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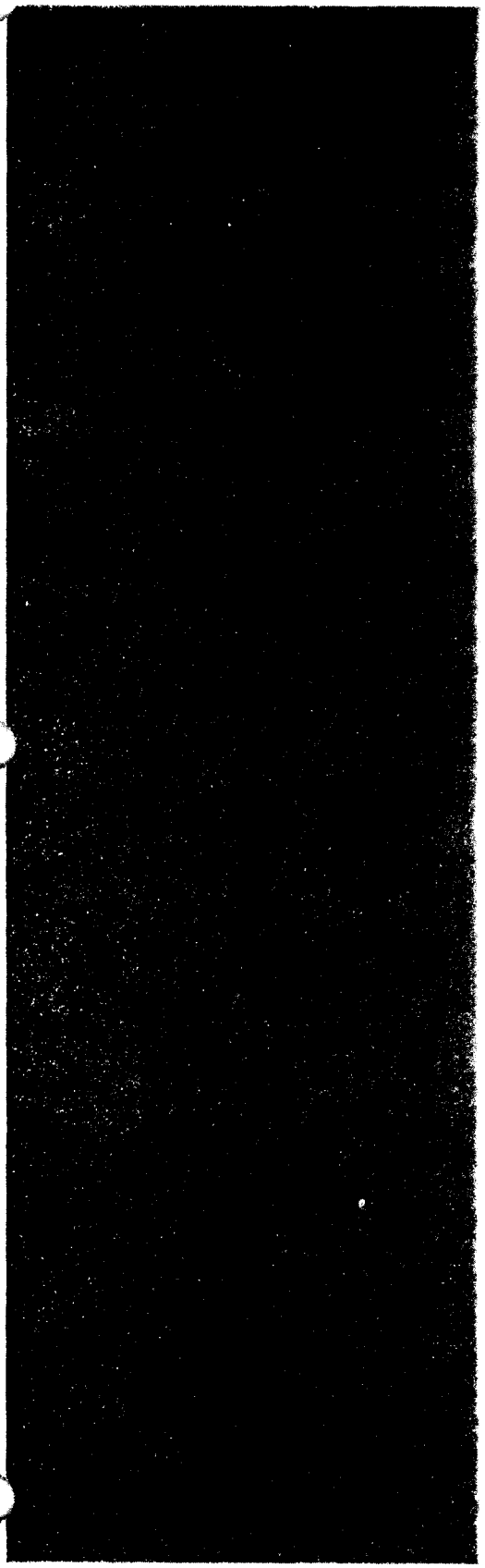

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Issued: February 1988

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SITE GEOLOGY AND HYDROLOGY OF TECHNICAL AREA 16, AREA P

by

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ABSTRACT

Two distinct units of the Quaternary Upper Bandelier Tuff were encountered during a geological investigation of Technical Area 16, Area P, at Los Alamos National Laboratory, Los Alamos, New Mexico. Unit 3, the uppermost unit encountered, consists of four distinct ashflows, and is characterized by a high degree of welding and low-moisture content. Unit 2, the lowermost unit encountered, is densely welded, and noticeably impeded drilling operations. The Water Canyon Fault Zone, which lies approximately 500 ft to the east of Area P, exhibits 10 to 15 ft of displacement in the subsurface with little surface expression apparent. No evidence for the existence of groundwater was detected.

I. INTRODUCTION

Technical Area 16, Area P (TA-16, Area P), at Los Alamos National Laboratory (LANL) has been used since the 1950s as an industrial landfill, and is regulated under the New Mexico Environmental Improvement Division's Hazardous Waste Management Regulations due to barium residues in excess of the Extraction Procedure (EP) toxicity limits. LANL desires to permanently close the landfill, and in an effort to address closure and postclosure requirements required by RCRA (Resource Conservation and Recovery Act), a geological site investigation was conducted by the LANL Environmental Surveillance Group (HSE-8) during the summer of 1987.

II. REGIONAL GEOLOGY

The regional geology of Los Alamos has been previously reported in detail (i.e., Smith and Bailey, 1966; Purtymun, 1974; Gardner and Goff, 1986). In summary, Los Alamos National Laboratory is located on the eastern flank of the Jemez Mountains, an area dominated by volcanic deposits associated with the formation and collapse of the Valle and Toledo Calderas. Eruptive activity culminated with the deposition of a large volume (about 400 km^3) of Quaternary Bandelier Tuff, a rhyolitic tuff ranging in thickness from 30 to 1000 ft. The Bandelier Tuff is composed of a series of ashfall and ashflow tuffs unconformably resting on Chino Mesa Basalt and Puye Conglomerate of the Santa Fe Group. Depth

to the main aquifer in the vicinity of Area P is about 1230 ft (Purtymun, 1984) (Fig. 1).

Deposits of Bandelier Tuff form broad plateaus that encircle the Jemez Mountains and dip gently away from the Valle Caldera. The plateau on the eastern side of the Jemez Mountains, the Pajarito Plateau, consists of a series of east to southeast trending mesas separated by deeply incised canyons. The Bandelier Tuff itself consists of upper (Tshirege) and lower (Otowi) members, each containing a prominent ashfall bed at the base. Generally, the upper (Tshirege) member is the more densely welded of the two, and welding tends to increase with proximity to caldera sources (Bailey et al., 1969; Gardner et al., 1986).

Four fault zones have been recognized in the Pajarito Plateau: Pajarito, Water Canyon, Guaje Mt., and Rendija Canyon Fault Zones (Dransfield and Gardner, 1985). The Water Canyon Fault Zone, which extends through TA-16, trends roughly north to northeast with about 30 to 100 ft of down-to-the-east displacement. Approximately 10 to 15 ft of displacement can be seen in the subsurface adjacent to Area P, with little or no surface expression apparent.

III. GEOLOGY OF AREA P

Area P lies near the eastern margin of the Jemez Mountains, in the saddle of a short east-west trending mesa. The Water Canyon Fault Zone cuts through the tuff approximately 500 ft to the east. To the north, the Canon de Valle has cut through the fault scarp, draining an area on the west of the Sierra de los Valles flanks. To the south is a small unnamed canyon containing intermittent discharge from local outfalls. The main technical centers of TA-16 are located west of Area P (Fig. 2).

The mesa is capped by approximately 800 ft of Bandelier Tuff (Purtymun, 1968). Five distinct units, composed of groups of ashflows, have been recognized in the Tshirege Member of the Bandelier Tuff (Griggs, 1964; Smith and Bailey, 1966), of which two units were encountered during drilling operations at Area P (Brown, 1987). In addition, scattered outcrops of El Cajete Pumice occur in the area.

In order to establish the shallow subsurface geology of Area P, a series of 17 boreholes (numbered P-0 through P-16) was drilled in the summer of 1987. Drilling was done with a CME-55 rotary drilling rig and 4-inch conventional auger. Continuous auger cuttings were retrieved for lithologic logging and moisture analysis, and one set of continuous core was recovered using 6-inch hollow stem auger and split-spoon core barrels.

Borehole logging of lithology was done on the basis of four characteristics: (1) color (Goddard et al., 1984), (2) degree of welding, (3) shape and abundance of pumice lapilli, and (4) distribution of lithic fragments. Four distinct types of welding were recognized during drilling operations:

1. Nonwelded: high porosity, low cohesion of glassy fragments and crumbly texture. In core samples, this can be recognized by disaggregation and little or no flattening of pumice lapilli.

2. Moderately welded: less porosity, moderate cohesion, brittle texture, and slight deformation of glassy fragments. In core samples, this texture crumbles easily in the hand and contains some noticeably flattened pumice lapilli.

3. Welded: low porosity, good cohesion, brittle texture, and noticeable deformation of glassy fragments. This texture normally requires a hammer to break, and the majority of pumice fragments are noticeably flattened.

4. Densely welded: texture noticeably impedes or halts drilling, with little or no penetration; poor core recovery.

Two major lithologic units have been recognized at Area P (person. comm., W. Purtymun, 1987). Unit 3, the uppermost unit encountered during drilling operations, consists of four individual ashflows that appear to have cooled contemporaneously, forming a single compound unit. These ashflows are herein designated as Subunits 3a, 3b,

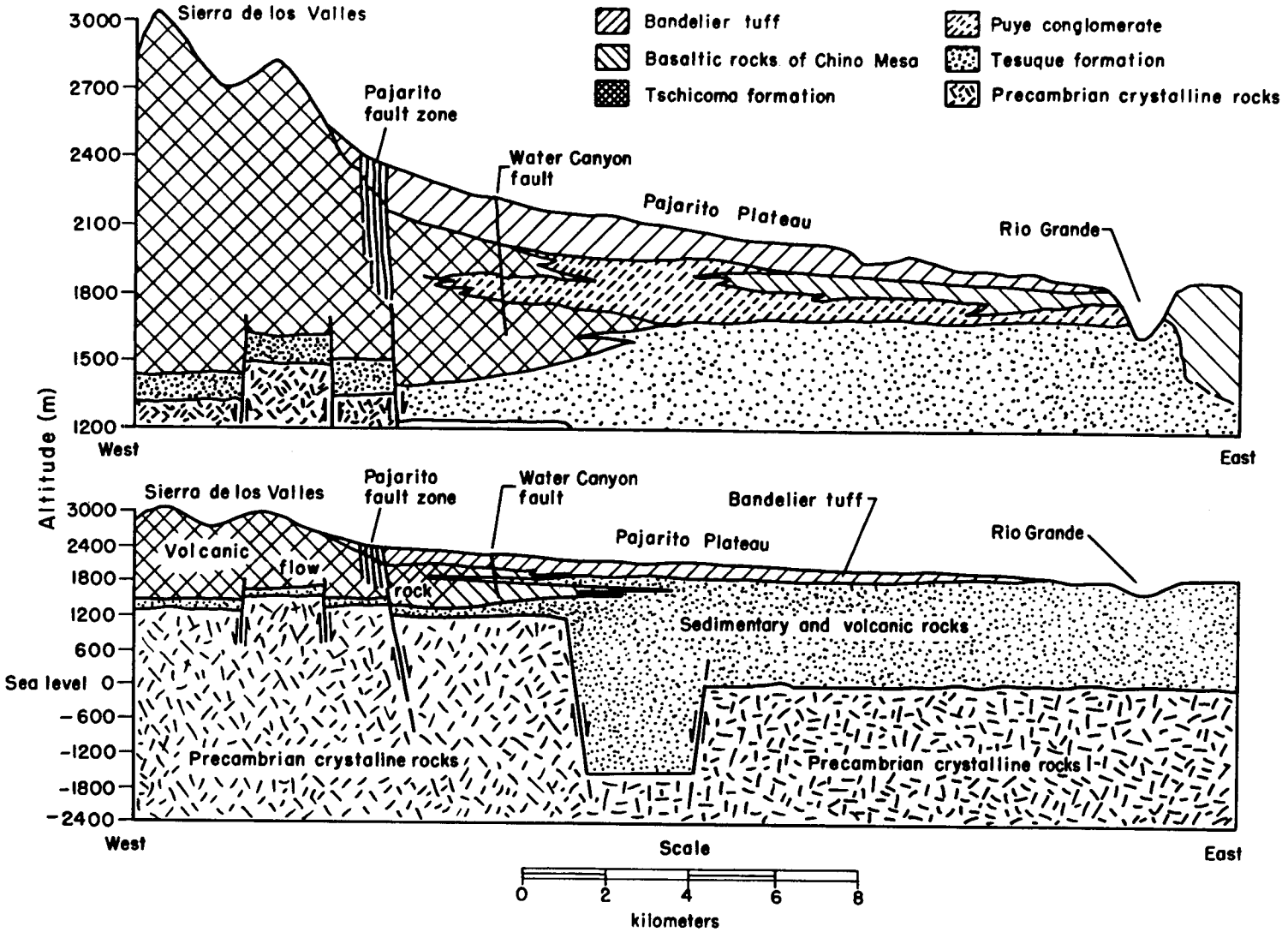

Figure 1. Geologic cross section through the Pajarito Plateau.

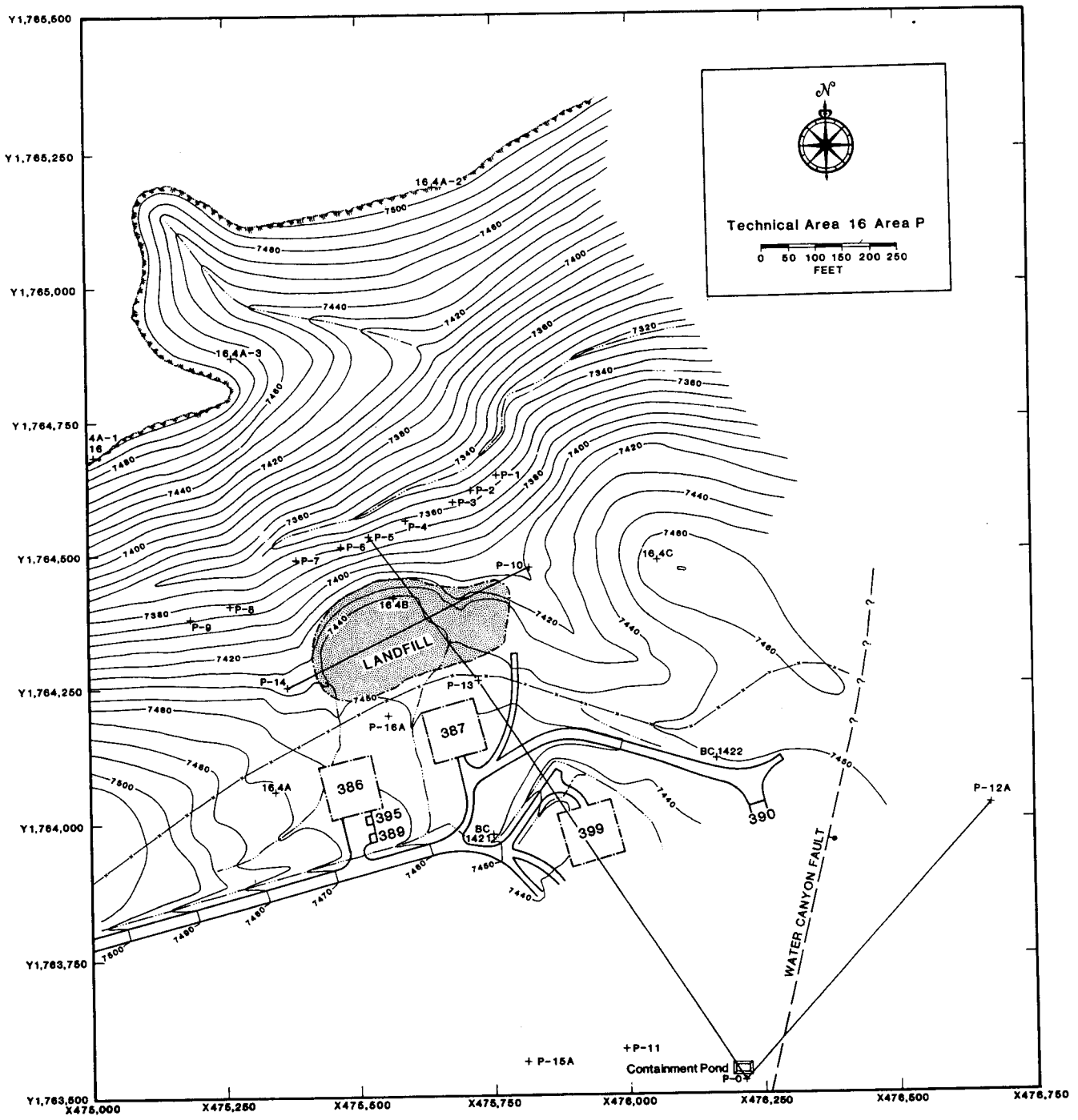

Figure 2. Site map of Technical Area 16, Area P. Boreholes are marked with crosses, numbered P-O through P-16A. Additional crosses are surveyer's marks.

3c, and 3d (bottom to top). Unit 3 rests conformably above Unit 2, the lowermost unit encountered. In general, the Bandelier Tuff dips 2 to 5° towards the east; in the vicinity of Area P dip is negligible, and the units are essentially horizontal and of uniform thickness.

Subunit 3a consists of a welded dark yellowish brown tuff, with rare pumice lapilli (slightly flattened), and abundant pebble-sized red porphyritic quartz latite and grey rhyolite lithic fragments. The ratio of quartz latite to rhyolite increases towards the base of the subunit. The contact between Subunit 3a and Unit 2 tends to be densely welded. East of the Water Canyon Fault this unit appears to be non-welded.

Subunit 3b consists of a welded pale yellowish brown tuff, with common grey and red pumice lapilli, (noticeably flattened), and rare pebble-sized rhyolite lithic fragments. This unit weathers to a dark brown, and contains abundant clayey pumice lapilli to the northwest.

Subunit 3c consists of a moderately welded brownish grey to yellowish brown tuff, with common grey pumice lapilli (noticeably flattened), and rare pebble-sized rhyolite lithic fragments. Clay-filled vertical fractures are common throughout this subunit. The contact between 3c and 3d tends to be densely welded.

Subunit 3d outcrops along the higher rim of the saddle, and consists of a moderately welded yellowish brown tuff, with rare pebble-sized rhyolite lithic fragments and common grey pumice lapilli. Subunit 3d is overlain by scattered deposits of El Cajete Pumice.

Locally, Unit 2 consists of a welded to densely welded tuff, light grey to pinkish grey in color, with common pumice lapilli and pebble-sized rhyolite fragments. Due to dense welding, the drill bit was only able to penetrate the upper 5 to 10 ft of Unit 2 (Fig. 3).

IV. *IN SITU* MOISTURE CONTENT

Hydrologic characteristics of tuff depend primarily on the degree of welding, with porosity and hydraulic conductivity decreasing as the degree of welding increases. At Los Alamos, saturated hydraulic conductivity for a moderately welded tuff ranges from 0.1 to 1.7 ft/day, and for a welded tuff ranges from 0.009 to 0.26 ft/day (Abeele et al., 1981). Samples of tuff recovered during drilling operations at Area P were not saturated.

Gravimetric moisture determinations were conducted to obtain a direct measurement of *in situ* water content of the tuff. Samples were taken from drill cuttings every 5 or 10 ft, and moisture determinations were made by weighing samples immediately after collection and after oven-drying 24 hrs at 105°C.

Although gravimetric moisture determinations are relatively easy to perform, care must be taken to ensure that the heat produced by drilling does not bias the samples collected. In the few cases where drill cuttings were noticeably warm to the touch, or water vapor was noticed coming from the borehole, samples were not collected for analysis. Care was also taken to maintain the drying oven at 105°C to ensure that no structural water was driven off.

Table I provides a summary of gravimetric data collected for Unit 3, and indicates a low overall moisture content for Area P. Although a range of 1.9 to 24.7% is considered low, this value slightly exceeds the gravimetric moisture content determined for technical areas further to the east [5-11% for TA-33 (Abrahams, 1963), 2-20% for TA-54 (Kearl et al., 1986)]. This higher range may be due to increased

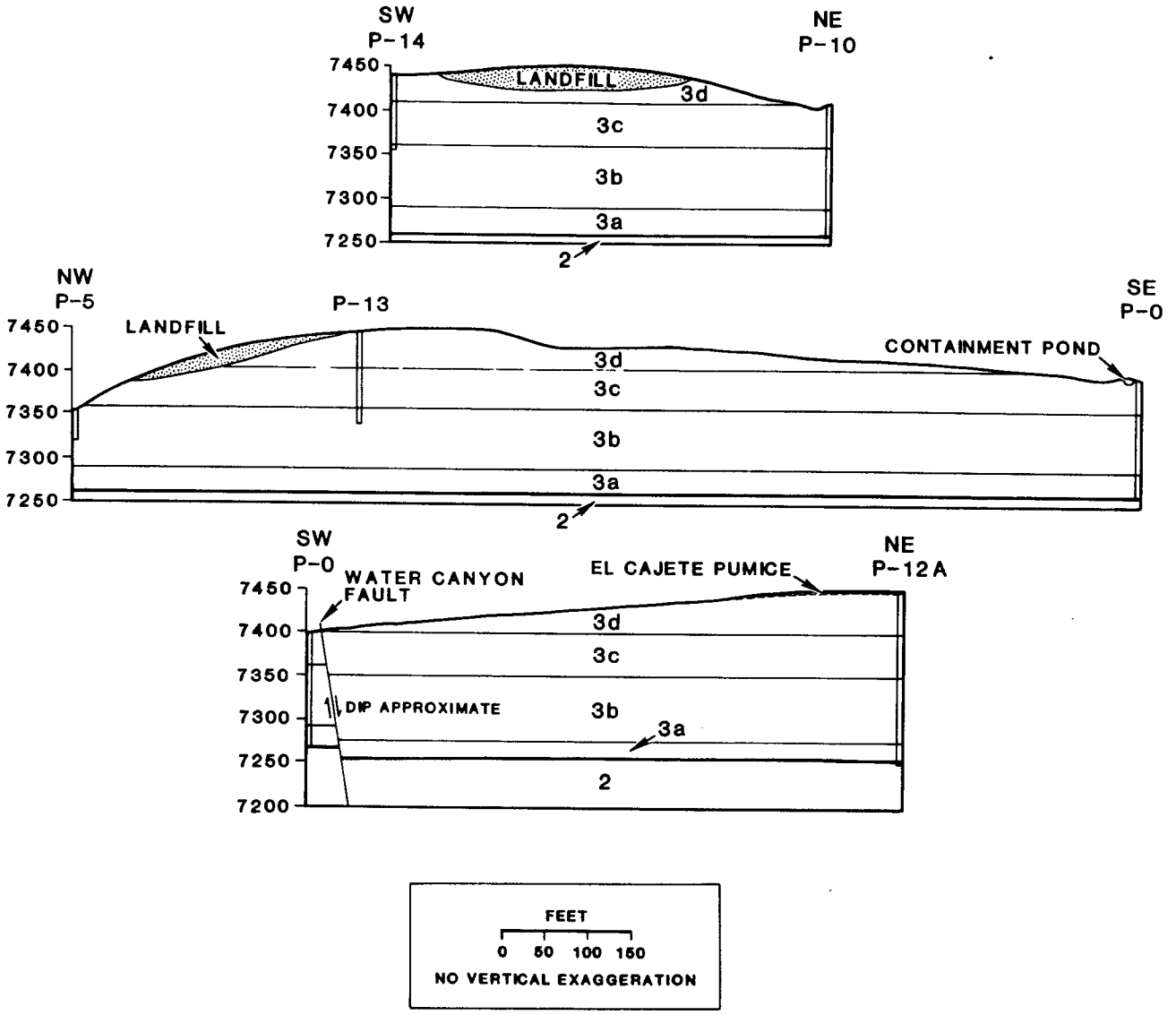

Figure 3. Geologic cross sections through Area P. Section lines are shown in Figure 2.

rainfall at TA-16, the result of orographic effects caused by the adjacent Jemez Mountains.

The energy relationship with moisture content for the Tshirege Member of the Bandelier Tuff was derived for volumetric moisture content by Abrahams (1963). Volumetric values can be converted to gravimetric values by dividing volumetric values by the average bulk density of the tuff. Repeated neutron and gamma probe calibration runs have established an average bulk density for the Tshirege Member of 1.4 g/cm^3. In addition, the density of 10 random samples was obtained after drying by weighing crushed tuff of a known volume. Average density for the 10 samples was 1.47 g/cm^3, with a standard deviation of 0.12.

Table I. Average Gravimetric Moisture Content. STD = Standard Deviation

Subunit	Mean (%)	STD	Range (%)
3d	5.2	3.6	2.2-17.7
3c	6.1	3.5	1.9-24.7
3b	5.7	2.1	2.3-11.4
3a	3.8	1.4	2.3-5.8
Total Unit	5.8	3.0	1.9-24.7

TA-16, Area P, lies in the vadose zone of the Bandelier Tuff, a zone defined by Everett et al. (1984) as existing beneath the topsoil and above the water table, in which moisture in pore spaces coexists with air or in which geological materials are unsaturated. Based on the results of Abrahams (1963), saturation of the Tshirege Member of the Bandelier Tuff, and thus groundwater, occurs when gravimetric moisture content is about 29%. When moisture content is below 7%, there is no movement of water; between 7 to 21% moisture is redistributed by diffusion; between 21 to 29% moisture distribution is by gravity and capillarity, and above 29% movement is by gravity drainage (Fig. 4). Table I suggests that the primary mechanism for moisture distribution at Area P is diffusion.

In summary, the shallow geology of TA-16, Area P, consists of two distinct units. The upper Unit 3 consists of four ashflows that appear to form a single compound unit. The lower Unit 2, a separate compound unit, is densely welded in the vicinity of Area P, and noticeably impeded drilling operations. There is no evidence of groundwater at Area P. The results of this investigation will be incorporated in the LANL landfill closure plan for Area P.

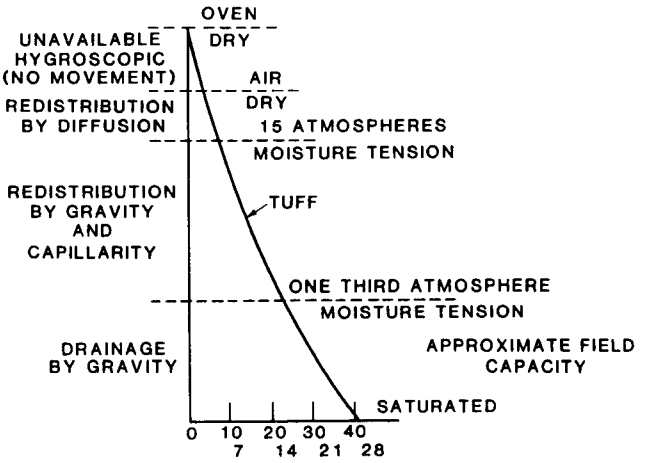

Figure 4. Energy relationship with moisture content of Bandelier Tuff (modified from Abrahams, 1963).

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