GEOLOGIC MAP AND DIGITAL DATABASE OF THE APACHE CANYON 7.5' QUADRANGLE, VENTURA AND KERN COUNTIES, CALIFORNIA

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Pamphlet to accompany:
Open-File Report 00-359
Version 1.0

2000

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GEOLOGIC EXPLANATION

Introduction

The Apache Canyon 7.5-minute quadrangle is located in southwestern California about 55 km northeast of Santa Barbara and 65 km southwest of Bakersfield. This report presents the results of a geologic mapping investigation of the Apache Canyon quadrangle that was carried out in 1997-1999 as part of the U.S. Geological Survey's Southern California Areal Mapping Project. This quadrangle was chosen for study because it is in an area of complex, incompletely understood Cenozoic stratigraphy and structure of potential importance for regional tectonic interpretations, particularly those involving the San Andreas fault located just northwest of the quadrangle and the Big Pine fault about 10 km to the south. In addition, the quadrangle is notable for its well-exposed sequences of folded Neogene nonmarine strata including the Caliente Formation of Miocene age from which previous workers have collected and described several biostratigraphically significant land-mammal fossil assemblages. During the present study, these strata were mapped in detail throughout the quadrangle to provide an improved framework for possible future paleontologic investigations.

The Apache Canyon quadrangle is in the eastern part of the Cuyama 30-minute by 60-minute quadrangle and is largely part of an erosionally dissected terrain known as the Cuyama badlands at the east end of Cuyama Valley. Most of the Apache Canyon quadrangle consists of public lands in the Los Padres National Forest. A few ranches and other dwellings are located in Quatal and Apache Canyons and on Apache Potrero. The paved Cerro Noroeste Road crosses the northern part of the quadrangle and unpaved roads provide access to Quatal and Apache Canyons.

Early geologic studies of the region encompassing the Apache Canyon quadrangle include those of English (1916) and Gazin (1930a). Hill and others (1958) developed the regional stratigraphy used for the Cuyama badlands area. Mammalian faunas of the Caliente Formation in the Cuyama badlands have been described and interpreted by Gazin (1930b), James (1963), Kelly and Lander (1988, 1992), and Kelly (1992). The stratigraphy and structure of the Cuyama badlands and the surrounding region have been summarized and interpreted by Dibblee (1982), Davis (1983), and Davis and others (1986, 1987).

Parts of the Apache Canyon quadrangle were previously mapped by Adams (1956), Exum (1957), Sierveld (1957), Van Amringe (1957), Ziony (1958), Frakes (1959), Newman (1959), Barker (1972), Davis (1983), and Davis and Duebendorfer (1987). The quadrangle was included as part of a regional geologic-map compilation at a scale of 1:62,500 by Crowell (1964) and also was mapped at that scale as part of the "Ventucopa" 15-minute quadrangle by Dibblee (1972). The map presented here is based on original field data although the previous maps were consulted frequently during the course of mapping and compilation.

Mapping along the eastern and southern margins of the quadrangle was done in association with U.S. Geological Survey colleagues S.A. Minor and K.S. Kellogg who were concurrently mapping the adjacent Sawmill Mountain, San Guillermo Mountain, and Reyes Peak quadrangles. The geologic map of the San Guillermo quadrangle is published (Minor, 1999); maps of the Sawmill Mountain and Reyes Peak quadrangles are in preparation. Some stratigraphic names and geologic interpretations used in this map of the Apache Canyon quadrangle differ from those used in the adjoining quadrangle maps; these differences remain to be resolved by future study.

Stratigraphy

The oldest rocks exposed in the Apache Canyon quadrangle consist of gneiss of probable Proterozoic age (Ᵽgn) that crops out along the northeastern edge of the quadrangle in upper Quatal Canyon. Granite and diorite of probable Mesozoic age (Mzg, Mzd) are discontinuously exposed stratigraphically beneath the Miocene Caliente Formation in the core of an anticline that extends east-southeastward across Quatal Canyon from Blue Rock Spring. Similar gneiss and plutonic rocks are extensively exposed in the adjacent Sawmill Mountain quadrangle to the east where they structurally overlie metamorphic rocks assigned to the Pelona Schist on the Sawmill Mountain fault (Dibblee, 1982; Davis and Duebendorfer, 1987). The basement complex of Pelona Schist, gneiss, and plutonic rocks structurally overlies the Caliente Formation along the low-angle Abel Mountain thrust which is exposed just east of the Apache Canyon quadrangle boundary (Ziony, 1958).

The northern part of the quadrangle is largely underlain by poorly bedded and generally poorly exposed sedimentary breccia, conglomerate, and sandstone of probable Miocene age. These rocks consist of a western gray facies, here called the sedimentary breccia of Apache Potrero (Tap), composed primarily of granitic detritus, and an eastern red facies, here called the sedimentary breccia and sandstone of Cowhead Potrero (Tcp), composed primarily of gneiss and schist detritus. Schist detritus in the eastern red facies is similar to Pelona Schist of the Sawmill Mountain area from which it probably was derived (Ziony, 1958). Both facies consist mainly of poorly sorted, angular clasts that apparently underwent little transport from their source areas prior to deposition, and may represent alluvial-fan environments.

The sedimentary breccia and sandstone of Cowhead Potrero depositionally overlies sandstone questionably assigned to the Oligocene Simmler Formation (Tsi) which is exposed in the canyon of Santiago Creek near the northwest corner of the quadrangle. The sedimentary breccia of Apache Canyon encloses a tongue of fine-grained Vaqueros Sandstone (Tv) near the northwest corner of the quadrangle and is depositionally overlain by the thin reddish-brown sandstone of Blue Rock Spring (Tbr) which probably is laterally equivalent to similar sandstone that forms the uppermost part of the sedimentary breccia and sandstone of Cowhead Potrero to the east.

Both the sandstone of Blue Rock Spring and the sedimentary breccia and sandstone of Cowhead Potero, as well as the Proterozoic(?) and Mesozoic(?) basement rocks, are depositionally overlain by the lower part of the Miocene Caliente Formation (Tcl). This thick unit consists of interbedded reddish-brown mudstone and gray arkosic-lithic sandstone and conglomerate of fluvial origin. Most conglomerate clasts in the lower Caliente are rounded as the result of substantial transport and many consist of volcanic rocks thought to have been derived from distant sources to the east (Carman, 1964; Ehlig and others, 1975). The lower Caliente thus marks a change in depositional environment and provenance from the underlying units of more local derivation.

The rocks here assigned to the lower part of the Caliente Formation are significant to vertebrate paleontologists for their land-mammal fossil assemblages. The first reports of such fossils from the Caliente Formation (Gazin, 1930b) were from localities in the Apache Canyon quadrangle, and many of the numerous localities later reported by James (1963) are in the quadrangle. The lower Caliente rocks in the Apache Canyon quadrangle are in the red-bed lithofacies of James (1963) and are primarily of Clarendonian age (late middle to early late Miocene, about 12 to 9 Ma) (Tedford and others, 1987).

Depositional contacts between the lower part of the Caliente Formation and the underlying sedimentary units are exposed in several places along the hills that bound the north side of Quatal Canyon. In the eastern part of the quadrangle, the contact between the lower Caliente and red sandstone and conglomerate at the top of the sedimentary breccia and sandstone of Cowhead Potrero is gradational as previously described by Ziony (1958) and Barker (1972). By contrast, to the west, the lower Caliente sharply overlies the sandstone of Blue Rock Spring and in one place overlaps a normal fault, suggesting a disconformable relation.

Only about 1 km south of these depositional contacts with the underlying sedimentary units, the lower part of the Caliente Formation rests nonconformably on crystalline basement rocks (Pgn, Mzg, Mzd) as is particularly well exposed near Blue Rock Spring. As noted by Sierveld (1957) and several subsequent workers, this relation indicates an abrupt southward pinchout of the strata that underlie the lower Caliente against the crystalline basement (see cross sections *A–A′* and *B–B′*). Bohannon (1975, 1976) and others have argued convincingly that basement rocks exposed in the Apache Canyon quadrangle were part of a paleotopographic high from which the sedimentary breccias to the north (Tap, Tcp) were derived. Several workers have inferred the presence of a pre-Caliente fault (commonly called the Blue Rock fault) along the northern margin of the basement high, although such a fault is not shown in the cross sections included in this report because of the lack of direct evidence for its existence.

The lower Caliente Formation is sharply overlain by light-gray sandstone, sandy mudstone, and conglomerate here assigned to the upper part of the Caliente (Tcu). These strata, which locally are divided into a lower subunit of sandstone and conglomerate and an upper subunit of sandstone and sandy mudstone, can be followed from the south side of Quatal Canyon across the divide into Apache Canyon near Nettle Spring. Lithologically the sandstones and conglomerates of the upper Caliente resemble those interbedded with the lower Caliente redbeds and apparently represent a similar fluvial environment. The only known fossil mammals from the upper Caliente, however, are interpreted to indicate a late Hemphillian age (latest Miocene, about 7 to 5 Ma) (James, 1963; Tedford and others, 1987), suggesting the possibility of a hiatus between this unit and the lower Caliente. The possibility of a hiatus or low-angle unconformity at this horizon also is suggested by the pinchout of the Clarendonian redbeds in the Dry Canyon area just east of the southern part of the Apache Canyon quadrangle as described by James (1963). Recent observations by the author confirm the existence of this pinchout and suggest that the low-angle unconformity previously noted by Gazin (1930a) and Adams (1956) between the Caliente Formation and the overlying Lockwood Clay in the Dry Canyon area more likely lies between the lower and upper parts of the Caliente Formation.

The reddish-brown to dark-brown Lockwood Clay (Tlc) of probable Pliocene age constitutes an extensive marker unit that was described in detail by Carman (1964) from exposures east of the quadrangle in Lockwood Valley. The clay is well exposed in a south-dipping homoclinal section from Nettle Spring westward into the cliffs on the south side of Quatal Canyon where it pinches out, apparently by depositional thinning. On the north side of Quatal Canyon, the clay is discontinuously exposed in a complex structural trough that extends eastward and westward from Blue Rock Spring. The stratigraphic relations of the clay are largely obscured in this area, but in its easternmost outcrop (in "Sequence Canyon" of James, 1963) it depositionally overlies light-gray, fine-grained sandstone assigned to the upper part of the Caliente Formation. Gazin (1930a) and Carman (1964) proposed that the dominantly montmorillonitic Lockwood Clay is a bentonite formed by alteration of a volcanic protolith, but no recent studies have been conducted to test that interpretation. As first noted by Gazin (1930a), the clay is in contact with a thin sill or flow of basalt (Tba) near the west edge of the quadrangle on the north side of Quatal Canyon, but the contact probably is faulted and a close original association between clay and basalt cannot be demonstrated.

Above the Lockwood Clay is a thick conformable sequence of nonmarine strata previously divided into the Pliocene Quatal Formation and the Pliocene and Pleistocene Morales

Formation (Hill and others, 1958). In this report, the lowermost part of this sequence, a distinctive unit of white to light-gray sandstone, is mapped separately as the sandstone of Nettle Spring (Tns). The Quatal Formation herein is restricted primarily to the overlying unit of yellowish-brown mudstone, sandstone, and conglomerate (Tq), the finer-grained portions of which are identical lithologically with the type Quatal in Ballinger Canyon to the northwest (Hill and others, 1958). The Morales Formation (QTm), a thick sequence of light-gray to light-brownish-gray sandstone, conglomerate, and mudstone, is mapped as defined by Hill and others (1958) and generally is quite distinct from the underlying Quatal on the basis of color. Locally near the southwest and southeast corners of the quadrangle, the basal Morales and uppermost Quatal appear to interfinger; elsewhere, the Morales sharply overlies the Quatal. The sandstone of Nettle Spring, Quatal Formation, and Morales Formation of this report are equivalent to units originally recognized and named the Corral, Castle, and Apache members of the San Pablo group(?) by Gazin (1930a).

The Quatal Formation contains abundant clasts of light-brown sandstone and may have been derived in large part from source terranes of Eocene sandstone such as that widely exposed in areas south of the Apache Canyon quadrangle. By contrast, the Morales Formation apparently was derived largely from granitic source terranes.

Near the southwest corner of the quadrangle, the Quatal Formation is depositionally underlain by strata herein called the sandstone and conglomerate of lower Apache Canyon. These strata consist of a lower conglomerate unit (Tac) and an upper sandstone unit (Tas) that also appear to interfinger with each other. The precise relation of these strata to the Caliente Formation, Lockwood Clay, and sandstone of Nettle Spring cannot be determined from outcrops in the quadrangle, but might be clarified by additional work in areas south and west of the quadrangle where the strata also are exposed.

The Morales Formation and older units are unconformably overlain by relatively flat lying gravel and sand of probable late Pleistocene age (Qoa) that form high erosional mesas and terraces in the northern two-thirds of the Apache Canyon quadrangle. Dibblee (1972, 1982) correlated most of these deposits with the Pliocene to Pleistocene Paso Robles Formation of the southern Salinas Valley, whereas Davis (1983) and Davis and Duebendorfer (1987) questionably correlated some of the deposits with the Paso Robles but tentatively correlated most of them with the Pleistocene (0.13-0.45 Ma) Riverbank Formation of the northeastern San Joaquin Valley. The deposits clearly postdate the youngest rocks in the Morales Formation, which may be as young as 0.76 Ma (A.M. Sarna-Wojcicki, written commun., 2000; see Description of Map Units), but their upper age limit is undated. The most detailed discussion of these deposits has been by Davis (1983) who considered them to be the erosional remnants of a broad alluvial apron that once extended continuously southwestward across the area of the Cuyama badlands from highlands north and northeast of the Apache Canyon quadrangle, including the Mt. Pinos area south of the San Andreas fault and the San Emigdio Mountains north of the fault. Dibblee (1982) noted that gravel remnants north of Quatal Canyon are composed mostly of clasts derived from bedrock source areas north of the San Andreas fault and apparently have been offset from those source areas by about 32 km of right-lateral displacement, an interpretation not evaluated during the present study.

The youngest deposits in the Apache Canyon quadrangle are sandy to gravelly alluvium related to the modern drainage system and landslides that locally cover substantial areas on the steep canyon walls characteristic of the quadrangle. Most of the alluvium forms relatively flat, forested surfaces that are crossed by numerous small channels and gullies. Neither the deposits nor the surfaces were studied in detail, but no major lithologic or geomorphic subdivisions were obvious from field observations or close inspection of aerial photographs; thus, most of the younger alluvium is mapped as a single unit (Qya). Deposits of the major washes in Quatal and

Apache Canyons are shown separately (Qam). Map-scale landslides (Qls) are common in the quadrangle, particularly where derived from older alluvium and Quatal Formation in the Quatal Canyon drainage. Most of the landslides shown are moderately to densely vegetated and are inferred to be hundreds to possibly thousands of years old. In addition to map-scale landslides, many smaller, unmapped landslides of more recent origin are present, particularly in narrow headwater canyons cut into the Quatal and Morales Formations in the southern part of the quadrangle. These landslides typically are about 20 to 50 m across and consist of hummocky masses of loose sediment, bushes and trees that recently slid down the canyon wall and now choke the canyon floor. Many and perhaps most of these very youthful landslides were generated as a result of heavy rainfall during the El Niño winter of 1997-1998.

Structure

The dominant structures of the Apache Canyon quadrangle are west-northwest-trending folds that affect units as young as the Morales Formation. The largest fold is the broad Cuyama syncline cored by the Morales Formation in the south half of the quadrangle; this fold extends west-northwest to the Cuyama River (Frakes, 1959; Dibblee, 1982; Ellis and others, 1993). To the north, extending diagonally across Quatal Canyon, are another prominent syncline and two prominent anticlines, the northern of which is cored by crystalline rocks lying nonconformably beneath the Caliente Formation. Near Blue Rock Spring, the Caliente Formation is folded by a southward-overturned anticline separated from the basement-cored anticline to the south by a complex, poorly understood structural trough marked by discontinuous slivers of Lockwood Clay. Near the south edge of the quadrangle, in the headwaters of Corral, Round Spring, and Sulphur Spring Canyons, prominent anticlines, locally overturned to the south, are exposed in the Quatal and Morales Formations. A well developed anticline folds the Caliente Formation, the sandstone of Nettle Spring, and the Quatal Formation in West Fork Dry Canyon near the southeast corner of the quadrangle.

Several folds in the quadrangle appear to terminate abruptly along strike. This characteristic is well displayed by three southward-overturned anticlines cored by the Quatal Formation in the south half of the quadrangle, all of which become much less prominent or lose their identity in the Morales Formation beyond the exposed cores of Quatal. The map pattern created by these three folds suggests a left-stepping en echelon relation. A similar relation is suggested by a pair of anticlines in the Caliente Formation north of Nettle Spring and a pair of synclines just south of Quatal Canyon wash. The significance of these apparent left-stepping fold patterns is unclear but the patterns are consistent with a stress system that included a component of left-lateral shear oriented approximately east-northeast in present-day coordinates (Wilcox and others, 1973).

Most of the folding in the Apache Canyon quadrangle probably took place after deposition of the Morales Formation, although the generally more tightly folded structure of the Caliente and Quatal Formations relative to that of the Morales suggests that some folding may have occurred before or during Morales deposition. Locally, dips of bedding in the lower part of the Morales Formation are 10 to 20° less steep than those in the underlying Quatal Formation, and in some other places dips in the basal Morales are the same as in the Quatal but decrease upsection.

Few important faults are exposed in the Apache Canyon quadrangle. Most prominent is a north-dipping thrust fault that can be followed discontinuously across most of the quadrangle on the north side of Quatal Canyon. This fault was first recognized by Sierveld (1957) and Van Amringe (1957) and was later mapped by Ziony (1958), Barker (1972), Dibblee (1972), Davis

(1983), and Davis and Duebendorfer (1987). Most previous workers, including Davis and Duebendorfer (1987), have referred to this structure as the Apache fault, whereas Dibblee (1982) used the name Quatal fault. The fault surface is locally difficult to recognize, especially where the same unit is exposed in both the upper and lower plates, and it has been mapped somewhat differently by everyone who has attempted to trace it. In this report, the fault is shown as three separate, unnamed segments that may represent a single surface but cannot be demonstrated to be connected as some previous mappers have inferred.

In the western part of the quadrangle, the thrust fault north of Quatal Canyon generally places the sedimentary breccia of Apache Potrero above the lower part of the Caliente Formation, although lower Caliente rocks are exposed in both the upper and lower plates near Blue Rock Spring and Apache Potrero rocks are exposed in both plates to the northwest where the fault loses its identity. The upper-plate strata are warped gently southward toward the fault surface and the lower-plate rocks are locally overturned to the south just beneath the fault. Displacement on the fault is uncertain but probably is no more than a few hundred meters (see cross section *A–A′*). In the eastern part of the quadrangle, the fault locally dips more steeply than in the western part and places the sedimentary breccia and sandstone of Cowhead Potrero above the lower Caliente. The fault in this area loses its identity both westward and eastward where it cuts across depositional contacts between the sedimentary breccia and sandstone of Cowhead Potrero and the lower Caliente. Upper-plate strata in this area appear to form an anticline (see cross section *B–B′*), and the exposed lower-plate strata are subparallel to the fault. As to the west, fault displacement in this area is uncertain but probably modest.

Movement on the thrust fault north of Quatal Canyon postdated at least some of the folding that involved the Caliente Formation. The central fault segment overrides a minor syncline-anticline pair in the Caliente, and relations exposed near Blue Rock Spring suggest that the Caliente was already steeply tilted on a fold limb before being overridden by the thrust.

In the vicinity of Blue Rock Spring, a high-angle, west-northwest-striking fault separates diorite (Mzd) and the depositionally overlying sequence of lower Caliente strata from steeply dipping, complexly deformed Caliente rocks on the north. A parallel fault is inferred to bound the north side of two discontinuous slivers of Lockwood Clay in contact with the deformed Caliente rocks. Westward, this fault zone is inferentially traced to the edge of the quadrangle where it bounds both sides of another Lockwood Clay sliver; eastward, the fault zone can be followed about 2 km along a relatively continuous band of Lockwood Clay in addition to some upper Caliente strata. The fault between diorite and lower Caliente appears to dip steeply south at Blue Rock Spring, but the presumed eastward continuation of this fault dips about 65° north in at least one place. The significance of the fault zone is uncertain but it may be a contractional structure related to the tight folding observed along its northern side. Frakes (1959) and some other previous workers have applied the name Blue Rock fault to this structure although it is clearly younger than the hypothetical subsurface Blue Rock fault that has been inferred to bound the north side of the pre-Caliente basement high discussed earlier.

Near the northeast corner of the quadrangle, a west-northwest-striking fault that dips about 75° north separates the sedimentary breccia and sandstone of Cowhead Potrero from the Simmler(?) Formation. Map relations suggest that this fault is a reverse fault that probably has a few to several hundred meters of displacement (see cross section *B–B′*). Van Amringe (1957) and Ziony (1958) mapped a fault they called the Pattiway Ridge fault in about the same place as this reverse fault. Based on a different stratigraphic interpretation of the rocks on the north side than that used in this report, they interpreted the Pattiway Ridge fault as a strike-slip fault with at least 8 km of right-lateral offset.

A second west-northwest-striking high-angle fault, not previously recognized, separates the Simmler(?) Formation from a sequence of sandstone and shale of uncertain stratigraphic affinity (Tsh, Tss) in the canyon of Santiago Creek just inside the northeast corner of the quadrangle. Additional work outside the quadrangle is needed to ascertain the significance of this fault and to identify the units on its north side.

Other faults mapped in the quadrangle include two northwest-striking faults and a northeast-striking fault that cut the Caliente Formation and the underlying strata on the north side of Quatal Canyon. These faults dip steeply with the west side down; at least one is a normal fault. In addition, the sedimentary breccia of Apache Potrero and the sandstone of Blue Rock Spring are cut by a northwest-striking, northeast-dipping normal fault overlapped by the lower Caliente Formation. Near the southwest corner of the quadrangle, the Quatal Formation is juxtaposed against the sandstone and conglomerate of lower Apache Canyon (Tas, Tac) in the core of an anticline along a northwest-striking fault that appears to die out abruptly in both directions. Finally, several outcrop-scale faults that cut the Morales Formation and older units are shown on the map with short fault symbols. These small faults are of variable orientation but most strike approximately north and dip steeply to moderately eastward.

Two questionable faults, both striking west-northwest with the south side down, are shown cutting old alluvium (Qoa) along the south side of San Emigdio Mesa. The northern of these is marked by a narrow canyon south of which the gently sloping mesa is about 10 m lower than on the north side. Ziony (1958) interpreted this apparent offset to have resulted from subsidence above the buried Lockwood Clay with which it is approximately aligned, but in this report the offset is interpreted as possibly unrelated to the Lockwood Clay (see cross section *C–C′*). The southern questionable fault juxtaposes a ridge capped by old alluvium against Morales Formation and an overlying veneer of debris-apron deposits (Qda) on the north. Northward dips of as much as 17° in the old alluvium on this ridge suggest that its northern boundary could be a south-dipping listric normal fault along which the ridge has been dropped and rotated.

Paleomagnetic data from the Cuyama badlands area indicate that the Morales Formation has undergone about 23° of clockwise rotation (Ellis and others, 1993) and that the Caliente Formation has undergone about 38° of clockwise rotation (McCardel and Prothero, 1997; McCardel and others, 1997). This rotation, which presumably occurred in response to right-lateral shear between the Pacific and North American plates, probably accompanied part or all of the deformation observed in the Apache Canyon quadrangle although the precise tectonic and chronologic relations between deformation and rotation are unknown.

DESCRIPTION OF MAP UNITS

Qam **Alluvium of modern stream channels (Holocene)—**Unconsolidated sand and gravel confined to modern stream channels. Commonly incised 0.5 to 1 m into young alluvium (Qya)

Qls **Landslide deposits, talus, and colluvium (Holocene and Pleistocene?)**—Unsorted deposits of loose rock, sediment, and soil. Particularly abundant where derived from Quatal Formation (Tq) and old alluvium (Qoa) on south rim of Quatal Canyon. Only largest, most prominent landslides were mapped

Qya **Young alluvium (Holocene and Pleistocene?)—**Unconsolidated to weakly consolidated sand and gravel comprising alluvial-fan and floodplain deposits of modern drainage basins

Qda **Debris-apron deposits (Holocene or Pleistocene)**—Unconsolidated to weakly consolidated gravel forming thin, gently sloping aprons that border old alluvium (Qoa) along south margin of San Emigdio Mesa

Qoa **Old alluvium (Pleistocene?)**—Weakly to moderately consolidated, poorly to well stratified gravel and sand (fanglomerate) that forms terraces capping ridges and uplands between modern drainages. Gravel ranges in size from pebbles to boulders and includes abundant clasts of granite, gneiss, and sandstone. Flat-lying to very gently dipping; unconformably overlies Morales Formation (Tm) and older units. Thickness locally as much as about 50 m. As mapped, may include some younger landslide deposits reworked from old alluvium

Qt **Tuff(?) (Pleistocene?)**—White altered sandy tuff(?) exposed locally beneath base of old alluvium (Qoa). Maximum thickness 5 to 10 m

QTm **Morales Formation (Pleistocene and Pliocene)**—Consists predominantly of light-gray to light-brownish-gray, medium- to coarse-grained arkosic-lithic sandstone, pebbly sandstone, and conglomerate, along with minor gray, fine-grained sandstone and mudstone primarily in lower part. Beds generally planar and moderately well defined; conglomeratic and sandy beds of varying grain size, typically a few to several centimeters thick, alternate irregularly. Some sandstone-conglomerate sequences are separated by thin mudstone partings. Sandstone composed of subangular to subrounded quartz, feldspar, lithic, and minor biotite sand in an argillaceous silty matrix or sparry calcite cement. Lithic grains include polycrystalline quartz, felsic volcanic rock, and fine-grained sedimentary rock. Conglomerate clasts range in size from small pebbles to boulders and are mostly subangular to subrounded. Clasts include massive to weakly foliated granitic rocks, gneiss, felsic to intermediate-composition volcanic rocks, sandstone, basalt, quartz, fine-grained quartzite(?), and chert(?); in addition, some beds contain angular fragments of white siliceous shale lithologically similar to Monterey Shale of Miocene age exposed in areas south, west, and northwest of quadrangle. Basal 20 to 50 m of formation generally consists of weakly consolidated coarse-grained sandstone and pebble to cobble conglomerate in which subrounded basalt clasts are locally abundant. This basal zone commonly is overlain by about 50 to 200 m of thin-bedded to laminated, fine-grained sandstone and mudstone; this zone grades upsection into the thick sandstone-conglomerate succession comprising the remainder of the formation. A thin tuff bed was found near top of exposed section (about 920 m above base) on north side of Apache Canyon (locality shown on map sheet). Maximum exposed thickness of formation in quadrangle is about 1,100 m; upper contact unconformable beneath old alluvium (Qoa). Age of unit previously based on sparse vertebrate fossil remains of Blancan (Pliocene) age northwest of quadrangle (Vedder, 1970) and on paleomagnetic stratigraphy (Ellis and others, 1993). Tuff near top of unit is interpreted as middle Pleistocene in age based on tephrochronologic analysis indicating close geochemical similarity to Bishop ash bed (~0.76 Ma) and slightly older ash beds of Glass Mountain (~0.8 to 1.2 Ma) in east-central California (A.M. Sarna-Wojcicki, written comm., 2000)

Tq **Quatal Formation (Pliocene)**—Consists predominantly of mudstone, fine- to coarse-grained arkosic-lithic sandstone, pebbly sandstone, and conglomerate, all characterized by a distinctive yellowish-brown color. Mudstone sequences typically massive to indistinctly bedded; sandstone-conglomerate sequences moderately well stratified to form irregular beds of differing grain size a few to several centimeters thick. Sandstone composed of subangular to subrounded, poorly sorted quartz, feldspar, and lithic grains in an argillaceous matrix. Lithic grains include felsic volcanic rock, siltstone to fine-grained sandstone, and chert or fine-grained quartzite. Conglomerate clasts are mostly subangular to subrounded pebbles, cobbles, and rare boulders of sandstone, granite, felsic to intermediate-composition volcanic rocks, basalt, quartzite(?), and chert(?). Sandstone clasts are brown and range from fine- to coarse-grained. In west-central part of quadrangle on south side of Quatal Canyon, formation is about 350 m thick and consists primarily of sandstone, pebbly sandstone, and conglomerate, with bedded gypsum locally present near base. Formation thins and decreases in grain size southeastward; near Nettle Spring, formation is about 60 m thick and consists of mudstone and fine-grained sandstone. Near east edge of quadrangle in upper Apache Canyon, formation consists of mudstone and thins to less than 5 m. In southwestern part of quadrangle, formation is about 250 m thick and consists primarily of sandstone, pebbly sandstone, and conglomerate; ochre mudstone locally forms lower 20 to 30 m. In southeastern part of quadrangle (West Fork Dry Canyon), main part of formation has a maximum thickness of about 100 m thick and consists primarily of yellowish-brown mudstone and fine- to coarse-grained sandstone like that near Nettle Spring; unit thins northward to less than 20 m. In this area, formation also includes:

Tql **Lower part**—Yellowish-brown mudstone to fine-grained sandstone interbedded with light-gray arkosic-lithic sandstone, pebbly sandstone, and pebble conglomerate containing subangular to rounded clasts of granite, felsic to intermediate-composition volcanic rock, sandstone, and minor gneiss, amphibolite, and chert(?). Some conglomerate beds also contain angular fragments of light-gray siliceous shale (Monterey Shale?). Thickness about 60 m

Tns **Sandstone of Nettle Spring (Pliocene)**—White to light-gray, medium- to coarse-grained arkosic-lithic sandstone, pebbly sandstone, and minor pebble conglomerate. Sandstone composed of loosely consolidated quartz, feldspar, lithic, and minor biotite sand with little or no matrix or cement. Lithic grains include volcanic rock, granite, and gneiss. Detrital grains angular to subrounded and poorly to moderately sorted. Conglomerate clasts range from angular to rounded and include granitic rocks, felsic to intermediate-composition volcanic rocks, and minor dark volcanic rocks and chert. Thickness about 75 to 100 m. Previously mapped as "Corral sandstone member" of "Sunset Ridge formation" (Adams, 1956), lower part of "Nettle Spring formation" (Ziony, 1958), and "Corral Canyon member" of Quatal Formation (Newman, 1959). Included in Caliente Formation by James (1963) and in Quatal Formation by Dibblee (1972)

Tnc **Sandstone of Nettle Spring and upper part of Caliente Formation, undivided (Pliocene and late Miocene)**—White to light-gray sandstone and conglomerate

Sandstone and conglomerate of lower Apache Canyon (Pliocene or late Miocene)—Underlies Quatal Formation in southwestern part of quadrangle. Stratigraphic relation to Lockwood Clay unknown; may be equivalent either to sandstone of Nettle Spring (Tns) or upper part of Caliente Formation (Tcu). Previously mapped as part of "Corral Canyon member" of Quatal Formation (Exum, 1957; Newman, 1959) and as part of Caliente Formation (Dibblee, 1972). Questionably included in Caliente Formation by James (1963). Divided into:

Tas **Sandstone**—White to light-gray sandstone and minor conglomerate; overlies and probably interfingers laterally with conglomerate (Tac)

Tac **Conglomerate**—Massive conglomerate, poorly exposed, forming dark-gray hills littered with loose, rounded to subrounded pebbles, cobbles, and boulders of felsic to intermediate-composition volcanic rock, granite, gneiss, and minor mafic volcanic rock. Base not exposed

Tlc **Lockwood Clay (Pliocene)**—Dark-brown to dark reddish-brown claystone and minor lenses of light-gray, fine-grained sandstone. Best developed from Nettle Spring northwestward to divide between Apache and Quatal Canyons where unit is about 50 m thick and forms a conspicuous marker horizon between upper part of Caliente Formation (Tcu or Tcu_2) and sandstone of Nettle Spring (Tns); depositionally pinches out northwestward from divide. North of Quatal Canyon wash, unit is discontinuously exposed in a faulted syncline or fault slice extending northwestward and southeastward from Blue Rock Spring. Included in Caliente Formation by James (1963) and in Quatal Formation by Dibblee (1972)

Tba **Basalt (Miocene?)**—Dark-gray basalt forming a thin sheet between lower part of Caliente Formation and Lockwood Clay near west edge of quadrangle north of Quatal Canyon. Composed of plagioclase microlites in a fine-grained groundmass of mafic minerals and iron oxides. Apparently intrusive into lower part of Caliente Formation; probably faulted against Lockwood Clay

Caliente Formation (late and middle Miocene)—Mudstone, sandstone, and conglomerate. Consists of:

Tcu **Upper part, undivided (late Miocene)**—Light-brown argillaceous sandstone and sandy mudstone (primarily in upper part), and white to light-gray arkosic-lithic sandstone and minor conglomerate (primarily in lower part). Forms a locally conspicuous light-colored band about 50 to 100 m thick between the underlying reddish-brown lower part of the Caliente Formation (Tcl) and the overlying Lockwood Clay (Tlc). Lower contact sharp and possibly disconformable. Locally divided into:

Tcu_2 **Unit 2**—Light-brown, fine- to medium-grained argillaceous sandstone and sandy mudstone. Composed of moderately sorted, loosely packed quartz, feldspar, felsic volcanic, and rare biotite and muscovite sand in an argillaceous matrix. Distinguished primarily south of Quatal Canyon wash but also in one small area north of wash ("Sequence Canyon" of James, 1963) where unit contains sparse vertebrate fossils that indicate a late Hemphillian (latest Miocene) age (James, 1963; Tedford and others, 1987; Kelly and Lander, 1992). About 50 m thick in western part of quadrangle; may pinch out southeastward into vicinity of Nettle Spring where unit is not recognized in undivided upper part of Caliente Formation (Tcu)

Tcu_1 **Unit 1**—White to light-gray, fine- to medium-grained arkosic-lithic sandstone and minor conglomerate. Generally well stratified in irregular, alternating beds of different grain size a few to several centimeters thick. Sandstone composed of subangular to subrounded quartz, feldspar, minor lithic, and rare biotite sand that commonly is tightly packed but weakly consolidated due to a paucity of matrix material or cement. Most lithic grains are felsic volcanic rock. Conglomerate clasts range from angular to rounded and are primarily light-colored granite and varicolored felsic to intermediate-composition volcanic rock, many of which contain white feldspar phenocrysts. Other clast types include quartz, basalt, schist, quartzite, and chert. About 50 m thick

Tcl **Lower part (late and middle Miocene)**—Reddish-brown sandy mudstone and white to light-gray arkosic-lithic sandstone, pebbly sandstone, and conglomerate, commonly interbedded to produce a distinctive banded appearance where exposed in steep canyon walls. Good exposures typically show moderately well stratified sandstone, pebbly sandstone, and conglomerate grading upward into sandy mudstone in sequences a few to several meters thick. Conglomeratic rocks contain mostly resistant, subrounded to rounded pebbles, cobbles, and locally boulders in a coarse-grained sandstone matrix. Clasts are mostly felsic to intermediate-composition volcanic rocks and light-colored granite but also include gneiss, schist, granodiorite to diorite, quartz, quartzite, chert, argillite, and sandstone. Clasts of brown to purple volcanic rock containing white feldspar phenocrysts are particularly common. In northeastern part of quadrangle, conglomerates near base of unit contain relatively abundant clasts of schist and gneiss similar to those in underlying sedimentary breccia of Cowhead Potrero (Tcp). White to light-gray sandstone associated with conglomeratic rocks is medium- to coarse-grained and composed primarily of quartz, feldspar, lithic, and rare biotite sand, commonly cemented by sparry calcite. Lithic grains are mostly felsic to intermediate-composition volcanic rock but include polycrystalline quartz, granitic rock, schist or gneiss, and argillite. Detrital grains are angular to subrounded, well sorted, and loosely packed; calcite cement commonly composes 25 to 30 percent of rock. Reddish-brown sandy mudstone is composed of about 50 percent silt, sand, and granules and 50 percent argillaceous matrix; fabric is matrix-supported. Detrital grains are angular to subrounded, poorly sorted, and consist primarily of quartz, feldspar, and felsic volcanic rock. Unit thickness, estimated from structural cross sections, ranges from about 500 m in western part of quadrangle to about 1,000 m in eastern part. Unit is equivalent to red-bed lithofacies of Caliente Formation as defined by James (1963). Abundant vertebrate fossils from this unit within quadrangle and from equivalent strata outside quadrangle indicate a late Barstovian to late Clarendonian (late middle to early late Miocene) age (James, 1963; Tedford and others, 1987; Kelly and Lander, 1992)

Tbr **Sandstone of Blue Rock Spring (Miocene)**—Reddish-brown, thick-bedded, coarse-grained, micaceous lithic sandstone that lies stratigraphically between lower part of Caliente Formation (Tcl) and sedimentary breccia of Apache Potrero (Tap) in vicinity of Blue Rock Spring. Composed primarily of angular to subangular, moderately sorted lithic, feldspar, and biotite sand in a sparry calcite cement. Lithic grains are mostly polycrystalline quartz and micaceous schist or gneiss. Red color of sandstone apparently caused by weathering of biotite. Thickness about 40 m. Upper and lower contacts sharp

Tcp **Sedimentary breccia and sandstone of Cowhead Potrero (Miocene)**—Purplish-red, reddish-brown, and reddish-gray sedimentary breccia and sandstone. Principal rock type is poorly sorted, massive to weakly bedded sedimentary breccia composed of angular to subrounded pebbles, cobbles, and boulders of dark-colored mafic gneiss, greenish-gray schist, and quartz in a red argillaceous sandstone matrix that consists partly of decomposed micaceous rock clasts. Thickness unknown but inferred to be at least 400 m based on structural relations (see cross section *B–B'*). Uppermost 100 to 150 m consists of relatively well bedded, red micaceous sandstone and schist-pebble conglomerate gradational with overlying lower part of Caliente Formation (Tcl); these rocks are lithologically similar and probably equivalent to sandstone of Blue Rock Spring (Tbr) exposed to west. In canyon of Santiago Creek, unit includes conglomerate containing subrounded to rounded clasts of granite, gneiss, diorite, and schist.

Miocene age of unit based on reported presence of Barstovian vertebrate remains in upper Quatal Canyon (Woodburne, 1975). Previously included in Caliente Formation (Van Amringe, 1957), "Cowhead Potrero" formation (Ziony, 1958), and Simmler Formation (Dibblee, 1972)

Tap **Sedimentary breccia of Apache Potrero (Miocene)**—Poorly sorted, light-gray to light-greenish-gray, massive to faintly bedded sedimentary breccia composed primarily of angular to subrounded pebbles, cobbles, and boulders of light-colored granitic and gneissic rock in an arkosic sandstone matrix. Subordinate clasts of mafic rocks generally are partially to thoroughly decomposed. Irregularly interbedded with subordinate reddish-brown silty to sandy mudstone. Poorly exposed except in walls of side canyons north of Quatal Canyon; much of unit forms soil-covered upland surfaces littered with loose granitic and gneissic rock debris as in vicinity of Apache Potrero. Thickness unknown but inferred to be at least 500 m based on structural relations (see cross section *A–A'*). Unit is inferred to pinch out southward against crystalline basement rocks (Mzg, Mzd) exposed in Quatal Canyon; in one area on south side of main wash (secs. 26 and 27, T. 9 N, R. 22 W.), unit is in contact with granitic basement along a possible buttress unconformity. Miocene age of unit based on intertonguing relation with Vaqueros Sandstone (Tv) near northwest corner of quadrangle. May interfinger eastward with sedimentary breccia of Cowhead Potrero (Tcp), although exposed contact with that unit is faulted. Previously included in Caliente Formation (Van Amringe, 1957; Sierveld, 1957; Frakes, 1959), "Cowhead Potrero formation" (Ziony, 1958), and Simmler Formation (Dibblee, 1972)

Tsc **Sandstone and conglomerate (Miocene)**—White sandstone and conglomerate containing rounded to subrounded pebbles of granitic and minor volcanic rocks. Lithologically similar to lower part of Caliente Formation; forms a thin lens enclosed by sedimentary breccia of Apache Potrero near northwest corner of quadrangle. Stratigraphically higher than Vaqueros Formation (Tv)

Tv **Vaqueros Formation (lower Miocene)**—Light-brown, thin- to thick-bedded, fine- to coarse-grained arkosic sandstone and minor pebbly sandstone. Composed primarily of tightly packed quartz, feldspar, and biotite sand in a silty to argillaceous matrix. Biotite sand forms 10 to 20 percent of rock. Detrital grains angular to subrounded and generally well sorted. Angular to subangular pebbles of granitic rock present locally; basal beds locally conglomeratic. Unit forms a lens 50 to 100 m thick enclosed by sedimentary breccia of Apache Potrero (Tap) near northwest corner of quadrangle. Previously mapped as "Vaqueros" beds (Sierveld, 1957), "Vaqueros" formation (Frakes, 1959), and Vaqueros Formation (Dibblee, 1972). Unit age based on marine fossils identified outside of quadrangle (Hill and others, 1958)

Tsi **Simmler(?) Formation (Oligocene?)**—Gray to maroon, thick-bedded to massive, fine- to coarse-grained arkosic-lithic sandstone. Composed of tightly packed quartz, feldspar, minor biotite and muscovite, rare epidote(?), and lithic sand in a silty to argillaceous matrix. Lithic grains include volcanic rocks, polycrystalline quartz, and schist. Detrital grains mostly subangular to subrounded. Unit underlies sedimentary breccia of Cowhead Potrero (Tcp) in canyon of Santiago Creek near northeast corner of quadrangle; base of unit faulted. Exposed thickness about 100 m. Lithologically similar to sandstone of Simmler Formation with which unit is in fault contact less than 1 km northwest of quadrangle boundary (P. Stone, unpub. data, 1999). Includes rocks previously mapped as

Caliente Formation and "Temblor" beds (Van Amringe, 1957); Ziony, 1958) and as Caliente and Vaqueros Formations (Dibblee, 1972)

Sandstone and shale (Tertiary?)—Sedimentary rocks of uncertain age and stratigraphic affinity exposed in northeast corner of quadrangle. Previously mapped as "Temblor" beds (Van Amringe, 1957; Ziony, 1958) and as Simmler and Vaqueros Formations (Dibblee, 1972). Consists of:

Tss **Upper sandstone unit**—White, thin- to thick-bedded, mostly coarse-grained arkosic-lithic sandstone and pebbly sandstone. Sandstone composed of tightly packed quartz, feldspar, biotite, and lithic grains in a silty to argillaceous matrix. Lithic grains include polycrystalline quartz and granitic, volcanic, metamorphic (schist and gneiss), and sedimentary rock fragments. Detrital grains mostly subangular to subrounded. Some planar beds separated by thin mudstone intervals may be turbidites

Tsh **Lower thin-bedded sandstone and shale unit**—Dark-brown, thin-bedded shale and sandstone. Sandstone beds are graded and probably are turbidites. Base of unit faulted against Simmler(?) Formation (Tsi)

Granite and diorite (Mesozoic?)—Plutonic rocks of probable Mesozoic age nonconformably overlain by Caliente Formation. Consists of:

Mzg **Granite**—Massive to weakly foliated, medium-grained, leucocratic granite. Equigranular to microporphyritic; average grain size 1 to 2 mm. Average composition about 30 percent quartz, 40 to 50 percent plagioclase, 20 to 30 percent potassium feldspar, and minor biotite. Plagioclase subhedral, partly sericitized, commonly forms microphenocrysts to 3 mm long. Potassium feldspar generally altered, anhedral. Quartz mostly interstitial. Probably intrusive into diorite

Mzd **Diorite**—Massive to weakly foliated, coarse-grained, dark-colored biotite-hornblende diorite. Composed of blocky euhedral to subhedral plagioclase crystals as much as 1 cm long in a dark groundmass containing hornblende and less abundant biotite. Average composition about 60 to 75 percent plagioclase, 25 to 40 percent hornblende and biotite, and less than 5 percent quartz; potassium feldspar rare to absent

Pgn **Gneiss (Proterozoic?)**—Fine- to medium-grained muscovite-biotite gneiss nonconformably overlain by Caliente Formation. Rock is strongly foliated with well-defined mafic and leucocratic segregations. Leucocratic layers are quartz-rich and characterized by blocky plagioclase crystals to 3 mm long. Biotite and muscovite equally abundant in mafic layers and commonly are intergrown

DIGITAL PUBLICATION AND DATABASE DESCRIPTION

Introduction

The results of this mapping are presented as a digital geologic map database. This section describes the types and general contents of files comprising the database. Information is also provided on how to both extract and plot the map.

The database package includes (1) ARC/INFO (Environmental Systems Research Institute, http://www.esri.com) version 7.2.1 Patch 1 coverages and associated tables, (2) a Portable Document Format (.pdf) file of this explanatory pamphlet, **apache_expl.pdf**, (3) a text file of this pamphlet, **apache_expl.txt**, (4) a PostScript plot file of the geologic map, Correlation of Map Units, and List of Map Units on a single sheet, **apache1.ps.gz**, (5) a PostScript plot file of three structural cross sections that accompany the geologic map, **apache2.ps**, and (6) a text file that includes all metadata for the report, **apache_met.txt**.

Database Contents

The files constituting the geologic map database of this report are listed below along with the interchange files from which they are extracted.

Data Package

All files listed below are in a compressed tar file named **apache.tar.gz** (7 MB); see section below titled, SOFTWARE UTILITIES.

ARC/INFO interchange files	Apache Canyon coverages	Contains
apache_geo.e00	apache_geo	Contacts, faults, geologic unit labels as annotation in annotation subclass, anno.geo
apache_str.e00	apache_str	Folds
apache_ldr.e00	apache_ldr	Annotation leaders
apache_pts.e00	apache_pts	Attitudes and their dip values. Dip values plotted as annotation
apache_ptsorn.e00	ap_ptsorn	Structural line ornamentation
apache_sample.e00	ap_sample	Sample locality
apache_xs.e00	apache_xs	Cross-section lines
lines.rel.e00	lines.rel	Line dictionary (Matti and others, 1997b)
points.rel.e00	points.rel	Point dictionary (Matti and others, 1997a)

The directory, info/, is produced in the process of importing interchange files to ARC coverages in ARC/INFO. The Apache Canyon info/ directory contains:

Feature Attribute tables

Polygon attribute table	apache_geo.pat
Arc attribute tables	apache_geo.aat, apache_ldr.aat, apache_str.aat, apache_xs.aat
Point attribute tables	apache_pts.pat, ap_ptsorn.pat

Additional tables*

lines.rel	Dictionary, contains all SCAMP line codes (Matti

	and others, 1997c)
points.rel	Dictionary, contains all SCAMP point codes (Matti and others, 1997a)

*These tables contain complete dictionary information for both lines and points.

Raster file*	Resultant image	Contains
apache.tif	Apache Canyon base map	Topographic base from 500 dpi scan of USGS Apache Canyon 7.5′ quadrangle, 1991

*Included as reference material. For plotting purposes the monochromatic raster scan of the topographic base was converted to grid format in ARC/INFO GRID and the color reassigned in order not to obscure the geologic data.

ASCII text file	
apache_expl.txt	This document

The following interchange files of the respective symbol sets used to plot the full geologic map sheet:

geoSCAMP2.lin.e00	Line set
geoSCAMP2.mrk.e00	Points (marker set)
SCAMP2.shd.e00	Colors (shade set)

Plot Package

The plot package consists of PostScript plot files of the geologic map and accompanying cross sections (see section below titled **Software Utilities** for additional information).

apache1.ps.gz	Geologic map, Correlation of Map Units, List of Map Units
apache2.ps	Cross sections

The file apache1.ps.gz is a compressed UNIX file requiring gzip to uncompress it. Uncompressed, it will plot a 1:24,000 scale, full-color geologic map of the Apache Canyon quadrangle on the topographic base. The plot is approximately 36 x 33 inches in size. The cross-section plot (apache2.ps) is approximately 36 x 22 inches in size. The plots are best reproduced on a large-format plotter at 600 dpi or greater.

Other Files

apache_expl.pdf	This document; .pdf file
apache1.pdf	Geologic map, Correlation of Map Units, List of Map Units; .pdf file
apache2.pdf	Cross sections; .pdf file

apache_met.txt	Federal Geographic Data Committee (FGDC) compliant metadata file derived from the digital database; plain text file

Custom fonts, called Stratagem Age fonts, are needed to create plot files from the geologic database (U.S. Geological Survey, 1999). Access to these fonts is available at http://geopubs.wr.usgs.gov/open-file/of99-430.

Software Utilities

Files which have the .gz file extension were compressed using gzip. Gzip utilities are available free of charge via the internet at the gzip home page, http://www.gzip.org.

The data package is additionally bundled into a single tar (tape archive) file. The individual files must be extracted using a tar utility, available free of charge via the internet through links on the Common Internet File Formats page, http://www.matisse.net/files/formats.html. One such utility is WinZip, available at http://www.winzip.com (WinZip can also decompress files).

Files in the plot package have been prepared to produce optimum plots using the shade, marker, and line sets included in the database. These are included in the **apache1.tar.gz** data package. The line and marker sets can also be obtained from the Southern California Areal Mapping Project (SCAMP) web site at http://wrgis.wr.usgs.gov/wgmt/scamp/scamp.html. At this web site, click on 'Scamp GIS Activities' and follow the instructions for downloading the line and marker sets.

How to Obtain the Digital Files

The export files, and subsequently the data and plot files, constituting the geologic map database of this report may be obtained in two ways, both over the Internet.

1. The files can be obtained via the Web from Western Region Geologic Information Server. Go to the web page at http://geopubs.wr.usgs.gov/open-file/of00-359 and follow the directions to download the files.

2. The files can also be obtained by anonymous ftp over the Internet from geopubs.wr.usgs.gov. The files are located in the directory /pub/open-file/of00-359. Be sure to use binary transfer mode.
   Note: .e00 files are best transferred using ascii mode.

How to Extract the Geologic Map Database from the Tar File

After downloading the files, they must be uncompressed using a gzip utility such as gzip itself or WinZip. The data files must then be extracted using the appropriate tar utility.

To do this	Type this at the Unix command prompt
Uncompress apache.tar.gz	gzip -d apache.tar.gz (or use gzip utility of choice)

to apache.tar

Go to the directory that will hold the directory apache/ (if different from local_directory)	cd local_directory
Extract the apache/ directory from the tar file	tar-xvbv {path to tar file}/apache .tar (or use tar utility of choice)

This process will create a directory, apache/, that contains the ARC/INFO interchange files and supporting files. The directory should contain the following files:

apache/
- apache_geo.e00
- apache_pts.e00
- apache_str.e00
- apache_ldr.e00
- apache_xs.e00
- apache_ptsorn.e00
- apache_sample.e00
- lines.rel.e00
- points.rel.e00
- apache.tif
- geoSCAMP2.lin.e00
- geoSCAMP2.mrk.e00
- SCAMP2.shd.e00
- apache_expl.txt

The following are not included in the database tar file, and are downloaded separately:

- apache1.ps.gz
- apache2.ps
- apache_expl.pdf
- apache_met.txt

Compressed Postscript Plot File

Make a 238 MB uncompressed file, apache1.ps (geologic map) by typing gzip -d apache1.ps.gz (or use gzip utility of choice).

Portable Document (.pdf) Files

The .pdf files are accessed using Adobe Acrobat Reader software, available free from the Adobe website http://www.adobe.com. Follow instructions at the website to download and install the software. Acrobat Reader contains an on-line manual and tutorial.

How to Convert the Arc/Info Export Files

The ARC interchange (.e00) files are converted to ARC coverages using the ARC command IMPORT with the appropriate <option>.

Change directories to the apache/ directory. From the ARC command line type:

import <option> <interchange_file> <output>
e.g., import cover apache_geo apache_geo

ARC interchange files can also be read by some other Geographic Information Systems, including ArcView (ESRI) and MapInfo (http://www.mapinfo.com). Please consult your GIS documentation to see if you can use ARC interchange files and the procedure to import them.

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