

Holocene Evolution of Canyons and Implications for Contaminant Transport, Pajarito Plateau

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Abstract—The preserved Holocene geologic record in canyons incised into the Pajarito Plateau indicates that sediment is cycled through canyons on time scales of tens to hundreds of years. Canyon stream systems draining the Sierra de los Valles and Pajarito Plateau exhibit episodic sediment transport and deposition during the Holocene, including multiple episodes of incision and aggradation during Holocene and recent (historic) time. Formation of a mid-Holocene fill terrace in Frijoles, Rendija, Los Alamos and Bayo canyons suggests that both the larger canyon systems draining the Sierra de los Valles (e.g., Frijoles and Los Alamos Canyons) and smaller canyons heading on the Pajarito Plateau (e.g., Rendija and Bayo Canyons) are responding synchronously to local or regional climatic changes. Although detailed correlations of the multiple late Holocene and historic surfaces between canyons has not been completed, the presence of Holocene valley floors indicates significant Holocene sediment storage in canyons on the Pajarito Plateau. Canyons examined contain between 3 and 6 ft of sediment less than 50 yrs old in some locations, and also contain one or more inset geomorphic surfaces of historic age. The late Holocene and historic record of multiple cut-and-fill events indicate that the potential exists for remobilization and transport of contaminants through canyon systems. Contaminants discharged into canyons discussed in this paper include (1) ^{90}Sr , natural and depleted uranium dispersed throughout a segment of Bayo Canyon during munitions testing; (2) plutonium discharged into Acid Canyon and transported into Pueblo Canyon; and (3) plutonium released into DP Canyon. Contaminants entrained as part of the sedimentary package have been transported through canyon systems; in Pueblo Canyon contaminants have been transported downstream through Los Alamos Canyon to the Rio Grande.

INTRODUCTION

Geomorphic mapping conducted in Bayo and Los Alamos Canyons provides a stratigraphic framework for comparison with the geomorphic and Holocene geologic record in DP, Frijoles, Pueblo, Rendija and Cabra canyons (Drakos and Inoué, 1993, 1994; Graf, 1995, unpubl. reports to Los Alamos National Laboratory; Reneau, 1993; Reneau and Gardner, 1993; Graf, in press; Fig. 1). These canyons were examined as part of the

Environmental Restoration Project at Los Alamos National Laboratory (LANL). The purpose of the geomorphic mapping conducted in the vicinity of LANL was to: (1) define historic and prehistoric Quaternary geomorphic surfaces through surface mapping at 1:1200 scale; (2) identify discrete stratigraphic units within the alluvium and colluvium and associated geomorphic surfaces and to identify areas of historic erosion and deposition; (3) estimate sediment transport rates; (4) identify potential contaminants within a canyon system; and (5) identify specific geomorphic units and underlying sediments as sampling locations for potential contaminants. An additional outcome of these investigations was the development of the Quaternary geologic history of individual canyons.

The geomorphic characterization of canyon segments involved field mapping, air photo analysis, profiling using a hand level and stadia rod, field soil and stratigraphic descriptions, and analysis of topographic maps and drillers' logs. Geomorphic features examined include drainage channels, areas of historic sedimentation and terrace formation, older sedimentary deposits and geomorphic surfaces along the valley floor, and talus or colluvial slopes between the valley floor and adjacent cliffs. Geomorphic surfaces were differentiated based on height above local base level, radiometric dating, the presence or absence of historic materials in the underlying deposits, the degree of preservation of depositional or constructional morphology, and where possible, relative soil development. A series of 1:1200 scale geomorphic and Quaternary geologic maps of the areas of Bayo, Los Alamos and DP canyons are available from LANL Facility for Information Management, Analysis, and Display (FIMAD).

GEOLOGIC SETTING

Canyons on the Pajarito Plateau in the vicinity of Los Alamos are incised into a sequence of the Tshirege Member of the Bandelier Tuff, overlying the Cerro Toledo interval and Otowi Member of the Bandelier Tuff (Fig. 2). The Bandelier Tuff ranges in age from 1.2 to 1.6 Ma, based on $^{40}\text{Ar} - ^{39}\text{Ar}$ dates for the Tshirege Member (1.2 Ma) and the Otowi Member (1.6 Ma) (Izett and Obradovich, 1994). The Otowi Member of the Bandelier Tuff is underlain by alluvial fan deposits that comprise the Plio-Pleistocene Puye Formation, Pliocene basaltic rocks of the Cerros del Rio volcanic field, and Santa Fe Group (Tesuque Formation) sediments.

Canyon incision into the Pajarito Plateau commenced during the Pleistocene following deposition of the Bandelier Tuff (Tshirege Member) at 1.2 Ma. In several canyons (e.g., Cabra, Los Alamos, Mortandad and Ancho

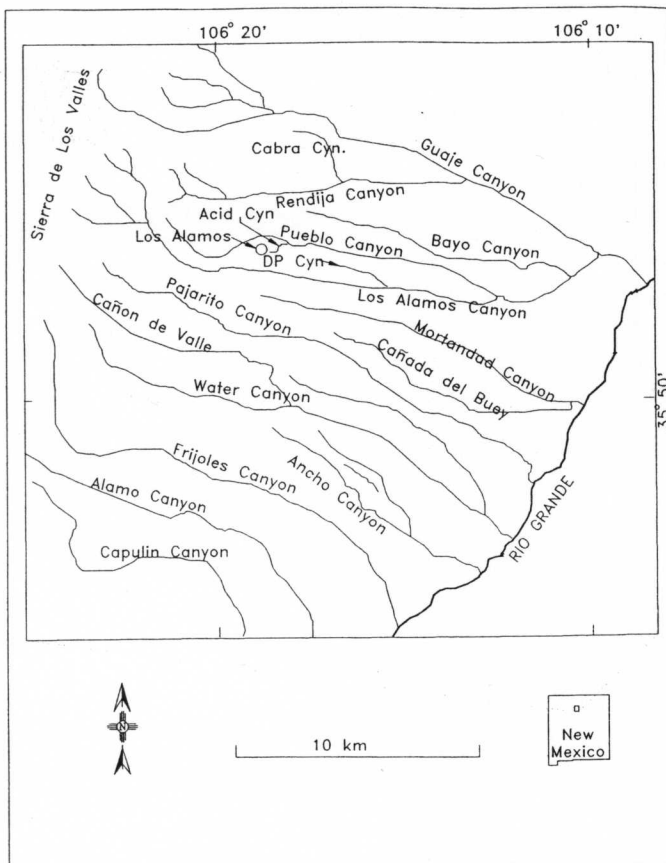


FIGURE 1. Map showing selected drainages on the Pajarito Plateau (adapted from Reneau et al., this volume).

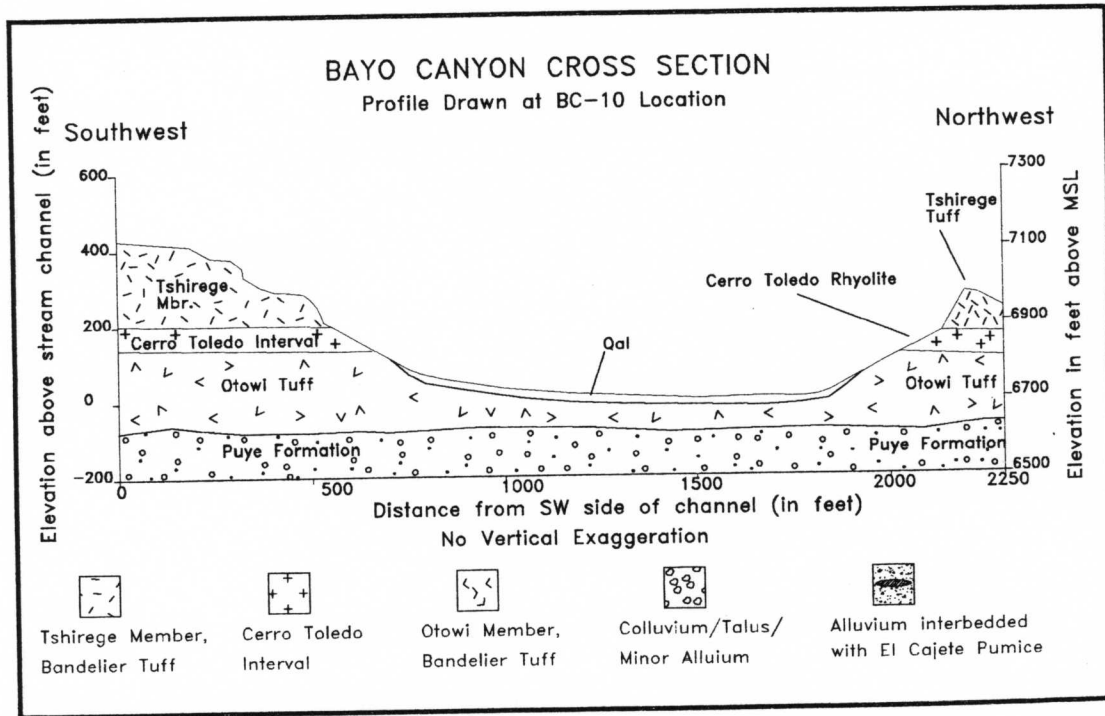
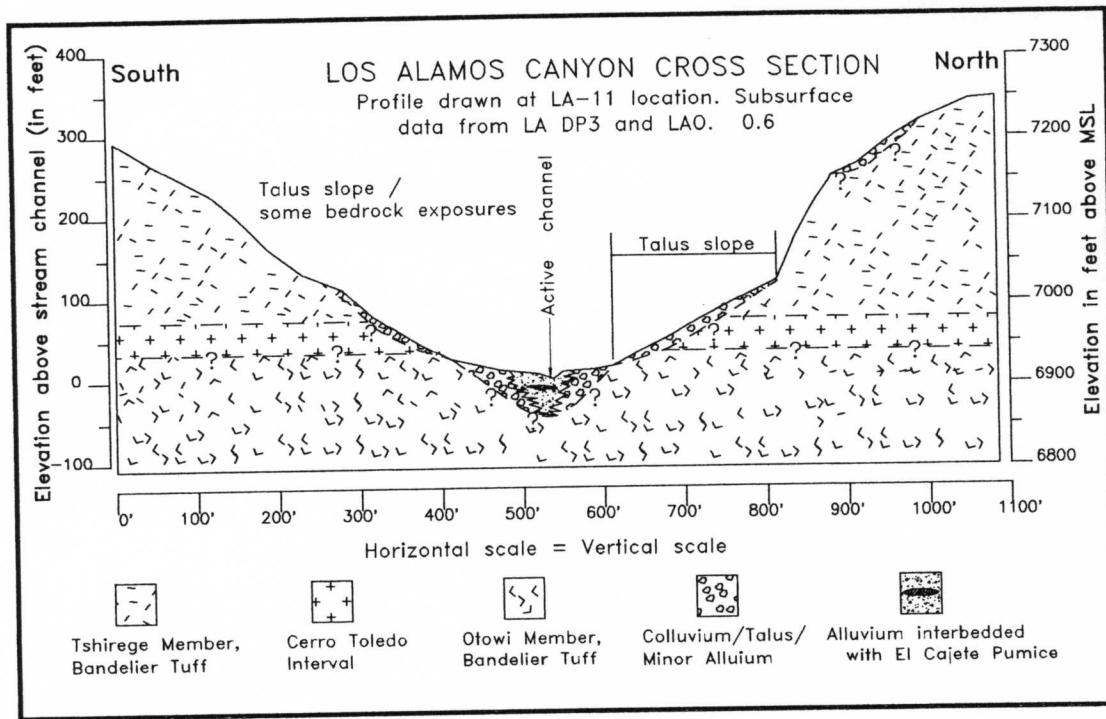


FIGURE 2. Los Alamos Canyon and Bayo Canyon cross sections.

Canyons) stream systems incised until the late Pleistocene, but have experienced aggradation during the past 50-60 ka (Reneau et al., this volume). Radiocarbon dating indicates that an episode of aggradation and terrace formation occurred at or near the Pleistocene-Holocene boundary in Frijoles, Rendija and Ancho canyons (Reneau et al., this volume), suggesting that a change in geomorphic processes and depositional patterns occurred at that time. Another period of apparently synchronous aggradation and terrace formation occurred in the mid-Holocene. The mid- to late Holocene geologic record in canyons on the Pajarito Plateau has generally been characterized by multiple episodes of alternating channel aggradation, incision, and relatively brief periods of stability.

STUDY AREAS

Bayo Canyon

Bayo Canyon was mapped in the area north of Kwage Mesa and south of Otowi Mesa, near the eastern terminus of each mesa (Fig. 3). This area of Bayo Canyon was selected for mapping because it was the location of LANL Technical Area 10 (TA-10). Potential sources of contamination pertinent to this study include shrapnel dispersed throughout the canyon as a result of firing site activities conducted from 1944 through 1963. Four firing pads apparently used for munitions testing were observed during mapping in Bayo Canyon. Approximately 1 to 2 % of this

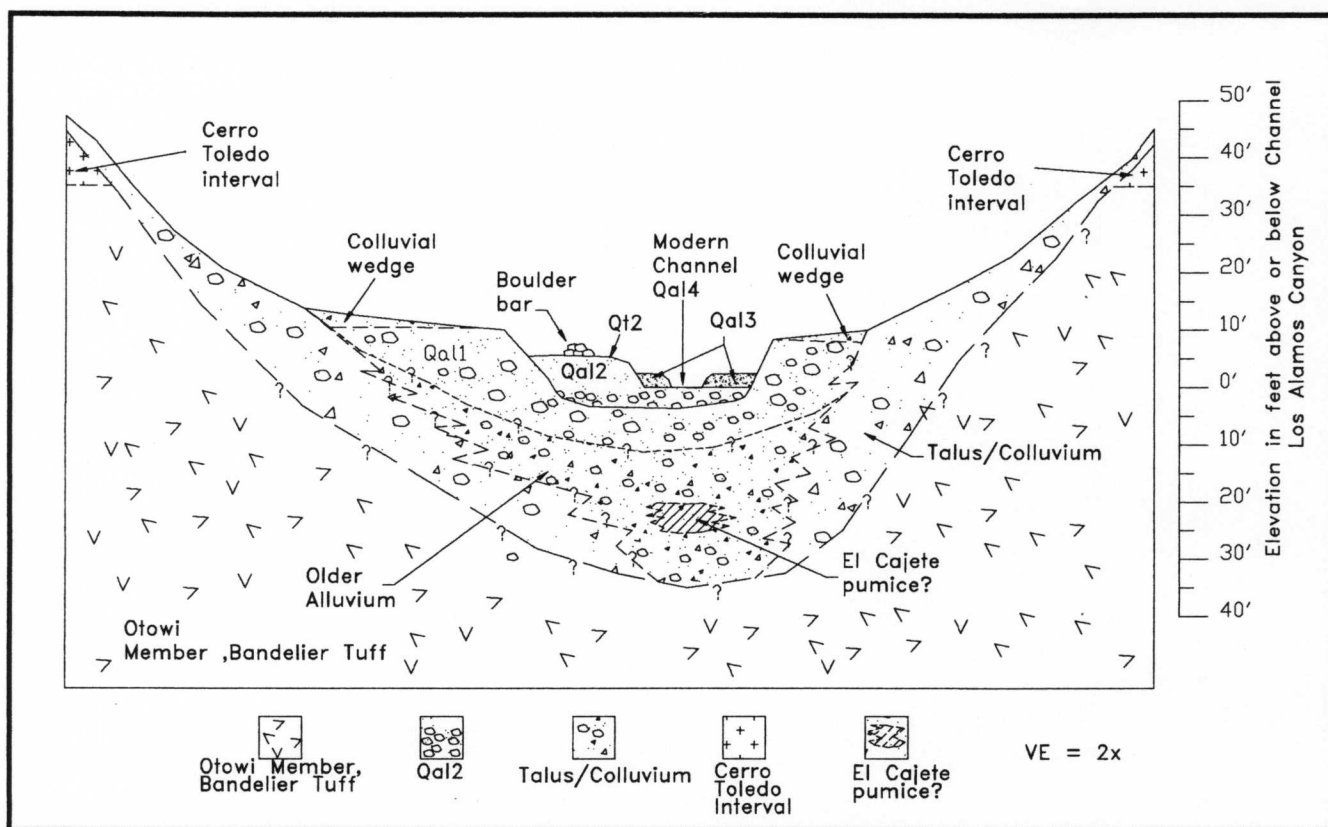


FIGURE 3. Diagram of inner canyon deposits and surfaces, Los Alamos Canyon. Subsurface data from Broxton et al. (1994).

shrapnel contains Strontium-90 (^{90}Sr) contamination or is composed of natural or depleted uranium. These contaminants are present because TA-10 was used to test conventional high explosives containing natural and depleted uranium and a radioactive tracer (Lanthanum-140 or ^{140}La) "source" with a half-life of 40.3 hrs. The ^{140}La was contaminated with a small amount of ^{90}Sr with a half-life of 28.8 yrs.

Bayo Canyon heads on the Pajarito Plateau, and therefore does not receive runoff from Sierra de los Valles. The primary landforms in the canyon are steep cliffs developed in the Tshirege Member of the Bandelier Tuff; slopes ranging from 10° to 30° mantled with talus derived primarily from the Tshirege Member and underlain by the Cerro Toledo interval and Otowi Member of the Bandelier Tuff; and a wide, relatively flat valley floor (Fig. 2). The valley floor can be subdivided into two sections consisting of broad, low-angle valley floor side slopes covered with 1–6 ft of colluvium, and a fairly narrow inner canyon consisting of the modern channel flanked by one to three stepped terrace surfaces.

Los Alamos Canyon

Los Alamos Canyon heads in the Sierra de los Valles and was mapped in the area south of and adjacent to the Los Alamos townsite. This area of Los Alamos Canyon was selected for mapping because it includes Technical Area 2 (TA-2) and Technical Area 41 (TA-41). TA-2 includes the facility for the Omega West Reactor, which is currently shut down and is planned for decommissioning. TA-41 is a weapons research facility. Los Alamos Canyon is bordered by the Los Alamos townsite to the north and South Mesa to the south and is incised approximately 350 ft into the Tshirege Member, Bandelier Tuff; Cerro Toledo interval; and Otowi Member, Bandelier Tuff (Fig. 2). Both the Rendija Canyon and Guaje Mountain fault zones have been projected through Los Alamos Canyon within the mapped area (Gardner and House, 1987; Vaniman and Wohletz, unpubl.). Both faults exhibit down-to-the-west displacement, although only the Rendija Canyon fault clearly offsets the Bandelier Tuff within Los Alamos Canyon.

The primary landforms in the canyon are steep cliffs developed in the Tshirege Member; slopes ranging from 10° to 35° mantled with talus

derived primarily from the Tshirege tuff and underlain by the Cerro Toledo interval and Otowi Member; and a narrow, relatively flat valley floor (Fig. 2). The valley floor can be subdivided into two sections consisting of laterally-restricted areas of colluvial deposition at the base of talus slopes and low angle valley floor side slopes underlain by colluvium; and a fairly narrow inner canyon consisting of the modern channel incised into one to three stepped terrace surfaces (Fig. 3). Several small landslide blocks (Qls) were observed at the base of steep side slopes.

The reach of Los Alamos Canyon between DP Canyon and the Rio Grande was also mapped as part of a study addressing plutonium transport through the Los Alamos Canyon system (Graf, unpubl. report for LANL, 1995; Graf, in press). The sections of Los Alamos Canyon examined by Graf were located downstream from plutonium disposal areas in Acid and DP canyons. The area of Los Alamos Canyon investigated by Graf is incised through the Puye Formation, basalt flows of the Cerros del Rio volcanic field, and underlying Santa Fe Group (Tesuque Formation) sediments.

DP Canyon

DP Canyon is a tributary to Los Alamos Canyon (Fig. 1), which was mapped in detail by Reneau (1995) because of previously documented transport of low concentrations of plutonium into this canyon from adjacent Technical Area 21 (TA-21) on DP Mesa (Purymun, 1971, 1974; Purymun et al., 1990; Reneau, 1995). DP Canyon was also examined to determine cliff retreat rates and the stability of subsurface Material Disposal Areas (MDAs) located within TA-21 (Reneau, 1995). DP Canyon is incised 70 to 100 ft into the Tshirege Member of the Bandelier Tuff and enters Los Alamos Canyon downstream from Technical Areas 2 and 41 (the mapping area described above for Los Alamos Canyon).

Pueblo Canyon

Plutonium-contaminated material had been discharged into Acid Canyon, which is a tributary of Pueblo Canyon (Fig. 1). Contamination of Acid Canyon occurred primarily between 1945 and 1952, during which time a sewer system from LANL buildings discharged liquid waste con-

