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Occurrence of the Lava Creek B tephra layer in the northwestern Española Basin, New Mexico

by *David P. Dethier, Nils Halverson, Lisa Marrack, Mark Meagher,* and *Eric Oelkers*, Department of Geology, Williams College, Williamstown, MA 01267
Charles D. Harrington, Earth and Environmental Sciences Division, Los Alamos National Laboratory, D462, Los Alamos, NM 87545
Andrei Sarna-Wojcicki and *Charles E. Meyer*, Branch of Western Regional Geology, U.S. Geological Survey, 345 Middlefield Road, Menlo Park, CA 94025

Abstract

The Lava Creek B tephra layer, which resulted from an eruption about 620,000 years ago in Yellowstone, Wyoming, is exposed in fluvial deposits of the ancestral Rio Chama in the northwestern Española Basin, New Mexico. The tephra consists of beds and lenses, generally less than 80 cm thick, of grayish-white vitric ash composed mainly of bubble walls and bubble-wall junction shards as much as 350 μm in diameter. Contaminants in the ash, bedding style, and lateral variations in thickness suggest that the tephra was reworked and deposited as silt-rich fluvial deposits by the ancestral Rio Chama. Ash-bearing Rio Chama deposits were buried and preserved by 10 to 30 m of sandy piedmont alluvium deposited by arroyos draining the northeastern Jemez Mountains. Stratigraphic and topographic relations suggest that the Lava Creek B tephra fell during a transition from cool, moist to warm, dry climate similar to the latest Pleistocene to Holocene change in climate.

Introduction

Tephra layers (volcanic ash beds) of known age are important tools for correlation and dating of Quaternary deposits because they are essentially isochronous layers and are often present in sediments that are difficult to date by other methods (Wilcox, 1965). Large volcanic eruptions have spread significant thicknesses of tephra over areas greater than 10^6 km^2 (386,100 mi^2) in Quaternary time (Izett and Wilcox, 1982). Evidence from historic eruptions suggests that in areas of thick tephra fall the response of natural systems may include forest death, alteration of types and rates of slope processes, and aggradation of fluvial systems overloaded with suspended sediment (for instance, Miller, 1989). In upland areas, newly deposited tephra is rapidly reworked, and both the tephra and the evidence of its impact on the landscape are removed. Tephra layers, however, are often well preserved in lacustrine or marine sediments (Izett, 1981), and most information about Quaternary tephra eruptions and their effects in the western United States comes from such sections. In this report we identify the Lava Creek B ash bed at a suite of locations in fluvial sediment of the ancestral Rio Chama. The Rio Chama locations preserve these ash beds in the northwestern Española Basin, about 1,000 km (621 mi) from the eruptive source of tephra in the Yellowstone caldera. The Lava Creek B ash was erupted shortly before a period of significant climate change and drainage-basin evolution in the intermountain western United States.

The Lava Creek B ash bed, formerly referred to as the Pearlette type O ash bed, was erupted from the Yellowstone caldera at about 620 ka (Naeser et al., 1973) and is widely distributed in the western United States (Izett and Wilcox, 1982; Sarna-Wojcicki et al., 1987). The plinian and ash-flow phases of this eruption were apparently coeval; the total volume of tephra erupted is estimated to be about 1,000 km^3 (Christiansen, 1979). The tephra consists mainly of rhyolitic glass shards—primarily bubble-wall and bubble-wall junction types—and small amounts of quartz, feldspar, ferro-magnesian aluminosilicate minerals, and oxides. Mineralogy and the concentration of major elements allow the Lava Creek B to be distinguished with confidence from most other widespread tephra layers in the United States.

Tephra of the Huckleberry Ridge ash bed was erupted from the Yellowstone area at about 2.0 Ma. The Huckleberry Ridge ash bed, however, is difficult to distinguish from the Lava Creek B ash bed on the basis of physical characteristics, mineralogy, or major-element chemistry (Sarna-Wojcicki et al., 1987). Concentrations of rare-earth elements such as Sc, La, Eu, and Nd, however, differ significantly in volcanic glass of the two tephra layers (Sarna-Wojcicki et al., 1987). The two tephra layers can also be distinguished by stratigraphic position where both are present at the same locality or where independent age control is available. The Bandelier tephra layers, erupted from the Jemez Mountains area of northern New Mexico, are chemically distinct from the Lava Creek B (Gardner et al., 1986), and tephra eruptions that occurred in the Valles caldera area between about 1.0 and 0.13 Ma are not known to have reached the northwestern Española Basin.

The Lava Creek B ash bed has not been reported previously in northern New Mexico. Izett and Wilcox (1982) compiled lists of Lava Creek B occurrences in the western United States, but none of their sites are in northern New Mexico. The Lava Creek B ash bed also has been reported from several locations in the Animas River basin of southern Colorado (Gillam et al., 1984) where it occurs on high surfaces as lenses tens of centimeters thick buried by piedmont alluvium. Lava Creek B tephra at the "Ash Mesa" site in Selden Canyon of the Rio Grande, in southern New Mexico north of Las Cruces, is as much as 3 m thick and occurs in the same geomorphic and stratigraphic setting as the Rio Chama deposits (Hawley and Kottlowski, 1969; Seager and others, 1975; Gile and others, 1981).

Geologic setting

The Rio Chama drains about 8,150 km^2 (3,147 mi^2) of northern New Mexico and adjacent southern Colorado; it flows into the northwestern Española Basin a few kilometers west of Abiquiu (Fig. 1). In that area the Rio Chama flows out of a gorge cut into Mes- ☞

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Coming soon

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ozoic rocks of the Colorado Plateau and east across the western boundary faults of the Rio Grande rift before turning south to join the Rio Grande between Chili and Española. The Española Basin is one of a series of right-stepping grabens that define the Rio Grande rift in northern New Mexico. Thick sections of terrestrial sediment composed mainly of Miocene alluvial-fan and eolian deposits (Galusha and Blick, 1971; Manley, 1979; May, 1980; Ekas and others, 1984) are exposed in the basin. Younger fill includes volcaniclastic deposits of the Pliocene Puye Formation, Pliocene basalt, and along the east flank of the Jemez Mountains, the Pleistocene Bandelier Tuff. Younger Pleistocene deposits lie above deformed Miocene and Pliocene(?) rocks and include axial channel, piedmont, and eolian facies as thick as 40 m. This sediment and the slightly consolidated Tertiary rocks are deeply dissected by arroyos tributary to the Rio Chama, particularly those that flow east from the Jemez Mountains. North-trending faults may offset the Pleistocene deposits locally, but field mapping has not disclosed any offsets where the Pleistocene deposits cross the largest structure in the area, the northeast-trending Embudo fault south of Chili (Harrington and Aldrich, 1984; Aldrich, 1986).

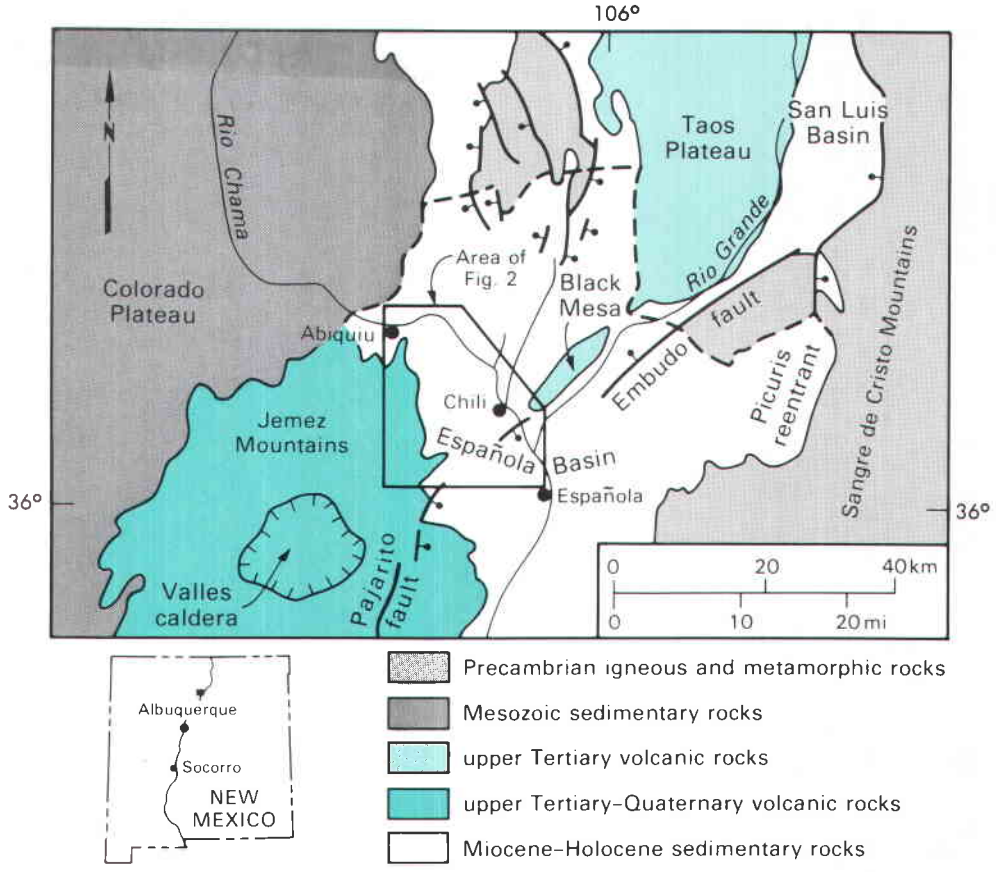

FIGURE 1—Location of the northern Española Basin and the Rio Chama in northern New Mexico (modified from Manley, 1979). Dashed line marks the approximate northern boundary of the Española Basin.

Field and laboratory studies

We mapped the Quaternary deposits that crop out within about 4 km (2.5 mi) of the modern Rio Chama–Rio Grande system from near Española to Abiquiu (Fig. 2). Our focus has been the distribution and sedimentology of gravel deposited at different elevations during incision by the axial drainage of the northwestern Española Basin, mainly the ancestral Rio Chama. However, we have also measured and sampled the finer-grained deposits that lie on each of these channel gravels and that represent Rio Chama slack-water sediment and sediment deposited as piedmont alluvium by tributary arroyos. Within this mainly sand and silt sequence we have collected gastropods, vertebrate fragments, and, at 22 locations, samples of vitric tephra exposed as thin beds and lenses. We examined the tephra using binocular and petrographic microscopes, separated the volcanic glass, and analyzed it by electron microprobe according to methods described in Sarna-Wojcicki et al. (1984; 1987). This report presents preliminary data about the stratigraphy and sedimentology of the Quaternary deposits, but it emphasizes the stratigraphic context and composition of the Lava Creek B tephra layer. The numerous localities of the tephra layer allow us to examine a brief interval in the geologic history of the Rio Chama drainage system without ambiguity in the age or correlation of the associated fluvial deposits.

Pleistocene deposits of the lower Rio Chama valley

Pleistocene deposits of the lower Rio Chama valley reflect the influence of both axial-channel and piedmont sources during a period of general incision along the Rio Chama–Rio Grande system. Incision may be a response to mid-Pleistocene shift to a different pattern of runoff, increased uplift rate, drainage integration, or a combination of these factors (Dethier et al., 1988; Kelson et al., 1986). We are not certain about how climate change affects the areal relationship between alluvial fans and the axial drainage. The width of the Rio Chama floodplain is determined, in part, by the interaction of several processes: lateral planation by the Rio Chama, arroyo aggradation, and progradation of the piedmont across the floodplain. Modern arroyos that drain the northeastern margin of the Jemez Mountains (for instance, Arroyo de la Plaza Larga, Fig. 2) infrequently transport sand and boulder gravel as traction or suspension load, or rarely as debris flows. The stratigraphic record suggests, however, that periods of extensive transport and arroyo aggradation have occurred episodically during Pleistocene time. Near Española (Fig. 1), the latest Pleistocene to mid-Holocene transition in climate has produced a narrowing of the Rio Grande floodplain as alluvial fans have encroached from both sides of the river (Love et al., 1987). Previous cool, wet to warm, dry transitions may have produced similar effects.

The stratigraphy and facies relations of Quaternary deposits are exposed along arroyos by incision of those channels and stabilization of erosion surfaces that truncate

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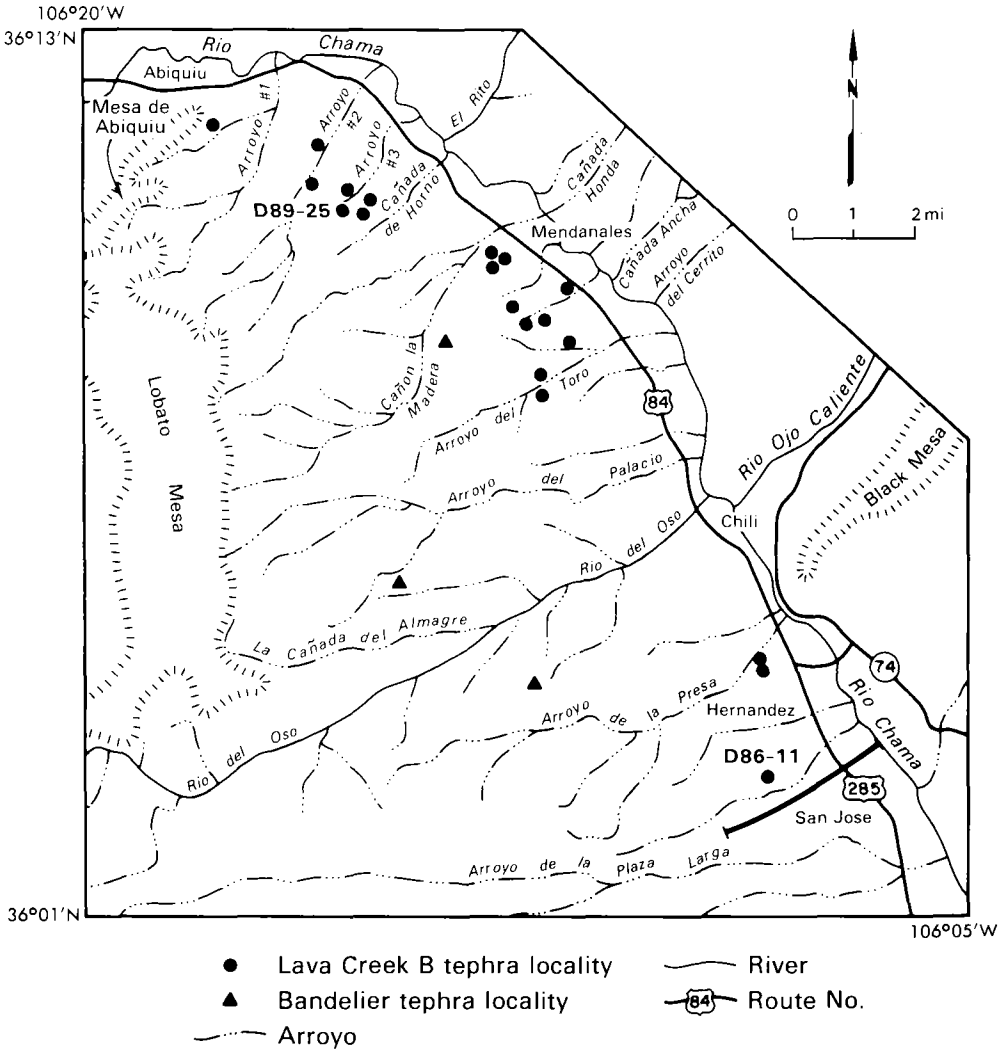

FIGURE 2—Sites where Lava Creek B tephra and Bandelier tephra are preserved near the Rio Chama between Abiquiu and San Jose, New Mexico. Northeast-trending line north of San Jose shows location of cross section (Fig. 3).

the deposits (Fig. 3). Dethier et al. (1988) proposed a chronology of periods of surface stabilization based on: 1) varnish/cation ratios from clasts on those surfaces; 2) total carbonate in soils; and 3) uranium-series ages on soil carbonate. In areas south of Arroyo de la Presa (Fig. 2) some composite surfaces truncate Quaternary deposits of several ages (Fig. 3) whereas near Abiquiu distinct steps are common for both erosion surfaces and the underlying sediment. The Quaternary section usually includes: 1) a basal Rio Chama cobble gravel that truncates bedrock; 2) an overlying layer of finer Rio Chama sediment; 3) a sequence of massive to medium-bedded sand cut by layers and channels of piedmont alluvium; and 4) a capping layer of poorly sorted, boulder-rich alluvium (Fig. 4). Layer 2 (Fig. 4) is 100 to 200 cm (39 to 79 inches) thick at most sites but is as thick as 500 cm (197 inches) in some of the younger deposits. Massive to locally crossbedded silty sand, fine sand, and thin partings of clay-rich silt are the predominant sediment types. Root casts, borings, and carbonate concretions are common in the coarser units, and gastropods, if present, tend to occur in greenish lenses of silty sand. Most of our fossil collections contain fewer than 6 genera (Arthur Metcalf, University of Texas at El Paso, written communication 1988) although we have found the gastropod genus *Succinea* at many sites. We are presently finishing amino-acid analyses of gastropods from 20 locations, which will allow us to estimate the approximate age of each of the Rio Chama sequences (D. P. Dethier, unpublished data, 1989). We know that the age of fluvial deposits about 110 m above the present river level is 620 ka because of the presence of the Lava Creek B ash bed in these sediments (20 sites) and in the piedmont alluvium (2 sites).

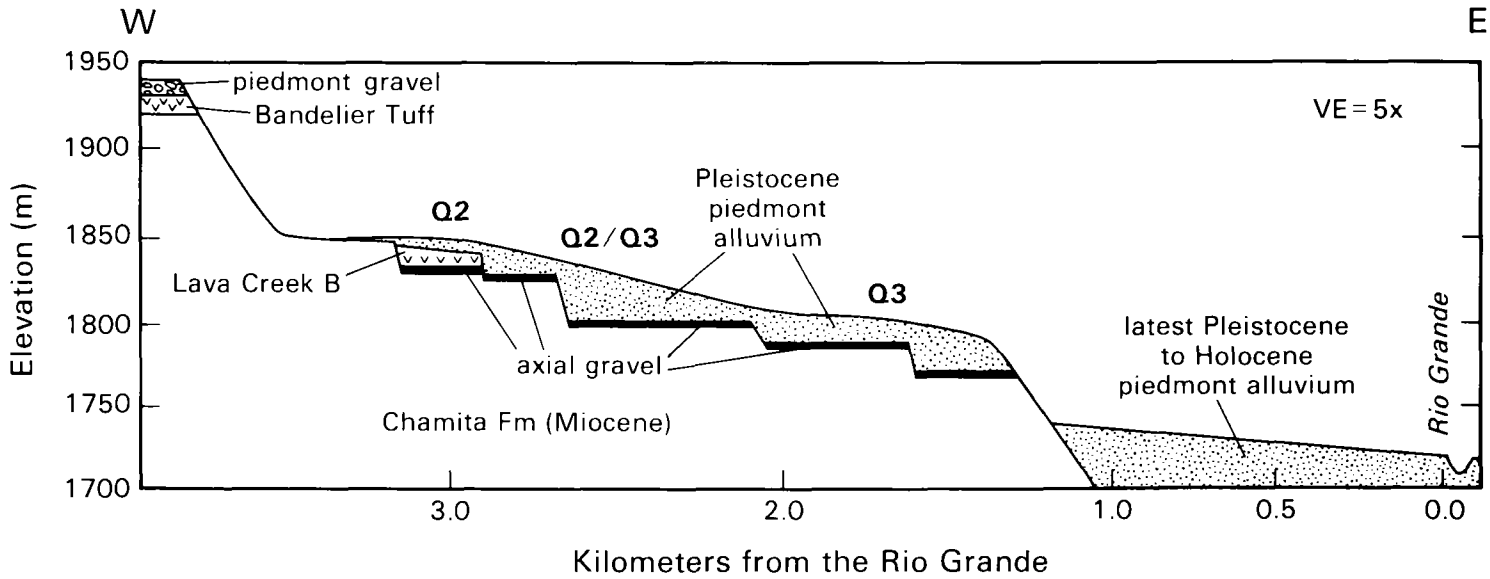

FIGURE 3—Generalized cross section showing Quaternary piedmont alluvium, erosion surfaces (Q2, Q2/Q3, Q3 of Dethier et al., 1988), and underlying bedrock (Chamita Fm) near San Jose, New Mexico. Line of section shown in Fig. 2.

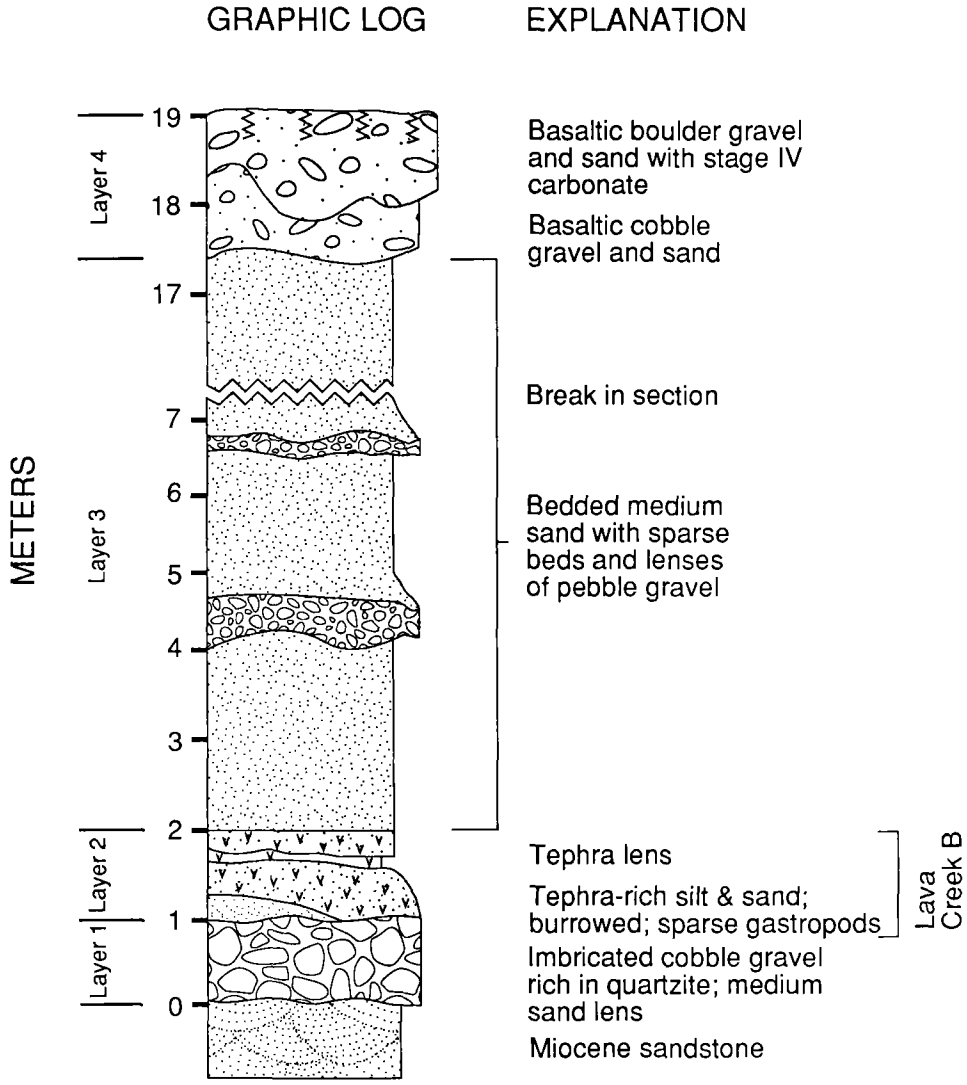

FIGURE 4—Diagram showing measured section D89–25 (north of Cañada de Horno) containing the Lava Creek B tephra layer.

Description of the Lava Creek B tephra

The tephra in the Rio Chama sediment (Fig. 4) consists of grayish-white, well-sorted vitric ash that is interbedded and mixed with fine-grained alluvium. Individual beds and lenses of tephra range in thickness from 20 to 120 cm (approximately 8 to 47 inches), and at some locations concentrations of tephra are found as much as 6 m (approximately 20 ft) above the basal bed. Most of the tephra is massive. We measured upward-fining sequences and crossbedding in the tephra layer at several sites; the top contact of the tephra is diffuse at almost all exposures. Microscopic study shows that the purest tephra contains 2–5% contamination with detrital quartz and feldspar grains and that some tephra beds contain more than 30% arkosic fine sand. We believe that the contamination and bedding style demonstrate that most of the tephra was "reworked" by fluvial and eolian activity after initial deposition. Mixing was not extensive, however, suggesting that local slopes and the floodplain were mantled with tephra and that suspended load in the Rio Chama consisted, for a time, mainly of tephra.

The morphology of glass shards in ash from site D86–11 is typical of material produced in many large eruptions (Fig. 5), but analyses of the glass by electron microprobe indicate a strong correlation with tephra that was erupted from the area of Yellowstone National Park in northwestern Wyoming. Glass shards are generally finer than 350 μm in diameter and consist mainly of unaltered, platy bubble walls and bubble-wall junctions. Elongated, tubular vesicular shards are also present along with minor amounts of glass-mantled microphenocrysts of feldspar and ferromagnesian minerals. The shard morphology of the Rio Chama ash bed is similar to that of the Bandelier, Bishop, and Yellowstone ash beds, and other widespread Quaternary tephras. Major-element analyses (Table 1) show that the tephra is chemically similar to the Lava Creek B and Huckleberry Ridge ash beds, but Fe_2O_3 and CaO values are essentially identical to those of the Lava Creek B and different from those of the Huckleberry Ridge ash bed. Analyses demonstrate that the tephra found along the Rio Chama is different from both the Bishop and Bandelier layers and from the Valles Rhyolite (Spell and Kyle, 1989). Furthermore, local stratigraphic relations and amino-acid ratios in shell interbedded with the tephra (Dethier et al., 1988) confirm the match with the Lava Creek B, rather than with the Huckleberry Ridge ash bed. The circa 2.0-Ma Huckleberry Ridge ash bed has not been found in the Española Basin, but the 1.4-Ma Otowi Member of the Bandelier Tuff crops out at several locations along the east edge of Lobato Mesa on higher surfaces than the ash bed in the ancestral Rio Chama deposits. Thus, the ash in the Rio Chama deposits must be younger than 1.4 Ma, providing supportive evidence that this ash bed is the Lava Creek B and not the Huckleberry Ridge ash bed.

Discussion

Identification of the Lava Creek B tephra along a 25-km (15.5-mi) section of the Rio Chama provides a marker horizon for Quaternary deposits and surfaces in the western Española Basin and suggests that the Lava Creek B tephra layer is likely to be present in Quaternary sequences elsewhere in the northern Rio Grande rift. The ash bed lies about 110 m (361 ft) above the modern Rio Chama, giving an average incision rate of about 16 cm/1,000 years since 620 ka, similar to rates calculated by Dethier et al. (1988) using ages estimated for erosion surfaces. We have not analyzed the paleogradient of the tephra-bearing sequence or of the younger sequences exposed between Abiquiu and Española. Thus we cannot be certain if the mid-Pleistocene sequence that includes the Lava Creek B layer is deformed where it crosses the Embudo fault zone. The data do permit a maximum of 30 m (98 ft) of down-to-the-south motion on this fault in the past 620 ka.

Local preservation of the Lava Creek B ash bed in piedmont alluvium demonstrates that tephra containing shards as large as 350 μm mantled slopes in the Rio Chama area after the eruption from Yellowstone, but we have not found tephra preserved in slope deposits. Lenses in piedmont alluvium are 20 to 60 cm thick and expose truncation surfaces typical of fluvial or eolian reworking. We thus have no unequivocal evidence for thickness of the original fall deposit. Tephra layers associated with Rio Chama deposits show that many floodplain areas locally accumulated more than a meter of glass-rich alluvium as overbank deposits. Large amounts of volcanic ash also must have been transported to the south along the Rio Chama–Rio Grande system, but ash has been reported from only a few scattered locations (Izett and Wilcox, 1982). From at least the Albuquerque Basin north, the tephra should be preserved in other

fluvial deposits at elevations about 100 m (328 ft) above the present axial channels. From Selden Canyon, about 30 km (19 mi) north of Las Cruces, New Mexico, to the Presidio Bolson area of Trans-Pecos, Texas, the Lava Creek B ash bed is from 100 to 60 m (328 to 197 ft) above the Rio Grande floodplain (Seager et al., 1975; Gile et al., 1981).

The Lava Creek B tephra is preserved in the Rio Chama area because it was deposited with fine-grained sediment of the ancestral Rio Chama, and these floodplain deposits were covered by coarse piedmont alluvium soon after deposition of the ash-bearing sediments. The piedmont alluvium ranges from 10 to almost 30 m (33 to almost 98 ft) thick. If the latest Pleistocene to Holocene piedmont aggradation in the Española area is a good model for mid-Pleistocene events, Lava Creek B deposition occurred at the beginning of a shift to warmer, drier climate marked by arroyo aggradation, alluvial-fan extension, and narrowing of the axial channel. Incision that began during the next wetter period occurred sufficiently rapidly to isolate fairly large areas that contained the volcanic ash. Dethier et al. (1988) have suggested that incision rates in the Española Basin increased after about 500 or 600 ka in response to climatic change or increased rates of uplift. If the climatic hypothesis is correct, preservation of the Lava Creek B tephra along the Rio Chama suggests that the magnitude or duration of glacial periods increased shortly after the warm, dry period that followed deposition of the Lava Creek B.

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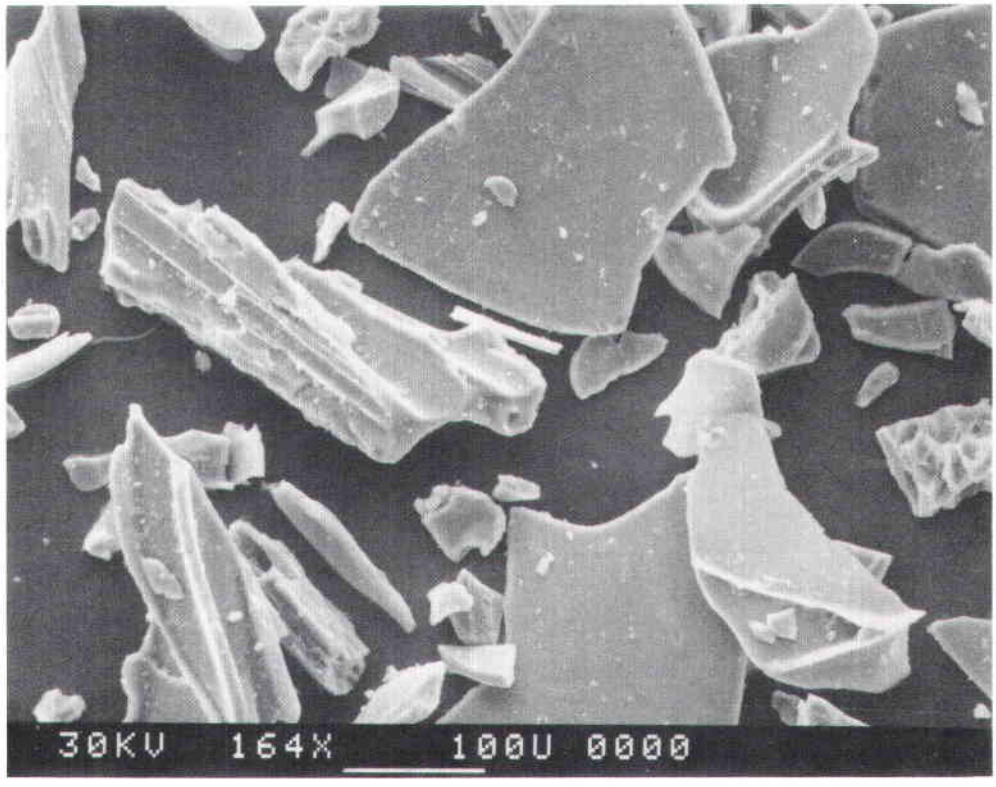

FIGURE 5—Scanning electron microscope image of Lava Creek B tephra from site D86–11, south of Hernandez (Fig. 2). Scale bar is 100 μm long.

TABLE 1—Comparison of major-element chemistry of glass from the Rio Chama tephra to the chemistry of some other widespread tephra layers by means of electron microprobe.[1]

Tephra	SiO_2[2]	Al_2O_3	Fe_2O_3	MgO	MnO	CaO	TiO_2	Na_2O	K_2O	Total
Rio Chama[3]	76.63	12.30	1.56	0.02	0.03	0.53	0.12	3.54	4.97	93.11
ash bed	0.09	0.04	0.04	0.01	>0.01	0.01	0.01	0.05	0.02	0.25
Lava Creek B[4]	76.60	12.41	1.57	0.02	0.03	0.54	0.11	3.57	5.16	94.28
ash bed	0.32	0.19	0.05	0.01	0.02	0.02	0.01	0.10	0.15	0.33
Huckleberry	76.45	12.33	1.76	0.02	0.04	0.61	0.13	3.49	3.16	94.55
Ridge ash bed[4]	0.24	0.12	0.07	0.01	0.01	0.05	0.01	0.14	0.15	0.51
Bandelier Tuff										
Upper	72.70	12.80	1.47	0.05	0.08	0.33	0.08	3.08	5.36	95.95
Lower	73.60	11.90	1.40	0.10	0.07	0.24	0.04	4.36	4.61	96.32
Bishop ash	77.55	12.64	0.74	0.04	0.03	0.45	0.06	3.70	4.78	94.02
bed	0.20	0.22	0.03	0.01	0.01	0.03	0.01	0.18	0.24	0.75
A.E.[5]	1.3%	2.2%	6.4%	6.6%	15%	6.2%	17.4%	3.9%	4.2%	

1. From Sarna-Wojcicki et al. (1987) except for Bandelier Tuff, which is from Gardner et al. (1986). Values given are in weight-percent oxide, recalculated to 100% on a fluid-free basis. Original oxide totals before recalculation are given to indicate the approximate degree of hydration of glass. Approximately 15 individual shards were analyzed for each sample, except for Bandelier Tuff. C. E. Meyer, analyst.
2. Values in percent $\pm 1\sigma$, except for Bandelier analyses, which do not include 1σ values.
3. Mean of samples from 4 sites.
4. Average of 7 samples.
5. Average analytical error, calculated from average of concentrations of the shard population (except Bandelier Tuff), expressed as a percentage obtained by dividing the average standard deviation for each element by the average concentration of that element, multiplied by 100.

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Summary of New Mexico state taxes on natural resource production as of July 1, 1990

compiled by *James M. Barker*, New Mexico Bureau of Mines and Mineral Resources

Commodity	Tax	Rate and base
Potash	Resource Processor; Service* Severance	0.50% of taxable value 0.125% of taxable value 2.5% of taxable value
Molybdenum	Resource Processor; Service* Severance	0.333% of taxable value 0.75% of taxable value 0.125% of taxable value
Other taxable resources (except potash and molybdenum)	Resource; Processor; Service*	0.75% of taxable value
Copper	Severance Service; Processor* Ad valorem	0.50% of taxable value 0.75% of taxable value Depend on local county and school district (see HB 428)
Gold, silver	Severance	0.20% of taxable value
Lead, zinc, molybdenum, manganese, thorium, rare-earth, and other metals	Severance	0.125% of taxable value
Clay, sand, gravel, gypsum, pumice, and other nonmetals	Severance	0.125% of taxable value
Coal: surface underground	Severance Severance	$1.17 per short ton until July 1, 1993 $1.13 per short ton until July 1, 1993 $0.57 exempt (surface) (see HB 283) $0.55 exempt (underground) (see HB 283)
Uranium	Resource Severance	0.75% of taxable value 3.5% of 50% of sales price
Oil, gas, and carbon dioxide	Severance Ad valorem	3.75% of taxable value Many rates (counties certify annually on September 1 to Taxation and Revenue Department)
Oil, gas, geothermal energy, carbon dioxide, coal, and uranium	Conservation School	0.18% of taxable value 3.15% of taxable value
Gas and hydrocarbons incidental to processing	Natural gas processor	0.45% of taxable value

*Subject to only one of these taxes at a time. Data source: Taxation and Revenue Department, P.O. Box 2308, Santa Fe, New Mexico 87504–2308 (505/827–2700). For information about severance and resource taxes contact Cindy Lovato (505/827–0812); for oil and gas taxes contact Michael Holden (505/827–0805); for copper ad valorem tax contact Richard Martinez (505/827–0895).