PRELIMINARY REPORT ON ENGINEERING GEOLOGY OF THIRTEEN TUNNEL SITES, NEVADA TEST SITE

By V. R. Wilmarth, F. A. McKeown, and F. Dobrovolny

Trace Elements Memorandum Report 773

UNITED STATES DEPARTMENT OF THE INTERIOR

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ABSTRACT

Reconnaissance of 13 areas in and adjacent to Nevada Test Site was completed. Of the 13 areas, Forty Mile Canyon, South-central Shoshone Mountain, and Southeast Shoshone Mountain named in order of preference, offer many advantages for carrying on future underground nuclear explosions.

INTRODUCTION

Reconnaissance of those areas in and adjacent to the Nevada Test Site in which 1,000 feet of vertical cover could be obtained with relatively short horizontal tunnels was completed as part of a program that the U. S. Geological Survey is conducting at the Nevada Test Site on behalf of the Albuquerque Operations Office, U. S. Atomic Energy Commission.

Described in this preliminary report are the major geologic features, amount and area of vertical cover, length of tunnel, and an estimate of drilling that would be required to determine suitability of 13 areas in Tippipah Spring, Cane Spring, Topopah Spring, Wheelbarrow Peak, Frenchman Lake, and Timber Mountain quadrangles for underground nuclear explosions. Inasmuch as the suitability of Rainier Mesa for tunnel locations has been evaluated by Dobrovolny and Eckel, (1956) it will not be included in this report.

Summarized in the following table are the preliminary results of this study.

Table 1.--Summary of engineering geologic data on 13 selected underground test sites

	Area	Vertical cover (ft.)	App. area of cover (sq. mi.)	Length of Tunnel (ft.)	Rock to be penetrated	Est. amt. of drilling (ft.)	Remarks
1.	Forty Mile Canyon	1,500	1	4,500	Rhyolite(?)		
		1,000	2.5	2,000	"	3,000	
2.	South-central Shoshone Mt.	1,300	.4	2,600	Welded Tuff	3,000	
		1-1,200	.5	1,600	"	3,000	
3.	Southeast Shoshone Mt.	1,000-1,200	.5	2,500-3,000	Tuff	3,000	
4.	Skull Mountain	1,000	.2-.5	2-3,000	Tuff	4,000	Max. cover of 1,200 ft. could be obtained with 2,500-3,500 ft. of tunnel.
5.	Twin Peaks	1,000	.2	2,500-3,600	Quartzite, tuff	2,000	
6.	One mile west of Twin Peaks	800-1,000	1.	2,600-3,400	Tuff	2,000	
7.	South-central Pahute Mesa	1,000	.5	2,000	Tuff	1,500	
8.	Quartzite Mountain	1,400	.5	25-3,000	Quartzite siliceous shale	2,000	
9.	Southwest of Quartzite Mt.	1,000	.2	3,600	" "	2,500	
10.	Souteast part of Rainier Mesa	5-600	.1	?	Carbonate	2,000	
11.	Northern part of Tippipah Spring Quadrangle	900-1,000	.2	5,800	Granite	1,500	
12.	Wheelbarrow Peak Quadrangle						
	Wheelbarrow Peak	1,000-1,500	1	2,500-5,000	Volcanic ?	?	Geology has not been mapped but presumed to be similar to that found on Rainier Mesa.
	A	1,000	.75	2,000	"	?	
	B	1,000	.6	2,600	"	?	
	C	1,000	1	2,800	"	?	
	Oak Spring Butte	1,000-1,600	.75	2-4,000	"	?	
13.	Near Aysees Peak	1,000-1,200	.1	2,800-3,500	?	?	

Area 1 - Forty Mile Canyon.--Area 1 contains the greatest relief over a large area that can be found anywhere in the western part of the Nevada Test Site except on Rainier Mesa (figs. 1 and 2). Area 1 lies within coordinates 551 to 557 E. and 4088 to 4096 N. in the Topopah Spring and Timber Mountain quadrangles. It is a broad rounded mesa bounded on 3 sides by deep steep-walled canyons and has a maximum relief of nearly 2,000 feet. The area in which 1,000 feet of cover can be obtained with a horizontal tunnel 1,500 to 2,300 feet long is at least 2.5 square miles. To reach the maximum cover area, approximately one square mile, with a vertical cover of 1,500 feet or more, a horizontal tunnel driven northwestward from an altitude of 4,400 feet would be about 4,500 feet long.

The mesa is capped by as much as 1,000 feet of basalt which overlies several hundred feet of rhyolite (fig. 2). Tuffaceous rocks similar to those excavated at the University of California Radiation Laboratories tunnel sites on Rainier Mesa underlie the rhyolite and are locally about 300 feet thick. Relations of the tuff and rhyolite in vicinity of proposed tunnel sites are complex. The rhyolite locally probably is 800 feet thick and represents a flow that filled a deep valley cut in the tuffaceous rocks. Several faults with vertical displacements of 200 feet and many faults with displacements of 20 to 50 feet cut the rocks in this area. Water probably will not be encountered in the proposed tunnels. Much of the tunneling probably would be in rhyolite, a hard, dense rock that would require somewhat longer to excavate than the tuffaceous rocks at the tunnels in Rainier Mesa. On the other hand, in contrast to the tuffs, rhyolites will stand well and require less support.

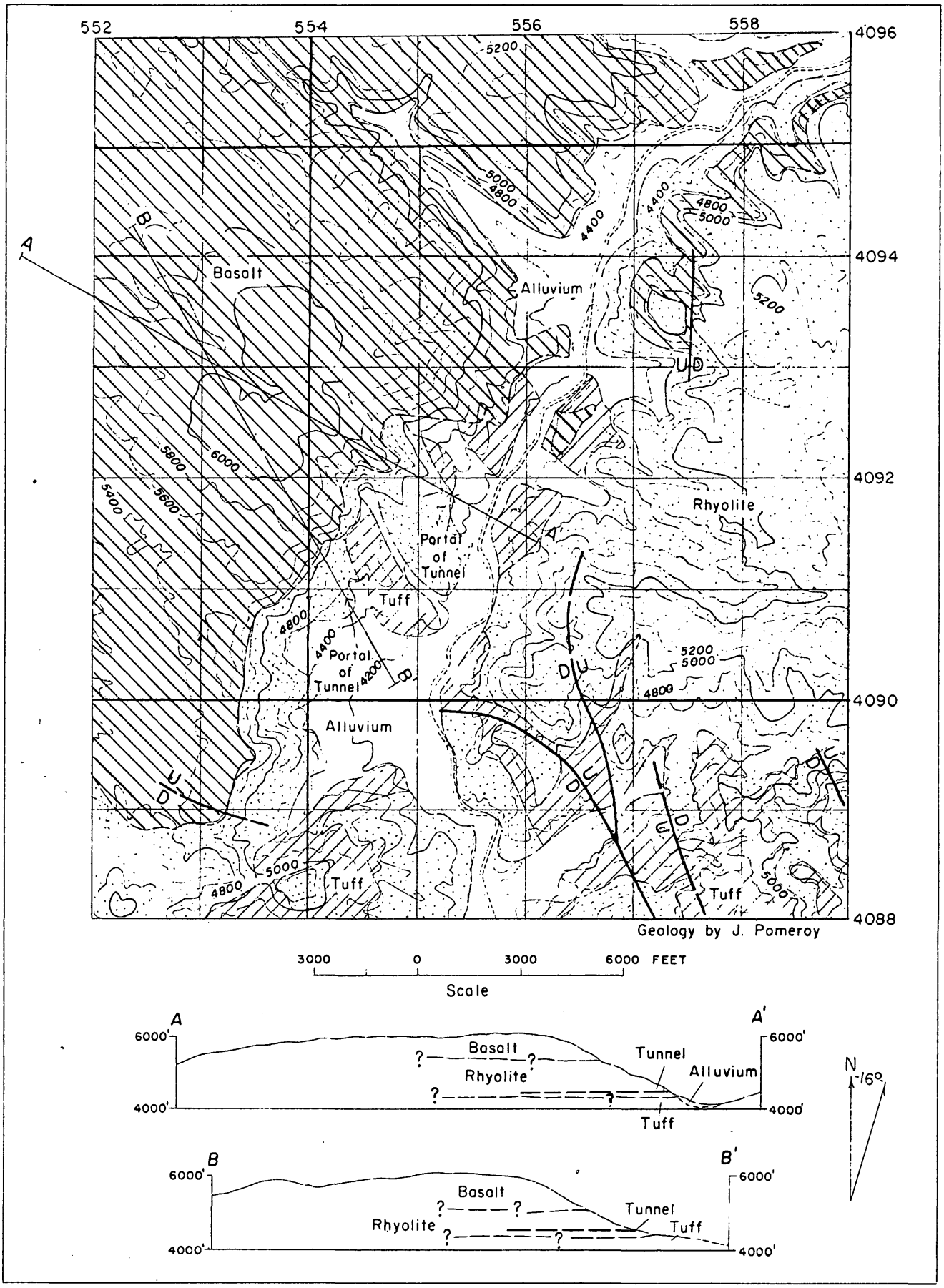


FIGURE 2.--GEOLOGIC MAP AND SECTIONS OF PROPOSED TUNNEL SITES, AREA I, FORTY-MILE CANYON, TOPAPAH SPRING AND TIMBER MOUNTAIN QUADRANGLES, NYE COUNTY, NEVADA

The principal advantages of the Forty Mile Canyon area are maximum cover per foot of tunnel and a large area in which many chambers requiring a cover of 1,000 feet can be obtained. However, the area is remote from existing facilities, and the properties of the rocks are unknown. The geology of this area is relatively little known and in order to determine the potential of this area for future underground nuclear explosions detailed geologic mapping of an area of about 3 square miles should be undertaken at a scale of 1:12,000 or greater. Drilling to determine hydrologic problems and type of rocks beneath the mesa should also be carried out in conjunction with the mapping. A minimum of 2 drill holes, totalling 3,000 feet is recommended.

Area 2 - South-central Shoshone Mountain.--Area 2 is about 10 miles north of Jackass Flat, in the northeastern part of Topopah Spring quadrangle (fig. 1). The area is bounded by coordinates 4086 to 4089 N. and 560 to 564 E., and is accessible only by 4-wheel drive vehicles. Two mesas, separated by a steep-walled canyon, have a maximum relief of about 1,400 feet. The eastern mesa has a total area of about one-half square mile in which there is minimum cover of 1,000 feet; the western mesa has an area of about one-third square mile with a minimum cover of 1,000 feet, and a maximum vertical cover of about 1,300 feet. The areas of high relief can be reached by horizontal tunnels driven northeastward and northwestward from the canyon for distances of 1,600 and 2,600 feet, respectively. A cover of 1,400 feet can be attained in the east mesa by a tunnel 4,500 feet long.

Reconnaissance of the area shows that about 100 feet of tuff, unconformably overlain by vitrophyre, crops out along the lower valley walls (fig. 3). Welded tuff of varying hardness and rhyolitic to andesitic flow rock comprise most of the upper 900 feet of the mesas.

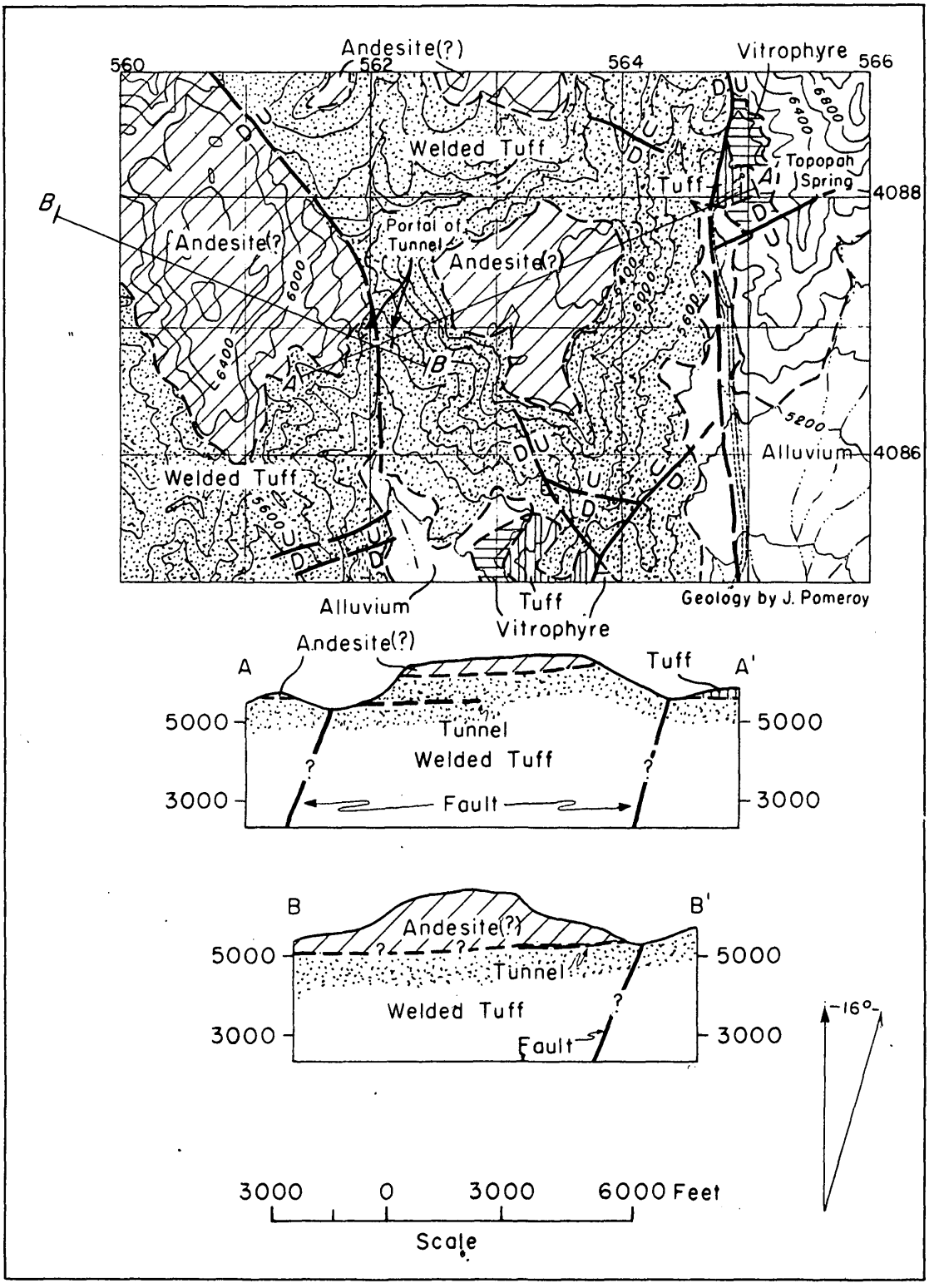


FIGURE 3.--GEOLOGIC MAP AND SECTIONS OF PROPOSED TUNNEL SITES, AREA 2, SOUTH-CENTRAL PART OF SHOSHONE MOUNTAIN, TOPOPAH SPRING QUADRANGLE, NYE COUNTY, NEVADA

Faults with breccia zones as much as 50 feet wide have displaced the rocks from a few to several hundred feet vertically. The location and attitude of these faults will govern to some extent the selection of tunnel sites. Portals of the tunnels will be in welded tuff, but the detailed geology is so little known that the rocks to be penetrated by the tunnels cannot be determined. The tunnels should be dry except for local seepage along fractures.

Drilling and detailed geologic mapping of Area 2 on a large scale will be necessary in order to select tunnel sites and plan future exploration intelligently. Minimum required drilling consists of one hole in each mesa, the total footage being about 3,000 feet.

The advantage of Area 2 is more area with 1,000 feet of cover is available for underground tests than elsewhere in NTS. Disadvantages are: (1) the area is remote from roads and power facilities; and (2) the properties of the rocks are unknown.

Area 3 - Southeast Spur of Shoshone Mountain.--A V-shaped mesa of high relief is on the southeast side of Shoshone Mountain in the northwest part of Cane Spring quadrangle, about 9 miles west of Yucca Pass (fig. 1). Coordinates of Area 3 are: 567 to 572 E. and 4085 to 4090 N. The steep slopes on the north and east of the mesa may be suitable for tunnel sites (fig. 4). Figure 4 shows the outline of the area (approximately one-half square mile) in which there is a minimum of 1,000 feet of vertical cover; the maximum cover is about 1,200 feet. The length of horizontal tunnel required to reach the minimum cover area ranges from 2,500 to 3,000 feet.

In the lower part of the slope, on the east side of the mesa resistant limestone and quartzite form prominent hills. On the steep upper part of the slope tuffaceous rocks of the Oak Spring formation crop out (fig. 4).

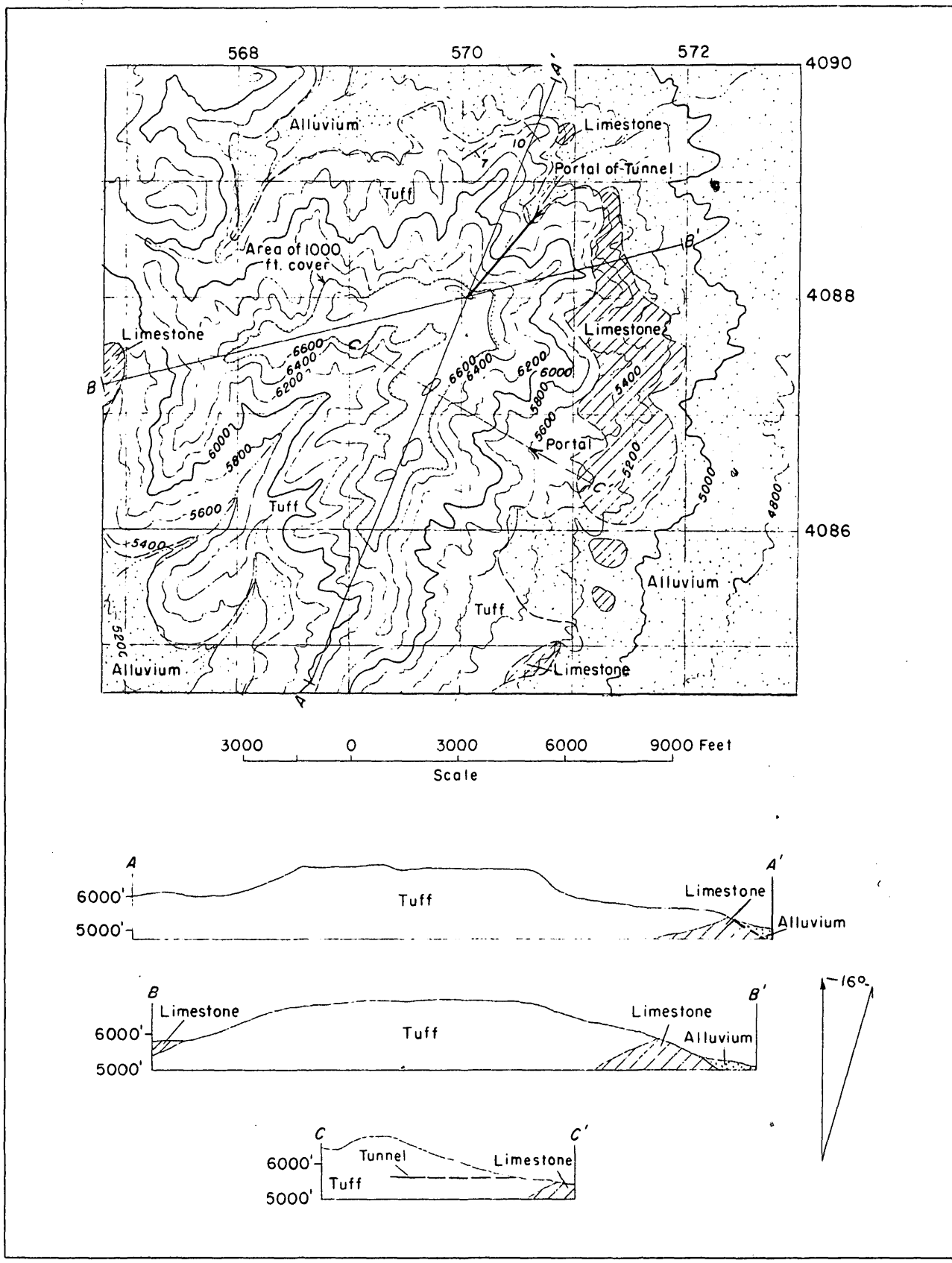


FIGURE 4.--GEOLOGIC MAP AND SECTIONS OF PROPOSED TUNNEL SITES, AREA 3, SOUTHEAST SHOSHONE MOUNTAIN, TIPPIPAH SPRING QUADRANGLE, NYE COUNTY, NEVADA

The Oak Spring formation consists of about 100 feet of marl and siltstone overlain by about 850 feet of interbedded tuff and flow rock. Beds in the limestone dip to the west at angles of 18° to 26° and the younger rocks dip to the west at angles of 4° to 12°. As the contact between the tuffaceous rocks and the limestones in other parts of NTS is irregular and locally has considerable relief, the position of this contact is important in the selection of tunnel sites for Area 2. Faults with moderate vertical displacements cut the older rocks but appear to be less numerous in the Oak Spring rocks. Water may be encountered along the faults and at the contact of the younger and older rocks, but tunnels in the tuffaceous rocks should be dry.

Further consideration of this area for test sites should be preceded by detailed geologic study of an area of approximately 3 square miles. The results of this study should be confirmed, especially along selected tunnel sites, by drilling. Based on present data, at least 2 drill holes totalling about 3,000 feet would be required.

Area 4 - Skull Mountain.--Skull Mountain is an elongate northeast-trending flat-topped mountain in the southwestern part of Cane Spring quadrangle and is in the area for which the areal geology has been mapped by Johnson and Hibbard (1957).

The maximum practicable vertical cover in Skull Mountain is about 1,200 feet, but only in small discontinuous areas. A vertical cover of 1,000 feet can be obtained in three areas totalling approximately one-half square mile. The largest of the three can be reached by a horizontal tunnel about 2,000 feet long driven from the north side of the mountain (fig. 5, sec. A-A'). Approximately 3,500 feet of tunnel would be required to reach the same amount of cover from the south side of the mountain (fig. 5, sec. B-B').

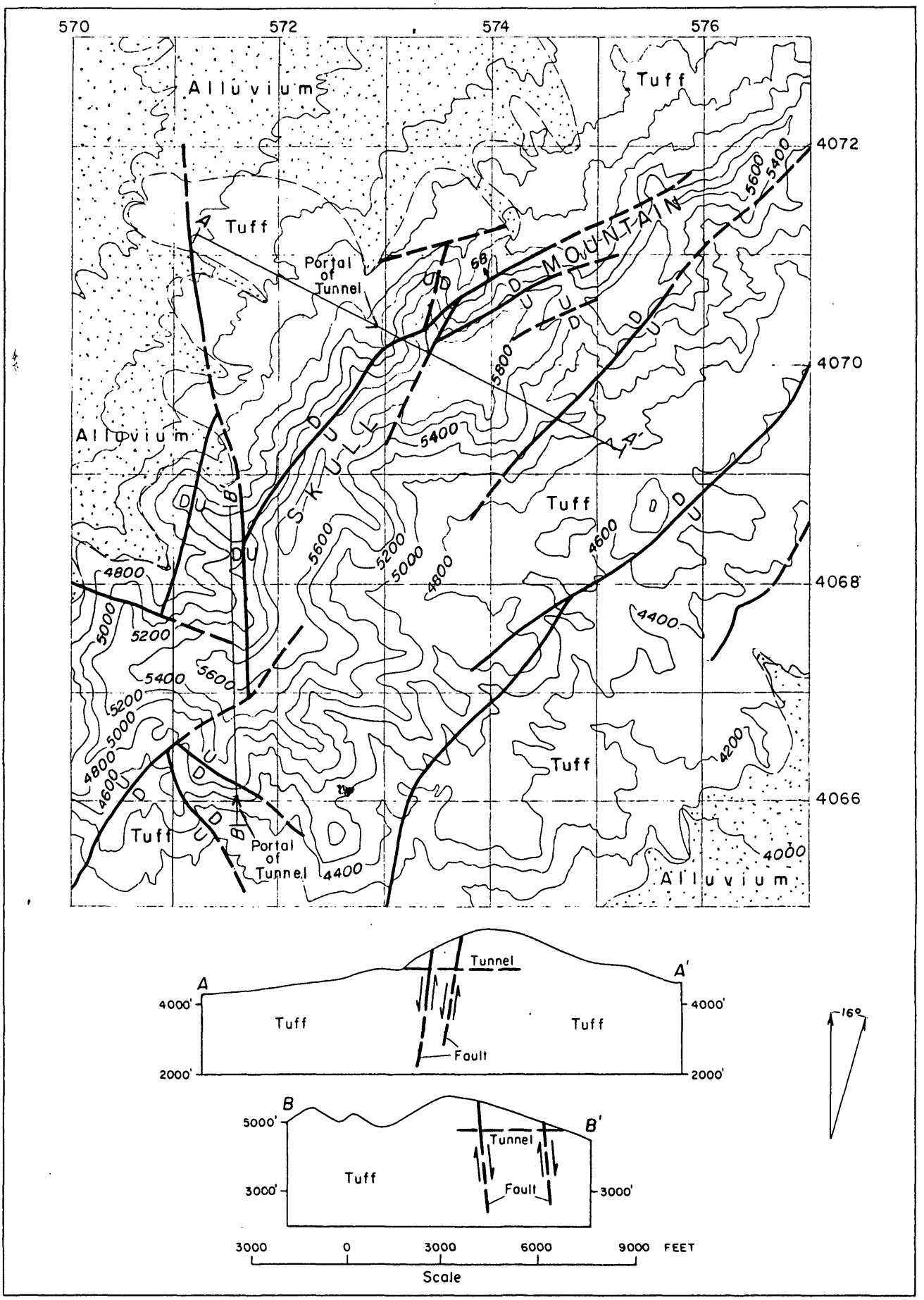


FIGURE 5.--GEOLOGIC MAP AND SECTIONS OF PART OF SKULL MOUNTAIN IN THE CANE SPRING AND SPECTER RANGE QUADRANGLES, AREA 4, NYE COUNTY, NEVADA

The rocks exposed in Area 4 are part of the Oak Spring formation and consist of interbedded varicolored tuffs, welded tuffs, and thin andesitic(?) flows. The rocks are broken by a series of steeply dipping, northeast-trending faults having more than 200 feet vertical displacement. Breccia zones are common along the faults, many of which transect the rocks in the area of greatest vertical cover and should govern to a large extent the suitability of the area for test sites. The tunnels probably will be dry but some water may occur along faults. Because of the complexity of the geology, particularly the distribution of the faults, the type of rock to be encountered in the tunnels cannot be determined without detailed geologic mapping and drilling. Approximately 4,000 feet of drilling at 3 sites will be required.

The Skull Mountain site has the following advantages: 1) Relatively short tunnels would provide 1,000 feet of cover; 2) portal of tunnels would be near existing roads and other facilities and 3) as far as can be determined, the physical and chemical properties of the rocks are similar to those at the University of California Radiation Laboratories tunnel. The principal disadvantages are: 1) Areas of high relief are small and discontinuous and cannot accommodate many shot chambers and 2) faults and breccia zones may cause tunneling and instrumentation problems.

Area 5 - Twin Peaks.--The Twin Peaks area is in the northern part of the Tippipah Spring quadrangle about 4 miles northeast of the tunnel sites in Rainier Mesa (fig. 1). The area is contained within coordinates 575 to 578 E. and 4119 to 4122 N., and is easily accessible.

The maximum amount of area in which 1,000 feet of vertical cover can be obtained is approximately 0.2 square mile. The area of high relief is an elongate north-trending ridge that forms Twin Peaks and is bounded on

the east and west by deep valleys. Cross sections along the proposed alignments of Tunnel No. 1 (B-B') and Tunnel No. 2 (A-A') show graphically the amount of vertical cover and the rocks likely to be encountered (fig. 6). The following table lists data on cover, length of tunnels, kind of rock likely to be penetrated.

	Maximum cover (feet)	Total length (feet)	Footage in volcanic tuff	Footage in quartzite
Tunnel No. 1 (B-B')	1,000	2,500	2,500	0
Tunnel No. 2 (A-A')	1,150	3,600	2,200	1,400

Figure 6 is a reconnaissance geologic map of the proposed tunnel site. The volcanic tuff shown in the southwest part of the map overlies the quartzite which is exposed in the northeast part. The volcanic tuff is moderately well cemented and can be penetrated easily by tunneling. In its lower part the tuff may probably be soft, require timbering and water may be present near the contact with the quartzite. The quartzite is a hard rock, highly fractured and difficult to penetrate by tunneling. Timbering will probably not be required.

All of the rocks dip to the west though locally there is considerable divergence in direction and degree of inclination. The contact between the tuff and quartzite is highly irregular; relief locally may be as much as several hundred feet. The position of this contact as shown in the cross sections (fig. 6) is the best average that can be determined from existing geologic data. It is emphasized that the true position of the contact may depart by as much as 200 feet from the line shown on the cross section. If it is necessary to maintain the tunnels in the volcanic tuff, the exact position of this contact must be determined by drilling. It is estimated that two drill holes totalling approximately 2,000 feet would be required to verify the position of the contact.

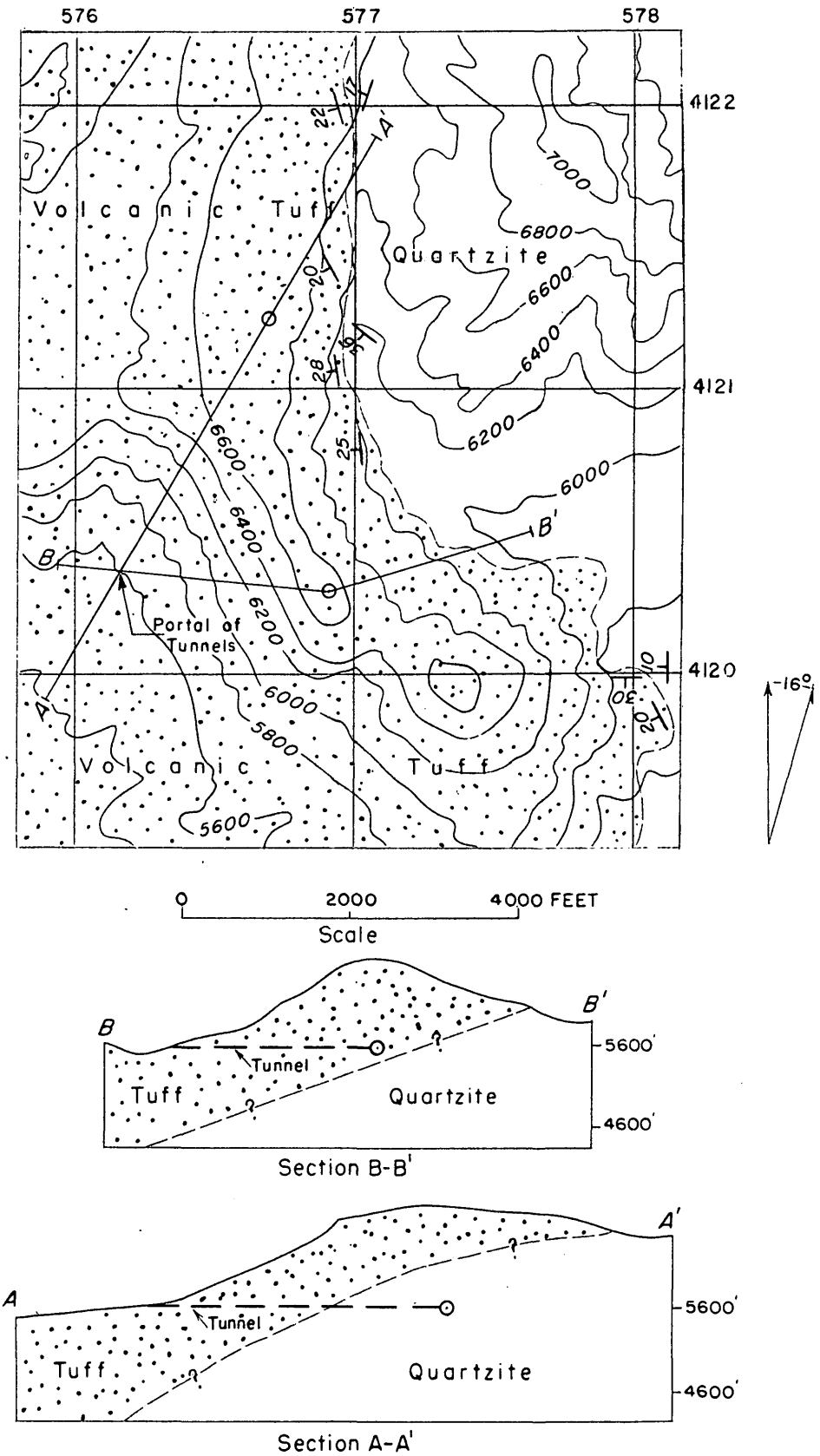


FIGURE 6.--GEOLOGIC MAP AND SECTIONS OF PROPOSED TUNNEL SITE, AREA 5, TWIN PEAKS AREA, TIPPIPAH SPRING QUADRANGLE, NYE COUNTY, NEVADA

The advantages of the Twin Peaks area are that roads and other facilities are nearby, and for a shot chamber in tuff the properties of the rocks are known. The major disadvantage is that only a few chambers with a 1,000-foot cover can be obtained.

Area 6 - One mile west of Twin Peaks.--Area 6 with coordinates of 573 to 576 E. and 4119 to 4122 N., is about one mile west of Twin Peaks (fig. 1). The area of maximum vertical cover consists of two flat-topped mesas separated by and bounded on the east and south by deep valleys.

Two possible tunnel site locations are considered (fig. 7). Available geologic information indicates that all underground workings would be in tuffaceous rock with physical properties similar to those at the UCRL sites. The rocks in this area form a broad syncline. Some free water may be found. A few selectively located drill holes would be required to verify the position of the contact with underlying limestone or hard shale and to determine the presence of ground water. Low topographic relief precludes the possibility of obtaining 1,000 feet of cover by horizontal tunneling. However, sufficient cover can be obtained by resorting to a shaft or incline.

Two types of tunnel designed to obtain the desired cover are illustrated in section B-B' at Site 1. An inclined tunnel (A) started at the square symbol near B', with a vertical angle of minus 9^{o}, and a length of approximately 3,400 feet will terminate at an elevation of approximately 5,300 feet. The same elevation may be reached directly with a vertical shaft approximately 240 feet deep. If a shaft is chosen, a horizontal tunnel (B) approximately 3,300 feet long is required to reach the same terminus as the inclined tunnel (A). From this terminus drifts can be driven at approximately right angles to tunnel (B) along

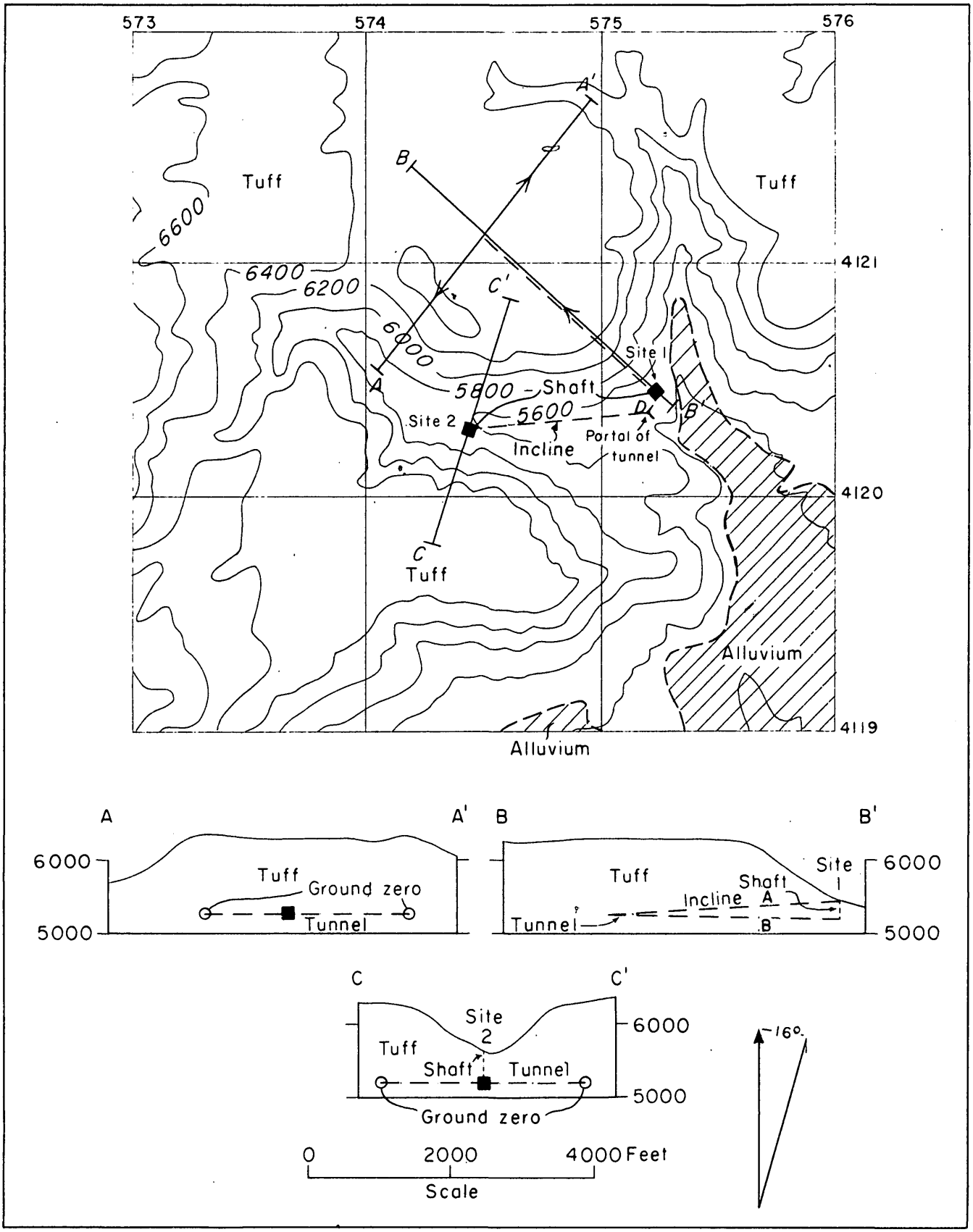


FIGURE 7.--MAP AND SECTIONS OF TUNNEL SITES 1 MILE WEST OF TWIN PEAKS AREA, AREA 6, TIPPIPAH SPRING QUADRANGLE, NYE COUNTY, NEVADA

section A-A'. Chambers requiring 1,100 feet of cover can be located 1,200 feet southwest or 1,800 feet northeast of the end of tunnel (B). By extending tunnel (B) at the same elevation to the northwest and by driving laterals on either side of it, many chambers having 1,100 or more feet of cover can be constructed. An even greater number of chambers having 800 or more feet of cover can be obtained by extending the lateral to the northeast along section A-A'.

At Site 2 access to 1,000 feet of cover can be obtained by either an incline driven from point D to the cross section C-C' or by a vertical shaft on the central part of cross section C-C' and then extending laterally along Section C-C'. An incline having a vertical angle of minus 8° and a length of approximately 2,600 feet, or a vertical shaft approximately 450 feet deep at the square symbol on Section C-C' will reach an elevation of 5,200 feet. From this point laterals can be driven in opposite directions along lines C-C'. Chambers located on the laterals at a distance of 1,500 feet will have 1,100 feet of cover. The lateral extending to the southwest is limited to one test; however, the lateral to the northeast could be extended for several thousand feet and additional laterals from it and extending to the northwest could be used for many tests requiring approximately 1,100 feet of cover.

Advantages of the general site are 1) a large area can be made available for future tests by extending outward from the same workings, 2) all excavations would be in tuffaceous rocks, 3) roads and facilities are near the site. Disadvantages of the site are 1) a shaft or inclined tunnel is necessary to attain a cover of 1,100 feet. Mining costs for an incline or shaft are higher than for a horizontal tunnel, 2) ground

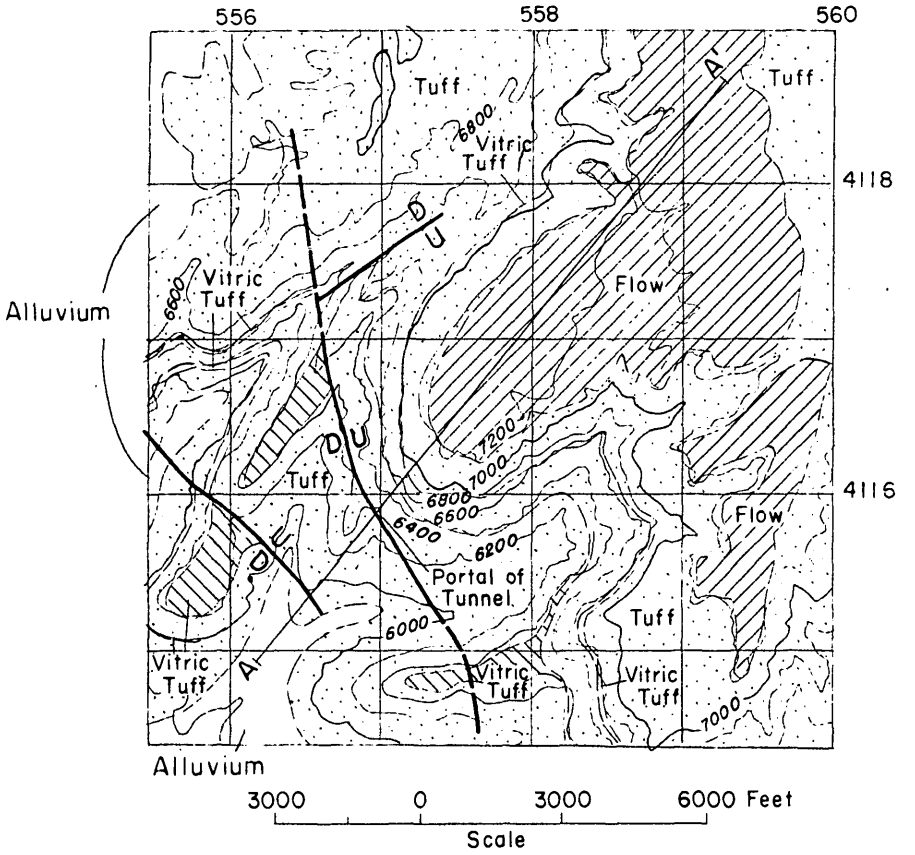
water may be present, 3) placement of cables and instruments is somewhat more difficult in a shaft or an incline than in a horizontal tunnel.

Area 7 - South-central Pahute Mesa.--A mesa lying between northeast-trending valleys in the south-central part of Pahute Mesa in the Timber Mountain quadrangle has a maximum relief of about 1,300 feet, (fig. 1). The area is within coordinates 555 to 560 E. and 4115 to 4119 N., and is accessible only by 4-wheel drive vehicles; the nearest passable road is some 6 miles to the east. A horizontal tunnel driven northeastward along line A-A' (fig. 8) would attain a vertical cover of 1,000 feet in about 2,000 feet. The area of maximum vertical cover is approximately 4,500 feet long and contains about 0.5 square mile.

Reconnaissance of the area shows that the mesa is capped by 150 feet of andesitic flow rock which is underlain by about 1,200 feet of interbedded tuffaceous sedimentary rocks, tuffs, vitric tuff, and welded tuff (fig. 8). The main faults trend northwest and have displaced the tuffs as much as 450 feet vertically. As far as can be determined the tunnels will be in tuff similar in physical properties to the rocks excavated in the tunnels on Rainier Mesa. Water will probably not be encountered in the tunnels.

Evaluation of Area 7 as a site for underground nuclear explosions would require detailed geologic mapping of approximately 2.5 square miles in order to determine the distribution of the rocks most easily excavated by tunnels. Drilling in conjunction with the mapping would be necessary to determine the rocks to be encountered beneath the mesa. It is estimated that one drill hole 1,500 feet deep would be required.

The disadvantage of this area, namely the remoteness from power and other facilities, outweighs the advantages of relatively short tunnels to



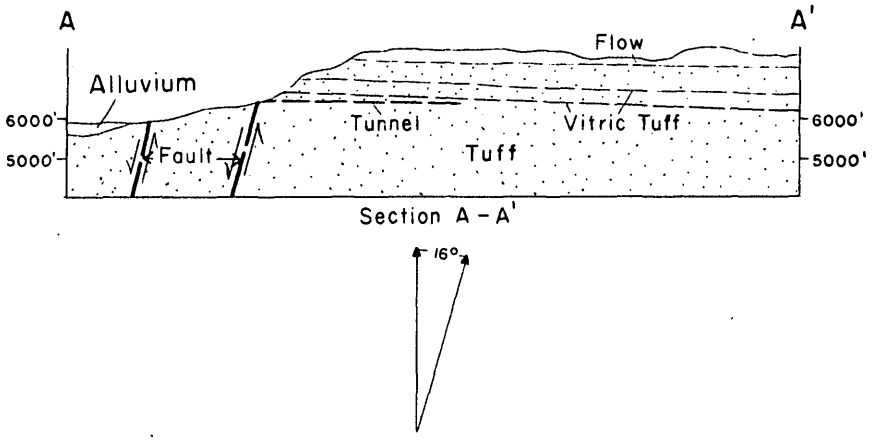


FIGURE 8.--GEOLOGIC MAP AND SECTION OF PROPOSED TUNNEL SITE, AREA 7, SOUTH-CENTRAL PAHUTE MESA, TIMBER MOUNTAIN QUADRANGLE, NYE COUNTY, NEVADA

obtain 1,000 feet of vertical cover and the ease of tunnelling in rocks for which the properties are well known.

Area 8 - Quartzite Mountain.--Quartzite Mountain is about 3 miles northeast of the tunnel sites on Rainier Mesa (fig. 1). It has steep slopes, a maximum relief of 1,800 feet, and consists of quartzite and siliceous shales. The maximum cover area is elongate, roughly 8,000 feet long and 500 to 3,000 feet wide, and has an area of about one-half square mile (fig. 9). The shortest horizontal tunnel to reach maximum cover area would be some 2,900 feet in length (fig. 9, sec. A-A'), driven southeastward from coordinates 579.65 E. and 4120.45 N. at an altitude of about 5,800 feet. Another favorable tunnel site (B) is about one-half mile southwest of section A-A' at an altitude of 5,600 feet. Tunnel length would be approximately 3,000 feet. The rocks to be penetrated by the two tunnels are quartzite and siliceous shale which are nearly as easily penetrated as the tuff in which the tunnels at Rainier Mesa are constructed. Some drilling, probably less than 2,000 feet, should be done in this area to determine the properties of the rocks at depth and the amount of ground water.

Advantages of this site are: 1) cover can be gained rapidly, 2) portal of the tunnel would not be far from existing roads and facilities, and 3) the rock will stand well without support. The disadvantages are: 1) properties of the rock are unknown, 2) time required to excavate a tunnel would be longer than in tuff and 3) area of high relief is small and only a few shots with 1,000 feet of cover can be detonated.

As shown on figure 9, section C-C', 1,000 feet of cover is attainable in quartzite and sileceous shale in Area 8 just northwest of A-A' (fig. 9).

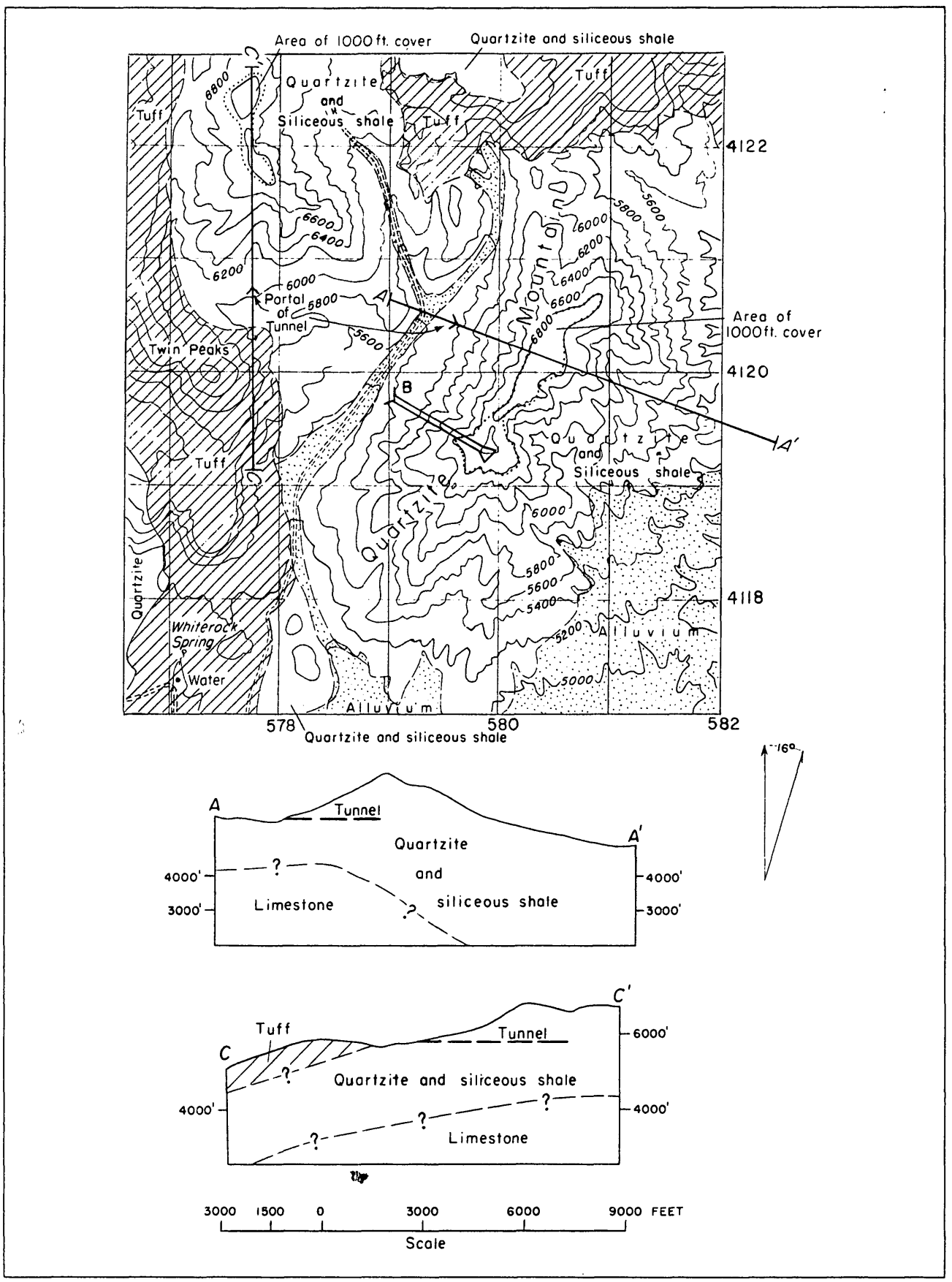


FIGURE 9.--GEOLOGIC MAP AND SECTIONS OF PROPOSED TUNNEL SITES, AREA 8, QUARTZITE MOUNTAIN AREA, TIPPIPAH SPRING QUADRANGLE, NYE COUNTY, NEVADA

Because of the limited area, less than one-fourth square mile, in which cover is 1,000 feet or more this area is undesirable for testing purposes. A tunnel length of 3,400 feet would be required to attain 1,000 feet of cover.

Area 9 - Southwest of Quartzite Mountain.--In Area 9, two areas totalling approximately one-fourth square mile would provide practicable cover of 1,000 to 1,200 feet. Typical topographic expression of the maximum cover areas is shown in figure 10, section A-A'. In order to attain a cover of 1,000 feet a horizontal tunnel approximately 3,600 feet would be required.

Structure in this area is complex and the rocks have been broken by many faults and other fractures. It will be necessary to map the geology of this area in detail (1:6,000) in order to delimit rock types and structures before an adequate drilling program can be planned. Based on the present data, drilling amounting to about 2,500 feet probably will be required.

Area 10 - Southeast part of Rainier Mesa.--Carbonate rocks, chiefly dolomite, comprise the bulk of the rocks exposed in Area 10 (fig. 11).

A tentative test site has been selected by the University of California Radiation Laboratories in Area No. 10, and results of detailed geologic studies will be available in the near future. The rocks are highly faulted hard dolomites with a maximum relief of about 600 feet. To obtain a vertical cover of 1,000 feet a tunnel inclined at minus 7° would be about 3,500 feet long. A vertical cover of 1,200

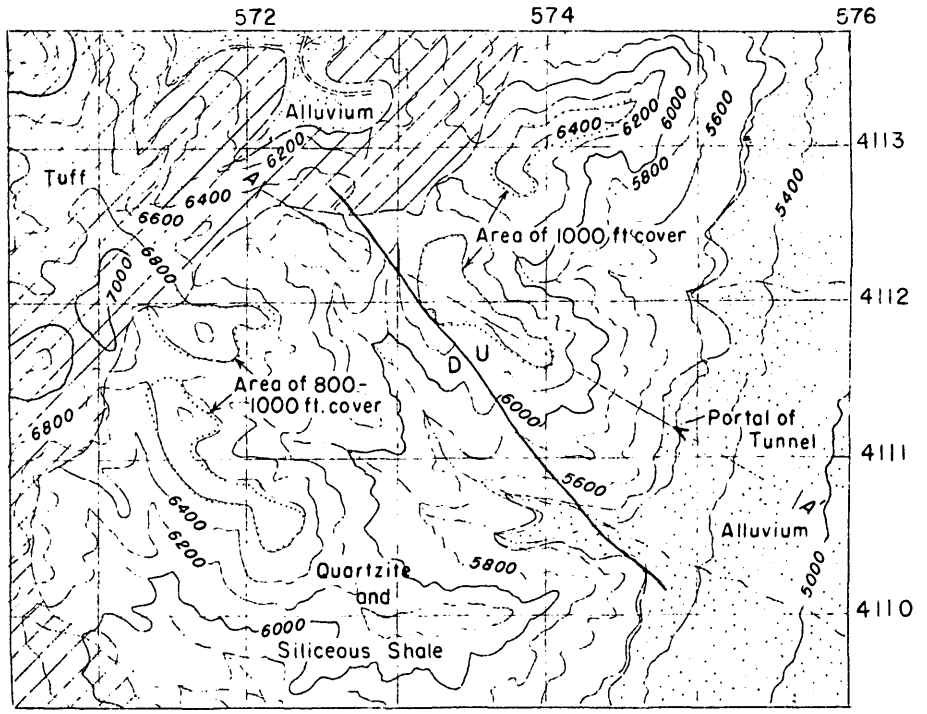


FIGURE 10.--GEOLOGIC MAP AND SECTION OF PROPOSED TUNNEL SITES IN ELEANA RANGE, AREA 9, TIPPIPAH SPRING QUADRANGLE, NYE COUNTY, NEVADA

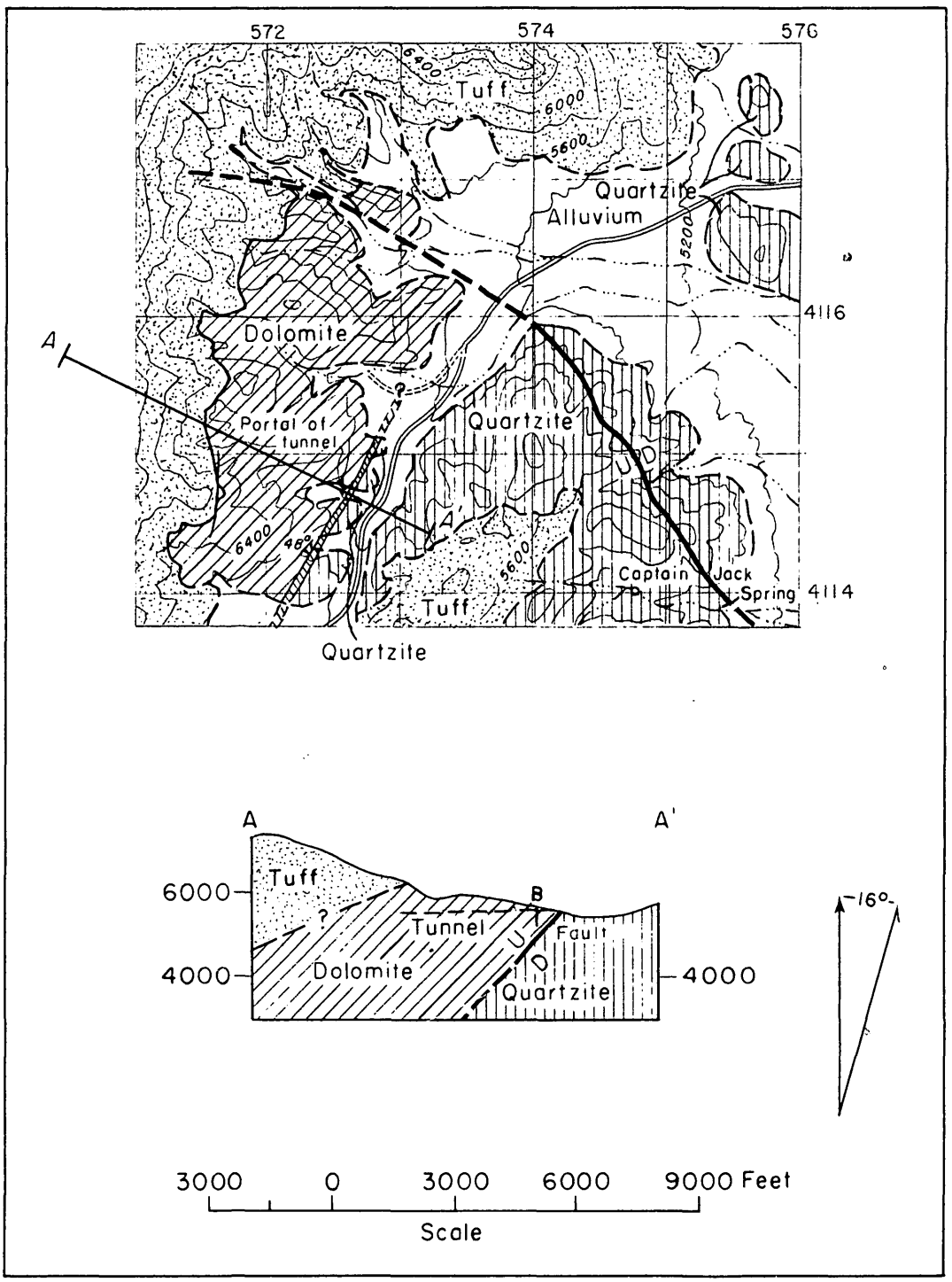


FIGURE 11.--GEOLOGIC MAP AND SECTION OF PROPOSED TUNNEL SITE, AREA 10, SOUTHEAST PART OF RAINIER MESA, TIPPIPAH SPRING QUADRANGLE, NYE COUNTY, NEVADA

feet could be attained with a tunnel 3,700 feet long and inclined at minus 9°. A chamber connected to the surface by a vertical shaft (B) about 430 feet deep and a horizontal tunnel about 3,300 feet long would have a vertical cover of 1,000 feet.

Area 11 - Northern part of Tippipah Spring quadrangle.- -Two granite masses are exposed on the Nevada Test Site. The easternmost mass in the Tippipah Spring Quadrangle is bounded by coordinates 4119 to 4122 N. and 583 to 585 E., and has an outcrop area af about 1 square mile (figs. 1 and 12). Maximum relief in the granite area is about 900 feet. Although the detailed geology and consequently the relative positions of the granite and enclosing rocks, particularly tuff of the overlying Oak Spring formation, is little known, it is estimated that a tunnel 5,800 feet long would be required to attain a maximum cover of 900 feet of granite. If as indicated on figure 12, the contact of granite and tuff of the Oak Spring formation is inclined at a shallower angle, the maximum cover would be increased. A vertical drill hole 800 to 1,500 feet deep would be necessary to determine this contact.

The second granite mass lies just north of Rainier Mesa and is bounded by coordinates 4119 to 4122 N. and 569 to 571 E. The granite is poorly exposed due to a thick cover of loose rock and soil. Total relief is less than 300 feet. The geology of this area is relatively unknown, but it is estimated more than 2 miles of tunnel would be required to obtain 1,000 feet of cover.

The granite in both masses is a coarse grained, hard, compact rock that fractures readily. Tunnel construction in the granite would have these advantages: 1) ease of drilling, 2) less overbreak in granite than tuff, and 3) walls stand well and require less lagging.

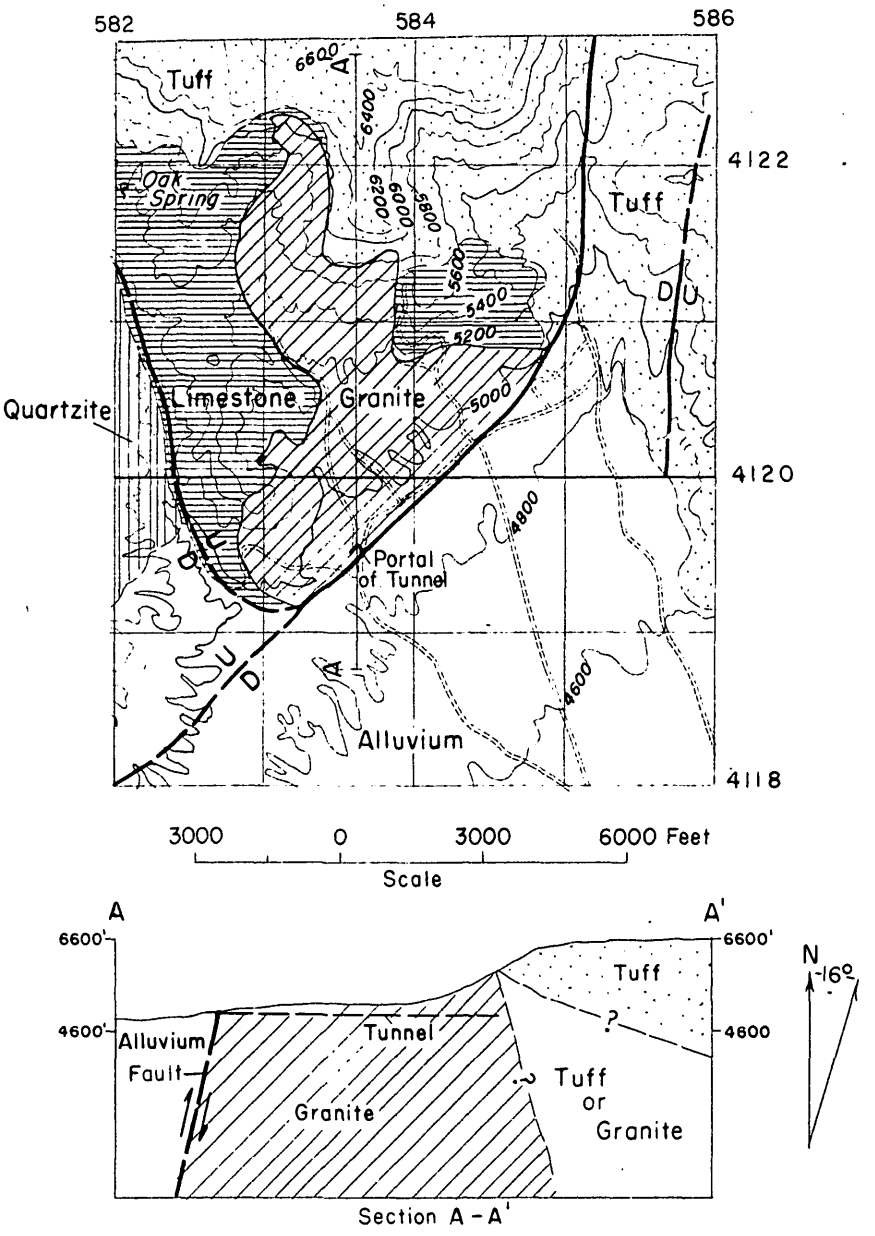


FIGURE 12.--GEOLOGIC MAP AND SECTION OF PROPOSED TUNNEL SITE, AREA II, NORTHERN PART OF TIPPIPAH SPRING QUADRANGLE, NYE COUNTY, NEVADA

Area 12 - Wheelbarrow Peak.--Within the Wheelbarrow Peak quadrangle, which lies just north of the Nevada Test Site (fig. 1), there are five areas in which 1,000 feet of vertical cover can be obtained with horizontal tunnels less than 3,000 feet long. These areas shown on figure 13 are Wheelbarrow Peak, 3 site areas along Kawich Valley and Oak Spring Butte. With the exception of Oak Spring Butte, the geology of these areas is unknown; however, from cursory examination of areal photographs for these areas, the tuffaceous rocks of the Oak Spring formation appear to thin and the flow rocks are more prominent. The structure is complex.

Wheelbarrow Peak bounded by coordinates 581 to 584 E. and 4143 to 4146 N., offers an area of approximately 1 square mile with a minimum cover of 1,000 feet (fig. 13). A horizontal tunnel driven southward from the north side of the Peak would attain 1,000 feet of cover in 2,500 feet. A small area of about 2,000 feet across near the center of the area has a maximum cover of 1,500 feet. It would require a tunnel 5,000 feet long to attain this amount of cover. The portal of the tunnel would be within one-half mile from an unimproved road in Kawich Valley.

Three areas (A, B, and C) along the east side of Kawich Valley and north of Rainier Mesa are suitable for tunnel locations.

The most northern area (A) is approximately 9 miles north of NTS and is bounded by coordinates 574 to 577 E. and 4137 to 4140 N. A 2,000-foot long horizontal tunnel driven eastward under an irregular northeast-trending mesa would reach the area of 1,000 feet of vertical cover. The area of high relief is approximately 2 miles long and is 3,500 feet wide at the widest part. It is estimated there are three-fourths square mile in which 1,000 feet of cover could be obtained.

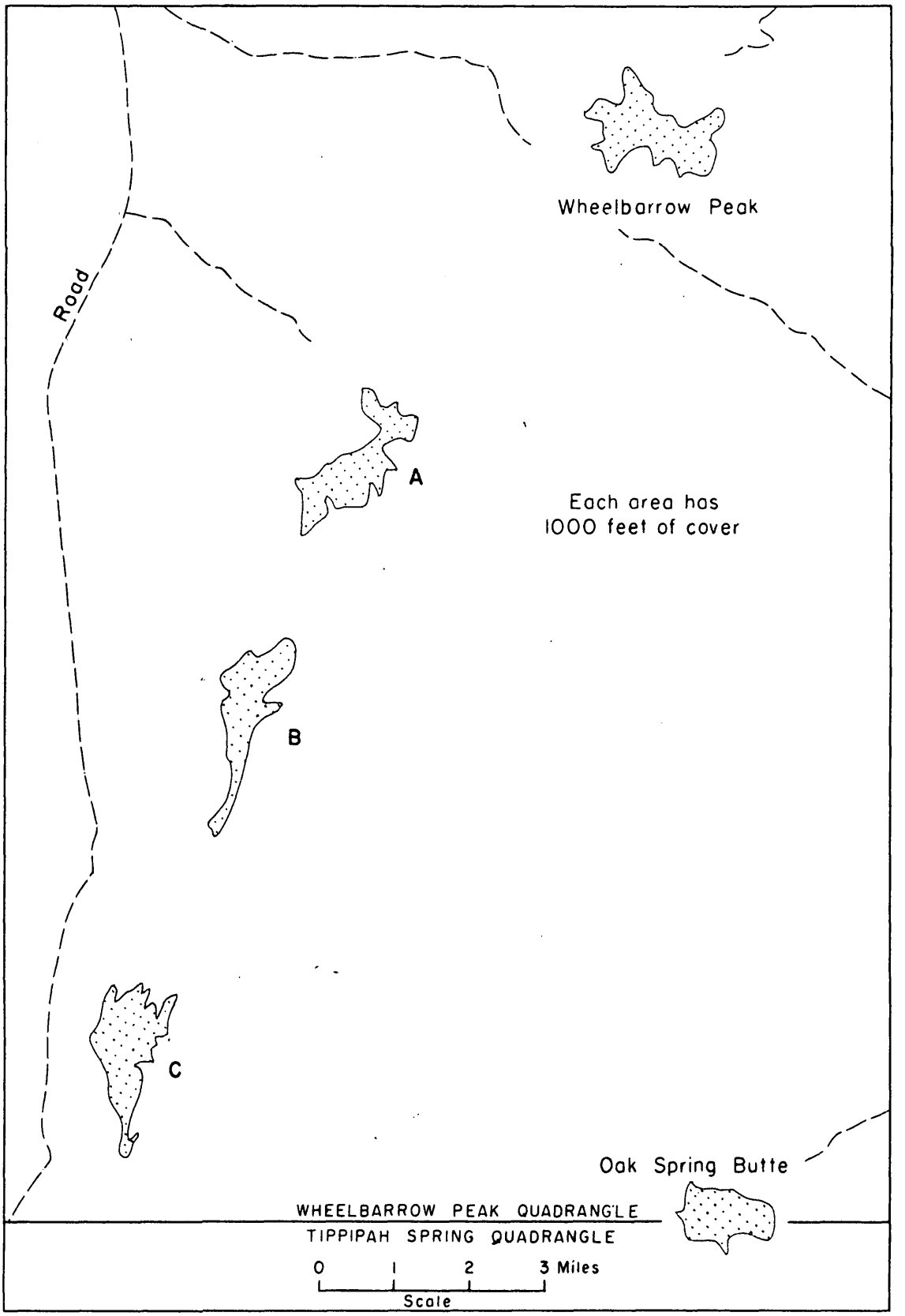


FIGURE 13.--PROPOSED TUNNEL SITES IN WHEELBARROW PEAK QUADRANGLE, AREA 12, NYE COUNTY, NEVADA

An elongate mesa (B) with steep sides facing Kawich Valley lies about 5 miles north of NTS. Approximately 0.6 square mile containing a minimum vertical cover of 1,000 feet is bounded by coordinates 573 to 574.5 E. and 4130.5 to 4134.5 N. To attain 1,000 feet of cover, a horizontal tunnel would be about 2,600 feet long. More than 1.5 miles of tunnel can be developed in the area with 1,000 feet of cover.

A mesa (C), extending 0.5 to 2.5 miles north of NTS contains an area of about 1 square mile with a minimum vertical cover of 1,000 feet. Coordinates of the area are 570 to 572 E. and 4124 to 4127.5 N. A horizontal tunnel driven eastward from the steep western slope of the mesa would attain 1,000 feet of cover in 2,800 feet.

Oak Spring Butte straddles the Tippipah Spring and Wheelbarrow Peak quadrangle boundaries and offers a limited area for which 1,000 feet of vertical cover can be obtained with a horizontal tunnel 2,000 feet long. The maximum cover area is roughly rectangular and amounts to about three-fourths square mile. Within this area a cover of 1,600 feet can be obtained with a tunnel approximately 4,000 feet long. The geology of the area is complex. Steeply dipping limestones and dolomites adjacent to an intrusive granite mass have been altered to marble and tactite. Tuffaceous rocks of the Oak Spring formation overlie the granite and altered carbonate rocks and are as much as 900 feet thick. Faults have displaced the rocks as much as 150 feet vertically but generally the displacement is much less. Oak Spring Butte area is easily accessible over unimproved roads from the northern part of NTS.

Area 13 - Aysees Peak Area.--Area 13 is an elongate mountain peak about 9.5 miles by unimproved road northeast of Frenchman Lake and about

2 miles northwest of Aysees Peak in the Frenchman Lake quadrangle, Lincoln County (fig. 1). The mountain being considered as a test site is bounded by coordinates 604 to 606 E. and 4083 to 4086 N., and has a maximum relief of about 1,500 feet. A horizontal tunnel driven southeastward from the northwest side of the mountain would attain a vertical cover of 1,000 feet with a length of about 2,800 feet. A vertical cover of 1,300 feet could be reached with a horizontal tunnel 3,500 feet long. The total area in which 1,000 feet of cover could be obtained is approximately 0.1 square mile.

The geology of Area 13 is unknown. In general it is believed to be relatively unsuited for underground nuclear explosions because of the small area of practical vertical cover, the remoteness of the area, and the relatively long tunnel length required to reach adequate cover.

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