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A Feasibility Study of Sites for the Proposed Superconducting Super Collider in Kansas

Preliminary geographic, geological and geotechnical assessments

by

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Introduction

The senior author and several staff members of the Kansas Geological Survey were asked in early 1986 to make a rapid geographic screening and geological assessment of potential sites in Kansas that were geotechnically and otherwise suitable for siting of the proposed superconducting-super collider (SSC) in Kansas. This assessment was made using existing data and knowledge. No field work or new studies were done.

From a review of the criteria available at that time, a short list of desirable characteristics was derived and used in the initial screening process.

In addition to a large enough area containing suitable geology, the following screening criteria were used as guides:

1) Proximity to an existing electrical power network with sufficient excess capacity, reliability and redundancy to support the SSC facility.

2) Proximity to existing or potential fresh-water resources or reservoirs with sufficient excess capacity to supply the design needs of the SSC.

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3) Direct access or close proximity to primary heavy transportation supply and communication networks or facilities such as interstate highways, major airline, railroad, barge, pipeline and telecommunications terminals or interconnections.

4) Proximity of technical construction resources and support facilities and a pool of existing or potential construction, technical and support personnel.

5) Proximity to a major metropolitan region with ready access to quality housing, educational, cultural and recreational opportunities and other amenities.

6) Proximity to a major university and/or similar scientific, research and technical centers.

Other criteria which were considered included: 1) climate; 2) population density; 3) minimum adverse impact on the environment, infrastructure and existing or potential land-use and development; 4) land acquisition and development costs and 5) other demographic considerations including a probable favorable attitude towards the project by the local population and public officials.

A number of possible sites were identified across the state. None of these has been excluded from future consideration but in order to best utilize the available time and energies of the rather small group of technical people and decision-makers involved in the evaluation, it was decided to focus the group's efforts on those areas that contained the greatest number of desirable characteristics as outlined above. In assessing those characteristics, emphasis was placed on the things which are necessary for development and support of the SSC and which are already in place or can easily be adapted to maximize economies in time, effort and cost without compromising the quality and ultimate objectives of the SSC project.

In other words, our search placed greater emphasis on identifying sites where the project was "doable" using existing features and technologies or with the least possible modification of them. We considered but placed less emphasis on the socio-economic and political aspects. We believe that this meshes with the scientific and philosophical objectives of the research which the proposed project supports and that it reflects the general attitude of the broad population it will eventually come to benefit and serve.

Description of the general site area

A general area in eastern Kansas, south and west of the Kansas City Metropolitan Region, meets all of the criteria outlined above (Figure 1).

Reasons for choosing this area--geology, water and electrical power supply

Attention was focused on this area initially because of its suitable geology, the presence of several U.S. Corps of Engineers' surface-water reservoirs for potential water supply and several large regional electrical generating plants for the power requirements of the SSC. The latter included the Wolf Creek Nuclear Generating Station (WCGS) located about 80 miles southwest of Kansas City. Wolf Creek Station, a Westinghouse designed pressurized water reactor with 1150 megawatts gross capacity, was licensed for operation in mid-Fall 1985. Built in anticipation of future increased demand, it is operating at only a small percentage of its capacity. The facility was designed to accommodate a second future reactor of the same size. Prior to WCGS going on line, power was supplied mainly by two relatively-new but smaller coal-fired stations operated by a sister utility near the Kansas-Missouri border about 60 miles south of Kansas City and several older units near Kansas City and Wichita. Plans were for the older units to be phased-out and decommissioned after WCGS became operational and the newer coal-fired plants were to be idled except for back-up or intermittent peak-demand supply. It is assumed that the newer units would still be available if some of the present excess capacity from WCGS is used for this project.

The northern part of the outlined area is also served by and is interconnected with the other main power utility company supplying the northern region of Kansas. It has a number of recently-constructed coal-fired units in northeastern Kansas, including one at Lawrence.

Transportation and supply networks

Major highways, railroads, pipelines, communication networks and airlines also fan out radially to and from the Kansas City hub and are readily accessible to the outlined area.

Topography and geology

The region has a gently-rolling mature topography underlain by well-studied, relatively horizontal, sedimentary-rock units that were laid down or deposited about 285 million years ago during the Late Pennsylvanian Geologic Period. The rocks consist of cyclically-deposited layers of marine limestone averaging 50-75 feet in thickness which contain thin interbedded shale units. Alternating with the limestone formations are thicker layers (averaging about 200 ft.) which are predominantly composed of shale containing intermittent lenses or stringers of sandstone and a few thin coals and limestones. The mode of deposition is called "cyclical" because the limestone-shale sequence is repeated many times in a more-or-less predictable vertical succession caused by the migration of shallow seas back and forth across a gently-sloping depositional surface during Pennsylvanian times.

Both the limestone formations and the thicker shale units are relatively uniform in thickness and physical composition across the entire region and because they are not complexly folded or faulted, their characteristics are predictable and correlatable even underground many miles back or west from their surface outcrops. Some of these relatively thin units can be correlated and traced in the subsurface throughout the entire width and length of Kansas using logs of oil and gas exploration drill holes.

In eastern Kansas the major beds dip or are inclined downward toward the northwest at about 20-25 feet per mile (about a quarter of a degree) away from the Ozark Plateau in Missouri. The land surface, on the other hand, slopes from the crest of the Flint Hills regional divide, which is just beyond the west edge of the region, downward to the southeast at an average rate of about four feet per mile. The effect of this is that successively younger rock units or formations crop out at the surface in stripes of varying widths arranged in slightly curved arcs concentric to the western and northwestern flanks of the Ozark dome. In the area of interest, the outcrop bands of the various units trend approximately northeast-southwest.

The limestone units are more resistant to erosion than the shale formations and their outcrops form a series of low, parallel, linear ridges trending in the same general NE-SW direction. The shales, being softer and less resistant to erosion, make steeper slopes below the capping limestones. In vertical cross-section this resembles a collapsed staircase with the limestones making the inclined treads and the shales forming the risers between the steps. Viewed obliquely from above the landscape appears as a series of subdued terraces with steeper east-facing slopes and broader, very gently inclined western slopes (Figure 1). This type of land form is called a "cuesta". It should be emphasized that the topography is interesting but gentle, similar in some ways to the Appalachians but much more subdued because of the nearly flat-lying rock units on which it is formed. The average maximum topographic relief is less than 300 feet and the general aspect is more plain-like except near the edges of the limestone-shale outcrops, where it is gently undulating. This area in Kansas is called the "Osage Plains" or "Osage Cuesta Plains," a subdivision of the Central Plains of the U.S.

The major regional streams in the area tend to cut into the series of terraces at near right angles to the outcrops and flow at low gradients even near their sources in the Flint Hills. The valleys are broad and shallow. The alluvial fill of the major stream valleys consists mainly of clayey material that ranges from about 20 to 60 feet in thickness. The soils developed on hillslopes and on the upland surfaces are relatively thin, averaging usually less than ten feet in thickness. They are generally silty clays.

Potential Collider-ring locations within the area

The location of potential sites for the collider main ring within this area is constrained more by trying to avoid, as much as possible, the man-made infrastructure, such as cities, reservoirs, transportation networks, etc., rather than by its geology and landscape.

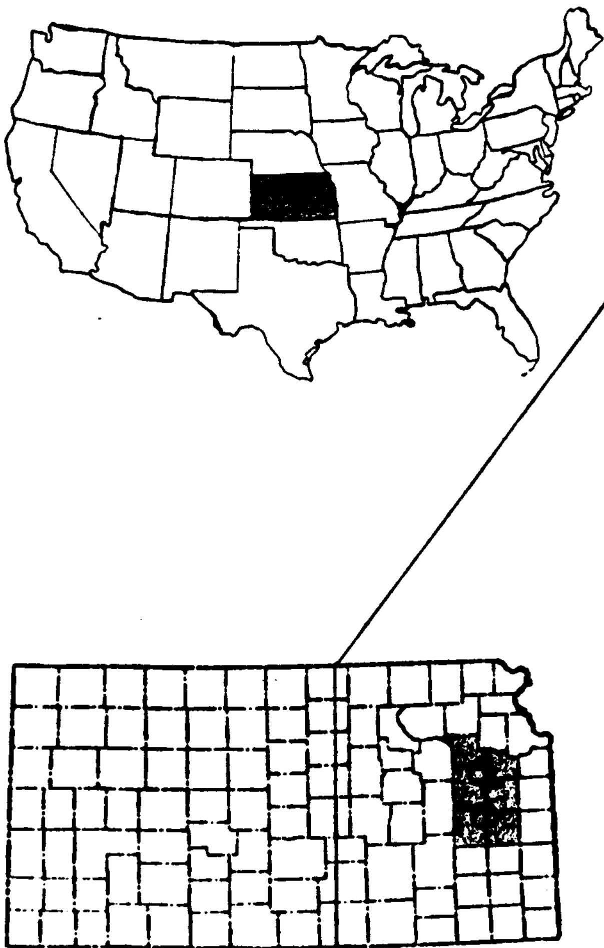


Figure 1. Index map showing location of proposed sites in Kansas.

Suitability for modern underground tunneling methods

Early in the evaluation, cut-and-cover tunneling of the entire collider ring was ruled out because of the shallow limestone bedrock, moderate topographic relief and its adverse impact on the environment. Underground tunneling by modern methods is entirely feasible in the mixed limestone-shale bedrock of this area. It was decided, however, that to use these methods to best advantage and reduce design and construction costs and time, that it would be desirable to locate the tunnel as much as possible in a uniform rock type that could be excavated rapidly by ordinary soft-rock tunnel-boring machines (TBMs) for the horizontal rings and raise-boring machines (RBMs) for drilling vertically upwards from or immediately adjacent to completed sections of the tunnel for access shafts rather than by using more conventional shaft-sinking methods. Raise boring has many practical and economic advantages over shaft sinking whether it is done by machine or hand methods. Either reinforced shotcrete or precast, segmented, reinforced-concrete may be considered for the tunnel/shaft liners. The latter can be assembled and installed from the rear of the TBM shield to provide quick support to the tunnel walls. The liner then provides a strong resisting structure for driving the TBM forward. Several TBMs and RBMs operating at the same time in several different segments of the ring could considerably reduce construction time while increasing the efficiency of the operation.

If possible, it was also considered desirable to locate the tunnel and its grade in such a way that it intersects or comes near the land surface at several locations around the perimeter of the ring. This would allow the TBMs to commence drilling at horizontal or sloping portals near grade rather than being lowered into or being assembled at the bottoms of large vertical shafts dug from the surface. It also would eliminate the more expensive and time-consuming process of hoisting "muck" up and construction materials down through vertical shafts or caissons. Locating the ring so that parts of it are at or slightly below the land surface was considered feasible and desirable if the surface or near-surface segments of the ring could be oriented so that some of the detector halls and other service or access structures could be constructed at or near ground level by conventional methods and tunneled material or "muck" used to construct protective mounds over and around them. Proper disposal or utilization of the large volume of excavated tunnel muck or spoil is considered to be the principal environmental problem associated with the project and constructive use of it would be desirable.

Tunneling medium for maximum cost efficiency

Shale was concluded to be the most desirable tunneling medium for rapid underground excavation using modern machine-boring methods.

Stratigraphy, thickness and engineering characteristics of the Douglas Group

The Douglas Group of rocks, consisting of about 200-350 feet of shale, some sandstone and thin limestone and coal, crops out near the east part and underlies the rest of the area. Figure 2 shows the generalized stratigraphy of the Douglas rocks in relation to those overlying and underlying it. Figure 2a shows the general topography and major cultural features. Figure 2b shows the elevation of the top of the Douglas and Figure 2c, the elevation of its base above mean sea level. It is overlain by the Shawnee Group which contains several limestone formations with thinner shales and is underlain by the Lansing-Kansas City Groups which are also principally limestone and thinner shales. The upper surface of the Douglas Group lies at a depth of about 200-300 ft. down-dip under the western part. The shales composing it are moderately strong (unconfined compressive strengths averaging about 30,000 pounds per square foot at average tunnel depth) yet are capable of being rapidly excavated to close tolerances with a minimum of overbreak using conventional carbide-tipped cutter heads. The shales are usually silty and the clay components are mainly illite, kaolinite with minor vermiculite(?) and montmorillionite. Swelling of the shale is not a problem especially in its unweathered condition although excavated surfaces may air slake if not protected. Slickensides and closed brittle fractures and joints were noted in cores taken at the Wolf Creek Nuclear Power Station site but these were judged to be the result of loading and compaction of the sediments after deposition several hundred million years ago or to Pennsylvanian-age tectonics. State-of-stress evaluations should be made, however, to determine whether residual stresses that might affect the tunnel are present in the shale.

Earthquake history and seismicity

Historic and present seismicity of the area is low as indicated by recent studies done for the Wolf Creek Nuclear power plant and by the Kansas Geological Survey for the U.S. Nuclear Regulatory Commission (Figure 3).

Engineering Geohydrology

The shales have low permeability in unweathered condition, especially at depth and water in-flows are not considered to be a problem. The sandstone stringers may contain some water but the sandstones are generally isolated and of limited extent.

The sandstones are medium- to fine-textured and sufficiently compacted so that any inflow of water will be limited and under low pressure. The chemical composition of any included formation water should be analyzed to determine its compatibility with tunnel-lining concrete and other materials. The fluids are not known or expected to be highly mineralized or corrosive.

Oil and gas exploration, production and effects on tunneling

Natural gas and petroleum is produced from relatively shallow depths in fields east and north of the outlined area. The presence of these wells and fields was one of the constraints considered in the tentative location of the ring sites. Although no production wells are located in the vicinity of the suggested ring sites, a number of "dry hole" tests have been drilled in

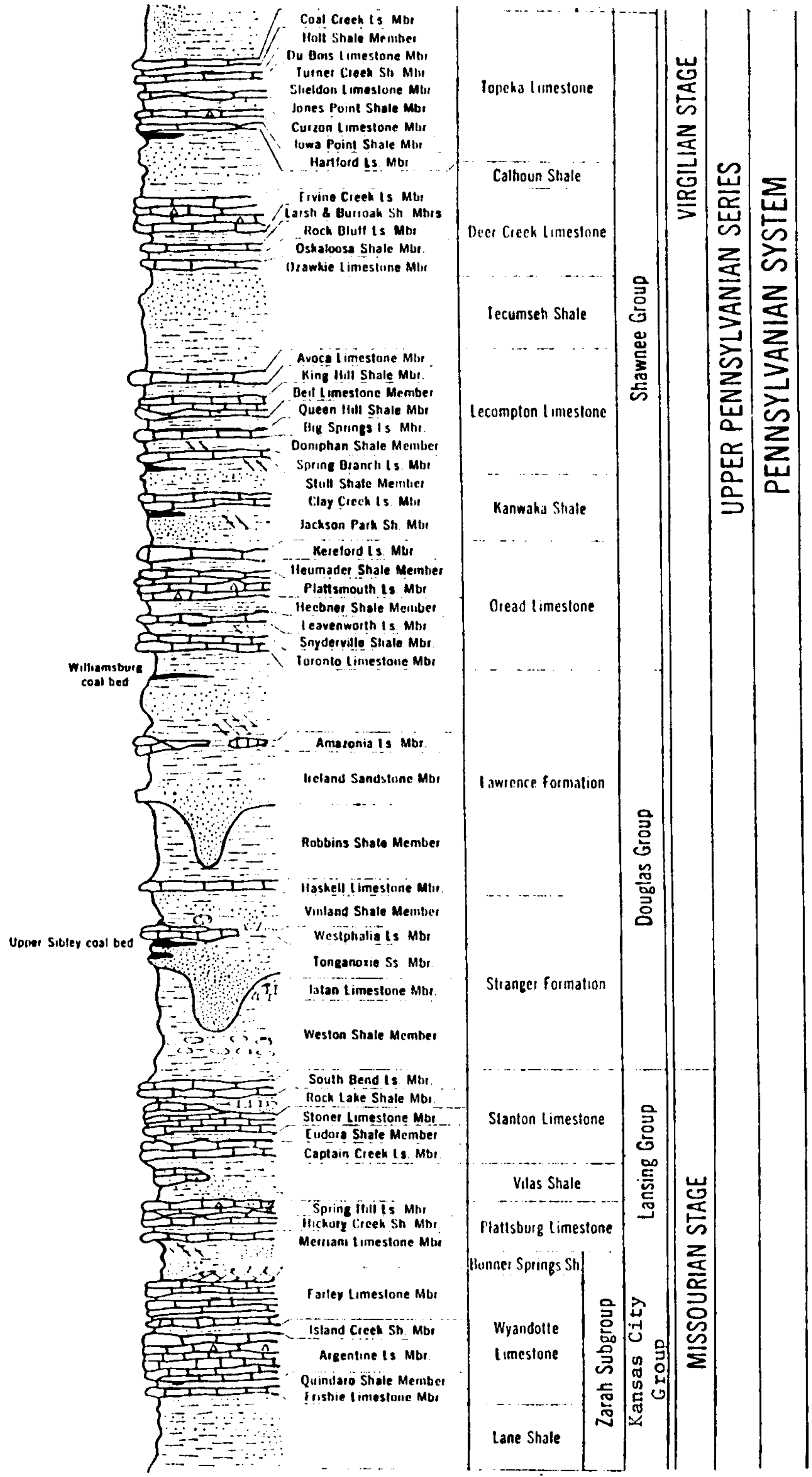


Figure 2. Generalized stratigraphic section showing relationship of Douglas Group to overlying and underlying rocks.

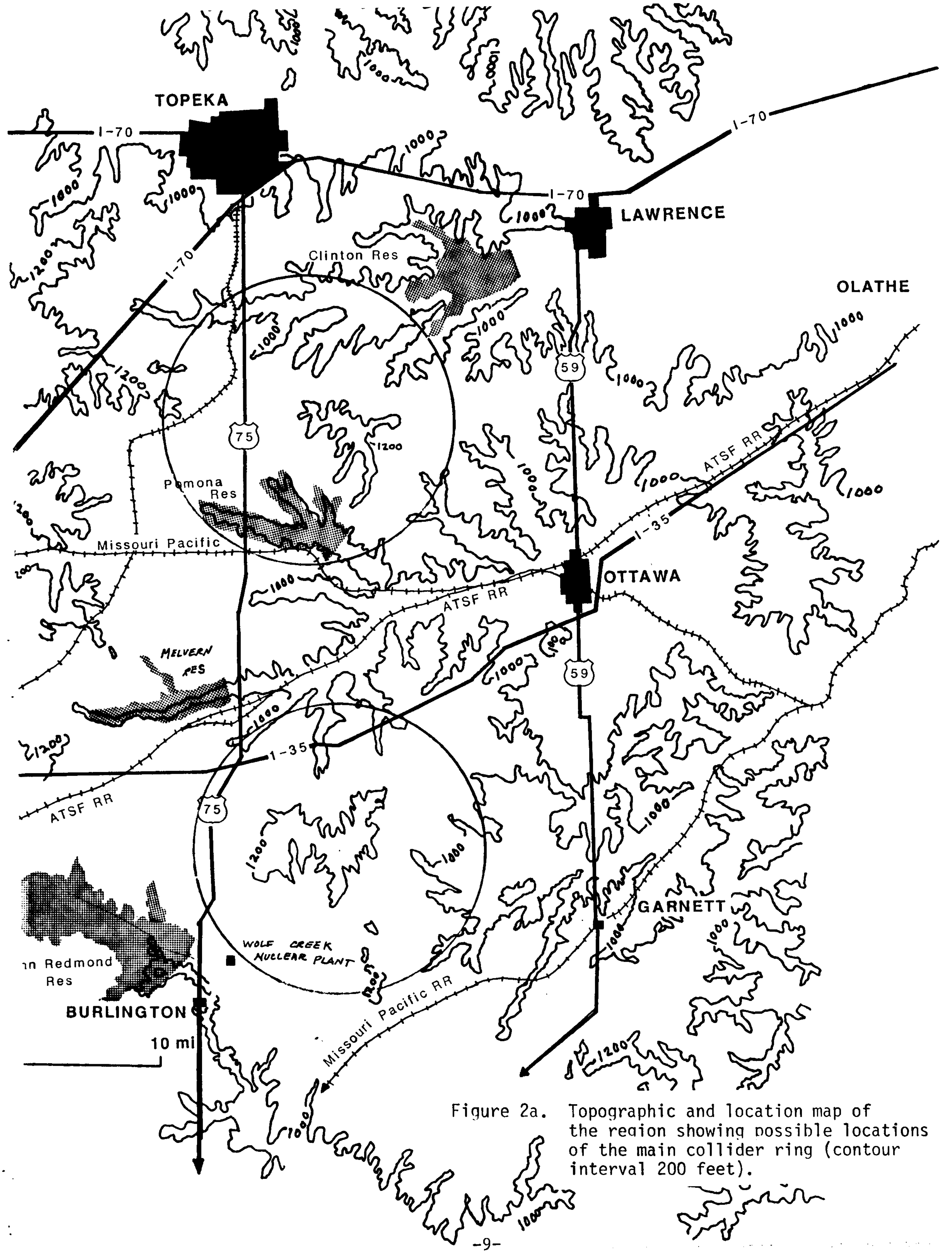
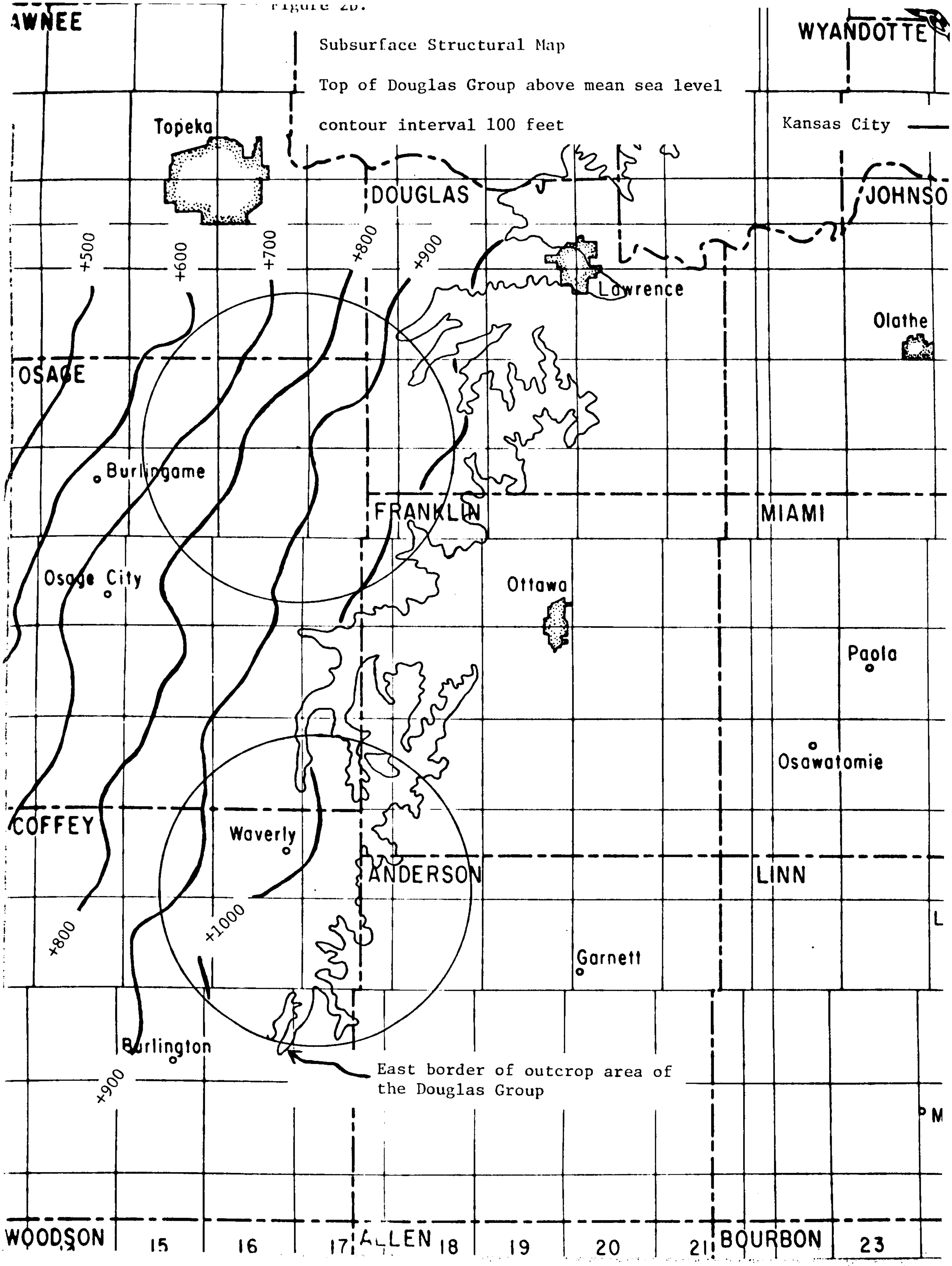


Figure 2a. Topographic and location map of the region showing possible locations of the main collider ring (contour interval 200 feet).

Figure 2b.



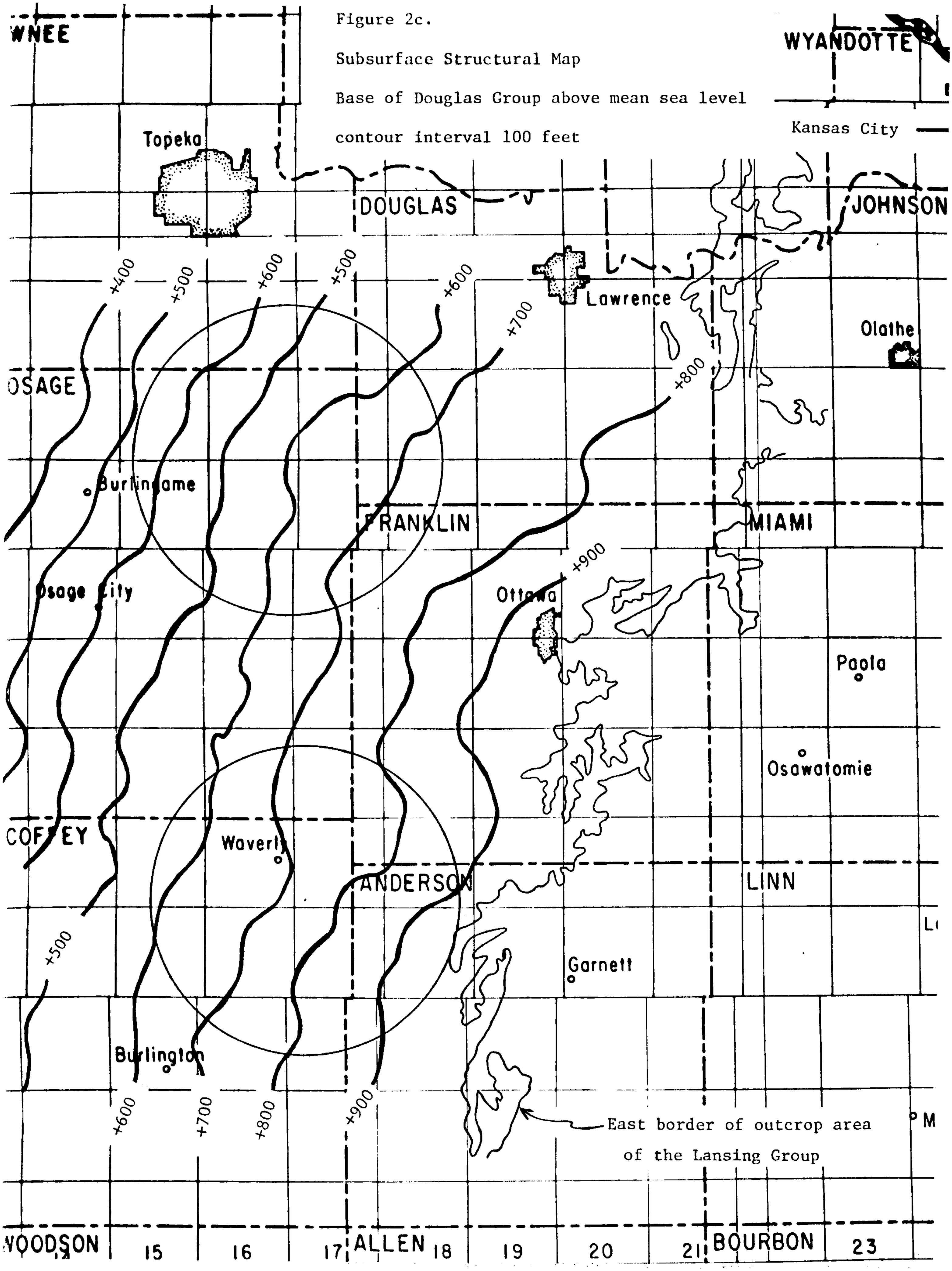
Subsurface Structural Map
Top of Douglas Group above mean sea level
contour interval 100 feet
AWNEE
WYANDOTTE
Kansas City
Topeka
DOUGLAS
JOHNSO
Lawrence
Olathe
OSAGE
Burlingame
FRANKLIN
MIAMI
Osage City
Ottawa
Paola
Osawatomie
COFFEY
Waverly
ANDERSON
LINN
Garnett
Burlington
+500
+600
+700
+800
+900
+1000
East border of outcrop area of the Douglas Group
WOODSON
ALLEN
BOURBON
15
16
17
18
19
20
21
23

Figure 2c.

Subsurface Structural Map

Base of Douglas Group above mean sea level

contour interval 100 feet



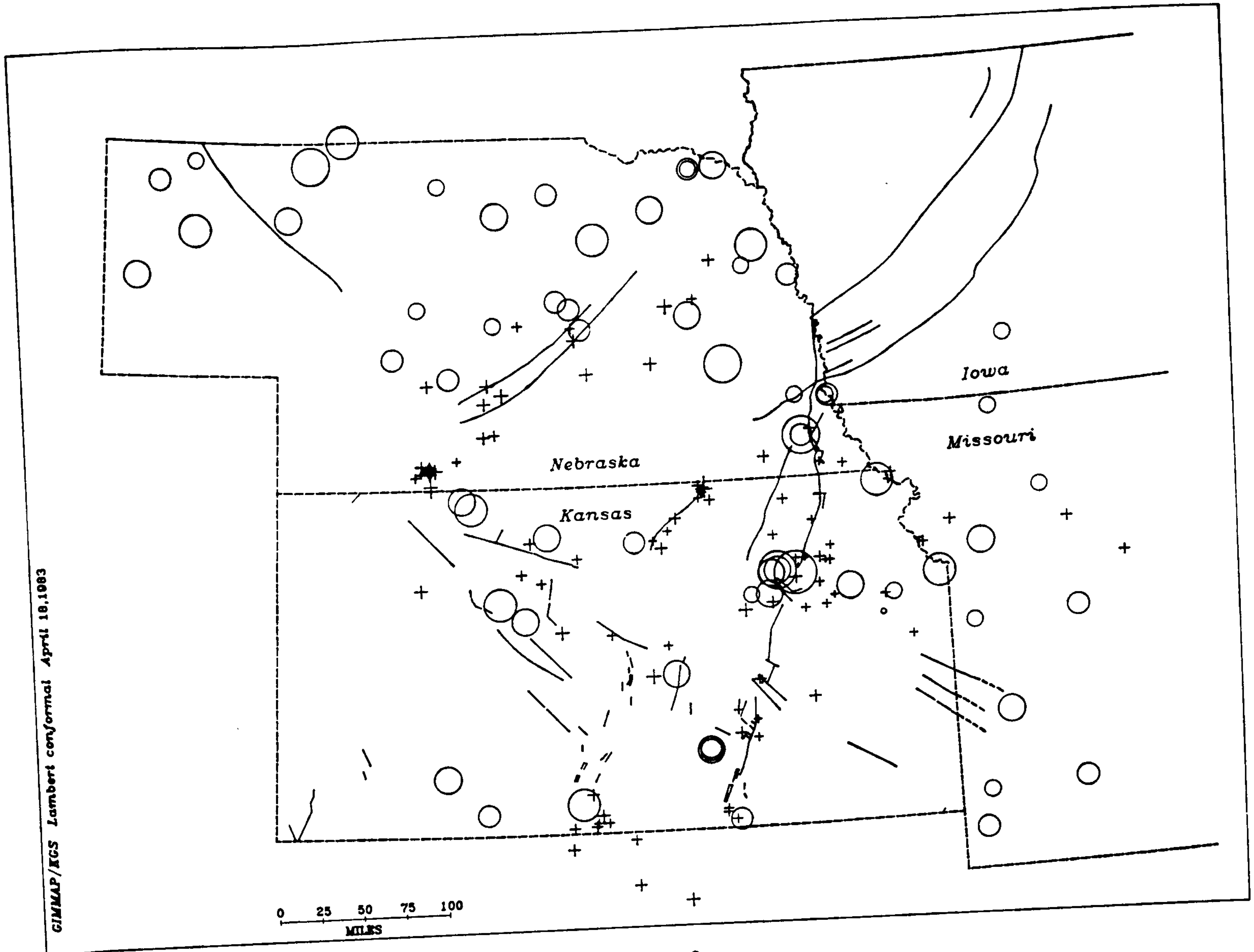


Figure 3.

◯ Historical Felt Earthquakes 1867 - 1986

(largest rings indicate Modified Mercalli Intensity VII)

✚ Microearthquakes recorded 1978 - 1983

(less than Richter magnitude 3)

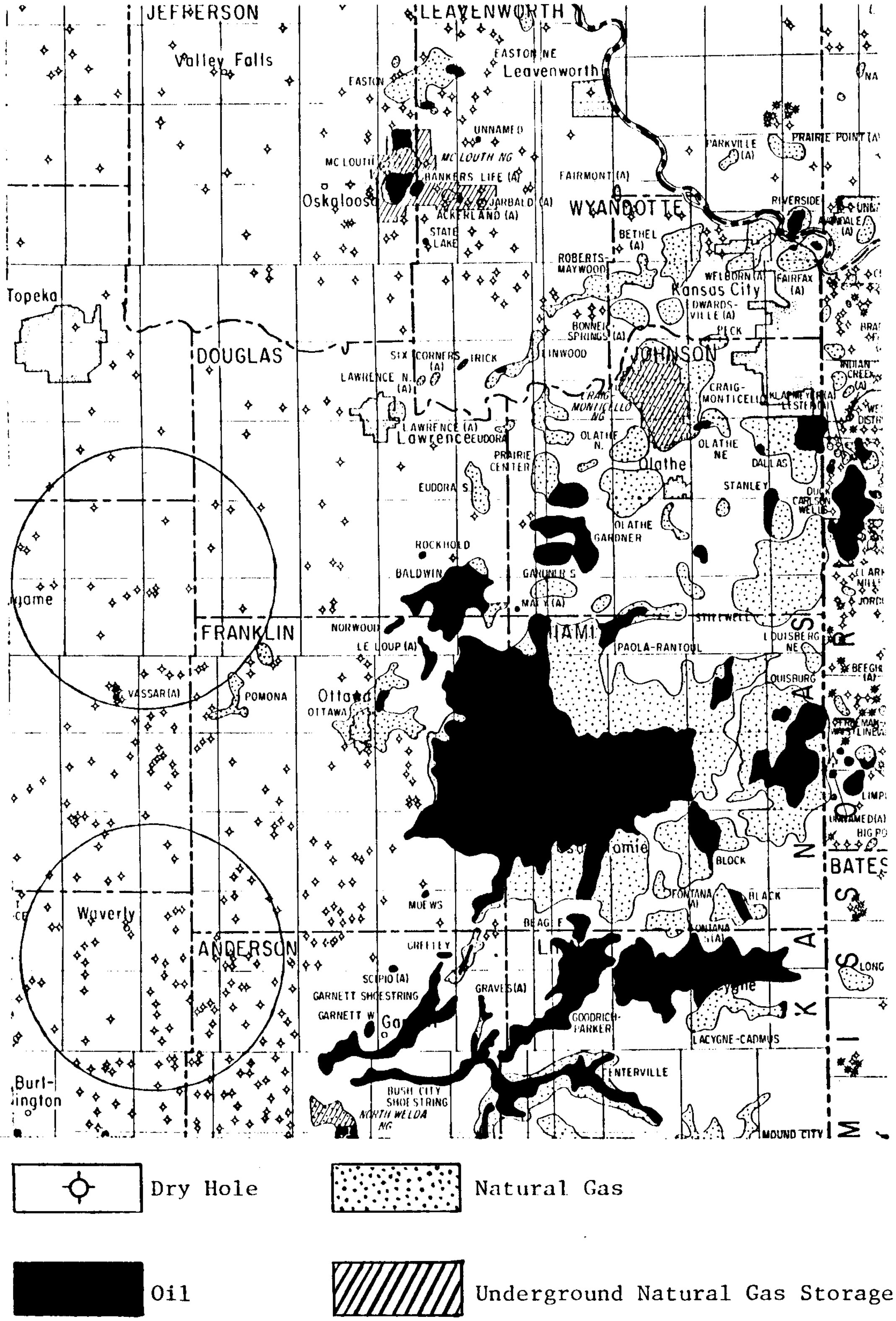


Figure 4. Oil and gas activities in area of proposed sites in Kansas.

the area and logs of these holes were used in this evaluation to determine the characteristics and extent of the buried geologic units (Figure 4). The possible occurrence of methane or other gases in quantities sufficient to cause problems during tunneling was considered and should be further investigated. Because of the relative impermeability of the formations to be tunneled, standard gas-detection monitoring and tunnel-ventilation practices that are commonly used in tunnel projects, should be adequate.

Summary of feasibility of the general site area

In summary, there appear to be no special geological or geotechnical problems or situations involved with the construction of the project in this geology and terrain. In fact, the project can utilize the natural situation to maximum advantage while, at the same time, minimizing its environmental effects. With proper or innovative planning, design and scheduling, the setting appears to be quite favorable for the application of rapid excavation and construction techniques which could result in completion of the project to high standards at low cost and in minimum time.

Potential collider-ring sites

Trial fits were made in the area using a 20-mile-diameter circle as an approximation of the ring. It is recognized that the final configuration can and may differ in shape from this for various reasons.

Two ring sites, as shown in figure 2, were chosen for more detailed evaluation. A third site northwest of Kansas City and west of Kansas City International (KCI) Airport was studied and tentatively rejected because it is in a more dissected glaciated terrain, the Douglas Group rocks are thinner and are mainly sandstone containing a potable water aquifer. Considerable shallow oil and gas production is present and is continuing to be developed in the area. It should be noted, as was mentioned above, that in all three areas, rocks of the Shawnee Group overlie and rocks of the Lansing-Kansas City Groups underlie the Douglas Group. These latter formations were not evaluated because they consist mainly of limestone with interbedded thinner shales and provide a less favorable, mixed-face tunneling medium lying at greater depths below the surface. Natural gas is produced from sand-bearing shales immediately below the Lansing-Kansas City Group both north and south of the Kansas City metropolitan region.

The landscape and geology of the two chosen sites, are quite favorable and approximately equal depending on how the main collider ring and its appurtenant structures are located in relation to the main ring and how the ring is fitted three-dimensionally into the surface and subsurface geology and the landscape. A number of options are possible but detailed discussion is premature at the present time.

Southern Location

The southern location, near the Wolf Creek Nuclear Generating Station, was chosen first because it meets all of the important technical criteria outlined above.

Geology

An area adjacent to and extending north and east of the nuclear power plant site is underlain by Douglas Group rocks. In this area, the formations are almost entirely shales totaling about 330 ft. in thickness. The topography, surface and subsurface geology is well-suited for accepting any of the likely ring configurations or orientations that might be considered.

Water Supply

Several sources of water supply are present in the area and the potential exists (and should be considered) for construction of a surface-water reservoir inside or immediately adjacent to the ring site. Such a reservoir could be dedicated primarily for the uses of the project. The U.S. Corps of Engineers had at one time proposed a reservoir immediately north and west of Garnett but consideration has since been dropped because of an unfavorable cost-benefit ratio. The flood-control objectives of the reservoir could be retained and utilization of water by the project would favorably affect the cost-benefit ratio. Excavated tunnel spoil could be utilized as a large component of the earth-fill dam and some of the valley-fill soils could be used for establishing a vegetative soil cover on the relatively infertile, unweathered shale excavated from the tunnel, however it might be used or disposed of on the project.

Transportation and communications

Two major railroads, an interstate and several other major federal and state highways are immediately adjacent to the proposed ring site as are several pipeline and telecommunications networks.

Population density and land use

Population density is low and land in the area is mainly agricultural, used for pasture and cultivation. Land costs are relatively low and parcels are fairly large compared to those closer to the Kansas City Metropolitan growth region.

Power Supply

The presence of the Wolf Creek Nuclear Power Station provides a number of important advantages. It is new but it will have been in operation for several years before the SSC project is scheduled to be started. It has an assured, long-term supply of nuclear fuel and should be exceptionally reliable. As previously stated, the plant has excess capacity which will not be utilized for a time, is capable of being expanded and has several relatively new back-up plants associated and interconnected with it in the system. Physical connection of power delivery lines to the proposed SSC site would be short and could conceivably be buried underground for maximum protection against natural and other hazards.

Utilization of existing technical and environmental studies done for WC Nuclear Plant site

Another major favorable consideration associated with the southern site is the fact that exhaustive preliminary- and final-safety-analysis reports, environmental reports and voluminous detailed technical and geotechnical data are available as a result of the nuclear plant studies. These existing reports contain all of the major information needed for the SSC site evaluation. The results of these studies and reports can be projected and applied to the proposed southern site with little or no modification.

The various studies and reports include sections on geology, geohydrology, seismicity, climatological, demographical, environmental (floral, faunal, archaeological, etc.) data, as well as detailed technical and geotechnical data. The existence and ready applicability of this information to the site would eliminate or reduce the time-consuming and expensive process of doing new studies and compiling or updating the technical and environmental data, compared to most other proposed sites in Kansas and other states. The reduction in lead-time and costs over doing equivalent new studies is substantial.

Demographic and socioeconomic considerations

A further intangible but important advantage of the southern site is that the general population, though not large, is stable. Most of its permanent residents are landowners or others who have an interest in the quality of life and the economic and other aspects of the area. Many have observed both the generally beneficial but sometimes detrimental effects of several major construction projects in the local region (three large dam and reservoir projects and a nuclear power facility). Having experienced this, they are more sophisticated and aware of the various issues and processes involved in such things. It is likely that they may also be more interested and responsive to the ideas and scientific importance of the scientific research that is the objective of this project.

Northern Location

The northern site, near Topeka and Lawrence, was also evaluated. The geology and terrain is similar to the southern area and is suitable but the vertical and horizontal range of orientations for fitting the trial ring into the geology and landscape is more constrained than at the southern site. The northern site area is favorable with respect to many of the infrastructure, socio-economic and other criteria of the project. Because of the greater population density, the degree of land development and the related infrastructure (such as transportation networks, lakes, cities, etc.), locating and orienting the ring is more complicated and the technical considerations and other favorable aspects must be weighed against a greater range of other, perhaps competing, interests.

Geology

The Douglas Group of rocks contain more sandstone in some parts of this area, especially in its lower part and near its outcrop on the east. These sandstones contain potable water, especially in the northeastern part of the area and moderately salty water in the southeastern part. Although the yield is not great (averaging less than 10 gallons per minute in small diameter wells), it is considered preferable to locate the ring so as to avoid the water-bearing zones as much as possible. It should be noted that the water-bearing sandstones are not geotechnical constraints to tunneling, although the presence of water must be considered in the design and construction phases. The effects of tunneling on the groundwater aquifer, an existing and potential resource, is the main consideration.

Water Supply

The actual and potential availability of surface water for the project, potable or otherwise, is about the same as for the southern site. The considerations are more socio-economic than technical because the area is in the growth corridors of the Kansas City metropolitan region and water is an extremely important element in that growth potential.

Power Supply

The area is in or near the contiguous service- and supply-networks of all three major power (electric and gas) utilities in eastern Kansas and the utility network interconnects in the area. The power supply is adequate. The considerations, as stated above, are again mainly technical and socio-economic, involving length and interconnection of transmission lines and the effects on development, or growth potential.

Transportation and communication facilities

The northern location is more favorably situated with regard to air and overland transportation and supply networks, terminals and facilities. KCI Airport north of Kansas City and Forbes Field at Topeka are served by major airlines with commuter-line access. Rental car and other services and facilities are available. Several interstate routes and major federal and state highways are located in or immediately adjacent to the possible SSC location. The same applies to the location of several major interstate railroads, pipelines and telecommunications lines or facilities. Barge loading- and unloading-facilities for heavy freight are available on the Missouri river at Kansas City and vicinity.

Technical support, supply and services

Sources of specialized technical supply, service and other support pertinent to the SSC project are present in or near the northern site. Other major and critical geology-related items associated with the construction and operation of the project are located in the region of both sites. These include, among others; abundant resources of petroleum, natural gas, helium, cement, construction aggregates and related production, transportation or manufacturing facilities.

Potential work force--Both sites

A considerable pool of specialized technicians and craftsmen exists and is available in or near both sites. Most of the work forces at the Wolf Creek Nuclear Generating Station in Kansas and others in Missouri and Nebraska, as well as at the several large coal-fired stations that have been constructed in the region, were locally recruited and trained. Many still live in the region.

General summary of suitability of proposed SSC sites in eastern Kansas

All of the factors outlined above relate generally or specifically to the geological or geotechnical aspects of the proposed project. Considered together with other favorable aspects of the Kansas sites, these factors represent possible large-scale economies in time, effort and cost that, in our opinion, put the potential Kansas sites at or near the top of the list of other sites that have been proposed for consideration.

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Open-file Report

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