Geology of the Tenmile Hill 7.5' Quadrangle, Socorro County, New Mexico

by
Charles A. Ferguson

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ACKNOWLEDGMENTS

The geologic map of the Tenmile Hill quadrangle is a product of two separate mapping projects. The southwest corner (everything south and west of sec. 3, T6S, R5W) was mapped during the summer and fall of 1983 as part of a Master's Thesis at New Mexico Institute of Mining and Technology (Ferguson, 1986). The rest was mapped during the spring and fall of 1986 as part of an independent project. Both projects were funded by the New Mexico Bureau of Mines and Mineral Resources.

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LOCATION

The Tenmile Hill 7.5' quadrangle is located in southwest Socorro County on the west side of Milligan Gulch, a 15 km wide half graben separating two north-trending basin and range uplifts (Magdalena and San Mateo Ranges). Topography of the quadrangle is dominated by a pediment surface sloping off the eastern foothills of the San Mateo Mountains. Three major east-flowing drainages (from north to south: Big Rosa Canyon, Rosedale Canyon, and North Canyon) dissect the pediment surface, and eventually feed into the southeast-flowing Milligan Gulch, the axial fluvial system of the half graben.

Elevations in the quadrangle range from 5,600' in the southeast corner to 7,400' on Horse Mountain in the southwest corner. Vegetation is dominated by high prairie grasses with scattered stands of white oak, juniper, and pinon pine in sheltered areas. At higher elevations, scrub oak, mountain mahogany and stands of ponderosa pine can be found.

GEOLOGIC SETTING

The map area is in the northeastern Mogollon-Datil volcanic field, a middle Tertiary mass of calc-alkaline rock that blankets much of southwest New Mexico. Two sequences comprise the stratigraphy of the volcanic field, the Datil Group (Osburn and Chapin, 1983), and a younger unnamed sequence. The Datil Group is a volcaniclastic sequence with some mafic lavas and minor silicic ash-flow tuffs. The younger sequence is dominated by five widely distributed voluminous silicic ash-flow tuffs (oldest to youngest: Hells Mesa Tuff, La Jencia Tuff, Vicks Peak Tuff, Lemitar Tuff, and South Canyon Tuff; Osburn and Chapin, 1983). High-precision $^{40}Ar/^{39}Ar$ sanidine dates of these ash-flow tuff sheets with relative error of ± 0.15 Ma are: 32.04, 28.78, 28.46, 27.97, and 27.36 Ma (McIntosh and others, 1986). Relatively minor volumes of other rock (basaltic andesite lavas, rhyolite lavas and tuffs, and volcaniclastics) occur locally throughout the younger sequence, and are mostly related to source cauldrons for each of the major tuff units. Miocene and younger rocks of the Santa Fe Group, a mostly sedimentary sequence with minor bimodal volcanics, overlie the younger volcanic sequence.

The stratigraphy of the Tenmile Hill quadrangle is dominated by the five major ash-flow tuff units of the younger volcanic sequence. Datil Group rocks are exposed in nearby areas to the south (Atwood, 1982), and presumably occur in the subsurface. The lowermost part of the Popotosa Formation (base of the Santa Fe Group) is present in the northern part of the quadrangle.

The Tenmile Hill quadrangle is bisected by the southeast margin of the Mt. Withington Cauldron (Deal 1973), source of the youngest regional ash-flow tuff in the Socorro area, the South Canyon Tuff (Osburn and Ferguson, 1986; Ferguson, 1986). The cauldron margin truncates outflow sheets of the four oldest regional ash-flow tuffs which crop out in the southern part of the quadrangle.

Structurally, strata in the Tenmile Hill quadrangle are tilted to the east, and broken into mostly north-south trending normal fault blocks. Regional extension is related to formation of the Rio Grande Rift (Chapin, 1979).

STRATIGRAPHY

PRE-MT. WITHINGTON CAULDRON UNITS

Outflow sheets of the four oldest regional ash-flow tuffs with a combined thickness of 500 to 900 m probably covered the entire map area prior to formation of the Mt. Withington cauldron. Petrographically, the oldest and youngest of these (the Hells Mesa and Lemitar Tuffs) are crystal-rich quartz, sanidine, plagioclase, and biotite bearing units. These units contrast sharply with the crystal-poor sanidine bearing La Jencia and Vicks Peak Tuffs. Petrographic data for all of the tuffs are summarized by Osburn and Chapin (1983b). More detailed descriptions of the tuffs (except the Hells Mesa) in this area are presented in Ferguson (1986).

Source cauldrons for the oldest two units (Hells Mesa, La Jencia Tuffs) are in the Magdalena Mountains to the east and northeast (Osburn and Chapin, 1983b). These units are sparingly exposed in the southern part of the quadrangle (never together) where they are both at least 200 m thick.

The Vicks Peak Tuff was erupted from the Nogal Canyon cauldron in the southern San Mateo Mountains (Deal and Rhodes, 1976). In the western part of the map area the Vicks Peak thickens rapidly to the south (towards East Red Canyon) from 0 to at least 300 m (Ferguson, 1986).

A source cauldron for the Lemitar Tuff is not presently defined, but is thought to be in the Magdalena Mountains. In the east-central San Mateo Mountains, Lemitar Tuff thickens eastward from 20 m to more than 200 m. The Lemitar Tuff also fills several east-directed paleocanyons (Ferguson, 1986) in this area. The east wall of one of these is exposed in the NE/4, sec. 28, T6S, R5W (Plate 1).

The only other Oligocene unit in the map area, not related to the Mt. Withington cauldron, is a basaltic andesite lava flow below the La Jencia Tuff that presumably overlies the Hells Mesa Tuff.

MT. WITHINGTON CAULDRON UNITS

The Mt. Withington cauldron was originally defined by Deal

(1973) as a circular structure encompassing the entire north end of the San Mateo Mountains, and the source of two units (Potato Canyon Tuff and A-L Peak Tuff) whose names are now considered obsolete Osburn and Chapin, 1983). Osburn and Ferguson (1986) redefined the Mt. Withington cauldron as a NE-SW elongate structure extending from the northeast San Mateo Mountains across Milligan Gulch to the western Magdalena Mountains (Figure 1), and as the source of the South Canyon Tuff which is at least 800 m thick in the cauldron.

South Canyon Tuff

The South Canyon Tuff is a crystal-poor to moderately-crystal-rich rhyolite ash-flow tuff containing phenocrysts of mostly sanidine and quartz in ratios ranging from 1:1 to 2:1. It also contains as much as 2% plagioclase and minor to trace amounts of biotite, sphene, and opaque minerals (Ferguson, 1986). Phenocryst content increases upward gradually from 2% to 25%. In some areas, the top of the unit contains more than 35% phenocrysts.

In the Tenmile Hill quadrangle, the structural margin of the Mt. Withington cauldron is a complex monoclinal sag overlain with angular unconformity by a northward-thickening wedge of South Canyon Tuff. Near the cauldron margin, discontinuous lenses of clast-supported lithic breccias 10 to 100 m thick occur vertically throughout the South Canyon Tuff (mapped separately on Plate 1). The maximum size of lithic fragments in the breccias decreases from 200 cm to 70 cm towards the center of the cauldron. The breccias are thought to be co-ignimbrite lag-fall deposits (Wright and Walker, 1977) associated with the collapse of nearby eruption column(s) during eruption of the South Canyon Tuff.

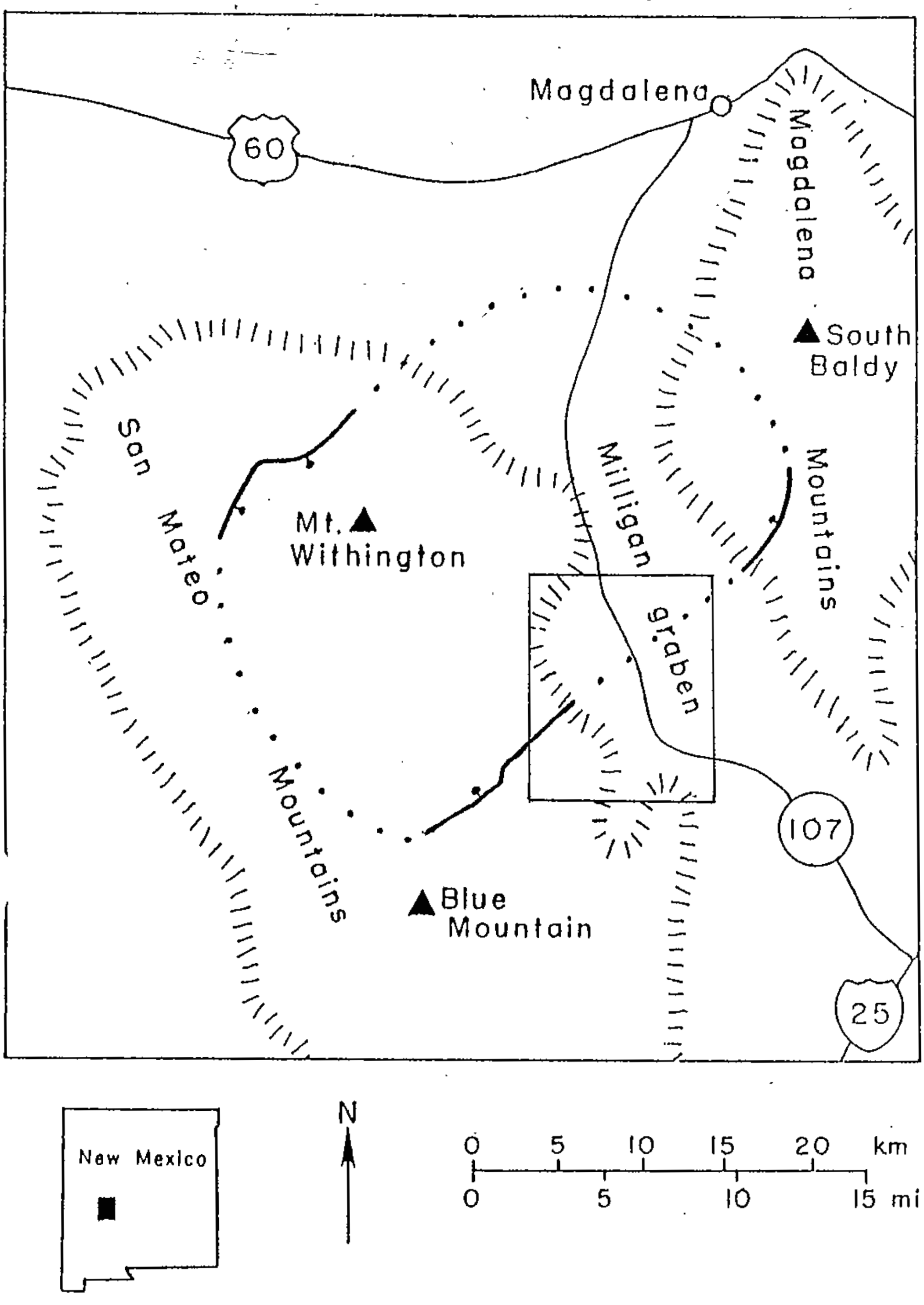

Figure 1. Map of the northern San Mateo Mountains and Magdalena Mountains showing the location of the Mt. Withington cauldron margin from detailed mapping (solid line), and inferred (dotted). Rectangular area represents area of the Tenmile Hill 7.5' quadrangle.

The South Canyon Tuff contains elongate preferentially oriented and flow-banded pumice fragments consistently oriented approximately E-W (Ø75° azimuth) throughout the cauldron. An exception is a narrow belt (2-3 km wide) along the southeast edge of the cauldron where azimuths are oriented NW-SE, probably a reflection of the gently northwest-sloping surface buried by the South Canyon here.

Cauldron-fill Units

Rocks that accumulated within and along the margin of the Mt. Withington cauldron after emplacement of the South Canyon Tuff include rhyolite domes and associated lavas, and the unit of East Red Canyon (Ferguson, 1986), a sequence of volcaniclastic fanglomerates and sandstones.

Rhyolite intrusions, some of which may seal vents for the South Canyon Tuff (Ferguson and Osburn, 1986), are concentrated along the structural margin of the cauldron. Most of these rhyolite lavas contain between 5% and 1Ø% phenocrysts of feldspaer (sanidine and plagioclase) and quartz with trace amounts of biotite, sphene, amphibole, and opaque minerals. One exception is the rhyolite on Wildcat Peak which does not contain quartz phenocrysts. Chemically, these are high-silica, high-potassium rhyolites with at least 77% SiO_2 and 4.5% K_2O (Ferguson, 1986, p. 82)

The unit of East Red Canyon consists of as much as 2ØØ m of volcaniclastic rocks, that occur along the inside edge of the Mt. Withington cauldron. Along the margin, the unit contains coarse conglomerates and debris-flow deposits that are interpreted as proximal alluvial fan deposits. The coarse deposits are dominated by clasts of rhyolite lava derived from the numerous lava domes that occur along the cauldron margin. Other clasts include crystal-rich tuff, which appears to be South Canyon, and farther south clasts of Vicks Peak Tuff are common. Minor lithic-rich unwelded ash-flow tuffs are interbedded with sediments along the margin, and are probably products of the rhyolite domes. To the northwest, the unit grades into medium- to thick-bedded tabular-planar cross-stratified sandstones, interpreted as eolian. Paleocurrent studies of the eolian sandstones (Ferguson, 1986) indicate northeasterly transport suggesting a sediment source to the southwest. The unit as a whole represents a northwest-directed alluvial-fan complex that interfingers with an intracaldera erg that may have blanketed a large part of the cauldron floor. The basin's western edge is a syn-depositional down-to-the-west fault with a displacement of about 200 m where it is exposed in East Red Canyon just southwest of the map area (Ferguson, 1986).

POST-MT. WITHINGTON CAULDRON UNITS

Tuff of Turkey Springs

The tuff of Turkey Springs is a crystal-poor to moderately-crystal-rich rhyolite ash-flow tuff. A lower unwelded and upper welded member comprise a simple cooling unit that is 100 to 160 m thick in the map area. The unwelded member is a distinctive cliff-former 5 to 15 m thick. It grades upward into the welded member, in which phenocryst and pumice percentages increase upward (5-20% and 2-15% respectively) Petrographically, the unit contains subequal amounts of sanidine and quartz, minor plagioclase, and traces of biotite, sphene, and opaque minerals. The unit's vertical mineralogical and textural variations are essentially identical to outflow sequences of the South Canyon Tuff (Ferguson, 1986), which explains why the unit was originally correlated with the South Canyon by three previous workers. Deal (1973) mapped it as Potato Canyon (South Canyon equivalent; Osburn and Chapin, 1983), Donze (1980) and Ferguson (1985) mapped it as South Canyon.

The tuff of Turkey Springs is distinguished from the South Canyon in the field only by its stratigraphic position. It also has a distinctly different paleomagnetic pole position, and high-precision $^{40}Ar/^{39}Ar$ dates from sanidine make it about 3 Ma younger than the South Canyon (McIntosh, personal communication).

Just below the unwelded member of the tuff of Turkey Springs is a 20 to 40 m thick interval within the unit of East Red Canyon of ash-fall tuff beds interlayered with massive pebbly sandstones. In the northern Tenmile Hill quadrangle this interval conatins 3 to 5 thin-bedded, well-sorted, mostly coarse ash, tuff sequences 0.3 to 2.0 m thick. Farther southwest, in the East Red Canyon area, there are as many as 10 of these tuff sequences that are thicker, and coarser grained (typically lapilli size). The tuffs are interpreted to be fallout deposits from plinian eruptions that preceded emplacement of the tuff of Turkey Springs.

A source for the Turkey Springs has not yet been identified. It is its thickest, 160 m with no exposed top, in East Red Canyon. Its known areal distribution extends north and east from East Red canyon to northern Milligan Gulch and the western Magdalena Mountains. South and west of East Red Canyon, it extends into the northern Black Range and southwest San Mateo Mountains (McIntosh, personal communication). Assuming an average thickness of 100 m over this NE-SW elongated area gives a volume of about 100 km^2.

Popotosa Formation

The tuff of Turkey Springs, which predates the beginning of the Miocene by about 500,000 years (McIntosh, personal communication), is overlain by the Popotosa Formation. The Popotosa is a sequence of volcaniclastic sedimentary rocks that also includes two volcanic units: a basaltic andesite lava, and some bedded unwelded rhyolite ash-flow tuffs. All three lithologies are mapped separately where they occur in the northern part of the quad. The sediments (0 to 65 m) are dominated by pebbly sandstones and conglomerates, and virtually void of clay-sized particles. They are also well-stratified, commonly in medium-bedded cross-stratified sets, suggesting a braided fluvial depositional setting. Scanty paleocurrent directions, from foresets, are east-directed.

Basaltic andesite lavas, up to 120 m thick overlie the sediments in the Big Rosa Canyon-Milligan Gulch, but farther northeast they directly overlie tuff of Turkey Springs. They appear to be a sequence of at least three flows in Big Rosa Canyon. Part of the lava is blocky, but massive vesiculated material is most common. Elongated vesicles are consistently oriented north-south.

Near the confluence of Milligan Gulch and Big Rosa Canyon, mafic lavas are overlain by up to 110 m of bedded and massive unwelded lithic-rich ash-flow tuffs. The tuffs are probably products of small eruptions from the B. O. Ranch rhyolite lava dome(s) which is younger than 18.3 Ma (Bobrow and others, 1983).

Quaternary

The Tenmile Hill quadrangle is dominated by broad, coalescent alluvial-fan deposits, the upper surfaces of which have undergone varying degrees of dissection and erosion. The alluvial-fan deposits consist of partially indurated sandy conglomerate and pebbly sandstone that is correlated with the Plio-Pleistocene Palomas Formation - upper Santa Fe Group (Lozinsky and Hawley, 1986). Up to 40 m of these sediments are exposed in Milligan Gulch along the east edge of the quadrangle

Most of the map area is covered by a constructional geomorphic surface that slopes about 1.5° east (A similar west-sloping surface is present in the northeast corner of the quadrangle). Within 1 to 2 km of the San Mateo foothills, the slope of this surface increases abruptly to about 3.0°. This steeper surface projects westward towards the upper reaches of Rosedale Canyon, North Canyon, and Exter Canyon where similar deposits occur. Partially consolidated gravels also occur as inset terraces along the sides of East Red Canyon. The highest of the alluvial-fan surfaces are probably equivalent in age to the Cuchillo surface (Lozinsky and Hawley, 1986b). Incision of this surface, if equivalent to the Cuchillo, represents a lowering of base level in response to initial entrenchment of the Rio Grande river system about 400,000 years ago (Gile and others, 1981).

Palomas Formation deposits are locally offset by at least two high-angle faults that extend from south to north across the central part of the quadrangle. The offset is most apparent along the north side of North Canyon where the uppermost surface is offset down-to-the-west about 8 m. Topographic breaks in the alluvial surface decrease gradually to the north across both of these faults. Sediments along the southern wall of North Canyon, upstream of the eastern fault, include fairly thick dark clays, atypical of the Palomas Formation in the map area. The clays probably record an episode of faulting that damned North Canyon, and allowed fine-grained sediment to accumulate. This style of sedimentation is also noted in southern Milligan Gulch adjacent to similar down-to-the-west fault scarps (Machette, 1987).

There is no known biostratigraphic control for the age of the Palomas Formation in the map area. There is a chance that organic debris in dark clays such as those mentioned above could be isotopically dated.

Unconsolidated gravels in canyon bottoms are mapped separately as alluvium that represents the most recent valley-fill episode.

STRUCTURAL GEOLOGY

Structural elements in the Tenmile Hill quadrangle can be divided into two categories: synvolcanic structures, and basin and range extensional structures related to formation of the Rio Grande Rift.

SYN-VOLCANIC STRUCTURES

Structures Related to the Vicks Peak Tuff

The oldest possible syn-volcanic structure expressed in the Tenmile Hill quadrangle is related to emplacement of the Vicks Peak Tuff. Ferguson (1986) describes a zone of roughly E-W trending

(Ø7Ø° azimuth), south-side-down folded and contorted Vicks Peak Tuff in the East Red Canyon area just south of the SW corner of the map area. The Vicks Peak thickens (from 12Ø m to 215 m with no exposed base) southward across the approximately 1 km wide structure. Elongate preferentially oriented pumice fragments in the Vicks Peak consistently trending about N2Ø°W are present within and south of this structure, but do not occur to the north. The paleomagnetic pole postion of steeply folded Vicks Peak Tuff within the folded belt is similar to its regional average pole position indicating that it cooled below the Curie temperature after deformation (McIntosh, 1983; McIntosh, personal communication), and that a south-facing scarp existed here during the Vicks Peak eruption. Along strike to the east a probably time-equivalent structure is exposed in North Canyon along the south-central edge of the quadrangle. In this area, an older unit (Hells Mesa Tuff) is brecciated into large blocks and tilted to the south 2Ø° to 7Ø° in an E-W trending belt at least Ø.5 km wide. Paleomagnetic pole position studies indicate that the blocks rotated after cooling below the Curie temperature (McIntosh, personal communication). This is not surprising, considering the brittle style of deformation here, and its probable syn-Vicks Peak Tuff age.

Brittle south-side-down deformation of the Hells Mesa Tuff, in a belt along strike from the folded Vicks Peak, lends credence to the interpretation that Vicks Peak Tuff was draped over an active fault scarp rather than erosional scarp (Ferguson, 1986). This is important because a paleovalley filled with Vicks Peak Tuff has been recognized in Cold Spring Canyon just to the south (Osburn, 1982). This additional structural evidence combined with the abrupt thickening and changes in rheology of the Vicks Peak Tuff south of the structure suggest that it is an important volcano-tectonic zone related to emplacement of the Vicks Peak Tuff.

Structure of the Mt. Withington Cauldron

The structural margin of the Mt. Withington cauldron has been mapped in three areas (Fig. 1). In the northern San Mateo Mountains near Monica Saddle, the margin is a near vertical south-side-down fault placing cauldron-facies South Canyon Tuff against outflow sheets of older units (Osburn and Ferguson, 1986). In the western Magdalena Mountains a west-facing structure partially obscured by younger rocks, also appears to be essentially a vertical fault bounding thick cauldron-facies South Canyon to the northwest. A third exposure extends from the southwest corner of the Tenmile Hill quadrangle towards the central San Mateo Mountains saddle. This margin segment is not a vertical fault, but a gently sloping (15° NW) monoclinal sag composed of northwest-tilted (20° to 60°) blocks of pre-cauldron strata repeated by closely-spaced southeast dipping normal faults (see west end of cross-section C-C'). The youngest unit offset by these faults is the basal unwelded member of the South Canyon Tuff. Welded South Canyon is draped over the deformed blocks, and its flattened pumice define a foliation consistent with the regional tilt of 15o east. This structural style continues along the margin to the southwest toward Cave Peaks where it is buried beneath the unit of East Red Canyon. To the northeast, the margin is buried beneath Palomas Formation deposits. The extension of the margin across Milligan Gulch is essentially a straight line between the central San Mateo and western Magdalena segments. In the eastern part of the quadrangle, cross-section B-B' (Plate 2) shows the cauldron margin with a structural style similar to that known to the west. The only evidence of a sagged margin here is two small hills of northwest-tilted welded tuff, probably the South Canyon Tuff or tuff of Turkey Springs (mapped as Turkey Springs on Plate 1). These occur just northwest of virtually flat-lying exposures of Lemitar Tuff.

BASIN AND RANGE FAULTING

The Least Principal Stress Direction

Basin and Range extension related to formation of the Rio Grande Rift (Chapin, 1979) has affected all Teriary strata in the map area. The least principal stress direction for this area during the Oligocene was oriented about N65°E. This direction is from the trends of four rhyolite dikes just southwest of the map area (Ferguson, 1986, p. 111). Two of these dike's ages are closely constrained between the Vicks Peak and Lemitar Tuffs, 28.46 Ma and 27.97 Ma (McIntosh and others, 1986). This stress direction is similar to a Miocene direction of N70°E reported by Zoback and others (1981, p. 423). Intruding the South Canyon along the structural margin of the Mt. Withington cauldron is a rhyolite dike trending N55°E. This trend is interpreted as a localized least principal stress created by tension orthogonal to the downwarped margin of the cauldron.

Fault Patterns

Normal faults in most of the map area are generally parallel to each other and trend about N30°W. An exception is in the southwest corner of the quadrangle to the south of the Mt. Withington cauldron margin. Two sets of of north-south (west-side-down) and east-west (south-side-down) trending faults occur here. This orthogonal strain pattern prevails in the East Red Canyon area (Ferguson, 1986), and is thought to reflect the influence of older basement structures on the N65°E least principal stress direction. Farther north, within the Mt. Withington cauldron, faults are oriented perpendicular to the stress direction possibly because the effects of basement structures were negated by the presence of a young isotropic sub-caldera pluton. The resultant vector of extension for both fault patterns is generally parallel to the least principal stress direction (Ferguson, 1986).

Magnitude and Duration of Extension.

Basin and range fault blocks are tilted to the east throughout the map area. The degree of tilt increases dramatically from 10-15° to 40-50° northward across the Mt. Withington cauldron margin. This corresponds to an increase in the amount of extension from about 20% to as much as 100%. This places intracauldron South Canyon Tuff within the moderately extended domain of Chamberlin and Osburn (1984). Younger rocks, including the tuff of Turkey Springs, that overlie the South Canyon are tilted only 5-15° suggesting that the interior of the Mt. Withington cauldron was extended as much as 80% between 27.4 Ma (age of the South Canyon) and before emplacement of the tuff of Turkey Springs just before the end of the Miocene about 24 Ma (Mcintosh and others, 1986). Deal (1973) interpreted this angular unconformity as evidence for resurgence of the Mt. Withington cauldron, and suggested the high areas of the northern San Mateo Mountains as being a remnant of this uplift.

The lack of reliable marker horizons in the South Canyon Tuff makes it difficult to desribe how large amounts of extension was achieved. Numerous normal faults are needed to repeat the steeply-dipping strata in the northwest corner of the quadrangle, but there is no indication of the dip of these faults. Cross-section A-A' shows numerous moderately-dipping faults to account for the large degree of extension that occurred prior to deposition of younger units. Younger high-angle faults, that offset the unit of East Red Canyon, are shown as steeper faults cutting the older faults. One of these faults (east edge of sec. 24, T5S, R5W) offsets a pedimented bedrock surface indicating that it is fairly young and probably high-angle.

Large degrees of extension may account for the oblong shape of the Mt. Withington cauldron oriented parallel to the least principal stress direction. However, flow-banded pumice in the South Canyon Tuff are oriented parallel to the cauldron's long axis indicating that it may have formed as an elongate depression.

North and west of the Tenmile Hill quadrangle lies an extremely rugged area (Mt. Withington Wilderness) underlain by thick cauldron-facies South Canyon Tuff. The structural geology of this, essentially unmapped area, is poorly understood. Further mapping in this area may help answer at least two critical questions about the interior of the cauldron. Are large amounts of tilting due to cauldron resurgence, or regional extension, or a combination of these? What is the nature of the transition from moderately extended to weakly extended South Canyon Tuff to the west. In the Grassy Lookout 7.5' quadrangle, this change occurs abruptly across a north-trending east-side-down fault. This fault runs just east of the high crest of the northern San Mateo Mountains juxtaposing "bottomless" steeply-tilted South Canyon to the east against gently-dipping South Canyon overlying Lemitar Tuff to the west (Ferguson, 1986).

Neotectonics

Two north-south trending faults that extend across the central part of the study area offset Plio-Pleistocene Palomas Formation deposits. The scarps associated with these faults are very subdued and probably were last active 100,000 to 200,000 years ago (Machette, 1987; p. 15). The eastern fault occurs just west of a series of small bedrock inselbergs that extend across the quadrangle. At the southern edge of the quadrangle this fault accommodates at least 600 m of west-side-down displacement in Oligocene units. It is possible that Palomas Formation deposits are very thick to the west of the fault, even though a minimum amount is shown on cross-section C-C'.

ECONOMIC GEOLOGY

Practically nothing is known about pre-Tertiary geology of the Tenmile Hill quadrangle. Tertiary Datil-Group rocks to the south overlie a thin sequence of upper Paleozoic strata above Precambrian crystalline basement (Atwood, 1982). The petroleum resource potential of the area is therefore very low, even though Grant and Foster (1988) suggest the possibility of great thicknesses of Cretaceous strata here.

The Rosedale epithermal gold district, hosted by intracauldron South Canyon Tuff, is located 3-4 km west of the quadrangle (Ferguson, 1986). The district is surrounded by a halo of argillically altered rock which extends along faults to the north and south of the mine. This kind of alteration was not observed in the map area. Palomas Formation sediments along the west edge of the quadrangle were derived form erosion of these rocks, and may contain economic placer deposits.

Another possible economic resource of the area is zeolite mineralization that effects pumice fragments in unwelded ash-flow tuffs of the Popotosa Formation in Big Rosa Canyon. The contact between basaltic andesite lavas and Popotosa sediments in this area is often altered and invaded by calcite veins, and some of the vesicles contain minerals (unidentified by the author) that could be of interest to collectors.

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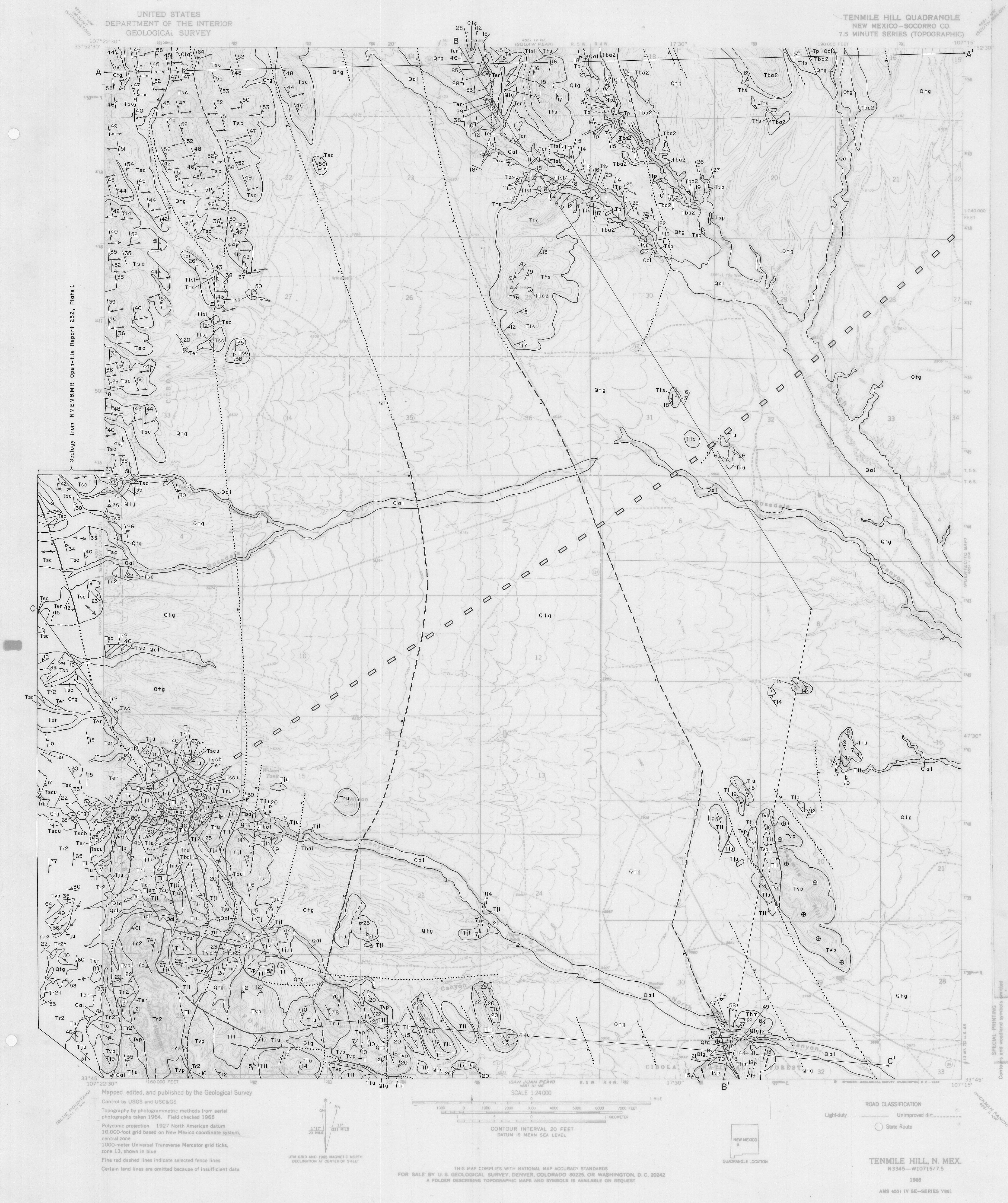
Geologic map of the Tenmile Hill 7.5' quadrangle, Socorro County, New Mexico

Plate 1

by Charles A. Ferguson June, 1987 New Mexico Bureau of Mines and Mineral Resources Open-File Map 283



EXPLANATION

Quaternary		Qal	Unconsolidated alluvial deposits in arroyos and canyons.
Quaternary		Qtg	Palomas Formation partially consolidated conglomerate and pebbly sandstone.
Tertiary	Miocene	Tsp	Unwelded bedded and massive lithic-rich rhyolite ash-flow tuffs, probably erupted from the nearby Squaw Peak and B. O. Ranch rhyolite lava domes. Thickness: up to 350 ft.
Tertiary	Miocene	Tba2	Basaltic andesite lava flows interbedded with Popotosa Formation epiclastic rocks. Thickness: up to 500 ft.
Tertiary	Miocene	Tp	Popotosa Formation. Fluvial volcaniclastic sandstone and conglomerate. Thickness: 0 to 200 ft.
Tertiary	Oligocene	Tts	Upper tuff of Turkey Springs (welded portion). Crystal-poor to moderately crystal-rich (quartz-sanidine) rhyolite ash-flow tuff. Thickness: 220 to 400 ft.
Tertiary	Oligocene	Ttsl	Lower tuff of Turkey Springs (unwelded portion). Crystal-poor (quartz-sanidine), lithic rhyolite ash-flow tuff. Thickness: 0 to 100 ft.
Tertiary	Oligocene	Ter	Unit of East Red Canyon. Tan- to red-colored volcaniclastic fluvial conglomerate and sandstone, diamictite (debris-flow deposits), and eolian sandstone. The upper part of the unit contains numerous thin- to medium-bedded unwelded plinian ash-fall tuffs, and medium- to thick-bedded unwelded lithic ash-flow tuffs. Thickness: 0 to 600 ft.
Tertiary	Oligocene	Tr2	Rhyolite intrusives and lava flows younger than the South Canyon Tuff. These rhyolites interfinger with deposits of the unit of East Red Canyon.
Tertiary	Oligocene	Tr2t	Poorly to moderately-welded rhyolite ash-flow tuffs interbedded between Tr2 lava flows in the Horse Mountain Canyon area. Thickness: <100 ft.
Tertiary	Oligocene	Tsc	South Canyon Tuff (welded member). Crystal-poor to moderately crystal-rich (quartz-sanidine) densely welded rhyolite ash-flow tuff. The tuff is strongly flow-banded (defined by elongated pumice fragments) in the northwest part of the quadrangle. Thickness: 0 to <3,000 ft.
Tertiary	Oligocene	Tscb	Clast-supported lithic breccia member of the South Canyon Tuff. The breccias contain lithic clasts of rhyolite intrusive/lava and older ash-flow tuffs (mostly Lemitar Tuff) that are up to 1.5 meters in diameter. The breccias occur in discontinuous lenses 10 to 100 meters thick. The lenses grade vertically and laterally into poorly welded and eventually densely welded South Canyon Tuff.
Tertiary	Oligocene	Tscu	Lowermost member of the South Canyon Tuff. Unwelded thin- to medium-bedded lithic-rich rhyolite ash-flow tuffs interbedded with rare beds of volcaniclastic sandstone. Thickness: 0 to 330 ft.
Tertiary	Oligocene	Tr1	Rhyolite intrusives and/or lava flows that are older than the South Canyon Tuff.
Tertiary	Oligocene	Tru	Unconstrained rhyolite intrusives. These are rhyolites whose age cannot be constrained relative to the South Canyon Tuff.
Tertiary	Oligocene	Tl	Lemitar Tuff undifferentiated (simple cooling unit). Crystal-poor to crystal-rich (quartz-sanidine-plagioclase-biotite) rhyolite ash-flow tuff. The Lemitar Tuff has a distinct vertical mineralogical zonation. Thickness: 300 to 600 ft.
Tertiary	Oligocene	Tlu	Upper member of the Lemitar Tuff. Moderately crystal-rich to crystal-rich (quartz-sanidine-plagioclase-biotite) rhyolite ash-flow tuff. The upper member starts at the base of a cliff-forming quartz-poor interval. Thickness: 300 to 600 ft.
Tertiary	Oligocene	Tll	Lower member of the Lemitar Tuff. Crystal-poor (quartz-sanidine) rhyolite ash-flow tuff. Thickness: 200 to 400 ft.
Tertiary	Oligocene	Tvp	Vicks Peak Tuff. Crystal-poor (sanidine) rhyolite ash-flow tuff. Thickness: 0 to 500 ft.
Tertiary	Oligocene	Tj	La Jencia Tuff undifferentiated (simple cooling unit). Crystal-poor (sanidine) rhyolite ash-flow tuff. The La Jencia Tuff has a distinct vertical textural zonation. Thickness: 300 to 900 ft.
Tertiary	Oligocene	Tju	Upper member of the La Jencia Tuff. Strongly flow-banded (sanidine) rhyolite ash-flow tuff. Thickness: 50 to 650 ft.
Tertiary	Oligocene	Tjl	Lower member of the La Jencia Tuff. Non-flow-banded crystal-poor (sanidine) rhyolite ash-flow tuff. Thickness: 250 ft.
Tertiary	Oligocene	Tba1	Basaltic andesite lava flow that underlies the La Jencia Tuff in North Canyon (southwest part of the quadrangle). Thickness: >200 ft.
Tertiary	Oligocene	Thm	Hells Mesa Tuff. Moderately crystal-rich to crystal-rich (quartz-sanidine-plagioclase-biotite) rhyodacite ash-flow tuff. Thickness: >700 ft.

Contact, dashed where approximate, dotted where buried by Quaternary deposits.

Fault (ball on downthrown side), dashed where approximate, dotted where buried by Quaternary deposits.

Fault buried by Tertiary deposits (arrow on downthrown side).

23 , ⊕ Strike and dip of eutaxitic foliation in ash-flow tuffs, flat-lying foliation.

34 , Strike and dip of foliation in lava flows or shallow intrusions, vertical foliation.

12 Strike and dip of sedimentary bedding.

Lineation defined by the elongation of pumice fragments in ash-flow tuffs or elongated vesicles in lava flows. Azimuth is corrected for tilting.

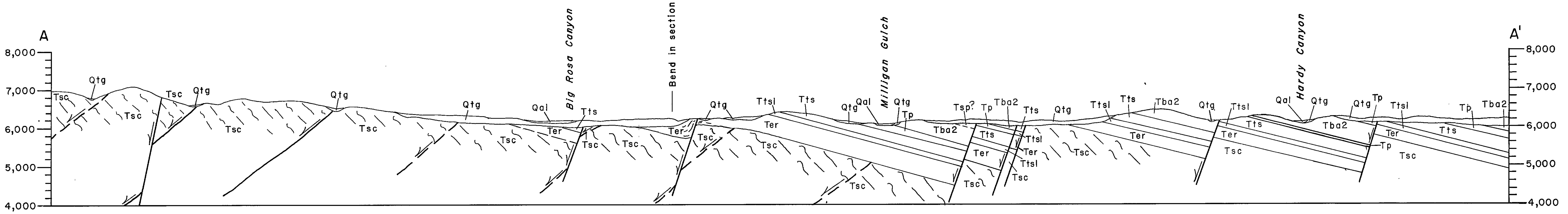
Paleocurrent direction from dip of foresets in cross-stratified sandstone/conglomerate.

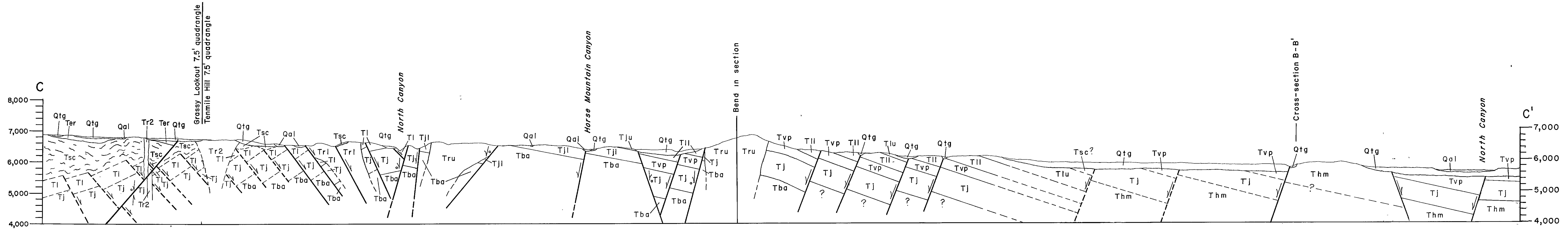
A A' Line of cross-section.

Approximate location of the southeast margin of the Mount Withington Cauldron.

Geologic cross-sections of the Tenmile Hill 7.5' quadrangle, Socorro County, New Mexico

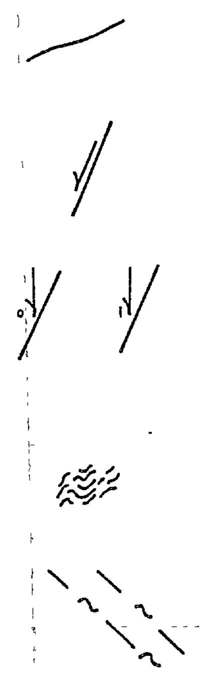
Plate 2 NMBM&MR Open-File Map 283





EXPLANATION

All subsurface contacts and faults are interpretive. Solid lines indicate there is surface evidence for the author's interpretation. Dashed lines indicate that there is no surface evidence for the interpretation. Cross-section A-A' uses surface information from mapping to the north (Donze, 1980, NMBM&MR Open-file Report 123) as well as information from this quadrangle.



Contact.

Fault, arrow showing movement of downthrown block.

Fault intersected at a low angle by the plane of the cross-section. o denotes arrow coming out of cross-section plane, i denotes into cross-section plane.

Contorted foliation or sedimentary bedding.

Apparent dip of eutaxitic foliation in the South Canyon Tuff.