Geologic Map of the Biscuit Flat 7.5' Quadrangle, Maricopa County, Arizona

by

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INTRODUCTION

The Biscuit Flat Quadrangle is located in the northwestern Phoenix metropolitan area, between Interstate 17 (I-17) and the Agua Fria River (Figure 1). The quadrangle is bounded by latitudes 33°45'00"N and 33°52'30"N, and longitudes 112°07'30"W and 112°15'00"W. Unlike areas to the south and southeast, the Biscuit Flat area is not (as yet) urbanized. However, knowledge of the distribution and character of bedrock and surficial deposits may be important to make informed decisions concerning future management of the land and its resources. Geologic mapping of the Biscuit Flat Quadrangle is related to other 1:24,000 scale mapping projects in and around the Phoenix metropolitan area (Figure 1). Geologic mapping was based on both field observations and interpretation of aerial photographs and soil surveys. Mapping of Quaternary surficial deposits was initially done by Huckleberry, whereas final mapping and interpretation of surficial deposits and bedrock areas was completed by Leighty. A limited amount of unpublished Arizona Geological Survey mapping (by Steve Reynolds and Mike Grubensky for the Phoenix North 1:100,000 scale geologic map) augmented the new mapping of this report. Also, the mapping of Tertiary rocks by Jagiello (1987) is locally similar to that of this report. Aerial photographic coverage of the quadrangle is available from various sources (e.g., U.S.G.S., Bureau of Land Management, etc.), and includes black-and-white (1:40,000 scale, dated 9-6-92), false-color high-altitude (dated 5-17-81), and color (1:24,000 scale, dated 10-25-77) photographs. Soil information was compiled from USDA Maricopa County soil surveys (Hartman, 1977; Camp, 1986). This project was funded by the Environmental Protection Agency through the State Indoor Radon Grant Program, the U.S. Geological Survey via the STATEMAP program, and the Arizona Geological Survey.

PREVIOUS STUDIES

Geologic investigations in the area encompassed by the Biscuit Flat Quadrangle are limited in number. The Proterozoic rocks exposed in the southern and southwestern areas have been described by Reynolds and DeWitt (1991), whereas the regional Proterozoic geologic setting has been summarized by several authors (e.g., Karlstrom et al., 1987; Karlstrom and Bowring, 1988, 1991; Anderson, 1989a,b; Karlstrom et al., 1990; Reynolds and DeWitt; 1991). More detailed studies of Proterozoic rocks have typically concentrated in the Phoenix Mountains, New River, New River Mountains, and Bradshaw Mountains areas (Aylor, 1973; Shank, 1973; Thorpe, 1980; Thorpe and Burt, 1978, 1980; Maynard, 1986, 1989; Anderson, 1989b; Reynolds and DeWitt, 1991; Bryant, 1994; Jones, 1996; DeWitt, unpublished mapping; Grubensky, unpublished mapping; Reynolds, unpublished mapping). Other geologic studies in the region have emphasized the Tertiary rocks and structures (Gomez, 1978; Gomez and Elston, 1978; Elston, 1984; Jagiello, 1987; Doorn and Péwé, 1991; Leighty et al., 1995; Leighty and Reynolds, 1996; Leighty, 1997). Bryant (1994) mapped the rocks in the New River Quadrangle to the north, and Huckleberry (1995) studied the Quaternary deposits of the Agua Fria River to the west. The uranium potential of Tertiary sedimentary deposits of the region was described by Scarborough and Wilt (1979), some of which are considered potential radon hazards (Duncan and Spencer, 1993; Harris, 1997; Harris et al., 1998). The Biscuit Flat area is also included in the 1:100,000 scale Phoenix North 30' x 60' Quadrangle (Demsey, 1988; Reynolds and Grubensky, 1993). This study is contiguous with 1:24,000 scale geologic mapping recently completed in several nearby quadrangles, including Hedgpeth Hills (Leighty and Huckleberry, 1998), Union Hills (Holloway and Leighty, 1998), New River SE (Leighty and Holloway, 1998), Cave Creek (Leighty et al., 1997), Wildcat Hill (Skotnicki et al., 1997), New River Mesa (Ferguson et al., 1998), and Humboldt Mountain (Gilbert et al., 1998) Quadrangles.

PHYSIOGRAPHY

Arizona can be divided into three physiographic/geologic provinces (Figure 1): the Colorado Plateau, the Transition Zone, and the Basin and Range. The Biscuit Flat Quadrangle lies within the Basin and

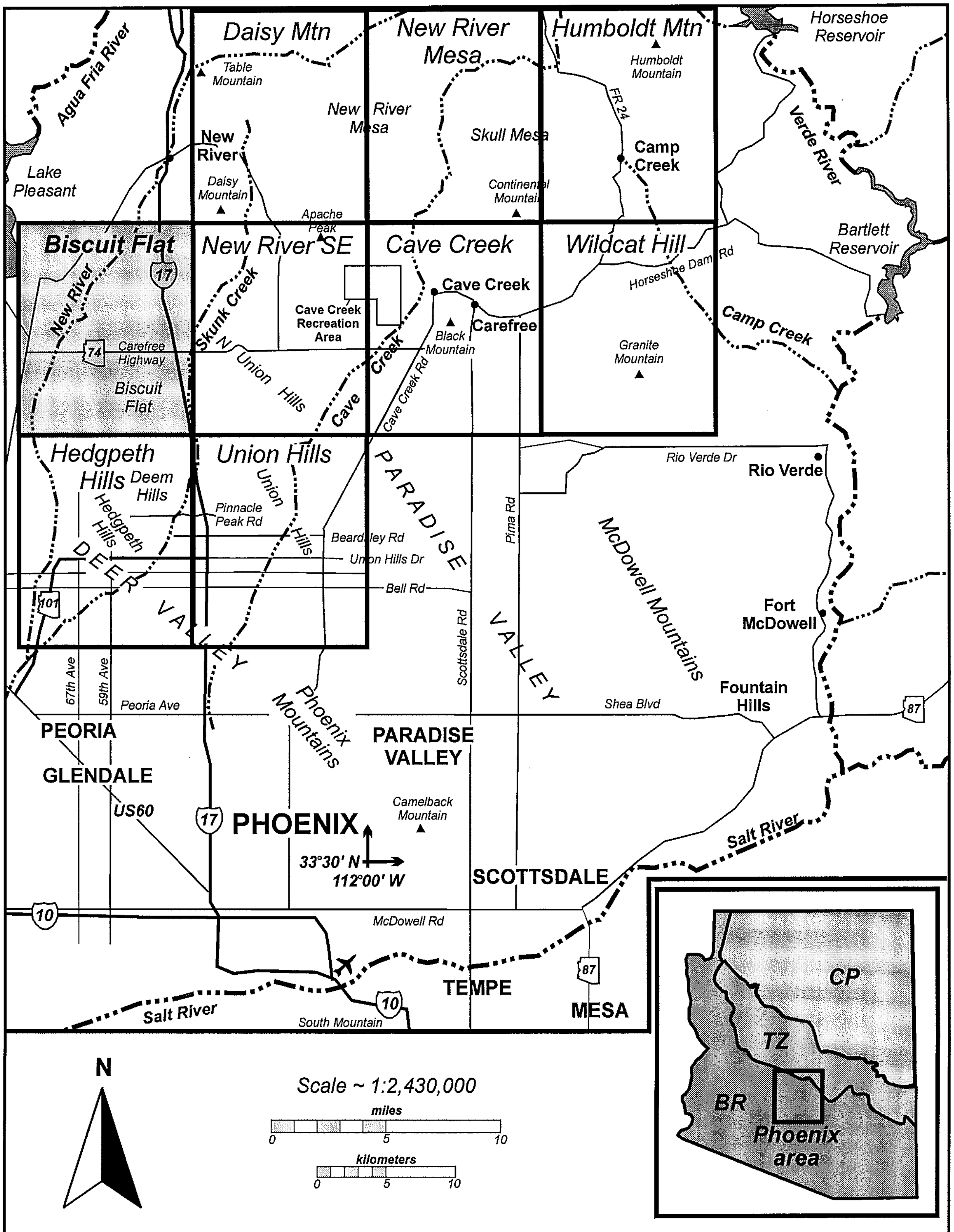

Figure 1. Location of the Biscuit Flat 7.5' Quadrangle in the Phoenix region. The inset map shows the location of the study area relative to the three physiographic provinces in Arizona: the Basin and Range (BR), Transition Zone (TZ), and Colorado Plateau (CP).

Range province in central Arizona, where the terrain includes NW-trending mountain ranges separated by alluvial valleys. The area north of Phoenix includes a number fault-bounded, NE-dipping, mountain ranges consisting of highly eroded Proterozoic and Cenozoic rocks. Although common in other parts of Arizona, Paleozoic and Mesozoic sedimentary rocks are absent in this area. The valleys are commonly filled with Cenozoic "basin-fill" sedimentary rocks and surficial deposits, with normal faults typically covered by alluvium. The Biscuit Flat Quadrangle contains geologic units that range in age from Early Proterozoic to Latest Cenozoic (Figure 2). Proterozoic rocks include Early Proterozoic metavolcanic rocks and Early to Middle Proterozoic granitic to dioritic rocks. Cenozoic rocks include Middle Tertiary silicic volcanic rocks, Early Miocene alkaline basalt, conglomerate, tuff, and tuffaceous sediment, Early to Middle Miocene andesite, Middle Miocene subalkaline basaltic lavas, and Plio-Pleistocene to Holocene river terraces and alluvium.

Much of the Biscuit Flat quadrangle is largely a low relief alluvial surface, with elevations varying between 1400 feet in southwestern areas and 1900 feet in northern areas. Several relatively small bedrock hills are present across the area, typically having between 100 and 600 feet of relief. The hills south of Deadman Wash and Biscuit Flat are eroded remnants of Proterozoic plutonic rocks that are generally surrounded by a low-relief, grus-covered pediment surface. The largest set of hills in this area (sections 13 and 24) are referred to in this report as the Snodgrass Tank Range. The NE-dipping ranges between the Carefree Highway and I-17 are the northwestern end of the North Union Hills. These hills are referred to in this report as, from south to north, the Rifle Range and the Deadman Wash Range, respectively. The Black Mountain area in the northwestern part of the quadrangle is the southern end of a moderately rugged basalt-capped terrain east of Lake Pleasant.

Several streams drain the Biscuit Flat area, including the New River, Skunk Creek, and Deadman Wash. The New River is a prominent, SW-flowing drainage that dominates the central and western parts of the quadrangle. The New River cuts into a broad, Middle Pleistocene alluvial plain, as well as Early Pleistocene terrace/fan deposits of the Agua Fria River. Several well-developed terraces (i.e., Qyr, Qlr, Qmr) are also present along this SSW-flowing drainage. The Agua Fria River is located just west of the quadrangle boundary and the New River joins the Agua Fria River further south. Skunk Creek is located on the southeastern boundary of the quadrangle and drains much of the Biscuit Flat area. Deadman Wash flows to the southwest, through the North Union Hills ranges, across Biscuit Flat, and joins the New River north of the Snodgrass Tank Range. Vegetation across the area is typical of the Sonoran Desert, with various desert grasses, ocotillo, brittle bush, creosote bush, buckhorn and teddy bear cholla, and other types of cacti, including saguaro.

Access for most parts of the Biscuit Flat Quadrangle is relatively good (Figure 2). Although the Carefree Highway (AZ 74) and the Lake Pleasant Road are the only major paved roads other than I-17, numerous variably maintained dirt roads make much of the quadrangle accessible. The Carefree Highway accommodates much of the traffic to Lake Pleasant Regional Park. A well-maintained dirt road connects the Lake Pleasant Road with I-17 and the New River area to the east. Access is restricted in several areas, including within the boundaries of the Ben Avery Shooting Range and the Federal Prison. Although the area adjacent to the Central Arizona Project (CAP) canal is restricted, the canal can be crossed at several locations (e.g., east of Pyramid Peak).

PROTEROZOIC GEOLOGY

The Proterozoic units exposed in the Biscuit Flat Quadrangle include Early to Middle Proterozoic granitic to dioritic rocks in the southern and southwestern areas, and Early Proterozoic metavolcanic rocks in the Deadman Wash Range. Similar Proterozoic rocks are also exposed in several nearby quadrangles (Anderson, 1989b; Reynolds and DeWitt, 1991; Reynolds and Grubensky, 1993; Bryant, 1994; Leighty et al., 1997; Holloway and Leighty, 1998; Leighty and Holloway, 1998; Leighty and Huckleberry, 1998).

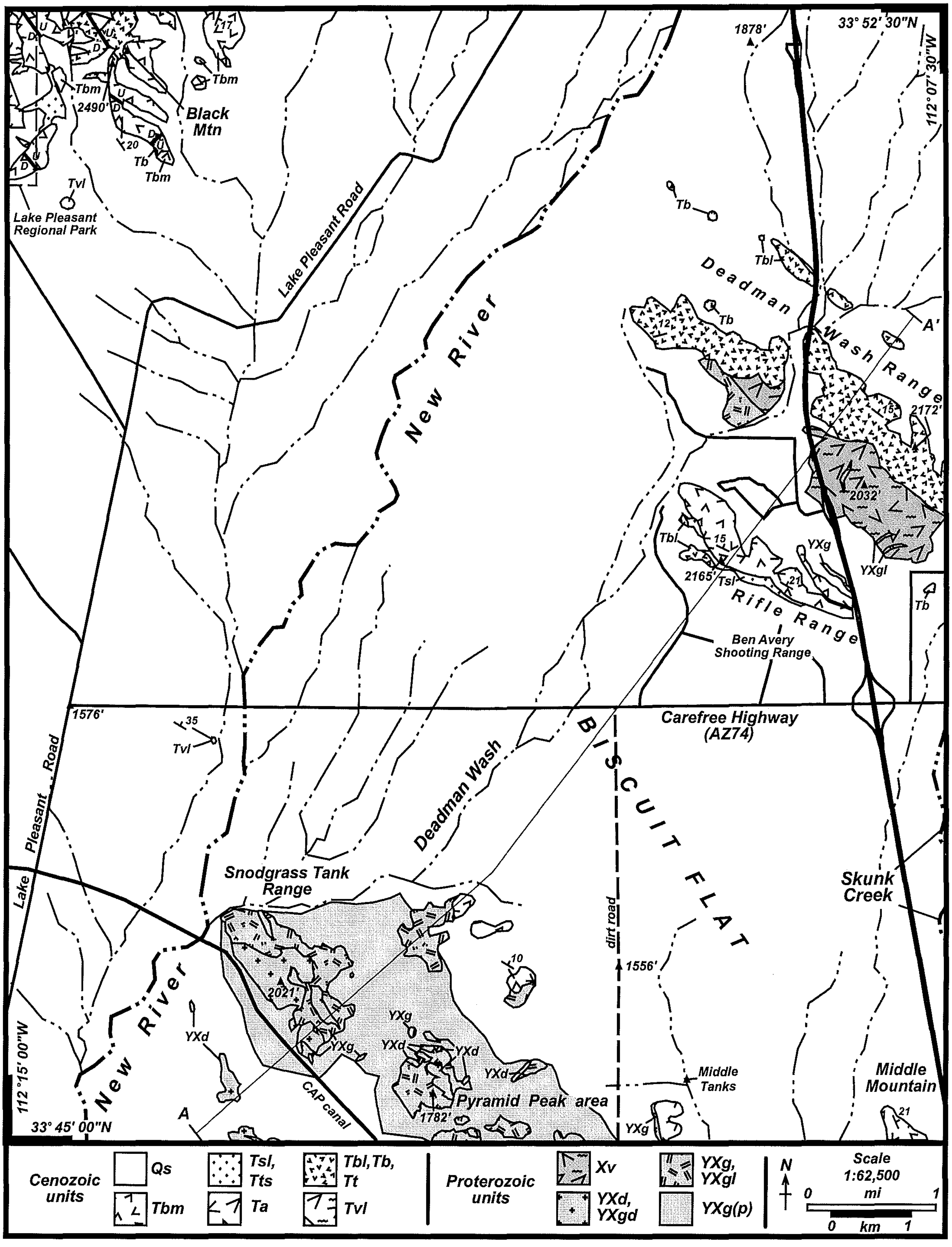

Figure 2. Generalized bedrock geology of the Biscuit Flat 7.5' Quadrangle with significant landmarks.

Early Proterozoic metavolcanic rocks

The metavolcanic rocks (Xva) exposed in the Deadman Wash Range represent the oldest Proterozoic units in the Biscuit Flat Quadrangle and include fine-grained metavolcanic rocks, amphibolite, quartzofeldspathic gneiss, and minor felsic tuffaceous and metasedimentary rocks. These rocks are intruded by several types of granitic rocks (i.e., YXg and YXgl) that are Early or Middle Proterozoic in age (1700 to 1300 Ma). This metavolcanic-dominated assemblage may correlate with similar rocks in the Union Hills, North Union Hills, and Daisy Mountain areas to the east. These units are part of an Early Proterozoic terrane containing rocks of similar age, metamorphic grade, and deformational fabric, largely correlative with the Tonto Basin Supergroup and Diamond Rim Intrusive Suite (1740 to 1680 Ma; Anderson and Guilbert, 1979; Maynard, 1986, 1989; Reynolds et al., 1986; Anderson, 1989a,b; Conway and Silver, 1989). The metavolcanic rocks of the Biscuit Flat Quadrangle may specifically correlate with the mafic to intermediate metavolcanic rocks of the Union Hills Group, the oldest part of the Early Proterozoic Tonto Basin Supergroup (Anderson and Guilbert, 1979; Karlstrom et al., 1987; Anderson, 1989a,b; Conway and Silver, 1989). The Union Hills Group (1740 to 1720 Ma) includes dominantly andesitic to dacitic flows and tuffs, and related volcaniclastic rocks, with subordinate iron-formation, and is exposed from the Phoenix area to the Sierra Ancha to the northeast (Anderson, 1989b; Reynolds and DeWitt, 1991; Leighty et al., 1997; Holloway and Leighty, 1998; Leighty and Holloway, 1998).

Early to Middle Proterozoic plutonic rocks

In the southwestern part of the quadrangle, a largely undeformed granodiorite-diorite complex (informally named the tonalite of Biscuit Flat; Reynolds and DeWitt, 1991) includes diorite, microdiorite (hypabyssal diorite?), tonalite, and granodiorite. Similar rocks are exposed to the south at East Wing Mountain and the Sunrise Relief Hills (in the Hedgpeth Hills Quadrangle). According to Reynolds and DeWitt (1991), these rocks appear fresh in outcrop, but are strongly metamorphosed and altered in thin section; plagioclase is extensively replaced by carbonate minerals, and epidote minerals constitute much of the groundmass. This style of alteration and metamorphism may be similar to that displayed in the Early Proterozoic (~1730-Ma?) Badger Spring pluton north of New River (DeWitt, unpub. data). The exact age relations of the granodiorite-diorite unit (YXd) are speculative, and this unit could represent 1) Early Proterozoic intrusions or 2) a comagmatic facies related to the coarse-grained granite (YXg).

A relatively unfoliated, coarse-grained granite (YXg) intrudes the metavolcanic rocks (Xva) and plutonic complex (YXd). This variably porphyritic granite has been informally referred to as the granite of Pyramid Peak (Reynolds and DeWitt, 1991). Most exposures of the granite contain scattered K-feldspar phenocrysts (as long as 2 cm). This coarse-grained granite is possibly correlative with the large, regionally extensive Middle Proterozoic (1422-Ma, C. Isaacson, pers. comm.) granitic batholith exposed north of the McDowell Mountains to the east, as well as other Middle Proterozoic (1425 to 1335 Ma) megacrystic granites in Arizona (Silver, 1968; Livingston and Damon, 1968; Reynolds et al., 1986). However, it is also possible that this largely unfoliated granite is a post-tectonic Early Proterozoic granite.

Areas marginal to granitic bedrock include granitic pediment or very thin mantles of alluvial deposits (typically a few meters or less thick) over pediment. These YXg(p) deposits are typically poorly indurated and are composed of granitic grus and sand- and silt-sized material shed from the granitic bedrock.

A relatively undeformed, leucocratic granitoid rock (YXgl) intrudes the metavolcanic rocks in the southeastern part of the Deadman Wash Range east of I-17. This rock likely correlates with the granite exposed along the Carefree Highway east of I-17 (Leighty and Holloway, 1998). These leucocratic granitic rocks may represent highly differentiated, pluton-marginal intrusions of either Early or Middle Proterozoic age.

CENOZOIC GEOLOGY

Cenozoic rocks in the Biscuit Flat Quadrangle include Late Oligocene to Miocene intermediate and felsic rocks, Early Miocene basaltic lavas, tuff, and fluvial-lacustrine deposits, Middle Miocene subalkaline basaltic lavas, and Quaternary surficial deposits. These Middle and Late Tertiary volcanic and sedimentary rocks are exposed in a few small tilt-block ranges (i.e., Rifle Range, Deadman Wash Range, etc.) and beneath the mesas in the Black Mountain area. Late Tertiary "basin-fill" sedimentary rocks are not exposed in the quadrangle, but are likely present beneath the cover of Quaternary surficial deposits.

Late Oligocene to Middle Miocene felsic/intermediate volcanic rocks

Although voluminous ash-flow-related volcanism occurred across the Arizona Basin and Range during the Middle Tertiary, exposures of rocks representing this volcanism are relatively sparse in the northern Phoenix area. Except for trachyandesite remnants (17.6-Ma) in the Tempe area (i.e., Bell Butte and Tempe Butte) and the West Wing Mountain dacitic flow and breccia unit, no significant ash-flow tuff units are present in the area. However, a significant volume of Early Miocene trachyandesite, rhyolite, and basalt are exposed in the Hieroglyphic Mountains (Ward, 1977; Satkin, 1981; Capps et al., 1986; Kortemeier et al., 1986; Leighty, 1997). Along the Basin and Range-Transition Zone boundary to the north, silicic volcanism was also generally potassic in composition (trachytic and trachyandesitic) and localized in extent. Late Oligocene to Early Miocene (26.5 to 17.7 Ma) trachyte, trachyandesite, and andesite domes and flows are exposed in several areas between the Agua Fria and Verde Rivers, including at western New River (26.5-Ma), Gavilan Peak (22.0-Ma), New River Mesa, and Camp Creek (Gomez, 1978; Esperança, 1984; Jagiello, 1987; Leighty, 1997). Many of these rocks are inclusion-bearing and host crustal xenoliths

In the Biscuit Flat Quadrangle, several relatively small exposures of intermediate and felsic volcanic rocks are present. In the Black Mountain area, Middle Tertiary (Late Oligocene to Early Miocene) felsic volcanic rocks (Tvl) are also exposed, largely beneath a thick sequence of Early to Middle Miocene tuff and tuffaceous sediment (Tts). A small exposure of NE-dipping felsic rock is exposed along the New River, but it is not known whether it correlates with the felsic rocks in the Black Mountain area or the dacitic flows and breccias in the West Wing Mountain area to the south (in the Hedgpeth Hills Quadrangle). All of these felsic rocks may be related to the Early Miocene rhyolite, latite, and dacite in the Hieroglyphic Mountains to the northwest (Ward, 1977; Satkin, 1981; Capps et al., 1986; Kortemeier et al., 1986; Leighty, 1997). The hill south of Middle Tanks is capped by a subporphyritic andesite lava (Ta), and may be equivalent to similar Early to Middle Miocene andesite in the Deem and Hedgpeth Hills to the south.

Early to Middle Miocene rocks

Scattered exposures of Early Miocene basaltic rocks, felsic tuffs, and fluvial-lacustrine sediments are present across the Biscuit Flat Quadrangle, including along the southern margin of Biscuit Flat, in the Rifle and Deadman Wash Ranges, and in the Black Mountain area in the northwestern part of the quadrangle. These rocks are typical of the Chalk Canyon formation (Gomez, 1978; Jagiello, 1987; Leighty, 1997) and similar lithologic sequences recognized at locations across the region (e.g., eastern Lake Pleasant, north Phoenix, New River, Black Canyon City, Cave Creek, etc.; Leighty, 1997). The Chalk Canyon formation be subdivided into lower and upper members: the lower member (23 to ~17 Ma) consists mainly of interbedded alkaline basalts and crystal/lithic tuffs, whereas the upper member is dominated by fluvial-lacustrine deposits (Lindsay and Lundin, 1972; Eberly and Stanley, 1978; Gomez, 1978; Scarborough and Wilt, 1979; Jagiello, 1987; Leighty, 1997).

Basaltic lavas. The basaltic lavas (Tbl, Tb) generally have porphyritic to vesicular overall textures, with microcrystalline, cryptocrystalline, and trachytic groundmass textures. Phenocryst assemblages (5-15% phenocrysts) include olivine and olivine + clinopyroxene. Euhedral to subhedral olivine microphenocrysts are partially to totally oxidized, whereas subhedral clinopyroxene microphenocrysts are typically unaltered. Groundmass phases are dominated by plagioclase, ranging from euhedral laths to cryptocrystalline microlites, with euhedral clinopyroxene, altered olivine, and opaque oxide grains being less abundant. Fine-grained clinopyroxene glomerocrysts are also common. Some of the lavas underlying the thin layer of lacustrine sediments in the Rifle Range contain hornblende pseudomorphs and orthopyroxene, and may be more andesitic or subalkaline (rather than alkaline basalt) in composition. These basalts are typically moderately vesicular (3-7%), having rounded, calcite-filled vesicles.

Other interbedded basalt-tuff sequences are exposed in nearby areas (e.g., New River Mesa, Sugarloaf Mountain, New River, Apache Peak, etc.). To the north in the New River Mesa Quadrangle, one of the lowest exposed alkaline basalt flows east of Sugarloaf Mountain (21.34 ±0.46 Ma, Scarborough and Wilt, 1979) overlies a lithic tuff containing an oreodont fossil, the oldest known mammal in Arizona (Lindsay and Lundin, 1972; Leighty, 1997). In the New River area at Pyramid Peak, basaltic and andesitic rocks (17.72 ±0.37 Ma, Scarborough and Wilt, 1979) are interbedded with several felsic tuffs, including a prominent vitrophyre.

Tuff. Felsic tuff and tuffaceous sandstone (Tt) are interbedded with the basaltic rocks in the east-central part of the quadrangle. In the Rifle Range, beneath the fluvial-lacustrine layer, tuff and poorly sorted tuffaceous sandstones containing pumice and andesite clasts, are interbedded with olivine+clinopyroxene basalts (Scarborough and Wilt, 1979; Jagiello, 1987). The tuffs are generally covered in the Rifle Range, but are more well-exposed in the Deadman Wash Range. A relatively thick section of tuff and tuffaceous sediment (Tts) is also exposed in the Black Mountain area. The tuffs and interbedded basaltic rocks exposed across the quadrangle correlate with the lower member of the Chalk Canyon formation.

Fluvial-lacustrine deposits. White lakebed sediments (Tsl) disconformably underlie the Middle Miocene basaltic lavas at the Rifle Range. These rocks include variably silicified dolomite and marl beds; the lower dolomitic unit is brecciated and contains extensive chert replacements and stringers, whereas the upper unit has only minor silicification (Scarborough and Wilt, 1979; Jagiello, 1987). These fluvial-lacustrine deposits are correlative with the upper member of the Chalk Canyon formation. Regionally, the top of the lacustrine unit generally forms the boundary between the Chalk Canyon and Hickey Formations. This contact typically has a slight angular discordance, and a thin paleosol is also common at this horizon. These relations suggest a hiatus of indeterminate length between the final deposition of Chalk Canyon formation lakebed sediments and the eruption of Hickey Formation basaltic rocks in this area (15.39 ±0.4 Ma, Scarborough and Wilt, 1979). In the Cave Creek Quadrangle to the east, basalt (15.4 Ma) and fluvial-lacustrine sediments of the upper member are overlain by a sequence of 13.4 Ma Hickey Formation basaltic lavas (Doorn and Péwé, 1991; Leighty et al., 1997). Hickey Formation basaltic flows (15.40 ±2.10 Ma, Eberly and Stanley, 1978) overlie (and may be interbedded with) the fluvial-lacustrine rocks in the Black Canyon City area to the north (Leighty, 1997).

Middle Miocene rocks

Middle Miocene basaltic volcanism was widespread across the Basin and Range and Transition Zone, and is dominantly represented by subalkaline lavas of the Hickey Formation and correlative rocks (Anderson and Creasey, 1958; McKee and Anderson, 1971; Eberly and Stanley, 1978; Gomez, 1978; Elston, 1984; Jagiello, 1987; Leighty and Glascock, 1994; Leighty, 1997). A series of Middle Miocene Hickey Formation basaltic flows (14.8 to 13.4 Ma) are well-exposed along the Basin and Range/Transition Zone boundary to the north of the Biscuit Flat Quadrangle. Indeed, Hickey Formation sheet lavas may have once extended across the much of the Biscuit Flat Quadrangle, and are exposed in several locations (e.g., the Rifle Range, the Black Mountain area, southwest of Biscuit Flat, and Middle Mountain). At the Rifle Range, the basaltic flows (15.39 ±0.4 Ma, Scarborough and Wilt, 1979) overlie Chalk Canyon formation dolomites with a slight angular unconformity. Similar intergranular plagioclase ± olivine ± clinopyroxene subalkaline basalts and basaltic andesites also cap many of the fault-block ranges in the north Phoenix area (e.g., Shaw Butte, Deem and Hedgpeth Hills, etc.). Intergranular vesicles and large, open vesicles (commonly in columns or trains) also make these lavas distinctive from older the Chalk Canyon formation lavas. These Hickey Formation lavas have been referred to as the New River Mesa basalt (Gomez, 1978; Jagiello, 1987), but they simply represent the local equivalent of the more regionally extensive Hickey Formation (Leighty, 1997).

Middle and Late Tertiary extensional tectonism

Middle to Late Tertiary extensional tectonism significantly affected the Phoenix area, forming the distinctive Basin and Range physiography. Across the region, Early Miocene extension was fundamentally different in magnitude, style, and orientation compared with the Middle to Late Miocene period of normal faulting. However, in the north Phoenix area, there are several similarities in the style and orientation of the two extensional phases.

Middle Tertiary. Following relative tectonic quiescence of the Early Tertiary, significant extensional tectonism occurred across the Arizona Basin and Range during the Middle Tertiary (Late Oligocene and Early Miocene), and has been referred to as the "mid-Tertiary orogeny" (Damon, 1964). The Transition Zone and Colorado Plateau did not experience significant upper crustal extensional deformation during this time, but the reversal of regional drainage and formation of the Mogollon Rim was a likely effect of middle to lower crustal deflation in response to extension in the adjacent Basin and Range (Spencer and Reynolds, 1989). Middle Tertiary tectonism was dominantly characterized by ENE-WSW-directed extension along low-angle normal faults (or detachment faults) and subsequent fault-block rotation, typically related to the development of metamorphic core complexes (Coney, 1973; Davis and Coney, 1979; Coney, 1980; Crittenden et al., 1980; Davis, 1980; Wernicke, 1981; Reynolds, 1982; Davis, 1983; Davis et al., 1983; Lister and Davis, 1983; Reynolds, 1985; Reynolds and Lister, 1987; Spencer and Reynolds, 1989). Middle Tertiary extension in Arizona was broadly related to the evolving plate-tectonic setting of the continental margin of western North America (Atwater, 1970), and more specifically to changes in plate motions and geometries compounded by overriding of the progressively thinner and hotter subducted Farallon plate (Coney and Reynolds, 1977; Coney, 1978; Damon, 1979).

In south-central Arizona, initiation of extension-related tilting occurred before or during felsic volcanism (roughly 25 to 20 Ma) and generally ended before 17-Ma, except in a NW-trending belt adjacent to the relatively unextended Transition Zone (Fitzgerald et al., 1994; Spencer et al., 1995). Movement on detachment faults related to the South Mountain-White Tank composite metamorphic core complex was responsible for relatively large amounts of Early Miocene extension in the Phoenix area (Spencer and Reynolds, 1989). In the northern Phoenix area, the South Mountain detachment fault is visible on seismic reflection profiles (Frost and Okaya, 1986) and projects in the subsurface to the northeast beneath the NW-trending, tilted fault-block ranges that represent the upper plate of the core complex (Spencer and Reynolds, 1989). This area of generally unidirectional, NE-tilting in the Basin and Range has been referred to as the Camelback tilt-block domain (Spencer and Reynolds, 1989). Several SW-dipping normal faults are responsible for the northeast tilting of the Rifle and Deadman Wash Ranges. The amount of displacement along these faults is not known, but the faults may be listric in geometry to account for fault-block rotation. Cross section A-A' shows a half-graben structure formed by SW-side-down movement along one or more normal faults. These faults are covered by Late Cenozoic deposits and can only be inferred from stratigraphic relations and well-log data. The cross section assumes that the depth to bedrock in this area is generally not more than 1000-1500 feet deep. Well-log and detailed gravity data are not available for much of the area.

During the Early and Middle Miocene, synextensional basaltic lavas, sedimentary rocks, and tuffs of the Chalk Canyon formation (23 to ~15 Ma) and Hickey Formation (16 to <10 Ma) were erupted/deposited across central Arizona. Hickey Formation sheet lavas may have extended across the much of the northern Phoenix area, where the youngest dated lavas are 15.4-Ma in the eastern Biscuit Flat Quadrangle. Similar lavas cap many of the other ranges in the Phoenix area. Accordingly, the NE-directed tilt-block rotation occurred sometime after 15.4-Ma (and possibly <13.4-Ma), probably with movement along large, possibly listric, SW-dipping normal faults. This extension may have been related to waning metamorphic core complex extension and/or block faulting of the Basin and Range Disturbance (Menges and Pearthree, 1989; Leighty and Reynolds, 1996). However, the post-15.4-Ma rotation of these fault-blocks is significantly younger than the inferred age of active metamorphic core-complex extension. Indeed, this rotational style of faulting may have overlapped to some degree with the beginning of high-angle normal faulting of the Basin-and-Range Disturbance (Menges and Pearthree, 1989; Leighty et al., 1996). To explain these relationships, it has been suggested that the long duration and magnitude of core-complex extension adjacent to the Transition Zone are consistent with a more passive mechanism of extension where the gravitational potential energy of the thicker Transition Zone crust caused southwest-directed collapse (Spencer et al., 1995).

Late Tertiary. The Basin-and-Range Disturbance represents a period of graben subsidence that occurred along high-angle normal faults, largely without major crustal block rotation. In the Arizona Basin and Range, it began ~15-Ma and ended ~8-Ma (Eberly and Stanley, 1978; Menges and Pearthree, 1989). Basin subsidence was probably not simultaneous, but mostly occurred before 8-Ma when differential vertical movement essentially ceased, pediments formed, and basins filled (Shafiqullah et al., 1980). Newly created basins filled with undeformed fluvial and lacustrine deposits and basaltic rocks that were deposited over tilted beds deformed by earlier mid-Tertiary normal faulting. Subsidence also disrupted the Early Miocene drainage, facilitating internal drainage in many basins (Shafiqullah et al., 1980). Similar elevations of pediment gravel layers suggest that basin subsidence occurred with little or no change in the absolute elevation of the surrounding ranges (Peirce, 1976; Peirce et al., 1979). From well log and geophysical data, the depth of several of the large, deep Miocene basins (e.g., the Paradise Valley basin) in the Phoenix metropolitan area exceeds 10,000 feet (Oppenheimer, 1980). Much of the Biscuit Flat Quadrangle is entirely covered by Quaternary surficial deposits, but existing geophysical evidence (Lysonski et al., 1980; Oppenheimer and Sumner, 1980, 1981) does not support the presence of large, high-angle normal faults nor deep structural basins.

Quaternary surficial sediments

Quaternary surficial deposits cover much of the Biscuit Flat Quadrangle, and include Early Pleistocene to Recent piedmont and fluvial units. Piedmont deposits were shed onto broad plains that slope gently down from several small mountain ranges. These piedmont deposits are generally poorly sorted (e.g., silt or clay to cobbles or boulders), but generally grade or interfinger downslope into finer-grained deposits. The older alluvial units (e.g., Qo, Qm) are typically extensively eroded, leaving rounded ridges between modern channels. Fluvial sediments include active channels and one or more terrace levels that record former, higher positions of stream channels. These deposits are differentiated from piedmont deposits by their diverse lithologic composition, clast rounding, and landform morphology that is commonly elongate and mimics the general trend of the modern rivers. Similar units have been described across the Phoenix region (Demsey, 1988; Pearthree et al., 1997).

Piedmont deposits. The oldest piedmont deposits (Qo) are restricted to the northeastern portion of the quadrangle. These Early Pleistocene deposits are weakly consolidated, with relatively weak soil development because the original depositional surface has typically been removed by erosion. Much of the Biscuit Flat Quadrangle is covered by broad Middle Pleistocene piedmont deposits (Qm). These surfaces have typically been eroded into shallow valleys and low ridges, with original depositional surfaces possibly preserved along ridge crests. Late Pleistocene alluvium (Ql), such as that covering the piedmont area on the southwestern side of Biscuit Flat, is typically moderately incised by stream channels, but still contains constructional, relatively flat, interfluvial surfaces. Holocene alluvial deposits (Qy) consist primarily of small active channels and low terraces. Qy terrace surfaces generally exhibit bar-and-swale topography, with the ridges typically being slightly more vegetated. Unconsolidated to moderately consolidated colluvium and talus deposits (Qc, Qct) are common on hillslopes. These undifferentiated Middle Pleistocene to Holocene deposits typically include poorly sorted, sand- to boulder-sized clasts. Adjacent and underlying bedrock lithologies dominate the clast compositions.

Fluvial deposits. Terrace and channel deposits include units related to the Agua Fria River, New River, and Deadman Wash. Early Pleistocene terrace deposits (Qor) related to the Agua Fria River are present to the west of the New River. These terrace deposits represent the highest and oldest terrace of the Agua Fria River, and may represent some of the oldest landforms in the northern Phoenix area. Qor deposits do not contain a well-developed desert pavement, nor do they contain a very thick argillic horizon. However, a petrocalcic-petroduric horizon is commonly exposed, with broken pieces commonly scattered across the surface. There is little infiltration into these indurated soils. Qor terrace soil is mostly degraded, with a Stage V+ petrocalcic horizon that extends over 4 m in depth. Other terraces (Qmr, Qlr, and Qyr) are exposed along the New River main drainage in the central part of the quadrangle. Other Late Pleistocene to Recent fluvial sediments (Ql, Qlr, Qyr, and Qycr) are restricted to fairly narrow bands along washes (e.g., Deadman Wash, Skunk Creek, etc.).

GEOLOGIC HAZARDS

A variety of potential geologic hazards exist in the study area. The primary geologic hazards that may affect this area are flooding, soil problems, and possibly radon. The general character of these hazards and the areas that may be affected by them are summarized below.

Flooding

Flooding is probably the most serious geologic hazard of the Biscuit Flat Quadrangle. Potential flood hazards consist of inundation and erosion along the New River and Skunk Creek and their larger tributaries, and flash-flooding associated with the smaller tributary streams that flow across the piedmonts of the area. New River is a moderately large drainage that heads in the Transition Zone north of the Biscuit Flat quadrangle. Large floods (e.g., 100-year floods) involve deep, high-velocity flow in channels, inundation of overbank areas, and may cause substantial bank erosion along the channels. Areas mapped as Qyc are likely to be affected by deep, high velocity flow during floods. Adjacent areas mapped as Qy are likely to be subject to shallower inundation, and local bank erosion. Areas near these large streams covered by older deposits (Ql, Qlr, and older) generally are not subject to inundation, but they may be affected by lateral stream erosion.

Flood hazards associated with smaller tributaries may be subdivided into (1) localized flooding along well-defined drainages, where there is substantial topographic confinement of the wash; and (2) widespread inundation in areas of minimal topographic confinement (i.e., active alluvial fans). Delineation of flood-prone areas along well-defined drainages is fairly straightforward; these hazards may be mitigated by avoiding building in or immediately adjacent to washes. The Central Arizona Project (CAP) canal alleviates some of the damaging effects of tributary flooding. Floods leave behind physical evidence of their occurrence in the form of deposits. Therefore, the extent of young deposits on piedmonts is an accurate indicator of areas that have been flooded in the past few thousand years. These are the areas that are most likely to experience flooding in the future. Accordingly, the extent of potentially flood-prone areas on a piedmont may be evaluated based on the extent of young deposits (Qy).

Soil/substrate problems

Several types of soil/substrate problems may be encountered in the Biscuit Flat Quadrangle. Soil compaction or expansion upon wetting or loading may be an important geologic hazard in limited portions of the quadrangle. Soil instability has caused extensive damage to buildings in Arizona (Christenson et al., 1978; Péwé and Kenny, 1989). Changes in soil volume beneath structures may cause damage ranging from nuisance cracks to serious structural damage. Deposits that are susceptible to compaction are typically relatively fine-grained, young sediments (e.g., Qy, Qyr, and Ql). Clay-rich soils associated with the well-preserved Early and Middle Pleistocene alluvial fans (Qo, and locally, Qm) may have some potential for shrinking and swelling during dry and wet periods, respectively. However, clay-rich horizons associated with these surfaces are generally less than 1 m thick, so their shrink-swell potential is probably limited.

The presence of cemented caliche (petrocalcic soil horizons) or shallow bedrock may impact construction excavation and leaching potential. Typically, the soils associated with Middle Pleistocene alluvium (Qm) in this area have significant accumulations of calcium carbonate, but strongly cemented carbonate soil horizons are not common. Petrocalcic horizons are common in Early Pleistocene alluvium (Qo), and are found in some Qm and thin hillslope deposits (Qct). Progressively less carbonate accumulation is associated with increasingly younger surfaces, such that Ql and younger deposits have weak carbonate accumulations. Some of the map area is composed of granitic pediment or very thin mantles of alluvial deposits (typically a few meters or less thick) over pediment. These YXg(p) deposits are typically poorly indurated and are composed of granitic grus and much sand- and silt-sized material shed from the granite bedrock and do not pose a serious obstacle to excavation. Weathered bedrock typically found beneath the alluvial deposits is generally highly weathered and easily excavated.

Radon

Radon, a colorless, odorless, radioactive gas, can pose potential health problem in certain circumstances. Radon can escape from the ground into overlying homes and other buildings, and result in elevated radiation exposure, and associated risk of cancer, to human lungs. Radon is a decay product of uranium, so areas with higher uranium concentrations present greater risk of elevated indoor radon levels (Peake and Schumann, 1991; Spencer, 1992). Uranium is present in all geologic materials, generally in concentrations of 1 to 10 ppm. Levels greater than 6 ppm U can be considered slightly anomalous. The alluvial basin cover in the region is not a significant radon hazard, but certain types of bedrock can have highly variable concentrations of uranium. In the Phoenix area, lithologies that have demonstrated elevated uranium levels, thus posing a potential radon hazard, include certain Proterozoic granitic rocks and Middle Tertiary sedimentary rocks (marl).

Since much of the Biscuit Flat Quadrangle is covered by Quaternary deposits, radon is probably not a significant hazard for much of the area. However, coarse-grained granite (YXg) underlies much of the south-central part of the quadrangle, and generally forms gentle slopes and low hills that are not an impediment to construction of new homes or other buildings. Uranium levels in this granite (6 ppm), measured *in situ* with a gamma-ray spectrometer, are considered moderate to marginally high (Harris et al., 1998). High variability of uranium levels observed in similar granitic rocks in the Cave Creek-Carefree area is possibly due to different amounts of leaching of uranium from weathered granite at or near the surface. The occurrence of local elevated uranium concentrations, plus the generally permeable character of weathered granite which allows radon to leak out of the ground (Peake and Schumann, 1991), indicate that elevated radon levels in homes built on this granite are probably more likely than on most other geologic materials in the Biscuit Flat area. The thin, calcareous sedimentary rocks (Tsl) of the Chalk Canyon formation in the Rifle Range contains anomalous uranium levels that could be a significant radon hazard (Scarborough and Wilt, 1979). Similar lakebed sediments with high radon potential are exposed in the New River, Cave Creek, and Carefree areas (Harris, 1997). This unit has limited exposure in the Biscuit Flat area, but its extent in the subsurface is unknown.

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UNIT DESCRIPTIONS

Quaternary piedmont deposits

Qc **Colluvium (<750 Ka)** - Unconsolidated to moderately consolidated colluvium on gently sloping hillsides. These deposits are typically weakly bedded, subangular to angular, poorly sorted sand and gravel. Adjacent and underlying bedrock lithologies dominate the clast compositions. These hillslope deposits probably range in age from Holocene to Middle Pleistocene.

Qct **Colluvium and talus, undivided (<750 Ka)** - Unconsolidated to moderately consolidated colluvium and talus deposits on steeper hillslopes. These deposits are typically include subangular to angular, poorly sorted, sand- to boulder-sized clasts. Adjacent and underlying bedrock lithologies dominate the clast compositions. These hillslope deposits probably range in age from Holocene to Middle Pleistocene.

Qy **Holocene alluvium (<10 ka)** - Holocene alluvial deposits consist primarily of small active channels, and low terraces. This unit is characterized by unconsolidated, stratified, poorly to moderately sorted sand, gravel, cobble, and boulder deposits confined to the modern tributary drainages of the New River, Deadman Wash, and Skunk Creek. Alluvial surfaces exhibit bar-and-swale topography, with the ridges typically being slightly more vegetated. Frequently mantled by sandy loam sediment. Qy surfaces have minimal or no rock varnish or desert pavement development. Late Holocene soils are minimally developed, but Middle and Early Holocene typically contain cambic horizons, weak calcic horizons (≤Stage I), and are noticeably reddened. Surface colors are light brown to yellowish brown, with a slight reddening with depth due to oxidation. Some of the older Qy soils may contain weakly developed argillic horizons. Qy soils are classified as Torrifluvents, Torriorthents, Camborthids, and Calciorthids. Because surface soils are not indurated with clay or calcium carbonate, Qy surfaces have relatively high permeability and porosity. All areas mapped as Qy may be subject to inundation during large floods.

Qyl **Holocene to Late Pleistocene fine-grained alluvium (<100 ka)** - Relatively young, Holocene to Late Pleistocene alluvium overlie Middle Pleistocene deposits in the Black Mountain area.

Ql **Late Pleistocene alluvium (10 to 250 ka)** - Late Pleistocene alluvial fan surfaces and terraces consisting of moderately sorted, clast-supported sandstone and conglomerate with abundant granitic or metamorphic gravel clasts in a tan to brown sandy to silty matrix. Ql surfaces are moderately incised by stream channels, but still contain constructional, relatively flat, interfluvial surfaces. Subdued bar and swale topography is common. Desert pavement and rock varnish development ranges from nonexistent to moderate. Surface colors are slightly more red (light brown to reddish yellow) than Qy surfaces. Ql soils are also more strongly developed than Qy soils. Ql soils commonly contain tan to red-brown argillic horizons that are weakly to moderately strongly developed. These soils typically have Stage II-III calcium carbonate development. Ql soils are classified as Haplargids, Camborthids, and Calciorthids. The relatively low infiltration rates of these surfaces favor plants that draw moisture from near the surface. Ql surfaces are generally not prone to flooding, except immediately adjacent to active washes.

Qm **Middle Pleistocene alluvium (250 to 750 ka)** - Dissected Middle Pleistocene alluvial fan and terrace deposits that include sandy to loamy, tan sandstones and minor conglomerates with sand- to boulder-sized clasts. Qm surfaces have typically been eroded into shallow valleys and low ridges. Original depositional surfaces may be preserved along ridge crests. Desert pavement and rock varnish development is moderate to strong on stable surfaces, but variable to weak on surfaces that have been significantly eroded. Locally, Qm has been subdivided into older (Qm_1) and younger members (Qm_2). Qm soils are moderately to strongly developed, with surfaces ranging in color from strong brown to reddish brown. These soils typically contain reddened argillic horizons that are moderately to strongly enriched in pedogenic clay. Calcic horizon development is typically fairly strong (Stage II-IV), but Qm soils generally do not have cemented petrocalcic horizons (caliche). These soils are classified as Calciorthids and Haplargids. Qm surfaces are not prone to flooding, except near active washes.

Qo **Early Pleistocene alluvial fan deposits (750 Ka to 1.6 Ma)** - Sandy to loamy, brown-colored conglomerates. These deposits are moderately consolidated and commonly are indurated by soil carbonate. Deposits are moderaately to deeply dissected by the larger drainages. Reddish-brown argillic horizons are moderately- to well-developed on planar, relatively well-preserved alluvial surface remnants. Cemented petrocalcic are commonly exposed on side slopes below ridge crests. Exposed southwest of Daisy Mountain in the northeastern part of the quadrangle.

Quaternary river deposits

Qycr **Active channel deposits (<1 ka)** - Deposits in the active channels of the New River. Predominantly sand and silt, especially in areas subject to overbank flooding, with clasts ranging in size from pebbles to boulders. Clasts are subrounded to well-rounded and lithologies vary substantially. Distributary and anastomosing channel patterns are common. Most of the channel surfaces are modern in age, but vegetated bars may be several hundred years old. Alluvium in these deposits is typically well-stratified and lack any appreciable soil development. Qycr soils are typically classified as Torrifluvents or Torriorthents. Qycr surfaces are prone to flooding.

Qyr **Holocene river terrace deposits (0 to 10 ka)** – Low terrace deposits composed of unconsolidated, moderately to poorly sorted, subrounded to rounded sand- and gravel-sized clasts in a sandy to silty matrix. Landforms typically are low terraces, but minor channels are common locally. Primary fluvial bedforms (gravel bars, fine-grained swales) near the surface are absent or weakly expressed due to bioturbation. These deposits have weakly developed soils that are light brown to yellowish brown on the surface, with a slight reddening with depth. There is typically organic accumulation in the uppermost soil horizons, with slightly oxidized horizons at deeper levels. Minimal or no rock varnish or desert pavement development. Weak calcic horizons (≤Stage I) are present in Middle and Early Holocene soils. Qyr terrace soils are Torrifluvents and Camborthids. Portions of Qyr surfaces have been inundated during historical floods, and lateral bank erosion is also a hazard.

Qlr **Late Pleistocene river terrace deposits (10 to 250 ka)** - Intermediate, moderately old terrace deposits. Unconsolidated, moderately to poorly sorted, subrounded to rounded sand- and gravel-sized clasts in a sandy to silty matrix. Soils have moderate clay accumulation and carbonate development (Stage II), but no cementation. Desert pavement and rock varnish is nonexistent to moderately developed. These surfaces are not prone to flooding, but lateral bank erosion may occur where proximal to active channels.

Qmr **Middle Pleistocene river terrace deposits (400 to 750 ka)** - Prominent, high, old terrace deposits of Cave Creek. Qmr alluvium is composed of unconsolidated sand, gravel, and cobble channel deposits with interbedded fine-grained overbank sediments. Some of the eroded Qmr landforms consist of low, rounded ridges and moderately incised stream channels. Desert pavement and rock varnish development is weak to moderate. Soils on Qmr terrace surfaces are strong brown to reddish brown and are strongly developed where they have not been highly eroded. Clay accumulation is variable, but well-preserved soils have strong, red argillic horizons with loam and clay loam textures. Well-developed calcic or petrocalcic horizons are also common (Stage III-V). Locally consists of a slightly older member (Qmr_1). Qmr terrace soils are classified as Calciortids, Paleorthids, and Paleargids.

Qor **Early Pleistocene river terrace deposits (750 ka to 1.6 Ma)** - Old terrace remnants of the Agua Fria River. Early Pleistocene terrace deposits of the Agua Fria River exposed west of the New River. These terrace deposits represent the highest and oldest terrace of the Agua Fria River, and may represent some of the oldest landforms in the northern Phoenix area. Deposits are weakly consolidated, moderately to poorly sorted, subrounded to rounded sand- to boulder-sized clasts in a sandy to silty matrix. Qor deposits do not contain a well-developed desert pavement, nor do they contain a very thick argillic horizon. Soil development is weak because the original depositional surface has been removed by erosion. However, a petrocalcic-petroduric horizon is commonly exposed, with broken pieces commonly scattered across the surface. There is little infiltration into these indurated soils. Qor terrace soil is mostly degraded, with a Stage V+ petrocalcic horizon that extends over 4 m in depth.

Tertiary volcanic and sedimentary rocks

Tbm **Basalt (Middle Miocene)** - Dark grayish brown to dark gray basaltic lava flows, correlative to the Middle and Late Miocene Hickey Formation. These cliff-forming basaltic lavas unconformably overlie an older basalt-tuff sequence (Chalk Canyon formation) and have been referred to as the New River Mesa Basalt (Gomez, 1978; Jagiello, 1987). These rocks are characteristically intergranular to porphyritic in overall texture, with clinopyroxene and altered olivine phenocrysts present within a framework of plagioclase crystals. Columnar jointing and zones of vesicles are common in outcrop. The vesicles are typically open, <2 cm in diameter, and may be rimmed with calcite. Chemical compositions are largely subalkaline (olivine-subalkali basalt and basaltic andesite), as defined by their major element (e.g., SiO_2, Na_2O+K_2O) and normative mineral abundances (e.g., normative hypersthene >> diopside, quartz $\geq$ 0, and nepheline = 0). Thin sediment and soil horizons also separate individual Hickey Formation flow units. The basaltic flows locally contain minor scoria and basalt-related breccia. Mesa-capping flow north of the Black Canyon Shooting Range has been dated at 15.39 ± 0.4 (Scarborough and Wilt, 1979).

Tsl **Tuffaceous sandstone and carbonate (Early to Middle Miocene)** - Creamy whitish-tan marl, limestone, tuffaceous sandstone, and minor orange chert. Exposed in the hills north of the Ben Avery Shooting Range (Rifle Range). This unit is unconformably overlain by Middle Miocene (15.39 ±0.4 Ma; Scarborough and Wilt, 1979) Hickey Formation basaltic lavas. These sedimentary deposits are likely correlative with the upper member of the Chalk Canyon formation.

Tts **Interbedded tuff and sedimentary deposits (Early to Middle Miocene)** - White tuff, reworked tuff, and tuffaceous sediment exposed west of Black Mountain in the northwestern part of the quadrangle. This unit is unconformably overlain by Middle Miocene (16.2 Ma; Reynolds, unpub. data) Hickey Formation basaltic lavas and is likely correlative with the the Chalk Canyon formation.

Tb **Basaltic rocks, undivided (Early to Middle Miocene)** - Miocene basaltic lavas correlative with either the Chalk Canyon formation or the Hickey Formation. Commonly exposed in isolated outcrops (e.g., near Middle Mountain) or between tuff and Hickey Formation basalt and/or andesite (e.g., Ludden Mountain). These lavas are typically olivine-phyric and lack the distinctive diktytaxitic texture of the Hickey Formation lavas. In the Hedgpeth Hills and at Ludden Mountain, these lavas are likely the upper part of the lower basalt-tuff sequence (Chalk Canyon formation).

Tt **Tuff (Early Miocene)** - Light gray to white nonwelded pumice-rich, vitric, and lithic tuff. These tuffs are variably reworked and are locally interbedded with tuffaceous sediments. This unit typically forms slopes, but is locally well indurated. Tuff beds are typically interbedded with olivine-phyric basaltic lavas. This unit is likely correlative with rocks of the lower member of the Chalk Canyon formation.

Ta **Andesite (Early to Middle Miocene)** - Moderately altered, purplish gray andesitic flow remnant exposed south of Biscuit Flat near Middle Tanks. This unit is subporphyritic, with distinctive glassy plagioclase and altered olivine(?) phenocrysts with plagioclase, clinopyroxene, orthopyroxene(?), and opaques in a microtrachytic groundmass. Sieved-cored plagioclase phenocrysts are also present. Correlative with andesite in the Hedgpeth Hills quadrangle to the south, where it overlies Hickey Formation basaltic rocks (e.g., Ludden Mountain, Hedgpeth Hills), but underlies Hickey Formation lavas in the Deem Hills. Precise age constraint is poor for the rocks exposed at Middle Tanks.

Tbl **Lower basalt (Latest Oligocene to Early Miocene)** - Basaltic lavas interbedded with and underlying the tuff unit (Tt) in the Deadman Wash and Rifle Ranges. Basaltic rocks in this area generally have porphyritic and vesicular overall textures, with microcrystalline, cryptocrystalline, and trachytic groundmass textures. Phenocryst assemblages (5-15% phenocrysts) include olivine and olivine + clinopyroxene. Euhedral to subhedral olivine microphenocrysts are highly to totally oxidized, whereas subhedral clinopyroxene microphenocrysts are typically unaltered. Groundmass phases are dominated by plagioclase, ranging from euhedral laths to cryptocrystalline microlites; euhedral clinopyroxene, totally altered olivine grains, and opaque oxides are less abundant. Fine-grained clinopyroxene glomerocrysts are also commonly present. These basalts are typically moderately vesicular (3-7%), with rounded, calcite-filled vesicles. In the Rifle Range, some of the lavas are presumed to be andesitic in composition because they contain hornblende pseudomorphs and orthopyroxene. These lower basalts are correlative with basaltic rocks of the lower member of the Chalk Canyon formation (23 to ~17 Ma; Leighty, 1997).

Tvl **Felsic volcanic rocks (Late Oligocene to Early Miocene)** - Felsic volcanic rocks exposed in the northwest portion of the quadrangle that may include trachyte, latite, rhyolite, and dacite compositions. Some of these rocks are flow banded, hypocrystalline (~90% glass) rocks with plagioclase and biotite microphenocrysts. This unit underlies Early to Middle Miocene tuff and tuffaceous sediment (Tts), and Middle Miocene (16.2 Ma; Reynolds, unpub. data) Hickey Formation basaltic lavas (Tbm).

Proterozoic rocks

YXg(p) **Granitic pediment deposits (Early to Middle Proterozoic)** - A layer of grus of variable thickness that mantles much of the low-relief pediment surface formed on granitic bedrock (YXg). These deposits are formed by the in situ weathering of the granite, and result in a subdued, rounded, and moderately dissected surface. Exposed in the Pyramid Peak area in the south-central part of the quadrangle.

YXg **Granite (Early to Middle Proterozoic)** - Coarse-grained, relatively unfoliated, porphyritic biotite granite exposed in the southern part of the quadrangle. Includes light gray to light pink microcline (0.5-2 cm), light gray to white plagioclase (2-6 mm), clear gray quartz (2-8 mm), and subhedral black biotite (2-4 mm). Informally named granite of Pyramid Peak for exposures at Pyramid Peak in the Hedgpeth Hills Quadrangle. Possibly correlative with the large granite batholith exposed north of the McDowell Mountains to the east exposed.

YXd **Diorite (Early to Middle Proterozoic)** - Largely unfoliated diorite and microdiorite phases exposed in the southern and southwestern part of the quadrangle. Together with the plutonic rocks at Sunrise Relief Mountain (located to the southwest in the Hedgpeth Hills Quadrangle), these rocks comprise an intermediate plutonic complex, informally referred to as the tonalite of Biscuit Flat (Reynolds and DeWitt, 1991). This unit is intruded by the coarse-grained granite of Pyramid Peak.

YXgl **Leucocratic granite (Early to Middle Proterozoic)** - Fine-grained granitic rock exposed in the Rifle Range and Deadman Wash Range. This leucocratic unit probably represents a derivative of a larger granitic pluton.

Xva **Andesitic metavolcanic rocks (Early Proterozoic)** - Fine-grained meta-andesitic rocks, with minor felsic tuffaceous and metasedimentary rocks. These rocks are exposed in the Deadman Wash Range and may correlate with the Union Hills Group of Anderson (1989b).

d **Disturbed area** - Areas of significant recent surficial disruption due to various human activities. Includes quarries (e.g., in the Pyramid Peak area), the Central Arizona Project canal, etc.