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Geologic map and cross section across the boundary between the Colorado Plateau and the Basin and Range southwest of Bagdad, Arizona

by

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INTRODUCTION

The Deep Crustal Studies program of the U.S. Geological Survey supported a project to study by geophysical surveys and geologic studies the crust of the southwestern United States along a transect from the Colorado Plateau to the Pacific Ocean, called the Pacific-Arizona Crustal Experiment (PACE). The boundary between the Colorado Plateau and Basin and Range provinces is an important feature addressed by this study. A variety of geophysical and geological data were obtained along or near a transect from Bagdad to the Bouse Hills in west-central Arizona. A geologic strip map and cross section at 1:100,000-scale herein furnishes a base of surface geologic information as a starting point for interpretation of the geophysical and geological studies to be compiled and released at the same scale in this part of the PACE transect.

DESCRIPTION OF MAP UNITS

[Plutonic rocks are named according to IUGS recommendations (Streckeisen, 1973). Names of plutonic rock units from map of Bagdad area (Anderson and others, 1955) retained, but their names in the IUGS system indicated in the unit descriptions. Volcanic rocks are named according to the chemical classification recommended by the IUGS (Le Bas and others, 1986), based on analyses of volcanic rocks from Otton (1982), Brooks (1984), and unpublished data. Chemical analyses of rocks that obviously had undergone potassium metasomatism were not used, but analyses of rocks that may have undergone less conspicuous potassium metasomatism were used, and such rocks may be more alkaline than the original magmas.

Thicknesses given are approximate. Most of the Tertiary units have varied thicknesses because of facies changes and(or) deformation during deposition. The thicknesses of the metamorphosed Proterozoic, Paleozoic, and Mesozoic rocks sedimentary and volcanic rocks are imprecisely known because the details of their deformation are uncertain.]

Qal **Young alluvial deposits (Holocene)**--Gravel, sand, and silt in washes and on modern flood plains and in alluvial and debris fans. Thickness 1 to 5 m.

Qp **Young pediment deposits (Holocene)**--Gravel, sand, and silt mantling gently sloping surfaces cut on older rocks Mostly sheetwash alluvium. Gravel caps those surfaces close to the mountains; pebbly sand and silt caps the surfaces farther from the mountains. Dissection of deposits as much as 2 m near the mountain fronts and less than a meter on distal parts. Locally may include some deposits of late Pleistocene age. Deposits subject to sheetfloods. Thickness 1 to 5 m

Qtc **Talus and colluvium (Holocene)**--Angular rock fragments, sand, and silt in various proportions; forms steep, even surfaces. Talus common on steep sides of plugs of felsic igneous rocks; colluvium and talus on sides of basalt-capped mesas. Thickness 1-5 m

Ql **Landslide deposits (Holocene and Pleistocene)**--Boulders and blocks of basalt in a matrix of silt, sand, or tuff. Forms an irregular hummocky surface. Thickness 2-15 m

Qu **Undifferentiated surficial deposits (Holocene and Pleistocene)**--Small areas of deposits composed of various types of surficial materials, including young and old alluvial deposits, young and old pediment deposits, talus, and colluvium. Thickness 1-5 m

Qe **Eolian sand (Holocene and Pleistocene)**--Fine to medium sand in blowout dunes having a relief of 5-10 m north and northwest of the Bouse Hills in the southwest part of the area. Locally unit is truncated by pediment surfaces and overlain by pediment gravel less than 1 m thick. Thickness 1-10 m

Qao **Old alluvial deposits (Pleistocene)**--Gravel and sand that contain rounded pebbles and cobbles along major drainages and angular clasts along tributary washes. Forms terraces 5-10 m above present drainage. Locally Includes debris fans. Thickness 1-5 m

Qpo **Old pediment deposits (Pleistocene)**--Gravel, sand, and silt mantling dissected gently sloping surfaces cut on older rocks. Thickness 1 to 5 m

QTg **Gravel and sand (Pleistocene or Pliocene)**--Gravel and sand on pediment surfaces that are several tens of meters above modern drainages. Also includes thick, dissected deposits that unconformably overlie Tertiary basin-fill deposits (Tbf). Thickness as much as 100 m

BASIN AND RANGE PROVINCE

Lower Plate Rocks

Tbr **Fault Breccia (Miocene)**--Chloritic fault breccia beneath the Buckskin detachment fault. Mapped south of the Bill Williams River between Alamo Lake and Reid Valley where breccia is in sharp contact with underlying nonbrecciated rock. Thickness 5-20 m

Tgr **Granodiorite and diorite (Miocene)**--Medium-grained hornblende-biotite granodiorite and hornblende diorite in Bouse Hills in southwestern part of area. Rock types intergrade. Clots of mafic minerals define foliation in rocks of intermediate composition. Contains rare cognate inclusions of diorite. Biotite K-Ar dates are 20 Ma (Spencer and Reynolds, 1990)

Tsp **Swansea Plutonic Suite (Miocene and Oligocene?)**--Medium- to coarse-grained gabbro, diorite, quartz diorite, granodiorite, granite, and porphyritic granodiorite and granite. Porphyritic varieties contain potassic feldspars as long as 3 cm and superficially resemble Proterozoic plutonic rocks. More mafic rocks are intruded by many small and some larger bodies of felsic rocks. Pegmatites are rare. Gabbro and diorite are nonfoliated to well foliated. Felsic rocks generally have a well developed mylonitic texture and a northeast-trending mineral lineation, although they retain some vestiges of igneous texture. One of the felsic units of the suite has a U-Pb zircon age of 21.6 ± 1.5 Ma (Bryant and Wooden, 1989). $^{40}Ar/^{39}Ar$ ages of hornblende from mafic units of the suite range from 26.2 to 29.9 Ma (Richard and others, 1990)

Tspf **Felsic rocks of Swansea Plutonic Suite (Miocene)**--Predominantly granite and granodiorite southwest of Clara Peak

Tspm **Mafic rocks of the Swansea Plutonic Suite (Miocene and Oligocene?)**--Predominantly gabbro and diorite north of Reid valley

Kg **Granite of Tank Pass (Upper Cretaceous)**--Mylonitic, leucocratic, medium- to coarse-grained biotite- and muscovite-biotite granite and biotite granodiorite that locally contains accessory garnet. Porphyroclasts of plagioclase and potassic feldspar are typically 2-4 mm long and as much as 1 cm long and occur in a matrix of quartz, feldspar, and biotite. Locally contains porphyroclasts of biotite typically 1-2 mm in diameter and inclusions of layered

migmatitic gneiss (Xlg) a few centimeters to tens of meters in diameter. Contains pegmatite lenses, stringers, and knots as thick as 1 m. Occurs as small plutons and numerous unmapped sills in layered gneiss (Xlg); the sills are especially numerous near the plutons. U-Pb age of zircon 78-80 Ma (DeWitt and Reynolds, 1990)

MPs **Metasedimentary rocks (Jurassic?, Triassic and Paleozoic?)**--Marble, siliceous marble, dolomitic marble, quartzite, calc-silicate granofels, and biotite-feldspar-quartz gneiss. Calc-silicate rocks typically contain epidote and tremolite or actinolite; some rocks contain diopside, locally with hornblende; both minerals occur as porphyroclasts that are commonly partly altered to actinolite and epidote. Unit occurs in fault slices below the Buckskin detachment fault; largest slice is on and southwest of Battleship Peak in southwestern part of map area. Lenses interpreted to be tectonic intercalations are common in the layered migmatitic gneiss (Xlg) below the Buckskin detachment fault; they are especially numerous in an area south of the Bill Williams River between Alamo Lake and Reid Valley. Unit contains sills of granite and pegmatite (Kg) and sills of rocks of the Swansea plutonic suite (Tsp). Maximum observed thickness of 1,100 m does not represent stratigraphic thickness because of deformation (Marshak and Vander Meulen, 1989)

YXpm **Porphyritic granodiorite to granite gneiss (Middle or Early Proterozoic)**--Well foliated biotite granodiorite and granite containing potassic feldspar porphyroclasts as long as 2-3 cm and zones of mylonite. Contains discordant and concordant pegmatites. Contact with granodiorite to granite gneiss (YXpm) gradational. In southwestern part of map area

YXgm **Granodiorite to granite gneiss (Middle or Early Proterozoic)**--Coarse- to fine-grained, well foliated, locally mylonitic, biotite and hornblende-biotite granodiorite gneiss containing potassic feldspar porphyroclasts as long as 1 cm. In southwestern part of area

Xlg **Layered migmatitic gneiss (Early Proterozoic)**--Mylonitic biotite-quartz-feldspar gneiss, hornblende-biotite quartz-feldspar gneiss, hornblende-biotite gneiss, amphibolite, and granitic gneiss. Contains numerous layers of leucocratic granite gneiss that are probably sills of the granite of Tank Pass (Kg); they are more numerous near larger bodies of the granite of Tank Pass (Kg). Some granitic layers may be of Proterozoic age. Contains small intrusive bodies of the Swansea Plutonic Suite (Tsp) near areas underlain by that unit. Probably metamorphosed during the Cretaceous based on Late Cretaceous and early Tertiary ^{40}Ar-^{39}Ar dates on hornblende (Richard and others, 1990; J.E. Fryxell, California State University, San Bernardino, written commum, 1989), on numerous intrusions of Cretaceous granite, and on regional metamorphism of Mesozoic supracrustal rocks. Variably mylonitized under greenschist facies conditions during extension in the Miocene based on ^{40}Ar-^{39}Ar data on muscovite and K-feldspar, K-Ar data on biotite, and fission-track data on ziron and apatite (Richard and others, 1990; J.E. Fryxell, California State University, San Bernardino, written commun, 1989; Spencer, Shafiqullah, and others, 1989; Bryant and others, 1991)

Tbf **Basin-fill deposits (Pliocene and Miocene)**--Gravel, sand, and silt; unit contains pebbles, cobbles, and boulders as much as 2 m in diameter. Locally contains beds of claystone, tuffaceous sandstone and conglomerate, and tuff. Moderately to poorly bedded and moderately to poorly consolidated. Grayish orange, yellowish gray, and pale yellowish brown except in Reid Valley and near Clara Peak where lower part is pale reddish brown to grayish red because of large amount of debris from older Tertiary sandstone and conglomerate. Generally separated from underlying rocks by an angular unconformity but locally contact with underlying conglomerate and arkose (Tcb) is disconformable or gradational. Locally indistinguishable from upper part of boulder conglomerate and arkose (Tcb). Unit includes rocks as old as the Sandtrap Conglomerate, which overlies the Cobwebb Basalt in the Artillery Mountains (Lasky and Webber, 1949). K-Ar whole-rock dates of the Cobwebb Basalt near its type area near the northwest margin of this map in the Artillery Mountains are 13.3±2.1 Ma (Eberly and Stanley, 1978) and 11.1±0.3 Ma (J.E. Spencer, written commun., 1992). In places unit may include at the top one or more younger pediment deposits, which were not mapped separately. These deposits were observed where they consist of gravels, only a few meters thick, that are separated by buried soils. Thickness as much as 1000 m

Tby **Young basalts (Miocene)**--Basalt and minor amounts of porphyritic basalt, basaltic andesite, trachyandesite, and andesite. Forms lava flows, dikes, small plugs, and cinder cones. Olivine and (or) plagioclase are the dominant phenocrysts in the porphyritic varieties; monoclinic pyroxene phenocrysts are less abundant. Locally contains sparse quartz xenocrysts. Included in this unit are interbedded or underlying,locally tuffaceous, conglomerate, sandstone, and siltstone beds. Underlies or is interbedded with basin-fill deposits (Tbf). Unit includes the Cobwebb Basalt of the Artillery Mountains (Lasky and Webber, 1949). K-Ar dates ages range from 13 to 9 Ma (Suneson and Lucchitta, 1979; Otton, 1982). Maximum thickness 150 m

Tcb **Boulder conglomerate and arkose (Miocene)**--Pale-reddish-brown, grayish-orange-pink, moderate-orange-pink, grayish-red, and locally pale-brown to medium-gray, well indurated to unconsolidated interbedded boulder and cobble conglomerate, granule conglomerate, sandstone, and siltstone. Unit is well-stratified to unstratified, chaotic, and shows no internal sedimentary structures. Typically contains clasts of a variety of rock types. Near the Big Sandy River and in the Artillery Mountains unit is rich in clasts of granitic and metamorphic rock but locally contains sedimentary breccia (Tbx) at the base. Clasts as much as 2.5 m in diameter. In Reid Valley includes the upper conglomerate of Spencer and Reynolds (1989) and contains clasts of upper-plate granite, Tertiary sandstone, conglomerate, limestone, and volcanic rock, and lower-plate mylonitic crystalline rocks, metasedimentary rocks and chloritic breccia. Locally interfingers with and grades into sandstone and conglomerate (Tsc). Thickness as much as 600 m.

Tcs **Conglomerate and sandstone (Miocene)**--Reddish-brown, grayish-red, and gray sandstone, conglomerate, and boulder conglomerate. Boulders as much as 1 m in diameter. Clasts from the conglomerate dominate colluvium on the unit, but conglomerate only makes up 10-40 percent of unit. Unit is gradational between conglomerate and arkose unit (Tcb) and the sandstone and conglomerate unit (Tsc). Only mapped north of Bill Williams River in T 12 N, R 12 W. Thickness as much as 200 m

Tsc **Sandstone and conglomerate (Miocene)**--Reddish-brown, grayish-red and gray, well-bedded sandstone containing beds and lenses of conglomerate and a few beds of limestone. Locally beds are dark-gray to black and rich in Mn oxides. In Rawhide Wash area contains more conglomerate and sedimentary breccia and grades to boulder conglomerate, sandstone, and breccia (Tcx). Interfingers with and grades into lacustrine sedimentary rocks (Tml) and into conglomerate and arkose (Tcb). Includes the Chapin Wash Formation in the Artillery Mountains (Lasky and Webber, 1949). Thickness 180 -400 m

Tu **Undifferentiated sedimentary and volcanic rocks--(Miocene)**--Conglomerate, arkose, siltstone. limestone, and andesite or basalt in isolated exposures

Tif **Felsic intrusive rock (Miocene and Oligocene?)**--Porphyritic trachydacite, dacite, and rhyolite intrusions containing phenocrysts of plagioclase, hornblende, biotite, and locally quartz in a glassy to cryptocrystalline matrix.

Tml **Lacustrine sedimentary rocks (Miocene)**--Medium- to dark-gray to dark-brown tuffaceous mudstone, reddish- to greenish-gray mudstone, tuffaceous siltstone, tuffaceous sandstone, sandstone, yellowish-gray silty limestone, dark- to pale-gray limestone, chert, calcareous shale, and carbonaceous siltstone. Sandstone is fine- to medium-grained and well-bedded. Contains reddish-brown, pale yellowish-gray, and gray siltstone and interbedded reddish-brown, brown, yellowish-gray, gray, and orange-brown, thin bedded sandstone in Reid Valley. Thickness 100-200 m

Tbc **Breccia and conglomerate--(Miocene)**--Deposits of angular clasts ranging in diameter from 1 cm to 10 m of hornblende rhyodacite, which is derived from a plug near confluence of Santa Maria and Big Sandy Rivers in T. 11 N., R. 12 W. Farther from plug, the unit contains beds of alluvial conglomerate and sandstone containing subrounded clasts from same source. Thickness at least 200 m

Tbx **Sedimentary breccia (Miocene)**--Deposits of angular fragments a few cm to hundreds of meters long of Mesozoic metasedimentary and metavolcanic rock, Paleozoic metasedimentary rock, and Proterozoic metamorphic and plutonic rock. Contains some interbeds of poorly bedded conglomerate, that contains subrounded boulders as much as 1 m in diameter and locally minor sand in matrix. Many breccia deposits are composed of one rock type, and stratigraphically younger deposits generally contain fragments of stratigraphically older rocks. Unit composed mostly of rock avalanche deposits (Yarnold and Lombard, 1989), but also contains some debris flows. Occurs at several stratigraphic levels in the Artillery Mountains. Maximum thickness 150 m

Tbo **Old basalts (Miocene and Oligocene?)**--Basalt, basaltic trachyandesite, trachybasalt, and minor amounts of andesite, and basaltic andesite

lava flows. Contains phenocrysts of monoclinic pyroxene, and, less commonly, of olivine and(or) plagioclase. Included are the basalts in the Artillery Formation of Lasky and Webber (1949). In the Artillery Mountains K-Ar dates range from 16.2 to 21.6 (Shafiqullah and others, 1980; Eberly and Stanley, 1978), and the basalts are stratigraphically below rhyolite having biotite with a K-Ar date of 18.5 Ma (Gassaway,1977), which suggests that the older date may be more correct. In Reid Valley unit has a minimum age of 20.2 Ma (Spencer, Shafiqullah and others, 1989). Maximum thickness 100 m

Tl **Limestone (Miocene and Oligocene?)**--Gray, bluish-gray, yellowish-gray, and green limestone, siltsone, mudstone, and sandstone; also reddish-brown and grayish-red sandstone and conglomerate. Deposited predominantly in a lacustrine environment periodically interrupted by alluvial deposition. Unit contains interbedded lenticular masses of sedimentary breccia composed of Mesozoic metasedimentary and metavolcanic rock, especially south of Artillery Peak. Contains a few beds of felsic tuff. Maximum thickness 400 m

Tst **Sandstone and siltstone (Miocene and Oligocene?)**--Grayish-orange-pink, pale-brown, and gray sandstone, siltstone, and sandy conglomerate. Mapped east of Big Sandy River in SE¼ T. 12 N., R. 12 W. Thickness about 100 m

Tab **Trachyandesite, basaltic trachyandesite, and basalt (Miocene and Oligocene?)**--Red-to reddish-brown, vesicular to amydaloidal lava flows agglomerate and tuff containing plagioclase as much as 2 mm in diameter and clinopyoxene as much as 1 mm. Some flows contain olivine as much as 1 mm in diameter. Also includes thin volcaniclastic and arkosic sandstone beds and small intrusive masses. Underlies a 22 Ma trachydacite and rhyolite unit southeast of map area. Whole-rock K-Ar date of 23.2 Ma on the unit was determined on a sample from 38 km east of outcrop area north of Santa Maria River in this map (H.H. Mehnert, written commun., 1991). Maximum thickness 300 m

Trl **Rhyolite (Miocene or Oligocene?)**--Welded and nonwelded rhyolite and trachydacite ash-flow tuff, flow breccia, and lithic airfall tuff. Welded tuff is pale-brownish-gray, pale purple, and pale pink and is aphyric to porphyritic, and contains phenocrysts of biotite, quartz, sanidine, and, locally, hornblende. Commonly flow banded where densely welded. Unit locally intertongues with basal arkose (Tba) and limestone (Tl). Sanidine K-Ar date of 24.3 Ma was determined on a sample from about 38 km east of outcrop area shown on this map north of the Santa Maria River (H.H. Mehnert, written commun, 1991). A possibly equivalent air fall tuff in the Artillery Mountains has ^{40}Ar-^{39}Ar dates of 26.3 for sanidine and 26.6 for biotite (Lucchitta and Suneson, 1991). Maximum thickness 100 m

Tba **Basal arkose (Miocene or Oligocene?)**--Grayish-red to pale reddish-brown, moderately to poorly sorted, poorly stratified to unstratified, moderately to poorly indurated arkose to boulder conglomerate containing clasts of Proterozoic metamorphic and granitic rocks. Thickness variations indicate that unit was deposited on an irregular topographic surface. Maximum thickness 200 m

Composite Units

Tcx **Boulder conglomerate, sandstone, and sedimentary breccia (Miocene)**--In Rawhide Wash area

Txv **Sedimentary breccia, andesite, and basalt (Miocene)**--Near mouth of Santa Maria River

Tla **Lacustrine rocks and basal arkose Miocene)**--Southeast of Artillery Peak

Tra **Rhyolite and basal arkose (Miocene or Oligocene)**--North of the Santa Maria River

MXp **Plutonic rock (Mesozoic, Middle Proterozoic, or Early Proterozoic)**--Medium- to coarse-grained granite containing mafic dikes, layered gneiss, gneissic granite, and pegmatite. In Reid Valley, locally includes sedimentary breccia

Pz **Paleozoic rocks (Permian, Pennsylvanian, Mississippian, Devonian, and Cambrian)**--Marble, quartzite, phyllite, and calc-silicate marble and quartzite. Occurs in fault slices above the Buckskin detachment fault

COLORADO PLATEAU TRANSITION ZONE

Ttg **Tuff and gravel (Pliocene and Miocene)**--White to brown airfall and waterlain tuff, tuffaceous sand, and gravel. Overlies young basalt (Tby) of Centipede Mesa and mesas east of Burro Creek. Thickness 3-30 m

Tg **Gravel (Pliocene and Miocene)**--Gravel and sand. Adjacent to Poachie Range, unit contains blocks as much as 5 m in diameter. In western Poachie Range, contains rare beds of airfall and waterlain tuff and tuffaceous sand and gravel, and in the Bagdad area contains a bed of white tuff and minor amounts of other volcaniclastic rocks near the top of the unit. In eastern part of Poachie Range, interfingers with and overlies 22-Ma volcaniclastic and epiclastic rocks (Tvc). Interfingers with young basalt (Tby) in the Poachie Range, and underlies young basalt (Tby) in the Bagdad area. Much of unit is equivalent to basin-fill deposits (Tbf) but it locally contains some older gravel. Maximum thickness 250 m.

Tby **Young basalts (Miocene)**--Olivine and olivine-pyroxene basalt and minor trachyandesite lava flows. Includes the Saunders Basalt near Bagdad, which has a K-Ar whole-rock date of 10.4 Ma (R.J. Miller, U.S.Geological Survey, written commun.,1991). In the Black Canyon area, lava in a basaltic cinder cone yields a K-Ar whole-rock date of 13.0 ± 1.3 Ma (Bryant and others, 1990). In the west central part of Sec. 27, T. 14 N., R. 11 W., just outside the map area, lava overlying Proterozoic basement rock has a K-Ar whole-rock date of 14.6 ± 1.6 Ma (Moyer and Esperança,1989). Upper flows at the Burro Creek bridge, about 4 km northwest of the point where U.S. Highway 93 leaves the northwest margin of the map area, have K-Ar whole-rock dates of 8-9 Ma (Shafiqullah and other,1980). On the south side of the Poachie Range near Government Wash 10.7 Ma flows, designated Tby_1, unconformably overlie tilted basalt lava flows 12.5 Ma (Bryant and

others, 1990). Flows and interbeds of gravel locally as much as 150 m thick

Tvg **Volcanic rocks and gravel (Miocene)**--White and brown tuff, mudstone, dolomite, gravel, and a few basalt lava flows. Tuff is fine- to medium-grained and is both airfall and waterlain. Locally tuff along Burro Creek, which was deposited in a lacustrine environment, has been altered to clay minerals. Interfingers with gravel (Tg) north of Bagdad. Map unit includes the Wilder Formation (Anderson and others, 1955); a basalt from the base of the formation on Wilder Creek yields a K-Ar whole-rock date of 13.3 ± 0.8 (H.H. Mehnert, U.S. Geological Survey, written commun. 1991). Maximum thickness 200 m

Tbgc **Basalt, gravel, and tuff (Miocene)**--Young basalt (Tby), gravel (Tg), and white crystal-vitric waterlain and airfall tuff and prevolcanic gravel (part of volcaniclastic and epiclastic rocks), undifferentiated. In Secs 22, 26, 27, T. 13 N., R. 10 W. Maximum thickness 100 m

Tvf **Trachydacite and rhyolite (Miocene)**--Felsic plugs, dikes, exogenous domes, and lava flows south of U.S. highway 93 contain phenocrysts of plagioclase, hornblende, biotite, and, rarely, quartz in a glassy matrix. K-Ar dates of biotite are 22.0 ± 0.8 Ma (Marvin and others, 1988) and 22.1 ± 0.8 Ma (Brooks, 1985) and of plagioclase 24.7 ± 0.4 (Brooks, 1985). Maximum thickness 200 m

Tvc **Volcaniclastic and epiclastic rocks (Miocene)**--Waterlain and airfall tuff, tuff breccia, and volcanic conglomerate. Forms carapace over volcanic domes and is interbedded with trachydacite and rhyolite flows (Tvf). Grades from coarse vent-facies tuff breccia to distal-facies tuff, lahar, ash-flow tuff, and conglomerate. Locally includes a thin pre-volcanic basal conglomerate. Maximun thickness 200 m

Kqp **Quartz monzonite porphyry (Upper Cretaceous)**--Generally hydrothermally altered granite porphyry intrusive rock containing phenocrysts of potassic feldspar, plagioclase, quartz, and, rarely, biotite in a medium-grained to cyptocrystalline matrix of quartz and alkali feldspar. Occurs as plugs and northwest-striking dikes in the Bagdad area. Intrudes diorite porphyry (Kdp) and quartz monzonite (Kqm)

Kdp **Diorite porphyry (Upper Cretaceous)**--Diorite, dacite, and trachydacite porphyry intrusions containing phenocysts of hornblende, biotite, plagioclase, and, less commonly, quartz in a matrix of fine-grained alkali feldspar or quartz and alkali feldspar. Occurs as plugs and northwest-striking dikes near Bagdad and to the southwest. One dike north of U.S. Highway 93 and south of 34°30' has a zircon fission-track date of 65.5 ± 11 Ma (Bryant and others, 1991). Intrudes quartz monzonite (Kqm) and rhyolite (Kr)

Kqm **Quartz monzonite (Upper Cretaceous)**--Equigranular to porphyritic biotite-hornblende and hornblende-biotite granodiorite and granite stocks and plugs in the Bagdad area, including a partly altered multiphase stock that hosts the porphyry copper deposit mined at Bagdad. Granite and wall rock locally extensively brecciated. One phase of mined stock has a K/Ar date on biotite of 72.6 ± 2.3 Ma (Damon and Mauger, 1966)

Kg **Granodiorite (Upper Cretaceous)**--Fine-grained, equigranular to porphyritic biotite-hornblende granodiorite locally containing

monoclinic pyroxene. Underlies Blue Mountain 9 km northeast of Bagdad

Kr **Rhyolite (Upper Cretaceous)**--Very fine-grained, white, locally altered intrusive rhyolite. Contains rare phenocrysts of quartz, plagioclase, and potassic feldspar as much as 1 mm in diameter. Forms plugs and dikes that mostly strike northeast near Bagdad, where they are locally intruded by quartz monzonite (Kqm), and southwest of the Grayback Mountains. A small plug north of U.S. Highway 93 and south of 34°30' yields a zircon fission-track date of 66.7±8.1 (Bryant and others, 1991)

Kra **Grayback Mountain Rhyolite Tuff (Upper Cretaceous)**--Porphyritic rhyolite welded ash-flow tuff containing alkali feldspar phenocrysts, collapsed pumice fragments, and numerous xenocrysts and xenoliths from Proterozoic plutonic and metamorphic rocks in a very fine-grained matrix. In northern exposures intruded by dikes of rhyolite (Kr). Zircon fission-track date 71.2±12 Ma (Bryant and others, 1991). Thickness 100-200 m. Unit includes a poorly defined intrusive mass of aphyric to porphyritic, flow-banded to massive rhyolite and steeply to vertically dipping blocks of ash-flow tuff on the central to western parts of Grayback Mountain

Ki **Intrusive rock (Upper Cretaceous)**--Hornblende granodiorite and augite-hornblende-biotite diorite as small plugs in the Poachie Range

Yd **Diabase (Middle Proterozoic)**--Hornblende-plagioclase diabase containing sparse thin plagioclase-rich veinlets. Forms dikes and sills ranging from 1 cm to 50 m thick. Contains laths of andesine or labradorite in a matrix of hornblende, accessory biotite, quartz, and, locally, augite altered to varying amounts to actinolite and(or) chlorite. Some is unaltered ophitic olivine-pyroxene gabbro. Age based on petrographic similarity to diabase in eastern and northwestern Arizona dated by various methods and workers as 900-1150 Ma (Damon and others, 1962; Banks and others, 1972; Creasy, 1980; Elston and McKee, 1982; Shastri and others, 1991; Silver, 1960, 1978)

Ys **Signal Granite (Middle Proterozoic)**--Mainly coarse grained, and locally porphyritic, granite and granodiorite batholith containing potassic feldspar crystals generally 2-3 cm long, but locally as much as 6 cm long and plagioclase and quartz as much as 1 cm in diameter. Biotite and hornblende crystals as long as 0.5 cm form aggregates long as 1 cm. Lath-shaped potassic feldspar crystals form flow foliation in most outcrops. Unit contains a coarse- to fine-grained leucocratic granite facies that grades into or cuts the main phase. Also contains a mafic facies of medium-grained to porphyritic biotite-hornblende tonalite to granite that is intruded by and grades into the main phase. Contains a few quartz-microcline pegmatite pods, dikes, and lenses 10 cm to 1 m thick and dikes of medium grained biotite granite. Also contains widely scattered inclusions of the mafic facies, mafic granodiorite, and hornblende-biotite gneiss and gabbro. Isotopic ratios of U-Pb in seven zircon separates from two samples of Signal Granite and one sample of an associated mafic granodiorite define a chord with an upper intercept at 1410±3 Ma (Bryant and Wooden, in press)

Lawler Peak Granite (Middle Proterozoic)--Two plutons of undeformed rock north and east of Bagdad. The pluton north of Bagdad yielded a U-Pb date on zircon of 1411±3 Ma (Silver and others, 1980)

Ylb **Porphyitic biotite-muscovite granite**--Grayish-orange granite containing potassic feldspar phenocrysts as long as 7 mm in a medium- to coarse-grained groundmass of potassic feldspar, plagioclase, quartz, biotite, and muscovite

Ylm **Porphyritic muscovite granite**--Grayish-orange granite containing phenocrysts of potassic feldspar as much as 7 cm long in medium- to coarse-grained groundmass of potassic feldspar, plagioclase, quartz, and muscovite. Forms irregular masses in gradual to abrupt transitional contacts with porphyritic biotite-muscovite granite (Ylb)

Yla **Aplite and pegmatite**--Aplite and pegmatite that cut porphyritic biotite-muscovite and porphyritic muscovite granite (Ylb and Ylm)

Granites of Olea Ranch (Middle Proterozoic)--Several closely related plutons having distinctly different textures. Isotopic ratios of U-Pb in zircon from one sample of coarse-grained granite (Yco) and one sample of porphyritic granite (Ypo) define a chord with an upper intercept at 1416±2 Ma (Bryant and Wooden, in press)

Yco **Coarse-grained granite**--Biotite granite and granodiorite containing potassic feldspar generally 1-2 cm long and, rarely, as long as 3 cm. Ranges from equigranular to porphyritic. Locally contains small amounts of primary muscovite

Ygo **Granite**--Fine- to medium-grained, locally porphyritic biotite and muscovite-biotite granite and rare granodiorite. Locally grades to pegmatite. Intrudes and locally grades to coarse-grained granite (Yco)

Ypo **Porphyritic granite and granodiorite**--Biotite granite and granodiorite containing generally well oriented tabular potassic feldspar phenocrysts generally 2-3 cm long and, locally, as much as 6 cm long that define a flow foliation

Ygp **Porphyritic granite (Middle Proterozoic)** Porphyritic biotite granite, containing potassic feldspar phenocrysts as long as 1.5 cm in a fine- to medium-grained matrix of quartz, plagioclase, potassic feldspar, and biotite. Contains a medium- to coarse-grained phase in area between the Signal Granite and the granites of Olea Ranch.

YXg **Granite (Middle or Early Proterozoic)**--Fine- to medium-grained undeformed biotite granite to granodiorite. Cuts and contains inclusions of coarse-grained granitic rocks (Xcg), migmatitic schist and gneiss (Xgs), metasedimentary rocks (Xms), metavolcanic rocks (Xmv) and mafic gneiss (Xmag). Includes the Cheney Gulch Granite in Bagdad area

YXa **Aplite and pegmatite (Middle or Early Proterozoic)**--Undeformed, small to large bodies of leucocratic rock having highly variable texture and grain size. Parts are intruded by the Lawler Peak Granite, but some of unit adjacent to plutons of Lawler Peak may be related to aplite and pegmatite associated with that granite (Yla). Small mapped and unmapped bodies particularly widespread in Hillside Mica Schist (Xhm) and could have been derived by partial melting of Xhm during Early Proterozoic metamorphism

YXbg **Biotite granodiorite (Middle or Early Proterozoic)**--Undeformed, fine- to medium-grained equigranular biotite granodiorite in elongate bodies parallel to foliation in Hillside Mica Schist (Xhm) near Big Shipp Mountain east of Bagdad. As mapped, may contain masses of Xhm and other rock types

Xgg **Gneissic granodiorite (Early Proterozoic)**--Medium- to coarse-grained granitic rock ranging in composition from biotite melagranite to hornblende tonalite, quartz diorite and diorite. Gneissic structure ranges from pervasive on northwest side of unit to local to absent elsewhere. Contains many xenoliths of Hillside Mica Schist (Xhm) near its contact. U-Pb single-crystal zircon studies indicate crystallization age of about 1,670 Ma (J.L. Wooden, U.S. Geological survey, oral commun., 1992)

Xg **Granite (Early Proterozoic)**--Fine- to medium-grained, massive to gneissose, biotite granite. Locally contains muscovite and inclusions of coarse-grained granitic rock (Xcg). Intrudes coarse grained granitic rock (Xcg) at the east end of the Poachie Range

Xp **Porphyritic melagranite (Early Proterozoic)**--Gray to grayish-orange biotite-rich porphyritic granite containing subhedral light-gray alkali feldspar phenocrysts as long as 5 cm. Weak to moderate subhorizontal foliation. Occurs along Burro Creek west of Bagdad. Probably the same granite dated about 13 km to the west as about 1700 Ma (J.L. Wooden, U.S. Geological Survey, written commun, 1986)

Xcg **Coarse grained granitic rock (Early Proterozoic)**--Equigranular to porphyritic hornblende-biotite and biotite granite, granodiorite, and quartz monzonite. Potassic feldspar commonly 1-2 cm long but locally as long as 4 cm. Contains small bodies of diorite and gabbro. Foliation well developed to absent. Contains scattered inclusions of metamorphic rocks, migmatite, diorite, and gabbro. Inclusions numerous near contacts with metamorphic rocks. Locally migmatitic. Cut by pegmatite, aplite, and fine-grained granite (Xg and YXg). U-Pb data on zircon from a gneissose biotite diorite define a chord with an upper intercept at 1706±3 Ma (Bryant and Wooden, in press)

Xpg **Porphyritic biotite granite (Early Proterozoic)**--Grayish-orange to brown, foliated to nonfoliated, porphryitic biotite granite containing potassic feldspar phenocrysts as long as 5 cm. Mapped as Lawler Peak Granite by Anderson and others (1955). U-Pb date on zircon about 1,710 Ma (L.T. Silver, California Institute of Technology, oral commun., 1976

Xan **Anorthosite (Early Proterozoic)**--Coarse-grained andesine-rich layers in gabbro (Xga) in large body west of Bagdad. Complete gradations from pure andesine rock to foliated hornblende gabbro indicate that the anorthosite layers are not dikes, as suggested by Anderson and others (1955). Layers range from a few centimeters to 8 m thick. A few thick layers or clusters of layers are shown schematically

Xga **Gabbro and diorite (Early Proterozoic)**--Coarse- to fine-grained hornblende and hornblende-pyroxene gabbro and diorite. Locally moderately to strongly foliated. Locally contains inclusions of metamorphic rocks. Occurs as small bodies in coarse grained granitic rock (Xcg) and in metamorphic rocks. Large body of

coarse-grained gabbro west of Bagdad contains layers of differentiated anorthosite (Xan)

Xu **Ultramafic rocks (Early Proterozoic)**--Pyroxenite masses intruded by porphyritic biotite melagranite (Xp) outside map area 15 km west-northwest of Bagdad

Xgs **Migmatitic schist and gneiss (Early Proterozoic)**--Biotite-plagioclase schist and gneiss, biotite-quartz-plagioclase schist, amphibolite, biotite-hornblende-plagioclase gneiss, and plagioclase-porphyroblast gneiss forming a belt east of the Signal Granite (Ys). A less common rock type is muscovite-garnet-biotite schist and gneiss that locally contain sillimanite. Unit contains pods of diorite and gabbro partly metamorphosed to amphibolite, and also pegmatite lenses, stringers, and pods. Mafic schist and gneiss in the northern part of the unit have compositions ressembing andesite and dacite and may represent metamorphosed tuff or volcanogenic sandstone. Metasedimentary rocks dominate the southern part of the unit

Xmag **Mafic gneiss (Early Proterozoic)**--Fine-grained biotite-hornblende-plagioclase schist, gneiss,and plagioclase porphyroblast gneiss. Ranges from tonalite to gabbro in composition. Contains numerous intrusions of porphyritic tonalite, granodiorite, and coarse-grained granitic rocks (Xcg) that contain feldspar phenocrysts as long as 2 cm, fine-to medium-grained granite, and variously metamorphosed gabbro and diorite. Locally cuts and contains inclusions of muscovite-biotite schist and gneiss of the metasedimentary rocks (Xms). Contacts with adjacent Proterozoic units gradational.

Xkp **King Peak Rhyolite (Early Proterozoic)**--Pale-yellowish-gray, gray and white, fine-grained, mostly aphyric, massive to moderately foliated intrusive rhyolite. Composed of quartz and feldspar and tiny scattered needles of amphibole in darker colored rocks. Intrudes the Bridle Formation (Xbf)

Xal **Alaskite and granophyre (Early Proterozoic)**--Ranges from unfoliated to weakly foliated, fine-grained, equigranular leucogranite and granophyre in the north to well foliated leucogranodiorite and leucotonalite gneiss in the south in the Grayback Mountains area west of Bagdad. Intruded as hypabyssal, crudely subhorizontal sheets into the Bridle Formation (Xbf). U-Pb zircon date from granophyre at north end of the Grayback Mountains is 1,729 ± 10 Ma (J.L. Wooden, U.S. Geological Survey, oral commun, 1988)

Xms **Metasedimentary rocks (Early Proterozoic)**--Muscovite-biotite quartz feldspar gneiss, muscovite-biotite schist, sillimanite-muscovite-biotite schist, and less common amphibolite and biotite-hornblende-plagioclase gneiss. Contains scattered pegmatites and a few intrusions of granite

Xmv **Metavolcanic rocks (Early Proterozoic)**--Amphibolite containing some layers of muscovite-biotite schist and gneiss. Cut by numerous intrusions of pegmatite and granitic rock

Bagdad supracrustal belt

Metamorphosed sedimentary and volcanic rocks, in which relict textures and structures in less strained rocks show facing directions and allow determination of a stratigraphic sequence (Anderson and others, 1955; Conway, 1986) that forms a

north- to northeast-trending belt through Bagdad. Recent work by Conway (1986; unpublished mapping) has led to the working hypothesis that the metavolcanic rocks in the type area of the Bridle Formation east of Bagdad are Butte Falls Tuff and that the southern and eastern exposures of the Butte Falls Tuff contain much more mafic volcanic rock than at the type locality. The Bagdad supracrustal belt has been metamorphosed to the amphibolite facies; the rocks in the south end of the belt are more strongly strained and recrystallized than in the north. The metavolcanic units in the south end of the belt contain more interlayered metasedimentary rock

Xhm **Hillside Mica Schist (Early Proterozoic)**--Muscovite schist, quartz-muscovite schist, and muscovite quartzite locally containing sillimanite and biotite in the northern part of the area. Muscovite near intrusive bodies commonly as much as 5 mm in diameter. Biotite-muscovite gneiss, garnet-muscovite-biotite gneiss, muscovite-quartz schist, and sillimanite- and(or) andalusite-muscovite-biotite and biotite-muscovite schist in the southern part of the belt. Contains tourmaline-bearing pegmatite and some tourmaline-bearing layers. Ranges from finely laminated to massive. Protoliths are shale, sandstone, and mixtures between the two rock types. Thickness probably many hundreds of meters

Butte Falls Tuff (Early Proterozoic)--Defined by Anderson and others (1955) as a variety of schistose rocks of primarily felsic volcanic parentage underlying the Hillside Mica Schist in the Boulder Creek area northwest of Bagdad. Here interpreted to overlie the Dick Rhyolite near Round Mountain and to underlie the Hillside Mica Schist near Miller Mountain and divided into two map units

Xfm **Mafic volcanic rocks** (Early Proterozoic)--Amphibolite, quartz-sericite schist, and metarhyolite in the north; fine-grained biotite-quartz-feldspar gneiss, amphibolite, hornblende gneiss, quartz-plagioclase-hornblende gneiss, and some layers of muscovite-biotite schist and gneiss, locally containing sillimanite and (or) andalusite to the south. Contains phyllitic schist and white, very fine-grained, siliceous layers. Protoliths are mostly basalt and subordinate felsic tuff, tuffaceous sedimentary rock, and rhyolite in the north; mafic to silicic volcanic rock and lesser amounts of tuffaceous sedimentary rock and shale to the south. More than several hundred meters thick

Xff **Felsic volcanic and volcaniclastic rocks (Early Proterozoic)**--Quartz-sericite schist, quartz-feldspar-biotite schist, and grayish-white, gray, and purple slate in type area. Sedimentary features give stratigraphic tops and indicate that protoliths are mostly felsic volcaniclastic rocks and minor mafic volcaniclastic rocks. Rhyolite tuffs, slaty tuffs, and possibly rhyolite flows between Miller Mountain and Round Mountain. More than 700 m thick

Xdr **Dick Rhyolite (Early Proterozoic)**--Mostly porphryitic rhyolite submarine tuff that is massive and resembles thick flows or hypabyssal sills. Contains a few percent quartz and alkali feldspar phenocrysts. Contains beds of fine- to coarse-grained rhyolite breccia, volcanic sandstone, shale, andesite, and rare massive sulfides and chert. Contains extensive areas of chloritized or silicified rock. Weakly foliated in northern part of the area but strongly foliated to south. In the south, unit is mostly a fine-grained biotite-quartz-feldspar gneiss locally containing quartz grains as much as 1 mm in diameter, lenses of mosaic-textured quartz as long as 2 mm, and

alkali feldspar grains as much as 0.5 mm in diameter in a matrix having a grain size of about 0.2 mm. Contains some layers of muscovite-biotite, sillimanite-muscovite, and andalusite-muscovite-biotite schist, and a few thin amphibolite layers. Southwest of U.S. Highway 93, contains many intrusions of granite (Yg) and coarse grained granite (Ycg) and more layers of metasedimentary rock than to the north. Thickness 1,000-2,000 m

Xbf **Bridle Formation (Early Proterozoic)**--Basaltic and andesitic submarine flows, mafic tuff, agglomerate, fine-grained felsic pyroclastic rocks, and a few beds of exhalative sulfide, chert, or sericite. Contains large areas of albitized, epidotized, silicified, or chloritized rock. Pillows, amygdaloidal textures, and pyroclastic texture are clearly discernable in many places despite regional amphibolite facies metamorphism. Near 34 30' latitude, unit consists of amphibolite, hornblende gneiss and quartz-plagioclase-biotite gneiss. Thickness as much as 2,000-4,000 m

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Contact--long dashed where approximately located; short dashed where inferred

Main detachment fault--Separates metamorphic core complex of the Buckskin and Rawhide Mountains from upper plate. Dotted where concealed. Double tics on upper plate

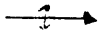
Detachment fault with less displacement--Near the main detachment. Dotted where concealed. Single tics on upper plate

Thrust and reverse fault--Dotted where concealed. Teeth on upper plate

Fault--Dashed where inferred; dotted where concealed. Bar and ball on downthrown side

Shear zone

Fold--Solid arrow shows direction of plunge



Anticline

Syncline

Strike and dip of bedding

Overturned

Inclined

Horizontal

Strike and dip of flow foliation

Inclined

Strike and dip of foliation and compositional layering

Inclined

Vertical

Strike and dip of foliation

Inclined

Vertical

Strike and dip of mylonitic foliation

Inclined

Bearing and plunge of mineral lineation--May be combined with foliation, mylonitic foliation, or foliation and layering

Inclined

Volcanic center--Shown in young basalt (Tby)

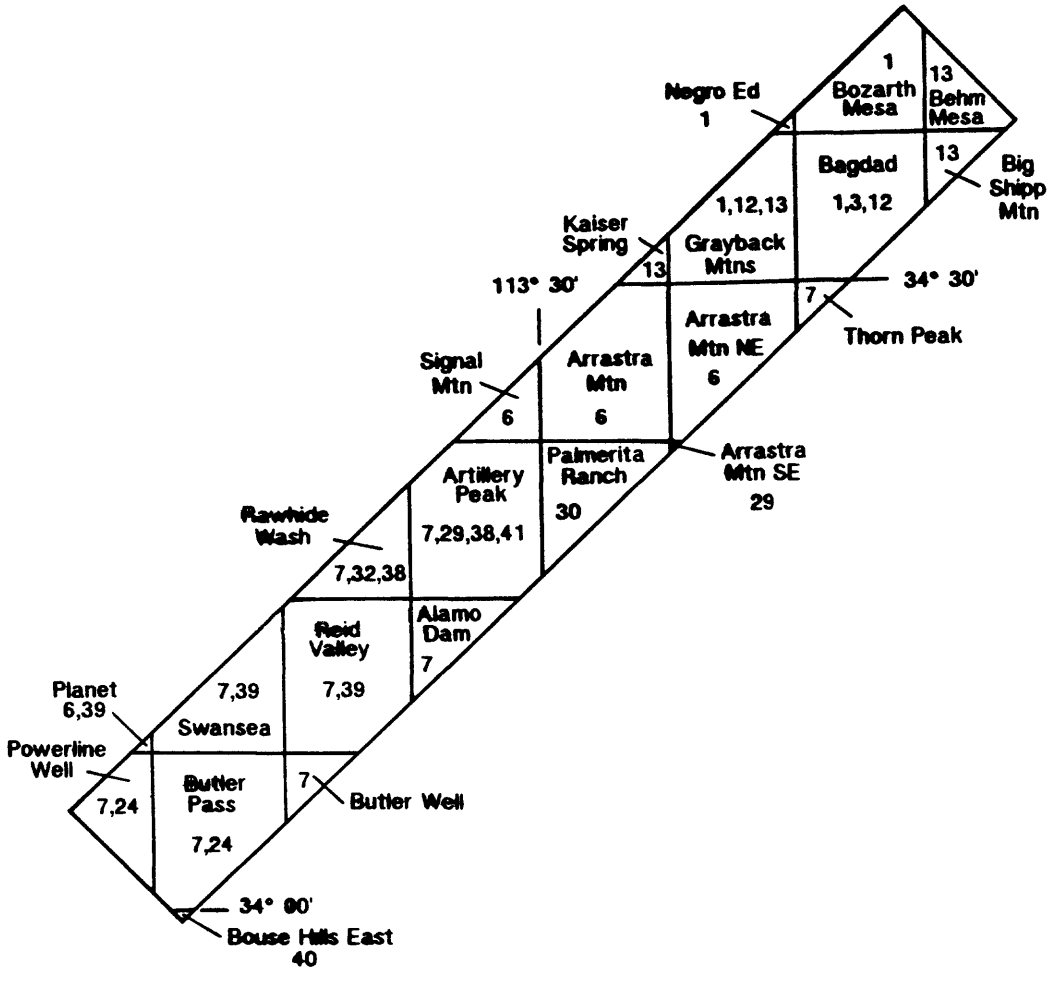


Figure 1. Index map showing names of 71/2' topographic quadrangles and sources of geologic map data. Numbers refer to entries in sources of geologic data. Areas north and south of 34°30' compiled by C.M. Conway and Bruce Bryant, respectively.

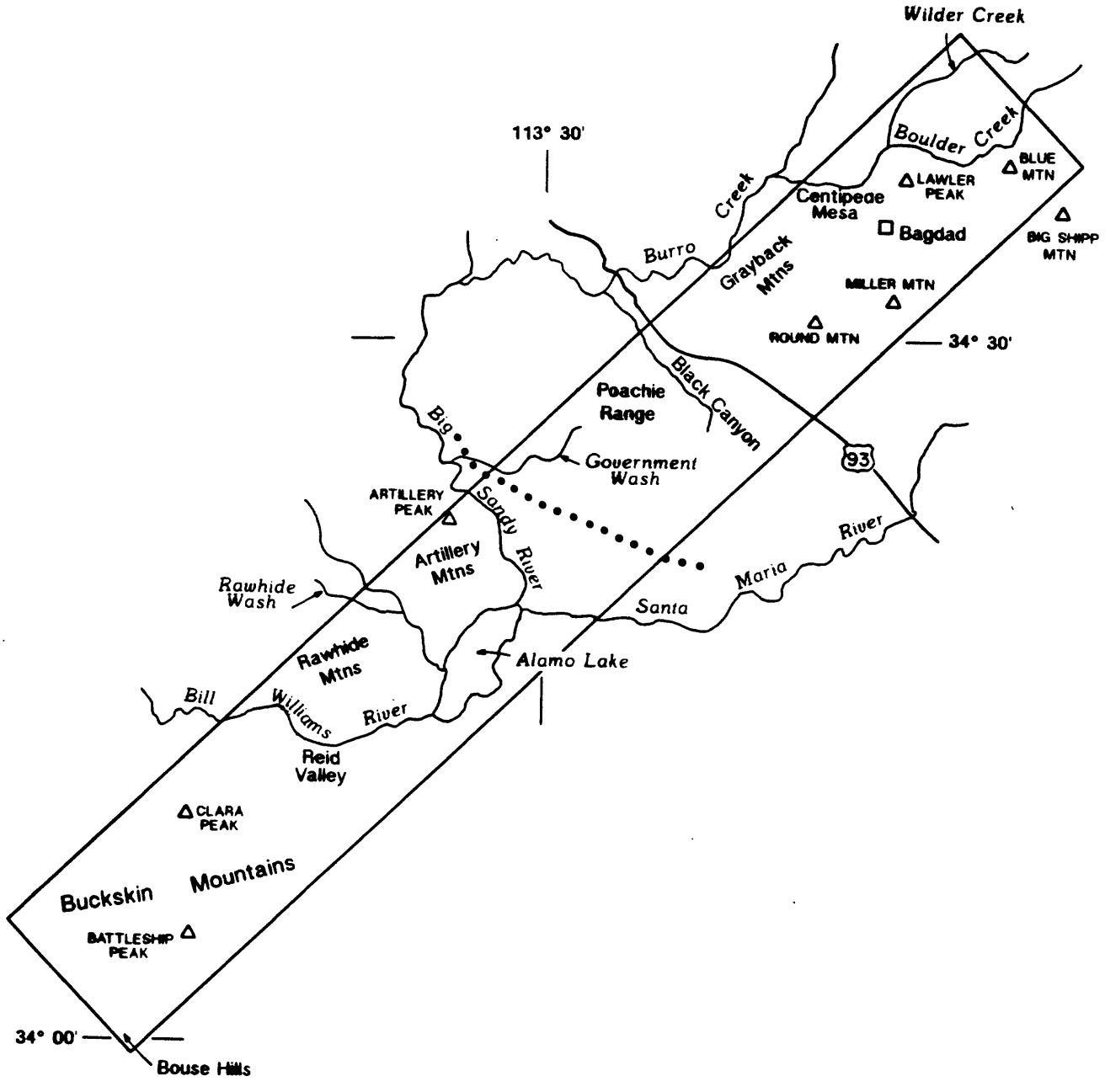


Figure 2. Geographic features in and near map area. Large solid dots indicate interpreted northeast margin of the Basin and Range province.

Correlation of Map Units