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GEOMORPHIC CHARACTERIZATION OF OPERABLE UNIT 1098 (OU-1098), TECHNICAL AREAS 2 AND 41, LOS ALAMOS NATIONAL LABORATORY, NEW MEXICO

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ABSTRACT

A geomorphic characterization of OU-1098 in Los Alamos Canyon was undertaken to identify discrete stratigraphic units within the recent alluvium and colluvium and associated geomorphic surfaces in Los Alamos Canyon. This characterization also identified areas of historic sedimentation and erosion. An additional objective was to identify specific geomorphic surfaces and underlying sediments as sampling locations for potential contaminants which may have been released from Technical Area 2 and Technical Area 41 in Los Alamos Canyon.

Quaternary surfaces Q1 through Q4, from oldest to youngest, were defined based on mapping conducted by Glorieta Geoscience, Inc. during this investigation. Quaternary deposits include alluvium in channels, terrace deposits along the main channel and tributary channels, fan deposits from side drainages, and colluvium and talus along valley side slopes. Sediments underlying Q3 and Q4 surfaces (Qal3 and Qal4) have been deposited concurrent with use of the technical areas in the canyon. Sediments underlying Q2 surfaces have been deposited during the past several hundred years and include some sediments deposited concurrently with development of TA-2 and TA-41. These units represent areas with significant sediment flux, and may therefore represent appropriate sediment sampling locations. Qal4 represents active deposition and is also an appropriate sampling target. Qal1 deposits are likely several thousand years in age and therefore should not be targeted as primary sediment sampling sites. Qal1 deposits may instead provide good sampling targets for evaluating background contaminant levels in LA Canyon.

Los Alamos Canyon is a very dynamic system in terms of sediment transport and deposition. At least two cycles of incision and aggradation followed by a third period of incision have occurred during the Late Holocene, likely during the past several hundred years. Up to 3 feet of sedimentation has occurred at locations within OU-1098 during the past 50 years.

I. INTRODUCTION

Glorieta Geoscience, Inc. (GGI) was retained by ERM Program Management Company (ERM) to conduct a geomorphic characterization of OU-1098 in Los Alamos Canyon (LA Canyon) near Los Alamos, New Mexico. As part of this project GGI has produced a 1:1200 scale geomorphic map of OU-1098. The purpose of this mapping was to identify discrete stratigraphic units within the alluvium and colluvium and associated geomorphic surfaces, and in particular to identify areas of historic sedimentation and erosion. An additional objective was to identify specific geomorphic units and underlying sediments as sampling locations for potential contaminants.

Technical Area 2 (TA-2) and Technical Area 41 (TA-41) are part of OU-1098, which is located in Los Alamos Canyon adjacent to the Los Alamos Townsite (Figure 1). TA-2 is the facility for the Omega West Reactor, which is currently shut down and is planned for decommissioning. TA-41 is a weapons research facility. LA Canyon is bordered by the Los Alamos Townsite to the north and South Mesa to the south (Figure 1), and is incised approximately 350 feet into the Tshirege Member, Bandelier Tuff, Cerro Toledo interval, and Otowi Member, Bandelier Tuff (Figure 2). These units have been mapped downstream in LA Canyon by Goff (1993). Both the Rendija Canyon and Guaje Mountain fault zones have been projected through Los Alamos Canyon within OU-1098 (Figure 1) (Gardner and House, 1987; Vaniman and Wohletz, 1990). Both faults exhibit down to the west displacement, although only the Rendija Canyon fault clearly offsets the Bandalier Tuff within OU-1098.

II. METHODS

The geomorphic characterization of OU-1098 involved a combination of field mapping, airphoto analysis, profiling using a hand level and stadia rod, field soil and stratigraphic descriptions, and analysis of topographic maps and drillers' logs. The entire map area was examined on the ground to define stratigraphic units, examine soils, and to conduct detailed

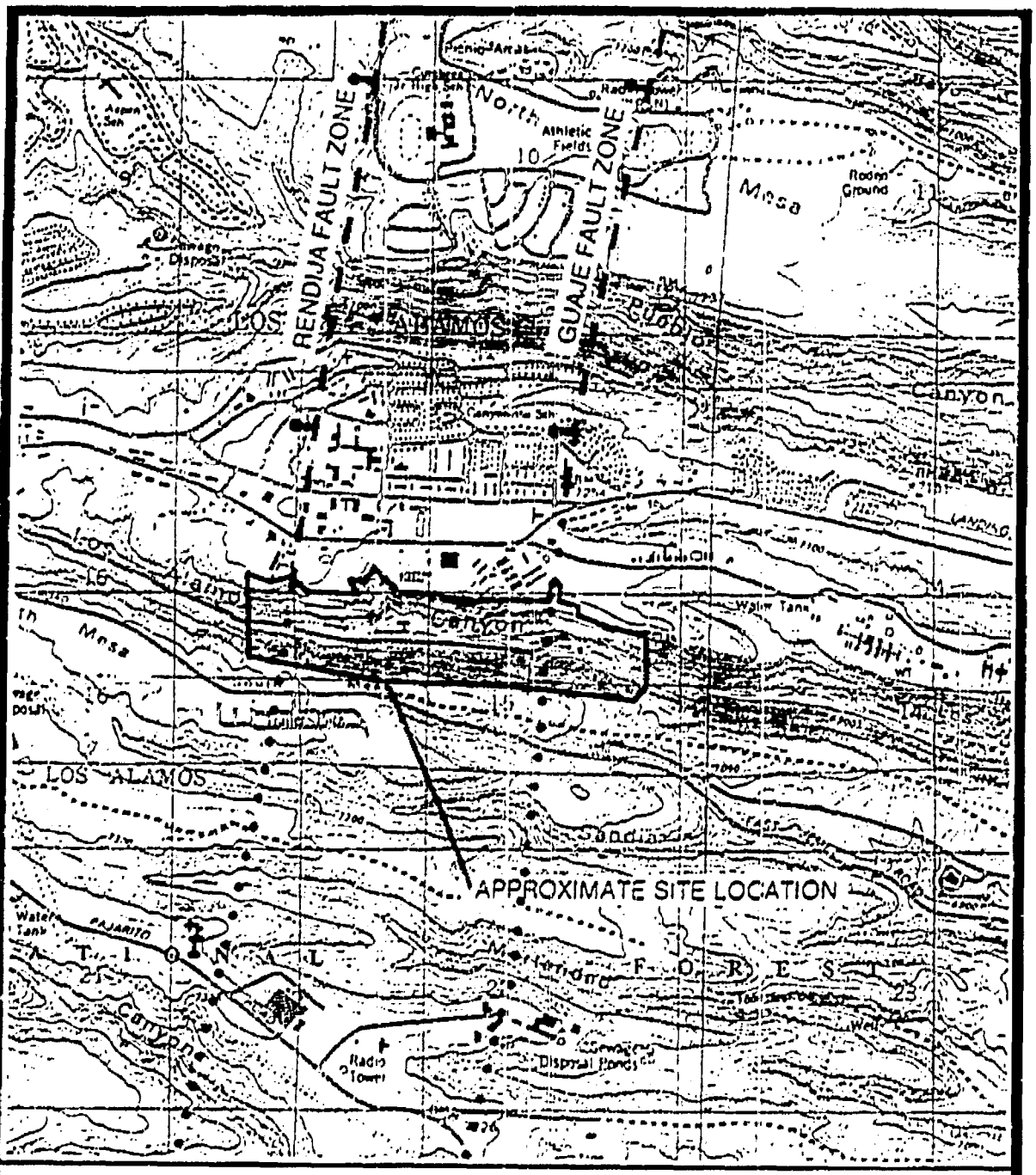

Figure 1. Site Location Map

Job Name: LA Canyon

Location: Los Alamos,N.M.

Scale: 1:24,000

N

Source: USGS 7.5 min. Guaje Mountain and Frijoles, NM Quadrangles

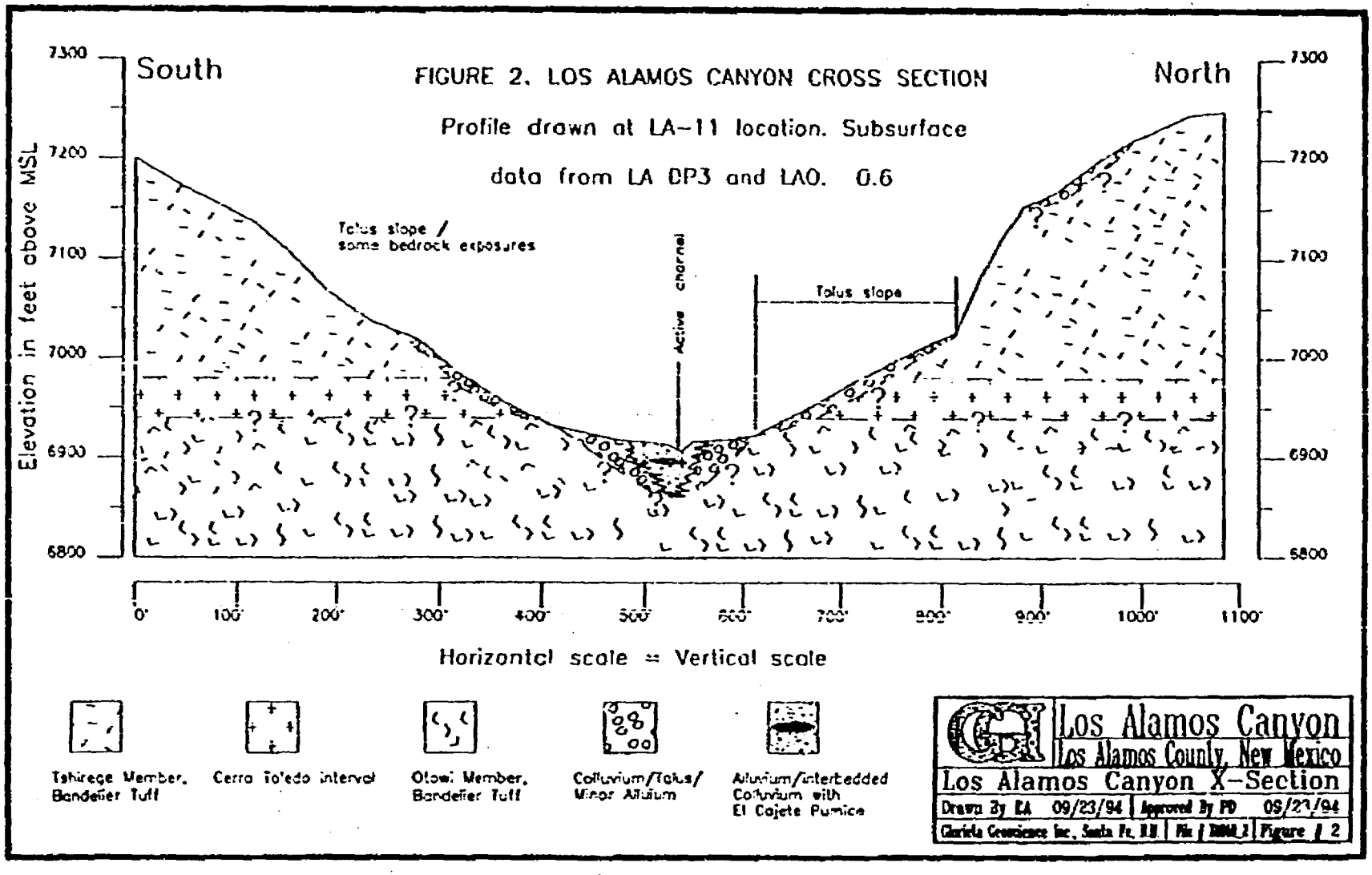

FIGURE 2. LOS ALAMOS CANYON CROSS SECTION

Profile drawn at LA-11 location. Subsurface data from LA DP3 and LAO. 0.6

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mapping of geomorphic units. The entire area was also examined on 1:7200 scale color air photos and 1:1200 scale orthophotos. Features observed on these photos and noted in the field were transferred to 1:1200 scale Facility for Information Management Analysis and Display (FIMAD) two-foot interval contour maps. 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 cliffs of Tshirege tuff. Photographs were taken of soil and stratigraphic exposures.

Separate nomenclature was used for geomorphic surfaces and associated underlying deposits. Geomorphic surfaces were used as mapping units and were designated as Q1 through Q4, from oldest to youngest. Surfaces were further subdivided using "t" for terrace surfaces, "f" for fan surfaces, and "c" for areas of colluvium. Mapping units therefore include designations such as Qt3, for Q3 terrace surfaces, Qf1, for Q1 fan surfaces, and any other appropriate symbol combinations. Underlying alluvium associated with each surface was identified with "Qal" followed by the surface number, e.g. Qal1, Qal2, Qal3, and Qal4.

Natural stream-bank exposures of valley-bottom and valley side-slope sediments were cleared off in preparation for the completion of soil and stratigraphic descriptions. Soils were described using methods described by USDA Soil Survey Staff (1975) and Birkeland (1984) using a hand lens, Munsell soil color charts, 2 millimeter sieve, 10% hydrochloric acid (HCl) and a soil knife. Sediment sampling locations in historic alluvium and associated geomorphic surfaces were identified based on the completed geomorphic mapping of the area.

A series of cross-canyon topographic profiles were measured using a hand level, tape, stadia rod, and clinometer (for measuring slope angles) to depict surface heights above base level and to measure widths of geomorphic surfaces. Profiles were measured approximately perpendicular to the longitudinal stream profile, and were generally measured to the lower talus slopes on either side of the canyon. Topographic profiles provided control for the

precise location of mapping units throughout the canyon. Profiles were plotted using Quattro Pro software and are presented in Appendix A.

III. RESULTS

A. STRATIGRAPHY

LA Canyon is cut into a sequence of the Tshirege Member of the Bandelier Tuff overlying the Cerro Toledo interval and Otowi Member of the Bandelier Tuff. Quaternary valley floor sediments in the vicinity of OU-1098 are inset into the Cerro Toledo Rhyolite and the Otowi Tuff (Figure 2). The Bandelier Tuff ranges in age from 1.2 to 1.6 million years (Ma), based on ^{40}Ar - ^{39}Ar dates for the Tshirege Member (1.2 Ma) and the Otowi Member (1.6 Ma) (Izett and Obradovich, 1994). The Cerro Toledo interval extends from the lower canyon slopes to near the valley floor (a maximum thickness of approximately 50 feet within the map area), where it is underlain by the Otowi Tuff (Figure 2). Based on the lithologic log from boring LADP3, located downstream from OU-1098 below TA-21 (Broxton et al., 1994), the canyon floor is underlain by approximately 60 feet of interbedded colluvium, alluvium, talus, and El Cajete pumice. El Cajete pumice was recorded at a depth of 29 to 31 feet below surface, and likely represents a reworked channel-fill deposit. El Cajete pumice has an estimated age of approximately 60,000 years (Steven Reneau, personnel communication, 1994). These data suggest that the valley inner canyon has experienced net aggradation during the past 60,000 years (60 ka). These valley-fill sediments are underlain by 243 feet of Otowi Member tuff overlying the Guaje Pumice and the Puye Formation at LADP3. Lithologic logs from soil borings for alluvial wells within OU-1098 (LAO - 0.3, 0.6, 0.8, and 0.91) indicate that the canyon floor is underlain by approximately 15 feet of alluvium overlying Tsankawi Pumice or other pyroclastic deposits of the Cerro Toledo interval (lithologic logs provided by ERM), although the pumice interpreted as Cerro Toledo interval may be reworked El Cajete pumice (Dan Katzman, personnel communication, 1994; also see Figure 2). The presence of El Cajete pumice buried by valley floor sediments at the alluvial well locations is consistent with the lithologic log from

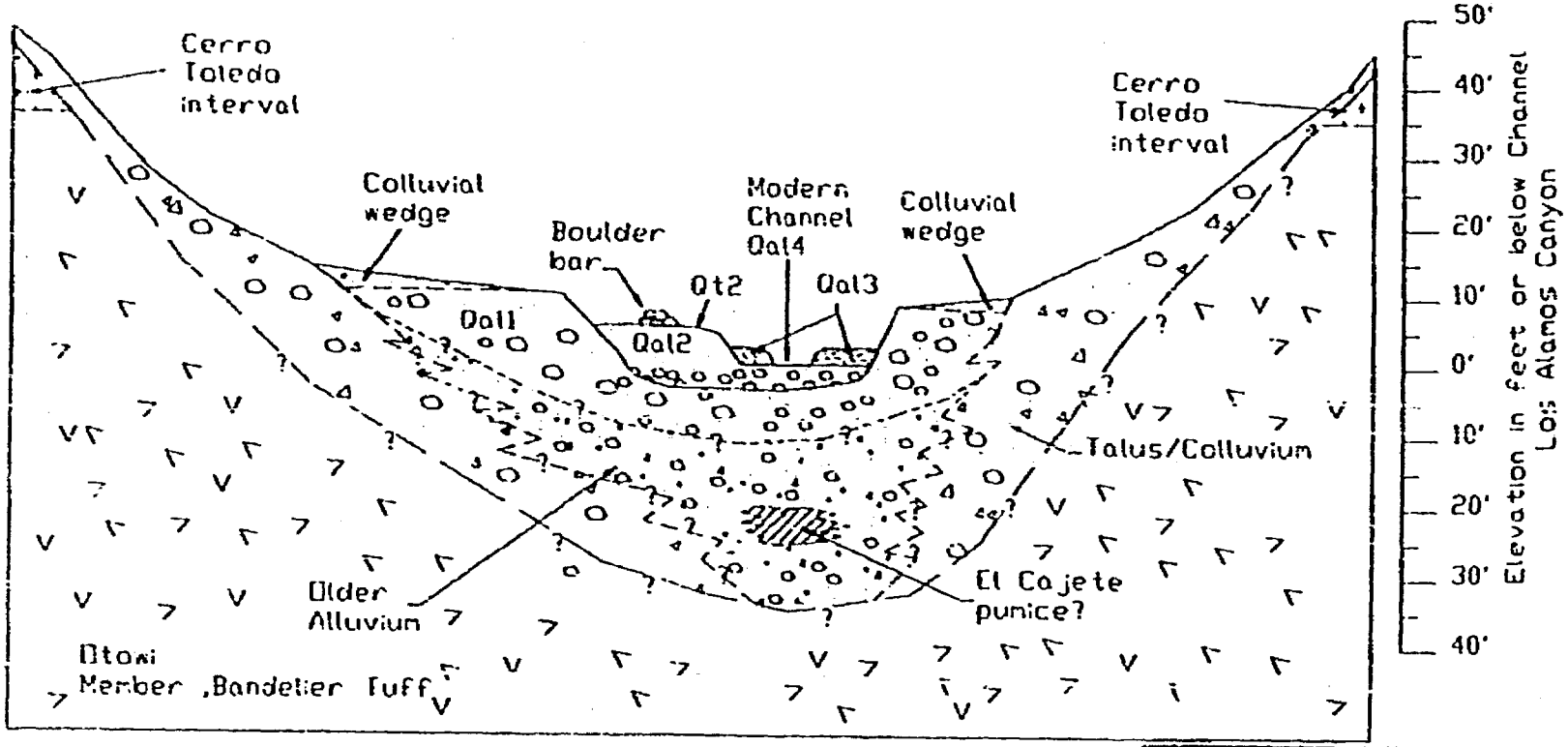
LADP3, and may indicate a greater thickness of alluvium at LAO well locations 0.3, 0.6, 0.8, and 0.91. The lithologic log from LAO-B, located near the western end of OU-1098, also shows 27.5 feet of sediment to the total depth of the boring, and gives a minimum thickness for the valley fill sediments at that location.

The primary landforms in the canyon are: (1) steep cliffs developed in the Tshirege Member of the Bandelier Tuff; (2) 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, Bandelier tuff, and; 3) a narrow, relatively flat valley floor (Figure 2). The valley floor can be subdivided into two sections consisting of: (a) laterally-restricted areas of colluvial deposition at the base of talus slopes and low angle valley floor side slopes underlain by colluvium, and; (b) a fairly narrow inner canyon consisting of the modern channel flanked by one to three stepped terrace surfaces. Several small landslide blocks (Qls) were observed at the base of steep side slopes (Plate 1).

Quaternary sediments are subdivided into deposits underlying surfaces Q1 through Q4, from oldest to youngest (Table 1). A schematic profile and a measured profile of the inner canyon surfaces and of the valley floor and lower talus slopes are shown in Figures 3a and 3b. Quaternary deposits include alluvium in channels, terrace deposits along the main drainage and tributary drainages, fan deposits from side drainages, and colluvium and talus along valley side slopes (Table 1; Figure 3).

Qt1 sediments consist primarily of fluvial terrace deposits near the valley floor and colluvium underlying valley side slopes (see Plate 1). Qc1 colluvium is generally graded to partially buried Qt1 terrace surfaces. Qt1 terrace deposits are a minimum of 5 feet thick at location LA-17 and a minimum of approximately 8 feet thick at location LA-21 and are overlain by one or more feet of colluvium in most locations (Figure 4). Qt1 terrace deposits are generally coarse-grained, comprising weakly-imbricated cobbly gravel (e.g. LA-17) which may overlie a fining-upward sequence from gravel to fine sand (e.g. LA-21 location). Charcoal was observed in fine-grained sediments at a depth of 2.5 feet in a burned layer or

FIGURE 3A DIAGRAM OF INNER CANYON SEDIMENT AND SURFACES, LOS ALAMOS CANYON



LA Canyon
Los Alamos County, New Mexico
Diagram of Inner Canyon Sediment & Surfaces
Drawn By EA 10/31/94 | Approved By FD 10/31/94
Glorieta Geoscience Inc., Santa Fe, N.M. | File | Figure 3A

GLORIETA GEOSCIENCE, INC.

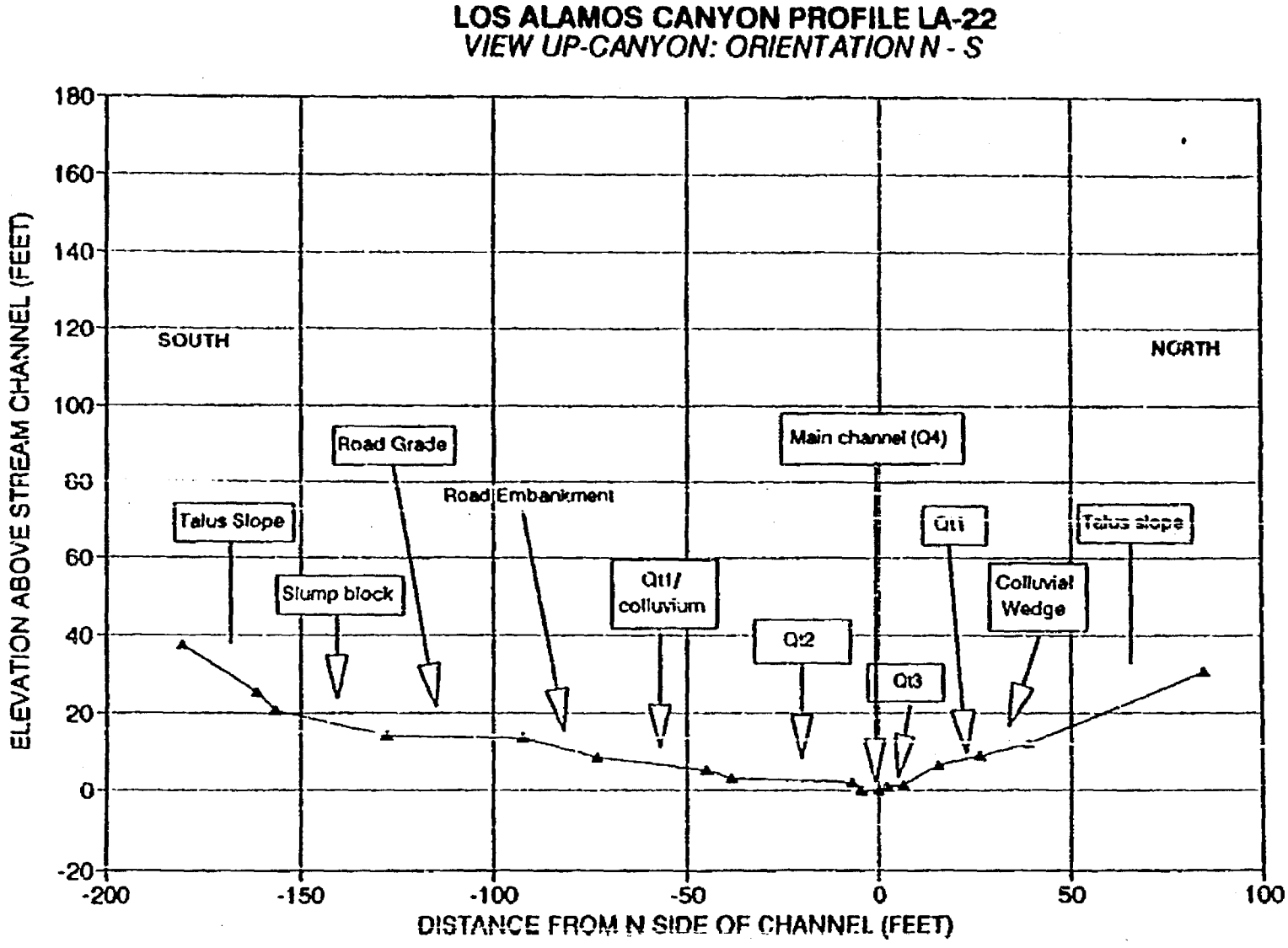


Figure 3b. Los Alamos Canyon cross-profile LA-22, showing Los Alamos Canyon geomorphic surfaces.

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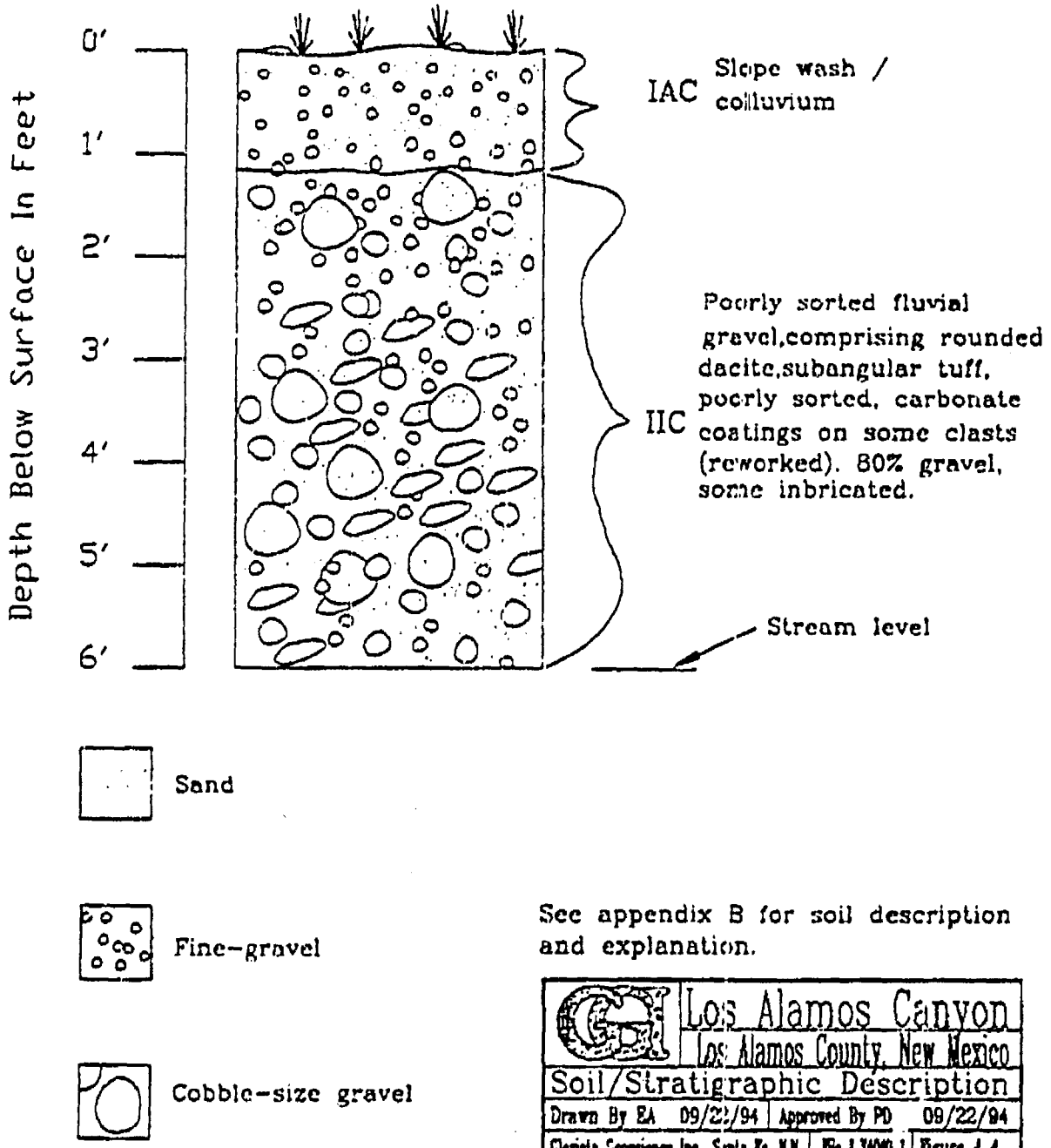
Table 1. Summary of Los Alamos Canyon Holocene Stratigraphy

UNIT	GEOMORPHIC SURFACES/ TYPE OF DEPOSIT	SURFACE HEIGHT*	AGE	BASIS FOR AGE ESTIMATE
Q4	Qa4 - Active channel (including main drainage and active point bar deposits), active alluvial fan and tributary drainage deposits. Qf4 - Active fan and side slope deposits	0	Modern	Evidence for active transport (flowing water in channel, pine needle mounds, fresh sedimentation or incision, etc.), deposits composed primarily of rounded quartzite and granite pebbles.
Q3	Qt3 - Historic terrace deposits and vegetated point bar deposits Qc3 - Historic colluvial deposition at the base of steep side slopes	1 to 3 feet	Less than 50 years	Presence of rounded quartzite and granite pebbles in Qal3 deposits, presence of recent flood debris, burial of tires, concrete, culverts, and other historic artifacts; lack of soil development.
Q2	Qt2 - Young terrace deposits Qb2 - Boulder bar deposits on Q2 surfaces	2 to 6 feet	Historic to several hundred years	Few rounded quartzite pebbles present in isolated locations in Qal2 deposits, preservation of bar and swale topography, presence of large trees on some surfaces, lack of soil development.
Q1	Qt1 - Older terrace deposits Qc1 - Older alluvial terrace deposits overlain by colluvium grading into valley side slope colluvial deposits	6 to 14 feet	Holocene (less than 10 ka)	Incipient soil development; stratigraphic position relative to Qal2; deposits lack historic artifacts.

* Terrace or fan height above local base level

FIGURE 4. SOIL/STRATIGRAPHIC DECRIPTION FROM STREAM CUT INTO CLI AT LA-17



See appendix B for soil description and explanation.

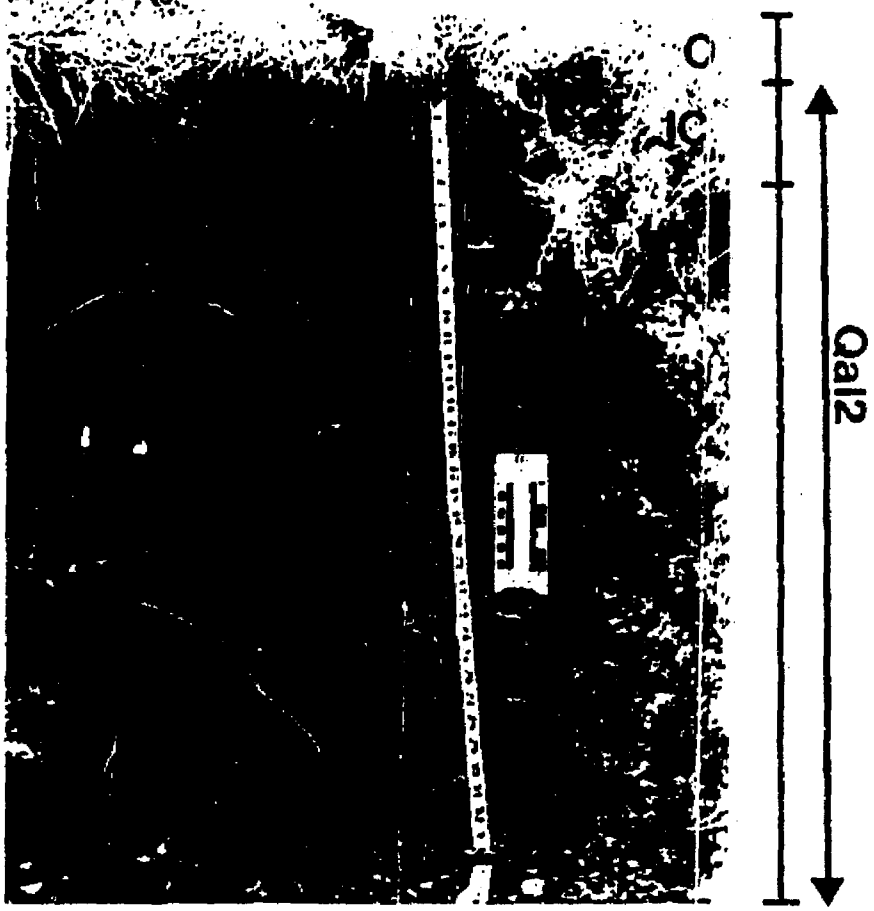
Los Alamos Canyon Los Alamos County, New Mexico		
Soil/Stratigraphic Description		
Drawn By EA 09/22/94	Approved By PD	09/22/94
Glorieta Geoscience Inc., Santa Fe, N.M.	File # 34040.1	Figure # 4

buried soil horizon below a cobble layer at LA-22. Qt1 terrace surfaces are located 6 to 14 feet above local base level and may include some truncated Qf1 fan surfaces (Figure 3; Table 1).

Qt2 sediments (Qal2) consist of terrace deposits at or near the valley floor. Qal2 is greater than 2.5 feet thick and typically consists of sandy, massive to weakly imbricated medium to coarse pebble-size gravel, fining upwards at some locations to gravelly sand (Figure 5). Isolated rounded quartzite pebbles are observed in some locations within Qal2. Black scoria up to 0.5" (b-axis or median diameter) are buried approximately 2.8 feet below the surface within Qal2 near the LA-1 profile location. The origin of these scoria fragments is unknown, but they are probably historic as there is no known source in the bedrock canyon. Some Qal2 deposits have a darkened surface horizon approximately 1 foot thick containing minor clay or silt which either represents a fining upward sequence or an AC horizon. Q2 terrace surfaces are located 2 to 6 feet above local base level (Table 1; also see Appendix A).

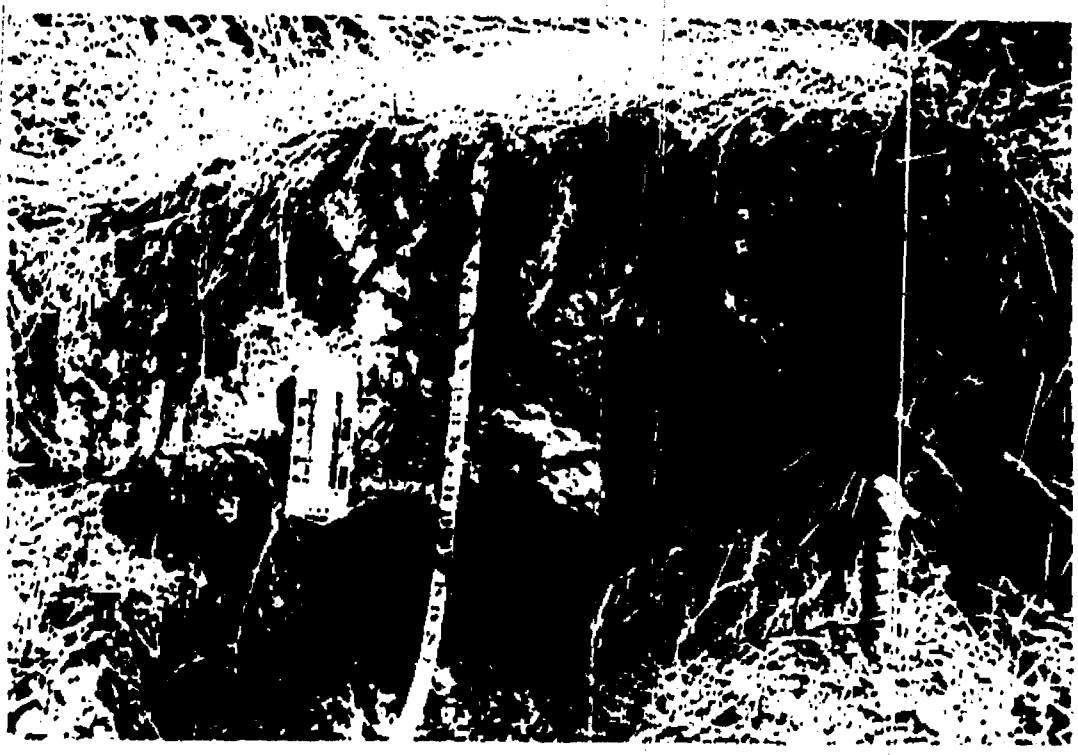
Qal3 sediments consist of terrace deposits along the main drainage and tributary streams, and colluvial deposits at the base of steep valley side slopes (Plate 1). Qal3 sediments are 1 to 3 feet thick and include buried pine needles, quartzite and granite pebbles, tires, concrete fragments, and a variety of other man-made materials which post-date the initial development of TA-2 and TA-41. Terrace deposits generally consist of medium sand overlying a coarse-grained gravel lag deposit (Figure 6), and include fining upward or massive sandy deposits. Qal3 typically overlies Qal2 sediments (Figure 6), where it may represent a strath terrace deposit.

Gravel composition in Qal1, Qal2, and Qal3 deposits consists primarily of pumice, subrounded to rounded Tschicoma dacite, and subangular to subrounded tuff. Rounded quartzite and granite pebbles occur rarely in Qal2 and commonly in Qal3. Qa4 deposits in the main channel and in tributary drainages contain a relatively greater proportion of rounded quartzite and granite pebbles reworked from the roadbed materials in LA Canyon or from the townsite above the canyon. Blocks of cemented aggregate are common both



O: Organic Matter
IC: Sandy, fine gravel
IIC: Fining upwards sequence of gravel to medium sand

Figure 5. Photograph showing stratigraphic and soil horizons of Qal2



* Medium sand with minor clay; gravel lag at base of deposit
**Fluvial, sandy gravel

Figure 6. Photograph showing stratigraphy and soil horizons in Qal3

in the main drainage and in tributary channels into LA Canyon.

B. SOILS

Soils developed in Qal1 through Qal4 in LA Canyon exhibit little or no pedogenic alteration with a maximum profile thickness of 1.1 feet (Table 2). Qal3 and Qal4 may, however, be distinguished from Qal1 based on soil development. Qal3 and Qal4 sediments exhibited no pedogenic alteration; no carbonate accumulation, soil structure development, or horizonation was observed (Table 2; Appendix B). By comparison, soils developed in Qal1 have a slightly darkened surface horizon (10YR4/2 dry color) which was designated as an AC horizon (Table 2; Appendix B). The AC horizon as defined for this report represents a surficial soil horizon which is slightly darkened, yet soil structure and other soil characteristics are absent or poorly developed so that it is transitional between an A and a C horizon. The AC horizon is 0.6 to 1.2 feet thick and has weak subangular blocky or granular structure. Most Qal2 soils exhibited no pedogenic alteration and could not be distinguished from Qal3 soils; however, one Qal2 profile (LA-23) exhibited a 1.1 feet thick AC horizon similar to that observed in Qal1 deposits. Qal2 deposits therefore cannot be distinguished from other deposits in the canyon based on soil development. All soils described in Los Alamos Canyon were non-calcic, with the exception of the discontinuous coatings on some reworked clasts in the LA-17 profile from Qal1 (Table 2; Appendix B).

C. ESTIMATED AGE OF DEPOSITS

The estimated ages of Qal1 through Qal4 are based on the presence of cultural materials which post-date the initial development of TA-2 and TA-41, relative soil development, stratigraphic relationships, and comparison with Quaternary deposits in adjacent DP Canyon at Technical Area 21 which have been radiogenically dated. Based on the estimated ages of sediments in Los Alamos Canyon, overall aggradation has occurred since the Late Pleistocene, and periodic erosion and deposition have occurred during the late Holocene. The presence of El Cajete pumice at a depth of approximately 30 feet and a total thickness

Table 2. Summary of Soil Characteristics for Los Alamos Canyon Deposits.

UNIT	DEPOSIT	PROFILE	AC HORIZON THICKNESS	CARBONATE	CLAY FILMS	COLOR/ MAXIMUM DARKENING (DRY)	STRUCTURE	AGE
Q4	Qal4	--	--	--	none	--	--	Modern
Q3	Qal3	IC IIC	0	none observed	none	10YR5/3	massive to weak sub-angular blocky	Less than 50 years
Q2	Qal2	IC or AC IIC C; O horizon sometimes present	0 to 1.1 feet	none observed	none	10YR5/2; O horizon is 10YR3/2	massive to weak subangular blocky	Less than 50 years to hundred years (trees greater than 12" dia.)
Q1	Qal1	AC C	0.6 to 1.2 feet	none observed in matrix, some carbonate coatings on clasts, (likely reworked)	none	10YR4/2	weak medium subangular blocky	Holocene (Less than 10 ka)

of valley fill sediments of approximately 60 feet at LADP3 (Broxton et. al., 1994) indicates that Los Alamos Canyon has aggraded during the latest Pleistocene and Holocene (e.g. during the past 60 ka) at that location. If El Cajete pumice is also present in the alluvial borings recently completed in LA Canyon within OU-1098, it is apparent that LA Canyon has also experienced net aggradation during the past 60,000 years throughout OU-1098. Based on the age estimates developed during this investigation, Pleistocene-age surfaces are not preserved in Los Alamos Canyon within OU-1098 and are likely buried by younger alluvium.

Unit Qal4 shows evidence for active transport which includes sediment mounds behind obstructions, buried vegetation, evidence of scouring, absence of or sparse vegetation, and flowing water in the main channel. In comparison, Q3 surfaces have been stable for a sufficient length of time to become vegetated with small trees, shrubs, and grasses. Qal3 deposits partially bury trees and contain buried pine needles, quartzite and granite pebbles, tires, concrete fragments, and a variety of other cultural materials buried below Q3 surfaces. These materials date from the time period between the early 1940's and the present during which TA-2 and TA-41 have been in use. Qal3 deposits are therefore less than 50 years old. Q3 surfaces also show evidence of recent flood deposits, including grass mats, mud, and cultural materials such as plastic bags suspended in trees above the height of Q3 surfaces and deposited on Q3. Qal3 is similar to the Qal3 deposit in Bayo Canyon, which is also less than 50 years in age (Drake and Inoue, 1993).

Qal2 deposits contain historic materials (rounded quartzite pebbles) in some locations (primarily in the area just west of TA-41), but appear to be devoid of historic artifacts in OU-1098 east of TA-41. Some Q2 surfaces, particularly in the area east of TA-2, support a growth of large (greater than 12 inch-diameter) Douglas Fir (*Pseudotsugas menziessi*) and Ponderosa Pine (*Pinus ponderosa*), suggesting a minimum age of several hundred years for Qal2 east of TA-2. Qal2 deposition may be time-transgressive in LA Canyon, and may represent cutting and filling to the Q2 surface elevation over a time period of several hundred years. Q2 surfaces in LA Canyon may therefore range in age from approximately

50 to several hundred years in age.

Age estimates for Qal1 are based on lack of cultural materials in Qal1 and relative soil development. Qal1 deposits do not contain historic materials and are therefore greater than 50 years old. Based on soil development and comparison with dated deposits in DP Canyon, Qal1 is Holocene rather than Pleistocene in age. In DP canyon, two Late Pleistocene deposits yielded stratigraphically consistent radiocarbon ages of 26.7 ka and 21.6 ka (Reneau, 1993). Both of these units are somewhat indurated clay-rich deposits which are apparently much older than the relatively loose Qal1 deposits. A slopewash deposit graded to a level approximately three feet above base level in DP canyon was deposited between 5.4 and 2.0 ka in DP Canyon (Reneau, 1993). The lack of soil development in this deposit and height of this surface above base level suggest that the 5.4 to 2 ka DP Canyon slopewash surface may be similar or slightly younger in age than Qal1.

The very weakly developed Los Alamos Canyon Q1 soils which lack B horizons (clay films are absent, soil structure is weakly developed or absent, no reddening was observed) and exhibit very little or no accumulation of pedogenic carbonate also indicate that Qal1 deposits are likely Holocene in age. Soils developed in Holocene alluvial deposits throughout the southwestern United States typically exhibit Stage I carbonate morphology (Machette, 1985). Although developed in sediments which differ lithologically from the LA Canyon deposits, soils described in the Española Basin and Galisteo Basin for which some age control is available also provide some basis for comparison. Soils developed in Holocene deposits in the Española basin exhibit stage I to II carbonate horizons, and soils developed in Late Pleistocene deposits exhibit Stage III carbonate horizons (Dethier et al., 1988; terminology after Gile et al., 1966). Soils developed in a deposit which buries a mammoth tusk located in the Galisteo Basin southwest of Galisteo at an elevation of approximately 6400 feet is late Pleistocene age (between 10,000 and 100,000 years old), exhibits a Stage II-III carbonate morphology and a well developed Bt horizon (Glorieta Geoscience, Inc., unpublished data). Based on the lack of B horizon, absence of a well-developed A horizon, or development of carbonate morphology, and based on comparison with the DP Canyon "slope wash" surface

(5.4 to 2 ka). Qal1 is likely Holocene in age (10 ka or less).

D. AREAL EXTENT OF SURFACES

With the exception of wider canyon floor areas occupied by TA-2 and TA-41, the LA Canyon bottom area occupied by Holocene surfaces Q1 through Q4 is approximately 200 feet wide. The road through the bottom of the canyon and construction associated with the technical areas occupies a portion of this area and has been mapped as "Disturbed" (see Plate 1). The remaining area covered by Q1-Q4 surfaces represents a narrow strip along the canyon bottom 50 to 200 feet wide between 10°-30° talus slopes and/or road bed construction (Plate 1; also see Appendix A). The majority of this narrow strip is occupied by Qt2 and Qt3 surfaces flanking the active channel (Qa4). Some isolated Qc3 deposits overlie Q2 surfaces or overlie older side slope and talus deposits. Unit Qa4 also includes active fan surfaces and drainages which typically head on the north side of the canyon or which head in disturbed areas on the south side of LA Canyon (Plate 1). Qa4 surfaces are superimposed on Q1, Q2, and Q3 surfaces (i.e. Qal4 fan deposits overlie the older historic and Holocene deposits in the canyon). Qt1 surfaces are preserved as narrow surfaces at the base of talus and valley side slopes, and are often buried by colluvium or talus. Qc1 surfaces are valley side slopes graded to Qt1 which are best exposed near the east end of OU-1098.

The terrace sequence within OU-1098 is best defined in the area between TA-41 and the eastern boundary of the Operable Unit. West of TA-41, a single low terrace is present between the modern channel and Q1 or valley side slopes. This surface was mapped as Q2, based on the presence of isolated, very narrow (less than five feet across) low, vegetated inset fill deposits and associated surfaces between the modern channel and Q2 surfaces (see profiles LA-20 and LA-22).

In addition to Q1 through Q4 surfaces, boulder bar deposits (Qb2) and slump blocks or partially detached landslide blocks were also mapped in LA Canyon. Unit Qb2 occurs as two isolated units, located near the east and west boundary of OU-1098 (Plate 1). Deposits

underlying Qb2 overlie Qt2 and consist of coarse gravel between 0.5 and 1 foot in diameter. Qb2 deposits likely represent the gravel lag deposited as a longitudinal bar from a single high-discharge flood event between the time of Qal2 and Qal3 deposition.

Several partially detached landslide blocks were mapped near the western end of OU-1098 (Plate 1). Several fresh scarps, 2 to 5 feet high, were observed at the top of the slump blocks. These small slump blocks are located above the road cut for the paved road through the canyon and have likely been caused by undermining of the slope by the road cut and by runoff which has been concentrated between the road and the talus slope.

E. STREAM FLOW

The main channel in LA Canyon is intermittent in nature during a significant portion of the year. Additional information regarding the nature of the interrelation between surface and shallow groundwater in the canyon could be obtained by installing stream gauges and piezometers along the main channel.

F. CONCENTRATION OF DEBRIS IN EMBAYMENT ADJACENT TO TOWNSITE

A concentration of debris from the Los Alamos Townsite was mapped in the embayed area above TA-41 (Plate 1). Debris appears to have been dumped over the canyon wall, and includes tires, broken glass, sheet metal, and concrete vaults which may be old septic tanks. Other areas which lie directly below the Townsite may also have concentrations of this type of debris but were not examined on the ground during this phase of mapping.

IV. DISCUSSION

A. SUGGESTED SAMPLING LOCATIONS

Any contaminants which may have been generated from TA-2 and TA-41 would likely occur within Qal3 and possibly Qal2, since these units have been deposited during the development of the Technical Areas in the canyon. The associated Q3 and Q2 surfaces also represent locations with sediment flux occurring at present. Q3, Q2, and associated underlying alluvium Qal3 and Qal2 should therefore be the primary sediment sampling targets for an evaluation of possible soil contamination in LA Canyon. Qal4 represents active deposition and is also an appropriate sampling target. Suggested sampling depths for Qal3 and Qal2 range from 0.5 to 3.0 feet below the ground surface, depending on the thickness of the deposit. Suggested sampling depths for sediments underling Q4 surfaces are 0 to 2.0 feet below the ground surface. Qal3 and Qal4 sediments located in the embayed area below the Townsite are also appropriate sediment sampling targets. Qal1 deposits are likely several thousand years in age and therefore should not be targeted as primary sediment sampling sites. Qal1 deposits may instead provide good sampling targets for evaluating background contaminant levels in LA Canyon.

B. RECENT GEOLOGIC HISTORY OF LOS ALAMOS CANYON

Incision of Los Alamos Canyon began sometime after deposition of the Bandelier Tuff (Tshirege Member) at 1.2 Ma. Evolution of the LA Canyon system was likely characterized by alternating incision and aggradation throughout the Pleistocene; however, net incision of the system occurred until approximately 60 ka (e.g. the latest Pleistocene), at which time the Canyon had incised to a depth between 30 and 60 feet below the level of the present valley floor. Subsequent to this period of net incision, Los Alamos Canyon has experienced net aggradation during the latest Pleistocene and Holocene, based on burial of reworked El Cajete pumice with an estimated age of 60 ka at a depth of 15 to 30 feet. Periods of incision likely occurred during this time period as well. It is possible that the timing for

aggradation of the valley floor is later than 60 ka, if El Cajete pumice was reworked and deposited in the canyon at a later time. No record of Pleistocene deposition or preservation of Pleistocene surfaces above the valley floor has, however, been identified in the vicinity of OU-1098. Any Pleistocene sedimentary deposits in the project area either have been eroded and transported downstream or are buried by Holocene sediments.

The Holocene sedimentary record indicates that multiple periods of erosion and deposition have occurred throughout the Holocene. The base of Qal1 has not been observed during this field investigation; it is therefore unknown if older alluvium or bedrock underlies Qal1 in LA Canyon within OU-1098. The presence of Qt2 and Qt3 surfaces and underlying deposits along the main drainage indicates that at least two cycles of incision and aggradation followed by a third period of incision have occurred during the past several hundred years, with the deposition of 0.5 to 3 feet of sediment since development started in Los Alamos Canyon. In areas where Qal2 is an historic deposit, these periods of incision and aggredation have occurred during the past 50 years.

The multiple episodes of recent erosion and deposition, lack of a sedimentary record of Pleistocene deposits in the area, and the presence of up to 3 feet of historic sediment indicate that the Los Alamos Canyon drainage network is a very dynamic system. Sediment is apparently cycled through Los Alamos Canyon on a time scale of 10^1 to 10^3 years, and sediments predating the Holocene have either been stripped and reworked, transported downstream, or buried beneath younger sediments.

V. CONCLUSIONS

Incision of Los Alamos Canyon began sometime after deposition of the Bandelier Tuff (Tshirege Member) at 1.2 Ma. Evolution of the LA Canyon system was likely characterized by alternating incision and aggradation throughout the the Pleistocene; however, net incision of the system occurred until the latest Pleistocene (at approximately 60 ka), at which time the Canyon had incised to a depth between 30 and 60 feet below the level of the present valley floor. Los Alamos Canyon has subsequently experienced net aggradation during the latest Pleistocene and Holocene (during the past 60 ka), although this time period was also likely characterized by alternating periods of incision and aggradation. The Holocene sedimentary record indicates that multiple periods of erosion and deposition have occurred throughout the Holocene.

Los Alamos Canyon is a very dynamic system in terms of sediment transport and deposition. At least two cycles of incision and aggredation followed by a third period of incision have occurred during the past several hundred years, with the deposition of 0.5 to 3 feet of sediment along the trunk stream since development started in Los Alamos Canyon.

Qal3 and possibly Qal2 have been deposited during the development of the technical areas in the canyon. Therefore, these units represent appropriate sediment sampling targets to identify potential contamination associated with usage of the technical areas. Qal4 represents active deposition and is also an appropriate sampling target. Qal1 deposits are likely several thousand years in age and therefore should not be targeted as primary sediment sampling sites. Qal1 deposits may instead provide good sampling targets for evaluating background contaminant levels in LA Canyon.

Soils developed in Qal1 through Qal4 in Los Alamos Canyon exhibit little or no pedogenic alteration with a maximum profile thickness of 1.2 feet (Table 2). Qal1 may be differentiated from Qal3 and Qal4 based the presence of a slightly darkened AC horizon with weakly developed soil structure in Qal1 deposits (Table 2). Qal2 soils exhibit

characteristics of both Qal3 and Qal1 soils, and therefore cannot be used to distinguish Qal2 deposits from other units identified in LA Canyon. Geomorphic surfaces in Los Alamos Canyon are underlain by deposits which are likely Holocene in age and include two surfaces that are several hundred years old or younger (Table 1). Terrace surfaces are located within 15 feet of modern base level, indicating that the trunk drainage in Los Alamos Canyon has been near its present base level during the multiple cycles of erosion and deposition that have occurred since the Mid-Holocene.

No age control is presently available for Qal1. Since charcoal has been observed buried within Qal1 at 2.5 feet below the surface at LA - 21, GGI recommends returning to this location to collect a sample for C^{14} analysis. A detailed soil and stratigraphic description should also be completed when the charcoal sample is collected. This will provide age control both for Qal1 and for the incipiently developed Qal1 soil.

VI. REFERENCES CITED

Birkeland, P.W., 1984, Soils and Geomorphology. Oxford University Press, New York, 372 p.

Broxton, D.E., Longmire, P.A., Eller, P.G., and Flores, D., 1994, Preliminary results for boreholes LADP-3 and LADP-4 at Technical Area 21, Los Alamos National Laboratory, New Mexico, Geologic Studies at TA-21: LANL Internal Report, 17 p.

Dethier, D.P., Harrington, C.D., and Aldrich, M.J., 1988, Late Cenozoic rates of erosion in the western Española basin, New Mexico: Evidence from geologic dating of erosion surfaces: GSA Bulletin, Vol. 100, no. 6, p. 928-937.

Drake, P., and Inoue, C., 1993, Geomorphic characterization of operable unit 1079 (OU-079), Formerly Technical Area 10, Los Alamos National Laboratory, New Mexico: Unpublished consulting report to Los Alamos National Laboratory, 28 p. plus appendices.

Gardner, J.N., and House, L., 1987, Seismic hazards investigations at Los Alamos National Laboratory, 1984 to 1985: LANL Report LA-11072-MS, 76 p. plus plates.

Gile, L.H., Peterson, F.F., and Grossman, R.B., 1966, Morphological and genetic sequences of carbonate accumulation in desert soils: Soil Science, v. 101, p. 347-360.

Goff, F., 1993, Geologic map of TA-21, Los Alamos National Laboratory, New Mexico: TA-21 OU RFI Phase Report, Appendix A, p. A-1 - A-18.

Izett, G.A., and Obradovich, J.D., $^{40}Ar/^{39}Ar$ age constraints for the Jaramillo Normal Subchron and the Matuyama-Brunhes geomagnetic boundary: Journal of Geophysical Research, Vol. 99, no. B2, p. 2925-2934.

Machette, M.N., 1985, Calcic Soils of the Southwestern United States, in Weide, D.L., ed., Soils and Quaternary Geology of the Southwestern United States, GSA Special Paper 203, p. 1-22.

Reneau, S.L., 1993, Geomorphic characterization of Technical Area 21, Los Alamos National Laboratory, New Mexico: LANL Report LAUR 93-2028, TA-21 OU RFI Phase Report 1A, Appendix D, p. D1 - D41.

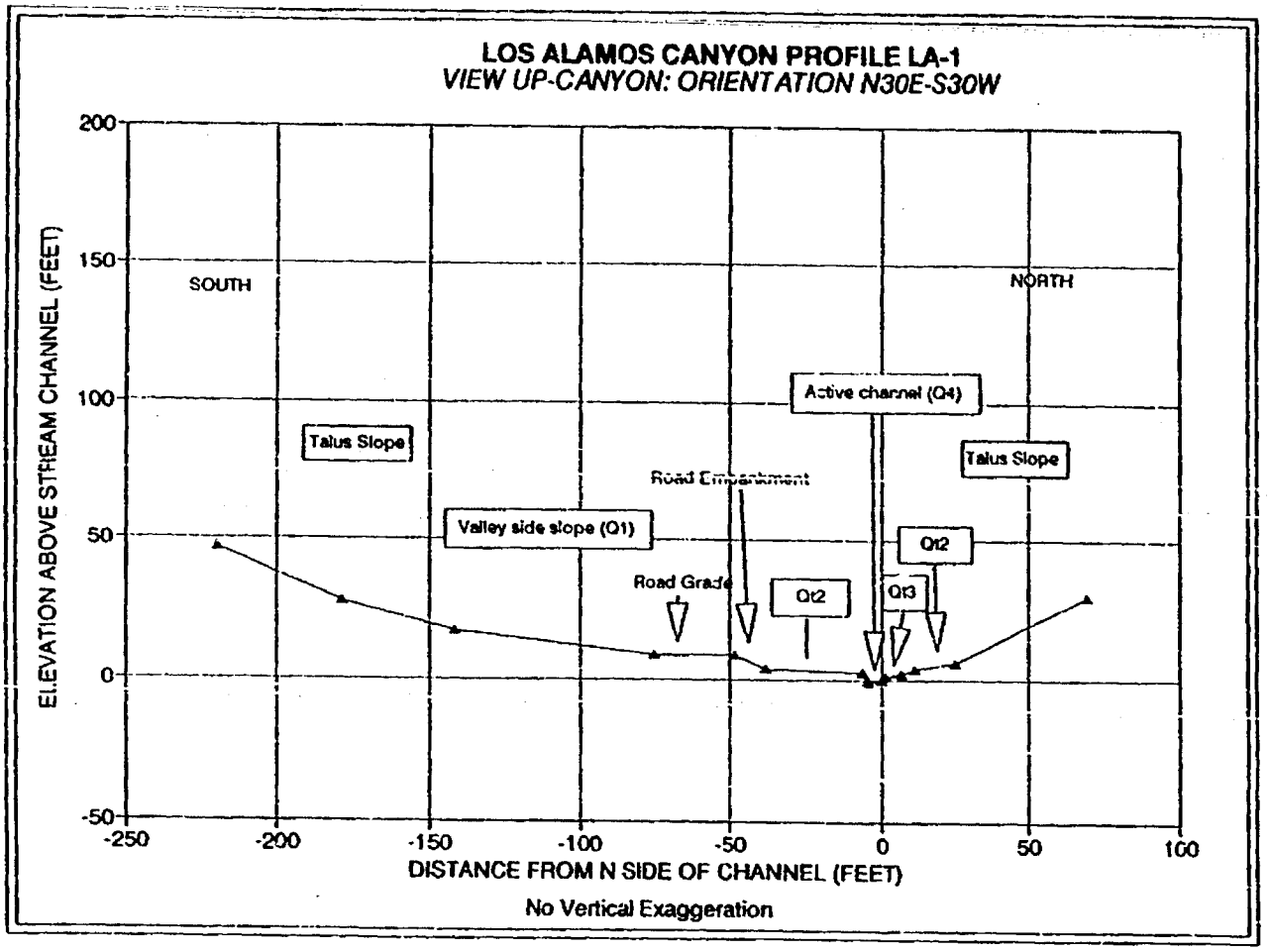
Soil Survey Staff, 1975, Soil Taxonomy: A Basic System of Soil Classification for Making and Interpreting Soil Surveys, U.S. Department of Agriculture, Washington, D.C., 754 p.

Vaniman, D., and Wohletz, K., 1990, Results of geological mapping/fracture studies: TA-55 Area: Internal Memorandum to J. Gardner, EES-1, Los Alamos National Laboratory, 23 p. plus figures.

Waresback, D.B., and Turbeville, B.N., 1990, Evolution of a Plio -Pleistocene volcanogenic-alluvial fan: The Puye Formation, Jemez Mountains, New Mexico: GSA Bulletin, v. 102, p. 298-314.

APPENDIX A

CROSS-PROFILE DATA AND PLOTS



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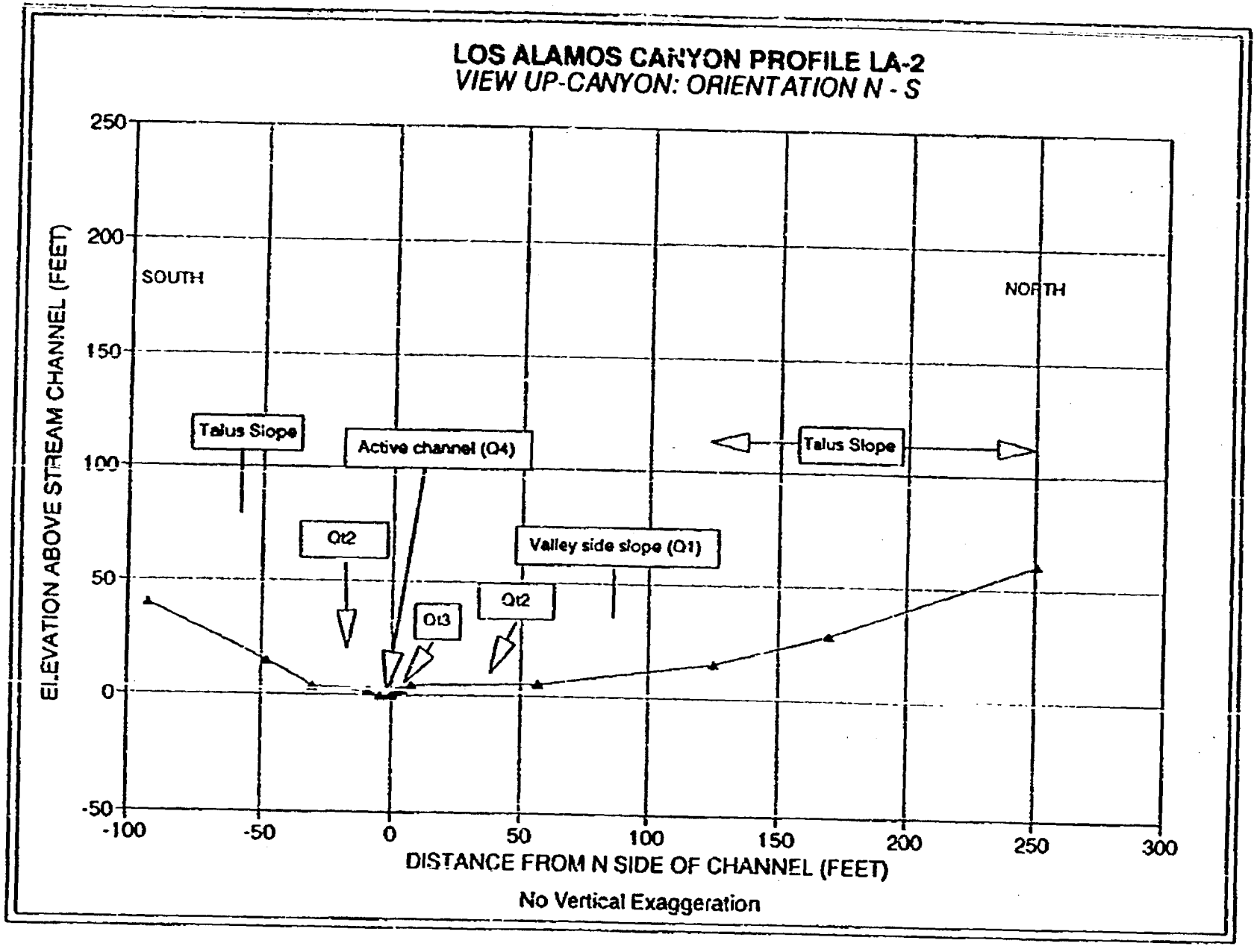
Los Alamos Canyon Profile LA-1. Orientation: N30E

Station	x Distance	x Total	y Distance	y Total	Comments
5N	44.1	69.5	23.47	30.0	Up lower talus slope, talus continues at similar angle to base of cliff to north
4N	14	25.4	2.20	6.6	Across terrace, base of talus
3N	4.5	11.4	1.90	4.4	Onto higher terrace (Q2 ?)
2N	5.4	6.9	0.80	2.5	Across terrace
1N	1.5	1.5	1.65	1.7	On low historic terrace (Q3 ?)
0	0	0	0.00	0.0	N side of channel
1S	-4.5	-4.5	-0.10	-0.1	S side of channel
2S	-1.8	-6.3	3.00	2.9	Onto second terrace (Q2 ?)
3S	-31.6	-37.9	1.35	4.3	Across terrace to base of enbankment
4S	-10.2	-48.1	4.70	9.0	Top of road bed
5S	-26.5	-74.6	-0.10	8.9	Across road to valley side slope
6S	-66.6	-141.2	8.66	17.5	Across valley side slope (Q1 ?), area has been modified with bulldozer cuts, piles of bouldery debris, etc.
7S	-37.2	-178.4	10.10	27.6	Lower talus slope
8S	-41.7	-220.1	19.44	47.1	Main talus slope, continues upward toward canyon rim



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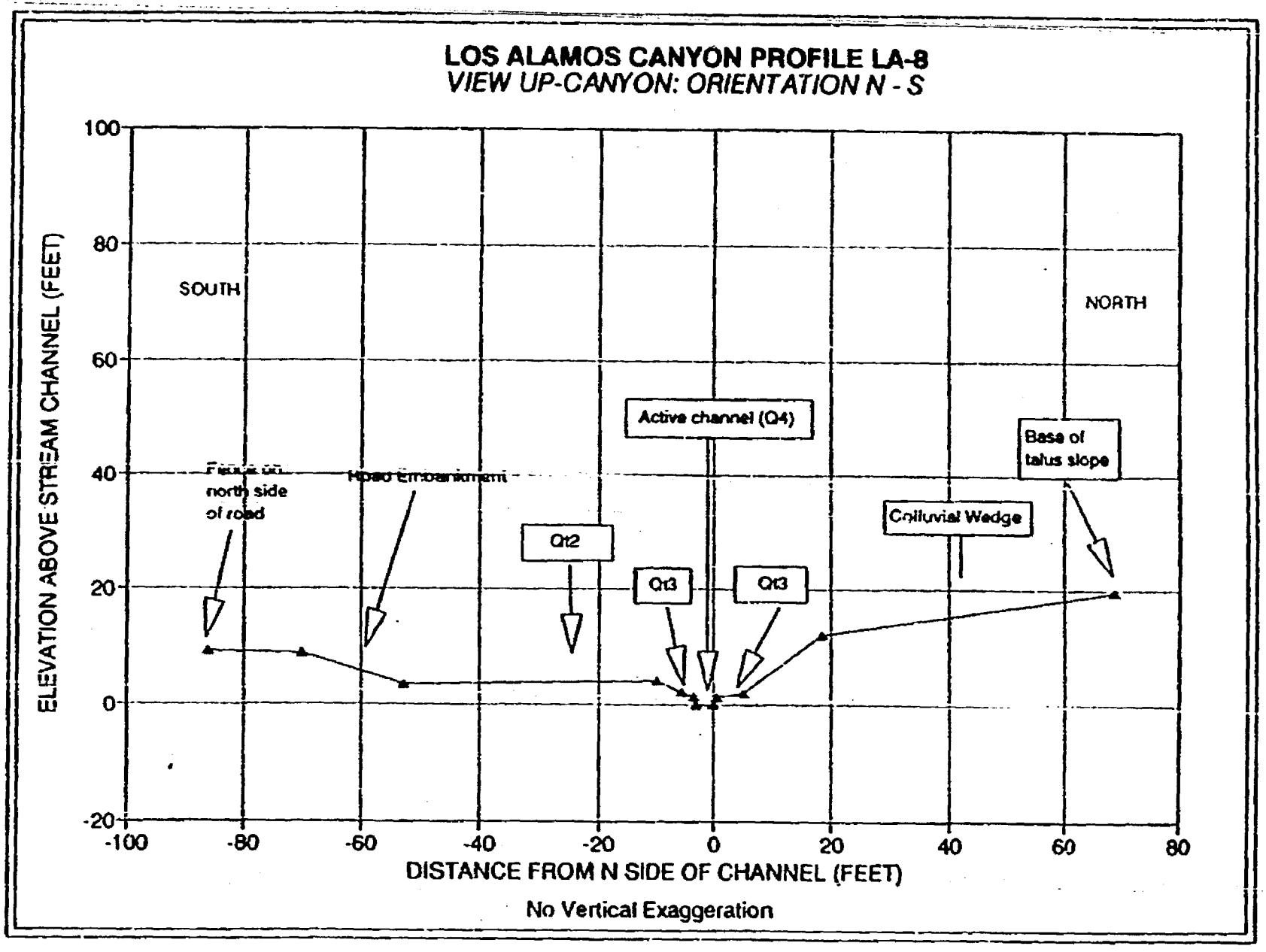
Los Alamos Canyon Profile LA-2. Orientation: N30E

Station	x Distance	x Total	y Distance	y Total	Comments
7N	81.3	250.9	33.00	60.6	Intermediate talus slope, slope steepens, talus is blocks of Tsherige Tuff
6N	44.2	169.6	12.70	27.6	Lower talus slope
5N	68.4	125.4	9.40	14.9	Across valley side slope to base of talus slope
4N	49.8	57	1.15	5.5	Across terrace-base of road enbankment
3N	3.4	7.2	2.30	4.3	On higher terrace (Q2 ?)
2N	1.8	3.8	0.60	2.0	Across terrace
1N	2	2	1.40	1.4	On low terrace (Q3 ?)
0	0	0	0.00	0.0	N side of channel
1S	-4.3	-4.3	-0.40	-0.4	S side of channel
2S	-4.1	-8.4	2.10	1.7	Onto Q2
3S	-22.4	-30.8	1.80	3.5	Across Q2
4S	-17.2	-48	11.10	14.6	Up old stream cut bank
5S	-43.9	-91.9	25.20	39.8	Up talus slope, talus slope continues to rim



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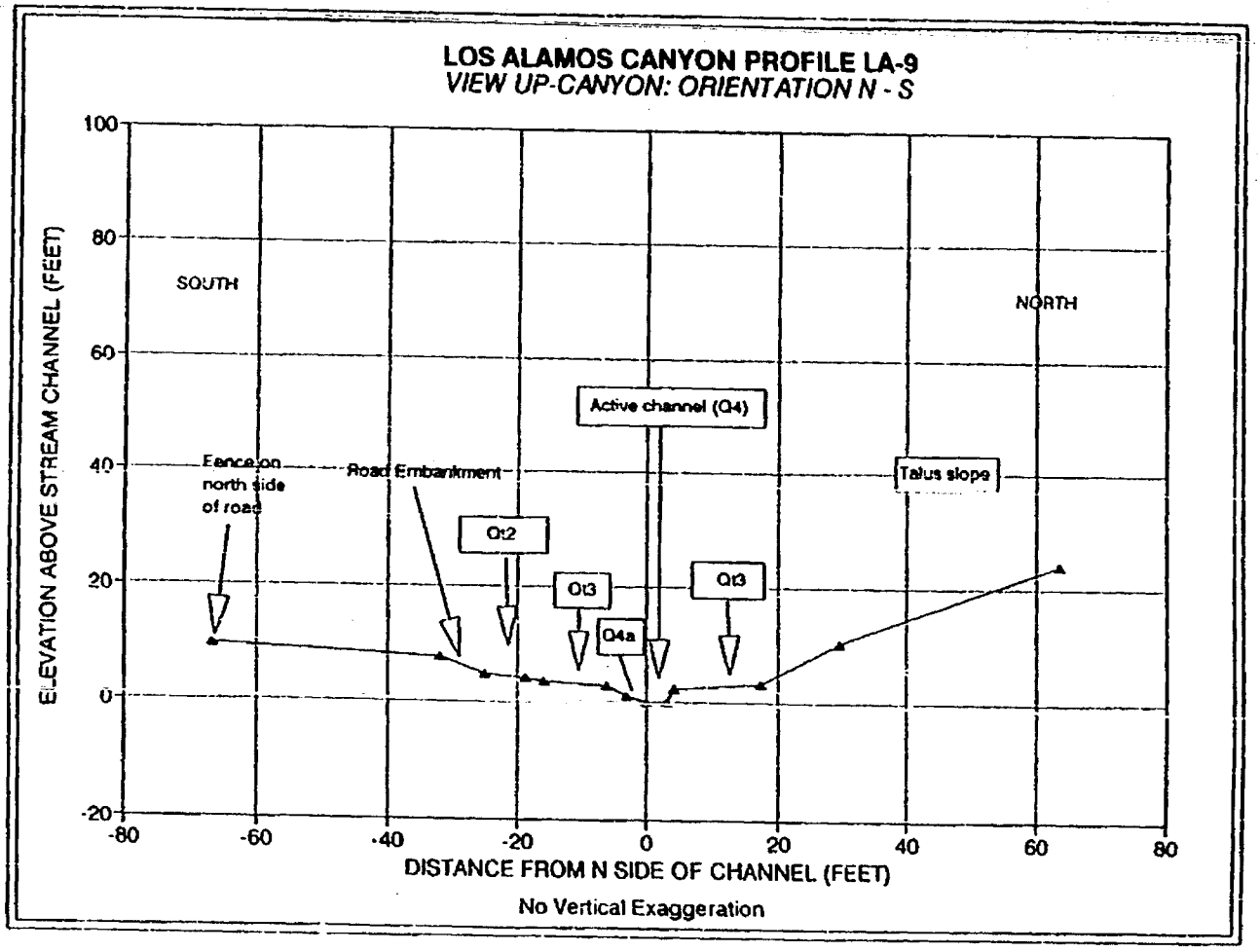
Los Alamos Canyon Profile LA-8. Orientation:N-S

Station	x Distance	x Total	y Distance	y Total	Comments
4N	50.5	69.1	7.55	19.6	Across colluvial wedge to base of talus slope
3N	13.5	18.6	10.00	12.0	Up stream cut to bouldery colluvial wedge
2N	4.5	5.1	0.70	2.0	Across Q3
1N	0.6	0.6	1.30	1.3	On Q3
0	0	0	0.00	0.0	N side of channel
1S	-3	-3	0.00	0.0	S side of channel
2S	-0.5	-3.5	1.55	1.6	Onto Q3
3S	-2.2	-5.7	0.60	2.2	Across Q3
4S	-4.4	-10.1	1.95	4.1	Onto Q2
5S	-42.5	-52.6	-0.75	3.4	Across Q2 to base of road enbankment
6S	-17.5	-70.1	5.50	8.9	To top of road enbankment
7S	-16	-86.1	0.3	9.2	To fence N of road



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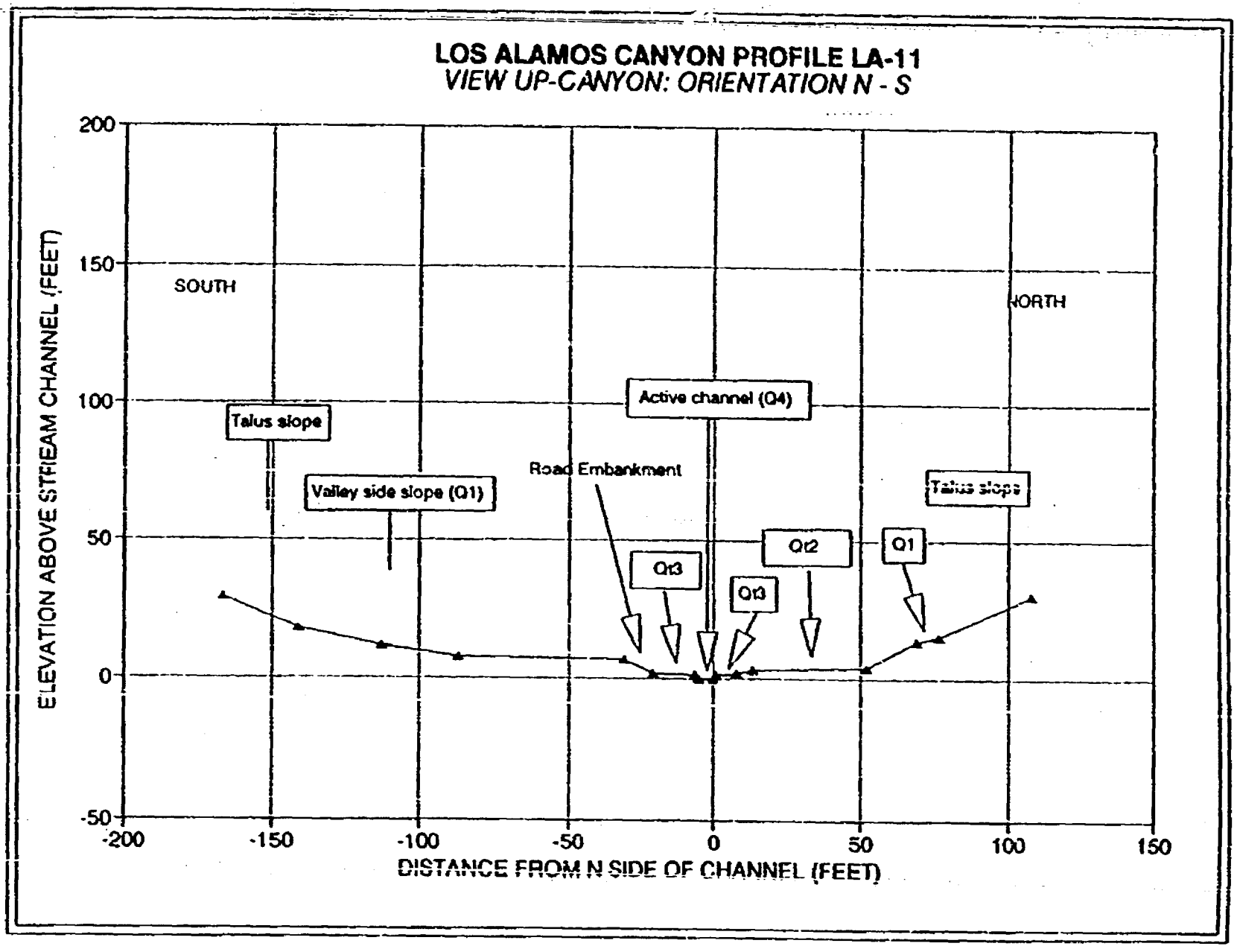
Los Alamos Canyon Profile LA-9. Orientation: N-S
Near gate to TA-2

Station	x Distance	x Total	y Distance	y Total	Comments
4N	34.2	63.5	13.82	24.0	Up lower talus slope
3N	12	29.3	6.95	10.2	Up stream cut
2N	13.1	17.3	0.90	3.3	Across Q3 to base of talus
1N	1.2	4.2	2.35	2.4	Onto Q3
0.5N	3	3	0.00	0.0	Across channel to north side
0	0	0	0.00	0.0	S side of channel
1S	-3	-3	1.05	1.1	Up onto small inset fill (Q4a ?)
2S	-3.2	-6.2	1.65	2.7	Onto Q3
3S	-9.8	-16	0.70	3.4	Across Q3
4S	-2.9	-18.9	0.60	4.0	Onto Q2 (?)
5S	-6	-24.9	0.70	4.7	Across Q2 tc base of road enbankment
6S	-7.1	-32	2.90	7.6	To tcp of road enbankment
7S	-34.5	-66.5	1.95	9.6	To fence on N side of road



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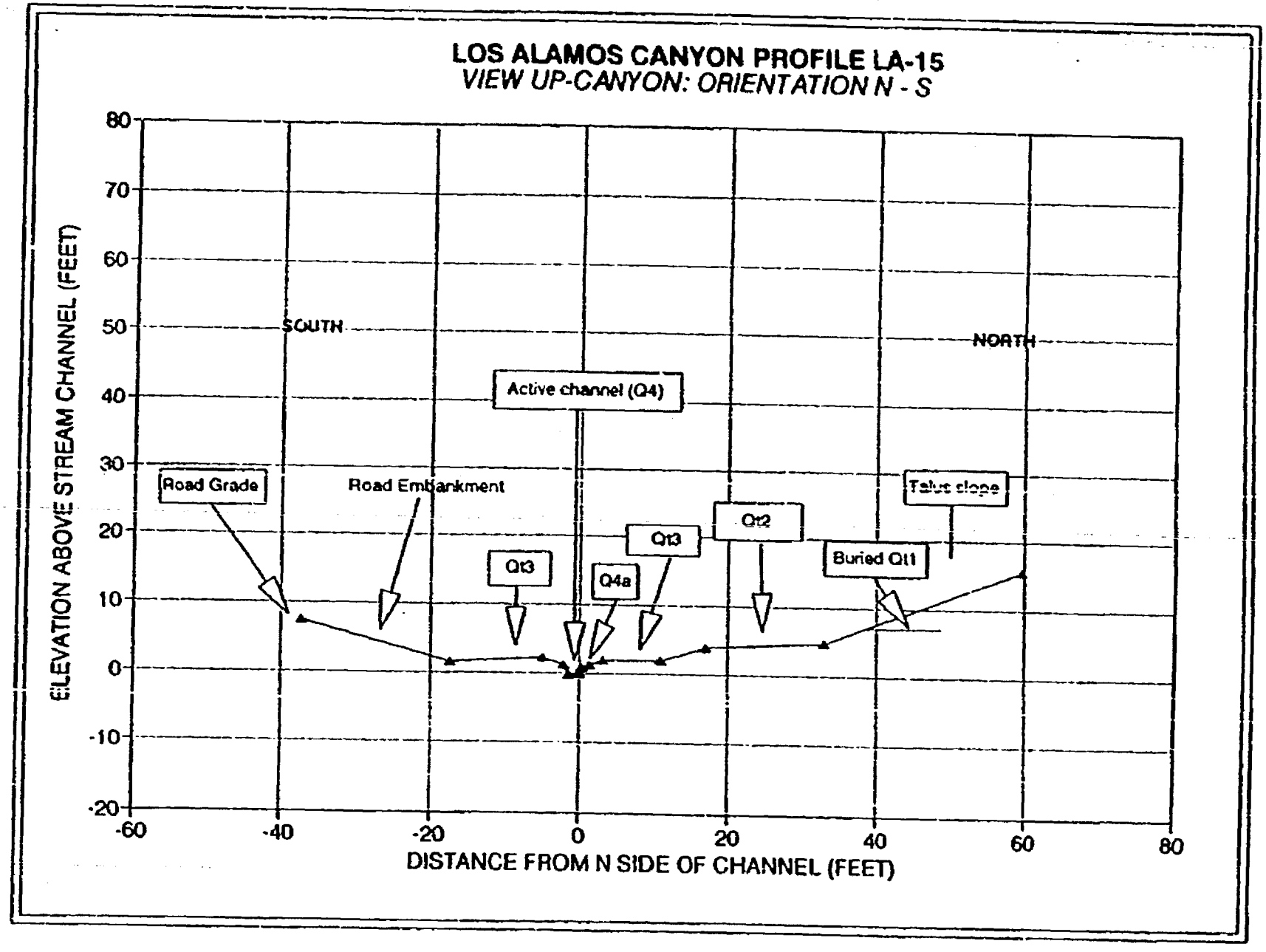
Los Alamos Canyon Profile LA-11. Orientation: N-S

Station	x Distance	x Total	y Distance	y Total	Comments
7N	31.7	108.3	14.80	30.3	Lower talus slope
6N	7.5	76.6	2.10	15.5	Across possible Q1 surface
5N	16.8	69.1	9.30	13.4	To top of possible truncated Q1 fan surface
4N	38.5	52.3	0.70	4.1	Across Q2, base of slope
3N	5.7	13.8	1.45	3.4	Onto Q2
2N	7	8.1	0.50	2.0	Across Q3
1N	1.1	1.1	1.45	1.5	Onto Q3
0	0	0	0.00	0.0	N side of channel
1S	-4.9	-4.9	0.15	0.2	On rocks next to channel, S side
2S	-1	-5.9	1.50	1.7	On Q3 above channel
3S	-14.4	-20.3	0.30	2.0	Across Q3, base of road enbankment
4S	-10	-30.3	5.05	7.0	To road grade
5S	-55.9	-86.2	0.55	7.6	Across road, base of valley side slope
6S	-26.7	-112.9	4.10	11.7	Valley side slope, fan deposit
7S	-28.6	-141.5	6.34	18.0	Valley side slope, old fan deposit
8S	-25.3	-166.8	11.53	29.5	Lower talus slope



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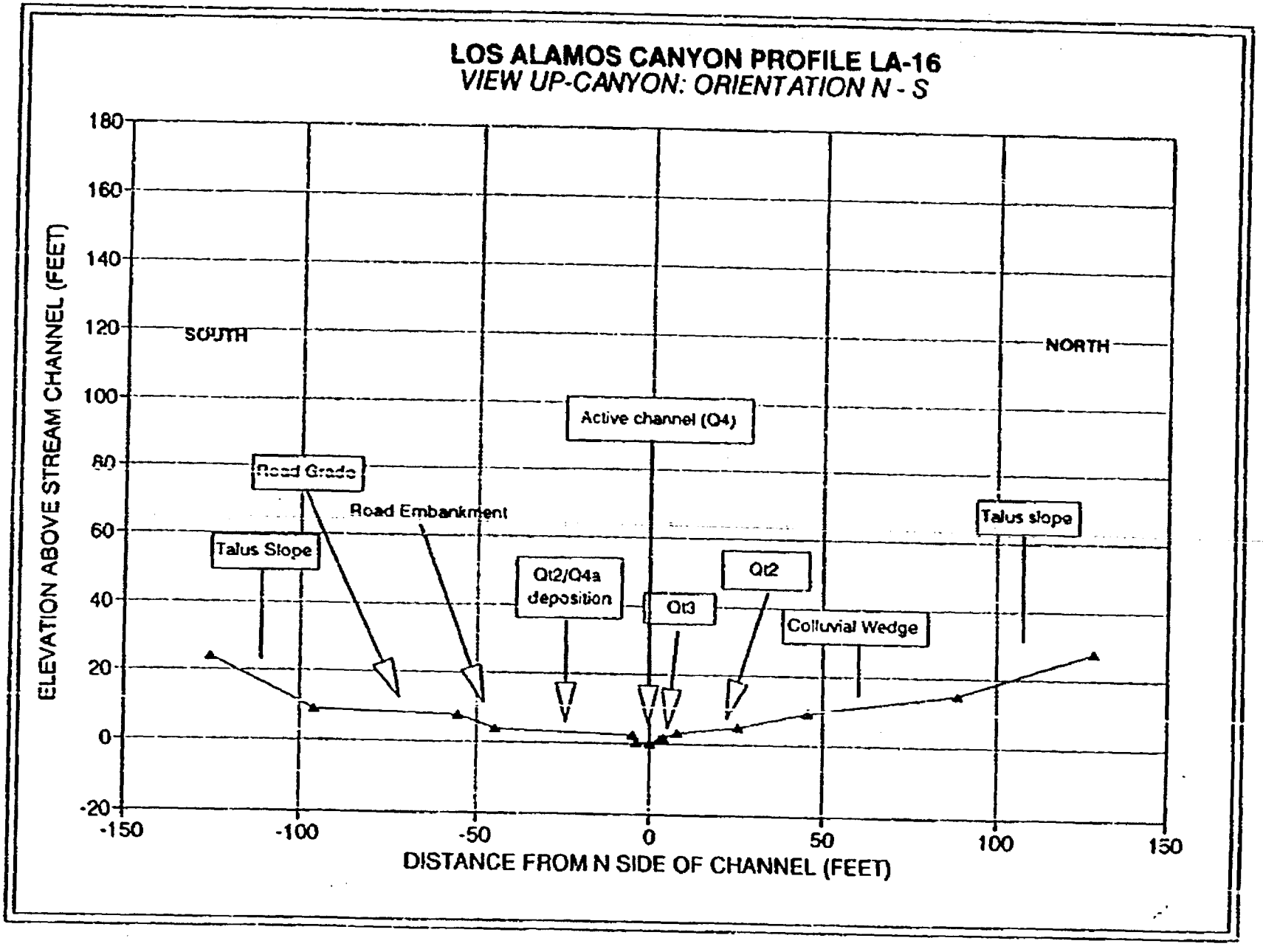
Los Alamos Canyon Profile LA-15. Orientation: N-S

Station	x Distance	x Total	y Distance	y Total	Comments
7N	26.9	59.7	10.77	15.6	Lower talus slope, talus overlies Qt1 gravel
6N	15.7	32.8	0.80	4.8	Across Q2, base of talus
5N	6.1	17.1	2.00	4.0	Onto Q2
4N	7.8	11	-0.05	2.0	Across Q3, base of Q2
3N	1.8	3.2	0.80	2.1	Onto Q3
2N	0.9	1.4	0.35	1.3	Across inset fill
1N	0.5	0.5	0.90	0.9	On small inset fill (Q4a)
0	0	0	0.00	0.0	N side of channel
1S	-1.2	-1.2	-0.05	-0.1	S side of channel
2S	-0.8	-2	1.35	1.3	Onto sloping Q3 surface above channel
3S	-2.8	-4.8	1.05	2.4	To top of Q3
4S	-12.6	-17.4	-0.75	1.6	Across Q3 to base of road embankment
5S	-19.8	-37.2	5.88	7.5	To road grade



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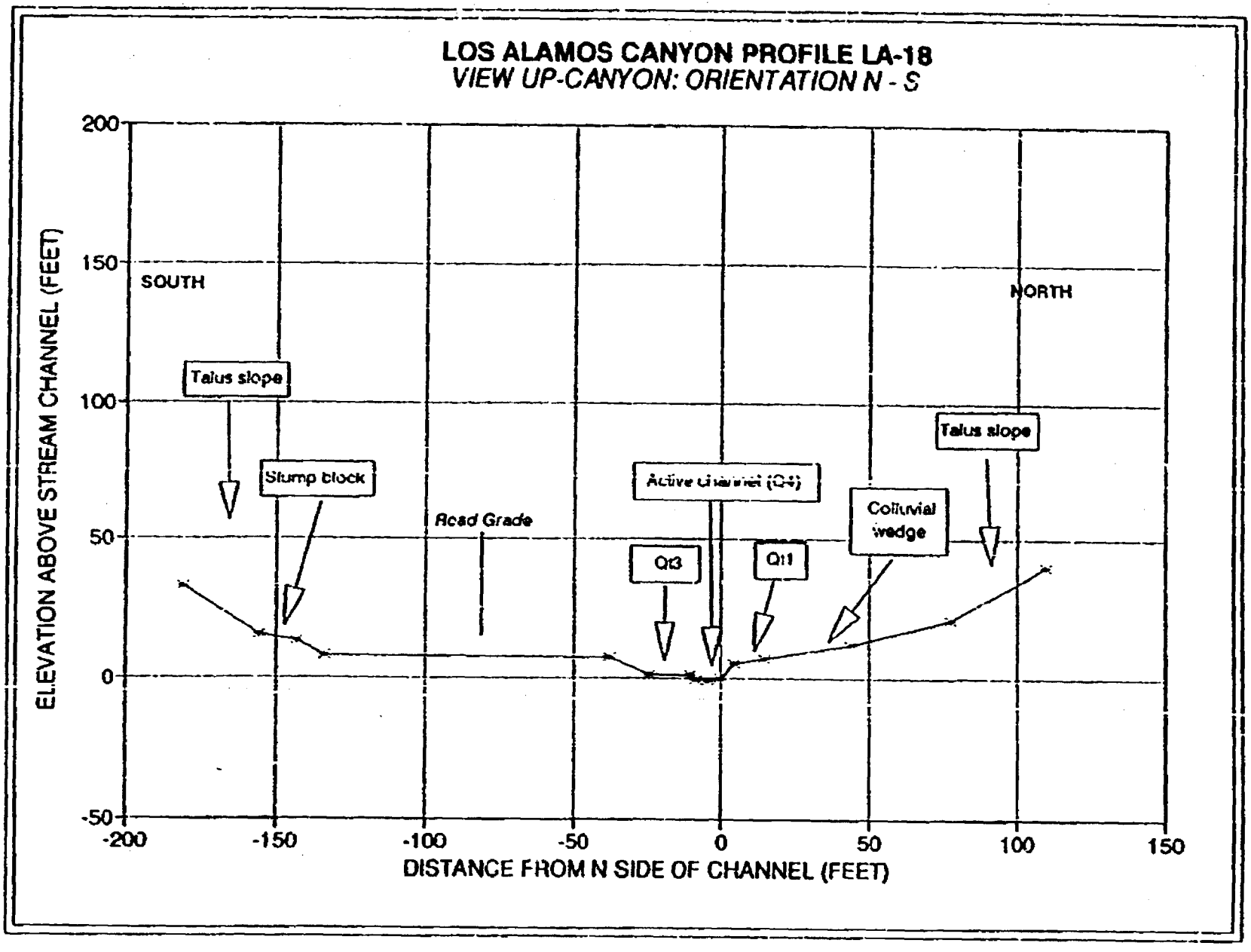
Los Alamos Canyon Profile LA-16. Orientation: N-S

Profile located adjacent to Q2 location where rounded quartzite pebble approx. 0.5x0.5x1.0 in. was found at 1.0 ft. below surface. Q2 surface also has numerous exotic clasts.

Station	x Distance	x Total	y Distance	y Total	Comments
7N	39.1	128.1	12.70	27.83	Lower talus slope, steeper talus slope above
6N	43.1	89.0	5.68	15.13	Across colluvial wedge
5N	20.3	45.9	4.45	9.45	Onto colluvium wedge at base of slope
4N	17.7	25.6	1.65	5.00	Across Q2
3N	4.0	7.9	1.25	3.35	Onto Q2
2N	1.1	3.9	0.45	2.10	Across Q3
1N	2.8	2.8	1.65	1.65	Onto Q3
0	0.0	0.0	0.00	0.00	N side of channel
1S	-4.1	-4.1	0.50	0.50	S side of channel, on small gravel bar
2S	-1.0	-5.1	2.20	2.70	Suspicious looking, hummucky area, likely modified
3S	-39.7	-44.8	1.35	4.05	Depositional area, possibly Q2 overlain by Q4a fan
4S	-10.7	-55.5	4.10	8.15	Onto roadbed
5S	-40.2	-95.7	1.05	9.20	Across road, base of talus slope
6S	-29.7	-125.4	14.81	24.01	Lower talus slope



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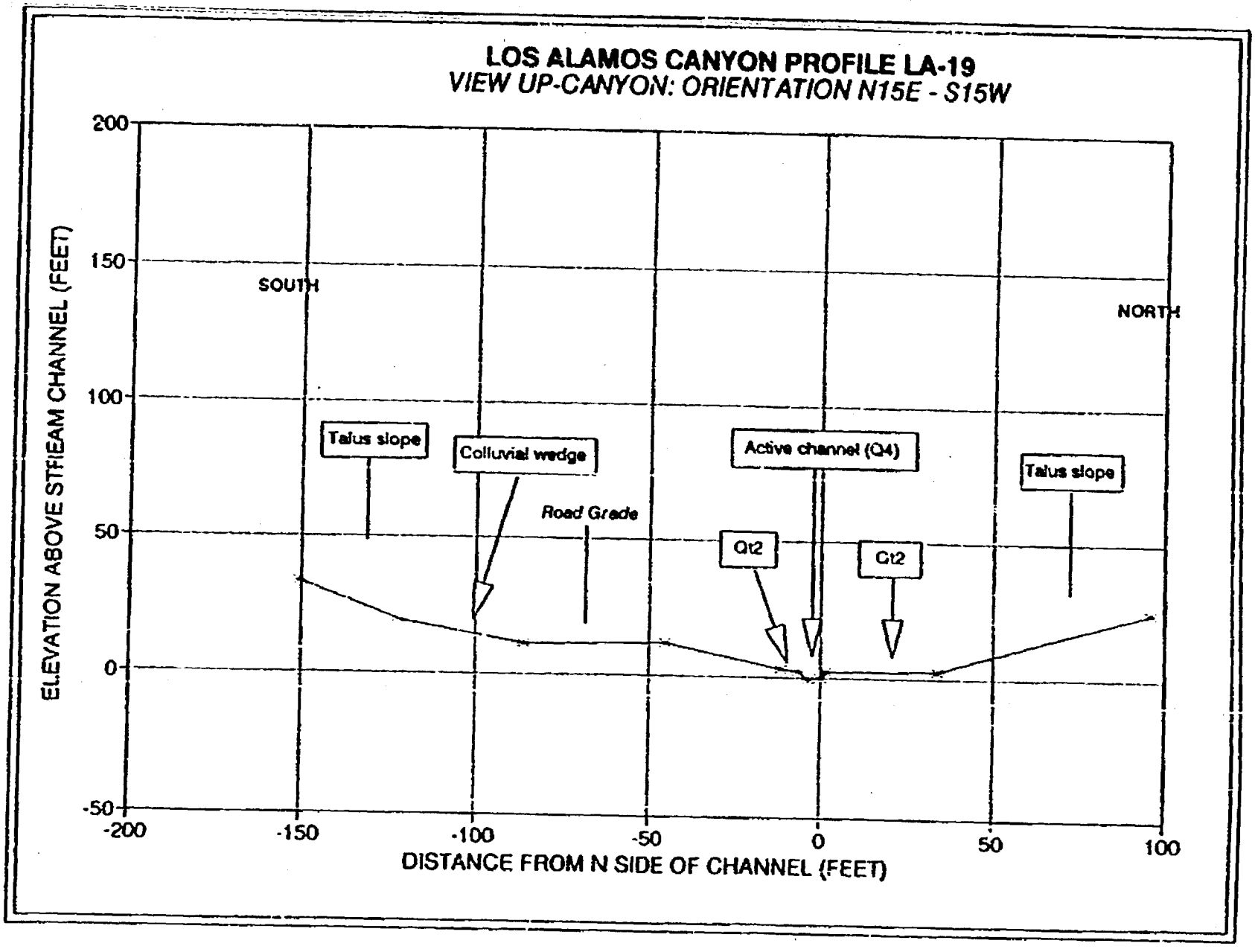
Los Alamos Canyon Profile LA-18. Orientation: N-S

Station	x Distance	x Total	y Distance	y Total	Comments
5N	32.6	110.4	19.10	40.1	Talus slope
4N	33.8	77.8	8.70	21.0	Base of talus, lower talus slope
3N	29.0	44.0	5.05	12.3	Across colluvial wedge on top of Q1
2N	10.3	15.0	1.60	7.2	Across Q1
1N	4.7	4.7	5.60	5.6	On Q1
0	0.0	0.0	0.00	0.0	N side of channel
1S	-4.2	-4.2	-0.60	-0.6	N edge of water
2S	-3.8	-8.0	0.15	-0.5	S side of channel (small bar)
3S	-1.7	-9.7	1.80	1.4	Onto Q3
4S	-14.7	-24.4	0.00	1.4	Across Q3, active surface with partially buried tire, base of enbankment
5S	-13.4	-37.8	6.40	7.8	Up to road grade
6S	-95.7	-133.5	0.50	8.3	Across road, base of talus slope
7S	-9.7	-143.2	5.05	13.3	On top of small slump block
8S	-12.0	-155.2	2.20	15.5	Across slump block, base of talus
9S	-25.6	-180.8	17.40	32.9	Lower talus slope



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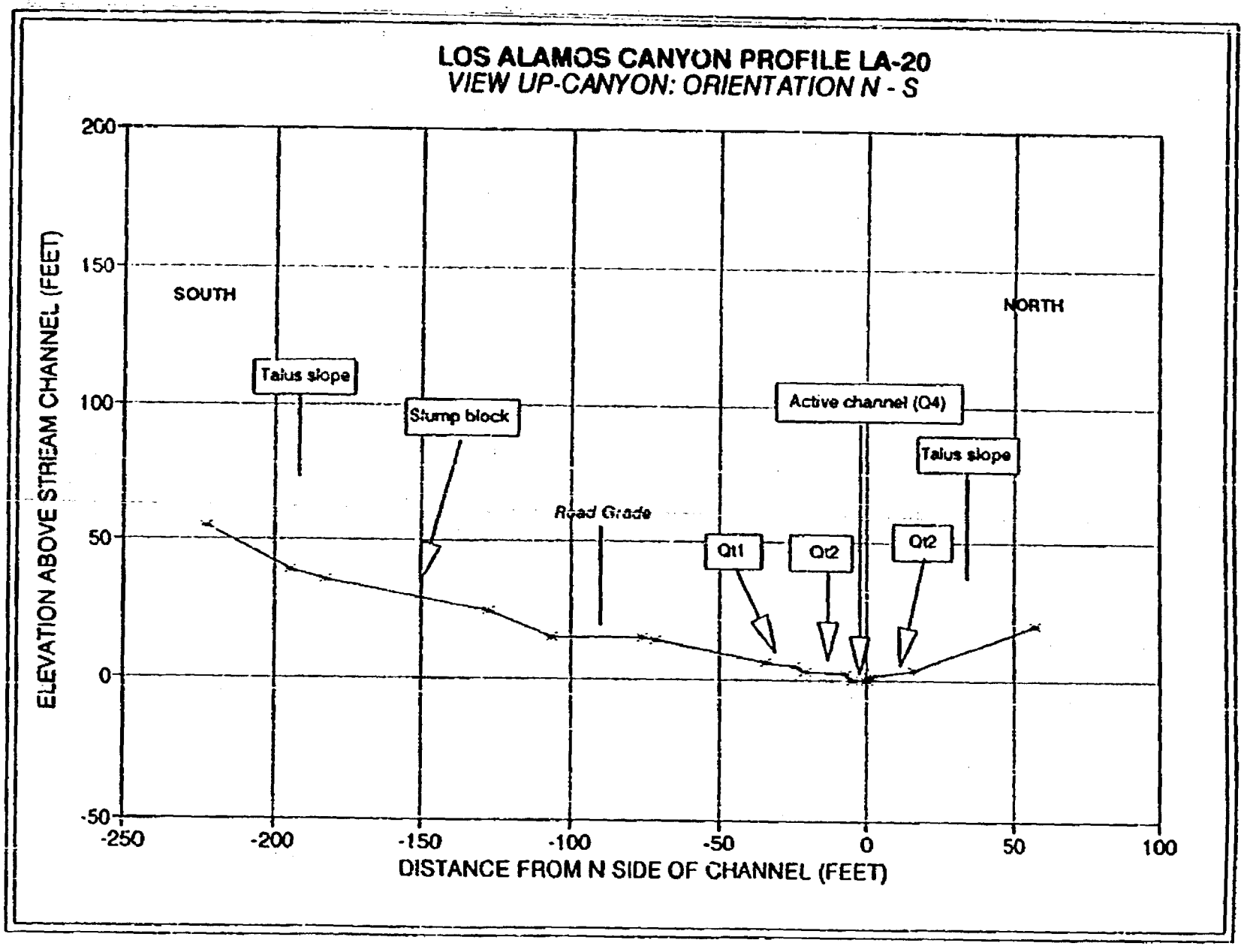
Los Alamos Canyon Profile LA-19. Orientation: N15E-S15W

Station	x Distance	x Total	y Distance	y Total	Comments
3N	62.5	96.3	21.52	24.47	Lower talus slope
2N	32.3	33.8	0.65	2.95	Across Q2 surface to base of valley side slope
1N	1.5	1.5	2.30	2.30	On Q2 surface
0	0.0	0.0	0.00	0.00	N side of channel
1S	-3.6	-3.6	-0.10	-0.10	S side of channel
2S	-3.0	-6.6	2.40	2.30	Onto Q2
3S	-5.0	-11.6	0.90	3.20	Across Q2, base of road enbankment
4S	-33.6	-45.2	9.18	12.38	To road bed
5S	-41.0	-86.2	-1.00	11.38	Across road, base of talus slope/colluvial wedge
6S	-35.1	-121.3	8.10	19.48	Colluvial wedge
7S	-29.2	-150.5	14.25	33.73	Talus slope



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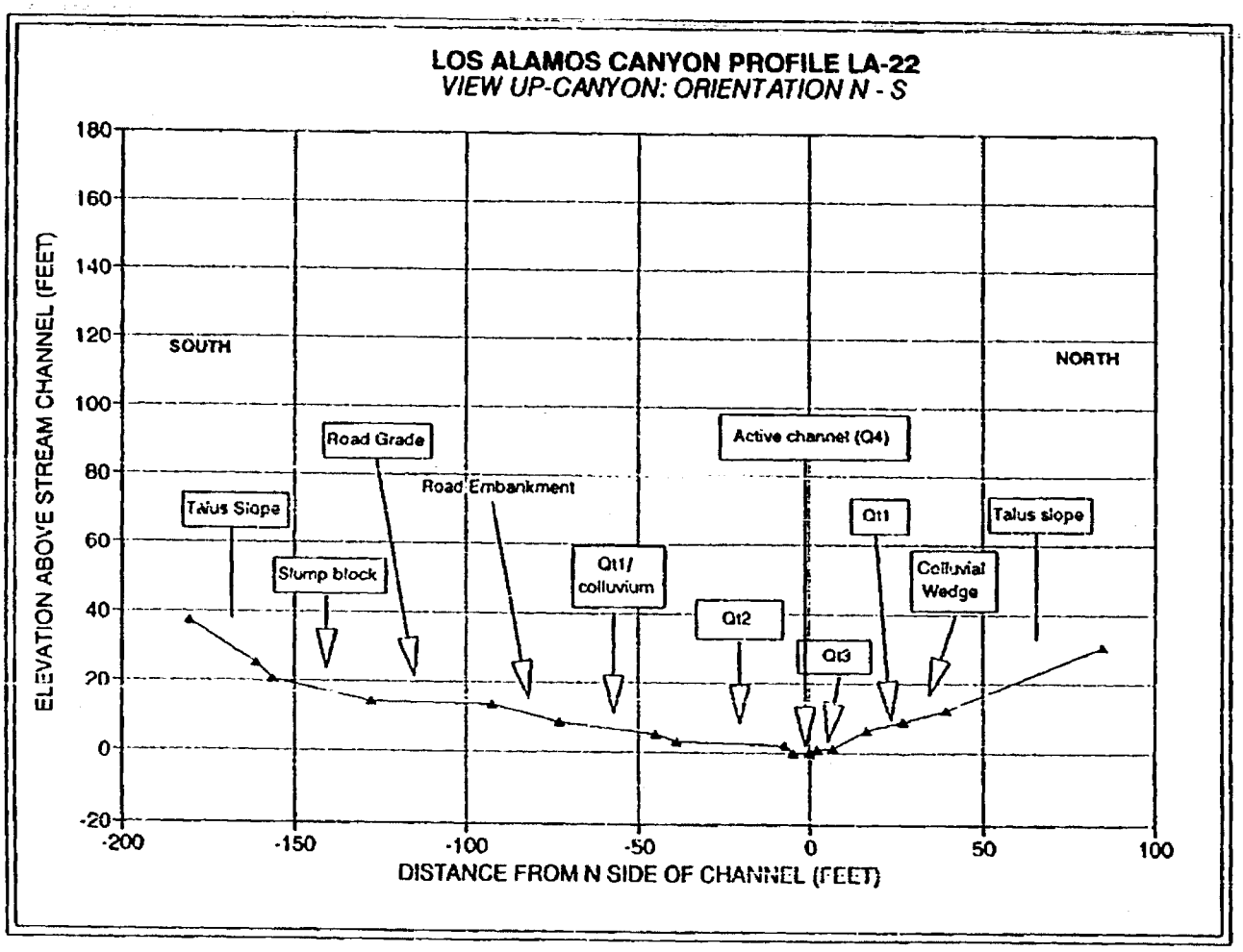
Los Alamos Canyon Profile LA-20. Orientation: N-S

Station	x Distance	x Total	y Distance	y Total	Comments
3N	42.1	57.9	16.57	20.22	Lower talus slope, likely underlain by Cerro Toledo Rhyolite
2N	14.2	15.8	2.40	3.65	Across fluvial surface to base of side slope, likely on Q2
1N	1.6	1.6	1.25	1.25	On small Q3 surface
0	0.0	0.0	0.00	0.00	N side of channel
1S	-5.0	-5.0	0.10	0.10	S side of channel
2S	-2.1	-7.1	2.25	2.35	Onto Q3/Q2 surface, underlain by imbricated gravel
3S	-13.3	-20.4	1.05	3.40	Across Q2 (?) surface
4S	-3.9	-24.3	1.85	5.25	Onto probable Q1
5S	-9.5	-33.8	1.10	6.35	Across to base of road embankment
6S	-37.5	-71.3	8.00	14.35	Near road grade
7S	-4.7	-76.0	0.90	15.25	Edge of road bed level
8S	-30.5	-106.5	0.25	15.50	Across road, base of slope
9S	-20.6	-127.1	9.20	24.70	Onto possible slump block
10S	-55.5	-182.6	11.28	35.98	Across possible slump block on valley side slope
11S	-11.7	-194.3	3.40	39.38	Lower talus slope
12S	-28.0	-222.3	15.50	54.88	Main talus slope



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Los Alamos Canyon Profile LA-22. Orientation: N-S

Station	x Distance	x Total	y Distance	y Total	Comments
6N	45.3	84.7	18.60	30.85	Up talus slope
5N	12.4	39.4	3.35	12.25	Across colluvium and talus overlying Qt1
4N	10.4	27.0	2.20	8.90	Across Qt1
3N	9.7	16.6	5.00	6.70	Onto Qt1
2N	4.7	6.9	0.60	1.70	Across Q3
1N	2.2	2.2	1.10	1.10	Onto Q3
0	0.0	0.0	0.00	0.00	N side of channel
1S	-4.5	-4.5	0.30	0.30	Across channel to south side.
2S	-2.7	-7.2	2.10	2.40	Onto low Qt2 surface
3S	-31.7	-38.9	1.05	3.45	Across terrace
4S	-6.1	-45.0	2.20	5.65	Onto possible Qt1 surface
5S	-28.0	-73.0	3.15	8.80	Across terrace
6S	-19.5	-92.5	5.00	13.80	To edge of road
7S	-35.3	-127.8	0.45	14.25	Across road - base of slump block
8S	-28.8	-156.6	6.66	20.91	Across slump block - base of slump escarpment
9S	-4.7	-161.3	4.40	25.31	Up slump scar
10S	-19.0	-180.3	12.36	37.67	Up talus slope

APPENDIX B

FIELD SOIL DESCRIPTION SHEETS

EXPLANATION

Color: obtained from Munsell Soil Color Charts; nr = not reported

Texture: g = gravelly, c = coarse, f = fine, s = sand, ls = loamy sand
sl = sandy loam, scl = sandy clay loam, sicl = silty clay loam
sil = silt loam, cl = clay loam, l = loam, st = stones and stoney; nr = not reported

Structure: Grade: 1 = weak, 2 = moderate, 3 = strong; Size: f = fine,
m = medium, c = coarse, vc = very coarse; Type: sg = single grain,
pl = platy, m = massive, gr = granular, sbk = subandular blocky,
abk = angular blocky, pr = prismatic; nr = not reported

Consistence: Dry: lo = loose, so= soft, sh = slightly hard, fr = friable,
h = hard, vh = very hard, eh = extremely hard
Wet: so,po = nonsticky, nonplastic; ss,ps = slightly sticky, slightly plastic;
s,p = sticky, plastic; vs, vp = very sticky, very plastic; nr = not reported

Clay Films: n.o. = not observed; Frequency: v = very few, 1 = few, 2 = common,
3 = many, 4 = continuous; Thickness: n = thin, mk = moderately thick,
k = thick; Morphology: pf = ped faces, po = pore linings,
br = bridges, co = colloidal stains on grains; nr = not reported

Roots, Pores: Size: vf(very fine); f((fine); m(medium); c(coarse); Abundance: 1(few); 2(common); 3(many);

Horizon Boundary: Distinctness: va = very abrupt, a = abrupt, c = clear, g = gradual
d = diffuse; Topography: s = smooth, w = wavy, i = irregular,
b = broken

Carbonates: effervescece in HCL: e = slightly effervescent; es = strongly effervescent;

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Soil description in sediments underlying Q3 surface east of TA-41, 1.5 feet above base level

Site: LA 14 Location: Qal3, east of TA 41				Date: 09/12/94		Vegetation: Grasses, willow, elm, ponderosa pine					Aspect: Exposure faces south Described By: P. Drakos, C. Inoue		
% Gravel	Horizon	Depth (ft)	Boundary	Color Dry	Color Moist	Texture	Structure	Consistence Dry	Consistence Wet	Clay Films	Roots Pores	CaCO3	Comments
< 2% subangular to angular 1/4", muscovite, rosequartz, and volcanics	C	0 - 1.7		not dry	10YR 3/2	sandy loam	m	ls	so,ps	n.o.	3fr, 1mr	non	Fining upward sequence 0.2 - 1.7' from coarse sand to fine sand. Med. sand from 0 - 0.2'.

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Soil formed in sediments underlying Q3 surface near eastern boundary of OU-1098, 1.5 feet above base level
Abbreviated description.

Site: LA - 5 Location: Qal3 sediments				Date: 09/8/94		Vegetation: Supports thick growth of grasses					Aspect: Exposure faces north Described By: P. Drakos, C. Inoue		
% Gravel	Hori-zon	Depth (ft)	Bound-ary	Color Dry	Color Moist	Tex-ture	Struct-ure	Consistence Dry	Consistence Wet	Clay Films	Roots Pores	Ca-CO3	Comments
fine-grained deposit, no gravel lag at base	IC	0 - 1.2	cs	10YR 5/3	10YR 4/2	loam	1msbk	so	ss,ps	n.o.	n.r.	non	Buries pine needle layer
Fining upward sequence from cobbles to med. sand	IIC	1.2 - 1.8 (base of pit)			10YR 4/2	sandy gravel	m	lo	so,po	n.o.	n.r.	non	Wet soil near level of strem bed

GLORIETA GEOSCIENCE, INC.

Soil formed in sediments underlying Q3 surface east of TA-2, 1.5 feet above base level

Site: LA 3 Location: Qal3 sediments				Date: 09/8/94		Vegetation: Grasses, shrub, briars, oak, ponerosa pine, minor fir					Aspect: Exposure faces south Described By: P. Drakos, C. Inoue		
% Gravel	Hori-zon	Depth (ft)	Bound-ary	Color Dry	Color Moist	Tex-ture	Struct-ure	Consistence Dry	Consistence Wet	Clay Films	Roots Pores	Ca-CO3	Comments
Gravel lag at base of deposit, cobble size 0.3 - 0.4' diam., overlain by med. sand with minor clay.	IC	0 - 1.35'	aw	10YR 5/3	10YR 4/2	loamy sand	1msbk	so	so,po	n.o.	3fr	non	More development than expected, 250 - 350 cpm.
30 - 40%	IIC	1.35 - 2.0' (base of pit)			10YR 4/3	sandy gravel (fines are coarse sand)	m	lo	so,po	n.o.	1fr	non	Wet soil near level of strem bed, buried pine needles by IC, flexible with some tensile strength. Quartz and quartzite pebbles in IIC horizon, SR to SA 1/4 - 1/2" diam., possible aggregate of road bed material, abundant euhedral quartz (<2mm sand), minor sanidine.

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Soil formed in sediments underlying Q2 surface east of TA-2, 4 feet above base level

Site: LA 4 Location: Qal2 terrace sediments				Date: 09/8/94		Vegetation: Minor grass, briar, poderosa, heavy pine needle layer, minor oak					Aspect: Exposure faces north Described By: P. Drakos, C. Inoue		
% Gravel	Horizon	Depth (ft)	Boundary	Color Dry	Color Moist	Texture	Structure	Consistence Dry	Consistence Wet	Clay Films	Roots Pores	CaCO3	Comments
0%	O	0 - +0.3	cw	10YR 3/2	10YR 2/2	loamy sand	m	lo	so,po	n.o.	n.o.	non	Pine needles, bark fragments, decaying wood, 100 - 250 cpm.
20 - 30 %	IC	0 - 0.7	cw	10YR 5/3	10YR 4/3	loamy sand	m	lo	so-lo	n.o.	3vfr	non	200 - 400 cpm, bone fragments (?). Gravel: volcanin lithics, tuff dacite, no obvious exotics, pumice to 2"
50 - 60 % Up to 0.2' int. axis dacite, SA, SR, volcanics, pumice, no obvious quartzite.	IIC	0.7 - 2.5 Base of cut		10YR 5/3	10YR 4/3	loamy sand	m	lo	so,po	n.o.	2fr	non	Fining upward sequence - cobble gravel to med. sand. Bimodal gravel 50%, approx. 0.2' diam., 50% 0.1 - 0.05'.

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Soil description in sediments underlying Q2 surface near west boundary of OU-1098, 2.1 feet above base level

Site: LA 23 Location: S. bank of stream, due N of pole 521				Date: 09/16/94		Vegetation: Grasses, small ponderosa pine, scrub oak, trees to 1' diameter					Aspect: Exposure faces north Described By: P. Drakos, C. Inoue		
% Gravel	Hori-zon	Depth (ft)	Bound-ary	Color Dry	Color Moist	Tex-ture	Struct-ure	Consistence Dry	Consistence Wet	Clay Films	Roots Pores	CaCO3	Comments
50%, welded tuff to 3", minor gravel 1/4" to 1" (20%), SR	AC	0 - 1.1	cs	nr	10YR 3/2	sandy loam	1msbk	so-lo	vss, vsp	n.o.	3fr, 1fp	non	moist soil, some distinct peds
SA-SR, tuff, dacite, 1/4" to 1.5"	C	1.1 - 2.0		nr	10YR 4/2	coarse sand	sg	lo	so,po	n.o.	1mr	non	coarse sand + gravel overlain by sandy loam, fluvial deposit, one rounded quartzite pebble (1/2") at 1.6' deep from upper surface

GLORIETA GEOSCIENCE, INC.

Soil description in sediments underlying Q2 surface east of TA-41, 3.5 feet above base level

Site: LA 13 Location: Qal2, east of TA 41				Date: 09/12/94		Vegetation: Grasses, ponderosa pine,					Aspect: Exposure faces south Described By: P. Drakos, C. Inoue		
% Gravel	Horizon	Depth (ft)	Boundary	Color Dry	Color Moist	Texture	Structure	Consistence Dry	Consistence Wet	Clay Films	Roots Pores	CaCO3	Comments
60% subrounded up to 4 - 5" volcanics: tuffs, dacite	C	0 - 1.7	none	10YR 5/2	10YR 3/3	sand	m	l	so,po	n.o.	3fr, 2fp	non	Sandy fluvial gravel, charcoal fragments at 1.05'

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Soil description in sediments underlying Q1 surface west of TA-41, 6 feet above base level

Site: LA 17 Location: West of TA 41, Q1 terrace				Date: 09/13/94		Vegetation: Grasses, ponderosa pine, scrub oak					Aspect: Exposure faces south Described By: P. Drakos, C. Inoue		
% Gravel	Hori-zon	Depth (ft)	Bound-ary	Color Dry	Color Moist	Tex-ture	Struct-ure	Consistence Dry	Consistence Wet	Clay Films	Roots Pores	Ca-CO3	Comments
10%, mainly pumice, tuff 1/4 - 3/4", minor dacite subangular to subrounded	IAC	0 - 1.15	cs	10YR 4/2	10YR 3/2	loamy sand	1msbk	so	so, vsp	n.o.	2fr, 1fp	non	200 - 300 cpm coarse. 200 - 400 cpm fines. Charcoal fragments in screen with gravel. IAC deposit is slopewash colluvium.
80%, 60% of gravel > 1" (1-4"); 40% of gravel 1/4 to 1", poorly sorted, rounded dacite, subanguiar tuff.	IIC	1.15 - 4.0		10YR 5/3	10YR 4/2	m. to c. sand	m	lo	so,po	n.o.	3fr	non, v.e. on some clasts	Reworked clasts (dacite 2-3") with carbonate coatings (likely stage 1), most clasts 1" to 8" subrounded to rounded, coatings on various sides of the clasts indicate reworking. 250 - 450 cpm (coarse). 150 - 350 cpm (fines). Minor fine charcoal in sieve (3 pieces, approx. 2mm each)

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Soil formed in sediments underlying Qf1 surface east of TA-41, 13.5 feet above base level

Site: LA 12 Location: Qf1 surface east of TA-41				Date: 09/12/94		Vegetation: Grasses, ponderosa pine, douglass fir, scrub oak					Aspect: Exposure faces south Described By: P. Drakos, C. Inoue		
% Gravel	Horizon	Depth (ft)	Boundary	Color Dry	Color Moist	Texture	Structure	Consistence Dry	Consistence Wet	Clay Films	Roots Pores	CaCO3	Comments
10%, angular-subrounded 1/4" dacite, pumice	AC	0 - 0.6	cs	10YR 4/2	10YR 3/2	sand	1msbk	so	so,po	n.o.	3fr, 1vfip	non	Slightly darkened surface horizon; slightly sticky due to presence of organic matter
10%, generally 1/8" to 1/2" volcanic lithics; pumice, minor dacite	C	0.6 - 2.0		10YR 5/3	10YR 4/3	sand	m	lo	so,po	n.o.	2fr, 1fp	non	0.6 ft. diameter oak tree stump on Qf1 surface 15 feet NE of pit has 53 tree rings

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