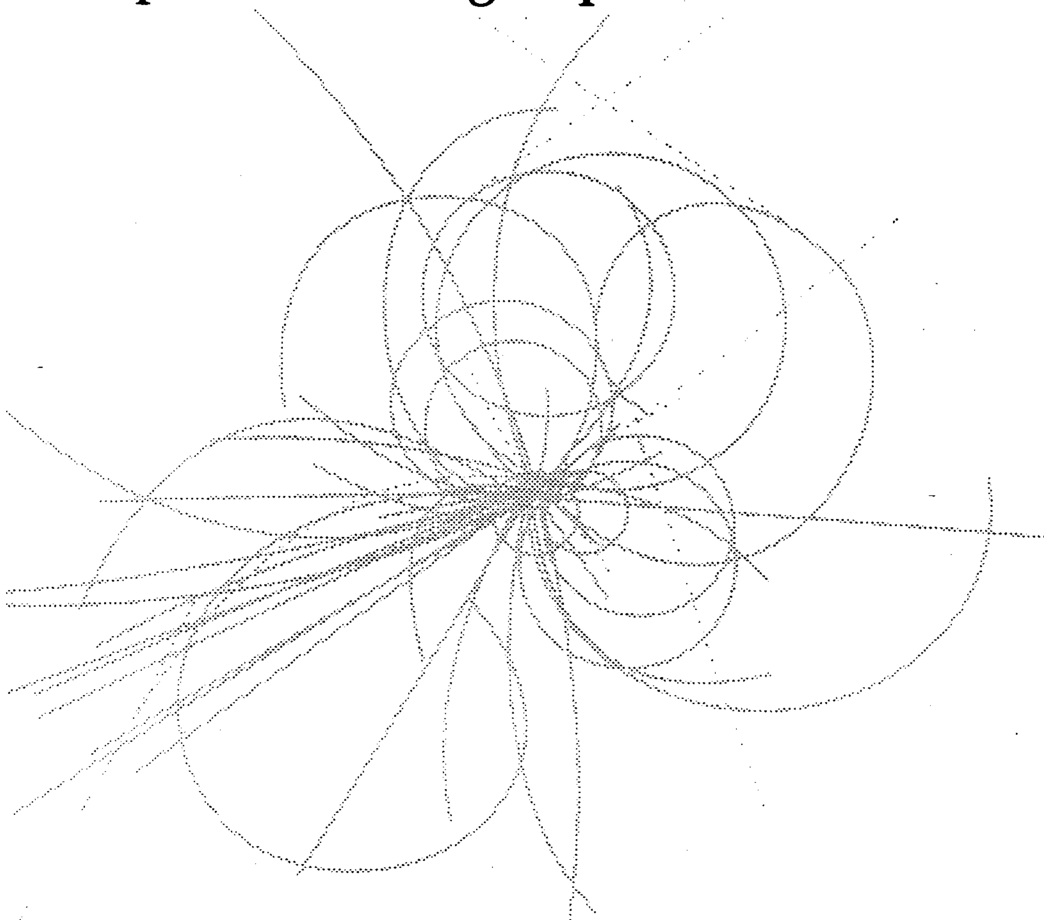
SSCL-319

Superconducting Super Collider Laboratory



The First Tunnel Section of the Superconducting Super Collider Project

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T. K. Lundin, C. Laughton and P. P. Nelson

Superconducting Super Collider Laboratory†
2550 Beckleymeade Ave.
Dallas, TX 75237

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Tracy K. Lundin, Chris Laughton, and Priscilla P. Nelson

Superconducting Super Collider Laboratory, Dallas, Texas

Abstract

The Superconducting Super Collider (SSC) project will be constructed for the United States Department of Energy at a competitively-selected site in Ellis County, Texas, about 30 mi (50 km) south of the central business district of Dallas. The injector system and main collider ring will be housed in 70 mi (110 km) of tunnel, and the project will include additional shafts and underground enclosures with clear spans up to 30 ft (10 m) at depths of more than 250 ft (75 m).

The first tunnel segment to be designed and constructed will include approximately 5.9 mi (9.4 km) of 12 ft (3.7 m) finished internal diameter tunnel, four shafts up to 55 ft (16.8 m) diameter, and various connecting tunnels and adits. Construction will be in weak rock lithologies, including mudstones, marls, and chalks with compressive strengths typically between 300 and 2500 psi (2.0 and 17.2 MPa). Design is underway, with an expected bid date before the end of 1990, and with start of construction following in the spring of 1991.

Le projet "Superconducting Super Collider" (SSC) sera construit pour le Département d'Énergie des États Unis a'un site, choisi par concours, dans le "county" d'Ellis, Texas, situé a'50 km de Dallas ville. Les accelerateurs d'injection et de collision seront installés dans une série de tunnels possédante un longeur cumulé de 110 km. La liason entre les tunnels et chambres souterraines (portées jusqu'a' 10 m) et la surface sera etabliée par une serié des puits verticaux d'une profondeur moyenne de 75 m.

Le premier tronçon d'être étudié et construit consistera de 9,4 km de tunnel de 1,85 m rayon fini, quatre puits avec des rayons finis jusqu'a' 8,4 m et quelques tunnels de connection. La construction sera executée dans une série de roches "faible"; des roches d'argile, des craies et des marnes, elle ont des résistances, en compression simple, typiquement entre 2,0 et 17,2 MPa. Les études sont bien entamées pour un lancement d'appel d'offre avant la fin d'année et un début des travaux au printemps 91.

Introduction

When completed and operating by the end of this century, the Superconducting Super Collider (SSC) project will be the largest underground "Big Physics" machine yet constructed. The SSC machine will be placed in underground enclosures, and the machine is designed to create and collide two counter-circulating beams of protons, each with an energy of 20 Trillion electron volts (Tev).

In 1988, a decision was made to select a Texas site for the Superconducting Super Collider (SSC). The selected location is in Ellis County, about 30 miles (48 km) south of the City of Dallas central business district, and the "footprint" of the surface-projected SSC ring is centered around the town of Waxahachie,

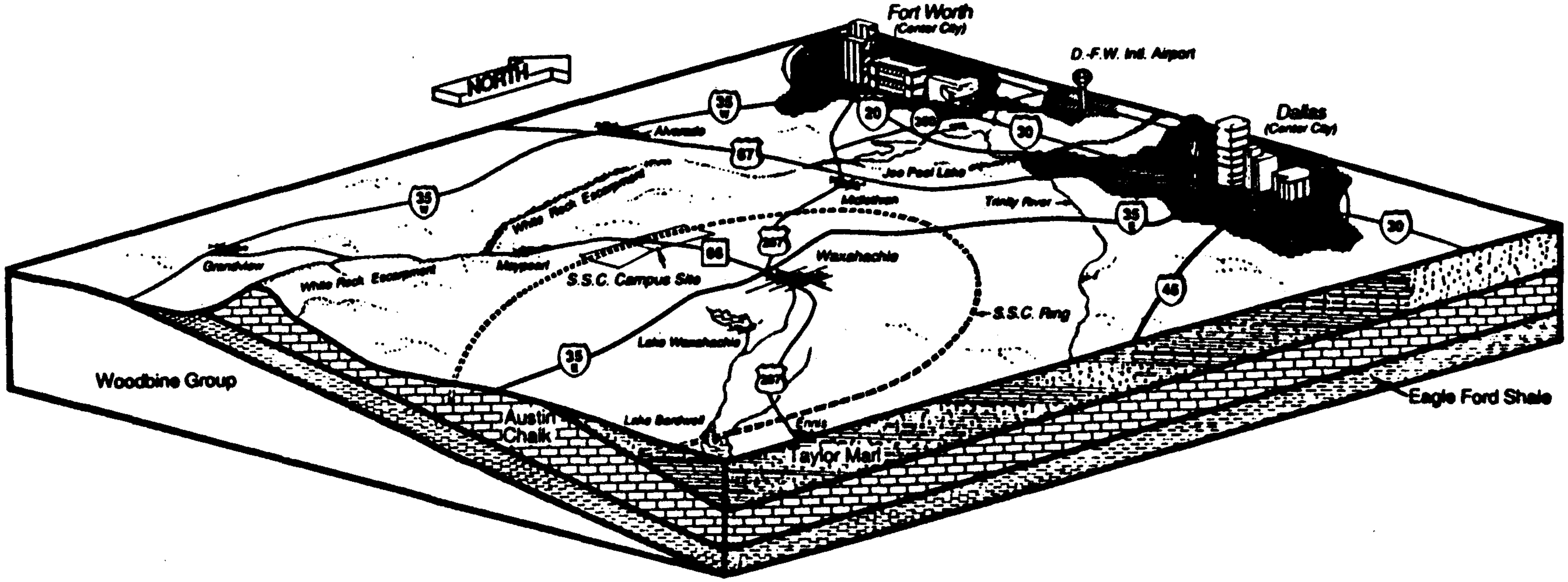


Figure 1 Schematic location of Superconducting Super Collider (SSC) facility.

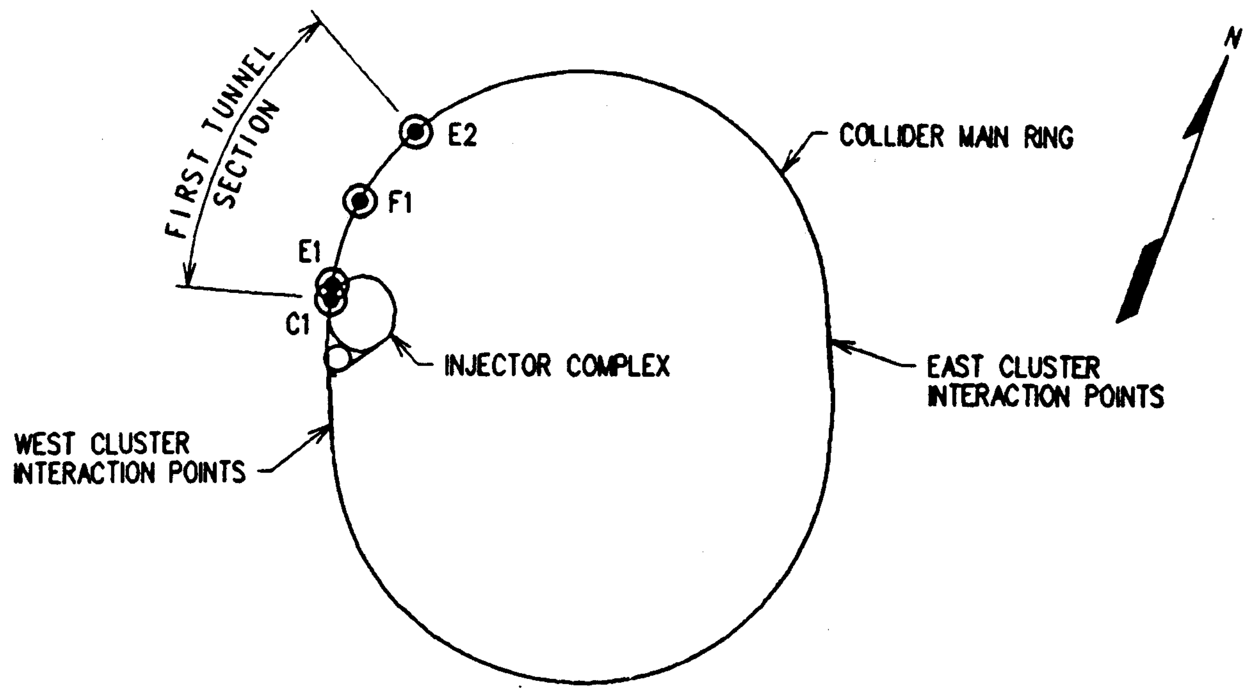


Figure 2 Location schematic for the first tunnel section to be under contract for the SSC facility.

Texas. The geologic conditions at the site are a uniformly bedded sequence of Cretaceous mudstones, marls, and chalk, with common interruptions from normal faults with typical offsets on the order of 20 to 30 ft (6 to 9 m). A schematic block diagram of the site is presented in Fig. 1. The site has excellent highway access via Interstate 35E, and topographic relief from the east to the west is only about 350 ft (110 m) across a distance of about 15 miles (24 km).

The project includes approximately 70 miles (113 km) of construction below grade, most of which will be tunnel. These underground enclosures include tunnel for four separate accelerator machines in the injector sequence, in addition to the 54.8 mi (87 km) long main collider tunnel. The first section of tunnel to be constructed will be approximately 5.9 miles (9.4 km) long and is located on the main collider ring as shown in Fig. 2.

Site Geology

The site characterization effort at the Texas SSC site has been ongoing since 1987 [1]. To date, more than 150 borings have been completed to an average depth of about 225 ft (69 m). The work currently underway will result in a coverage of borings at an average spacing of less than 2,000 ft (600 m) around the main collider ring and injector tunnels.

Geologic Setting

Three stratigraphic intervals of Upper Cretaceous rock will be encountered during excavation of underground facilities for the SSC project. The subsurface location of these units is indicated in the Fig. 1 schematic, and is also shown in the cross-section around the collider ring presented as Fig. 3. This cross-section is drawn so that the left and right edges

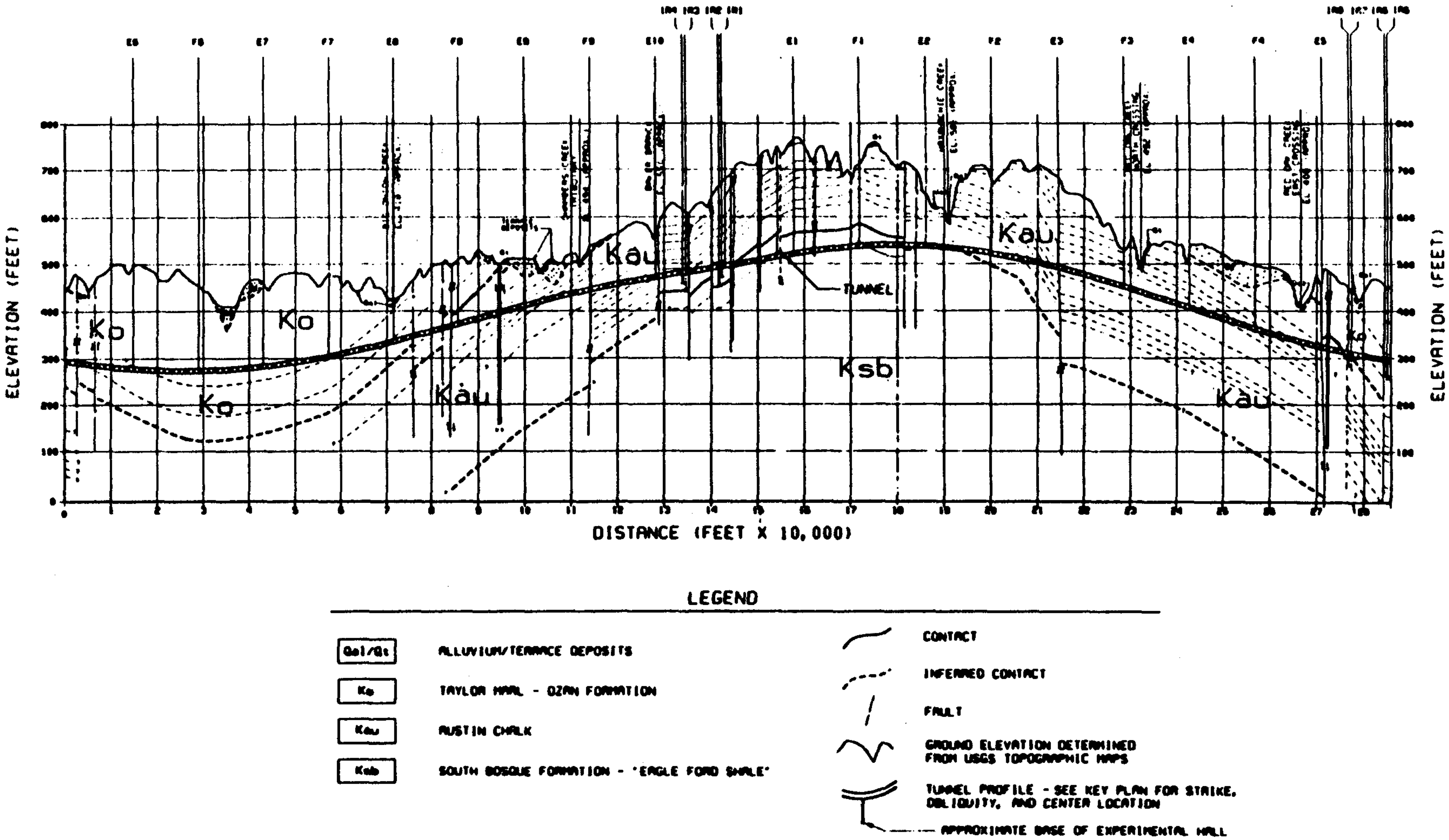


Figure 3 Geologic profile along the alignment of the main SSC collider ring.

TABLE 1 -- Statistics of weathered zone thickness

Formation	Thickness of Weathered Zone, ft (m)		
	Average	COV (%)	Maximum
Taylor Marl	13.1 (4.0)	96	44.0 (13.4)
Austin Chalk	8.9 (2.7)	73	32.5 (9.9)

of Fig. 3 correspond to the East Campus area in the vicinity of Ennis (see Fig. 1). The main West Campus area is between points labelled IR4 and E1 on the Fig. 3 cross-section.

Rock units encountered in underground construction include the lower formation of the Taylor Group, the entire thickness of the Austin Group, and the uppermost unit of the Eagle Ford Group. The lower unit of the Taylor is a marl or calcareous claystone, the Austin Group consists primarily of chalk, and the upper part of the Eagle Ford is predominantly shale or mudstone [2].

Only the Taylor and Austin units outcrop within the "footprint" area of defined by the vertical projection of the collider ring. These units typically have accumulated residual soils, but at a few locations the bedrock is overlain by Recent alluvial deposits along stream courses and Quaternary age terrace deposits. The regional dip of the Cretaceous strata in this area is towards the east-southeast at about 90 ft (27 m) per mile. The bedrock is disrupted locally by inactive faults and fractures related to the Balcones (Laramide) Fault Zone. Maximum faulted offset recorded in the area is on the order of 100 ft (30 m).

Stratigraphy

Alluvial and weathered materials: Where present, Recent alluvial and Quaternary terrace deposits can be up to 50 ft (15 m) in thickness. Alluvium includes unconsolidated sediments in modern stream channels and low terraces that are frequently flooded. The Recent alluvium consists of unconsolidated clays and silty clays with local occurrences of calcareous, clayey sand and a basal water-bearing gravel with a total combined thickness commonly ranging from 0 to 20 ft (6 m). Terrace deposits are topographically higher than the modern floodplain and are composed primarily of unconsolidated calcareous clay, silt, and sand with a basal sequence of water-bearing clayey sands and gravels. The maximum observed thickness is about 50 ft (15 m) but is typically less than 25 ft (8 m).

Boring descriptions include measurements of the thickness of accumulated residual soils and weathered bedrock. A summary of information concerning weathered zone thickness is presented in Table 1, with the scatter among measurements reflected in the tabulated values for coefficients of variation (COV), calculated as the standard deviation divided by the mean, and expressed as a percentage in the table. A thin veneer of residual topsoil is present above the Austin Chalk, and bedrock weathering generally extends to a mean depth of approximately 9 ft (3 m). Weathering above the Taylor Marl has been more extensive, with mean weathered depths of 13 ft (4 m) very common [3]. Residual soils formed in both geologic materials at the site are montmorillonitic, and are highly susceptible to shrink/swell volume changes.

TABLE 2 -- Statistical descriptors of fracture zone width

Formation	Average Zone Width ft (m)	Coefficient of Variation for Width (%)	Maximum Fracture Zone Width ft (m)	Percent of Recovered Core Length Logged as "Fractured" (%)
Taylor Marl	1.8 (0.5)	94	5.6 (1.7)	0.7
Upper Austin Chalk	1.9 (0.6)	163	14.6 (4.5)	1.9
Middle Austin Chalk	2.5 (0.8)	124	9.8 (3.0)	0.8
Lower Austin Chalk	1.1 (0.3)	136	7.0 (2.1)	0.6
Eagle Ford Shale	1.1 (0.3)	100	5.9 (1.8)	4.3

Taylor Marl: The youngest bedrock unit present in the site area is the Taylor Group which lies unconformably over the Austin Chalk. The lowermost portion of the Taylor Group is formally named the Ozan Formation, but is commonly referred to as the "Taylor Marl". About 18 miles (29 km) of the collider main tunnel will be excavated in the Taylor Marl.

The Taylor Marl characteristically is a fine-grained laminated claystone containing varying amounts of calcareous material which improves its strength characteristics. Typically the marl contains 60 to 70 percent illite and montmorillonite clay particles and has thin interbeds of bentonite and chalk. The maximum thickness of the unit in the site area is about 500 ft (150 m).

Austin Chalk: The well-bedded rock of the Austin Group will be the host rock for 29 miles (47 km) of the 54 mile (87 km) collider main tunnel and 16 miles (26 km) of other accelerator underground enclosures. The Austin Chalk is primarily a micro-granular calcite matrix with occasional claystone, marl, and bentonitic interbeds. The calcium carbonate content of the chalk is commonly greater than 75 percent and averages about 85 percent. Except for local variations such as bed thickness and fossiliferous content, the physical characteristics of the chalk are quite uniform. The thickness of the chalk in Ellis County ranges from about 300 ft (90 m) in the south to about 500 ft (150 m) in the north.

Eagle Ford Shale: The Eagle Ford Group is divided into two units in the Dallas-Fort Worth area; only the upper unit, herein referred to as the Eagle Ford Shale, will be encountered by project excavations. The Eagle Ford is a montmorillonitic mudstone with marked slake susceptibility and with significant potential to develop long term swelling strains and/or pressures. The Eagle Ford Shale is slightly calcareous to noncalcareous, and may contain pyrite on bedding planes. The upper part of the formation contains bentonite seams while flaggy limestone beds are more common in the lower part . The Eagle Ford Shale underlies the Austin Chalk on the western side of the site, and about 12 mi (19 km) of tunnel and several other underground structures will be excavated in Eagle Ford Shale. The maximum thickness of Eagle Ford in the vicinity of the site is about 250 ft (76 m).

Structural Geology

The SSC site is in a tectonically stable region, on the eastern margin of the Texas Craton, in a sedimentary sequence which is broken locally by faults of the Balcones Fault System. Most faults of the Balcones system in the site area strike east-northeast and are dip-slip normal faults. As previously stated, maximum displacement on individual faults in the project area is approximately 100 ft (30 m). Fault planes typically dip at about 70 degrees. Shear zones are generally not present. No recent faulting has occurred, and there is no evidence of aseismic "growth" faulting as has been well-documented in the Houston area. The most recent documented episode of fault offset rejuvenation was in the Miocene (>13 million years ago).

Jointing is associated with faults of the Balcones system. Similar to the faults, fractures are generally tight, typically with some calcite healing but no clay infilling. Fracture zone widths are generally 1 to 2 ft (0.3 to 0.6 m), and statistical descriptions of zone thicknesses as observed in retrieved core are detailed in Table 2. Note that the actual frequency distribution of this data is highly skewed in a pattern far from a normal distribution. This skewness is reflected in the high values for the coefficient of variation (COV) for measurements in each unit.

Geohydrology

The Eagle Ford Shale, Austin Chalk, and Taylor Marl together comprise a thick aquitard immediately beneath the ground surface at the site, and all permanent SSC facilities will be located within this quasi-impermeable matrix. These formations are believed to be saturated, but there is little water circulation via primary pore spaces. Free water is generally not present except in near surface weathered zones and in relatively shallow localized sets of open jointing. The Eagle Ford Shale separates the the project facilities from the shallowest regional aquifer, called the Woodbine Group. The stratigraphic position of the Woodbine is shown in the schematic diagram in Fig. 1.

Small quantities of circulating groundwater are present above the bedrock in terrace and alluvial deposits, as found in some of the upland stream divides in the eastern and southern areas of the site. Modern stream valley alluvium is restricted to active water courses and flood plains and is a limited source of groundwater. The terrace deposits and stream valley alluvium overlay the impermeable chalk and marl, so that the groundwater in these deposits is effectively perched. Because of the low hydraulic conductivities of the shale, chalk, and marl (less than 10^{-7} cm/sec), groundwater movement through these units is thought to be limited to localized fracture flow.

The First Tunnel Section

Description

The first tunnel section to be constructed will be located along the west-northwest portion of the main collider ring, as illustrated in Fig. 2. The fully developed concept of the SSC Laboratory (SSCL) for this first underground construction includes four shafts, 5.9 mi (9.4 km) of 12 ft (3.7 m) minimum inside finished diameter tunnel, and 15 side excavations called niches.

In consideration of possible funding limitations, the SSCL has developed an alternative first contract definition which incorporates provision for a reduced initial scope. For this shorter underground section, one of the shafts (E1), is isolated and is to be designed and built as a separate contract. The E1 shaft would therefore be an associated part of the early surface magnet development facilities, and would be constructed simultaneously with the start of surface construction. Such an excavation contract would also include an underground magnet test tunnel approximately 330 ft (100 m) long.

The remaining shafts and underground components of the first collider tunnel segment

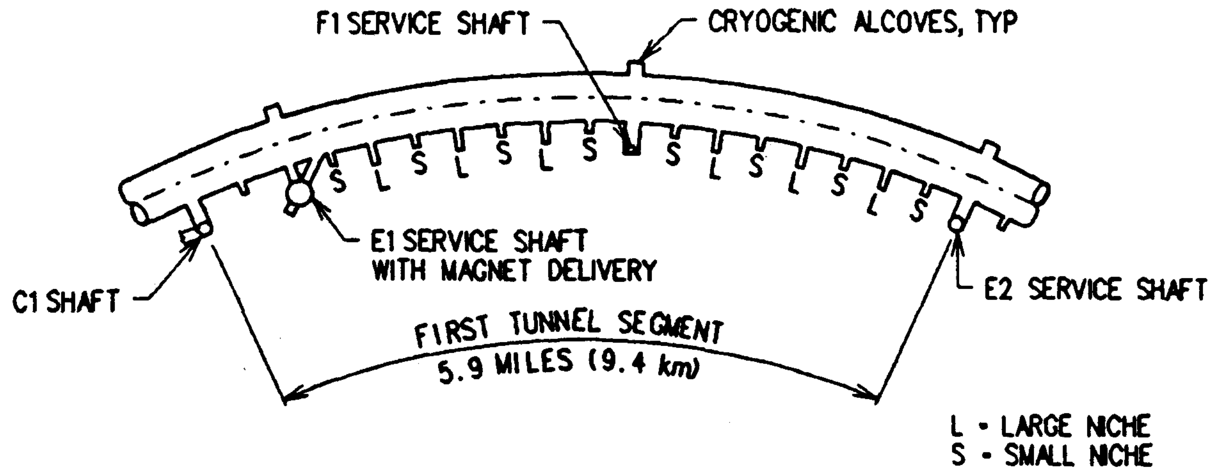


Figure 4 Schematic layout for SSC first tunnel section.

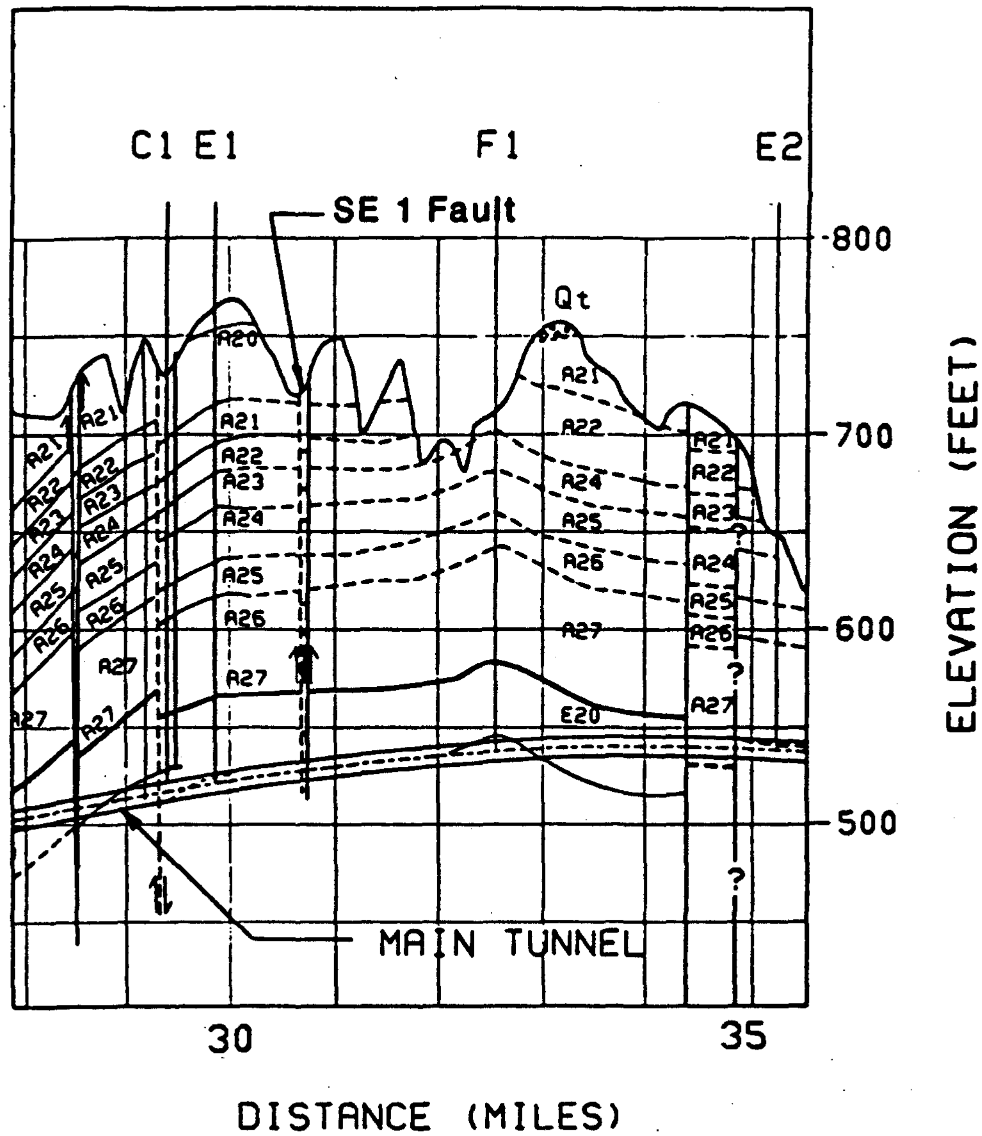
are schematically illustrated in Fig. 4. This contract includes two 30 ft (9.1 m) diameter shafts (the RF North or C1 shaft, and the E2 shaft), one 15 ft (4.6 m) diameter shaft (the F1 shaft), and approximately 5.9 mi (9.4 km) of 12 ft (3.7 m) minimum inside diameter tunnel. In addition, the contract will include 15 niche excavations about 30 to 45 ft (9 to 14 m) long and with cross-sectional dimensions the same as for the main collider tunnel.

Geotechnical Considerations

The underground structures of the first tunnel section lie in the Eagle Ford Shale and Austin Chalk at depths ranging from approximately 110 ft (34 m) to 250 ft (76 m). The Austin Chalk is generally the preferred excavation and host material for the SSC underground openings. The history of performance of subsurface structures in the chalk is excellent. The well-known suitability of the chalk to serve as a construction material in surface and subsurface application played a major role in the final selection of the site. Initial site-specific study of the Texas SSC location considered placing as much of the underground construction as possible into the chalk. However, the current plan is to provide a minimum of 50 ft (15.2 m) natural cover over beamline. This consideration, along with a requirement for planarity and dip limitations, has resulted in the northwestern portion of the collider profile being depressed down into the Eagle Ford Shale.

A cross-section of the geologic profile for the first tunnel section is shown in Fig. 5 to a greatly exaggerated vertical scale. This view is expanded from that presented in Fig. 3 to show the area from the initial southern-most C1 shaft to the final northern-most E2 shaft. The majority of this tunnel length, approximately 5 mi (8 km), will be in Eagle Ford Shale, with the remaining 0.9 mi (1.5 km) either in the Austin Chalk or in chalk/shale "mixed face".

The site investigation program for the first contract has only recently been completed. Throughout this and previous site investigations, particular attention has been given to minimizing the time between core recovery and testing. Experience indicates that important strength changes occur if testing is not performed expeditiously. Shale specimens usually deteriorate and exhibit characteristics of reduced strength; however, strength



Qt-Terrace Deposits

A20 to A27-Austin Chalk

E20-Eagle Ford Shale

Figure 5 Geologic profile along the SSC first tunnel section alignment.

increases are notable for chalk specimens when they are permitted to dry.

A summary of the results of material property testing conducted during 1990 is presented in Table 3. A summary of interpreted geotechnical design parameters which are recommended for preliminary design has been prepared and communicated to the architect-engineer [4].

The Austin Chalk samples had an average uniaxial compressive strength of about 2100 psi (14.5 MPa). Some samples were tested under triaxial confinement, but there was little noticeable effect of confining pressure on deviatoric stress at failure. The modulus ratio (stiffness divided by strength) was about 200. Some specimens were put through an unload/reload cycle before failure. In these tests, the reload modulus was typically 40 to 50 percent higher than the initial tangent modulus. The ratio of uniaxial compressive strength to tensile (Brazil) strength was about 8.5 on the average, lower than typical ratios reported for stronger rock.

The Eagle Ford Shale samples had an average uniaxial compressive strength of about 290 psi (2.0 MPa). With increasing triaxial confinement, deviatoric stresses at failure showed only minor increases, indicating a general undrained response of this material to the fairly fast loading rates used. Additional

TABLE 3 -- Summary of geotechnical testing results on Austin Chalk and Eagle Ford Shale core

Geotechnical Parameter *	Eagle Ford Shale		Austin Chalk	
	Average	COV, %	Average	COV, %
Moisture Content, %	16.0	13	12.8	20
Liquid Limit	88	20		
Plasticity Index	56	25		
Dry Density, pcf (kN/m^3)	118 (18.5)	4	124(19.5)	6
Specific Gravity	2.72	1	2.67	1
Uniaxial Compressive Strength, psi (MPa)	291 (2.0)	43	2102 (14.5)	36
Young's Modulus - Initial Load at 50% failure, ksi (GPa)	86 (0.59)	45	422 (2.91)	61
Young's Modulus - Reload at 50% failure, ksi (GPa)	170 (1.17)	36	597 (4.12)	50
Poisson's Ratio	0.29	55	0.19	53
Brazil Tensile Strength, psi (MPa)			247 (1.7)	27
Slake Durability, Id_2, %	25	42	96	3
Swell Pressure, psi (MPa)	38 (0.3)	41		

* Material property data presented here reflect only test results reported during 1990 site investigation.

testing to ascertain the drained response of the shale material is underway, but results were not available at the time of writing. The modulus ratio for the shale material was about 300. Under load-cycled tests, the reload modulus was typically twice that evaluated for the initial loading cycle, reflecting the observation that the effects of stress-relief during coring and sample retrieval are more severe for this material than for the chalk.

The durability of the Eagle Ford Shale is low to moderately low, and the measure of slake durability is very sensitive to the initial moisture content of the material at the start of the test. Air-dried material can be observed to slake nearly instantaneously upon exposure to water. Such an anticipated response indicates that quick protection should be applied to shale exposures during construction. The shale material has also been tested to evaluate zero-strain swell pressures. The average swell pressure was about 38 psi (262 kPa), with maximum pressures over 80 psi (550 kPa) recorded. Considering that some amount of strain can occur in real construction environments, the tunnel lining can be safely designed for swell pressures less than the maximum or average observed in testing.

Given that the tunnel will be located at a depth of about 250 ft (76 m), the total vertical stress to be expected at tunnel depth is on the order or 250 psi (1.7 MPa). During construction and operation, it is expected that drained and locally reduced (nonhydrostatic with respect to near-surface perched aquifers) conditions will prevail. With the vertical (total or effective) stress on the order of the strength of the Eagle Ford Shale, some attention must be given to evaluating in situ horizontal stress magnitudes, and to designing underground openings for potentially overstressed conditions. The SSCL has directed that a subcontract be executed for pressuremeter testing to evaluate K_o, the coefficient of earth pressure or the ratio of horizontal to vertical total stresses. Although only preliminary testing has been completed, results indicate that K_o can be assumed to be less than 1.0 [5]. These results reinforce the frequently made observation that construction experience in Eagle Ford Shale indicates that high in situ horizontal stresses are not present in the Eagle Ford Shale.

Identification of the location of faults is also of significant importance to the success of this first tunnel drive. Experience has instructed that faults of small offset (about 20 to 30 ft or 6 to 9 m) can occur in the bedrock without any surface expression which could be identified by air photo interpretation or lineament analysis. With reference to Fig. 3, it is clear that much of the tunnel alignment is more than 30 ft (9 m) from a stratigraphic boundary. Therefore, any undetected fault would not be likely to displace a stratigraphic contact enough to bring about an excavation transition from one material into another.

However, the expanded cross-section shown in Fig. 5 indicates that the section of tunnel between shafts F1 and E2 will run very near the interface between Austin Chalk and Eagle Ford Shale. Under such a condition, identification of relatively small-offset faults will be of interest to both the designer and contractor. The SSCL elected to utilize some of the recently evolved capabilities in high resolution seismic reflection, and results of a preliminary seismic survey in the West Campus area indicated that the method was capable of detecting faults present [6]. The SSCL therefore authorized continuation of reflection surveying in the first tunnel contract section. The combination of relatively inexpensive reflection surveys and more expensive verification borings has worked to good effect.

One of the faults in the first tunnel contract will be encountered in the vicinity of mile marker 30.8 in Fig. 5. This fault zone, referred to as the SE1 fault structure, is a fairly typical graben feature, which was detected in the reflection survey and later cored out using inclined and vertical borings. A more detailed view of the interpreted structure is presented in Fig. 6, with a vertical exaggeration equal to 1.0. The two major faults show the common steep dips and dip-slip movement. The extension of the faults into the Eagle Ford Shale is hypothetical; in fact, most evidence accumulated to date indicates that faults such as these show reduced dip in the upper Eagle Ford, and "sole-out" as asymptotic to bedding planes within the upper 30 to 50 ft (9 to 15 m) of the Eagle Ford Shale.

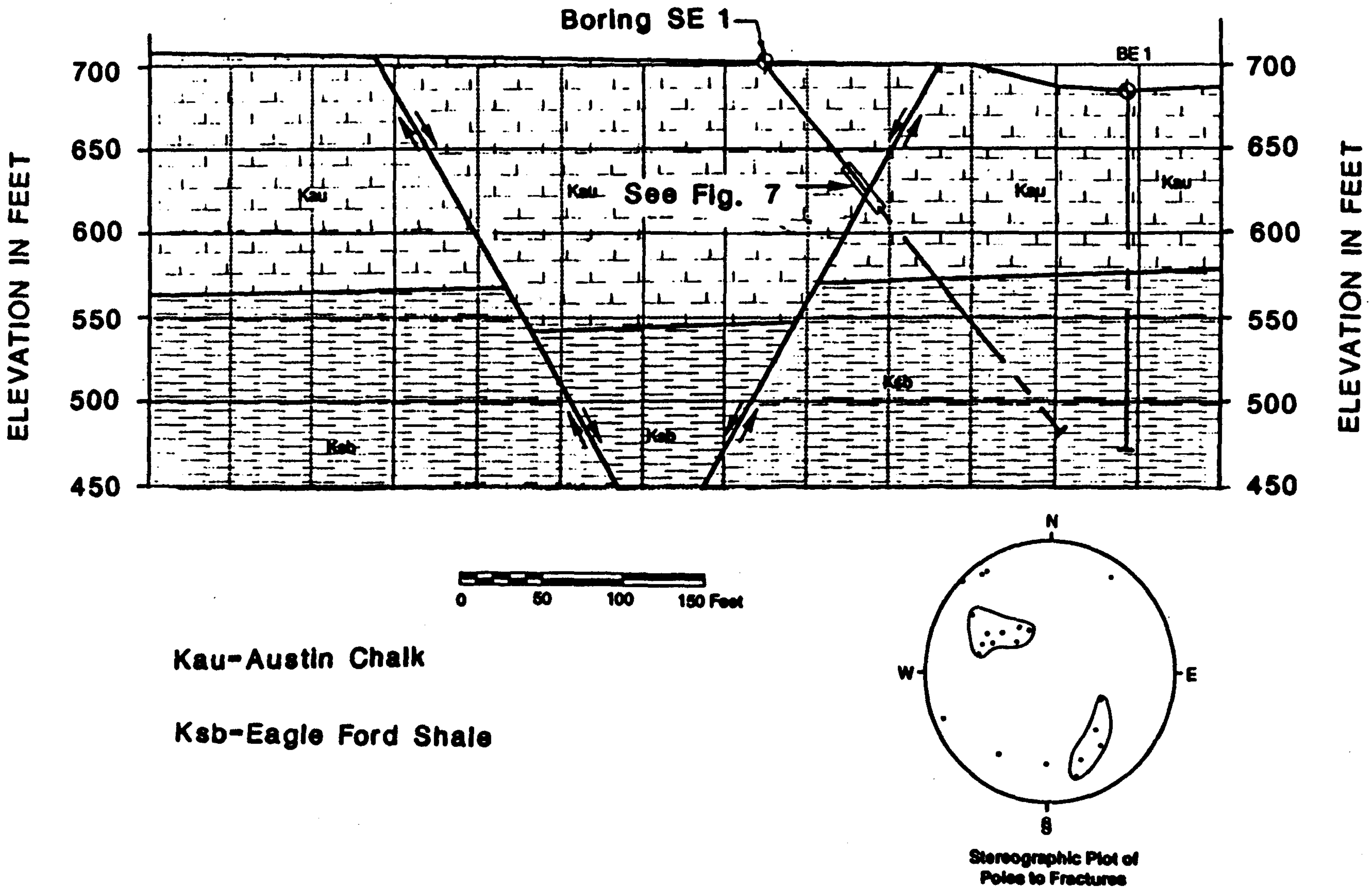


Figure 6 Detailed geologic cross-section of the SE1 fault zone.

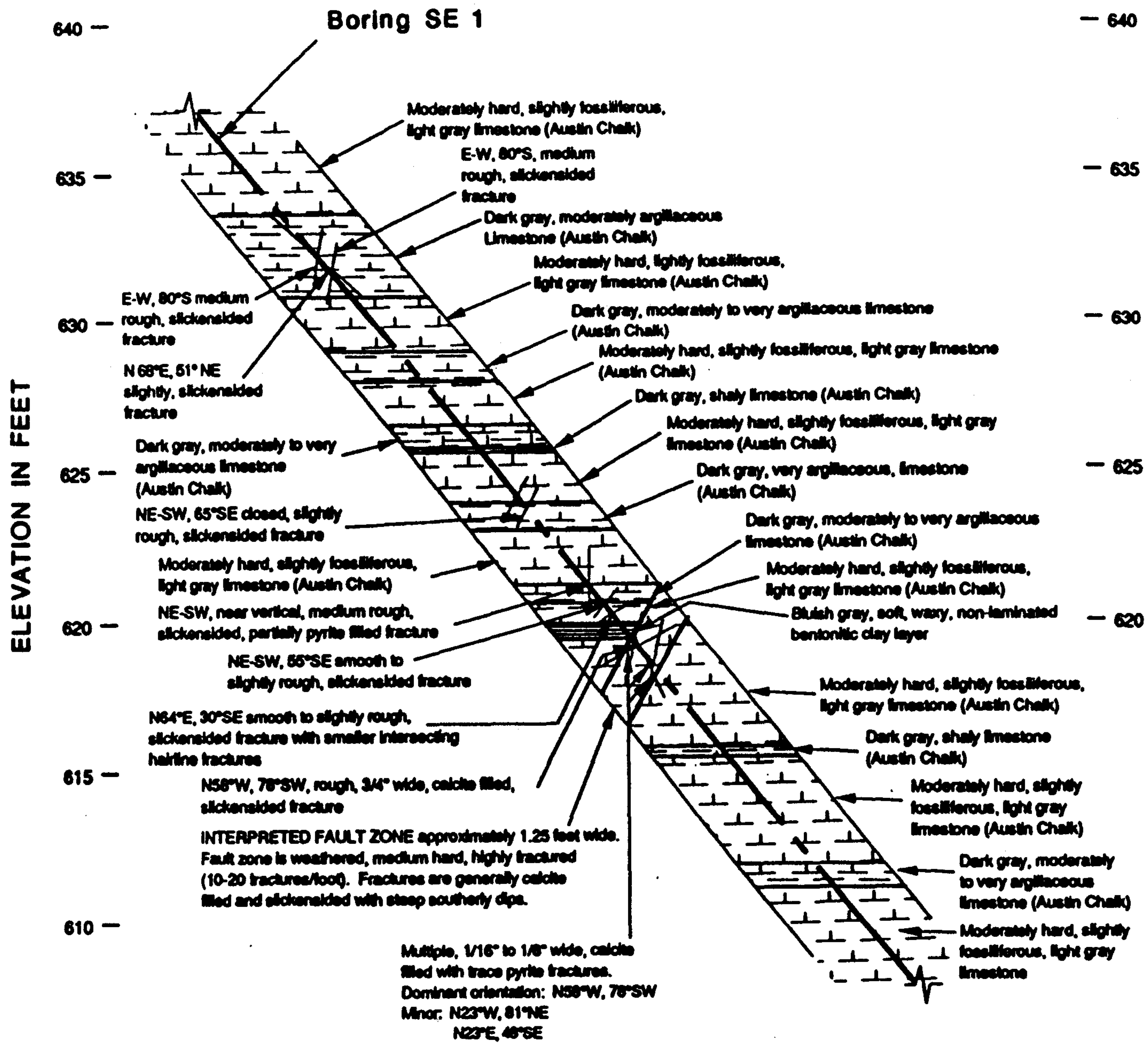


Figure 7 Detailed geologic description of recovered core from inclined boring SE1.

Figure 6 also contains a stereographic plot of poles to fractures observed in the inclined core taken as Boring SE1. A zone along the core axis in the vicinity of one of the fault planes is marked in Fig. 6, and a detailed description of the core recovered in this zone is presented in Fig. 7. The increased frequency of jointing in the immediate vicinity of the fault plane is notable, as is the narrowness of the actual fault zone (1.25 ft or 0.4 m). Although many of the discontinuities are noted to be slickensided, the surfaces are typically rough and healed with calcite (often coarsely crystalline, locally referred to as "diamonds").

Tunneling Considerations

Preliminary consideration of requirements for successful construction should take into account all that is known from previous projects. While there is a wealth of experience concerning excavation characteristics of the Austin Chalk, little local underground construction experience has been gained in the Eagle Ford Shale. During the early stages of the conceptual design, local Eagle Ford Shale excavations were visited and reference made to design studies conducted to support other design work, most notably investigations of the Dallas Area Rapid Transit Authority (DART) and the Dallas-Fort Worth International Airport Authority.

Most of the construction in Eagle Ford Shale has been for shallow foundations and retention systems, and no experience has been accumulated concerning shale response at the depths envisaged for the collider facilities. The Eagle Ford Shale excavations around the Dallas/Fort Worth area to the north of the SSC site are in a somewhat different stratigraphic levels from that of the SSC, and some variation in ground conditions and behavior from site to site can be anticipated. However the basic excavation characteristics of the Shale experienced in the area, are expected to be encountered at the first tunnel contract site.

For shallow foundations in the West Campus area and at shafts, local experience in the shale material has shown it to be highly susceptible to shrink/swell phenomena. Residual soils are renown for giving foundation problems and open-cut and tunneling operations need to take account of the rapidity with which the claystone material can alter, if left exposed to the atmosphere for any amount of time.

Underground excavation in unweathered Eagle Ford Shale rock strata should be easily achieved using mechanical excavation techniques. The use of a soft ground, shielded full-face tunnel boring machine (TBM) is anticipated, equipped with picks or possibly disc cutters. The length of drive and the need for an intrinsically stable tunnel structure make the TBM the obvious choice of excavation equipment. Note that, although it is certain that continuous miners or roadheaders could also be effectively used for mining, it is doubtful that partial face excavation at one or two headings could maintain the rates of advance (averaging more than 100 ft or 30 m per day) required by project scheduling.

Along the Eagle Ford Shale portion of the tunnel, a precast concrete segmental lining installed directly behind the boring machine is envisaged as providing the final rock support structure. Such a grouted lining is shown in the tunnel cross-section presented in the right half of Fig. 8. Given the comparatively small minimum bored diameter (13.7 ft., 4.2 m), the cohesive nature of the ground and the limited amount of fracturing exhibited by the rock mass, "block type" instability in the roof and sidewalls of the opening is not expected to hinder erection of the precast lining.

With consideration for the depths of the shale tunnel structure and the susceptibility of the exposed rock material to alter and generate swell pressures, grouting operations should be performed in a timely manner following excavation. Grout injection should occur for the full circumference of the ring. The establishment of continuous contact between the rock and lining will ensure that rock alteration is inhibited. Such an integral contact will act to encourage the early establishment of a convergence-confinement equilibrium between the rock mass and the lining, and to reduce the possibility that swelling pressures or extensive yield zones could develop in the rock mass.

Excavation at the northern-most end of the contract drive is also envisaged using

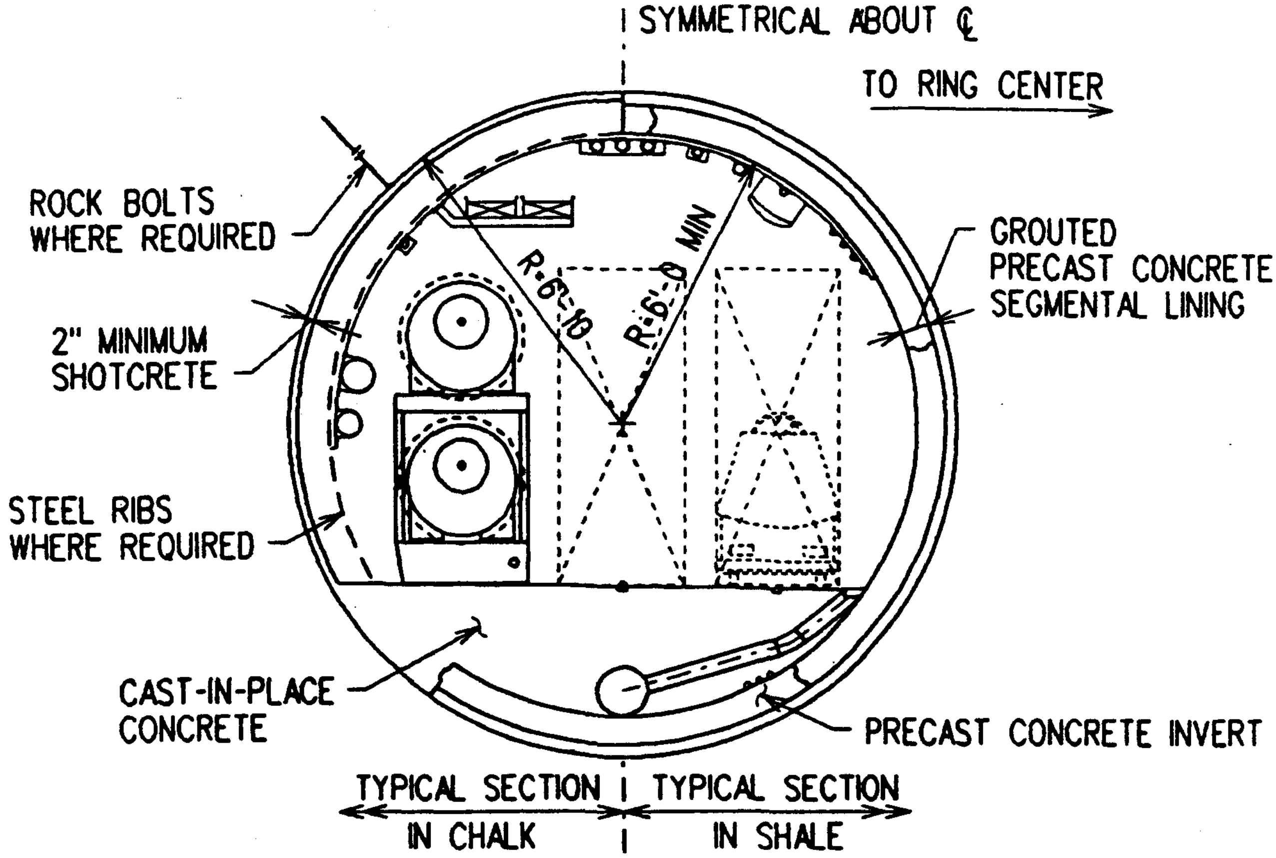


Figure 8 Prototypical SSC main collider tunnel cross-sections, showing preliminary linings designed for Austin Chalk and Eagle Ford Shale tunnel sections.

mechanized excavation by full-faced shielded tunnel boring machine(s) (TBMs). For long sections of chalk, only spot bolting with local arch support and shotcrete are envisaged to fulfill the final tunnel support needs, as shown in the left half of the tunnel cross-section included in Fig. 8. However, given the short length of tunnel in Austin Chalk and the probability of "mixed chalk-shale" conditions in the northern limits of the contract, it is likely that the contractor will stay with the excavation and support configuration similar to that adopted for the Eagle Ford Shale.

The finishea cast-in-place floor in the tunnel will serve as a foundation for particle beam equipment. For both short- and long-term, stability of the floors is paramount to the overall successful operation of the project. In the main tunnel, the beam trajectory must be aligned and maintained to tenths of millimeters accuracy for the duration of each operating cycle. From a longer term standpoint, periodic adjustment of the beam components, to compensate for "year on year" -type, millimetric displacements, could be undertaken. However, given the size and number of such elements, it is essential to maximize the structural stability of each beam component.

With early sealing of the rock surface and establishment of a supporting stress by grouting closely behind the tunnel face, potential for significant time-dependent ground movements along the main tunnel will be greatly reduced. However, plans are underway for instrumentation to be installed in the first tunnel segment. This monitoring program is directed to provide the designer with an early opportunity to investigate the in situ behavior of the rock mass and support systems. Such an investigation is well-warranted to provide guidance for the design of the more complex openings in Eagle Ford Shale, located to the south of the C1 shaft, where tunnels and large equipment chambers and detector halls will be excavated, as will additional connecting adits which intersect with the main collider tunnel.

Although not of claimed critical importance to physicists, the particle accelerators should be installed and operated in a dry environment. At the Texas SSC site, little water infiltration is expected along the first tunnel segment. Given the low primary permeability of the rock mass, inflows which may potentially occur will be associated with isolated fracture systems which are in communication with the superficial water tables. To date, open fracturing has mainly been encountered in weathered zones in the Austin Chalk, and therefore inflows may be anticipated during the northern-most portion of the first tunnel section excavation. Where precast segments are used for the tunnel lining, reducing flow rates and draining residual flow will introduce few problems. Where shotcrete linings are used, reservation has been made in the profile to allow for local cast-in-place lining and drainage where necessary.

Status of the First Tunnel Contract

Since the site was selected in 1988, conceptual work has continued towards the design phase. In February, 1990 a joint venture team of Parsons Brinckerhoff and Morrison Knudsen (The PB/MK Team) was selected by the SSC Laboratory, and the selection was approved by the Department of Energy, to be the architect-engineer and construction manager for the SSC project. Conceptual designs prepared by the SSCL conceptual design contractor (RTK, a joint-venture team of Kaiser Engineers inc., Tudor Engineering Co., and Keller Gannon-Knight) are beginning to be turned over to the PB/MK team who will complete preliminary and final designs for all project surface and underground facilities. Currently details such as the size, orientation, and location of underground components are being finalized as the accelerator technical components come into focus. Ongoing conceptual work also includes studies to address construction tolerances and groundwater infiltration limits required to support the accelerator machines.

The SSCL baseline schedule calls for the design of the E1 shaft and first tunnel segment to be completed by very early in 1991, with construction following immediately thereafter.

Conclusions

The Superconducting Super Collider (SSC) project is moving from the conceptual stage towards reality. Geotechnical exploration and testing has moved from the site characterization stage into the design. Components and requirements of the accelerator machine are being refined and finalized. An architect-engineer and construction manager has been selected and is beginning to mobilize its design effort.

The first tunnel segment of the project will be constructed in the least favorable geologic material to be encountered on the project. Although the geologic materials are expected to be well-behaved, the sheer size of the project and the potential for overstress conditions and time-dependent displacements will present both design and construction challenges to the underground industry.

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