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OPERATION CLIFF DWELLER -- DETERMINATION OF SITE LOCATION FOR HARDENED AIRCRAFT BASES

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SUMMARY

Locations suitable for a (super) hardened aircraft base are present in the United States. However, no one location has all of the features that would be desirable for such a facility. Important requirements are:

1. A steep slope with a minimum of 2,000 feet of relief in which to locate entrance and exit tunnels,
2. At least 1000 feet of rock above the main installation,
3. An open flat area adjacent to the steep slope for construction of surface runways or use as natural runways,
4. Absence of strong earthquake activity,
5. Location providing adequate potential target coverage as governed by the range of the aircraft, and
6. Feasible operational conditions, i.e., logistics, climate, etc.

A site in the northwest or northeast U. S., north of the 43rd parallel, would have the best Soviet target coverage. However, the high and steep topographic relief in these regions is not likely to have adjacent flat land suitable for natural runways and winter weather conditions would probably hinder operations.

Although a site in the western U. S., south of the 42nd parallel, would have less favorable Soviet target coverage, this region has dry lakes which may be useable for natural runways and a more favorable climate.

Detailed study by geologists and meteorologists familiar with the geology, topography, and climate of the United States will be required to determine the best possible site in the U. S. Because of the expense in constructing the proposed installation and the importance of success of such an operation, it is believed that a detailed preliminary study is justified.

INTRODUCTION

This report discusses the geographic, topographic and geologic criteria that should be considered in choosing the best possible site for a super-hard airplane base and maintenance facility. Areas in the United States which have the desired characteristics are then discussed and some example site locations are presented.

In addition to protecting the runways, personnel, supplies, fuel, and maintenance facilities, it also must be possible to get the aircraft out of the protected base and into the air as quickly as possible because the aircraft will be vulnerable when outside the protection of the base. It would also be desirable to be able to get aircraft into the facility as rapidly as possible between periods of heavy attack.

Two basic solutions to the problem exist. (1) Provide protective cover for the aircraft, the required maintenance and supply facilities, personnel, and runways and/or catapult systems. (2) Provide protective cover for everything but the runways and build the facility next to a natural runway so large that it may be considered indestructable and provide a method for rapidly moving the aircraft between the facility and the natural runway. Solution number 2 eliminates the problems and expenses connected with building long underground runways or a large catapult system and operating powerful jet engines underground. Also because of the great difficulty or impossibility of designing an underground runway with a protected entrance that an airplane can fly into, it appears that the base must be located adjacent to a natural runway for the planes to be able to return to the base after it has been attacked. Protected underground runways and/or catapults could also be included and used for take-off between closely spaced periods of heavy attack. Such a design would provide great flexibility of operation in that between periods of attack the aircraft would be able to return to the base and under more severe conditions the planes could get out of and away from the base very rapidly. A natural runway would also provide an emergency landing area in the event of engine failure during takeoff.

Because of the very great offensive capabilities of the aircraft that would be protected, the enemy would try very hard to knock out such a base. The exits and entrances for aircraft will be the most vulnerable. In order to reduce the effectiveness of a missile or bomber attack, an active defense system and protection against internal sabotage should be provided. These subjects are not considered in this report. It will be assumed that any defensive measures will not be one hundred per cent effective and that the base must be designed so that at least an effective portion of the base and aircraft will be able to survive many near and direct bomb hits.

TOPOGRAPHIC

PROTECTIVE COVER

Emergency personnel housing, supplies, maintenance area, and other facilities will be located under at least 1000 ft of rock. In this paper it will be assumed that this will provide adequate protection against the effects of several direct hits by nuclear weapons. The exits and/or entrances will be the most vulnerable, and could be collapsed near the tunnel mouth where there is less cover or be blocked with debris. As shown in Fig. 1, both of these possibilities are minimized by locating the exit on a steep slope. In this case, the tunnel mouth is self-clearing because most of the debris will accumulate at the base of the slope below the tunnel mouth. Also, a large amount of cover will be present very close to the tunnel mouth.

Figure 2 shows a section through the tunnel after several hits, and indicates that a minimum of 2000 ft of relief is required to provide 1000 ft of cover and the required space for the accumulation of debris. Even though slopes on typical mountain fronts are variable, near-vertical continuous slopes of more than a few hundred feet, are rare. However, many of the mountain slopes in the Western United States have much more than 2000 ft of relief. If more than 2000 ft of relief is available, the average slope below the tunnel mouth only needs to be greater than the angle of repose of the rock debris to provide space for accumulations. The location of a tunnel mouth in a typical mountain face is shown in Fig. 3.

NATURAL RUNWAY

Figure 3 also shows a typical topographic profile between a mountain front and a natural runway such as a dry lake bed or salt flat.

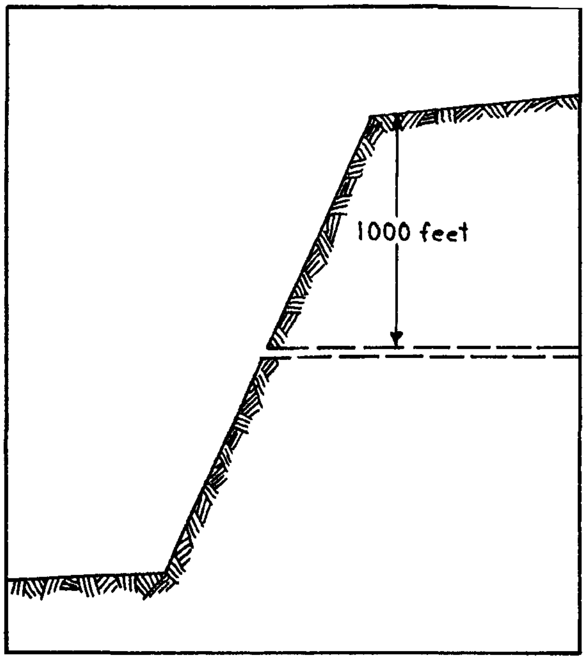


Figure 1 Vertical section through tunnel located in idealized steep slope.

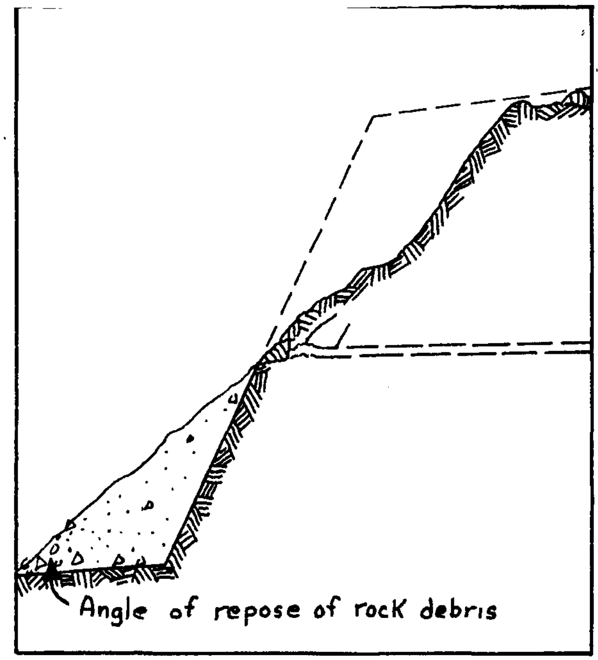


Figure 2 Vertical section showing blocked tunnel.

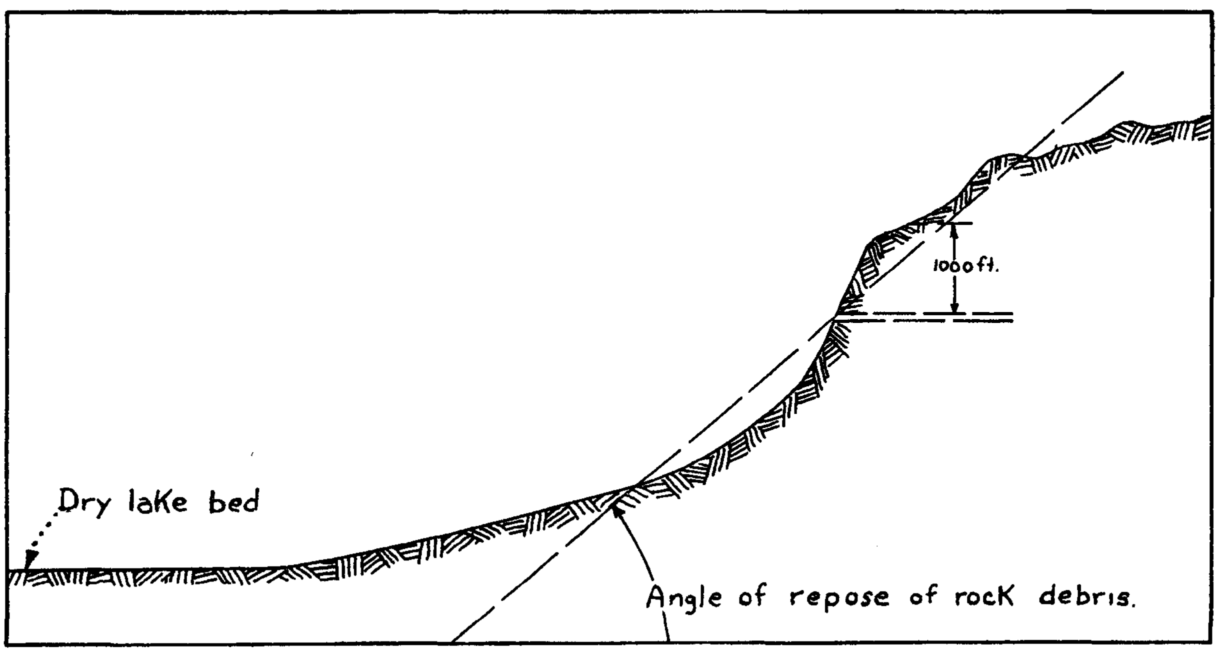


Figure 3 Vertical section through an ideal mountain slope.

The mouth of an access tunnel to be used for normal peacetime operations can be located near the level of the natural runway. The mouth of such a tunnel will be vulnerable and would very probably be blocked with unmanageable quantities of debris by a direct or close hit.

The feasibility of using a natural runway after hostilities have started depends on the following factors:

1. Can a natural runway sufficiently large, smooth, and strong be found? Large dry lakes occur in the intermontane areas of the Western United States and many are located adjacent to steep mountain slopes with several thousand ft of relief. However, many of the dry lake beds are cut by sharp topographic breaks along ancient shore lines and are gullied by recent stream action. Also, some of the dry lake beds have very shallow water tables so that a heavy load can break through the hard surface crust into the soft and wet material beneath. Because the hardness and smoothness of individual dry lake beds are so variable and sufficient data are usually not available, field studies of any proposed natural runway will be required.

2. Can an invulnerable and easily cleared tunnel mouth for an entrance be built? Figure 4 shows a possible design for such an entrance. Blast protection is provided by locating the tunnel mouth below a very steep slope. The access path is located on a ridge which could be modified with the fill material available from the tunnelling. Although the path is not completely self clearing, the volume of debris which could accumulate and block the entrance is very small, and could be blasted and/or bulldozed out of the way. The path could also be cratered by bomb hits. Therefore excavation and smoothing of the path may be required after an attack; this will require heavy excavation equipment. The danger from residual radioactivity

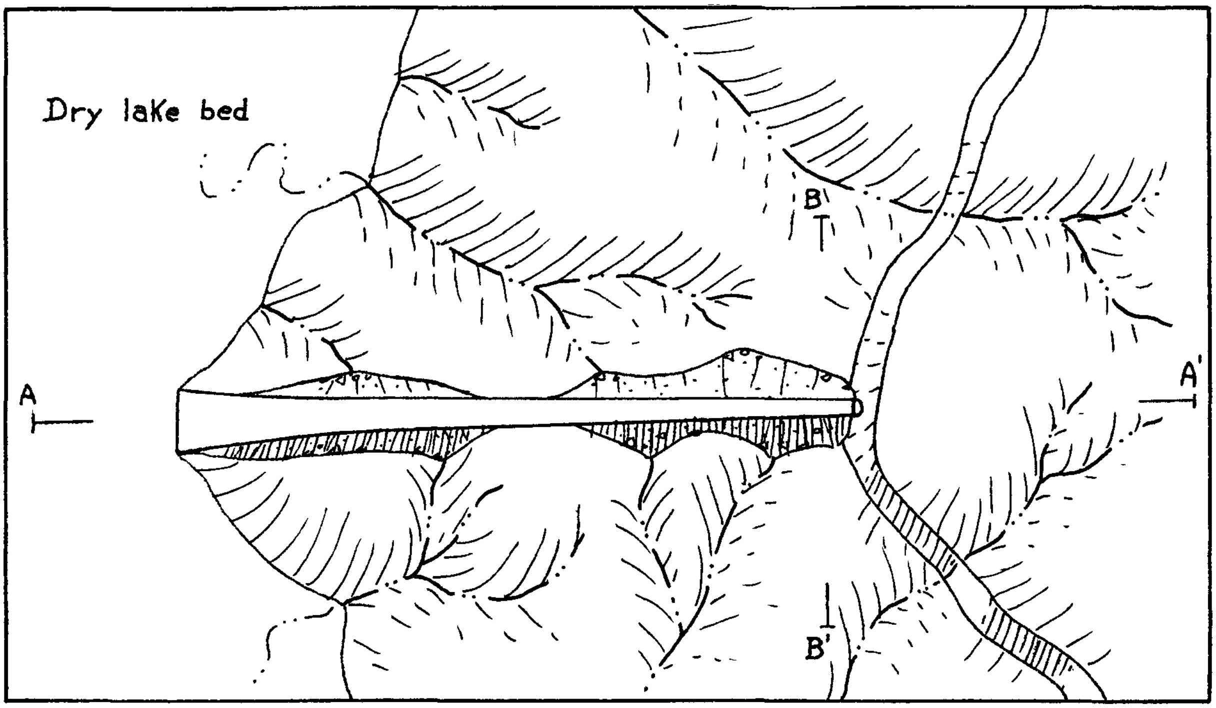


Figure 4 Map view of proposed entrance ramp and tunnel design.

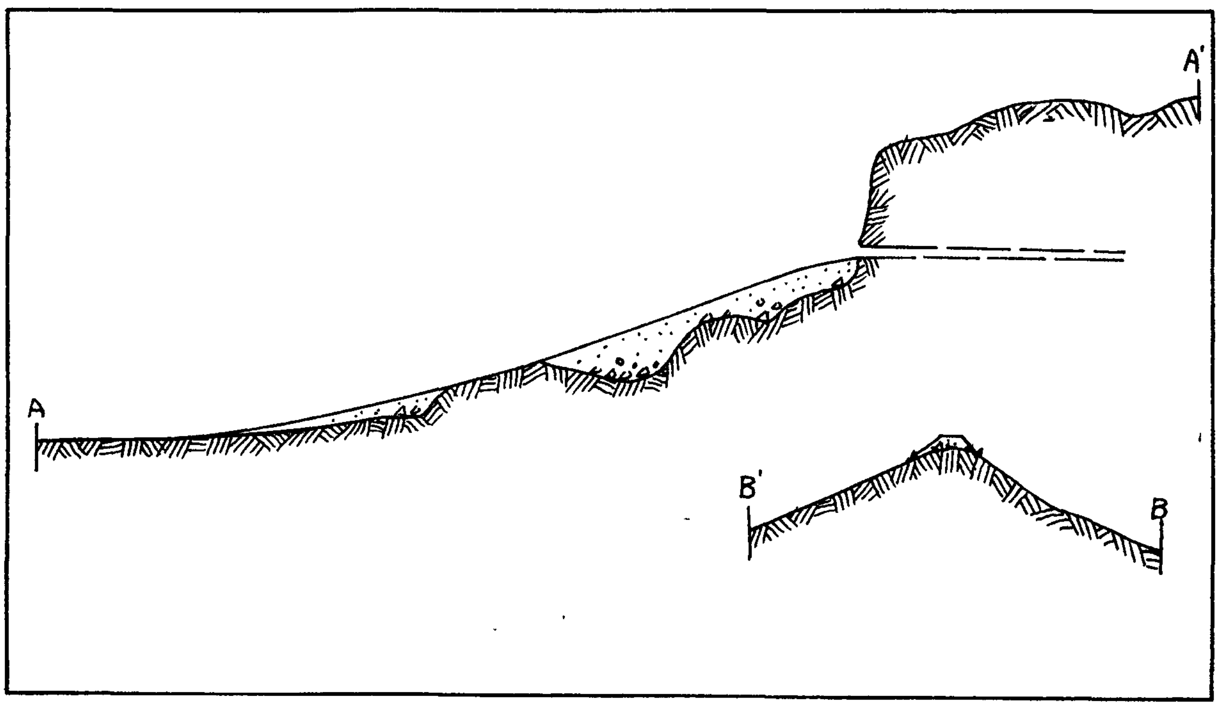


Figure 5 Vertical sections of proposed entrance ramp and tunnel.

to the operators could be reduced by heavy shielding of the cabs of such equipment or be eliminated by remote operation using television cameras. A more detailed study is required to determine whether the path can be cleared and smoothed rapidly enough to make the entrance tunnel useable a sufficient percentage of the time. The amount of maintenance work that would be required will depend on the path smoothness and strength required for the landing gear. The bearing pressure could be reduced by providing a carriage for each wheel assembly. Also portable metal runways could be stored inside the base and placed over the path between the natural runway and entrance tunnel. A major disadvantage in using a natural runway will be the time required to move the plane between the base and runway. Providing the path is prepared and any necessary auxiliary equipment is waiting on the runway, it should be possible to move the airplane in thirty minutes. If the maximum ICBM warning time is less than this, the aircraft will be vulnerable. Other more imaginative systems of moving the aircraft between the tunnel mouth and natural runway on portable rails or on cables seem impractical. Also such systems would probably require more time to assemble or repair following an attack than the time required to repair a smooth path on solid rock and/or fill.

3. Would periodically lobbing in a bomb make it impossible to operate on a natural runway by maintaining a prohibitively high level of radioactivity and obscuring vision with clouds of dust? This may be cheaper for the enemy than an attempt to dig the base out with a single heavy attack. However, such a strategy probably would not neutralize the protected runways and/or catapults and only the ability to get planes back into the base would be lost. Also, it would require the enemy to hold back and protect many missiles and/or bombers.

FACING DIRECTION

It has been suggested that the tunnel entrances should face south or away from the most probable direction of a missile attack. Although most of the mountain ranges in the United States trend north-south, it should be possible to attain a south facing entrance by using the local irregularities or ridges and canyons on a north-south trending mountain front.

GEOLOGICAL

EARTHQUAKE DANGER

An earthquake could collapse portions of the tunnels, or block the entrances by landslides. In addition, offset along an active fault during an earthquake could block tunnels and disrupt pipe lines, tracks and communication cables. It should be emphasized that very violent and destructive earthquakes have occasionally occurred in areas with no previous or subsequent history of earthquakes. Therefore, the possibility of earthquake damage is reduced but not eliminated by locating the base in an area with no previous history of earthquake activity. An installation that is designed to resist the effects of several direct hits by high yield nuclear weapons is not necessarily earthquake proof because the energy released by an earthquake is many times greater than that released by the most powerful weapons.

TUNNELLING PROBLEMS AND BLAST PROTECTION

The excavation and internal support of large, deep, underground tunnels and rooms involves many geologic engineering factors. Our problem is more difficult because the necessity of providing blast protection not only magnifies the geologic problems inherent in any underground installation, it also creates some additional problems. The geologic influences that must be considered in the usual underground installation are well summarized elsewhere.(1) Therefore, in this paper the geologic considerations that may influence the degree of blast protection will be emphasized.

In choosing the type of rock which will give the best protection, we are faced with the following enigma: the strongest, most homogeneous and least fractured rock will best resist the effects of the shock waves at the tunnel surfaces. However, fractured, inhomogeneous, weak rock will attenuate the shock waves the most. Therefore, the most desirable location would have very strong and homogeneous rock at tunnel depth overlain by soft, fractured and/or layered rock. Also multiple layers of hard and soft materials might tend to channel off and attenuate blast energy because of extensive refraction and reflection at discontinuities. Under certain geologic conditions, it may be advantageous to fracture a portion of the overlying rock by setting off charges at the bottom of core holes.

Under the topographic criteria for site location, it was shown that it would be desirable to locate the tunnel mouths in very steep slopes. It was also suggested that the tunnel could be blocked with unmanageable quantities of rubble when the original steep slope was reduced to the angle of repose of the rock debris. Therefore the rock forming the steep slope should be strong and stable in order to resist the effects of nuclear explosions.

It should be noted that a very high steep slope does not imply great strength for the rock forming the slope. For example, very soft stream deposits will commonly stand in almost vertical cliffs. The stability of the slope will depend in part on the orientation of the internal structure (bedding, foliation, joints, and faults) of the rock with respect to the slope. Unless the steep slope is the result of very recent fault, movement or rapid stream or glacial errosion it will be formed naturally in the most stable configuration.

Some of the underground shots in Nevada caused movement on pre-existing faults cutting tunnels although adjacent portions of the tunnels were unaffected.(2) Therefore, faults should be avoided or the facility should be designed so that movements along faults which cannot be avoided would not cause serious damage. Slippage along bedding, joints, or foliation might also be induced by a nuclear blast.

Water can be a serious problem in any underground installation. The proposed facility would also be vulnerable to water flows that could be caused by the blast effects. For example, a perched water table well above the tunnel level and which caused no trouble during excavation could drain into the installation along fractures formed by nuclear explosions. This would be particularly serious while the base is "buttoned up" unless adequate and reliable drainage tunnels are available.

The author has not discussed in great detail the types of rock and geologic structure that should be found for the installation. This is because the physical characteristics of a rock within a single homogeneous rock mass or between rock masses of similar composition are so variable. For example, the same rock unit may be unweathered and unfractured in one area and deeply weathered and/or fractured in a nearby location because of a different geologic history and structure. Also because of the necessity of strong, stable slopes and tunnel surfaces and the desirability of shock wave attenuation by weak rock almost any geologic configuration will provide some desirable features. It should also be noted that the steep slopes required are most common in areas which are undesirable because of earthquake activity. This further complicates the problem of site selection.

GEOGRAPHICAL

It would be advantageous to locate the base in the northern part of the United States or in Alaska so that the distance to targets in Russia can be kept to a minimum. However, portions of the northern United States have a wet climate, and because of more rapid errosion and weathering, the mountain slopes will on an average not be as steep except in areas of severe earthquake activity such as Alaska. And, of course, the discovery of a dry lake bed or other dry natural runway in a wet climate appears unlikely. Also, in some parts of the northern United States and Alaska, operations would undoubtedly be hindered by dense fog, snow and heavy rain.

It will be advantageous to close the public to a large area around the base in order to keep the details of the location, design, and operation of the base as restricted as possible. Therefore, it would be desirable to locate the facility in an isolated area so that the dislocation of mining, agricultural, and recreational activities could be kept at a minimum. Also, because of the extremely high level of radioactive fallout to be expected in the vicinity of the base if it is attacked, the base probably should not be located close to a population center. However, if possible the facility should be built close to an existing air base to eliminate the necessity for building personnel housing and the other surface facilities required for the normal peacetime operation of an airbase. Convenience to existing railroads and highways would also be desirable.

A location close to the coast would be undesirable because of the danger from missiles and commando type raids that could be launched from submarines and/or surface ships. Also near the coast or the boundaries of the United States, it would be difficult to provide a local defense system in depth.

EVALUATION

INTRODUCTION

This portion of the paper gives a general evaluation of favorable regions for sites in the United States. The relative importance of the factors considered will control the final selection of site location.

TOPOGRAPHY

Topographical provinces most likely to fulfill the topography requirements are outlined on Map A . Two main and widely separated areas are delineated. The largest area and the one containing most of highly favorable conditions, that is, a very steep mountain front exceeding 2,000 feet adjacent to a large flat valley, is in the western United States. Major divisions in this area include the Rocky Mountain system, Colorado Plateaus, Basin and Range province, Cascade-Sierra complex and the Coast Ranges. A smaller area, whose physical features are generally on a smaller scale than those in the west, is the Appalachian Highlands, which semi-parallels the east coast and extends from New England to Alabama. More information on topography, drainage, and climate is available from terrain studies done in the Second[3], Third[4], Fourth[5], and Sixth[6] U. S. Army Areas. The Fifth U. S. Army Area study is reported to be completed but is not yet published.

GEOLOGY

General areas which are considered unfavorable for site locations because of earthquake activity are shown on Map B. The circles on the map represent the destructive and near destructive earthquakes of the United States through 1957.[7] Multiple earthquakes in a vicinity are accompanied by the appropriate number.

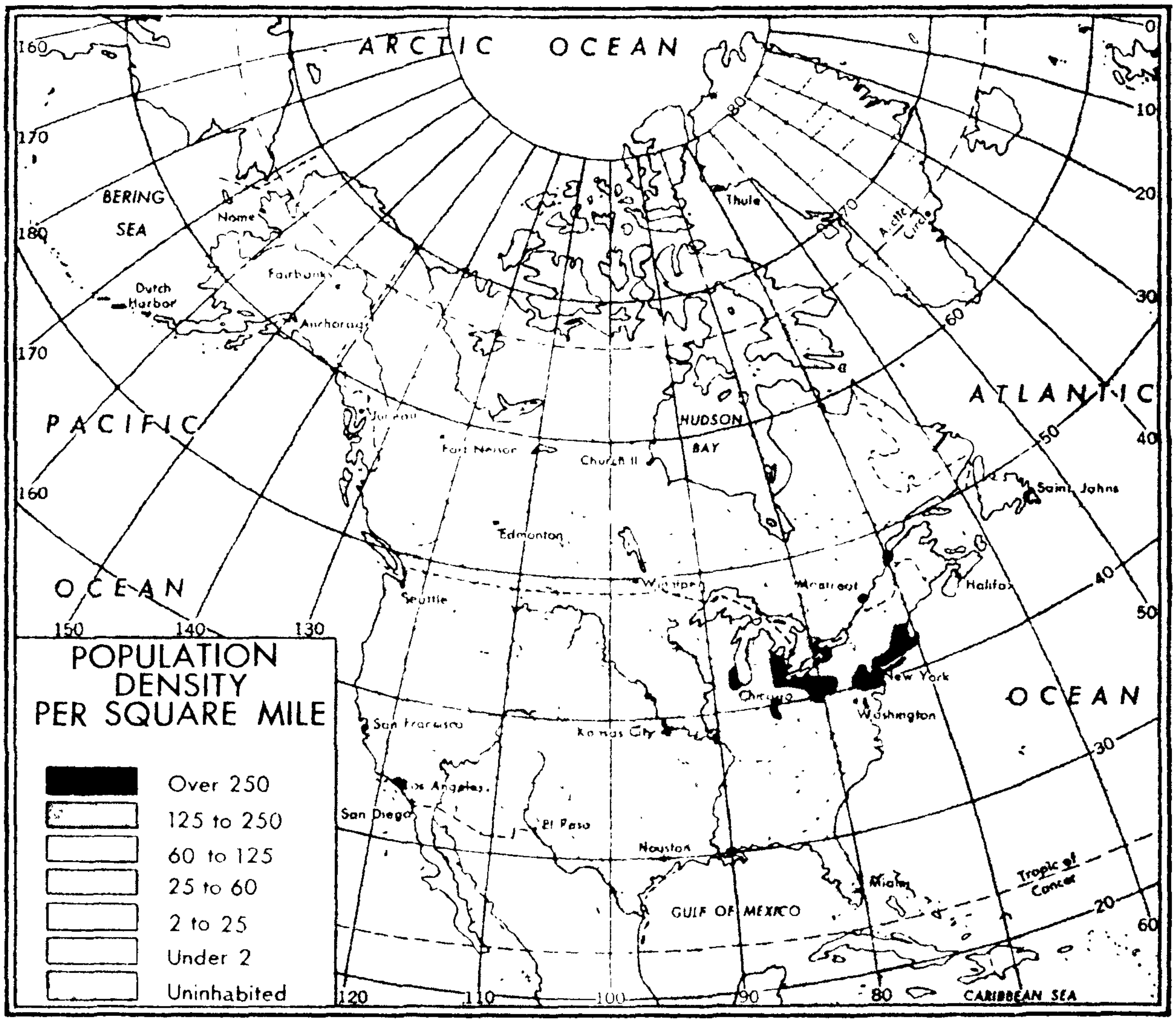
Because the geological criteria, i.e., rock type, structure, presence of ground water, noxious gases and combustibles, are complex and may vary considerably over relatively short distances, generally favorable regions are difficult to delineate. A detailed geological study in the vicinity of a site location prospect is needed. A guide to probable stability of the facility can be obtained by evaluation of excavations in geologically similar localities. Determination of its invulnerability from nuclear blasts may be estimated from what limited studies have been made regarding rock properties, properties in connection with blast damage and attenuation and/or from any measured results of damage from nuclear weapon tests as they become available.

GEOGRAPHY

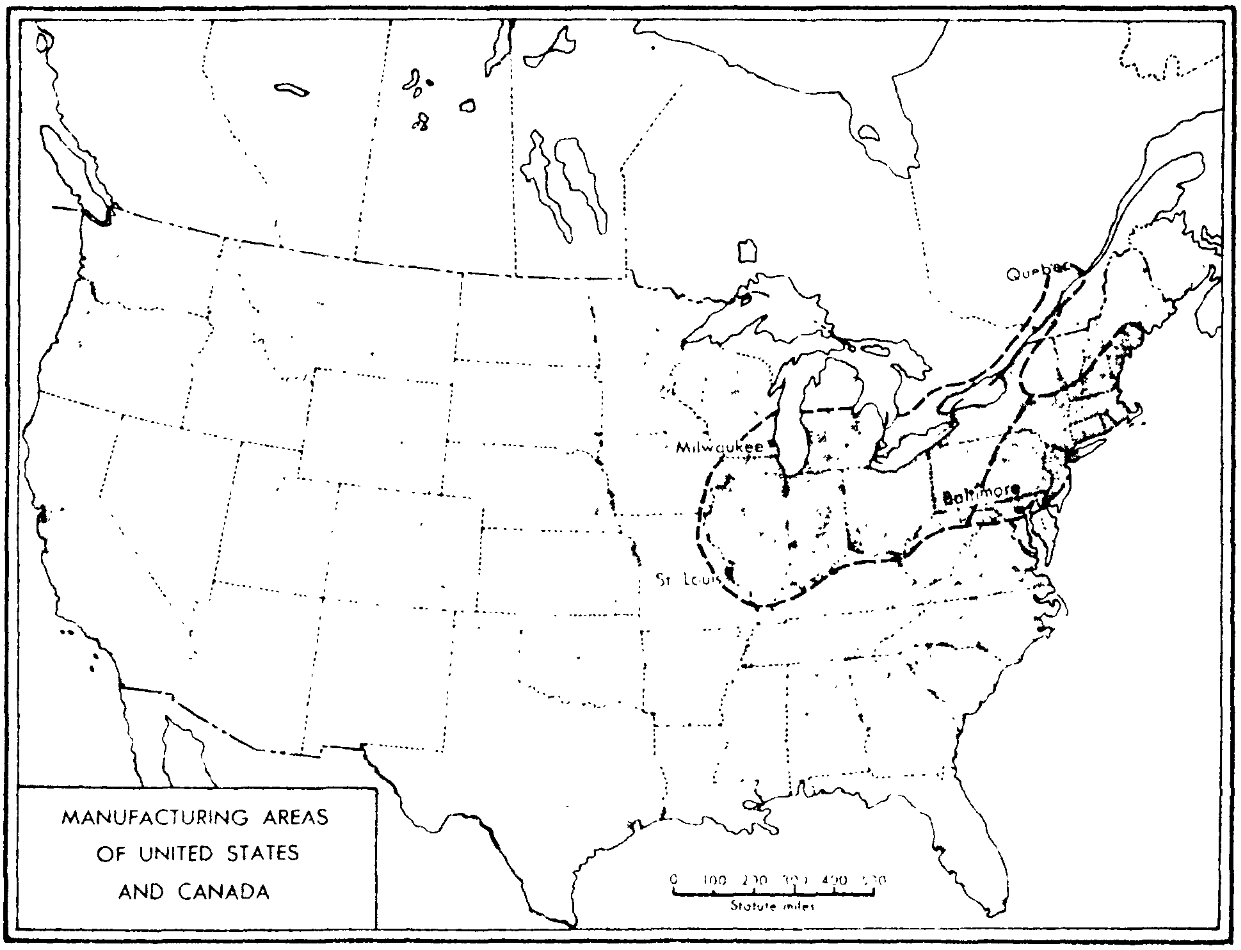
United States population density and manufacturing areas are shown on Maps C and D respectively. Their distribution is closely associated and is concentrated in the northeastern states, which makes the northeast U. S. a primary target area. A bomber site located in this area would make targeting that much more convenient for the enemy. Other disadvantages, if the site was attacked, would be additional nuclear fallout near population centers and proximity to the country's periphery.

Having a site located near an existing military airfield would be economically advantageous from the standpoint of available manpower and operational facilities. As level land is desirable for aircraft runways, many of the present airfields are in regions of flat to low topography. However, listed below are examples of some Air Force bases that have relatively rugged topographic relief nearby.

Holloman, New Mexico
Kirtland, New Mexico
Hill, Utah


ARCTIC OCEAN
BERING SEA
Nome
Fairbanks
Dutch Harbor
Anchorage
PACIFIC
OCEAN
Juneau
Fort Nelson
Churchill
HUDSON BAY
Thule
Arctic Circle
ATLANTIC
OCEAN
Saint Johns
Edmonton
Winnipeg
Montreal
Halifax
Seattle
Chicago
New York
Washington
San Francisco
Kansas City
Los Angeles
San Diego
El Paso
Houston
Miami
GULF OF MEXICO
Tropic of Cancer
CARIBBEAN SEA
POPULATION DENSITY PER SQUARE MILE
Over 250
125 to 250
60 to 125
25 to 60
2 to 25
Under 2
Uninhabited

MAP C


Quebec
Milwaukee
Baltimore
St Louis
MANUFACTURING AREAS
OF UNITED STATES
AND CANADA
Statute miles

MAP D

Peterson, Colorado

Lowry, Colorado

Stead, Nevada

Nellis, Nevada

Kingsley, Oregon

*Mountain Home, Idaho

*Malmstrom, Montana

*Fairchild, Washington

*Plattsburgh, New York

*good relief more distant

Another economic factor is land acquisition for the site. Location on existing federal land would be highly desirable, if the necessary criteria could be found in these areas. Land in the non- to sparsely populated areas would normally be more easily acquired than more populated areas. However, national parks, wild life refuges, wilderness areas, and scenic recreational areas are to be avoided.

The most geographically restrictive factor in determining site location is the range of the aircraft. Without refueling, the maximum range of the B-70 is about 6,500 nautical miles. With refueling, it is about 7800 nautical miles. To get an idea of how many Soviet and Soviet Satellite targets(8) the B-70 can reach from various locations in the U.S., maps have been made to compare the relative geographical and numerical target coverage from representative take-off points. The take-off points used were Air Force bases: Loring, Maine; Plattsburgh, New York; Walker, New Mexico; Ellsworth, South Dakota; Malmstrom, Montana; Fairchild, Washington; Elmendorf, Alaska; and Eielson, Alaska. Because returning the aircraft directly back to the contingent U. S. would result in very poor target coverage, a different post-strike base or return trip refueling area has been used.

Thule, Greenland was chosen to allow greater target penetration and to provide the Greenland ice cap as an emergency natural landing field in case home bases are destroyed or the fuel supply depletes faster than expected. This would also be about the first post-strike area where aircraft could refuel before continuing back to other bases in the U. S. In the case of operations from the Alaska bases, when the distance from the target to Thule exceeds the distance from target to home base, the aircraft returns to Alaska after completing its mission.

Although it would be best not to have to rely on refueling en route to target, both the 6500 n miand the 7800 n mi ranges have been reviewed to determine whether the additional target penetration gained by refueling makes it worth serious consideration. Maps E and F show 6500 n mi and 7800 n mi ranges respectively. Table I shows target coverage figures and percentages for both ranges.

Using the 6500 n mi range target coverage from any one U. S. base is not outstanding. Eielson, Alaska, scores the highest with 384 out of a total of 597 targets or 64%. However, it misses part of the important southwestern section. The best located contingent U. S. base, Loring, scores 53%, but it is in a low topographic area. The next best base, Plattsburgh, scoring 46%, is in a more favorable topographic area. Ellsworth and Malmstrom tie with 21% and have similar target coverage, i.e., complete east-west sweep in the northern part of the Asiatic continent. Fairchild, at 17%, covers northeastern Asia a little better than Malmstrom. The low score of 6% for Walker precludes this general area as a possible site, even though it has some of the most favorable site characteristics. The best geographic location of a site based on 6,500 n mi range then is Alaska, New England and Northern Rocky Mountains respectively.

Table I

	BASE	A	B	C	D	E	F	T	P
				AIRFIELDS					
6500 n mi RANGE	I Ellsworth	11	5	53	18	41	---	128	21%
	II Fairchild	10	4	54	16	16	---	100	17%
	III Great Falls	11	6	55	18	38	---	128	21%
	IV Loring	54	23	91	37	112	---	317	53%
	V Plattsburg	38	18	80	31	108	---	275	46%
	VI Walker	1	1	34	---	---	---	36	6%
	VII Elmendorf	76	21	92	60	84	31	364	61%
	VIII Eielson	83	23	93	63	91	31	384	64%
7800 n mi RANGE	I Ellsworth	96	32	102	59	124	---	413	69%
	II Fairchild	106	35	106	71	115	---	436	73%
	III Great Falls	109	35	109	68	122	1	441	74%
	IV Loring	112	44	112	59	131	---	444	74%
	V Plattsburg	108	41	108	52	131	---	430	72%
	VI Walker	49	16	49	35	108	---	291	49%
	VII Elmendorf	120	48	120	74	131	65	546	91%
	VIII Eielson	125	49	125	82	131	65	560	94%
	MAXIMUM TOTALS	131	52	108	86	131	89	597	100%

CODE

A Industrial Cities
B Population cities not included in "A"
C Airfields, primary, Soviet Union
D Airfields, secondary, Soviet Union
E Airfields, European Satellites
F Airfields, Asiatic Satellites
T Total
P Percentage of T to maximum total of 597

*Target data is from RAND RM-1683 by E. P. Oliver and J. A. Wilson, dated February 7, 1956

Using the 7800 n mi range, the Alaska bases still have the most target coverage, totaling about 92%. The Northern Rocky area averaging about 74% ties for second place with the New England area. The Walker area at 49%, compares favorably only with 6500 n mi coverage for the other bases, except Alaska's.

The amount of increased target coverage gained by the longer range seems to indicate that it should be used if at all possible. A certain percentage (20-40%) of the aircraft could be programmed for the longer range, and then if at the time of strike, refueling en route is not possible, these aircraft would adopt a prearranged alternate, shorter range mission.

In the case where 6500 n mi is the maximum range because refueling en route to target is not available, the success and coverage of the mission could be greatly enhanced by having more than one home base. With one base in the Northeast and one in Alaska and/or the Northwest, shallower penetration over hostile territory could be planned for the same target coverage and dispersal would improve survival of the operation. The same advantage, perhaps to a slightly lesser extent regarding target coverage, would apply to 7800 n mi maximum range. Maps G and H are examples of target coverage using two bases with 6500 n mi and 7800 n mi ranges respectively.

In brief summary, the most likely areas for a suitable site are Alaska, Northwest U. S. or Northeast U. S., with more than one site being most desirable. See Map I.

Because a site in contingent U. S. seemed best from an operational standpoint, Alaska wasn't seriously considered until the range restictions revealed the importance of a very high latitude location. Consequently, paucity of time did not permit preparing maps for this area. Alaska has topographically favorable areas, especially in the southeast and northeast. A narrow earthquake belt borders southern Alaska and extends inland from about the center of the coast. Population and manufacturing areas are sparse. The climate ranges from marine west coast through subarctic to tundra in a northerly direction.

NORTHERN UNITED STATES

Because of the convenience to targets in Russia, the continental United States between the Great Plains and Pacific Ocean and north of the 43rd parallel was studied in greater detail on available topographic maps at a scale of 1:250,000 (published by U. S. Army Engineers). It was found that several suitable mountain slopes with between 3000 and 4000 feet of relief occur in this region. The areas are shown on Map I. All of these possible base locations are located adjacent to fairly smooth open areas on which surface runways could be constructed. However, data on the terrain, climate, and vegetation indicate that none of these possible base locations are located near a natural runway. Regional study indicates that large dry, lakes and salt flats which may be suitable for a natural runway and which are located near a slope with more than 2000 feet of relief do not occur in the western United States north of the 42nd parallel (northern boundary of Utah).

It was also found that the topographically favorable areas in the northwest United States fall in climatic regions with the following characteristics: (1) average annual precipitation of 7 to 29 inches, (2) average of 60 to 120 days per year with 0.01 inch or more of precipitation, (3) average annual snowfall of 30 to over 100 inches, (4) average minimum temperature of the coldest month 0 to 20°F.[(6)] The above data indicate that weather conditions would hinder operations during the winter months in these topographically favorable areas and make it difficult to use a hardened base as a maintenance facility during peacetime.

It should also be noted that some of the areas in Montana have the disadvantage of being located in an area of moderate earthquake activity.

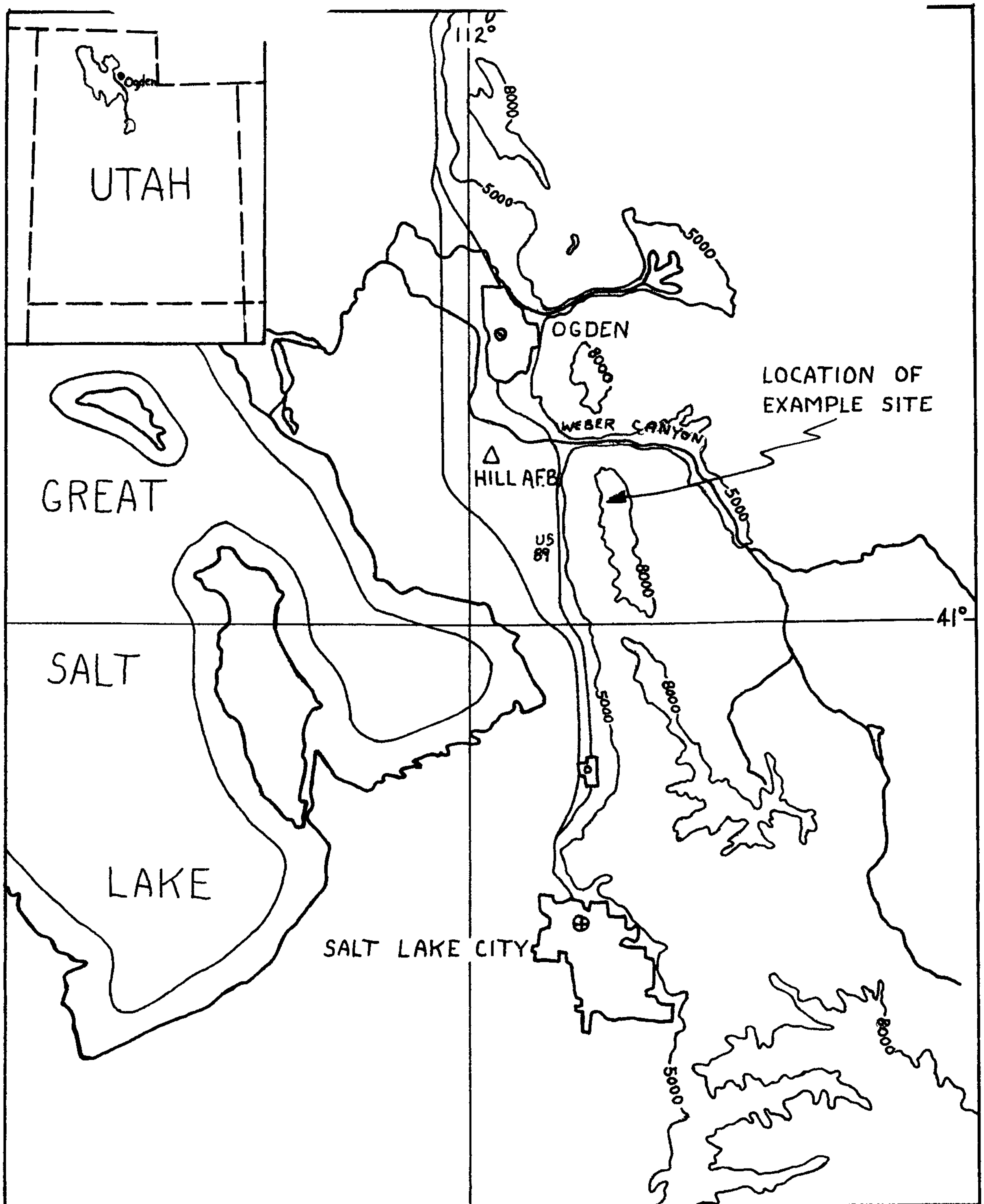
The Northeastern part of the United States was not studied in detail. However, it is believed that topographically favorable areas are present. The northeastern U. S. would also have the disadvantage of severe winter weather and lack suitable natural runways.

AN EXAMPLE SITE

East of the Great Salt Lake in Utah the Wasatch Range has a westerly facing steep escarpment. The section of the range south of Weber Canyon, which is the example site area, has a maximum topographic relief of 4,900 feet. The steepness of the slopes commonly range from 45° to 26°. The slopes are indented by streams at irregular intervals of about 2,000 to 4,000 feet.

The eastern side of the valley adjacent to the mountain varies from about 4200 feet to 4800 feet in elevation above sea level and has a slope of approximately 1-1/2° near the base of the range. This valley is an intermontane basin which has internal drainage, a condition which leads to the development of very flat areas due to deposition of water transported sediment. A lake often forms in the lowest place and if the climate is arid enough the lake is dry most of the time. Such basinal areas may be suitable for natural runways.

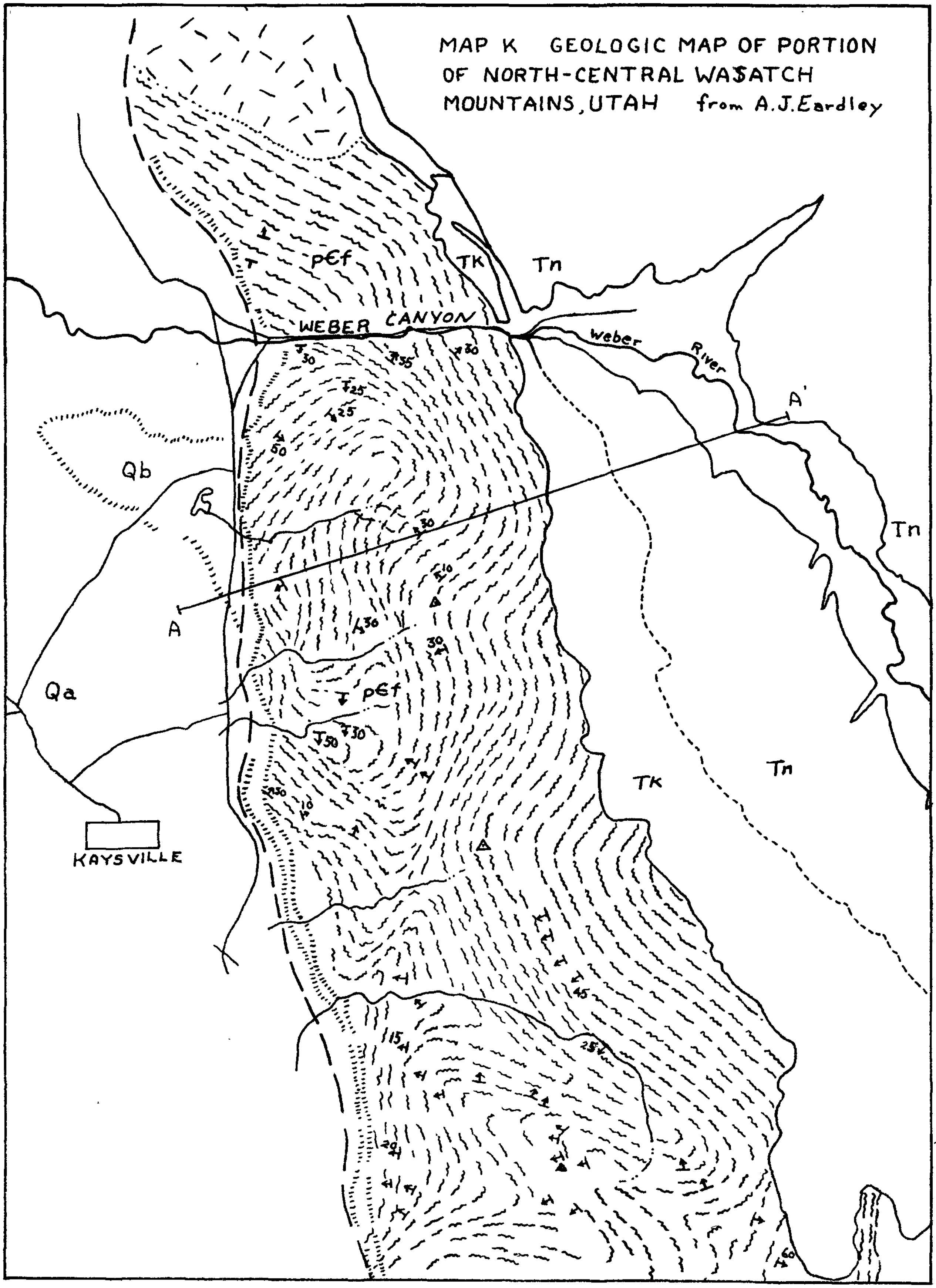
The geology of the north-central Wasatch mountains is very complex.[9] Several periods of faulting, folding and volcanic activity have occurred. However, as shown on the geologic map and cross-section, the example site location has a relatively simple geologic structure. The mountain mass is predominantly composed of rocks of the Farmington Canyon complex. This unit is a stratified crystalline complex of metamorphic rocks; this type of rock is characteristically well indurated. The foliation generally parallels bedding. On the east slope of the range, the Farmington Canyon is overlain by younger rocks of the Knight formation and Norwood tuff respectively. The Knight formation is a series of deep-red conglomerate sandstone and shale. The Norwood tuff is composed dominantly of light-colored tuff (a very

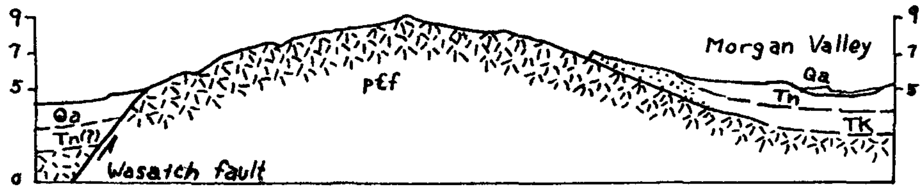


MAP J - INDEX MAP

0 10 20 30 MILES

SCALE 1: 500,000


MAP K GEOLOGIC MAP OF PORTION
OF NORTH-CENTRAL WASATCH
MOUNTAINS, UTAH from A.J.Eardley
p€f
TK
Tn
WEBER CANYON
Weber
River
A'
Tn
Qb
A
Qa
p€f
TK
Tn
KAYSVILLE



CROSS SECTION A - A'

EXPLANATION

MAP SYMBOL	FORMATION	AGE	THICKNESS (FEET)
Qa, Qb	VALLEY ALLUVIUM LAKE BONNEVILLE SEDIMENTS	PLEISTOCENE AND RECENT	50 - 1000 +
ANGULAR UNCONFORMITY			
Tn	NORWOOD TUFF	LOWER OLIGOCENE	50 - 2000
ANGULAR UNCONFORMITY			
TK	KNIGHT FORM.	LOWER EOCENE	5000 ±
ANGULAR UNCONFORMITY			
pЄf	FARMINGTON CANYON COMPLEX WAVY LINES SHOW STRATIFICATION WHERE KNOWN.	MIDDLE PRE-CAMBRIAN	10,000 +

FAULT, approx. LOCATION

25 ATITUDE OF STRATIFICATION

LAKE BONNEVILLE BEACH

fine-grained volcanic rock) with lenses of volcanic conglomerate. In the basin west of the range, valley alluvium and Lake Bonneville sediments are exposed at the surface. The Wasatch fault parallels the base of the range on the west.

The relatively simple structure and lack of any major faults crossing the mountain mass indicate this area may be suitable for a site. Published areal geologic reports rarely have sufficient data to evaluate engineering geology requirements, so additional field work is needed. Just south of, and sub-paralleling, Weber Canyon a water tunnel has been constructed, and data from this may help a person to evaluate the area.

Salt Lake City area has a history of one near destructive earthquake, and in the past decade is has had a number of smaller quakes.

The Index Map shows some major features near the example site. Ogden has a population of 57,100 (1950 census) and Salt Lake a population of 182,100 (1950 census). Hill Air Force base is about 3-1/2 miles west of the mountain.

The climate(6) in the basin is cool subhumid with 7 to 29 inches precipitation distributed throughout the year, and snowfall from 30 to 60 inches. The temperature range from the low of the coldest month to the high of the hottest month is 10° to 90°F. The climate of the mountainous area is cold subhumid with 7 to 30 inches of precipitation distributed throughout the year and snowfall from 30 to 100 inches. The maximum temperature range is from 0° to 89°F.

A possible configuration for the hardened aircraft facility is shown on the Example Site Map. The multiple exits facing in different directions enhance the versatility and survival of the installation. Placement of tunnel exists at indentations in the slope helps to protect them from nearby blasts. Tunnel runways of different lengths, providing natural take-off, catapult and zel launch capabilities, would add to the potential operational success of the facility. Location of the maintenance center under the crest of the range provides the maximum protective cover. It is expected that the facility design will be adjusted to mountain geometry and geology, and the desired size of the installation.

The advantages of the example area are good topographic relief and mountain configuration, adjacent flat basin, and proximity to an Air Force base. The disadvantages are proximity to an active earthquake area and location 400 to 500 miles more distant from Soviet targets than a site near the northern U. S. boundary.

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