

Scenic Trips to the Geologic Past No. 9



# ALBUQUERQUE

*Its Mountains, Valley, Water, and Volcanoes*

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COVER—Rio GRANDE, fall cottonwoods, and a Sandia backdrop as seen from the west bank of the Rio north of Corrales.

(FRONTISPIECE)

*(Photo by Dick Kent)*

ALBUQUERQUE AND ITS GREAT SANDIA BACKDROP

Downtown lies on the lowlands floodplain of the Rio Grande. The wide  
East Mesa  
stretches between downtown and the mountains. Alluvial fan slopes  
descend gradually  
onto the mesa from the canyons of the Sandias.





SCENIC TRIPS TO THE GEOLOGIC PAST NO. 9

# ALBUQUERQUE

*Its Mountains,  
Valley, Water, and Volcanoes*

*by*

VINCENT C. KELLEY The  
University of New Mexico

1969

STATE BUREAU OF MINES AND MINERAL RESOURCES  
NEW MEXICO INSTITUTE OF MINING & TECHNOLOGY  
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## *Preface*

Most of the Scenic Trips publications are designed to make geologic observation, as viewed from the highways and byways of the state, interesting both to local residents and to tourists. This guidebook, No. 9 in the series, describes the Albuquerque area, including the Sandia Mountains; it differs from previous ones in containing sections on special geologic aspects. These include accounts of the mesas, Rio Grande floodplain, water supplies, volcanoes, and, of course, the Sandia Mountains. These descriptions are presented in order that readers may better understand the influence that geologic features and processes have upon the city. It is also hoped that a better appreciation of the physical or geologic environment may enhance living in Albuquerque.

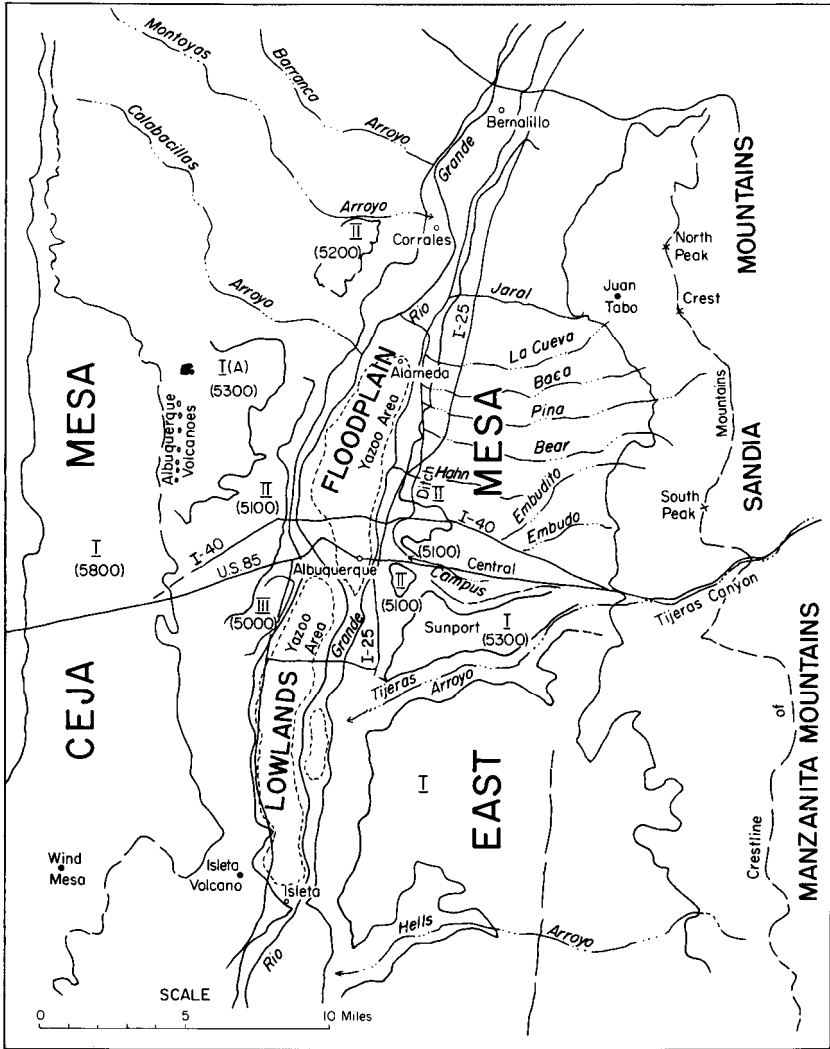
The writing is keyed mostly toward the layman but not at so elemental a level that there is nothing for the geologist, engineer, or student who is interested enough to follow the road logs or to ponder the problems of water and flooding. Some scientific and technical terms have been used, but these are usually explained, or they are of such general acceptance as to be found in a standard dictionary. Examples of the rocks and minerals and illustrations of the formations in which they occur may be seen in the museum displays of the Department of Geology at the University of New Mexico.

My purpose in writing this booklet has been to educate and to satisfy the interest of as many people as possible in their natural surroundings. There are descriptions, explanations, and illustrations designed to help teachers, of significance and importance to city and suburban planners, and of interest to engineers and geologists.

Certain parts of this publication refer to engineering works around Albuquerque. The several agencies concerned with these helped me in various ways. The U.S. Bureau of Reclamation, U.S. Corps of Engineers, and the Middle Rio Grande Conservancy were especially helpful in matters pertaining to flood control and irrigation systems. The U.S. Geological Survey, Albuquerque Water Engineering Office, and the State Engineer's Office freely supplied data.

Many individuals helped the author in many ways and appreciation is expressed to the following: Frank J. Bailey, Howard T. Bolton, Tommy F. Dill, Alan F. Goodman, Otis J. Killian, Robert J. Nordhaus, Robert E. Rowen, Edward N. Sanchez, Thomas M. Smylie, W. P. Walker, and George E. Zimmerman. Particular thanks and credit are extended to Edward C. Beaumont, Rowland W. Fife, William E. Hale, Glen Hammock, and Stephen E. Reynolds, who critically read and materially contributed to the improvement of the manuscript.

VINCENT C. KELLEY



PHYSIOGRAPHIC MAP SHOWING LOWLANDS, MESAS, AND MOUNTAINS

## *Introduction*

Most communities reflect something of their natural physical environment. Albuquerque does so strongly. The layout of the city, its principal highways, agricultural areas, flood problems, and water-supply system are all determined by its immediate physical environment: river direction, mountain position, mesa forms, and climate. This does not mean that man is without influence; local positioning of railroads, highways, city centers, schools, and the like reflects the hand of man, although not always Albuquerque man. The Santa Fe Railway, by choosing its route parallel to the east side of the Rio Grande floodplain, determined the direction (nine degrees east of north) of the principal downtown streets, such as Second and Fourth, and coincidentally those laid out at right angles to the track, such as Central, Lead, and Copper avenues. On the other hand, most of the streets in the Heights area run true north-south and east-west, and the main arterials, such as Carlisle, San Mateo, and Louisiana or Lomas, Gibson, and Montgomery boulevards, follow section lines whose positions were determined by the early U.S. Land Office surveys, which used base lines of reference many miles from Albuquerque.

To properly measure and describe land that people and the government wished to use, the Land Office adopted a rectangular survey system with reference to states, particularly their populated and developed areas. In New Mexico, the Rio Grande's cultivated areas influenced selection of the intersection of the north-south Principal Meridian and the east-west Base Line. U.S. Deputy Surveyor John W. Garretson chose the initial point for the land grid on a small hill north of the river near San Acacia in 1855. From there, the survey extended township by township and section by section. The Albuquerque Heights area fell mostly in Township 10 North, Range 3 East, and thus the section lines of the survey became the major streets. In a sense, then, Garretson determined the locations and directions of important Albuquerque Heights' intersections such as San Mateo and Gibson or Wyoming and Menaul boulevards.

Central Avenue in the Heights, on the other hand, follows the oblique path of Old Tijeras Arroyo to the canyon route through the Sandias.

Much of Albuquerque's scenic flavor comes from three grand, physiographic features: (1) the Sandia-Manzano mountain backdrop, (2) the naturally wooded lowlands of the river floodplain, and (3) the western mesa and volcano skyline. These features have probably had a subtle but real influence on the way Albuquerqueans have chosen their houses, faced their living rooms, and decided to live in the lowlands or on the mesas. The slopes between mesas and lowlands are a bit inhospitable in many places, being broken into raw surfaces, gullies, and bluffs. The rugged, bouldery escarpment of the Sandia Mountains has as yet proved too formidable for much population.

The discussion that follows relates Albuquerque to its geologic setting

and describes the major geologic features that have an impact on the city and its people. It tells the story of the Sandia Mountains; the formation of the Rio Grande Valley with its Great Trough, Inner Valley, and floodplains; the mesas, fans, and arroyos of the lower slopes; and the Albuquerque volcanoes, and it describes the efforts of the city to control water-flooding and to obtain water for industrial and domestic purposes.

### SETTING

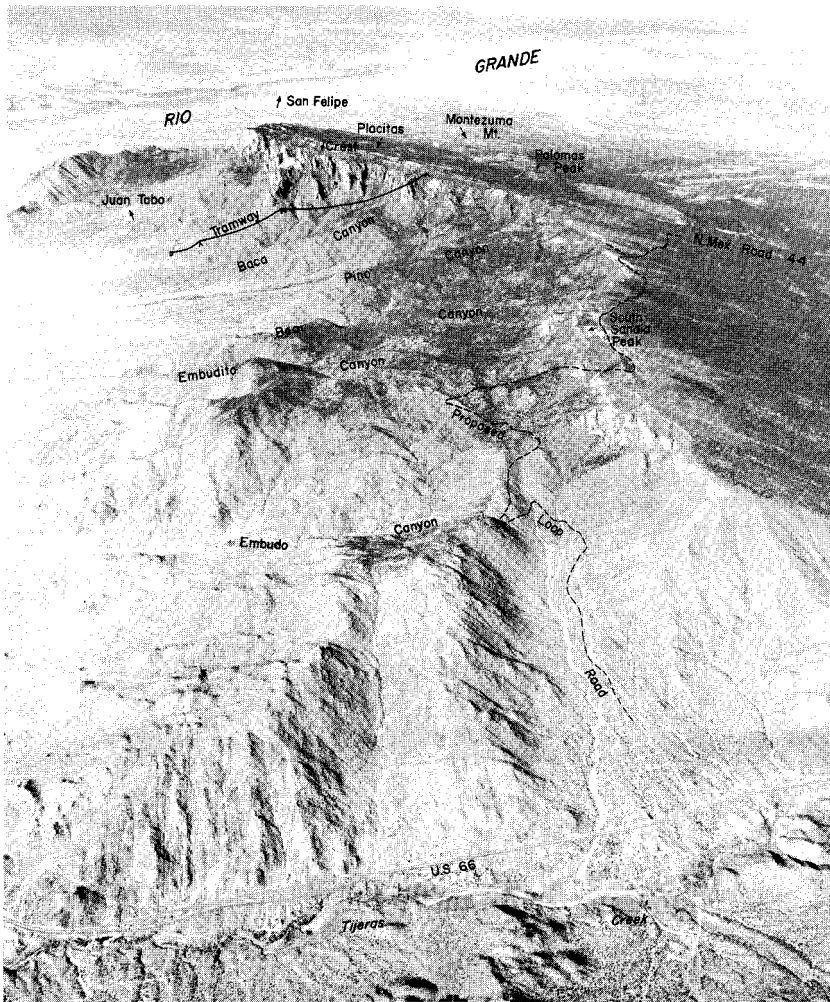
Albuquerque lies along the Rio Grande, which rises in high and remote parts of Colorado, flowing southward 1640 miles to the Gulf of Mexico. Through New Mexico, the Rio Grande winds its way between staggered mountain ranges and high mesas, its system of valleys rather nicely dividing the state into western and eastern parts. In the vicinity of Albuquerque, the river flows along the Inner Valley floodplain that slopes southward about 4 feet a mile and ranges in width from 2.5 to 4 miles. The elevation of the river bed just west of downtown Albuquerque is 4950 feet above sea level. West of the river floodplain, the land rises through low bluffs and gradual slopes to a high mesa 5600 to 6000 feet altitude, some 8 to 12 miles from downtown Albuquerque. Immediately east of the river plain, the land rises somewhat more abruptly, to the East Mesa at 5100 to 5300 feet altitude, and stretches northward from the Sunport runways nearly to 1-40. North of the freeway, the high, flat mesa disappears and, instead, the ground slopes gradually upward from the river bottom for nearly 8 miles to the foot of the Sandia Mountains.

The base of the mountains lies generally at 6000 feet, although near the Juan Tabo area and in the mouth of Bear Canyon, the base lies at 6400 feet. The highest point on the mountain, 10,678 feet, is Sandia Crest; the altitude at South Sandia Peak, directly east of Albuquerque, is 9782 feet.

### THE MOUNTAINS

Albuquerque's mountains, the Sandias, and to a lesser extent the Manzanitas south across Tijeras Canyon from them, are giant blocks of the earth's crust tipped up sideways. Albuquerque views the bold, tipped-up side. The tipping is very much the same action and effect obtained when one steps on the edge of a loose patio brick, causing one side to rise and the other to sink.

The Sandia block tilts only 15 degrees, but because of the simultaneous subsidence of the Rio Grande trough, the block exposes a magnificent west-tern escarpment 13 miles long that averages 4000 feet high. The eastern side of the mountains corresponds to the upper surface of the tilted block, although it has had many layers stripped by erosion. The stripping of this upper surface, one layer after another, caused the over-all smooth appearance of the east slope that contrasts so sharply with the more irregular west side. You can observe this contrast, especially the general smoothness of the



*(Photo by Limbaugh Engineers, Inc.)*

#### SANDIA MOUNTAINS

Notice the smoothly stripped and forested eastern dip slope.

eastern "dip slope," from such distant points as the Santa Fe highway, the road from Jemez, and U.S. 66 from Corner's Summit, or when flying across the mountains.

The gentleness of the slope, together with somewhat more moisture from the east, has resulted in a thicker, more luxuriant stand of trees on the east side. The vegetation contrast between the two sides appears greater than it is because the steepness and cragginess of the west side presents a





*Photo by Dick Kent*

BOLD WESTERN ESCARPMENT OF THE SANDIAS

Jemez Mountain caldera on skyline beyond the Crest. The Great Unconformity separates the bedded veneer of the Pennsylvanian limestones from the rugged, ancient granite below.

wider view of the ground surface and rocky outcrops. The west side is far from barren; the upper one third, especially, has some fine stands of forest.

The grandeur of the western escarpment of the Sandias stems from several geologic features. The most important of these is undoubtedly its ruggedness, its many prominent cliffs, massive spurs, and pinnacles. A second, less obvious, feature is the light-colored granite, which makes the Sandias light-colored. Most people are hardly conscious of this aspect, but mountain ranges frequently consist of dark, often somber, rocks, even in arid, barren regions. A third feature is the rim, or capping, rock that forms the crest of the range. Like a veneer on a piece of furniture, this covers what would otherwise be a rough and less "finished" surface. If erosion had removed these protective rim rocks, the skyline of the Sandias would be less regular and the eastern side would be more rugged, perhaps more barren. The veneer in this instance comprises several hundred feet of light-gray limestone with alternating beds of dark shale, and although readily seen from all Albuquerque views, it often goes unnoticed.

These capping rim rocks are most strikingly observed from near the top of the Sandia Peak Tramway ride, where the great ledges of limestone stand out prominently as "laminations" of the veneer.

Geologically, the rim beds form part of the Magdalena Formation of Pennsylvanian age, some 250 m.y. (million years) old, and like most limestone were deposited in an ocean. These particular beds contain abundant fossil remains of life that existed in the Paleozoic Pennsylvanian seas. At many places along the crest or down the veneered eastern slope, fossils are found. Commonly, the fossils are "frozen" into the limestone and are difficult or impossible to extract individually. Those from the intervening dark shale beds are easier to dig out, and places just above or below a limestone ledge usually provide the best hunting grounds. The picture illustrates the fossils most often found in the Sandias.

Back to the grandeur of the great western facade.

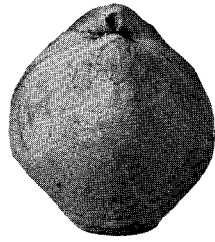
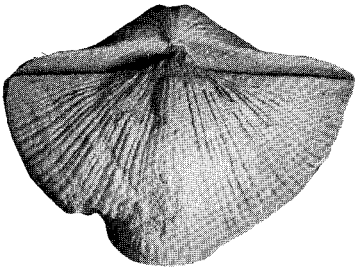
Granite is a homogeneous, massive kind of rock formed by slow cooling and solidifying of a molten material, termed *magma*, many thousands of feet beneath the surface of the earth. We see it only after great uplift and after erosion has removed the overlying rock, such slow processes that a deep-formed rock like granite is never exposed until long after it solidified.

The Sandia Granite, 1350 m.y. old, is composed predominantly of feldspar, quartz, and a dark mica (biotite) in a coarse, tightly interlocked aggregate. In common with all granite, it is regularly fractured or jointed into rectangular blocks of various dimensions, much as though the granite were put together as a pile of building blocks. This common jointing appears to result variously from brittle adjustment as the magma solidified, from deformation during mountain uplifting, and from expansion upon release of pressure as erosion removed the thick covering. Regardless of origin, the joint blocks have a remarkable effect upon the details of landscape throughout the granite area.

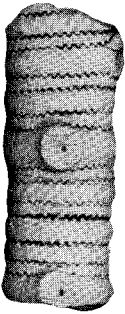
In the high part of the mountains, the jointed granite weathers out in craggy knobs, spires, and small peaks or in narrow chimneys and crevasses. Joint faces are laid bare for tens or even hundreds of feet where adjacent blocks have tumbled away. Forms are sharp, angular, and fresh as the result of energetic erosion under the rigors of the high altitude.

In the low part of the mountains, with its less steep slopes, weathering on a rock surface continues longer before the rock tumbles or wears away. As a result, the corners of the joint blocks round off as the rock decomposes. Slowly, over a long time, the blocks become large, rounded boulders right in place, although some of these may be so "rotted" out and undermined around the base that they roll and come crashing down a hillside. Termed *residual exfoliation boulders*, they are abundant in the Sandias, and one sees them in profusion north of the highway in Tijeras Canyon and all along the western base of the mountains.

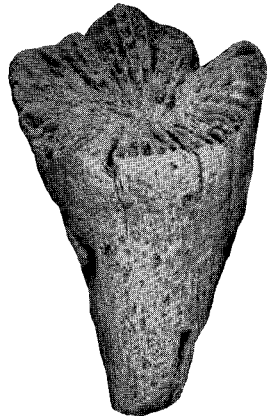
The weathering of the granite into boulders and the slabbing off of blocks *en masse* from the high part of the mountains have contributed greatly to the vigorous carving of canyons in the western escarpment. Geo-



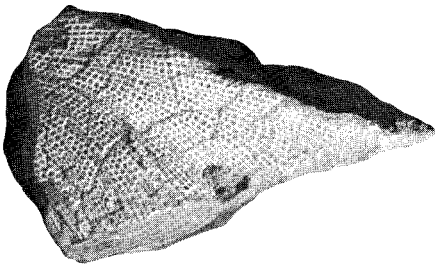
Brachiopods



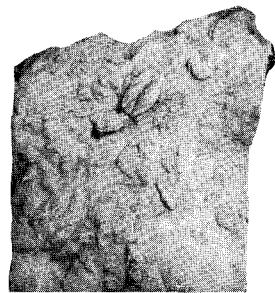
Crinoid stem



Coral



Bryozoan



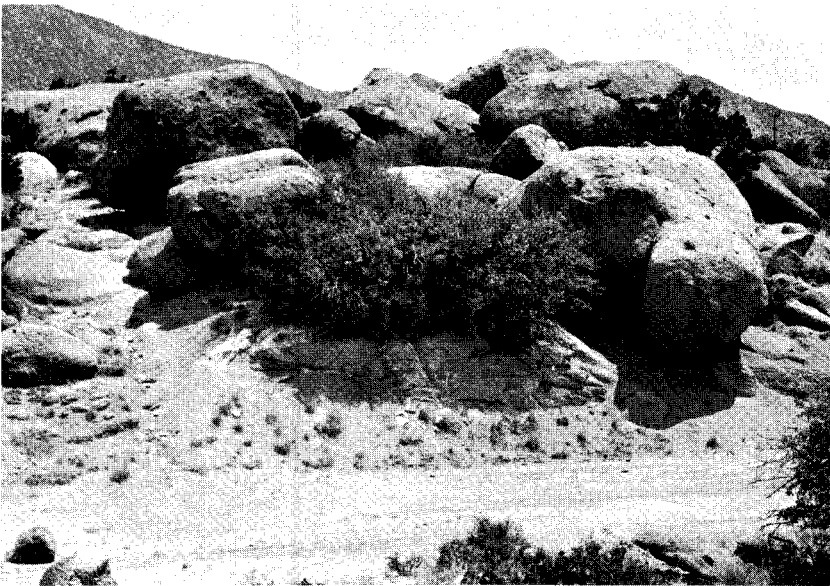
Fusulinids in rock

Fossils

logic time is so long and erosion so slow that we find it difficult to conceive of the volume of erosion along the western front of the Sandias; however, probably not more than 15 to 20 per cent of all the rock originally lifted above the valley is still preserved as mountain.

The great fault at the base of the mountains is poorly or not at all visible. Geologists estimate, from one or two exposures along the Sandias and from better exposures at the bases of similar tilted, fault-block mountains elsewhere, that the Sandia fault inclines steeply (60 to 70 degrees) toward the west. If there had been no erosion, just uplift, the west face of the mountain would rise the full amount of the uplift, which from the present mesa level, would have made it more than three times its present height and would have made it look nearly vertical because of the steep incline. People living near its base would feel that it was hanging over their heads!

The impression of steepness in a "straight-on" view of mountains is exaggerated more than most people realize. We see them steeper than they truly are. People standing at the base of the Sandias generally guess the degree of the slope to the top at twice its actual figure. From the Juan Tabo picnic grounds to the TV towers on Sandia Crest, the slope measures only 22 degrees; from the lower tramhouse to the second tower, 20 degrees; and from the west base of the mountain to South Sandia Peak, only 12 degrees. Standard automobiles can easily drive up a 12-degree slope. The



SPHEROIDALLY WEATHERED RESIDUAL BOULDERS OF GRANITE,  
TIJERAS CANYON

These rocks resulted from weathering of the jointed and weathered granite beneath.

University basketball and football bleachers slope respectively 23 and 20 degrees. You do not fall off grades like these, but many people have a fear of falling off mountains. Of course there are local cliffs and steep inclines; but the immediate lower steep part of the Sandias north of Embudo Canyon slopes only 21 degrees, and the first 2000 feet immediately below the crest on the west side slope only 30 degrees. The greatest cliffs in the high, rugged face of the Sandias rarely tower more than 500 feet and few slope steeper than 20 to 30 degrees from vertical.

#### THE GREAT TROUGH

The term *Rio Grande Valley* is a bit of a misnomer in that, strictly defined, a valley is an elongate depression carved out by a river; in form, it typically branches upstream. The Rio Grande did not erode the great depression it follows, except in a minor way. From Colorado to Texas, the Rio Grande flows along a series of linked troughs, or long segments of the crust of the earth that have subsided between mountain uplifts. For such a trough to form, the crust must pull apart and hot, plastic material beneath it must move away to accommodate the sinking segment.

In the Albuquerque area, this subsided segment of the crust measures 25 miles wide from the mountains on the east and is 100 miles long, with Albuquerque nearly at the center but a little toward the east side. How much has the trough subsided and how do we determine this amount? The questions are answered by matching identical formations and measuring the difference in their positions inside and outside the trough. For example, we know the youngest layered (sedimentary) rock formation at the surface around Albuquerque. We obtained its thickness partly from drill-hole data (in the valley) and partly from actually measuring exposed areas of it in the hills or mountains outside the trough. In this same manner, we have measured the thicknesses of all the other layered formations down to their base on the old granitic rocks like those we see near the top of the Sandia Mountains. Now from almost anywhere in Albuquerque that we look at the mountains, we can see the oldest layered rock resting on the Sandia Granite; it is strikingly apparent from the tram car near the top of the ride. Geologists refer to this contact as the *Great Unconformity*, and it marks the bottom of the pile of all the sedimentary rocks in this area.

We can use this contact as a reference plane to figure out how much the great Rio Grande trough has subsided near Albuquerque. The highest point (projected) on the Great Unconformity in the Sandia Mountains is 11,000 feet above sea level. The thicknesses of all the sedimentary rocks known to lie beneath the surface sediments around Albuquerque totaled 20,000 feet. So where is the top of the granite beneath Albuquerque? . . . 20,000 feet down, or, since Albuquerque is about 5000 feet above sea level, the granite lies 15,000 feet below sea level.

Now, if we combine the 11,000-foot position of the Great Unconformity

## GEOLOGIC FORMATIONS

ERA	SYSTEM†	SERIES†	AGE (M.Y.)*	FORMATIONS†	THICKNESS
CENOZOIC	Quaternary	Holocene		Gravel, sand, mud in lowlands, arroyos, low terraces, and alluvial fans	5-100
		Pleistocene	1	Gravel, sand, caliche; lava flows	10-50
	Tertiary	Pliocene	12	<i>Santa Fe Formation</i> : sand, clay, and gravel	10,000±
		Eocene		<i>Galisteo Formation</i> : red and buff sandstone and mudstone	1000±
MESOZOIC	Cretaceous	Upper	90	<i>Mesaverde Formation</i> : shale, sandstone, and coal	1500
		Lower	125	<i>Mancos Shale</i> : shale with thin limestone and sandstone beds <i>Dakota Formation</i> : sandstone, conglomerate, shale	1500 5-100
	Jurassic	Upper	165	<i>Morrison Formation</i> : variegated mudstone and sandstone	400-800
				<i>Summerville Formation</i> : red and buff mudstone and sandstone	200
				<i>Todilto Formation</i> : gypsum and limestone	100-200
				<i>Entrada Sandstone</i> : red and buff sandstone	150-200
Triassic	Upper	185	<i>Chinle Formation</i> : red and tan mudstone and claystone	1500	
			<i>Santa Rosa Formation</i> : sandstone and conglomerate	200-400	
PALEOZOIC	Permian	Upper	215	<i>Bernal Formation</i> : sandstone, siltstone, and limestone	100
		Middle	225	<i>San Andres Formation</i> : limestone <i>Glorieta Sandstone</i>	30-100 50-100
		Lower	235	<i>Yeso Formation</i> : red and tan sandstone, limestone, and gypsum	600-800
				<i>Abo Formation</i> : red sandstone and mudstone	600-900
	Pennsylvanian		270	<i>Madera Formation</i> : limestone, shale, and sandstone	100±
				<i>Sandia Formation</i> : sandstone, shale, and limestone	100-200
Mississippian		300	<i>Terrero Formation</i>	0-100	
Precambrian		1400-3000	<i>Sandia Granite</i> , gneiss, quartzite, greenstone, and schist		

\*M.y.=millions of years from the beginning of the system or series.

† A formation is a number of beds that are distinguishable from others above and below because of differences in composition, color, or other features. Series and systems are larger groupings of formations based on fossils, age, etc. Definitions of rocks comprising the formations may be found in any standard dictionary.

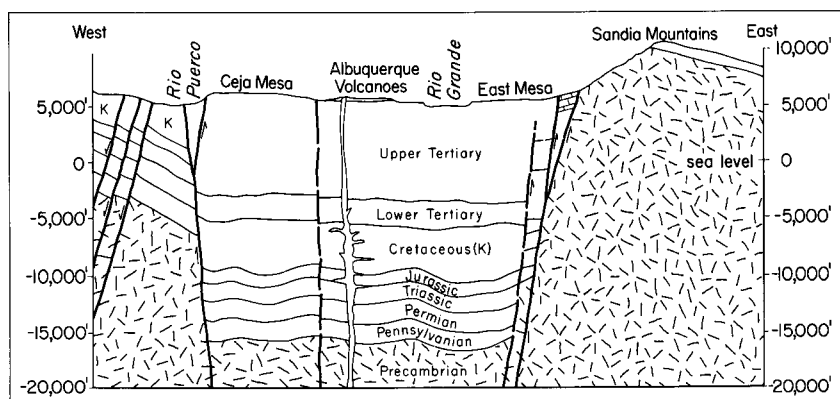
in the Sandias and its minus 15,000-foot position beneath Albuquerque, we find that the trough subsided 26,000 feet, or about 5 miles with respect to the rim of the mountains. This is one of the greatest troughs on earth. West of the Manzano Mountains east of Belen, the subsidence might amount to nearly a mile more but in most places it is 1 to 2 miles less. Thus, the Great Trough of the Rio Grande subsided approximately 3 to 4 miles in relation to the surrounding country.

Of the total thickness of 20,000 feet of sedimentary rocks under the Albuquerque area, the upper one half, 10,000 feet thick, filled in as debris during subsidence of the Trough. A trench in the ground attracts water, and water running on the surface carries with it mud, sand, and gravel. So instead of the Rio Grande's cutting a valley, it actually has valiantly endeavored to fill up a gigantic cave-in of the earth's crust. Imagine what this area would be like if it had not been filled by sediment brought in by the Rio Grande and its tributaries; the trough would have been larger and more desolate than the Dead Sea!

When a river deposits sediment, it gives something of itself to the mud and sand. An important 10 to 20 per cent of the fill in the Rio Grande's trough consists of buried river water in pores within the sand, silt, and gravel. This constitutes the most important resource that Albuquerque has, for the annual rainfall of about 8 inches and the flow of the river alone would fall far short of satisfying Albuquerque's present water needs, much less those of the future.

### INNER VALLEY, FLOODS, AND YAZOOS

In very late geologic time, the Rio Grande eroded the trough-filling deposits into an Inner Valley which comprises that part of the trough between the flanking mesa rims. At Albuquerque, it extends from about the



CROSS SECTION OF THE RIO GRANDE TROUGH  
Vertical scale exaggerated three to one; horizontal distance about 35 miles.



University of New Mexico west along U.S. 66 (Central Avenue) to the top of Nine Mile Hill. This is a distance of 10 highway miles or 9 airline miles. Elsewhere, the valley narrows and widens and in places is hard to define because active side streams eroding their way down from the mountains have washed away the rims. One of the best places from which to see the breadth of the Inner Valley is at the top of the hill by the City Museum near the Sunport, which is very close to the valley's eastern rim.

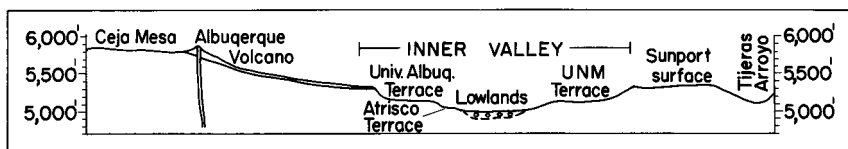
A good, logical question is, Why has the river cut a valley if its principal job has been filling the Great Trough?

The answer is complex and involves a number of factors such as climatic changes, uplift of the whole region, and local differences in the rate of subsidence of the trough. Before cutting its Inner Valley, the Rio Grande probably meandered on a wide plain that extended from the level of the high mesa, or the lava flows, on the west to the surface of the Sunport on the east. At that time the river was depositing sand and mud at a position roughly 200 to 250 feet above Fourth and Central, about at the top of the National Building (238 feet) in the five-hundred block of Marquette Avenue. The subsequent period of valley cutting may have occurred several hundred thousand to perhaps only twenty thousand years ago, after which the river began filling again. At present, the Albuquerque lowlands contain about 75 feet of fill that the river has returned to its Inner Valley. The fact that the river has been filling its own erosional valley for at least 20,000 years accounts for many of the problems of flooding and drainage that have accompanied settlement of the valley.

The way of a river often conflicts with that of man. Man's activities commonly upset the normal processes of the river and unleash its powers against him. So far, man has controlled the Rio Grande and has drained and ordered its floodplain. What was the river like when modern man first came to it, and what has happened since?

We have seen that the river was in the process of filling its own valley. We have the geologic background picture of a slowly subsiding trough (which, incidentally, may still be subsiding today). To fill a valley or trough, a river must silt up its channel, cut and overflow its banks, shift into lower ground, and generally meander about its own floodplain to spread and even out the surface.

The Rio Grande at Bernalillo, some 18 miles north of Albuquerque,



TERRACES AND MESAS

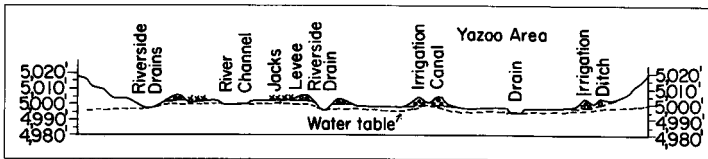
Profile of the Rio Grande Valley showing relationships of the principal mesas and terraces to the Inner Valley.



flows along the west side of its floodplain. Passing Corrales, it swings toward the east bank, only to swing again rather sharply back to the west side in a broad, 8-mile curve to a point about 1 mile west of Old Albuquerque. Here, the river turns abruptly southeastward and comes back to the east side again just south of the Barelas Bridge near Five Points.

The Villa of Albuquerque began its existence along this southeastward swing of the river, first at Old Town in 1706 and, later, farther southeast along the railroad, which was built in 1879.

It so happened that this was the southern end of the low area that had been developing ever since the river took up its course along the west side of the lowlands in the 8-mile stretch between Alameda and Albuquerque. It probably took this course less than one or two thousand years ago having shifted from an earlier one that flowed down the east side between Second and Twelfth streets. However, once the river chose the west-side course,



RIVERS, DRAINS, AND IRRIGATION DITCHES

which at that time must have been as low as or probably lower than the Second Street course, it began to build up its channel and form flanking banks, or natural levees, until the channel bottom of the new river was several feet higher than the old course between Second and Twelfth streets. These kinds of low areas alongside rivers are commonly called *Yazoo*s and are bad things to have, especially when it is wet! Since the level of the river bottom more or less determines the level of the water table in the surrounding floodplain, a river level at or above the adjacent plain creates a swampy and poorly drained condition in the *Yazoo* area.

The term *Yazoo* comes from Mississippi, where the *Yazoo* River enters a similar low area in the Mississippi River floodplain and must flow parallel to the larger river for many miles before the *Yazoo* can join it at Vicksburg where the Mississippi crosses to the east side of its floodplain. Many rivers of the world whose floodplains are confined by bluffs have these *Yazoo* situations. The Rio Grande has others—near Belen, Los Lunas, and Bernalillo but none near such a populated area as Albuquerque. Unlike Mississippi's *Yazoo* River, Albuquerque's drainage into its *Yazoo* comes from normally dry arroyos. Eight of these (from north to south, Jaral, La Cueva, Baca, Pino, Bear, Hahn, Embudo, and Campus) have brought much water and sediment to the *Yazoo* during torrential downpours in recent years.

In the early 1930's the Middle Rio Grande Conservancy District completed a series of drainage ditches that began lowering the water table, and

this, coinciding with dry periods in the 1930's and 1940's, made it possible to occupy much reclaimed swampland. Further lowering of the water table resulted from pumping municipal and industrial wells. Prior to the period of reclamation and conservation, runoff from the arroyos into the Yazoo area just stood until it evaporated, because it could not sink into ground already saturated with water to the surface. Recent flooding in this area has not been so aggravated because most of the water can sink in gradually. Remember, it is uphill westward to the river from the low Yazoo area, and to the south, it is also locally slightly uphill or so low in slope that drainage is very, very slow.

The threat of flooding in the low Yazoo has been ever present; much effort and money have been expended to try to stop or alleviate the situation. Construction of a drainage ditch southward through the downtown area would involve such expensive right of ways as to be prohibitive. Clearly, the best solution is to prevent water from the mountains and the Heights from draining into the Yazoo area. Completion of the "Twin Ditches" diversion channels should fulfill this solution. It is easy to project



*U.S. Corps of Engineers photo*

VIEW SOUTHEAST ALONG THE RIO GRANDE BETWEEN OLD TOWN  
BRIDGE AND BARELAS BRIDGE

Notice the riverside drains on either side of the river levees. Atrisco to  
right of river  
and Albuquerque Country Club golf course.

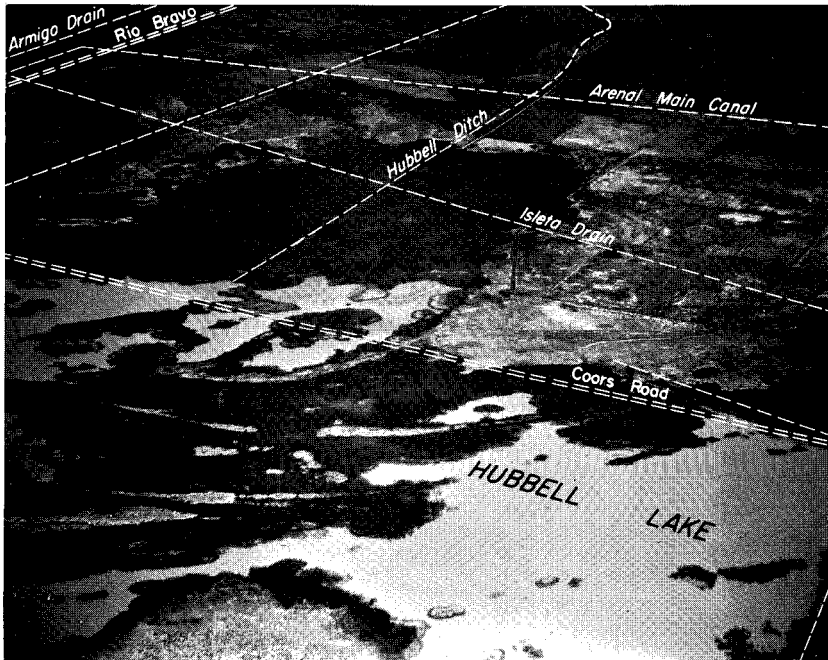
from damage done by recent cloudbursts of 1 to 3 inches what fearful damage might be done by sudden downpours of record of as much as 5 to 7 inches. The damage would likely be several times the cost of the diversion channels.

The North Diversion Channel begins at Lomas, where it picks up the flow from Campus Arroyo and the mesa as far east as Sandia Base. It then slopes gradually northward for 10 miles, intercepting all the major arroyos named above, as well as lesser ones, and discharges into the Rio Grande a mile or so north of Alameda. The channel is trapezoidal in cross section, concrete-lined, and 10 to 23 feet deep. In some places, it is diked on either side or both sides; in others, it is dug into the ground. The South Diversion Channel, although much smaller and lower, will catch runoff from several gullies that drain westward from the Ridgecrest area and the Sunport. Starting from near Coal Avenue and Broadway, when completed, it will run 6.7 miles south to empty into Tijeras Arroyo, the lower end of which will be ditched across the valley bottom into the Rio Grande. The ditch will be lined with riprap. When these diversion channels are completed, water and mud from the Sandias and the East Mesa will no longer reach the low Yazoos but instead will go directly to the river and will constitute an addition to its flow (as well as potential for flooding) and bed build-up.

What about the danger of floods on the Rio Grande itself from swollen waters upstream? The Rio Grande has a long history of alternating years of large and small flow. Danger potential is considered present when flow rises above 5000 cubic feet a second. Of the past 100 years, this flow rate has been reached in 66. In 41 years, peaks reached or exceeded 10,000 cubic feet a second and in 8 exceeded 20,000 cubic feet a second; in 2 years, 1874 and 1884, peaks exceeded 40,000. The flow in 1884, the worst year of record, is thought to have exceeded 100,000 cubic feet a second.

Severe floods struck Albuquerque and vicinity in 1874, 1884, 1891, 1903, 1909, 1912, 1920, 1937, and 1941. In 1874, 24 square miles of water lay between Bernalillo and Albuquerque from April to June, and the peak flow reached more than 40,000 cubic feet. The extent of the 1884 flood is not well recorded but its peak flow has been estimated from water marks on a church at Tome. Main bridges have been washed out or badly damaged on several occasions. The railroad tracks have been washed out or covered along various stretches. River banks and levees have been overtopped and breached numerous times and places. Relatively high Old Town has suffered flooding on one or two occasions and has been made an island on others. Most large floods occur from mid-April to mid-June, but some destructive fall floods have resulted in peak flows on the river of about 20,000 cubic feet a second. With all this, it is doubtful that the Rio Grande has ever abandoned its present channel during the post-Coronado period in favor of the slightly lower course along Second Street.

With the coming of the railroad to New Mexico in 1879, lumbering and livestock operations expanded rapidly, and there followed increased erosion of soils in grazing and cut or burned-out forest areas. At the same

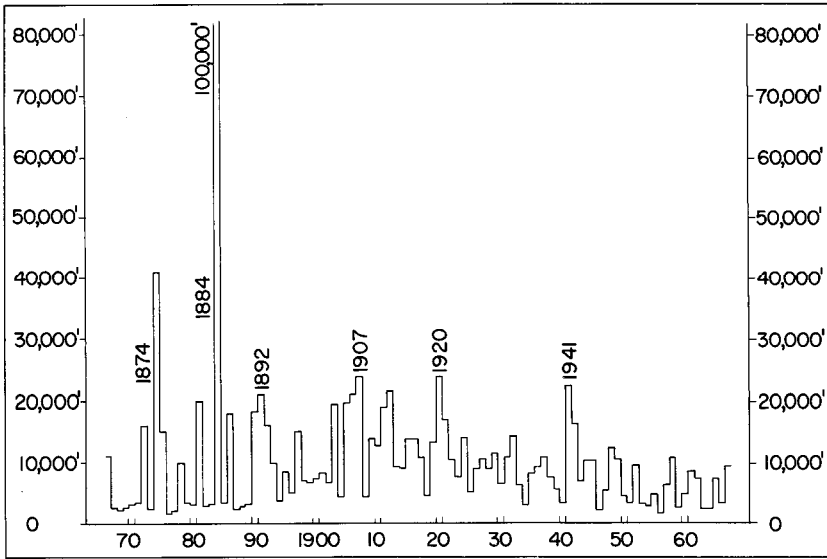


*Photo courtesy Middle Rio Grande Conservancy District*

SOUTH VALLEY LOWLANDS SOUTHWEST OF BARCELONA SCHOOL IN 1930 The view, northeast, shows the early undrained, unreclaimed, nature of the valley floodplain. Hubbell Lake, a water-table lake, developed in a Yazoo area. The direction of this view is shown by an arrow on the air view of the south valley (p. 86).

time, irrigation development also decreased the volume of river flow. Flooding involves two things: (1) damage by water flow and inundation and (2) burial by mud. Commonly, the two go hand in hand; an increase in the volume of water brings a corresponding increase in the volume of sediment. Therefore, with the increased use of water, increased evaporation, and lowering of water tables, the volume of water in the Rio Grande by the time of the droughts of the 1930's had already been decreased by more than 50 per cent. Much of this loss occurred in Colorado, where the streams are relatively clear. However, most sediment was supplied by tributaries in arid parts of New Mexico where there was also a relative decrease in the proportion of water to mud. The loss of water volume meant simply loss in capacity to carry sediment, and this resulted in silting and clogging of the channel and raising of the river bed. The raising of the river bed led to rises in adjacent water tables and waterlogging of farm lands and made it necessary to shore the levees and build artificial ones. The battle was begun to confine the river, control its flow, and drain the waterlogged bottomlands.

Early Rio Grande culture was, of course, agrarian, and from the begin-



MIDDLE RIO GRANDE PEAK FLOWS

ning, man built acequias (ditches) to get the river water to his crops. It has been estimated that the middle Rio Grande Valley had 125,000 acres under cultivation in 1850. However, no drains were installed with the system of acequias, so in time the land became more boggy and alkaline. As a result, by 1925 only 40,000 acres remained under cultivation, and in most places the water table lay at or within 3 to 4 feet of the ground surface.

As late as 1952, crews under the direction of the U.S. Corps of Engineers patrolled the levees around Albuquerque for several days during a high stage of the river, and as recently as 1962, the Santa Fe Railway sandbagged its yards and other installations against anticipated high river levels upon melting of great snow packs around the headwaters of the Rio Grande. Necessary factors generally agreed upon for dangerous flooding on the Rio Grande consist of thick winter snow packs in the headwaters area, abnormal warming over the high country with rapid melting in May or June, and unusually heavy, early summer rains along the upper river. These conditions prevailed to cause the destructive floods of the past.

Recognizing the problems and dangers, a community group formed the Middle Rio Grande Conservancy District in 1925 to direct flood control, drainage, and irrigation. Jurisdiction extends from near Cochiti Pueblo on the north to near Socorro on the south. The Conservancy District constructed the principal system of levees, drains, and irrigation ditches between 1930 and 1935, improving and modifying it progressively to the present. It built 190 miles of levees on either side of the river, creating a floodway 1500



feet wide between levees and averaging about 8 feet above the normal river bed. The principal permanent work of the Conservancy District constituted digging and constructing drains and ditches on the floodplain. Later, the Bureau of Reclamation also rehabilitated, expanded, and improved the system. Waterlogging was essentially eliminated, and irrigation and farming became widespread.

Presently, the U.S. Bureau of Reclamation maintains the drains and irrigation ditches under contracts with the Middle Rio Grande Conservancy District, which raises its money from assessment of member landowners.

The Conservancy District was financially unable to construct flood-control dams or to tackle the problem of aggradation of the river bed. The levee-lined floodway alone could not give the protection needed, as dem-



*Photo by C. E. Redman  
Courtesy Albuquerque  
Journal*

#### FLOOD OF JULY 24, 1950

The water came down Menaul Arroyo (Stronghurst) from a severe storm in the East

Heights. The view looks east from over Fourth Street and shows curving Second

Street between Phoenix Avenue NW on the right and Claremont Avenue NW

across upper left. Flooded Third Street runs across lower central part of picture;

Menaul Boulevard is a few blocks to the right of the picture. Forty blocks, including

200 houses, were flooded, and damage was estimated at \$250,000.



*Photo courtesy Albuquerque*

Tribune FLOOD OF MAY 1959 VIEWED NORTH ALONG BROADWAY AT LOMAS

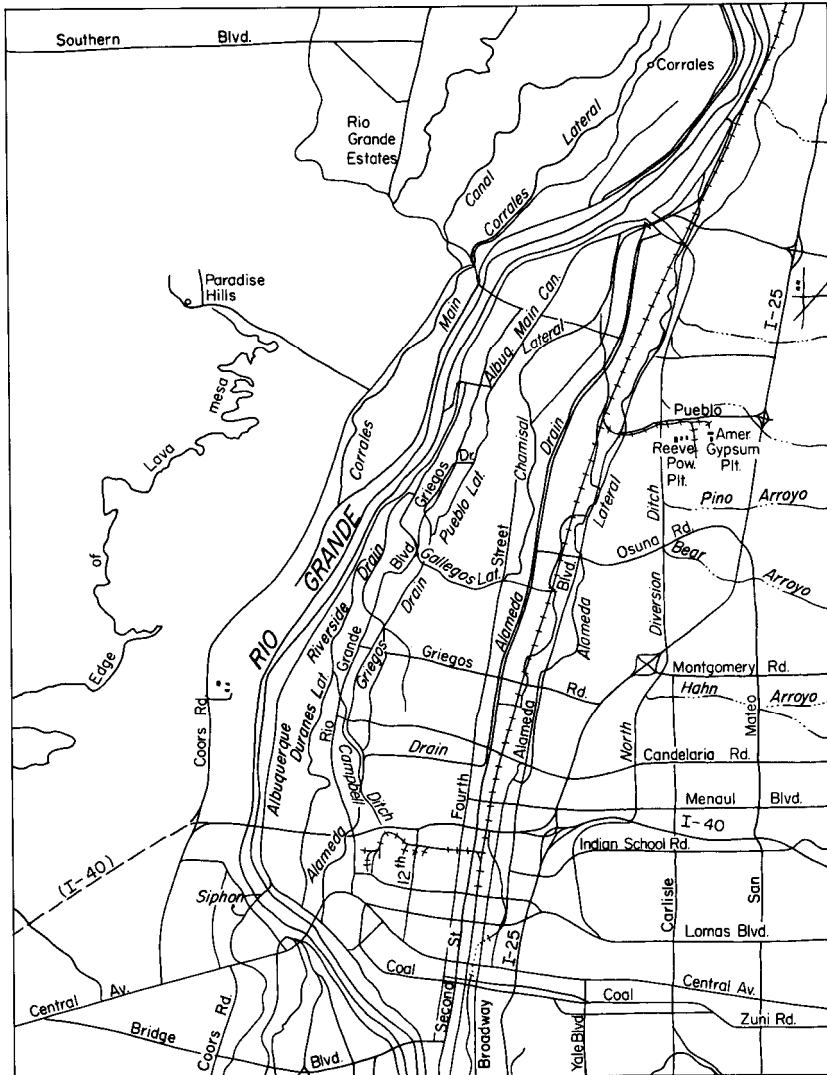
onstrated during the big flood of 1941, which lasted for two months; the river broke the levees in 25 places, and damage from flooding occurred at 80 locations. In 1950, the U.S. Corps of Engineers and the U.S. Bureau of Reclamation collaborated in planning and constructing flood-control, or detention, dams: One on Jemez Creek was completed in 1953, one on the Chama River near Abiquiu in 1962; a 180-foot dam is currently under construction at Cochiti Pueblo and another on Galisteo Creek.

These two Federal agencies are also trying to improve the Rio Grande by protecting the levees with a system of jetties and by maintaining a cleared 600-foot-wide channel inside the 1500-foot-wide floodway. The confined inner channel should reduce water loss from evaporation, increase sediment transport, and help protect the levees.

Therefore, the danger of flooding from the Rio Grande itself, as well as from the Sandia Mountain arroyos, appears to be almost eliminated in the Albuquerque area. This happy development results from (1) reduction in the volume of flow in the Rio Grande, arising from exhaustion of water through evaporation, transpiration from plants, and industrial nonrevolving uses; (2) lowering of water tables that formerly fed directly or seeped to the river; (3) channelization of the floodway; (4) construction of flood-control reservoirs; and (5) construction of diversion channels east of the Albuquerque lowlands.

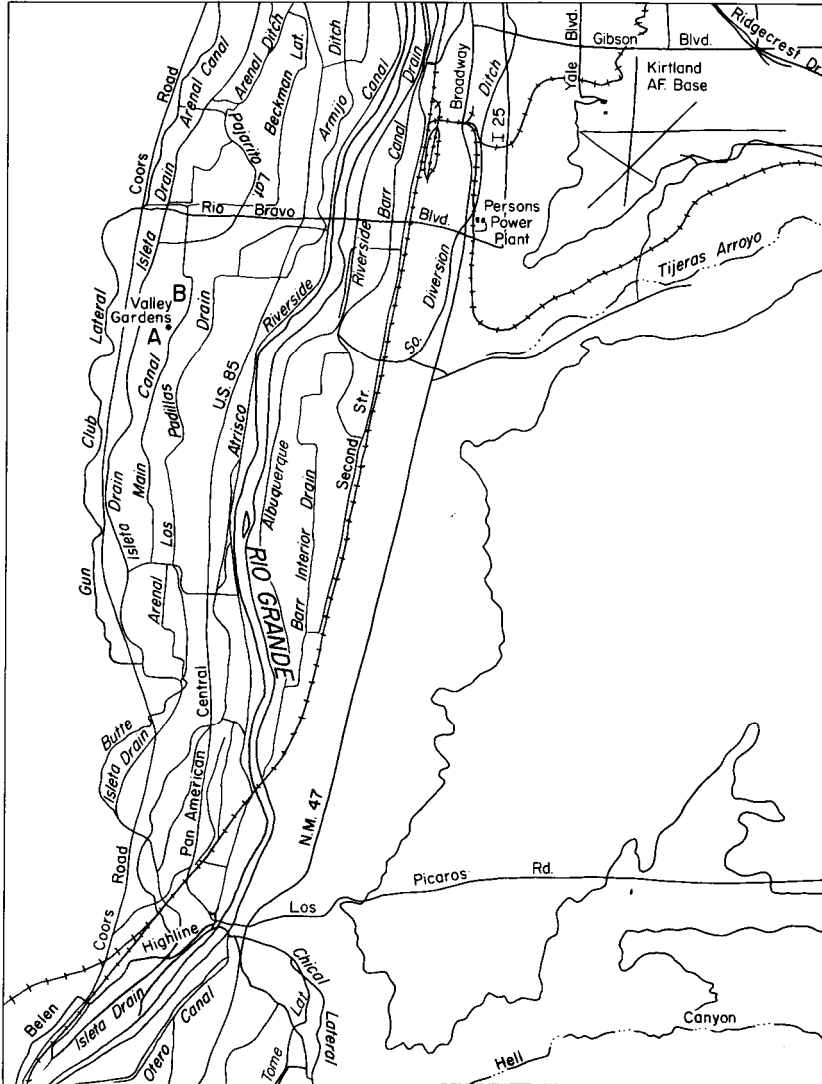
The permanency and effect of some of these developments have yet to be fully assessed. Aggradation of the river bed poses one of the major uncertainties. As long as sediment is fed to a river course; as long as the over-all gradient cannot be increased; and as long as the water volume does not substantially increase, the river-bed levels should continue to rise. Channelizing

may flush sediment downriver for a while, but in time, the sediment must back up the river from base water levels at dams and reservoirs. Reservoirs eventually fill with sediment and, even before their complete filling, their flood-protection value greatly diminishes. Another worrisome situation arises from the dumping of sediment by the North Diversion Channel into the

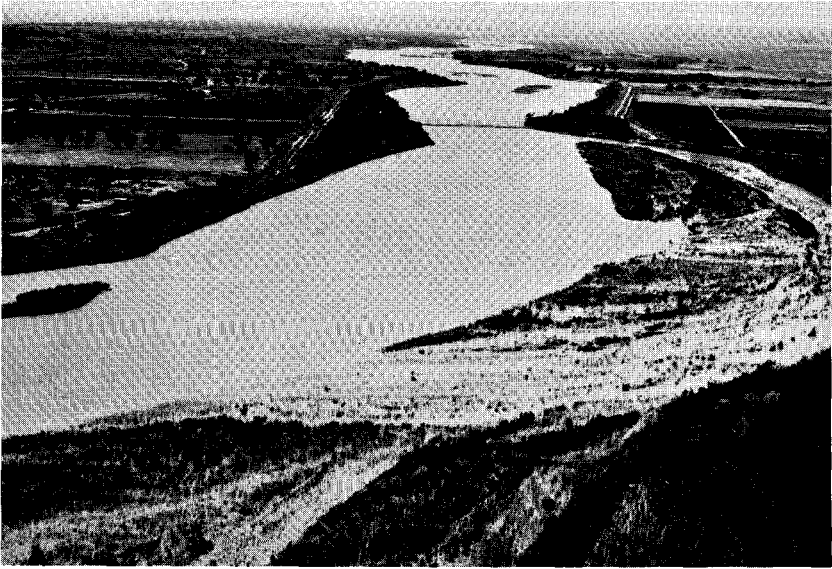


CANALS, DRAINS, AND LATERAL DITCH SYSTEM OF THE NORTH VALLEY

river north of Alameda. The addition of this sediment to the Rio Grande will probably cause some additional rise in the level of the river bed. How nice it would be to have an unused Yazoo into which to deposit this sediment! Before the city and farms spread into the Yazoo area, we could have planned it that way.



CANALS, DRAINS, AND LATERAL DITCH SYSTEM OF THE SOUTH VALLEY



*Photo courtesy Bureau of Reclamation*

RIO GRANDE NEAR FLOOD STAGE, MAY 28, 1948, JUST ABOVE ALAMEDA  
(CORRALES) BRIDGE

Notice the riverside drains. The river nearby broke through to the right  
of the  
bridge during a larger peak flow in 1941.

### ARROYOS, FANS, AND MESAS

The areas east and west of Albuquerque's Inner Valley consist of mesas dissected by numerous arroyos. The East Mesa, where so much of the city has expanded since the early 1930's, is covered along the base of the mountains by gravel spread from the canyons of the Sandias.

Before the river cut its Inner Valley, beginning several hundred thousand years ago, the high mesas on either side of it today joined in a very broad plain through which the Rio Grande meandered sluggishly, some 250 feet above its present level. West, this old plain surface is preserved at the top of Nine Mile Hill on U.S. 66 and beneath the lava flows around the Albuquerque volcanoes; east, it is preserved from the Sunport to Sandia Base and south of Tijeras Arroyo. It sloped to the river probably no more than one or two degrees. The contrast between the general flatness of this plain and the slopes of the present, incised, Inner Valley is best seen from around the Sunport. South down the Rio Grande Valley from Isleta to about the U.S. 60 junction, the line between the plain (mesa) surface and the Inner Valley slopes appears as a white caliche soil rim visible for many miles.

In the Albuquerque area, the mesa edges, which normally form a distinct

rim along the Inner Valley, have been eroded and, in places, completely cut through by broad arroyos that sweep down from the uplands. A concentrated and sustained drainage, such as Tijeras Creek, following its natural tendency, will cut a steep-sided arroyo through the flanking mesa. Tijeras Creek rises behind the Sandias in a large water-catchment area, and its sustained flow and strength enabled it to cut an arroyo apace with the Rio Grande's carving of its Inner Valley. The view of this large arroyo from vantage points south of the Sunport gives a picture of how the Inner Valley appeared at an early stage in its development. No other drainage in the Albuquerque area has had the sustained volume of water power necessary to cut an arroyo the size of Tijeras.

Although Tijeras Arroyo is south of Albuquerque and has had little



*Photo courtesy Bureau of Reclamation*

VIEW OF DOWNTOWN ALBUQUERQUE

Barelas bridge and Santa Fe shops are lower right. The river here is crossing the lowlands diagonally to the east side. Notice the numerous braiding channels. In the dry part of the bed, channel flow lines are directed sharply at the levee bank and with high peak flow, such oblique directions would threaten the bank.

At the top left of the picture, the river may be traced in its diagonal flow from the east to west side. The big Yazoo lies between the river at the top and the river at the bottom.



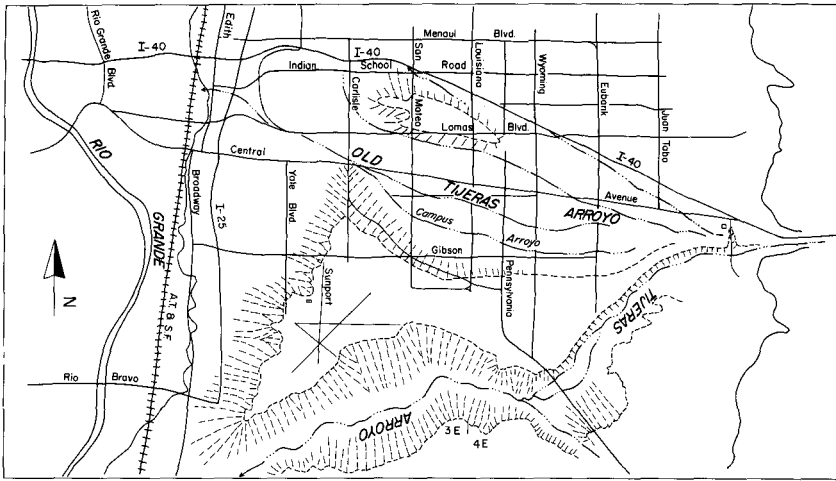
D. A. Hovey photo courtesy U.S. Bureau of Reclamation  
 LOOKING SOUTHEAST TOWARD THE CONTRASTING CULTIVATED  
 FLOODPLAIN AND ARID DISSECTED ALLUVIAL JUAN TABO FAN

Present Juan Tabo Arroyo swings sharply north out of its canyon and off the picture in the upper left corner. Notice other distributary arroyos that diverge across the fan toward the viewer. The railroad, U.S. 85, and a riverside drain are lower left. Tramway Road, leading up the mesa, is visible in the upper right, and beyond are Pino and Bear canyon alluvial fans.

effect on the growth and settlement of the city,\* the past history and course of Tijeras Creek have directly affected the layout of a considerable part of Albuquerque. Prior to cutting the present Tijeras Arroyo, and during the beginning stages of the Rio Grande's cutting its Inner Valley, Tijeras Creek flowed out of its mountain canyon onto an alluvial fan, the apex of which lay just south of the Sheraton Western Skies Motor Hotel. From this point, the creek expanded fan-shaped toward the University and the center of the town, ultimately emptying into the river. While the Inner Valley deepened, the lower end of this Old Tijeras Arroyo, with a goodly supply of water, began to erode its way up the valley's side, especially along what is now Campus Boulevard. As a result, it cut a swath through the mesa rim 2 to 2.5 miles wide and 60 to 80 feet deep in the area between

\* Future Albuquerque plans call for development on the mesa south of Tijeras Arroyo.





OLD TIJERAS ARROYO AND PRESENT TIJERAS ARROYO

Carlisle and San Mateo boulevards. The south side of this Old Tijeras Arroyo is still preserved and is especially well observed as you go along Morningside or Aliso drives toward the Ridgecrest district, which was laid out overlooking this arroyo. Its north rim lay along high ground that today extends from the intersections of Constitution Avenue and Washington Street to Lomas and Louisiana boulevards. Simultaneous and subsequent wearing down of the old mesa surface by Juan Tabo, La Cueva, Baca, Pino, and Bear arroyos, the main drainage systems leading west from the Sandia escarpment, has left the north side of Old Tijeras Arroyo indistinct. From Bear to La Cueva, the closely spaced arroyos frequently pick up considerable precipitation; their concerted erosional power has cut the former mesa level down about 100 feet in the area between San Mateo and Louisiana boulevards north of Indian School Road.

Tijeras Creek appears to have jumped to the south side of its alluvial fan before Old Tijeras Arroyo could deepen its channel all the way eastward to its apex at the mouth of Tijeras Canyon. It missed this complete entrenching by about 2 miles and perhaps a few thousand years. Had entrenchment reached the canyon, the creek's course would have become fixed, and the Ridgecrest district would now look down into a "Tijeras Valley" some 200 feet deep. Instead, Tijeras Creek cut its present channel southwestward 4 miles down the side of its fan to a junction with Coyote Creek, which then flowed down the north side of its fan. Thus reinforced, the two turned west to the Rio Grande and, in time, carved the present Tijeras Arroyo, 9 miles long and 80 to 250 feet deep, that roughly bounds Kirtland and Sandia military reservations on the south.

Had Tijeras Creek's old course prevailed, Albuquerque's highways,

streets, and buildings would have differed considerably from those of today. For instance, the mesa north of Coronado Freeway (I-40) would have been considerably more dissected by tributary canyons joining the Old Tijeras Arroyo; even the Bear Canyon drainage probably would have discharged into the arroyo. The military reservations and the Sunport would have had an unlimited expanse to the south, since the present arroyo would not have formed.

Alluvial fans are so named because the alluvial deposits of a stream form a convex, fan-shaped surface at the mouth of a mountain canyon. Streams debouching onto open, valley plains tend to branch into many ill-defined channels that may diverge 90 degrees or more. The water from these streams runs into all or several of a dozen or so distributing arroyos. Most of the discharge, though, flows straight out and builds a center to the fan higher than its sides; in time, the slope of the sides of the fan becomes steep. Therefore, change of major flow from one arroyo to another usually occurs during heavy rainfall, because the power of a torrential downpour is enormous. If the stream chooses a side channel at flood stage, the flow becomes entrenched and abandons the apex channel until the next heavy flood.

Alluvial fans are a characteristic of arid regions. Sort of "dry-land" deltas, they form best and most typically at the bases of abrupt mountain uplifts. Eroded material from the mountain canyons spreads fanlike onto the valley. Numerous such fans dot the base of the Sandias and coalesce on their sides to form a more or less smooth, alluvial piedmont along the mountainside.

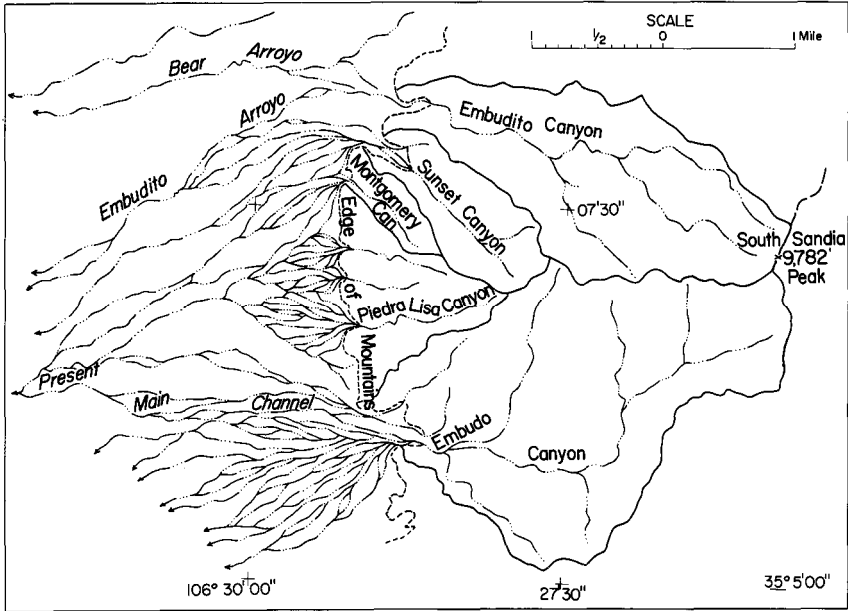
Emubdo (funnel), the best of these fans, radiates 90 degrees from the mouth of Embudo Canyon and extends westward 4 miles. It reaches a maximum north-south width of 2 miles and, in this same direction, crowns at about 100 feet above the lower interfan areas.

In the Bear-Pino canyon re-entrant, confinement by mountain ridges north and south has prevented development of an ideal fan form. Instead, the distributary arroyos interlace and form a long, steady slope almost to the river.

At the mouth of Embudito Canyon, near Glenwood Hills, a rather odd asymmetrical fan has formed, largely because the "corner" on the mountain front has permitted the Bear Canyon distributaries to destroy the northern half of the fan, leaving it looking incomplete. As a result, Embudito Arroyo curves southward parallel with the sharply turned distributary flow from Sunset Canyon.\* The apex crowns of Embudito and Embudo fans are about 100 feet higher than the interfan area between them, east of the Holiday Park subdivision. The interfan areas are susceptible to considerable concentration of potential flood waters.

During times of torrential rains in the Sandias, powerful and destructive fingers of boulder-rafting mud flow for miles from the mountains. Buried

\* Albuquerque city engineers have recently cut a diversion ditch from Embudito Arroyo, just north of Glenwood Hills, northward to Bear Arroyo. This should remove much of the threat of flooding by torrential flow from Embudito through the residential areas. Sunset Canyon should be diverted by this ditch also.



ALLUVIAL FAN DISTRIBUTORIES FROM CANYONS IN THE SOUTHERN PART OF THE SANDIA MOUNTAINS

boulders a foot or more in diameter have been encountered within 50 feet of the surface during drilling and excavation on the University of New Mexico campus. Boulders of gneiss, limestone, granite, quartzite, and sandstone make up the bottom layers at the head of the North Diversion Channel (north of the University's Physics building on Lomas Boulevard). These partly rounded boulders clearly came from Tijeras Canyon during severe storms.

Inasmuch as flooding, deposition, or destruction on a fan depends upon the size of the canyon that feeds it, you may find this table interesting:

CATCHMENT AREAS OF SANDIA MOUNTAIN CANYONS

CANYON	ACRES
Bear	3830
Pino	2410
Baca	1880
Embudo	2780
Embudito	1730
Sunset—Montgomery	680

The first three, totalling 8120 acres, drain across the East Mesa north of the principal Heights area. The last three, totalling 5190 acres, converge in

a rather heavily inhabited part of the mesa and pose something of a threat to the community. The diagram of the alluvial fan distributaries, page 29, shows the drainage systems of this Embudo group. Notice the headward, treelike branching in the mountain canyons and the distributing, rootlike branching of the arroyos on the fans.

Albuquerque's striking western skyline, unbroken except for the volcanoes, is formed principally by a long, north-trending mesa, noticeably higher than the east-side mesas. This great mesa has no formal name, but we shall call it *Ceja Mesa*, the name applied years ago to its eyebrowlike western edge that faces the Puerco Valley. (See page 2.)

The mesa is about 5 miles wide and is remarkable for its great length; it extends some 20 miles north and 50 miles south of Albuquerque. At the top of Nine Mile Hill on U.S. 66, the mesa's altitude of 5650 feet is 350 feet higher than that at the Sunport. Ceja Mesa was most likely continuous with the Sunport. surface of the old, gentle Rio Grande plain prior to erosion of the Inner Valley. The fact that it is higher than the East Mesa is explained in part by the greater distance of the Ceja from the center of the Inner Valley; its edge is 6 miles away, whereas the East Mesa edge is only 3 miles distant. If we project the slight eastward slope of the Ceja 3 miles, we can account for only 100 feet, which still leaves Ceja Mesa 300 feet higher. When one follows the Ceja southward to Belen, its altitude becomes almost precisely that of the east-side mesa. Clearly, the surfaces merged before incision of the Rio Grande's Inner Valley. Therefore, some other geologic event must explain the 300-foot difference in altitude near Albuquerque of the same two old surfaces.

The reason lies in uplifting of the Ceja Mesa in the Albuquerque area after the river cut the Inner Valley, or at least since the formation of the old plain. In the vicinity of Albuquerque, a fault zone runs along the eastern edge of the Ceja Mesa; similar faults occur along its west side, in particular, several miles north of U.S. 66. Ceja Mesa begins its disparity with the east-side mesa at about Los Lunas, 20 miles south of Albuquerque, and continues northward as an abnormal slope to its eroded northern end just south of San Ysidro, where it reaches 6600 feet. Regional geologic maps show that this uplifting of the long Ceja Mesa appears to be the southern, subdued end of the much greater uplift of the Nacimiento Mountains, which lie to the west of Jemez and northwest of San Ysidro.

North of Albuquerque's latitude, the uplifting increased only on the faults along the west side of the Ceja, and as a result, the mesa changes into a long, dissected slope or cuesta. East of the Albuquerque volcanoes, lava flows appear to cross a surface inclined toward the Rio Grande 2 to 3 feet in 100 feet, whereas the Ceja Mesa surface slopes eastward at less than 1 foot in 100 feet. The surface on which the lava lies is probably also Ceja Mesa surface tilted downward toward the subsiding trough axis along the Rio Grande. Thus, the surface beneath the lava-capped mesa west of the University of Albuquerque is probably the same as that of the Ceja Mesa, but lower because of dropping and tilting just east of the mesa. The lava

flow appears already to have been on the surface when it tilted toward the river (IA on page 2).

As most Albuquerqueans well know, the West Mesa overlooks steep bluffs along the Rio Grande. This mesa surface, at an altitude of 5100 feet, is 1 mile wide and 6 miles long and lies almost entirely north of U.S. 66. Just south of the highway, a lower mesa, or terrace, stands at 5000 feet. Both these surfaces are river terraces, sites of former river levels left by the Rio Grande during its cutting of the Inner Valley. These terraces stood relatively higher a few thousand year ago, before the river began filling its Inner Valley.

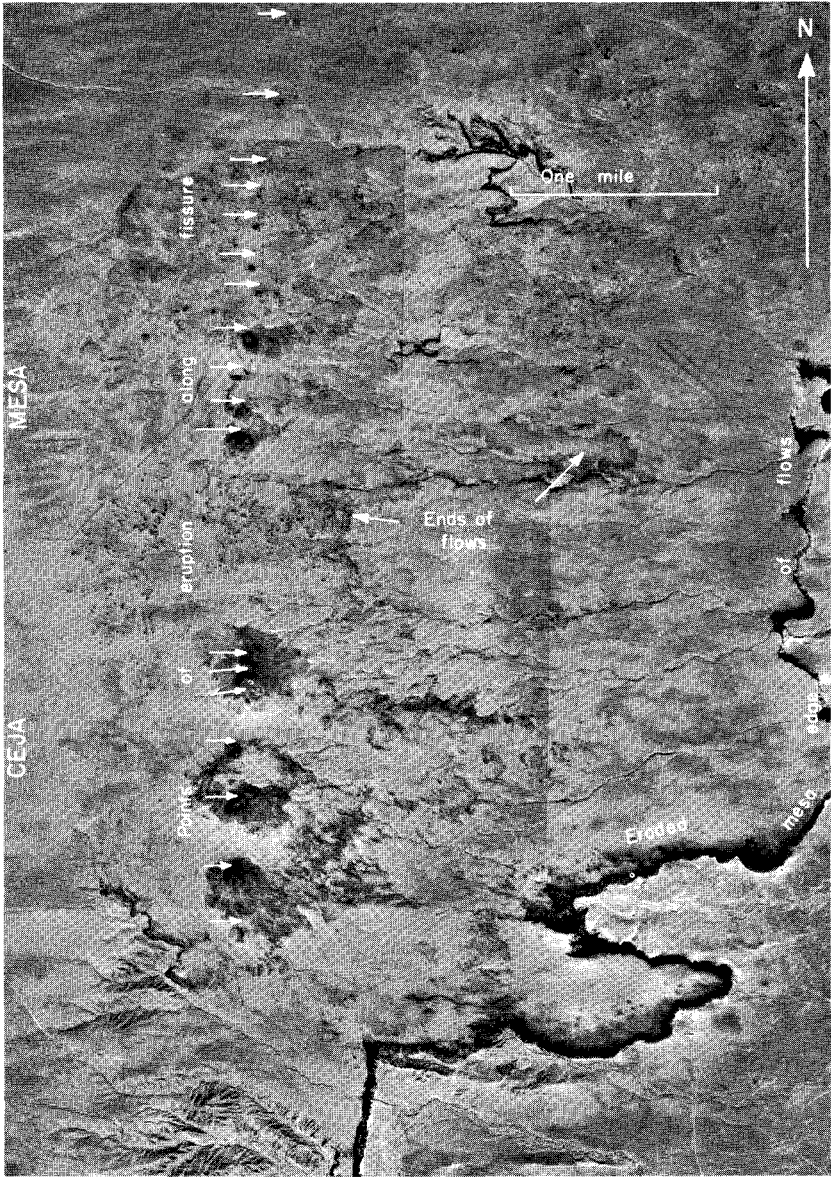
Arroyos directly west of Albuquerque are short and small because of the terraces and the shorter distance to the edge of Ceja Mesa. Northwest of the city and from Paradise Hills north, the distance from the floodplain to the top of the Ceja is as much as 16 miles along the cuesta. In this area, several arroyos, principally Barranca, Montoyas, and Calabacillas, running down the long slope to the Inner Valley are similar to Embudo, Bear, and Pino on the east side in their work of dissecting the mesas and carrying sediment to the Rio Grande.

Along the east side of the valley, another mesa, lower than the East Mesa and also 5100 feet high, is much obscured by arroyo dissection and city development in its southern part and is modified by the great Pino and Bear arroyos in its northern part. It is best preserved along Yale Boulevard SE, at the main campus of the University, and along Las Lomas Road nearly to Medical Arts Square (II on page 2).

#### VOLCANOES

Probably no major city in the United States has such an array of extinct volcanoes nearby as does Albuquerque. The Albuquerque volcanoes are only 7 miles from Fourth Street and Central Avenue; the University of Albuquerque is only 4 miles from them. Canjilon and San Felipe Pueblo volcanoes are only 20 and 28 miles upriver; Isleta Pueblo and Los Lunas volcanoes are only 12 and 21 miles downriver. A large area of some 17 cones, referred to as either the Isleta or Wind Mesa volcanic field, lies 19 miles south of Albuquerque. A most unusual volcano, the giant Jemez caldera occupies the skyline 60 miles to the north. Fifty-five airline miles to the west, behind the Albuquerque volcanoes, the great snow-capped Mount Taylor rises nearly half a mile above its base and reaches an elevation of 11,301 feet. It towers in a field of some 200 lesser volcanoes and stumps of volcanoes. In all, 270 volcanoes or stumps thereof lie within 65 miles of Albuquerque.

The Albuquerque group forms the familiar skyline of five small cones along the edge of Ceja Mesa. At least five smaller cones and another 8 nubbin points of eruption can be discerned along the fissure line, making 18 in all. All the volcanoes along the Rio Grande trough erupted basalt, a kind of lava that rose through the crust of the earth from depths of 40 miles to possibly several hundred miles. The Albuquerque lava rose along one of the fissures on which the Rio Grande trough subsided. Quite likely, the



*Army Map Service photo*

THE ALBUQUERQUE VOLCANOES

The dark edge of flows on the right is the mesa edge. The ends of several younger flows east of the volcanoes are clearly visible. Although there are only five large cones in the field, eighteen small "points" of eruptions in all may be seen following the north-trending fissures along which the lava rose.

first eruption fountained as a curtain of lava that fell and flowed away in a highly liquid, thin layer, as do many Hawaiian flows. Some of these flows probably reached the river, but later cutting of the Inner Valley eroded them back to the edges that we see today just east of the volcanoes. The flows may have covered an area of as much as 40 to 50 square miles, but we cannot say precisely because the eastern part has eroded away.

The volcanic activity probably lasted no more than a few months or a year, and the spread of flows over the mesa could have occurred in a matter of days; as many as five or six flows have piled up east of the volcanic cones. Toward the end of the eruption period, gaseous-charged lava became the rule. Small explosions and spattering interlaid cindery deposits and shorter flows, building the present cones. (Additional descriptions appear in Trip 5, the Albuquerque Volcanoes.)

#### WATER SUPPLIES

Water supplies are generally classed as surface and subsurface.

Surface supplies in the Albuquerque area are largely confined to the Rio Grande and include the water flowing through irrigation and drainage ditches or standing in low areas on the floodplain. A small quantity of ephemeral surface flow occurs in Tijeras and other arroyos draining from the mountains.

Most of Albuquerque's water comes from the subsurface at or beneath a level of soaked sand and gravel known as a water table. In the Rio Grande trough, nearly all the subsurface beds are fairly porous and permeable enough to allow slow movement of the water. This saturating water in sand and gravel is known as *ground water*. Since all the rocks in the trough are permeable, we say the ground water is unconfined. This means that the upper level or *table* of the ground water may fluctuate up and down, depending upon the amount of rainfall, the river flow, or the use of water from wells and ditches. Being unconfined, the subsurface ground water has complete connection, or freedom of movement, with the river surface water. Thus, if it rains enough, the water table may rise to coincide with the surface of the earth. Before man began to use water in large quantities and before the digging of drainage ditches, the water table in the valley bottom coincided with the surface in many places to make water-logged soils or rose above the surface in lower areas to cause swamps and lakes. The drainage ditches did away with these conditions by lowering the water table. When the water table stood at or near the ground surface, the water drained poorly or evaporated during dry seasons, leaving the soil salty or alkaline. The drainage ditches helped wash the alkali out of the soil, and as the soil was irrigated, the water table was lowered everywhere below the surface. It continues to be lowered, especially near Albuquerque where well withdrawals are large.

It is not especially good to have the water table at ground surface, because rain or river water cannot seep in and thus is lost by evaporation. Even with

the drainage ditches and considerable withdrawal from wells, the water table on the Inner Valley floor is generally less than 10 feet and rarely more than 20 feet below the surface. Large trees, such as the Rio Grande cottonwoods that trace the path of the river, sustain themselves by extending their roots to the water table.

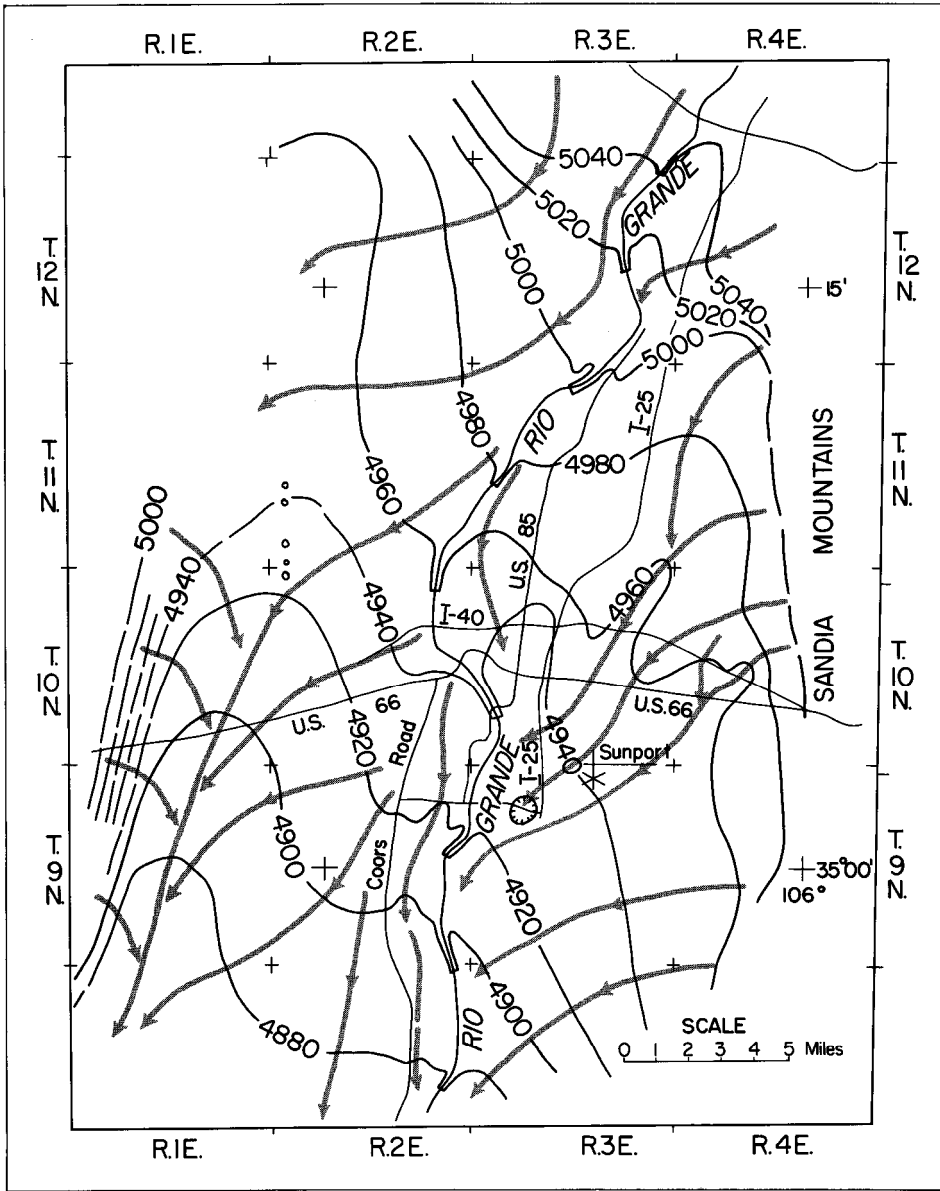
Good rainfall and surface flow, particularly in arroyos and on the flood-plain, recharge the ground water and help keep the water table up. Years of heavy precipitation result in rising water tables shortly thereafter.

The Rio Grande trough is filled with at least several thousand feet of sand and gravel very much like that seen at the surface or penetrated by water wells in the first few hundred feet. Sand, gravel, and mud brought into the trough by water, along with part of the water itself, were deposited and buried. Water usually comprised a part of its sediment from the beginning of trough filling. Therefore, if we know the porosity (percentage of voids between the grains), we can calculate the volume of water contained in the sediments.

Economists and engineers have forecast that Albuquerque will need to pump 160,000 acre-feet of water a year by 1990 for a population of about 750,000. At that rate, how long would it take to use up the ground water? It would depend on the porosity of the sediment and how large and deep an area we work with. Say we assume an area for Albuquerque of 12 by 15 miles, or 180 square miles. Since there are 640 acres in a square mile, the area would contain about 115,000 acres. An acre-foot of water is the volume of water needed to cover one acre to a depth of one foot. Imagine that those 115,000 acre-feet of water begin in the saturated sands below the water table. Because porosity of the sand is 20 per cent, we need consider only 20 per cent of the 115,000 acres at Albuquerque, or 23,000 acre-feet of water in that first foot beneath the water table. Let us now assume that in the future we shall want to pump water to a depth of 1500 feet beneath the present ground-water level. By multiplying 1500 by 23,000, we find that we could expect to take about 35 million acre-feet of water from the ground supplies by pumping all the water from the sand. That is a lot of water; in fact, enough to fill a lake 50 miles wide by 55 miles long by 20 feet deep. Now, by the estimate above, if we pumped this water at the rate of 200,000 acre-feet a year, it would take 170 years to drain the supply. Presently, the city pumps only 55,431 acre-feet a year for a population slightly more than 300,000.

The 170-year estimate is based on "mining" the water as in mining coal, for example—without replenishing it. The time estimate is not very realistic because the river continues to pour in more water, and about half of what is pumped is discharged to the river where it may seep back into the water table. Far more important is how much water the law will allow Albuquerque to pump and how much in water rights the city, and industry, can buy. The people downstream must be protected. The State Engineer must determine these things, and decisions depend on what happens to the water table and the long-term volume of the river.





WATER-TABLE AND GROUND-WATER FLOW LINES

There is little or no chance of a water shortage, even with a substantial increase in population. Probably no other large city in the arid Southwest has such a bountiful supply of good water as Albuquerque has. Water everywhere in the trough is no more than a few hundred feet beneath the surface. Nearly 200 industrial, municipal, or institutional wells now draw on ground water in the greater Albuquerque area. With population projections of nearly 1,000,000 by the year 2000, hydrologists estimate that the water table around Albuquerque would be lowered no more than 80 feet.

#### LAWS AND USES

Man's use of and social adjustment to water is one of the oldest and most fundamental aspects of his existence. Concepts of water rights for kings, individuals, and the public were developed early in history.

In England, a man owning land along a river or lake had what is termed riparian rights to the water (to the middle of the stream). The water was his in any amount as part of the land, regardless of whether he used it or not. Early laws were gradually modified to control diversion, damming, and pollution to protect the public and individuals with similar rights.

In the United States, and particularly in the West, the English doctrines were modified to incorporate the appropriation and use of water into establishment of rights to it. Priority of appropriation and use of water in accordance with law determined the better right. In areas of water scarcity and abundant population, more regulation became necessary to protect the individual and the public and to ensure continued good water supplies for the future.

Water is a peculiar mineral resource in that it is partly replenishable and at the same time partly exhaustible or degradable. Thus, underground supplies that took geologic time to form may be withdrawn or depleted by overpumping in a few decades. Water may also be made unusable by pollution or less desirable by salting or warming.

In 1907, the New Mexico legislature enacted a water law declaring that all river waters, excluding existing rights, belonged to the public. The courts determined the size of rights existing prior to 1907. People may use the waters in compliance with legal regulations as long as such use does not infringe upon a prior right. New rights can only be granted upon demonstration by the State Engineer that such rights would not be detrimental to existing rights. Land along a river usually carries with it water rights in the form of a certain number of acre-feet a year for each acre of land owned, provided the water is used beneficially. The State Engineer limits the amount of right on the basis of purpose of use, location, and nature of the land and the known flow of the river and demonstrated or established need or use of the water. Obviously, there is a limit to the number of rights that he can assign along a particular river.

Prior use of the water determines first right. One does not have a right to use the water merely because it flows by his land; one may own land along a river without having established any water rights. Land and water

rights can be sold independently, but irrigation water rights, if sold, must be transferred to some other place for purposes approved in application to the State Engineer. Land some distance from a river must also have water rights, as pumping from wells affects the water table level.

It takes much longer, of course, to affect the river by pumping from wells several miles away than it does by pumping from those near it. Therefore, the buying or retiring of water rights for a pumping well on the East Mesa, for example, may be deferred, at least in part, for many years.

In the early days, officials did not recognize the close relationship between surface water and underground water, so one could circumvent river water rights by drilling a well. Thus, a person without legally assigned water rights could drill a well near a river, or even at some distance from it, and get "free" water that in reality came underground from the river by seepage.

The Middle Rio Grande Conservancy District regulates water use and contracts with the U.S. Bureau of Reclamation to operate much of the irrigation system. The Conservancy District assesses its members a given amount an acre a year for its service. About 3 acre-feet an acre a year is the amount of water generally needed, but in dry years, this much might not be delivered. Delivery of water is regulated by ditch riders elected by users in an area or "beat."

Fortunately, in 1931 the New Mexico legislature, upon recognizing the interconnection between surface and ground waters, empowered the State Engineer to regulate ground-water usage together with river usage. By this law, the Engineer's Office could, and does, declare and outline certain ground-water areas, as, for example, the Roswell artesian basin or the Rio Grande basin.

Because of these regulatory powers bestowed upon the Engineer, everyone, including industries, farmers, and many municipalities, must obtain permission to drill a well in the basins. In the Rio Grande basin, small domestic wells ordinarily are exempt from retiring rights. If a city, an institution, or an industry receives a permit to drill a well, it must retire, or buy and retire, surface-water rights in quantities determined by the size of the well and its proximity to the river, in such a way as to offset the effects upon the flow of the river. In other words, the well source is exchanged for the river source.

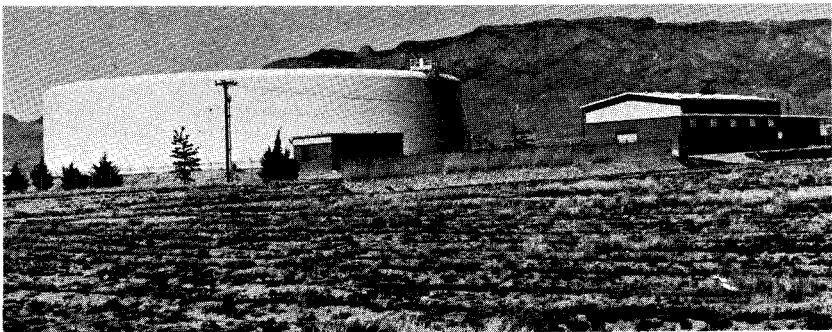
For the most part, the water table in the Albuquerque area slopes toward the river, and therefore the subsurface water percolates in that direction also. If enough wells are drilled and pumping is sustained in the adjoining hills and mesas areas, percolation to the river is slowed, and the flow of the river may decrease, especially if the used water is exhausted to the air and not returned to the ground. To adhere to the interstate agreements and to protect the water rights of surface owners, subsurface water use must be controlled.

One might think that this regulation would hamper the development of a city and its industries, but this is not true. In regions where no such reg-

ulation is in effect, industries and farming enterprises that have based their development on subsurface water are in jeopardy from the possibility of lawsuits brought by surface owners claiming that their surface rights have been damaged. In the Rio Grande basin, well water obtained in a regulated way is essentially guaranteed.

In 1938, New Mexico, Texas, and Colorado reached a formal legal agreement to provide a fair apportionment to each state of the Rio Grande waters above Fort Quitman, Texas, a town about 75 miles downstream from El Paso. Division of the water was based upon records of flow along the river in each state and had the objective of maintaining the status quo of 1929. By the agreement, termed the Rio Grande Water Compact, downstream users are to receive so many acre-feet of water, based on acre-feet of water passing upstream gauging stations. This amount varies, of course, from year to year. The upstream users must deliver water, if available, but because of overuse and the vagaries of precipitation, they often owe water to the downstream users. As long as water is owed, it must be released from upstream reservoirs except for certain permanently granted reserves for recreation or maintenance of fish and bird life. The Rio Grande Water Compact is one of the prime reasons for the control of water use, especially in the Albuquerque area.

Albuquerque's municipal water system is supplied by a series of wells and reservoirs strategically distributed throughout the city. The accompanying table lists and locates the wells and reservoirs. There are currently 28 reservoirs fed by 74 wells within the system, which is fully automated. From a master control building, all water flow and reservoir levels are recorded and controlled. Pumps in wells are automatically started and stopped as water is needed. Likewise, booster pumps to keep all reservoirs supplied and water pressures adequate are automatically controlled.

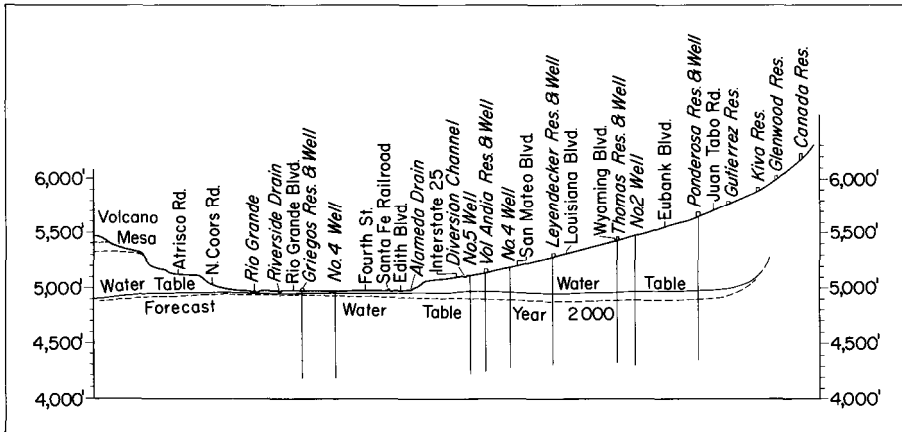


*Photo by Alan Goodman*

LEYENDECKER RESERVOIR

Capacity, 6,000,100 gallons; adjoining well house and pump station. This fine municipal installation on Montgomery Boulevard at Andrew Drive is modern every respect. The small building in front of the reservoir contains the chlorine room and Well No. 1 of the Leyendecker field of four wells. The large building contains the big pumps.





SURFACE AND WATER-TABLE PROFILE ACROSS THE RIO GRANDE VALLEY ALONG GRIEGOS AND MONTGOMERY ROADS

It is a problem to keep pressures in water lines adequate and uniform in a city where altitudes range through 2000 feet. To do this, the water system is arranged into 16 pressure zones. Irregular north-south strips away from the river, each zone is nearly a separate water system in itself. If water is drawn heavily in one area, other water may be "pulled" from an adjoining zone until pressures at the zone boundaries adjust to predetermined levels. Thus, water in some mains occasionally flows in reverse directions, and, therefore, water to a given hydrant or faucet may come from different reservoirs or wells.

Wells range considerably in size, depth, yield, and pump capacities, depending on when the well was drilled, the need at a locality, and the yield of water from the aquifer (the ground-water supply). Present city well capacities range from 500 to 3500 gallons a minute, their depths from 300 to 1000 feet. They are drilled below the water table to differing depths, depending upon how much water comes into the hole. Some beds are tighter than others, so that, in a well encountering more permeable beds, one need not drill so deeply as in tight beds to gain a given supply.

Well fields may have several wells scattered around a reservoir that they feed. A few reservoirs have only one well, others none. Almost all have booster-pump stations and all have chlorine-treatment equipment. Booster stations at reservoirs contain as many as six huge pumps, some having individual capacities of 7,000,000 gallons a day. Reservoir capacities range from 125,000 to nearly 13,000,000 gallons. The city has a storage capacity of more than 100 million gallons.

Water consumption in Albuquerque ranges from about 98 gallons a day a person in the winter to 386 gallons in the summer. Maximum consumption for the city during a peak summer day has reached 100,000,000 gallons.

ALBUQUERQUE WATER FACILITIES

Well Fields, Wells, and Reservoirs

NAME	PRESSURE ZONE	RESERVOIR	PUMP	NO. OF WELLS	DEPTH (feet)	DEPTH OF		LOCATION
		CAPACITY (thous. gals.)	CAPACITY (gpm)			WATER TABLE JUNE 1968 (feet)		
Franciscan	4 West	1529		0				Snow Addition
Don	2 West	None	Booster	0				Snow
Don	3 West	4030	1200	1	1440	430		Atrisco Grant
Volcano Cliffs	3 West	6000	4200 (est.)	2	895-1076	382-386		Volcano Cliffs
West Mesa	2A West	4005	2250	2	1180-1450	265-260		Central West
Valley Gardens	0 West	500	Pump	2	450-500	10-20		South Coors
Atrisco	0-1 West	3081	8750	11	207-813	24-58		Between Bridge & Central
Duranos	1 West	4286	12,900	7	815-1020	22-29		Rio Grande & 1-40
Main Field	1 East	—	5650	8	60-715	20±		Abandoned
Griegos	1 East	3000	9870	5	800-900	32-52		Rio Grande & Griegos
Candelaria	1 East	620	3300	4	288-553	3546		Broadway & Candelaria
San Jose	1 East	2500	8050	6	306-1032	14-50		S. Broadway & Gibson
South Barbara	1 East	3750	3400	1	984	186		Candelaria & Carlisle
Yale	2 East	8062	Booster	0				Yale and Central
UNM Campus	2 East	1400	1320	2	286-414	60		Tennis Courts & Physics Bldg.
Vol Andia	2 East	6000	18,000	6	1010-1033	151-260		Montgomery Heights
Burton	2 East	9033	5700	3	845-1000	367-404		Carlisle & Kathryn
Lyendecker	3 East	6001	9400	4	1010-1020	319-378		Montgomery & Louisiana
Wells	3 East	7000	12,000 (est.)	4	1016-1052	330-370		Prospect & Mesilla
Thomas	4 East	6051	6500	4	1096-1200	490-542		Montgomery & Wyoming
Ridgecrest	4 East	8612	1500	1	1260	514		N. edge Sandia Base
Ridgecrest	4 East	2600	None	0				South Eubank
Love	5 East (4B)	12,734	7000	5	1096-1280	456-520		Lomas & Morris
Lomas	6 East	9985	1400	1	1300	545		Panorama & 1-25
Linda Vista	7 East	5958	Booster	0				N. of Sheraton Hotel
Supper Rock	8 East	4014	Booster	0				Near Supper Rock
Sandia Manor	8 East	125	None	0				Near Supper Rock
Ponderosa	6 East	6027	325	1	1242	726		Montgomery near Morris
Gutierrez	7 East	6003	Booster	0				Montgomery near Juan Tabo
Kiva	8 East	2820	Booster	0				Montgomery & Ponderosa
Glenwood Hills	9 East	1700	Booster	0				Glenwood Hills
Canada	10 East	None	Booster	0				Glenwood Hills
Simms	11 East	2520	None	0				Glenwood Hills



*Dick Kent photo*

VIEW NORTH OF THE CULTIVATED RIO GRANDE LOWLANDS FROM ABOVE  
LOS PABLANOS RANCH

Griegos lateral, left of center; Rio Grande Boulevard, extreme right.



*Dick Kent photo*

SANDIA MOUNTAINS VIEWED FROM ABOVE THE CREST TOWARD SOUTH  
SANDIA PEAK (UPPER RIGHT)

Estancia Valley in distant background and eroded scarp of the eastward-  
tilted fault block  
to the right of the crest.





*Dick Meleski photo*

VIEW EAST ACROSS THE INNER VALLEY TOWARD THE MOUTH OF  
TIJERAS ARROYO

Highly braided Rio Grande and its floodway at bottom of picture.



*Dick Meleski photo*

VIEW NORTHWEST OF RIO GRANDE LOWLANDS TOWARD THE ALBUQUERQUE  
VOLCANOES

Barelas Bridge (foreground) and Old Town Bridge up river. Riverside  
drains can be seen  
either side of the Rio Grande floodway.



*Dick Meleski photo*

ALBUQUERQUE VOLCANOES

Jemez and Nacimiento mountains on the northern skyline. Cones are aligned north-south along faults.





# Trip Logs

The following series of trips point out geological features, works of man, historical items, and something of the vegetation. Numerous ordinary check points are given around Albuquerque and in the Sandia Mountains. Many of the features may be seen while driving, but often you will find it better to park in a safe place along the road to read the log and observe. If possible, a passenger in the car should read the log aloud. Several stops also include short walks to features of interest.

All odometers do not agree on mileage distances, so you may have to allow for these differences at check points.

The trips begin in Albuquerque at points either well known or readily identified on a street map of the city, although you may find it more convenient to start the tour from another mileage point along the way.

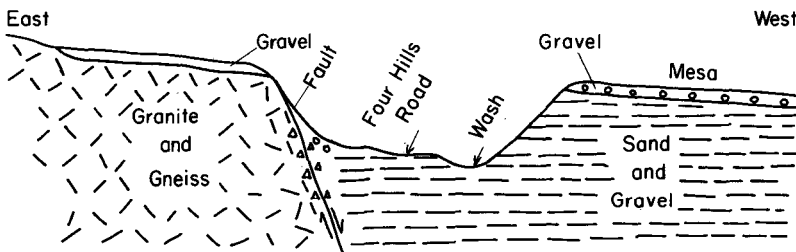
## Trip 1

### SANDIA MOUNTAINS

This trip goes through Tijeras Canyon, north on N. Mex. 10 to Sandia Crest, and down the northern route out of the mountains through Placitas. You will see the principal rock formations, structural and physiographical features of the mountains, and vegetation of the several life zones along the way. Length: 56.3 miles; time: 4 to 7 hours, half to a full day, depending on the number and length of stops (true of each trip).

The trip starts near the junction of U.S. 66 and 1-40 at the mouth of Tijeras Canyon, 8.5 miles east of downtown Albuquerque. Here the rock to several hundred feet beneath the surface consists of sand and gravel eroded from the Sandia Mountains. The depth, or thickness, of this material increases toward Albuquerque because of the westward slope of bedrock beneath the sand and gravel and the great faults along the western base of the Sandia Mountains.

In most places, these faults are buried by material that has long been eroded from the mountains and spread across the valley. One of the very few places you



CROSS SECTION OF TROUGH-FILLING SEDIMENT FAULTED DOWN AGAINST GRANITE AND GNEISS OF THE PRECAMBIAN IN THE SANDIA UPLIFTED BLOCK

can see such a fault is along Four Hills Road, only 0.4 mile south from the front of the Western Skies Hotel; follow the road east around the hotel and the short distance down Four Hills Road. You may see or climb up to the fault in the low slope east of the road. This may well be part of the main fault on which the Sandia Mountains were uplifted.

This trip begins at the Sheraton Western Skies Motor Hotel.

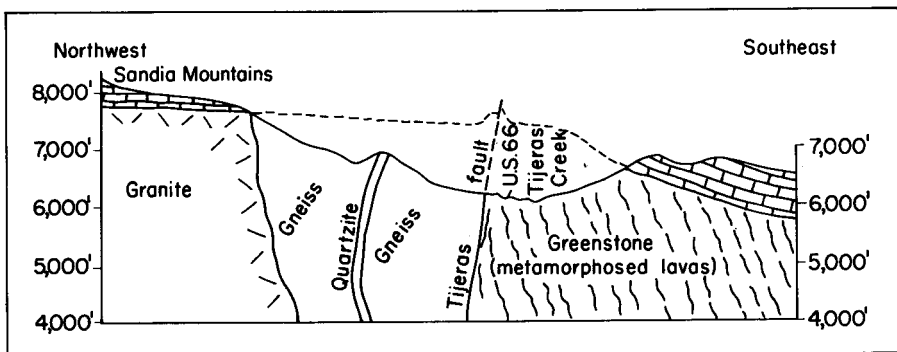
0.0 Follow Central Avenue (U.S. 66) east onto 1-40 and continue into Tijeras Canyon. Outcrops of Sandia Granite show in the roadcuts as well as in the surrounding hills. The outcrops have a very bouldery appearance, but these are not boulders in the sense that they were transported or made by river or glacial erosion; rather, they are residual boulders formed by weathering away of the edges of jointed blocks of the granite. Notice the gradation of these boulders downward into the blocky, often fresher, granite in several of the roadcuts for the next 3 miles. Notice especially the roadcut at 2.6 miles, where fresh granite was blasted open in the base of the big bank on your left. A transition upward may be seen from fresh to weathered and spheroidally rounded residual boulders at the top of the cut.

2.9

2.9 Village of Carnuel. Trees here are mostly juniper (Upper Sonoran life zone), but along Tijeras Creek, native mountain cottonwoods grow.

Side road on right just ahead leads south across Tijeras Canyon. The pinkish colored hill to your right is granite-like gneiss (NICE. a metamorphic layered or banded rock). Slightly to the left of the road ahead, the hills along the ridge are also of this Tijeras Gneiss as far as the saddle beneath the steep rise to Sandia Crest. The granite outcrops look grayish compared to the pinkish ones of the gneiss.

To your left (north) on the high mountain crest, layered sedimentary beds (limestone, shale, and sandstone) of Pennsylvanian age (300 m.y.million years) cap the ancient Sandia Granite (1350 m.y. old). Notice that



SECTION ACROSS TIJERAS CANYON

the weathered bouldery granite outcrops give way at high altitude to bold, craggy, and pinnacled outcrops.

0.6

3.5 About here, the Sandia Granite grades into the pinkish Tijeras Gneiss. The layered or banded aspect of the granite gneiss is not readily apparent; the best way to see it is to pull off to the right of the road and walk around on the outcrops.

0.5

4.0 Ahead, gray quartzite (metamorphosed sandstone) comprises the knoblike hill to the left of the road. This outcrop extends southward across Tijeras Canyon and may be seen again at mileage point 4.1 just before entering the big, double roadcut. In the roadcut, the rocks are heavily faulted and sheared gneiss. CAUTION: sharp left turn ahead.

0.7

4.7 Gravel terraces in roadcuts indicate a higher position for Tijeras Creek before it eroded to its present level. These terraces formerly were probably continuous with the gravel of the mesa surface around the Western Skies Hotel. Pinon trees now intermix with the juniper.

STOP and examine the somber, dark-green and brownish rocks on the canyon slopes to your right. These *greenstones* come from slightly metamorphosed ancient lava flows. The greenstone on the ridge lies under Pennsylvanian sedimentary rocks of the Magdalena Formation. High to the north of the road, a thin cap of the same formation lies on top of granite and gneiss like that you have already seen. The greenstone and sedimentary beds south of Tijeras Canyon in the Manzanita Mountains have dropped several hundred feet compared to the gneiss and sediments north of the canyon. This downward displacement occurred on what is termed the Tijeras fault. The fault roughly follows the canyon bottom from the saddle (back down the road) to just left of the green and white houses on the hillside in line with the road ahead.

0.3

5.0 The fault has now crossed to the left side of the road and lies between the greenstone in the roadcuts and the pinkish gneiss in the hills.

0.3

5.3 Seven Springs Cafe and historic marker: "TIJERAS CANYON This pass between the Sandia and Manzano mountains was used for centuries by Indians, Spanish explorers, traders, trappers, and the 49'ers. Both mountain ranges top 10,600 feet. Canyons crossing at Tijeras resemble open scissors, which gave the village (2 miles ahead) its Spanish name." [T. M. Pearce's *New Mexico Place Names* says that more likely the name came from a Spanish family surname.]

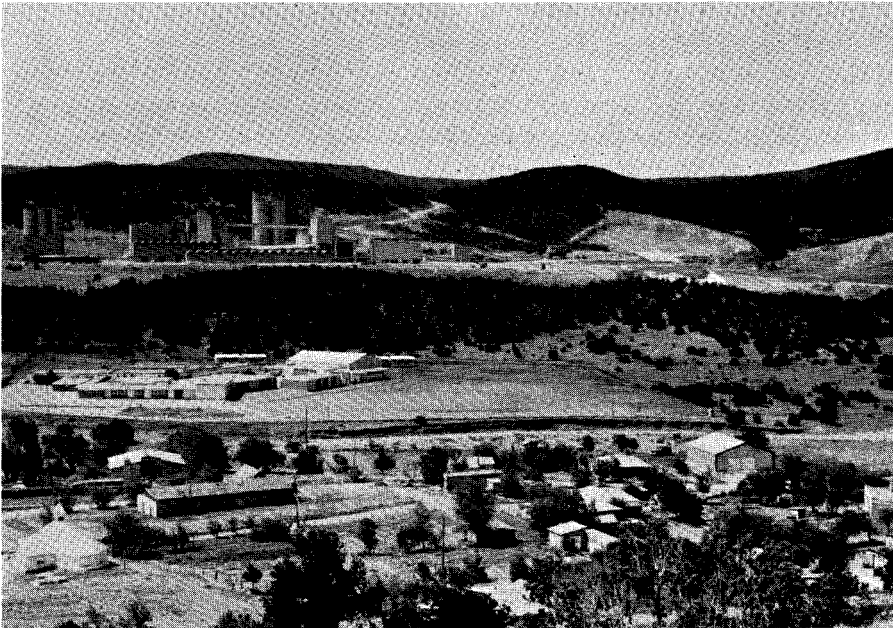
0.3

5.6 Roadcuts again in greenstone and gravel. The limestone beds of the Magdalena Formation have descended in outcrop to the bottom of the canyon on your right and crop out again in the roadcuts ahead on your left. As you pass by, notice the gray and red shale layers interbedded with the gray limestone. These beds tilt rather steeply here as the result of dragging action as they dropped along the Tijeras fault.

0.6

6.2 Tijeras Post Office. The village of Tijeras ahead is as old as 1856, and the post office has been used intermittently since 1888. Stop here and walk back to the roadcuts. *Be careful of heavy traffic!* The limestone and shale in the ridges to the south contain numerous assorted fossils; if you want to hunt for some, watch out for occasional rattlesnakes!

The reddish-brown beds in the roadcuts are mudstone and sandstone of the Abo Formation of Permian age (270 m.y.). They lie on top of the Magdalena Formation and are thought to have been deposited by rivers on a vast floodplain, perhaps under tropical conditions. Unlike the Magdalena, the Abo Formation contains no marine fossils such as shell forms or corals;



IDEAL CEMENT COMPANY PLANT

Limestone quarries on

right.



however, in places, primitive plant remains and footprints of reptiles have been found.

0.3

6.5 Tijeras settlement and school on right, with the large Ideal Cement Company plant beyond. In the quarries to the right of the plant, both limestone and shale are mined as raw materials for the manufacture of cement. The school, part of the Albuquerque Public School System, is the Roosevelt-A. Montoya, with grades through junior high.

The Ideal Cement Company plant, built in 1957, is constructed almost wholly of concrete, is modern in design, and is fully automated. Its present rated cement capacity is 3,000,000 barrels a day.

0.7

7.2 Junction, N. Mex. 10, north. Red beds of the Permian Abo Formation all around.

You may now turn left, following the main trip, or you may elect to take the following side trip, a loop of 1.8 miles.

#### TIJERAS BASIN SIDE TRIP

This side trip continues for a short distance on 1-40, along Tijeras Creek through red sandstones and mudstone of Permian formations, for an excellent view of an anticline.

0.25 End of divided highway.

0.3

0.6 Road to left is an abandoned U.S. 66. Continue straight ahead.

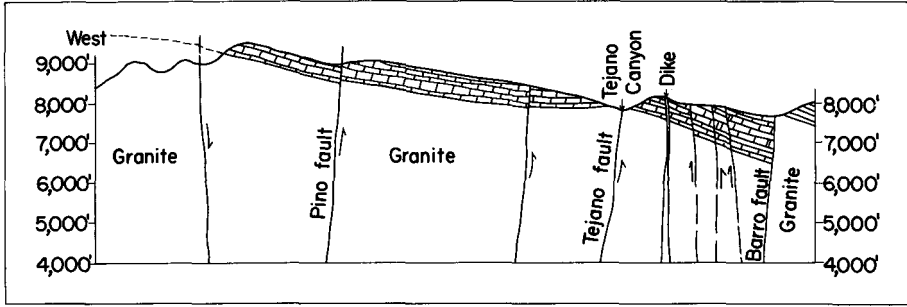
0.4

0.65 Highway crosses Tijeras Creek.

0.5

0.9 STOP on right near concrete table. At this point you have a good view of the back slope of the tilted Sandia Mountains fault block. Across the valley to the northwest is a semicircular outcrop ridge of the Upper Cretaceous Mesaverde Formation (90 m.y.). The beds on the left side of the valley incline west; those on the right, east. They arch across the valley in a fold termed an *anticline*. Anticlines often have oil or gas trapped in them in sandstones beneath the surface. This, the Tijeras anticline, has been drilled unsuccessfully in the search for oil. The cross section shows this anticline with downfolded synclines on either side.

Notice that the anticline and synclines are depressed between large faults. From this point, the view to the anticline looks across the Gutierrez fault, which lies on the other side of the valley near the abandoned U.S. 66 highway. The granite "basement" beneath the Great Unconformity is near sea



CROSS SECTION OF SANDIA MOUNTAINS

level beneath the anticline, but it occurs about 9000 feet above sea level on South Sadia Peak, northwest of here.

0.9

1.8 Return to N. Mex. 10, north, TURN RIGHT, and resume main trip (mileage point 7.2).

7.2 TURN LEFT onto N. Mex. 10, north. Historic marker: "Ancient home of Sandia Man, among the earliest of cave-dwelling humans known on this continent. Cibola National Forest has heavily timbered picnic areas, ski run, deer, bear, wild turkey, bighorn sheep. Nearby are picturesque villages and churches, ghost towns, mines worked since prehistoric time." The thick cover at this altitude consists mostly of pinon and several varieties of juniper interspersed with some cholla cactus, ground spruce, and scrub oak.

At mileage point 7.4, the road crosses a buried fault; we know this because in roadcuts at the next mileage point, we see grayish sandstone and shale of the Mesaverde Formation of late Cretaceous age (80 m.y.). This is a great fault inasmuch as it has dropped these cretaceous beds some 2000 feet against the red Permian beds to the south. For several miles, the road crosses Cretaceous beds until it again crosses the Tijeras fault, which brings up the older rocks once more. Thus, the section between mileage points 7.4 and 9.7 is a large, dropped wedge of younger beds.

0.7

7.9 The steep ledges that cap the hills on both sides of the road are sandstone of the Mesaverde Formation. This formation also contains thin coal beds that have been mined in the down-dropped wedge, an area known to geologists as the Tijeras coal basin.

0.2

8.1 The reddish soil in the roadcuts on your left washed down the canyon from the red Permian and Triassic rocks to the west.

0.3

8.4 Old village of San Antonio, an early trading point along an ox-cart route from Albuquerque to Santa Fe.

0.2

8.6 Cedar Crest Post Office; this area has long served Albuquerque as a mountain health resort. Small quarry on ridge left produced building stone and flagstone.

0.1

8.7 Terrace stream gravel in roadcut on your left. The canyon on your right, which the road now follows, is Arroyo San Antonio.

0.3

9.0 Flat skylines ahead are high levels of gravel that probably were once continuous with the Albuquerque mesa around the Western Skies Hotel.

0.3

9.3 Forest Park. Sandstone ledges east of Arroyo San Antonio still belong to the Mesaverde Formation.

0.4

9.7 About at the "40 MPH" curve sign just ahead, the buried Tijeras fault crosses the road diagonally from the left and continues up the valley on the right side of the road. Here the right, or east, side of the fault dropped about 1500 feet and forms part of the Tijeras basin, or graben. Ponderosa pines begin to appear prominently here on the hills and along the road.

0.4

10.1 Bella Vista Restaurant.

0.5

10.6 Side road left leads to the village of Canoncito (0.5 mile) and to Cole Springs picnic area (3 miles). The valley is eroded in red-brown Triassic shale of the Chinle Formation. The ridge back of the church at Canoncito is Triassic shale of the Santa Rosa Formation. It lies beneath the Chinle Formation and extends at depth beneath the road, as all the formations on this side of the Sandia Mountains incline to the east. The Santa Rosa Formation here was mined during the 1930's for flagstone used in walks and for floors in a number of Albuquerque buildings.

Notice again the high crest of the Sandias to the west and the regular, tree-covered slope, formed by erosional stripping parallel to the beds of limestone of the Magdalena Formation. This relationship is shown on the lines of ledge outcrops northwest of here.

The small quarry in the hill to the right of the road once produced gypsum (white) for the Ideal Cement Company. About 3 per cent gypsum added to the mixture in making cement acts as a retarder to keep the cement from setting too rapidly. This deposit proved too difficult and too small to

mine; the company now gets its supply from a larger deposit north of the Sandia Mountains.

0.9

11.5 Reddish-brown Chinle shale on both sides of road.

0.3

11.8 Summit of hill; road crosses into the area of San Pedro Creek, which drains the east side of the Sandias from here north around the mountains and empties into the Rio Grande near San Felipe Pueblo. South of this divide, Tijeras Creek and its tributaries drain the mountains.

0.8

12.6 Fine stands of juniper on your left, mostly Rocky Mountain variety.

0.2

12.8 San Antonito, another trading point on the old ox-cart route to Santa Fe. TURN LEFT on N. Mex. 44, which leads to Sandia Crest. N. Mex. 10 continues past the ruins of the ancient pueblo of Paa-ko (2 miles) and on to Madrid, Golden, Cerrillos, and Santa Fe. Paa-ko, formerly used by the University of New Mexico for field studies is now a State Monument. The mining ghost towns of San Antonito, Madrid, Golden, and Cerrillos offer the traveler a peek into the past. Madrid, which still has coal, was the site of a widely known Christmas pageant. Golden still provides the amateur "gold panner" the thrill of finding a little gold in the nearby hills.

The wide valley here still lies in Chinle shale, although far to the southeast, the curving valley rimmed by a tree-covered ridge lies east of the great Tijeras fault where the rocks are again Cretaceous in age. The hills to the northeast (Monte Largo) comprise a complex mixture of gneiss and quartzite with numerous large intrusions of igneous rocks like the Sandia Granite.

0.9

13.7 KEEP RIGHT on N. Mex. 44. Sandia Park Post Office (Tilton Store) to your left on road up Cienega Canyon (2 miles). Ponderosa pines begin to dominate over pinion and juniper in the forest. The mountain loop road from here to Placitas was built in 1926 and 1927.

0.2

13.9 Road cuts reddish sandstone and shale of the Abo Formation, the same Permian red beds as those around the village of Tijeras (mileage point 6.2).

0.5

14.4 Elm trees along creek, left; some large scrub oak appears ahead.

0.1

14.5 Road now passes into the Magdalena Formation. Notice the limestone ledges in the slopes on your right and the limestone, black shale, and sandstone beds in the roadcuts ahead.

0.3

14.8 White fir trees, left, just before "Sulphur Canyon" sign. A tenth of a mile farther, base of the Magdalena Formation and its contact with the underlying Sandia Granite. You can find good fossils in the limestone and shale south of the contact in the roadcuts.

This is the same geologic contact, the Great Unconformity, that we see high on the western face of the Sandia Mountains, where the strongly stratified sedimentary "rim rocks" lie on the bold granite cliffs of the mountains. This unconformity, or old erosional surface, represents a gap in the record of geologic time of more than one billion years between the 1390-m.y. granite and the 250-m.y. Magdalena beds. Much of the missing record, however, does appear in surrounding regions—southern New Mexico, the Grand Canyon, and Colorado.

The discoloration and somewhat "rotten" look of the granite beneath this unconformity comes partly from recent weathering and partly from weathering on the ancient erosion surface prior to burial by the sedimentary beds. A little gravel is present in the first bed above the granite, and marine fossils occur 5 to 6 feet above the base and in scattered beds upward in the sequence. The sandstone and shale beds are typically micaceous, suggesting an erosional source from a mica-rich rock, such as the granite.

Hundreds of feet of Magdalena Formation beds underlie the crest and highest slope of the Sandias. It is strange that the granite is exposed here. It happens because a large north-trending fault, called the Barro Canyon fault, lies just a few hundred feet west of the road. This fault "broke the back" of the Sandias and raised a replica in miniature of the major Sandia Mountains block, thus exposing the granite. The road ahead crosses this fault.

Box elder, scrub and Gambel oak, cottonwood, some juniper, and pine trees line the canyon bottom to your left. Abert or tassel-eared squirrels are common here.

0.2

15.0 Side road to Doc Long picnic ground, long a favorite spot of Albuquerqueans.

0.3

15.3 Pines and scrub oaks on both sides.

0.1

15.4 Hairpin curve. Notice dikes in the granite of the roadcut and juniper trees above the pines on the hillside across the canyon.

0.1

15.5 The Barro Canyon fault shows in the roadcut at the "Watch For Rocks" sign. Rocks west of the fault are the uppermost beds of the Magdalena Formation, which in this area may be some 1200 feet thick. As the road turns

the corner ahead and goes up Tejano (Texan) Canyon, it descends strati-graphically through eastward-dipping beds; in the next 0.75 mile, you descend stratigraphically through almost the entire 1200 feet of the formation. Many fossil-bearing beds occur in the roadcuts along this stretch.

0.5

16.0 North slope across canyon to left has thick stands of white fir, whereas the sunny south slopes above roadcuts have mostly pinon with some juniper. Ahead up the canyon along road switchback slopes, an old burn area contains only oak and small firs and pines.

0.3

16.3 Dike of igneous rock, 18 feet wide, cuts limestone beds in the roadcut. The dike must occupy a fault, because the beds on opposite sides of the dike do not match.

0.2

16.5 Hairpin curve. Contrast the vegetation east and west. East: scrub oak, yuccas, sparse juniper caused by overexposure on a west-facing slope. West: mostly white fir and pine; Canadian zone.

0.6

17.1 As you round the curve for a view across Tejano Canyon, notice the big,



ANDESITE DIKE CUTTING MAGDALENA LIMESTONE BEDS



GREAT UNCONFORMITY BETWEEN PRECAMBRIAN GRANITE BELOW AND BEDS OF THE MAGDALENA FORMATION OF PENNSYLVANIAN AGE  
Notice the residual knob and boulder being overlapped by the sediment.

prominent ledges of the Magdalena Formation. These are the same ones on the high west face of the mountains that you see from Albuquerque. Uplift of another miniature fault block and erosion bring them to view here.

0.4

17.5 Again, the Great Unconformity contact on the left, inclined northward up the roadcut. If you examine the contact carefully, you may find several rounded, residual boulders of the type you noticed as you entered Tijeras Canyon. The covering Magdalena sediment fills in and overlaps these boulders. The exposures here, and even more so in the old roadcuts some 100 feet above, attest vividly to the fact that the same kind of weathering occurred 300,000,000 years ago in early Pennsylvanian or Magdalena time. These same sediments overlie the blocky granite outcrops across Tejano Canyon. This slope provides a good example of the generally poor exposures from which geologists must trace formation boundaries, so you can understand why they love roadcuts!

0.4

17.9 Landslide debris in roadcut on left. This old landslide, now completely overgrown, slid down only a short distance from the hill to the west.

0.1

18.0 Limestone ledges on right dip west here instead of east as the result of having been dragged (bent) along a fault.

0.3

18.3 Luxuriant stands of white fir on north slopes, left.

0.8

19.1 Dry Camp picnic ground on right. The purplish-brown rocks, left, are the highest beds in the Magdalena Formation.

0.4

19.5 View into the valley of San Pedro Creek, with the igneous Ortiz Mountains in the distance and the San Pedro Mountains to your right. Far to the north, you can see the Santa Fe Range, southern member of the great Sangre de Cristo chain.

0.4

19.9 Sandia Peak Winter Sports Area. The lower part of this ski run, especially around the lodge, is a widened, somewhat flatter, area on an old landslide.

A chairlift from here operates year around to the top of the mountain, where one can meet the tramway car coming up the west slope. The chair-lift, 7000 feet long, takes about 15 minutes to reach the Summit House restaurant.

0.3

20.2 View right looks across La Madera (Timber) Canyon and into the upper part of San Pedro Valley. Two mountains appear across the valley right of the winding course of N. Mex. 10. The lower one, Monte Largo, consists of gneiss and quartzite; the higher, three-peaked one with the horizontal tree-line around it, South Mountain, is an igneous intrusive mass (laccolith). The mountain to the left is San Pedro.

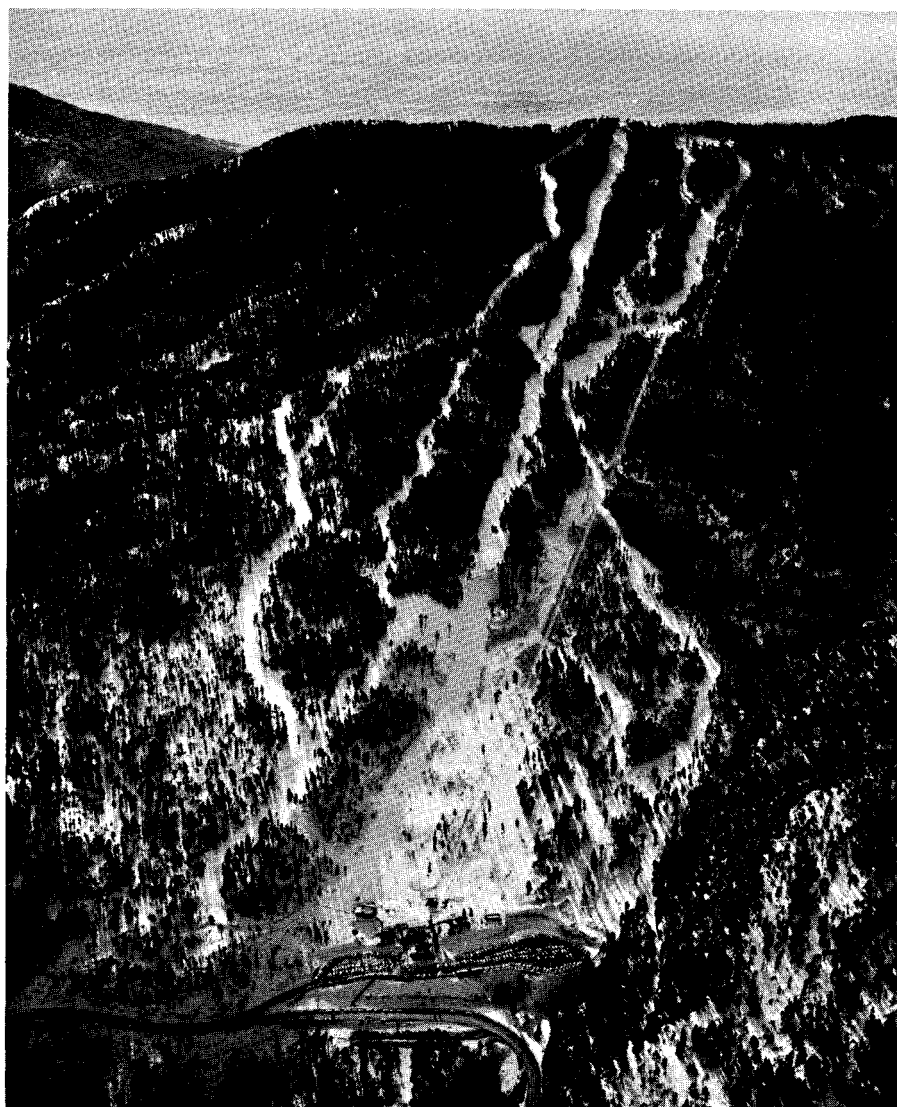
0.3

20.5 Junction, N. Mex. 536. TURN LEFT and follow switchback road to the crest of the Sandia Mountains. The road from here to the crest was built in 1928 and paved in 1962. The road is on a gentle slope that more or less parallels the inclination of the beds, although slightly less steeply, so that the beds at the beginning of the road here are perhaps one or two hundred feet higher, stratigraphically, than those at the end of the road and on the crest. Mostly white fir here, some pine and scrub oak for the next half mile. Capulin turn-off at mileage point 21.1.

0.7

21.2 Sharp turn left. Small thorny locust on right side of curve. Just around curve, still on your right, a large Douglas fir (short needles, small cones hanging downward with "snake tongue" barb on end; red often shows





*Photo by Dick Kent courtesy of Sandia Peak Ski Area*  
VIEW OF THE SANDIA WINTER SKI AREA

Rio Grande Valley across the top of the mountains. The chairlift from near the parking area to the summit, where one can meet the tramway, is 7500 feet long. Although this view of the east side of the mountains appears very steep, this slope eroded on the gently dipping limestone beds. The over-all slope is only 12 degrees. The far left run is upper and lower Cibola; the middle run is Exhibition and lower slalom; the right runs are Aspen, The Bowl, and Diablo.

through cracks in bark, as here). Douglas fir usually begins to appear near the top of the Subalpine zone.

0.1

21.3 First aspen (white bark) near road on your left; forest still dominated by white fir.

0.6

21.9 Much aspen, old and young.

0.5

22.4 Mostly white fir, but several large Douglas firs and pines on both sides of road.

0.6

23.0 A large, droopy, Ponderosa pine, left, with several Douglas firs nearby and numerous small white firs all around.

0.8

23.8 Sharp hairpin turn right at Forest Service "Free Wood Area" sign; 2.5 miles more to Sandia Crest. Good examples of Douglas fir in the next 100 yards; some smooth-barked Subalpine fir also appears.

0.3

24.1 Gentle curve left with two Englemann spruce (stiff, small needles, scaly bark); also white fir and large aspens. About 200 feet from next hairpin curve sign, Englemann spruce and a Subalpine fir (board nailed to trunk; see corky bark).

0.5

24.6 Limestone ledges, right.

0.2

24.8 Hairpin turn right. Service road south, not open to public, leads to Summit House restaurant.

0.5

25.3 "Spruce-Fir" sign on left; much fir, aspen, and some Englemann spruce.

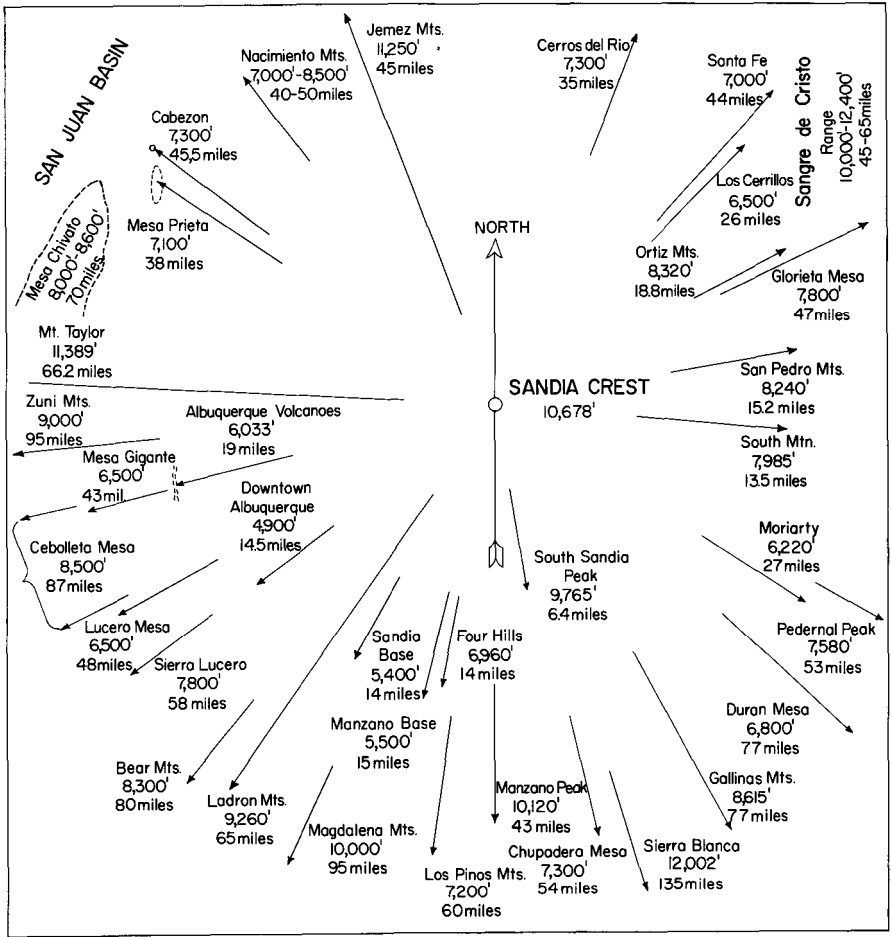
0.5

25.8 Hairpin curve left to Sandia Crest; good examples of Englemann spruce on outside of curve. Notice gnarled and bent aspen, caused by deep snow packing.

0.5

26.3 Parking lot, Sandia Crest; 10,678 feet above sea level. Park and walk to the viewpoint.

The accompanying panoramic index identifies 36 prominent features



PANORAMIC INDEX FROM SANDIA CREST

that, on a clear day, you can easily see for a radius of 100 miles. On exceptionally clear days, you can see the peak of Sierra Blanca, 135 miles south, near Ruidoso. The total area of view encompasses about 15,000 square miles. The Sangre de Cristo Mountains to the northeast represent the southern end of the Rocky Mountains. The Jemez Mountains to the northwest comprise a giant crater known as a caldera. Mammoth Mount Taylor to the west is the largest preserved volcano in New Mexico. Almost due south, the Manzano Mountains continue the faulted eastern edge of the great Rio Grande trough. Just try to imagine the magnitude of sinking of the valley at Albuquerque: the Great Unconformity, just a few hundred feet below the crest, lies 15,000 feet *below sea level* under Albuquerque!

Note the TV towers north along the crest. From south to north, they are KOB, KGGM, KNME, and KOAT and are said to be the highest in the world. Altogether, 37 installations are clustered on the Crest, including TV, radio, and telephone microwave facilities for the Forest Service, State Police, AEC, Fish and Game Dept., and other agencies.

Return to N. Mex. 44.

5.6

31.9 Junction, TURN LEFT onto narrow dirt road (continuation of N. Mex. 44). Generally, odometers register 0.2 to 0.3 of a mile shorter coming down from Sandia Crest than going up; probably slight spinning of tires on the way up and jumping on the way down causes this.

0.2

32.1 Hairpin turn right down Capulin (Wild Cherry) Canyon.

0.7

32.8 Road crosses fault into upthrown Precambrian quartzite.

0.1

32.9 Hairpin curve; view ahead of San Pedro Valley and Hagan basin, with Ortiz Mountains in the middle distance and Santa Fe and the Santa Fe Range on the northern horizon. Granite inside curve, and more quartzite. Ledge-capped mountain a short distance northwest is Palomas (Dove) Peak, composed of Magdalena Formation.

0.6

33.5 Sandstone in roadcut on left in lower part of the Magdalena Formation.

0.2

33.7 Sharp turn left, Magdalena sandstone again on inside of curve; this sandstone rests on granite just around the curve. Palomas Peak on your right, with the great limestone ledges seen on the west face of the Sandias. The same ledges across the big Las Huertas (Orchard) Canyon run down the slopes to a much lower altitude than the equivalent beds high on Palomas Peak. Another large, north-south fault follows Las Huertas Canyon and has lifted the east side again by nearly 1000 feet to the position in Palomas Peak. The shoulder below the big ledges on the profile of Palomas Peak shows the position of the Great Unconformity.

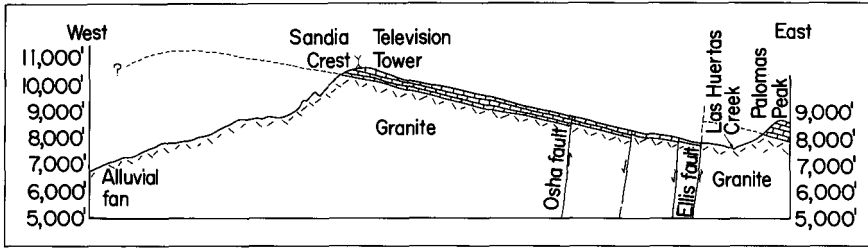
0.2

33.9 Roadcut. Notice how rotten the granite has become from weathering in the humid environment of the forest. Many such cuts ahead.

0.7

34.6 Sharp turn right. Two-story cabin across creek was built by George C. Ellis in 1872.

1.0



CROSS SECTION OF SANDIA MOUNTAINS

35.6 Side road to Las Huertas picnic ground; a stream, and a nice place for a picnic, hike, or rest, if not too crowded on a weekend or holiday. Still the rotten, decomposing granite in the roadcuts.

0.5

36.1 Granite

outcrop

s. 0.3

36.4 Now the Magdalena ledges have sloped to the canyon bottom and replace the granite in roadside exposures.

0.6

37.0 Sandia Cave, the site of Sandia Man, appears as the large hole with the yellow stain around it in the big limestone ledge high on your right. The principal cave of this group extends into the limestone hill 460 feet. Dr. Frank C. Hibben, of the University of New Mexico, made the famous archaeological finds of Folsom implements (8000 to 9000 years old) overlying more primitive implements of the pre-Folsom Sandia culture, dating by carbon-14 methods from 12,000 to 24,000 year old. He also found the remains of bison, camel, horse, ground sloth, mammoth, and mastodon and younger ware of Pueblo III, IV, and V cultures near the entrance to the cave.

The mouths of the caves may have eroded 5 to 10 feet from where they were when Sandia Man occupied them, and their entrances may have been even more difficult of access than now.

0.6

37.6 Numerous outcrops of thin- to medium-bedded limestone and shale flank the road. The many holes, small caves, and enlarged crevices formed by solution of the limestone in water.

1.8

39.4 Valley opens out into fields. Paved road. Montezuma Ridge ahead and to your right. Beds in the slope left of the road are high in the Magdalena Formation, whereas Precambrian rocks lie along the base of Montezuma Ridge. This indicates that a fault follows the bottom of Las Huertas Canyon

west of the ridge and that the rocks of the ridge itself have been lifted more than 1000 feet higher than those along the road.

1.8

41.2 Side road right leads north along San Francisco Valley. Just to the right of the road here, you may be able to discern a swath of ground where a buried 16-inch pipeline of the Texas–New Mexico Pipelines Company transports crude oil and gas from southeastern Utah to Texas. A little way farther, a side road leads to a pump station on the pipeline.

0.7

41.5 The village of Placitas (little plaza or market place), which occupies this valley, spreads primarily along the left-hand side of the road. It was built on the site of an ancient Indian pueblo and many Indian artifacts have been found here.

This area bounds the northern end of the Sandia Mountains, where the uplift begins its rise to the south, and contains much complicated faulting and folding covered by outwashes of sand and gravel from the mountains.

0.8

42.3 Greenish beds of the Jurassic Morrison Formation in the roadcut, left, lie beneath thin, rusty, sandstone beds of the Cretaceous Dakota Formation.

1.3

43.6 The valley here overlies soft shale of the Mancos Formation. On the skyline to your left, Cabezon (Big Head) Peak, an eroded stump of an old volcano, rears its head. Also on your left, spectacular granite shields and capping limestone beds mark the Great Unconformity. This great facade is the fault scarp of the Sandia Mountains.

0.9

44.5 The roadcut on the right exposes another, younger, unconformity. Here Pliocene Santa Fe Formation gravel overlies Mancos Shale, and missing (eroded) formations represent a time interval of 80 m.y. The erosional interval at the Great Unconformity near the top of the mountains represents about one billion years missing from the geologic record.

0.6

45.1 Road descends across westward-sloping surface on Santa Fe Formation sand and gravel. On the skyline directly ahead is the southern end of the Nacimiento (Nativity) Mountains and to the right, the southern rim of the great Jemez caldera. In the middle distance, across the Rio Grande and to the right, you can see the lava-capped Santa Ana Mesa. Notice how faults have dislocated the lava surfaces. Cabezon Peak appears again on the skyline, left of the Nacimiento Mountains.

3.0

48.1 Junction, N. Mex. 422, north, exit to Santa Fe; CONTINUE

AHEAD across overpass and take "Albuquerque" exit; follow 1-40 and N. Mex. 422, south.

1.0

49.1 Highway sign "Albuquerque 15, Belen 47." Reddish exposures of sand, mud, and gravel in roadcuts and arroyo banks here and ahead belong to the Santa Fe Formation. Notice the Rio Grande cultivated floodplain, right, and the pinkish Santa Fe beds in the low slopes across the valley.

0.7

49.8 Junction, exit to Bernalillo (from a family name), originally a trading center. County seat of Sandoval County. Continue straight ahead.

1.9

51.7 The prominent mountain mass on your left, known as Rincon (Corner) Ridge, forms the northern "spur" of the Sandias and partly encircles the Juan Tabo recreation area. It stands in front of the main granite escarpment of the Sandias and consists of mica schist and quartzite (metamorphic rocks) cut by numerous igneous dikes.

3.3

55.0 From here south, the road traverses the East Mesa surface, underlain by Santa Fe sand and gravel and younger alluvium.

0.5

55.5 Bernalillo county line.

0.8

56.3 Exists to Alameda (farming community, site of a Tiwa Indian pueblo in the seventeenth century), U.S. 85, and Tramway Road. Freeway continues to Albuquerque exits.

End of Trip 1.

## Trip 2

### WEST BASE OF THE SANDIA MOUNTAINS

This trip takes you north across the alluvial fans to the lower terminal of the Sandia Peak Tramway, returning by way of 1-25 near the Coronado Airport. Length: 20.8 miles. Time: 1.5 to 2 hours, exclusive of the tram ride. Allow another hour for the tram trip.

You will see alluvial outwash fans, arroyos, canyons, and the bold western escarpment; some limestone dropped from the crest of the mountains; and great strings of boulders weighing several tons that have washed miles from their sources in the mountain canyons. Also included is a log of features seen from the tramway as it proceeds to Summit House.

This trip begins at East Central Avenue and Eubank Boulevard.

0.0 Go north on Eubank. For about one block, Eubank crosses the level mesa surface near the apex of the Old Tijeras Canyon alluvial fan; it then descends toward the Old Tijeras Arroyo. The view from here toward the mountains looks across the head of the old arroyo to the alluvial fans. Notice especially the fan from Embudo (funnel) Canyon, back of the Manzano High School stadium.

An alluvial fan, in geologic parlance, spreads stream debris from the base of a mountain or the mouth of a canyon. It "fans" outward, sometimes through more than 90 degrees, as the result of the streams' branching away from the apex. Fans from adjacent large canyons coalesce outward, but the interfan area between them commonly lies several tens of feet lower than the apexes of the fans.

0.6

0.6 Main wash of Old Tijeras Arroyo. Continue northward, crossing overpass of 1-40.

0.4

1.0 Traffic signal; TURN RIGHT (east) up Lomas Boulevard. Road ascends alluvial fan; right, you can see the Old Tijeras Arroyo.

1.0

2.0 Traffic signal at Juan Tabo Boulevard; continue east.

0.2

2.2 Manzano High School on right.

0.3

2.5 Chelwood Park Boulevard. Notice the high crest of the Embudo Canyon

fan near the Blue Cross Building on your left (north). Continue east.

0.5



3.0 STOP SIGN, Panorama Boulevard; continue east. Abandoned, wide gravel pit. The gravel here came from along a low wash that drains the south side of the Embudo fan.

0.3

3.3 Continue toward mountains along the curve of dirt road northeastward. Notice the alluvial fan from the canyon near the "U" rock to the south and the high crest of Embudo fan to the northeast. The ground is low between the two fans and to the west of the limestone hill straight ahead. This hill consists of the same limestone layers that you can see on the top of South Sandia Peak above the head of Embudo Canyon.

0.2

3.5 Road swings east again. PARK at side of road and walk over the limestone hill. The rocks are dense, gray, and obscurely bedded. Near the west base, some sandy and gravelly limestone beds occur. Some are reddish or greenish in color because of staining by iron oxides, and a few crinoid stems and poorly preserved brachiopod fragments can be found. On the east side of the hill, you can detect local granite outcrops beneath the limestone.

This is the only locality along the west base of the mountains where limestone is found. How did it get here? By sliding, by bending down from the beds on top of the mountain, by faulting? Most geologists believe that a north-south fault lies in the small valley just east of this hill and that the limestone beds were dropped relative to their high position on South Sandia Peak to this position by downward movement along the fault. All the slopes of the Sandias here are granite.

Turn around and retrace route to Chelwood Park Boulevard.

1.0

4.5 STOP SIGN; TURN RIGHT (north) on Chelwood Boulevard. The road ascends the south side of the large Embudo alluvial fan. The crest of the fan lies just beyond Constitution Avenue about at the Chelwood Elementary School and the Blue Cross building.

0.5

5.0 STOP SIGN at Constitution Avenue. TURN RIGHT up the fan. Follow Constitution around curve to Indian School Road. At the stop sign, you get a good view east into Embudo Canyon. Turn left down Indian School Road and follow it northeastward past the Blue Cross building back to Chelwood Boulevard. Notice the expansive view down to the East Mesa residential area from this high position on the alluvial fan.

The ditch to the right of the road at Chelwood is the main course on the fan out of Embudo Canyon. It is not very large!

Continue west to Juan Tabo.

1.4

6.4 STOP SIGN, Juan Tabo Boulevard. TURN RIGHT.

0.1

6.5 Road descends northward across swale between the Embudo and Embudito alluvial fans that you can see ahead to the north.

0.4

6.9 Menaul Boulevard. Straight ahead. The lowest part of the male occurs along here. The runoff through this area comes from both sets of fans, but principally from Embudito Canyon and the small fan apex in the Glenwood Hills subdivision. At 7.0, notice to the east the small alluvial cone from the "mouth" of Piedra Lisa Canyon.

0.2

7.1 Road crosses culvert over small drain that picks up water from several of the canyons east of here. During a very severe cloudburst in the mountains, it could even get water from Embudo Canyon.

0.3

7.4 STOP SIGN, Candelaria Road. Parts of the Holiday Park subdivision lie in the swale that drains Sunset Canyon and Embudito Arroyo near Glen-



GRANITE BOULDERS, WEIGHING 10 TO 15 TONS. ALONG EMBUDITO ARROYO AT JUAN TABO

These were carried three miles from Embudito Canyon during a severe storm, probably not more than a few thousand years ago.

wood Hills. Road ahead ascends Embudito alluvial fan.  
Notice culvert drain through Holiday Park at 7.7.

0.5

7.9 Comanche Road, continue north. Shortly after you cross Comanche, you come to a small arroyo (Embudito, little funnel) and culvert. Notice the string of giant granite boulders along it. They rest in gravelly granite out-wash on the Embudito fan. Although they have been moved around during local road building, the boulders occupied this site before man arrived. The largest weigh 15 to 20 tons and attest to the mighty power of cloudburst waters; they should serve as grim warnings to Albuquerque builders and residents along the base of the Sandia Mountains. These boulders probably came from Embudito Canyon, but they could have come from Sunset Canyon!

Similar coarse finger deposits of boulders occur elsewhere on these fans. Those just north of Montgomery Boulevard probably came from Bear Canyon, because they contain limestone boulders as well as granite. Hardly any limestone crops out in Embudito Canyon.

0.5

8.4 STOP SIGN. Montgomery Boulevard. Look west and east; notice the numerous city reservoir tanks along Montgomery and the high crest of the great fan that Juan Tabo crosses here. TURN RIGHT and STOP.

Look back at the swale to the south and on across Old Tijeras Arroyo to the Veterans Hospital on the Sunport mesa.

0.3

8.7 Gutierrez Pump Station on left. Notice the interfan swale to the south, and the Embudo fan with the Blue Cross building on its apex, and another inter-fan swale beyond it. The fan you are on comes from Embudito Canyon, east of the reservoir tanks. Embudito fan is a large one. Observe that runoff from Sunset Canyon, descending the mountain from the southeast, also feeds it. Together, these two canyons have a catchment area of about 2300 acre-feet. If 2-3 inches of rain fell in the catchment basin of these canyons during a cloudburst, the discharge onto the apex of the fan would be enormous, and large boulders would be carried out of the canyon.

Presently, the arroyo from Sunset Canyon at Glenwood Hills is channeled south past the power station (three quarters of a mile ahead on your right) into the residential, interfan area.

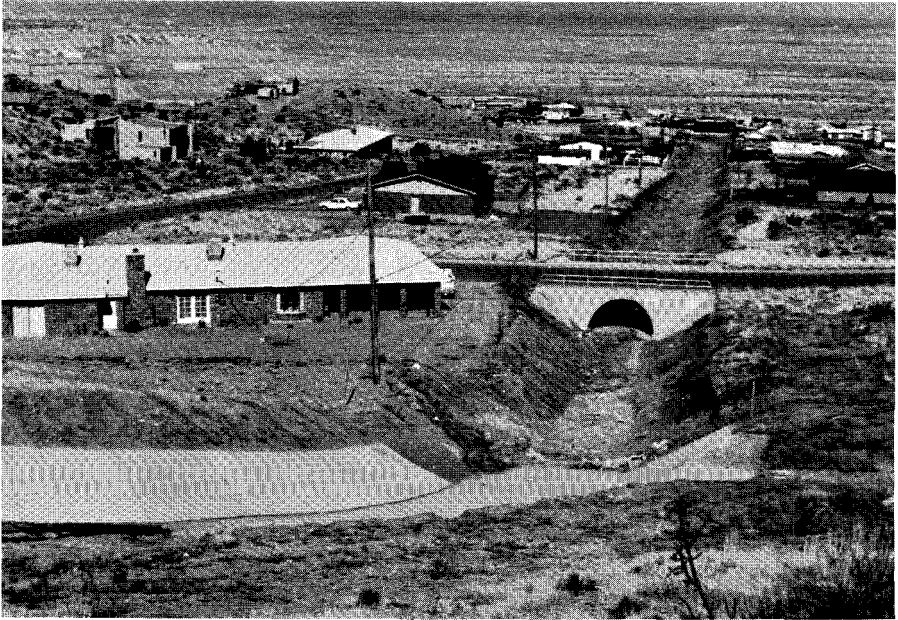
0.6

9.3 Kiva Pump Station left. Tramway Boulevard. TURN LEFT (north).

0.3

9.6 Embudito Arroyo. Notice the large granite boulder on your right; this weighs about 16 tons.

0.5



LOOKING OUT OF SUNSET CANYON THROUGH THE GLENWOOD HILLS ADDITION  
Montgomery Road upper left. It is doubtful that this drain could handle a  
sudden runoff  
during a torrential downpour.

10.1 Look back to right toward Glenwood Hills and see the large cut on the south side of the arroyo. This is a diversion ditch that brings runoff from Embudito Canyon to Bear Canyon. The diversion should have been made nearer the mountains to include a channel from the mouth of Sunset Canyon. Granitic gravel in roadcuts ahead. Notice boulders of granite scattered about, especially along the arroyo left of road. Boulders in succeeding cuts are not so large because the distance to the mountains from here is much greater than near Montgomery Boulevard and Glenwood Hills.

0.3

10.4 Tramway Boulevard runs due north toward a spur from the mountains known as Rincon Ridge, which bounds the Juan Tabo recreation area on the north. The mountain front swings eastward in a wide embayment known as the Bear/Pino canyon re-entrant. These major canyons drain out of the mountains in this embayment, Bear Canyon (south) and Pino Canyon (north). Just what causes the embayment is not clear, but most likely, it is caused by an eastward deflection of the frontal fault of the Sandia uplift. The crest has a similar arcuate curve that more or less parallels this embayment. This nearly middle part of the uplift may have moved first; hence, it is older and greater and has eroded longer. Certainly Bear and Pino are the

largest and most mature of the canyons on the west side of the Sandias. Again, large boulders strewn in arroyos on right.

0.8

11.2 Pino Arroyo. Notice its width, its length to the west, the view east into Pino Canyon, and the string of large boulders along the north bank. Imagine the power and transporting capacity of the water and gravelly mud that carried these boulders to this position from the canyon several miles east.

1.0

12.2 Bouldery fan material along gullies comes from Baca Canyon. About one mile east, the juniper-covered apex of the Baca fan is also covered with very large boulders.

0.2

12.4 Wide Baca Arroyo.

0.4

12.8 East, Sandia Peak Tramway terminal at base of mountains; notice the tram tower on the high spur.

The re-entrant straight ahead in the mountains is called Juan Tabo, a developed recreation area. "Tabo" is a Spanish diminutive of "Octaviano," but in the Philippines, it means "cup made from coconut shell." A priest and an Indian of this name are each said to have lived nearby (T. M. Pearce, *New Mexico Place Names*).

A fault on which the Sandias were uplifted probably lies very near the base of the steep mountains. Their front is geologically youthful, as the narrow, V-shaped, steep canyons that notch the lower slope indicate. The areas between the canyons, where the front is rather smooth and undissected, are referred to as "triangular fault scarp facets." These facets form the face of the mountains adjacent to the two, large, youthful canyons just north of the terminal. The fact that great faulting formed this mountain escarpment is additionally proved by outcrops of tilted sedimentary beds of Eocene age (60 m.y.) exposed beneath a veneer of alluvial fan material in the entrance to the Juan Tabo recreation area.

0.7

13.5 TURN RIGHT and proceed to the Sandia Peak Tramway. The main north-south fault on which the mountains uplifted, or on which the Rio Grande trough dropped, must occur along here. Probably another fault, all of which is in the granite, lies near the base of the mountains.

0.3

13.8 From here to the terminal, the bedrock is granite, and gravel or soil form only a thin veneer. Most of the boulders are residual and have not moved more than a few feet. The fanlike surface, termed a "rock fan," is cut on granite, not built of alluvium. Fast-moving water, debris-laden, cut the bedrock fan.

0.3

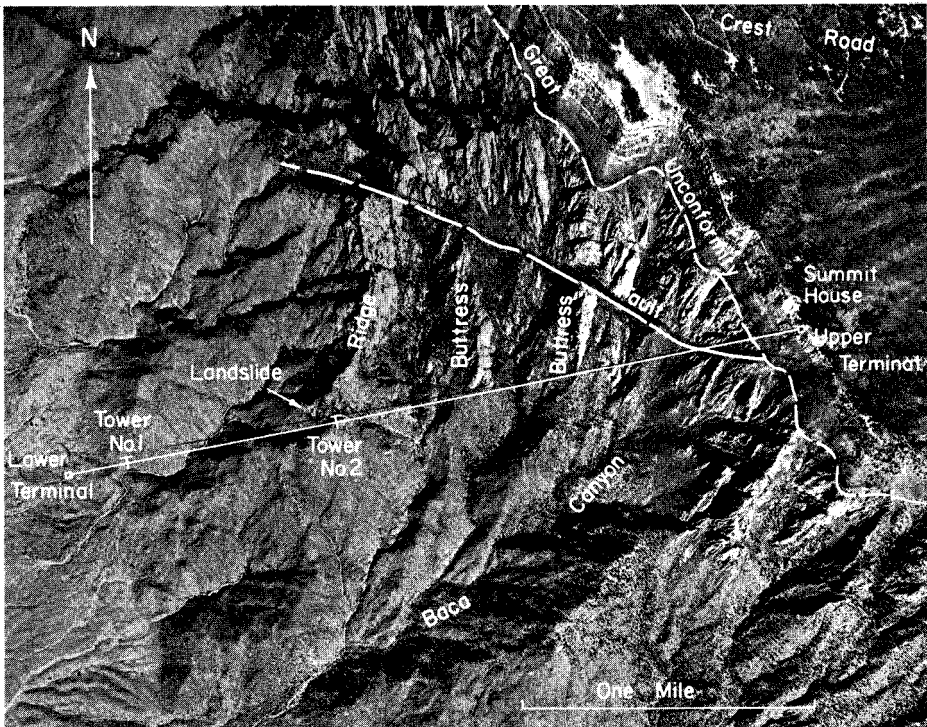
14.1 Sandia Peak riding stables.

0.2

14.3 Tramway toll station (50 cents a year for parking). 0.3

14.6 Parking lot. Visit the museum, natural gardens, and/or the tramway and take the ride to the top of the mountain. The Sandia Peak Museum emphasizes Southwest history, displaying animal-drawn transportation, fire engines, coaches, and a hearse, as well as an unusually good collection of household and other frontier paraphernalia. Some items may be purchased. Admission 25 cents.

Castetter Gardens presents an unusually fine display of cacti plants of this area and the Southwest. Their labels bear both scientific and common names. An easy path with benches in rest areas winds through the giant residual granite boulders, which formed very near their present locations by weathering and rounding of the solid corners of large joint blocks in the bedrock granite. Notice the large, rectangular crystals of feldspar that dominate the rock. The blackish or dark-brown matrix consists largely of biotite mica,



VERTICAL AIR PHOTO OF SANDIA TRAM AREA

with some small grains of magnetite. Quartz shows as the grayish, glassy grains among the feldspar and biotite. Various inclusions of foreign rocks caught up by the original intruding magma appear in the granite, which is Precambrian in age and about 1400 m.y. old.

The tramway ride affords magnificent views of the great granite outcrops that form the precipitous escarpment. Near the top, you can observe the Great Unconformity, where marine limestone rests on the old, bevelled, granite surface. At the top, you may see, stretching far to the south, the mountains that form the eastern rampart of the Rio Grande Valley. Westward, the wide (Ceja) mesa drops down to meet the Rio Grande floodplain. Beyond and farther west lie the great expanses of mesa lands that characterize so much of New Mexico.

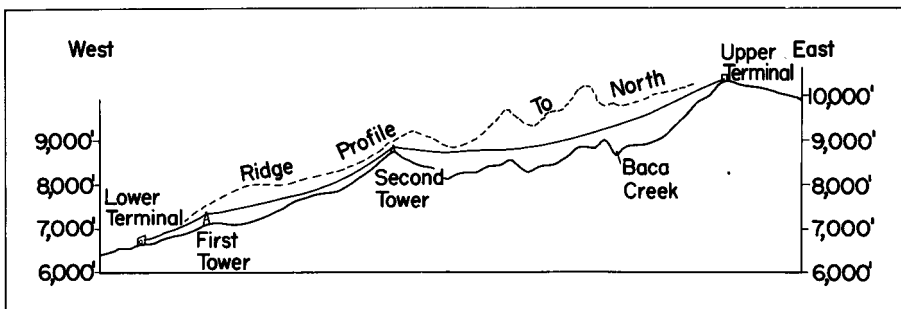
#### LOG OF TRAMWAY RIDE

The thrill and magnificence of the comfortable and easy ride to the top of the mountain are largely due to the sheer granite cliffs and pinnacles that rise close to the tramway. In less than 15 minutes, the car rises from 6539 to 10,378 feet, in a distance of 2.7 miles. During the ascent to the first tower (2 minutes), you get a good look at the hill to the north, armored with great boulders formed by weathering of the sharp edges and corners of large jointed blocks of granite. The residual, spheroidal boulders give way upward to angular blocks and sharp angular outcrops. As you approach the second tower, left of the car near the top of the ridge, a light-colored, smooth, joint surface marks a landslide scar where a lightning bolt knocked down some 4000 tons of rock in 1936.

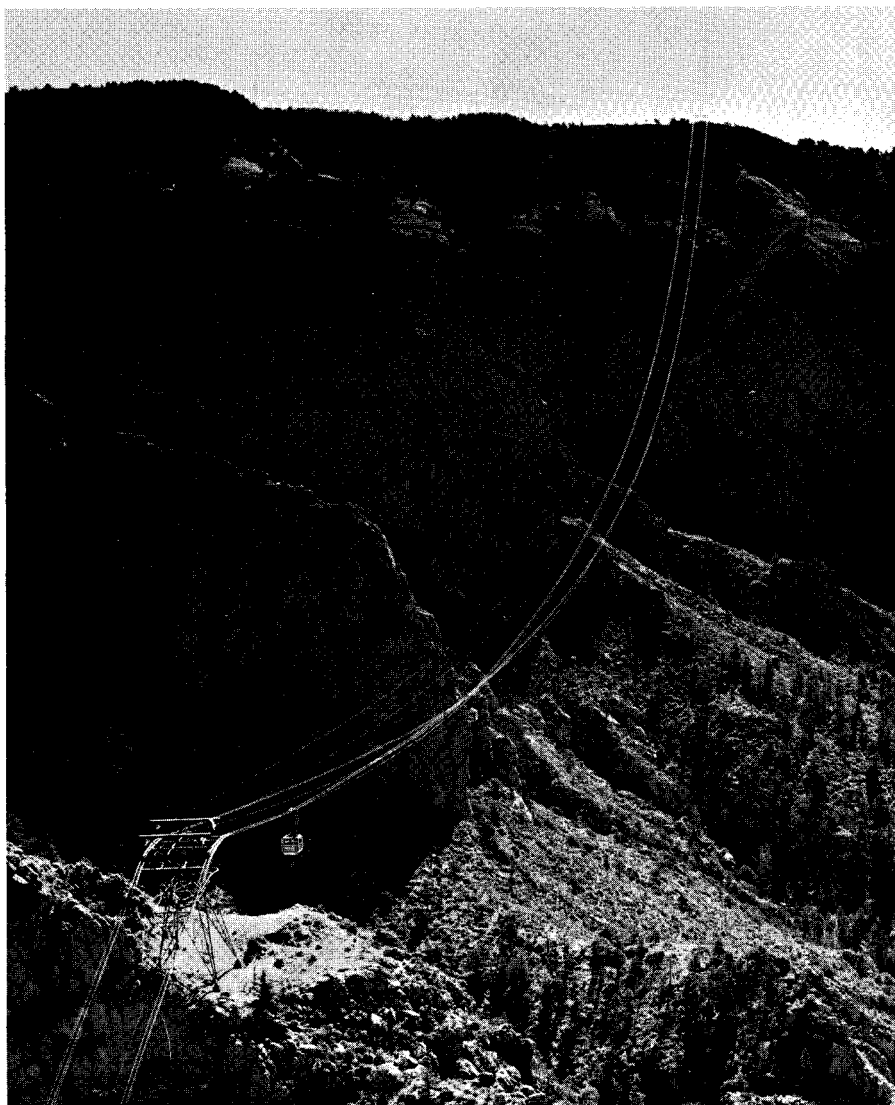
If you look out of the front or back of the car at the suspending cables, you will see orange-colored markers with numbers about a minute apart. There are 11 such markers along the cable-haulage carriers.

The second tower, at 8750 feet, stands on a sharp, precipitous ridge. The cable now levels off as it swings across the Baca Canyon tributaries and ascends to the crest in a single span 7700 feet in length. Over the deepest canyon (about marker 10), it hangs 600 to 700 feet above the ground.

To the southwest, you can see where the narrow mouth of Baca Canyon starts its alluvial fan. The two large canyons forming the mountain re-



SANDIA PEAK TRAMWAY PROFILE



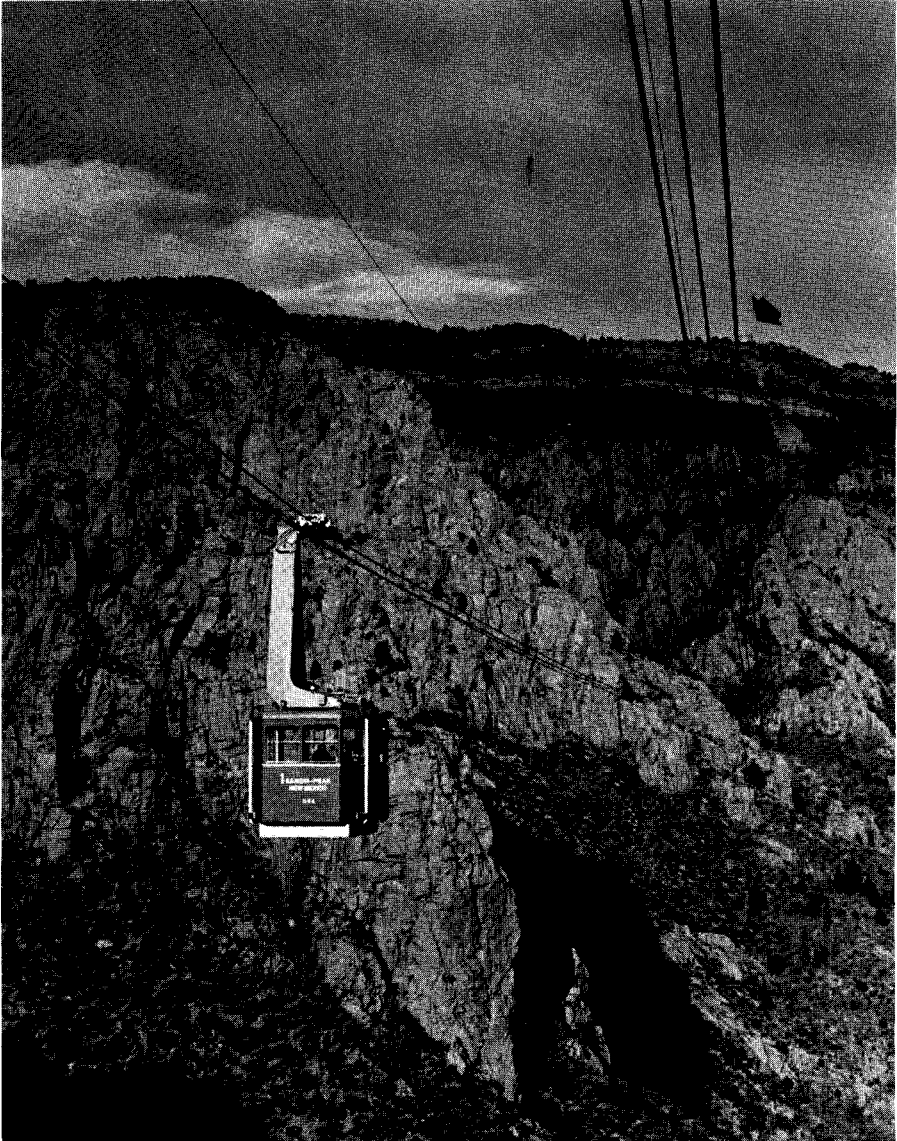
*Photo by Dick Kent*

THE SANDIA PEAK TRAMWAY

The great upper span (7500 feet) as it stretches from the middle tower to the upper terminal.

Notice the two great ridge buttresses facing the span.





*Photo courtesy Robert J.  
Nordhaus, Sandia Peak  
Tramway Company*

VIEW ALONG TRAM CAR RIDE

Toward upper terminal (arrow). Notice the two granite ridge buttresses,  
only 200 to 300  
feet from the cables.

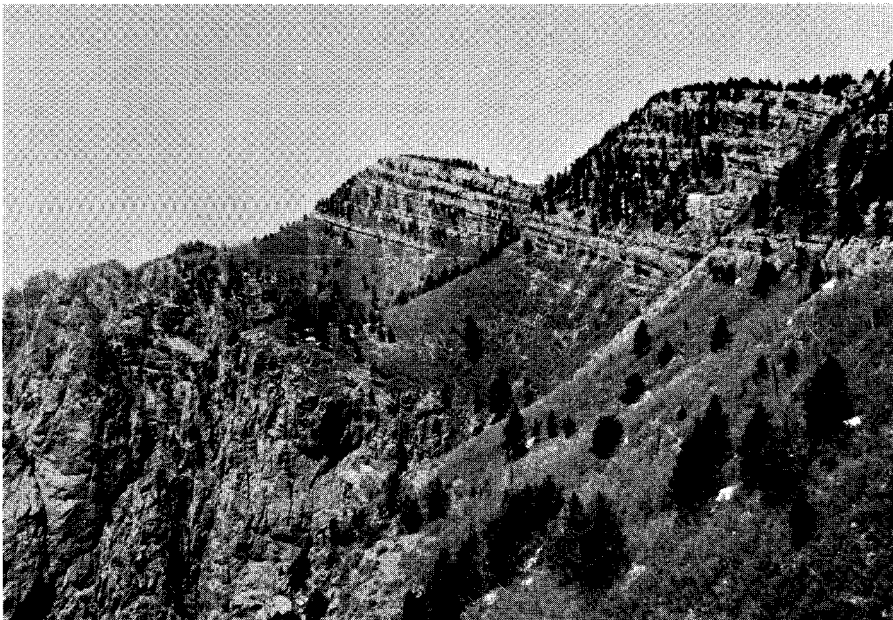
entrant south of this fan are Pino and Bear. North of the car, about midway of the span, you pass two gigantic and imposing granite buttresses, one between markers 7 and 8 and the other at 9. These buttress-like spurs were formed by huge slabs of rock spalling away from great joint fractures. The distance from the car to the first buttress is about 300 feet; to the second, about 200 feet.

Past the second buttress, you rise rapidly toward the crest, and soon the Great Unconformity comes into view. The sharp crags of the granite give way to smooth, brush-covered slopes in the layered sedimentary rocks. More than one billion years elapsed between the time the granite cooled and formed deep in the earth and the time it was exposed, then buried in the sea by sedimentary beds.

If you look out of the north side of the car between markers 10 and 11 and along the base of the cliffs back toward the northwest, you may be able to make out a great fault passing through saddles and gulches across the buttress ridges.

From the top of the mountain, use the accompanying panoramic index to find many prominent features seen from the Summit House.

From the Summit House, which offers refreshments and a "top o' the



THE HIGH, WESTERN CREST OF THE SANDIA MOUNTAINS

From the tramway car. The Great Unconformity is at the top of the granite cliffs. Shale and sandstone underlie the brush-covered slope, with limestone ledges above.



TRAM CAR DOCKING AT THE UPPER TERMINAL

At dusk, looking down onto the alluvial fans at the base of the mountains.  
Lights of  
Albuquerque East Mesa residential area.

mountain" view to visitors, you can walk a short distance to the upper terminal of the Sandia Peak Ski Area chairlift for a ride down the other side of the mountain. The altitude here is 300 feet lower than that at Sandia Crest. After enjoying the view from the tram car on the ride back down the mountain, retrace your route down the hill.

1.2

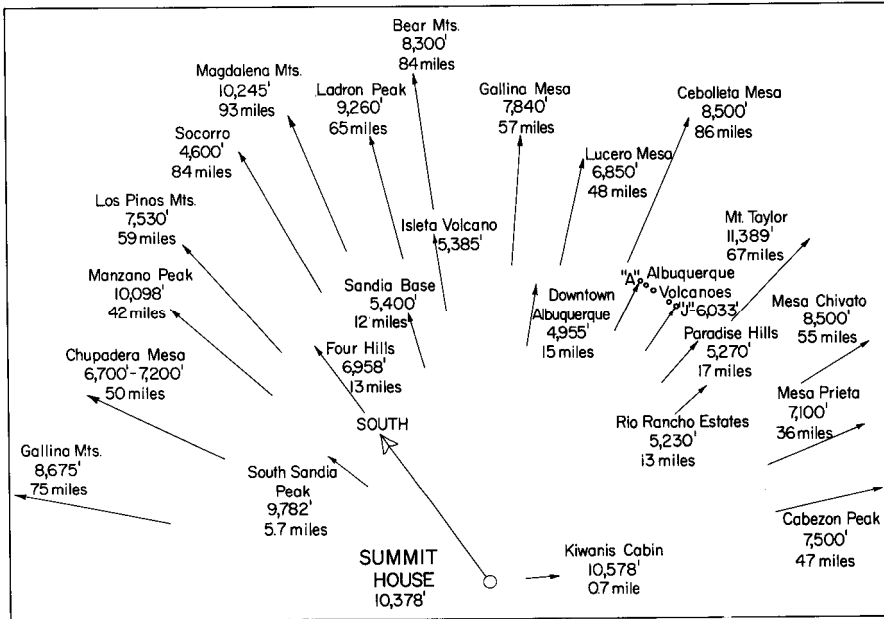
15.8 TURN RIGHT.

0.2

16.0 Bouldery material of alluvial fan in cuts around curve in road.

0.6

16.6 Notice the red and buff outcrops about 300 yards up the arroyo on your right. These Eocene Galisteo Formation sandstone beds are faulted down into this position at the base of the Sandia uplift. The gravelled side road right leads to the Juan Tabo recreation area, established by the U.S. Forest Service more than 30 years ago. Its picnic tables and other facilities have pro-



PANORAMIC INDEX FROM THE SUMMIT HOUSE

vided Albuquerqueans a pleasant spot for relaxation close to, yet away from, the city. A foot trail, La Luz, scales this rugged face of the mountain to Sandia Crest. Continue on paved road. The rocks in Rincon Ridge immediately north of this road and along the Juan Tabo road consist of schist, a metamorphic rock of mica and quartz, highly foliated. The white pegmatite dike crossing the ridge consists of quartz and feldspar.

0.6

17.2 The road descends a long alluvial apron of coalesced fans that reach to the Inner Valley floor. Gullies and small arroyos have eroded these originally smooth fans. The gulleying resulted from later erosion brought about by cutting of the Inner Valley.

Notice the Rio Grande crossing its floodplain diagonally from the east to the west side. It stays on the west side until just south of downtown Albuquerque, where it crosses back to the east. Because a river tends to deposit sediment on a gentle floodplain such as this, it has built its plain higher on the west, giving rise to most of the flooding in Albuquerque's east lowlands.

3.6

20.8 1-25. Follow the signs to return to Albuquerque on the freeway. The road to Alameda (straight ahead) leads to the Rio Grande lowlands.

End of Trip 2.

## Trip 3

### TIJERAS ARROYO AND SUNPORT SURFACE

This trip shows you the outer mesa features of the Heights area and the old and new Tijeras arroyos. It points out the physiographic influences on the Ridge-crest residential district and the Sunport, the relationships of the high east and west mesas, and the nature of the Inner Valley of the Rio Grande. Length: 16.1 miles. Time: 1 hour.

Trip begins at intersection of Carlisle Boulevard and East Central Avenue. The "dip" (Campus Boulevard) angling across Central Avenue just north of this intersection is part of the Old Tijeras Arroyo.

0.0 Drive south on Carlisle. Road ascends south side of Old Tijeras Arroyo and at Coal Avenue tops out on a small spur that extends northwestward from the Sunport surface, although at Coal (0.2), it lies some 60 feet below the surface. Along Carlisle, the slope dips to the west toward the Inner Valley of the Rio Grande.

0.3

0.3 Traffic signal, Highland Avenue. Continue south on Carlisle. Diagonal road to left is Ridgecrest Drive, which runs southeastward high along the southwest side of Old Tijeras Arroyo and about 20 feet below the rim of the Sunport surface. This area was built and developed in the middle 1930's as an exclusive real estate subdivision with a view.

0.5

0.8 Carlisle tops out on the Sunport surface. Burton Park and city reservoir on right. Jog left with Carlisle into the undivided street.

0.2

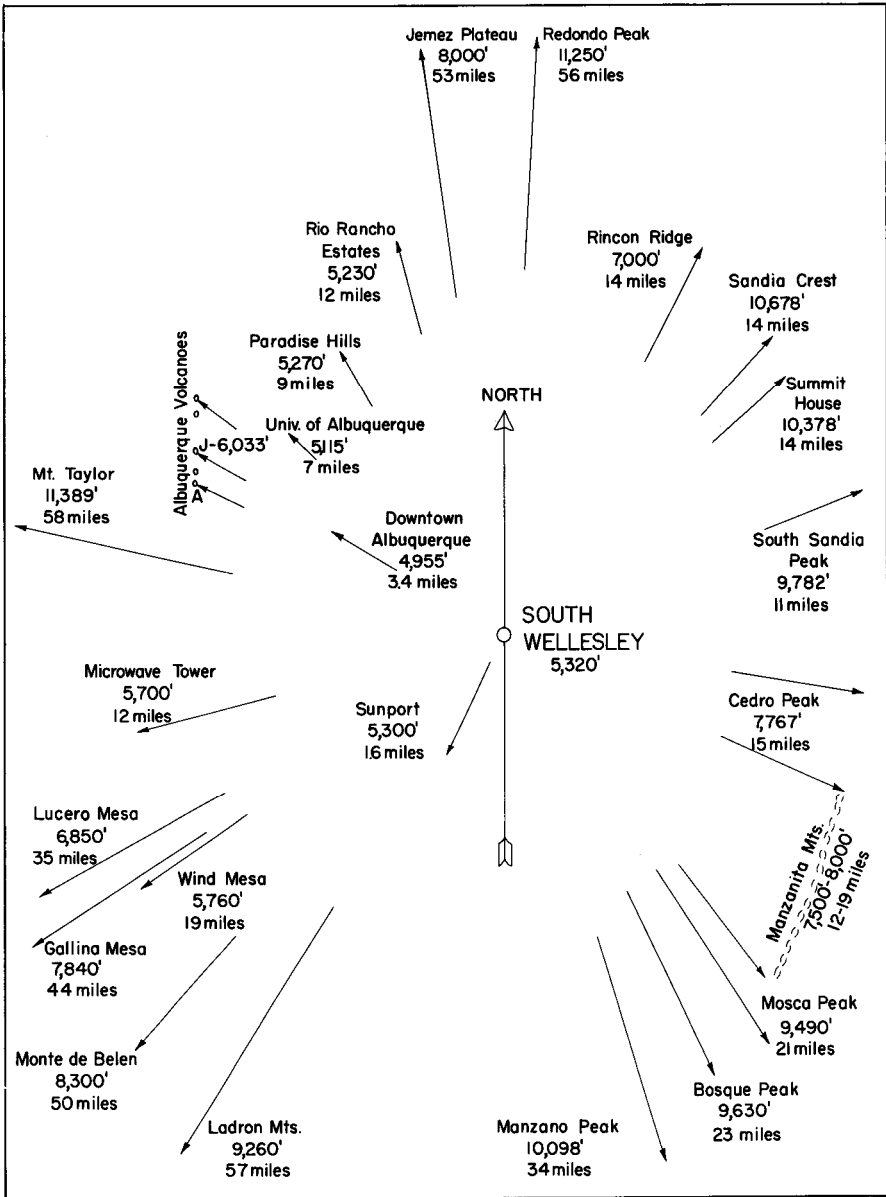
1.0 TURN RIGHT (west) on Kathryn Avenue along south side of park, then TURN LEFT (1.2) (south) on Wellesley Drive.

0.5

1.5 STOP. From here you have an excellent view of the Inner Valley of the Rio Grande. Prior to erosion of this valley, the smooth Sunport surface extended to the far surface of the Ceja Mesa on the western skyline and to the surface beneath the thin lava flow above the "WM" (for West Mesa High School) on the slope of the mesa. You are now nearly 400 feet above the valley bottom due west and 125 feet above Campus Boulevard (Old Tijeras Arroyo) that you noticed from Carlisle and Central. Use the panoramic index to locate many geologic and geographic features.

Continue south.

0.2



PANORAMIC INDEX FROM STOP ON WELLESLEY DRIVE

1.7 STOP SIGN, Gibson Boulevard. TURN LEFT (east). Kirtland Air Force Base, south of Gibson, was established in 1941 to train pilots, bombardiers, and mechanics. In its present function, it is responsible for nuclear and civil engineering research, development, and testing.

0.3

2.0 Traffic signal, Carlisle Boulevard. Entrance to Kirtland base (2.2).

1.0

3.0 Traffic signals, intersection of Gibson and San Mateo boulevards and Ridge-crest Drive. Turn diagonally right onto Ridgecrest Drive, between the U .S. Veterans Hospital on your right and the Bataan Memorial Hospital on your left. The drive follows the side of Old Tijeras Arroyo, which is shallow here. Gibson Boulevard, north of you, runs nearly alongside the broad bottom of Old Tijeras Arroyo, whereas the Veterans hospital sits on the Sunport surface at the arroyo's rim.

You can also see the alluvial fans spread onto the East Mesa from the canyons of the Sandia Mountains, Embudo Canyon a short distance north of the "U" and the great Bear-Pino fan complex at the mountain re-entrant farther north.

0.9

3.9 Ridgecrest Drive ascends the Sunport surface.

0.2

4.1 STOP SIGN, Louisiana Boulevard. Continue straight ahead through the Wherry housing development of Sandia Base. Ridgecrest Drive bears left at 4.3.

0.5

4.6 STOP SIGN, Pennsylvania Street. TURN RIGHT (south). The central administrative and technical sections of Sandia Base lie northeast of here.

Sandia Base is the hub of the atomic energy industry for peacetime uses and weapons applications. The Base houses (1) Department of Defense's Defense Atomic Support Agency (DASA) controlling nuclear stockpiling and nuclear testing (Field Command), (2) Atomic Energy Commission (AEC) Operations Office, and (3) Sandia Corporation, (subsidiary of Western Electric) which is the prime contractor of AEC in nuclear ordnance. Southward from Pennsylvania, the high Manzano Mountains etch the skyline to the southeast. The low range between the higher Sandias and Manzanos is the Manzanita Mountains. The lower ridge immediately to the east is the Four Hills, encompassed by Manzano Base, a nuclear ordnance storage area on Sandia Base and under DASA Field Command.

0.3

4.9 A good panoramic view of the Sunport surface from far to the west at the Sunport east to Tijeras Canyon.

Tijeras Canyon presently runs southwestward from the canyon mouth, and its deep arroyo, eroded in the mesa, lies between you and Four Hills Ridge. Some 50,000 years ago, it ran more directly west and at times along the surface through here, then the apex of an Old Tijeras Canyon alluvial fan. Just before occupying its present channel, the water followed a course 1 to 3 miles to the north where the Old Tijeras Arroyo cut a wide swath toward the University of New Mexico. Its present course is along the south side of the old fan, having switched its position from the north side by jumping its banks close to the apex of the fan, at the mouth of Tijeras Canyon. This probably took place near the site of the Western Skies Hotel during runoff from a large cloudburst. (See page 27.)

0.2

5.1 Ordnance Road intersection. Stay on "Pennsylvania" and curve left.

0.9

6.0 Railroad crossing. Manzano Base is straight ahead at foot of the Four Hills. 0.2

6.2 Descend into Tijeras Arroyo. The arroyo here is 80 feet deep and half a mile wide; farther southwest, it is 200 feet deep and 1.5 to 2 miles wide. Gravel in the roadcuts ahead consists of rocks brought from Tijeras Canyon and from formations east of the Sandias where the canyon heads.

0.2

6.4 Bottom of hill. TURN AROUND and retrace route to Ordnance Road. At 6.7 notice view left down Tijeras Arroyo all the way to the Rio Grande lowlands.

1.2

7.6 TURN LEFT (west) onto Ordnance Road. 0.5

8.1 STOP SIGN, Louisiana Boulevard. TURN LEFT, then RIGHT, crossing the railroad. Road parallels north edge of arroyo and drops into arroyo within a mile.

1.1

9.2 TURN LEFT. Runways on right belong to Kirtland Air Force Base and the Albuquerque Sunport.

0.3

9.5 Broad curve right, continue west.

0.3

9.8 TURN LEFT. Road right leads to Sunport traffic control tower. Winding road next mile.

0.3



10.1 Fork, bear

right.

0.7

10.8 Air National Guard Comptroller facility. TURN LEFT onto dirt road.

Roadcut right contains rounded pumice gravel and mud balls, some of which contain cobbles of hard rock with mud armor. The pumice could have come only from the Jemez Mountains. Thus, the ancient Rio Grande, which flowed southward as today, deposited this gravel, not tributary arroyos from the Sandias. These beds can be traced east more than a mile, indicating that the ancient Rio Grande once flowed southward along a course 4 to 6 miles east of its present course.

0.3

11.1 TURN RIGHT. Side road right, continue straight. City Police Honor Prison Farm across Tijeras Arroyo on left.

0.3

11.4 Railroad crossing. The beds in the hills near the track consist of gravel alternating with clay, mud, and sand and also include numerous rounded, volcanic pebbles derived from far upriver; pebbles of granite and white, green, red, and brown quartz, including some jasper; some fragments of pumice; and a few small pieces of obsidian. Beds similar to these in other places near Albuquerque have yielded petrified wood and bones. The alternation of gravel and mud beds indicates that the ancient river varied from clear and swift to muddy and sluggish, perhaps because of climatic changes.

0.2

11.6 Cross Tijeras

Arroyo. 0.2

11.8 Side road east back to City Police Honor Prison Farm. TURN RIGHT (southwest) down Tijeras Arroyo along paved Los Picaros Road.

0.7

12.5 Side road left, up south rim of arroyo, leads to drag-racing strip. Continue straight ahead on paved road.

0.7

13.2 Road curves right. Gully on right incises the broad valley floor. These gullies result from changes in the volume and composition of the stream, which may be due to changes in climate, vegetative cover, and the like.

14.2 Approaching mouth of Tijeras Arroyo, where it debouches onto the floor of the Inner Valley.

0.2

14.4 STOP SIGN. N. Mex. 361 (South Broadway). TURN RIGHT. The elevation here is 4960 feet; the river bed west of here is 4910 feet. The valley bottom is nearly 2 miles wide.

0.7

16.1 Rio Bravo Boulevard (N. Mex.

500). End of Trip 3.



INTERSECTION OF EMBUDO DRAIN AND EMBUDO ARROYO  
With the North Diversion Channel, seen at Menaul Boulevard bridge over the channel.

## Trip 4

### LOWLANDS AND CONSERVANCY WORKS

This trip explores the floodplain, or lowlands, adjacent to the Rio Grande. Length: 27.8 miles. Time: 2 to 2.5 hours.

The plain is 2 to 2.5 miles wide and quite flat. Although it slopes over-all toward the south, the ground locally slopes noticeably "sideways" from the river banks into adjoining low areas (Yazoos), some of which you will see, as well as levees, floodways, and jetty systems in the river channel. Parts of the trip follow the sides of the Inner Valley for panoramic views, views of river terraces, and a view of the flood-control North Diversion channel. Irrigation canals and drainage ditches, together with gates and water-measuring flumes, are also pointed out.

The trip begins at the intersection of Central Avenue (U.S. 66) and Yale Boulevard. University of New Mexico campus north of Central.

The University of New Mexico was established in 1889 as a normal school in territorial days. It has grown to a large diversified yet integrated university with strong professional and graduate programs which mark it as the leading institution in the State. It is unique because of its distinctive Pueblo, Spanish, and Territorial architectural styles.

0.0 Proceed west on Central

Avenue. 0.1

0.1 Edge of East Mesa. Central Avenue begins descent into the Inner Valley.

Notice the low University of Albuquerque terrace above the river bluffs across the Rio Grande. Ceja Mesa, equivalent to the high Sunport surface 2 miles south, forms the smooth skyline.

Proceed down Central to 1-25. Pass under the freeway, TURN LEFT (south), cross Lead and Coal avenues, following the signs, and enter the freeway.

1.9

2.0 Notice gravel of old river bed to left and right of freeway.

0.3

2.3 Miles Road turnoffs; continue straight ahead.

1.4

3.7 Bridge over railroad spur to Kirtland Air Force Base. Freeway along here crosses the lower east slope of the Inner Valley. Lowlands of the Rio Grande floodplain and the long west slopes to the river from the high Ceja Mesa skyline to your right. The Albuquerque volcanoes interrupt the smooth skyline back toward the northwest, and far to the southwest, across the Rio Grande, you can see the low Isleta and Los Lunas volcanoes (almost on line) and the high, pyramid-shaped Ladron Mountains beyond and just to the right of the Isleta Volcano.

0.4

4.1 University of New Mexico Golf Course left. Clubhouse high on the slope is reached along south Yale Boulevard.

0.6

4.7 EXIT RIGHT onto Rio Bravo Boulevard (N. Mex. 500).

0.5

5.2 Public Service Company power plant on right. Railroad crossing, spur line to Sandia Base 5 miles east.

0.2

5.3 Traffic signal, intersection Rio Bravo (N. Mex. 500) and South Broadway (N. Mex. 361). Stay on Rio Bravo Boulevard. Road descends alluvial apron from the side of the valley to the edge of the floodplain at the San Jose Lateral (drainage ditch, about mileage point 5.6). The valley bottom here is a Yazoo, 15 feet lower than the east levee of the Rio Grande, 1.3 miles ahead, and 5 feet below the river bed where the Rio Bravo Bridge spans the river.

0.6

5.9 San Jose

Drain.

0.1

6.0 Railroad (Santa Fe main line) crossing and traffic signal at Second Street; continue straight ahead. Notice how the railroad bed is built up about 6 feet to be above the potentially floodable Yazoo.

Road rises over the Barr irrigation canal and descends toward the edge of the Rio Grande.

0.3

6.3 Notice the higher ground here, part of the natural levee of the Rio Grande. Radio station KGGM towers on right.

Road ascends an artificial fill and crosses the artificial levees, then the Albuquerque Riverside Drain.

0.5

6.8 Rio Bravo Bridge crosses river. Notice the 1500-foot cleared floodway. Atrisco Riverside Drain lies just across the bridge. This low ditch, dug 6 to 8 feet into the floodplain, prevents seepage from the river from waterlogging or flooding the bottomland west of the levee. Prior to construction of this (Conservancy) ditch in the middle 1930's, the ground west of the river remained swampy.

0.3

7.2 Armijo irrigation ditch, just before the junction with Isleta Boulevard, U.S. 85 (Pan-American Central Highway). TURN RIGHT.



*Photo courtesy U.S. Soil Conservation Service*

VERTICAL AIR VIEW OF THE SOUTH VALLEY TAKEN IN 1935

An old course of the river curves through the cultivated area west of the Rio Grande. It is marked by differences in shades of soil and vegetation, as well as roads, ditches, and cultivated fields, all of which appear to have been influenced by old sloughs or swampy ground. The embayment of the lowlands along the lower left is a still older course. The dark areas in the embayment were swampy Hubbell and Gun Club lakes. Arrow shows direction of the view on page 18. Dots follow route of lowlands trip.

1.8

9.0 KEEP LEFT for left turn onto Arenal Road and almost immediately jog right (north) onto Goff Boulevard. The village of Armijo surrounds this junction. Bear left to remain on Goff Boulevard at junction with Sunset Road.

0.8

9.8 Intersection, TURN LEFT onto Bridge Boulevard.

0.1

9.9 Arenal irrigation ditch.

0.4

10.3 Atrisco irrigation ditch.

0.1

10.4 Isleta Drain. Traffic signal at Atrisco Drive; stay on Bridge Boulevard.

0.3

10.7 West edge of floodplain and main Arenal Canal. Road goes up the slope to a low river terrace at Coors Boulevard, where you come to a STOP SIGN. TURN RIGHT (10.9), north. Coors is a fairly recent state highway, having been built in 1945.

0.8

11.5 This low river terrace (Lavaland) that Coors Boulevard follows rises 50 feet above the Rio Grande. View to right looks across the lowlands, flood-plain, and downtown Albuquerque to the East Mesa east of the Inner Valley and the backdrop of the Sandia-Manzanita-Manzano mountains on the skyline.

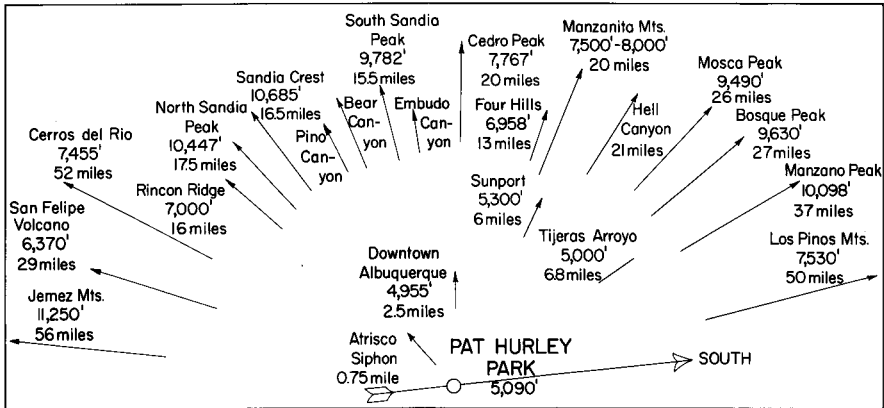
0.5

12.0 KEEP LEFT for LEFT TURN onto west Central Avenue (U.S. 66) and almost immediate RIGHT TURN at traffic signal onto Yucca Drive.

0.3

12.3 Road climbs onto the University of Albuquerque terrace and comes to Pat Hurley Park. Continue past the first park sign and follow the one-way arrows just beyond the "Dip" sign to parking place (12.6). Use the panoramic index to locate features of the view from here.

Nearby baseball grounds and tennis courts are on the floodplain at the base of bluff, cut when the Rio Grande swung in a meander against its western bank. The Atrisco Ditch lies beyond the baseball grounds. This ditch gets its water from the *east* side of the Rio Grande by means of a siphon that crosses beneath the river (on a line with the high crest of the Sandias). You can see the culvert where the ditch enters the siphon through the levee on the east side of the river.



PANORAMIC INDEX FROM PAT HURLEY PARK

Notice the broad sweep of the alluvial fans from canyons in the Sandias. Exit from park (follow one-way route) and TURN RIGHT (north) on Yucca Drive.

0.8

- 13.1 Bear right onto Palisades Drive and TURN RIGHT again onto Vista Grande Drive; follow along the edge of the mesa to junction with Atrisco Drive.

0.4

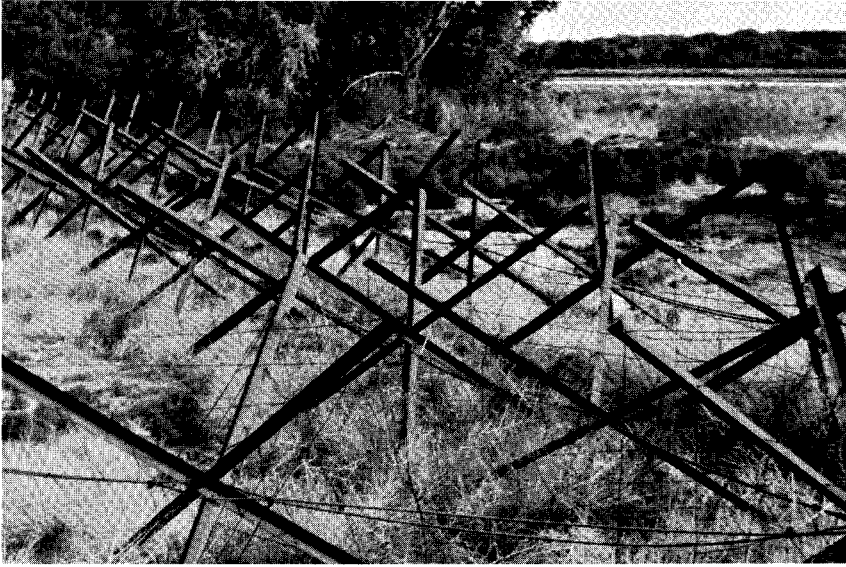
- 13.5 Make SHARP TURN RIGHT (southeast) and take Atrisco back down hill. STOP SIGN. Houses hereabouts are built on sand dunes deposited in the lee of the bluffs by the prevailing westerly winds. Notice the Rio Grande bed and the Old Town Bridge crossed by U.S. 66.

0.4

- 13.9 Bear left for turn across divided road at Arenal Ditch. Park near pump house east of road and walk across the ditches past the pump house to the levee where the Atrisco siphon appears from beneath the river.

The top of the levee here is about 10 feet above the river. Notice the jack field in the river bottom and how the jacks are laced with wire and cable. Designed to confine, or channelize, the flow of the river, they serve to keep a swollen, flooding river from directing its force against the levee and possibly washing it out. Engineers also hope that the jacks, together with the trees, will hold the mud and sand deposited by the river during overflow, thereby preventing the river from silting up the inner channel or floodway so quickly.

The siphon pipe, 6 feet in diameter and 1400 feet long, lies 20 feet beneath the river bed. Three ditches converge at the pump station: the main Arenal



JETTY JACKS ALONG THE RIVER AT WEST END OF OLD TOWN BRIDGE

Canal lies under the road; the Armijo Ditch parallels the river southward just east of the pump; and the Arenal Ditch is the small, high one fed by the pumps.

Proceed southward on divided Atrisco Drive.

0.7

14.6 U.S. 66. TURN LEFT (east) at traffic signal and LEFT again into the Hedges gas station (just before the bridge) and park in the lots to the rear. Walk back toward the Old Town Bridge for a look at the levee and protecting jack field in the river bed. Notice the old slough (drain) next to the levee; formerly, this was the west Riverside Drain. North of the vacant lot behind the station, you may look up the Armijo Ditch toward the pump house you just left. Walk down to the footbridge over the ditch. The bridge crosses a gate used to regulate the flow of water down the Armijo Ditch; just above the gate, a side gate through a pipe opens into the smaller Atrisco Ditch that crosses beneath U.S. 66 just west of the Hedges station. About 100 feet from the bridge along either ditch are Parshall flumes, devices for measuring and recording the volume of water flowing into the ditches. The larger one, on the Armijo Ditch, has a flat-bottomed channel tapered downstream. Near the bottom on the side of the recorder, a small hole allows water to enter the float cylinder wherein the water lifts the float to the height of its level in the flume. A foot-scale on the side of the flume opposite





*Photo courtesy Bureau of Reclamation*

LAYING THE ATRISCO SIPHON BENEATH THE RIVER BED

Photo taken March 22, 1956. The 6.5-foot pipe is as deep as 32 feet. Beds in the trench are all sand or small gravel. During a very large peak flow, deepening of the channel by the river could reach the siphon. View toward east bank.

the recording device serves to calibrate the graph on the recording drum in the box above the float housing.

Return to U.S. 66 and TURN LEFT (toward downtown area) across Old Town Bridge.

1.2

15.8 Traffic signal at Rio Grande Boulevard (N. Mex. 194) and U.S. 66 (Central Avenue). TURN LEFT onto Rio Grande. Old Town Albuquerque is just east of here. Established in 1706 and made "old" when the center of town moved to the Santa Fe Railroad in 1879, it continued to exist and later revived as a nostalgic reminder of the past—Mexican in flavor with shopping and tourist attractions. The Plaza provides the setting for concerts, dancing, and art shows on occasion.

0.2

- 16.0 Traffic signal, Mountain Road. Stay on Rio Grande to Candelaria Road. 1.9
- 17.9 TURN RIGHT onto Candelaria Road (east), almost immediately crossing the Campbell irrigation ditch (high) and the Griegos Drain (low).  
0.8
- 18.7 Traffic signals at Fifteenth Street (near the Griegos Lateral irrigation ditch and at Twelfth Street. (Stay on Candelaria).  
0.9
- 19.6 Traffic signal, Fourth Street. This Yazoo area, from here to Edith Boulevard and north to Griegos Road (about half a mile) and south along Second Street and the railroad to Marquette Avenue (2.2 miles), has seen some of Albuquerque's most severe flooding. Cross the Alameda Drain just this side of Second Street.  
0.2
- 19.8 Traffic signal, Second Street. Keep straight ahead, crossing the railroad tracks of the Santa Fe main line. The railroad raised its tracks in this manner in 1936, at the time of the building of the downtown underpasses at Central and at Tijeras avenues, to avoid high water.  
0.2
- 20.2 Traffic signal, Edith Boulevard (N. Mex. 98). TURN LEFT. You cross the Alameda Lateral at Carmony Road and then, in succession, the Hahn Arroyo, the winding Alameda Lateral (again), Muscatel Avenue (21.9) (on right only; Gallegos Ditch off to your left), and Vineyard Arroyo (22.9).  
2.4
- 22.6 STOP SIGN, Osuna Road. TURN RIGHT.  
0.6
- 23.2 Gravel pit on right is in the Edith gravel beds. They are extensive at about this level all along the east slope of the Inner Valley.  
0.3
- 23.5 Bear Arroyo to left of road. This arroyo formerly received heavy floods from the large Bear Canyon area in the Sandias. Now, the North Diversion Channel intercepts it near where the channel passes beneath Osuna Road.

TURN LEFT just before reaching the bridge. Park to see the Bear Arroyo entry into the North Diversion Channel. Reinforced concrete 8 to 10 inches thick lines the trapezoidal ditch, which is 23 feet deep with sides sloping 1:2. It is 9 miles long from its beginning near Lomas and Campus boulevards to its outlet into the Rio Grande near Alameda. Along its course, it intercepts Campus, Embudo, Bear, Pino, Baca, and numerous smaller arroyos.

The channel has a maximum discharge capacity at its outlet of 44,000 cubic feet a second.

Follow the road along the west side of the channel.

0.7

24.2 Walk over to see the Pino Arroyo junction with the channel.

0.5

24.7 Entry of an unnamed arroyo across the ditch.

0.1

24.8 Reeves Public Service Company power plant on right and sand and gravel pit on left.

0.2

25.0 Power line and railroad spur to the American Gypsum Plant (red, white, and blue) east of the power plant. The gypsum used in this plant comes from



*Photo courtesy U.S. Corps of Engineers*

#### SOUTH UP THE NORTH DIVERSION CHANNEL

At the Pino Arroyo inlet during the finishing stage of construction, January 1968.

the Todilto Formation of Jurassic age (170 m.y.) in beds near San Ysidro, some 60 miles northwest. Trucks bring it to the plant.

0.1

25.1 Road crosses channel, but TURN LEFT onto El

Pueblo Road. 0.2

25.3 Notice gravel beds to right, which extend all the way to Albuquerque and provide most of the commercial gravel used in the Albuquerque area. The ancient Rio Grande deposited this gravel long before the modern Rio Grande cut the present Inner Valley.

0.2

25.5 STOP SIGN, Edith Boulevard (now N. Mex. 425). TURN RIGHT. Park off Edith (25.8) to examine the sand and gravel. The lower 25 feet of the bluff are sand and pebble gravel consisting largely of pumice, with some pumice cobbles. Notice their light weight. The top of the bluff contains cobble gravel consisting of rounded quartzite and hard, dense, volcanic fragments brought from far to the north. The pumice was showered and washed into the ancient Rio Grande and its Jemez Creek tributary and then carried to this locality.

0.4

26.2 Notice the Alameda Lateral on the left and the picturesque church (Nativity of the Blessed Virgin Mary) across the river plain at Alameda.

A side road right leads to the Nazareth Psychiatric Hospital. An arroyo passes beneath Edith here, but the diversion ditch whose embankment lies east of the telephone line has also intercepted its flow. A side trip (0.4 mile loop) up the hospital road affords another good view of the channel.

0.6

26.8 STOP SIGN, junction with Alameda Road (N. Mex. 296) which leads to the suburb of Alameda. Continue north on Edith (unpaved), which parallels the floodplain for many miles.

0.7

27.5 Notice the Santa Fe tracks a short distance to the left and the elevation of the railroad bed above the floodplain.

La Cueva Arroyo comes in from right; its flow is intercepted by the channel, which is below the surface and out of sight, but you may drive or walk just 100 yards up the arroyo to see it.

0.2

27.7 Bridge over the channel. Cross it and park for a good view of the channel as it makes its curving entry onto the floodplain. In time, the channel will

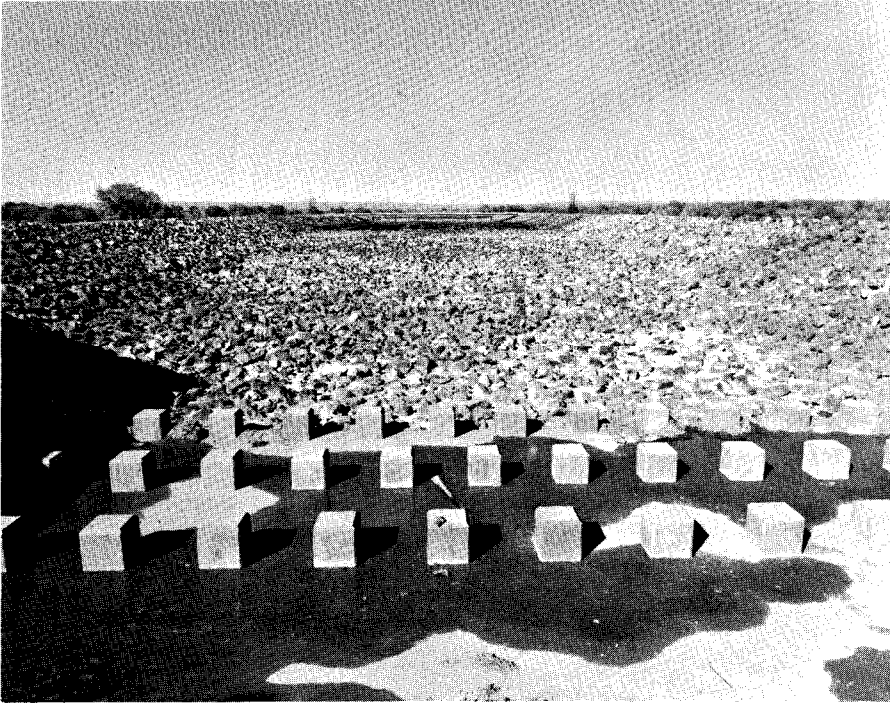


Photo courtesy U.S. Corps of Engineers

RIPRAP-LINED OUTLET OF THE NORTH DIVERSION CHANNEL

Looking from the Santa Fe bridge to U.S. 85 highway bridge.

fill up here, even with the riprap west of the railroad tracks. This diversion ditch will keep downtown Albuquerque, particularly the north Second to north Fourth streets area, from being flooded by torrential runoff from the East Mesa and the Sandias.

Notice that the concrete-lined channel empties into a widened riprap-lined channel on the floodplain, so designed to slacken the flow. The water course passes under the railroad and U.S. 85 bridges before flowing into the Rio Grande about a half mile to the northwest.

Turn around and retrace route to the paved roads at Alameda Road and Edith Boulevard for return routes to town. Alternately, you may drive up the side road to the right just beyond the bridge, through the Alameda sand and gravel pits and north to Tramway Road, returning to Albuquerque by 1-25.

End of Trip 4.

## Trip 5

### ALBUQUERQUE VOLCANOES

This trip takes you to see one of the several small volcanoes that form Albuquerque's western skyline. Length: 15.1 miles. Time: 1.5 to 2 hours. In the past, all the volcanoes were fairly accessible by dirt roads, but in recent years, the fencing of private property and locking of gates makes the volcanoes more difficult to reach. However, there is probably little objection to one's hiking to the cones from nearby fences. The trip leads west on Central Avenue (U.S. 66) up Nine Mile Hill to Ceja Mesa, a distance of 4.6 miles west of North Coors Boulevard, to the projected junction of I-40 and U.S. 66.



*Photo by Linbaugh Engineering*

#### LOOKING ACROSS LOWLANDS TO THE ALBUQUERQUE VOLCANOES

After flooding in August 1963 following an East Mesa storm. Water stands in the Yazoo area between the Alameda drain and Candelaria Road along north Second Street.

A dirt road runs northward over the rolling Ceja surface 4.5 miles to the north boundary of the old Atrisco Grant and thence east along the fence to the southernmost of the volcanoes.

Eruption of lava has occurred on a north-south line of deep fractures for 4.5 miles. Eighteen points of eruption can be detected along this line. Five of these eruptions grew to small cones easily observed from Albuquerque along the west skyline.

The southern volcano is in many respects the most interesting of all. It has a small, steep, scoriaceous cone surmounting a larger one that forms a shouldered base. It appears that during eruption of the lower part, swelling, or *tumescence*, caused cracks of expansion to radiate on the flanks. At this time, the domed lava was fiery hot, with the cracks glowing red, especially at night. Its vent gave forth bits and blobs of rough, bubbly lava known as spatter, which built much of the top cone. Even while this was going on, lava from the inside leaked out through the radial cracks, mostly in the lower swelling part, but also in places from the upper steep cone. The leaks formed radial dikes and perhaps locally short "dribbles" of lava on the slopes.

From the end of the road, you may walk through the fence and see the narrow, locally branching dikes and dribble flows. On the high cone, notice the scoriaceous spatter and dikes and toes of lava that broke through the sides.

A small crater lies on the top, but late lava flows over-welled or broke away the east rim of the crater and flowed down the flank, particularly in the area where the "JA" has been painted on the ground.

Trip begins at the intersection of West Central Avenue and North Coors Boulevard, 1.9 miles west of the bridge over the Rio Grande.

0.0 Follow U.S. 66 west; notice descent of road westward at 0.3 into broad valley that had eroded from the south into the terrace.

1.3

1.6 Dirt road right leads to West Mesa Reservoir and well No. 1.

0.2

1.8 Ninety-eighth Street south leads to Snow subdivision. Notice municipal Franciscan Reservoir on the slope to the west.

Continue west up Nine Mile Hill, named from its distance west of downtown Albuquerque. Albuquerque volcanoes and flows plainly visible to the north.

0.9

2.7 Don Reservoir and city Don well No. 1 on left. The reservoir has a capacity of 4,030,000 gallons. The well reaches a depth of 1440 feet, and the static water level in the well is at 430 feet.

1.1

3.8 White caliche capping on Ceja Mesa visible to the north.

0.3

4.1 Top of Nine Mile Hill (and top of Ceja Mesa.) Continue straight ahead.

0.2

4.3 Power line.

0.3

4.6 TURN RIGHT on dirt road and go straight ahead; fork to right leads to borrow pits, where there are good exposures of caliche beds that formed on the Ceja Mesa surface. Caliche is a chalky white precipitate of calcium carbonate formed by long weathering of a surface under arid or semiarid conditions. Moisture from rain or snow entering a soil dissolves the calcium and carries it downward, where it cements or replaces the soil. Deposition of the caliche is generally caused by drying out of the soil.

0.1

4.7 Follow right fork to north. Assorted gravel on road ahead is primarily black chert.

0.6

5.3 Top of old sand dune on Ceja surface.

0.1

5.4 Fork; go straight ahead.

1.1

6.5 Power line; continue straight ahead. Sand dunes on left horizon lie along the western edge of Ceja Mesa. They are piled where strong westerly winds rise up the slope to the top of the mesa.

2.7

9.2 TURN RIGHT along fence; north boundary of the Town of Atrisco Grant.

1.0

10.2 Side road leads southeast; continue straight ahead.

0.5

10.7 Western eroded edge of lava flow along gully to left. Road curves right and descends into arroyo at 10.8. Follow road down arroyo along the edge of the flow. There was no arroyo here at the time the lava flowed; the arroyo has been eroded since. The blocks of lava (basalt) on the side of the arroyo have slumped or tumbled down the slopes. At 11.2, notice columnar joint block clusters with rounded, swollen, heads on each column. These were caused by leavening as gas escaped.

0.7

11.4 Road crosses arroyo and ascends onto the low end of flow. In a tenth of a mile, make a sharp turn right and then left toward volcano. The lava



shoulders around the volcanic peak are short flows piled on the earlier lava flow on which the road runs.

0.3

11.7 Intersection; continue to base of volcano. 0.1

11.8 Park and walk to the volcano. Look for the radial dikes just inside the fence and west of the old road. Climb the south side of the high cone and see the scoria spatter with a radial dike forming a rib with small knobs. Observe the crater, its rim, and the breakout of lava through the rim and down the east slope.

The volcano to the north has a small crater but lacks the radial dikes. Between the second and third (J) volcanoes are small quarries where scoria and cinder have been mined for block manufacture. The walk to these requires about 1.5 miles, round trip.

Turn around and follow road back to south.



*Photo by Koogle and Pouls*

**AJ CONE, ALBUQUERQUE VOLCANOES**

Small, steep-sided cinder cone stands on a broader flow dome. Small dikes have broken through the sides of the cone. Radiating black lines (f) are dikes and short flows that broke through the dome as it swelled.

0.1

11.9 Side road straight ahead. This road is rough but leads around the east side of the volcanoes to Volcano Cliffs addition.

0.1

12.0 Fork; straight ahead to left. Right fork is the route you followed coming to the volcanoes. Either route leads back to Albuquerque but the log continues on the left fork.

0.2

12.2 Road descends edge of flow. In a tenth of a mile, take left fork detour across gully.

0.5

12.7 Intersection; route curves east. Good view of volcano back to left. Albuquerque and lowlands of Inner Valley. Road ahead lies on gravel washed from the mesa to the west; here, this recent alluvial outwash covers the edge of the lava flow.



*Photo by Gordon A. Macdonald*

LAVA MOUNTAINS ALONG A "CURTAIN OF FIRE"

Puna, near Kilauea on the "Big Island" of Hawaii during 1955. Lava in the foreground flowed from the fissure or "rained" from the fountains. The Albuquerque volcanoes may have resembled this view.

0.5

13.2 Turn right for descent into arroyo, and as you cross it, notice how the edge of the lava flow is covered by gravel several feet thick. Lava flow is 4 to 10 feet thick along here.

0.4

13.6 Road crosses arroyo and tips around side of hill. CAREFUL! Gate ahead.

0.2

13.8 Notice large talus blocks of lava that have slid down the side of the mesa from the thin, capping flow. The sand and gravel beneath the flow comprise the Santa Fe Formation, deposited probably 1 or 2 m.y. ago. The lava flow is probably 500,000 to 1,000,000 years old, and the gravel capping the lava back up the arroyo is probably 20,000 to 50,000 years old. Follow road down arroyo. Hills alongside are Santa Fe Formation.

0.7

14.5 Power line road. Go straight ahead.

0.2

14.7 Power line and crossroad. Stay straight ahead.

0.4

15.1 Arroyo and power line. Follow road to U.S. 66 (or 1-40, when completed).

End of Trip 5.