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Plate I of II.

NEW MEXICO BUREAU OF MINES AND MINERAL RESOURCES
A DIVISION OF **NEW MEXICO INSTITUTE OF MINING & TECHNOLOGY**

Dr. Peter A. Scholle
Director* and *State Geologist

Dr. Paul W. Bauer
Geologic Mapping
Program Director

Geology of the Tijeras quadrangle, Bernalillo County, New Mexico

Plate I of II.
5 April 2000 Revision

by
Karl E. Karlstrom[1], Sean D. Connell[2], Charles A. Ferguson[3],
Adam S. Read[4], Glenn R. Osburn[5], Eric Kirby[1], John Abbott[6],
Christopher Hitchcock[7], Keith Kelson[7], Jay Noller[7],
Thomas Sawyer[7], Steven Ralser[6], David W. Love[4],
Matthew Nyman[1], and Paul W. Bauer[4]

[1]*Department of Earth and Planetary Sciences, University of New Mexico, Albuquerque, NM 87131*
[2]*New Mexico Bureau of Mines and Mineral Resources, Albuquerque, NM 87106*
[3]*Arizona Geological Survey, 416 W. Congress, #100, Tucson, AZ 85701*
[4]*New Mexico Bureau of Mines and Mineral Resources, Socorro, NM 87801*
[5]*Department of Earth and Planetary Sciences, Washington University, St. Louis, MO 63130*
[6]*Department of Earth and Environmental Science, New Mexico Institute of Mining and Technology, Socorro, NM 87801*
[7]*William Lettis & Associates, Inc., 1777 Botelho Dr., Suite 262, Walnut Creek, CA 94596*

David J. McCraw
Mark M. Mansell
Glen E. Jones
Digital Cartography

COMMENTS TO MAP USERS

A geologic map displays information on the distribution, nature, orientation and age relationships of rock and deposits and the occurrence of structural features. Geologic and fault contacts are irregular surfaces that form boundaries between different types or ages of units. Data depicted on this geologic quadrangle map are based on reconnaissance field geologic mapping, compilation of published and unpublished work, and photogeologic interpretation. Locations of contacts are not surveyed, but are plotted by interpretation of the position of a given contact onto a topographic base map; therefore, the accuracy of contact locations depends on the scale of mapping and the interpretation of the geologist(s). Any enlargement of this map could cause misunderstanding in the detail of mapping and may result in erroneous interpretations. Site-specific conditions should be verified by detailed surface mapping or subsurface exploration. Topographic and cultural changes associated with recent development may not be shown.

The map has not been reviewed according to New Mexico Bureau of Mines and Mineral Resources standards. Revision of the map is likely because of the on-going nature of work in the region. The contents of the report and map should not be considered final and complete until reviewed and published by the New Mexico Bureau of Mines and Mineral Resources. The views and conclusions contained in this document are those of the authors and should not be interpreted as necessarily representing the official policies, either expressed or implied, of the State of New Mexico and the U.S. Government.

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UNIT DESCRIPTIONS

CENOZOIC DEPOSITS

Neogene (Quaternary and Tertiary) System

Colluvial, landslide, eolian, and anthropogenic deposits

Thin surficial deposits derived from wind and mass-movement processes, or extensive areas disturbed by open-pit aggregate mining or construction.

af — **Artificial fill (Historic) —** Dumped fill and areas affected by human disturbances. Locally mapped where areally extensive or geologic contacts are obscured.

Qca — **Colluvium and alluvium, undivided (Holocene to upper-middle Pleistocene) —** Poorly consolidated, poorly sorted and stratified, fine- to coarse-grained, clast- and matrix-supported deposits derived from a variety of mass-movement hill slope processes, including debris flow, shallow slump and creep. Gravel clasts are typically angular to subangular and composition reflects local provenance. Soils locally exhibit Stage I to III carbonate morphology. Clasts are typically angular and composition generally reflects local provenance. Commonly surrounds small undivided inliers of Madera Formation limestone on the eastern dip-slope of the Sandia Mountains. Differentiated where areally extensive, thick, or where geologic contacts are obscured. Variable thickness, up to 12 ft (4 m).

QTt — **Travertine and spring deposits (upper Pleistocene to upper Pliocene?) —** Light-gray nodular to massive constructional mounds of travertine interlayered with mudstone and conglomerate derived from local upland sources. Unit is commonly associated with springs along the eastern dip-slope of the Sandia Mountains. Variable thickness, ranging from 3-30 ft (1-10 m).

Stream-valley Alluvium

Typically contains poorly to well sorted and stratified, clast- and matrix-supported sand and gravel with minor muddy sand interbeds associated with modern and late Pleistocene entrenched arroyos and streams originating in the Sandia and Manzanita Mountains. Deposits unconformably overlie Santa Fe Group deposits and older rocks, and are differentiated on the basis of inset relationships and soil-morphology.

QHa, QHao — **Youngest stream alluvium, undivided (Historic to upper Holocene) —** Unconsolidated deposits of brown, light gray-brown, and yellowish-brown (10YR) sand, silty to clayey sand, and gravel. Underlies modern arroyos and inset against younger stream alluvium (*Qay*). Color and clast composition varies with drainage-basin composition, but gravel typically contains limestone, gneiss, quartzite, sandstone, granite and metarhyolite. Deposit surface exhibits no pedogenic development, and unit locally forms small alluvial fans within low-order tributary drainages of Madera and Tijeras Canyons. Locally divided into an older terrace (*QHao*) on the basis of inset relationships. Deposits locally contain asphalt fragments and construction debris. The age is constrained by radiocarbon dates ranging between 1,000 to 3,000 years BP (Thomas *et al.*, 1995, p. 2-37 and 2-43). Correlative to units *H8* and *H9* of Thomas *et al.* (1995), and correlative to geomorphic surface Q9 of Connell (1995, 1996). Variable thickness from 0-10 ft (0-3 m).

Qay — **Younger stream alluvium (Holocene to uppermost Pleistocene) —** Poorly consolidated deposits of light-brown to dark-gray, fine-grained silty sand with minor pebbly sand and clayey sand interbeds; pebble lenses are common along basal contact. Unit forms broad terraces ranging from 8-30 ft (3-9 m) above *Tijeras* and *Madera Creeks*. Two terrace levels are locally recognized, but not differentiated, within Tijeras Canyon. Clasts are chiefly rounded limestone with minor granite, metavolcanic and gneiss within Madera Canyon. The trunk stream of the Tijeras Canyon drainage is divided into unit Qay_t. Locally includes undivided stream alluvium (*QHa*) in narrow arroyos. Soils are weakly developed and exhibit Stage I and II carbonate morphology. Deposit age is constrained by a radiocarbon of about 10,000 years BP (Thomas *et al.*, 1995, p. 2-43). Correlative to unit *H7* of Thomas *et al.* (1995), and correlative to geomorphic surfaces Q8-Q9 of Connell (1995, 1996). Variable thickness from 0-20 ft (0-6 m).

Alluvium of Tijeras Creek

Typically contains moderately to well sorted and stratified, clast- and matrix-supported sand and gravel with minor muddy sand interbeds associated with the Tijeras Creek drainage. Deposits are differentiated into a trunk stream that interfingers with steeper tributary drainages to Tijeras Canyon (unit *Qay*). Clasts are commonly subangular to subrounded granite, metarhyolite, limestone, yellowish-brown and reddish-brown sandstone derived from the headwaters of the Tijeras Canyon drainage-basin. Unconformably overlie Santa Fe Group deposits and older rocks, and are differentiated on the basis of inset relationships and soil-morphology.

Qay_t — **Younger stream alluvium of Tijeras Canyon (Holocene) —** Deposits contain variable proportions of gneiss, limestone, sandstone and minor granite within the Tijeras drainage. Locally includes undivided stream alluvium (*QHa*) in narrow arroyos. A minimum age is constrained by a radiocarbon date of 1,790±90 years BP (***Locality 1***, Beta Analytic Labs No. 104958) near the top of the deposit. Correlative to unit *H7* of Thomas *et al.* (1995) and unit Qa_2 of Smith *et al.* (1982), and correlative to geomorphic surfaces Q8 and Q9 of Connell (1995, 1996). Variable thickness from 0-20 ft (0-6 m).

Qvm_t — **Middle stream alluvium of Tijeras Canyon, undivided (upper to middle Pleistocene) —** Moderately to well-consolidated gravelly alluvium containing subrounded to subangular clasts of limestone with minor sandstone, gneiss and metavolcanic rocks. Unit represents former position of the ancestral *Tijeras* and *Madera Creeks* and is differentiated into three subunits on the basis of inset relationships. Soils are moderately to well developed and possess Stage II to III calcic horizons in Tijeras Canyon (Smith et al., 1982). This unit commonly contains unmapped inclusions of younger stream alluvium (*Qay*, Qay_t, and *QHa*). Thickness is variable from 0-15 ft (0-5 m).

Qvm_{t3} — **Youngest subunit (upper Pleistocene) —** Poorly to moderately consolidated deposits of sandy gravel and cobble to boulder gravel. Unconformably overlies crystalline rocks with an irregular contact. Inset against stream alluvium of units Qvm_{t1} and Qvm_{t2}. Correlative to eastern-margin piedmont alluvium (Qpm_3) and units Qf_{1b} and Qf_2 of Smith *et al.* (1982), and generally correlative to unit *P6* of Thomas *et al.* (1995).

Qvm_{t2} — **Middle subunit (upper to middle Pleistocene) —** Moderately consolidated deposits of sandy to cobbly gravel, with local accumulations of boulders. Minor light-brown to reddish-brown silty sand interbeds. Clasts are composed of rounded to subangular limestone, granite, quartzite and sandstone. Basal contact is irregular and sits about 50 ft (15 m) above top of the youngest stream alluvium (*QHa*). Inset against stream alluvium of unit Qvm_{t1} and pediment surface Qpx_1 and forms gravelly alluvium within Tijeras Canyon. Two terraces are recognized near Seven Springs, but not differentiated. Soils are moderately developed and exhibit Stage II to III carbonate morphology in gravel. Surface is typically overlain by thin (<1 ft) layer of grus where inset against the Sandia granite (*Ys*). Correlative to eastern-margin piedmont alluvium (Qpm_2) and units Qf_{1a} and Qa_1 of Smith *et al.* (1982), and generally correlative to unit *P5* of Thomas *et al.* (1995).

Qvm_{t1} — **Older subunit (middle Pleistocene) —** Moderately consolidated pebble to cobble gravel. Deposits surface (top) is approximately 50-55 ft (15-17 m) above *Tijeras Creek* and represents the highest stream gravel west of Seven Springs in Tijeras Canyon. Unit is locally overlain by about 5 ft (1.5 m) of grus where inset against the Sandia granite (*Ys*). Soils locally exhibit Stage III carbonate morphology. Clasts are dominated by granite, with local accumulations of metavolcanic, gneiss, sandstone and limestone. Correlative to eastern-margin piedmont alluvium (Qpm_1) and units Qf_{1a} and Qa_1 of Smith *et al.* (1982), and generally correlative to units *P3-P4* of Thomas *et al.* (1995).

Qvm_{tc} — **Well cemented stream alluvium, undivided (middle Pleistocene) —** Indurated, scattered lensoidal accumulations of calcium-carbonate cemented, subangular to subrounded pebbly sandstone and pebble to cobble conglomerate. Unconformably overlying pediments developed on Sandia granite (*Ys*). Probably correlative to older subunit of the alluvium of *Tijeras Creek* ($Qvmt_1$). Unit is less than 6 ft (2 m) thick.

Eastern-margin piedmont slope deposits

Typically contains poorly to moderately sorted and stratified, clast- and matrix-supported sand and gravel with minor muddy sand interbeds associated coalescent range-front alluvial fans in the Sandia Mountains and Four Hills salient. Deposits unconformably overlie Santa Fe Group deposits and older rocks, and are differentiated on the basis of inset relationships and soil-morphology. Clasts are commonly angular to subangular granite with minor subrounded limestone.

Qpy — **Younger eastern-margin piedmont alluvium (Holocene to uppermost Pleistocene) —** Poorly to moderately sorted and stratified gravel, sand with minor silt-clay mixtures inset against eastern-margin piedmont alluvium (*Qpm*). Deposit surface (top) is moderately dissected and exhibits well developed to subdued bar-and-swale topography. Soils possess Stage I to II carbonate morphology and weakly to moderately developed clay films. Generally correlative to units *H7-H9* of Thomas *et al.* (1995). Variable thickness from 0-30 ft (0-9 m).

Qpm — **Middle eastern-margin piedmont alluvium, undivided (upper to middle Pleistocene) —** Poorly to moderately consolidated deposits of very pale-brown to strong-brown and light-gray (7.5-10YR) sand and silty- to clayey-sand, and gravel. Deposit surface (top) is 30-165 ft (9-50 m) above local base level. Gravel clasts are predominantly subangular granite and schist with minor subrounded limestone derived from the western front of the Sandia Mountains and Four Hills salient. Slightly to moderately dissected deposit surface exhibits subdued constructional bar-and-swale topography on interfluves. Weakly developed soils exhibit Stage II to III+ carbonate morphology and minor to moderate clay film development. Locally divided into three subunits (Qpm_1, Qpm_2, and Qpm_3). Variable thickness from 0-30 ft (0-9 m).

Qpm_3 — **Youngest subunit (upper Pleistocene) —** Poorly consolidated and poorly to moderately sorted gray-brown to reddish-brown, subangular to subrounded, pebble to cobble gravel with silty sand interbeds. Inset against middle subunit Qpm_2. Soils are moderately developed and exhibit Stage II carbonate morphology. A radiocarbon date of more than 21,000 years BP reported by Thomas *et al.* (1995, p. 2-36, unit *Pf5*) indicates a late Pleistocene age. Correlative to stream alluvium of Tijeras Canyon (Qpm_{t3}), and generally correlative to units *P5-P6* of Thomas *et al.* (1995).

Qpm_2 — **Younger subunit (upper to middle Pleistocene) —** Poorly to moderately consolidated and poorly to moderately sorted deposits of very pale-brown to strong yellowish-brown (7.5-10YR), poorly to moderately stratified and sorted, silty clay and loamy sand and gravel. Deposit surface (top) along the mountain front is slightly to moderately dissected and exhibits subdued bar and swale topography on interfluves. Soils are moderately developed and possess Stage II to III carbonate morphology and few to common, thin to moderately thick clay films. Correlative to the geomorphic surface Q7 of Connell (1995, 1996). Correlative to stream alluvium of Tijeras Canyon (Qpm_{t2}), and generally correlative to unit *P5* of Thomas *et al.* (1995).

Qpm_1 — **Older subunit (middle Pleistocene) —** Poorly to moderately consolidated deposits of light- to strong-brown (7.5YR) and very pale-brown to light-gray (7.5-10YR), poorly to moderately stratified and sorted, sand clayey sand and gravel. Deposit surface (top) is dissected and commonly exhibits erosional ridge-and-ravine topography. Moderately well developed soils with Stage III+ carbonate morphology and many moderately thick clay films. Correlative to the geomorphic surface Q6 of Connell (1995, 1996) and to stream alluvium of Tijeras Canyon (Qpm_{t1}). Generally correlative to units *P3-P4* of Thomas *et al.* (1995).

Alluvium of Madera Canyon

Typically contains poorly to well sorted and stratified, clast- and matrix-supported sand and gravel with minor muddy sand interbeds associated with modern and late Pleistocene entrenched arroyos and streams originating in the northern Manzanita Mountains. Deposits unconformably overlie pre-Cenozoic rocks, and are differentiated on the basis of inset relationships and soil-morphology. Clasts are commonly angular to subrounded limestone, metarhyolite, gneiss, and quartzite.

Qvm — **Middle stream alluvium of Madera Canyon, undivided (upper to middle Pleistocene) —** Poorly to moderately consolidated deposits of very pale-brown to strong-brown and light-gray (7.5-10YR) sand and silty- to clayey-sand, and gravel. Deposit top is 30-165 ft (9-50 m) above local base level. Gravel clasts are predominantly subangular granite and schist with minor subrounded limestone derived from the western front of the Sandia Mountains and Four Hills salient. Slightly to moderately dissected deposit surface exhibits subdued constructional bar-and-swale topography on interfluves. Weakly developed soils exhibit Stage II to III+ carbonate morphology and minor to moderate clay film development. Locally divided into three subunits (Qvm_1, Qvm_2, *and* Qvm_3). Variable thickness from 0-30 ft (0-9 m).

Qvm_3 — **Youngest subunit (upper Pleistocene) —** Poorly consolidated and poorly to moderately sorted gray-brown to reddish-brown, subangular to subrounded, pebble to cobble gravel with silty sand interbeds. Inset against middle subunit Qvm_2. Soils are moderately developed and exhibit Stage II carbonate morphology. A radiocarbon date of more than 21,000 years BP reported by Thomas *et al.* (1995, p. 2-36, unit *Pf5*) indicates a late Pleistocene age. Probably correlative to stream alluvium of Tijeras Canyon (Qpm_{t1}), and generally correlative to units *P5-P6* of Thomas *et al.* (1995).

Qvm_2 — **Younger subunit (upper to middle Pleistocene) —** Poorly to moderately consolidated and poorly to moderately sorted deposits of very pale-brown to strong yellowish-brown (7.5-10YR), poorly to moderately stratified and sorted, silty clay and loamy sand and gravel. Soils are moderately developed and possess Stage II to III carbonate morphology and few to common, thin to moderately thick clay films. Probably correlative to stream alluvium of Tijeras Canyon (Qpm_{t1}), and generally correlative to units *P5-P6* of Thomas *et al.* (1995).

Qvm_1 — **Older subunit (middle Pleistocene) —** Poorly to moderately consolidated deposits of light- to strong-brown (7.5YR) and very pale-brown to light-gray (7.5-10YR), poorly to moderately stratified and sorted, sand clayey sand and gravel. Deposit surface (top) is dissected and commonly exhibits erosional ridge-and-ravine topography. Moderately well developed soils with Stage III+ carbonate morphology and many moderately thick clay films. Probably correlative to stream alluvium of Tijeras Canyon (Qpm_{t1}), and generally correlative to units *P3-P4* of Thomas *et al.* (1995).

Eastern-slope alluvium

Qpo — **Older eastern-slope alluvium (middle to lower Pleistocene) —** Poorly to moderately consolidated deposits of yellowish-brown (10YR), poorly to moderately sorted and stratified, gravel and sand with thin silty-clay interbeds. Forms alluvial fans that developed along relatively steep tributary drainages to the *Arroyo de San Antonio* and *Tijeras Creek*. Gravel clasts are predominantly subrounded limestone with a greater proportion of sandstone that in old eastern-slope alluvium (*QTp*). Overlies a formerly extensive erosional surface (pediment) developed on the eastern dip-slope of the Sandia mountains. Deposit surface (top) is dissected and soils are generally stripped, but locally exhibit Stage III carbonate morphology. Deposits grade to high pediment surface *QTpx* in Tijeras Canyon. Variable thickness from 0-16 ft (0-5 m).

QTp — **Old eastern-slope alluvium (lower Pleistocene to upper Pliocene(?)) —** Moderately consolidated and poorly to moderately sorted gravel that forms the highest gravel preserved along the southeastern flank of the Sandia Mountains. Locally contains two undivided subunits. Contains subrounded to subangular clasts of limestone with minor (< 5%) sandstone and highly weathered, grussified granite and metamorphic rocks. The basal contact is about 40-200 ft (12-60 m) above local base level. Deposits cover a formerly areally extensive pediment developed along the southeastern flank of the Sandia Mountains that may be correlative to the Tuerto gravel of Stearns (1953). Deposit surface (top) is dissected and soils are generally stripped, but locally exhibit Stage III+ carbonate morphology. Variable thickness from 0-30 ft (0-10 m).

Santa Fe Group

QTsp — **Piedmont deposits (lower Pleistocene to Miocene) —** Subhorizontally stratified to slightly east-tilted, reddish-brown to yellowish-brown and very pale-brown (7.5-10YR) conglomerate, gravelly sandstone, and sandstone with subordinate siltstone and rare mudstone. Conglomerate clasts are predominantly composed of subangular to subrounded granite with subordinate metamorphic rocks, and minor subrounded limestone. Unconformably overlies Sandia granite (*Ys*) and is unconformably overlain by eastern-margin piedmont alluvium. A monitoring well (**4H**) near the intersection of *Tijeras Creek* and Four Hills Road (Richey, 1991) encountered 69 ft (21 m) of eastern-margin piedmont alluvium and Santa Fe Group piedmont deposits just west of the Sandia fault. These deposits interfinger with and overlie early Pleistocene (Irvingtonian land mammal "age") fluvial deposits of the ancestral *Rio Grande* near the mouth of *Tijeras Arroyo* (see Lucas *et al.*, 1993). May be correlative with piedmont-slope and alluvial fan deposits of the Sierra Ladrones Formation (Machette, 1978) exposed at the southern margin of the Albuquerque Basin. Estimated hydraulic conductivity is low. Base is not exposed, but deposit thickens to the west across the Sandia fault zone to where it is several thousand feet thick.

Pediments

Pediments, as mapped within the study area, are areally extensive, low-relief surfaces of erosion that were probably cut by fluvial processes. Pediments grade to the former levels of major piedmont drainages and have smooth, generally concave-up, surfaces that are commonly marked by tors and corestones. They are primarily developed on Sandia granite (*Ys*), but are rarely preserved on Madera Formation, quartzite and metavolcanic rocks. Pediments are also recognized as short benches preserved on spur ridges along the northwestern slope of Cerro Pelon. Two generations of weathering rinds developed on corestones indicate that these surfaces have experienced multiple periods of erosion (Smith *et al.*, 1982), resulting in the formation of broad weathering-limited slopes underlain by grus and Sandia granite. Up to 15 ft (4.5 m) of grussified granite, and rare interbedded pebble lenses of weathered granite are locally preserved on pediment slopes. Locally divided into four units on the basis of inset relationships and height above local base level.

Qpx_1 — **Younger pediment surface —** Exposed erosional surface between Sandia granite (*Ys*) and overlying younger stream alluvium (*Qay*).

Qpx_2 — **Middle pediment surface —** Broad, relatively low relief erosional surface on the Sandia granite (*Ys*). Surface is lower than the pediment surface of Qpx_1 and correlated to the base of older eastern-margin piedmont alluvium (*Qpo*). Surface projects between 50-100 ft (15-30 m) above *Tijeras Creek*.

Qpx_3 — **Older pediment surface —** Broad, relatively low relief erosional surface on Sandia granite (*Ys*). Surface projects to the basal contact of eastern-margin piedmont alluvium (*Qpo*). Surface projects between 50-100 ft (15-30 m) above *Tijeras Creek*.

QTpx — **Oldest pediment surface —** Deeply dissected and commonly grussified, formerly extensive south-sloping surface of erosion cut mostly upon Sandia granite (*Ys*). Surface projects about 120-200 ft (35-60 m) above *Tijeras Creek*. Probably correlative to the basal contact of old eastern-slope alluvium (*QTp*).

Tertiary Intrusives

Tmi — **Mafic to intermediate dikes (Oligocene?) —** Generally deeply weathered mafic to intermediate, steeply dipping, north trending dikes. Dikes are probably correlative to an Oligocene mafic to intermediate dike exposed on the northern flank of the Sandia Mountains (*cf.*, Connell *et al.*, 1995).

MESOZOIC ROCKS

Cretaceous

Kv — **Mesaverde Group, undivided —** A complex unit of marine, marginal marine, and fluvial sandstones, shales, and siltstones with several intervals of coal-bearing strata. The sequence is divided into three interbedded map units: sandstone (*Kvs*), marine shale (*Kvm*) and terrestrial shale (*Kvt*). Note that these subdivisions are defined differently from the three subdivisions of the Mesaverde Group as recognized in the northerly adjacent Sandia Park quadrangle; marine sandstone and shale (*Kvm*), terrestrial sandstone and shale (*Kvt*), and shoreface sandstone (*Kvs*). The exposed thickness of the incomplete Mesaverde Group section is approximately 1,400 ft (430 m).

Kvs — **Mesaverde Group, sandstone unit —** Feldspathic arenite to quartz arenite, locally with abundant dark-colored chert grains. Four types of sandstones are included in this unit: 1) resistant, medium- to thick bedded, trough and wedge-planar cross-stratified, light-colored sandstones, 2) recessive, massive or flaggy-weathering, argillaceous, greenish-brown colored sandstones and siltstones with abundant woody debris and mud chip clasts, 3) resistant, clean (non-argillaceous), well-sorted, light-colored, planar-bedded to low-angle cross-stratified sandstone, and 4) recessive weathering, thin- to medium-bedded, dark brown to greenish colored, argillaceous and variably calcareous sandstone containing abundant molluscan shell fragments (chiefly bivalves). The first two lithotypes were mapped as terrestrial sandstones (*Kvt*) in the northerly adjacent Sandia Park quadrangle (Ferguson *et al.* 1996), and interpreted as alluvial, or distributary channel sandstones. The third type, which is also characterized by the upper shoreface environment restrictive trace fossil *Macaronichnus* (c.f. Mieras *et al.*, 1993), is interpreted as a shoreface or beach sandstone which were mapped as *Kvs* in the Sandia Park quadrangle to the northeast. The fourth type is a marine sandstone that was mapped as part of a marine sandstone and shale unit (*Kvm*) in the Sandia Park quadrangle.

Kvt — **Mesaverde Group, terrestrial shale unit —** Shale and mudstone with thin-bedded siltstone interbeds. Characterized by the absence of marine fossils, abundant woody debris and common association with coal seams. These rocks correlate partially with the terrestrial sandstone and shale unit (*Kvt*) of the Sandia Park quadrangle to the north-east (Ferguson *et al.* 1996).

Kvm — **Mesaverde Group, marine shale unit —** Shale and mudstone with thin-bedded, commonly limonitic siltstone interbeds. Characterized by a lack of coal seams and abundant woody debris, and by the presence of molluscan fossils and shell fragments. These rocks correlate partially with the marine sandstone and shale unit (*Kvm*) of the northerly adjacent Sandia Park quadrangle.

Km — **Mancos Shale, undivided —** Dark gray shale, slightly calcareous shale, and septarian nodule-bearing shale, with rare, thin, black micrite beds and at least two ~10 ft-thick (3-4 m), medium-bedded calcareous sandstone intervals. The micrites and sandstones are typically fossiliferous yielding abundant molluscan shell fragments indicating a late Turonian age for the youngest part of the sequence. Total thickness is approximately 1,300 ft (400 m).

Kms — **Mancos Shale, sandstone unit —** A discontinuous, <5 meter-thick interval of medium-bedded, resistant, non-argillaceous sandstone with abundant vertical burrows. In the northerly adjacent Sandia Park quadrangle, this sandstone unit overlies a fossiliferous shale containing late Turonian guide fossils. The sandstone may correlate with the Tocito sandstone, and it appears to pinch-out to the south were its approximate stratigraphic position is occupied by a massive, non-calcareous sandstone body interpreted as the northern pinch-out of the Gallup Sandstone.

Kd — **Dakota Formation —** Medium-bedded, pervasively silica-cemented, plane-bedded to tabular cross-stratified, quartz arenite, typically with abundant vertical, lined burrows, many of which are *Diplocraterion* traces. Approximately 300 ft (90 m) thick.

Upper Jurassic

Jm — **Morrison Formation, undivided —** Three members are commonly recognized in northern New Mexico but are not differentiated in this map area. In descending stratigraphic order, the members are: the Jackpile Sandstone, the Brushy Basin Shale, and the Salt Wash Sandstone (the Westwater Canyon Sandstone of former usage, Lucas *et al.*, 1995). The Recapture Shale member has been redefined by Lucas *et al.* (1995) as the Summerville Formation of the upper San Raphael Group (Lucas and Anderson, 1997). Due to poor exposure in the study area, these units are not differentiated. Medium- to thick-bedded, light-colored, generally poorly-sorted, feldspathic sandstones, with green and red shaley interbeds. Sandstones contain abundant quartz granules and greenish mud-chip clasts, and the feldspar grains are typically strongly altered to white clay minerals. The upper part of this unit, in some areas, is a moderately to well-sorted, moderately bioturbated feldspathic sandstone which may be equivalent to the Jackpile Member. Abundant dark grayish-green shaley intervals with thin dark-colored micritic limestones are present in some areas near the base of the map unit. Total thickness is approximately 500 ft (150 m).

Jet — **Entrada and Todilto Formations, undivided —** Cross section only. Estimated total thickness is up to 100 ft (30 m).

Jt — **Todilto Formation (chiefly Luciano Mesa Member) —** In most areas the only part of this unit that is exposed is the Luciano Mesa Member, a laminated, fetid, dark-gray, micritic limestone. Laminations in the limestone appear to be algal in origin and consistently lack of macrofossils. Rarely, the overlying Tonque Arroyo Member, a thin-bedded to laminated gypsum unit is preserved.

Je — **Entrada Formation —** A poorly exposed, light green-colored, massive (bioturbated?) sandstone unit that rarely displays high-angle cross-stratification.

Upper Triassic

Ŧc — **Chinle Group, undivided (probably Petrified Forest Formation) —** Mudstone with lenticular beds of lavender-gray sandstone; mudstones are reddish-brown to orange-tan in the upper part, and purple to reddish-brown in the lower part. Green reduction spots are common, as are local limestone-pebble conglomerate lenses, particularly near the base of the unit. Total Chinle Group thickness is about 1,300 ft (400 m).

Ŧz — **Chinle Group, Agua Zarca Formation —** The only distinct sub-unit of the Chinle Group recognized during this study (differentiated where possible). It is a tan- to light-grayish pink, resistant, thin- to medium-bedded quartz arenite and feldspathic arenite. The lower contact with the underlying Moenkopi Formation (*Ŧm*) is disconformable. The unit is about 350 ft (105 m) thick.

Middle and Lower Triassic

Ŧm — **Moenkopi Formation —** A recessive-weathering, dark red-colored micaceous shale, silty shale and thin-bedded feldspathic sandstone. Approximately 200 ft (60 m) thick.

PALEOZOIC ROCKS

Upper Permian

Psg — **San Andres and Glorieta Formations, undivided —** The upper two lithostratigraphic units of the Permian are complexly interleaved. The lithotypes, which may not strictly correlate with formations of the same names, are gray limestone (San Andres, *Ps*) and white quartz arenite (Glorieta, *Pg*). These were differentiated where possible.

Ps — **San Andres Formation —** Light gray and less commonly tan colored, medium- to thick-bedded limestone. The limestones are mostly micrites or skeletal wackstones, commonly with some component of quartz sand. The San Andres Formation is interbedded with the Glorieta Formation (*Pg*) with a total upper Permian (*Ps* and *Pg*) thickness of approximately 400 ft (120 m).

Pg — **Glorieta Formation —** White and pink (along the contact with the underlying Yeso Formation), massive or plane-bedded to low-angle planar cross-stratified quartz arenite. Locally, the sandstones are extensively bioturbated by *Macaronichnus*, and near the contact with Yeso Formation they are feldspathic. The sandstones are typically well sorted, but a thin, feldspathic quartz-pebble conglomerate occurs just below the base of the lowermost San Andres Formation limestone in the Arroyo Armijo area along the boundary between Sandia Park and Sandia Crest quadrangles. These sandstones and the limestones of the San Andres Formation are interbedded with each sandstone bed generally less than 30 ft (10 m) thick.

Lower Permian

Pay — **Abo and Yeso Formations, undivided —** The lower two lithostratigraphic units of the Permian represent a red-colored feldspathic to quartzose siliciclastic sequence that, because of generally poor exposure, was mapped as a single unit throughout the study area. The Yeso Formation is a reddish to pink or tan-colored, medium- to thin-bedded, feldspathic sandstone, shale and silty shale with interbedded massive or laminated micritic gray or tan limestone (*Pyc*) near the top. The sandstones are typically cross-stratified and/or cross-laminated and virtually identical to those within the underlying Abo formation except that, rarely, salt hopper casts and molds are present. The Abo Formation is a red and locally tan-colored (particularly near the base), medium- and thin-bedded arkose and feldspathic sandstone interbedded with red, micaceous siltstone and shale, commonly with green reduction spots. The lowermost arkoses are typically lighter-colored and coarser-grained than the younger feldspathic sandstones, and at least one of them is strongly bioturbated (*Macaronichnus*). The sandstones are cross-stratified (typically trough and wedge-planar geometries) and the finer grained rocks are commonly ripple cross-laminated. In addition, mud-chip clasts and plant debris are common. The upper contact with the Yeso Formation (Py) is conformable but difficult to distinguish in the field. The lower contact with the Madera Formation (*IPm*) is gradational with interbedded limestone and reddish-brown mudstone. The top of the lowermost laterally continuous and relatively thick limestone bed is chosen as the Madera Formation contact. Total thickness for the Abo and Yeso formations combined is approximately 1,300 ft (400 m).

Pyc — **Yeso Formation, upper limestone unit —** Intervals of massive or algal/cryptalgal-laminated limestone within the upper part of the Yeso Formation. The limestones are typically micritic, fenestral fabrics are commonly preserved, and they contain abundant quartz sand. Differentiated where possible east of the Village of Cañoncito. Generally less than 16 feet (5 m) thick.

Upper and Middle Pennsylvanian

IPm — **Madera Formation, undivided —** Two informal members, an arkosic limestone and a gray limestone, are recognized but not differentiated. The upper and lower members are respectively generally correlative to the Wild Cow Formation and Los Moyos Limestone (Formation) of the Madera Group of Myers and McKay (1976). These informal member names are used because the units were lithostratigraphically defined on the Sedillo (Read *et al.*, 1999) and Tijeras (Karlstrom *et al.*, 1994) 7.5-minute quadrangles rather than biostratigraphically defined and may therefore not strictly correlate with the units defined by Myers and McKay (1976). The Madera Group nomenclature was abandoned because of the gradational contacts between members and the difficulty of distinguishing these contacts in the field. Total thickness is approximately 1,320 ft (402 m) near Cedro Peak to the southeast (Myers and McKay, 1976) and 1,260 ft (385 m) on the Crest of Montezuma (Picha, 1982) to the north (consistent with thickness estimates based on map relationships in the study area).

IPm_u — **Madera Formation, upper arkosic limestone —** A gray, greenish-gray, olive-gray, tan and buff-brown fossiliferous limestone (comprises slightly more than half of member) interbedded with intervals of sub-arkosic sandstone and mudstone. The limestone is thinly to thickly bedded and massive, with sparsely disseminated chert. Sandstones and mudstones vary from reddish-brown to maroon to greenish-gray and gray. Sandstones and arkosic sandstones, while sometimes lenticular and laterally discontinuous, can be often traced over distances of several kilometers (see Read *et al.*, 1998). These arkosic sandstones are typically coarse- to medium-grained and often contain granules and pebbles. The base of this member is defined as the first occurrence of a thick and relatively continuous arkosic sandstone bed. Petrified wood is seen locally throughout this member.

IPm_l — **Madera Formation, lower gray limestone —** A sequence of often fossiliferous and massively bedded cliff-forming wavy laminated and cherty micritic limestone interbedded with shales. Shale is particularly abundant near the base of this member where it grades into the Sandia Formation. Generally correlative with the Los Moyos Limestone of Myers and McKay (1976).

IPs — **Sandia Formation —** Consists of a variety of lithologies including, in descending stratigraphic order: interbedded brown claystone and gray limestone, massive gray limestone, and a lower olive-brown to gray, subarkosic, fine- to coarse-grained sandstone. The contact with overlying Madera Formation (*IPm*) is chosen at the base of the lowest thick, ledge-forming limestone. The lower contact is unconformable with the Arroyo Peñasco Group or Proterozoic crystalline rocks. Isolated thin outcrops in Tijeras Canyon of sandstone and limestone from the Espiritu Santo Member of the Arroyo Peñasco Group (see Szabo, 1953; Armstrong, 1967; Armstrong and Mamet, 1974, Kelley and Northrop, 1975) generally remain undifferentiated from the Sandia Formation. Limestone in the Sandia Formation is distinct from limestone in the overlying Madera Formation as they are typically thinner-bedded, clast-supported, greenish, and contain abundant siliciclastic material. Approximately 170 ft (50 m) thick.

Mississippian

Ma — **Arroyo Peñasco Group, Espiritu Santo Formation(?) —** A poorly exposed outcrop of sandstone and limestone along a splay of the Tijeras fault. Several measured sections of thin remnants of the Arroyo Peñasco Group were described by Szabo (1953) and Armstrong (1967) but remain undifferentiated on this map (see the Sandia Formation description above).

PROTEROZOIC ROCKS

Mesoproterozoic igneous rocks

Ya — **Aplite dikes —** Light colored, fine- to medium-grained, and often sugary-textured aplite dikes consist of quartz, orthoclase, accessory muscovite, and in places are garnet-bearing (Kelley and Northrop, 1975). These dikes are generally thin planar dikes but may also be pods and stringers (up to approximately 500 ft, or 150 m, in diameter); interpreted to be coeval with the Sandia granite (*Ys*).

Yp — **Pegmatite dikes —** Pegmatite dikes, pods, and lenses ranging from <1 in to >50 ft (<30 cm to >15 m) in thickness and up to about 3,000 ft (915 m) in length; interpreted to be coeval with the Sandia granite (*Ys*).

Yps — **Sandia granite porphyry —** Fine- to med- grained phase of the Sandia granite (*Ys*) with scattered K-feldspar phenocrysts (up to several cm). Interpreted to be coeval with the intrusion of the Sandia granite.

Ys — **Sandia granite —** Mainly megacrystic biotite monzogranite to granodiorite. K-feldspar megacrysts, up to several cm long, are commonly aligned in a magmatic foliation; contains numerous ellipsoidal enclaves of microdiorite, fine-grained granite, and gabbro (interpreted to be mingled mafic magmas, *Ye*), and xenoliths of quartzite, mica schist, and mafic metavolcanic rock. Pegmatites (*Yp*), aplites (*Ya*), and quartz veins are ubiquitous. Various dates are available from geochronologic sample ***Locality 3***: U-Pb zircon plus sphene 1,455±12 Ma (Tilton and Grunenfelder, 1968, recalculated by S. Getty, unpublished); U-Pb zircon of 1,437±47 Ma (Steiger and Wasserburg, 1966, recalculated in Kirby *et al.*, 1995); U-Pb zircon of 1,446±26 Ma (D. Unruh, unpublished data); ***Locality 3*** also has $^{40}Ar/^{39}Ar$ analyses from hornblende of 1,422±3 Ma (Kirby *et al.*, 1995); ***Locality 2*** has an $^{40}Ar/^{39}Ar$ date of 1,423±2 Ma (Karlstrom *et al.*, 1997b).

Yss — **Sheared Sandia granite —** Plastically deformed megacrystic monzogranite to granodiorite, enriched in biotite due to depletion of quartz-feldspar from the matrix.

Ye — **Mafic enclaves —** Cross section only. A high density of ellipsoidal enclaves of microdiorite. These mafic enclaves often define magmatic foliation within the Sandia granite.

Paleoproterozoic rocks

Xlg — **Leucocratic granite and aplitic granite —** Light-colored biotite-poor granite in dikes and pods within the Manzanita granite.

Xmg — **Manzanita granite —** Strongly foliated very coarse-grained biotite monzogranite (biotite is chloritized). U-Pb zircon date of 1,645 ±16 Ma (Brown *et al.*, 1999) from the Mt. Washington 7.5-minute quadrangle (Karlstrom *et al.*, 1997a).

Xbg — **Biotite granite —** Biotite-rich, medium-grained, massive to foliated granite; occurs as mixed zones in the Manzanita granite.

Xc — **Cibola granite, undivided —** Biotite-muscovite monzogranite with U-Pb dates of 1,632 ±45 Ma (geochronologic sample ***Locality 5***), from north of the Tijeras fault and 1,659±13 Ma (***Locality 6***) from south of the Tijeras fault (D. Unruh, 1998 unpublished data).

Xcf — **Fine-grained Cibola granite —** Leucocratic two-mica granite.

Xcm — **Medium-grained Cibola monzogranite —** Equigranular, medium-grained, two-mica monzogranite; average grain size is 1-3 mm.

Xcc — **Coarse-grained Cibola monzogranite —** Two-mica monzogranite, contains scattered cm-size phenocrysts.

Xms — **Mica schist, quartz-muscovite schist, and phyllite —** Commonly rust red from hematitic staining, strongly crenulated and commonly crowded with boudinaged and folded stringers and lenses of vein quartz. Includes Coyote schist and Coyote phyllite of Cavin (1985).

Xq — **Quartzite —** Thick-bedded to massive and gray to milky-white quartz arenite with crossbedding and bedding defined by bands of iron oxides. Pelitic partings and interbeds contain aluminum silicates. Includes Cerro Pelon and Coyote quartzites of Cavin (1985) and Cibola quartzite of Connolly (1981). ***Locality 4*** has an $^{40}Ar/^{39}Ar$ date of 1,423±2 Ma (Kirby *et al.*, 1995).

Xp — **Chlorite-amphibole phyllite and schist —** Metasedimentary and volcaniclastic rocks that grade from mafic metavolcanics to lithic arenites. Includes metasedimentary rocks of the Tijeras greenstone of Connolly (1981) and part of the Coyote phyllite of Cavin (1985).

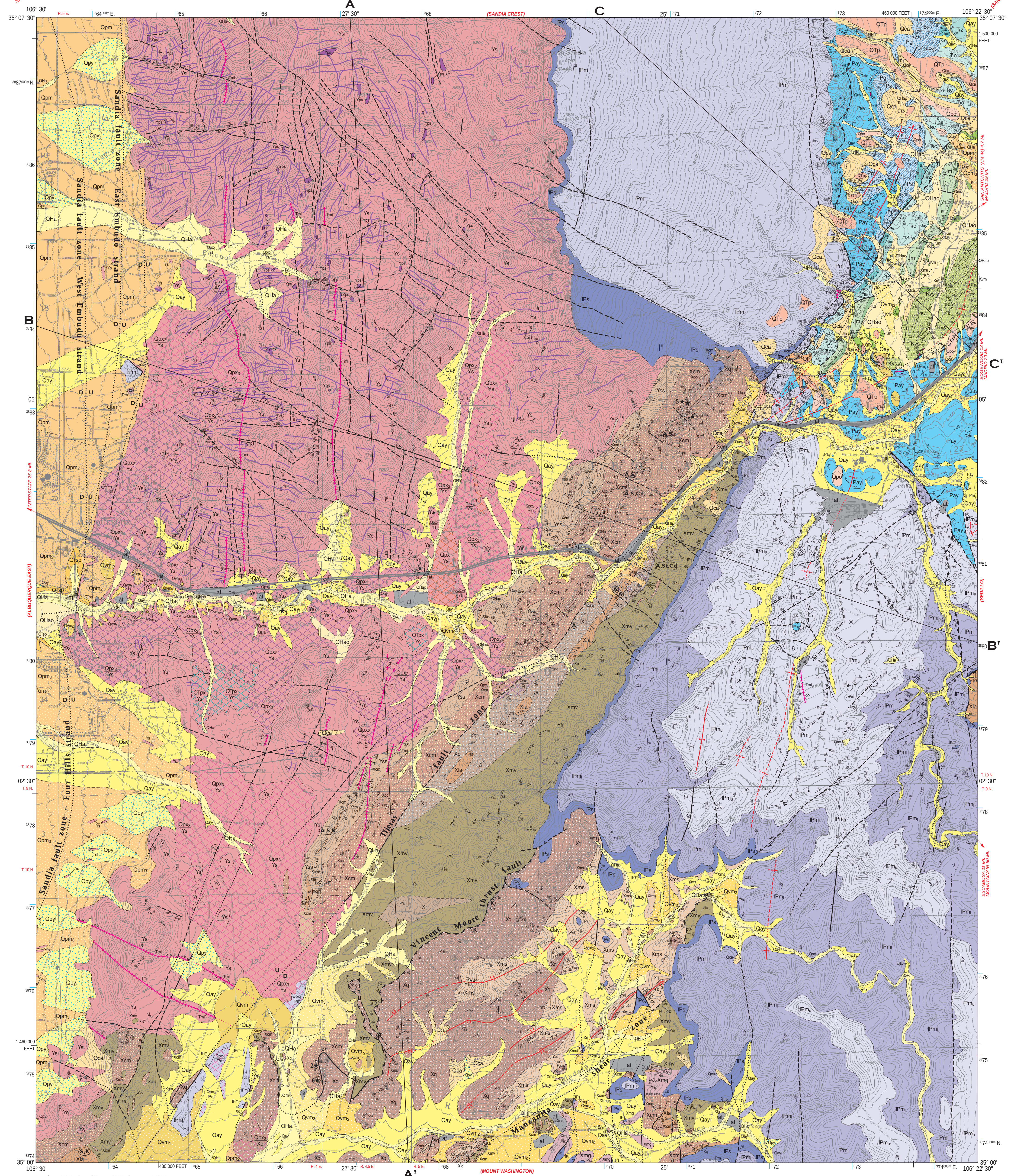
Xla — **Metamorphosed lithic arenite —** Quartz schist, quartz-chlorite schist, and quartzite (*Xq*), interlayered with volcaniclastic schists (*Xp*); quartzite locally contains alumino-silicates. Includes the Tijeras quartzite of Connolly (1981) and the Isleta metasediments of Parchman (1981).

Xdt — **Metamorphosed dacitic tuff —** Gray to light green metavolcanic and volcaniclastic schist and phyllite with local fragments of phyllite, chlorite phyllite, greenstone, and jasper.

Xmv — **Mafic metavolcanic rocks —** Heterogeneous unit consisting of massive to schistose metabasalt and meta-andesite with subordinate chlorite phyllite and schist of volcaniclastic origin. Coarse dioritic units may locally intrude the volcanic rocks. Includes the Tijeras greenstone of Connolly (1981), Coyote greenstone of Cavin (1985), and Isleta metavolcanics of Parchman (1981).

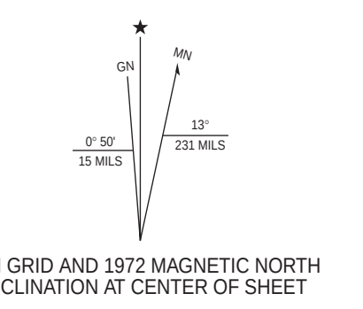
Xr — **Metarhyolite and to felsic metavolcanic rock —** Coarse-grained, buff to reddish-orange felsic metavolcanic rock, commonly banded, locally contains quartz and feldspar phenocrysts. Includes Tijeras felsic metavolcanics of Connolly, (1981).

TIJERAS QUADRANGLE
NEW MEXICO

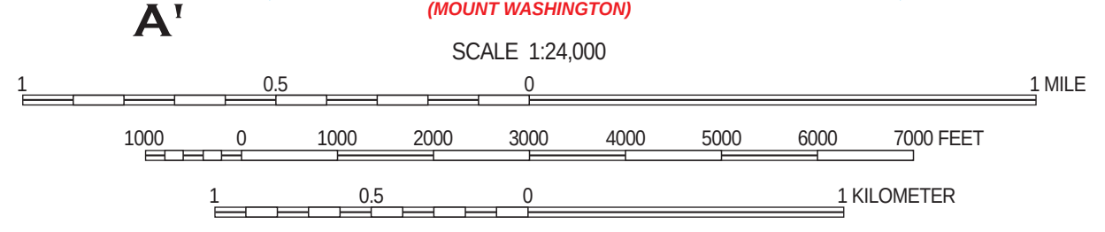


Base from U.S. Geological Survey 1954, photorevised 1961
Polyconic projection, 1927 North American datum, 10,000-foot grid based on New Mexico coordinate system, cental zone
1000-meter Universal Transverse Mercator grid ticks, zone 13, shown in blue

K. E. Karlstrom: mapping and compiliation of Proterozoic rocks, cross sections; S. D. Connell and D. W. Love: Quaternary mapping and unit descriptions (Connell); C. A. Ferguson and G. R. Osburn: Phanerozoic mapping and stratigraphy, (northeastern area of quad), unit descriptions, correlations, and regional structural interpretation; A. S. Read: differentiation of the Madera formation (southeastern area of quad), final map and cross section compilation; and P. W. Bauer: intellectual contributions.



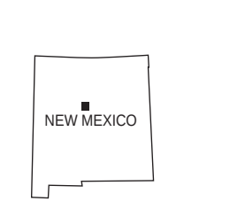
UTM GRID AND 1972 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET



SCALE 1:24,000

CONTOUR INTERVAL 40 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929

Mapping of this quadrangle was funded by a matching-funds grant from the 1994 STATEMAP program of the National Geologic Mapping Act coordinated by the U.S. Geological Survey and the New Mexico Bureau of Mines and Mineral Resources.

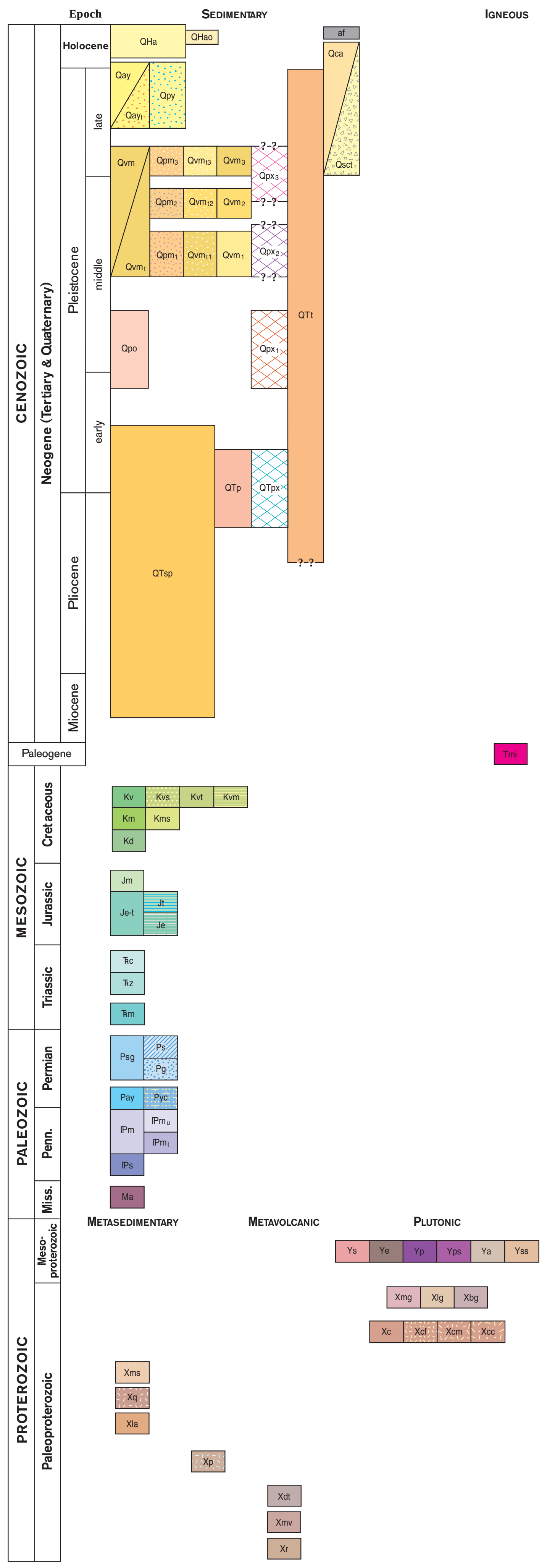


QUADRANGLE LOCATION

Geology of Tijeras quadrangle, Bernalillo County, New Mexico

June 1, 1994
5 April 2000 Revision

CORRELATION OF UNITS



EXPLANATION OF MAP SYMBOLS

B—B' Location of geologic cross section

Geologic contact—solid where exposed, dashed where approximately located; dotted where concealed

Geologic contact based upon interpretation of aerial photography

Normal fault—Tic showing dip, arrow showing trend and plunge of slickensides where measurable; solid where exposed, dashed where approximately located, dotted where concealed, queried where inferred; ball and bar on downthrown side, upthrown (U) and downthrown (D) sides indicated where concealed and/or interpreted

Reverse fault—Tic showing dip; solid where exposed, dashed where approximately located, dotted where concealed; square teeth on upthrown side

Thrust fault—Tic showing dip; solid where exposed, dashed where approximately located, dotted where concealed; triangular teeth on upthrown side of thrust

Anticline—Trace of axial plane showing direction of plunge; dashed where approximately located, dotted where concealed, queried where inferred

Syncline—Trace of axial plane showing direction of plunge; dashed where approximately located, dotted where concealed, queried where inferred

Overturned anticline—Trace of axial plane showing direction of plunge; dashed where approximately located, dotted where concealed, queried where inferred

Overturned syncline—Trace of axial plane showing direction of plunge; dashed where approximately located, dotted where concealed, queried where inferred

Shear zone—Tic showing dip

Breccia or gouge zones

Slickensides on fault or minor fault

Minor fold axis, trend and plunge, with map view sketch of fold

Strike and dip of bedding

Horizontal bedding; overturned bedding

Strike and dip of joint or fracture; vertical joint or fracture

Strike and dip of S_1 foliation, arrow indicates trend and plunge of lineation defined by elongate minerals and stretched grains

Strike and dip of S_2 foliation

Magmatic foliation in granite defined by alignment of mafic enclaves

Magmatic foliation in granite defined by alignment of feldspar megacrysts

Strike and dip of pegmatite or aplite dikes and veins

(A, S, K) Metamorphic mineral occurrences and assemblages: K = kyanite; A = andalusite; A,S = andalusite + sillimanite; A,S,K = andalusite+sillimanite+K-spar; A,St,Cd = andalusite+staurolite+chloritoid; A,S,Cd = andalusite+sillimanite+chloritoid; S,K = sillimanite+K-spar

Prospect

Quarry

★5 Geochronologic sample location (U-Pb, ^{14}C, etc.; see table and unit descriptions)

4H Exploratory or groundwater monitoring well, including abbreviation

Table of Geochronologic Samples

Locality	Date	Formation	Method	Reference
1	1,790 ±90 BP	Qay_t	^{14}C	Sample No. Beta-104958 (*this study*)
2	1,423±2 Ma	Xcm(sz)	$^{40}Ar/^{39}Ar$ (whole rock)	Karlstrom *et al.* (1997b)
3	1,455±12 Ma	Ys	U-Pb zircon + sphene	Tilton and Grunenfelder (1968), recalculated by S. Getty (unpubl.)
	1,437±47 Ma	Ys	U-Pb zircon	Stieger and Wasserburg (1966), recalculated in Kirby *et al.* (1995)
	1,446±26 Ma	Ys	U-Pb zircon	D. Unruh, (unpublished); Karlstrom (1999)
	1,422±3 Ma	Ys	$^{40}Ar/^{39}Ar$ (hornblende)	Kirby *et al.* (1995)
4	1,423±2 Ma	Xq	$^{40}Ar/^{39}Ar$ (muscovite)	Kirby *et al.* (1995)
5	1,632±45 Ma	Xcm	U-Pb zircon	D. Unruh, (unpublished); Karlstrom (1999)
6	1,659±13 Ma	Xcm	U-Pb	D. Unruh, (unpublished); Karlstrom (1999)