REPORT ACCOMPANYING:

GEOLOGIC MAP OF SANTA FE QUADRANGLE, SANTA FE COUNTY, NEW MEXICO

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New Mexico Bureau of Geology and Mineral Resources
Open-file Geologic Map OF-GM 032,
scale 1: 24,000
(mapped at 1:12,000)

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DRAFT

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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 Data depicted on this geologic map are based on field geologic mapping, compilation of published and unpublished work, and photogeologic interpretation.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.

Any enlargement of this map could cause misunderstanding in the detail of mapping and may result in erroneous interpretations. The information provided on this map cannot be substituted for site-specific geologic, hydrogeologic, or geotechnical investigations. The use of this map to precisely locate buildings relative to the geological substrate is not recommended without site-specific studies conducted by qualified earth-science professionals.

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.

Description of Map Units

Grain sizes follow the Udden-Wentworth scale for clastic sediments (Udden, 1914; Wentworth, 1922) and are based on field estimates. Sand is classified according to Pettijohn et al. (1987). The term "clast(s)" refers to the grain size fraction greater than 2 mm in diameter. Clast percentages are based on percent volume and were estimated in the field with the aid of percentage charts. Colors of unconsolidated sediment are based on visual comparison of dry samples to the Munsell Soil Color Charts (Munsell Color, 1994). Surficial units were only delineated on the map if they are estimated to be at least 1 m thick. Soil horizon designations and descriptive terms follow those of the Soil Survey Staff (1992) and Birkeland et al. (1991). Stages of pedogenic calcium carbonate morphology follow those of Gile et al. (1966).

Cenozoic Rocks

Quaternary Hillslope Deposits

Qcs **Colluvium and sheetwash deposits (Middle(?) Pleistocene to Holocene) --** Generally light yellowish brown to yellowish brown (10YR 5-6/4) gravel, sand, silt, and minor clay. Gravel is angular to subangular, poorly to moderately sorted, mostly matrix-supported, and generally cobbles and pebbles. Bedding is non-existent or very vague, thin, and lenticular. Sediment is loose to weakly consolidated and 1 to 12(?) m thick. Unit includes minor alluvium.

Quaternary Anthropogenic Deposits

Qaf **Artificial fill (Historical) --** Brown (10YR 5/3) silt, sand, and gravel. Sediment is poorly sorted and lacks bedding. Sand is subrounded to subangular and an arkosic arenite. Sediment is loose and of variable thickness.

Qdg **Disturbed Ground**

Quaternary Alluvial Deposits

Qac **(labeled Qa also) Alluvium in modern drainage channels (Active) –** Sand, pebbles, cobbles, and boulders found in active drainage channels. Gravel is composed primarily of granitic clasts. Sand is generally medium- to very coarse-grained, subangular to subrounded, an arkosic arenite, and poorly to moderately sorted. Sediment is loose and generally less than 2 m thick.

Qca **Colluvium/alluvium (Uppermost Pleistocene to Holocene) –** Deposited on steeper slopes than Qvf with generally angular heterolithic clasts. Hillslope processes appear to dominate.

Qvf **Valley fill (Uppermost Pleistocene to Holocene) –** These locally-derived deposits were probably largely fluvial in origin but hillslope processes and sheetwash also appear to have contributed sediment. Some areas mapped as Qvf are low terraces formed by recent incision of the modern channel. Generally loose but locally may be harder because of pedogenesis or high clay content.

Qf **Alluvial fans, undifferentiated (uppermost Pleistocene to Holocene) –** Locally derived, unconsolidated gravel, sand, silt, and clay deposited at the mouths of steep minor tributary drainages of Arroyo Hondo.

Qfy **Younger alluvial fan deposits (uppermost Pleistocene to Holocene) –** Alluvial fans deposited at the mouths of small tributary drainages to the Santa Fe River. The upper portions of these fans prograde over Qts3 at SF-31 and so are younger than Qts3. Sediment generally consists of light yellowish brown to light brown (7.5YR-10YR 6/4) sandy gravel and gravelly sand plus minor mud. Sediment is clast-supported and in very thin to medium, lenticular or channel-shaped beds. Gravel is generally pebbles and cobbles; is poorly sorted; and consists of 10-15% quartzite, 2-3% amphibolite, trace to 1% yellowish Paleozoic siltstone and sandstone, 1% chert, and 80% granitic clasts (including associated feldspar and quartz). Quartzite clasts are well-rounded to subrounded, cobbles and coarse to very coarse pebbles are generally subrounded, and very fine to medium pebbles are subrounded to subangular. Sand is mostly medium- to very coarse-grained, moderately to poorly sorted within a bed, subrounded to subangular, and an arkosic arenite. Sediment is loose and 1 to 12(?) m thick.

Qfo **Older alluvial fan deposits (upper Pliocene(?) to upper Pleistocene) –** Reddish yellow (7.5YR 6/6) to light yellowish brown (10YR 6/4) sand, gravel, and clayey sand. Gravel and sand beds are very thin to medium and lenticular or channel-shaped. Clayey sand beds tend to be thick or massive. Gravel is clast-supported; composed of pebbles, cobbles, and boulders; is poorly sorted; and is angular to subangular except for the boulders and some cobbles (which are subrounded). Gravel consists of 1-3% amphibolite and 97-99% granitic clasts (including associated feldspar and quartz). Sand is very fine- to very coarse-grained but generally medium- to very coarse-grained, mostly subangular, poorly to moderately sorted, and an arkosic arenite. One exposure (SF-41) shows a soil with a 10-15 cm Bt horizon (2csbk ped development and 3dpf clay films) underlain by a calcic horizon with Stage II carbonate morphology. The lower part of this unit is correlative in age to QTa but the upper part of this unit is interpreted to prograde over QTa. It is interpreted that Qtc1 post-dates this unit (see Qtc1 description below) and if so the age of Qfo is greater than the age of the sampled charcoal in Qtc1 (i.e. about 9,500 radiocarbon years before present). 1 to 6(?) m thick

Qt__ **Terrace deposits along drainages (Pleistocene to Holocene) –** Terraces are denoted by drainage (third letter) and number (oldest to youngest) e. g. Qtc1, Qtc2 etc. Note that correlation is presumed between drainages with respect to terrace number

Qtc_ **Terrace deposits along the mountainous reach of Arroyo de Los Chamisos (Upper Pleistocene to Holocene) –** Composed of loose gravel, sand, and silt. Terraces are denoted as Qtc1, Qtc2, and Qtc3 (oldest to youngest). Qtc1 is interpreted to be more or less equivalent in age with the upper Qfo unit west of Arroyo Mora. East of St. Johns College, the surface of Qfo is slightly higher than the surface of Qtc1 because Qfo has the classic convex transverse profile of an alluvial fan. There is only one tread (i.e. surface) associated with Qtc1 and it is interpreted to represent a single, major aggradational event; this event is also interpreted to have induced contemporaneous aggradation of the upper Qfo unit to the north. Qtc2 and Qtc3 are inset into Qfo and are thus younger than Qfo.

Qtc3 (Holocene) – Loose sand and gravel. No natural exposure of sediment.

Qtc2 (Holocene) – Yellowish brown (10YR 5/4) sand and gravel. Deposit lacks well-defined beds. Gravel is poorly sorted, subangular to subrounded, and consists of pebbles, cobbles, and boulders. Gravel includes 2-10% amphibolite and 90-98% granitic clasts (including associated feldspar and quartz). Sand is generally coarse- to very coarse-grained, subangular, moderately sorted, and an arkosic arenite.

Qtc1 (upper Pleistocene to lower Holocene) – Light yellowish brown to yellowish brown (10YR 5-6) sand and gravel, and pale brown to brown (10YR 5-6/3) silt, mud, and very fine- to fine-grained sand. Sand and gravel are prevalent downstream of the national forest boundary and silt, mud, and very fine- to fine-grained sand are the predominant sediment upstream of the national forest boundary.

Sand and gravel are generally in very thin to medium, lenticular or channel-shaped beds. Gravel consists of clast-supported and poorly sorted pebbles, cobbles, and boulders. Clasts consist of approximately 5-10% amphibolite and 90-95% granitic clasts (including associated feldspar and quartz). Boulders are generally subrounded, cobbles are generally subrounded to subangular, and pebbles tend to be subangular. Sand is very fine- to very coarse-grained, subangular to subrounded, poorly sorted, and an arkosic arenite.

Silt and mud are in vague, very thin to thick, tabular beds that are interbedded with approximately 10% well-defined, very thin to thin, lenticular beds of medium- to very coarse-grained sand and very fine to fine pebbles. Muds may be blackish because of high organic content. Disseminated charcoal is commonly found in these black intervals and was sampled at SF-37-QMVF. This sample returned a C-14 date of 9470 ˜ 60 radiocarbon years before present (Beta Analytic, Inc, 2001).

Both fine and coarse sediment are loose to weakly indurated, 6-8 m thick, and commonly overlie 1-3 m of exposed granitic bedrock.

The age of Qtc1 is approximately 9500 radiocarbon years based on the C-14 date from sample SF-37-QMVF, and this date may be used to constrain ages of nearby deposits. The tread of Qtc1 appears to be slightly lower than the surface of Qfo found immediately to the north of Arroyo de los Chamisos and west of Arroyo Mora, but this relationship is somewhat equivocal. However, the degree of soil development observed on the Qfo surface is greater than that observed on the tread of Qtc1. The former has calcic horizon(s) possessing up to stage II calcium carbonate morphology overlain by a distinct Bt horizon, whereas the soil of the latter exhibits calcium carbonate morphology weaker than stage II and the Bt horizons are less distinct, if present at all. More detailed soil work is needed in regards to this comparison. Based on the available data, it is interpreted that Qtc1 is inset into Qfo and is thus younger than Qfo. There is only one tread (i.e. surface) associated with Qtc1 and it is interpreted to represent a single, major aggradational event, perhaps triggered by climatic changes that marked the transition from the latest Pleistocene to Holocene. After this aggradation, the stream re-incised to its present grade. North of the national forest boundary, this locally involved incising through as much as 3 m of granitic bedrock.

Qts **Terrace deposits along the Santa Fe River (Pleistocene to Holocene) –** Generally poorly sorted and sandy gravel. Terraces are denoted as Qts1, Qts2, and Qts3 (oldest to youngest). All are inset into the older Ancha and Tesuque Formations. These terrace deposits are readily distinguished from the underlying Tesuque Formation because of the contrast in their color and gravel lithology. The terrace deposits have more amphibolite, less Paleozoic clasts, and less quartzite than the Tesuque Formation. Each of the associated deposits are generally 2-5 m thick and are described below.

Qts3 (middle to upper Holocene(?)) – Reddish yellow or strong brown (7.5YR 5-6/6) to yellowish brown (10YR 5/4) to light brown or light yellowish brown (7.5-10YR 6/4) sandy gravel. Clast-supported and in vague, thin to medium, lenticular to channel-shaped beds. Cross-stratification is present within the beds and generally less than 80 cm in height. Gravel has minor boulders but is mostly cobbles and pebbles; is poorly sorted; and is composed of 3-15% amphibolite, mafic-rich gneiss, or gabbroic clasts, 1% $CaCO_3$-indurated Tesuque sandstone, trace yellowish Paleozoic siltstone and sandstone, 0.5% muscovite schist, 1-3% quartzite, and 80-90% granitic clasts (including associated feldspar and quartz). Quartzite clasts are well-rounded to rounded. For other clasts, cobbles and coarse to very coarse pebbles are rounded to subrounded; very fine to medium pebbles are subangular to subrounded. Sand is fine- to very coarse-grained but mostly medium- to very coarse-grained, subangular to subrounded, an arkosic arenite, and poorly to moderately sorted. Two stacked units, 1-1.5 m thick and separated by a planar scour, may locally be present. Imbrication and cross-stratification generally indicate westward-flowing paleocurrents. Soil developed on the surface is weak but generally possesses a calcic horizon(s) with Stage I calcium carbonate morphology. Buried soils having calcic horizons better developed than Stage I or having Bt horizons were not found. Sediment is loose to weakly consolidated and generally 2-5 m thick.

East of Cerro Gordo, the terrace tread is approximately 1 m above the active stream channel and probably receives some overbank deposition during extreme flood events. West of Highway 84, the terrace tread is 3-6 m above the channel and the terrace strath commonly overlies up to 3 m of exposed Tesuque Formation. Qts3 is a fill terrace and probably correlates to the Qay2 alluvial unit (middle to upper Holocene) mapped downstream in the Turquoise Hill quadrangle (Koning and Hallett, 2000). Charcoal was collected from a 30 cm-thick and 79 cm-long, slightly muddy, sand bed at sample locality SF-8.

Qts2 (lower to middle Holocene) – Silt, sand, gravel, and minor clay. Gravelly sediment tends to be redder (e.g. 5YR-7.5YR 6/4) and muddier sediment more yellow (e.g. 10YR 5-6/3-4). Bedding is not well-exposed. Gravel is generally clast supported; poorly to moderately sorted; lacks boulders; consists of 1-10% amphibolite, mafic-rich gneiss, and gabbroic clasts, 1-5% quartzite, trace muscovite- biotite-schist, trace yellowish Paleozoic siltstone and sandstone, and 85-98% granitic clasts (including associated feldspar and quartz). Quartzite clasts are well-rounded to rounded. For other clasts, cobbles and coarse to very coarse pebbles are rounded to subrounded; very fine to medium pebbles are subangular to subrounded. Sand is very fine- to very coarse-grained, poorly to moderately sorted, subangular to subrounded, and an arkosic arenite. Silty or muddy overbank deposits are laminated to massive, have minor sand, and are locally organic-rich. One organic-rich locality contains charcoal that was sampled for C-14 analyses (sample locality SF-10). These analyses returned a radiocarbon age of 7960 ˜ 60 yr B.P. (Beta Analytic Inc., 2001, sample SF-10-Qt2). Exposures showing surface soils or buried soils were not found. Sediment is loose and 3 m thick at SF-5 to greater than 4 m thick at SF-11.

The tread of Qt2 is 2-4 m above the tread of Qt3 at site SF-10 and 2 m at SF-2. The tread of Qts2 is 4-9 m above the active stream channel in the basin and 6-7 m in the mountains. Qts2 is reasonably thick but paired terraces are not observed. Thus, it is neither a simple strath or fill terrace but rather is intermediate between these two designations.

Qts1 (middle to upper Pleistocene) – Reddish yellow, light reddish brown, or light brown (5YR-7.5YR 6/4-6) sandy gravel. Clast-supported and in vague, thin to thick, lenticular beds. Minor, thin cross-beds are present. Gravel is generally subrounded (with quartzite clasts being rounded to well-rounded), poorly sorted, and consists of 5% quartzite, 2% amphibolite, and 93% granitic clasts (including associated feldspar and quartz). Gravel is mostly cobbles with some pebbles and 2-3% boulders. Sand is generally medium- to very coarse-grained, moderately sorted, subrounded to subangular, and an arkosic arenite. Exposures showing surface soils or buried soils were not found. Sediment is weakly consolidated and 2-3 m thick.

Natural exposures of Qts1 are only found within 1 km of the western boundary of the quadrangle or in the mountains. In the basin, available exposures and the contour line patterns suggest that Qts1 consists of several strath terraces. The treads of Qts1 are about 2-6 m above the tread of Qts2 near the west margin of the quadrangle but increase to 5-9 m in the west-central portion of the quadrangle and in the mountains. The highest Qts1 terrace tread is 9-12 m above the active stream channel in the west portion of the quadrangle, 12-18 m in the central part of the quadrangle, and 9-18 m in the mountains. In the basin, the upper contact of this unit was mapped where there is a significant increase in slope.

Qth Terrace deposits along Arroyo Hondo (Pleistocene to Holocene)

Qth5 – Terrace Gravel (upper Holocene?) Fill terrace gravel with treads approximately 10 feet above the modern grade of Arroyo Hondo

Qth4 – Terrace Gravel (middle to upper Holocene?) Fill terrace gravel with treads approximately 20 feet above modern grade.

Qth3 – Terrace Gravel (middle to upper Holocene?) Fill terrace gravel with treads approximately 35 feet above modern grade.

Qth2 – Terrace Gravel (upper Pleistocene to lower Holocene?) Strath terrace gravel with treads approximately 60 feet above modern grade.

Qth1 – Terrace Gravel (middle to upper Pleistocene?) Strath terrace gravel with treads approximately 80 feet above modern grade.

Qtt Terraces in the Big Tesuque Drainage (Pleistocene to Holocene)

Qt_3 Terrace Gravel (upper Pleistocene?) – Fill-terrace gravel with a tread approximately 30 m above modern grade along the Big Tesuque (but possibly converging upstream); base not exposed.

Qt_2 Terrace Gravel (middle Pleistocene?) – Fill terrace gravel with a tread approximately 50-60 m above modern grade along the Big Tesuque. In many places it is clear that the base of this gravel deposit is below the elevation of the modern valley floor so the maximum thickness of the fill is unknown. Rare exposures along steep ravines reveal a complicated fill stratigraphy of alternating cobble-to-boulder gravel and pebbly sand with rare intervals of laminated silt.

Qt_1 Terrace Gravel (middle Pleistocene?) – Fill terrace gravel with a tread approximately50-70 m above modern grade along the Big Tesuque. Distinguished from Qt_2 by its slightly higher elevation and much thinner fill, which is generally less than 6-7 m thick.

Qao Older alluvium (Lower to middle Pleistocene) -- Several high, localized remnants of former terrace deposits whose original treads have largely been eroded. These deposits are located above Qts1 along the Santa Fe River. Deposits are strong brown (7.5YR 6/6) sandy gravel. Sediment is massive or in thin to medium, lenticular beds. Gravel is clast supported, poorly sorted, subrounded to angular, and composed of pebbles, cobbles, and boulders. Gravel clasts consist of 5-8% amphibolite, trace quartzite, trace muscovite schist, and 90-95% granitic clasts (including associated quartz and feldspar). Amphibolite clasts are thoroughly decomposed. Sand is generally medium- to very coarse-grained, poorly sorted, subangular, and an arkosic arenite. Sediment is loose to weakly consolidated or harder because of CaCO3-induration. Sediment is generally less than 2 m thick.

Quaternary (and Pliocene?) Gravel Deposits:
--Gary Smith

I mapped three terrace gravels, which included dividing *Qth* of Spiegel and Baldwin (1963) into Qt_1 and Qt_2 . The distinction between Qt_1 and Qt_2 seems clear in some places and vague in others. The tread elevations for the two terraces are nearly identical but the fill associated with Qt_1 is much thinner than for Qt_2. Unambiguous buttress unconformities between Qt_1 and Qt_2 were not observed suggesting that Qt_1 gravel may simply be alluvium from tributary gullies that prograded over thick fills of the main stream (e.g., Big Tesuque Creek). Therefore, the interpretation could be made that these two terrace deposits should be lumped into one (as shown by Spiegel and Baldwin). I am inclined to believe, however, that they are separate deposits while conceding that the alternative view cannot be excluded on the basis of what I have seen in the field.

Spiegel and Baldwin portray pediment gravel remnants at various elevations as Ancha Formation. The relationship of these pediment gravels to the thick Ancha Formation fill south of the Santa Fe River has not been demonstrated. It would seem prudent, therefore, not to map these gravels as Ancha Formation. It is also difficult to map all such gravel as terrace deposits because not all of them have a clear relationship to modern drainages and some actually cap the highest points in the local landscape rather than being inset along valley margins. It is also clear that not all of these gravels are coeval because they occupy different landscape positions, even in close proximity to one another in the absence of obvious faults that could be called upon to have displaced a once continuous surface. A Pliocene age for some of these deposits cannot be ruled out suggesting that, although geomorphically distinct from the Ancha Formation, some or all of these pediment-gravel remnants may be age equivalent to the Ancha Formation.

Santa Fe Group

Qlbt **Quaternary lower Bandelier Tuff (Pleistocene, 1.66 ± 0.030 Ma, Jeff Winick, 1999 NMGRL unpublished report)**. This pumice/ash layer is covered by ~1 m of Ancha Formation along Arroyo Hondo.

QTa **Ancha Formation (lower Pliocene(?) to lower Pleistocene) --** Sand, muddy sand, gravel, silt, and clay that collectively represent a relatively thick, extensive, aggradational sediment fill in the Santa Fe Embayment south of the Santa Fe River. These unconsolidated to poorly consolidated sediments are locally derived (shed from the foothills and the Sangre de Cristo Mountains), and are of alluvial origin (predominately fan material). The Ancha formation is generally more than 10 m thick, and has a gentle south-westward dip of ~ 5 degrees. Contacts with underlying units are generally poorly exposed, but typically form a distinct angular unconformity with the more steeply dipping Tesuque formation. The Ancha Formation is generally a beige-colored unit that becomes lighter in color near the upper surface from calcium carbonate-rich soils. The underlying Tesuque Formation is reddish which helps to distinguish it from the lithologically similar Ancha Formation. The Ancha formation contains Qlbt in upper 1-2 meters in places along Arroyo Hondo which places a minimum age of 1.66 ± 0.030 Ma on most of the unit and an approximate age for the formation of the Ancha constructional before net incision of the region occurred in the early Pleistocene. Aggradation appears to have continued into the middle to late Pleistocene in some canyons along the mountain front (Koning, Pazzaglia, and McIntosh, 2002).

QTg **Stream gravel terrace deposits (Upper(?) Pliocene to lower Pleistocene) --** Reddish yellow (7.5YR 6/6) sandy gravel that caps several hills north of the Santa Fe River. Gravel is generally clast-supported pebbles and cobbles; moderately to poorly sorted; and consist of 7-20% amphibolite, mafic-rich gneiss, or gabbroic clasts, 0.5-5% muscovite- biotite- schist, 0.5-2% quartzite, trace yellowish Paleozoic siltstone and sandstone, and 73-92% granitic clasts (including associated quartz and feldspar). Gravel is angular to subrounded and quartzite clasts are rounded. Sand is medium- to very coarse-grained, subangular to subrounded, poorly sorted, and an arkosic arenite. The soil developed on top of this unit is generally being eroded; on some surfaces with low slopes there may be a stage III to III+ calcic horizon (60-120 cm thick) overlain by a 1-20 cm-thick Bt horizon (1-2msbk ped structure and 3dpf clay films). Sediment is weakly consolidated and 1-4 m thick. Gravels appear to be capping pediment surfaces cut on Tesuque Formation and pre-Tertiary rocks. These surfaces are located at several positions in the landscape and the gravels are not, therefore, all age equivalent. Some of these gravels may represent QTa, but that relationship is equivocal.

Tg **Stream gravel terrace deposits (Pliocene) --** I did not describe these but did correlate them to similar stream gravel terrace deposits to the west (Figure 2). These deposits are thin and further to the west, in the Horcado Ranch quadrangle, they are inset into older Tesuque Formation (Koning and Maldonado, work in progress). Thus, they reflect a time of general erosion and down-cutting. The straths of these deposits project slightly above the Cerros del Rio basalt flows and so are slightly older than these flows. These flows were dated at 2-2.8 Ma (Bachman and Mehnert, 1978; Manley, 1976; and WoldeGabriel et al., 1996).

Tesuque Formation

--Gary Smith

The Tesuque Formation near the Sangre de Cristo Mountains front has long been recognized as being composed of two members. The Nambé Member is detritus eroded from pre-Tertiary rocks, is generally arkosic in composition, and typically pink in color. The Bishop's Lodge Member is distinctly volcaniclastic, composed of white tuffaceous mudstone and gray, conglomeratic volcanic-lithic sandstones. My representation of the distribution of the two members differs slightly from that illustrated by Spiegel and Baldwin (1963). The Spiegel and Baldwin map portrays areas of Bishop's Lodge Member near Bishop's Lodge, north of Big Tesuque Creek, and in isolated outcrops in the Arroyo de la Piedra drainage where I have mapped Nambé Member. The discrepancy seems mostly related to use of color versus composition in distinguishing the two members. Some Nambé strata lack the red coloration considered most typical of the member but retain the distinctive arkosic or lithic-arkosic composition and lack obvious volcanic components definitive of the Bishop's Lodge Member. I mapped the Bishop's Lodge Member on the basis of composition as judged by hand-sample examination in the field. The two members are intimately interbedded with one another, as considered by Spiegel and Baldwin and but contrary to the view of Ingersoll et al. (1991), following Galusha and Blick (1971), that the Bishop's Lodge Member is disconformably overlain by Nambé Member. As described below, there are two distinct Bishop's Lodge intervals within the map area, separated by and underlain by Nambé Member. A basalt flow alternates between resting on Bishop's Lodge volcaniclastics and Nambé arkosic strata, also demonstrating the intercalated nature of the sedimentary deposits with contrasting provenance.

The Bishop's Lodge Member has generally been considered a distal correlative of the Abiquiu and Picuris Formations of northern New Mexico (Spiegel and Baldwin, 1963; Galusha and Blick, 1971; Ingersoll and Cavazza, 1991). Miller et al. (1963) even mapped Bishop's Lodge strata as Picuris Tuff. The volcaniclastic strata of the Abiquiu and Picuris Formations were clearly derived from the San Juan and Latir volcanic fields (Ingersoll and Cavazza, 1991; Smith, 1995). Three observations suggest that the Bishop's Lodge Member does not share this provenance and, although possibly age equivalent to parts of the Abiquiu and Picuris Formations, is not their distal equivalent. First, andesite/latite clasts in the Bishop's Lodge Member are as large as 50 cm in the map area (and as much as 65 cm south of the Santa Fe River), which is coarser than the closest Abiquiu and Picuris Formation outcrops to the north. Second, a pumice-fall layer present north of the Big Tesuque Creek contains pumice lapilli to 3 cm across and lithic clasts as large as 1 cm across, indicating derivation from a volcanic source much closer than the San Juan and Latir fields. Third, in conjunction with observations by Borchert (1998) in the Tesuque quadrangle and reconnaissance farther north, the Bishop's Lodge strata appear to become finer grained and thinner, eventually pinching out, to the north.

I hypothesize that the Bishop's Lodge Member of the Tesuque Formation is more directly correlative with the uppermost Espinaso Formation. This correlation is supported by (1) the apparent northward fining and thinning of the volcaniclastic strata; (2) relatively close proximity of Espinaso Formation source areas in the La Cienega-Cerrillos-Eldorado area; (3) similarity of Fe-augite $\pm$ biotite mineralogy in Bishop's Lodge clasts to that seen in the late-stage alkalic latites and monzonites of the Espinaso Formation and its source intrusions (Erskine and Smith, 1993); (4) lack of geophysical expression of younger volcanic centers buried in the basin fill near Santa Fe (T. Grauch, personal communication, 1999). A biotite ^{40}Ar-^{39}Ar of 30.45 $\pm$0.16 Ma was obtained by the NMGRL for the pumice-fall bed mentioned above. The youngest ^{40}Ar-^{39}Ar ages known for the Espinaso Formation and its source intrusions are on the order of 28 Ma. The youngest Espinaso Formation, depositionally overlying a 28.5 Ma monzonite intrusion near La Cienega, has not been dated by ^{40}Ar-^{39}Ar. K-Ar ages (Baldridge et al., 1980) of 25.8 $\pm$0.9 Ma (hornblende) and 25.9 $\pm$0.6 Ma (groundmass) may accurately represent the age of the youngest extrusive activity. Although Espinaso Formation volcaniclastic strata are typically not tuffaceous (Smith et al., 1991; Erskine and Smith, 1993), it may be that late-stage activity whose deposits have heretofore not been well studied, actually do relate to more explosive eruptions.

Ttn **Nambé Member (upper Oligocene(?) to lower Miocene)** – Poorly sorted sandy pebble to cobble conglomerate, sandstone, and minor mudstone composed of detritus eroded from pre-Tertiary rocks. Color is typically red to pink but is locally white to very pale pink or buff. Base is unconformable on Proterozoic or Pennsylvanian rocks at various locations in the map area. Basal contact is highly irregular in part because of erosional relief along the basal unconformity and also because of interpreted deposition of lower parts of the member in small half grabens. In the Big Tesuque watershed there are at least 400 m of Nambé Member locally present below the Bishop's Lodge Member. These lowest Nambé strata are distinctive for their abundance of Paleozoic clasts (25-60%, typically 50-60%). Nambé strata between Bishop's Lodge volcaniclastic intervals in the Bishop's Lodge-Arroyo de la Piedra area contain 25-35% Paleozoic clasts and Nambé beds above the Bishop's Lodge Member contains <10% Paleozoic clasts. These variations in clast composition have been demonstrated through 16 conglomerate-clast counts (100 clasts per count) and provide a basis for tracing stratigraphic intervals in the Nambé Member. The abundance of Paleozoic clasts in the lower Nambé Member is curious since these strata rest on Proterozoic rocks. Although one cannot discount the possibility of Paleozoic rocks cropping out in the vicinity of the current Santa Fe Range during Tesuque deposition, it is also possible that the Paleozoic clasts originated from localities east of the Picuris-Pecos fault. The latter interpretation would require Neogene west-side up motion of that fault zone, which has been suggested previously but has not been supported by structural studies along the fault.

A zone of unusually coarse blocks of Paleozoic limestone and sandstone at the base of the Nambé Member near Big Tesuque Creek is indicated on the map by closed-box symbols (■). These clasts are 2->4 m across. Spiegel and Baldwin portrayed a dip slope containing such clasts above Proterozoic rocks on the north side of Big Tesuque Creek as Pennsylvanian bedrock. Despite the large size of the Paleozoic clasts found on that slope, there is no outcrop of such rocks and exposures along the USFS Winsor Trail, at the southern end of that slope, clearly show the large blocks to be in the basal Tesuque Formation. The origin of these large clasts is unknown and is especially puzzling in the absence of nearby Paleozoic outcrops. They may be a residual lag of Pennsylvanian clasts resting on exhumed Precambrian outcrops and then buried beneath Tesuque Formation. Otherwise, clast sizes in the Nambé Member are generally 2-20 cm, with Paleozoic limestone and some Proterozoic granite clasts approaching 40-50 cm in easternmost exposures.

Ttnb **Olivine basalt (upper Oligocene or lower Miocene)** – Black to gray, coarse-grained, altered olivine basalt. A single flow, 1-1.7 m thick, vesicular and amygdaloidal throughout. Interior of flow has a relatively coarse subophitic texture with 5-10% olivine to 2 mm and plagioclase to 1 mm surrounded by clinopyroxene. Olivine and pyroxene are strongly altered to smectite or chlorite. The basalt crops out in three areas and is arguably the same flow in all locations. Along Bishop's Lodge Road, southeast of the Dempsey benchmark, the basalt rests directly on tuffaceous mudstone of the Bishop's Lodge Member and is overlain by Nambé Member arkosic sediment. About 0.6 km to the north, the basalt is interbedded in Nambé strata, several tens of meters above Bishop's Lodge strata. In poorly exposed outcrops along the north side of Big Tesuque Creek, the basalt rests on Nambé siltstone, within a few meters of Bishop's Lodge volcaniclastic beds. The same or likely correlative basalt is found in a similar stratigraphic position on the Tesuque (Borchert, 1998) and Cundiyo quadrangles. Baldridge et al. (1980) reported a 24.9 $\pm$ 0.6 Ma K-Ar age for such basalt in the Cundiyo quadrangle. A ^{40}Ar-^{39}Ar dating attempt for a sample collected in the Tesuque quadrangle failed to reach a plateau but suggests an age between 22 and 29 Ma. The basalt is arguably correlative with the tholeiitic basalt, nephelinite and basanite flows comprising the Cieneguilla Limburgite of Sun and Baldwin (1958), which directly overlies the Espinaso Formation near La Cienega. Baldridge et al. (1980) reported a 25.1 ±0.7 Ma K-Ar age for the Cieneguilla Limburgite.

Ttbl **Bishop's Lodge Member (upper Oligocene?)** – White tuffaceous mudstone, gray pebbly volcaniclastic sandstone and pebble to cobble conglomerate. Clasts of light to dark gray pyroxene (± biotite) latite as large as 50 cm but typically 5-20 cm. Also includes variable amounts of detritus from pre-Tertiary rocks near contacts with the Nambé Member. Near and south of Bishop's Lodge there are clearly two volcaniclastic intervals. The lower interval, exposed at Bishop's Lodge, is approximately 60 m thick and composed mostly of volcaniclastic sandstone and conglomerate with tuffaceous mudstone being prominent in the lower 5-10 m. This interval is also exposed along Bishop's Lodge Road directly west of Bishop's Lodge and in fault contact with Pennsylvanian limestone along the east side of Arroyo de la Piedra. Along Little Tesuque Creek, the Bishop's Lodge Member is mapped as resting directly upon Pennsylvanian bedrock although, in reality, there are ~ 4 m of limestone-clast conglomerate intervening between the Paleozoic outcrops and the lowest recognizable volcaniclastic strata. North-northeast of the Bishop's Lodge compound an increasing thickness of nonvolcaniclastic Nambé Member intervenes between the pre-Tertiary rocks and volcaniclastic sedimentary beds. The upper volcaniclastic interval is approximately 10-20 m thick and consists almost entirely of tuffaceous mudstone with conspicuous biotite-bearing pumice lapilli 0.5-3 cm across; cobbles to 30 cm are found in a discontinuous sandy zone near the top of this interval. The upper volcaniclastic interval is exposed along Bishop's Lodge Road beneath a basalt flow, southeast of the Dempsey benchmark and is then replaced, toward the north, by Nambé arkosic strata. An isolated outcrop of tuffaceous mudstone in the Arroyo de la Piedra drainage, west of the more continuous outcrop belt of Bishop's Lodge Member, is likely correlative with this upper volcaniclastic interval. The Bishop's Lodge Member that crops out north of the Big Tesuque is also most likely correlative with the upper volcaniclastic interval because (1) the thickness of ~16-22 m more closely resembles that of the upper interval farther south; (2) these strata are composed almost entirely of tuffaceous mudstone with sand and gravel restricted to discontinuous lenses in the upper few meters; (3) these beds are in close stratigraphic proximity to an olivine basalt thought to correlate to the lava overlying volcaniclastic strata along Bishop's Lodge Road; and (4) underlying Nambé strata contain 25-30% Paleozoic clasts and overlying beds contain <5% Paleozoic clasts. Therefore, the lower, thicker volcaniclastic interval is believed to wedge out south of the Big Tesuque and the upper interval onlaps farther to the northeast. Two, primary to slightly reworked tephra-fall deposits have been seen in the upper volcaniclastic interval north of Big Tesuque Creek. The trace of the uppermost and coarser of the two is marked by a dotted line (····), about 4 m below the top of the Bishop's Lodge interval. This layer is about 30-40 cm thick and consists of biotite-bearing pumice to 3 cm and gray, latite lithic fragments to 1 cm overlain by 1-3 cm of coarse ash. This is the tephra that was dated at 30.45 ±0.16 Ma

Tla **Latite/Andesite (Oligocene) –** Lava flows exposed in Arroyo Hondo and in scattered outcrops along I-25 and near Seton Village contain hornblende and plagioclase phenocrysts in an aphanitic dark-brown matrix. K-Ar date of 29.3 ± 0.6 Ma (Baldridge et al., 1980).

Te **Espinaso Formation (Oligocene)** –Distinctly red volcaniclastic unit exposed in Arroyo Hondo. A 40Ar/39Ar date of 31.48±0.33 Ma (Peters, 1999, NMGRL unpublished report) was obtained from an ash layer found near the base of the Espinaso Formation exposed on the flanks of the Sunlit hills. This middle-Espinaso age date indicates that the lower Espinaso did not reach the mountain front.

Tg? **Galisteo Formation (Eocene)** -- Brick red sandstone and conglomerate unconformably overlies Proterozoic basement in the vicinity of Arroyo Hondo and I-25. No volcanic clasts are present in this section overlain by the Espanaso Fm. These rocks may not be Eocene and could represent younger reworked Galisteo sediments (Cather,1992)

Paleozoic Rocks

IPm **Pennsylvanian Madera Group undifferentiated** – Limestone, calcareous siltstone, shale, and minor fine to medium grained sandstone, includes isolated thin outcrops of Mississipian rocks and some coarse sandstones that may represent Pennsylvanian Sandia Formation.

Mu **Mississippian(?) limestone (undifferentiated)** - Approximately 10 m of brecciated gray limestone, with red silty matrix in fractures, present only on a low ridge about 0.6 km northeast of Bishop's Lodge. Limestone overlies Proterozoic mylonite and wedges out to the south below a calcareous siltstone more typical of basal Pennsylvanian strata seen elsewhere. The crackle-breccia texture and red-silt fracture filling material is suggestive of karst dissolution prior to deposition of the overlying calcareous siltstone. The brecciation and abrupt lateral pinchout of the limestone strongly suggest that these strata are Mississippian, rather than Pennsylvanian, in age.

Ma_{dp} **Del Padre Member of the Mississippian Espiritu Santo Formation** – a distinctive silica-cemented white sedimentary quartzite sometimes seen in float along the Paleozoic/Proterozoic unconformity. Generally exposures are to thin to differentiate on the map.

Proterozoic Rocks

Ymg **Megacrystic granitoid (Mesoproterozoic?) –** Coarse unfoliated granite contains quartz, biotite, and large (up to 10cm) K-spar megacrysts. Looks quite similar to the Sandia Granite. High magnetic susceptibility suggests that this rock may be responsible for pronounced magnetic highs in the Seton Village quadrangle (Mark Hudson, personal communication, 2003).

Yg **Microcline-qtz-muscovite granitoid (Mesoproterozoic) –** Fine to medium grained unfoliated to weakly foliated granitoid.

Ypeg **Pegmatite (Mesoproterozoic?) –** Simple pegmatite veins and pods, unfoliated

Xgd **Granodiorite to Diorite (Paleoproterozoic?) –** Weakly to undeformed pods and irregularly shaped bodies of intermediate intrusive rocks best exposed along the lower end of the Ski Basin Road.

Xd **Granodiorite to Diorite (Paleoproterozoic?) –** Generally medium-grained dark, weakly foliated-to-unfoliated massive diorite. Forms pod-like bodies within surrounding gneisses suggesting late emplacement. Cut by Ypeg.

Xpg **Pink Granitic Gneiss (Paleoproterozoic) –** Fine-grained quartz-Kspar mylonitic gneiss is distinctly pink in outcrop. This rock appears to be more resistant to weathering than the coarser biotite-bearing gneisses and forms the bulk of the Sunlit Hills.

Xbg **Biotite-rich granitic gneiss (Paleoproterozoic) –** Coarse grained strongly foliated biotite-bearing gneiss often contains microcline augen and appears to be less resistant to weathering than Xpg. Forms much of the broad valley east of the Sunlit hills that I-25 travels along. Unit is broadly generalized due to poor exposure.

Xqm **Quartz muscovite schist (Paleoproterozoic) –** Generally strongly foliated and often crenulated quartz-muscovite schist. Muscovite is often very coarse suggesting pervasive annealing similar to that seen in other nearby uplifts.

Xms **Quartz biotite schist (Paleoproterozoic)**

Xa **Paleoproterozoic strongly foliated amphibolite and mafic schist**, may include Xd in places. Mafic units tend to weather poorly and are often mantled by Yg and Xbg float. Consequently, Xa and other mafic units are probably vastly under-represented on the map.

Comments on Faults in the Vicinity of Bishops Lodge Area

--Gary Smith

General Obscurity of Faults in the Tesuque Formation: Faults are generally not obvious within the Nambé Member unless anomalous bedding attitudes are present and recognizable. Where obvious marker horizons, such as white Bishop's Lodge strata or the olivine basalt are present many small-displacement faults can be recognized and mapped. Otherwise cryptic faults are also seen in roadcuts west of Bishop's Lodge within the Nambé Member. These observations suggest the strong likelihood of many, small-displacement (perhaps generally less than 10 m) faults that were not recognized during the mapping effort.

Range-Front Faults: Bishop's Lodge Member is in fault contact with Pennsylvanian rocks from the vicinity of Hyde Park Road northward nearly to Bishop's Lodge. Spiegel and Baldwin terminated this fault just south of Arroyo de la Piedra, but it is also evident where it crosses the arroyo. Farther north the fault is inferred to be present because of the necessarily near-vertical contact between Tesuque Formation and Pennsylvanian strata indicated by outcrops in area of generally poor exposure. Nonetheless, the fault does not appear to continue across the Little Tesuque Creek valley at Bishop's Lodge. Magnitude of displacement across this range-front fault is unclear because of the variable thickness of Nambé Member below Bishop's Lodge volcaniclastic beds. Because the lower Bishop's Lodge Member interval rests on Pennsylvanian rocks along Little Tesuque Creek it is likely, however, that the fault in the Arroyo de la Piedra area has less than a 100 m of dip-slip throw. Along the east side of the Arroyo de la Piedra valley, the lower Bishop's Lodge interval is also bounded by a fault on its west side. This fault is readily seen in a number of roadcuts including on Hyde Park Road just west of the intersection with Gonzalez Road. This fault is not obviously present north of Arroyo de la Piedra. Displacement is probably no more than 10-20 m if the discontinuous lens of volcaniclastic mudstone west of the fault correlates to the upper Bishop's Lodge interval along Bishop's Lodge Road. Neither of these down-to-the-west displaces the high-level gravel deposits (QTg) suggesting a lack of Quaternary motion.

Faults Juxtaposing Tesuque Formation and Proterozoic Rocks: Four conspicuous down-to-the-east faults juxtapose Oligo-Miocene and Precambrian rocks; two on each side of Big Tesuque Creek. Continuity of these fault zones across the Big Tesuque drainage is unlikely because the two northern faults appear to be terminated by northeast-striking cross faults on the north side of the creek. I was unable to find exposures of the fault surfaces but all appear to be reasonably steep (> 50^o). Surfaces in brecciated granite paralleling the easternmost fault north of the Big Tesuque dip 58^o to the east. If this fault were active prior to tilting of the Tesuque Formation, the previous dip would be about 80^o east. Pennsylvanian strata are thicker and more widespread on the footwalls of the two faults south of the Big Tesuque. If the large Paleozoic blocks north of the Big Tesuque are indicative of close proximity to the Great Unconformity, then the footwall of the adjacent fault would also expose a higher structural level in the pre-Tertiary rocks than is represented on the hangingwall. Although these observations are not conclusive, they suggest the possibility that these east-facing normal faults are inverted Laramide-age structures. The westernmost of the faults south of the Big Tesuque is especially interesting because it parallels an earlier ductile mylonite fabric. In addition, although Mississippian(?) and Pennsylvanian strata are preserved on the footwall, they are absent from the proximal hangingwall. Proterozoic rock in the footwall is a mylonitic granite whereas a small outcrop below Tesuque Formation on the hangingwall is a brecciated amphibolite, which contains nonfoliated granite but no mylonite. This suggests multiple brittle reactivation of an original ductile fault.

Northeast Striking Faults: A zone of northeast-striking faults is present along the lower Big Tesuque Creek valley and apparently continuing through the Bishop's Lodge area. Spiegel and Baldwin portray only one segment of one of these faults north of the Big Tesuque where they curved it to connect with a north-south structure. The northeast fault does, however, clearly continue to the southwest where it terminates outcrops of Bishop's Lodge Member that otherwise mysteriously end along strike on Spiegel's and Baldwin's map. Spiegel and Baldwin depict this fault as having down to the southeast motion, necessitated by their connection of the structure to the north-striking fault, which has uplifted Proterozoic rocks on its west side. I conclude, however, that this northeast fault exhibits down to the northwest motion for two reasons. First, a sliver of Bishop's Lodge volcaniclastic sediment in the fault zone is slid upward on the southeast side. Second, Nambé strata to the southeast of the fault are rich in Paleozoic clasts, which is typical of pre-Bishop's Lodge strata but not younger Nambé Member. This interpretation is stratigraphically significant because it places the ≥400 m of Nambé Member in the footwall of the northeast-striking fault below Bishop's Lodge volcaniclastic beds of likely late Oligocene age. Farther to the southwest, this fault *appears* to terminate against a north-south fault that uplifts Proterozoic rocks in its western footwall. The north-south fault does experience an eastward deflection here, however, and a prominent northeast-trending ravine in the Proterozoic rocks is arguably eroded out along a crush zone. This zone of brecciation in the Precambrian rocks is best seen at the southwest end of this ravine. A down-to-the-southeast fault with northeast strike juxtaposes Nambé and Bishop's Lodge beds and strikes toward this crush zone from the southwest. Although this northeast-striking fault in Tertiary strata has an opposite displacement sense from the fault exposed east of the Precambrian outcrops, the two faults strike toward one another and appear linked by the crush zone in the older rocks. This suggests that northeast- and north-striking faults actually cross each other here. Notably, the displacements on north-south faults appear less to the north of the northeast-striking faults than to the south.

The two north-south faults that uplift Proterozoic rocks north of Big Tesuque Creek appear to terminate southward against northeast-striking, southeast-down faults that follow a remarkably linear segment of the stream. In the case of the westernmost of these two uplifted, west-tilted blocks, faults splay toward the southwest on the north side of the stream and apparently control the location of a prominent spring. The easternmost uplifted Proterozoic block is terminated by a northeast-striking fault that is present on the north side of the streambed. Nambé strata cemented along the fault project above alluvium in the streambed to form a small rapid. I infer this northeast-striking fault to continue below alluvium in the linear segment of the stream and to continue southwestward toward Bishop's Lodge. Although largely concealed beneath alluvium and terrace gravel continuation of this structure would explain anomalous bedding attitudes (northeast strike with southeast dip) and an apparent fault repeat of Bishop's Lodge strata north-northeast of the Bishop's Lodge compound.

Another northeast-striking fault is implied northwest and west of the Bishop's Lodge compound. Notably, Bishop's Lodge strata and the olivine basalt flow exposed west of Bishop's Lodge Road end abruptly in an area of unusual eastward and southwestward dips. North-south faults cannot be traced beyond this area either. Along strike to the east of the road is a conspicuous northeast-trending ridge also characterized by anomalous bedding attitudes. Although the actual fault surface was never seen this narrow northeast-striking zone of unexpected bedding attitudes and bed terminations is a strong indication of the presence of a fault. If projected northeastward below terrace gravel and alluvium it could join the principal northeast-striking structure north of the Big Tesuque where it crosses the uplifted Proterozoic block.

This zone of northeast-striking faults generally defines a horst, although down-to-the-northwest throw on the northernmost faults of the zone seem greater than the southward throw along the southeast edge of the zone. Only the northernmost of the several faults in the zone appears to cross cut north-south faults and it curves to a more northerly strike where exiting the quadrangle to the north. Deflections and apparent offsets of north-south faults where they cross this northeast-striking structure suggest a small component of right slip, although the outcrop pattern suggests dominance of dip slip motion.

Geomorphology and Interpretation of Geologic History

Daniel J. Koning

During the late Oligocene to Miocene, the Tesuque Formation was deposited on an alluvial slope by generally ephemeral streams or small rivers in a slowly subsiding Espanola Basin. One particularly large drainage may have existed near the present-day Santa Fe River canyon, and this drainage may be responsible for the relatively high amount of Paleozoic sedimentary clasts and quartzite clasts in the Tesuque Formation near the northwest corner of the Santa Fe quadrangle. During the late Miocene and early Pliocene, significant faulting occurred in the basin to the north (Koning and Maldonaldo, 2001; Borchert, in progress; Kelley, 1978) but mapped faults are few in this quadrangle except for near the Sangre de Cristo Mountain Front.

High-level, relatively thin gravel deposits associated with units Tg and QTg occupy several different terrace levels (Figure 2) and are inset into the older Tesuque Formation in the Horcado Ranch quadrangle to the northwest (Koning and Maldonado, 2001), thus reflecting a general down-cutting environment. Most of these terraces project slightly above the Cerros del Rio basalt flows to the west and consequently are slightly older than these flows (2-2.8 Ma based on work by Bachman and Mehnert, 1978; Manley, 1976; and WoldeGabriel et al., 1996).

Since incision of the Rio Grande in the middle Pliocene to middle Pleistocene (Dethier, 1997), the Rio Tesuque drainage has been down-cutting more rapidly than the Santa Fe River drainage. This down-cutting has resulted in several Quaternary terraces along the Rio Tesuque (Qg1 - 3 in this quad, Qsg1 through Qsg5 in the Tesuque quadrangle, and Qgt1 through Qgt5 in the Horcado Ranch quadrangle). In contrast, down-cutting of the Santa Fe River has produced only four mapped terraces along the Santa Fe River (Qts1-3 in this quadrangle and unit Qao1 (Speigel and Baldwin's (1963) "airport surface") in the Turquoise Hill quadrangle). In addition, at Rio Tesuque there is approximately 90 m of difference between the active river channel and the lowest terrace deposit containing Guaje pumice. However, there is only approximately 30 m of difference between the top of the Ancha Formation (which has Guaje pumice within approximately 15 m of its top (Koning and Hallet, 2000) and the modern Santa Fe River. Because of this difference in incision magnitudes, there is a relatively steep slope north of the drainage divide separating the Rio Tesuque and Santa Fe River and a gentler slope south of it. Also, the Rio Tesuque has a relatively narrow bedrock inner gorge at its mouth in the Sangre de Cristo Mountains whereas the bedrock gorge of the Santa Fe River is wider (the inner bedrock gorge width/upstream river length ratios for the Rio Tesuque are 0.005 to 0.003 and for the Santa Fe River are 0.008). The difference in incision magnitudes between the two is probably a result of: 1) a longer stream length between the Rio Grande and the mountain front (32 km for the Rio Tesuque compared to 50 km for the Santa Fe River) and 2) the fact that the lower Santa Fe River is cutting through hard, indurated rocks of the Espinaso Formation, basalts of the Cerros del Rio, and various Oligocene intrusives whereas the Rio Tesuque only has to cut through relatively soft Tesuque Formation. Kelley (1979) attributes the difference in down-cutting rates to differences in the hardness of the rock and strata through which the two rivers are eroding.

In the Santa Fe River drainage, a relatively young stream capture event has occurred at Arroyo Mora at the eastern terminus of the Qfo unit, where Arroyo Mora bends sharply to the north and there is a pronounced bedrock knickpoint in the stream. This stream capture is responsible for the cessation of major aggradation on the Qfo unit. Because Qfo is interpreted to be older than Qtc1 and charcoal collected in Qtc1 returned a C-14 date of approximately 9500 radiocarbon years, this piracy event very likely pre-dates 10 ka.

Lastly, the significant difference in gravel clast lithology between Qts terraces and the Tesuque Formation is interpreted to reflect either 1) unroofing of the Sangre de Cristo Mountains or 2) the presence of a relatively large drainage during the Miocene which tapped into Paleozoic strata and Paleoproterozoic Hondo Group quartzites on the east side of the Picuris fault. This drainage likely exited near the present-day lower Santa Fe River canyon and its location may have been controlled by the ruptured hanging-wall hinge-zone uplift hypothesized by of Smith and Roy (2001). The lack of amphibolite in the Tesuque Formation along the Santa Fe River is puzzling but perhaps may be explained by relatively wet climatic conditions and rapid weathering rates during the time of deposition – a hypothesis that is supported by the lack of limestone clasts.

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