GEOLOGIC MAP OF TA-21, LOS ALAMOS NATIONAL LABORATORY, NEW MEXICO

by

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TA-21

ABSTRACT

A geologic map of TA-21 was prepared using color photographs of canyon walls as well as conventional field mapping on a topographic base at a scale of 1 in = 350 ft, and the general bedrock relations were studied. Exposed bedrock geology consists of three principal units (bottom to top): 1. Otowi Member, Bandelier Tuff, consisting primarily of nonwelded, lithic-rich, rhyolitic ignimbrite (1.50 Ma); 2. the Cerro Toledo interval, consisting of interbedded rhyolitic pyroclastic falls and epiclastic gravels of dacitic composition; and 3. Tshirege Member, Bandelier Tuff, composed of nonwelded to welded rhyolitic ignimbrite (1.13 Ma). The Bandelier Tuff was derived primarily from explosive volcanic eruptions in the Valles caldera west of TA-21. The Tshirege Member was subdivided into five subunits because of distinct boundaries caused by depositions of flow units, variations in welding, and variations in alteration. The bedrock units are partially covered by alluvium, terrace gravels, talus/colluvium, mesa top soils, and disturbed alluvium. Contacts between the three bedrock units are generally undulatory due to periods of erosion between emplacement. Nonetheless, thicknesses of most units and subunits, except for the bedded Cerro Toledo interval, are relatively constant. No faults were found in the map area in exposed bedrock units. One cold spring (DP Spring) was found in eastern DP canyon issuing from a contact between colluvial and valley fill deposits and Tshirege unit 1g. This spring discharges from the north cliff face about 20 ft above the canyon bottom.

I. INTRODUCTION AND PREVIOUS MAPPING

This study presents a geologic map and cross sections of rock units at Technical Area 21 (TA-21). This map supports RFI studies at TA-21 by showing the distribution and thickness of rock units. These data provide a geologic framework for evaluating potential contaminant transport pathways and background information for evaluating various remediation alternatives.

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TA-21 (DP site) lies on the Pajarito Plateau which is located on the east flank of the Jemez Mountains and on the west margin of the Española Basin. The Pajarito Plateau is composed primarily of the slightly eroded Tshirege Member of the Bandelier Tuff, a large volume, rhyolitic ash-flow tuff (ignimbrite) erupted from the Valles caldera of the Jemez volcanic field (Smith and Bailey, 1966). All designated waste sites at TA-21 are built in the upper zones of this ignimbrite sheet or in overlying soils. Discussions of the geology of the upper portions of DP Mesa and the history of disposal facilities can be found in several reports (Rogers, 1977; Nyhan et al., 1984; Gerety et al., 1989; Merrill, 1990; LANL, 1991).

Regional geologic maps that cover all or part of the Pajarito Plateau include those of Griggs (1964) for geohydrologic investigations centered around Los Alamos, Smith et al. (1970) for volcanologic investigations of the Jemez Mountains, and Kelley (1978) for tectonic investigations associated with the Rio Grande rift. Geologic maps of nearby areas that have bearing on the stratigraphic and tectonic context of the Pajarito Plateau to the greater regional picture have been published by Weir and Purtymun (1963), Baltz et al., (1963), Galusha and Blick (1971), Aubele (1978), Dethier and Manley (1985), Goff et al. (1990), and Dethier (in press). Detailed geologic mapping and fracture measurements were completed for an area around TA-55 (Vaniman and Wohletz, 1990). Unpublished mapping is completed for large areas of U. S. Department of Energy land on the plateau by M. A. Rogers. The most recent synthesis of geologic and tectonic studies on the Pajarito Plateau has been published by Dransfield and Gardner (1985) and Gardner and House (1987) as part of the Los Alamos investigation of the seismic hazard of faults within the region. The latter report includes some recent detailed mapping along strands of the Pajarito fault zone.

II. GEOLOGY OF BEDROCK UNITS, TA-21

Stratigraphic units described within the Tshirege Member of the Bandelier Tuff follow the usage of Vaniman and Wohletz (1990). Estimates of degree of welding in the Bandelier ignimbrites are based on hand sample evaluations of pumice compaction. Detailed descriptions of lithologic and mineralogical variations can be found in Appendix C of this phase report. No mappable faults or folds cross the TA-21 site although zones of intense fracturing occur that correspond to the southern projections of mapped faults (Appendix B of this phase report). Descriptions of post-Bandelier alluvium, colluvium, landslides, terrace gravels, soils, and disturbed fill can be found in Appendix D of this phase report.

Because of the steep cliffs along most of the south side of the TA-21 area (north wall, Los Alamos Canyon), bedrock geology of this zone was mapped on a set of color photographs that will be available through the ER records processing facility. Representative photographs of rock units are displayed in Figs. A-1 to A-3. The geologic map (Plate 1) and cross-sections (Figs. A-4a to A-4e) show the distribution of rock units at the site. The geologic map is a compilation of bedrock geology (this report) and post-Bandelier sedimentary deposits (Appendix D of this phase report).

A. Otowi Member, Bandelier Tuff

The upper part of the Otowi Member of the Bandelier Tuff is very poorly exposed in Los Alamos Canyon because of extensive cover by talus and colluvium (Plate 1). Better exposures occur in the mouth of DP Canyon. The base of the Otowi is not exposed but is described from cuttings taken in well Otowi-4 at the mouth of DP Canyon (Stoker et al., 1992), in unpublished lithologic descriptions for EGH-LA-1 at Sigma Mesa, and from core recovered at hole SHB-1 at TA-55 (Gardner et al., 1993).

Where exposed, the Otowi Member consists of white, massive, nonwelded, rhyolitic ignimbrite containing about 5% pumice clasts >2 cm in diameter and about 5% clasts of pre-Bandelier lithologies of sand to cobble size (mostly intermediate composition volcanics). The ignimbrite matrix consists of poorly-sorted ash, pumice, crystal, and lithic fragments. Phenocrysts in pumice clasts consist of quartz (~20%) and sanidine (~80%). Mafic phenocrysts are rare and extremely difficult to see in hand specimens. No flow unit boundaries are observable in the few outcrops of Otowi found in the map area.

The Otowi Member is relatively soft and easily eroded. An exposure in the bottom of Los Alamos Canyon along the dirt road (site C-1, Plate 1) reveals several feet of massive ignimbrite overlain by a remnant of older alluvium composed primarily of dacitic rocks from sources upstream. The older alluvium is ≤3 ft thick and is overlain by colluvium of mostly Tshirege Member, Bandelier Tuff.

Near the mouth of DP Canyon (sites C-2 and C-4, Plate 1), the top of the Otowi Member consists of an irregular erosional surface overlain by bedded tuffs and epiclastic sedimentary rocks of the Cerro Toledo interval and by older alluvium and recent colluvium.

The base of the Otowi Member contains a pyroclastic fall unit named the Guaje Pumice Bed (Griggs, 1964; Bailey et al., 1969) which is not exposed in the map area but which is found in nearby wells. It is shown diagrametrically on the cross-sections of Figs. A-4b to A-4e.

B. Cerro Toledo Interval

Many discontinuous exposures of the Cerro Toledo interval can be observed in the lower slopes and cliffs of Los Alamos Canyon and near the mouth of DP Canyon. Complete sections occur only in DP Canyon (Plate 1). The Cerro Toledo interval in the map area consists of at least five pyroclastic eruption sequences of the Cerro Toledo Rhyolite interbedded with epiclastic deposits of mostly fluvial origin (Fig. A-1). Cross-cutting relations, pinch-outs of beds, and channeling of fluvial and sheet-wash deposits into underlying pyroclastic beds are commonly observed characteristics. Locally, old soils are preserved within the unit. Tuffaceous deposits associated with the Cerro Toledo Rhyolite are described by Griggs (1964), Bailey et al. (1969), Heiken et al. (1986), Gardner et al. (1986), and Stix et al. (1988). Heiken et al. (1986) and Gardner et al. (1993) also describe epiclastic sediments associated with the Cerro Toledo interval.

Pyroclastic sequences consist of 1.7 to 5.0 ft thick beds of white fine ash, pumice and pumice lapilli and contain up to 5% lithic clasts of Pre-Bandelier volcanic units (Heiken et al., 1986; Stix et al., 1988). Most pyroclastic beds are normally graded. Phenocrysts are rare in pumice clasts of the Cerro Toledo Rhyolite (usually <2%). Most phenocrysts consist of quartz and sanidine but may include trace amounts of pyroxene, biotite, hornblende, and opaque oxides; thus, Cerro Toledo Rhyolite pumice is usually distinct from Bandelier Tuff pumice.

Epiclastic deposits display tremendous variations in thickness, cobble size, and sorting. An outcrop in Los Alamos Canyon (site C-8, Plate 1) exposes the upper part of a poorly-sorted bed of boulders (diameters ≤ 3 ft) overlain by a series of pyroclastic deposits. In lower DP Canyon, several poorly-sorted epiclastic deposits ≤ 10 ft thick show channeling into relatively soft pyroclastic layers (Fig. A-1). Cobble sizes are mostly <1.7 ft in diameter. Epiclastic clasts are invariably composed of dacitic to andesitic rocks from sources to the west but the finer-grained matrix between fragments contains some rhyolitic ash and pumice. These epiclastic beds resemble many of the deposits of the Puye Formation because the sources of materials (dacitic rocks to the west) and mechanisms of deposition are similar.

The thickness of the Cerro Toledo interval is variable. Maximum thickness in DP Canyon is about 66 ft but thickness decreases to east to as little as 13 ft. Exposed thickness on the west side of the map area (site C-12, Plate 1) near Omega East is about 50 ft. Some top and bottom contacts of the Cerro Toledo interval are irregular, although most contacts appear planar. The Cerro Toledo interval is overlain by the Tsankawi Pumice Bed of the Tshirege Member, Bandelier Tuff and locally by older alluvium that post-dates the Tshirege Member.

C. Tshirege Member, Bandelier Tuff

The Tshirege Member of the Bandelier Tuff is well exposed in the map area and forms most of the spectacular cliffs throughout the Pajarito Plateau (Fig. A-3). Thick sections are observable at several locations along Los Alamos Canyon and near the mouth of DP Canyon. Because of variations in welding and devitrification textures and of variations in distribution of flow units and cooling units, other workers including (Baltz er at., 1963; Weir and Purtymun, 1963; Crowe et al., 1978; Vaniman and Wohletz, 1990 and 1991) have subdivided the Tshirege member into mappable subunits whose continuity across the Pajarito Plateau is not yet completely demonstrated. The basic unit subdivisions of Vaniman and Wohletz are used for this report and map (Plate 1) because their recent map overlaps with the TA-21 map area and because their subunits are based on the physical property of erodability, a property easy to recognize in the field.

The Tshirege Member according to Vaniman and Wohletz (1990; 1991) consists of five subunits of ignimbrite and a basal pyroclastic fall unit named the Tsankawi Pumice Bed (Bailey et al., 1969). For the purposes of the report, the Tsankawi pumice is described separately but, because it is ≤3 ft thick, the Tsankawi is included in the lowermost ignimbrite unit for the map and cross-sections.

Tsankawi Pumice Bed

The Tsankawi Pumice Bed is roughly 1.7 to 3 ft thick in the map area (Fig. A-2) and consists of a distinct package of ash falls composed of bedded ash, crystal-rich ash, pumice and <5% lithic fragments (Bailey et al., 1969). Tsankawi pumice contains "sparse phenocrysts of quartz and sanidine and rare black specks of oxides and ferromagnesian minerals" (Bailey et al., 1969). The Tsankawi Pumice Bed also contains rare (0-10%) hornblende dacite pumice that is quite distinctive because of their color and phenocryst assemblage (Bailey et al., 1969). In addition, the Tsankawi Pumice Bed commonly rests on a poorly developed soil in the uppermost

pyroclastic fall of the Cerro Toledo interval. This soil horizon is often damp or erodes differentially. In spite of these features, there is some argument about assignment of individual beds to the Tsankawi Pumice Bed or the Cerro Toledo Rhyolite based on chemical and petrographic criteria (Self et al., 1986; Heiken et al., 1986; Stix et al., 1988). For the purposes of the maps and cross-sections, the original definition of Bailey et al. (1969) is used.

Tshirege Unit 1 Ignimbrite

Unit 1 Ignimbrite is divided into Units 1g (glassy) and 1v (vapor-phase) in (Fig. A-3) and by Vaniman and Wohletz (1990 and 1991), but is shown only as unit 1 on the geologic map (Plate 1). Units 1g and 1v are separated from each other by a persistent and mappable pink-colored, erosional notch in which the pumices are extremely "soft" (Vaniman and Wohletz, 1990). This notch is also described by Crowe et al., 1978 and is referred to as the vapor-phase notch (Fig. A-3). Vaniman and Wohletz (1991) and Broxton et al. (Appendix C of this phase report) include the vapor-phase notch as the lowermost part of unit 1v.

Unit 1g rests on the Tsankawi Pumice Bed (Fig. A-2) and underlies the vapor-phase notch. It consists of ≤83 ft of white-to-gray nonwelded tuff that weathers pale orange. Although the ignimbrite is soft, unit 1g generally forms cliffs where not covered by talus and colluvium. Unit 1g commonly contains abundant holes ≤ 5 ft in diameter arranged in vertical tiers that give a "swiss-cheese" appearance to the unit (Fig. A-3)

Unit 1v overlies unit 1g. Within the map area unit 1v is consistently ≤40 ft in thickness. It consists of white-to-pink nonwelded to slightly welded tuff that weathers pale orange. Vapor-phase alteration of individual pumice fragments is pervasive and distinctive due to color and textural changes. Although the ignimbrite is soft, unit 1v also forms cliffs. The top of unit 1v is often defined by a thin bench but the actual contact between units 1v and 2 is not sharp. More often than not, the contact is defined by change in color and erodability.

Tshirege Unit 2 Ignimbrite

Unit 2 ignimbrite has been further subdivided into welded and nonwelded units by Vaniman and Wohletz (1991) but is described as one unit herein and shown as one unit on the geologic map. The contact between these units is completely gradational in the map area. Unit 2 ignimbrite consists of ≤100 ft of white-to-orange-to-brown, nonwelded (bottom) to moderately welded (top) tuff. Both pumice and groundmass of moderately welded tuff are dense and hard. The

nonwelded base weathers white-to-pale pink and generally forms a steep slope whereas the moderately welded top weathers dark brown-to-orange and forms broadly-jointed cliffs. The bottom contact of unit 2 ignimbrite often forms a thin erosional bench with unit 1v. The top of unit 2 forms a wide bench below the mesa top; extends along the entire length of the north wall of Los Alamos Canyon within the map area (Fig. A-3).

Tshirege Unit 3 Ignimbrite

Unit 3 ignimbrite is divided into welded and nonwelded units by Vaniman and Wohletz (1991). These units are shown separately on the west and central parts of the geologic map (Plate 1) but are undivided on the eastern part of the map because the units thin and become indistinguishable eastward.

The nonwelded unit is ≤50 ft thick where subdivided on the map and consists of white-to-gray pumice-rich ignimbrite that weathers pale pink. The nonwelded unit forms broad slopes generally covered with talus, brush, and scattered trees.

Unit 3 ignimbrite is nonwelded to partially welded tuff that is about 50 ft thick on the east side of the map area but as thin as 26 ft in the central map area. Differences in relative thickness were noted in north-south directions as shown on the cross-sections. Where partially welded, the ignimbrite consists of gray tuff that weathers to a pale orange and forms broadly-jointed, low cliffs that can be climbed at numerous locations. The upper surface of unit 3 ignimbrite is covered with mesa top soil and alluvium or with disturbed alluvium from construction of roads and buildings.

III. CONCLUSIONS

Bedrock geology of TA-21 consists primarily of Otowi and Tshirege Members of the Bandelier Tuff. The thicknesses of these tuffs are rather constant over the map area. In contrast, the Cerro Toledo interval, which lies between the two members of the Bandelier Tuff, vary from 13 ft to 66 ft in thickness. The Cerro Toledo interval deposits display large-scale variations in lithologic properties both vertically and laterally. No obvious surface expression of faults was found in the map area. One cold spring (DP Spring) was found in eastern DP canyon issuing from a contact between colluvial and valley fill deposits and Tshirege unit 1g.

The geologic map presented in this report and the detailed stratigraphic and lithologic descriptions (Appendix C of this phase report) complete the geologic characterization of bedrock geologic units in the upper vadose zone for the TA-21 RFI work plan. Additional work is underway to characterize the fracture mineralogy of these bedrock units; results of these studies will be reported at a later date. The data in this report provide a geologic framework for evaluating potential subsurface transport pathways and will be particularly useful for understanding the distribution of contaminants when characterization bore holes for the MDAs are completed. The map accompanying this report shows the thickness and distribution of geologic units in the upper part of the vadose zone and will support the interpretation of subsurface geologic units penetrated by planned deep bore holes at TA-21.

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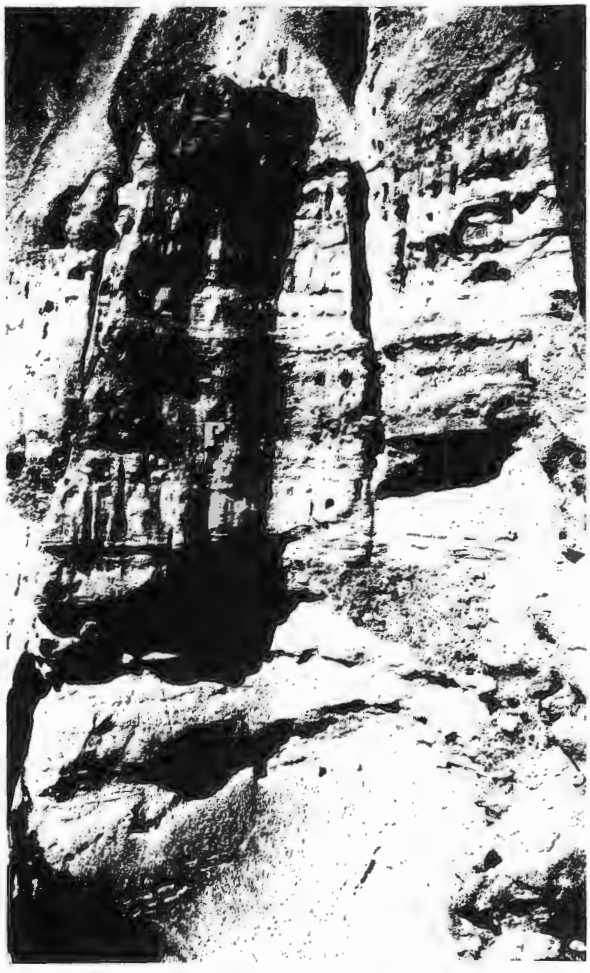

Figure A-1. Photo of the Cerro Toledo interval in eastern DP Canyon in general area of site C-4 (Plate 1). Cerro Toledo interval consists of several layers of pyroclastic falls and surge interbedded with layers and lenses of fluvial-derived gravels. The Cerro Toledo interval overlies massive ignimbrite of Otowi Member, Bandelier Tuff and underlies Tsankawi Pumice Bed and unit 1g ignimbrite of Tshirege Member, Bandelier Tuff.

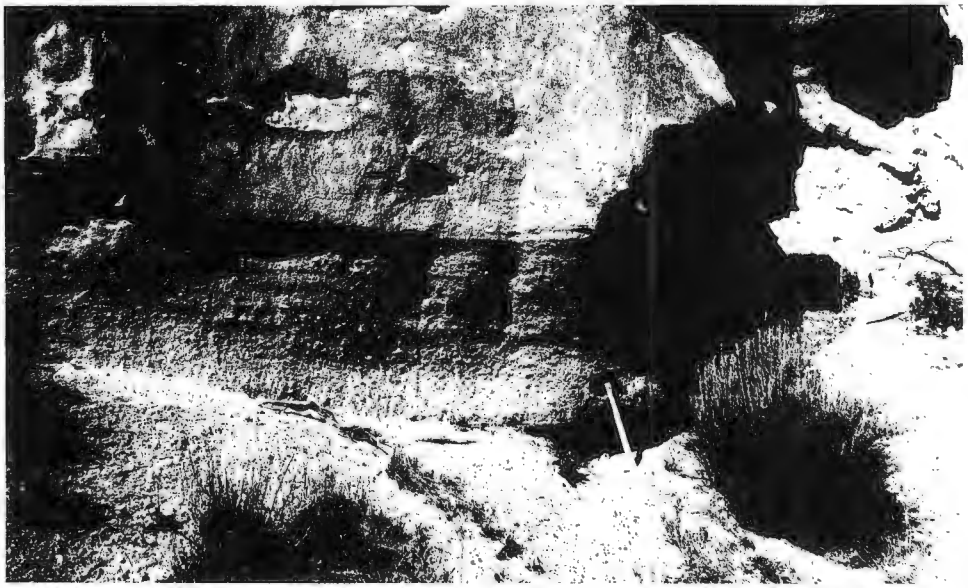

Figure A-2. Photo of 3 ft thick Tsankawi Pumice Bed on the nose of DP Mesa (site C-6, Plate 1). Tsankawi Pumice overlies soil in top of the Cerro Toledo interval (next to lower half of hammer handle) and underlies unit 1g massive ignimbrite, Tshirege Member, Bandelier Tuff.

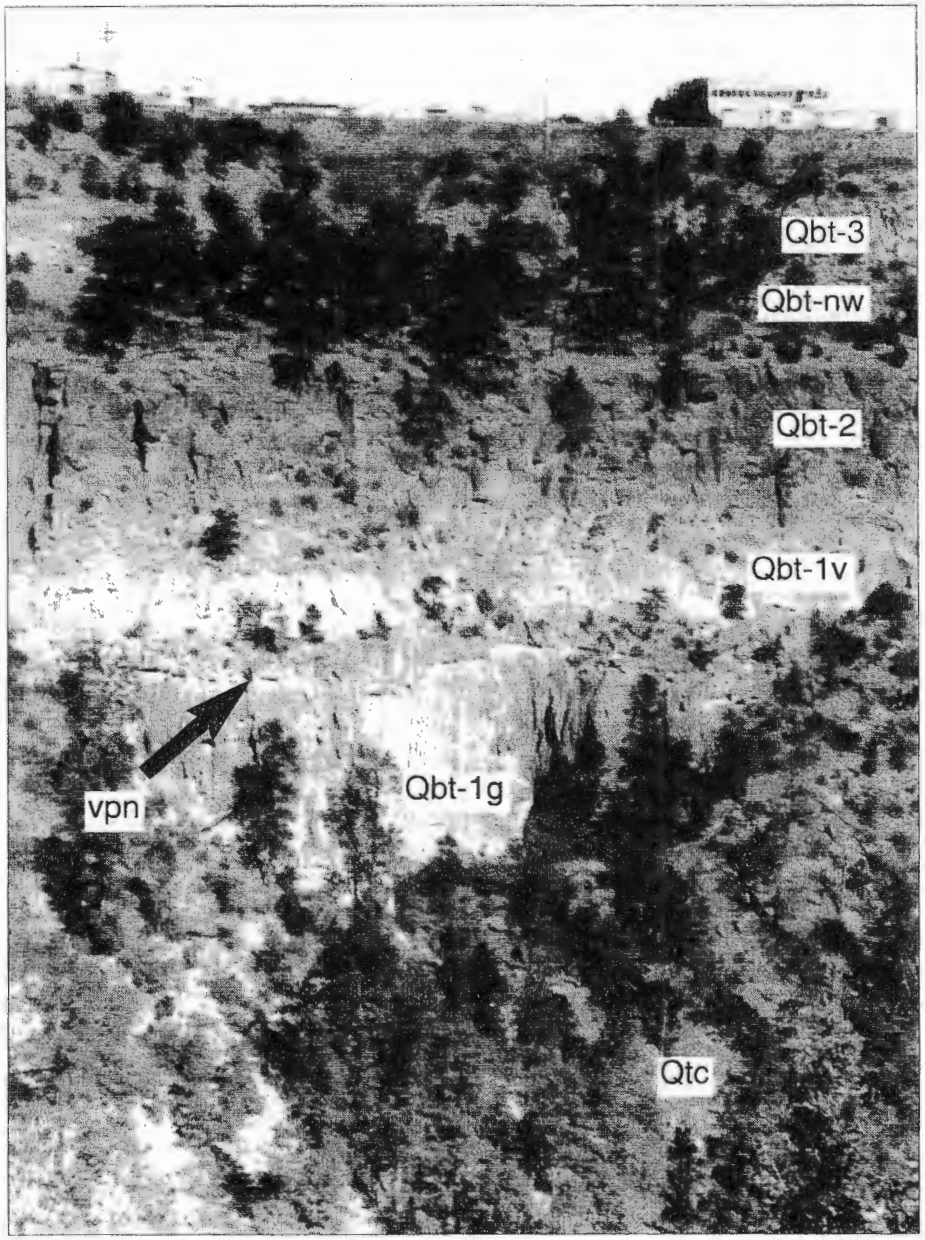

Figure A-3. Representative photograph of the south wall of DP Mesa (north wall of Los Alamos Canyon); locations of photographs are shown on geologic map (Plate 1). Symbols: Qbt-1g = unit 1g, Qbt-1v = unit 1v, Qbt-2 = unit 2, Qbt-nw = nonwelded unit, and Qbt-3 = unit 3. These are various subdivisions of the Tshirege Member, Bandelier Tuff; vpn = vapor phase notch; Qtc= post-Bandelier talus and colluvium.

LEGEND

	Qf		Fill and disturbed alluvium
Qal	Qmt	Qtc	Alluvium, mesa top soil, talus/colluvium
	Qoal		Older alluvium
	Qbt-3		Tshirege Member, Bandelier Tuff; unit 3, nonwelded unit, unit 2, unit 1 (includes vapor-phase notch, not shown, and Tsankawi Pumice Bed shown by dots at base of unit)
	Qbt-nw		
	Qbt-2		
	Qbt-1		
	Qct		Cerro Toledo Interval
	Qbo		Otowi Member, Bandelier Tuff; undivided (Guaje Pumice Bed shown by dots at base of unit)
	QTp		Puye Formation
	QTb		Cerros del Rio Basalt

Figure A-4a Key to the geologic units shown on cross sections in Figs. A-4b through A-4e.

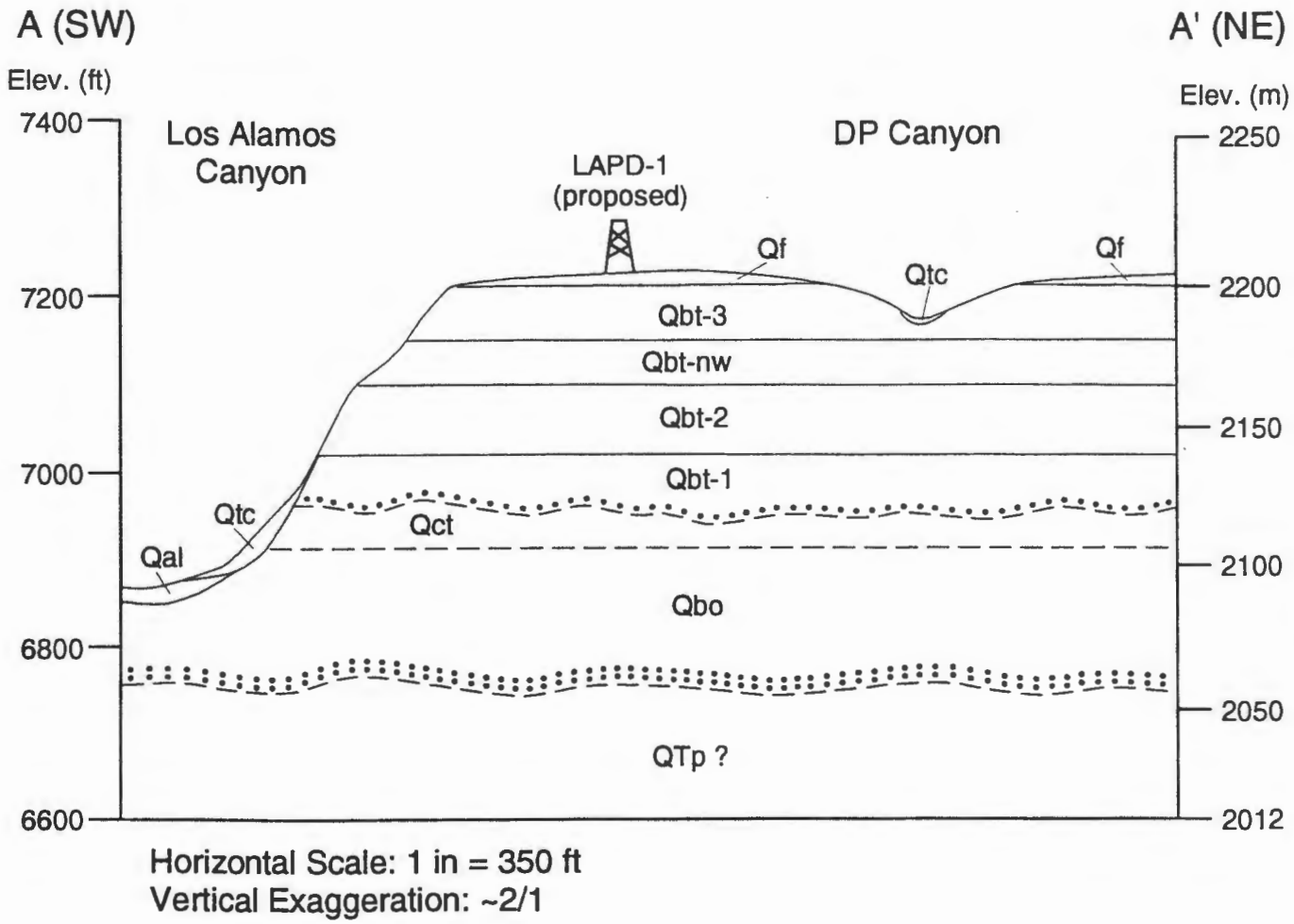

Figure A-4b Cross section A-A' for geologic map of TA-21. Unit abbreviations defined in Fig. A-4a. Line of cross section section shown on geologic map (plate 1) in pocket of this phase report.

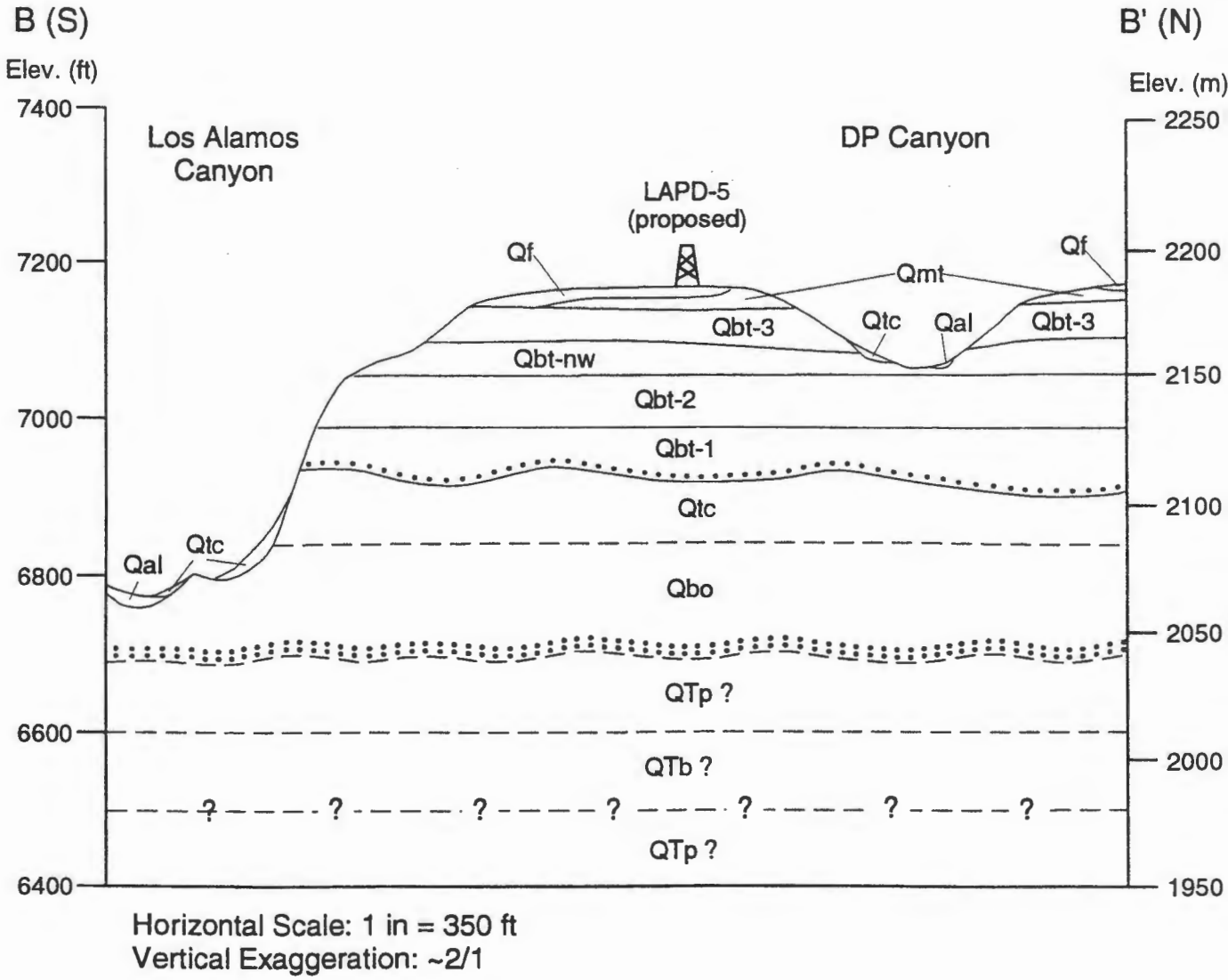

Figure A-4c Cross section B-B' for geologic map of TA-21. Unit abbreviations defined in Fig. A-4a. Line of cross section section shown on geologic map (plate 1) in pocket of this phase report.

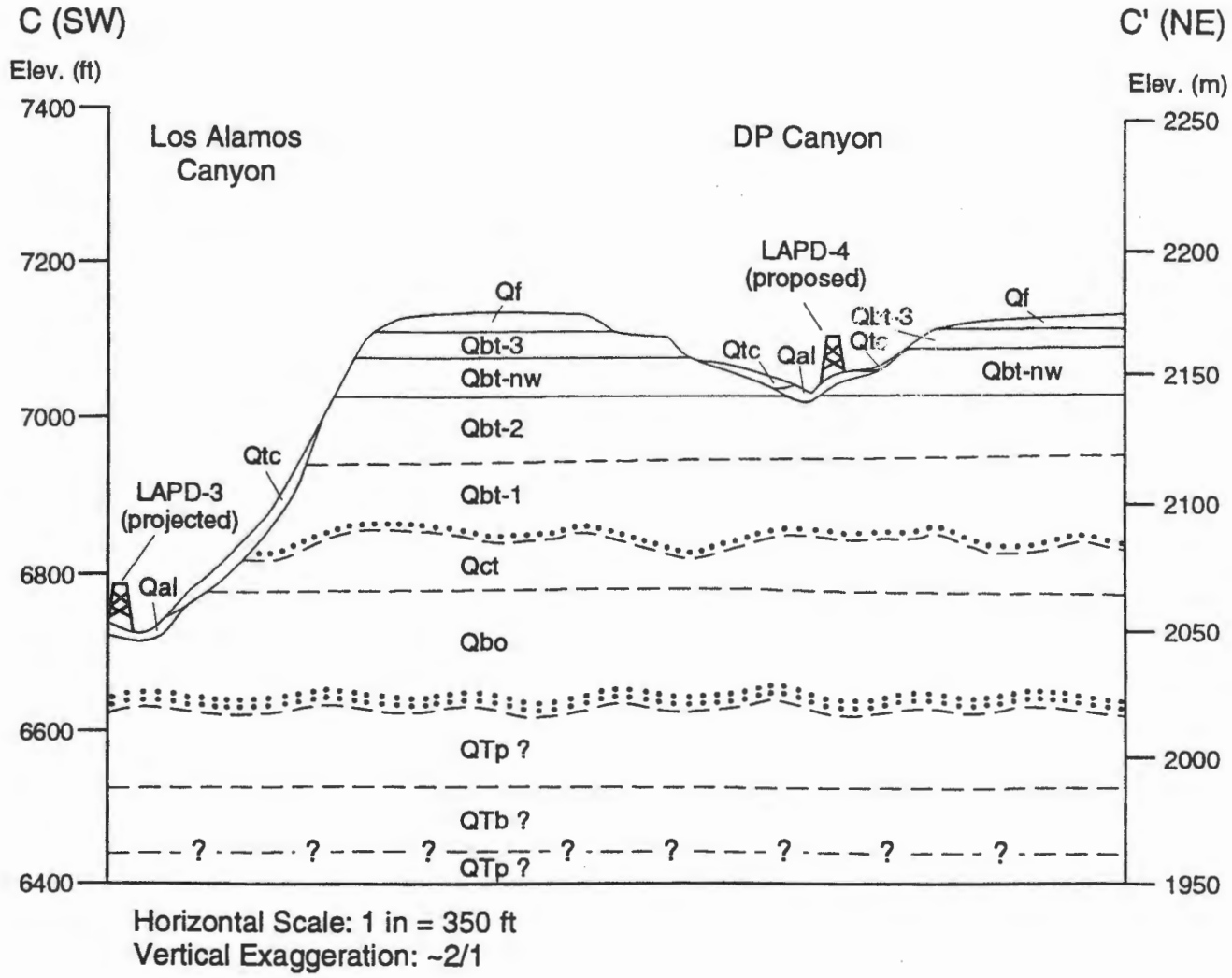

Figure A-4d Cross section C-C' for geologic map of TA-21. Unit abbreviations defined in Fig. A-4a. Line of cross section section shown on geologic map (plate 1) in pocket of this phase report.

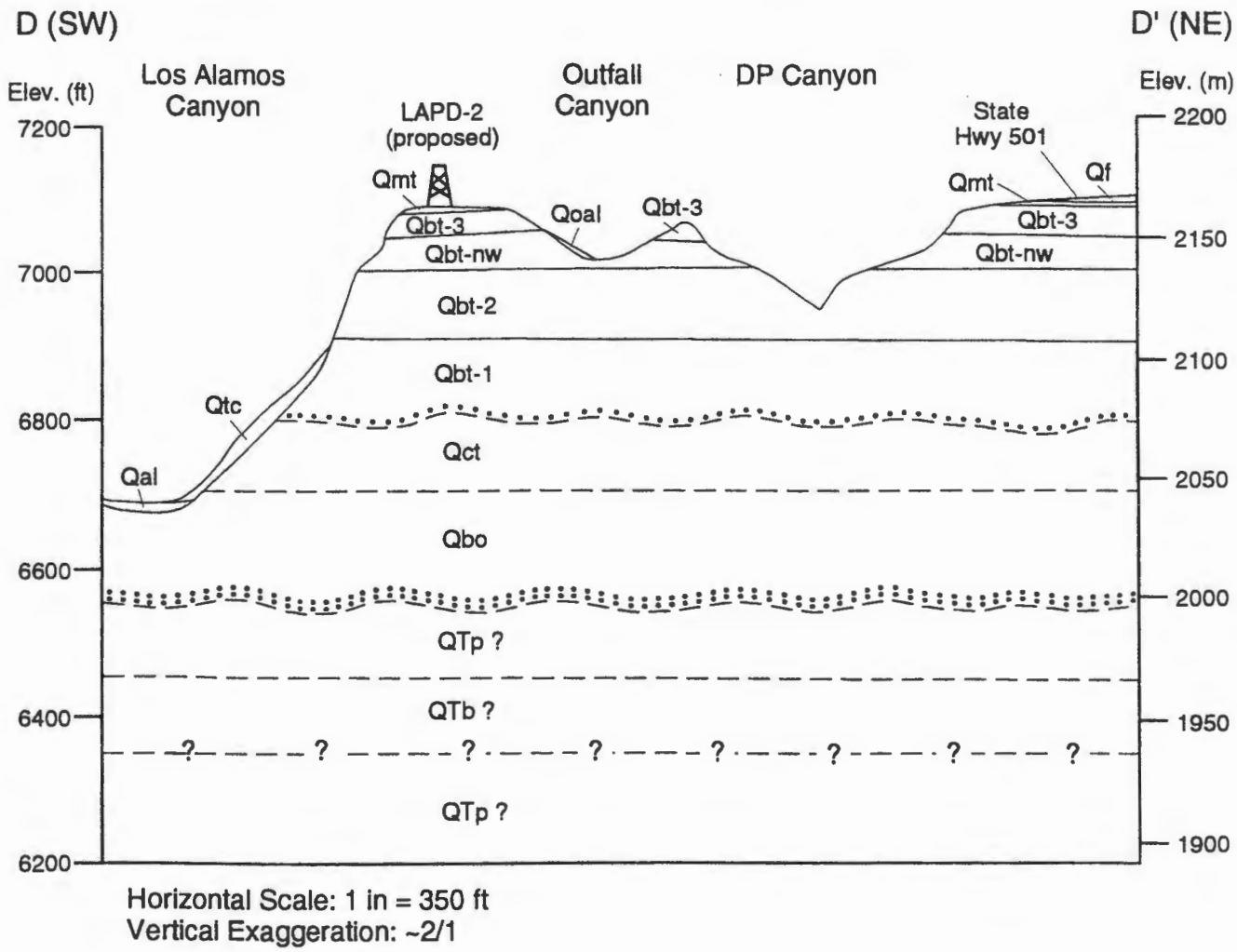

Figure A-4e Cross section D-D' for geologic map of TA-21. Unit abbreviations defined in Fig. A-4a. Line of cross section section shown on geologic map (plate 1) in pocket of this phase report.