This form is subject to change, please contact RPF for latest version.

Los Alamos Environmental Restoration Records Processing Facility

ER Record I.D.# 0021587

DATE RECEIVED: 07/22/93 PROCESSOR: MSG

LOS ALAMOS

LOS ALAMOS NATIONAL LABORATORY

ENVIRONMENTAL RESTORATION
Records Processing Facility
ER Record Index Form

PAGE COUNT: 29

Quick Index: Complete all fields; indicate if not applicable or appropriate; please write legibly.

DOCUMENT TO: — ORGANIZATION: —

ORIGINATOR NAME: B.N. Turbeville ORGANIZATION: University of Texas

SYMBOL: DOCUMENT DATE: 1/1/89

SUBJECT/TITLE: Lava-Dome Growth and Explosive Volcanism in the Jemez Mountains, New Mexico: Evidence from the Plio-Pleistocene Puye Alluvial Fan
Article in Journal of Volcanology and Geothermal Research

RECORD TYPE (Circle relevant type for primary record; type of attachments should be selected on *Keywords List*):

Analytical Data	Excerpt	Map	Procedure	Summary
Article	FAX	Memo	Purchase Request	Table
Chain-of-Custody	Figure	Microform	Receipt Acknowledgment	Telephone Record
Chart	Form	Notebook	Report	TOC
Computer Output	Interview	Outline	Review	Transcription
Contract	Letter	Personal Notes	Sow	Video
Controlled Distribution	List	Photo	Study	Work Plan
Drawing	Logbook	Plan		Other

RECORD CATEGORY: P
(P for Programmatic or R for Reference)

RECORD PACKAGE: —

FILE FOLDER:

RECORD FILMED (Y/N): Y

RECORD LOCATION: —
(Indicate location of record if not filmed.)

Complete all fields; indicate if not applicable or appropriate; please write legibly. Use *ER Record Index Form Attachment Sheet* if needed.

ATTACHMENTS FILMED (Y/N):
(Were attachments to this record filmed?)

LOCATION: —
(Indicate location of attachments if not filmed.)

2971

Journal of Volcanology and Geothermal Research, 36 (1989) 267–291
Elsevier Science Publishers B.V., Amsterdam — Printed in The Netherlands

LAVA-DOME GROWTH AND EXPLOSIVE VOLCANISM IN THE JEMEZ MOUNTAINS, NEW MEXICO: EVIDENCE FROM THE PLIO-PLEISTOCENE PUYE ALLUVIAL FAN

B.N. TURBEVILLE*, DAMON B. WARESBACK and STEPHEN SELF

Department of Geology, University of Texas at Arlington, Arlington, TX 76019, U.S.A.

(Received March 25, 1988; revised and accepted June 1, 1988)

Abstract

Turbeville, B.N., Waresback, D.B. and Self, S., 1989. Lava dome growth and explosive volcanism in the Jemez Mountains, New Mexico: Evidence from the Plio-Pleistocene Puye alluvial fan. *J. Volcanol. Geotherm. Res.*, 36: 267–291.

The Plio-Pleistocene Puye Formation, north-central New Mexico, is a 200 km² volcanogenic alluvial fan shed eastward from the Tschicoma volcanic center, part of the Jemez Mountains volcanic field. The fan contains > 15 km³ of volcaniclastic material derived from closely spaced lava domes in the northeastern portion of the Tschicoma center. Interbedded in the fan sediments are at least 25 primary pyroclastic units from explosive eruptions of dacitic and rhyolitic lava domes. Tephra occur mainly as pumice falls but include several pumiceous ignimbrites and two thick proximal block-and-ash pyroclastic flows. The upper part of the fan also contains rhyolitic plinian deposits erupted from sources in the central portion of the Jemez field and basaltic ash derived from the central Rio Grande rift.

Fanglomeratic (pyroclastic and epiclastic) facies exhibit considerable lateral variation. Primary tephra deposits, however, provide a stratigraphic framework for reconstruction of the growth of individual lava domes. While only volcanic domes and lava flows are exposed in the Tschicoma center, Puye tephra layers show that vulcanian, subplinian and plinian activity, and block-and-ash pyroclastic flows accompanied many dome-forming events. Degradation of these lava domes produced coarse-grained debris flows dominated by lava and dome carapace clasts. From these epiclasts it is possible to identify lithologies of lavas that are either currently buried or have been obliterated by erosion or by collapse of the Valles calderas.

The preservation of Puye deposits reflects very high rates of aggradation and gradual down-faulting in the Española basin of the central Rio Grande rift. This record of pyroclastic and epiclastic deposition allows detailed interpretation of the evolution of a volcanic center from its pyroclastic and erosion products, and is the first example of a volcanogenic alluvial fan in an intracontinental rift setting to be described in detail. This study emphasizes that interpretation of any ancient volcanic terrain based solely upon data derived from mapping, radiometric dating, and chemical analysis of lavas or existing denuded edifices is likely to greatly underestimate both the role of explosive volcanism in the build-up of volcanic centers and subsequent estimates of the volumes of material produced.

Introduction

Explosive volcanism occurred throughout the 13.5-million year development of the Jemez Mountains volcanic field (JMVF; Fig. 1) of north-central New Mexico. Most work in this area has concentrated primarily on either the voluminous Quaternary rhyolitic ignimbrites (Smith and Bailey, 1966; Izett et al., 1981) and related calderas (Smith and Bailey, 1968), or on the petrology and age relationships of long-

*Current address: Department of Geological Sciences, University of Texas at Austin, Austin, TX 78713-7909, U.S.A.

lived episodes of lava effusion and dome growth (Gardner et al., 1986; Singer and Kudo, 1986; Loeffler et al., 1988), particularly in the Paliza Canyon and Tschicoma Formation sequences (Fig. 2). A neglected area has been study of the extensive volcaniclastic sequences that relate eruptive activity and erosion of individual Jemez volcanic centers to Rio Grande rift-controlled sedimentation. Detailed documentation of these sequences is crucial to understanding the volcanological evolution of this field, as they contain abundant pyroclastic deposits interstratified with epiclastic debris. These relationships are rarely evident in the central Jemez field but are particularly well displayed in the Puye Formation, a large volcaniclastic fan shed from the Tschicoma volcanic center in the northeastern part of the field (Fig. 1). The Puye Formation is ideal for study because of its excellent exposure and close spatial, temporal, and lithologic association with the Tschicoma center. Pyroclastic and epiclastic deposits in the Puye fan, therefore, provide valuable insight into the history of Plio-Pleistocene explosive eruptions and lava dome development in the northeastern JMVF.

Tschicoma volcanic center

The Jemez Mountains are situated on the western margin of the Rio Grande rift at its intersection with the Jemez Lineament (Fig. 1). Erupted products have been divided into three stratigraphic groups representing three successive periods of magmatic evolution and eruption (Bailey et al., 1969; Smith et al., 1970). The proposed divisions are the Keres (including the Paliza Canyon Formation), Polvadera (including the Tschicoma Formation), and Tewa (primarily Bandelier Tuff and post-caldera lava domes) Groups, in age sequence (Fig. 2). These volcanic and volcaniclastic deposits span the period 13.5 to 0.1 Ma (Gardner et al., 1986).

The Tschicoma volcanic center (7.40–2.9 Ma; Gardner et al., 1986; Singer and Kudo, 1986; Baldridge et al., 1987) contains >500 km^3 of dacitic lava flows and domes in the northern and eastern Jemez Mountains with subordinate amounts of 2-pyroxene andesite, rhyodacite, and low-silica rhyolite (Baldridge and Vaniman, 1986; David Broxton, unpubl. data). Andesitic lavas generally underlie the dacitic and rhyodacitic lavas and domes. Much of the southwestern part of the Tschicoma center has been obliterated, initially by formation of the Toledo Embayment (Fig. 1), and later by collapse of the Valles I (or Toledo; Smith, 1979) and II calderas at 1.4 and 1.1 Ma, respectively (Baldridge and Vaniman, 1986; Self et al., 1986). Surviving volcanic features of this center suggest a strong tectonic control on magmatism with the early development of basaltic and andesitic stratovolcanoes in the northwestern JMVF and later growth of dacitic and rhyodacitic dome complexes farther eastward (Singer and Kudo, 1986; Baldridge et al., 1987).

Magmatic activity in the northeastern JMVF began to wane between 4 and 2 Ma as several small, isolated lava domes (i.e. pumiceous flank domes) were emplaced onto Tschicoma Formation deposits (Fig. 1). These domes form the El Rechuelos Rhyolite and Cerro Rubio Quartz Latite (Fig. 2; Bailey et al., 1969), the latter sequence more recently recognized as part of the Tschicoma Formation (Gardner et al., 1986). The youngest El Rechuelos Rhyolite lavas are distinguished mineralogically and chemically from the "older (Tschicoma) rhyolites" of Loeffler et al. (1988), but are mineralogically similar to several tephra deposits in the upper Puye Formation. Epiclastic material from this center, however, is poorly represented in Puye deposits due to topographic barriers existing at the time of eruption of these domes.

The youngest euptives hitherto reported from the Tschicoma volcanic center are 2.9 Ma (Baldridge et al., 1987), although this study emphasizes that portions of the center remained active up to 2 Ma (or less; Turbeville, 1986), and that evidence for younger dacite and rhyodacite lava domes (since destroyed by ero-

Fig
Pa
Rh
Gr
Ts
sec

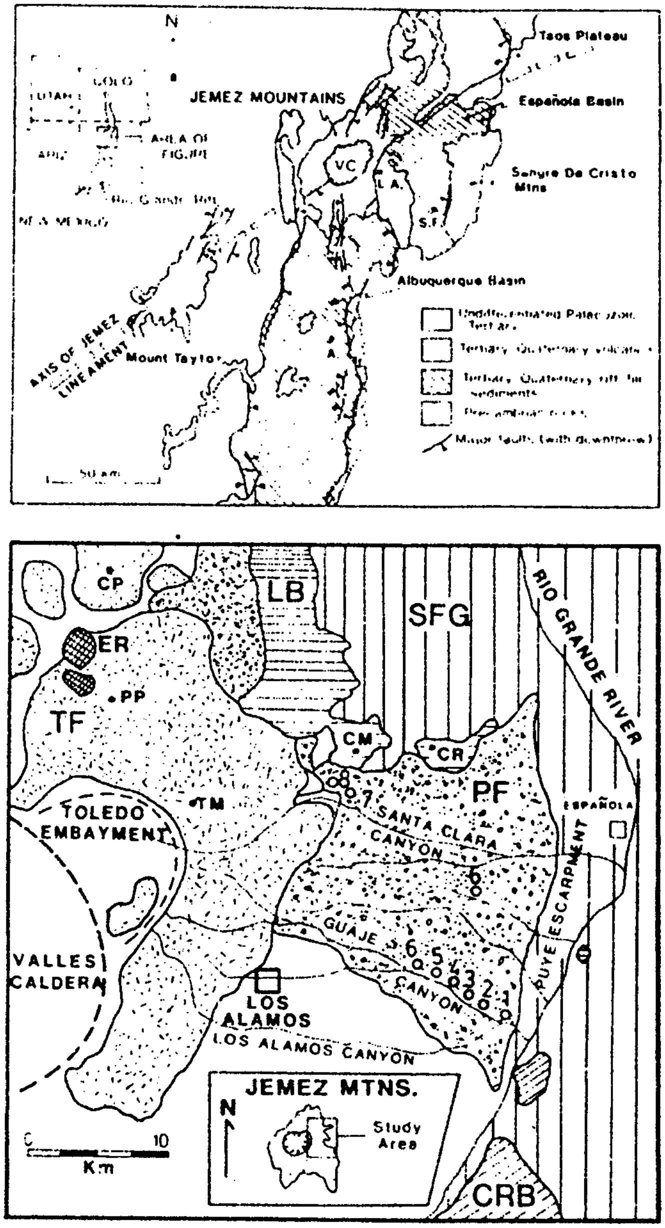

Fig. 1. Location map of the Jemez Mountains and Valles Calderas (*VC*), New Mexico (above), and the study area, eastern Pajarito Plateau (partly after Smith et al., 1970). Shown are surface extent of the Tschicoma Formation (*TF*), El Rechuelos Rhyolite domes (*ER*), the Puye Formation (*PF*), Loboto Basalt (*LB*), Cerros del Rio basalt field (*CRB*), and Santa Fe Group deposits (*SFG*). Also included are prominent local topographic features, Cerro Pelon (*CP*), Polvadera Peak (*PP*), Tschicoma (also Chicoma) Mtn. (*TM*), Cerros Mtn. (*CM*) and Clara Peak (*CR*); location numbers refer to composite sections in Fig. 5.

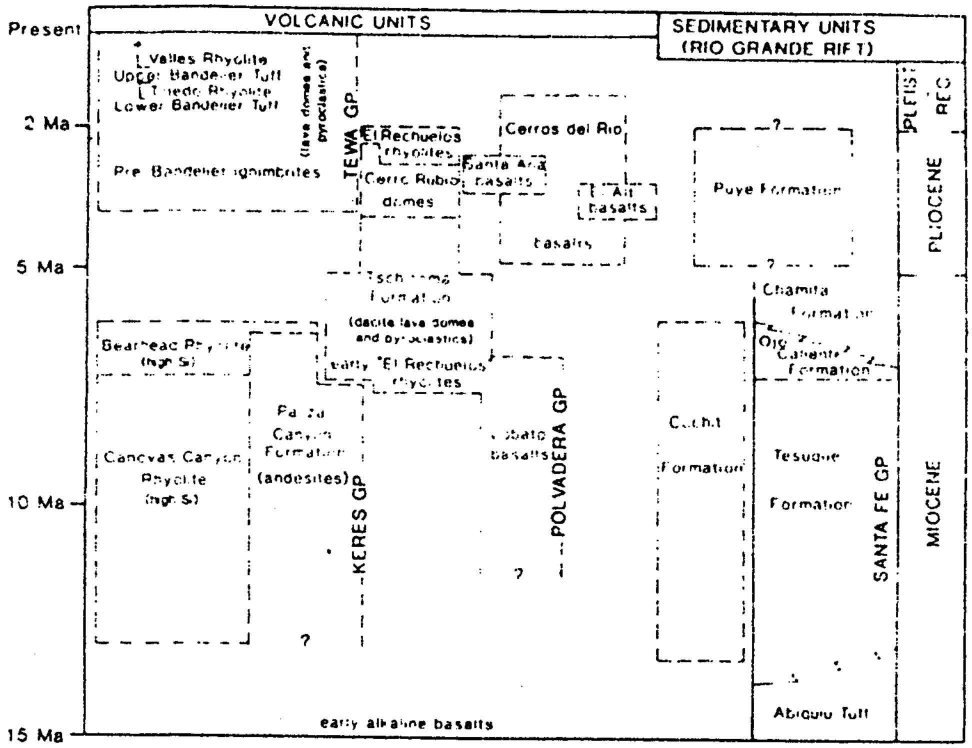

Fig. 2. Stratigraphy of major volcanic units of the Jemez Mountains volcanic field and associated sedimentary sequences of the Española basin, central Rio Grande rift (after Self et al., 1986).

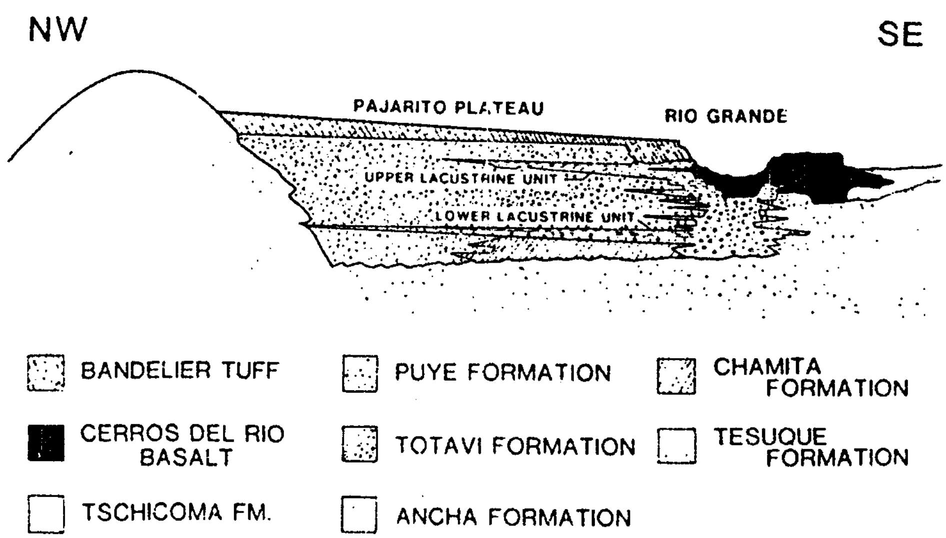

Fig. 3. Schematic cross section of the Pajarito Plateau, eastern Jemez Mountains, showing relationships between the Puye alluvial fan, the Tschicoma Formation volcanic pile (to the west), and Santa Fe Group sediments and Cerros del Rio basalts (to the east and southeast); note especially the interfingering between Puye fanglomeratic deposits and lacustrine fluvial sediments of the Totavi Formation (ancestral Rio Grande deposits; Waresback, 1986).

TABLE 1

Whole-rock compositions of representative Puye Formation pumices and a Tschicoma Formation dacite lava flow

	Lower Group P2	Lower Group P4	Middle Group Puye Ignimb.	Upper Rhyolite G22	Tschicoma Dacite* (5 Ma)
Major elements (wt %)					
SiO_2	66.48	66.4[illegible]	65.64	72.95	67.[illegible]
TiO_2	0.45	0.44	0.44	0.09	0.5[illegible]
Al_2O_3	15.54	15.36	15.69	11.[illegible]	15.28
Fe_2O_3*	3.49	3.51	3.47	1.[illegible]	3.68
MnO	0.06	0.06	0.05	0.06	[illegible]
MgO	1.81	1.71	1.48	0.26	1.69
CaO	3.45	3.42	3.40	0.33	3.40
Na_2O	4.31	3.45	4.20	3.34	3.90
K_2O	3.72	3.90	3.80	5.24	3.18
P_2O_5	0.16	0.16	0.17	0.01	0.14
LOI	1.60	1.50	1.70	4.62	1.46
Total	100.05	99.96	99.99	99.77	100.51
Trace elements (in ppm)					
Sc	6.9	6.46	5.5	2.2	5.1
Cr	36	51	34	0.6	22
Rb	60	66	90	153	79
Cs	0.86	0.94	2.32	3.68	1.4
Ba	1200	1200	995	100	1180
La	33.3	33.5	36.4	48.8	44.1
Ce	64.2	65.3	62.1	95.4	54
Sm	4.4	4.5	3.45	7.06	4.4
Eu	1.1	1.1	0.91	0.13	[illegible]
Tb	0.46	0.50	0.42	1.17	–
Yb	1.34	1.37	1.32	4.16	1.5
Lu	0.20	0.20	0.22	0.64	–
Hf	4.5	4.7	4.0	7.6	3.5
Ta	0.74	0.77	1.21	4.62	–
Th	4.37	4.58	8.22	18.70	7.5

Major elements by XRF, trace elements by INAA; see Turbeville (1986) for analytical methods and quality of data.
*Total iron as Fe_2O_3 from analysis.
*Chemical data from Gardner et al. (1986).

sion and caldera collapse) survives exclusively in the Puye Formation.

The Puye Formation

The Puye Formation (Griggs, 1964; Manley, 1976, 1979; Waresback and Turbeville, in press) is the exposed upper part of a thick volcaniclastic sequence emplaced contemporaneously with the Pliocene development of the Tschicoma volcanic center. The Puye Formation contains > 15 km³ of Plio-Pleistocene alluvial sediments derived mainly from lava domes in the northeastern part of the Tschicoma center (Figs. 1, 3). This alluvial fan records a history of explosive activity that produced abundant dacitic to rhyodacitic tephra (Table 1) during the later development of the Tschicoma center (3.5–1.9 Ma; Gardner et al., 1986; Turbeville, 1986). The well-exposed parts of the fan show medial to distal volcanogenic fanglomeratic facies with abundant epiclastic material emplaced as subaerial mass flows and hyperconcentrated flood flows (c.f., Smith, 1986), stream channel deposits, and sheetflood conglomerates. These sediments are interbedded with primary and redeposited pyroclastic deposits and, to a lesser extent, areally extensive mafic lava flows and associated breccias. In addition, lacustrine deposits (including abundant water-lain felsic and basaltic tephra) are volumetrically significant in distal parts of the fan.

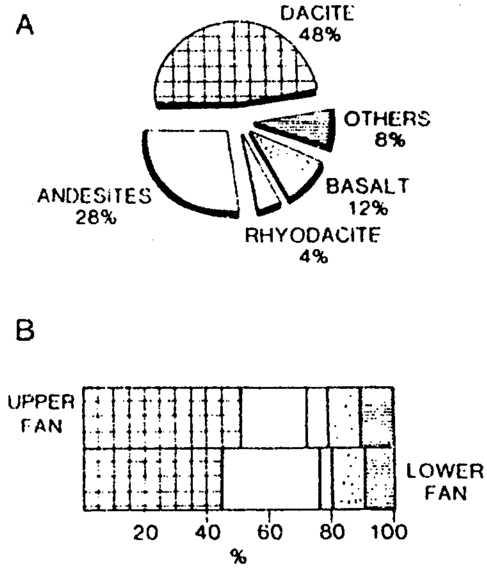

Fig. 4. A. Approximate volume percentages of rock types found as epiclasts (see Table 2) in Puye fanglomerates (values derived from representative counts of clasts > 10 mm; $n = 200$ per deposit).
B. Variations in the percentage of these clast types between the lower and upper portions of the medial fan facies of the Puye Formation (see Figs. 5, 6).

Explosive eruptions that accompanied the

TABLE 2

Puye Formation epiclastic rock types (classification based on modal mineralogies)

Epiclast	Lithic type	Salient features
I	Porph. gray dacite	Large plag. glomerocrysts and qtz with hb-bi-cpx-opx in an interstitial matrix of subparallel plag. microlites in dark gray glass.
II	Porph. red dacite	Similar to type I except much larger phenocrysts and distinctly lineated fabric, qtz rare, hbl replaced by Fe oxides
III	Porph. light gray dacite	Equigranular pl-qtz-cpx-opx-hb-bi-phen. in a matrix of stubby, randomly oriented plag. laths (orthophyric), glomerocrysts rare
IV	Flow banded andesite	Alternating bands of glassy, microlite-poor and densely microlitic seriate lava; plag. and Fe oxides in parallel fabric, equant opx within cpx prisms
V	Porph. pink dacite	Strongly embayed plag. megacrysts (up to 6 mm) in dense groundmass of fragmental microlites and glass; abund. bi-hb-px-mt microlites in seriate matrix.
VI	Sl. porph. gray rhyodacite	Plag. megacrysts (up to 8 mm) with qtz in very dense matrix of lath-shaped plag., altered cpx and Fe oxides, groundmass strongly spherulitic
VII	Gray to black porph. basalt	Plag. megacrysts (up to 11 mm) with equant cpx-olivine microphen. in matrix of stubby pl-cpx-opx-mt microlites in glass; ol-plag. intergrowths common
VIII	Gray perlitic 2-px andesite	Fibrous-flowbanded (pyroclastic-like) texture, spherulitically devitrified groundmass lacks plag.; abund. "andesite" lithics and large (>2 mm) isolated Fe oxide phenocrysts.
IX	Light gray hbl. andesite	Unusual orthophyric texture with stumpy plag. laths and hy-bi-hbl in spherulitically devitrified (microbrecciated) groundmass; large green biotite crystals are conspicuous
X	Red banded dacite	Similar to types I and II except for distinctive color banding and occurrence of large biotite crystals in dark red-brown groundmass
XI	Porph. gray dacite	Pyroclastic-like groundmass, wavy shard-like features outline a weak flow banding; tan-brown devitrified matrix exhibits "stretched skin" appearance.
XII	Volcanic breccia	Individual basaltic clasts (<30 cm diam.) in hydrothermally altered and banded, gray-brown groundmass; unusual skeletal aggregates of bladed augite
XIII	Fine grained basalt	Distinctive flow texture imparted by plag. microlites, plag. phenocrysts strongly embayed, ol-px-mt microlites in brown, glassy groundmass; high crystal/glass ratio.
XIV	Gray 2-px andesite	Large plag. glomerocrysts and subophitic augite in gray-brown glassy groundmass with few plag. microlites.
XV	Tan-brown hbl-bi dacite	Large plag. glomerocrysts in dense, oriented-interstitial microlite groundmass, large bi-hbl crystals and qtz microphenocrysts
XVI	Gray hbl andesite	Large plag. phenocrysts with hy-bi-hbl in randomly oriented microlitic matrix, mt-px-qt microphen. in radiating or dendritic clusters
XVII	Black porphyry	Latite-rhyodacite with plag. phen. rimmed by perthitic or granophyric overgrowths in weakly flow-banded, dark gray groundmass; K-feldspar anomalously abundant as large tabular crystals.
XVIII	Agglomerate	Flow banded lava clasts in distinctly pumiceous, microbrecciated matrix, crystal and lithic fragments common.

growth of Tschicoma lava domes were probably instrumental in remobilizing large portions of talus-covered dome surfaces (c.f., Rose, 1987; Scott, 1987). Steep topography and sporadic (possibly episodic) flood frequency and runoff in this semi-arid region (Kelley, 1979; Dethier and Demsey, 1984) contributed to the apparently high erosion rates associated with the denudation of these domes, providing abundant epiclastic material to the growing fan. For this reason, we believe that the Puye alluvial fan adequately represents an inverted stratigraphic succession of Plio-Pleistocene lava dome development and erosion in the northeastern part of the Tschicoma center.

Puye Formation epiclastic deposits contain a highly variable suite of lava lithologies (Table 2; Fig. 4); this is in sharp contrast to the exposed rock types of the Tschicoma eruptives (Baldridge and Vaniman, 1986). Unfortunately, direct correlation of fan deposits with the currently denuded volcanic center is greatly inhibited by limited exposure in the area where lava flows and fan sediments interfinger. Similarity between available mineralogical and geochemical characteristics of Puye tephra and Tschicoma lavas, however, strongly supports the contemporaneity of these rocks (see below).

The Puye fan also contains basaltic ash derived from phreatomagmatic eruptions in the Cerros del Rio volcanic field of the central Rio Grande rift (Figs. 1, 3; Aubele, 1979; Fisher et al., 1984). The combined influences of contemporaneous volcanism from these two adjacent volcanic centers are reflected in the fan by the development of distinctive cyclical depositional sequences. In essence, the Tschicoma center steadily supplied large quantities of volcaniclastic material to the prograding fan, whereas volcanism in the Cerros field strongly influenced sedimentation from the eastern basin margin, by lake development and variations in local fluvial base levels.

Pyroclastic stratigraphy

Analysis and correlation of primary pyroclastic deposits in the Puye Formation (see below) suggest that several explosive eruptions from the Tschicoma center produced widespread fall blankets across the growing Puye fan. Localized preservation of these deposits depended on the rapid accumulation of a protective cover of epiclastic debris or additional pyroclastic material. The absence of coeval pyroclastic deposits beyond the limits of this alluvial system suggests that the surrounding environments were therefore not suitable for the preservation of tephra. Any tephra emplaced to the southwest of the Tschicoma center was obliterated, along with Tschicoma lava flows and domes, by later episodes of caldera collapse and infilling by intracaldera Bandelier ignimbrite (Nielson and Hulen, 1984).

Explosive eruptions and closely associated epiclastic sedimentation produced cyclical sequences of one or more pumice falls, often underlain by thin mudflow deposits and overlain by either ignimbrite or thick pumiceous mudflows (Fig. 5). These sequences reflect individual eruptive events and are separated by intereruptive debris flow and hyperconcentrated flood flow deposits (including volcanic mudflows), fluvial sediments (i.e. braided stream conglomerates), and deposits of sheetflood activity. The latter reflect high rates of aggrada-

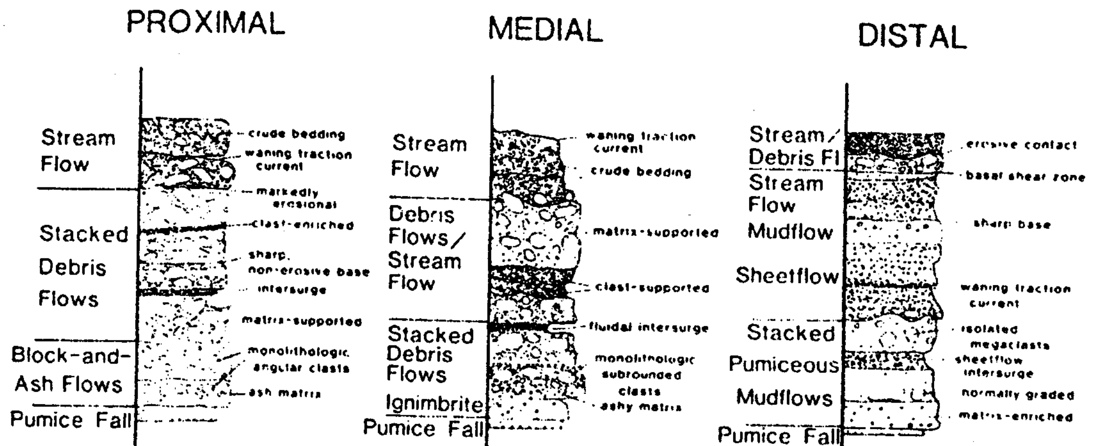

Fig. 5. Generalized depositional sequences related to individual explosive eruptions and inter-eruptional phases of sedimentation in proximal, medial, and distal Puye Formation exposures (see text for details).