Geologic Map of the Boundary Cone 7½' Quadrangle, Mohave County, Arizona

by

Jon E. Spencer, Charles A. Ferguson, Philip A. Pearthree,
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INTRODUCTION

The Boundary Cone 7 ½' Quadrangle includes part of the Black Mountains and most of the piedmont between the Colorado River floodplain and the Black Mountains southeast of Bullhead City, Arizona. Production of this new geologic map continues the Arizona Geological Survey mapping program in the rapidly developing lower Colorado River corridor, and complements geologic mapping to the northwest and west of this quadrangle (Figure 1). This mapping was done under the joint State-Federal STATEMAP program, as specified in the National Geologic Mapping Act of 1992, and was jointly funded by the Arizona Geological Survey and the U.S. Geological Survey under STATEMAP Program Contract award number 05HQAG0078. Mapping was compiled digitally using ESRI ArcGIS software.

SURFICIAL DEPOSITS

Mapping Methods. Surficial deposits of this quadrangle were mapped primarily using aerial photographs and other remote sensing information, with extensive field observations. The principal imagery utilized are 1:24,000-scale color and false-color infrared aerial photos taken in 1979 for the Bureau of Land Management and false-color digital orthophotoquads taken in 2004 for the U.S. Geological Survey. Quartz-rich Colorado River deposits were detected and mapped using thermal infrared remote sensing data provided by Simon Hooke of the Jet Propulsion Laboratory. Numerous field observations were made between fall 2004 and fall 2006. The physical characteristics of Quaternary alluvial surfaces (channels, terraces, alluvial fans, and floodplains) and associated deposits evident on remote-sensing imagery and in the field were used to differentiate them by age. Ages of surficial deposits of the map area were estimated by correlated with regional deposit – soil chronosequences (Gile et al, 1981; Machette, 1985; Bull, 1991) and map units in adjacent quadrangles (Pearthree and House, 2005; Pearthree, 2007). Mapping was compiled in a GIS format over the digital orthophotoquad base, and the final geologic map was generated from the digital data.

Multiple criteria were used to differentiate and map various piedmont and river alluvial deposits. The presence of mature, quartz-rich, typically cross-bedded sand or well-rounded gravel is the primary factor used to differentiate Colorado River deposits from piedmont deposits. The oldest river and tributary deposits in the map area (Tcb and Tfb, respectively) are eroded and partially mantled by younger deposits, and do not have preserved alluvial surfaces associated with them. Relative ages of all younger deposits may be determined from topographic relationships between adjacent alluvial surfaces – older surfaces are higher above active washes. Significant soil development begins beneath an alluvial surface after it becomes isolated from active flooding and depositional processes (Gile et al., 1981, Birkeland, 1999). Over thousands of years, distinct soil horizons develop. In the arid lower Colorado River Valley, calcic horizons (zones of calcium carbonate accumulation) are the most obvious indicator of soil age. Comparison of calcic horizon development on the Black Mountains piedmont with other soil sequences in the western United States is the primary method used to estimate the ages of the different alluvial surfaces (Gile et al, 1981; Machette, 1985; Bull, 1991; Amoroso, 2006). Calcic horizon development varies from very thin, discontinuous coatings of calcium carbonate on gravel clasts in young soils to thick soil horizons cemented with calcium carbonate or silica (caliche) in very old soils.

Several surface characteristics are critical to the mapping process because they are recognizable on the ground and are evident on aerial photographs. Surface color varies with age because of rock varnish and desert pavement development. Piedmont deposits of Holocene age typically are light gray to light brown in color, reflecting the color of the volcanic pebbles and cobbles that make up most of the deposits. Local topography is quite rough because of deposition of relatively coarse sediment in bars alternating with finer-grained swales (Figure 2A). Intermediate-age surfaces have a dark brown color because they have been smoothed by erosion of bars and infilling of swales and are mantled by darkly varnished pebbles and cobbles in desert pavements (Figure 2B). Older intermediate-age surfaces are typically have some very darkly varnished patches, but overall are somewhat lighter in color because erosion has exposed more underlying soil. Old surfaces commonly have some very darkly varnished boulders but limited desert pavement preservation. They generally are lighter in color because of the presence of calcium carbonate litter derived from underlying soil horizons (Figure 2C). Differences in the drainage patterns between surfaces provide clues to surface age as well. Young alluvial surfaces that are subject to flooding commonly display braided (splitting and rejoining) or distributary (branching downstream) channel patterns; young surfaces may have few channels if unconfined shallow flooding predominates. Active channels commonly are incised less than 1 m below adjacent Holocene deposits. Dendritic tributary (joining downstream) drainage patterns are characteristic of older surfaces that are not subject to extensive flooding, and typically older deposits are increasingly more deeply incised and eroded by tributary drainages. The net result of all of these varying surface characteristics is that surfaces of different ages have quite different aspects on the ground and on aerial photographs.

Plio-Quaternary Geologic History. The surficial geology of the Boundary Cone quadrangle reflects the complex interplay of the Colorado River and piedmont drainages that flow from the Black Mountains to join the river. The history of the Colorado River in this area began with the influx of water and sediment from the north after 5.5 Ma (House et al., 2005). The first deposits associated with entry of the river into this area contain only locally-derived sediment from the northern margin of Mohave Valley (these deposits are found in the Davis Dam 7 ½' Quadrangle; Faulds et al., 2001; House et al., 2005). These deposits are succeeded by the fine-grained Bouse Formation, which was probably deposited in a series of lakes as the developing Colorado River spilled over successive divides (Spencer and Patchett, 1997; Spencer and Pearthree, 2001; House et al., 2005). Bouse deposits that record this lacustrine phase of river development are preserved in one tributary valley in the Black Mountains in the Boundary Cone quadrangle (T. 18 N., R. 20 W., Secs. 34 and 35), and are exposed more extensively in other parts of Mohave Valley (e.g., Metzger and Loeltz, 1973; House et al., 2005). After the Colorado River was integrated through Mohave Valley, it began a major phase of aggradation that resulted in the accumulation of hundreds of feet of river sand and gravel (the Bullhead alluvium, unit Tcb). River deposits interfinger with tributary gravel and sand (unit Tfb), which are predominant on the piedmont above 1200 ft above sea level (asl). The maximum level of river aggradation in this area of about 1300 feet asl was attained by about 4 Ma, as evidenced by fairly extensive exposures of the Lower Nomlaki tephra in tributary deposits that are overlain by the highest Colorado River deposits (House et al., 2005; T. 18 N., R. 21 W., Secs. 13 and 24). As a result of this major phase of river aggradation, much of the western 1/2 of the quadrangle is underlain by Pliocene river sand and gravel with some tributary gravel deposits. By 3.3 Ma, the river had begun to incise into the valley fill (House et al., 2005). The river downcut to a level close to the modern river by the early Quaternary, but subsequently evidence for at least one major aggradation event during the late Quaternary is preserved in immediately west of the Boundary Cone Quadrangle (Lundstrom et al., 1998; Pearthree, 2007). The highest preserved Quaternary aggradation sequence peaked at about 800 feet asl in this area; younger Pleistocene and Holocene terraces are inset at several levels and the modern Colorado River channel is at about 480 feet above sea level.

Tributary washes have responded to the variations in base level imposed by the Colorado River during the past 5 million years or so. As the river aggraded early during this period, tributary drainages deposited sediment that is interfingered with the Colorado River deposits between about 800 and 1300 ft asl. Above about 1300 feet asl, deposits of this period are exclusively tributary fan gravel and sand (unit Tfb). As the river began to incise after 4 Ma, tributary alluvium (unit QTa) was deposited over erosion surfaces cut onto the underlying Black Mountain fan deposits and Bullhead alluvium. Several subsequent aggradation periods occurred in the early and middle Quaternary (units Qo and Qi_1). The next widespread, well-preserved piedmont alluvial deposit (unit Qi_2) is graded to a river level below the highest level of late Quaternary river aggradation. At least 2 younger late Pleistocene sets of deposits are found along many washes (Qi_3 and Qi_{3b}), and locally there may be 3 different terrace levels. Holocene piedmont deposits typically occupy valley bottoms, with up to 2 m of local topographic relief between active channels (Qy_c) and the oldest Holocene surfaces (Qy_1). These surfaces are graded to the historical floodplain of the river. In most of the quadrangle the piedmont is moderately to deeply dissected and modern washes are entrenched well below surrounding remnants of older deposits.

Flooding. Surficial geologic mapping reveals a long history of flood inundation that can be used in conjunction with hydrologic and hydraulic modeling to assess the extent and character of flood hazards, including alluvial-fan flooding. Mapping of deposits of different ages on piedmonts outlines the extent of areas that may be prone to flooding. Substantial parts of the piedmont in this quadrangle are covered by Holocene alluvial deposits, and thus has been subject to significant inundation and associated erosion and deposition during the past 10,000 years. Areas subject to widespread, generally shallow flooding (sheetflooding and/or alluvial fan flooding) are characterized by extensive young deposits (units Qy_c, Qy_2, and depending on local relief, Qy_1) and minimal channel incision. Areas such as these are found only in the northernmost part of this quadrangle (Figure 3A). Most piedmont drainages have incised tributary, and locally distributary, channel systems, where much of the area between channels is composed of surfaces that are tens to hundreds of thousands of years old. The older surfaces are topographically higher than adjacent channels and young terraces, and their presence indicates that the channels are relatively stable; greater topographic relief implies increasingly stable channel positions (Figure 3B).

The distribution of young deposits on the piedmont provides evidence of areas that may be prone to flooding. In the northwestern part of the quadrangle, Holocene deposits are quite extensive, channel patterns commonly are anastomosing and locally are distributary, and topographic relief between active channels and adjacent Holocene and late Pleistocene alluvial surfaces is typically 20 feet or less. Sheetflooding is certainly extensive in parts of this area where topographic relief is minimal. Active alluvial fans exist in a few areas where piedmont washes at major distributary channel junctions (Figure 3A). In most of the quadrangle, flooding is confined to broad valley bottoms by topography associated with older deposits (Figure 3B).

Aggregate Resources. Late Cenozoic Colorado River deposits in the Boundary Cone Quadrangle are potentially a voluminous source of construction aggregate. In the Bullhead City area to the north, several large aggregate operations are mining extensive and thick Pliocene Colorado River deposits (Bullhead alluvium, unit Tcb). Similar deposits are exposed in the western 1/2 of the Boundary Cone Quadrangle and probably underlie much of the middle piedmont. Thus, the western part of this quadrangle has significant potential aggregate resources.

BEDROCK GEOLOGY

Bedrock consists of lower to middle Miocene volcanic rocks and one small outcrop area of early Proterozoic metamorphic and igneous rocks. The Miocene volcanic and volcaniclastic sequence is compositionally diverse, and includes rocks of basaltic to rhyolitic composition as well as trachybasaltic to trachytic composition (classification of Le Bas et al., 1986; Table 1; Figure 4). The widespread, 18.5 ± 0.2 Ma Peach Spring tuff (Young and Brennan, 1974; Glazner et al., 1986; Nielson et al., 1990; Hillhouse and Wells, 1991) is mapped in the sequence. The volcanic rocks are cut by several northwest-trending, northeast-side-down normal faults related to early to middle Miocene regional extension in the Colorado River extensional corridor (Spencer, 1985; Howard and John, 1987; Campbell-Stone et al., 2000). The stratigraphically highest basalts are not as steeply tilted as the stratigraphically lowest Miocene rocks, which indicates that faulting and volcanism were broadly synchronous.

The most productive mines of the Oatman gold district are located in Miocene volcanic rocks just north of the Boundary Cone 7.5' Quadrangle (Thorson, 1971). The epithermal vein deposits and altered host rocks of this district yielded 2 million ounces of gold between 1870 and 1980, more than any other mining district in Arizona (Keith et al., 1983). Although most of the gold and silver produced from the district was derived from veins in the center of the district near the town of Oatman, numerous veins are scattered over many square kilometers of the surrounding area, including in the Boundary Cone 7 ½' Quadrangle (Clifton et al., 1980; Durning and Buchanan, 1984; DeWitt et al., 1991). Many veins intrude the northwest-trending faults, and some of the veins are brecciated by continued faulting. It thus appears that epithermal mineralization was broadly synchronous with Miocene faulting, which was also broadly synchronous with magmatism.

ACKNOWLEDGMENTS

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REFERENCES

Amoroso, Lee, 2006, Age calibration of carbonate rind thickness in late Pleistocene soils for surficial deposit age estimation, Southwest USA: Quaternary Research, v. 65, p. 172-178.

Birkeland, P.W., 1999, Soils and Geomorphology (3rd Ed.), New York: Oxford University Press, 429 pp.

Bull, W.B., 1991, Geomorphic Response to Climatic Change, New York: Oxford University Press, 326 p.

Campbell-Stone, E., John, B.E., Foster, D.A., Geissman, J.W., and Livaccari, R.F., 2000, Mechanisms for accommodation of Miocene extension: Low-angle normal faulting, magmatism, and secondary breakaway faulting in the southern Sacramento Mountains, southeastern California: Tectonics, v. 19, n. 3, p. 566-587.

Clifton, C.G., Buchanan, L.J., and Durning, W.P., 1980, Exploration procedure and controls of mineralization in the Oatman mining district, Oatman, Arizona: Society of Mining Engineers of AIME preprint 80-143, 38 p.

DeWitt, E., Thorson, J.P., and Smith, R.C., 1991, Geology and ore deposits of the Oatman district, northwestern Arizona, *in* Epithermal gold deposits - Part II, Chapter I, in Shawe, D.R., and Ashley, R.P., eds., Geology and resources of gold in the United States: U.S. Geological Survey Bulletin 1857-I, p. I1-I28.

Durning, W.P., and Buchanan, L.J., 1984, The geology and ore deposits of Oatman, Arizona, *in* Wilkins, J., Jr., ed., Gold and silver deposits of the Basin and Range Province, western U.S.A.: Arizona Geological Society Digest, v. 15, p. 141-158.

Faulds, J.E., House, P.K., Ramelli, A.R., Bell, J.W., and Pearthree, P.A., 2001, Preliminary geologic map of the Davis Dam Quadrangle and the eastern part of the Bridge Canyon Quadrangle, Clark County, Nevada, and Mohave County, Arizona: Nevada Bureau of Mines and Geology, Open File Report 03-5, 1:24,000.

Faulds, J.E., Smith, E.I., and Gans, P., 1999, Spatial and temporal patterns of magmatism and extension in the northern Colorado River extensional corridor, Nevada and Arizona: A preliminary report, *in* Cenozoic geology of the northern Colorado River extensional corridor, Nevada and Arizona: Economic implications of extensional segmentation structures: Nevada Petroleum Society, Field Trip Guide, p. 171-183.

Gile, L.H., Hawley, J.W., and Grossman, R.B., 1981, Soils and geomorphology in the basin and range area of southern New Mexico -- guidebook to the Desert Project: New Mexico Bureau of Mines and Mineral Resources Memoir 39, 222 pp.

Glazner, A.F., Nielson, J.E., Howard, K.A., and Miller, D.M., 1986, Correlation of the Peach Springs Tuff, a large-volume Miocene ignimbrite sheet in California and Arizona: Geology, v. 14, no. 10, p. 840-843.

Gray, F., Jachens, R.C., Miller, R.J., Turner, R.L., Knepper, D.H., Jr., Pitkin, J.A., Keith, W.J., Mariano, J., Jones, S.L., and Korzeb, S.L., 1990, Mineral resources of the Warm Springs Wilderness Study Area, Mohave County, Arizona, Chapter F, *in* Mineral resources of Wilderness Study Areas: Black Mountains region, Arizona: U.S. Geological Survey Bulletin 1737-F, p. F1-F24, 1 sheet, scale 1:62,500.

Hillhouse, J.W., and Wells, R.E., 1991, Magnetic fabric, flow directions, and source area of the lower Miocene Peach Springs Tuff in Arizona, California, and Nevada: Journal of Geophysical Research, v. 96, p. 12,443-12,460.

House, P.K., Pearthree, P.A., Howard, K.A., Bell, J.W., Perkins, M.E., Faulds, J.E., and Brock, A.L., 2005, Birth of the lower Colorado River – Stratigraphic and geomorphic evidence for its inception near the conjunction of Nevada, Arizona, and California, *in* Pederson, J., and Dehler, C.M., eds, Interior Western United States: Geological Society of America Field Guide 6, p. 357-387, doi 10.1130/2005.fld006(17).

Howard, K.A., and John, B.E., 1987, Crustal extension along a rooted system of imbricate low-angle faults: Colorado River extensional corridor, California and Arizona, *in* Coward, M.P., Dewey, J.F., and Hancock, P.L., eds., Continental Extensional Tectonics: Geological Society Special Publication No. 28, p. 299-311.

Keith, S.B., Gest, D.E., DeWitt, E., Toll, N.W., and Everson, B.A., 1983, Metallic mineral districts and production in Arizona: Arizona Bureau of Geology and Mineral Technology Bulletin 194, 58 p., 1 sheet, scale 1:1,000,000.

Le Bas, M.J., Le Maitre, R.W., Streckeisen, A., and Zanettin, B., 1986, A chemical classification of volcanic rocks based on the total alkali-silica diagram: Journal of Petrology, v. 27, p. 745-750.

Lundstrom, S.C., Mahan, S.A., and Paces, J., 1998, Late Pleistocene sedimentation and erosion of the lower Colorado River, Nevada and Arizona: possible evidence for catastrophic floods: Geological Society of America Abstracts with Programs, v. 30, p. 31, A-14.

Machette, M.N., 1985, Calcic soils of the southwestern United States, *in* Weide, D.L., ed., Soils and Quaternary Geology of the Southwestern United States: Geological Society of America Special Paper 203, p. 1-21.

Metzger, D.G., and Loeltz, O.J., 1973, Geohydrology of the Needles area, Arizona, California, and Nevada: U.S. Geological Survey Professional Paper 486-J, 54 p.

Nielson, J.E., Lux, D.R., Dalrymple, G.B., and Glazner, A.F., 1990, Age of the Peach Springs Tuff, southeastern California and western Arizona: Journal of Geophysical Research, v. 95, p. 571-580.

Pearthree, P.A., 2007, Geologic map of the Needles NE 7 ½' Quadrangle, Mohave County, Arizona: Arizona Geological Survey Digital Geologic Map DGM-53, scale 1:24,000.
Pearthree, P.A., and House, P.K., 2005, Geologic map of the Davis Dam SE 7 ½' quadrangle, Mohave County, Arizona, and Clark County, Nevada: Arizona Geological Survey Digital Geologic Map DGM-45, scale 1:24,000.
Spencer, J.E., 1985, Miocene low-angle normal faulting and dike emplacement at Homer Mountain and surrounding areas, southeastern California and southernmost Nevada: Geological Society of America Bulletin, v. 96, p. 1140-1155.
Spencer, J.E., and Patchett, J., 1997, Sr isotope evidence for a lacustrine origin for the upper Miocene to Pliocene Bouse Formation, lower Colorado River trough, and implications for timing of Colorado Plateau uplift: Geological Society of America Bulletin v, 109, p. 767-778.
Spencer, J.E., and Pearthree, P.A., 2001, Headward erosion versus closed-basin spillover as alternative causes of Neogene capture of the ancestral Colorado River by the Gulf of California, *in* Young, R.A., and Spamer, E.E., eds., The Colorado River: Origin and evolution: Grand Canyon, Arizona, Grand Canyon Association Monograph 12, p. 215-219.
Thorson, J.P., 1971, Igneous petrology of the Oatman district, Mohave County, Arizona: Santa Barbara, University of California, Ph.D. dissertation, 189 p., 2 sheets.
Young, R.A., and Brennan, W. J., 1974, The Peach Springs Tuff -- Its bearing on structural evolution of the Colorado Plateau and development of Cenozoic drainage in Mohave County, Arizona: Geological Society of America Bulletin, v. 85, p. 83-90.

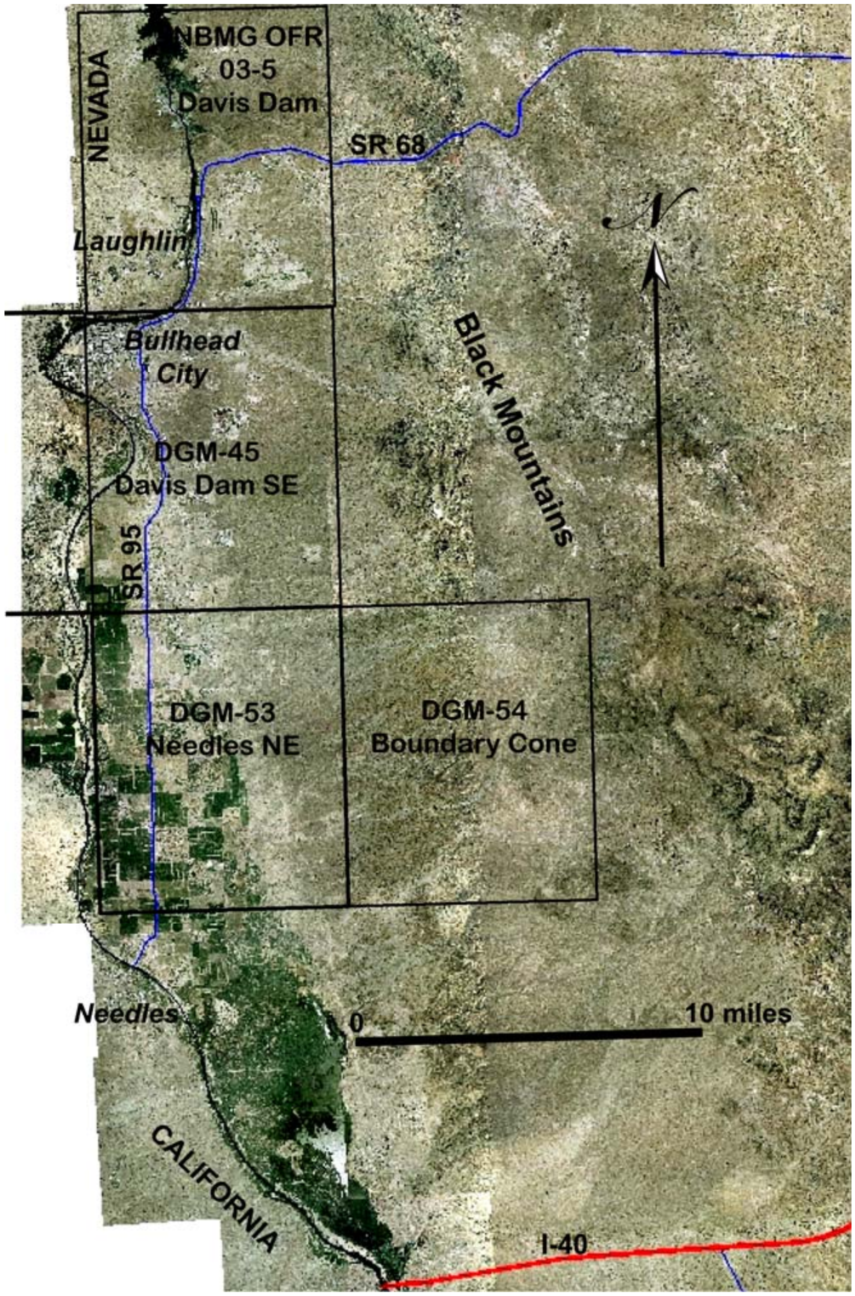

Figure 1. Location of Boundary Cone 7 ½' Quadrangle in Mohave Valley. Nearby, previously mapped 7 ½' quadrangles, also shown here, are as follows: Davis Dam (Faulds et al., 2004), Davis Dam SE (Pearthree and House, 2005), and Needles NE (Pearthree, 2007), which is directly west of the Boundary Cone 7 ½' Quadrangle.

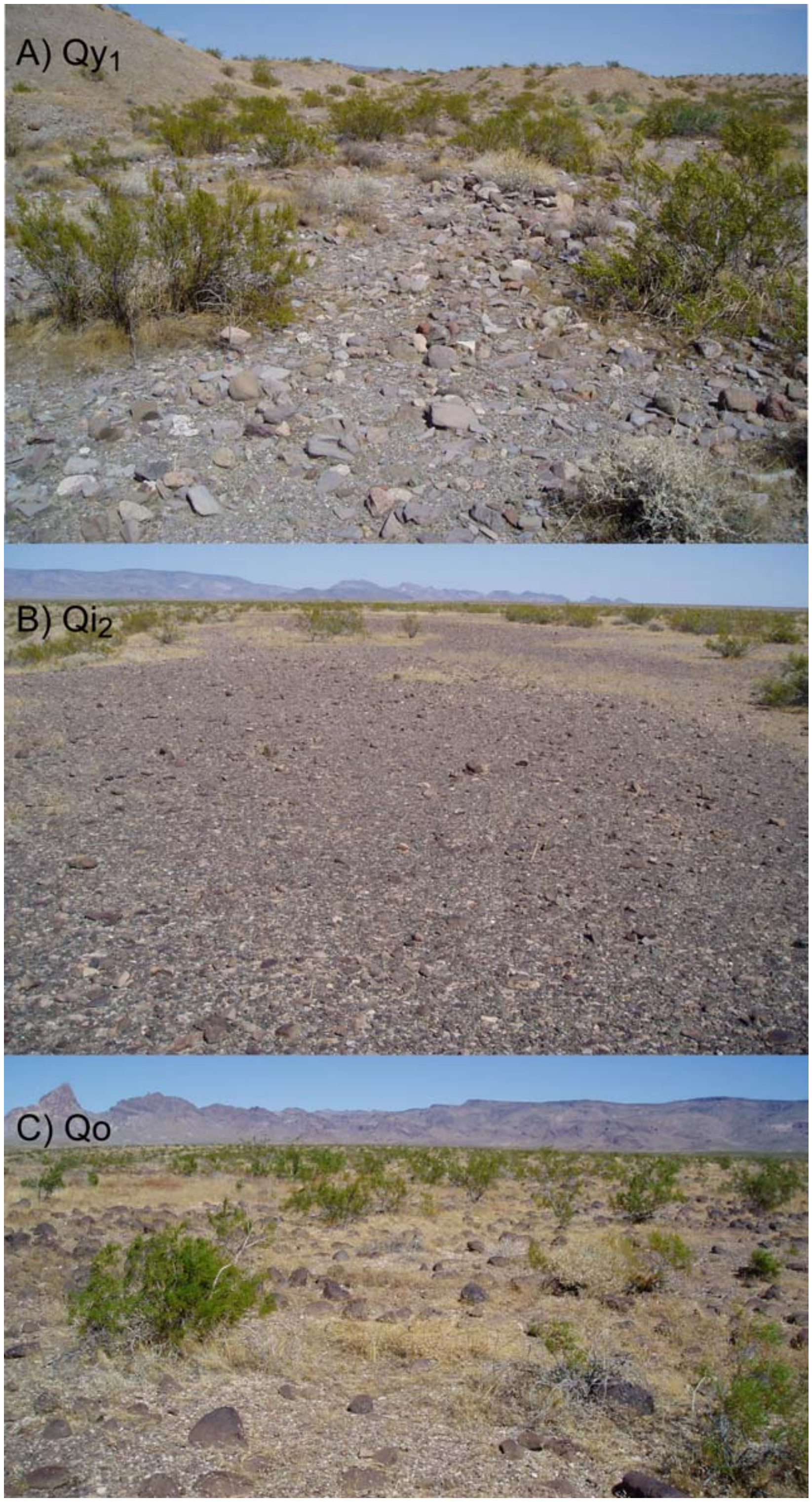

Figure 2. Ground photos of Holocene (Qy_1), late Pleistocene (Qi_2), and early to middle Pleistocene (Qo) piedmont surfaces. Holocene surfaces are fairly rough and lightly varnished; late Pleistocene surfaces are smooth and darkly varnished; older Pleistocene surfaces have some very darkly varnished surface clasts but are lighter in color overall because of exposure of carbonate soil fragments.

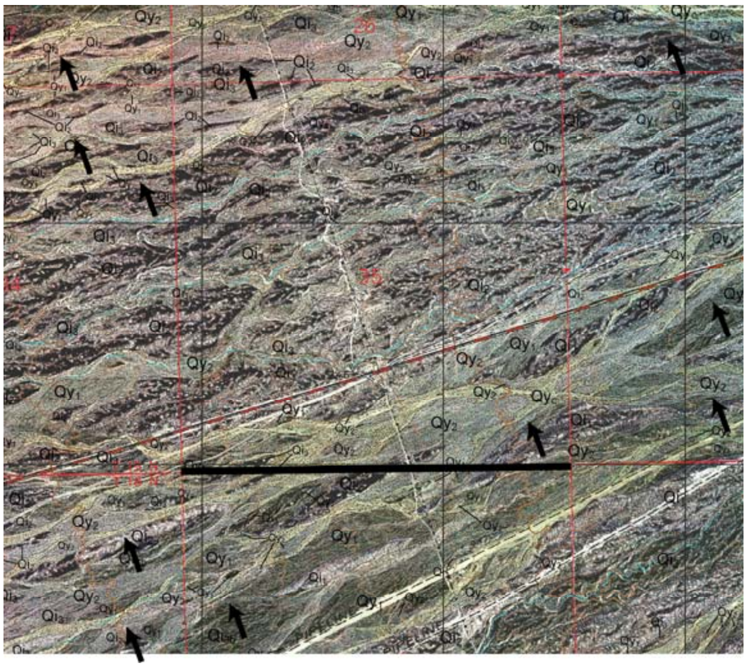

Figure 3A. Minimally dissected landscape in the northwestern corner of the quadrangle (centered on Sec. 35, T. 18 N., R. 21 W.). Virtually all of the deposits are late Pleistocene or younger in age and local topographic relief is 20 feet or less. Complex branching and distributary flow paths are common. Arrows point to some of the flow paths associated with large washes that head in the Black Mountains to the east.

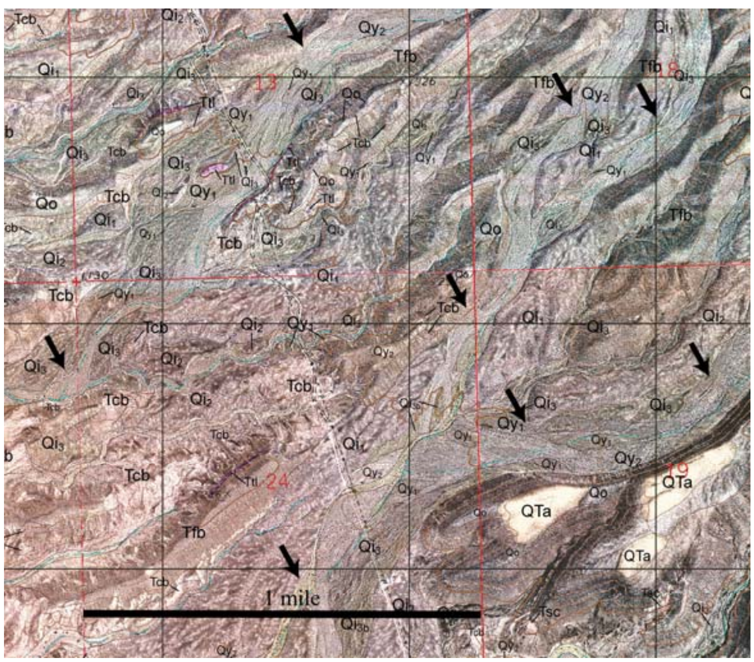

Figure 3B. Dissected landscape in the south-central part of the quadrangle (centered on Sec. 24, T. 18 N., R. 21 W.). Deposits vary widely in age and height above active washes. The oldest (QTa) surfaces are about 120 feet higher than adjacent washes. Significant flood hazards are restricted to broad valley bottoms. Arrows point out large incised washes that head in the adjacent Black Mountains.

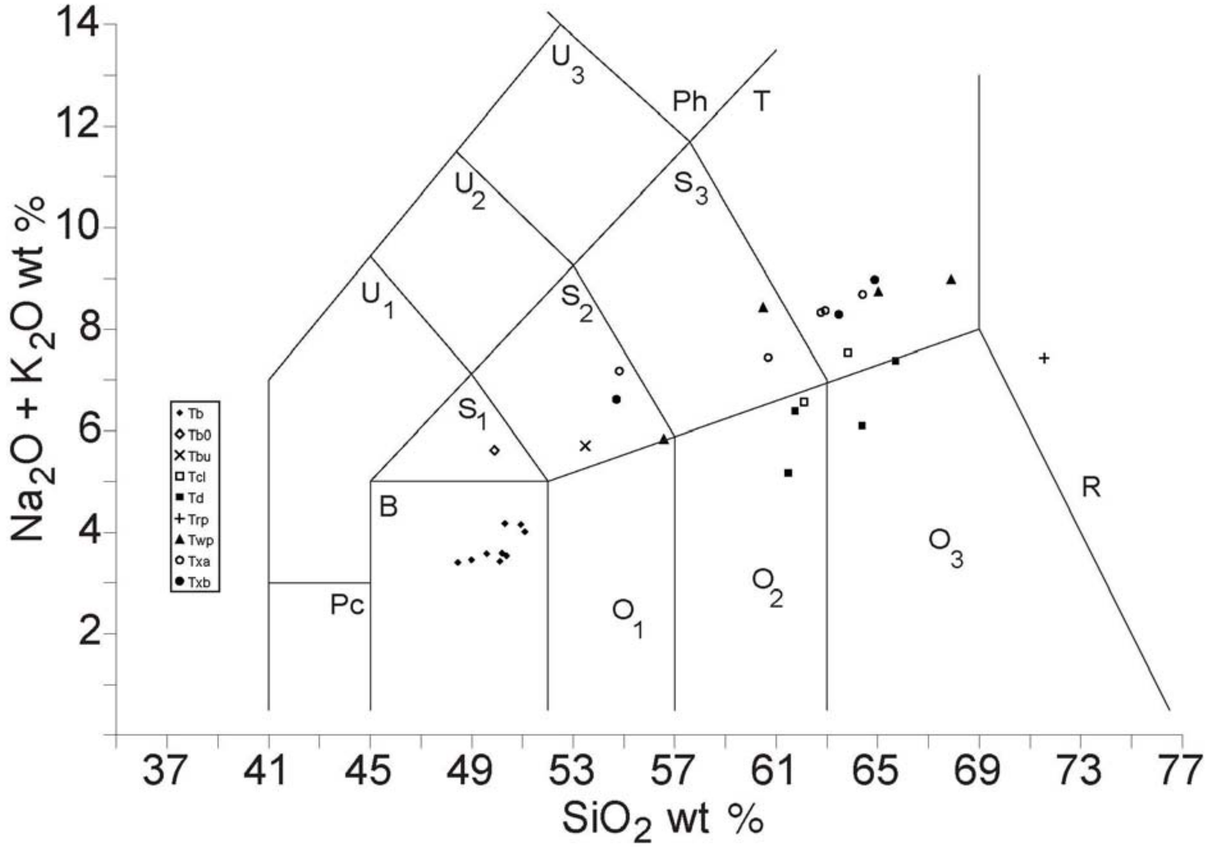

Figure 4. Total alkali versus silica diagram of Le Bas et al. (1986) showing analyses of Miocene volcanic rocks from the Boundary Cone Quadrangle, Black Mountains, Mohave County, Arizona. Field name abbreviations are Pc = picrobasalt, B = basalt, O1 = basaltic andesite, O2 = andesite, O3 = dacite, R = rhyolite, S1 = trachybasalt, S2 = basaltic trachyandesite, S3 = trachyandesite, T = trachyte.

MAP UNIT DESCRIPTIONS

Late Miocene to Quaternary Deposits

d **Disturbed ground** – Mine dump in section 10, east of Green Quartz Mine.

Qtc **Quaternary talus and colluvium, undivided**

Qy_c **Modern sand and gravel deposits associated with active channels of tributary washes –** Very poorly sorted sand, pebbles, cobbles, boulders and minor silt deposits in active channels. Gravel clasts consist of mixed volcanic rocks. Surfaces vary from nearly flat-bottomed large channels to undulating smaller channels and bars with up to 1 m of local topographic relief. Channel patterns are variable and include large single channels and multiple smaller distributary or anastomosing channels. Channels are unvegetated or lightly vegetated, although channel margins commonly are lined with denser and larger vegetation. Only channels that are large enough to depict at 1:24,000 scale are mapped as unit Qy_c; mapping is based on interpretation of digital orthophoto quadrangles from 2005.

Qy_2 **Late Holocene sand, pebble, cobble, boulder, and silt deposits in active stream channels, low terraces, and alluvial fans** – Very young deposits on active floodplains, alluvial fans and low terraces. Channel deposits typically consist of sand, pebbles, cobbles and some small to medium boulders; deposits remain quite coarse across the map area. Terrace and fan deposits typically consist of gravel, sand and silt. Fan and terrace surfaces typically are gently undulating, with gravel bars and finer-grained swales. Desert pavement development is minimal and rock varnish is very light or nonexistent. Soil development is very weak. Surfaces are minimally eroded with channel incision of less than 1.5 m. Channel patterns are variable, including linked anastamosing or distributary channels, discontinuous channels, and separate small tributary channels feeding into larger channels.

Qy_1 **Late to early Holocene deposits on channel bars, terraces and active alluvial fans** – Young deposits associated with recently active washes and alluvial fans. Deposits typically are poorly sorted, consisting cobbles, pebbles, sand, boulders and silt. Bar and swale topography is common where deposits are gravelly. Soil development is weak, with minimal soil structure and minor carbonate accumulation, but gravelly surfaces appear darker brown than younger Qy_2 surfaces due to moderate rock varnish accumulation.

Qyf **Fine-grained Holocene alluvium –** Thin, fine-grain Holocene alluvial deposits formed in swales on high remnant early Pleistocene fan deposits. These deposits are very thin, typically less than 0.5 m thick, but locally may be 1 m or more thick. Sediment typically is brown (7.5YR) mainly silt and sand, with occasional deposits of open, unvarnished, fine gravel lag. Soil development is minimal, with substantial disseminated carbonate but little visible carbonate accumulation.

Qys **Holocene sandy channel and fan deposits –** Young sand deposits derived from older Colorado River deposits. These deposits typically consist of thin sheets of reworked, quartz-rich sand in valleys cut into Pliocene Colorado River sand deposits or along the flanks of eroded river deposits. Soil development is minimal.

Qy **Holocene alluvial deposits, undifferentiated**

Qi_3 **Late Pleistocene alluvial fan and terrace deposits** – Younger intermediate deposits associated with inactive alluvial fans and terraces along washes. Deposits typically are poorly sorted mixtures of silt, sand, pebbles and cobbles with some small boulders. Surfaces are moderately dissected by tributary drainages that head on the surfaces and through-going distributary channels. Local surface topographic relief varies from about 1 to 3 m. Soil development is weak, with no clay accumulation and weak (stage I) calcic horizon development with fine filaments and discontinuous clast coatings. Desert pavement development typically is moderate to strong, and rock varnish is brown to dark brown.

Qi_{3b} **Late Pleistocene alluvial fan and terrace deposits, younger member –** Youngest intermediate terrace deposits. Deposit character and surface appearance are quite similar to Qi_3 deposits, with moderate pavement development and brown rock varnish, bar and swale topography; terrace surfaces are inset slightly below adjacent Qi_3 terraces.

Qi_2 **Late Pleistocene alluvial fan deposits** – Intermediate-age deposits associated with extensive relict alluvial fans. These deposits are graded to a river level below the maximum level of late Quaternary Colorado River aggradation, which has been dated at 60-100 ka (Lundstrom et al., in review). Deposits are poorly sorted, including sand, pebbles, cobbles, and boulders, with minor silt and clay. Qi_2 surfaces are drained by extensive, incised tributary drainage networks. Surfaces are moderately to deeply dissected, with local topographic relief varying from about 2 to 5 m. Original depositional topography typically is modified by erosion along incised valleys, but surfaces commonly are quite smooth between valleys. Well-preserved surfaces are typically dark brown due to darkly varnished, tight pebble-cobble pavements. Soils have weak clay accumulation and slight reddening in the upper 30 cm beneath the surface, and calcic horizons typically are stage II with continuous coatings on gravel clasts and some whitening of the soil matrix.

Qi_1 **Middle to late Pleistocene alluvial fan deposits** – Oldest intermediate deposits associated with relict alluvial fans. These surfaces have low fluvial scarps cut into them near the ~800 foot level (above sea level) of late Quaternary Colorado River aggradation, so predate that aggradation. Deposits are poorly sorted, including sand, pebbles, cobbles and boulders. Surfaces are moderately to deeply dissected, with local topographic relief varying from about 2 to 10 m. Original depositional topography has been extensively modified by erosion, and surfaces are rounded and seldom planar. Surfaces are slightly higher and are much more eroded than adjacent Qi_2 surfaces, but are inset well below adjacent Qo surfaces.

Qi **Middle to late Pleistocene alluvial fan and terrace deposits, undivided**

Qo **Middle to early Pleistocene alluvial fan deposits –** High, old relict alluvial fan deposits. These surfaces are truncated at high erosional scarps associated with the 800-foot-elevation terrace of the Colorado River. Deposits typically are very poorly sorted, including angular to subangular cobbles, pebbles and boulders, with sand and minor silt and clay. Surfaces are moderately to deeply dissected, with 5 to 30 m of relief between channels and ridgecrests. Original fan surfaces have been removed by erosion in many areas; in these areas the characteristic topographic expression is alternating ridges and valleys. Planar surfaces are preserved locally, however, and these are quite smooth with concentrations of very darkly varnished boulders. Soil development is strong and is dominated by carbonate accumulation. Surfaces typically have some carbonate fragments derived from eroded or perturbed petrocalcic horizons, which combined with dark remnant boulder bars gives Qo surfaces an alternating light and dark appearance on aerial photographs.

QTa **Late Pliocene to early(?) Pleistocene alluvial fan deposits –** Coarse, ancient fan deposits capping the highest ridges and fan remnants in the upper piedmont. Deposits consist of cobbles, pebbles, boulders and sand. Surfaces typically are 20 to 50 m above active washes. Surfaces are very light in color because they are covered with debris churned up from massive, 2+ m thick petrocalcic horizons. QTa deposits rest unconformably on underlying Bullhead alluvium and tributary fan deposits (units Tcb and Tfb). A volcanic tephra found in similar deposits along Silver Creek to the north has been identified as the 3.3 Ma Nomlaki tephra (House et al., 2005), so the older deposits in this group likely date to the late Pliocene.

Ttl **Early Pliocene ash-fall tephra –** Thin, discontinuous, white to gray tephra beds exposed extensively in a portion of the upper piedmont on the Boundary Cone quadrangle. Tephra bed is up to about 1 m thick, and locally the upper part is mixed with tributary sand and pebbly sand (fine gravel). Tephra is found within fine tributary gravels of unit Tfb, at elevations ranging from 1240 to 1180 feet above sea level. An exposure of a tephra that may be correlative with this unit is present at 1400 feet elevation near the southeast corner of the map area (west edge of section 3). Samples from the primary tephra outcrop area have been identified as the ~3.6-4.2 Ma Lower Nomlaki tephra (House et al., 2005).

Tcb **Early Pliocene river deposits** – A thick sequence of Colorado River deposits that consist of river sand, gravel and silt with a substantial component of tributary sand and gravel. These deposits are informally named “Bullhead alluvium” (House et al., 2005). They are extensively exposed in some parts of the piedmont and minimally exposed on other areas, but they likely underlie most of the middle and lower piedmont. Deposits are variably indurated and are typically gray in color, but are locally oxidized. River sands typically are fairly coarse and cross bedding is common. Exposures reveal abundant minor unconformities, but no strong buried soils or other evidence of major depositional hiatuses was observed. In the middle and lower piedmont below about 1100 ft above sea level (asl), this unit consists primarily of Colorado River deposits. Above that level, piedmont deposits predominate, but locally Colorado River sand and gravel can be found as high as 1300 ft asl. River deposits and tributary alluvium are clearly interfingered in some locations.

Tcb_g **Early Pliocene river deposits, gravelly member –** Areas where Bullhead alluvium contains a substantial component of cobbles, pebbles, and small boulders in addition to quartz-rich medium to coarse sand. Gravel consists of both well-rounded, far-traveled clasts and locally derived, subangular to subrounded volcanic clasts.

Tsc **Early Pliocene marginal river and/or lake deposits** - Very fine sand and silty sand, locally calcareous, and very poorly lithified. Fine sand and silt grades upward over 15 m into, and is interbedded with, pebble to cobble conglomerate. This unit may represent a transgressive sequence, deposited subaqueously in a lake associated with the Bouse Formation, with a coarser nearshore facies outboard of alluvial fan terminus, with nearshore facies prograding over fine-grained offshore facies. Alternatively, it may represent deposition marginal to the Colorado River flood plain at the time of maximum river aggradation in the early Pliocene, with progradation of tributary fan deposits onto the flood plain at the top of the sequence.

Tfb **Late Miocene to middle Pliocene alluvial-fan deposits –** Very old tributary-fan deposits exposed in the middle and lower portions of high, eroded ridges. This alluvium was deposited before the arrival of the Colorado River and during the early Pliocene aggradation of the river. Deposits typically are poorly sorted to very poorly sorted, including angular to subangular cobbles, pebbles, sand and boulders, with minor silt and clay. Deposits typically are moderately indurated and form steep faces where they have been undercut by recent erosion.

Tbo Latest Miocene to Early Pliocene lake deposits of the Bouse Formation – One- to three-m-thick, pale white to buff-colored, very fine marl and silty to sandy marl, weakly to very weakly consolidated. Generally this unit rests on erosion surfaces cut on well lithified volcanic rocks, but at one location it rests on 2-3 m of weakly consolidated silty sand with sparse pebbles and cobbles in somewhat channelized zone at base. Contains sparse, 1-2 mm, generally vertical worm(?) burrows that extend below the marl into underlying sandy deposits and are white because of calcareous cement.

Early to Middle Miocene Bedrock Map Units

Trb Boundary Cone rhyolite – Massive, resistant, rhyolite intrusion that contains 10-15%, 1-3 mm quartz, and <5%, 1-2 mm feldspar.

Tba Basaltic trachyandesite – Basaltic lava containing sparse phenocrysts of plagioclase and/or mafic phenocrysts. Analysis of a single sample indicates that this rock unit is a basaltic trachyandesite according to the classification system of Le Bas et al. (1986) (Table 1; Figure 4).

Tb Upper basaltic lava – Basaltic lavas dominated by 2-7% mafic phenocrysts of pyroxene and olivine ranging in size from 0.5-3.0 mm. Subordinate plagioclase phenocrysts are typically less than 1-2 mm. Nine major element analyses of this unit all fall in the basalt field of Le Bas et al. (1986) (Table 1; Figure 4). A sample of a "basalt flow", probably from this unit, yielded a $^{40}Ar/^{39}Ar$ whole-rock date of 16.91 ±0.12 Ma (Faulds et al., 1999, location plotted on map according to their listed latitude and longitude).

Tmd Mafic dike, undivided – Generally dark, fine-grained, aphanitic mafic dike rock.

Ttu Bedded pyroclastic rocks and volcaniclastic sedimentary rocks – A generic unit of bedded and massive pyroclastic rocks, and variably pumiceous volcaniclastic rocks. Lacking a reasonable set of distinguishing characteristics, the unit represents sequences of undifferentiated supracrustal rocks that occur between defined volcanic units throughout the stratigraphic sequence. This highly variable unit ranges from thin-bedded ash-fall tuff and surge deposits to thin- to medium-bedded volcaniclastic pebbly sandstone and thick-bedded, monolithic to oligomict, volcaniclastic diamictite and conglomerate, some of which may be entirely volcanic in origin.

Txa Trachyte of McHeffy Butte – Phenocryst-rich lava containing 10-20%, 2-6 mm euhedral plagioclase phenocrysts, and 2-5%, 1-4 mm clumps of pyroxene or hornblende, with sparse to 1-2%, biotite phenocrysts up to 2 mm diameter. The lava is typically massive with a vitric to very fine-grained crystalline, dark green to gray matrix. Autobrecciated basal and upper zones are thin or nonexistent in most areas. The lava is typically crumbly weathering. Five out of six chemical analyses indicate classification as trachyte (Table 1; Figure 4).

Tt Peach Springs Tuff – Densely welded ash-flow tuff containing 12-20%, 0.5-4.0 mm phenocrysts of sanidine and plagioclase (with much larger and much more abundant sanidine than plagioclase), up to 2%, 0.5-2 mm quartz, and 1-3%, 0.5-1.5 mm biotite. The tuff also contains sparse hornblende and sphene (<1 mm). This unit forms a thick composite sequence of flow units in the south overlain by and underlain by flows of basaltic trachyandesite (Txb) which also occurs along flow-unit boundaries within the tuff. The base of flow units are commonly brown to black vitrophyres up to 5 m thick. The unit is correlated with the Peach Springs Tuff based on its phenocryst assemblage, in particular, the somewhat unusual dominance of sanidine, both in size and abundance, over plagioclase (see Young and Brennan, 1974, p. 86).

Trl **Rhyolite lava** – Glassy, phenocryst-poor, partly autobrecciated lava flows with possible stretched fiame and glass shards.

Trx **Phenocryst-rich rhyolite lava** –Very glassy, partly autobrecciated lava flows with up to 40%, <8 mm feldspar (mostly sanidine?), and <3%, <1 mm biotite.

Tri **Rhyolitic lava** – Tan to pale orangish tan to medium brown weathering, blocky weathering, felsic lava. Contains 3-5%, 1-4 mm quartz and < 1%, < 2 mm biotite. Rocks are moderately to strongly lineated as if stretched during intrusion. No contacts with older rock units are exposed.

Ttp **Ash flow tuffs –** A distinctive sequence of one to three massive, thick to very thick-bedded, very phenocryst-poor to aphyric ash-flow tuffs containing 10-30% pumice lapilli. A complete sequence includes a lower gray tuff, an upper tan tuff and locally an uppermost, welded, phenocryst-poor tuff.

Trp **Rhyolite lava –** Rhyolite lava containing 2-5%, 1-3 mm phenocrysts of feldspar and quartz, and very sparse mafic phenocrysts, probably mostly biotite. A single geochemical analysis indicates that the rock is a rhyolite (classification of Le Bas et al., 1986; Table 1; Figure 4).

Txb **Basaltic trachyandesite –** Vesicular basaltic andesite, medium gray, vesicular, with 4-6%, 1-4 mm plagioclase (locally up to 10 mm plagioclase), 2-7%, 0.3-5 mm, dark oxidized clinopyroxene(?), and 3-5% pale-green alteration product after orthopyroxene(?). Two chemical analyses indicate classification as a basaltic trachyandesite (classification of Le Bas et al., 1986; Table 1; Figure 4). A sample of a “basalt flow”, probably from this unit or from underlying trachybasalt of map unit Tb0, yielded a ^{40}Ar/^{39}Ar whole rock date of 18.35 ±0.06 Ma (Faulds et al., 1999, location plotted on map according to their listed latitude and longitude).

Ttdl **Dacitic, lapilli, ash-flow tuff** – Tuff is exposed near Tipperary Mine in the adjacent Warm Springs 7.5' Quadrangle just east of the edge of the Boundary Cone 7.5' Quadrangle. At the one location where mapped, the unit rests on trachybasalt of map unit Tb0.

Tb0 **Trachybasalt –** A suite of phenocryst-poor (≤ 2%), to nearly aphyric basaltic lava containing very sparse plagioclase and/or mafic phenocrysts typically <1 mm, but rarely up to 2 mm. Analysis of a single sample indicates that this rock unit is a trachybasalt according to the classification system of Le Bas et al. (1986) (Table 1; Figure 4). These lavas occur both above and below the trachyte of Wrigley Peak. In some areas, phenocryst-poor varieties of the trachyte of Wrigley Peak are difficult to differentiate from this unit, and there may be gradational transitions between the two types of lava.

Tbp **Basaltic andesite** – Phenocryst poor lava flows containing 0.5-3% (rarely up to 5%), 1-2 mm, greenish, variably altered pyroxene (possibly both orthopyroxene and clinopyroxene) and possibly olivine as dominant phenocrysts. Plagioclase phenocrysts sparse to absent.

Twp **Lava of Wrigley Peak (Miocene) –** Phenocryst-poor lava flows. Unit is characterized by abundant, closely spaced fractures (commonly 1-3 cm) that change orientation by many tens of degrees over tens of meters and result in weathering into thin slabs and sheets. Contains <1 %, <2 mm biotite and 2-3%, <2 mm iron oxides after olivine or pyroxene, and <1%, <1 mm plagioclase. The lava is typically dark gray to lavender, and mostly massive coherent facies with thin scoriaceous and/or autobrecciated zones at the base of flow-units. Locally the unit includes very phenocryst-poor to aphyric zones, typically near the base of thick flow sequences. Flow foliation is defined by bands of contrasting vesicularity, by parallel fractures, and by variation in weathering color and in resistance to weathering across layering on scale of 3-30 mm. Autobreccia is locally pervasive. The average composition of three geochemical analyses indicate that the rock is a trachyte (classification of Le Bas et al., 1986; Table 1; Figure 4).

Tdt **Lapilli tuff (Miocene)** – Lapilli tuff containing 10-20%, 1-3 mm, plagioclase phenocrysts, 1-2% biotite phenocrysts, and 2-30% heterogeneous volcanic lithic clasts.

Tdu **Phenocryst-rich dacitic lava –** Dacitic lava containing 25-30%, 1-8 mm, but mostly 2-4 mm, euhedral blocky plagioclase and potassium feldspar, and 1-5%, 1-3 mm biotite, plus or minus sparse pyroxene.

Tss **Sandstone and conglomerate** – Volcaniclastic sandstone and conglomerate.

Tts **Tuff and reworked tuff** – Pale white tuff, tuffaceous sandstone, and volcaniclastic sandstone and pebble to, rarely, cobble conglomerate. Some bedded tuff could be ash-fall with variations in grain size across 1-10 cm thick planar beds due to ash-fall sorting. At a large area of exposure southwest of McHeffy Butte, rocks of this unit grade into pale greenish gray colors that could reflect the presence of zeolite known to be in this area (Gray et al., 1990).

Td **Dacite –** Pale gray lava with 4-8%, <3 mm biotite phenocrysts (locally up to 5 mm). Also contains 1-2%, <1 mm, acicular hornblende, and 3-9%, 1-5 mm plagioclase (and possibly K-feldspar) that is locally up to 8 mm. Two of four geochemical analyses indicate that this unit is an andesite, and two indicate that it is a dacite (Figure 4; Table 1). Average of all four is slightly in the dacite field of Le Bas et al. (1986), so this unit is here classified as dacite. Crude layering is locally defined by variations in concentration of vugs. Dacite has fragmental character in some areas, locally with lower percentage of phenocrysts in matrix than in clasts. Top of dacite unit is clearly autobrecciated over approximately zones up to 100 m, with strongest brecciation at top. Two samples from this unit yielded $^{40}Ar/^{39}Ar$ biotite dates of 19.19 ±0.06 Ma and 19.59 ±0.03 Ma (Faulds et al., 1999, location plotted on map according to their listed latitude and longitude).

On the north side of hill 1838 (NW ¼, sec. 33, about 2 km south of McHeffy Butte), this unit consists of fine-grained biotite-hornblende dacite with pale amber-green feldspar. Anhedral feldspar up to 6 mm (two seen with flat phenocryst faces without albite twinning, but not quite as flat and clear as sanidine). Greenish-amber feldspar found in a band, or zone, within the dacite unit which is pink and oxidized elsewhere. Thin, irregular bands of pink within gray dacite at margins suggest incipient oxidation along marginal zones. Gradational nature of contact suggests that this is not an intrusion, but rather is unaltered dacite within generally oxidized dacite.

Tdf **Phenocryst-rich dacitic lava –** Fine-grained, moderately phenocryst-rich dacitic lava containing 10-25% phenocrysts of <2 mm, euhedral to subhedral plagioclase phenocrysts and 1-3%, <2 mm, altered mafic phenocrysts, probably mostly biotite.

Tbf **Biotite felsite** – Felsite characterized by 2-3%, 1-2 mm, brassy biotite phenocrysts. The biotite flakes commonly have a tabular crystal habit viewed along the C-axis, rather than the typical equant hexagonal shape. Groundmass is aphyric. Unit is relatively resistant, commonly forming hill tops or cliffs. Autobreccia is locally present at base.

Th **Hornblende felsite lava** – Felsite with conspicuous, 3-7%, acicular, euhedral hornblende phenocrysts, 1-6 mm long. Groundmass light pinkish gray to lavender to dark gray. Although difficult to see in most samples, the lava also contains 1-3%, 1-3 mm plagioclase phenocrysts, and some samples contain sparse, <2 cm, biotite-rich, fine-grained dioritic clots. Also includes phenocryst-poor rocks with aphanitic to very fine-grained groundmass, platy close jointing, and hornblende and biotite phenocrysts.

Thi **Hornblende felsite dike** – Unit consists of two dikes of hornblende-rich porphyry that probably represent intrusive equivalents of the hornblende felsite lava of map unit Th.

Tdp **Coarse andesite** – Conspicuously porphyritic andesite containing 15-20%, 2-6 mm plagioclase and 1-3 mm, mafic phenocrysts. Typically has abundant amygdaloidal cavities, generally less that 1 cm in longest dimension. Groundmass is fine-grained to locally glassy. Sparse quartz phenocrysts are present.

Tda **Dacitic lava of Alcyone Mine** – Dark gray, fine-grained matrix, moderately phenocryst-rich dacitic lava that overlies the lower dacitic lava of Cook Mine in the northern part of the map area. The lava contains 7-15%, 1-6 mm phenocrysts of euhedral, tabular to equant plagioclase. Sparse, <1-2%, <1-2 mm, severely chloritic-altered, unidentifiable mafic phenocrysts are also present. The lava is distinguished from the upper dacitic lava of Cook Mine, which contains a higher percentage of plagioclase phenocrysts, by the fact that it overlies a heterolithic breccia that contains clasts of the upper dacitic lava of Cook Mine. Lava is commonly massive but locally vesicular or fragmental. Sparse, rounded, embayed, quartz phenocrysts, 2-3 mm in diameter, are present in many places. This rock is differentiated from pyroxene andesite and older basalt by greater abundance of phenocrysts and presence of conspicuous plagioclase phenocrysts. Contact with phenocryst-rich dacite northwest of Green Quartz Mine seems to be gradational through one or more lava flows. In fault block southwest of Green Quartz Mine, the andesitic rock appears to pinch out in a buttress unconformity against the margin of phenocryst-rich dacite that possibly forms a dome complex.

Tfq **Quartz porphyry felsite –** Pale grayish white quartz porphyry, with 6-8%, <1 mm quartz of undetermined intrusive or extrusive origin.

Tdx **Heterolithic, clast-supported dacitic breccia** – Unit is dominated by clasts of phenocryst-rich dacitic lava with plagioclase phenocrysts less than 4 mm diameter, but also with locally abundant dacitic lava clasts containing plagioclase phenocrysts greater than 8 mm. The two types of clasts in the breccia resemble the lower and upper dacitic lavas of Cook Mine suggesting that massifs of these lavas were the source for this unit.

Tcu **Upper dacitic lava of Cook Mine –** Dark gray, fine-grained matrix, phenocryst-rich dacitic lava containing 15-35% euhedral tabular to equant plagioclase phenocrysts with 2-5%, 2-6mm euhedral, strongly altered hornblende phenocrysts. The lava is similar to the dacitic lava of Alcyone Mine, but is distinguished by its greater percentage of plagioclase phenocrysts.

Tcui **Intrusive dacite of Cook Mine –** Unit consists of 3-50 m thick dikes of gray to purplish-gray, crystalline matrix dacitic porphyry containing 15-25% phenocrysts of euhedral, mostly equant plagioclase. Plagioclase phenocrysts are coarser towards the middle of the thickest dikes, ranging from 1-3 mm near dike margins to 4-8 mm in dike cores. The cores of some dikes contain 2-3%, up to 6 mm hornblende phenocrysts.

Tclu **Upper flow-unit of the lower dacitic lava of Cook Mine –** An upper flow-unit of the lower dacite of Cook Mine recognized only in the northern part of the map area. The lava is virtually indistinguishable from the main mass of the unit but is separated from it by a prominent flow boundary that helps define structure in the Alcyone Mine area. The lava appears to grade laterally into the heterolithic dacitic clast breccia of map unit Tdx.

Tcl **Lower dacitic lava of Cook Mine** – This is a compositionally variable unit in which the mafic phenocryst mineralogy is not differentiated on the map either because of alteration or insufficient study. It typically consists of massive lava containing 10-50%, 1-8 mm plagioclase phenocrysts, and 1-10%, 1-3 mm mafic phenocrysts. Varieties are apparent based on mafic phenocryst abundance and mineralogy, including hornblende plagioclase dacite, hornblende biotite plagioclase dacite, plagioclase dacite, hornblende biotite pyroxene dacite. Some localities include glomeroporphyritic clots of feldspar and hornblende(?). Unit also includes fragmental rocks with similar mineralogic variation. One chemical analyses of this unit yielded classification as an andesite, and another indicates trachyte (classification of Le Bas et al., 1986; Table 1; Figure 4).

Tclf **Dacitic fragmental rocks of Cook Mine** – Dacitic fragmental rocks with 10-40%, 1-10 mm plagioclase, 0.1-1 mm, 5-10 %, commonly acicular hornblende, and biotite. Generally massive fragmental rock dominated by clasts of one or more varieties of the phenocryst-rich dacite family of lava types. Most of unit is monolithologic and probably much or most of the monolithologic variety is autobreccia. Heterolithic fragmental rocks resembles heterolithic, clast-supported dacitic breccia of map unit Tdx. Mafic minerals include abundant 0.1-0.3 mm phenocrysts of uncertain mineralogy. Fragmental character is clear, commonly with no difference in weathering between clasts and matrix except matrix is slightly purplish whereas clasts are more grayish. Fragments mostly 1-10 cm, generally 0.1-100 cm, rare blocks up to 5 m, with some color variations that seem to be related to alteration rather than to primary mineralogy. Fragmental rocks include mixed phenocryst-poor and phenocryst-rich clasts. At one locality, a phenocryst-rich clast was within a phenocryst-poor clast that was within phenocryst-rich host matrix. Rare sandstone beds within fragmental volcanic rocks consist of poorly sorted, medium to coarse sandstone to pebbly sandstone with angular clasts. Moderately to poorly defined beds are 2-20 cm thick. Some beds are characterized by bedding-plane fractures and partings.

Tbl **Older basalt** – Dark gray, phenocryst-poor lava typically characterized by 1-3%, 1-2 mm mafic phenocrysts including brown-altered olivine and green pyroxene. In general, this unit has slightly fewer phenocrysts than basaltic andesite of map unit Tbp and appears to contain significantly lower pyroxene/olivine ratio.

Tsv **Sandstone and lapilli tuff or scoria -** Dark gray, thin-bedded, non-resistant sandstone, and lapilli-tuff or scoria, derived from phenocryst-poor to aphyric, mafic volcanic rocks. This unit depositionally overlies Proterozoic crystalline rocks.

Tvu **Volcanic rocks, undivided** – Volcanic rocks exposed in two outcrop areas about 2 km west of McHeffy Butte.

Proterozoic Bedrock

Xgm **Crystalline rocks, undivided (early Proterozoic)** – Complex of fine-grained, quartzo-feldspathic gneiss, locally garnet-bearing, medium-grained biotite granitoid, and dark-gray, coarse-grained, biotite-rich monzodiorite(?). Monzodiorite(?) locally contains 3-5 cm K-feldspar phenocrysts.

TABLE 1A. Geochemistry of volcanic rocks, major elements																	
Unit	**Sample Number**	**Station**	**UTME†**	**UTMN†**	**SiO_2 (%)**	**Al_2O_3 (%)**	**Fe_2O_3 (%)***	**MnO (%)**	**MgO (%)**	**CaO (%)**	**Na_2O (%)**	**K_2O (%)**	**TiO_2 (%)**	**P_2O_5 (%)**	**LOI (%)**	**Total (%)**	**K_2O + Na_2O (%)**
					FUS-ICP	FUS-ICP	FUS-ICP	FUS-ICP	FUS-ICP	FUS-ICP	FUS-ICP	FUS-ICP	FUS-ICP	FUS-ICP	FUS-ICP	FUS-ICP	
Txb	14642	CAF-2-14642	739811	3862202	54.81	15.24	7.22	0.07	4.31	7.10	3.34	3.83	1.37	0.86	2.39	100.50	7.17
Trp	14655	CAF-2-14655	739212	3863119	71.54	12.05	0.79	0.04	0.43	0.68	2.59	4.84	0.13	0.02	5.66	98.77	7.43
Tba	14707	CAF-2-14707	738615	3862982	53.47	17.47	8.28	0.13	4.86	7.73	3.77	1.93	1.46	0.45	0.83	100.40	5.70
Tb	14711	CAF-2-14711	738841	3862869	50.93	16.75	10.10	0.16	7.01	9.54	3.09	1.06	1.11	0.27	0.49	100.50	4.15
Tb	14775	CAF-2-14775	740164	3863333	51.09	16.56	9.76	0.15	7.32	9.23	3.04	0.97	1.05	0.23	0.72	100.10	4.01
Tb	14848	CAF-2-14848	736822	3868364	50.10	17.14	10.01	0.17	7.52	9.94	2.81	0.61	1.22	0.17	0.71	100.40	3.42
Tb	14850	CAF-2-14850	736869	3868221	50.37	17.11	9.83	0.16	7.74	9.84	2.81	0.72	1.23	0.18	0.48	100.50	3.53
Tb	14851	CAF-2-14851	736935	3868097	50.19	17.06	9.66	0.16	7.52	9.99	2.81	0.77	1.23	0.18	0.72	100.30	3.58
Txa	14855	CAF-2-14855	737112	3867582	62.92	16.01	3.85	0.06	1.58	3.49	3.32	5.04	0.74	0.25	2.71	99.98	8.36
Tb	14909	CAF-2-14909	736887	3868217	49.59	17.58	10.24	0.17	7.83	9.71	2.88	0.69	1.28	0.18	0.21	100.40	3.57
Twp	14926	CAF-2-14926	737397	3868641	65.01	16.77	3.87	0.05	0.70	2.46	3.99	4.74	0.69	0.34	1.77	100.40	8.73
Txa	15153	CAF-2-15153	736877	3867782	62.75	15.96	3.82	0.06	1.61	3.70	3.42	4.90	0.73	0.24	2.54	99.72	8.32
Td	15178	CAF-2-15178	738511	3867270	64.37	15.56	3.30	0.06	1.64	3.59	4.03	2.06	0.51	0.17	4.71	100.00	6.09
Twp	15421	CAF-2-15421	738112	3872111	67.88	16.33	2.82	0.05	0.51	2.02	4.35	4.63	0.49	0.20	1.07	100.40	8.98
Twpp	15423	CAF-2-15423	738388	3871976	56.56	16.68	6.97	0.09	3.19	6.46	3.61	2.22	1.15	0.33	3.23	100.50	5.83
Txb	15434	CAF-2-15434	739262	3872586	54.70	16.46	6.72	0.14	4.38	5.24	3.39	3.22	1.29	0.51	2.94	98.98	6.61
Txa	15440	CAF-2-15440	739551	3873018	64.39	16.13	4.26	0.04	1.01	3.05	3.68	5.00	0.82	0.26	0.92	99.56	8.68
Tb	15443	CAF-2-15443	739624	3872923	48.45	17.58	10.15	0.16	7.79	9.90	2.77	0.63	1.19	0.17	0.78	99.58	3.40
Tb	15444	CAF-2-15444	739648	3872917	48.99	17.40	10.09	0.17	7.60	10.00	2.82	0.63	1.24	0.17	0.76	99.86	3.45
Txa	15510	CAF-2-15510	739925	3873672	60.67	15.62	5.14	0.08	2.36	4.25	3.22	4.22	0.90	0.34	2.28	99.06	7.44
Tb0	15562	CAF-2-15562	740297	3868254	49.89	17.75	8.18	0.10	4.78	7.33	3.64	1.97	1.49	0.45	3.06	98.64	5.61
Tcl	15584	CAF-2-15583	736773	3875719	63.81	16.21	4.13	0.05	1.17	3.75	3.94	3.59	0.72	0.29	1.81	99.47	7.53
Tb	1-26-06-5	JES-06-175	737427	3862278	50.30	16.76	9.97	0.15	7.25	9.73	3.18	0.99	1.10	0.25	0.53	100.20	4.17
Txa	2-8-06-5	JES-06-245	736560	3867356	64.87	16.20	4.03	0.06	1.19	3.23	3.64	5.33	0.80	0.26	1.08	100.70	8.97
Txa	2-10-06-3	JES-06-267	737024	3868128	63.45	16.24	3.91	0.06	1.61	3.53	3.35	4.93	0.77	0.24	2.70	100.80	8.28
Td	2-28-06-4	JES-06-299	737831	3866326	65.69	15.97	4.18	0.04	1.47	3.79	3.69	3.68	0.72	0.28	1.31	100.80	7.37
Td	3-1-06-12	JES-06-316	737036	3865123	61.47	16.01	4.21	0.07	2.80	4.75	3.83	1.33	0.73	0.25	4.78	100.20	5.16
Twp	3-2-06-9	JES-06-338	737298	3866133	60.47	17.02	4.75	0.08	0.56	4.25	4.13	4.29	0.90	0.52	1.99	98.96	8.42
Td	3-3-06-3	JES-06-348	736640	3865527	61.73	16.05	4.47	0.07	2.88	4.72	3.57	2.81	0.77	0.28	2.47	99.81	6.38
Tcl	3-4-06-1	JES-06-358	736100	3873120	62.09	16.06	4.32	0.06	1.96	4.17	3.23	3.33	0.74	0.30	2.45	98.72	6.56

*Total iron as Fe_2O_3

†NAD 27, Zone 11

Analyses by: Activation Laboratories Ltd., 1336 Sandhill Drive, Ontario, L9G 4V5, CANADA (2006)

TABLE 1B. Geochemistry of volcanic rocks, trace elements

Unit	Sample Number	Station	UTME[†]	UTMN[†]	Au (ppb)	Ag (ppm)	As (ppm)	Ba (ppm)	Be (ppm)	Bi (ppm)	Br (ppm)	Cd (ppm)	Co (ppm)	Cr (ppm)	Cs (ppm)	Cu (ppm)	Hf (ppm)	Hg (ppm)	Ir (ppm)	Mo (ppm)	Ni (ppm)
					INAA	MULT INAA / TD-ICP	INAA	MULT INAA/FUSICP	FUS-ICP	TD-ICP	INAA	TD-ICP	INAA	INAA	INAA	TD-ICP	INAA	INAA	INAA	INAA	TD-ICP
Txb	14642	CAF-2-14642	739811	3862202	9	< 0.5	< 2	579	1	< 2	< 1	< 0.5	39	262	< 0.5	67	2.5	< 1	< 5	< 5	104
Trp	14655	CAF-2-14655	739212	3863119	< 5	< 0.5	< 2	516	1	2	< 1	< 0.5	39	321	< 0.5	64	2.1	< 1	< 5	< 5	115
Tba	14707	CAF-2-14707	738615	3862982	< 5	< 0.5	2	249	1	< 2	3	< 0.5	41	310	< 0.5	53	2.9	< 1	< 5	< 5	110
Tb	14711	CAF-2-14711	738841	3862869	< 5	< 0.5	< 2	254	1	< 2	< 1	< 0.5	39	292	< 0.5	49	2.8	< 1	< 5	< 5	109
Tb	14775	CAF-2-14775	740164	3863333	< 5	< 0.5	< 2	265	1	< 2	< 1	< 0.5	40	312	< 0.5	49	2.8	< 1	< 5	< 5	107
Tb	14848	CAF-2-14848	736822	3868364	< 5	< 0.5	< 2	247	1	< 2	< 1	< 0.5	41	258	< 0.5	58	2.8	< 1	< 5	< 5	111
Tb	14850	CAF-2-14850	736869	3868221	< 5	< 0.5	< 2	232	1	< 2	< 1	< 0.5	42	264	< 0.5	51	3	< 1	< 5	< 5	126
Tb	14851	CAF-2-14851	736935	3868097	< 5	< 0.5	4	250	1	3	3	< 0.5	14	85	2.8	50	7.8	< 1	< 5	< 5	107
Txa	14855	CAF-2-14855	737112	3867582	< 5	< 0.5	< 2	715	1	< 2	< 1	< 0.5	41	311	0.6	61	2.6	< 1	< 5	< 5	104
Tb	14909	CAF-2-14909	736887	3868217	< 5	0.6	28	874	2	< 2	< 1	< 0.5	26	63	< 0.5	37	4.5	< 1	< 5	< 5	44
Twp	14926	CAF-2-14926	737397	3868641	5	0.9	< 2	857	2	< 2	< 1	< 0.5	28	45	< 0.5	44	4.4	< 1	< 5	< 5	41
Txa	15153	CAF-2-15153	736877	3867782	< 5	0.5	3	1600	2	< 2	< 1	< 0.5	8	81	0.9	12	4.4	< 1	< 5	< 5	24
Td	15178	CAF-2-15178	738511	3867270	< 5	< 0.5	5	1350	2	< 2	< 1	< 0.5	11	76	< 0.5	6	5.4	< 1	< 5	< 5	18
Twp	15421	CAF-2-15421	738112	3872111	< 5	0.6	12	1670	2	< 2	< 1	< 0.5	10	48	296	9	4.5	< 1	< 5	< 5	20
Twpp	15423	CAF-2-15423	738388	3871976	< 5	0.5	175	1390	2	< 2	< 1	< 0.5	12	88	6.7	13	4.6	< 1	< 5	< 5	48
Txb	15434	CAF-2-15434	739262	3872586	< 5	1.1	13	1290	2	< 2	< 1	< 0.5	12	67	227	11	4.9	< 1	< 5	< 5	35
Txa	15440	CAF-2-15440	739551	3873018	< 5	0.8	< 2	1360	2	< 2	< 1	< 0.5	12	87	11.5	18	4.8	< 1	< 5	< 5	41
Tb	15443	CAF-2-15443	739624	3872923	< 5	< 0.5	6	281	3	< 2	< 1	< 0.5	< 1	54	15	2	3	< 1	< 5	< 5	1
Tb	15444	CAF-2-15444	739648	3872917	< 5	1.2	84	1800	3	< 2	< 1	< 0.5	< 1	50	4.6	2	8	< 1	< 5	< 5	2
Txa	15510	CAF-2-15510	739925	3873672	< 5	1.5	8	1920	3	< 2	< 1	< 0.5	< 1	65	5.9	2	8.9	< 1	< 5	< 5	2
Tb0	15562	CAF-2-15562	740297	3868254	< 5	1	9	1800	2	< 2	< 1	< 0.5	5	29	2.8	2	7.2	< 1	< 5	< 5	< 1
Tcl	15584	CAF-2-15583	736773	3875719	< 5	0.8	4	967	2	< 2	< 1	< 0.5	23	74	< 0.5	22	4.9	< 1	< 5	< 5	49
Tb	1-26-06-5	JES-06-175	737427	3862278	< 5	0.8	4	1220	3	< 2	2	< 0.5	14	74	2.3	18	7.5	< 1	< 5	< 5	29
Txa	2-8-06-5	JES-06-245	736560	3867356	< 5	1.3	4	1370	3	< 2	< 1	< 0.5	8	74	1.9	19	8.4	< 1	< 5	< 5	22
Txa	2-10-06-3	JES-06-267	737024	3868128	< 5	0.8	5	1320	3	< 2	< 1	< 0.5	10	37	2.3	6	9.7	< 1	< 5	< 5	14
Td	2-28-06-4	JES-06-299	737831	3866326	< 5	0.6	5	1380	3	< 2	< 1	< 0.5	8	53	2	15	8.6	< 1	< 5	< 5	18
Td	3-1-06-12	JES-06-316	737036	3865123	< 5	1.3	5	1340	3	< 2	3	< 0.5	8	63	5.4	22	8.8	< 1	< 5	< 5	14
Twp	3-2-06-9	JES-06-338	737298	3866133	< 5	0.6	6	1600	3	< 2	< 1	< 0.5	10	80	8.8	9	8.3	< 1	< 5	< 5	16
Td	3-3-06-3	JES-06-348	736640	3865527	< 5	1.3	52	2000	3	< 2	2	< 0.5	21	291	3.5	38	8.1	< 1	< 5	< 5	136
Tcl	3-4-06-1	JES-06-358	736100	3873120	< 5	1.5	29	1090	3	< 2	< 1	< 0.5	25	67	6.9	99	6.6	< 1	< 5	< 5	57

[†]NAD 27, Zone 11

TABLE 1C. Geochemistry of volcanic rocks, more trace elements

Unit	Sample Number	Station	UTME[†]	UTMN[†]	Pb (ppm)	Rb (ppm)	S (%)	Sb (ppm)	Sc (ppm)	Se (ppm)	Sr (ppm)	Ta (ppm)	Th (ppm)	U (ppm)	V (ppm)	W (ppm)	Y (ppm)	Zn (ppm)	Zr (ppm)
					TD-ICP	INAA	TD-ICP	INAA	INAA	INAA	FUS-ICP	INAA	INAA	INAA	FUS-ICP	INAA	FUS-ICP	TD-ICP	FUS-ICP
Txb	14642	CAF-2-14642	739811	3862202	< 5	< 20	0.006	< 0.2	28.3	< 3	582	< 1	2.7	< 0.5	182	< 3	23	71	117
Trp	14655	CAF-2-14655	739212	3863119	< 5	< 20	0.008	< 0.2	27.2	< 3	566	< 1	2.6	< 0.5	166	< 3	20	71	109
Tba	14707	CAF-2-14707	738615	3862982	< 5	< 20	0.008	< 0.2	36.5	< 3	321	< 1	2.2	< 0.5	206	< 3	30	64	128
Tb	14711	CAF-2-14711	738841	3862869	< 5	< 20	0.033	< 0.2	34.6	< 3	1035	< 1	1.8	< 0.5	205	< 3	29	61	133
Tb	14775	CAF-2-14775	740164	3863333	< 5	< 20	0.01	< 0.2	33.6	< 3	337	< 1	1.9	< 0.5	198	< 3	29	62	135
Tb	14848	CAF-2-14848	736822	3868364	< 5	< 20	0.005	< 0.2	34.5	< 3	340	< 1	1.7	< 0.5	205	< 3	30	68	136
Tb	14850	CAF-2-14850	736869	3868221	< 5	< 20	0.006	< 0.2	32.6	< 3	318	< 1	1.8	< 0.5	196	< 3	29	65	127
Tb	14851	CAF-2-14851	736935	3868097	< 5	110	0.005	0.5	11.5	< 3	332	< 1	17.3	3.1	202	< 3	29	64	130
Txa	14855	CAF-2-14855	737112	3867582	< 5	< 20	0.072	< 0.2	26.8	< 3	587	< 1	2.2	1.1	177	< 3	21	69	111
Tb	14909	CAF-2-14909	736887	3868217	< 5	60	0.014	0.7	20.6	< 3	810	< 1	4.6	< 0.5	187	< 3	26	77	213
Twp	14926	CAF-2-14926	737397	3868641	< 5	< 20	0.006	0.3	20.5	< 3	811	< 1	4.5	< 0.5	184	< 3	25	76	211
Txa	15153	CAF-2-15153	736877	3867782	20	< 20	0.03	1	5.3	< 3	924	< 1	8.6	2	78	< 3	17	65	254
Td	15178	CAF-2-15178	738511	3867270	15	50	0.006	0.7	7.6	< 3	914	< 1	9	1.4	81	< 3	17	60	229
Twp	15421	CAF-2-15421	738112	3872111	22	660	0.002	7.6	6.5	< 3	1447	< 1	6.9	< 0.5	62	< 3	13	62	180
Twpp	15423	CAF-2-15423	738388	3871976	16	90	0.043	44.8	7.8	< 3	886	< 1	8.9	< 0.5	75	< 3	17	51	199
Txb	15434	CAF-2-15434	739262	3872586	16	270	0.009	3.9	8.1	< 3	1154	2	8.2	2	85	< 3	17	59	198
Txa	15440	CAF-2-15440	739551	3873018	19	110	0.02	0.4	8.3	< 3	982	< 1	9	1.3	89	< 3	17	61	205
Tb	15443	CAF-2-15443	739624	3872923	28	230	0.002	1.5	1.2	< 3	105	1	16.4	3.4	5	< 3	10	25	91
Tb	15444	CAF-2-15444	739648	3872917	21	140	0.001	60	4.2	< 3	861	< 1	13.6	3	23	< 3	25	81	366
Txa	15510	CAF-2-15510	739925	3873672	26	120	0.01	0.4	4.1	< 3	668	2	14.1	3	14	< 3	25	82	425
Tb0	15562	CAF-2-15562	740297	3868254	16	110	0.07	4.4	4.8	< 3	1085	< 1	11.7	2.1	20	< 3	24	81	322
Tcl	15584	CAF-2-15583	736773	3875719	< 5	< 20	0.002	2.5	13.9	< 3	733	< 1	5	< 0.5	131	< 3	21	80	209
Tb	1-26-06-5	JES-06-175	737427	3862278	14	140	0.017	0.5	10.6	< 3	644	< 1	16.2	2.9	91	< 3	29	59	346
Txa	2-8-06-5	JES-06-245	736560	3867356	24	130	0.005	0.7	7.9	< 3	548	< 1	17.5	3.5	67	< 3	31	64	399
Txa	2-10-06-3	JES-06-267	737024	3868128	24	130	0.004	< 0.2	8.9	< 3	568	< 1	18.6	4.2	66	< 3	28	57	383
Td	2-28-06-4	JES-06-299	737831	3866326	21	130	0.004	0.7	7.9	< 3	559	< 1	17.2	2.9	63	< 3	27	57	379
Td	3-1-06-12	JES-06-316	737036	3865123	20	140	0.005	0.4	7.7	< 3	582	< 1	17.1	3.4	65	< 3	27	56	388
Twp	3-2-06-9	JES-06-338	737298	3866133	25	160	0.033	1.7	7.3	< 3	543	2	16.7	3	67	< 3	28	51	393
Td	3-3-06-3	JES-06-348	736640	3865527	13	100	0.023	7.2	15.1	< 3	1533	< 1	16.9	3.6	123	< 3	32	71	386
Tcl	3-4-06-1	JES-06-358	736100	3873120	12	130	0.002	1	14.2	< 3	867	< 1	16.4	2.8	192	< 3	25	83	317

[†]NAD 27, Zone 11

TABLE 1D. Geochemistry of volcanic rocks, rare earth elements

Unit	Sample Number	Station	UTME[†]	UTMN[†]	La (ppm)	Ce (ppm)	Nd (ppm)	Sm (ppm)	Eu (ppm)	Tb (ppm)	Yb (ppm)	Lu (ppm)
					INAA	INAA	INAA	INAA	INAA	INAA	INAA	INAA
Txb	14642	CAF-2-14642	739811	3862202	25.8	49	23	4.8	1.4	0.7	2	0.32
Trp	14655	CAF-2-14655	739212	3863119	23.2	46	19	4.4	1.2	< 0.5	2	0.29
Tba	14707	CAF-2-14707	738615	3862982	14.5	31	13	3.8	1.2	< 0.5	3.2	0.47
Tb	14711	CAF-2-14711	738841	3862869	14.6	34	12	3.7	1.3	< 0.5	3	0.5
Tb	14775	CAF-2-14775	740164	3863333	15.5	37	16	3.8	1.1	0.7	3.1	0.47
Tb	14848	CAF-2-14848	736822	3868364	14.4	31	13	3.8	1.3	0.6	3.5	0.51
Tb	14850	CAF-2-14850	736869	3868221	13	28	12	3.4	1.2	0.6	3.1	0.47
Tb	14851	CAF-2-14851	736935	3868097	87.6	150	52	9.5	1.9	< 0.5	2.5	0.35
Txa	14855	CAF-2-14855	737112	3867582	23.9	45	18	4.5	1.3	< 0.5	2	0.27
Tb	14909	CAF-2-14909	736887	3868217	41.9	80	35	6.2	1.7	< 0.5	2.4	0.33
Twp	14926	CAF-2-14926	737397	3868641	44.7	82	29	6.3	1.7	< 0.5	2.5	0.36
Txa	15153	CAF-2-15153	736877	3867782	48.9	83	24	4.6	1.1	< 0.5	1.3	0.18
Td	15178	CAF-2-15178	738511	3867270	57.8	96	34	5.5	1.4	< 0.5	1.4	0.22
Twp	15421	CAF-2-15421	738112	3872111	37.3	66	22	4.2	1	< 0.5	1.1	0.17
Twpp	15423	CAF-2-15423	738388	3871976	49	85	29	5.8	1.3	0.5	1.5	0.22
Txb	15434	CAF-2-15434	739262	3872586	48.2	82	26	5.3	1.2	< 0.5	1.4	0.21
Txa	15440	CAF-2-15440	739551	3873018	49.8	84	31	5.8	1.4	< 0.5	1.5	0.22
Tb	15443	CAF-2-15443	739624	3872923	41.7	56	12	1.8	0.3	< 0.5	1.2	0.14
Tb	15444	CAF-2-15444	739648	3872917	100	177	66	10.2	2.4	0.8	1.9	0.28
Txa	15510	CAF-2-15510	739925	3873672	94.9	168	57	9.5	2.2	0.7	2	0.32
Tb0	15562	CAF-2-15562	740297	3868254	95.9	170	65	10.4	2.3	0.9	1.8	0.3
Tcl	15584	CAF-2-15583	736773	3875719	41.4	76	29	5.7	1.5	< 0.5	1.8	0.28
Tb	1-26-06-5	JES-06-175	737427	3862278	83.8	145	51	9	1.8	< 0.5	2.5	0.37
Txa	2-8-06-5	JES-06-245	736560	3867356	85	150	52	8.7	1.7	0.7	2.8	0.35
Txa	2-10-06-3	JES-06-267	737024	3868128	100	171	50	10.1	2	< 0.5	2.9	0.44
Td	2-28-06-4	JES-06-299	737831	3866326	86.5	151	53	8.8	1.7	< 0.5	2.5	0.39
Td	3-1-06-12	JES-06-316	737036	3865123	86.4	152	55	8.7	1.7	0.9	2.4	0.36
Twp	3-2-06-9	JES-06-338	737298	3866133	82.3	145	45	8.4	1.7	< 0.5	2.3	0.34
Td	3-3-06-3	JES-06-348	736640	3865527	131	235	92	16.9	3.8	< 0.5	2.2	0.33
Tcl	3-4-06-1	JES-06-358	736100	3873120	82.3	151	55	10	2.1	< 0.5	2	0.28

[†]NAD 27, Zone 11