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Reference

LOS ALAMOS PROJECT - PUMICE INVESTIGATIONS

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FINAL REPORT NO. 2 - FIELD SURVEY

Geology and Pumice Deposits of the Pajarito Plateau, Sandoval, Santa Fe, and Rio Arriba Counties, New Mexico

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ABSTRACT

The rocks of the Pajarito Plateau consist of nearly horizontal volcanic and sedimentary beds which range in age from Middle Tertiary to Quaternary. The oldest rocks, known as the Chicoma volcanic group, occur along the western edge of the plateau and in the Jemez Mountains. The late Tertiary Santa Fe Formation consisting of sand, silt, clay, and gravel with some interbedded basalt crops out along the eastern escarpment of the plateau. The Bandelier rhyolite tuff is the youngest formation present, and it is the principal rock of the plateau. The bottom bed of the Bandelier formation consists of high-quality pumice which is as much as 35 feet thick. This lower member of the Bandelier formation is here termed the Santa Clara pumice bed.

The best pumice of the Santa Clara bed underlies the plateau in a central, north-south band 5 miles wide and at least 20 miles long. In this band the pumice probably averages 25 feet in thickness, and reserves amount to over two billion cubic yards. In the northeastern part of the plateau the Santa Clara pumice forms surface blankets covering some 45,000,000 square yards. It is estimated that these surface deposits contain nearly 242,000,000 cubic yards of pumice.

The nearest of the blanket surface deposits to Los Alamos is at Guaje Flats where reserves of about 7,000,000 cubic yards are available.

LOS ALAMOS PROJECT - PUMICE INVESTIGATIONS

Final Report No. 2 - Field Survey

Geology and Pumice Deposits of the Pajarito Plateau, Sandoval, Santa Fe, and Rio Arriba Counties, New Mexico

By
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INTRODUCTION

Location

The Pajarito Plateau lies at the east base of the Jemez Mountains. It is a generally level surface, seven to ten miles wide, which has been divided into many narrow segments by sharp, deep canyons cut by streams flowing eastward from the mountains to the Rio Grande. The major part of the plateau is included on the accompanying geologic map (Plate 1).

The map includes about 220 square miles and comprises small parts of the Jemez Mountains along the west edge and the Rio Grande along the east edge. The area extends from about Santa Clara Creek on the north to a short distance south of Frijoles Canyon on the south, a distance of about 17 miles.

Purpose and Nature of the Survey

The purpose of the geological work was to find pumice deposits in close proximity to the Los Alamos Project which would be suitable for use in pumice concrete construction. Several beds of pumice were examined and the most suitable of these, here termed the Santa Clara bed, was mapped throughout the area. In connection with the pumice exploration the entire geology of the area of Plate 1 was mapped. This was necessary in order to obtain the stratigraphic position of the bed and its probable continuity and extent within the plateau. The general geologic relations and stratigraphy that were determined

make it possible to forecast the presence, probable thickness, and character of the bed beneath most of the plateau.

The geologic mapping was done on vertical aerial photographs made available by the Soil Conservation Service at Albuquerque. The geology was plotted on the aerial photographs and transferred to a planimetric base with a Vertical Sketchmaster. Only about seven of the fourteen days in the field at Los Alamos were spent in the geologic mapping, the remainder being spent in assisting and advising the engineers during their testing and sampling of selected deposits. Although the outcrop of the Santa Clara pumice bed is shown as nearly continuous from north to south on the map, it should be understood that it is not everywhere of suitable grade and thickness.

GENERAL GEOLOGY

Only Tertiary and Quaternary rocks are exposed in the Pajarito Plateau and these range in age from Miocene (?) to Recent. In a general way the younger Quaternary rocks form the plateau and occupy a wide middle belt on the accompanying map. The Tertiary rocks form outcrop bolts on either side of the Quaternary rocks. The rocks of the western edge of the map, in the Jemez Mountains, are the Chicoma volcanic group (Miocene ?), and those along the eastern side in the plateau escarpment consist largely of the Santa Fe formation (Pliocene).

Chicoma Volcanic Group

The Chicoma volcanic group (Tc) consists of andesite, latite, and rhyolite which issued from volcanoes in the form of flows, and explosive showers of breccia and tuff. In the foothills immediately west of Los Alamos these rocks consist largely of dark purplish-gray porphyritic latite flows and breccias. These rocks were but briefly examined during the survey as they were important only in marking the westward extent of the Santa Clara pumice bed. In late

Tertiary time the Chicoma rocks were deeply eroded and then in early Quaternary time buried by the Bandelier tuffs. Recent erosion has stripped part of the tuff cover and, locally, as between Guaje and Rendija canyons re-exposed hills of the older Chicoma rocks.

Santa Fe Formation

The Santa Fe formation consists of poorly consolidated sand, silt, clay, and gravel which crops out along the base of the eastern escarpment of the Pajarito Plateau. It is dominantly an alluvial fan and flood-plain deposit, but near the top there are fanglomerate beds, basalt flows, and lake clays. These have been delineated as members on the accompanying map.

The oldest member designated as the Santa Fe sand, silt, and gravel (Tsf) is only the upper few hundred feet of a thick series of beds which crops out in the wide Espanola Valley between the Rio Grande and the Sangre de Cristo Range. The materials of this formation appear to have been carried into their present position by the ancient Rio Grande and its tributaries arising mostly in the Sangre de Cristo Range. Approaching Los Alamos from Pajoaque the pinkish Santa Fe member can be seen clearly in the lower parts of the cliffs of the mesa segments. It is well exposed at the junction of Los Alamos and Guaje canyons where it is overlain more or less conformably by the much coarser Puye gravel and fanglomerate (Tp).

The Puye gravel occupies the top of the segmented-mesa cliffs facing the Rio Grande northward from Los Alamos Canyon. Typical outcrops are exposed in the Laudermilk gravel pits. In the northern half of the Pajarito Plateau outcrops of the Puye extend for many miles up the deeper canyons and in Guaje and Santa Clara canyons it overlaps the Santa Fe sand member and lies upon the older Chicoma volcanics. The Puye is distinctly coarser than the underlying member and contains many cobbles and boulders, especially in the upper part, of the Chicoma volcanic rocks. It is coarse alluvial fan material or fanglom-

erate which was transported to its present position by erosion from the nearby Chicoma volcanic highlands. The member ranges in thickness from 125 feet along the east edge of the Plateau to 500 feet near the Jemez Mountains.

In the northern half of the plateau the Puye is overlain by the Santa Clara pumice bed. In the southern half of the plateau, especially along the west side of White Rock Canyon, the Puye gravel is overlain by and interbedded with the White Rock Canyon basalt flows (Twb).

The White Rock Canyon basalt flows occupy the upper part or rim of White Rock Canyon and their resistance to erosion is largely responsible for the gorgelike character of the canyon. Locally, as in Frijoles Canyon, the flows fill ancient valleys that had been cut into the underlying gravel and sand. These flows were extruded from volcanoes that existed principally in the Cerros del Rio and possibly also in Mesa de los Ortizes both of which are east of the Rio Grande. As many as three or four flows are present separated by sand, gravel, and silt which covered the lower ends of the successive flows. Along the west side of White Rock Canyon the individual flows are only a few tens of feet thick, but locally, and especially on the east side of the canyon, they are more than 100 feet thick.

Erosion cut shallow valleys in some of the earlier flows and sediments, and locally, later basalt flowed into these valleys. The flow of basalt which occupies the mesa at the entrance to Los Alamos Canyon is one of these, and, although it appears to be stratigraphically below the higher flow on Culebra Hill, it is actually younger.

To the west of the Rio Grande the flows are in most places covered by the younger Bandelier rhyolite tuff. The western edge of these flows, however, does not appear to have been more than three or four miles west of the present course of the Rio Grande in White Rock Canyon. The general effect of the basaltic eruptions was to shift the ancient Rio Grande to the west where it

flowed around the end of the flows.

The highest of the basalt flows immediately underlies a flat expanse of mesa upon which the town of White Rock is to be built. Although not shown on the map, this basalt flow is slightly covered by recent alluvial wash of pumice and tuff from the low mesas to the west of the town site. Excavations for buildings in this area, if into the basalt, will be much more difficult than at other places on the plateau.

The basaltic eruptions which originated very near to the ancient course of the Rio Grande dammed the river and caused the formation of small lakes. The basalt flow exposed in the road cut on Culebra Hill formed one such dam. Northward from the edge of the flow, remnants of the excellent clay deposits formed in the ancient lake may be found over an area of about four square miles. These lake clays with interbedded sand and gravel, here termed Culebra lake clay and gravel (Tcl), aggregate about 105 feet in thickness as follows:

No.	Description	Thickness (feet)
5.	Greenish-gray, plastic clay	27
4.	Rusty-buff conglomeratic sandstone	11
3.	Conglomerate of well-rounded pebbles and cobbles	7
2.	Light-buff, fine-grained, evenly-stratified sandstone with thin clay partings	40
1.	Light-gray, laminated, plastic clay	20
	Total	105

The clay beds 1 and 5 of the above section are of commercial quality.

The Culebra lake clay and gravel, which is at the same general stratigraphic position as the upper basalt flow, overlies the Puye gravel and is overlain by the Bandelier rhyolite tuff.

Bandelier Rhyolite Tuff

The Bandelier rhyolite tuff is Quaternary in age. It was derived by violent explosive outbursts in the Jemez Mountains. The Pajarito Plateau is dominantly made up of this formation. It consists of light-gray, white, and pinkish massive beds which generally stand up in bold cliffs. There appears to have been six or eight principal eruptions each depositing rather homogenous massive beds which differ only slightly in composition. The principal eruptions are separated by intervals of little or no deposition or slight local erosion of the tops of the massive beds. In many places thin water-laid pumice beds separate the thick massive tuff beds. Differential erosion of the successive beds during the cutting of the present canyons causes each successive bed to be set back from the underlying ones on slopes or narrow benches on the otherwise cliffy canyon walls.

Throughout most of the plateau the formation rather conformably overlies the Puye gravel, but along the eastern edge it has filled irregularly into canyons that were cut earlier by the ancient Rio Grande. Just as the basalt flows from the Cerros del Rio shifted the Rio Grande course to the west, the great accumulations of Bandelier tuff, originating from the west, displaced the river channel eastward where by subsequent valley cutting it superimposed itself down through the tuff, basalt, and underlying sand and gravel to form its present gorge.

As the tuff accumulated on the Puye alluvial fans it also overlapped and buried the hills of Chicoma volcanics in the eastern flanks of the Jemez Mountains. The Bandelier rhyolite tuff was deposited subaerially, and only locally or in a few thin beds was deposition in water. Although many of the exploded clouds of tuff rose high into the atmosphere to settle down as a "rain" of fragments, it appears also that many of the explosions were heavy, low-rolling, gaseous and incandescent clouds which rushed down the hillsides of the

volcano to come to rest and consolidate on the plain below.

The following is a section of the Bandelier rhyolite tuff measured near the junction of the Los Alamos and Bayo canyons.

No.	Description	Thickness (feet)
	(Top eroded)	
Upper Member:		
9.	Massive, pink, pumiceous rhyolite tuff with lithic and crystal fragments (upper pink cliff).....	35
8.	Massive, gray, lithic rhyolite tuff with some pumice fragments and coarser fragments than in the underlying bed (middle cliff).....	75
7.	Massive, pinkish, sandy, pumiceous rhyolite tuff, pocked with many weathering holes in lower part (lower cliff).....	108
Middle Member:		
6.	Coarse, even-bedded, light-gray, angular rhyolite pumice breccia.....	1
5.	Pinkish, sandy, pumiceous rhyolite tuff.....	4
4.	Like no. 6	1
3.	White, slope-forming, pumiceous rhyolite tuff-breccia, much fine pumice powder (pumicite).....	140
2.	Stratified (water-laid) rhyolite pumice tuff; sandy in lower part, coarser in upper part.....	5
1.	Santa Clara pumice bed (Qbs): unstratified, light-gray to white breccia and sand-size fragments....	35
	(Basalt flow) Total.....	404

Some of the higher beds have been stripped from the mesa where the above section was measured. An undetermined small thickness of the upper beds of the formation appear to have been widely stripped from the upper level of all the plateau.

The thickness of the formation ranges considerably, being thinner where it overlaps the old Chicoma topography, thicker in the central part of the plateau, and thinner again near the Rio Grande. It probably averages about 500 feet thick along the central part of the plateau.

Alluvium and Landslides

During the Recent cutting of deep canyons into the Pajarito Plateau, sand and gravel have been deposited along the canyon floors and spread on small alluvial fans between the eastern foot of the plateau and the Rio Grande.

Large landslides are prevalent along the Rio Grande Valley where the rigid massive basalt flows overlie unconsolidated and somewhat plastic sands and silts of the Santa Fe formation. Also where the massive Bandelier tuffs overlie the plastic Culebra lake clays (see Plate 1) landslides are especially common. None of these landslides, however, has been shown on the accompanying map.

Structure

The structure of the Pajarito Plateau is simple. All the formations are nearly horizontal. The structure of the Chicoma volcanic group is most complicated, but these complications are probably largely the original irregularities of the volcanics. They undoubtedly have been modified by later faults, but little attention was given to the Chicoma during this survey.

The Santa Fe formation appears to have been slightly or very broadly folded and given a slight regional tilt to the west. Although a few eastward dips may be found locally in the formation, at many places along the eastern escarpment of the plateau dips of as much as 5° - 10° to the west are present.

The White Rock Canyon basalt flows are nearly horizontal but appear to have their original slight inclination westward in the direction that they flowed. The Bandelier tuff dips about two degrees eastward in most places and this appears to be due to a slight tilt given to the beds after their deposition. Locally, as just west of Los Alamos, the tuff beds are flexed down slightly

westward. This flex together with erosion parallel to the beds has given rise to the slight depression on the plateau near the residential district west of Los Alamos. A few high-angle normal faults of northerly trend (see Plate 1) broke the beds of the plateau in post-Bandelier time.

Geologic History

The order of events leading to the present geologic picture in the Pajarito Plateau is outlined below beginning with the building of the ancient Jemez Mountains volcano in middle Tertiary time.

1. Eruption of andesite, latite, and rhyolite flows and breccias (Chicoma volcanic group) in Miocene time.
2. Erosion of the Chicoma volcanics.
3. Deposition of the thick Santa Fe formation in the Rio Grande depression.
4. Uplift of the Chicoma volcanics by faulting along the eastern edge and dropping of the Santa Fe beds deeper into the depression. Minor warping and broad westward tilting of the Santa Fe.
5. Spreading of the Puye alluvial fan from the Chicoma volcanics onto the earlier Santa Fe sands.
6. Erosion of canyons along the Rio Grande.
7. Eruption of basalt from the Cerros del Rio volcanoes.
8. Damming of the Rio Grande and deposition of lake clays.
9. Erosion of canyons along the Rio Grande.
10. Deposition of the Bandelier rhyolite tuff from great explosions in the Jemez Mountains.
11. Minor north-south faulting of the Bandelier and older formations.
12. Erosion of the present canyons in the plateau and deposition of alluvial fans in the Rio Grande Valley.

PUMICE DEPOSITS

General

Pumice deposits are confined to the Bandelier rhyolite tuff on the Pajarito Plateau. The entire formation is pumiceous, but only in certain localized beds is the pumice quite pure and sorted to usable grades. The principal concentration is in the Santa Clara pumice member which lies at the base of the Bandelier tuff. Somewhat thinner and poorer beds lie higher in the tuff in the southern part of the plateau. These are shown on Plate 1. The lower one designated as P-2 lies between beds 8 and 9 as shown on page 8 of this copy. The upper one designated as P-3 lies over bed 9 and may be found at many places on the top surface of the plateau. These beds were mapped and tested during the present survey, but they are of little or no commercial worth.

Santa Clara Pumice Bed

The Santa Clara pumice bed is named for the occurrences on the Santa Clara Indian Reservation in the northern part of the Pajarito Plateau where it forms the surface of the plateau over wide areas. The Santa Clara bed is the product of the first violent explosion from the Jemez rhyolite volcano, reborn in early Quaternary time. In most places on the plateau it directly overlies the coarse Puye gravel. Along the southeastern edge it generally overlies White Rock Canyon basalt flows, although locally it lies in the bottom of small canyons cut through the basalt into the underlying Santa Fe sand and gravel.

The Santa Clara pumice is a continuous bed which underlies the plateau in a band six to eight miles wide. The eastern edge is irregularly serrated by the canyons which have cut into the plateau and eroded much of the pumice bed. The western margin is irregular in thickness where it laps onto the old topography of the Chicoma volcanics. The best of the deposit is in the central part of this band where its original thickness may be nearly everywhere 25-35 feet thick. Furthermore, in this central band the pumice has the best size grading

and is of the excellent quality shown in the Cullum pit and in the trenches dug during this survey on Guaje Flats. The average size of pumice fragment in the bed shows a slight diminution from west to east across the plateau. The pumice that was showered onto the foothills of the Jemez Mountains appears to have been soon washed by water into the nearby valleys. This reworking of the original fall by water has made the deposits along the western edge more irregular in shape and stratification and less uniformly graded as to size. The eastern part of the bed is deficient in large fragments and is progressively higher in fine sizes eastward away from the source of the material.

The pumice fragments making up the deposit are light-gray to white glass with tubular cell structure ranging from microscopic to megascopic in size. Quartz crystals are the principal impurities in the pumice fragments. Quartz also occurs in free grains in the aggregate. The quartz is of rather uniform size and most particles are about one-half to one millimeter in diameter. The proportion of quartz in the aggregate is somewhat greater than that in the individual pumice fragments.

Throughout most of the plateau the Santa Clara pumice is covered by the tuff, and on the plateau surface such as at the town of Los Alamos the pumice bed is at a depth of 400-500 feet. In the bottoms of the nearby Los Alamos, Sandia, and Pueblo canyons, however, the Santa Clara bed is in many places not more than 100-150 feet below the surface.

The principal outcrops of the Santa Clara bed are east and northeast of Los Alamos along the eastern slopes of the plateau as shown on Plate 1. In many places the outcrops are on moderate slopes at the bases of cliffs and the width of the outcrop is narrow. To the southeast where the outcrops of the bed lap onto the basalt it is much thinner or in places nearly absent; and the width of the outcrop has been somewhat exaggerated in places on the map.

To the east and northeast of Los Alamos good pumice could be mined along any of the outcrops as shown on the map. However, where the outcrop band on the map is narrow the slopes are steep and surface mining would in many places necessitate removal of considerable talus overburden and excavation of the pumice in long narrow benches. A localized operation in such places would necessitate underground mining and leaving of many pillars to support the rather weak, white and powdery pumice bed that overlies the Santa Clara bed.

The most desirable locations for pumice mining operations are northeast of Los Alamos where the overlying tuff has been eroded leaving the soft Santa Clara pumice bed as a blanket on the lower mesa segments of the plateau. At this lower level the surface is held up by the Puye gravel which resists rapid lateral erosion. On this surface all but the most torrential rainfall readily seeps into the permeable pumice and gravel thus diminishing the concentration of water into streams which can erode the surface.

On these lower mesa segments the pumice lies as a blanket on the surface with only a thin overburden of soil or sand washed onto the surface from nearby higher mesas. Near Santa Clara Canyon thin deposits of Recent terrace gravel cover some of the pumice locally. As can be seen from the accompanying map, the most desirable of the pumice deposits from the point of view of size and proximity to Los Alamos is at Guaje Flats.

Reserves

The Guaje Flats area contains at least seven million cubic yards of pumice that could be mined by stripping operations. Estimated reserves of pumice occurring in blanket surface deposits are shown in the following table.

Blanket Surface Deposits of the Santa Clara Bed

Location	Cubic Yds. per Yd. Depth	Average Depth (Yds.)	Cubic Yards
1. Guaje Flats	1,400,000	5	7,000,000
T. 19 N., R. 7 E.			
2. Parts of secs. 5, 6, 7, & 8	1,500,000	5	7,500,000
3. Parts of sec. 3	500,000	5	2,500,000
T. 20 N., R. 7 E.			
4. Parts of secs. 32 & 33	1,200,000	5	6,000,000
5. Parts of sec. 31	400,000	6	2,400,000
6. Parts of secs. 27, 28, & 29	1,400,000	5	7,000,000
7. Parts of secs. 20, 21, 22, 23, & 24	4,800,000	4	14,400,000
8. Parts of secs. 14, 15, 16, & 17	5,600,000	5	28,000,000
9. Parts of secs. 7, 8, 9, & 10	3,500,000	6	21,000,000
10. Parts of secs. 1, 2, 3, 4, 5, & 6	12,000,000	6	72,000,000
T. 20 N., R. 6 E.			
11. Parts of secs. 1, 2, & 12	3,000,000	4	12,000,000
T. 21 N., R. 7 E.			
12. Parts of secs. 32, 33, 34, & 35	10,000,000	6	62,000,000
Totals:	45,300,000		241,800,000

It may be seen from the above table that blanket surface deposits occur over an estimated area of about 45 million square yards. Without many test holes, it is difficult to give an accurate estimate of the depth of pumice below the surface in the blanket deposits. Some of the original bed has undoubtedly been eroded. In several places on the plateau full thicknesses of 8-12 yards have been measured, and it is felt that the average depths of 4-6 yards used in the above table to arrive at the total reserves of pumice are conservative. Nearly

242 million cubic yards of good pumice are present in these readily minable surface deposits in the northeastern part of the plateau.

The surface deposits are, however, only a small part of the total pumice reserve of the Pajarito Plateau. Assuming an average thickness of 8 yards, the 20-mile long and 5-mile wide central belt of the Santa Clara bed contains over 2 billion cubic yards of pumice. This is pumice, exclusive of the surface blankets, that would have to be mined underground.

It is interesting to note that in terms of recent national output of pumice that the surface deposits alone contain enough pumice to last about 900 years.

The Santa Clara bed extends for many miles to the south of Plate 1 and appears again in the Cochiti district under conditions favorable for mining. These deposits together with large deposits in the Valle Grande constitute an inexhaustible supply under present rates of consumption of pumice.

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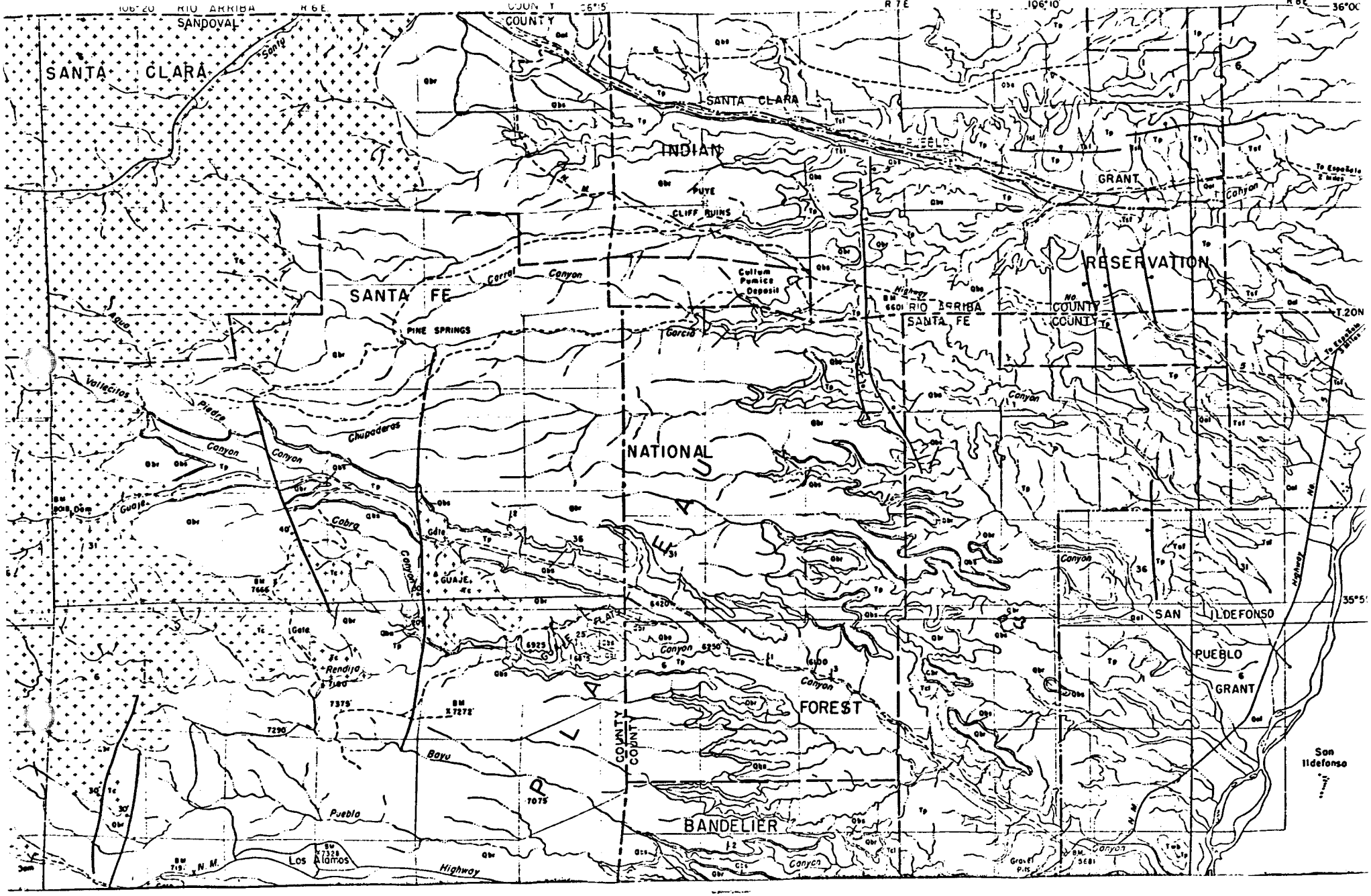
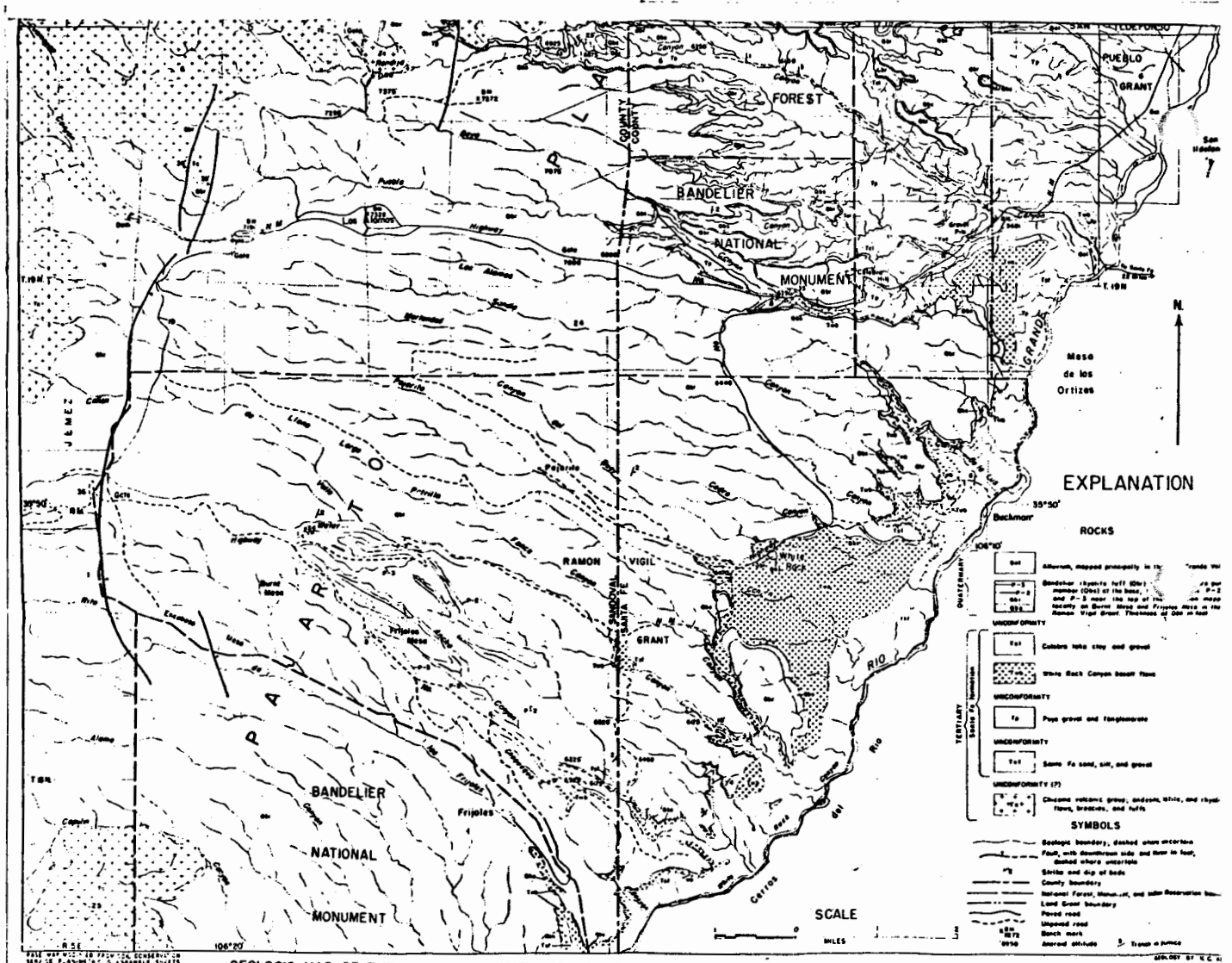
No.	Description	Thickness (feet)
	(Top eroded)	
Upper Member:		
9.	Massive, pink, pumiceous rhyolite tuff with lithic and crystal fragments (upper pink cliff) ---	35
8.	Massive, gray, lithic rhyolite tuff with some pumice fragments and coarser fragments than in the underlying bed (middle cliff) ----------	75
7.	Massive, pinkish, sandy, pumiceous rhyolite tuff, pocked with many weathering holes in lower part (lower cliff) ----------	108
Middle Member:		
6.	Coarse, even-bedded, light-gray, angular rhyolite pumice breccia ----------	1
5.	Pinkish, sandy, pumiceous rhyolite tuff ----------	4
4.	Like no. 6 ----------	1
3.	White, slope-forming, pumiceous rhyolite tuff-breccia, much fine pumice powder (pumicite) ----------	140
2.	Stratified (water-laid) rhyolite pumice tuff; sandy in lower part, coarser in upper part ----------	5
1.	Santa Clara pumice bed (Qbs): Unstratified, light-gray to white breccia and sand-size fragments ----	35
	(Basalt flow) Total ----------	404


SANTA CLARA
INDIAN
RESERVATION
SANTA FE
NATIONAL
FOREST
PUEBLO
GRANT
SAN ILDEFONSO
BANDELIER
PINE SPRINGS
CLIFF RUINS
Cultum Pumice Deposit
Corral Canyon
Garcia
Vallecitos
Piedra
Chupaderos
Canyon
Cobra
Guaje
Rendija
Bayu
Pueblo
Los Alamos
Highway
RIO ARRIBA
SANDOVAL
COUNTY
106°20
106°10
36°00
35°5
T.20N
R.6E
R.7E



GEOLOGIC MAP OF THE PAJARITO PLATEAU, SANDOVAL, SANTA FE, AND RIO ARRIBA COUNTIES, NEW MEXICO

NOVEMBER, 1948