality of age dating sample and major-element oxide sample

Felsic dike (Tdf)

Mafic to intermediate dike (Tdm)

Table 2 (part 1). Major element oxide analyses from western Gila Bend and southern Eagletail Mountains, Yuma and Maricopa Counties, Arizona.

Rock Unit	Tb			Tm					Tf		Tfv		Tdf
Map Symbol	C	G	N	D	H	P	Q	R	E	O	F	I	--
Sample #	91WG33b	2-6-92-1	CFB	11-18-91-5	92WG16	91-32	91-27	92WG104	11-21-91-6	CWPP	91WG96a	92WG13	GD-RHY
Laboratory	CH	CH	ACME	CH	CH	ACME	ACME	CH	CH	ACME	CH	CH	BC
Quadrangle	NB	COP	COP	NB	COP	HNE	HNE	HNE	NB	COP	NB	HNE	CRP
SiO_2	49.50	46.95	52.57	57.71	48.13	57.29	56.20	52.50	67.63	64.41	67.86	66.35	73.56
TiO_2	1.15	1.13	1.04	0.82	1.24	0.88	0.94	1.02	0.34	0.47	0.38	0.34	0.08
Al_2O_3	15.50	14.72	16.98	16.38	17.32	16.70	16.53	17.05	15.79	15.79	15.01	14.52	13.46
Fe_2O_3	9.30	9.51	8.63	6.36	10.50	6.90	7.89	8.92	2.91	3.57	2.67	2.58	0.51
FeO	0.39	6.05	--	4.19	2.24	--	--	4.66	2.07	--	1.04	0.29	0.19
MgO	8.30	10.54	5.39	3.55	3.93	3.03	3.74	4.75	1.05	1.56	1.04	1.03	0.13
MnO	0.14	0.15	0.13	0.12	0.15	0.08	0.09	0.14	0.06	0.07	0.06	0.05	0.03
CaO	8.18	10.65	7.74	6.55	9.40	4.84	6.24	7.63	1.69	2.81	2.61	2.46	0.60
Na_2O	3.38	3.01	3.60	3.78	2.97	4.19	3.68	3.84	3.36	3.63	4.20	3.42	5.20
K_2O	1.64	1.04	1.18	2.54	1.18	2.34	0.99	1.58	6.25	4.41	3.39	4.17	5.30
P_2O_5	0.48	0.63	0.26	0.33	0.34	0.20	0.19	0.33	0.22	0.19	0.18	0.19	0.13
LOI	0.65	0.40	2.20	1.80	3.46	3.10	3.20	0.67	1.23	3.00	2.98	5.30	0.70
Cr_2O_3	--	--	0.017	--	0.03	0.002	0.022	0.01	--	0.002	<0.01	<0.01	--
BaO	0.08	0.08	--	0.10	--	--	--	--	0.19	--	--	--	--
Total	98.30	98.80	99.74	100.05	98.65	99.55	99.55	98.42	100.70	99.63	100.40	100.40	99.89
Comments													Lat. 33° 16' 00" Long. 113° 14' 25"

-- Not Analyzed

Laboratory: CH - Chemex Labs, Ltd.; ACME - ACME Analytical Labs.; BC - Bondar-Clegg, Inc.

Quadrangle: COP - Columbus Peak; CRP - Cortez Peak; NB - Nottbusch Butte; HNE - Hyder NE

Samples G-S located on map in this report; samples A-F located in Gilbert and Spencer (1992).

Table 2 (part 2). Major element oxide analyses from western Gila Bend and southern Eagletail Mountains, Yuma and Maricopa Counties, Arizona.

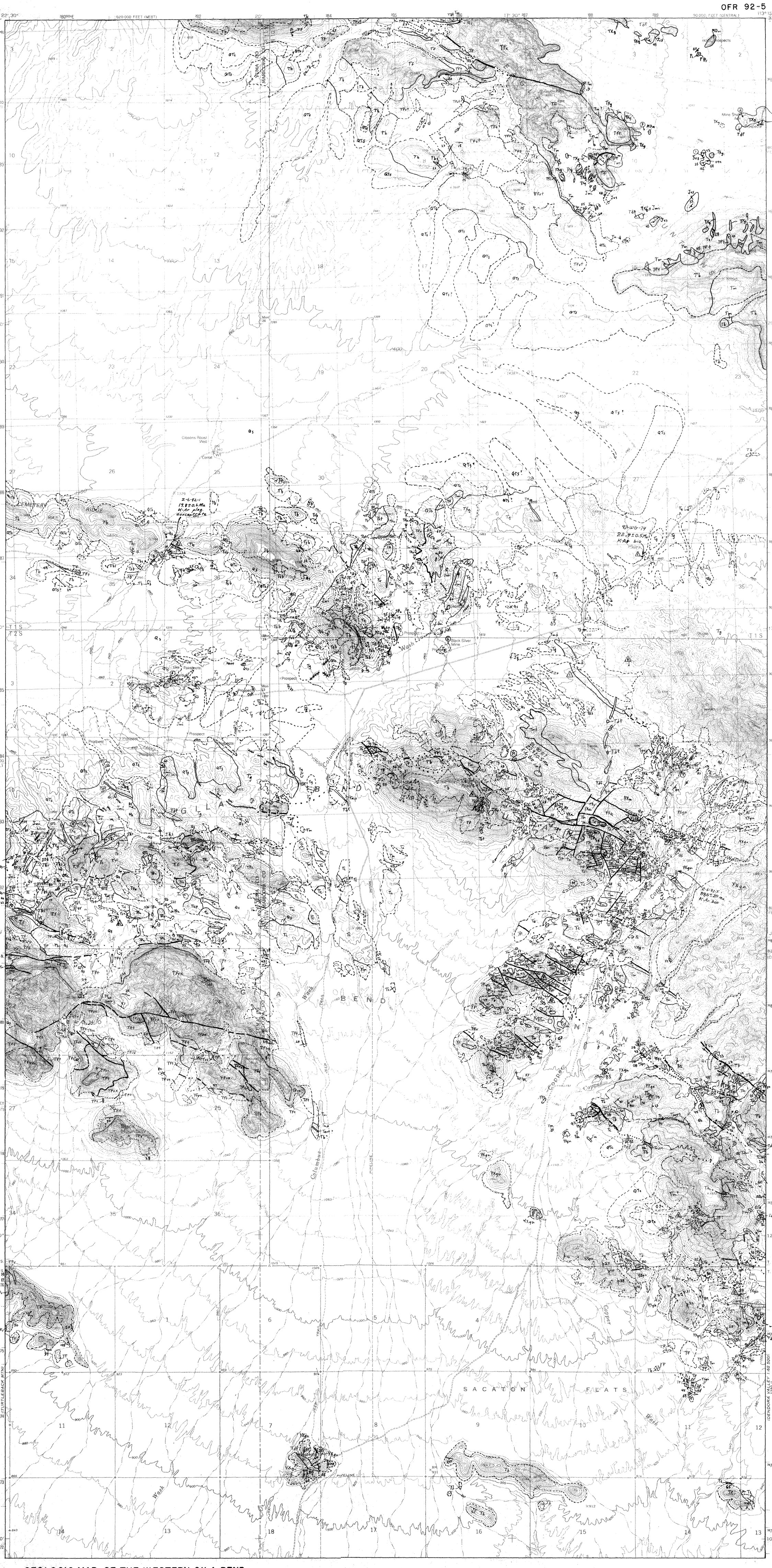
Rock Unit	Tg						Tmd			YXgn
Map Symbol	A	B	J	K	M	--	L	--	--	S
Sample #	91WG46	91WG12	92WG74	9174	90117	GD-13b	88-1	L-5	89-4	92WG102
Laboratory	CH	CH	CH	ACME	ACME	BC	BC	BC	ACME	CH
Quadrangle	NB	NB	COP	COP	COP	CRP	COP	CRP	CRP	HNE
SiO_2	72.47	70.30	68.31	78.37	70.73	67.45	59.95	51.03	54.10	69.95
TiO_2	0.23	0.27	0.35	0.11	0.36	0.37	0.73	1.14	1.03	0.30
Al_2O_3	14.01	14.15	15.32	12.59	13.96	15.09	16.89	17.48	15.73	16.02
Fe_2O_3	1.80	2.11	2.77	0.73	2.57	0.49	5.33	3.79	7.21	2.77
FeO	0.52	0.17	0.85	--	--	0.38	--	3.46	--	1.40
MgO	0.48	0.73	1.11	0.13	1.24	1.10	2.27	4.74	7.39	0.99
MnO	0.05	0.05	0.05	0.01	0.06	0.03	0.08	0.13	0.15	0.05
CaO	1.14	0.65	2.45	0.60	2.84	3.42	4.15	8.10	6.17	3.12
Na_2O	3.74	2.22	4.25	3.29	4.02	5.64	4.46	4.05	3.31	4.50
K_2O	5.02	8.33	3.98	3.80	2.77	2.51	3.44	1.85	2.74	2.49
P_2O_5	0.14	0.16	0.19	0.01	0.14	0.22	0.35	0.54	0.26	0.16
LOI	0.46	1.06	0.58	0.30	1.00	1.30	2.00	1.60	1.50	0.54
Cr_2O_3	--	--	--	0.002	0.006	--	0.002	--	0.039	0.02
BaO	0.15	0.19	0.14	--	--	--	--	--	--	--
Total	99.69	100.20	99.49	98.00	99.70	98.00	99.65	97.91	99.59	100.90
Comments				Aplite dike	K/Ar sample	Lat. 33° 16' 16" Long. 113° 14' 36"		Lat. 33° 16' 16" Long. 113° 14' 00"	Lat. 33° 15' 56" Long. 113° 14' 35"	

-- Not Analyzed

Laboratory: CH - Chemex Labs, Ltd.; ACME - ACME Analytical Labs.; BC - Bondar-Clegg, Inc.

Quadrangle: COP - Columbus Peak; CRP - Cortez Peak; NB - Nottbusch Butte; HNE - Hyder NE

Samples G-S located on map in this report; samples A-F located in Gilbert and Spencer (1992).



GEOLOGIC MAP OF THE WESTERN GILA BEND AND SOUTHERN EAGLETAIL MOUNTAINS, MARICOPA AND YUMA COUNTIES, ARIZONA

Wyatt G. Gilbert, Daniel P. Laux, Jon E. Spencer and Stephen M. Richard

1992

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ARIZONA GEOLOGICAL SURVEY
Open File Report 92-5

Scale 1:24,000

Plate 1

Open-File REPORT

GEOLOGIC MAP OF SADDLE MOUNTAIN, MARICOPA COUNTY, ARIZONA

by

Michael H. Ort[1] and Steve Skotnicki

Arizona Geological Survey
Open-File Report 93-6

May, 1993

PUBLISHED BY THE

ARIZONA GEOLOGICAL SURVEY

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GEOLOGIC MAP OF SADDLE MOUNTAIN, MARICOPA COUNTY, ARIZONA

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Michael H. Ort[1] and Steve Skotnicki

Arizona Geological Survey
Open-File Report 93-6

May, 1993

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Includes map, scale 1:24,000, and 11 page text.

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probably had local sources and did not flow in from distant vents. Ash-flow and fallout tuffs of intermediate composition are present within the basaltic sequence, especially in the top few hundred meters. The fallout tuffs are dominantly pumice fall and crystal fall, with minor fine ash beds. These tuffs commonly change character over distances of 100's of meters, either in grain size or changing from ash flow to fallout deposits or vice versa. This suggests that they are pyroclastic deposits of local small- to moderate-sized eruptions.

Lava flows of the same composition as the tuffs (biotite-hornblende andesite and/or dacite) are also present within the basalt sequence (Fig. 4). These lavas represent the proximal deposits of the same eruptions that produced the tuffs. Biotite-hornblende andesite lavas and tuffs are progressively more abundant upsection. Vents are present in several localities where lava domes are surrounded by monolithologic breccias. Hornblende-pyroxene andesite lavas are the youngest rocks at Saddle Mountain. They cover the basalt and biotite-hornblende andesite sequence with a mixture of lava flows and breccias. The major vent for the hornblende-pyroxene andesite appears to have been just west of the Saddle Mountain summit, with Saddle Mountain itself consisting of the lava flows and associated breccias.

One remarkable aspect of the Saddle Mountain rocks is the great thicknesses of monolithologic breccias (Plate 1; Fig. 4). These breccias are associated with lavas of the same composition that occur as lobate flows within and surrounded by the breccias. The breccias were probably produced by complex interactions of flows and flow breccias. The clast-supported breccias are generally weakly bedded, and probably represent flow breccias. The matrix-supported breccias contain both vitrophyric and moderately vesicular blocks and are interpreted as, at least in part, block-and-ash flow deposits. Auto-brecciation and small avalanches from the moving lava flow may also have produced these deposits. Their great thickness, however, needs explanation. Evidence of a loss of stratification within the clast-supported breccia in one locality, near the saddle 1596' northwest of Saddle Mountain, suggests that at least some of the breccias were "bulldozed" and thickened by the lava flows. Bulldozing of flow breccias and block-and-ash flow deposits by the lava flows and subsequent intrusion into the breccias by the lava can explain the outcrop pattern. Similar features are described in a Quaternary lava flow by Huppert and others (1982).

STRUCTURE

Foliation in Proterozoic metamorphic rocks of the Saddle Mountain area strikes northerly and dips steeply to the west or east. Cenozoic volcanic rocks dip 10° to 25° to the west or southwest. Rare Tertiary faults have N-S or E-W trends. A conglomerate near the base of the volcanic section contains clasts of basalt and a granodiorite of probable mid-Tertiary age, implying the granodiorite was exhumed within a few million years of emplacement.

DESCRIPTION OF ROCK UNITS

Qs **Surficial deposits (Quaternary)**--Unconsolidated alluvium and colluvium, talus, sand and gravel in modern washes, and unconsolidated to poorly consolidated gravel, sandy gravel, and sand, locally with silt or boulders, that typically forms flat, locally incised surfaces up to 5 meters above modern drainages. Also includes moderately steep slopes mantled by boulders and underlain by weathered and disaggregated rock rubble.

Tpax **Matrix-supported monolithologic breccia derived from pyroxene-hornblende andesite (Tertiary)**--Massive, matrix-supported monolithologic breccia composed exclusively of clasts derived from pyroxene-hornblende andesite (map unit Tpa). Poorly sorted angular blocks are up to 60 cm in diameter and range from dense vitrophyre through devitrified to ~30% vesicular andesite. Matrix is ash and lapilli. Breccia beds reach 300 m in thickness and commonly form convolute lensoid shapes in outcrop. Rocks of this unit are intimately associated with andesite lava flows of map unit Tpa.

Tpac **Clast-supported monolithologic breccia derived from pyroxene-hornblende andesite (Tertiary)**--Blocks up to 40 cm diameter of vitrophyre and devitrified lava in a matrix of ash and lapilli. Rocks of this unit are associated with map units Tpa and Tpax.

Tpa **Pyroxene-hornblende andesite (Tertiary)**--Forms thick flows and domes, commonly intricately interfingered with map unit Tpax and, in the southwestern part of Saddle Mountain, with map unit Tpac. Flows are generally dense, and most are devitrified, although several glassy, nearly vitrophyric flows are present. Some rocks are flow banded. Contains 1-5% clinopyroxene, 0-1% orthopyroxene (at least some is xenocrystic), <1-3% hornblende (commonly with resorbed cores), 5-15% zoned plagioclase (commonly resorbed cores or rims), <1% opaques, <1% biotite, and accessory titanite. Matrix is composed of plagioclase microlites and glass.

Tbax **Matrix-supported monolithologic breccia derived from biotite-hornblende andesite (Tertiary)**--Poorly sorted, angular blocks up to 60 cm in diameter typically composed of dense and devitrified andesite, with minor vitrophyre blocks and <30% vesicular blocks. Matrix is ash and lapilli. Breccia beds reach 30-40 m in thickness and form lensoid shapes in outcrop. Rocks of this unit are intimately associated with lava flows of map unit Tba.

Tbac **Clast-supported monolithologic breccia derived from biotite-hornblende andesite (Tertiary)**--Commonly crudely bedded in beds up to 10 m thick. Clasts of vitrophyre and devitrified biotite hornblende andesite in a matrix of ash and lapilli. Rocks of this map unit are typically associated with map units Tba and Tbax.

Tbap **Porphyritic biotite-hornblende andesite (Tertiary)**--Crystal-rich, coarsely porphyritic biotite-hornblende andesite containing plagioclase crystals up to 7 mm diameter. Rocks of this unit are similar to map unit Tba except for coarse plagioclase.

Tba **Biotite-hornblende andesite (Tertiary)**--Forms thick flows and domes, commonly with flow breccia at base. Some flows are glassy and nearly vitrophyric, whereas most are devitrified. Flows are dense, generally with less than 5% vesicles. Flow banding and foliation are common. Lava is commonly found intricately interlayered with map units Tbax and Tbac. Rock contains 2-5% biotite, 1-5% hornblende, 7-10% plagioclase, <1% augite, and <1% opaque minerals. Matrix is composed of plagioclase microlites, tiny biotite crystals, and glass. Titanite and apatite are accessory minerals. In some samples, augite forms cores of hornblende crystals.

Tbm **Interbedded tuff, breccia, and basalt flows (Tertiary)**--Tuff consists of moderately well-

sorted biotite-hornblende andesite fragments (some pumiceous) and crystals and occurs as laminated beds 1 to 10 cm thick. Tuff probably represents fallout or surge deposits. Breccia consists of basalt and biotite-hornblende andesite clasts, commonly as planar beds 1 to 10 m thick and locally crossbedded. Clasts are sub-angular, up to 7 cm diameter (average 2-3 cm). Matrix is basalt or biotite-hornblende andesite grains; in some cases exclusively one or the other. Matrix grains are sub-rounded. Interpreted as fluvial sedimentary rocks. Basalt is same as map unit Tb.

Tt **Bedded and massive tuffs (Tertiary)**--Bedded tuffs, interpreted as fallout, consist of clast-supported, moderately well-sorted ash and lapilli fragments that commonly form laminated to thin bedded layers up to 2 m thick. Clasts up to 3 cm diameter consist of pumiceous biotite-hornblende andesite. Ash is devitrified, hydrated, and chalky. Pumice clasts are also devitrified and chalky. Massive tuffs, interpreted as ash flows, consist of poorly sorted, non-welded ash and lapilli tuffs that form beds up to 10 m thick. Beds vary significantly in thickness over 500 m lateral distances. Angular pumice clasts of biotite-hornblende andesite are up to 10 cm in diameter. Angular basaltic fragments are common, but make up <1% of the rock, and fragments of Proterozoic metavolcanic rocks (map unit Xm) are rare. The matrix is devitrified ash, with 0.5-2 mm diameter crystals of biotite, plagioclase and hornblende. Bedded tuffs are interpreted as fallout, surge, and reworked tuffs, whereas massive tuffs are thought to be small-volume pyroclastic flow deposits.

Tb **Olivine-clinopyroxene basalt and clinopyroxene basaltic andesites (Tertiary)**--Basalt typically contains <1% olivine and clinopyroxene phenocrysts with seriate-porphyritic plagioclase microlites and glass in matrix. Basaltic andesite contains 7 to 30% plagioclase with resorbed cores, <1-2% clinopyroxene, 0-1% hornblende, and plagioclase-quartz, plagioclase-hornblende, and plagioclase-spinel-orthopyroxene-clinopyroxene-Fe-Ti-oxide clots up to 1 cm in diameter. Rocks of this unit commonly form interbedded lava flows and cinders. In some localities, cinders are very abundant, with few flows. Flows commonly have flow breccias at their bases and tops. Phenocrysts and glass are commonly altered, hydrated, and/or replaced with calcite.

Tgc **Matrix-supported conglomerate of granite and basalt fragments (Tertiary)**--Consists of sub-angular basalt clasts up to 10 cm diameter (2 cm average) and sub-rounded to rounded granite clasts up to 70 cm (20 cm average) in a basalt granule matrix.

Tg **Biotite-hornblende granodiorite (Tertiary?)**--Consists of 40% plagioclase, 30% quartz, 25% K-feldspar, 2-3% biotite and 2-3% hornblende (commonly altered to clinopyroxene). Exposed only in southeastern sector of map area where it forms low rounded outcrops. A possibly correlative granodiorite, the Columbus Wash Granodiorite in the Gila Bend Mountains, has been dated at 22.9 Ma (Gilbert and others, 1992).

Xb **Banded iron formation (Proterozoic X)**

Xm **Slaty metavolcanic rocks (Proterozoic X)**--Green, fine-grained metavolcanic rocks with slaty cleavage that contains K-feldspar and amphibole phenocrysts. Protolith was probably andesite. Map unit contains lenses of banded iron formation and quartz veins and crops out north of Salome Highway and as an isolated hill in the southeastern part of the map area.

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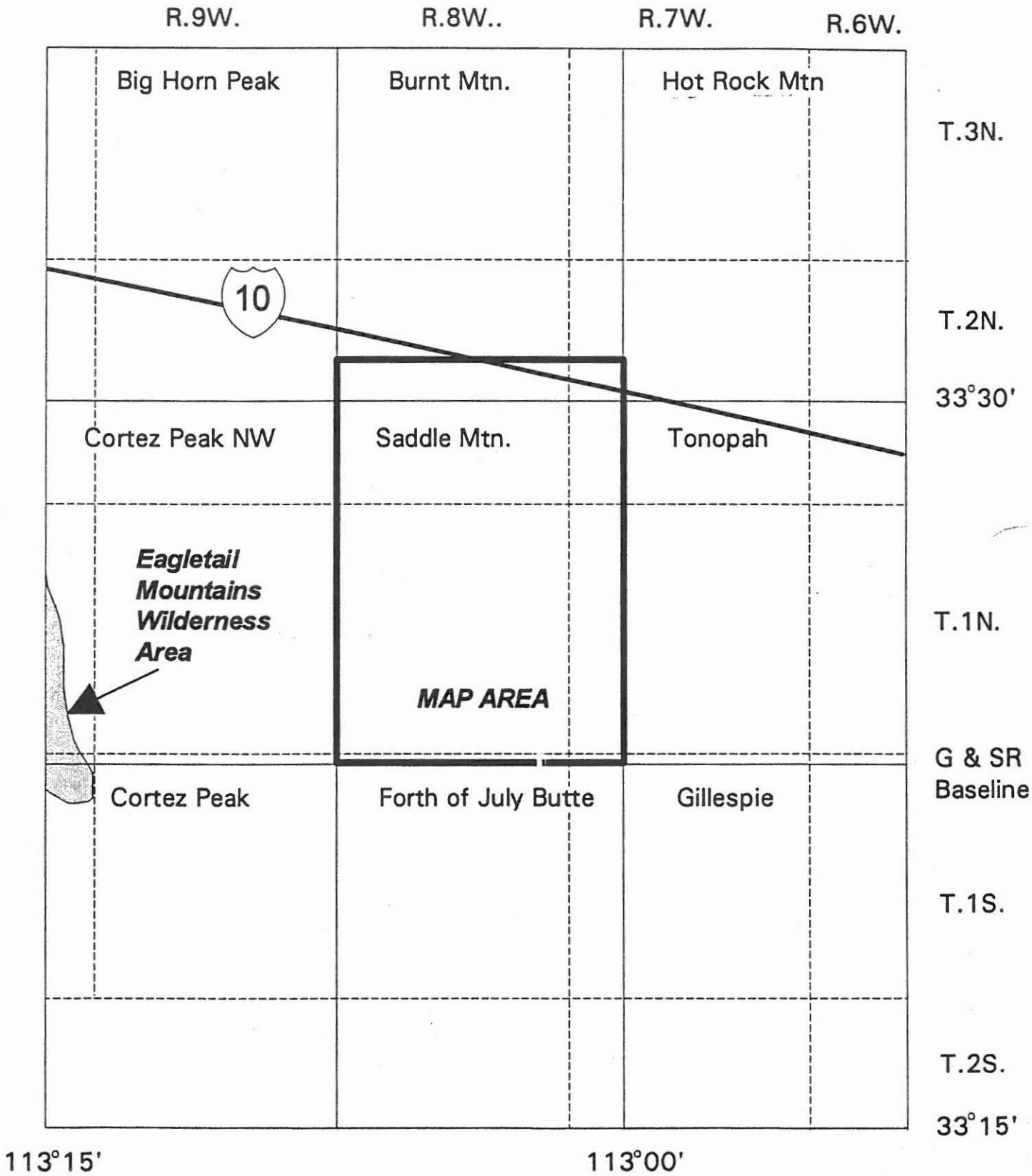

Fig. 1. Location of study area.

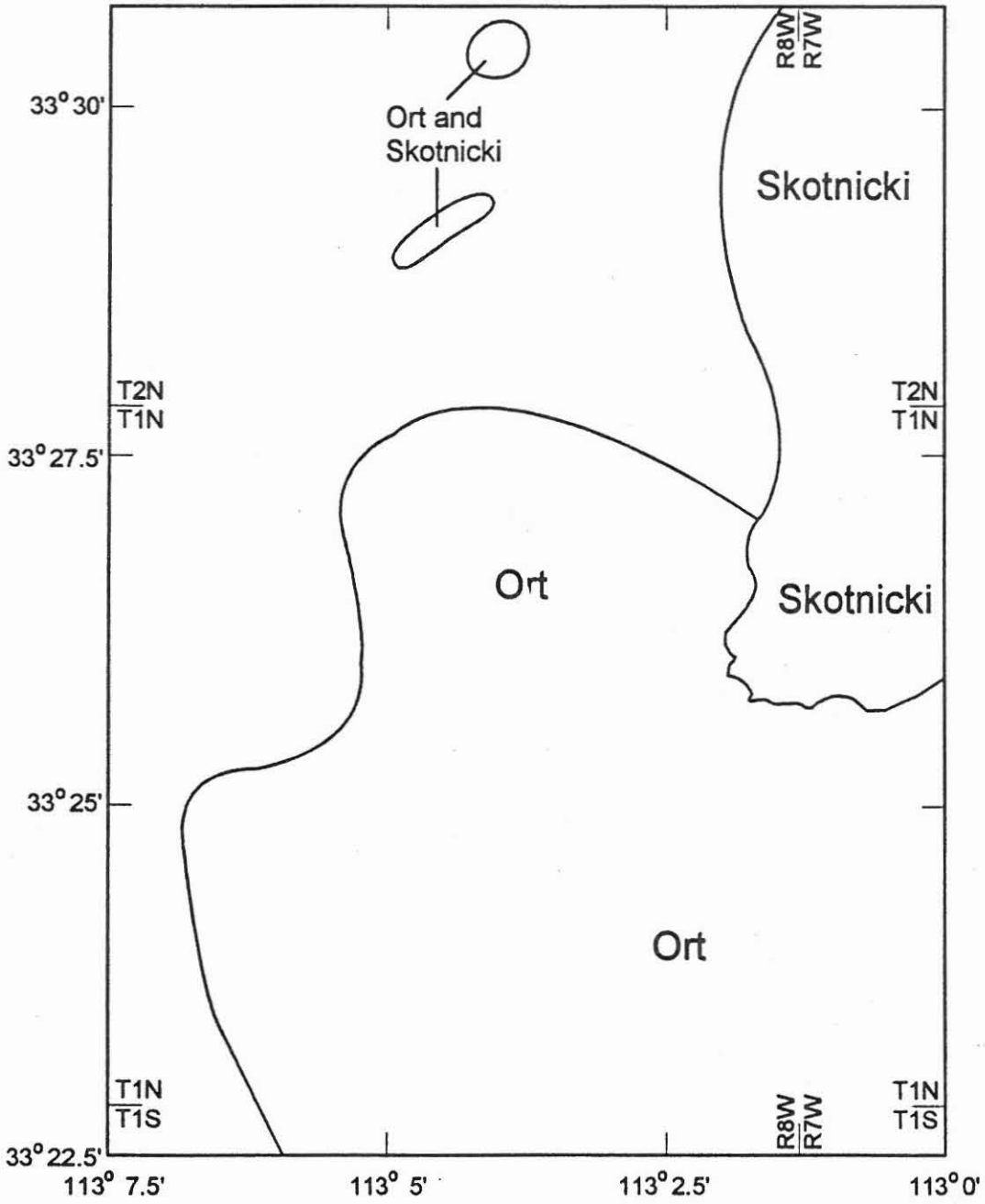

Fig. 2. Source of map data.

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Figure 3. Correlation of Map Units

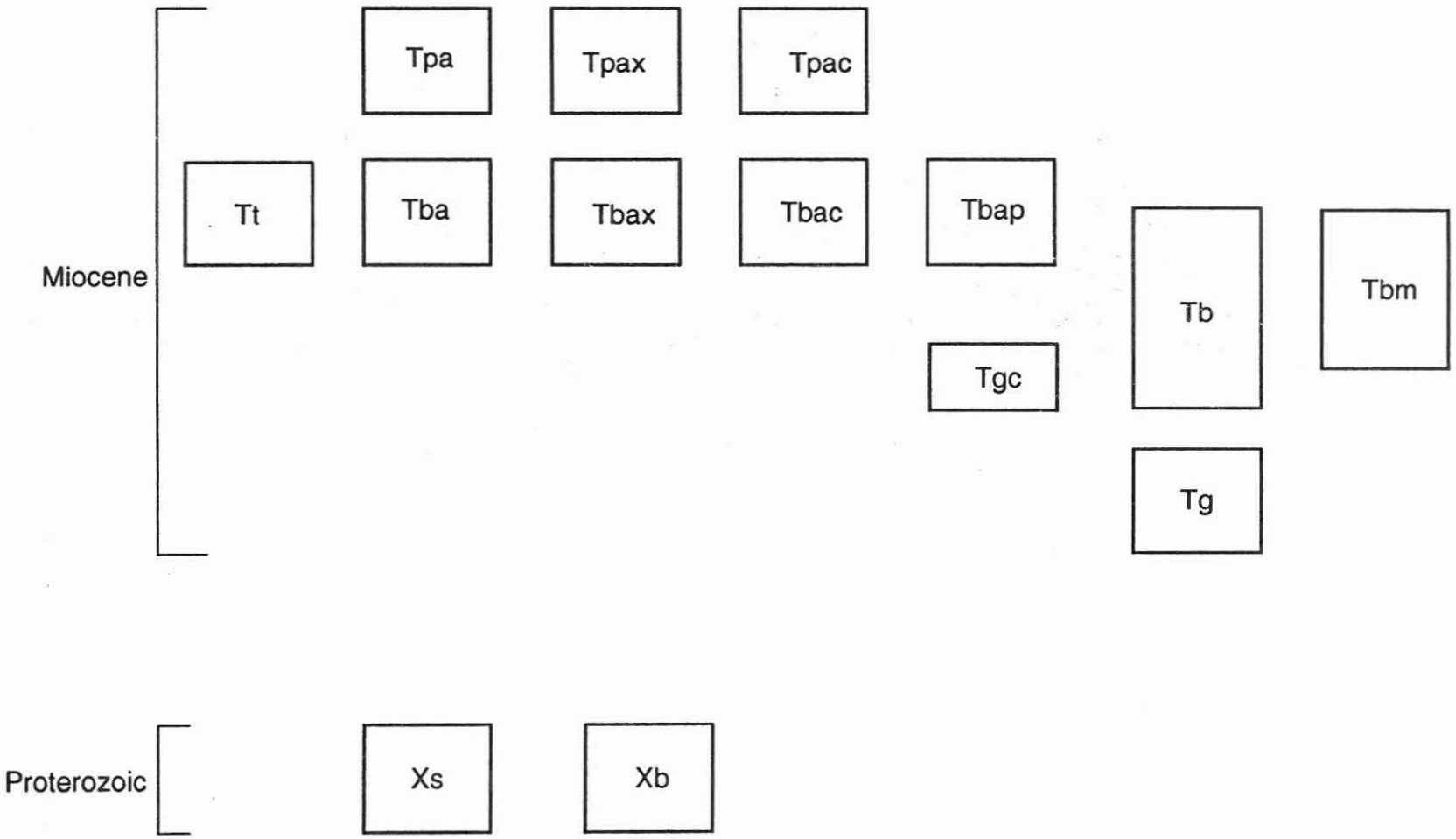


Figure 4. Cartoon diagram of generalized stratigraphy of Saddle Mountain

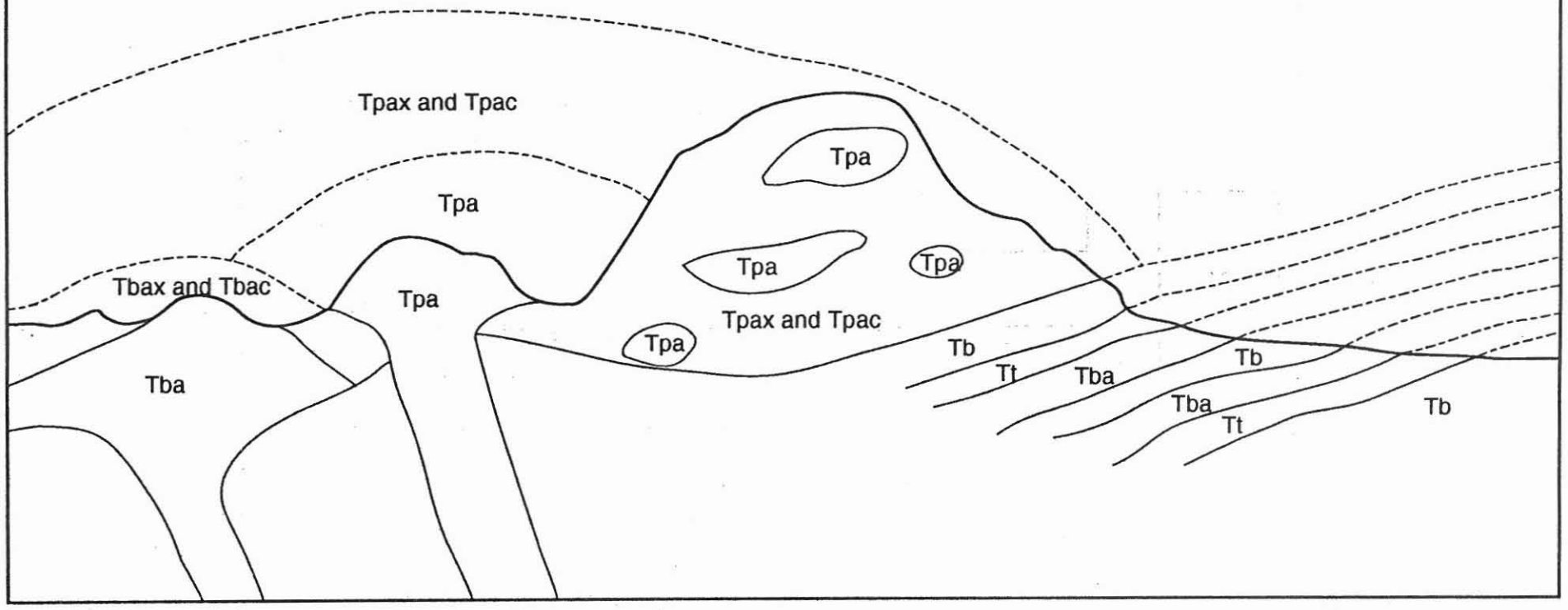


Table 1

Map Symbols

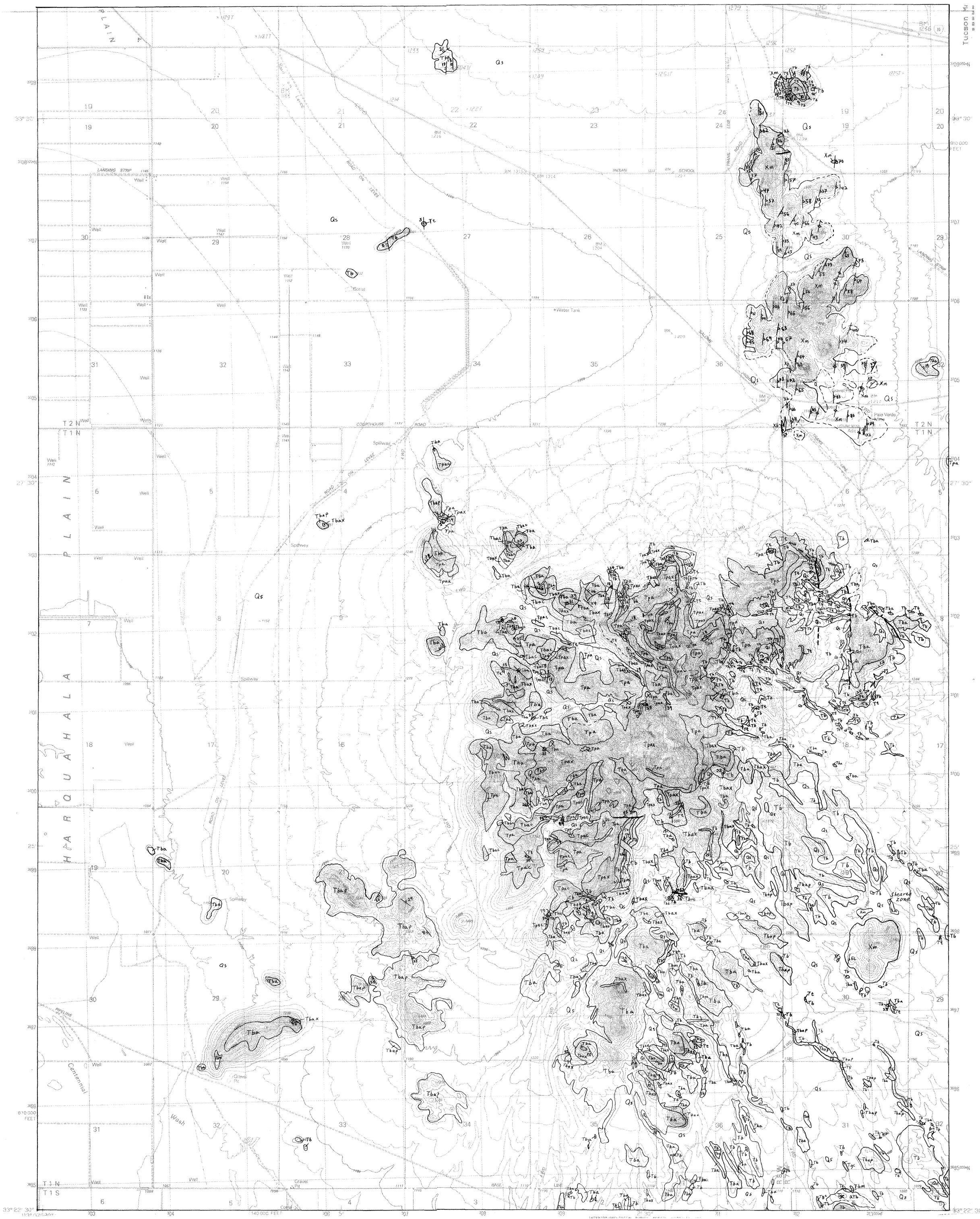
——— - - - - - -	Contact, dashed where approximate
——— - - - - - -	Fault, dashed where approximate
22	Strike and dip of bedding
22	Strike and dip of lava flow foliation
22	Strike and dip of cleavage
	Strike and dip of vertical cleavage
++++++++++	Mafic to intermediate dike

GEOLOGIC MAP OF SADDLE MOUNTAIN, MARICOPA COUNTY, ARIZONA

1993

Michael H. Ort and Steve Skotnicki

scale: 1:24,000



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Open-File REPORT

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INTRODUCTION

The area described in this study includes the western Eagletail Mountains, Yuma county, Arizona and includes much of the Eagletail Mountains Wilderness Area (Figure 1). Bedrock in this area consists largely of Miocene silicic volcanic rocks and subordinate mafic and intermediate volcanic units (Plate 1). Sources of data are shown in Figure 2, rock-unit correlations and relative ages are shown in Figure 3, and map symbols are shown in Table 1.

The area was mapped in part with funds provided to the Arizona Geological Survey by the U.S. Geological Survey COGEOMAP program, contract #1434-92-A-1061. Field work was carried out by the authors in the winter of 1993. 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.

Additional mapping, done in 1997 by J. Spencer and S. Richard, was intended to clarify the structure and stratigraphy of two areas, as follows: (1) an inaccessible area in the southwestern foothills of the Eagletail Mountains (southern part of map area) that had only been mapped previously by aerial photograph interpretation, and (2) a layered sequence of volcanic rocks intruded by dikes on the steep northeastern range front that had not been satisfactorily mapped. K-Ar radiometric dates are also located on the updated map.

PREVIOUS INVESTIGATIONS

Previous geologic studies of the area include reconnaissance studies incorporated into State geologic maps by Wilson and others (1969) and Reynolds (1988), and reconnaissance mapping by Miller and others (1989). The eastern Eagletail Mountains were mapped by Spencer and others (1992). The area to the south and southeast of the study area was mapped by Gilbert and others (1992) and Gilbert and Spencer (1992), the area directly to the west was mapped by Grubensky and Demsey (1991), and the Little Harquahala Mountains to the northwest were mapped by Spencer and others (1985). Mineral deposits in the eastern Eagletail Mountains were described by Lane (1986) and Miller and others (1989). The upper Cenozoic surficial deposits were mapped and described in reconnaissance by Demsey (1990). K-Ar dates are summarized by Spencer and others (1995).

GEOLOGIC SETTING

The study area is within the Basin and Range physiographic and tectonic province, much of which underwent severe Tertiary extension and magmatism (Spencer and Reynolds, 1989). The region around the study area is characterized by northwest-trending normal faults and fault blocks, and the northwest trend of the Eagletail Mountains is probably due to Tertiary normal faulting and southwestward tilting of the range. Pre-Tertiary rocks exposed along the northeastern flank of the range consist of Jurassic to Proterozoic granitoid rocks. Early to middle Miocene magmatism produced a thick sequence of flows, flow domes, and hypabyssal intrusions with local mafic. Dominantly felsic magmatism was followed by early to middle Miocene basaltic magmatism.

Cenozoic sedimentary and volcanic rocks

QTs **Surficial deposits (Quaternary and Pliocene)**--Unconsolidated alluvium and colluvium, including talus, sand and gravel in modern washes, and unconsolidated to poorly consolidated gravel, sandy gravel, and sand, locally with silt or boulders, that typically forms flat, locally incised surfaces up to 5 meters above modern drainages. Also includes older unconsolidated alluvium and colluvium that form rounded hills and gentle hill slopes.

QTbr **Basalt rubble (Quaternary to Tertiary)**--Slopes and hilltops mantled with boulders and cobbles of resistant basalt.

QTrr **Rhyolite rubble (Quaternary to Tertiary)**--Slopes and hilltops mantled with boulders and cobbles of resistant rhyolite.

QTc **Pedogenic carbonate (Quaternary to Tertiary)**--Buff crystalline carbonate with siliceous stringers and laminations parallel to bedding, and 1-4 cm diameter irregular siliceous clots. Outcrops as bed 1-2 m thick, with bedding broadly parallel to the hillslope, but warped into an open syncline. Lamination defining bedding within the unit is warped into minor monoclinal folds and cut by microfaults. Outcrop distribution suggests rock is pedogenic carbonate mantling topography, but folds and minor faults in the unit suggest that it is older and interbedded with basalt (map unit Tb).

Tc **Conglomerate (Tertiary)**-- Massive, unorganized boulder conglomerate with tan, very fine-grained sand matrix. Matrix is moderately indurated. Unit is exposed only in washes. Clasts are mostly basalt boulders up to about 1 m diameter, and include of a variety of types of basalt (vesicular, non-vesicular, different phenocryst assemblages). Clasts are subrounded to subangular. Other minor clast types include fine-grained equigranular biotite granite, very fine-grained pink quartzose sandstone (Supai Formation?), Bolsa Quartzite, sparse gray Paleozoic carbonate clasts, and metabasalt (greenstone). Source of Paleozoic clasts was unmetamorphosed. Unit is locally permeated by chalcedony-calcite veinlets.

Tb **Basalt (Tertiary)**--Dark reddish brown, vesicular and nonvesicular basalt and basaltic andesite(?). Contains 1 to 3%, 1 to 2 mm pyroxene. In the northwestern part of the map area, rocks of this unit are of uncertain stratigraphic relationship to rocks included with unit Tb elsewhere, and could be correlative with map units Tbau or Tblh.

Tbx **Basalt breccia (Tertiary)**--Angular to subangular basalt fragments in indurated basaltic rock matrix. Unit is generally massive and matrix poor. Locally includes red oxidized zones and highly vesiculated rock suggestive of autobreccia, but other outcrops have the appearance of rock avalanche deposits or tectonic breccia.

Tblh **Basalt of Little Horn Mountains (Tertiary)**--Blue-gray, variably resistant basalt and basaltic andesite lavas mapped by Grubensky and Demsey (1991) in the western part of the map area. Probably correlative with map units Tb or Tbau.

Tif **Intermediate to felsic, quartz-poor volcanic rocks (Tertiary)**--Tan flows(?) with up to 5 to 10%, 1 to 7 mm plagioclase, 1 to 3%, 1 to 2 mm biotite, and little or no quartz. Approximately one half mile north of the northeast corner of section 2, T. 1 N., R. 12 W., rocks of this unit are dark gray, slightly vitrophyric, with sparse fine-grained biotite and K-feldspar.

Tad **Crystal poor andesite-dacite (Tertiary)**--Medium to dark purplish grey andesite or dacite with 2-3 mm blocky plagioclase crystals, and 1-2 mm hornblende or biotite crystals typically replaced by chlorite. Plagioclase crystals are commonly poikilitic, enclosing hornblende and biotite crystals.

Tau **Andesite (Tertiary)**--In northwestern part of map area this unit consists of pyroxene andesite flows and medium brown to purplish tan, biotite-hornblende-feldspar (typically 1-3mm diameter) intermediate composition flows with sparse potassium(?) feldspar phenocrysts up to 7 mm diameter. Unit is resistant to weathering in this area and may form cliffs.

Tbau **Basalt and basaltic andesite, undivided (Tertiary)**--Basalt, basaltic andesite, and possible andesite lavas and flow breccias. Variably vesicular to non-vesicular, commonly dark reddish brown to dark gray to black. Locally interbedded with bedded pyroclastic rocks. Stratigraphic position relative to map units Tb and Tba, which are lithologically similar, is not clear.

Tbap **Pyroxene basaltic andesite (Tertiary)**--This unit is exposed only in one area in the northwestern part of map area directly west of the Clanton Well Road. This unit consists of slope forming, locally vesicular, crystal poor, medium to light gray flows that weather pale orange and contain 1 to 2%, 1 to 3 mm pyroxene (augite?), sparse albite twinned plagioclase phenocrysts, and abundant (40-50%) plagioclase microlites. Elongate pits, 5 to 30 mm, on weathered surfaces are probably vesicles and vesicles enlarged by weathering.

Tvs **Volcanic-lithic sandstone and bedded pyroclastic rocks (Tertiary)**--Includes bedded pyroclastic rocks, tuff, volcanic-lithic sandstone and conglomerate with sparse volcanic and granitoid clasts.

Tsl **Sandstone and limestone (Tertiary)**--Variably tuffaceous limestone and sandy limestone beds up to perhaps 1 m thick within a sequence of tuffaceous sandstone, siltstone, and sparse conglomerate.

Trv **Rhyolite vitrophyre (Tertiary)**--Massive, medium gray vitrophyre with 3 to 5% phenocrysts of 1 to 2mm biotite, hornblende, and feldspar.

Trb **Big crystal rhyolite (Tertiary)**--Pale tan to grayish tan rhyolite flows and flow breccias. Characterized by 2 to 5 mm sanidine crystals. Commonly contains varying amounts of 1 to 3 mm biotite, plagioclase, hornblende, and tiny (<1mm) pyroxene crystals. Quartz is present locally but in many areas is conspicuously absent. Vitrophyre common near contacts with other units; locally unit is vitric throughout. Devitrified, hydrated zones are reddish gray.

Trbq **Big crystal quartz rhyolite (Tertiary)**--Similar to Trb, but 1-2 mm quartz crystals are present.

Tr **Biotite rhyolite (Tertiary)**--Generally tan, pale gray, or reddish brown. Commonly crystal poor. Locally contains 1 to several percent, 1 to 3 mm aligned biotite, and minor fine grained (≈1mm) quartz, plagioclase, sanidine, and locally, hornblende(?). May contain hornblende and plagioclase. Locally flow banded or vitrophyric. Some rocks of this unit are very light weight because of microvesicles(?) or pumice fragments(?). In some areas rhyolite light violet-gray, crystal rich, and contains 5 to 10% 1mm crystals of quartz, feldspar (sanidine and plagioclase), and biotite and/or hornblende.

In thin section biotite is commonly altered to opaque iron oxides(?). Local brown hornblende is typically partially altered. Most samples contained abundant fresh albite-twinned plagioclase,

generally < 1mm. One sample was characterized by 1 to 3 mm thick bands of alternating gray, fresh to weakly altered rhyolite and red, weakly altered rhyolite. Locally bands are stringers or elongate, rounded blobs.

Trx **Rhyolite breccia (Tertiary)**--Monolithologic rhyolite breccias, both clast- and matrix-supported. Matrix is same composition as clasts. Clasts vary from dense to 30% vesicles. Deposits are interpreted as flow and carapace breccias, and as block-and-ash flow and small-volume pyroclastic flow deposits. In some localities near domes, pods of stratified, fine-grained vitric tuff, each with a different orientation, occur within this unit, and are interpreted to indicate disrupted bedded tuff deposits.

Ta **Andesite (Tertiary)**--This unit is exposed along base of range front in northeastern part of the map area. It consists of medium to dark brown, reddish gray, or pinkish brown andesite to dacite(?) lava flows and fragmental rocks with 1%, 1 to 2 mm hornblende, 3 to 8%, 2 to 6 mm K-feldspar, and 0 to 2%, 1 to 2 mm quartz.

Tba **Andesite and basaltic andesite (Tertiary)**--Basalt, basaltic andesite and andesite lavas. Dark grey lavas with tiny plagioclase, pyroxene and olivine crystals. Interbedded with all other rock units, but generally forms a subordinate part of the section. One thin section revealed embayed quartz.

Tbp **Bedded pyroclastic rocks (Tertiary)**--Bedded tuff, tuffaceous sediments and pyroclastic rocks. Distinguished by presence of bedding. Generally light yellowish tan, pale tan, or white. Commonly contains 1 to 3%, locally fresh biotite up to 2 mm and sparse quartz and feldspar up to 2 mm diameter. May be moderately friable. Pyroclastic deposits include moderately well-sorted beds of 0.5-1 cm diameter pumiceous clasts or ash, poorly sorted beds of pumice, ash, and lithic fragments, and well-sorted beds of fine-grained, laminated, wavy- or cross-bedded ash. Beds are typically 2-20 cm thick, although a few are massive and up to 5 m thick. Channel deposits are rare in the pyroclastic deposits. Waterlain deposits are volcanogenic sandstones and pebbly sandstones, with sub-angular to sub-rounded clasts. Beds are typically 2-20 cm thick and moderately well-sorted, although a few are massive and up to 5 m thick. Channel deposits are common. In cliff exposures, low angle unconformities are commonly visible, with angular discordance up to 20°. Interbedded with all other rock units, but most commonly found between rhyolite flows.

In southeastern part of map area rocks of this unit locally contain abundant pumice fragments that weather to form elongate pits up to 3 cm long. Locally in this area rocks of this unit also include (1) volcanogenic conglomerate, (2) vesicular basalt fragments, 2 to 20 cm diameter (locally up to 50 cm diameter), in light tan, bedded, volcaniclastic matrix, and (3) breccias composed of rhyolite vitrophyre clasts in rhyolitic matrix.

Tu **Undivided sandstone, conglomerate, tuff, mafic lava and breccia (Tertiary)**--Lithologically diverse rocks at base of section.

Tsb **Sedimentary breccia (Tertiary)**--Massive angular-clast conglomerate with good evidence for mixing with epiclastic sandstone matrix; monolithologic to polymictic. Predominant clast types include: (1) medium grained, equigranular biotite granitoid, (2) porphyritic biotite monzogranite that is lithologically identical to granitoid in Black Rock Hills at southern end of the Little Harquahala Mountains, and (3) Jurassic quartz porphyry identical to unit Jqp on this map and to Black Rock volcanics of Little Harquahala Mountains (Spencer and others, 1985).

Tx **Debris avalanche deposits (Tertiary)**--Lenses of shattered and brecciated rock with little or no discernible epiclastic matrix. Protolith rocks consist primarily of medium-grained, equigranular to moderately porphyritic, biotite granitoid, and with less abundant Tertiary basalt, tuff, and Jurassic hypabyssal quartz (up to 10 mm) porphyry with K-feldspar phenocrysts up to 50 mm long and with white (plagioclase?) rims. In most areas this unit is a monolithologic granitoid breccia.

Cenozoic intrusive rocks

Intrusive rocks Intrusions distinguished by nature of well exposed contacts and geometry of rock bodies. Lithologically identical lavas are present for all intrusive rocks.

Tmd **Mafic dikes (Tertiary)**--Basaltic to andesitic intrusions. Locally vesicular, medium to dark gray, with abundant 1 mm plagioclase. Lithologically similar to map unit Tba.

Tifd **Intermediate to felsic, quartz-poor dikes (Tertiary)**--Characterized by plagioclase, biotite, and hornblende crystals, light to medium grey color, and absence of significant quartz.

In the northeastern part of the map area dikes of this unit dip gently to moderately northeastward along steep range front, and may form dip slopes. In this area dikes are light gray, with 10 to 20%, 1 to 3 mm white plagioclase, 1 to 3 %, 1 to 2 mm biotite, and < 1% 1mm hornblende. These dikes intrude along normal faults.

In the southern part of the map area a single dike of this unit consists of a light gray, aphanitic matrix, 2 to 4%, 1 to 3 mm feldspar, at least some of which is potassium feldspar, 1 to 3%, 1 to 3 mm biotite, up to 1% hornblende phenocrysts <4 mm long, and little or no quartz.

Tpp **Plagioclase porphyry**--Intermediate to felsic, massive, hypabyssal intrusive porphyry containing 10 to 15%, 2 to 8mm, white plagioclase, 1 to 3 %, 1 to 3 mm biotite. Two to 10 cm mafic inclusions are common. Forms massive, rounded outcrops with little or no hint of layering. Rocks of this unit are probably coarse-grained equivalent of nearby, quartz-poor, intermediate to felsic dikes (map unit Tifd).

Tri **Hypabyssal rhyolite (Tertiary)**--In thin section contains 2 to 3% green hornblende < 0.5 mm long, < 1% biotite, and sparse twinned plagioclase.

Tsi **Silicic intrusive rocks (Tertiary)**--Characterized by abundant quartz phenocrysts in some areas, in other areas consists of almost aphyric felsite with sparse 1mm quartz phenocrysts.

Pre-Cenozoic rocks

Jqp **Quartz porphyry (Jurassic)**--Highly fractured, greenish gray, massive quartz porphyry. Represents extrusive or hypabyssal intrusive rock that is probably correlative with virtually identical Jurassic volcanic and hypabyssal rocks in the Little Harquahala Mountains (Richard and others, 1987).

JXmg **Sore Fingers monzogranite (Jurassic to early Proterozoic)**--Medium- to coarse-grained monzogranite, with 20-50% K-feldspar in phenocrysts up to 7 cm in diameter, 20-25% quartz in anhedral grains up to 8 mm diameter, 30-35% plagioclase in 2-5 mm subhedral crystals, and 5-10% biotite generally greatly in excess of hornblende. Biotite is variably recrystallized to very fine-grained aggregates. K-feldspar phenocrysts are irregularly distributed in rock body; locally they occur packed together in cumulate zones which may consist of >50% phenocrysts. Sparse aplite dikes intrude the monzogranite. Correlated with the Sore Fingers Monzogranite (Spencer and others, 1985) of the southern Little Harquahala Mountains based on lithologic similarity. A sample of this rock in the southern Little Harquahala Mountains yielded a K-Ar minimum age of 140 Ma (Rehrig and Reynolds, 1980). U-Pb data from a probably correlative monzodiorite in the northern Little Harquahala Mountains indicates an age of near 160 Ma (S. M. Richard and N. R. Riggs, unpublished data).

JXlg **Fine-grained, equigranular, leucocratic granite (Jurassic to early Proterozoic)**--In some areas contains up to 2 to 3 percent biotite. Commonly contains pegmatite dikes.

JXg **Porphyritic granodiorite (Jurassic to early Proterozoic)**--Medium- to fine-grained biotite and hornblende-biotite granodiorite to monzogranite with gray potassium feldspar phenocrysts up to 4 cm long. Large K-feldspar phenocrysts may be rounded with long axes subparallel to local tectonic lineation. Local foliation and lineation are not obviously mylonitic, and are crosscut by younger quartz veins up to 5 cm thick. Locally includes medium- to fine-grained hornblende diorite(?) with up to 40% mafic minerals in bodies ranging from enclaves with diameters <1 m to pendants up to several 10's of m long. In more highly deformed zones near the margins of the body, the large K-feldspar phenocrysts are commonly recrystallized to rounded quartz-feldspar aggregates, which appear granitic; hornblende is typically moderately to completely replaced by biotite in these zones as well. Contacts on both the northwest and southeast are gneissic shear zones (shown as unit JXgn).

JXgn **Undivided gneiss (Jurassic to early Proterozoic)**--Typically fine-grained feldspar-quartz-biotite (±hornblende) gneiss, but also includes leucocratic quartzofeldspathic gneiss and sparse hornblende-plagioclase gneiss. Thin to very thin compositional banding defined by variations in mineralogy; banding mostly planar to curviplanar; ranges from well defined to subtle. Unit includes irregular small intrusions of medium- to fine-grained equigranular leucogranite, granodiorite, and diorite. These range from cross cutting to concordant. This unit is interpreted to mostly consist of orthogneiss formed along the margins of adjacent granitoids.

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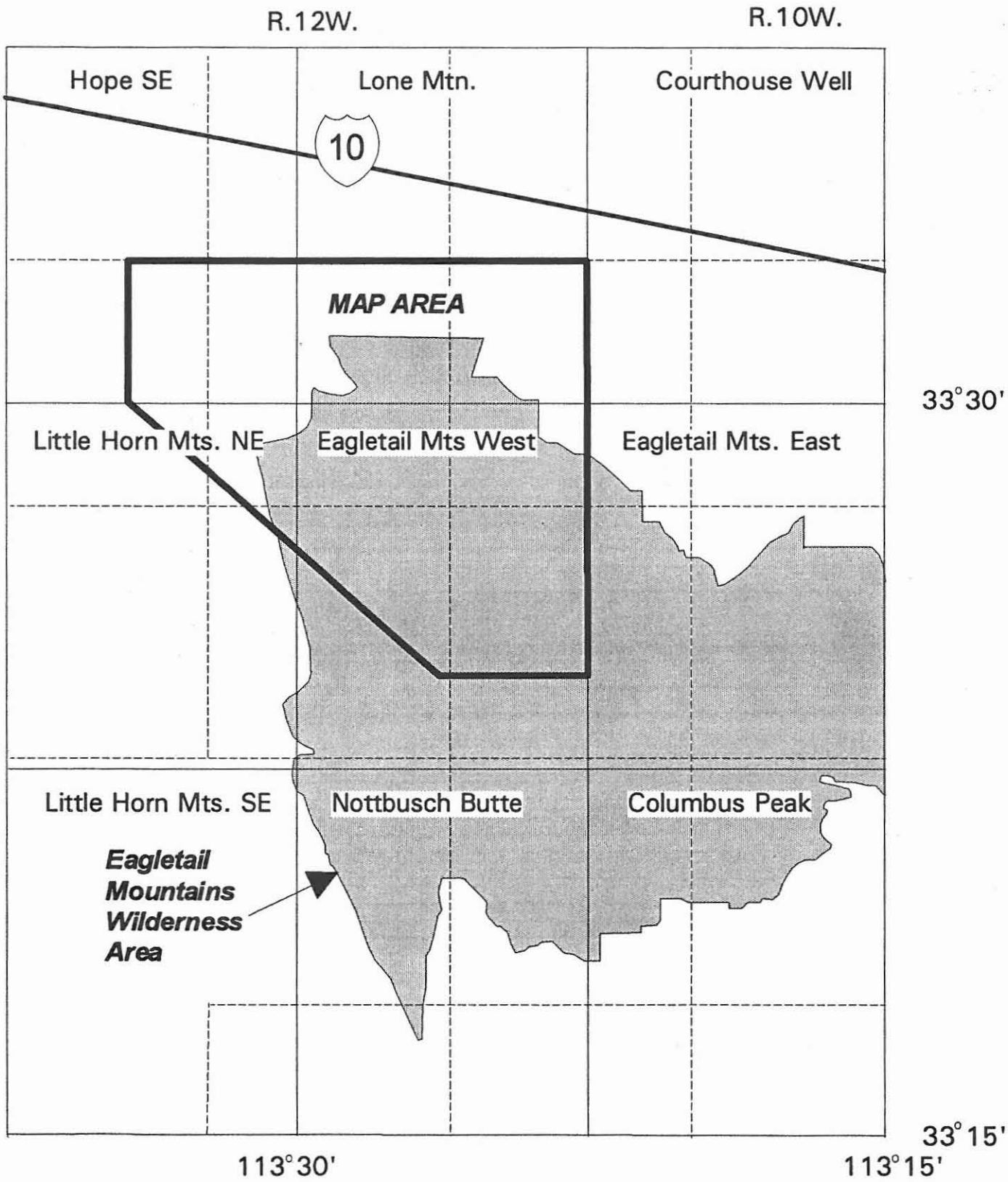

R.12W.
R.10W.
Hope SE
Lone Mtn.
Courthouse Well
10
MAP AREA
33°30'
Little Horn Mts. NE
Eagletail Mts West
Eagletail Mts. East
Little Horn Mts. SE
Nottbusch Butte
Columbus Peak
Eagletail Mountains Wilderness Area
33°15'
113°30'
113°15'

Fig. 1

FILE: MSOURCE.DRW

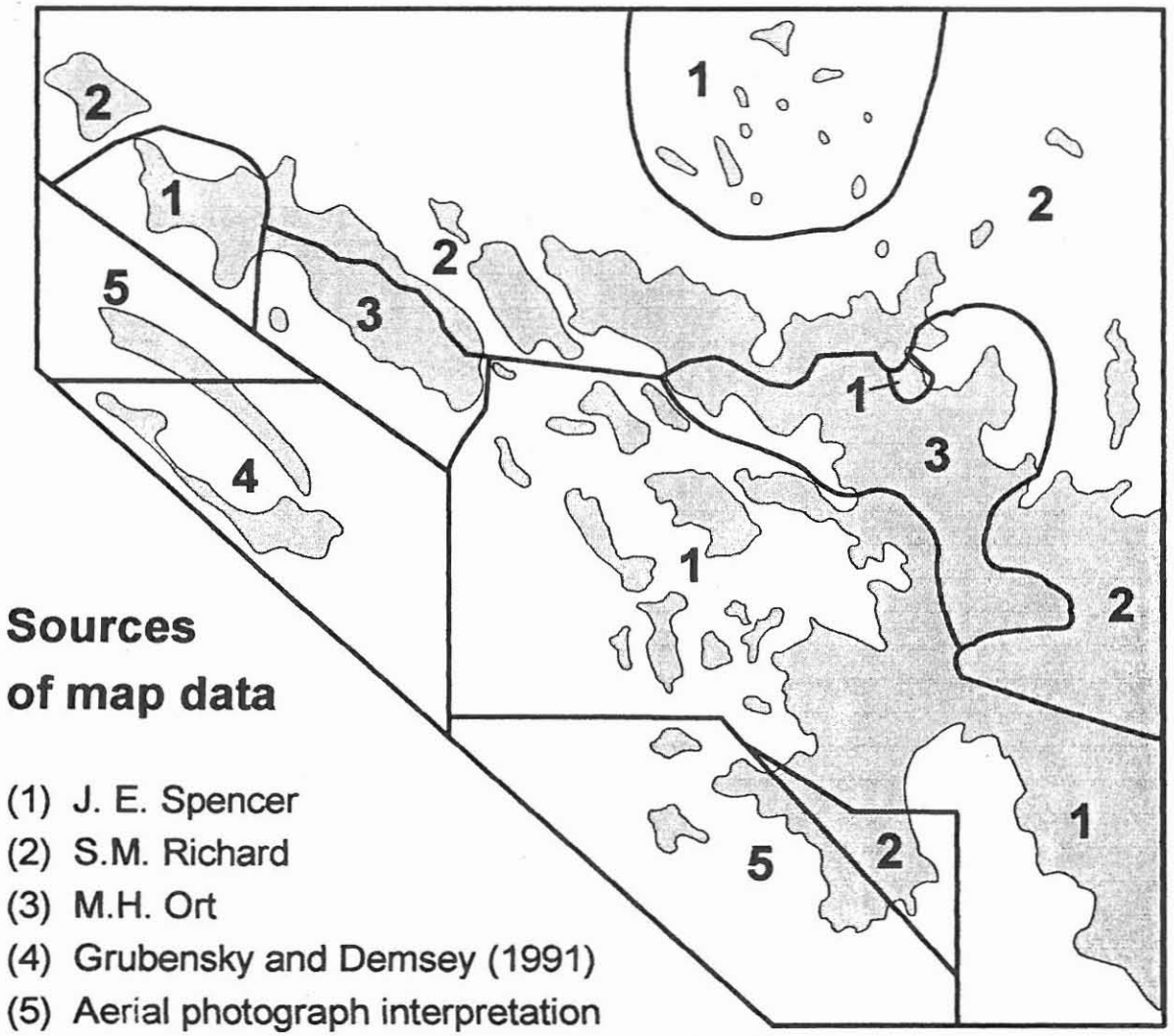


Fig. 2

Correlation of Map Units

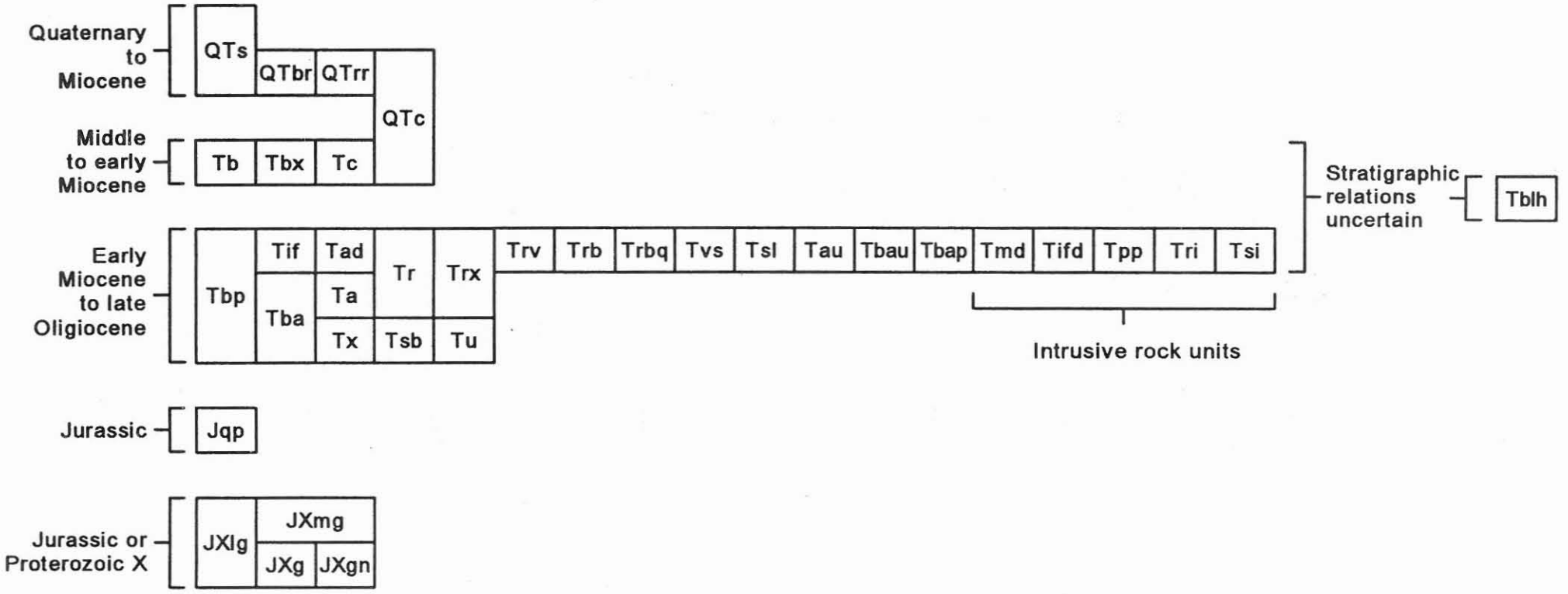


Fig. 3

Map Symbols

bedding

flow foliation

inclined vertical approximate

curviplanar bedding

Protomylonite; S-tectonite

Joint

Compositional Banding

quartz vein

66

Fault, showing dip; dashed where approximate, dotted where concealed.

Low-angle normal fault

Detachment fault; chloritic breccia present in footwall

39

Depositional or intrusive contact, showing dip; dashed where approximate, dotted where concealed.

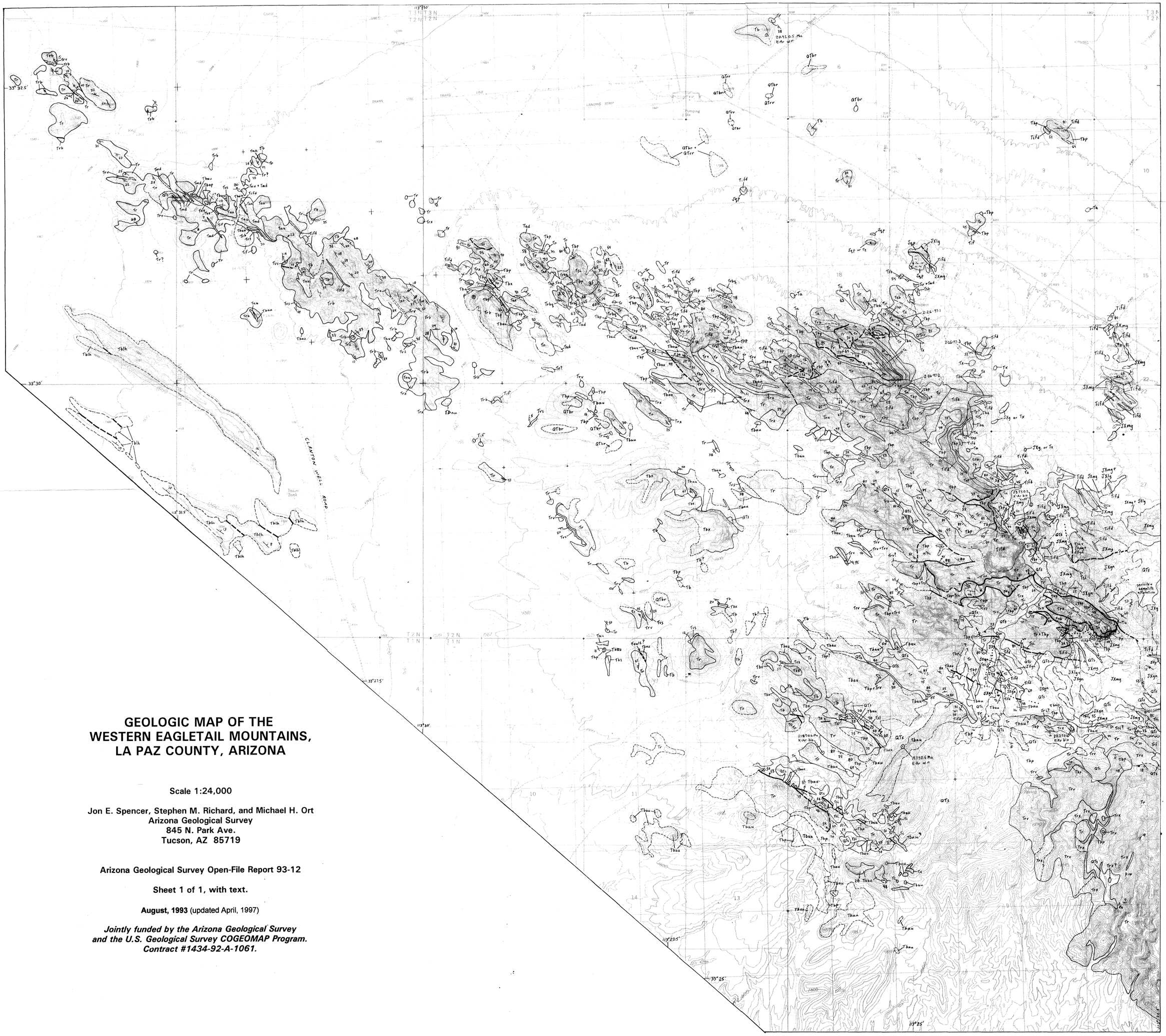
massive volcanogenic breccia zones

v v v v v v vitrophyre zone

mafic dike

alteration zone; rock silicified, bleached or hematite stained

TABLE 1



GEOLOGIC MAP OF THE WESTERN EAGLETAIL MOUNTAINS, LA PAZ COUNTY, ARIZONA

Scale 1:24,000

Jon E. Spencer, Stephen M. Richard, and Michael H. Ort
Arizona Geological Survey
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Tucson, AZ 85719

Arizona Geological Survey Open-File Report 93-12

Sheet 1 of 1, with text.

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Open-File REPORT

Geologic Map of the Salome 30'x60' Quadrangle, West-central Arizona

by

Stephen M. Richard, Jon E. Spencer, and Stephen J. Reynolds*

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Open-File Report 94-17

October, 1994

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This report is preliminary and has not been edited
or reviewed for conformity with Arizona Geological Survey standards

MAP UNITS

Late Tertiary and Quaternary deposits

Q Undivided surficial deposits. **(Quaternary)** Alluvium and talus, undifferentiated.

Qyc Active alluvium. **(Holocene)** Primarily sand and silt (hue 7.5 to 5 YR), confined to active and recently active deposits of major axial drainages. No soil development has occurred on any of the deposits.

Qye Eolian deposits. **(Holocene)** Fine-grained, non-indurated sand. Mapped where sand dunes, generally stabilized by vegetation, make up more than 50% of the surficial deposits.

Qy Young Alluvium. **(Holocene and late Pleistocene)** Surfaces primarily underlain by well-sorted sand and silt, with local occurrences of fine gravel. Surfaces are very slightly but abundantly dissected by active gullies and washes, with ≤0.5 m of relief. Remnant bar -and-swale topography is preserved locally. Surface material typically fine-grained, and surfaces appear smooth. Incipient to light desert varnish is developed on mafic clasts where a surface pavement is present. Surfaces exhibit minimal soil development; the most strongly developed profiles contain cambic horizons (hue 7.5 YR) over stage I to II calcic horizons [Machette, 1985]. Soils typically belong to Torriorthents, Calciorthids, or Camborthids great groups.

Qt Talus. **(Holocene and late Pleistocene)** Unconsolidated, poorly sorted, angular gravel to boulder-size sediment on steep slopes.

Qm Middle alluvium, undifferentiated. **(Late to middle Pleistocene)** Undivided younger and older middle alluvium (includes Qm_1 and Qm_2). Primarily represents surface remnants in which the two units are mixed to a degree that precludes differentiation at the scale of this map. In a few places this broader designation is used because of uncertainty in estimating the age of a particular remnant.

Qm_2 Younger middle alluvium. (Late to middle Pleistocene) Surfaces underlain by deposits of silt to coarse gravel, and slightly to moderately dissected with ~1 to 4 m of relief above active channels. Remnants have smooth and fine-grained surface or planar, gravelly pavement. Pavements commonly have moderate to dark desert varnish on mafic clasts. Soils on the remnants exhibit slightly of moderately developed textural B horizons (hue 7.5 to 5 YR), typically above a stage II or III calcic horizon. Soils are Camborthids to Haplargids.

Qm_1 Older middle alluvium. **(Middle Pleistocene)** Surfaces underlain by sand and fine gravel to large cobbles, generally moderately sorted. Surfaces are moderately dissected, with ~3 to 6 m of relief above active channels. Remnants are generally rounded by erosion near their edges, and have a gravelly to cobbly capping pavement. Mafic clasts in the pavement are consistently darkly varnished, and surface remnant are normally among the darkest on the piedmont. Underlying soils are characterized by moderately to very strongly developed argillic horizons (hue 5 to 2.5 YR), and commonly overlie a stage III to IV calcic horizon. Soils are Haplargids or Paleargids.

Qo Older alluvium. **(Middle to early Pleistocene)** Surfaces underlain by coarse gravel and cobbles to boulders, with minor amounts of finer-grained material. Commonly forms a 1-5 m thick veneer unconformably overlying older basin fill or bedrock. Surfaces are relatively deeply dissected, with ~7 to 10 m of relief above active channels. Remnants are comparatively small, and are found on well rounded ridges between entrenched channels. Pavement of the surfaces is not well preserved due to extensive erosion and/or clast weathering. Remnants are typically covered with abundant fragments of pedogenic carbonate, many of which are >5 mm thick, derived from brecciated laminar petrocalcic horizons and carbonate clast-coatings. The fragments and coated clasts commonly lend a lighter-colored appearance to these remnants. Soils are generally stripped by erosion to expose remnants of stage V or VI petrocalcic horizons (Paleorthids).

QTbx Breccia and Rubble. **(Quaternary or Tertiary)** Boulders and cobbles of shattered basalt or rhyolite mantle the surface of several hills on the NW side of the Eagletail Mountains. Exposure is too poor to determine the nature of the underlying deposit.

Tertiary sedimentary and volcanic units

Tsy Younger sedimentary rocks. **(Pliocene or Miocene)** Polymict conglomerate with clasts up to 30 cm in diameter. Generally weakly to moderately indurated, very poorly bedded, and overlies Tertiary and pre-Tertiary rocks on an angular unconformity. Erosional unconformity typically separates Tsy from younger alluvium where the contact is well exposed. Clast types reflect rock types in adjacent outcrops. Clast size in conglomerate is generally coarser than in younger deposits, but as distance from bedrock outcrop increases, this distinction is difficult to make. Original surfaces are not preserved. Generally mapped morphologically because of poor outcrop; occurs as deeply dissected old alluvial fans with >10 m of relief above active channels.

Tsl Lacustrine sedimentary rocks. **(Miocene)** Primarily buff-colored, laminated tuffaceous mudstone that crops out east and west of Black Butte in the western Vulture Mountains. Locally includes silica nodules, gypsiferous beds, and gray colored beds that are celestite-bearing. Includes subordinate tuff and lapilli tuff.

Tsm Sedimentary rocks. **(Miocene)** Massive conglomerate, ranges from pebble and cobble conglomerate to boulder conglomerate with scattered large blocks up to about 5 m in diameter. A few thin sandstone units are interbedded. Generally buff colored, poorly to moderately indurated, and nonresistant. The unit commonly forms low hills with little or no outcrop, but steep cliffs a few meters high occasionally occur in washes. In the Big Horn Mountains, includes monolithologic sedimentary breccia and landslide megabreccia, and some overlying, less consolidated, sand and gravel deposits equivalent to unit Tsy. Clast composition reflects local source areas. The irregular distribution of the conglomerate in the southern Plomosa Mountains suggests that it was deposited on a steep paleotopography. Conglomerate in this unit is mostly coarse alluvial deposits and possible debris flow deposits. The thickness is highly variable; in the southern Plomosa Mountains a maximum of about 190 m of section is exposed. The deposits are flat lying to slightly tilted, and generally appear to have been deposited during the final stages of the early Miocene extension event.

Tbu Upper basalt. **(Miocene)** Vesicular basalt lavas with a dark gray very fine-grained groundmass of plagioclase, opaque oxides, and olivine and phenocrysts of pyroxene, plagioclase, and olivine (mostly altered to iddingsite) in varying amounts. Plagioclase phenocrysts are usually subordinate. Zeolite minerals and calcite partially fill vesicles and diktytaxitic voids. Includes Hot Rock basalt in Big Horn Mountains [Stimac et al., 1994], and basalt of Black Mesa in the southern Plomosa

Mountains [Sherrod et al., 1990]. These basalt lavas typically cap mesas and high hills, and are not tilted or are only very gently tilted. The maximum thickness is about 20 m at Hot Rock Mountain, and up to about 90 m on Black Mesa. Reported K-Ar dates from this unit include 15.01 ± 0.42 Ma from Hot Rock Mountain in the southern Big Horn Mountains [Shafiqullah et al., 1980]; 15.62 ± 0.35 Ma from Black Butte in the western Vulture Mountains [Scarborough and Wilt, 1979], and 17.23 ± 0.43 from Black Mesa in the southern Plomosa Mountains [Shafiqullah et al., 1980]

Tfu Upper felsic volcanic rocks. **(Miocene)** Consists of light gray to pink-colored, crystal-poor rhyolite flows, flow breccias, and lithic tuffs. Phenocrysts (<1 to 5%; <2 mm) are biotite, quartz, and opaque minerals. The groundmass exhibits a medium-grained granophyric texture. Some outcrops may be remnants of small domes. The maximum thickness of the flows is about 50 m. The lithic tuffs reach a maximum thickness of 20 m, and do not persist laterally beyond the limit of the overlying flows. This unit is equivalent to the Beer Bottle rhyolite member of the Big Horn volcanics of Stimac et al. [1994], which is the youngest volcanic rock in the central Big Horn Mountains. This rhyolite overlies older volcanic rocks (Tbl and Tf) with a significant angular unconformity. Age estimate is based on a K-Ar feldspar date of 16.4 ± 0.2 Ma [Capps et al., 1985].

Tf Felsic volcanic rocks. **(Miocene)** Includes dacitic to rhyolitic lavas and associated pyroclastic rocks, which form a major part of the Tertiary volcanic section in the Vulture, Big Horn, and Eagletail Mountains and the Bouse Hills. In most areas the lavas formed dome complexes with associated breccia rinds and block and ash deposits. Central parts of the complexes are typically light-colored, massive to flow-banded felsite with variable amounts of biotite, hornblende, quartz, sanidine and plagioclase crystals. These grade laterally into breccia and tuff, and the distal parts of each flow grade into light gray to white non-welded tuff. For more complete descriptions of the highly variable lithology and stratigraphy of this unit, see the descriptions in Grubensky [1989], Stimac et al [1994], Spencer et al. [1993], and Spencer and Reynolds [1990].

Tbx Megabreccia and sedimentary breccia. **(Miocene)** Includes monolithologic and polymict sedimentary breccia and megabreccia near the base of the Tertiary stratigraphic section in the Eagletail Mountains and near the top of the stratigraphic section in the Big Horn Mountains. Sedimentary breccia is massive angular-clast conglomerate with good evidence for mixing of clasts with epiclastic sandstone matrix, interpreted as landslide or debris flow deposits. Megabreccia consists of shattered and brecciated rock with little or no discernible epiclastic matrix, generally interpreted to be rock avalanche deposits. Lenses of megabreccia are typically interbedded with sedimentary breccia and conglomerate. In the Big Horn Mountains the Tbx unit interfingers with conglomerate and sandstone (unit Tsm), and breccia blocks consist of virtually all rock types present in the area as well as blocks of Paleozoic formations in the extreme western part of the range [Stimac et al., 1994]. In the Eagletail Mountains, the Tbx unit is present at the base of the section and is interbedded in its upper part with unit Tbl [Spencer et al., 1993]. Predominant clast types include granitoid resembling underlying crystalline rocks and Jurassic(?) quartz-feldspar porphyry similar to that exposed at the southern tip of the Little Harquahala Mountains (unit Jv) [Spencer et al., 1985], and less abundant Tertiary basalt, tuff, and Jurassic hypabyssal quartz porphyry with K-feldspar phenocrysts up to 50 mm long having white (plagioclase?) rims.

Tbm Middle basalt unit. **(Miocene)** Includes Burnt Mountain volcanic rocks of Stimac et al. [1994] in Big Horn Mountains. The Burnt Mountain Volcanics consists of several members including the Moon Anchor andesite, Pump Mine Wash andesite, Upper mafic flows, and andesite lavas and lahars of Burnt Mountain. Burnt Mountain, at the southern tip of the Big Horn Mountains, appears to be an andesitic volcanic center, and probably represent the source vent for part of the Burnt Mountain

volcanics. Rock types include aphyric to crystal-poor, slightly vesicular basalt lava, gray and brown variably porphyritic and vesicular andesite lava flows, and associated tuffs, lahars, and breccia. The andesites contain up to about 30% crystals, including variable amounts of plagioclase, biotite, pyroxene, amphibole, rare quartz and opaque minerals. These volcanic rocks overlie several different members of the Big Horn volcanic rocks of Stimac et al. [1994] (units Tf and Tbl on this map) either concordantly or with intervening erosional or angular unconformities, and are locally deposited directly on Pre-Tertiary rocks. Parts of this unit may be identical with rocks mapped in other areas as Tb, Tbl or Ta.

Tb Basalt, undifferentiated. **(Miocene or Oligocene)** Basalt to andesite lavas and local hypabyssal intrusive rocks equivalent to Tbu, Tbm, Tbl, and Tmi. Mapped where data are insufficient to determine correlation.

Tbl Lower basaltic volcanic rocks. **(Miocene or Oligocene)** Includes mafic volcanic rocks that typically predominate in the lower part of the Tertiary volcanic sections throughout the map area. Unit is mapped in the Bouse Hills, Big Horn Mountains, Eagletail Mountains, and along the eastern edge of the Harquahala Mountains. In the Bouse Hills includes vesicular to amygdaloidal lavas ranging in composition from andesite to basalt. Crystals of pyroxene or olivine altered to iddingsite are visible in many of the lavas. The rocks are widely altered, and is nearly completely replaced by brown to tan calcite in some areas. The unit includes interbedded brown to reddish-brown sandstone, felsic tuff, conglomerate, monolithologic breccia and sparse gray limestone with orangish Fe-stained siliceous layers.

In the Eagletail Mountains consists of a thin interval of dark gray basalt, basaltic andesite and andesite lavas that contain tiny crystals of plagioclase, pyroxene and olivine. The mafic volcanic rocks are interbedded with sedimentary breccia at the base and overlain by felsic lavas and associated tuffaceous rocks.

The unit is thickest and most extensive in the Big Horn Mountains, where this unit includes rocks mapped as Dead Horse formation by Stimac et al. [1994]. The Dead Horse formation consists of 0 to >300 m of mafic lavas with subordinate tuff and clastic rocks. Typical rocks are dark-gray, dark-green, and reddish-brown, vesicular to massive, porphyritic to nearly aphyric basalt lava flows, flow breccias, and cinder beds. Basalts contain 2 to 20% phenocrysts, including 2 to 10% olivine, 2 to 15% clinopyroxene, 2 to 5% plagioclase, and more rarely <3% orthopyroxene. Opaque oxides and fine-grained olivine are abundant in a matrix of flow-foliated plagioclase laths. Glomerophenocrysts consisting of olivine, clinopyroxene, biotite, and plagioclase are present in a few flows. Red, reddish-brown, brown, and green-gray massive to vesicular, platy, andesite lava flows and breccias form much of the unit in the Big Horn Peak area. The andesites contain <2 to 15% phenocrysts including of biotite, amphibole, clinopyroxene, plagioclase, and opaque oxides in a groundmass dominated by flow foliated plagioclase microphenocrysts. The mafic lavas are interbedded with and overlain by felsic lavas and associated tuffaceous rocks (unit Tf and Tfu). Interbedded tuff and tuffaceous sedimentary rocks are welded to nonwelded, typically contain phenocrysts of sanidine, quartz, and biotite, and form thin ridges and ledges. Feldspathic to arkosic sandstone and conglomerate are interbedded with basalt lavas, particularly in the NW Big Horn Mountains, where 30-40% of the exposed section is clastic rocks. The sandstone and conglomerate contain abundant clast of pre-Tertiary igneous and metamorphic rocks that can not be matched with rocks in the Big Horn or Harquahala Mountains, and cobbles to boulders of welded ash-flow tuff containing sanidine, plagioclase, and quartz. An interbedded tuff in the Bouse Hills yielded a K-Ar biotite date of 22.5±0.7 Ma [R. Miller, written communication to J. E. Spencer, 1986]

Tt Ash flow tuff and tuff. **(Miocene or Oligocene)** Welded to non-welded tuff in the southern Plomosa Mountains, western Vulture Mountains and Bouse Hills. Tuffs in the southern Plomosa Mountains include the tuff of Twin Peaks and tuff of Felipe Pass [Sherrod et al., 1990]. In the Vulture Mountains, includes the lower lithic tuff and Lucky Cuss tuff of Grubensky [1989]. In the Bouse Hills includes hornblende-biotite tuff [Spencer and Reynolds, 1990]. Except for the tuff of Felipe Pass, which appears to have a wide distribution to the south and west [e.g. Sherrod and Tosdal, 1991], these tuffs appear to be locally derived, and are probably related to nearby felsic dome complexes (unit Tf). Similar tuffs are included in unit Tf, particularly in the Big Horn Mountains, where the tuff units have not been broken out in order to simplify the map pattern.

Tts Tuff and associated sedimentary rocks. **(Miocene or Oligocene)** Interbedded tuff, tuffaceous sandstone, and conglomerate units present in various parts of the Tertiary section.

Buff to white thin to medium bedded massive tuff and laminated reworked or air-fall tuff. Crystal and lithic content is variable. The thickness is highly variable depending on proximity to sources. In the canyon on the southeast side of Black Mesa (SW corner of the map area), the lower part of the Tts section, with a maximum thickness of approximately 65 m, dips 30-50° to the S or SW; dips decrease up section, and on the order of 60 m of non-tilted tuff underlies the basalt of Black Mesa. The tuffaceous rocks overlying Tsm in the southern Plomosa Mountains thicken to the east to a maximum of about 100m thick at the SE edge of the map area. In the Eagletail Mountains Tts is interbedded with felsic lavas and breccias, and probably represents pyroclastic aprons erupted from adjacent dome complexes. In the western Vulture Mountains, rocks mapped as Tts are equivalent to unit Ttv of Grubensky [1989], which consists of light-yellow, tuffaceous conglomeratic sandstone and volcaniclastic breccia interbedded with basalt lava (unit Tbu) on the south flank of Black Butte. Conglomeratic sandstone is thin to medium bedded (5-20 cm thick beds) and locally laminated. It contains subrounded pebbles and cobbles of rhyolite and basalt lava. Volcaniclastic breccia composed of angular fragments (as much as 80%) of porphyritic, stony rhyolite lava and subordinate basalt in a tuffaceous sandy matrix. Maximum clast dimensions vary from 1-50 cm. The unit is up to 180 m thick in the western Vulture Mountains.

Contacts with felsite (unit Tf) and welded tuff (Tt) are gradational zones of increasing welding. Other contacts are generally abrupt. Irregular and generally anomalously steeply dipping atitudes measured in this unit where it is deposited on pre-Tertiary rocks reflect pre-existing topography.

Ta Andesite. **(Miocene or Oligocene)** Intermediate composition lavas and hypabyssal intrusive rocks, with associated breccia and tuff. Typically includes dark red brown to gray massive volcanic rocks with crystals of altered mafic minerals (hornblende or biotite) and plagioclase, with less abundant pyroxene or rarely quartz or K-feldspar. Forms large masses in which bedding or flow foliation is highly variable, obscuring the original orientation of the deposit, and the intrusive or extrusive nature cannot be determined. The Ta unit in the southern Little Harquahala Mountains apparently represents a deeply dissected, but little deformed andesitic volcanic center. In the northwestern Eagletail Mountains, rocks mapped as Ta are distinguished from Tf by the absence of quartz or sanidine phenocrysts. The andesitic rocks in the northwestern Bear Hills (volcanic rocks of Bear Hills [Sherrod et al., 1990]) are the southeastern continuation of a large andesitic volcanic complex in the central Plomosa Mountains [see Miller, 1970]. In the Bouse Hills, Ta includes the 'medial felsic volcanic unit', 'feldspar porphyry' and 'tuff and andesite' units of Spencer and Reynolds [1990]; this unit includes a polymictic sedimentary breccia unit, several rhyolite lavas and tuffs in addition the more typical intermediate composition volcanic rocks. Rocks mapped as Ta are probably coeval in part with rocks mapped as Tbl, Tbm and Tf in other parts of the map.

Tertiary intrusive rocks

Ti Hypabyssal Intrusive rocks. **(Miocene or Oligocene)** Undivided felsic to mafic hypabyssal intrusive rocks. Includes Tif and Tim.

Tif Felsic intrusive rocks. **(Miocene or Oligocene)** Light colored dikes and small intrusions that have an aphanitic groundmass and characteristically are light-colored and contain crystals of quartz or K-feldspar. The matrix of the dikes varies from fresh to extensively altered. Along the NE side of the NW Eagletail Mountains the mapped Tif units are thick dikes that have been tilted 30-40° to the southwest and are now like flatirons that form the steep buttresses with high peaks along the range front; these were probably feeder dikes for Tf in this area.

Tim Mafic to intermediate intrusive rocks. **(Miocene or Oligocene)** Dark green to olive, brown, and black-colored aphanitic to medium-grained basaltic, andesitic, and dioritic dikes and small irregular intrusions. Fresh dike rock consists of hornblende and plagioclase with an ophitic to intersertal texture. Grain size depends on dike thickness. Aphanitic chilled margins are generally 2-5 cm thick, dikes more than 1.5 to 2 m thick have a fine-grained core, and 3-5 m thick dikes have a medium-fine grained core. Most dikes are less that 2 m thick. These form a vertical to steeply NE-dipping, NW-trending dike swarm in the central Harquahala Mountains. Dikes are locally mineralized and altered. The alteration assemblage is generally sericite-chlorite-pyrite-earthy hematite (commonly after pyrite), with minor secondary copper minerals. In the Big Horn Mountains, these dikes are typically extensively altered, and poorly exposed, except in mine workings and washes.

Tg Granitoid. **(Miocene or Oligocene)** Fine- to medium-grained, equigranular, biotite±hornblende granitoid rocks exposed in the eastern Bouse Hills. Map-scale compositional layering characterizes this unit in the easternmost Bouse Hills and is visible on air photographs. Light layers are typical granite or granodiorite with little or no hornblende. Dark layers contain much hornblende and little quartz. A weak, steeply dipping crystalloblastic foliation in the NE Bouse Hills is defined by biotite orientation. Crystalloblastic foliation is parallel to compositional layering, which is locally visible in outcrop, and suggests that both are primary features related to magma emplacement and are unrelated to postmagmatic deformation. Locally, in the southern part of the eastern Bouse Hills, this unit is composed of fine-grained biotite granite or granodiorite that is moderately resistant to weathering and forms generally N-trending, resistant ridges. Gently dipping epidote-filled fractures are the dominant control of the ridge-crest morphology. No pegmatites were seen in this unit and no evidence of hydrothermal alteration or mineralization at the margins of this unit was recognized except rare and thin epidote- and hematite-filled fractures. Samples of this unit have yielded biotite K-Ar dates of 20.0±0.6 Ma, 20.2±0.5 Ma [Spencer et al., in press], and 16.5±0.5 Ma [Shafiqullah et al., 1980]. A ~20 Ma age for the pluton is supported by two of these three dates, and by a 19.7±0.5 Ma K-Ar biotite date on a silicic dike that is probably genetically related to the pluton [Spencer et al., in press].

Cretaceous and Jurassic intrusive rocks

Kg Leucocratic granitoids

Kg_1 Tank Pass Granite. **(Cretaceous)** The Tank Pass granite is a light colored, medium-grained, equigranular to slightly porphyritic granite to granodiorite. In the Granite Wash and western Harcuvar Mountains, it contains about 1 to 5% biotite and local sphene crystals up to 1 mm long. Quartz eyes 1 to 3 mm in diameter and plagioclase phenocrysts are also locally present. This phase contains distinctive disseminated biotite books that are 0.5 to 1 mm in diameter, and about 0.25 mm

thick. Porphyritic outcrops contain scattered K-feldspar phenocrysts 0.5 to 2.5 cm in diameter. Leucocratic aplite to pegmatite dikes are associated with the granite; these are generally composed of quartz and predominantly alkali feldspar, with biotite, minor reddish-brown garnet, and rare muscovite. Some of the aplitic dikes have garnetiferous and pagmatitic bands parallel to their margins. A granodioritic border phase is locally present, especially where the pluton contains abundant inclusions of metamorphic rock.

In the west-central part of the Harcuvar Mountains, the Tank Pass granite consists mostly of a medium-grained equigranular biotite-muscovite granite, with abundant aplite and pegmatite. It is nearly white on fresh surfaces, but commonly weathers a tan to orangish-brown color. Muscovite (1-2%) and biotite (1-3%) are present as very thin platelets to discrete books 0.5 to 4 mm thick. This phase also contains <1% garnet in outcrops on the south flank of the range southwest of Cottonwood Pass. In the central part of the Harcuvar Mountains abundant sills of fine- to coarse-grained leucocratic granite, pegmatite and layered aplite-pegmatite locally coalesce into bodies of mappable dimension that consist mostly of granitoid. Similar sills are abundant in unit Xm. Most of the aplite-pegmatite dikes and sills are probably late-stage differentiates of the granite, but some may be younger than and unrelated to the Tank Pass granite.

Kg_2 Brown's Canyon granite. **(Cretaceous)** Light colored, fine-grained granitoid mapped as Brown's Canyon granite and Stone Corral Granite in the northeastern Harquahala Mountains [Richard, 1988]. The granite of Brown's Canyon is an equigranular, aplitic, fine to medium-fine grained monzogranite. The rock typically consists of sub-equal amounts of anhedral, interlocking microcline, plagioclase, quartz, 1-2% biotite and muscovite in varying proportions, sparse garnet, and accessory apatite and zircon. The grain size and distribution of micas and garnet are variable within the pluton. Small areas have been observed in which the rock consists of up to about 5% of 1 to 3 mm garnet. Muscovite grains commonly are ragged on edges of books, suggesting possible decomposition before complete crystallization of body. Abundant pegmatite dikes are associated with the Brown's Canyon granite, especially high on the southeast and along the northwest side of the pluton. The dikes increase in abundance towards the main body of the granite, but are not observed cutting the internal parts of the pluton. Swarms of garnet-muscovite pegmatite dikes flood the country rock above the pluton on its southeast side, and the contact between the granite and country rock is a mixed zone. Brown's Canyon pegmatites are generally planar and range in thickness from several centimeters to several meters. They are zoned, with alternations of very coarse and medium grained quartz, albite and muscovite; no systematic zoning pattern was discerned. Very fine-grained garnet is an ubiquitous component. The southwest side of the Brown's Canyon granite, near Sunset Canyon, is a steep, abrupt contact zone that sharply truncates fabrics in the wall rocks. Few pegmatites are observed in this area. The north side of the pluton is a strongly deformed injection complex in which numerous dikes and irregular bodies of leucocratic garnet-biotite granitoid have been transposed along with the pre-existing gneissic foliation in the country rocks into a moderately SW-dipping gneissic foliation. The concordant sills of leucogranite in this complex, near the Sunshine mine, are indistinguishable from foliated granite in the border zone of the pluton along its east side. The foliated granite in this border zone grades into unfoliated granite of the main phase in Brown's Canyon. On its east side, the bottom of the pluton is a Tertiary high strain zone localized along the intrusive contact of the pluton with underlying heterogeneous plutonic and metamorphic rocks. Igneous foliation within the Brown's Canyon granite, defined by grain size variations in undeformed rock, is parallel to SW-dipping syn-plutonic fabric. Hornblende from a small inclusion near the border of the Brown's Canyon granite yielded an $^{40}Ar/^{39}Ar$ maximum cooling age of 69 Ma, interpreted to indicate the minimum age of the granite. Granite cropping out below the bounding shear zone on the east side of the Brown's Canyon granite is lithologically very similar to the Brown's Canyon granite and is probably related. Richard [1988]

referred to this phase as the Stone Corral granite. It consists of very light gray or tan, medium-grained, equigranular, biotite-garnet granite, and is locally slightly porphyritic with 1 cm K-feldspar phenocrysts. Garnet in is present in trace amounts, concentrated near leucocratic-pegmatitic bands. The pluton is generally weakly to moderately foliated. It grades into the mixed KXgn gneiss, which contains numerous sills of leucocratic granitoid resembling Kg_2.

Kgd Hornblende-biotite granodiorite units

Kgd_1 Big Horn granodiorite. **(Cretaceous)** Light-gray, gray, and tan coarse- to medium-grained granodiorite averaging approximately 30% plagioclase, 30% potassium feldspar, 5 to 12% biotite, >10% quartz, and trace amounts of sphene, opaque oxides, and other accessory minerals. Locally grades into gray, or pink equigranular medium- to fine-grained granite. In the southwestern part of the Big Horn Mountains, near Big Horn Peak, grades into porphyritic granite to monzogranite containing abundant K-feldspar megacrysts up to 4 cm long. This pluton has complex contacts with Proterozoic rocks, typically with a dioritic border phase along the northwest side and a granitic border phase along the northeast side. Numerous irregular apophyses of the intrusion project into adjacent Proterozoic metamorphic rocks. Sparse biotite-rich xenoliths are present. A sample of granodiorite from the Dead Horse Wash area yielded a K-Ar biotite date of 70.8 ± 0.5 Ma. K-Ar biotite dates of 63 ± 1.9 and 68 ± 2.0 Ma were determined for porphyritic granite phase in the Big Horn Mountains Wilderness Study Area [Miller and Gray, 1993, in prep.]. The pluton crops out in a ENE-trending belt through the northern part of the Big Horn Mountains. The unit forms very poor outcrops, typically making up small grus-covered hills and pediment.

Kgd_2 Granite Wash granodiorite. **(Cretaceous)** Light gray, medium-grained, equigranular granodiorite. Rock consists of 25-30% quartz, 50-65% plagioclase, 10-15% K-feldspar, 5-7% biotite in 1-2 mm diameter flakes, 1-5% hornblende in subhedral prisms up to 1.5 cm long, and accessory sphene. Biotite typically has chloritized rims, and hornblende is extensively but weakly altered to epidote, actinolite and biotite. Some outcrops SE of Winchester Peak in the southern Granite Wash Mountains contain repetitive 1-5 cm thick bands defined by subtle variations in mineralogy and grain size.

Kd Dioritic border phase. **(Cretaceous)** The Big Horn granodiorite and Granite Wash granodiorite both have dioritic border phases found near the margins of the plutons. The border phase is more abundant on the north side of both plutons (although the southern intrusive contact of the Big Horn granodiorite is mostly covered. In the Big Horn Mountains, the border phase forms small, irregular bodies in the Proterozoic country rock. The rock consists of hornblende and plagioclase; sphene is significantly more abundant than in main phase (Kgd). Grain size is quite variable, ranging to very coarse-grained hornblendite. Some small bodies are agmatitic. In the Granite Wash Mountains the border phase is found along contacts of the granodiorite, and forms most of the smaller apophyses. The dioritic rocks are characterized by lithologic diversity. Rock types observed include: 1) medium-grained, equigranular to slightly porphyritic granodiorite with 10-20% hornblende and biotite; 2) medium- to coarse-grained diorite or tonalite with 15-40% hornblende; 3) fine- to medium-grained porphyritic diorite with several percent hornblende phenocrysts that give the rock a spotted appearance; 4) hornblendite with less than 15% plagioclase; and 5) fine-grained microdiorite mostly composed of plagioclase and hornblende. Hornblende is typically more abundant than biotite, and scattered hornblende phenocrysts 0.5 to 2 cm long are present at least locally in all units.

KJgd Granodiorite. **(Cretaceous or Jurassic)** Fine grained dark gray equigranular to slightly porphyritic granodiorite containing sparse 1-2 cm long K-feldspar phenocrysts, subhedral plagioclase phenocrysts 3-4 mm in diameter in a groundmass of quartz, plagioclase, and biotite. Contains inclusions

of Paleozoic quartzite. This rocks is unfoliated, but contains extensive weak sericitic alteration similar to pre-cleavage alteration in other parts of western Harquahala Mountains.

KJd Hypabyssal mafic rocks. **(Cretaceous or Jurassic)** Sills and irregular intrusions of fine to very fine-grained equigranular diorite or gabbro, consisting of altered hornblende or pyroxene and plagioclase. Hornblende is typically altered to chlorite and actinolite(?); plagioclase is commonly sericitized. In the western Granite Wash Mountains, some plagioclase feldspar crystals preserved calcic (~An_{50}) compositions, and pseudomorphs after olivine are present. Some sills are porphyritic with crystals of hornblende or plagioclase in varying proportions. These intrude Jurassic or Cretaceous sedimentary rocks (KJc, KJs, KJsh, KJsq, KJss) in the southern Plomosa and Granite Wash Mountains, forming sills up to about 135 m thick in the southern Plomosa Mountains. Contorted bedding and narrow zones of hornfels are present near many intrusive contacts. Vesicular and fragmental units are present in both the Ramsey Mine and Granite Wash sections, indicating that some of these rocks are extrusive or possibly intruded wet, unlithified sediments. Geochemical analysis [Laubach et al., 1987] of rocks from the Granite Wash Mountains reveal that these rocks are slightly alkalic and have trace-element affinity to "within-plate basalts" of Pearce and Cann [1973]

Jg Granodiorite or monzogranite. **(Jurassic)** Porphyritic biotite granitoid and leucogranite in the Granite Wash Mountains The porphyritic granitoid contains 1-2 cm long, pink K-feldspar in a groundmass of blocky 2-4 mm plagioclase, 1-2 mm anhedral quartz, and 3-6% biotite. The leucogranite is fine-grained, and mostly equigranular, but 2-4 mm-diameter quartz phenocrysts are locally present. Both granitoids intrude Paleozoic rocks in the western Granite Wash Mountains. Age interpretation is based on lithologic similarity with dated plutonic rocks of the Jurassic Trigo Peaks superunit [Tosdal et al., 1989] and contrast with lithology of known Cretaceous or Tertiary plutonic rocks.

Jg_1 Granitoid porphyry. **(Jurassic)** Medium grained, ubiquitously altered, porphyritic monzogranite; contains 1-3 cm long, elongate K-feldspar phenocrysts in a groundmass of 10-20% quartz in 2-3 mm 'eyes', 60-70% altered plagioclase, 2-3% 2-3 mm clots of chloritized biotite, and a trace of accessory sphene. The granitoid is mostly undeformed, but is cut by sparse, thin mylonite zones. Grades to southeast into hypabyssal quartz-feldspar porphyry included in unit Jv. The gradational contact with Jv suggests a Jurassic age similar to that for the Black Rock volcanics.

Jg_2 Granodiorite to diorite. **(Jurassic(?))** Dark gray equigranular to porphyritic monzodiorite, diorite, and granodiorite in the western Harquahala and northern Little Harquahala Mountains. Abundant dikes and small irregular bodies of aplitic leucogranite are ubiquitous throughout the unit. In the northern Little Harquahala Mountains, is a porphyritic monzodiorite consisting of 10-20% potassium feldspar phenocrysts up to 3 cm in diameter, 50-60% plagioclase in 3-5 mm subhedral, blocky crystals, 10% quartz in equant 1-3 mm grains, 15% biotite, and abundant accessory euhedral apatite and anhedral sphene. Plagioclase is nearly completely replaced by sericite and epidote. A very fine-grained, recrystallized aggregate of biotite, quartz, albite(?), and epidote forms a groundmass between the larger feldspar and quartz crystals. Some biotite-epidote-plagioclase clots with aligned biotite crystals appear to pseudomorph hornblende prisms. The monzodiorite becomes more equigranular (resembling the granodiorite phase in the western Harquahala Mountains) to the south, and the contact into the mixed Proterozoic-Jurassic crystalline rocks (JXi) is gradational.

In the western Harquahala Mountains, the unit consists mostly of equigranular diorite at the western end of the range, intruded by granodiorite on the east. The diorite phase is mostly medium-fine grained and texturally and compositionally variable, ranging from gabbro(?) to granodiorite. Gra-

nodioritic zones are locally porphyritic and rare megacrystic phases strongly resemble the monzodiorite phase of the northern Little Harquahala Mountains. The dioritic phase is metamorphosed and deformed to a biotite-plagioclase-quartz semi-schist in the 'S' Mountain area. Leucogranite dikes and intrusions truncate some foliation in this area. Small pods of massive to weakly foliated, texturally and compositionally variable dioritoid are common in adjacent rock units (YXgg, Xgn, Xgp); these may be related to Jg_2 or to unit JYd.

Granodiorite intrudes the diorite phase on the east; the contact is variably sharp or gradational. The granodiorite is equigranular, dark gray, medium-grained and consists of 65-75% plagioclase, 10-20% quartz, and 7-10% biotite in very fine-grained recrystallized aggregates with epidote and plagioclase. It is locally slightly porphyritic with K-feldspar phenocrysts up to 1 cm in diameter. The granodiorite is interleaved with augen gneiss (Xgp) at its eastern contact, but inclusions of augen gneiss in granodiorite indicate that the granodiorite intrudes the augen gneiss. A single zircon fraction from a monzodiorite sample (04-10-85-16), collected at 33°43.60'N, 113°25.05'W in the northern Little Harquahala Mountains, yielded U-Pb ages of $^{206}Pb/^{238}U$: 165.5Ma, $^{207}Pb/^{235}U$: 166.6; $^{207}Pb/^{206}Pb$: 182Ma (N.R.Riggs and S. M. Richard, unpublished data, 1987); w.r. Rb/Sr analysis of one sample yielded an $^{87}Sr/^{86}Sr$ ratio of .70766±.00004, with a Rb/Sr ratio of 0.4166 (P. Damon and M Shafiqullah, written communication, 1984). Rb/Sr model ages are older than 200 Ma if the assumed initial ratio is less than 0.7065. These data strongly indicate that the monzodiorite is Jurassic, probably crystallized at about 165 Ma.

Jg_3 Sore Fingers granite. **(Jurassic)** Coarsely porphyritic biotite granite (monzogranite) consisting of 20-50% K-feldspar in 2-3 cm blocky, equant phenocrysts, 30-40% plagioclase in 2-5 mm subhedral, blocky crystal, 20-25% 2-5 mm rounded quartz grains, and 5-10% biotite. K-feldspar crystals are locally up to 8 cm in diameter, and are irregularly distributed in the rock body; some cumulate zones consist of >50% phenocrysts. A few equigranular, non-porphyritic zones are also present. Minor hornblende is present in the outcrops in the Eagletail Mountains. Only one small area was found in the southern Little Harquahala Mountains where igneous hornblende was preserved; throughout the rest of the body there, igneous hornblende and biotite have been recrystallized to fine-grained aggregates of secondary biotite, epidote and plagioclase. Ubiquitous weak alteration in the granite is concentrated along joints filled with chlorite and epidote. Alteration becomes more intense in parts of the southern Little Harquahala Mountains. In the most intensly altered areas, the granitoid becomes a dense, black, silicified rock in which the igneous texture is obliterated and biotite clots surround sparse relict quartz and feldspar crystals. Sparse aplite dikes intrude the Sore Fingers granite. The sore Fingers granite intrudes foliated porphyritic granitoid to augen gneiss (unit JXi) on the north. The contact is subtle, but sharp where it is not disrupted by minor faulting. A K-Ar biotite date of 140±4 Ma was reported by Shafiqullah et al. [1980]; sample location 33°38.2'N, 113°29.9'W. Lithologic similarity of the most mafic parts of this unit with the porphrytic monzodiorite phase of the diorite-granodiorite unit (Jg_2) suggest that these are part of the same plutonic suite.

Mesozoic and Paleozoic supracrustal rocks

Jurassic or Cretaceous clastic rocks.

Middle to late Mesozoic clastic rocks, including mostly brown to gray lithic-feldspathic sandstone, siltstone, conglomerate and minor limestone, are exposed in three major stratigraphic packages on the Salome 1:100000 sheet. These will be referred to as the Ramsey Mine [Sherrod and Koch, 1987; Richard and Spencer, 1994], Granite Wash [Laubach et al, 1987] and Little Harquahala [Richard et al., 1987] sections. Other less complete sections are exposed at the southern tip of the Harquahala Mountain

and in isolated hills in the northern part of the Harquahala Plain [Richard et al., 1987]. The age and correlation of these clastic rocks remains unresolved in detail because of the lack of fossils and distinctive, laterally continuous marker units, but they most likely correlate with some part of the McCoy Mountains Formation [Harding and Coney, 1985; Tosdal and Stone, 1994, and references cited above]. One lithologically distinctive unit is present in the McCoy Mountains Formation--the basal unit one of Harding and Coney [1985] (Jksq on this map), but an angular unconformity separates this unit from overlying rocks in the southern Plomosa Mountains just west of this map area. Outcrops of lithologically identical rocks in this map area are faulted against all adjacent pre-Tertiary rocks, so their stratigraphic position is indeterminate. Formalization of stratigraphic nomenclature for these rocks awaits a consensus on their age and correlation from range to range. In light of these difficulties, the Jurassic or Cretaceous clastic rocks have been mapped on a purely lithologic basis on this map.

Kc Conglomerate. **(Cretaceous)** Approximately 300 m of brown, calcite-cemented, feldspathic sandstone, conglomeratic sandstone, and boulder conglomerate are exposed in the Red Hills in the northern part of the Harquahala Plain. Fine-grained sandstone is interbedded with coarse-grained sandstone and conglomeratic grit in thin to thick beds. Low-angle cross-beds are locally present. Massive conglomerates include clasts of unmetamorphosed rocks from all parts of the Paleozoic section in the Little Harquahala Mountains, a variety of granitic rocks, and rounded vitreous quartzite. The granitic clasts, such as those of equigranular, medium- to fine-grained muscovite leucogranite, correspond to rock types present in the Harquahala Mountains. Boulder beds in the conglomerate are derived from different sources; some contain predominantly Paleozoic rock types, others contain mostly granitic rocks. Granitic clasts up to 70 cm in diameter and Kaibab Limestone clasts up to 2 m in diameter are present. Detrital K-feldspar and muscovite are present in the sand matrix of the conglomerate. These rocks have been informally named the Red Hills conglomerate and correlated with the conglomerate member of the McCoy Mountains Formation [Harding and Coney, 1985], based on the abundance of locally derived basement clasts and relatively weak diagenesis of this conglomerate [Richard et al., 1987].

KJc Conglomerate. **(Cretaceous or Jurassic)** Massive pebble to boulder conglomerate is present in the lower part of the Little Harquahala section, as a thick wedge in the lower middle part of the Ramsey mine section, and as a thin maker bed in the Granite Wash Section. Clasts include varying proportions of predominantly Jurassic volcanic rocks (Jv), upper Paleozoic sedimentary rocks (gray crystalline carbonate, laminated quartzite, calcareous sandstone, siltstone), and Proterozoic(?) tan vitreous quartzite. Conglomerate in the Ramsey Mine section contains sparse lithofeldspathic sandstone (recycled Mesozoic?) and possible Jkd clasts. Bedding is rarely indicated by thin sandstone lenses. Clasts are rounded to sub-rounded. The conglomerate in the Ramsey Mine section disappears abruptly along strike; whether this is due to rapid stratigraphic variation or to structural removal cannot be determined. In the southern Little Harquahala Mountains the conglomerate thins rapidly to the northwest and grades laterally into an interval of shale with minor interbedded gypsum. Thickness is up to 160 m in the Ramsey Mine section, 200 m in the southern Little Harquahala Mountains, and 5-10 m in the Granite Wash section.

KJsh Fine-grained clastic rocks. **(Cretaceous or Jurassic)** Composed predominantly of siliceous gray shale (now phyllite and slate), but also includes thin layers of fine-grained calcareous siliciclastic rock, calcareous feldspathic siltstone, lithic-feldspathic sandstone, and rare conglomerate layers with 2-4 cm diameter clasts. Sandstone in the unit is dominantly composed of volcanic lithic grains, plagioclase feldspar, and quartz. Load casts are present at the base of some thin sandstone beds. Grades upward into overlying sandstone and conglomerate (Kc). Fine-grained rocks form a thick enough section to map separately only in the Granite Wash Mountains, but similar fine-grained units, too thin to show on this map, are present interbedded in the Ramsey Mine section

and in the upper part of the southern Little Harquahala section. These fine-grained sediments are generally very thin bedded, locally laminated, mudstone, siltstone and very fine-grained lithofeldspathic sandstone, with sparse, thin, interbedded cobble conglomerate. They are light tan-gray to gray-green weathering. In the Ramsey Mine section, thick fine-grained intervals are invariably adjacent to thick conglomerate lenses, except in the stratigraphically highest part of the section. Poorly preserved Branchiopod conchonstraca (identified by R. Forrester, personal communication, 1985), belonging to the "nodose-rib type", and resembling Estheriella (Estheriella) cf evadridgian, Upper Jurassic of Zaire (Paul Tasch, written communication, 1985) are present in a shale bed in the upper part of the Little Harquahala section (see photo in Richard et al., 1987). These fossils indicate a nonmarine depositional environment with temporary bodies of standing water. Miller [1966] reported the presence of branchiopods in the southern Plomosa Mountains sections (location not given specifically), but non have been found in the course of recent mapping in the area [Richard et al, 1993; Richard and Spencer, 1994]

KJsq Quartzite, quartzite cobble and maroon mudstone. **(Cretaceous or Jurassic)** Interbedded, thin- to thick-bedded, quartzite-cobble conglomerate, quartzite, calcareous quartz arenite, and purple siltstone or mudstone. Crops out south of the Ramsey Mine section in the southern Plomosa Mountains, in isolated inselbergs along the northeastern side of the New Water Mountains, and in the Little Harquahala Mountains. Quartzite units range from tan or white orthoquartzite, becoming tan to dark brown weathering with increasing calcareous cement; sand is fine- to coarse-grained. Clasts in conglomerate are sub-rounded to well rounded, and consist mostly of light-colored, vitreous quartzite of uncertain provenance. Clasts of Bolsa and Coconino quartzite can also be recognized, along with black or red chert clasts, microporphyritic to aphyric white felsite and rare intermediate-composition volcanic rocks. Conglomerate clasts are typically cobbles, although clasts up to about 40 cm are present in thick conglomerate beds in the northern Black Rock Hills (southern Little Harquahala Mountains). Although conglomerate, sandstone and mudstone are interbedded throughout, 50-100 m-thick intervals of finer-grained rock, in which mudstone predominates and conglomerate is uncommon, alternate with coarser-grained intervals in which sandstone predominates and conglomerate is common. This unit is equivalent to the continental red bed deposits of Miller [1970] in the adjacent Quartzsite quadrangle, with basal unit one of the McCoy Mountains Formation [Harding and Coney, 1985; Stone, 1990; Tosdal and Stone, 1994], and with Crystal Hill formation, an informal name proposed by Richard et al. [1993]. The unit is a minimum of 530 m thick in the southwestern part of the map area.

KJs Sandstone. **(Cretaceous or Jurassic)** Most of the Jurassic or Cretaceous clastic section consists of thin- to thick-bedded brown to drab-gray weathering lithic-feldspathic sandstone, interbedded with mudstone, siltstone, and conglomerate. The stratigraphy tends to be laterally variable. Sandstone:conglomerate:mudstone ratios vary irregularly, with fining-up and coarsening-up sequences on scales ranging from 10's to 100's of meters. Coarser grained parts of the section typically consist of medium to thick bedded, massive to vaguely laminated sandstone, conglomeratic sandstone and conglomerate, with thin, discontinuous mudstone or siltstone partings. Conglomerate lenses up to 20 m thick may be present. One such conglomerate bed forms a continuously mappable marker horizon in the Granite Wash section, indicated on the map by an ornamented line. Finer grained parts of the section typically consists of thin- to very thin-bedded sandstone, often with sedimentary structures including plane lamination, small-scale cross bedding and sole marks on the base of beds, interbedded with laminated to massive mudstone and siltstone. Mudstone may make up >70% of the section over 10-20 m thick intervals. The finer grained intervals have rhythmic bedding and sedimentary structures suggestive of deposition by sediment gravity flow, particularly in parts of the Granite Wash and Ramsey Mine sections. Mudstone rip-up clasts are common near

the base of sandstone beds. Poorly preserved fossil plant(?) material has been observed on bedding planes in many of the fine-grained units. Laminated, medium to dark gray limestone beds are present in the fine-grained parts of the sections.

Jurassic and older volcanic and sedimentary rocks

Jvs Sedimentary rocks derived from volcanic rocks. **(Jurassic)** Jurassic volcanic rocks are overlain by volcanic-lithic sandstone and conglomerate that ranges in thickness from ~20 m above the Black Rock volcanics in the southern Little Harquahala Mountains, to a minimum of 1400 m in the rocks of Harquar in the central Little Harquahala Mountains. These sediments are greenish gray volcanic lithic sandstone consisting of quartz and feldspar grains derived from volcanic phenocrysts and various microcrystalline volcanic rock fragments. Clasts in conglomerate are sub-round to angular and include a wide variety of volcanic rock-types representative of the underlying volcanic units. Sparse vitreous tan quartzite and gray crystalline carbonate clasts are also present; these are typically sub-rounded to well rounded. Bedding in sandstone is rarely visible as faint lamination, fine-grained partings or grain-size variations, but parts of the upper sandstone unit of the rocks of Harquar are well bedded with mudstone partings; mud cracks and mudstone rip up clasts are common in this unit. The lower contact with volcanic rocks is gradational, and in strongly deformed sections (Granite Wash and at the western end of the Harquahala Mountains), the contact between volcaniclastic and epiclastic rocks is virtually impossible to define precisely (Jv and Jvs are not differentiated in these areas for this reason). Where the sediments derived from volcanic rocks are overlain by lithofeldspathic sandstone of unit JKs, the contact is a gradation over 5-10 m of section in most places, but along part of the contact in the southern Little Harquahala section (at the top of the Needle formation of Spencer et al. [1985]) 20-30 m of gypsiferous shale separate the volcanic-lithic and lithofeldspathic sandstones. Where the quartz arenite-rich unit of the basal McCoy Mountains Formation (unit KJsq) overlies Jvs, the contact is generally sharp.

Jv Volcanic rocks. **(Jurassic)** Jurassic volcanic rocks crop out in nearly all the ranges where pre-Tertiary rocks are exposed in the map area, except for the Harcuvar and Big Horn Mountains and Bouse Hills. The most common rock type is a massive, light gray, quartz-feldspar porphyry, with 3-7% chloritized biotite. Quartz phenocrysts, forming 5-20% of the rock, are typically 2-3 mm diameter 'eyes', but in some units may be up to 1 cm in diameter. Plagioclase is the most abundant feldspar, but K-feldspar is present in some units. Phenocrysts form 5-30% of the rock, and are typically 2-4 mm in diameter, but in the Granite Wash Mountains a porphyry unit contains zoned plagioclase megacrysts up to 5 cm in diameter. The groundmass is typically a very fine-grained aggregate or recrystallized quartz, plagioclase, sericite, epidote and very fine-grained green biotite or chlorite. Secondary calcite is often abundant. Possible relict fiamme and lithic fragments are rare. This sort of quartz-feldspar porphyry forms massive, homogeneous stratiform units in all the Jurassic volcanic sections within the map area; these include three separate units in the Ramsey Mine section, with maximum thicknesses ranging from 70 to ~800 m [Richard and Spencer, 1994], the lower volcanic sequence (up to 1 km thick) in the Granite Wash Section [Reynolds et al.,1989]; the upper volcanic unit of the Needle formation (335 m maximum thickness), a large part of the Black Rock Volcanics, and the silicic subunit of the Hovatter volcanic unit in the Little Harquahala Mountains [Spencer et al., 1985], and the Jv unit at the western end of the Harquahala Mountains. In the Little Harquahala Mountains, and the Ramsey Mine section in the Plomosa Mountain, the Jv unit includes some more intermediate-composition lavas and fragmental rocks. These include dark gray andesitic rocks with sparse phenocrysts of plagioclase and chloritized mafic minerals and purplish to greenish-gray lava, tuff, and breccia with 1-3 mm plagioclase phenocrysts. The Jurassic volcanic rocks grade up section into epiclastic rocks derived from the volcanic rocks (Jvs).

MzPzS Sedimentary rocks, undivided. **(Mesozoic and Paleozoic)** Mixed Cambrian through lower Jurassic(?) sedimentary rocks in structurally complex areas.

JTrs Buckskin and Vampire Formations, undivided. **(Jurassic or Triassic)** Lower Mesozoic clastic rocks are present between Permian carbonate rocks and Jurassic volcanic rocks in the Little Harquahala, western Harquahala and Granite Wash Mountains. This unit typically consists of tan, orange and brown-weathering quartzose sandstone, quartzite-cobble conglomerate and sparse red-brown mudstone. Sandstones are typically calcareous, and range from quartz arenite to feldspathic quartz arenite; detrital chert, K-feldspar and mica are present. Fine-grained sandstone beds are typically well sorted, and the degree of sorting decreases with increasing grain size. Conglomeratic sandstone is very poorly sorted. Cobbles in conglomerate are Paleozoic limestone and quartzite or vitreous quartzite of uncertain origin. In the Granite Wash Mountains, the unit contains calc-silicate rocks and small lenses and pods of brown and gray crystalline carbonate. Gypsiferous zones in this section are associated with greenish, fine-grained quartz arenite, greenish phyllite, and cream-colored limestone, and are generally found near the base of the section. These sediments are correlated with the Buckskin formation of the Buckskin Mountains [Reynolds et al., 1987] based on lithologic similarity and similar stratigraphic position. Overlying quartzite and sparse massive conglomerate with cobbles to boulders of quartzite and Proterozoic igneous and metamorphic rocks is correlated with the Vampire Formation of the Buckskin Mountains [Reynolds et al.,1987] on the same basis. A similar quartzite and conglomerate unit overlies Cambrian quartzite on the west face of Salome Peak in the Granite Wash Mountains.

Pzs Sedimentary rocks, undivided. **(Paleozoic)** Units Pzl and Pzu, undivided.

Pzu Upper Paleozoic sediments, undivided. **(Permian and Pennsylvanian)** Includes Supai formation, Coconino Quartzite, and Kaibab Limestone. The Supai formation consists of interbedded white, vitreous quartzite, calcareous sandstone, maroon mudstone, limestone and dolomite. Sandstone is nearly pure quartz arenite, and is uniformly fine-grained and well sorted. Beds are .5 to 3 m thick, and can be trace along strike for 10's of meters in the least deformed section (southern Little Harquahala Mountains). Plane lamination and medium-scale troughy cross bedding is present in undeformed sandstone beds. The unit forms prominently banded dark-brown desert-varnished outcrops. At the base of the unit is a red brown to dark gray shale and siltstone unit that contains discontinuous chert pebble to cobble conglomerate beds.

The Coconino quartzite is a white orthoquartzite with prominent lamination. The sand is fine- to very fine-grained and well sorted. Mudstone laminations produce a prominent parting, which persists even in very deformed quartzite.

The Kaibab formation consists of medium to thick bedded variably fossiliferous or cherty limestone and dolomite. The unit can be divided into 5 units in the southern Little Harquahala Mountains. From the base, these are: Unit 1- Basal sandy dolomite, which grades up into cherty, fossiliferous dolomitic limestone with large crinoid columnals, echnoid spines and brachiopods; capped by a tan, silty sandstone; probable Toroweap Formation equivalent; Unit 2- Massive, cherty, medium gray limestone; crinoid grainstone; large Productid brachiopods abundant in the upper part; Unit 3- Even, medium-bedded dark-gray limestone; poorly preserved fusilinids and large gastropods present; Unit 4- Thick-bedded light gray, cherty and fossiliferous limestone; abundant chert at top. Fossils include Chaetetes corals and brachiopods; Unit 5- Tan silty sandstone overlain by cherty, light pink-gray limestone [Richard, 1983]. In more metamorphosed sections, the unit consists of light gray to white calcite marble, with local lenses of dolomite-tremolite marble along the contact with Coconino Quartzite. One or two 1-3 m thick dark gray marble markers units are present in the middle of the unit; these may be relicts of unit 3 in the unmetamor-

phosed Kaibab. Aligned siliceous clots and color variations define foliation; foliation is commonly contorted with abundant, showy intrafolial isoclinal folds.

Pzl Lower Paleozoic sediments, undivided. **(Mississippian through Cambrian)** Includes Bolsa Quartzite, Abrigo Formation, Martin Formation, and Redwall limestone. Bolsa Quartzite consists of maroon-gray feldspathic sandstone. Grit and pebble conglomerate at the base grade up into medium- to fine-grained sandstone with siltstone partings up section. The Bolsa quartzite-Abrigo formation transition is a gradation into dark gray, maroon and gray-green sandy shale with a few thin, locally bioturbated siltstone beds. Planar tabular cross beds are common in quartzite beds in the lower part. In more metamorphosed sections (NE Harquahala Mountains, Granite Wash Mountains), the fine- to coarse-grained feldspathic quartzite is generally massive in the lower part, but phyllite partings with slaty cleavage are common in the upper part; bedding is rarely visible as magnetite-rich laminations. This grades into fine-grained muscovite-epidote-quartz-biotite schist and phyllite with a well developed slaty cleavage in the Abrigo interval.

The Martin formation consists of medium-bedded gray and tan dolomite and dolomitic limestone. The lower part is dark gray, medium bedded dolomite. This is overlain by a poorly exposed interval of about 5 m of light pink gray calcareous fine-grained sandstone. Above this is interbedded massive medium to dark gray dolomite and finely laminated light to medium gray dolomite.

The Redwall limestone consists of massive limestone with lenticular stratiform chert nodules, which is variably dolomitized in its lower part. In the least-deformed and recrystallized sections, concentric structure within these nodules is preserved. At the top of the section a paleo-karst zone is preserved, with carbonate cemented breccias and irregular (cavern-filling?) pods of purple mudstone. In more metamorphosed sections, the dolomite marbles of the Martin formation cannot be differentiated from the dolomite marble of the lower Redwall formation, and the upper Redwall forms a prominent unit of white calcite marble with siliceous lenses.

Proterozoic igneous and metamorphic rocks

Ygm Muscovite granitoid. **(Middle Proterozoic)** Medium grained monzogranite in western Harquahala Mountains; consists of 20-30% anhedral quartz 1-3 mm, plagioclase, K-feldspar, 1-4% biotite in very fine grained aggregates, and up to 4% muscovite in .5-2 mm flakes. Equigranular in general, but grades into porphyritic phases with elongate K-feldspar phenocrysts up to 3 cm long. Rock near margins of pluton is texturally variable fine to medium fine-grained aplitic granite with 1-2% biotite. Intrudes Yg5 as dikes near contact north of Socorro Peak. Inclusions of Yg5 are present in the aplitic border zone in the San Marcos Mine area.

Yg Middle Proterozoic granitoid. **(Middle Proterozoic)** Undivided equigranular to porphyritic biotite monzogranite to granodiorite. These granitoids lack pre-Mesozoic tectonic fabric. Where mapped in the Little Harquahala Mountains consists mostly of mixed megacrystic and porphyritic biotite granite (Yg_5) and muscovite granite (Ygm).

Yg_1 Blue Tank granite. **(Middle Proterozoic)** Medium-grained, porphyritic biotite granitoid consisting of: 2-4% biotite, normally in 1-3 mm very fine-grained aggregates, but in least altered and recrystallized rock occurs as 2-3 mm diameter books; subequal parts of microcline, in 2 to 3 cm long, elongate phenocrysts, and anhedral plagioclase and quartz; abundant accessory sphene in 1 mm crystals. Sphene is visible only in unaltered rock; it is replaced by leucoxene in altered samples. Silicified alteration zones are commonly present near the contacts of the Blue Tank granite, and obscure contact relations. When exposed in unaltered rock, the contact is sharp and abrupt. Contact with Xg_1 is sheared, but sharp intrusive contacts are preserved in low strain zones. The

main phase of the Blue Tank granite is very similar to the porphyritic biotite granite of the Socorro suite (Yg_5); it is doubtful if a contact could be mapped between these rocks if they were in direct contact. However, the two granites are associated with different suites of intrusive rocks.

Yg_2 Harquahala granite. **(Middle Proterozoic)** Megacrystic biotite granodiorite to granite. 5-30% equant, blocky K-feldspar phenocrysts up to 5 cm in diameter; 5-7% biotite in very fine-grained aggregates; 10-20% quartz; accessory magnetite; rare accessory sphene only in westernmost exposures. Variably foliated and recrystallized parts of the unit in the central Harquahala Mountains typically have 1-3% of 1-2 mm muscovite grains, which are probably secondary. A border phase along the western margin of the unit consists of medium- to medium fine-grained, equigranular to slightly porphyritic granitodiorite with 15% quartz in 1-5 mm grains, 7% biotite in very fine-grained aggregates, plagioclase in 2-4 mm grains, and sparse K-feldspar in elongate 1-3 cm phenocrysts. The relationship between the Harquahala and Socorro (Yg_5) granites is obscured by alteration. The Harquahala granite generally contains more biotite and less quartz than Socorro granite, and its texture is more distinctly porphyritic. The Harquahala granite grades into fine-grained equigranular granodiorite (YXgg) on the southwest, and is overlain depositionally by Cambrian Bolsa Quartzite on the south. The contact with Xgs NE of Harquahala Mountain is complexly interdigitated due to deformation superimposed on an irregular intrusive contact. Sparse inclusions of Xgs in Harquahala granite indicate that it intrudes Ygs. Harquahala granite is intruded by fine-grained biotite granitoid (Yg_3) north of Harquahala Mountain, but the contact is locally gradational.

Yg_3 Fine-grained granitoids. **(Middle Proterozoic)** Fine-grained, equigranular monzogranite consisting of subequal amounts of anhedral microcline, plagioclase, and quartz, and 1-2% biotite and muscovite. Also includes medium fine-grained slightly porphyritic monzogranite body on ridge NW of Harquahala Mountain. Muscovite-biotite ratio ranges from 0 to 1. Plagioclase is mostly untwinned and difficult to distinguish from quartz in thin section. Fine-grained monzogranite intrudes the Harquahala granite as dikes, locally grading to homogeneous bodies; much of the unit is irregularly mixed with Harquahala granite (Yg_2). The slightly porphyritic monzogranite has sharp intrusive contacts. Similarity of trace-element chemistry and spatial association suggests that this unit is related to the Harquahala granite (Yg_2) (Richard and DeWitt, unpublished data, 1987).

Yg_4 Blue Tank granite, fine-grained phases. **(Middle Proterozoic)** Includes two medium- to fine-grained granitoid phases associated with the Blue Tank granite (Yg_1). The northern outcrops mapped as Yg_4 are a medium- to fine-grained, slightly porphyritic biotite granodiorite to monzogranite. This rock consist of 20-30% equant, subhedral to euhedral K-feldspar, 3-7 mm in diameter; 5-7% biotite in very fine-grained recrystallized clots; 20-30% quartz in 2-3 mm diameter, granular, irregular clots and as sparse 4 mm rounded 'eyes'; about 30-40% plagioclase in 2-4 mm anhedral and weakly to moderately sericitized grains; ~1 mm diameter muscovite grains are a sparse but ubiquitous accessory. The southern part of the area mapped as Yg_4 is an equigranular, fine-grained, hypidiomorphic-granular, biotite monzogranite to two-mica granite. Potassium feldspar in this rock is distinctly more euhedral than the recrystallized plagioclase and quartz with which it is intergrown; biotite occurs as very fine-grained aggregates, and rarely as 0.5-2 mm diameter flakes. This rock type forms a border zone along parts of the margin of the Blue Tank granite (Yg_1), and also along the margins of the slightly porphyritic biotite granite phase of this unit. The contacts of both of these units are commonly zones of silicification and chloritization, obscuring the field relationships in the contact zones.

Yg_5 Biotite granitoid of the Socorro suite. **(Middle Proterozoic)** Includes the Socorro granite of Varga [1977] and the porphyritic biotite granite of the Centennial plate [Richard, 1988; Spencer et al.,

1985]. The porphyritic biotite granite of the Centennial plate consists of 20-25% quartz up to 8 mm in diameter, K-feldspar in elongate ('boxcar') phenocrysts up to 2 cm long, plagioclase, 5% biotite in very fine-grained clots up to 2 mm in diameter and locally as 1-2 mm flakes. Generally medium to dark gray even when altered. Locally grades to quartz-feldspar porphyry . Resembles deformed biotite granitoid phase of the augen gneiss unit (Xgp). The border zone is medium fine-grained equigranular leucogranite. The Socorro granite consists of medium- to coarse-grained porphyritic granitoid consisting of 20-30% anhedral quartz up to 7 mm diameter, plagioclase up to 1 cm diameter, K-feldspar in blocky, equant phenocrysts 2-4 cm in diameter, and 2-4% biotite. Locally it is equigranular. The Socorro granite is generally coarser-grained, contains more quartz, and phenocrysts are more equant than porphyritic granitoid of Centennial plate; also, the grain size difference between the phenocrysts and groundmass is not as great. Thin dikes of aplitic leucogranite are common. The contact between Socorro granite and porphyritic granitoid of Centennial plate is gradational. Medium- to fine-grained leucogranites are present near contacts north-northeast of Socorro Peak; fine-grained leucogranites contain 2-4 mm rounded quartz phenocrysts. The Socorro granite is overlain depositionally by Bolsa Quartzite.

YXg Porphyritic granodiorite. **(Middle or Early Proterozoic)** Moderately to strongly deformed biotite granitoid of uncertain affinity in the northwestern Granite Wash Mountains and eastern Harquahala Mountains. In the Granite Wash Mountains the unit includes scattered fault-bounded outcrops. The most widespread forms the western face and northern half of Butler Ridge (the NW tip of the Granite Wash Mountains). It varies from a medium- to coarse-grained, porphyritic, biotite granite to a medium-grained, nonporphyritic to porphyritic biotite granodiorite. Phenocrysts in the pluton include K-feldspar up to 2 cm long, and bluish-gray quartz 3-6 mm in diameter. Where the granite is overlain by Cambrian quartzite, its upper 1-2 m is particularly micaceous and has pronounced quartz eyes, possibly due to weathering of feldspar prior to burial. A single whole-rock Rb-Sr analysis indicates a Proterozoic age for the granite [Reynolds et al., 1989]. Similar rocks are present on the isolated ridge SW of Butler Ridge (Sec. 10&11, T6N, R15W), but here the unit includes medium- to coarse-grained biotite granite and granodiorite with quartz eyes as large as 6 mm in diameter. This granite is very porphyritic and contains up to 40% rectangular feldspar phenocrysts 5 to 15 mm wide and 1-2 cm long, about 10% biotite, and numerous pods of biotite schist. A similar, but generally coarser-grained granite underlies Cambrian quartzite and Mesozoic sandstone on the west slope of Salome Peak. The isolated outcrop north of the Cobralla Mine (north of the eastern Granite Wash Mountains) includes abundant pegmatite.

In the eastern Harquahala Mountains, the unit consists of medium- to medium fine-grained, porphyritic granodiorite to hypidiomorphic granular monzogranite. Monzogranite consists of 3-4 mm subequant K-feldspar (25-40%) in fine grained quartz (20%)-feldspar-biotite groundmass; 3-7 % biotite, locally 1% muscovite (metamorphic?), and sparse 1-2 mm blocky opaque grains (illmenite?). Quartz locally forms 3-4 mm granular eyes. The porphyritic phase contains 1-2 cm K-feldspar phenocrysts and 7-10% biotite. Variations in the original igneous texture and subsequent strain make the character of the unit highly variable. This unit resembles Harquahala granite (Yg_2), coarser phases of Blue Tank granite (Yg_1), and porphyritic phases of Weldon Hill granite (Xg_1). Isolated outcrops and strong deformation make definite correlation based on field observations impossible. Mafic gneiss (Xma) is interleaved with the granitoid at their contact. Contains locally abundant inclusions/screens of biotite-muscovite quartzo-feldspathic gneiss and muscovite schist. Intruded by Kbc pegmatites

YXgm Muscovite granitoid. **(Middle or Early Proterozoic)** Light gray medium grained equigranular to slightly porphyritic granite, consisting of about 40% moderately to strongly sericitized plagioclase, 10-15% 0.5-1.5 cm blocky K-feldspar phenocrysts and 10-30% subhedral to anhedral K-feldspar

grains 2-4 mm in diameter, 20-25% quartz in 2-3 mm rounded grains; 3-5% biotite in very fine-grained secondary clots. Intrudes Weldon Hill granite (Xg_1), and is distinctly less foliated. Aplitic/fine grained phase near contact on SW.

YXgg Deformed granitoid and augen gneiss. **(Middle or Early Proterozoic)** Mostly deformed porphyrytic biotite monzogranite that consists of elongate ('boxcar') K-feldspar phenocrysts to 4 cm long, 10-20% quartz in 2-4 mm equant/round to 5 mm anhedral irregular grains, ubiquitously sericitized plagioclase, and 5-10% biotite in very fine-grained aggregates to 2 mm flakes. Contains fine-grained mafic enclaves to 0.5 m long. Augen gneiss is a minor component; it consists of rounded to blocky 2-4 cm K-feldspar augen, commonly with ragged, corroded margins, enclosed in recrystallized groundmass of 20-30% quartz in 3-10 mm anhedral grains, anhedral plagioclase in 3-10 mm-diameter grains, and 5-10% very fine-grained clots of biotite 3-5 mm in diameter. Resembles Socorro granite (coarse-grained phase of Yg_5). In Tenahatchipi Pass the unit grades into mixed metamorphosed and deformed biotite granitoids, including fine-grained equigranular granodiorite or quartz diorite, Socorro granite, deformed Socorro granite or augen gneiss, porphyritic biotite monzogranite and irregular pods of diorite and leucogranite. Rocks in this area are extensively chloritically altered and poorly exposed.

XYgs Foliated biotite granitoid and pelitic gneiss. **(Middle and Early Proterozoic)** Mixed biotite granitoid and quartz-feldspar-biotite-muscovite schist in the northeastern Harquahala Mountains. In the thin sheet within Kg_2 at the northeast end of the range, the granitoid phase is variably foliated (ranging to augen gneiss), medium gray granodiorite, with 1-2 cm diameter K-feldspar augen and 5-7% biotite. This granitoid locally resembles the Harquahala granite (Yg_2) or the porphyritic granodiorite unit (YXg) exposed on the southwest and south side of the Brown's Canyon granite. Dark gray biotite-rich schist includes quartzo-feldspathic layers that may represent granitic melt or the product of metamorphic segregation; the schist resembles biotite schist inclusions common in the Sunset Canyon granite (Xg_2 and Xgs). Moderately to strongly retrograded garnet or staurolite(?) are locally present in the schist. Variably foliated, fine-grained to pegmatitic leucogranite forms a significant component of the NE outcrop area; it is generally equigranular with 1-2% fine-grained biotite, sparse muscovite and trace of garnet. This leucogranite is interpreted to be a foliated early phase of the Brown's Canyon granite (Kg_2). Dark gray amphibole-plagioclase pods are a sparse but ubiquitous component of the assemblage. The granitoid component in outcrops on the NE side of lower Sunset Canyon is less strongly foliated and is probably equivalent to Harquahala granite (Yg_2); leucogranite is much less abundant in these outcrops. Contacts with Kg_2 in the NE outcrop area are Tertiary(?) high strain zones interpreted to be deformed intrusive contacts.

Xg Granitoid. **(Early Proterozoic)** In the western Vulture Mountains consists of two strongly foliated varieties: 1) A leucocratic variety that consists of light-gray, coarse-grained, equigranular, biotite or garnet granitoid with 1-3% garnet, 15-20% mostly chloritized biotite, 30-35% quartz, <5% epidote, and two feldspars; and 2) a mafic variety that consist of medium-gray, mesocratic, medium- to coarse-grained, quartz-poor, equigranular granitoid with 15-35% biotite, amphibole, and epidote, and saussuritized feldspar. The mafic variety also includes amphibole-rich melanocratic granitoid interleaved with biotite-amphibole schist on a scale of approximately 30 m. A small outcrop of granite mapped in the NW Big Horn Mountains is similar to the leucocratic variety, and the assemblage of granitoid phases in this unit is similar to the granitoid phase of unit Xga in the NW Big Horn Mountains.

In the NE Harquahala Mountains, granitoid mapped as Xg in the area N of Sunset Pass consists of biotite granitoid, abundantly intruded by dikes and irregular masses of aplite to pegmatite related to the Brown's Canyon granite (Kg_2). The biotite granitoid is fine- to medium fine-grained with 20-25% blocky to rounded, equant K-feldspar, in a groundmass of granular, anhedral, 1 mm-

diameter quartz and plagioclase, with 2-5% biotite in 1 mm diameter flakes and recrystallized aggregates, a trace of muscovite, and sparse but ubiquitous 2-3 mm blocky opaque grains (illmenite?). The biotite granitoid is texturally variable; in some places it strongly resembles Sunset Canyon granite (Xg_2), in other places it resembles Weldon Hill granite (Xg_1), and sparse, more porphyritic phases are very similar to the porphyritic granodiorite (YXg) south of the Brown's Canyon granite (Kg_2). The blocky opaque grains are distinctive.

Xg_1 Weldon Hill granite. **(Early Proterozoic)** Medium- to medium fine-grained, equigranular biotite monzogranite to granodiorite. Named for a low hill in the south-central Harquahala Mountains underlain mostly by this rock. Most of the rock consists of recrystallized anhedral plagioclase and potassium feldspar; 6-9% biotite is present in 2-3 mm very fine-grained aggregates, along with 5-10 % quartz in 2-7 mm granular aggregates. Quartz grains are commonly very round, giving the rock a "quartz-eye" look. The rock is locally slightly porphyritic with .5 to 1 cm long K-feldspar phenocrysts. Dark gray, fine-grained, quartz-feldspar-biotite enclaves are ubiquitous. Intrusive contacts are mixed zones, but in general the pluton is more homogeneous and more biotite-rich than the Sunset Canyon granite (Xg_2). The Weldon Hill granite is associated with mostly mafic-gneiss (Xma) wall rocks, whereas the Sunset Canyon granite intrudes pelitic gneisses and contains much more abundant screens of the gneissic wall rocks. Mixed-contact style, and equigranular texture suggest this is an Early Proterozoic rock, but the biotite-rich petrography and local gradations into porphyritic phases is like Middle Proterozoic granitoids.

Xg_2 Sunset Canyon granite. **(Early Proterozoic)** Foliated, fine-grained, equigranular granodiorite to granite in the central Harquahala Mountains. Named for outcrops along the NE and SW sides of lower Sunset Canyon. The mineralogy varies considerably from a local hornblende-diorite border phase in the upper part of Arrastre Gulch to muscovite-biotite granite. Superimposed deformation and metamorphism obscure the primary igneous mineralogy. The Sunset Canyon granite is characterized by fine to medium-fine grained equigranular texture; recrystallization generally obscures igneous textures. Typically contains 1-3% very fine-grained biotite, and a trace to 3% of muscovite. Locally the unit is slightly porphyritic. Internal contacts between different phases can be mapped for short distances, but the various phases grade into one another, and relative ages based on the lithology of cross-cutting dikes are inconsistent, indicating that these phases are all related. Faint to strong, laminated differentiated foliation is characteristic; this foliation is concordant with that in the ubiquitous screens of biotite schist and gneiss. Contacts are typically zones of mixed igneous and metamorphic rock.

Xg_3 Equigranular biotite granitoid. **(Early Proterozoic)** In the northern Granite Wash Mountains, corresponds to unit Xgd [Reynolds et al., 1989] or Xg [Reynolds et al., 1991]. This unit consists of deformed medium-grained, equigranular to slightly porphyritic granodiorite and feldspar-quartz-biotite±hornblende schist interpreted to be its deformed equivalent. The rocks are medium gray and homogeneous in composition over entire outcrops, but the composition varies between adjacent thrust slices. The granitoid generally contains 15-20% biotite, 15-25% quartz, and 60% feldspar. Where strongly deformed it becomes schistose, in some places with laminated compositional differentiation.

Xg_4 Equigranular biotite granitoid. **(Early Proterozoic)** Crops out in the northern Big Horn Mountains, where it consists of tan, fine to medium fine-grained, equigranular granitoid with about 5% biotite in flakes up to 2 mm in diameter. The rock has a weak foliation, and spheroidal weathering when not altered. It forms a relatively large (2 km^2) and homogeneous pluton in the Pegrin well area. Contains 5-10% amphibolite inclusions as discrete xenoliths. Very weakly foliated pegmatite dikes intrude the granite. Near its borders the granitoid becomes texturally more variable and more leu-

cocratic (~1% biotite) and resembles the leucogranite phase of unit Xga. Intrudes compositional banding in wall rock-gneisses; foliation in this pluton corresponds to S_2 fabric observed in gneisses in vicinity of the contact.

Xgm Hyduke leucogranite and pegmatite. **(Early Proterozoic)** Medium fine- to fine-grained, equigranular muscovite leucogranite. Named for outcrops along Hyduke Canyon in the central Harquahala Mountains. Although the modal mineralogy of these granitoids makes them granodiorites, the petrographic texture of the potassium feldspar suggests abundant albitization. Primary plagioclase occurs in anhedral, twinned grains and is albite or oligoclase. Potassium feldspars occur within very fine-grained aggregates of untwinned plagioclase (albite?), white mica, epidote and quartz; the potassium feldspar is commonly in crystallographic continuity with the plagioclase. If these aggregates were originally potassium feldspar grains, the rock would have been a monzogranite. Muscovite ranges in abundance from about 2% to 10%, and occurs as 1 to 3 mm flakes. The granite occurs in mixed zones with the pelitic schist unit (Xms), and in many areas the two units cannot be mapped separately. Contacts with unit Xms indicate where schists predominate over the leucogranite. More homogeneous bodies of muscovite leucogranite intrude the heterogeneous gneiss unit (Xgn); contacts of these bodies are sharp with much less mixing of rock. Voluminous pegmatites are associated with the leucogranite; these are especially prominent in the pelitic schist, and on the ridge west of Harquahala Mountain. Pegmatites consist of quartz, albite, muscovite, and minor microcline; they intrude as irregular, unzoned sills and dikes.

Xm Metamorphic rocks, undifferentiated. **(Early Proterozoic)** Diverse gneiss, schist, amphibolite, and granitoid throughout the northeastern half of the map area. In the SE Granite Wash Mountains includes quartz-feldspar-biotite gneiss, biotite schist, amphibolite, quartzite and quartz-rich gneiss, granitic gneiss and foliated granitoid, and leucogranite. One distinctive phase is a foliated porphyritic granite containing several percent of large K-feldspar phenocrysts and 10-15% biotite in shreddy, irregular clots; around the margins of the granite are less deformed fine-grained leucogranite and pegmatite, some of which is muscovite-bearing. In the northern Granite Wash Mountains, includes quartzo-feldspathic gneiss, mica schist and foliated granitoid, with a steep gneissic foliation; some thin zones of amphibolite, biotite schist derived from amphibolite and dioritic rocks are present.

In the Harcuvar Mountains includes compositionally diverse metamorphic and deformed plutonic rocks. Common rock types are: 1) Gneiss that consists of interleaved mica schist, amphibolite, granitic gneiss and quartzo-feldspathic layers, in part probably representing metamorphic segregations and lit-par-lit intrusion. 2) Black to dark greenish gray amphibolite, with or without feldspathic segregations. 3) Fine- to medium-grained quartz-feldspar-biotite-muscovite and quartz-feldspar-actinolite schists, with thin (<0.5 m) banded quartzite layers and quartz-feldspar segregations up to 1 cm thick that define the gneissic layering. Protolith is probably sedimentary. 4) Granitic gneiss and various metaplutonic rocks, including aplite, pegmatite and foliated leucogranite containing 1-5% biotite. 5) Foliated granite and light-gray foliated granodiorite to granite with 5% scattered biotite, and rare phenocrysts of feldspar. Early steeply dipping layering in this phase is concordant with that in adjacent gneisses. 6) Foliated granodiorite and quartz diorite locally similar to rocks mapped as JXg. 7) Fine-grained siliceous gneiss, schist and laminated tan-buff quartzite. Rocks mapped as Xm NE of Big Horn Peak in the Big Horn Mountains have not been described.

Xgn Heterogeneous gneiss. **(Early Proterozoic)** Generally intermediate-composition (Quartz-feldspar-biotite±hornblende) gneisses in the central and southwestern Harquahala Mountains and northwestern Big Horn Mountains In the central Harquahala Mountains, the unit is characterized by quartz-feldspar-biotite gneiss, but a wide variety of other rock types are present. These include

pelitic schist, actinolitic hornblende-feldspar-quartz gneiss, biotite-epidote-amphibole-rich gneiss, and rare quartz-magnetite granofels. To the northeast the rocks grade into mostly dark gray, biotite-muscovite-feldspar-quartz schist and gneiss. In the southwestern part of the Harquahala plate, the foliation defined by mineralogical and textural variations is generally regular and planar. The gneisses become migmatitic to the northeast, and the foliation becomes contorted. Chlorite is common in the southwestern part of the Harquahala plate but is absent in the Harquahala Mountain area. Small, irregular bodies of medium-grained biotite granitoid are present in the southwest. Mineral assemblages indicate upper greenschist to lower amphibolite facies metamorphism.

In the southwestern Harquahala Mountains, includes rocks informally referred to as Tenahatchipi gneiss [Richard, 1988], named for outcrops in Tenahatchipi Pass. In this area, the gneiss includes heterogeneous, fine-grained, quartzo-feldspathic to mafic gneiss. Quartz-feldspar-muscovite-biotite gneiss contains 2-20 cm-thick banding defined by mineralogical and textural variations, especially biotite concentrations; abundant leucogranite injections are discordant to subconcordant with this fabric. A superimposed schistosity related to the Centennial thrust in the outcrops northwest of Tenahatchipi Pass results in 'pencil' weathering. This unit is interleaved with augen gneiss (Xpg) over 10-20 m at the contact. On top of Twin Peaks contains lenses of highly deformed medium-grained equigranular biotite granitoid. Gneissic foliation is highly contorted on northern side of Twin Peaks, but becomes more planar and regular to south.

In the Big Horn Mountains consists of feldspar-quartz-biotite-amphibole gneiss to quartz-feldspar- biotite gneiss. In the SW part of the outcrop area, consists of mineralogically variable, fine-grained, feldspar-quartz-biotite-amphibole gneiss, grading into amphibolite gneiss, which forms a significant component of the assemblage. All of these variants are probably part of the same original protolith assemblage. A minor component in this assemblage is fine-grained, quartz-feldspar gneiss with 1-3% biotite, and irregular, nebulitic foliation. To the northeast, two sorts or quartz-feldspar-biotite gneiss become prominent. Both are fine-grained and contain 25-35% quartz, 40-60% plagioclase, minor K-feldspar, and 3-5% biotite. One is slightly finer-grained (1-2 mm), and contains a foliation defined by anastomosing, discontinuous biotite-rich laminations spaced 1-10 cm; rare K-feldspar porphyroblasts are present. The other consists of 2-3 mm grains, possibly with slightly more K-feldspar, and a foliation defined by more planar and continuous biotite laminations; plagioclase in this gneiss weathers white to give weathered surfaces a characteristic speckled look. Both types of gneiss contain highly flattened inclusions of amphibolite and intermediate gneiss that resemble deformed igneous xenoliths. These gneisses are interpreted to be highly deformed and metamorphosed granodioritic plutons that intruded the older gneiss assemblage represented by the feldspar-quartz-biotite-amphibole gneisses in the southwestern part on the unit. Textural reworking and mixing of these compositionally similar rock bodies during metamorphism and deformation makes separation of the units on the map impractical. The protolith is interpreted to be a mafic to intermediate volcanic and plutonic rocks. These rocks experienced intense deformation and metamorphism before and during intrusion of the igneous complex represented by the leucogranite and biotite granite phases of unit Xga.

Xga Mixed granitoids and amphibolite. **(Early Proterozoic)** Heterogeneous complex consisting of varying proportions of leucogranite, biotite granitoid, and amphibole-rich gneiss in the northwestern Big Horn Mountains. The leucogranite phase consists of fine-grained equigranular monzogranite (mapped as Xlg on Stimac et al., 1994), which contains 1-2% biotite, 25-35% quartz, 20-35% K-feldspar, 40-55% plagioclase and has an aplitic texture. The leucogranite intrudes the more mafic phases of this complex as thin dikes or small irregular plutons. It rarely forms relatively homogeneous bodies (with <~10% inclusions) larger than several 10's of m. In general it is characterized by abundant wall rock inclusions and textural and compositional gradation to more mafic phases. Weak foliation is defined by biotite alignment, and by compositional and textural variations.

Contact zones between leucogranite and gneissic wall rocks commonly contain abundant pegmatite as irregular pods and stringers. The pegmatites consist of quartz and feldspar, with little muscovite.

The biotite granitoid phase consists of medium- to medium fine-grained, equigranular, biotite monzogranite to granodiorite (mapped as Xbg by Stimac et al., 1994). This phase consists of 30-40% quartz, 10-20% potassium feldspar, 40-60% plagioclase, 4-10% biotite, and a trace of sphene. Relatively unfoliated zones weather spheroidally. As with the leucogranite, it rarely occurs as homogeneous masses, but normally crops out in heterogeneous, texturally variable mixed zones with abundant wall rock inclusions, many of which are partially resorbed. Rare, sharp contacts vary from concordant to discordant in different areas. Gradational mixed contacts are the most common; compositions grade both to gneissic diorite (amphibole-rich gneiss phase) and to leucogranite. Foliation is variably developed, ranging from weak and irregular to a well developed, uniform shape fabric and biotite schistosity.

The amphibole-rich gneiss component (mapped as Xag by Stimac et al., 1994) is fine-grained amphibole-plagioclase gneiss with well developed planar fabric defined by aligned amphibole and laminated compositional banding of amphibole- or plagioclase-rich layers, or locally by 1-15 cm thick quartzo-feldspathic layers. Ranges from homogeneous amphibolite gneiss to mixed amphibolite and amphibole-plagioclase-biotite-(quartz) gneiss with concordant and discordant granitic lithosomes. In the area near the Lion's Den Mine, grades into a massive to gneissic diorite or gabbro. Other small gabbroic pods scattered through the complex are typically agmatitic.

Xms Pelitic metasedimentary rocks. **(Early Proterozoic)** Muscovite-quartz-biotite-feldspar schists are the major component of this unit. In the southwestern part of the Harquahala Plate, the unit consists of muscovite schist and fine-grained quartz-feldspar-mica schists; primary sedimentary features are locally preserved. The typical mineral assemblage in the southwest is quartz-muscovite-chlorite-biotite indicating lower greenschist facies metamorphism. Staurolite and garnet are common in Proterozoic pelitic schists in the Sunset Canyon area, but because Mesozoic schists with similar compositions contain the same assemblages, the higher grade observed in Proterozoic rocks may be a result of Mesozoic metamorphism. To the north and northeast, the schists become more biotite rich; the large screens associated with the Sunset Canyon granite typically consist of biotite-muscovite-feldspar-quartz-garnet-staurolite schist and are dark gray instead of silvery in color. The muscovite-rich and biotite-rich schists have not been differentiated, but they may have different protoliths.

On the north side of the Brown's Canyon granite, consists of light tan-gray fine-grained feldspathic quartzite, commonly with abundant very fine-grained epidote; medium gray, fine grained elephant-hide weathering marble, and quartz-feldspar-rich psammitic schist to coarse-grained muscovite-biotite-garnet schist. Concordant to cross cutting leucogranite (Kg?) intrusions are abundant. This is the oldest component of the gneiss complex north of the Brown's Canyon granite.

In the western Bouse Hills, consists of black-weathering, variably micaceous, locally and variably calcareous and quartzose schist. Steep, east- to NE-striking foliation is defined by schistosity and by compositional layering. The protolith of these metamorphic rocks is interpreted to be siltstone, calcareous siltstone, and quartzose sandstone.

In the east central Big Horn Mountains includes fine- to medium-grained, muscovite-rich schist and phyllite, feldspar-muscovite-chlorite-epidote schist, plagioclase-chlorite schist, calc-silicate gneiss or hornfels; and less abundant ferruginous-quartzite layers a few meters thick. The protolith includes silicic to intermediate volcanic rocks, volcaniclastic units, quartzose feldspathic-lithic sandstones, pelitic rocks, and ferruginous cherts. Relict depositional structures (bedding?, fragmental textures) are rarely visible. A well-developed, northeast-striking, steep continuous cleav-

age is present throughout in the micaceous units. The unit is commonly monotonous on a 1-10 m scale, but displays significant lithologic variation on a larger scale. Similar pelitic and quartz-rich metasedimentary rocks are exposed at the SE corner of the map area. There are the northern end of more extensive exposures of metasedimentary rocks between the Big Horn Mountains and Saddle Mountain [Ort and Skotnicki, 1993]

Xma Mafic gneiss. **(Early Proterozoic)** Mafic gneiss includes compositionally banded hornblende-rich gneisses ranging from amphibolite to plagioclase-biotite-hornblende gneiss. The typical gneiss is fine-grained and equigranular, with 2-15 cm thick bands defined by plagioclase-rich and plagioclase-poor layers. The foliation is generally quite regular. Foliated gabbro or diorite bodies and aphanitic to very fine-grained white quartz-feldspar granofels that contain sparse 2-3 mm quartz porphyroclasts are a minor component; these are especially abundant in the canyon southwest of Blue Tank Canyon in the central Harquahala Mountains.

Xa Mafic to intermediate metavolcanic rocks. **(Early Proterozoic)** Dark-green and greenish-gray to black, massive, fine-grained hornblende schist, consisting of 50-80% hornblende with variable amounts of plagioclase, chlorite, epidote and biotite. Light-greenish quartz-epidote layers and lenses of muscovite-rich schist are locally present. Grades to the northwest into Xga unit with increasing metamorphic grade and granitoid intrusion.

Xgs Sunset Pass complex. **(Early Proterozoic)** Sunset Canyon granite (Xg_2) with concordant inclusions of schist and gneiss from several meters to several hundred meters long. Schist and gneiss are very similar to unit Xgn on the southwest side of Harquahala Mountain. These are mostly fine- to medium-grained biotite-muscovite-quartz-feldspar-garnet-staurolite schist and gneiss. The rock contains a differentiated foliation that ranges from lamination in schistose layers to quartzo-feldspathic layers 10 to 20 cm thick. Foliation is normally irregularly planar, but in some areas is quite contorted. Fine-grained amphibolite pods are locally present; these may be relict dikes.

Xpg Augen gneiss. **(Early Proterozoic)** Dark gray weathering augen gneiss containing 2-3 cm diameter, rounded K-feldspar augen with irregular, corroded margins. Augen are commonly fractured with quartz filling, or have quartz and feldspar inclusions. The groundmass is an aggregate of granular quartz and feldspar with disseminated very fine-grained biotite. About 15-25% of rock is quartz, mostly in 1-3 mm granular aggregates and anhedral grains in a mat of sericitized plagioclase, chloritized biotite and microgranular epidote. Some quartz aggregates are up to 7 mm in diameter. Plagioclase is moderately to strongly sericitized. Medium to fine-grained leucogranite dikes and concordant pods and lenses of medium grained diorite or gabbro are common. Strongly resembles foliated Socorro granite (coarse phase of Yg_5), but contains less quartz and more biotite. Interleaved with Tenahatchipi gneiss at the contact. Intruded by diorite/granodiorite of Jg_2.

Phanerozoic or Proterozoic crystalline rocks

TXgg Crystalline rocks. **(Tertiary, Cretaceous, and Proterozoic)** Heterogeneous igneous and metamorphic rocks in the central Bouse Hills. Includes granitoid rocks similar to TXg and their foliated equivalents, medium-grained leucocratic muscovite granite, and quartzo-feldspathic gneiss. Tertiary siliceous dikes become progressively more abundant towards the contact with unit Tg, and form most of TXgg near the contact. Weak, NE-striking, steeply dipping crystalloblastic foliation is present in granitoid rocks in some areas; quartz veins up to 10 cm thick, oriented parallel to foliation, are present in some areas. Local shear zones contain protomylonitic to weak crystalloblastic foliation. Compositionally variable granitoids within these zones are gneissic. Granitoid rocks of this unit also contain local inclusions (up to many meters in diameter) of compositionally layered

metasedimentary rocks. In the southeastern exposures of this unit, distinctive porphyritic granite consists of plagioclase, 10 to 50% K-feldspar phenocrysts up to 2 cm long, 20 to 40% quartz, and 2 to 10% biotite that is commonly altered or associated with epidote.

KXg Granitoid rocks. **(Tertiary, Cretaceous, and Proterozoic)** Fine- to coarse-grained equigranular to porphyritic, medium- to light-gray, biotite granite or granodiorite with local fine-grained leucocratic phases. Exposed only in the Bouse Hills. Porphyritic varieties contain 1- to 2-cm-diameter, stubby potassium-feldspar phenocrysts. Plagioclase is variably sericitized. Zone of mixed granitoids near contacts of Tertiary granite in Bouse Hills.

KXgd Gneissic to unfoliated granitoid. **(Cretaceous, Jurassic, or Proterozoic)** Includes fine-grained, foliated to gneissic granodiorite, and unfoliated granodiorite to monzogranite in the western Harquahala Mountains. Unfoliated parts resemble both the Jurassic or Cretaceous fine-grained granodiorite (unit KJgd), and the hypidiomorphic-granular granodiorite to monzogranite border phase associated with the Harquahala granite (Yg_2). Foliated to gneissic phases resemble equigranular granodiorite of probable early Proterozoic age exposed in the hanging wall of the Harquahala Thrust (Xg_1, parts of Xgs). Contacts between the various phases are subtle.

KXgn Quartzo-feldspathic to amphibolite gneiss. **(Cretaceous, Jurassic and Proterozoic)** Heterogeneous assemblage consisting mostly of intermediate to mafic gneiss injected by massive to gneissic leucocratic granitoid, mapped along the northern side of the NE Harquahala Mountains. Gneiss is typically fine-grained, and consists of feldspar, quartz, biotite, and hornblende, with thin to laminated banding defined by variations in mafic mineral content. Nearly massive hornblende-plagioclase gneiss dominates the assemblage NE of the Linda Mine. The leucogranite injection component is aplitic to pegmatitic granodiorite to granite related to the Brown's Canyon granite (Kg_2), and contains 1-4% biotite, muscovite or garnet. North of Brown's Canyon, lenses of porphyritic biotite granitoid, (Yg_2?) are relatively common. Along the northern edge of the Harquahala Mountains, a variety of biotite granitoids are more abundant than the older gneiss component in the complex. Some of these are lithologically identical to rocks mapped as Xg on the NW ridge of the mountain drained by Brown's Canyon. Equigranular fine- to medium-fine-grained biotite and hornblende-biotite granitoids in this assemblage contain more mafic minerals and clots of opaque grains than Brown's Canyon granite (Kg_2), but are lighter colored and finer grained than the typical Proterozoic(?) granitoid (Xg). One distinctive phase is an equigranular leucogranodiorite with .7-1 cm long hornblende crystals that crops out in NE sec. 7, T N, R9W. These rocks have not been studied in detail. The general appearance of the assemblage is highly variable due to variations in the degree of deformation related to three foliation-forming events recognized in these rocks: 1) Proterozoic metamorphism and deformation that formed the primary gneissic foliation in the older gneiss component. 2) Cretaceous(?) metamorphism and deformation that has largely transposed this older fabric. Brown's Canyon granite dikes are concordant or discordant to this foliation, and in a few places can be observed cutting the older gneissic foliation where it can be distinguished from the Cretaceous(?) fabric. 3) Tertiary mylonitization and retrogression that has largely transposed both older fabrics along the northern edge of the range. Miocene(?) mafic dikes (Tim) are mostly broken up and rotated to near parallel with the mylonitic foliation, but a few cross-cutting mafic dikes were observed. To the SW, the unit grades into a mixed biotite granitoid complex (Xg). Granitoids in this complex intrude the older gneiss component in KXgn.

JYd Hypabyssal mafic rocks. **(Jurassic or Middle Proterozoic)** Includes a small fine-grained dioritoid intrusion in the east-central Little Harquahala Mountains, and older mafic dikes in the central Harquahala Mountains. The body in the Little Harquahala Mountains consists of equigranular, fine- to medium-grained plagioclase, chloritized mafic minerals (hornblende or biotite?), and minor

quartz. Secondary epidote is abundant. Older mafic dikes in the central Harquahala Mountains consist of very fine-grained, cleaved, biotite-chlorite-sericite-plagioclase-quartz semi-schist. Sparse hornblende phenocrysts replaced by biotite are present. These dikes lack evidence of chilled margins characteristic of Tertiary mafic dikes (Tim). The body in the Little Harquahala Mountains intrudes JXi along its southern contact. The older dikes in the central Harquahala Mountains intrude a variety of Proterozoic crystalline rocks.

JXg Undivided granitoid rocks. **(Jurassic or Early Proterozoic)** Heterogeneous, typically granodioritic and equigranular, massive to gneissic granitoid mapped in the western Harcuvar, southeasternmost Little Harquahala and Eagletail Mountains. In the western Harcuvar Mountains consists of variably deformed and metamorphosed tonalite to granite. Less deformed outcrops in this area are generally equigranular to slightly porphyritic hornblende-bearing granodiorite or tonalite containing 5-10% mafic minerals, including both biotite and hornblende. Epidote is very common. A porphyritic granodiorite phase contains plagioclase and quartz phenocrysts 0.5 to 2 cm in diameter; the most porphyritic phases are also the coarsest grained. A local porphyritic granite phase contains 10% 1-3 cm diameter K-feldspar phenocrysts. Less common rock types included in this unit are fine-grained equigranular granodiorite, quartz diorite, quartz diorite gneiss, miscellaneous gneiss and schist, and rare amphibolite. Exposures of deformed granitoids are generally homogeneous over large outcrops. In high-strain zones this unit is deformed and metamorphosed to a medium- to dark-gray, strongly foliated feldspar-quartz-biotite-amphibole schist, commonly with a gneissic aspect due to the presence of 0.1 to 5 cm-thick feldspar segregations. Schistose, mylonitic, muscovite-rich granodiorite is present directly beneath the Cottonwood Pass thrust. These igneous rocks are probably Proterozoic or Jurassic, but the structural fabric is probably Cretaceous. Leucogranite becomes more abundant to the west and this unit grades into JXl or Jxi.

The northwesternmost ridge of the Granite Wash Mountains is underlain by medium-grained, equigranular to locally porphyritic, foliated granodiorite containing 5-7% biotite. Feldspar phenocrysts up to 1 cm in diameter are locally present. This unit is complexly interleaved with Paleozoic to lower Mesozoic metasedimentary rocks (MzPzs) to the southeast along a pre-metamorphic contact that may be an older fault, an intrusive contact or, less likely, an unconformity.

Rocks mapped as JXg on Lone Mountain on the west side of the Harquahala Plain are a compositionally variable, medium- to fine-grained, equigranular diorite(?) to granodiorite plutonic suite, locally grading into a granitic phase with approximately equal parts of plagioclase and K-feldspar. Pegmatite dikes intrude this complex. Anhedral apatite and sphene, 1-2 mm in diameter are ubiquitous in the less leucocratic phases. More felsic members of this suite are apparently younger.

Moderately to strongly chloritized, sericitized and hematite stained aplitic leucogranite, locally with a laminated mineralogical differentiation foliation, and slightly porphyritic medium-grained biotite granodiorite, mapped as JXg, crop out over a small area in the northern Eagletail Mountains. These rocks are faulted against quartz-feldspar porphyry that is lithologically identical to the Black Rock volcanics (Jv).

JXh Hypabyssal rocks. **(Jurassic or Early Proterozoic)** Hornfels, consisting of a dark gray, aphanitic groundmass containing white to pinkish, broken-appearing, 1-4 mm diameter K-feldspar crystals. Rock unit is probably related to Jv, but origin is unclear. Exposed on 2 small hills on pediment north of Lone Mountain.

JXi Granitoid and gneiss. **(Jurassic or Early Proterozoic)** Mixed augen gneiss, granite to granodiorite and leucogranite. Similar to JXg, but typically includes equigranular to megacrystic biotite granite to granodiorite as a major component with leucogranite. In the northern Granite Wash Mountains

consists of mixed aplitic leucogranite, pegmatite, and megacrystic, variably foliated to gneissic biotite granitoid with K-feldspar phenocrysts or augen up to 4 cm in diameter. In the northern Little Harquahala Mountains consists of 40-60% fine- to medium-grained leucogranite, intruding amphibolite gneiss and less abundant biotite granitoid. In the southern Little Harquahala Mountains consists of weakly to moderately foliated porphyritic biotite granite with 1 to 3 cm rounded K-feldspar phenocrysts or augen, intruded by abundant dikes and small irregular bodies of fine-grained equigranular leucogranite and medium grained, equigranular biotite granite; a minor component of this assemblage is metasedimentary gneiss or schist. Jurassic granite (Jg_3) intrudes JXi in the southern Little Harquahala Mountains.

JXl Leucogranite. **(Jurassic or Early Proterozoic)** Aplitic leucogranite and pegmatite, typically in mixed assemblages with older gneissic rocks and biotite granitoids. Leucocratic end of a continuum from JXl to JXi to JXg with decreasing leucogranite and increasing diorite to granodiorite in mixed granitoid assemblages. JXl is mapped in the Little Harquahala and Granite Wash Mountains. The leucogranite is medium to fine-grained, equigranular, and contains 1-3% biotite and, in the Granite Wash Mountains, 1-2% muscovite.

JXmi Mixed orthogneiss and paragneiss. **(Jurassic through Early Proterozoic)** Paleozoic and lower to middle Mesozoic metasedimentary rocks (MzPzs) structurally interleaved with Jurassic or Proterozoic metaplutonic rocks (JXl, JXg) and Proterozoic metamorphic rocks (Xm)

GEOCHRONOLOGY

Available isotopic age dates for rocks within the map area are located on the map. Each point on the map is labeled with an idetifying number, a two letter code for the isotopic system used to obtain the date, an apparent age, and an uncertainty. Where two or more mineral fractions from the same sample were analyzed, these are show on consectutive lines. Table1 provides more information about these ages dates. Abbreviations used on the map are explained below the table.

Table 1. Isotopic dates from the Salome Quadrangle

Map #	Sample ID	Rock type	Unit	method	material	Date	Latitude	Longitude	Reference
1	86WAG001	rhyodacite tuff	Hummingbird mbr, Big Horn volcanics	KA	biot	20.0 ±0.6	33° 32.37'	113° 3.33'	Miller and Gray, in press
2	86WAG002	andesite	Burnt Mountain volcanics	KA	w.r.	17.7 ±0.6	33° 32.37'	113° 3.50'	Miller and Gray, in press
3	UAKA-73-107	basalt	Eagletail volcanics	KA	w.r.	20.9 ±0.5	33° 32.92'	113° 26.50'	Shafiqullah and others, 1980
4	84WAM73	rhyolite	Hummingbird mbr, Big Horn volcanics	KA	biot	20.2 ±0.8	33° 34.83'	113° 6.32'	Miller and Gray, in press
5	84WAB140	basalt	Deadhorse basalt	KA	w.r.	19.8 ±0.8	33° 36.00'	113° 7.33'	Miller and Gray, in press
6	84WAB17	monzonite	Big Horn granodiorite(?)	KA	biot	68.1 ±2.0	33° 37.67'	113° 7.68'	Miller and Gray, in press
7	UAKA-73-20	granite	Sore Fingers granite	KA	biot	140.0 ±4.0	33° 38.20'	113° 29.90'	Shafiqullah and others, 1980
8	84WAM23	rhyolite	Hummingbird member	KA	biot	18.5 ±0.6	33° 38.55'	113° 10.75'	Miller and Gray, in press
			Big Horn volcanics	KA	sani	19.4 ±0.5			
9	85WAM40	leucocratic granite	Big Horn granodiorite?	KA	biot	63.0 ±1.9	33° 38.63'	113° 8.78'	Miller and Gray, in press
10	84WAM30	basalt		KA	w.r.	18.8 ±0.5	33° 38.75'	113° 6.92'	Miller and Gray, in press
11	BHC-212	rhyolite		KA	biot	20.3 ±0.2	33° 39.26'	113° 5.03'	Spencer et al., 1995
12	1-15-88-7	tuff		KA	fl_c	19.6 ±0.4	33° 39.42'	113° 39.26'	Spencer et al., 1995
				KA	biot	21.5 ±0.5			
13	12-16-88-4	basalt		KA	pl_c	19.4 ±0.4	33° 40.05'	113° 40.87'	Spencer et al., 1995
14	BH-89	basalt		KA	pl_c	16.1 ±0.2	33° 41.44'	113° 5.68'	Spencer et al., 1995
15	LHA-1	porphyritic granite	Little Harquahala monzodiorite	KA	biot	66.0 ±2.2	33° 43.00'	113° 36.30'	Shafiqullah and others, 1980
16	BHC-213	rhyolite		KA	biot	21.4 ±0.3	33° 43.28'	113° 5.31'	Spencer et al., 1995
17	4-10-85-16	diorite	Sore Fingers monzodiorite	AA max	k-sp	60.0 ±0.5	33° 43.60'	113° 36.95'	Richard et al., 1995
				FT	apat	19.0 ±2.0			
18	1-31-84-1	granite	Socorro suite, muscovite granite	AA max	musc	1144.9 ±6.4	33° 44.46'	113° 30.36'	Richard et al., 1995
				AA max	k-sp	54.6 ±0.6			
19	BHC-215	rhyodacite		KA	biot	19.6 ±0.2	33° 44.59'	113° 1.88'	Spencer et al., 1995
20	3-2-86	granodiorite	Granite Wash granodiorite	AA tg	biot	65.5 ±0.4	33° 44.51'	113° 40.45'	Richard et al., 1995
				AA max	k-sp	51.0 ±0.3			
				AA ms	horn	80.0 ±0.4			
22	89-09		Granite Wash granodiorite	FT	apat	21.0 ±2.0	33° 44.73'	113° 40.42'	Foster et al., 1993

Map #	Sample ID	Rock type	Unit	method	material	Date	Latitude	Longitude	Reference
23	ES:94	granodiorite	Granite Wash granodiorite	KA	biot	70.8 ±0.0	33° 44.76'	113° 40.45'	Eberly and Stanley, 1978
24	UAKA-66-03	granodiorite	Granite Wash granodiorite	KA	biot	66.5 ±3.6	33° 45.00'	113° 40.50'	Shafiqullah and others, 1980
25	HLA-2	diorite dike		KA KA	biot horn	22.1 ±1.3 28.6 ±1.9	33° 45.70'	113° 17.80'	Shafiqullah and others, 1980
26	4-1a-86	Meta granodiorite	Sore Fingers plutonic suite(?)	AA ms	biot	55.7 ±0.4	33° 45.71'	113° 32.40'	Richard et al., 1995
27	4-28-85-2	granite	Blue Tank Suite, border phase	AA tg AA max	biot musc	55.7 692.8 ±4.8	33° 45.96'	113° 21.78'	Richard et al., 1995
28	853-26-1A	granodiorite		KA	biot	70.8 ±0.5	33° 46.14'	113° 3.00'	Spencer et al., 1995
29	UAKA-77-64	phyllite	McCoy Mtns. Fm.	KA	w.r.	67.1 ±1.4	33° 46.80'	113° 44.00'	Shafiqullah and others, 1980
30	4-24-85-3	Quartz-feldspar-biotite schist	Abrigo Formation	AA ms	biot	42.7 ±0.3	33° 46.97'	113° 18.53'	Richard et al., 1995
31	83-11-8-3	alaskite-pegmatite	White Marble Mine pegmatite	KA	musc	573.0 ±19.0	33° 47.04'	113° 24.37'	Hardy, 1984
32	HVR-1	mica schist	Calcite Mine schist	KA	musc	64.6 ±1.5	33° 47.00'	113° 41.30'	Shafiqullah and others, 1980
33	83-11-8-2	gneiss		KA	biot	58.4 ±2.2	33° 47.15'	113° 24.47'	Hardy, 1984
34	4-26-85-1	mafic dike		AA is	horn	22.3 ±2.0	33° 47.24'	113° 17.30'	Richard et al., 1995
35	4-15-85-6	amphibilite gneiss		AA tg	horn	96.2	33° 47.20'	113° 23.17'	Richard et al., 1995
36	83-11-8-4	mylonitic schist	Harquahala thrust zone	KA	musc	62.5 ±2.3	33° 47.44'	113° 24.88'	Hardy, 1984
37	83-11-8-5	mylonitic schist	Harquahala thrust zone	KA	biot	56.1 ±2.1	33° 47.44'	113° 24.88'	Hardy, 1984
38	D4-11-84-1d	gneiss		AA tg	horn	188.2	33° 47.64'	113° 16.40'	Richard et al., 1995
39	4-5-86-1	amphibolite gneiss	Proterozoic amphibolite	AA max	horn	133.1 ±3.0	33° 47.82'	113° 15.49'	Richard et al., 1995
40	83-11-8-1	porphyritic granite	Harquahala granite	KA	biot	49.5 ±1.9	33° 47.99'	113° 25.04'	Hardy, 1984
41	4-5-85-2	granite	Harquahala granite	AA ms AA max AA tg FT	musc k-sp biot apat	54.8 ±0.4 76.9 ±1.0 51.8 20.0 ±2.0	33° 48.03'	113° 25.05'	Richard et al., 1995 Foster et al., 1993
42	2-18-86-3	schist	Proterozoic schist	AA ms AA max	biot musc	26.0 ±0.1 48.5 ±0.6	33° 48.18'	113° 18.08'	Richard et al., 1995
43	4-2-86-3	metadiorite		AA tg	horn	219.7	33° 48.13'	113° 41.89'	Richard et al., 1995

Map #	Sample ID	Rock type	Unit	method	material	Date	Latitude	Longitude	Reference
44	1-1-86	schist	Sunset Pass assemblage	AA tg	biot	21.4 ±0.2	33° 48.62'	113° 17.72'	Richard et al., 1995
45	11-28-84-7	pegmatite		AA max	musc	100.3 ±0.6	33° 48.78'	113° 21.82'	Richard et al., 1995
46	AWL-7-83	felsic dike	Salome dike	KA	feld	56.5 ±2.3	33° 49.10'	113° 44.20'	Kress and others, 1985
47	11-27-84-3	Amphibolite gneiss		AA ms	horn	72.2	33° 49.39'	113° 20.90'	Richard et al., 1995
48	3-5-84-4	granite	two mica granite (Harquahala suite?)	AA max AA tg AA pl	k-sp biot musc	37.2 ±0.6 43.5 ±0.3 51.8 ±0.3	33° 49.55'	113° 22.37'	Richard et al., 1995
49	11-27-84-6	pegmatite	Brown's Canyon granite	AA pl	musc	51.1 ±0.3	33° 49.64'	113° 21.15'	Richard et al., 1995
50	2-1-86	granite	Brown's Canyon granite	AA tg AA is	biot musc	20.0 ±0.2 30.0 ±0.1	33° 49.95'	113° 14.04'	Richard et al., 1995
51	2-2-86	granite	Brown's Canyon granite	AA max	musc	26.9 ±0.2	33° 50.20'	113° 14.11'	Richard et al., 1995
52	UAKA-73-126	granite	Tank Pass granite	KA	biot	47.5 ±1.0	33° 50.67'	113° 41.55'	Shafiqullah and others, 1980
53	UAKA-78-31	basalt	Black Butte basalt	KA	w.r.	15.6 ±0.4	33° 50.76'	113° 1.87'	Scarborough and Wilt, 1979
54	2-19-86-3	amphibolite	Brown's Canyon granite	AA tg	horn	64.4	33° 50.70'	113° 14.51'	Richard et al., 1995
55	17-1 TO 17-3	granite	Sunset Pass two-mica granite	SR SR	musc w.r.	50.3 ±0.4 53.0 ±0.4	33° 50.76'	113° 20.52'	Rehrig, 1981
56	UAKA-77-63	granite	Tank Pass granite	KA	biot	55.0 ±1.2	33° 51.20'	113° 45.10'	Shafiqullah and others, 1980
57	D11-22-84-2	granite	Brown's Canyon granite	AA tg AA max AA max	biot musc k-sp	20.3 ±0.1 32.5 ±0.2 26.0 ±0.5	33° 51.35'	113° 16.68'	Richard et al., 1995
58	D4-5-84-2	amphibolite		AA ms	horn	68.9 ±0.4	33° 51.59'	113° 16.05'	Richard et al., 1995
59	D4-9-84-2	amphibolite		AA tg	horn	93.8	33° 51.53'	113° 20.40'	Richard et al., 1995
60	UAKA-78-48	basalt	Vulture volcanics	KA	w.r.	20.0 ±0.4	33° 51.62'	113° 2.80'	Scarborough and Wilt, 1979
61	2-23-86-2	amphibolite	Brown's Canyon granite	AA pl	horn	67.9 ±0.4	33° 51.63'	113° 12.30'	Richard et al., 1995
62	9-2-86	amphibolite	Brown's Canyon granite	AA ms	horn	63.5 ±0.3	33° 51.62'	113° 12.32'	Richard et al., 1995
63	HVR-2	granite	Tank Pass granite	KA	biot	44.1 ±1.3	33° 52.00'	113° 41.30'	Shafiqullah and others, 1980
64	9-1a-86	granite	Brown's Canyon	AA tg	biot	13.7 ±0.1	33° 52.16'	113° 11.97'	Richard et al., 1995

Map #	Sample ID	Rock type	Unit	method	material	Date	Latitude	Longitude	Reference
			granite	AA max	k-sp	22.4 ±0.5			
65	89-12			FT	apat	16.0 ±2.0	33° 53.08'	113° 37.88'	Foster et al., 1993
66	87G16			AA is	musc	55.4 ±0.7	33° 53.00'	113° 43.50'	Knapp and Heizler, 1990
67	87G29	granitoid	JXg	AA is	biot	45.5 ±3.8	33° 53.00'	113° 44.00'	Knapp and Heizler, 1990
68	87G36	granitoid	JXg	AA is	biot	37.1 ±3.4	33° 53.00'	113° 46.00'	Knapp and Heizler, 1990
				AA is	k-sp	21.3 ±0.3			
69	UAKA-77-65	granite	Tank Pass granite	KA	biot	51.0 ±1.1	33° 53.10'	113° 37.80'	Shafiqullah and others, 1980
70	87G30	granitoid	JXg	AA is	horn	129.0 ±5.0	33° 53.30'	113° 44.00'	Knapp and Heizler, 1990
71	4-8-85-5	mafic dike		AA tg	horn	32.3	33° 55.10'	113° 9.62'	Richard et al., 1995
72	12-12-88-5	granite		KA	biot	20.0 ±0.6	33° 55.27'	113° 50.92'	Spencer et al., 1995
73	89-14			FT	apat	17.0 ±2.0	33° 55.32'	113° 37.17'	Foster et al., 1993
74	12-6-84-3	tuff		KA	horn	18.4 ±0.5	33° 55.93'	113° 55.28'	Spencer et al., 1995
				KA	biot	21.5 ±0.5			
75	2-10-85-1	basalt		KA	w.r.	19.5 ±0.3	33° 56.07'	113° 55.00'	Spencer et al., 1995
76	ES:90	andesite	Bouse Hills andesite	KA	biot	20.5 ±1.1	33° 56.62'	113° 55.52'	Eberly and Stanley, 1978
77	853-11-2	tuff		KA	biot	22.5 ±0.7	33° 57.37'	113° 58.82'	Spencer et al., 1995
84	32-2-85			FT	apat	18.9 ±6.5	33° 57.48'	113° 36.63'	Bryant et al., 1991
				FT	zirc	18.0 ±1.4			
78	853-11-1	tuff		KA	biot	24.0 ±0.7	33° 57.48'	113° 58.75'	Spencer et al., 1995
79	UAKA-73-127	granodiorite	Bouse Hills granodiorite	KA	biot	16.5 ±0.5	33° 58.10'	113° 49.80'	Shafiqullah and others, 1980
80	SJR-HV-78-1	amphibolite	Cunningham Pass gneiss	KA	horn	70.3 ±2.9	33° 58.94'	113° 33.67'	Shafiqullah and others, 1980
81	UAKA-75-107	gneissic granite	Harcuvar gneissic granite	KA	biot	25.3 ±0.5	33° 59.00'	113° 34.00'	Shafiqullah and others, 1980
82	12-14-88-4	dike		KA	biot	19.7 ±0.5	33° 59.24'	113° 54.05'	Spencer et al., 1995
83	12-14-88-3	granite		KA	biot	20.2 ±0.5	33° 59.88'	113° 50.75'	Spencer et al., 1995
85	4-8-83-1	rhyolite	Black Rock Volcanics	U-Pb	zirc	160.0	33° 4.00'	113° 37.50'	Reynolds et al., 1987

Abbreviations: Dating methods: AA-$^{40}Ar/^{39}Ar$ method (is-isochron age; tg-total gas age; ms-mean of several steps; max or min-of age gradient; pl-plateau); KA-potassium argon; SR--rubidium-strontium; U-Pb-uranium-lead; FT-Fission track.

Material dated: apat-apatite; biot--biotite; feld-feldspar; pl_c--plagioclase concentrate; sani--sanidine; w.r.--whole rock; zirc-zircon.

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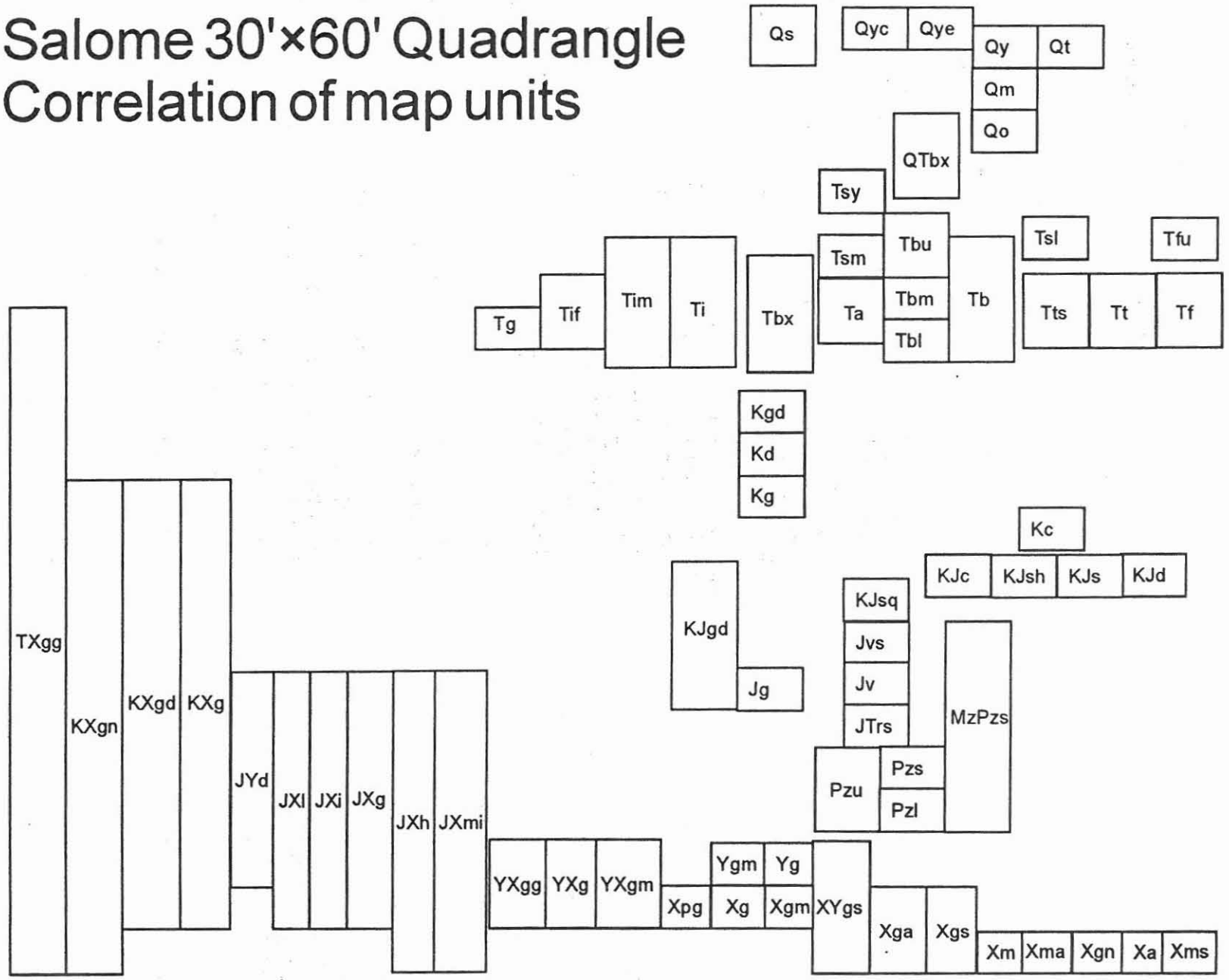
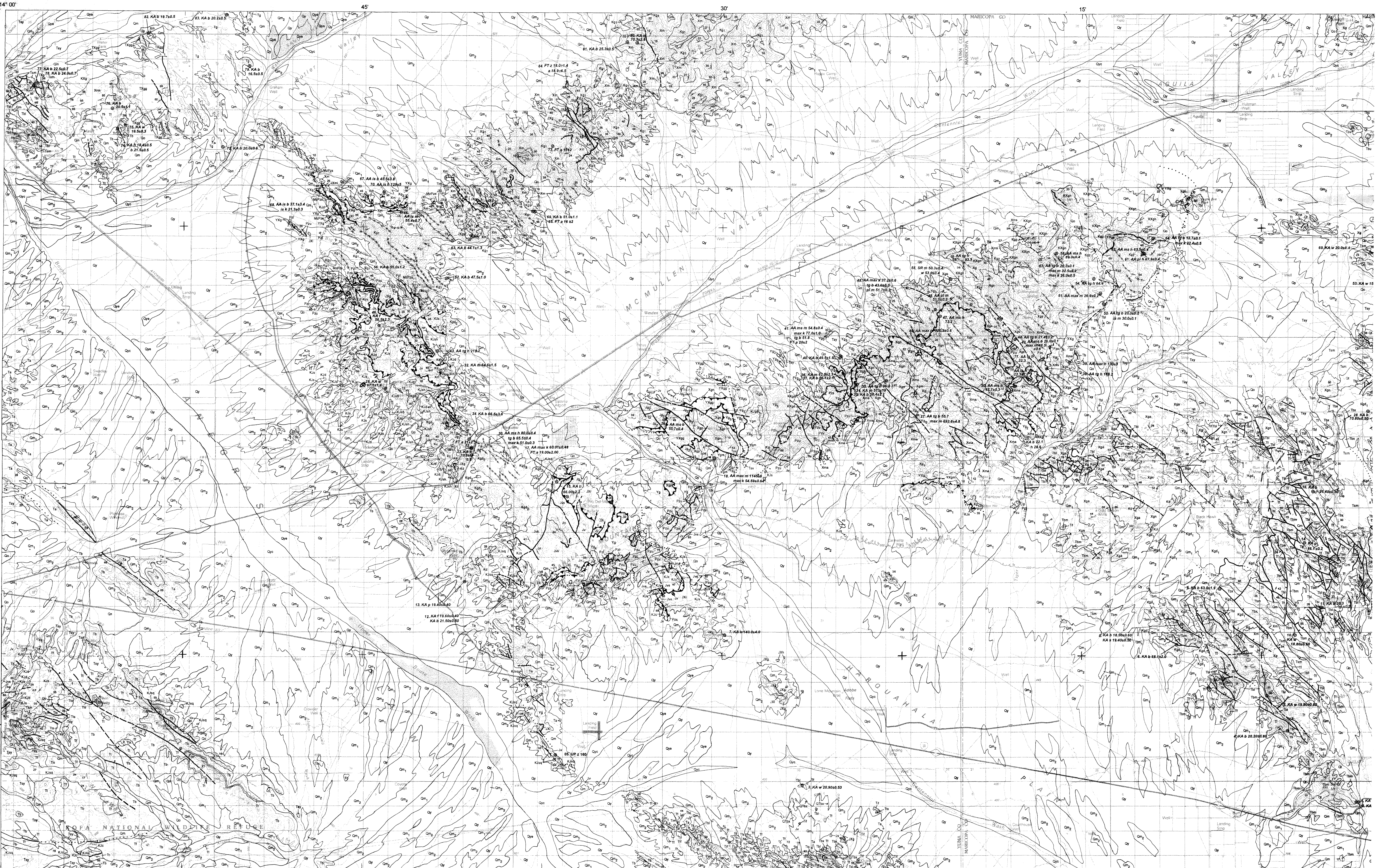
Salome 30'×60' Quadrangle
Correlation of map units





GEOLOGIC MAP OF THE SALOME 30'×60' QUADRANGLE, WEST-CENTRAL ARIZONA

Stephen M. Richard, Jon E. Spencer,
and Stephen J. Reynolds

Arizona Geological Survey Open-File Report 94-17

October, 1994

Scale 1:100,000

1 0 2 4 6 8 MILES
500 0 10000 20000 30000 40000 FEET
1 0 2 4 6 8 10 KILOMETERS

Jointly funded by the Arizona Geological Survey and the U. S. Geological Survey STATEMAP Program.
Contract # 1434-93-A-1144

EXPLANATION

SYMBOLS

PLANAR FEATURES; strike and dip

Broken and wavy lines may be used to indicate approximate measurments or curviplanar foliation in conjunction with any symbol

Bedding

upright vertical overturned horizontal

Tectonic foliations

Generic foliation, with lineation — Disjunct cleavage — Gneissic foliation

Tectonite foliation — Mylonitic foliation (with lineation indicated) — Flow foliation in igneous rocks

Dikes (outcrop trace)

Mafic (Tim) — Intermediate (Ti) — Felsic (Tif) — Pegmatite (Kg) — Old mafic (JYd)

CONTACTS

Solid lines indicate precise location, dashed lines approximate location, dashed with queries very approximate, and dotted inferred beneath younger blanketing or intrusive units.

intrusive or depositional contact

FAULTS

HIGH ANGLE (ball on down-thrown side, arrow indicates dip)

low-angle normal fault, tics on hanging wall

detachment fault, tics on hanging wall

thrust fault, barbs on hanging wall

MISCELLANEOUS

Tie line joining regions underlain by same map unit

Map Units

Numbered subunits (e.g. Kg_2) on map are explained in the accompanying text.

Qs	Undivided surficial deposits. *(Quaternary)*
Qyc	Active alluvium. *(Holocene)*
Qye	Eolian deposits. *(Holocene)*
Qy	Young Alluvium. *(Holocene and late Pleistocene)*
Qt	Talus. *(Holocene and late Pleistocene)*
Qm	Middle alluvium, undifferentiated. *(Late to middle Pleistocene)*
Qm_2	Younger middle alluvium. *(Late to middle Pleistocene)*
Qm_1	Older middle alluvium. *(Middle Pleistocene)*
Qo	Older alluvium. *(Middle to early Pleistocene)*
QTbx	Breccia and Rubble. *(Quaternary or Tertiary)*

Tertiary sedimentary and volcanic units

Tsy	Younger sedimentary rocks. *(Pliocene or Miocene)*
Tsl	Lacustrine sedimentary rocks. *(Miocene)*
Tsm	Sedimentary rocks. *(Miocene)*
Tbu	Upper basalt. *(Miocene)*
Tfu	Upper felsic volcanic rocks. *(Miocene)*
Tf	Felsic volcanic rocks. *(Miocene)*
Tbx	Megabreccia and sedimentary breccia. *(Miocene)*
Tbm	Middle basalt unit. *(Miocene)*
Tb	Basalt, undifferentiated. *(Miocene or Oligocene)*
Tbl	Lower basaltic volcanic rocks. *(Miocene or Oligocene)*
Tt	Ash flow tuff and tuff. *(Miocene or Oligocene)*
Tts	Tuff and associated sedimentary rocks. *(Miocene or Oligocene)*
Ta	Andesite. *(Miocene or Oligocene)*

Tertiary intrusive rocks

Ti	Hypabyssal Intrusive rocks. *(Miocene or Oligocene)*
Tif	Felsic intrusive rocks. *(Miocene or Oligocene)*
Tim	Mafic to intermediate intrusive rocks. *(Miocene or Oligocene)*
Tg	Granitoid. *(Miocene or Oligocene)*

Cretaceous and Jurassic intrusive rocks

Kg	Leucocratic granitoids *(Cretaceous)*
Kgd	Hornblende-biotite granodiorite units *(Cretaceous)*
Kd	Dioritic border phase. *(Cretaceous)*
KJgd	Granodiorite. *(Cretaceous or Jurassic)*
KJd	Hypabyssal mafic rocks. *(Cretaceous or Jurassic)*
Jg	Granodiorite or monzogranite. *(Jurassic)*

Mesozoic and Paleozoic supracrustal rocks

Kc	Conglomerate. *(Cretaceous)*
KJc	Conglomerate. (Cretaceous or Jurassic)
KJsh	Fine-grained clastic rocks. *(Cretaceous or Jurassic)*
KJsq	Quartzite, quartzite cobble and maroon mudstone. *(Cretaceous or Jurassic)*
KJs	Sandstone. *(Cretaceous or Jurassic)*
Jvs	Sedimentary rocks derived from volcanic rocks. *(Jurassic)*
Jv	Volcanic rocks. *(Jurassic)*
MzPzs	Sedimentary rocks, undivided. *(Mesozoic and Paleozoic)*
JTRs	Buckskin and Vampire Formations, undivided. *(Jurassic or Triassic)*
Pzs	Sedimentary rocks, undivided. *(Paleozoic)*
Pzu	Upper Paleozoic sediments, undivided. *(Permian and Pennsylvanian)*
Pzl	Lower Paleozoic sediments, undivided. *(Mississippian through Cambrian)*

Proterozoic igneous and metamorphic rocks

Ygm	Muscovite granitoid. *(Middle Proterozoic)*
Yg	Middle Proterozoic granitoid. *(Middle Proterozoic)*
YXg	Porphyritic granodiorite. *(Middle or Early Proterozoic)*
YXgm	Muscovite granitoid. *(Middle or Early Proterozoic)*
YXgg	Deformed granitoid and augen gneiss. *(Middle or Early Proterozoic)*
XYgs	Foliated biotite granitoid and pelitic gneiss. *(Middle and Early Proterozoic)*
Xg	Granitoid. *(Early Proterozoic)*
Xgm	Hyduke leucogranite and pegmatite. *(Early Proterozoic)*
Xm	Metamorphic rocks, undifferentiated. *(Early Proterozoic)*
Xgn	Heterogeneous gneiss. *(Early Proterozoic)*
Xga	Mixed granitoids and amphibolite. *(Early Proterozoic)*
Xms	Pelitic metasedimentary rocks. *(Early Proterozoic)*
Xma	Mafic gneiss. *(Early Proterozoic)*
Xa	Mafic to intermediate metavolcanic rocks. *(Early Proterozoic)*
Xgs	Sunset Pass complex. *(Early Proterozoic)*
Xpg	Auger gneiss. *(Early Proterozoic)*

Phanerozoic or Proterozoic crystalline rocks

TXgg	Crystalline rocks. *(Tertiary, Cretaceous, and Proterozoic)*
KXg	Granitoid rocks. *(Cretaceous through Proterozoic)*
KXgd	Gneissic to unfoliated granitoid. *(Cretaceous, Jurassic, or Proterozoic)*
KXgn	Quartzo-feldspathic to amphibolite gneiss. *(Cretaceous, Jurassic and Proterozoic)*
JYd	Hypabyssal mafic rocks. *(Jurassic or Middle Proterozoic)*
JXg	Undivided granitoid rocks. *(Jurassic or Early Proterozoic)*
JXh	Hypabyssal rocks. *(Jurassic or Early Proterozoic)*
JXi	Granitoid and gneiss. *(Jurassic or Early Proterozoic)*
JXl	Leucogranite. *(Jurassic or Early Proterozoic)*
JXmi	Mixed orthogneiss and paragneiss. *(Jurassic through Early Proterozoic)*

Acknowledgments

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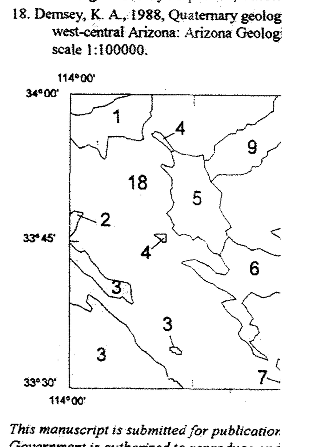

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