GEOLOGY OF THE BOSQUE PEAK 7.5-MINUTE QUADRANGLE, TORRANCE, BERNALILLO AND VALENCIA COUNTIES, NEW MEXICO

by
Karl E. Karlstrom, Sean D. Connell, Duncan L. Edwards, Jake Armour, John Lewis, and Patricia B. Jackson

Geologic mapping by
Karl E. Karlstrom (Proterozoic), Sean D. Connell and Patricia B. Jackson (Cenozoic), and Jake Armour and John Lewis (Paleozoic)
with previous mapping by Duncan L. Edwards, Mark A. Parchman, Donald A. Meyers, and E.J. McKay

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801 Leroy Place
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INTRODUCTION

The Bosque Peak 7.5-minute quadrangle comprises an area of about 158 km^2 (61 mi^2) in Torrance, Bernalillo and Valencia Counties, New Mexico (Fig. 1). The quadrangle contains the boundary between the Rio Grande rift on the west and the mountainous rift-flank on the east. The rift-flank consists of the southern Manzanita Mountains and the northern Manzano Mountains. Earlier studies of the Manzano Mountains were done by Reiche (1949), Myers and McKay (1971), and Edwards (1978). The geologic map (Plate I) is the result of additional detailed field mapping and integration of previous work that has refined the structure and stratigraphy of this quadrangle.

Geologic mapping was completed in cooperation with the University of New Mexico (UNM) and the New Mexico Bureau of Mines and Mineral Resources (NMBMMR). The topographic base for the geologic map is the Bosque Peak quadrangle, 7.5-minute topographic series, published by the United States Geological Survey at a scale of 1:24,000 (one inch equals 2000 feet). Proterozoic rocks and structures were mapped at a scale of 1:12,000; Quaternary and Tertiary deposits were delineated at a scale of 1:24,000 and compiled at a scale of 1:12,000. Compilation of data from various sources and scales of mapping onto the geologic map resulted in significant variations in the apparent precision of mapping across the study area; therefore, differences in map detail are inevitable. Paleozoic rocks and associated structures were mapped in reconnaissance, with some modifications after Myers and McKay (1971; scale 1:24,000). Tertiary and Quaternary features were mapped with the help of 1993 color air photos (approximate scale 1:6,000) from the U.S. Forest Service.

Principal contributions and revisions to previous work include: correlation of Proterozoic metasedimentary units with other areas in the Sandia-Manzano uplift; U-Pb dating of the Ojito granite and co-mingled mafic units; identification of a contact aureole around the Ojito pluton; identification of probable 1.1 Ga cross-cutting diabase dikes; refinemant of understanding of the Laramide Montosa and related faults; differentiation of the piedmont stratigraphy; recognition and refined mapping of range-bounding structures; and incorporation of subsurface data (Table 1).

Comments To Map Users

Mapping of this quadrangle was funded by a matching-funds grant from the 1998 STATEMAP program of the U.S. Geological Survey, National Cooperative Geologic Mapping Program, under USGS award number 1434-HQ-97-AG-01781, to the New Mexico Bureau of Mines and Mineral Resources (Dr. Charles E. Chapin, Director; Dr. Paul W. Bauer, P.I. and Geologic Mapping Program Manager).

This quadrangle map has been Open-Filed in order to make it available as soon as possible. The map has not been reviewed according to NMBMMR standards, and due to the ongoing nature of work in the area, revision of this map is likely. As such, dates of revision are listed in the upper right corner of the map and on the accompanying report. ***The contents of the report and map should not be considered final and complete until it is published by the NMBMMR.***

A geologic map graphically displays information on the distribution, nature, orientation, and age relationships of rock and surficial units and the occurrence of structural features such as faults and folds. Geologic contacts are irregular surfaces that form boundaries between different types or ages of units. Data depicted on this geologic map are based on 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. Significant portions of the study area may have been mapped at scales smaller than the final map; therefore, the user should be aware of potentially significant variations in map detail. 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 everywhere.

The cross-sections in this report are constructed based on surficial geology, and where available, subsurface and geophysical data. The cross sections are interpretive and should be used as an aid to understand the geologic framework and not used as the sole source of data in locating or designing wells, buildings, roads, or other structures.

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 U.S. Government.

Accessibility

The north portion of the Bosque Peak quadrangle is on the Isleta Pueblo; the southeastern portion is part of the Cibola National Forest; and the southwestern portion is on private and public (Bureau of Land Management and State of New Mexico) land. Travel within the Isleta Reservation is prohibited without permission from the tribal government. Several graded dirt and paved roads allow access to portions of the study area. The western portions of the area are accessible from dirt roads off of N.M. State Road 147. The eastern parts of the area are accessible from the Torreon-Tajique Loop road south of Tajique, and trails from this road into the Manzano Mountains.

Geologic and Physiographic Setting

The quadrangle traverses the western flank of the southern Manzanita and northern Manzano Mountains and the eastern margin of the Albuquerque basin (Kelley, 1977). At the north end of the quadrangle, the Laramide Montosa fault steps from the east side of the range, west into the Rio Grande rift and causes the abrupt step to higher elevations in the Manzano Mountains (in the south) relative to the Manzanita Mountains (in the north). The mountain-front is segmented into 4-5 km long sections by Tertiary faults and is slightly embayed by moderate size canyons, such as Ojito Canyon and Cañon de los Seis. The western half of the quadrangle forms a slightly to moderately dissected west-sloping piedmont. The piedmont associated with the Manzano-Manzanita mountain front is on the footwall of the Hubbell Springs fault zone, about 4-5 km west of the study area. Topography is generally steep and rugged in upland areas, which are held up by resistant Pennsylvanian sedimentary and Proterozoic crystalline rocks. Neogene (?) and Quaternary deposits are locally exposed in incised arroyos. The study area exhibits 1210 m (3970 ft) of maximum topographic relief, with a maximum elevation of 2929 m (9610 ft) at Bosque Peak.

STRATIGRAPHY

The age and stratigraphic relationships of map units are summarized below and in the Correlation of Map Units (Figs. 3 and 4).

Quaternary and Pliocene Deposits

Alluvial Deposits

Quaternary and Pliocene alluvial deposits contain variable proportions of gravel, sand and silt, deposited by intermittent and ephemeral streams draining the southern Manzanita and northern Manzano Mountains; mass-movement deposits typically occur on hill slopes. Map-unit differentiation is based on stratigraphic position (inset or depositional relations), surface morphology, degree of soil-profile development (Gile et al., 1981) and sedimentary character. Deposits consist of poorly sorted, poorly to moderately stratified, predominantly clast-supported alluvium, having predominantly gravelly to sandy textures; silt-clay textures are rare. Clast constituents typically reflect bedrock composition of local upland drainage systems associated with the western flank of the Manzanita and Manzano Mountains. Dominant clast types include the Ojito granite and assorted metamorphic rocks. Alluvial fans associated with the larger mountain-front drainages, such as Cañon de los Seis, Los Moyos, Ojito, and Garcia canyons, typically contain granite, metamorphic, and minor limestone clasts. These deposits record episodes of deep valley entrenchment and partial back-filling that are graded to the Llano de

Manzano and to former base levels on the footwall of the Hubbell Springs fault zone, approximately 4-5 km west of the western quadrangle boundary. Alluvial deposits range in age from historical to late Pliocene(?) in age and are informally defined, mapped and correlated on the basis of stratigraphic superposition, surface morphology, landscape-topographic position, and to a limited extent, soil-profile characteristics.

Alluvial deposits are at least 4 m thick and may be as thick as 30 m. These deposits overlie Santa Fe Group deposits, which may be as thick as 1-1.5 km (V.J.S. Grauch, 1999 unpubl., USGS gravity model of Albuquerque Basin). Alluvial deposits are divided into valley-floor and piedmont alluvium, and colluvium.

Valley-floor alluvium (Qvy and Qa subunits) — Stream (floodplain, fill-terrace) deposits are restricted to major entrenched valleys, such as Garcia and Ojito Canyons. Units typically have an elongated planform shape and are differentiated on the basis of inset relationships and surface morphology.

Piedmont-slope alluvium (Qp subunits) — Stream and alluvial-fan deposits on constructional and erosional parts of piedmont slopes. Units include fan and debris-flow deposits and shallow-valley fills that are not graded to major entrenched arroyo systems.

Colluvium and spring deposits (Qca) — Mass-movement deposits recognized in upland regions and valleys.

Upland regions are dominated by erosion with only local, short-term sediment storage on hillslopes and valley floors. Mass-movement deposits are common on hillslopes; hyperconcentrated-flow, debris-flow and local stream-flow deposits occur in higher order drainages. Piedmont-slope deposits extend westward from the mountain front and form constructional landforms on coalescent piedmont alluvial-fan complexes that form the Llano de Manzano. Colluvium is common along unit margins and on terrace risers associated with major drainages. Valley-floor deposits occupy former floodplain positions of major drainages.

Unit QTpo is recognized along the mountain front and forms the highest alluvial deposit resting unconformably upon Proterozoic rocks. Deposits are commonly preserved on the footwall of the Manzano frontal fault. Clasts are commonly cobble to boulder size. Granite clasts are commonly deeply pitted, fractured, and moderately grussified. The matrix is predominantly sand and pebbly sand derived from decomposed granite (grus). Local stream-cuts expose strongly developed soil with stage III to IV carbonate morphology. Deposits are over 6 m thick.

Unit Qpa represents an undivided sequence of piedmont deposits (units Qpo, Qpm, Qvy and Qa) derived from the Manzano and Manzanita Mountains. This unit underlies the Llano de Manzano geomorphic surface of Machette (1985)

Unit Qpo is inset against QTpo and forms. This unit is poorly exposed, but is commonly light yellowish-brown to strong-brown (7.5YR 4/6 to 10YR 6/4-5/4) and dark grayish-brown (10YR 4/2) grussified silty sand and cobbly to bouldery gravel. Deposits locally exhibit stage III calcium-carbonate morphology and locally, multiple buried soils, indicating episodic aggradation. Deposits within 1.5 km of the mountain front are commonly clast supported and predominantly boulder and cobble size. Distal deposits are commonly clast- and matrix- supported cobble and pebble gravel. Granite clasts are commonly deeply pitted, fractured and grussified. Phyllitic and schistose clasts are commonly split. Unit is locally divided into two subunits (Qpo1, older; Qpo2, younger) on the basis of soil development and clast weathering. Along the southern margin of the study area, unit Qpo1 commonly contains abundant weathered metamorphic clasts and strongly developed calcic soils that exhibit stage III to IV carbonate morpholgy. This deposit is unconformably overlain by unit Qpm. Deposits are at least 4 m thick.

Unit Qpm is inset against Qpo and forms local sandy to gravelly alluvial fan deposits along the mountain front. Deposits are poorly exposed light yellowish-brown (10YR 6/4) to reddish-brown (5-

7.5YR 4/4), fine-to medium-grained sand, pebbly to cobbly sand, and silty sand. Gravel clasts are not as large as units Qpo and QTpo. Soils are weakly to moderately developed and exhibit stage I to II+ carbonate morphology. Granite clasts are slightly to moderately pitted and slightly split. The undersides of cobbles at the surface are slightly rubefied

Unit Qvy is inset against Qpm and forms sandy to conglomeratic stream-terrace deposits that are over 4 m in thickness. A prominent terrace at the mouth of Cañon de los Seis is about 4.8 m above the modern drainage.

Unit Qa is inset against Qvy and Qpa and forms low valleys associated with modern streams. Clasts are commonly angular to subrounded and are not pitted or split. Boulder bars are common and bars are recognized 4.5 km west of the mountain front in major stream valleys, such as Ojito Canyon.

Paleozoic Rocks

Upper Paleozoic strata exposed within the quadrangle include the Sandia Formation (Ps) and Madera Group (Pm): lower (Pml) and upper (Pmu). They represent marine and non-marine sedimentary deposits of Pennsylvanian age. Upper Paleozoic strata of the New Mexico region were deposited in and adjacent to widespread shallow seaways, with the Pedernal highland to the east. These were part of a system of widespread syntectonic basins that formed during the development of the Ancestral Rocky Mountains, which may have formed during collision of the South and North American continents in the region that now includes Texas and Oklahoma (Kluth and Coney, 1981). Alternatively they may have formed during collision of island arcs along the SW margin of the continent in the region of northern Mexico (Ye et al., 1996).

Proterozoic Rocks

Paleoproterozoic rocks in the Bosque Peak quadrangle consist of ductiley deformed and metamorphosed volcanic, sedimentary and plutonic rocks. These rocks generally formed in volcanic arcs and related arc basins along the growing southern periphery of cratonic North America ca. 1.6–1.7 Ga. The metavolcanic and metasedimentary succession is probably equivalent to rocks dated at 1670-1680 Ma in the southern Manzano Mountains (Bauer et al., 1993). They are intruded by various igneous units, most notably the Ojito granite dated at 1659 ± 5 Ma (NW1/4, Sec. 29, T7N, R5E) by the U-Pb zircon method (Unruh, unpublished data). Cross-cutting granitic to pegmatitic dikes (Ya) may be of Mesoproterozoic age (about 1.4 Ga) based on similarities to dated muscovite granite/rhyolite dike in the adjacent Mount Washington quadrangle (New Mexico Geochronology Research Laboratory; M. Heizler, written commun. 1997). Northwest-striking diabase dikes may be 1.1 Ga based on similarities in lithology and orientation to other diabase dikes in the Southwest (Howard, 1991).

Mapping in the Bosque Peak quadrangle has led to an extension of the new proposed Paleoproterozoic stratigraphy for the Sandia-Manzano uplift that was developed in quadrangles to the north (Chamberlain et al. 1997). This proposed stratigraphy is based on correlation of similar lithologies across major folds and thrusts, so the stratigraphic interpretation is strongly based on the accompanying structural interpretation. In particular, we have correlated mafic to intermediate metavolcanic packages (Xmv and Xiv) that have been variously named (from north to south) the Tijeras (Connolly 1982), Coyote (Cavin, 1985), Isleta (Parchman, 1981), and unnamed greenstone of Edwards (1978). These metavolcanic units are overlain by a dacite beccia (Lacoracah metadacite of Parchman, 1981) that was also identified as a thin unit at the top of the metavolcanic rocks in the northern part of the Bosque Peak quadrangle. Metavolcanic units contain a heterogeneous assemblage of metavolcanic and volcaniclastic units and appear to be the base of a gradational supracrustal sequence that gets more sediment- dominated and increasingly mature upsection. Gradationally above the dacite, the stratigraphic sequence includes: phyllite (Xp) and dirty lithic arenites (Xla). These are equivalent to the Bosque metasediments of Edwards (1978) and Lower Metaclastic series of Reiche (1949) and probably correlative with Moyas metasediments of Edwards (1978). Lithic arenite is gradationally overlain by schist (Xs), mature cross bedded quartzite (Xq—Sais metaquartzite of Stark and Daples (1946) and Stark (1956, and more schist (Xs).

A diverse assemblage of intrusive units are present in the Bosque Peak quadrangle. Intrusive units within the greenstone include quartz diorite (Xqd) that may be related to the main intrusive mass, the Ojito granite, within the quadrangle. Most of the Proterozoic rocks of the quadrangle are part of the Ojito pluton. The main unit of the Ojito pluton is a quartz monzonite called the Ojito granite (Reiche, 1949; Edwards (1978). This unit yields a new U-Pb zircon date of 1659 ± 5 Ma (Unruh, unpublished data). It contains within it numerous mingled and mixed magmas that are part of a single intrusive complex. These include gabbro (Xg), olivine gabbro (Xgo), quartz gabbro (Xqg), porphyritic quartz diorite (Xqd), and granodiorite (Xgd). These units are completely gradational and represent the product of magma mingling and mixing as shown by cuspate gradational contacts, mutual crosscutting realtionships, and isolated felspar phenocrysts within gabbro enclaves. Mafic units yield two zircons that fall on the same discordia line as the main Ojito granite (Unrue, unpublished data). The Ojito pluton is intruded by several younger dikes: a discontinuous set of muscovite-bearing granite and pegmatite dikes (Yg) that resemble the 1.4 Ga dike in the Mount Washington quadrangle, and a set of NW-trending diabase dikes(Yd) that we speculate are 1.1 Ga based on chilled margins, characteristic diabase textures and regional correlations with other 1.1 Ga diabases. Lamprophyre (spessartite) dikes of Edwards (1978) may be 1.1 Ga, but may also be related to the Ojito gabbro.

STRUCTURAL GEOLOGY

Folds, faults and shear zones in the Bosque Peak quadrangle exhibit several styles of deformation related to different periods of tectonic activity since the Proterozoic. This section discusses some of the recent refinements to the structure of the study area.

Quaternary and Neogene Structures

Major, down-to-the-west, range-bounding structures most likely represent dip-slip normal faults associated with extension across the Rio Grande rift in middle to late Cenozoic time. Examples are the Manzanita and Manzano frontal faults. Extensional faulting may have removed earlier components of crustal shortening (reverse faulting) from many pre-existing fault zones of Laramide and late Paleozoic ancestry.

The mountain front is marked by discontinuous and degraded west- and northwest-facing fault scarps with inferred down-to-the-west displacement. These scarps have weak to moderate topographic expression and cut units QTpo and Qpo, but are buried by younger piedmont and stream deposits (Qpm and Qvy). A prominent vegetation lineament is recognized near Garcia Canyon where deposits of Qpm bury any topographic expression of movement. The range-bounding faults locally split into two strands near a 2 km east step in the mountain front. Youngest displacement of deposits by faults along the mountain front are probably middle Pleistocene in age.

The Sanchez fault was named for an inferred northwest-trending fault on the adjacent Mount Washington quadrangle (Karlstrom et al., 1997). This fault may accommodate thickening of Santa Fe Group basin fill from about 30 m on the northern Hubbell bench to well over 190 m on the Bosque Peak quadrangle. The southeast projection of this inferred structure trends towards Cañon de los Seis, where the Montosa fault enters the basin.

Paleozoic and Younger Structures

Paleozoic and younger structures consist primarily of faults and gentle- to steep- limbed drape or drag folds adjacent to these faults. Most faults trend N-S; less common and shorter fault segments locally trend NW, NNW, and NE. Reiche (1949) recognized strike slip, reverse and normal faults in the Manzanita Mountains area. New mapping for this report suggests a complex slip history for many faults in the Bosque Peak quadrangle. Several faults, for example the NW-trending faults near Cerro Blanco, end at the basal Pennsylvanian contact and are interpreted to be either Ancestral Rockies in age and/or 1.1 Ga (similar in age and orientation to the diabases).

The main fault system on the east side of the Manzano Mountains consists of the Montosa fault and related structures. These are interpreted to be of Laramide age based on their contractional character as east-side-up reverse faults. These faults have associated east-facing monoclines in the Paleozoic strata as shown in the E-W cross section (plate II). Total vertical separation on these strucutures is at least 1500 ft. The Montosa fault system bends west in the vicinity of Canon de los Seis and apparently merges with the rift-flank fault, the Manzanita fault. This left-bend is also a reverse fault, as shown by Proterozoic rocks faulted against Pennsylvanian rocks in Canon de los Seis. Right-lateral strike slip has been proposed for the Montosa fault in other areas. If so, the left-bend would be a restraining bend, compatible with contractional separation across the fault. This left step in the Montosa fault system coincides with the Sanchez fault and with a major gravity high in the Albuquerque basin (Karlstrom et al. 1999) and may be a reflection of an older, Proterozoic structure. This fault bend also has significance in terms of topography. It explains the change in elevation between the low-lying Manzanita Mountains and the higher elevation Manzano Mountains, as the crest of both ranges is held up by the resistant Madera Group rocks. Thus, we interpret the variation in physiography of the rift flank to have Laramide ancestry and the present segmentation of the rift flank to be in part of Laramide in age in this area. Subsidiary Laramide reverse fault splays continue north on the east side of the Manzanita Mountains from Canon de los Seis and merge to the north with the Hells Canyon fault system.

The west side of the Manzano Mountains is controlled by major, down-to-the-west, range-bounding structures that most likely represent dip-slip normal faults associated with spreading along the Rio Grande rift in middle to late Cenozoic time. These faults are named the Manzanita fault to the north (Chamberlain et al. 1997) and the Manzano fault to the south (Kelley, 1977). To the west, the Hubbell Springs fault zone shows evidence of Pliocene to Pleistocene normal displacement associated with extension along the Rio Grande rift.

No clear evidence of Quaternary faulting was found in the Mount Washington quadrangle. However, warping and displacement along the range bounding faults has probably influenced the distribution and thickness of Pliocene alluvial deposits (eg. QTspc) in the western portion of the quadrangle (Table 1).

Proterozoic Structures

The character of Proterozoic structures is illustrated in the accompanying N-S cross section (Plate III). Metamorphic and plutonic rocks are ductilely deformed and show evidence for multiple generations of deformation. The main tectonic fabric is a penetrative foliation (Sl) that strikes northeast at the south and north ends of the quadrangle, parallel to the regional trend. In the central portion of the quadrangle, S1 foliation forms a broad west-plunging synformal bend that mimics the contact with the Ojito pluton. Foliations dip moderately, 30°–70° beneath the pluton on the north and east sides suggesting that the pluton is a large sheet-like intrusion within the lithic arenite unit, rather than a "stock" as interpreted by Reiche (1949). This is also supported by shallowly dipping magmatic foliations within the pluton. The pluton is not penetratively deformed, but contains discrete shear zones that indicate it has undergone partitioned ductile deformation. We interpret the pluton to have been emplaced before N-directed thrusting and N-verging folding associated with the 1.65 Ga Manzanita thrust belt (Brown et al. 1999), but its mafic composition and greater strength relative to the metasedimentary rocks allowed it to undergo less strain as it was transported by thrusts. Foliation in the southern aureole of the pluton dips moderately southeast, suggesting the pluton is beneath the metasedimentary rocks here. This interpretation is also supported by the presence of shallowly-dipping roof pendants and screens near the southern contact.

The north part of the quadrangle contains the south limb of the Hells Canyon anticlinorium, cored by metavolcanic rocks. This is part of a fold pair that was mapped in the Mount Washington quadrangle and interpreted to be a ramp anticline related to a ramp at depth within the thrust belt. Thus, the Ojito pluton is interpreted to be part of a thrust sheet above the Isleta thrust. In the Mount Washington quadrangle, the synclinorium is defined on the basis of opposing graded bedding indicators in the lithic sandstone unit (Xla) and by repetition of a distinctive chert marker layer. The anticlinorium was mapped by Parchman (1981) based on repetition of a distinctive dacitic tuff unit (Xdt) both north and south of Hells Canyon. Units in these folds are transposed parallel to the northeast-striking axial plane (Sl) of the folds. Numerous parasitic folds at all scales occur in the metasedimentary units, as shown schematically in the cross section (Plate III).

A second generation of ductile structures occurs as variably-developed, but often weakly expressed crenulations of the main foliation. Timing of formation of these structures could be either Early or Middle Proterozoic.

PROTEROZOIC METAMORPHISM

The regional metamorphic grade away from the Ojito pluton is upper greenschist facies as shown by the assemblage in mafic metavolcanic rocks: actinolite (some hornblende), chlorite, sodic plagioclase (An_6), epidote (and clinozoisite), quartz, white mica (rare), and sphene. Phyllites typically contain quartz, sericite,clinozoisite/epidote, chlorite, and muscovite.

The southern margin of the Ojito pluton has a well-developed contact aureole, with sillimanite within 200 m of the contact and andalusite within about 700 m of the contact. These minerals occur within the lithic arenite unit and are similar to the contact aureole described by Brown et al. (1999) around the Manzanita pluton to the north. The syntectonic character of the andalusite porphyroblasts suggest a ca. 1650-1660 Ma age of deformation and metamorphism in the Manzano Mountains.

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REFERENCES CITED

Bates, R. L., and Jackson, J. A., eds., 1987, Glossary of geology: Alexandria, Virginia, American Geological Institute, 788 p.

Bauer, P. W., Karlstrom, K. E., Bowing, S. A., Smith, A., and Goodwin, L. B., 1993, Proterozoic plutonism and regional deformation—new constraints from the southern Manzano Mountains, central New Mexico: New Mexico Geology, v. 15, no. 3, p. 49–55.

Brown, C.L., Karlstrom, K.E., Heizler, M., and Unrue, D., 1999, Proterozoic deformation, metamorphism, and $^{40}Ar/^{39}Ar$ thermal history of the 1.65 Ga Manzanita pluton, Manzanita Mountains, New Mexico: New Mexico Geologic Society Guidebook 50, in press.

Cavin, W. J., 1985, Precambrian geology of the Manzanita Mountains, Bernalillo County, New Mexico [M.S. thesis]: Albuquerque, University of New Mexico, 144 p.

Edwards, D.L., 1978, Petrology and structure of Precambrian rocks in the Bosque Peak quadrangle, north Manzano Mountains, central New Mexico: unpublished MS thesis, University of New Mexico, 105 p.

Gile, L. H., and Hawley, J. W., 1966, Periodic sedimentation and soil formation on an alluvial-fan piedmont in southern New Mexico: Soil Science Society of America Proceedings, v. 30, p. 261–268.

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

Howard, K.A., 1991, Intrusion of horizontal dikes: Tectonic significance of middle Proterozoic diabase sheets widespread in the upper crust of the southwestern U.S.: Journal of Geophysical Research, v. 96, p. 12,461-12,478.

Karlstrom, K. (compiler), et al., 1994, Geology of the Tijeras 7.5-minute quadrangle, Bernalillo County, New Mexico: New Mexico Bureau of Mines and Mineral Resources Open-File Report 396.

Karlstrom , K.E., Cather, S.M., Kelley, S.A., Heizler, M.T., Pazzaglia, F.J., and Roy, M., 1999, Sandia Mountains and Rio Grande rift: Ancestry of structures and history of deformation: New Mexico Geologic Society Guidebook 50, in press.

Karlstrom, K. E., Dallmeyer, R. D., and Grambling, J. A., 1997, $^{40}Ar/^{39}Ar$ evidence for 1.4 Ga regional metamorphism in New Mexico: Implications for thermal evolution of lithosphere in the southwestern USA: Journal of Geology, v. 105, p. 205–223.

Karlstrom, K.E., Chamberlin, R.C., Connell, S.D., Brown, C., Nyman, M., Cavin, W., Parchman, M., Cook, C., Sterling, J., 1997, Geology of the Mt. Washington 7.5-minute quadrangle, Bernalillo and Valencia Counties, New Mexico, New Mexico Bureau of Mines and Mineral Resources, Open-file Digital Geologic Map OF-DM 8, scale 1:12,000 and 1:24,000.

Kelley, V. C., 1977, Geology of the Albuquerque basin, New Mexico: New Mexico Bureau of Mines and Mineral Resources Memoir 33, 60p.

Kluth, C. F. and Coney, P. J., 1981, Plate tectonics of the ancestral Rocky Mountains: Geology, v. 9, p. 10–15.

Love, D. L. (compiler), et al., 1996, Geology of the Hubbell Springs 7.5-minute quadrangle, Bernalillo and Valencia Counties, New Mexico: New Mexico Bureau of Mines and Mineral Resources Open-File Report 426.

Machette, M.N., 1985, Calcic soils of the southwestern United States, *in* Weide, D.L., and Faber, M.L., eds., Soil and Quaternary geology of the southwestern United States: Geological Society of America Special Paper 203, p.1-42

Myers, D. A., and McKay, E. J., 1971, Geologic map of the Bosque Peak quadrangle, Torrance, Valencia, and Bernalillo counties, New Mexico: U.S. Geological Survey Miscellaneous Investigations Series Map I-948.

Parchman, M. A., 1981, Precambrian geology of the Hell Canyon area, Manzano Mountains, New Mexico

[M.S. thesis]: Albuquerque, University of New Mexico, 108 p.
Reiche, P., 1949, Geology of the Manzanita and north Manzano Mountains, New Mexico: Geological Society of America Bulletin, v. 60, no.7, p. 1183–1212.
Stark, J.T., 1956, Geology of the south Manzano Mountains, New Mexico: New Mexico Bureau of Mines and Mineral Resources, Bulletin 34, 46 p.
Stark, J.T. and Dapples, E.C., 1946, Geology of the Los Pinos Mountains, New Mexico: Geological Society of America Bulletin, v. 57, p. 1121-1172.
U.S. Geological Survey, and Sander Geophysics, Ltd., 1998, Digital data from the Isleta-Kirtland aeromagnetic survey, collected south of Albuquerque, New Mexico: U.S. Geological Survey Open-File Report 98-341, CD-ROM.
Ye, H., Royden, L., Burchfiel, C., Schuepbach, M., 1996, Late Paleozoic deformation of interior North America: The greater Ancestral Rocky Mountains: American Association of Petroleum Geologists, v. 80, p. 1397-1432.

Figure 1

Figure 2

Figure 3

figure 4

Table 1. Summary and interpretation of driller's logs for water-supply wells on Bosque Peak 7.5-minute quadrangle (Plate I).

Well No.: **RWP-002**
Date drilled: 1952
Drilling method: unknown
Location: 6N.4E.23.123, NMPM
Elevation: 5745±20 feet (from topographic map)

Depth (ft)	Driller's Log	Interpretation	Notes
0-10	Top soil gravel	piedmont alluvium	
10-40	Boulders	and Santa Fe Group,	
40-45	Hard brown sand	undivided (Qu-Tsp)	
45-55	Brown shale		
55-60	Gravelly brown shale		
60-85	Sandy brown shale		
85-110	Conglomerate, shale, gravel		
110-170	Conglomerate, shale, bounders		
170-190	Hard white	limestone clasts	
190-215	Brown shale		Water at 200 ft
215-250	Blue shale		
250-265	Water sand		
265-270	Sand		
270-275	Blue shale		
275-285	Broken formation (shale, sand)		
285-310	Sand		

Well No.: **RWP-25**
Date drilled: 1967
Drilling method: unknown
Location: 6N.5E.18.243 (projected), NMPM
Elevation: 6135±20 feet (from topographic map)

Depth	Driller's Log	Interpretation	Notes
0-5	Top soil	Piedmont alluvium	
5-70	Sand and gravel fill	(Qu)	
70-110	Sand & gravel boulders	Santa Fe Group	
110-482	Sand & gravel boulders	(Tsp)	16 days drilling water at 455 ft.

Well No.: **ECW-001**
Date drilled: 1934
Drilling method: unknown
Location: 6N.4E.11.144, NMPM
Elevation: 5715±20 feet (from topographic map)

Depth	Driller's Log	Interpretation	Notes
0-200	Sand	Piedmont alluvium	
200-220	Granite wash	and Santa Fe Group,	water at 109 ft
220-239	Hard granite wash	undivided (Qu-Tsp)	

Well No.: **BLL-1** (Bonita Land and Livestock Company test well)
Date drilled: 1998
Drilling method: Rotary mud
Location: 6N.4E.11.131, NMPM
Elevation: 5700±20 feet (estimate from topographic map)
Logged by: P.B. Jackson (cuttings)

Depth (ft)	Description of cuttings (colors are dry)	Interpretation
0-90	Not available	Piedmont alluvium (Qu)
90-100	Pebble gravel (95% gravel, 5% silt and sand), well sorted, angular clasts, dark gray (7.5YR 4/1). Clast composition: granite, metamorphic (phyllite-schist), and limestone. Carbonate cement.	
100-160	Medium- to very coarse-grained pebbly sand (10-15& gravel, 80-85% sand, 5% silt), moderately to well sorted, subangular to subrounded sand grains, angular pebble clasts, light brown to brown (7.5YR 6/3-5/3). Clast composition: granite, metamorphic (phyllite-schist), limestone. Carbonate cement.	Santa Fe Group (Tsp)
160-170	Pebble gravel (95% gravel, 5% silt and sand), well sorted, angular clasts, dark gray (7.5YR 4/1). Clast composition: granite, metamorphic (phyllite-schist), and limestone.	
170-200	Medium- to coarse-grained sand and pebble gravel (40-50% gravel, 50-60% sand, 5-10% silt-clay), well sorted, angular to subangular sand grains, angular pebble clasts, gray (7.5YR 4/1). Clast composition: granite, metamorphic (phyllite-schist), and limestone. Carbonate cement.	
200-210	Pebble gravel (85% gravel, 10% sand, 5% silt), well sorted, angular clasts, dark gray (7.5YR 4/1). Clast composition: granite, metamorphic (phyllite-schist), and limestone. Carbonate cement.	
210-460	Silty-clayey sand (80% sand, 20% silt-clay), well sorted, medium-to coarse-grained, subrounded to rounded grains, brown (7.5YR 5/3). Sand composition: quartz, granite, metamorphic and lithic fragments.	
460-480	Silty-clayey sand (80% sand, 20% silt-clay, trace gravel), well sorted, medium- to coarse-grained, subrounded to rounded grains, brown (7.5YR 5/3). Sand composition: quartz, granite, metamorphic and lithic fragments.	
480-620	Clayey-silty sand (60% sand, 40% silt-clay), well sorted, fine-grained, subrounded to rounded grains, brown (7.5YR 5/3).	

DESCRIPTION OF MAP UNITS

Cenozoic Rocks and Deposits

Valley-floor alluvium

Qa Stream alluvium, undivided (upper Holocene to historic) — Poorly to moderately sorted, poorly consolidated pebble- to cobble conglomerate and fine-to coarse-grained sand with local accumulations of cobbles and small boulders as much as 4 km west of the mountain front. Units commonly form narrow to broad streams with elongate cobble and boulder bars and floodplains that are inset against Qvy and Qpa. Bar and swale topography is well developed. Soils are very weakly developed and possess disseminated to no pedogenic carbonate. Estimated thickness is <1 m to 4 m.

Qvy Stream alluvium, undivided (upper Pleistocene to Holocene) — Poorly to moderately sorted, poorly consolidated light-brown and light reddish-brown to gray-brown pebble and cobble conglomerate and sand with minor accumulations of boulders and silt-to clay-rich beds. Clasts are subangular to subrounded and typically not weathered nor pitted. Unit forms terraces inset against unit Qpa. Bar and swale topography is locally well developed. Terrace tread < 5 m above modern streams. Estimated thickness is <4 m.

Piedmont-slope alluvium

Qu Piedmont alluvium, undivided (Quaternary) — Undivided piedmont units (Qpa and QTpo) shown in Cross Section A-A′ (Plate II).

Qpa Piedmont alluvium, undivided (Holocene to lower Pleistocene) — Poorly to moderately sorted, moderately consolidated pebble and cobble conglomerate and pebbly sand. Soil development is variable typically possesses multiple (cumulic) buried soils with Bk horizons that exhibit stage II and IV calcium-carbonate morphology. The unit forms a complex of piedmont and valley-floor deposits that marks local base level for mountain front drainages. Unit contains slightly to moderately dissected valley-floor deposits and terraces inset against unit Qpo. Unit is locally mantled by Qa and Qvy in narrow to broad swales. Forms constructional surface of the Llano de Manzano piedmont slope.

Qpm Piedmont alluvium (middle Pleistocene) — Poorly sorted, moderately consolidated pebble to cobble conglomerate and pebbly sand. Soil development is variable and typically possesses multiple (cumulic) buried soils with Bk horizons that exhibit stage II and III calcium-carbonate morphology. The unit forms slightly to moderately dissected valley-floor deposits and terraces inset against unit Qpo. Unit is locally mantled by Qvy in narrow to broad swales.

Qpo Piedmont alluvium, undivided (lower to middle Pleistocene) — Poorly sorted, poorly to moderately consolidated and calcium carbonate cemented sand and subrounded to subangular cobble to pebble conglomerate inset against unit QTpo. Unit is locally differentiated into two subunits (**Qpo1**, older; **Qpo2**, younger) on the basis of inset relationships. Soils are partially stripped, but locally exhibit stage III to IV carbonate morphology.

QTpo Piedmont alluvium (upper Pliocene(?) to lower Pleistocene) — Poorly sorted, calcium-carbonate cemented, clast supported cobble to boulder conglomerate commonly found on the footwall of the range-bounding faults. Clasts are dominantly granite, phyllite, greenstone. Minor limestone is present in alluvial fans derived from major drainages (i.e., Ojito, Garcia, Sand, Cañon de los Seis, Cañon de los Moyos, and White Rock Canyons. Clasts are commonly highly split, deeply pitted and weathered and grussified. Sand is composed mostly of grussified Ojito granite. Deposit surface is moderately dissected and locally exposes partially stripped soils with stage III to IV carbonate morphology.

Artificial fill and Colluvium

af Artificial fill (historic) — Dumped fill and areas effected by human disturbances. Mapped where deposits are areally extensive.

Qca Colluvium and alluvium, undivided (Holocene to upper 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. Clasts are typically angular and composition generally reflects local provenance. Colluvium is common on hillslopes, but is differentiated where areally extensive.

Santa Fe Group

Tsp Santa Fe Group, piedmont alluvium (lower Pleistocene(?) to Miocene) — Poorly to moderately sorted, well consolidated, calcium-carbonate cemented conglomerate and sandstone exposed on the footwall of the Hubbell Springs fault. Unit is not exposed in the study area and is shown only in cross section A-A′′ Deposits are described to about 620 ft in well BLL1 (Table 1). Conglomerate is clast supported and contains abundant granite, metamorphic and minor limestone. North or the study area, the Santa Fe Group rests unconformably on upper Paleozoic, Triassic, and lower Tertiary deposits (Love et al., 1996; Karlstrom et al., 1997; Thomas et al., 1995). South of the study area, in the Capilla Peak quadrangle, an oil test (Leroy Bennett Aguayo-Comanche No. 1, T6N, R5E, Sec. 31; NMBMMR Log No. 11,695) encountered "Quaternary pediment gravels and sands" (upper Santa Fe Group) to 505 ft, which overlie tuff-bearing Popotosa Formation (lower Santa Fe Group) to 1655 ft. No pre-Tertiary rocks were reported in the log. Unpublished gravity modeling (V.J.S. Grauch, 1999, USGS) suggests that Mesozoic and older rocks may be approximately 1.25-1.5 km below ground surface.

Tertiary Intrusive Rocks

Tmi Mafic dike—Dark green to black dikes intruded along some north-trending faults or fissures. Dikes are chloritically altered and composed mostly of calcic plagioclase and pyroxene (Parchman, 1980). These undated basaltic dikes may be associated with early extension along the Rio Grande rift in middle Cenozoic time.

Cretaceous and Tertiary Rocks

KTu Cretaceous and or Tertiary sedimentary rocks—Pre-rift "basement" for the Tertiary Santa Fe Group. May in clude Tertiary baca Formation and/or Cretaceous Menefee Group rocks in the subsurface of the Rio Grande rift.

Paleozoic Rocks

ℙmu Madera Group, upper arkosic unit (Pennsylvanian to Lower Permian?)—Interbedded arkosic conglomeratic sandstone, sandstone, siltstone, mudstone and limestone; mostly slope to ledge forming. Yellowish to reddish brown and light gray arkosic to feldspathic sandstones and conglomeratic sandstones are lenticular and grade into pale yellow brown, gray and purplish gray mudstones and micaceous siltstones. Clastic units locally contain silicified wood. Tabular, ledge-forming, light to dark gray, fossiliferous, limestones are commonly interbedded with mudstones and may locally contain feldspathic detritus. Red muddy soils are common on the upper arkosic member. Generally equivalent to Pine Shadow and La Casa Members of Wild Cow

Formation of Myers (1973) or Ꮲmuc and Ꮲ mud of Myers and McKay (1970). As much as 400 ft (120 m) thick, with erosional top.

Ꮲml Madera Group, lower cherty fossiliferous limestone unit (Pennsylvanian)—Mostly cliff-forming, gray fossiliferous limestone with minor interbedded shales and quartzose to feldspathic sandstones and conglomeratic sandstones. Individual massive to nodular limestone beds are commonly 20–30 feet (3–9 m) thick and may be as much as 60 feet (18 m) thick. Irregular masses of black to reddish orange chert are common in massive limestone beds. Nodular limestones often weather to mottled gray and brown surfaces. Limestones are interbedded with light to dark gray and yellowish brown shales, nodular shales and yellowish brown to greenish gray siltstones that are often micaceous. Siltstones locally grade upward into lenticular to tabular quartz arenites and quartz pebble conglomerates of light gray to yellowish brown color. Clastic units locally contain silicified wood. Includes Los Moyos Limestone and overlying Sol se Mete Member of Wild Cow Formation of Myers (1973), orᏢml and Ꮲmub of Myers and McKay (1970). These mostly cliff forming units are often separated by a gentle slope break (or breaks), but otherwise appear to be lithologically similar. Additional study of the Wild Cow/Los Moyos contact and its lithologic mapability seems warranted. Approximate thickness 500 to 800 feet (150–240 m).

Ꮲs Sandia Formation (Middle Pennsylvanian)—Mostly slope-forming shales and siltstones grading down into basal quartz pebble conglomerates and up into thin bedded limestones. Limestones and shales occur in uppermost 20 ft (7 m) near gradational contact into overlying cliff-forming limestones of Madera Formation. Well indurated (siliceous) basal quartz pebble conglomerates are thickest (20–40 ft; 6–12 m) in northwestern third of quadrangle and generally thin to low ledge-forming conglomerates (1–2 m thick) and sandstones in southeast quadrant. Sparse metamorphic and limestone pebbles or shell fragments are locally present in thinner (lower energy?) basal zones. Light gray to yellowish brown conglomerates of basal zone grade upward into yellowish brown, gray and greenish gray sandstones and micaceous siltstones interbedded with yellowish brown, gray and black shales or carbonaceous shales. Medial shaley zone is 100–150 ft (30–45 m) thick and commonly mantled with blocky limestone colluvium (generally not mapped) derived from overlying Madera Formation.

Proterozoic Rocks

Yd Diabase dike—Dark green to black basaltic and diabasic dike composed of labradorite, augite, epidote, chlorite, magnetite, and sphene. Chilled margins are very fine grained basalt; dike cores are typical diabase texture consisting of randomly oriented plagioclase laths in matrix dominated by pyroxene. Dikes are pre-Pennsylvanian and are inferred to be 1.1 Ga based on chilled margins and regional correlations.

Ya Aplite and granite dike—light gray to pink muscovite-bearing granite, aplite, or pegmatite, post-dates foliation in country rock.

Xqv Quartz veins—veins and veinlets of massive, milky-white quartz generally parallel to the regional fabric although smaller veinlets (2-5 cm) locally cross cut the fabric. In some locations, thin quartz veinlets are folded with the main fabric as axial plane. Mappable quartz veins consist of white quartz with minor hematite and brown calcite.

Xog Ojito granite—medium grained massive quartz monzonite composed of quartz, sodic andesine, microcline, biotite, and accessory hornblende, sphene, epidote, apatite, and tourmailine; U-Pb zircon date of 1659 + 5 Ma. Comingled with mafic units Xqd, Xqg, and Xog, and Xg.

Xs Lamprophyre dike (spessartite)—massive aphanitic to porphyritic black dikes composed of hornblende and plagioclase phenocrysts in matrix of pyroxene, hornblende, hypersthene, magnetite, biotite, and trace pyrite and quartz.

Xqd Porphyritic quartz diorite—porphyritic rock composed of hornblende and plagioclase phenocrysts in a medium grained groundmass of quartz, andesine, hornblende, biotite, and accessory chlorite, opaques, and apatite; gradational with other mafic units and the Ojito pluton because of magma mingling and mixing.

Xqg Quartz gabbro—medium grained rock composed of quartz, labradorite, hornblende, and accessory chlorite, epidote, biotite, opaques, and apatite. Occurs as large intrusive masses and as mafic enclaves in the Ojito granite; gradational with other mafic units.

Xgo Olivine gabbro— medium grained gabbro containing labradorite (locally sericitized), biotite, hornblende (after pyroxene), hypersthene, augite, and olivine, with accessory opaques, apatite, muscovite, antigorite, quartz, calcite, and chlorite.

Xg Gabbo and diorite undivided— mafic plutonic rocks undivided: quartz diorite, quartz gabbro, olivine gabbro, often as enclaves and variably mingled with Ojito granite.

Xs Schist and phyllite—Mottled quartz-rich schist and phyllite with red, hematitic and green fuchsite-rich (?) zones that occurs as discontinuous layers of variable thickness. Schistosity is variably injected with lense-shaped quartz pods. Parent rocks for the schist probably consisted of impure quartz-rich siltstones. This unit may correlate with the Coyote Schist and Coyote Phyllite of Cavin (1985).

Xq Massive to thickly-bedded, gray- to milky white quartzite—Original bedding in the quartzite consists of 1-5 mm-thick black and red hematite-rich layers. Cross bedding is locally preserved. Interlayered with the quartzite are greenish-gray micaceous quartzite that contain up to 35% muscovite and chlorite. Protolith for the thickly bedded quartzite was pure quartzose sands intermixed with impure sandstones and siltstones. Correlates with the Cerro Pelon and Coyote quartzites of Cavin (1985) and Sais Quartzite.

Xla Lithic arenite—This rock unit consists of a variety of metasedimentary rocks including metawacke, meta-arkose and impure metaquartzite. Up to 50% of this unit is a brown weathered impure arkosic metaquartzite with light green to gray fresh surfaces. Schistosity is variably developed throughout most of the unit. Compositional layering (S0) is commonly preserved and is generally at low angles to the dominant schistosity (S1). Metamorphic grade and field appearance of this unit varies towards the Ojito granite, indicating development of a contact aureole associated with granite emplacement. Away from the Ojito granite metasedimentary rocks have a granular appearance with a weak foliation. Samples of metasediments near the Ojito granite are granoblastic schists with porphyroblasts of sillimanite, andalusite, and chloritoid. Includes the Bosque and Moyas metasedimentary units of Edwards (1978; interpreted here to be correlative) and the Lower Metaclastic series of Reiche (1949). Includes siliceous lithic arenite lenses that form resistent outcrops (Xsla)

Xp Phyllite and schist—This rock unit is interlayered and gradational with the lithic arenite but has been mapped as a separate unit in several zones where it constitutes greater than 90% of the exposure. This unit also occurs in the mafic metavolcanic rock unit (Xmv) and the lithic arenitie unit (Xla) as <5 m thick beds that were too small to map as individual units. This unit consists of blue to light grayish green phyllite that become more schistose and massive (high grade) in exposures closer to the Manzanita granite. Parent rocks for this lithology were siltstones.

Xc Metachert and jasperoid—Metachert occurs as prominent, low-lying outcrops infolded and interlayered with the metasedimentary and blue phyllite unit. These layers range from several cm to m thickness and are discontinuous along strike frequently pinching off within phyllitic layers or adjacent to chlorite-rich amphibolites. This unit varies from white to hematite-stained quartz-rich sediment with narrow micaceous zones parallel to local foliation. Jasperoids consist of red-stained, discontinuous pods of jasper. This unit marks the transition from volcanic to clastic deposition.

Xdt Dacite tuff—The metatuff unit is gray to light grayish green dacite with a well-developed schistosity. Major parts of this unit contains flattened ovoid shaped fragments of light gray to buff phyllite, chlorite phyllite, metaquartzite and greenstone. These fragments range in size from 4 to 30 cm and are aligned parallel with the schistosity. Towards the gradational contact with the metasedimentary unit the metatuff contains abundant (up to 80%) blue to blue-gray phyllite fragments. The matrix of the metatuff is fine grained, gray to greenish gray. The metatuff is interpreted to be the metamorphic equivalent of a crystal and vitric-crystal tuff that is dominantly dacite with minor andesite. Includes the Lacorocah metatuff of Parchman (1980).

Xiv Intermediate metavolcanics rocks—Buff, schistose bands intimately interfingered with the greenstone (Xmv) and metatuff (Xdt) units. This unit also defines broad, regional folds. Lithologies within this unit consists of a mixture of volcaniclastic rocks including quartz-mica phyllites and volcanic rocks with an andesitic composition (Parchman, 1980). In outcrop this unit has a brown to gray-green color with a moderately well-developed schistosity.

Xmv Mafic metavolcanic rocks—Heterogeneous metavolcanic unit composed of basaltic greenstones, intermediate volcanics, volcaniclastic greenschists (quartz-actinolite-chlorite schists) and metapelites. Rare epidote-rich bands are present in some areas and may denote margins of metamorphosed pillows. Other primary features include compositional layering defined by white, plagioclase(?)-rich layers that are parallel to foliation and plagioclase-phenocrystic volcanic rocks. Unit grades upwards to volcaniclastic rocks (Xdt) and may be interlayere□d with mappable units of felsic to intermediate volcanic rocks (Xiv), volcanic breccias, dacite breccia (Xdt), chert (Xc) and fine grained phyllite (Xp). Unit correlates with Coyote greenstone and Isleta greenstone of Cavin (1985) the lower part of Tijeras greenstone of Connolly (1981), greenstone complex of Reiche (1949), and unnamed greenstone of Edwards (1978).

Geologic Map of the Bosque Peak 7.5 minute Quadrangle
Explanation of Map Symbols

Contact, dashed where approximately located or gradational, dip shown where well exposed.

Fault trace, dashed where approximately located, dotted where concealed, queried where uncertain or continuity uncertain. Where dip direction and sense of slip uncertain, U=upthrown side, D=downthrown side.

Normal fault, ball and bar on downthrown hanging wall block.

Reverse fault, barb on upthrown hanging wall block.

Fault trace inferred from degraded topographic scarp

Fault trace inferred from vegetation lineament.

Approximate location of selected high-resolution aeromagnetic anomaly (from U.S. Geological Survey and Sander Geophysics, Ltd., 1998).

Strike and dip of bedding.

Horizontal bedding.

Trace of axial plane of anticline and overturned anticline showing plunge direction, dashed where approximately located.

Trace of axial plane of syncline and overturned syncline showing plunge direction, dashed where approximately located.

Overturned bedding

Sl compositional layering in Proterozoic rocks

Mylonitic layering

S2 crenulation cleavage showing F2 fold axis

Minor dike, showing dip and strike

Water well, alpha-numeric symbol refers to well listed in Table 1

Location of geologic cross sections (Plates II and III)

Location of radiometrically dated sample

FIGURE 4. CORRELATION OF PALEOZOIC AND PROTEOROZOIC ROCK UNITS

KTu	Cretaceous-Tertiary rocks undivided
Pm	Pennsylvanian Madera Group undivided
Pmu	Pennsylvanian upper Madera Group
Pml	Pennsylvanian lower Madera Group
Ps	Pennsylvanian Sandia Formation

FIGURE 4. (CONT.) CORRELATION OF PROTEROZOIC ROCK UNITS

Yd	Diabase dikes
Ya	Aplite, granite and pegmatite
Xqv	Quartz veins
Xl	Lamprophyre
Xog	Ojito granite
Xqd	Quartz diorite
Xqg	Quartz gabbro
Xgo	Olivine gabbro
Xg	Gabbro and diorite undivided
Xs	Schist and phyllite
Xq	Quarztite
Xla	Lithic arenite
Xsla	Silliceous lithic arenite
Xp	Phyllite
Xc	Chert
Xdt	Dacite tuff and breccia
Xiv	Intermediate metavolcanic rocks

Xmv Mafic metavolcanic rocks