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Leslie M. Ekas, Raymond V. Ingersoll, W. Scott Baldridge, and Muhammad Shafiqullah

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THE CHAMA-EL RITO MEMBER OF THE TESUQUE FORMATION, ESPANOLA BASIN, NEW MEXICO

LESLIE M. EKAS', RAYMOND V. INGERSOLL', W. SCOTT BALDRIDGE, and MUHAMMAD SHAFIQULLAFF
'Department of Earth and Space Sciences, University of California, Los Angeles, California 90024; 'Earth and Space Sciences Division, MS J978, Los Alamos National Laboratory, Los Alamos, New Mexico 87545; 'Laboratory of Isotope Geochemistry, Department of Geosciences, University of Arizona, Tucson, Arizona 85721

INTRODUCTION

The Chama—El Rito is the lowest member of the Tesuque Formation on the north and west sides of the Espanola Basin (Galusha and Blick, 1971; Manley, 1979; May, 1979; Tedford, 1981). The Tesuque Formation and the underlying Abiquiu Formation mark the earliest deposition of sediments in the Espanola Basin of the Rio Grande rift (Galusha and Blick, 1971). The Chama—El Rito Member is a thick sequence (440-460 m; May, 1980) of arkosic and volcaniclastic sandstones and mudstones with interbedded volcanic-rich conglomerates. It includes sparse airfall tuffs and limestones to the southeast and volcanic vents with associated debris-flow deposits (May, 1980). The sediments were deposited in alluvial channels on a broad plain at the distal edge of an alluvial fan. They are relatively undisturbed, showing faulting with minor offset and minor eastward tilting. In general, they are poorly lithified and eroded to a badlands topography. Since the sediments are relatively flat-lying, the best exposures are in areas of rapid erosion.

Hayden (1869) first applied the name "Santa Fe Marls" (now called the Santa Fe Group). Spiegel and Baldwin (1963) defined the Tesuque Formation in the southern part of the type area of the Santa Fe Group. Galusha and Blick (1971) further subdivided the Santa Fe Group into two formations (Tesuque and Chamita), and subdivided these formations into members. The Chama—El Rito and Ojo Caliente Members in the western part of the basin are laterally equivalent to the Nambé, Skull Ridge, and Pojoaque Members in the Tesuque Formation to the east. Kelley's (1978) map of the Espanola Basin delineates the extent of the Chama—El Rito Member. May (1980) mapped the Chama—EI Rito and surrounding units in detail and described the lithology.

This paper summarizes stratigraphic, sedimentologic, and petrographic data from a recent study of the Chama—El Rito (Ekas, 1984), and presents new radiometric and chemical data on volcanic clasts of intermediate composition and interbedded basaltic-vent deposits. This information provides new constraints on the paleotectonic and paleoenvironmental development of the Espanola Basin in particular, and the northern Rio Grande rift in general.

REGIONAL SETTING

The southwest part of the Espanola Basin is covered by the Jemez volcanic complex; the basin is bordered by the Brazos uplift (Tusas Mountains) to the north, the Taos Plateau to the northeast, and the Sangre de Cristo Mountains to the east and southeast (Fig. 1). The Espanola Basin is one of a series of approximately northeast-trending structural and topographic depressions that lie along the Rio Grande valley from central Colorado to southern New Mexico (Chapin and Seager, 1975). This depression resulted from crustal extension that produced the Rio Grande rift (Chapin, 1979; Chapin and Seager, 1975; Lucas and Ingersoll, 1981; Riecker, 1979).

The Espanola Basin probably became a depression during Abiquiu deposition (Vazzana and Ingersoll, 1981). The Abiquiu and related units [Picuris Formation and Bishops Lodge Member of the Tesuque Formation (Manley, 1979)] occur stratigraphically below the Chama—El Rito Member in exposures on both sides of the Espanola Basin. The Chama—El Rito Member extends to the western edge of the Espanola Basin, but is not exposed along the east side except in the Dixon area (e.g., Steinpress, 1981). Deposition of the east-derived Tesuque members (Nambé, Skull Ridge, and Pojoaque) concurrently with the north-derived Chama—El Rito and their interfingering in the center of the Espanola Basin suggest that the Espanola Basin had become a down-dropped area by the beginning of Tesuque deposition.

AGE

Based on land-mammal fossils, Tedford (1981) assigned the ChamaEl Rito Member middle Hemingfordian to early Clarendonian ages (corresponding approximately to 18-10 m.y. ago). This age is older than Galusha and Blick (1971) suggested, but more in agreement with Manley's (1979) suggestion of 20 to 10 m.y.

Our date on a basalt bomb (basanite, Tables 1-3) from a vent (Fig. 2) in the lower part of the middle Chama—El Rito (May, 1980; this guidebook) is 15.3±0.4 0.4 m.y., in agreement with Tedford's (1981) age estimates. Manley and Mehnert's (1981) date on a basalt from the same location is 13.5 -± 2.8 m.y.

STRATIGRAPHY AND SEDIMENTOLOGY

The Chama—El Rito Member is composed primarily of tan arkosic sandstones and mudstones with interbedded gray, volcanic-rich gravel lenses (Fig. 3). The sandstones are thinly to thickly bedded, and the red mudstones form very thin beds. In most exposures the bedding features are difficult, if not impossible, to detect because the lithology and grain size are homogeneous and the rocks are poorly lithified. Where bedding features are evident, the sandstones and mudstones are laterally extensive and parallel-bedded, but individual layers are difficult to trace due to nondistinctive character of individual layers. The gray volcani-

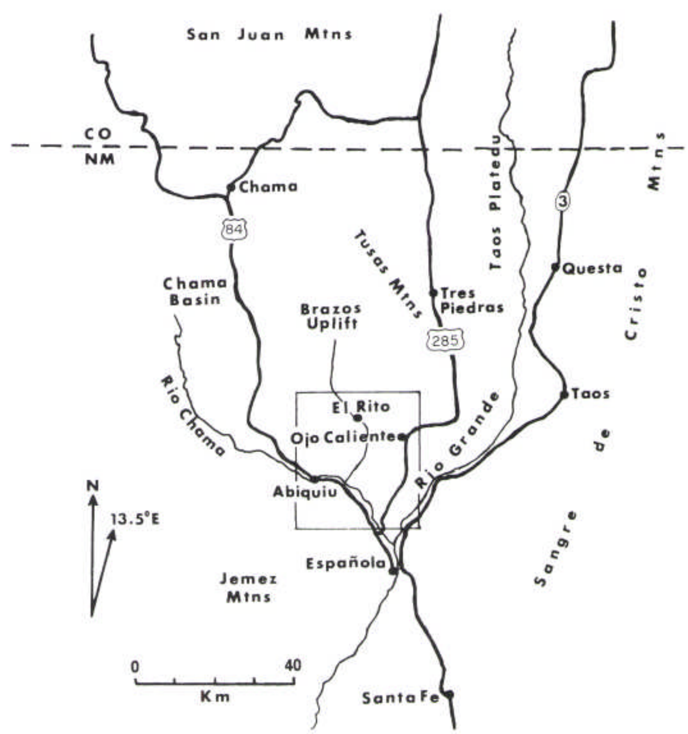

FIGURE 1. Location map of study area. Area of Figure 2 is indicated by rectangle.

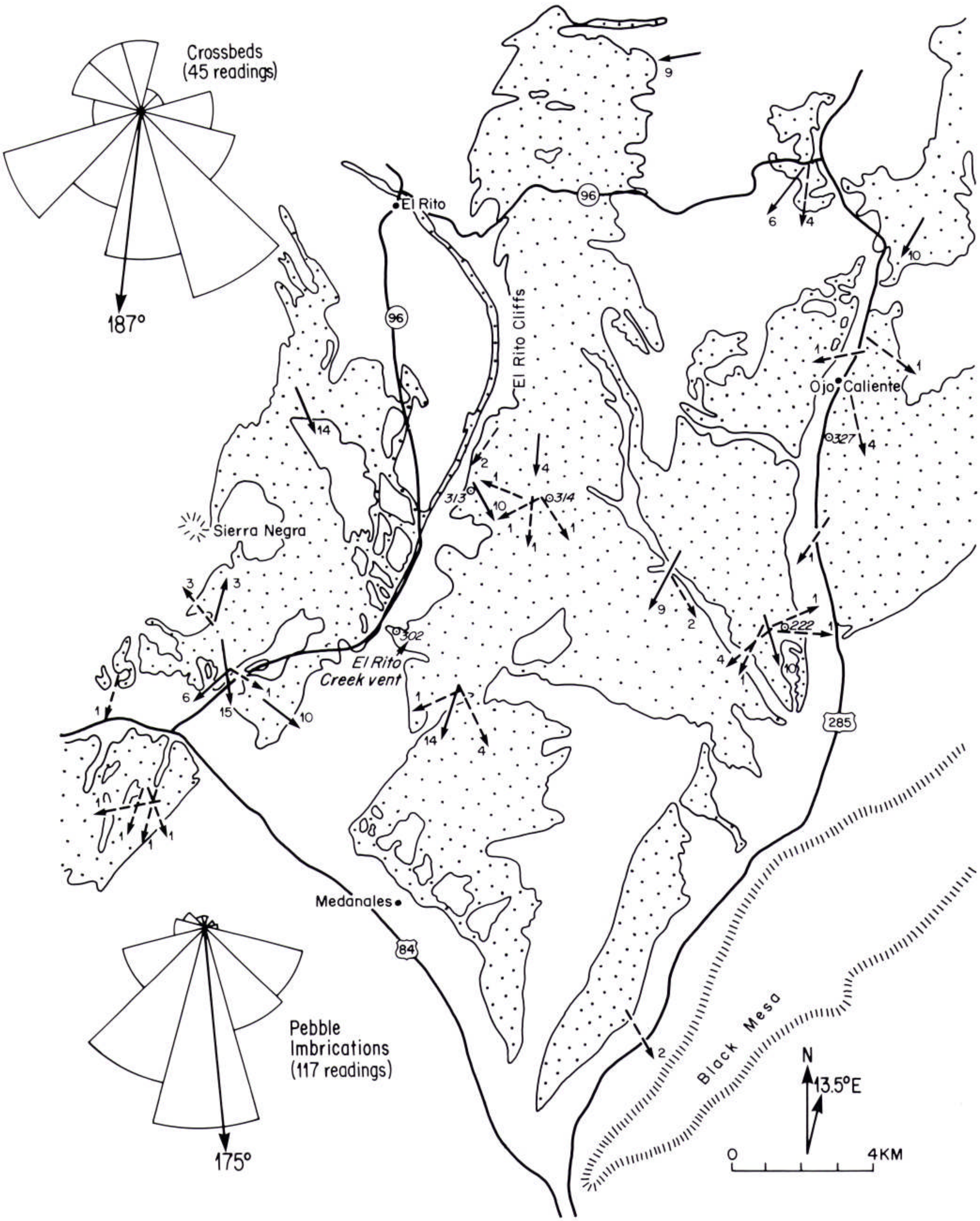

FIGURE 2. Paleocurrent azimuth vectors and sample localities within the Chama–El Rito Member (stippled). Solid arrows are pebble imbrications; dashed arrows are crossbeds; numbers of measurements at each location are indicated at ends of arrows. Northernmost measurements are shown south of actual locations. Also shown are summary diagrams of all pebble imbrications and crossbeds with mean azimuths (base map after Kelley, 1978).

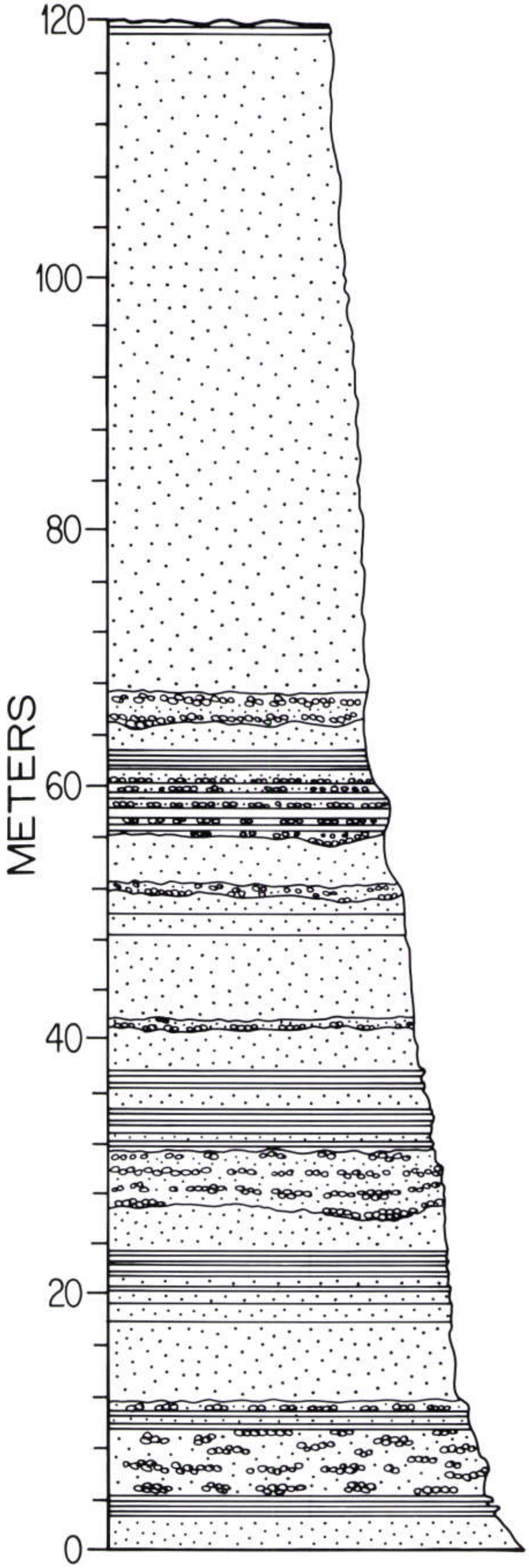

FIGURE 3. Typical section of Chama–El Rito Member: lines = mudstones, dots = sandstones, circles = conglomerates.

TABLE 1. Weight-percent compositions and Barth–Niggli cation norms (cation %) of clasts and basalt bomb from the Chama–El Rito. See Table 3 for sample descriptions and ages.

	222	302	313	314	327
SiO_2	60.15	43.45	58.89	66.46	64.30
TiO_2	0.69	1.92	0.79	0.70	0.69
Al_2O_3	15.22	13.31	18.66	14.37	14.66
Fe_2O_3	4.04	7.47	4.83	2.56	3.57
FeO	0.32	5.06	0.26	1.12	0.23
MnO	0.05	0.23	0.06	0.05	0.05
MgO	1.24	10.34	1.89	1.78	1.42
CaO	6.66	11.95	4.23	4.14	5.73
Na_2O	3.52	2.56	5.07	4.03	3.90
K_2O	2.98	0.72	4.46	3.25	3.38
P_2O_5	0.28	1.19	0.52	0.25	0.21
TOTAL	95.15	98.20	99.66	98.61	98.14
Mg-value †					
Q	15.74	–	2.28	20.06	17.11
or	18.67	4.34	26.17	19.56	20.47
ab	33.52	12.34	45.22	36.86	35.90
an	17.96	23.17	14.89	11.74	12.83
ne	–	6.67	–	–	–
wo	2.02	–	–	–	1.40
di	7.26	23.52	0.87	6.02	8.04
hy	–	–	4.75	2.00	–
ol	–	23.42	–	–	–
mt	–	1.27	–	1.28	–
ilm	0.61	2.73	0.49	0.99	0.45
hm	2.99	–	3.34	0.96	2.55
sp	0.62	–	0.90	–	0.81
ap	0.62	2.54	1.08	0.53	0.45

† Calculated based on $Fe^{3+}/Fe^{2+} = 0.1$

Analyses by x-ray fluorescence. FeO by spectrophotometric determination of ICl reaction (Bower, 1984).

TABLE 2. Trace-element compositions (PPM) of clasts and basalt bomb from the Chama–El Rito. See Table 3 for sample descriptions and ages.

	222	302	313	314	327	1σ error (rel. %)
V	43	182	61	34	33	13
Cr	19	188	18	25	22	4
Co	14	49	19	29	25	6
Ni	<75	257	<75	<75	<75	5
Zn	54	108	48	46	38	6
Rb	36	22	81	70	65	3
Sr	627	1166	901	592	584	5
Y	14	27	16	6	20	6
Zr	162	200	201	156	156	7
Ba	1149	1270	1360	977	987	10
La	50	63	41	36	27	10
Ce	76	170	135	63	83	13

TABLE 3. Descriptions, locations, and ages of clasts and basalt bomb from the Chama–El Rito. Constants used: $\lambda_\beta = 4.963 \times 10^{-10}\ yr^{-1}$, $\lambda_e = 0.581 \times 10^{-10}\ yr^{-1}$, $\lambda = 5.544 \times 10^{-10}\ yr^{-1}$, $^{40}K/K = 1.167 \times 10^{-4}$ atom/atom.

SAMPLE NUMBER	SAMPLE DESCRIPTION & LOCATION	K-ANALYSES INDIVIDUAL % K	K-ANALYSES MEAN	RADIOGENIC $^{40}Ar \times 10^{-12} m/g$ INDIVIDUAL ANALYSES	RADIOGENIC $^{40}Ar \times 10^{-12} m/g$ MEAN	% ATMOSPHERIC ^{40}AR INDIVIDUAL ANALYSES	% ATMOSPHERIC ^{40}AR MEAN	AGE IN MILLION YEARS
UAKA 83-185 (222)	Biotite in hornblende dacite. Phenocrysts of plagioclase, hornblende, quartz, and biotite. Microphenocrysts of magnetite and sphene. Much secondary carbonate. Clast from channel-lag deposit in Chama-El Rito Member, Tesuque Formation, Lyden Quad., Rio Arriba County, New Mexico Lat. 36°3.50'N, Long. 106°3.39'W	7.211 7.144 7.117 7.192 7.149 7.196	7.162	272.3 272.4 272.6 272.4 272.5	272.4	33.4 33.0 33.4 33.3 33.2	33.3	21.8±0.5
UAKA 83-186 (302)	Groundmass of basanite. Phenocrysts of olivine. Bomb from vent within Chama-El Rito Member, Tesuque Formation, Medanales Quad., Rio Arriba County, New Mexico Lat. 36°14.20'N, Long. 106°11.50'W	0.4663 0.4660 0.4571 0.4567 0.4596	0.4611	12.20 12.40 12.37 12.06 12.25	12.26	42.8 41.9 42.1 43.3 42.3	42.5	15.27±0.39
UAKA 83-184 (313)	Biotite in andesite. Phenocrysts of plagioclase, hornblende (replacing augite), and biotite. Magnetite microphenocrysts. Clast within alluvial deposit of Chama-El Rito Member, Tesuque Formation, El Rito Quad., Rio Arriba County, New Mexico Lat. 36°16.37'N, Long. 106°9.40'W	7.370 7.341 7.350 7.378 7.365	7.361	277.5 277.0 278.2 280.1 279.4 278.4 280.3 279.0 279.0 277.9 278.4 279.0	278.7	40.2 40.1 40.0 40.0 40.1 40.1 40.8 41.0 41.4 41.6 41.5 41.4 41.4	40.7	21.7±0.5
UAKA 83-187 (327)	Biotite in hornblende dacite. Phenocrysts of plagioclase, hornblende, quartz, and biotite. Microphenocrysts of magnetite and sphene. Clast from tongue of Los Pinos Formation gravels in the Chama-El Rito Member, Tesuque Formation, El Rito Quad., Rio Arriba County, New Mexico Lat. 36°16.34'N, Long. 106°8.48'W	6.860 6.852 6.816 6.888 6.866	6.856	269.5 268.4 268.3 268.3 266.8 268.3	268.3	37.3 37.4 38.8 39.2 39.8 38.7	38.5	22.6±0.5
UAKA 83-187 (327)	Biotite in hornblende dacite. Phenocrysts of plagioclase, hornblende, biotite, and quartz. Microphenocrysts of magnetite and sphene. Much secondary carbonate. Clast in channel-lag deposit of Los Pinos Formation that is interbedded with Chama-El Rito Member, Tesuque Formation, on the east Ojo Caliente Quad., Rio Arriba County, New Mexico Lat. 36°17.30'N, Long. 106°2.58'W	7.253 7.295 7.316 7.308 7.342 7.356 7.383 7.330	7.323	290.0 287.8 288.6	289.2	40.2 40.5 40.5	40.4	22.6±0.5

elastic units contain broad lenses of pebbly sand to conglomerate (1 cm to 7 m thick). These lenses represent alluvial channels because they usually have erosional bases, channel-lag deposits, crossbeds, overall upward-fining grain size, graded bedding within beds, and minor lateral extent (e.g., Bull, 1972). The sandstones and mudstones show few sedimentary structures; they represent the waning stages of flooding and overbank deposition in distributary systems. Some sands between channels may be eolian. At the top of the Chama—El Rito in the southeast and in the middle of the area north of Sierra Negra, some of the sand is clearly eolian. These sands are well sorted and compositionally homogeneous, and have large, wedge-shaped sets of crossbeds similar to the overlying Ojo Caliente sandstones.

In general, the amount of coarse-grained material in the Chama—EI Rito decreases to the south. In addition to eolian sands, a few limestone beds occur in the southeastern region. These characteristics corroborate a northern source for the alluvial complex, with more distal parts in the south.

At the El Rito Cliffs and west of Ojo Caliente (Fig. 2), May (1980) mapped tongues of the Cordito Member of the Los Pinos Formation (Manley, 1981) interfingering with the Chama—El Rito. The Los Pinos Formation contains mainly gravel, whereas the majority of the ChamaEl Rito is sandstone. In addition, the Los Pinos gravels in this region contain more Precambrian-derived clasts than does the Chama—El Rito (May, 1980). However, the Chama—El Rito also shows a slight enrichment in Precambrian-derived debris, such as quartzites and metasedimentary and metavolcanic clasts where it interfingers with the Los Pinos. In general, however, the petrology and provenance of the Cordito Member of the Los Pinos and the Chama—El Rito are indistinguishable (see below). The Cordito Member is interpreted to represent the more proximal part of the Chama—El Rito fan complex.

Around the vent near El Rito Creek (Fig. 2) the rocks are dominantly maroon, tuffaceous material mixed with abundant basaltic spatter and bombs interbedded with more typical Chama—El Rito sandstone (May, 1980). To the southwest of the vent, on the southeast side of Sierra Negra, is a fault-bounded outcrop of similar lithologic facies. Interbedded with the arkosic sandstones are red to maroon, matrix-supported breccias. The debris is dominantly basaltic and tends to be very poorly sorted. These characteristics suggest that these units are debris-flow deposits (e.g., Johnson, 1970) that may have been derived from the vent or another buried or eroded source. Basaltic cobbles south and southwest of the vent indicate that regional paleocurrent directions are towards the south.

PALEOCURRENTS

Dip azimuths of crossbeds and pebble imbrications were measured in the Chama—El Rito Member to resolve paleocurrent directions. One hundred sixty-two directions were measured throughout the section over the entire area. The regional dip was removed using a stereonet and the original paleocurrent azimuths were resolved. The mean paleocurrent azimuth of each area and the number of readings are plotted in Figure 2.

The vector mean for all pebble-imbrication azimuths (Fig. 2) is almost directly south (175°; standard deviation of 52). Two problems in measuring pebble imbrications were encountered. First, there were few cobble layers where measurement could be made. About 80-90% of the Chama—El Rito is sand-sized or finer. Second, most of the clasts are volcanic and tend to be ellipsoidal, thereby decreasing the tendency for imbrication relative to flat clasts.

The summary diagram for the crossbed azimuths (Fig. 2) shows more variation than that for the pebble imbrications. The mean azimuth is 187° (standard deviation of 84). Crossbed directions are more variable probably because they represent overbank deposits as well as main channel directions.

All the paleocurrent data indicate a southerly direction of flow. This is consistent with the general decrease in grain size to the south, the south and southwestward transportation of basaltic debris from the vent near El Rito Creek, and the presence of limestones in the southeast.

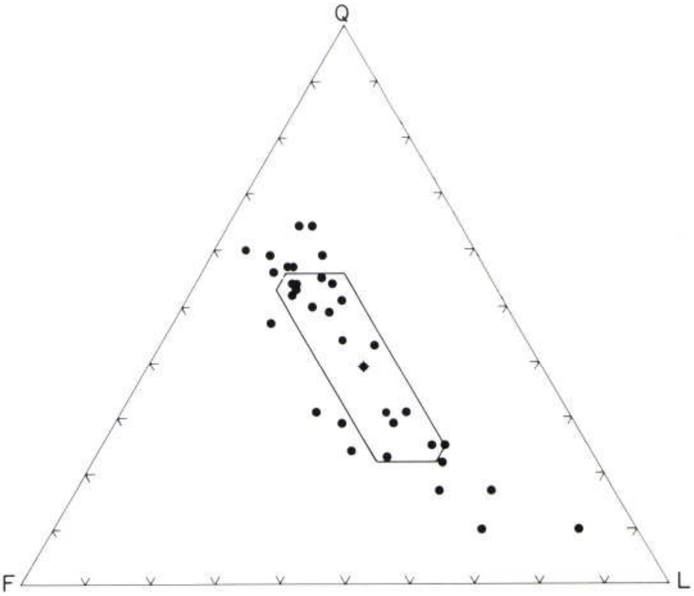

FIGURE 4. Quartz (Q)–feldspar (F)–lithics (L) triangle for sand petrology of the Chama–El Rito Member. Circle with cross and hexagon indicate mean and standard deviation, respectively, for all samples (see Ingersoll, 1978).

PETROLOGY AND PROVENANCE

The provenance of the Chama—El Rito Member was determined by combining the following information: paleocurrent data; sand-petrology data; pebble—cobble compositions; and geochemistry and age dates of volcanic clasts. The methods outlined by Dickinson (1970), Ingersoll (1978), and Ingersoll and others (1984) were used to study sand petrology. Since the sandstones tend to be poorly lithified or completely unlithified, the samples were impregnated; then they were stained for potassium feldspar and plagioclase. A statistical point count was made of each section using a petrographic microscope, and the results were recalculated as illustrated in Figures 4-7. Ekas (1984) discusses the methods and results in detail.

The sand composition can be divided into two groups, although a continuum of compositions probably exists. The tan, medium- to fine-grained, moderately well-sorted sands are arkosic, with quartz com-

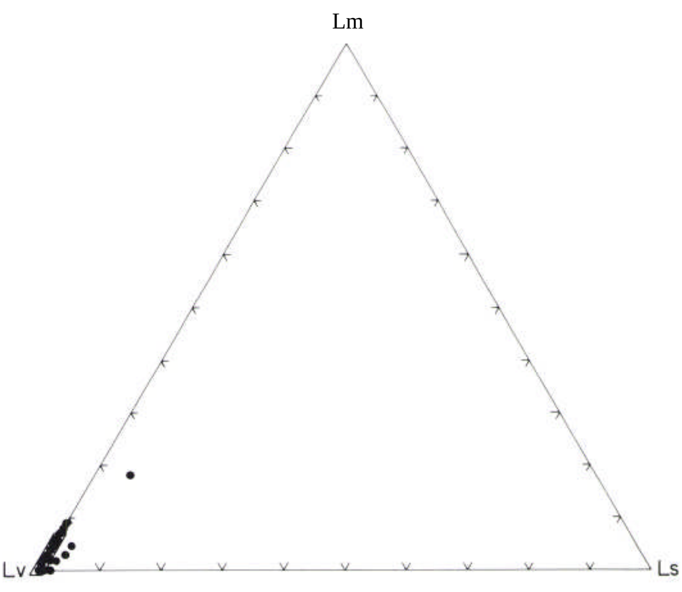

FIGURE 5. Metamorphic (Lm)–volcanic–hypabyssal (Lv)–sedimentary (Ls) lithic-fragments triangle for sand petrology of the Chama–El Rito Member. (See also caption of Figure 4.)

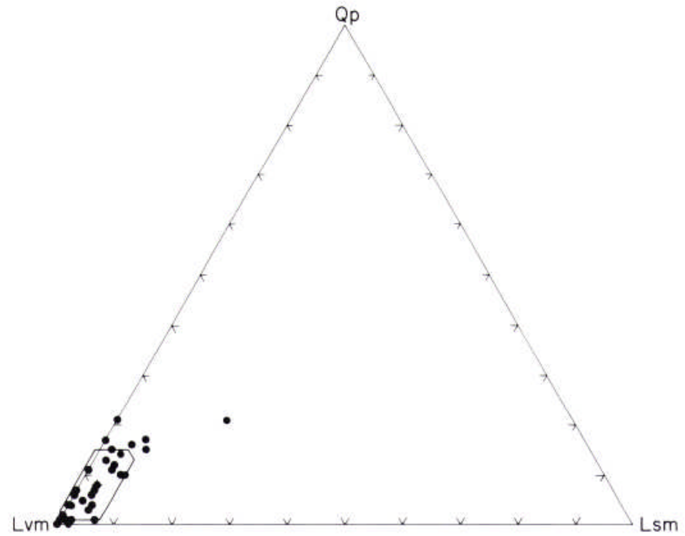

FIGURE 6. Polycrystalline-quartz (Qp)–volcanic–metavolcanic (Lvm)–sedimentary–metasedimentary (Lsm) lithic-fragments triangle for sand petrology of the Chama–El Rito Member. (See also caption to Figure 4.)

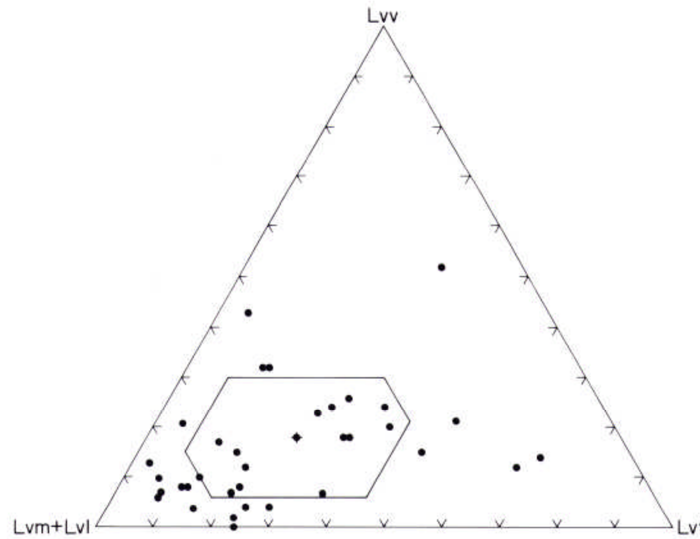

FIGURE 7. Vitric (Lvv)–microlitic-lathwork (Lvm + Lvl)–felsitic (Lvf) volcanic-lithics triangle for sand petrology of the Chama–El Rito Member. (See also caption of Figure 4.)

prising 47-66%, feldspars 23-37%, and lithic fragments 9-24% of the QFL populations. The gray, medium- to coarse-grained, poorly sorted sands are volcaniclastic, with 30-81% lithic clasts, 10-31% quartz, and 9-39% feldspars (Fig. 4). Volcaniclastic detritus is dominant in the lithic populations (Figs. 5, 6). The volcanic lithic fragments have been subdivided based on their textural characteristics (e.g., Dickinson, 1970) (Fig. 7). There are generally two groups of volcanic lithic types: one group is rich in microlitic and lathwork textures (generally intermediate compositions), corresponding to the gray volcaniclastic sands, whereas the other group is a combination of microlitic, lathwork, and felsitic textures, representing a wide range of compositions and corresponding to the arkosic sands. Petrology of samples in the Los Pinos Formation north of Ojo Caliente shows the same compositions.

Compositions of the conglomerates were determined by making point counts on a 100-point grid at 31 stations in the area and throughout the section. Volcanics are the most common lithic types (Figs. 8, 9). There is an enrichment of basaltic clasts south of the vent. In general though, dacites and andesites are dominant, and rhyolitic tuffs and other silicic volcanics of varying compositions form significant components. Quartzites (Q) form a significant minority of clasts, but are less than 23% of each sample.

The petrology and lithology of the Chama—El Rito suggest that a primary sediment sources was a volcanic terrane. Paleocurrent information supports northern sources. Possible sources of volcanic rocks to the north are the San Juan field (Colorado), the Latir volcanic field (Questa area), and intermediate rocks of the Taos Plateau. In order to determine the source terrane, we analyzed and dated four representative coarse clasts from various locations (Fig. 2). (Note that two of the clasts, 314 and 327, come from interbedded "Los Pinos" gravels, thus confirming a common source for the Los Pinos and the Chama—El Rito.) The ages are very similar, ranging from 21.7 to 22.6 ± 0.5 m.y. (Table 3). Three of the samples are hornblende dacites and the fourth is an andesite. The most probable source for these volcanic rocks is beneath the Taos Plateau. Lipman and Mehnert (1979, table 1) describe "early rift volcanics" of the Brushy Mountain area as "compositionally diverse intermediate to silicic" volcanic rocks that were erupted between 25

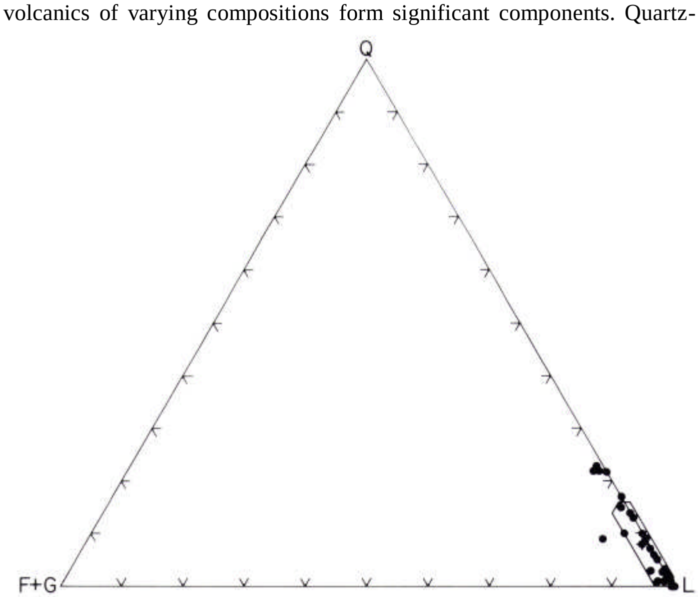

FIGURE 8. Quartz–quartzite (Q)–felspar–granitic (F + G)–other lithics (L) triangle for conglomerate counts of the Chama–El Rito Member. (See also caption of Figure 4.)

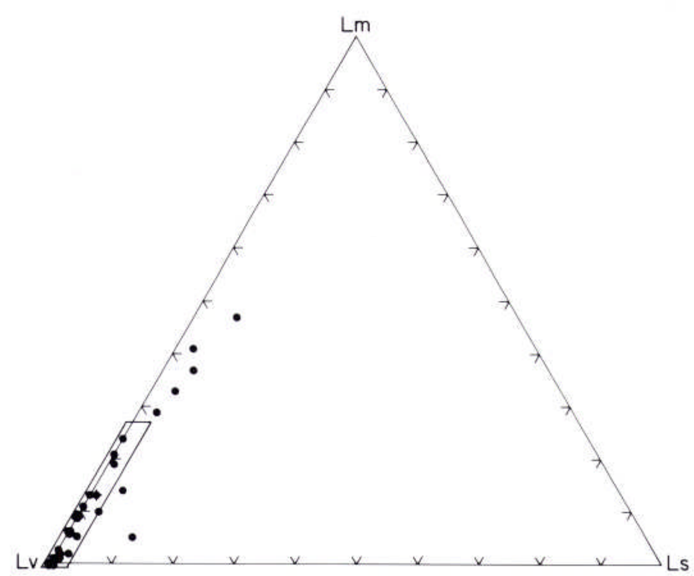

FIGURE 9. Metamorphic (Lm)–volcanic-hypabyssal (Lv)–sedimentary (Ls) lithics triangle for conglomerate counts of the Chama–El Rito Member. (See also caption of Figure 4.)

and 22 my. ago. These dates and compositions coincide well with those of the four analyzed clasts [67L-69A,74L-214 (Lipman and Mehnert, 1979, table 3) match well the geochemistry of the four clasts (Table 1)]. Due to the amount of alteration and secondary mineralization in the clasts from the Chama-El Rito, a closer comparison is not possible. Volcanic rocks of similar composition in the San Juan volcanic field are too old to have been the source of the clasts (e.g., Lipman and others, 1970). The Latir volcanic field near Questa may also be too old. Lipman (1983) reported volcanic ages of 35-26 my., although intrusive rocks are younger (P. W. Lipman, oral comm. 1984); thus, volcanic rocks young enough to have been sources for the clasts could have been present in the Latir field and subsequently been eroded. In this case, clasts in the Chama-El Rito may be the only known record of this field (which may have been continuous with the early-rift volcanics of the Taos Plateau area).

The main source of the arkosic component of the petrology is probably the Sangre de Cristo Mountains. The quartz and feldspar in the more arkosic samples are fine- to medium-grained and are better sorted than the more volcaniclastic samples, thus signifying transport from a more distal source, possibly by a combination of alluvial and eolian processes. Furthermore, the arkosic samples have higher proportions of K feldspar (lower P/F ratio). In contrast, plagioclase is the dominant feldspar in the volcaniclastic sands. This enrichment in K feldspar (predominantly microcline) and quartz along with their scarcity in the volcanic petrology suggest ultimate granitic, metavolcanic, and quartzitic sources (e.g., Precambrian rocks of the Sangre de Cristo and Tusas Mountains) for the arkosic sands.

CONCLUSIONS

The Chama-El Rito Member of the Tesuque Formation is a thick sequence of arkosic sandstones and mudstones with interbedded volcaniclastic pebbly sandstones and conglomerates. These sediments were deposited on the distal edges of an alluvial fan whose source was to the north. A vent in the middle of the section has an age of 15.3 m.y, in agreement with age estimates of 18-10 m.y. (Tedford, 1981) and 18-12 my. (May, this guidebook).

The sand and gravel petrology indicates two source terranes: a volcanic source, and one rich in quartz and feldspar. The volcanic clasts have dominantly intermediate compositions (dacite to andesite). The arkosic component of the sandstones was derived from granitic, metavolcanic, and quartzitic sources (possibly Sangre de Cristo and Tusas Mountains), although eolian transport from distant sources cannot be discounted. Four andesitic to dacitic clasts have K-Ar ages of approximately 22 m.y. The combined paleocurrent, petrologic, and chronologic data from the Chama-El Rito imply derivation from early rift volcanics of the Taos Plateau, and possibly the Questa area, and secondary source areas of Precambrian rocks in the Sangre de Cristo and Tusas Mountains.

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Taos Pueblo, ca 1920. Photo by Burt Harwood.