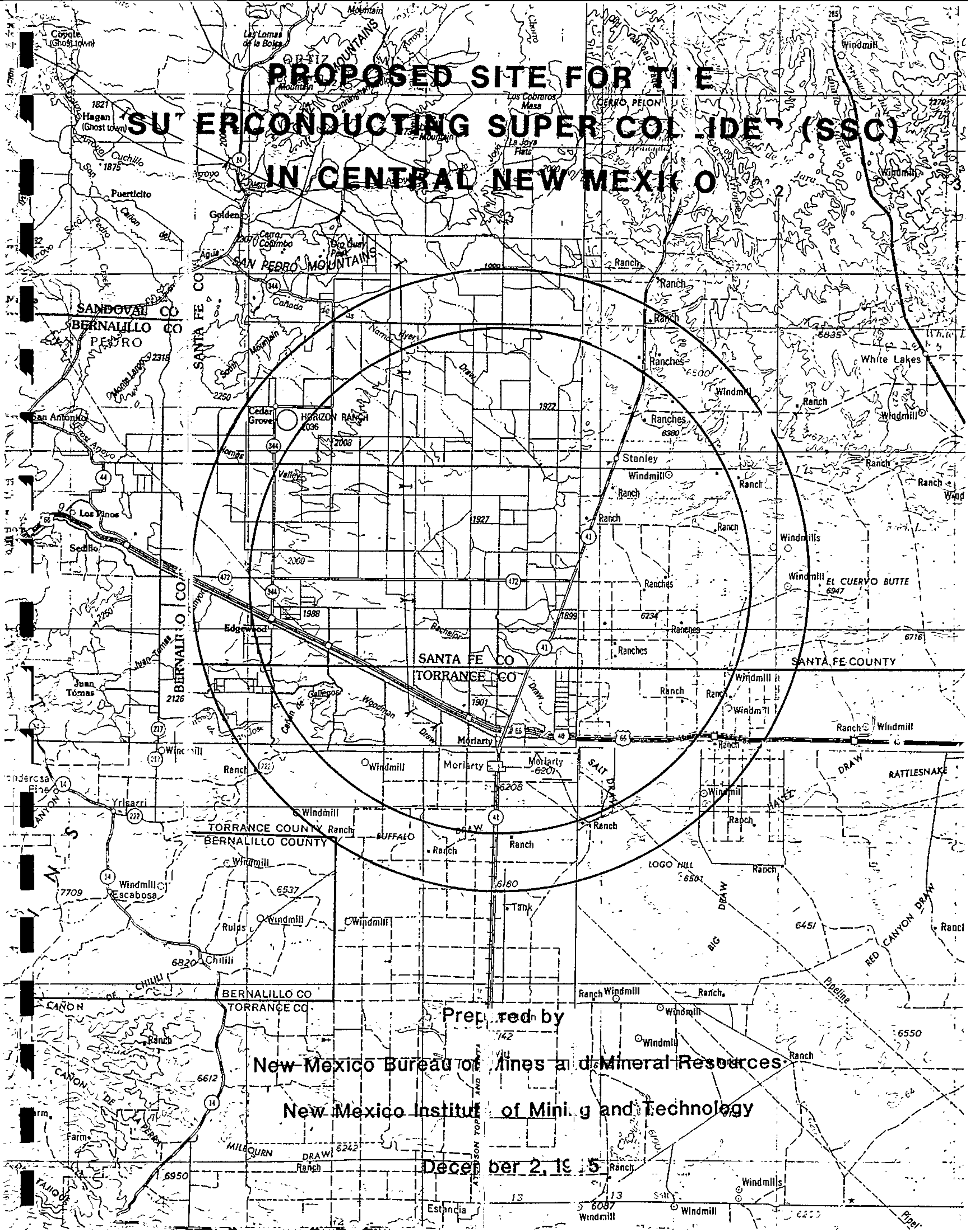
PROPOSED SITE FOR THE SUPERCONDUCTING SUPER COLLIDER (SSC) IN CENTRAL NEW MEXICO



Prepared by

New Mexico Bureau of Mines and Mineral Resources

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December 2, 19 5

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INTRODUCTION

The northern part of the Estancia Valley, some 15 to 30 miles due east of Albuquerque (fig. 1), is the proposed site for the Superconducting Super Collider (SSC) in central New Mexico. The valley is a closed topographic depression having no external drainage. Water enters upland recharge areas on the valley margin and generally flows toward lower discharge points associated with playas in the southeastern part of the valley.

The center of the proposed site is 6 mi north of Moriarty and 3 mi north of the Santa Fe-Torrance County Line at the intersection of sections 13, 14, 23, and 24, T8E, R10N. Two rings, one with a radius of 9 mi and the other with a radius of 11 mi, were drawn surrounding this location (fig. 1). The ring, with an 18 mi inside diameter and a 22 mi outside diameter, allows location flexibility in evaluating the proposed SSC site with its 20-mile (or less) diameter. A preliminary sketch by the SSC Central Design Group (revision 1 dated 11/21/85) shows an ellipsoid with a minimum radius of 12.52 km (7.78 mi) and a maximum dimension of 31.64 km (19.66 mi) in its longest direction. The circumference of this configuration is about 55.3 mi and this figure would fit easily within the proposed site (fig. 1).

The lowest elevation within the ring is 1875 m (6150 ft) and found in the southeastern part of the proposed site. The highest points are in the southwest and northwest portions of the ring and are about 370 m (1190 ft) above the lowest point. A slight tilt of the plane of an SSC surface around the low point and upward to the northwest (striking N 28° E, dipping

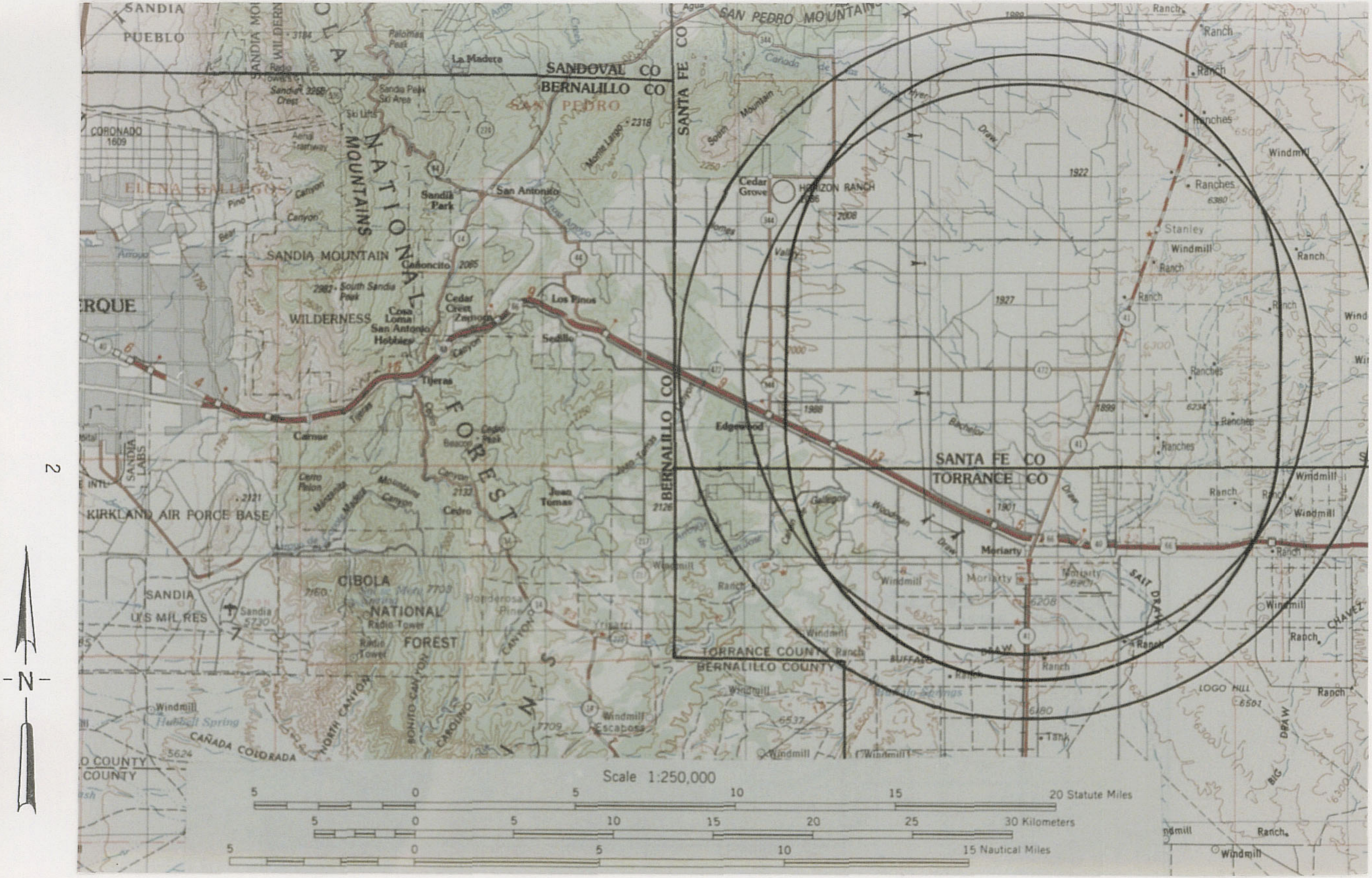


Figure 1. Topographic map of Albuquerque and northern Estancia Basin with proposed SSC site. Ring diameters are 18 mi inside and 22 mi outside. The ellipse-like form within the ring is the possible shape of the SSC as of November 21, 1985. It has maximum and minimum diameters of 19.66 and 15.6 mi respectively.

0.32° SE) could raise the SSC so no point would be more than 215 m (700 ft) below the surface. If the north-south oriented ellipsoidal shape is selected for the Super Collider, the plane of a surface dipping slightly to the south would be no more than 91 m (300 ft) below the surface (fig. 2). Once the size and shape is finalized, linear regression can be used to optimize tilt to a minimum depth.

The Estancia Valley has a deficit water budget of 1220 mm (48 inches) annually (Bachhuber, 1982). Several hundred feet of sand, gravel and clay were deposited in the valley in a Quaternary lake that existed up to 10,000 years ago. The gently undulating surface is now used principally for ranching and farming (fig. 3). The ownership is dominantly private with some state and minor federal lands (fig. 4).

Four small communities are located within the proposed SSC site, Moriarty in the south, Edgewood in the west-southwest, Stanley in the northeast, and Cedar Grove in the northwest (fig. 1). All are easily avoided by proper placement of the SSC within the area.

The proposed Superconducting Super Collider site is within a short distance from Albuquerque International Airport and interstate highways (fig. 1). The airport is serviced by six major carriers: American, Delta, Eastern, TWA, United and Western airlines, plus Frontier, Continental, Southwest, America West, and several commuter lines.

Sandia National Laboratories is in Albuquerque as is the University of New Mexico. Both are sources of expertise and research facilities. Los

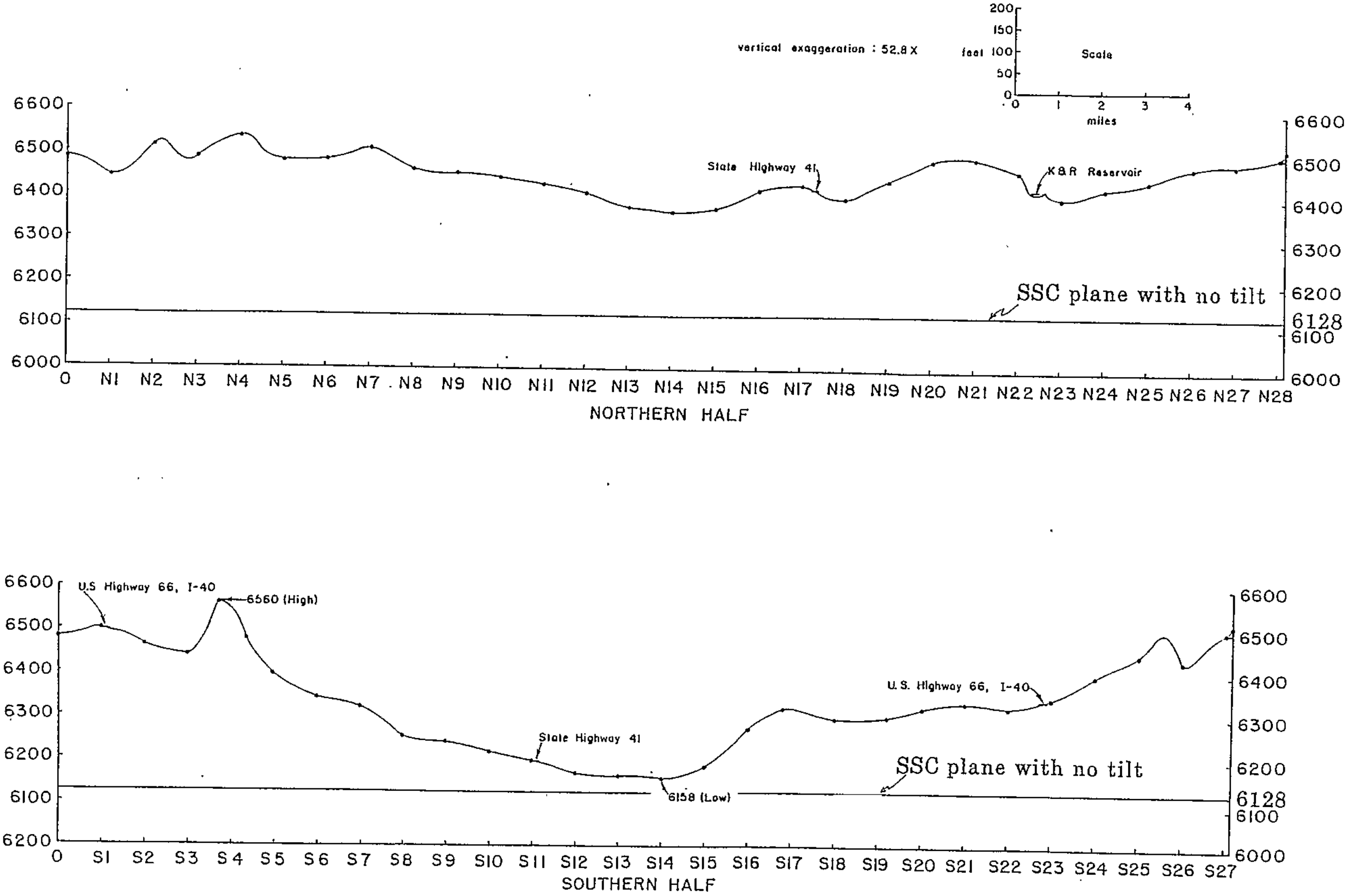


Figure 2. Perimeter profile of north-south ellipsoid in Estancia Valley.

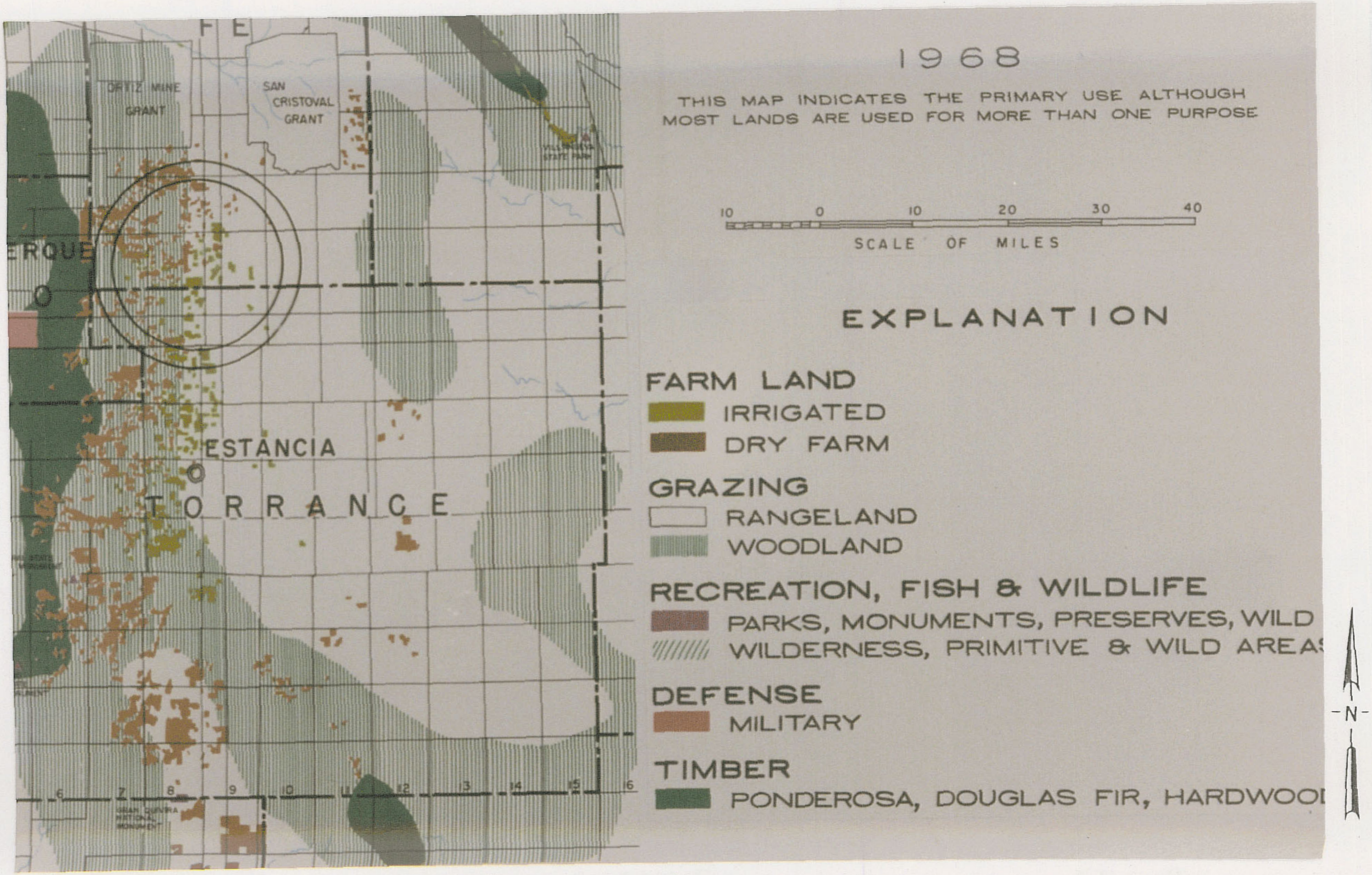


Figure 3. Land use map of proposed site (after State Engineer and Interstate Stream Commission of New Mexico, 1968).

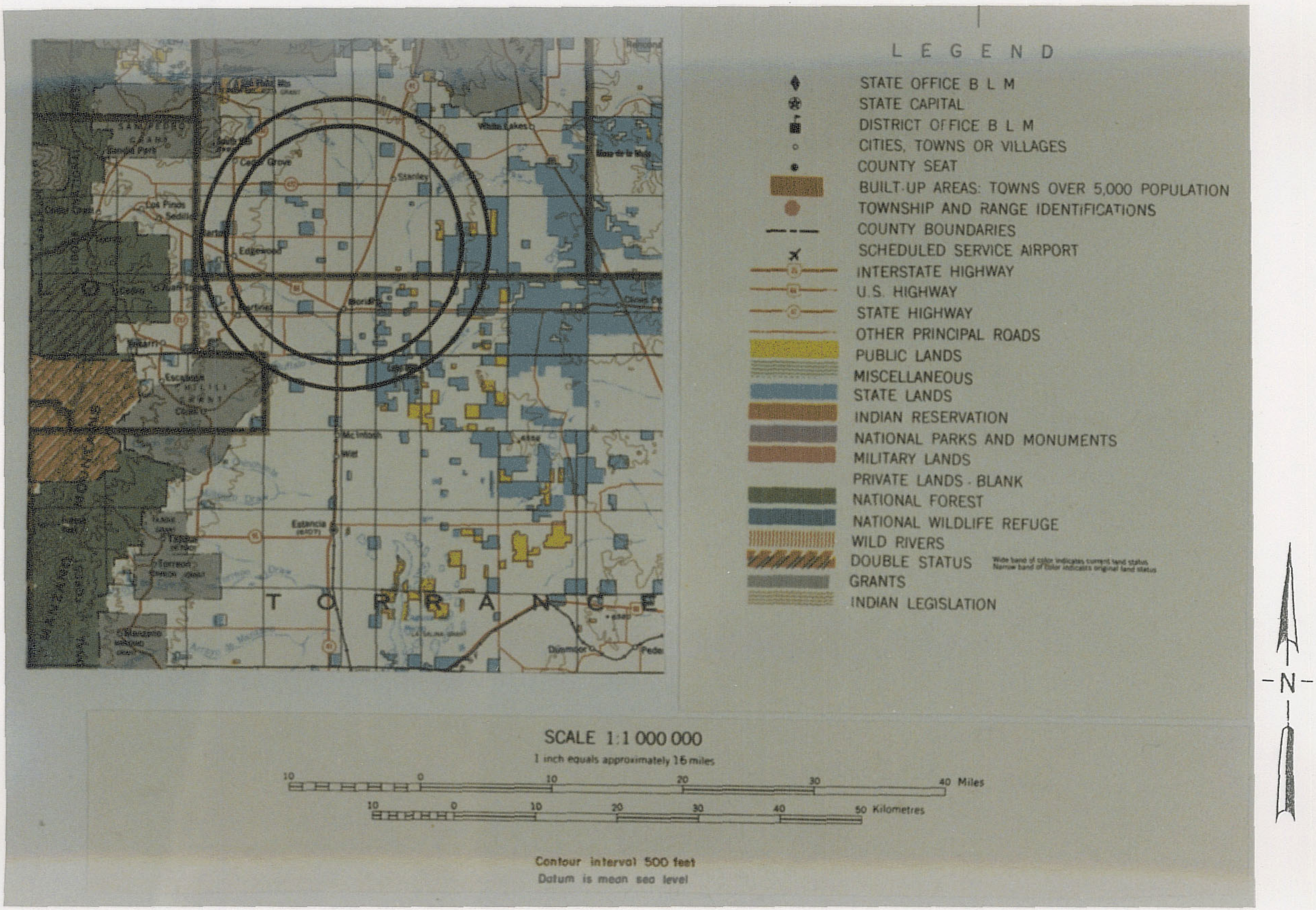


Figure 4. Ownership map of proposed site (after Bureau of Land Management, 1982).

Alamos National Laboratory and the New Mexico Institute of Mining and Technology are within two hours' driving time of Albuquerque. All are part of the Rio Grande Research Corridor.

The Albuquerque metropolitan area has a population of more than 470,000. The city has a moderate climate, excellent cultural advantages, very good secondary education programs, and a wide range of nearby recreation facilities. As the business center of New Mexico, Albuquerque offers abundant skilled labor as well.

GEOLOGY

Precambrian

Precambrian rocks are exposed on the east edge of the Estancia Valley at Lobo Hill and on the northwest edge at Monte Largo west of South Mountain (figs. 1, 5, and 6). The Precambrian at Monte Largo consists mostly of gneiss and schist (Kelley and Northrop, 1975). The Precambrian at Lobo Hill (fig. 1, mislabelled "Logo Hill") is schist (Kelley, 1972), although metamorphic quartzite and granitic crystalline rocks may be present nearby in the subsurface. The exact size of the Precambrian body at Lobo Hill is not known, but the geologic subcrop map below the valley fill probably depicts the area occupied by Precambrian with reasonable accuracy (fig. 7). Lobo Hill may be the surface expression of a compressional fault block of late Paleozoic age, but valley fill obscures its geometry and structure.

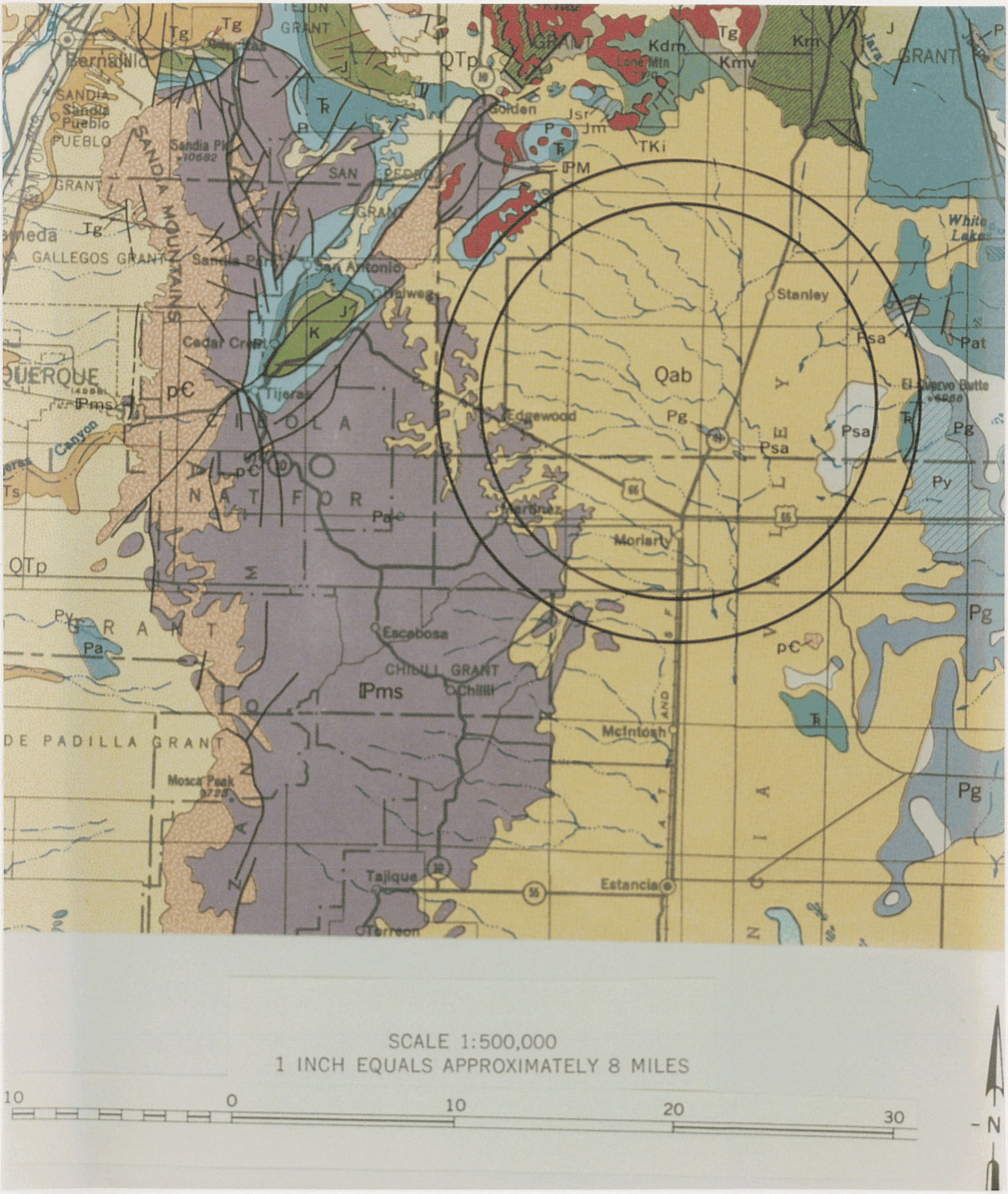
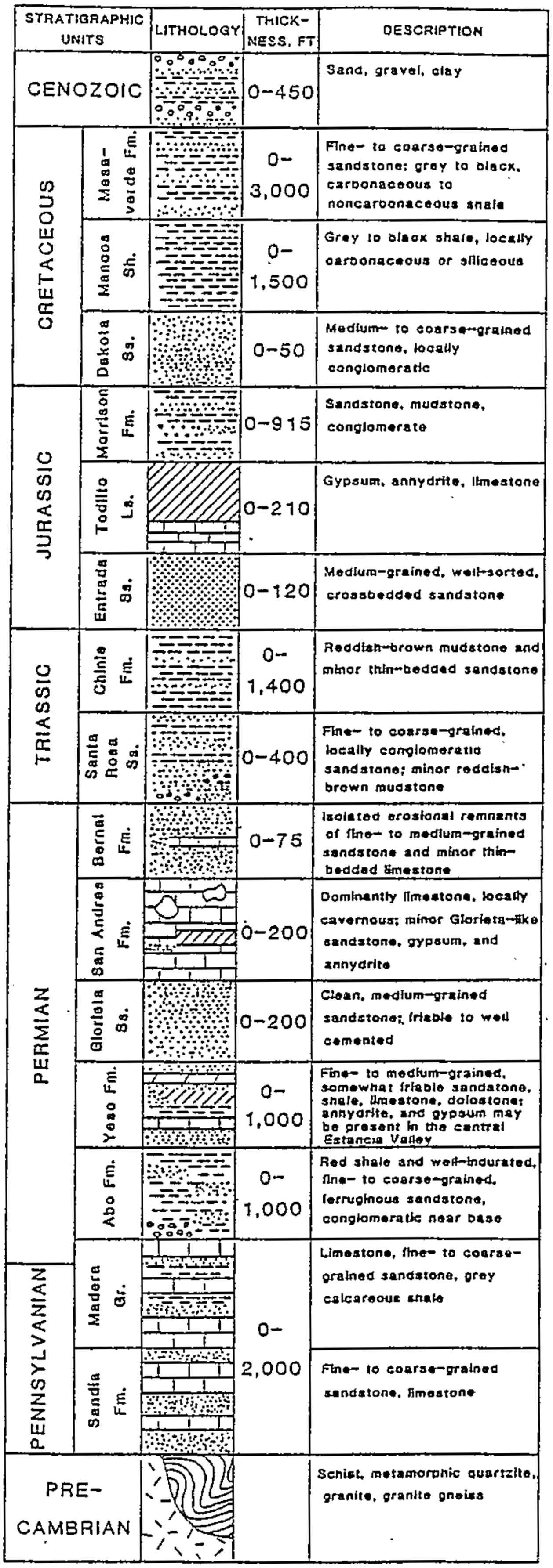


Figure 5. Geologic map (surface) of proposed site. Originally printed at scale of 1:500,000 (after Dane and Bachman, 1965).



STRATIGRAPHIC UNITS		LITHOLOGY	THICKNESS, FT	DESCRIPTION
CENOZOIC			0-450	Sand, gravel, clay
CRETACEOUS	Mesaverde Fm.		0-3,000	Fine- to coarse-grained sandstone; grey to black, carbonaceous to noncarbonaceous shale
	Mancos Sh.		0-1,500	Grey to black shale, locally carbonaceous or siliceous
	Dakota Ss.		0-50	Medium- to coarse-grained sandstone, locally conglomeratic
JURASSIC	Morrison Fm.		0-915	Sandstone, mudstone, conglomerate
	Todilto Ls.		0-210	Gypsum, annydrite, limestone
	Entrada Ss.		0-120	Medium-grained, well-sorted, crossbedded sandstone
TRIASSIC	Chinle Fm.		0-1,400	Reddish-brown mudstone and minor thin-bedded sandstone
	Santa Rosa Ss.		0-400	Fine- to coarse-grained, locally conglomeratic sandstone; minor reddish-brown mudstone
PERMIAN	Bernal Fm.		0-75	Isolated erosional remnants of fine- to medium-grained sandstone and minor thin-bedded limestone
	San Andres Fm.		0-200	Dominantly limestone, locally cavernous; minor Glorieta-like sandstone, gypsum, and annydrite
	Glorieta Ss.		0-200	Clean, medium-grained sandstone; friable to well cemented
	Yeso Fm.		0-1,000	Fine- to medium-grained, somewhat friable sandstone, shale, limestone, dolostone; annydrite, and gypsum may be present in the central Estancia Valley
	Abo Fm.		0-1,000	Red shale and well-indurated, fine- to coarse-grained, ferruginous sandstone, conglomeratic near base
PENNSYLVANIAN	Madera Gr.		0-2,000	Limestone, fine- to coarse-grained sandstone, grey calcareous shale
	Sandia Fm.			Fine- to coarse-grained sandstone, limestone
PRE-CAMBRIAN				Schist, metamorphic quartzite, granite, granite gneiss

Figure 6. Stratigraphic column of geologic units present in the Estancia Basin.

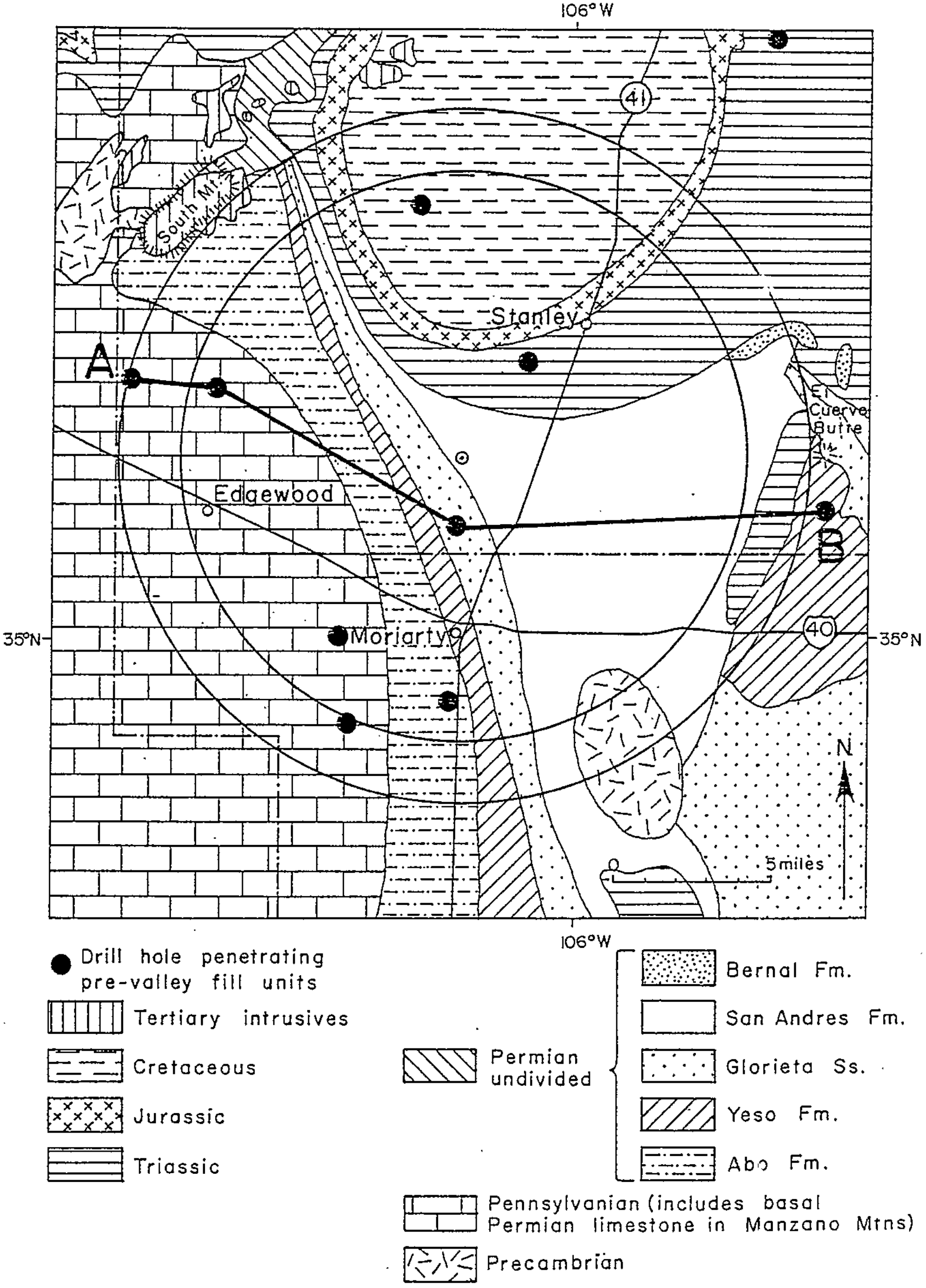


Figure 7. Subcrop geologic map of rock units below the Cenozoic valley fill.

Mississippian

Scattered but small erosional remnants of the Mississippian Arroyo Penasco Formation are probably present in the subsurface of the Estancia Valley. Data from the Sandia Mountains (Kelley and Northrop, 1975) indicate that these remnants are probably less than 100 ft thick. The Arroyo Penasco consists dominantly of limestone. If it is present in the Estancia Valley, it will be at depths greater than 2,000 ft and would not be encountered during construction of the Super Collider.

Pennsylvanian

Pennsylvanian strata of the Sandia Formation and Madera Group crop out in the Manzano and Sandia Mountains along the western edge of the Estancia Valley and dip eastward into the subsurface (figs. 7 and 8). Pennsylvanian strata underlie all but the easternmost part of the Estancia Valley near Lobo Hill, El Cuervo Butte, and the Pedernal Hills. Average combined thickness of the Sandia Formation and Madera Group is probably about 1,500 ft in the Manzano Mountains (Myers and McKay, 1976). The Sandia and Madera thicken eastward to approximately 2,000 ft in the subsurface of the western part of the Estancia Valley (Titus, 1973). The Sandia Formation and Madera Group consist predominantly of interbedded limestone, fire- to coarse-grained sandstone, and calcareous shale. In the southern and central parts of the Estancia Valley, the uppermost part of the Madera Group is Permian in age.

Permian

The Abo Formation is the oldest mappable stratigraphic unit of Permian age in the Estancia Valley. It is present throughout the subsurface of the eastern two-thirds of the valley but is truncated by Cenozoic

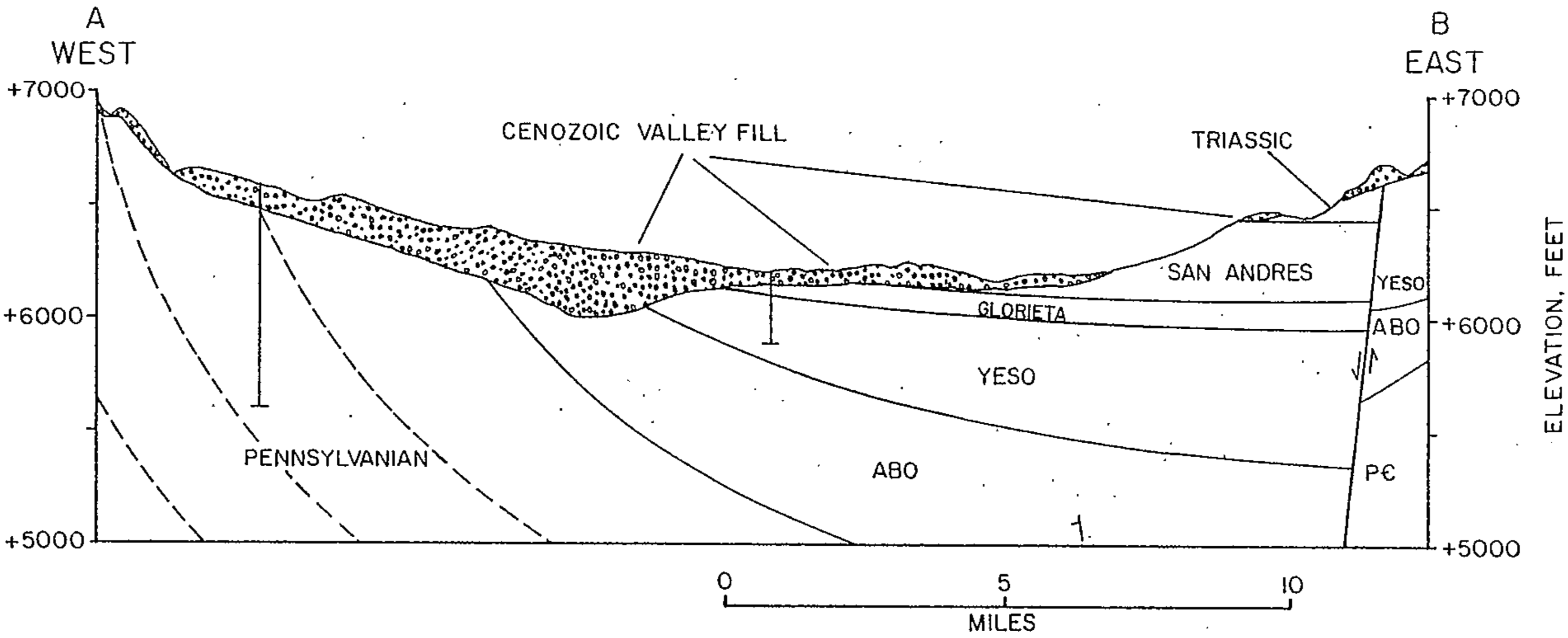


Figure 8. Geologic cross section through proposed SSC site. Construction along east-west A-B line on Figure 7.

valley-fill sediments just west of Moriarty (figs. 7 and 8). The Abo is approximately 1,000 ft thick in the subsurface of the central part of the Estancia Valley (Titus, 1973). It thins to less than 300 ft on the eastern flank of the valley near El Cuervo Butte (fig. 8). The Abo consists primarily of interbedded red shale and lenticular, well-indurated, fine- to coarse-grained, ferruginous, arkosic sandstone.

The Yeso Formation overlies the Abo Formation in the Estancia Valley. Similar to the Abo, the Yeso is present in the subsurface of the eastern two-thirds of the Estancia Valley but is truncated by Cenozoic valley fill near Moriarty (figs. 7 and 8). The Yeso is approximately 500 ft thick in the Sandia Mountains (Kelley and Northrop, 1975) and 530 ft thick at El Cuervo Butte. The Yeso is at least 1,000 ft thick in the subsurface of the central Estancia Valley. It consists of interbedded shale, limestone, dolostone, gypsum, anhydrite, salt, and evenly bedded, fine- to medium-grained, somewhat friable sandstone. Although no significant amounts of gypsum, anhydrite, or salt appear to be present in the Manzano Mountains (Titus, 1980) or at El Cuervo Butte (fig. 5), wells drilled in the central part of the Estancia Valley south of the proposed SSC site indicate that several hundred feet of gypsum and anhydrite are present there and at least as far north as the town of Estancia (Titus, 1973). It is not known if significant amounts of gypsum or anhydrite are present in the subsurface of the central Estancia Valley as far north as the town of Moriarty.

The Glorieta Sandstone overlies the Yeso Formation in the Estancia Valley. It is present in the subsurface of the eastern two-thirds of the valley but is truncated by Cenozoic valley fill just east of Moriarty (fig. 8). The Glorieta is 65-125 ft thick in the Sandia Mountains (Kelley and Northrop, 1975) and 150-200 ft thick in the outcrop area east of Lobo Hill (Read and others, 1944). Similar thicknesses are probably present in the subsurface of the central part of the Estancia Valley. The Glorieta is a clean, white, medium-grained quartz sandstone. Bedding is usually massive and texture varies from friable to well cemented (Kelley and Northrop, 1975).

The San Andres Formation overlies the Glorieta Sandstone in the Estancia Valley. The San Andres has a maximum thickness of 200 ft in the Sandia Mountains (Kelley and Northrop, 1975), 200-300 ft on Chupadera Mesa at the southern end of the valley (Bates and others, 1947), and only 100 ft at the northern rim of the Estancia Valley (Read and others, 1944). In the Sandia Mountains, the San Andres consists mostly of grey to black, thin- to medium-bedded, finely crystalline limestone. The limestone is locally cavernous (Kelley and Northrop, 1975). Some gypsum, anhydrite, and sandstone are also present in the San Andres Formation (Titus, 1973).

The Bernal Formation overlies the San Andres Formation. Only small, isolated, erosional remnants of the Bernal are present in the Sandia Mountains and Estancia Valley. The Bernal is up to 75 ft thick in the Sandias where it consists of tan-brown, fine- to medium-grained sandstone with local thin limestone beds; gypsum is not apparent (Kelley and Northrop, 1975).

Triassic

Triassic rocks in the Estancia Valley consist of the Santa Rosa Sandstone and the Chinle Formation. The Santa Rosa is 100-400 ft thick in the Sandia Mountains and the Chinle has a maximum thickness of 1300-1400 ft in the Sandias (Kelley and Northrop, 1975). Only thin erosional remnants of the Santa Rosa and Chinle are present in the Estancia Valley. The Santa Rosa consists mostly of white to brown, fine- to coarse-grained, locally conglomeratic sandstone and minor reddish-brown mudstone beds; the Chinle consists predominantly of reddish-brown mudstone with numerous thin sandstone beds (Kelley and Northrop, 1975).

Jurassic

Jurassic strata are present only in the northernmost part of the Estancia Valley. (fig. 7). The Jurassic section (fig. 6) consists of, in ascending order: Entrada Sandstone, Todilto Limestone, and the Morrison Formation. In the Sandia Mountains, the Entrada is 60-120 ft thick and consists of fine- to medium-grained, well-sorted, cross-bedded sandstone. The Todilto consists of a lower gypsum member as thick as 190 ft and an upper limestone member 5-20 ft thick. The Morrison is 760-915 ft thick in the Sandia Mountains and consists of sandstone, mudstone, and conglomerate (Kelley and Northrop, 1975).

Cretaceous

A Cretaceous section is preserved north of Stanley (fig. 4). The Cretaceous section is composed of, in ascending order: Dakota Sandstone, Mancos Shale, and the Mesaverde Formation. In the Hagan Basin north of Stanley, the Dakota is 5-50 ft thick and consists dominantly of medium- to coarse-grained sandstone. The Mancos may be as thick as 1,500 ft and consists of grey to black shale that is locally carbonaceous or siliceous. The Mesaverde may be as thick as 3,000 ft and consists of interbedded fine- to coarse-grained sandstone and grey to black, noncarbonaceous to carbonaceous shale (Kelley and Northrop, 1975).

Cenozoic

The Cenozoic Era ranges from 66 million years ago to the present and is divided into the Tertiary and Quaternary Periods. Although the Cenozoic Era is well represented by rocks north and west of the northern Estancia Valley, most of these rocks were eroded or never deposited within the area of the SSC ring. Three major groups of rocks are represented. First, shallow tongue-shaped igneous intrusive rocks make up South Mountain and the Ortiz Mountains. These Tertiary intrusives range from 27 to 37 million years in age and locally contain economic metallic ore deposits.

The second group of Cenozoic deposits consists of sand and gravel shed from the mountains to the west and range in age from about 4 to 12 million years old. The deposits range up to 50 feet thick where preserved on the margins of the basin. The stable upper surface of these deposits has been indurated by a zone of caprock caliche.

The third group of deposits is the basin fill of the northern Estancia Valley. The deposits consist of gravel, sand, silt, and clay over 400 ft thick (fig. 9 and Table 1). The sediments were eroded from the valley sides as the Estancia basin began to sag only a few million years ago. The lowest deposits in the basin may be equivalent in age to the second group of deposits described above, but most of the basin fill is latest

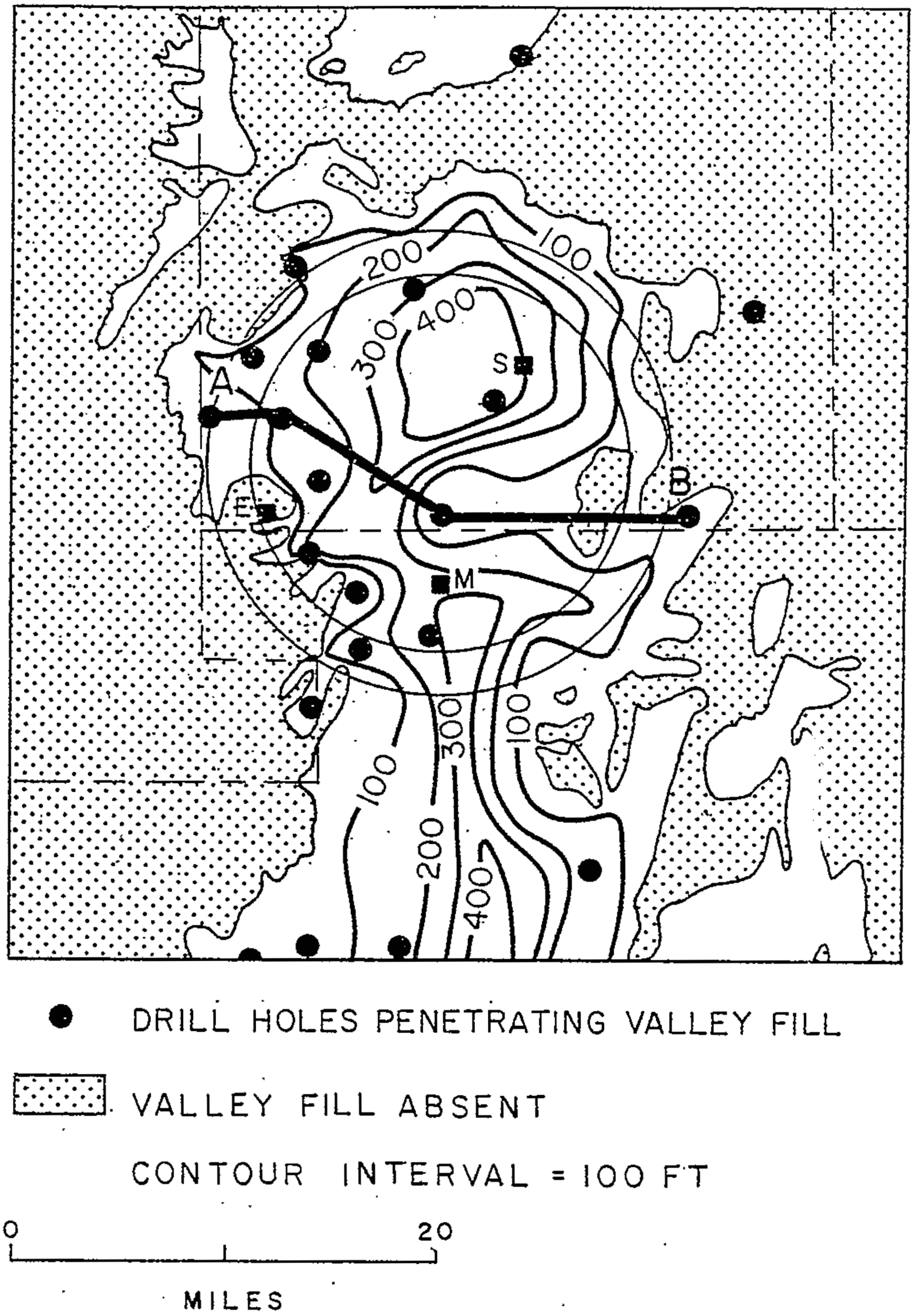


Figure 9. Isopach map of Cenozoic valley fill in northern Estancia Basin. Figure 8 is cross section A-B.

Table 1. Log of well 2 mi south of Moriarty (after Smith, 1957)

Material	Thickness (feet)	Depth (feet)
Quaternary and Tertiary(?) valley fill		
Soil	3	3
Caliche	9	12
Clay, sticky	28	40
Clay, sandy	31	71
Sand and gravel; water	5	76
Clay	22	98
Sand and gravel; water	4	102
Clay	10	112
Gravel; water	6	118
Clay	10	128
Sand and gravel; water	6	134
Clay, sandy	21	155
Sand and gravel	8	163
Clay	8	171
Sand and gravel	9	180
Gravel	12	192
Clay	6	198
Sandstone shells	4	202
Gravel	8	210
Sand and gravel	5	215
Gravel	5	220
Conglomerate	21	241
Clay and gravel	7	248
Conglomerate	23	271
Clay	7	278
Probably Abo formation		
Clay, light-red	4	282
Sandstone, red	5	287
Clay, red	6	293
Conglomerate	7	300
Red bed	3	303

Tertiary and Quaternary in age. The deposits at the surface consist of stream sediments, alluvial fans, lake deposits, and windblown dunes. The soils developed on much of the sediment indicate that the landscape higher than 6225 ft has been stable for more than 100,000 years. A large Wisconsinan lake occupied the basin below 6225 ft between 10,000 and 20,000 years ago. Earlier lakes of larger extent may have filled the basin to a sill at an elevation between 6340 and 6350 ft (fig. 10). Present areas of active erosion and deposition are primarily confined to stream valleys, sand-dune fields, and active agricultural areas.

HYDROGEOLOGY

Ground water flows from upland recharge areas on the Estancia Valley margins toward lower discharge points associated with playas in the southeastern part of the valley. Pumpage and zones of higher conductivity complicate this otherwise simple flow system. The floor of the valley is covered by fill of late Pliocene (?) to Pleistocene age. Underlying this fill is a sequence of gently eastward-dipping Paleozoic bedrock units (figs. 7 and 8). Each of these materials serves as a principal aquifer for some part of the valley (fig. 11). Aquifer characteristics are summarized in Table 2 and are not repeated below. Depth to water in the valley is shown in Figure 12.

Valley Fill Material

Valley fill is the principal aquifer in the main part of the Estancia Valley (Smith, 1957; fig. 11). Heterogeneity of this material is shown by the log of a well 2 mi south of Moriarty (Table 1). The fill is 340 ft thick 6 mi south of Moriarty and 405 ft thick 2 miles south of Stanley

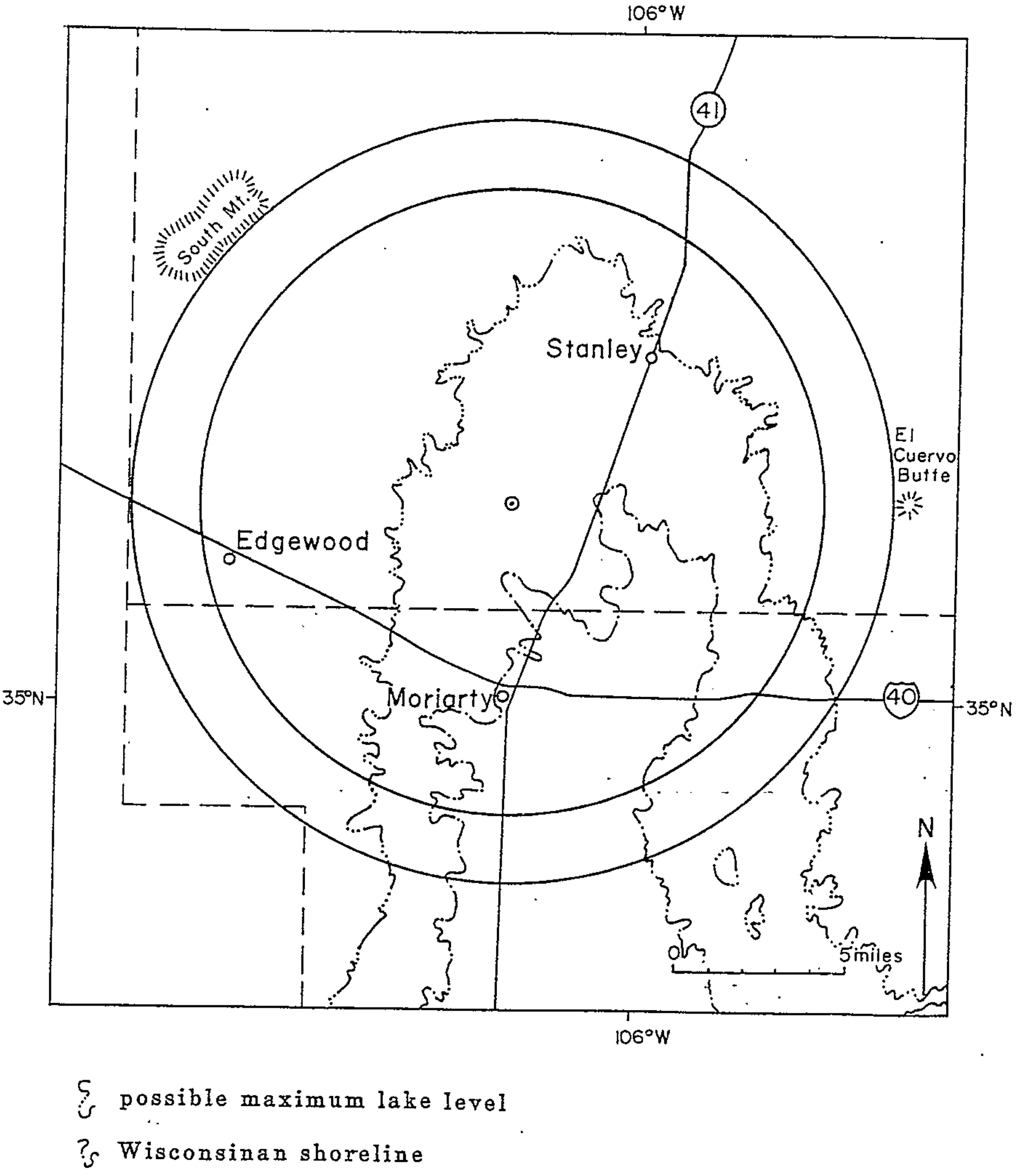


Figure 10. Possible maximum extent of latest Glacial Lake Estancia at maximum level and the prominent Wisconsinan shoreline.

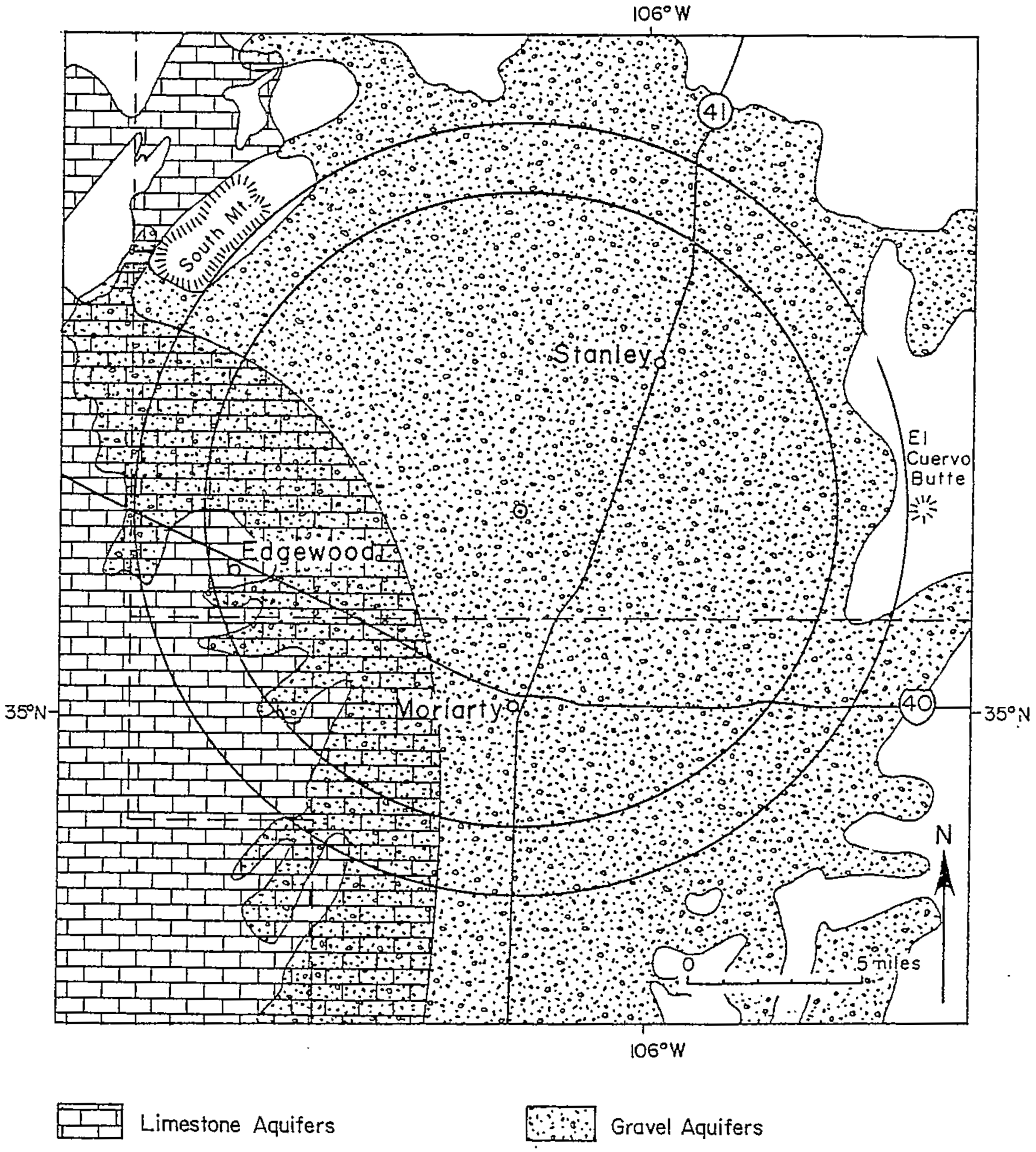


Figure 11. Principal sand and gravel (Cenozoic) and limestone aquifers in central New Mexico.

Table 2. Summary of Aquifer Characteristics, Estancia Valley.

Aquifer	Lithology	Thickness (ft)	Depth to Water (ft)	Maximum Yield (gpm)	Total Dissolved Solids (ppm)	Source*
Valley Fill	gravel, sand, clay	0 - 405	0 - 250	2,300	207 - 6,170	1,2
Glorieta Sandstone	sandstone	0 - 200	25 - 200	>3,000	592 - 5,270	1
Yeso Formation	sandstone, shale, limestone, anhydrite	380 - 700	20 - 625	3,000	220 - 12,300	1
Abo Formation	sandstone, mudstone	300 - 1,000	5 - 900	10	258 - 504	1
Madera Group	limestone, shale, siltstone, conglomerate, sandstone	0 - 2,700	5 - 1,100	1,100	<459	1,2,3,4

* 1 = Smith (1957), 2 = Mourant (1980), 3 = Jenkins (1982), 4 = Titus (1980)

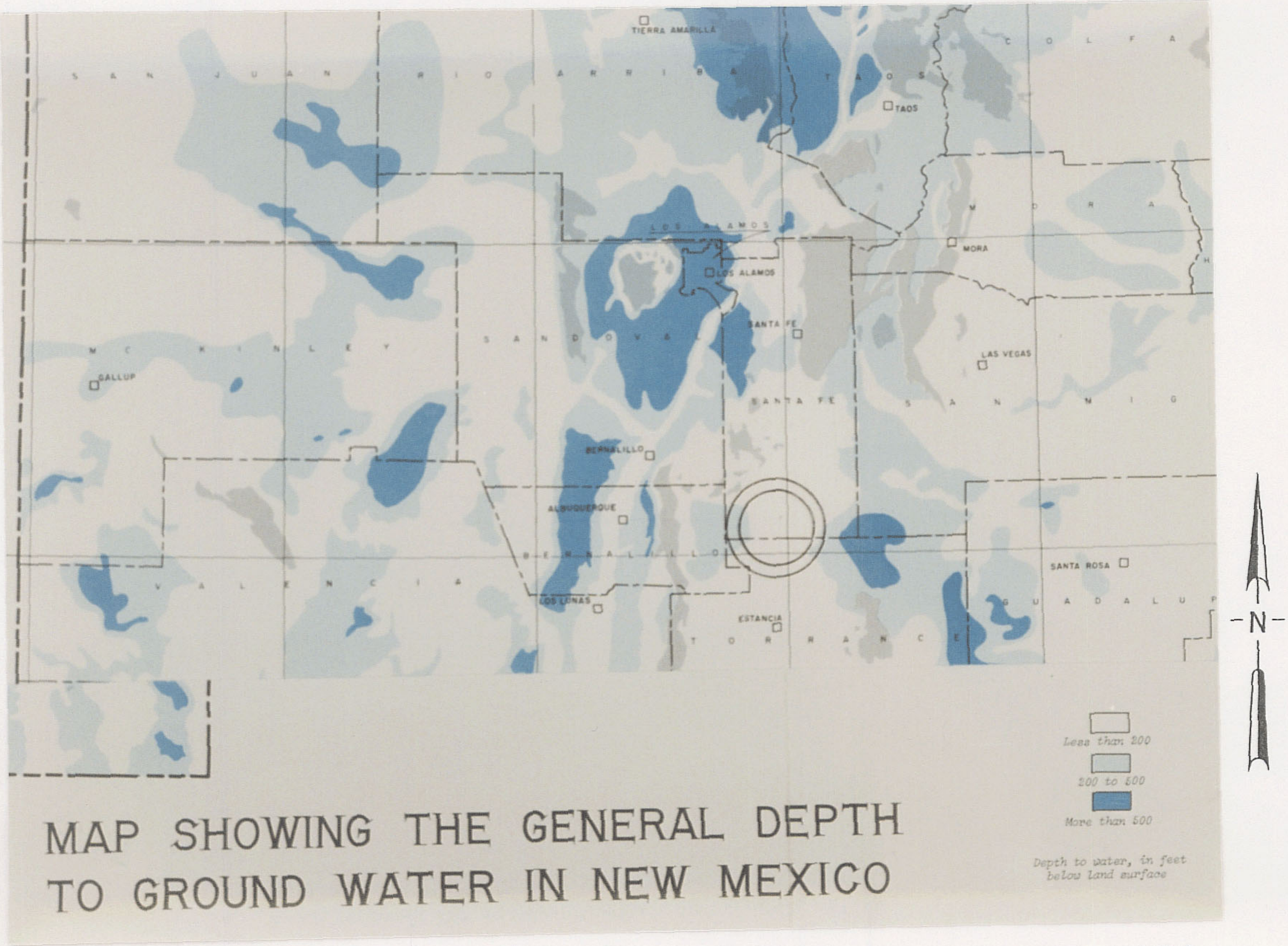


Figure 12. Depth to water table in central New Mexico (after Bureau of Reclamation, 1976).

(Smith, 1957; see also fig. 9). Titus (1980) reported that near Edgewood the water table was near the base of the valley fill or in the underlying Paleozoic bedrock. In response to irrigation pumpage, ground-water levels have declined. By 1971, declines of as much as 40 ft were observed in the vicinity of the Torrance/Santa Fe County line north of Moriarty (Bureau of Reclamation, 1976). The average yield of a good valley-fill well 30 years ago was 1200 gpm (Smith, 1957). Quality of water from the valley fill varies with location. Salinity increases along flow lines. In places, the water is satisfactory for all uses; in others it is suitable only for use by livestock (Smith, 1957).

San Andres Limestone and Glorieta Sandstone

No significant wells are completed in the San Andres Limestone, but fractured Glorieta Sandstone is the principal aquifer in the northeastern part of the valley (Smith, 1957). Locally, yields are high with little drawdown. For example, at well 10.8.35.211, north of Moriarty, only 6 ft of drawdown resulted from the pumping at more than 3,000 gpm (Smith, 1957). Water quality is highly variable based on five analyses reported by Smith (1957). Poor quality water is probably due to hydraulic connection with the anhydrite-bearing Yeso Formation below.

Yeso and Abo Formations

The Yeso Formation is the principal aquifer in the southern and eastern parts of the valley (Smith, 1957). Porosity is largely secondary with significant fracture zones associated with movement along major structural axes (Smith, 1957). Wells in Mountainair yielded 100 gpm from limestone in the Yeso. Elsewhere, yields range from those suitable for windmills to 3,000 gpm. Quality of water in the Yeso varies with location and type of rock penetrated by the well. According to Smith (1957), the Abo Formation is the principal aquifer only in the extreme southwestern part of the valley outside the area of the proposed site.

Madera Group

The Madera Group is the principal aquifer along the western margin of the Estancia Valley (Smith, 1957; Jenkins, 1982; fig. 11). This is especially true in a narrow belt where the overlying valley fill is generally less than 100 ft thick.

Shallow depths to water are associated with the western part of the valley. According to Smith (1957), initial yields may be high, but sustained yields are more on the order of a few hundred gpm. Titus (1980) gave an average yield of 12 gpm for 46 wells yielding less than 100 gpm.

Wells in the Madera produce water from secondary porosity: joints, fractures, and solution cavities (Jenkins, 1982). Two zones of high conductivity are known in the western Estancia Basin. One occurs in T6-8N, R7-8E and may be associated with karst features. The other lies a few miles north of Edgewood in the Bachelor Draw area (between Sec. 30, T11N, R7E and Sec. 31, T10N, R8E). Considerable variability in well success has been experienced in the Edgewood area north of I-40, between NM 344 and the county line (Jenkins, 1982). Least favorable locations appear to be those between the east-west-trending drainageways in the limestone ridge roughly following the county line. The best wells lie along projections of these drainageways, which reportedly are fault controlled.

Most water is potable and meets county and state water-quality standards (Jenkins, 1982). However, Titus (1980) noted locally elevated values of magnesium, sodium, potassium, fluoride, and nitrate. The secondary porosity, which enhances well yields in the Madera Group, also makes this aquifer very susceptible to pollution (Jenkins, 1982). Some of the nitrate anomalies reported by Titus (1980) may be attributed to recirculation of sewage effluent through open fractures and solution channels.

Recommendations

This brief overview is based on existing data, as presented in but a few of the previous works done on the Estancia Valley. Additional site-specific hydrogeologic data will be required not only for developing a water supply for the Super Collider, but also for the various engineering activities associated with its construction.

In order to obtain the quantity and quality of water needed (2,000 gpm; at least 500 gpm potable), it is recommended that the facility headquarters and/or water supply equipment be located on the western side of the Estancia Valley, near Edgewood (fig. 1). The Madera Group is an excellent source of water there.

As noted elsewhere, installation of the Super Collider may require excavation into the Madera in the southwestern part of the ring. Such excavation will no doubt encounter water and dewatering measures may be required. If properly designed, the water-collection system used in dewatering may also serve as the means of obtaining project water. If additional water is needed, conventional wells in the Madera should provide it. Alternatively, depending on the location and depth of excavation, dewatering of other aquifers may provide water in other areas along the course of the Super Collider.

Any waste-disposal activities must be carefully planned. This is especially important in view of the vulnerability of the water supply in the area (Titus, 1980; Jenkins, 1982).

SEISMICITY

Earthquake data for New Mexico was summarized by Sanford, Olsen, and Jaksha (1981). Information on locations and strengths of earthquakes prior to 1962 is based mostly on noninstrumentally determined values of earthquake intensity. No seismic centers were detected within the ring area prior to 1962 (Sanford, Olsen, and Jaksha, 1981). Similarly, no epicenters with magnitudes of greater than 2.5 (Richter) were recorded from 1961 to 1982 in the proposed site (Machette, unpublished data, 1982; fig. 13). Jaksha (unpublished data, 1985; fig. 14), however, does indicate some seismic centers with a Richter magnitude of less than 1.5 within the ring area for the period between 1976 and 1981. Earthquakes with a Richter magnitude of less than 1.5 are imperceptible to most people and are only measured by the most sensitive instruments.

Recommendations

Although the northern Estancia Valley is nearly aseismic, the presence of valley fill with water-bearing gravel, sand, silt, and clay as thick as 450 ft (Smith, 1957) means that nearby earthquakes may cause some

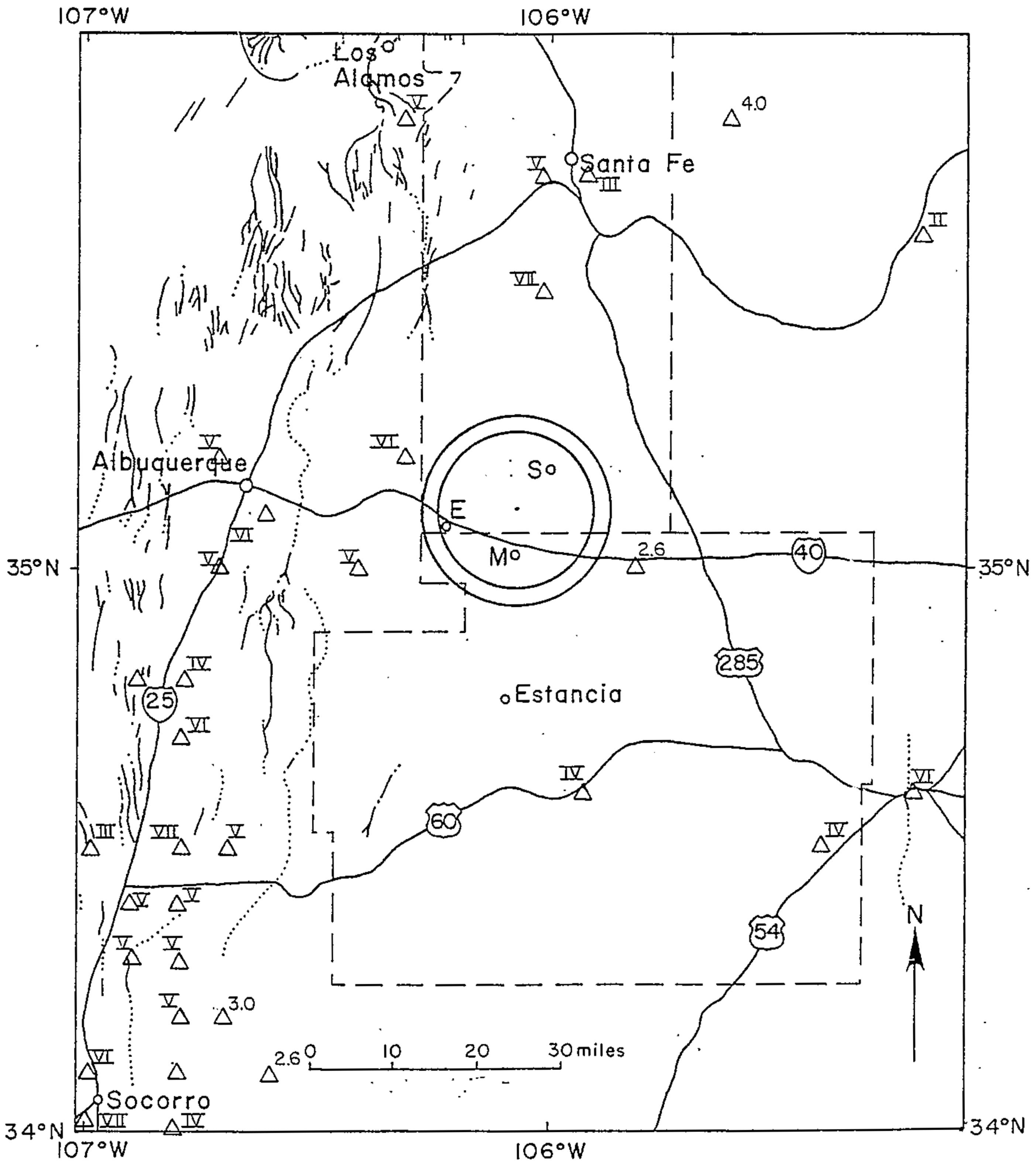


Figure 13. Historical seismic epicenters (Δ) and major faults in central New Mexico. Roman numerals indicate the intensity on the Mercalli scale, Arabic numbers denote Richter intensities (after Machette, unpublished data, 1983). S = Stanley, E = Edgewood, and M = Moriarty.

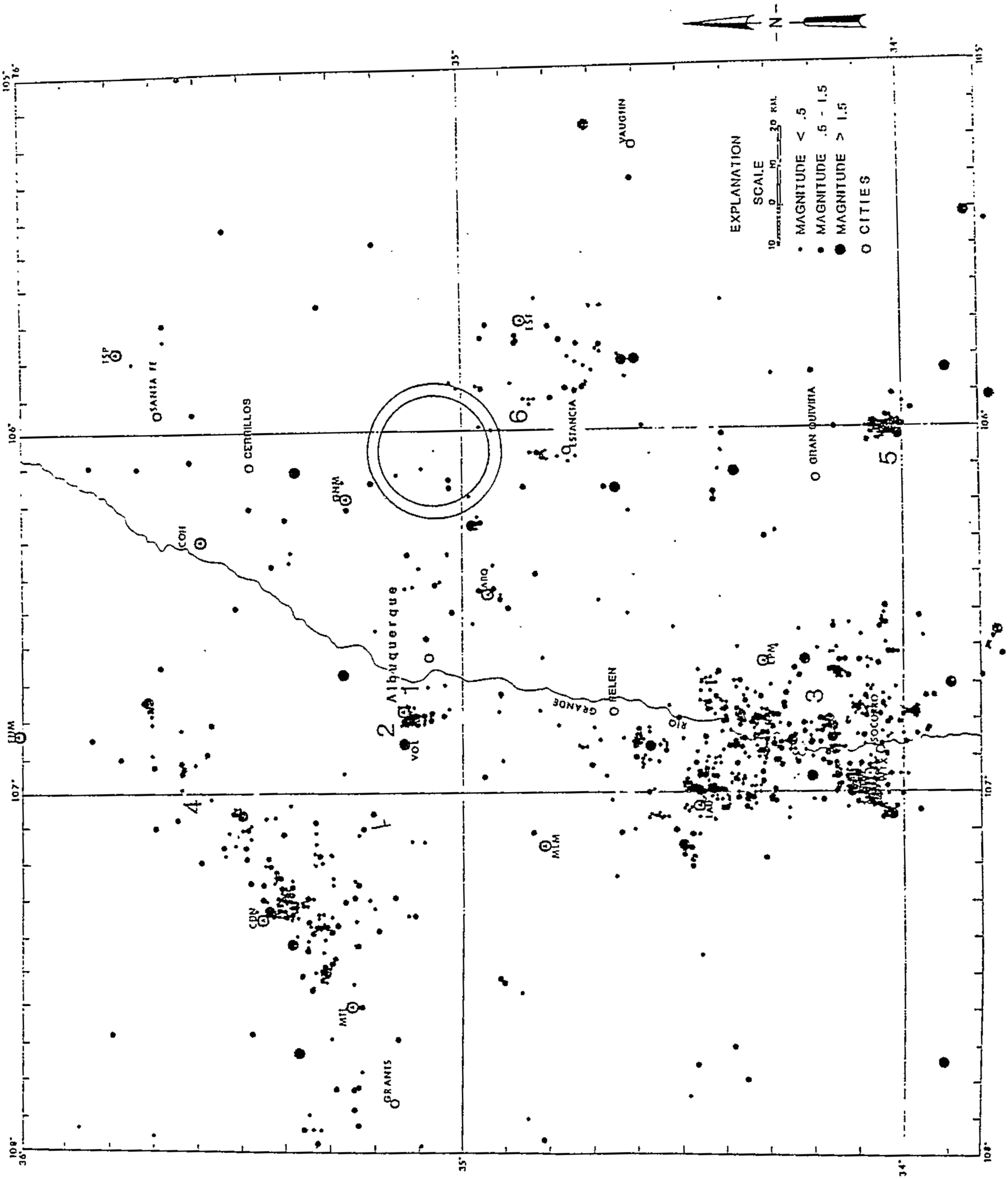


Figure 14. Seismicity map derived by U.S. Geological Survey from a seismic network centered on Albuquerque, NM. The study covered a 66-month period between January 1976 and November 1981. Approximately 1,000 epicenters are plotted and magnitudes range up to 3.2 on the Richter scale (after Jaksha, unpublished data, 1985).

movement and high amplitudes within the valley fill of the ring area as compared to the underlying bedrock. Susceptibility of the valley fill to seismicity should be tested.

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