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Geology and Hydrology of Mesita del Buey

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GEOLOGY AND HYDROLOGY OF MESITA DEL BUEY

by

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ABSTRACT

Mesita del Buey is used for the disposal of wastes contaminated by radionuclides, of toxic or explosive chemicals, and of classified materials. These are buried in pits or shafts dug into the mesa surface. The mesa, covered by a clay-like soil, is underlain by a series of ashfalls of rhyolite tuffs from 240 to 590 ft thick. The tuffs are above the main aquifer of the Los Alamos area which lies at a depth of about 1,000 ft. Stream flow in adjacent canyons is intermittent. Water in the alluvium of the stream-connected aquifer in the canyon south of the mesa is recharged by storm runoff. The hydrologic characteristics and conditions of the soil, tuff, and seal material used to cover the wastes indicate no recharge to the stream-connected aquifer or main aquifer through the soil, buried wastes, or tuff at Mesita del Buey.

INTRODUCTION

Mesita del Buey is part of the Pajarito Plateau about 4 miles southeast of the community of Los Alamos, New Mexico (Fig. 1). The mesa, designated Technical Area 54, is used for the disposal of wastes contaminated by radionuclides, of toxic or explosive chemicals, and of classified materials. These are buried in pits or shafts dug into the mesa surface. Disposal operations on the mesa began in 1956.

The geology and hydrology of Mesita del Buey were studied. The mesa, covered by a clay-like soil, is underlain by a series of ashflows and ashfalls of rhyolite tuff. The ashflow units underlying the mesa top were mapped. Logs of a supply well and test holes in Pajarito Canyon, south of the mesa, were used to correlate the subsurface geology. Joint systems in the upper ashflows in the disposal areas were analyzed. Hydrologic data on soil and tuff moisture, surface water, stream-connected aquifers, and the main aquifer were collected. The erosion rates of the tuff were estimated. The study was to determine the geohydrologic pattern in relation to the disposal operations.

Mesita del Buey is a narrow southeast-trending mesa about 2 miles long and a quarter of a mile wide (Fig. 2). The mesa surface slopes gently from an altitude of about 6,900 ft near its western margin to about 6,600 ft near its eastern end. It is bounded on the north by an unnamed canyon and Canada del Buey, and on the south by Pajarito Canyon. The canyons have cut 50 to 100 ft below the surface of the mesa. The edges of the mesa are vertical or near-vertical cliffs, with steep slopes at their bases. The ashflows on the north-facing slopes at the foot of the mesa are covered with detrital alluvium, whereas those on the south-facing slopes are exposed.

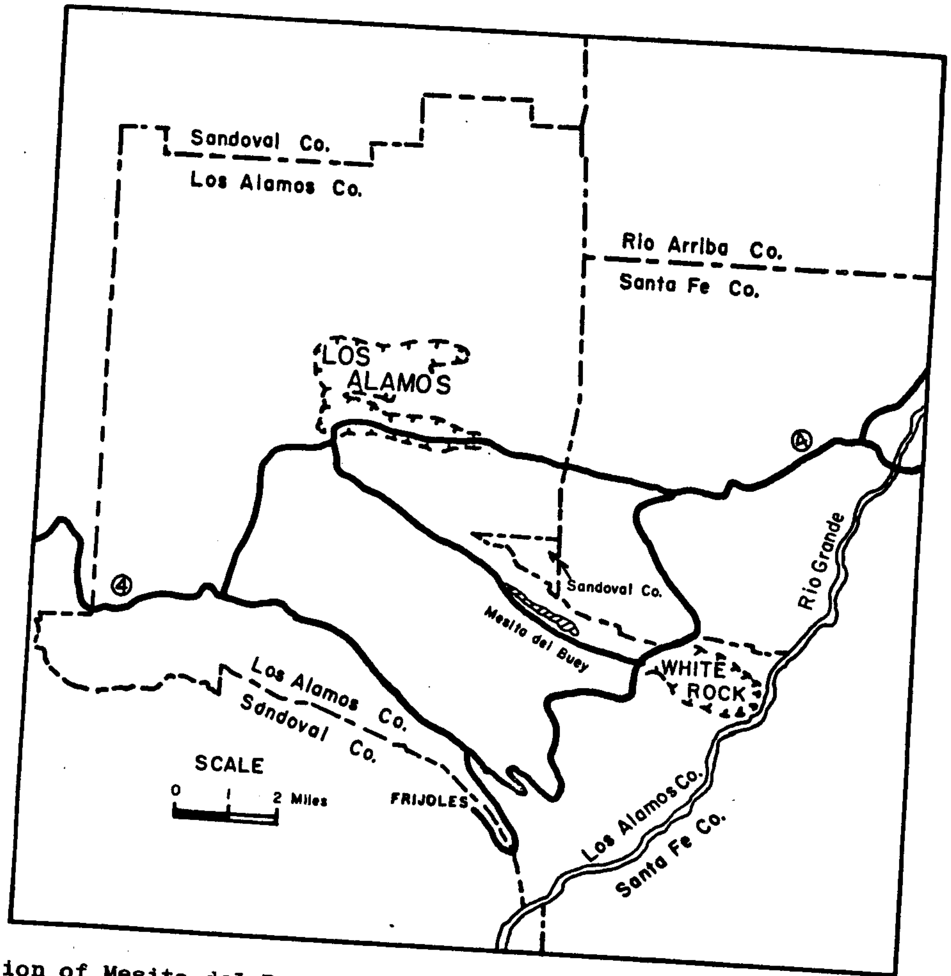


Fig. 1. Location of Mesita del Buey.

GEOLOGY

The Pajarito Plateau forms a topographic high area along the western part of the Rio Grande depression in north central New Mexico. Mesita del Buey is a part of the Pajarito Plateau. The plateau is formed by a series of Pleistocene ashfalls and ashflows of Bandelier Tuff.[1] In the subsurface are the sediments and volcanic rocks of the Santa Fe Group of Middle Miocene to Pleistocene age. The formations in the Santa Fe Group, from oldest to youngest, are the Tesuque and Puye with interbedded Chino Mesa basalt (Griggs' "basaltic rocks of Chino Mesa").

STRATIGRAPHY

Santa Fe Group. Santa Fe Group formations are not exposed at Mesita del Buey, but were penetrated by supply well PM-2 in Pajarito Canyon near the western part of the mesa. The Tesuque Formation consists of silty sandstones, sandstones with lenses of clay, and pebbly conglomerate. The well penetrated about 1,200 ft of this formation. The Puye Formation overlies the Tesuque. The lower 70 ft of the Puye is poorly consolidated channel-fill deposit; the upper 640 ft is volcanic debris. The Chino Mesa Formation is composed of basalt flow rocks and interbedded sediments. It overlies the main body of the Puye Formation, and only a thin section of the Puye overlies the basalts (Fig. 3). Supply well PM-2 penetrated about 270 ft of the Chino Mesa basalt.

Bandelier Tuff. The ashflows and ashfalls of the Bandelier Tuff overlie the Chino Mesa basalt (Fig. 3). The Bandelier has been divided into three members. In ascending order, they are the Guaje, Otowi, and Tshirege Members.

Guaje Member. The Guaje Member is an ashfall pumice with a thin layer of water-laid pumiceous tuff that rests on the Puye Formation and the Chino Mesa basalt. The Guaje consists of gray lump-pumice fragments as large as 2 in. in diameter. Glass shards and crystals of quartz and sanidine are present in the cellular structure. The upper 2 to 3 ft is reworked pumice and tuff. The Guaje does not outcrop at Mesita del Buey, but below the surface it varies from about 30 to about 10 ft thick from west to east in Pajarito Canyon.

Otowi Member. The Otowi Member is a light gray, nonwelded, pumiceous, rhyolitic tuff. It contains quartz crystals, glass shards minor amounts of mafic minerals, and varying amounts of rock fragments of rhyolite, latite, and pumice in a fine-grained ash. The Otowi is mostly ashflows, but contains several beds of reworked tuff and pumice at the top. It does not outcrop at Mesita del Buey but is found subsurface (Fig. 3).

Tshirege Member. The Tshirege Member is a series of ashflows of rhyolite tuff which have been classified according to degrees of welding, i.e., nonwelded, moderately welded, and welded tuffs.[2] The nonwelded tuff has high porosity, only light cohesion of glassy fragments, and crumbly fracture. The moderately welded tuff has less porosity, moderate cohesion, slight deformation of glassy fragments, and a somewhat brittle fracture. The welded tuff has low porosity, good cohesion, a high degree of deformation by flattening of glassy fragments, and a brittle fracture. Most of the pores are capillary in size. The following shows porosity range in each classification.

	Range (Vol %)
Nonwelded tuff	40 to 60
Moderately welded tuff	30 to 55
Welded tuff	15 to 40

The Tshirege Member has been divided into three units, determined by Baltz et al.[3] where it outcrops in Mortandad Canyon. The Tshirege at Mesita del Buey was mapped using these units. At Mesita del Buey, as at Mortandad Canyon, Unit 1 has been subdivided into units 1a and 1b, and Unit 2 into 2a and 2b (Fig. 2). At Mesita del Buey, Unit 3, a nonwelded to moderately welded pumiceous tuff, is absent.

Unit 1. The lower unit of the Tshirege Member consists of two layers, similar in lithology but different in color and welding. The lower layer is designated Unit 1a and the upper, Unit 1b.

Unit 1a is a light orange to light brown, pumiceous tuff breccia. It contains numerous pumice lumps as much as 6 in. long, with small quartz crystals and rock fragments of latite and rhyolite. The tuff ranges from nonwelded to moderately welded and weathers to a steep slope. In places, a vertical wall with a talus slope at the base has formed. Unit 1a overlies the reworked sediments at the top of the Otowi Member. The upper part of the unit is exposed in Canada del Buey along the eastern edge of the mesa (Fig. 2). In the subsurface at the western part of the mesa, Unit 1a is about 30 ft thick, thinning to less than 10 ft to the east.

Unit 1b is a grayish brown tuff containing larger quartz crystals but fewer and smaller rock fragments of pumice, latite, and rhyolite. The unit is moderately welded and weathers to a vertical wall or steep talus slope. It is separated from the underlying Unit 1a by a notch, caused by weathering in a vertical wall, or is recognized as a talus slope lying on the bench formed at the top of Unit 1a. Unit 1b outcrops in lower Canada del Buey east of the mesa. Its thickness averages about 25 ft.

Unit 2. Unit 2 forms the walls and surface of Mesita del Buey. It consists of several ashflows, divided into lower

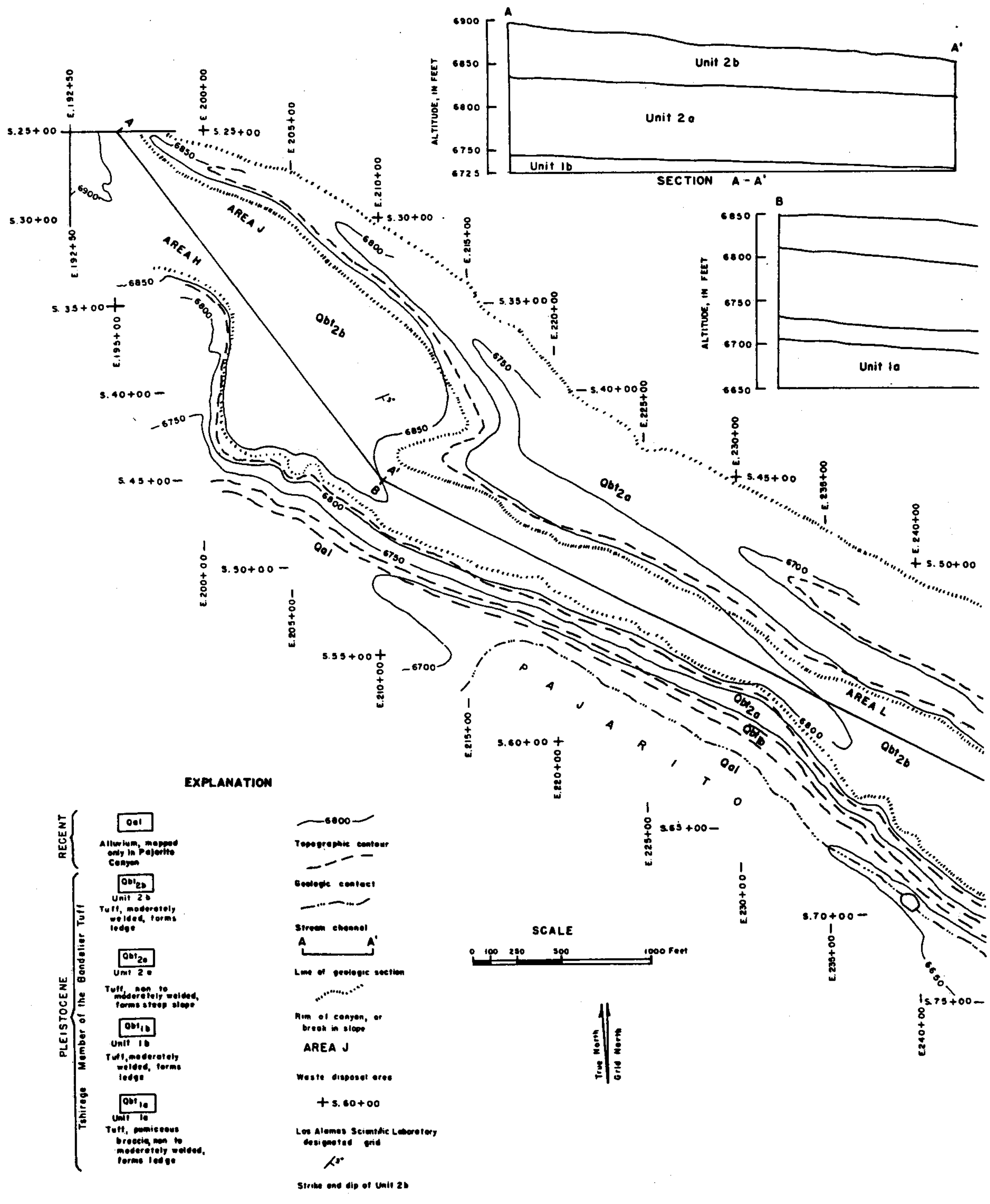
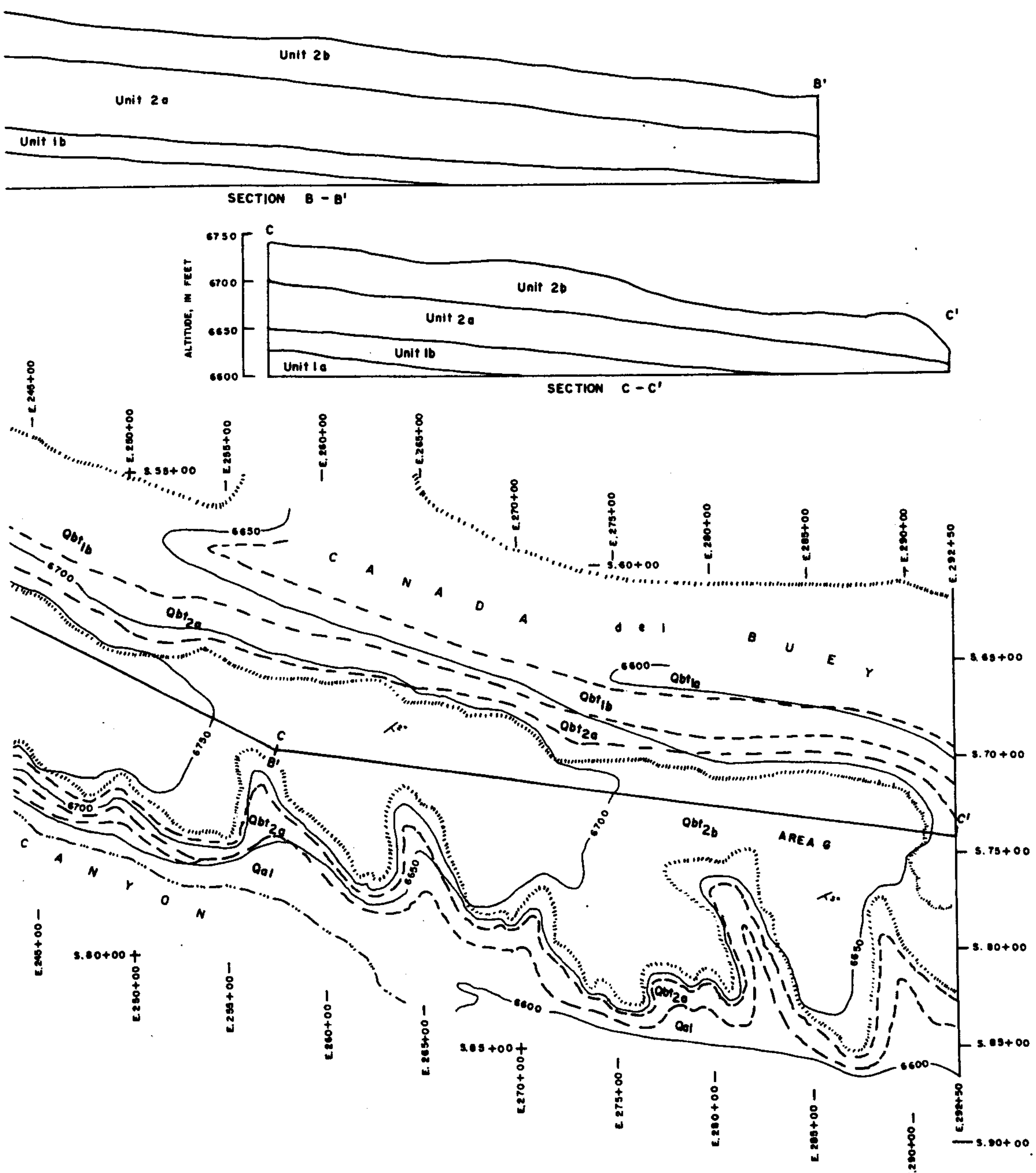


Fig. 2. Geologic map and sections of Mesita del Buey.


Unit 2b
Unit 2a
Unit 1b
B'
SECTION B - B'
C
6750
6700
6650
6600
ALTITUDE, IN FEET
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Unit 2a
Unit 1b
Unit 1a
C'
SECTION C - C'
C A N A D A del B U E Y
C A N Y O N
AREA G
Qbt1b
Qbt2a
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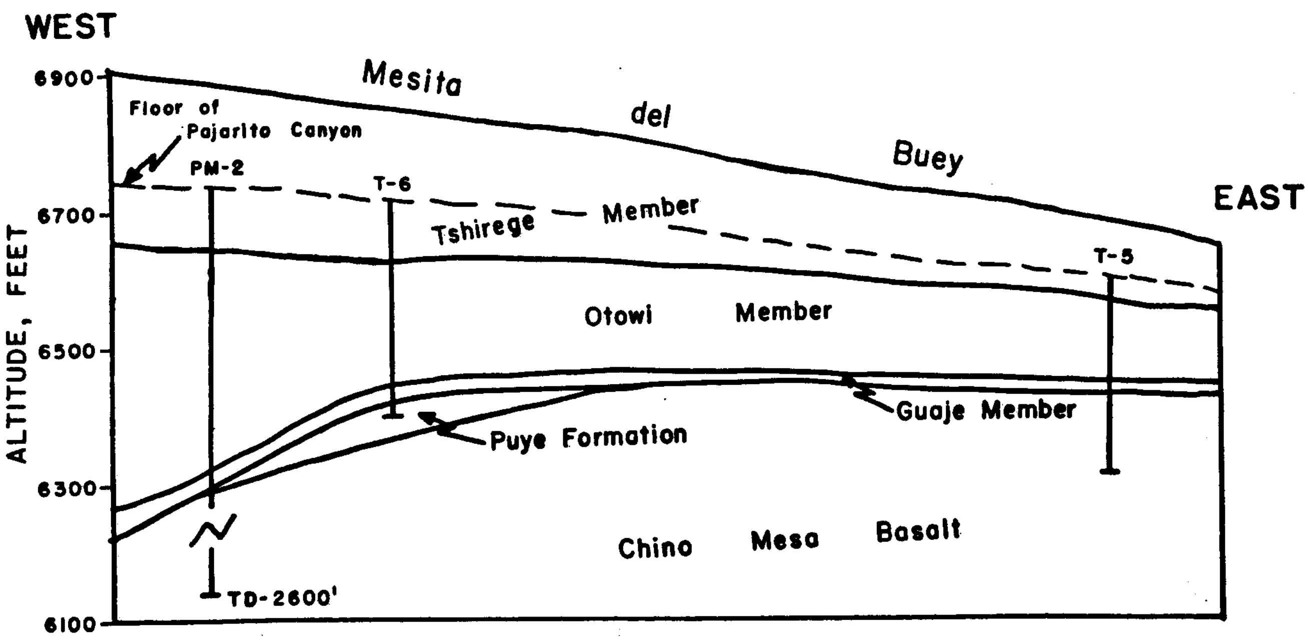

Fig. 3. Geologic cross section (East-West) showing relationship of the Chino Mesa basalt to the Bandelier Tuff.

Unit 2a and upper Unit 2b.

Unit 2a is a light-gray pumiceous tuff that contains rock fragments of pumice, latite, and rhyolite, with some quartz crystals in a light-gray ash. The pumice fragments are devitrified and dark brown. The rock fragments in the lower part of the unit may be as long as 3 in., but they decrease in size toward the top of the unit. The western part of the unit is a moderately welded tuff that forms a vertical wall along the canyons. Eastward, the welding decreases to a non-welded unit where it forms a talus slope. There are two ashflows or ashfalls in Unit 2a. The upper part of the unit near the western margin of the mapped area (Fig. 2) is moderately welded tuff that becomes nonwelded as one progresses eastward. The nonwelded portion is apparently an ashfall containing numerous pumice fragments and some reworked tuff. Unit 1b is somewhat transitional into Unit 2a, and the contact is recognized by a gradual change in color and by a lithologic change. Unit 2a varies from about 85 ft thick on the west to about 30 ft thick to the east. Most of the thinning occurs in the upper ashfall.

Unit 2b is a light gray to brown, weathered rhyolite tuff with some pebble-size rock fragments of pumice, latite, and rhyolite and numerous crystals and crystal fragments of quartz and sanidine. It is a moderately welded to welded tuff that forms the upper walls and surface of the mesa. It forms ledges, benches, and vertical walls around the edge of the mesa. Unit 2b is separated from the underlying Unit 2a by an erosional contact, marked by a thin layer of silt, sand, and pumice. Unit 2b is composed of at least two ashflows that cooled as a single unit. The contact between these two flows is not evident where they outcrop, but in pits dug at Area "G" (Fig. 2) it is recognized by increased size and number of pumice fragments with an occasional deposit of reworked tuff and pumice. Unit 2b is about 60 ft thick.

Soil and Alluvium. The soil cover is 3 to 4 ft thick along the axis of the Mesa and thins toward the canyon rims where the tuff is exposed. The light, brown, clay-like soil is derived from weathering of the tuff. The primary soil constituents are quartz and feldspar with the clay minerals montmorillonite and illite.[4]

The alluvium overlying weathered tuff in the stream channels north of the mesa is probably no more than 3 to 4 ft thick. It consists of sand-size quartz and sanidine crystals and crystal fragments, and pebble-to cobble-size fragments of latite, rhyolite, and pumice derived from weathering and erosion of the tuff.

The alluvium in Pajarito Canyon, south of the mesa, is 20 to 30 ft thick. About 1/2 mile southeast of Area "G" the canyon has cut to base level on the basalt, and the alluvium fans out on top of the basalt. The canyon heads on the flanks of the mountains and contains pebbles, cobbles, and boulders of latite and rhyolite, the volcanic flow rocks that form the mountains. The sand-grain-size material is derived in part from weathered tuff. Gravels from pits in this canyon have been used for road construction and concrete mix.

GEOLOGIC STRUCTURE

The Rio Grande depression near Los Alamos is 25 to 30 miles wide. Mesita del Buey lies within the depression. The estimated thickness of volcanic rocks and sediments overlying the basement complex of Precambrian crystalline rocks is about 12,000 ft.[5]

The upper ashflows at Mesita del Buey dip 2 to 3 degrees to the southeast. The ashflows of the Bandelier Tuff thin eastward because these younger rocks lie on top of the older basalt (Fig. 3). The basalts originated from volcanic centers to the east, and flow was north and west into the area, forming a topographic high before the tuff was laid down.

Joint Systems. The ashflows of the Bandelier tuff are broken into a number of blocks by joints, formed by shrinkage (tension) as the ashflow cooled. The near-vertical attitude of most of these joints and the curved form of some, are indicative of formation by cooling. The joints are more numerous in welded than in nonwelded tuffs because the welded tuffs were laid down at higher temperatures.

The joints are classified as master and minor joints. Master joints are numerous and long, and may pass through one or more ashflows. A single unit may contain several ashflows emplaced at different times, but the joint pattern of the older layer may tend to govern formation of joints in the younger layer as it cools. Also, two or more ashflows may be laid down in rapid succession and cool as a single unit with joints forming in the flows at the same time.

The master joints are vertical or nearly vertical and generally dip 70 degrees from the horizontal. The vertical trend may be straight or slightly curved. The dip is deflected slightly when the joint enters a unit with different density or degree of welding.

Minor joints dip at angles less than 70 degrees. They are more numerous near the tops of ashflows and do not persist as they intersect the master joints.

A joint traced vertically through an ashflow may be closed in places and open in others. Locally the opening may be as much as 2 in. wide, but most openings are less than 1/4 in. wide. Joints terminating in the base of the soil zone or in exposed tuff on the mesa surface are filled with light-brown clay which may extend 3 to 4 ft below the surface. Below the brown clay, the joint openings are filled, or the joint faces are plated, with a light-gray clay. The light-gray clay is derived from weathering of the tuff and from minerals leached from the tuff by water and precipitated along joint openings before development of the near-surface brown clay that seals the joint at the surface.

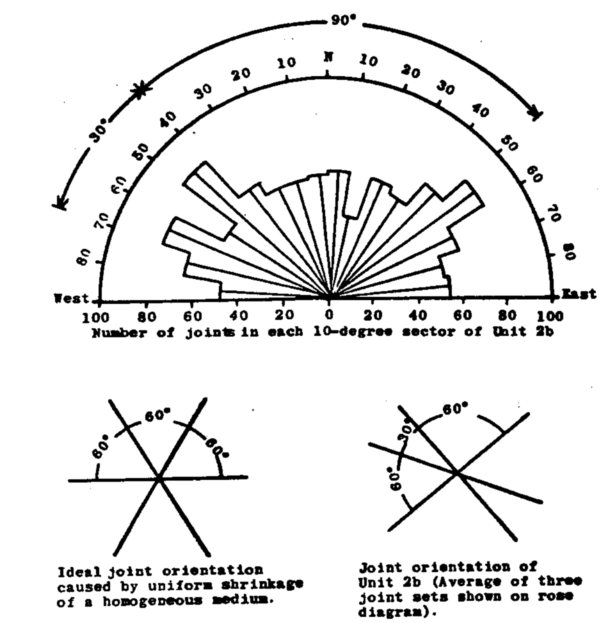

Fig. 4. Orientation of joints in Unit 2b.

The master joints are tension joints formed by the contraction of the tuff as it cooled. In a cooling homogeneous molten liquid, rupture occurs as three vertical fractures intersecting at angles of 120 degrees and radiating out from numerous centers.[6] If the centers are evenly distributed, the fractures bound vertical hexagonal columns. A rose diagram illustrating the orientation of joints formed from a homogeneous molten liquid would show three joint sets (a number of joints with the same characteristic pattern) intersecting at angles of 60 degrees (Fig. 4).

The heterogeneous characteristics of the tuff did not allow joint sets to form vertical hexagonal columns. A rose diagram prepared using the orientation of 1,078 master joints (492 in Area G (Fig. 2), 296 in Area L, and 290 in Areas J and H) showed the average of the three joint sets intersecting at angles of 30 and 90 degrees (Fig. 4). The three joint sets, N30°W to N50°W, N60°W to N80°W, and N40°E to N60°E, comprise 40% of the joints measured for the study.

The blocks formed by the joints range from a few square feet to as much as 500 ft^2 at the surface. In the walls of the pits there is about one master joint for every 7 ft of horizontal wall.

HYDROLOGY

The annual precipitation on the Pajarito Plateau is about 18 in. Most occurs in July and August as thunder showers. Some precipitation infiltrates the soil and tuff on the mesa, and the rest flows off into the canyons. Part of the surface flow in the canyons recharges stream-connected aquifers in the stream channel alluvium, and the rest is lost to evapotranspiration. Surface water drainage is eastward toward the Rio Grande. Water in the main aquifer lies at a depth of about 1,050 ft along the western margin of Mesita del Buey and at 850 ft at the eastern margin. Water in the aquifer moves eastward toward the Rio Grande.

SOIL AND TUFF MOISTURE

Part of the precipitation that falls on the Mesa surface infiltrates the soil and tuff. Where the soil cover has not been disturbed, little if any water from precipitation infiltrates the underlying tuff.[7]

Where the soil cover has been disturbed, as in the disposal areas, the moisture content of the tuff indicates that precipitation may have infiltrated to a depth of 10 ft. The moisture ranges from 2 to 8% by weight, decreasing with depth. Below 10 ft, the moisture content ranges from 0.5 to 2% by weight, showing that the moisture is redistributed by diffusion.

Tests of infiltration of precipitation in the tuff used to cover the waste in pits showed that moisture from a single storm may reach a depth of 6 ft, but in the weeks after the storm it is returned to the atmosphere by evaporation.

Open joints in the ashflow may allow precipitation to move into the tuff. The joints are now filled to a depth of 3 to

4 ft with clay that acts as a seal and prevents precipitation from infiltrating the tuff.

SURFACE WATER

Stream flow in the canyons north of Mesita del Buey is intermittent flow from storm runoff. These canyons head on the Pajarito Plateau and have a small drainage area. Stream channels in the canyons are narrow with few if any cut banks, indicating small and infrequent runoff.

Pajarito Canyon, south of the mesa, heads on the flanks of the mountains to the west and has a large drainage area. The intermittent flow in the canyon is from spring snowmelt and summer thunder showers. Gravel pits in the canyon usually contain ponded water. Some intermittent return flow occurs about 1 mile southwest of the mesa, where the alluvium laps on to a basalt flow.

STREAM-CONNECTED AQUIFERS

The alluvium in the canyons north of Mesita del Buey is thin and contains no perennial water owing to the small amount of runoff.

The intermittent stream in Pajarito Canyon, however, recharges a perennial body of water in the stream-connected aquifer in the alluvium. As is typical of stream-connected aquifers. the water table is highest during the spring from snowmelt and in late summer from showers. In the fall and early summer the water table declines. Gravel pits in the canyon have been dug into the top of the stream-connected aquifers.

MAIN AQUIFER

The top of the main aquifer (capable of municipal and industrial water supply) lies at a depth of about 1,200 ft along the flanks of the mountains to the west and slopes gently eastward toward the Rio Grande. The aquifer is recharged by precipitation on the mountains and in deep canyons cut into the western part of the Plateau.[8] The water moves eastward toward the Rio Grande where part is discharged into the river through seeps and springs. The rate of water movement computed from aquifer tests of supply wells is estimated to be 1 ft/day.[9] From Mesita del Buey to the Rio Grande is about 4 1/2 miles, so we estimate that any water will take over 60 years to move from beneath the mesa to the river.

EROSION RATES OF TUFF

Vital to the containment of wastes buried at Mesita del Buey is the rate at which the tuff encompassing the wastes erodes. Some of the wastes contain radionuclides with a very long half-life.

There is no practical method to determine the erosion rate of the tuff during the short time that the mesa has been used for waste disposal. Erosion rates can be approximated by relating the age of the tuff to its past erosion. Erosion rates based on these assumptions are conservative because the tuff probably eroded faster initially than at present. The area is more stable since the stream channels in Canada del Buey and Pajarito Canyon have cut to a temporary base level on the resistant basalt.

Radiometric dating indicates that the tuff was emplaced about 1.1 million years ago.[5] The thickness of Unit 3 tuff eroded from the surface of the mesa at Area G is estimated to be about 80 ft on the basis of geologic sections on the plateau where this unit is preserved. Its erosion rate for the past 1.1 million years is about 7.2×10^{-5} ft/year. Vertical downcutting in the canyons has been estimated at 1.9×10^{-4} ft/year in Canada del Buey and 1.6×10^{-4} ft/year in Pajarito Canyon. Wilden and Criley[5] estimated the vertical downcutting in major canyons to be 5 to 8×10^{-4} ft/year. At Area G, horizontal erosion at the top of the mesa is estimated to be about 4.5×10^{-4} ft/year.

Wastes are buried in the natural confines of the tuff to a level 2 ft below the mesa surface and then covered and mounded over with 6 to 8 ft of tuff. Considering the vertical erosion of 2 ft of tuff on the mesa top at a rate of 7.2×10^{-5} ft/year, it would take 27,000 years for the mesa top to erode to the top of the wastes.

The edges of the pits are 50 ft or more from the edge of the mesa. Considering the horizontal erosion of 60 ft of tuff at a rate of 4.5 x 10^{-4} ft/year it would take more than 110,000 years for the tuff to erode far enough to expose the wastes in the pits.

WASTE DISPOSAL AREAS

There are four areas on Mesita del Buey used for disposal of wastes contaminated by radionuclides, of toxic or explosive chemicals, and of classified materials. The disposal areas are pits and shafts located according to guidelines set up by the U. S. Geological Survey, the U. S. Atomic Energy Commission, and the Health and Engineering Divisions of the Los Alamos Scientific Laboratory (Appendix A).

Access to the disposal areas is from Pajarito Road. The mesa is fenced from canyon to canyon at its western margin.

AREA G

Area G has been designated for the disposal of solid wastes and packaged sludges that contain radioactive nuclides. The solid wastes range from rubber gloves and glasswear to parts of buildings or trucks that cannot be cleaned.[10] The wastes are buried in pits or shafts dug into the mesa surface.

The pits are 100 ft wide, 600 ft long, and 30 to 35 ft deep. There is a ramp at each end of the long dimension to facilitate entering the pit with trucks to dispose of the wastes. The wastes are buried in 6- to 8- ft-deep layers, and each layer is covered with 1 to 2 ft of tuff. The pits are filled to 2 to 4 ft below the land surface and then covered with 6 to 8 ft of tuff, slightly mounded for surface-water drainage.

There are a number of shafts for disposal of organic material, oil, or solid wastes. The shafts are 2 to 6 ft in diameter and up to 64 ft deep. Special shafts for certain types of wastes have been prepared by lining them with concrete or by coating their walls with asphalt. The entire area surrounding the pits and shafts is fenced and locked.

The pits and most of the shafts extend into Unit 2b, and the deeper (64 ft) shafts extend through Unit 2b into the top of Unit 2a of the Tshirege Member of the Bandelier Tuff.

AREA H

Area H has been designated for the disdisposal of classified materials. The materials are placed in 6-ft-diam shafts about 60 ft deep. The area is fenced and locked. The shaft currently in use has a locked cover. Filled shafts are capped with 5 to 6 ft of concrete. The shafts extend through Unit 2b into the top of Unit 2a.

AREA J

Area J is used for the disposal of wastes from areas where explosive chemicals are processed. It consists of pits 50 ft wide, 250 ft long, and about 15 ft deep. There are ramps at the ends of the long dimension of the pits. The area is fenced but not locked. The pits extend into Unit 2b.

AREA L

Area L is used for the disposal of chemicals or possibly toxic materials in pits or shafts. The pit is 12 ft wide, 200 ft long, and about 12 ft deep with ramps on the long dimension. Shafts are 6 ft in diameter and about 60 ft deep. The area is fenced and locked. The pit extends into Unit 2b, and the shafts extend through Unit 2b into the top of Unit 2a.

WASTE DISPOSAL AND THE GEOHYDROLOGIC ENVIRONMENT

Total containment of contaminants is of paramount importance in the disposal of wastes at Mesita del Buey. Initial containment is accomplished with the burial of wastes in pits or shafts. After burial, the major means of transport of contaminants to the environment would be in the hydrologic cycle.

Transport of contamination by surface runoff on the mesa seems unlikely because the wastes are buried.

Little if any water from precipitation or surface runoff infiltrates through the seal material overlying wastes in filled pits. There is not enough water to leach the contaminants from the wastes and move them into the tuff. The bottoms of the pits are underlain by about 590 ft of tuff along the western part of the mesa and about 240 ft of tuff along the eastern edge. The hydrologic characteristics and conditions of the soil, seal material, and tuff indicate no recharge to the stream-connected aquifers or main aquifer through the surface soil, buried wastes, or underlying tuff at Mesita del Buey.

The natural moisture content of the unsaturated tuff is in the range in which moisture is redistributed by diffusion. Contaminants may be transported by diffusion if gases or volatile fluids are placed in shafts or pits. Diffusion may take place through the tuff where there are large amounts of pore space, through open joints, or along contacts between ashflows.

Vertical and horizontal erosion rates of the tuff surrounding the waste in pits or shafts indicate that under present climatic conditions the estimated life of the pits will be about 27,000 years. Routine maintenance to control erosion of the seal material will extend this life.

REFERENCES

1. R. L. Griggs, "Geology and Ground Water Resources of the Los Alamos Area, New Mexico," U. S. Geological Survey Water Supply Paper 1753, 1964.
2. W. D. Purtymun and F. C. Koopman, "Physical Characteristics of the Tshirege Member of the Bandelier Tuff with Reference to Use as Building and Ornamental Stone," U. S. Geological Survey open-file report, 1965.
3. E. H. Baltz, J. H. Abrahams, Jr., and W. D. Purtymun, "Preliminary Report on the Geology and Hydrology of Mortandad Canyon near Los Alamos, N. M., with Reference to Disposal of Liquid Low-Level Radioactive Wastes," U. S. Geological Survey open-file report, 1963.
4. Eugene Staritzky, "Report on the Petrographic Examination of Local Soils," Los Alamos Scientific Laboratory report LA-741 Series A (1949).
5. R. Wilden and E. E. Criley, "Geology of Los Alamos," in "Geologic Studies and Material Properties Investigations of Mesita de Los Alamos," Los Alamos Scientific Laboratory report LA-3728 (1968).
6. M. P. Billings, Structural Geology, Prentice-Hall, Inc., New York, 1942.
7. J. H. Abrahams, Jr., J. E. Weir, Jr., and W. D. Purtymun, "Distribution of Moisture in Soil and Near-Surface Tuff on the Pajarito Plateau, Los Alamos County, New Mexico," in short papers in geologic and hydrologic sciences. Articles 293-435, U. S. Geological Survey Prof. Paper 424-D, 1961.
8. R. L. Cushman, "An Evaluation of the Aquifer and Well Characteristics of the Municipal Well Fields in Los Alamos and Guaje Canyons near Los Alamos, N. M.," U. S. Geological Survey Water Supply Paper 1809-D, 1965.
9. C. W. Theis and C. S. Conover, "Pumping Test in the Los Alamos Canyon Well Field near Los Alamos, N. M.," U. S. Geological Survey Water Supply Paper 1619-I, 1962
10. J. W. Enders, "Solid Radioactive Waste Disposal at the Los Alamos Scientific Laboratory," in "Disposal of Radioactive Wastes into the Ground," International Atomic Energy Agency, Austria, 1967.

APPENDIX A

GUIDELINES FOR CONSTRUCTION OF PITS ON MESITA DEL BUEY*

These guidelines were formed during a meeting held at Los Alamos on June 23, 1965, with the following people in attendance: Salvatore Russo, Eng-3; Ben Williams, Eng-3; Dean Meyer, H-1; William Kennedy, H-6; C. W. Christenson, H-7; of the Los Alamos Scientific Laboratory; and Dr. C. V. Theis, F. C. Koopman, and William D. Purtymun of the U. S. Geological Survey.

Construction

Pits should be a minimum of 50 ft from the canyon rim.

Pits should be no deeper than adjacent canyon floors.

The long dimensions of pits should be parallel (as near as possible) to surface topographic contours.

Large open joints should be filled with seal material (tuff removed from pit during construction).

Drainage around open pits should be such that runoff from precipitation on the mesa does not enter the pit while it is being filled.

Size and shape of pit are not important.

Pit bottoms need not be level.

Burial of wastes

Burial of wastes in layers (layer of waste covered by layer of tuff) should be continued.

Wastes should be buried in the confines of the natural tuff.(If the soil zone is exceptionally thick, this unusual condition would indicate instability in that immediate area.) The wastes should be buried below the soil zone within the tuff.

Surface seal of pits

Pits can be filled with wastes to within 2 ft of the land surface.

Seal material (tuff) overlying the wastes should be 6 to 8 ft thick.

The surface of the seal material over the pit should be slightly rounded.

Adequate drainage should be provided to remove runoff from precipitation on the mesa.

Drainage ways should be located so that they do not cross the surface of a sealed pit.

Planting of native vegetation on the surface of sealed pits should be considered.

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* From letter to S. E. Russo, LASL Group ENG-3, from F. C. Koopman, U. S. Geological Survey, June 30, 1965.

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