LACKLAND AIR FORCE BASE

SAN ANTONIO, TEXAS

GEOLOGICAL AND FOUNDATION INVESTIGATION

BY

WAYNE E. McINTOSH

ROBERT C. BEHM

U. S. ARMY ENGINEER DISTRICT, FORT WORTH

CORPS OF ENGINEERS

FORT WORTH, TEXAS

APRIL 1967

PLATES

APPENDIXES

SUMMARY

Building foundation distress in the San Antonio area, including Lackland Air Force Base, has long been attributed to the action of swelling surface soils. More recent design and construction practice has been to separate building foundations from these soils but the problem has still occurred. Recent studies show that, while active surface soils can cause considerable distress to a structure, uplift forces against deep pier shafts and footings have also resulted in building distress.

Lackland Air Force Base is located within the Balcones fault zone and is underlain by clay shales of the Upper Cretaceous Navarro group and Tertiary Midway group. These strata have been severely faulted and are weathered, jointed, and fractured to depths of 30 to 40 feet below ground surface. They are, in turn, mildly weathered to depths of 50 to 60 feet below ground surface. Mineralogical studies show the Navarro and Midway clay shales contain about 30 and 70 percent Ca-montmorillonite, respectively. Based on laboratory and field tests, these shales appear to be moisture deficient, particularly below the base of severe weathering.

It is considered that much of the distress developed in buildings constructed on deep drilled and underreamed piers landed in clay shales is the result of uplift forces developed by swelling montmorillonitic clay shales. The swelling apparently occurs as these moisture deficient materials take on water from overlying gravel beds, the ground surface, or possibly from the concrete placed in the pier holes. It is believed that this problem can be overcome by designing pier footings for higher allowable bearing capacities and water proofing the walls of the pier holes.

The recently conducted studies showed that the most suitable foundation media at Lackland AFB have been the dense gravel stratum at the base of the overburden. No distress has occurred to any buildings founded on this material. Unfortunately, the gravel is not of sufficient thickness and density throughout the base area so that all buildings can be founded on it.

No evidence was found to support the theory that recent faulting or mass movement of foundation clay shale strata caused or contributed to building distress at Lackland Air Force Base.

INTRODUCTION

The San Antonio, Texas, region has long been considered a foundation problem area occasioned by expansive soil conditions affecting buildings and engineering structures. In an effort to minimize or eliminate the effects of these expansive soils, design engineers working in the area have adopted a foundation design for most structures utilizing drilled, underreamed, cast-in-place piers. Also, floor slabs are suspended and voids are formed under grade beams. These measures isolate the structures from the effects of these expansive soils. The Corps of Engineers has adopted the following criteria for projects within the Southwestern Division, including the San Antonio area, where expansive soils occur:

1. Structural slabs are used when practicable. If necessary to use a slab on grade, such as for large warehouses or heavy equipment floors, the top 18 inches of soil is removed and replaced with select, low plasticity material, and the underlying 6 inches of soil is scarified and recompacted to not less than 85 nor more than 90 percent modified density, wet of optimum.

2. Voids are provided under all grade beams.

3. Footings are placed below zones of seasonal moisture change and bearing values are selected to minimize differential settlement.

4. The pier shafts are reinforced with at least 0.75 percent steel.

5. In situ terrace gravel is used for the bearing stratum when sufficient thickness and continuity are found and when the water table is encountered at or below the top of gravel. Otherwise, the bearing stratum has been clay shale at depths of 30 feet or more with the final depth dependent on the weathering characteristics of the upper portion of the clay shale and its settlement properties as determined by laboratory testing.

By the fall of 1965 there was an accumulation of evidence of structural distress ranging from minor to major in buildings of various types constructed within the past six years at both Kelly and Lackland Air Force Bases, the most severe distress having occurred in the lighter and most recently constructed structures. These buildings included a one-story steel frame structure with masonry walls, a three-story combination reinforced concrete frame structure with masonry walls and steel frame with insulated metal panel walls, and a multistory (conbination of one to thirteen stories) reinforced concrete frame structure with reinforced concrete walls. In each of these buildings the foundation design utilized the drilled, underreamed, cast-in-place reinforced concrete piers. Footings were bottomed at depths which varied from 30 to 67 feet below existing grade. The distress noted in these facilities included cracking of exterior masonry walls and interior partitions, accompanied by warping of door frames and, in the lighter one-story building, structural failure of the reinforced concrete plinths and piers.

From extensive investigation of these particular structures it became apparent that the buildings were experiencing progressive differential movement with consequent structural distress. Further, the studies indicated that movement was occurring as a result of forces generated by the primary strata acting on the cast-in-place reinforced concrete piers rather than as a result of surface soils acting on the structures. In view of the construction program anticipated at Lackland Air Force Base and considering the related history of building foundations subjected to horizontal and vertical movement, the United States Air Force directed that a comprehensive program of foundation investigations and geologic studies be made prior to the initiation of foundation design for future construction at the base. Both the Air Force and the Corps of Engineers concurred that this information was essential to modify or to qualify design criteria then in current use and that the conclusions derived from the study, together with the information developed from associated studies, should result in foundation design concepts which would minimize distress to buildings and allow for the construction of structurally safe, attractive, and functional facilities.

PROJECT LOCATION

The principal area investigated, Lackland Air Force Base, is located in west central Bexar County, approximately 9 miles southwest of downtown San Antonio, as shown on plate 1. This is roughly a rectangular area encompassing approximately 1,000 acres. It is bounded on the north by U. S. Highway 90, on the east by the Kelly Air Force Base, on the south by Dyer Road, and on the west by Interstate Highway 410. Military Highway (Loop 13) bisects the base in a northwest-southeast direction and is the major access artery.

Lackland Air Force Base is referred to in this report as the Study Area. Within the scope of the study special emphasis was directed toward the development of detailed subsurface geology and foundation conditions related to the proposed expansion of the Wilford Hall Medical Facility, which is hereinafter referred to as the Hospital Complex area. Work was also done in Bexar County to develop the regional geology.

INVESTIGATIONS

Research of Available Data

Research of available geologic data included a review of pertinent published and unpublished reports in the files of the Corps of Engineers, U. S. Geological Survey, San Antonio City Water Board, Texas Water Development Board, and other governmental and private agencies. Conferences were held with geologists and engineers of The University of Texas, Bureau of Economic Geology, Trinity University, San Antonio College, Texas Water Development Board, and the Texas Highway Department (San Antonio District). No detailed geologic information could be obtained from the present operators of the Gas Ridge oil field which was discovered in 1912 and is located just south of the Lackland Air Force Base. Literature concerning this oil field states that oil is being produced out of thin sand lenses in the lower 300 feet of the Navarro group and natural gas from the Anacacho limestone. Contacts with other oil and gas companies revealed no useful information, as this has not been an area of active interest. With data from the above sources for background, field trips were made to local exposures of formations known to underlie the study area, and stratigraphic units were mapped that would be encountered in the exploration program.

Previous Investigations

Corps of Engineers - The Fort Worth and Galveston Districts, Corps of Engineers, drilled approximately 285 relatively shallow core and auger borings at various locations at Lackland AFB to obtain foundation data for design of various structures. In addition, two geology reports, "Geology of Kelly-Lackland Quadrangle, Bexar County, Texas," and "Lackland Air Force Base 2000 Acres Project," were prepared in 1952 by Mr. John Murchison. The purpose of these reports was to incorporate geologic data with foundation design for future construction and to supplement the previous investigations with more detailed geologic information on a 2,000-acre site under consideration for purchase by the Air Force. This site was located about one mile west of Lackland AFB and is presently known as Medina Base or Lackland Annex.

Soil Conservation Service - The Soil Conservation Service has drilled a large number of shallow overburden auger borings to obtain data for their publication, "Soil Handbook for Soil Survey - Metropolitan Area of San Antonio." Plate 6, has incorporated much of the data presented in this handbook.

United States Geological Survey, Texas Board of Water Engineers and San Antonio Water Board - These agencies have collaborated on a number of publications which have been useful in the preparation of this report. Of special note is USGS Bulletin 5911, "Ground Water Geology of Bexar County, Texas," by Ted Arnow. Included in this bulletin is a geologic map of Bexar County. Information from this map, together with recent data not available when the bulletin was published, has been incorporated into plate 2.

Field Investigations

Surface Mapping - Surface geologic investigations of the study area commenced with several trips to the vicinity of the Lackland, Kelly, and Medina Bases. Alluvial deposits mask rock formations over much of the study area, and surface exposures were found to be confined to the immediate vicinity of Leon Creek between Lackland and Kelly Air Force Bases, along Medio Creek on Medina Base, and in a few road cuts. Numerous bedrock exposures were sampled for study and were mapped on existing topographic sheets.

Micropaleontological Studies - Due to the similarity of outcrop materials observed and sampled, and the lack of accurate information from the available literature, it was decided that micropaleontological studies were needed to define stratigraphic contacts accurately. Mr. Porter Montgomery of Montgomery Stratigraphic Services, 1511 Milam Building, San Antonio, Texas, was retained for these services. A copy of his study is included as Appendix B within this report. Surface samples collected by the Corps of Engineers in company with Mr. Montgomery, together with a few samples he had previously collected, were identified and plotted. An understanding of the area geology obtained from this surface work permitted the development of a detailed subsurface exploration program. Structural features, such as fault A-A on plate 7, which previously had been only vaguely located, were accurately located as a result of these studies.

Drilling Program - The drilling program for the detailed study was planned and initiated after first developing the general structural geology of the area from review of available geological data, correlating results of surface mapping, and micropaleontological studies and review of available electric logs. Drill locations were laid out so that more precise geological correlation could be made and details of faulting could be developed. The drilling program was begun in June of 1966 using Fort Worth District, Corps of Engineers, forces and equipment. This program consisted of drilling seventeen 3-1/8-inch fishtail borings located as shown on plate 7. The average depth of these borings was 200 feet, with one boring, 3F-8, drilled to 400 feet to intercept the Navarro-Taylor contact. While this drilling program was in progress, representative samples from previously drilled core borings were examined and identified by Mr. Montgomery. In all, a total of 4,400 linear feet of fishtail drilling was performed for this phase of the investigation.

Electric Logging - Early in the investigational program it became obvious that resistivity and/or gamma-type electric logs could be used effectively for correlation of various horizons within the primary strata. As the study progressed, permission was obtained from local water well drillers to log deep wells under construction. Also, Kelly AFB officials granted permission to run gamma logs in two abandoned water wells located on the base. Information collected from these wells was very helpful in checking subsurface data obtained from other sources and in correlating over a larger area. Plates 4 and 5 are two geologic sections developed from this information. The U. S. Geological Survey assisted in the logging of these wells, using a logger capable of furnishing both the gamma log and the conventional electrical resistivity log. The gamma log was especially valuable in logging portions of wells in which casing had been installed. Logging equipment was used cooperatively by the USGS and the Texas Water Development Board, with expenses shared equally by the two agencies.

Resistivity and, in many cases, gamma-ray logs, were run in all borings drilled by the Corps of Engineers with excellent results. Being able to correlate with the "e" logs was most gratifying for it greatly reduced the number of more expensive core borings that otherwise would have been required to delineate subsurface formations and structures.

Acknowledgments

The cooperation and assistance of many individuals and organizations are gratefully acknowledged. In addition to those individuals and organizations enumerated in Appendix A, acknowledgment is also made of the generous assistance received from personnel of the Base Engineer's office at Lackland and Kelly Air Force Bases. Local water well drillers J. R. Johnson and Glen Haskins furnished much valuable information by making their well records available for study and permitting logging of their new wells in and near the Study Area.

REGIONAL GEOLOGY

Physiography

Portions of two physiographic provinces are involved in the geology of the region: the Edwards plateau, located northwest of the Balcones escarpment, and the Coastal Plain, located to the southeast of the escarpment. The Edwards plateau is underlain principally by limestone beds that regionally dip very slightly to the southeast. Many small streams have dissected this plateau, resulting in a rugged, hilly terrain with topographic relief from 1100 to 1900 feet above msl. The Balcones escarpment trends in a northeast-southwest direction across the northern part of Bexar County and shows an abrupt change in elevation as well as a change from the hill country to the northwest to the rolling plains of the southeast. The Coastal Plain is a rolling prairie underlain by beds of marl, clay, and poorly consolidated sands. These beds range from 425 to about 700 feet above msl and generally dip toward the southeast at a greater rate than those of the Edwards plateau region.

Stratigraphy

Gravel beds found immediately overlying primary strata in the Lackland AFB vicinity are remnant Uvalde terrace deposits of the Pliocene series, Tertiary system. The nearby Edwards plateau region has been identified as the source area for these alluvial deposits. In this region the Uvalde gravels are now found deposited only on areas of higher relief but once covered extensive areas in and south of the Balcones fault zone. The deposits range from 5 to 15 feet in thickness and consist of limestone and chert gravel, and boulders up to 6 inches in diameter, embedded in a matrix of clay or silt. In many locations these gravels are also found to be caliche cemented. Alluvial materials, clay, silt, sand, and gravel overlying these Uvalde gravels, are of Recent age. They were derived from the Cretaceous and Tertiary system sedimentary rocks which occupy the entire surrounding region. The alluvium ranges in thickness from 0 to about 45 feet, with the thickest and most extensive deposits in the stream valleys. Distribution of surface soils in the Study Area is presented on plate 6.

The rock units underlying the region discussed in this report belong to the Cretaceous and Tertiary systems. The Cretaceous includes the Edwards and associated limestones, Grayson shale, Buda limestone, Eagle Ford shale, Austin chalk, Anacacho limestone, Taylor marl, and the Navarro group. The Tertiary includes the Midway group. The Taylor, Navarro, and Midway groups comprise the foundation rocks in the Study Area and are discussed in detail under succeeding paragraphs. The areal extent of these formations in Bexar County is shown on plate 2, and their sequence and approximate thickness are shown on plate 3.

Structure

Regional structural features that have greatly influenced the physiography and geology of the Study Area are the Balcones fault zone and the Culebra anticline. The Balcones zone of faulting is of variable width, includes areas of moderate to intense faulting, and is generally surficially characterized by a prominent escarpment. The fault zone extends from McLennan County in central Texas to Kinney County in southwest Texas. Interstate 35 follows a route more or less paralleling this feature from Austin to San Antonio. Faults comprising this system are generally steep angle, normal or gravity faults which are downthrown to the south or southeast. Single faults within the system exhibit displacements up to 700 feet, with the total cumulative displacements across the zone being up to 1500 feet. The cause of the faulting has generally been attributed to tensions created as the Coastal Plain settled under its continual depositional load. Once the tensional forces exceeded the elasticity of the rocks, faulting or rupturing was inevitable, and the prominent escarpment between the Edwards plateau and the Coastal Plain was developed. Fault trends and topographic expression of these features are shown on plate 2.

Structural geology features resulting from Balcones faulting are shown on plates 4 and 5. The location of these profiles which encompass the Study Area is shown on plate 2. The other structural anomaly, the Culebra anticline, is a broad, southwest plunging anticline which extends from north central Bexar County into eastern Medina County. The fold, 7 to 9 miles wide, consists of a core of Austin chalk overlapped by beds of Taylor and Navarro age. Faults border and terminate the flanks of this anticline.

GEOLOGY OF THE STUDY AREA

Physiography

The area encompassing Lackland AFB is characterized by a very gently rolling topography that has been modified by construction grading and leveling. The principal drainage for the area is controlled by Leon Creek which traverses the northeast and eastern boundary of the base. Within the eastern area, Leon Creek has incised its channel near the toe of a fairly steep bluff. This has resulted in a topographic feature that exhibits approximately 84 feet of relief.

Stratigraphy

The overburden materials at Lackland AFB are approximately 20 feet thick and consist of silty, limy clays derived from the clay shales of the underlying formations. Chert and limestone gravel beds of varying thickness which have been derived from the nearby Cretaceous formations are also present throughout the area. Subsurface data indicate an average of 5 feet of clayey gravel overlying primary strata. Clay content in these materials is variable; at some localities they are clay choked and relatively impervious, whereas, at other localities, the clay is absent and they are free draining. Water is usually present in the gravel beds and discharges from them in exposed surfaces or in drill holes. Rate of discharge ranges from slow seepage to free flow, dependent on the clay content. Several commercial gravel pits are being operated along Leon Creek, outside the military bases.

Three geologic units are represented in the subsurface strata within the Study Area. Primary strata of Cretaceous system include the Taylor marl and the Navarro group, and those of the Tertiary system are represented by the Midway group.

The Taylor marl is a soft to moderately hard, calcareous shale or marl which is found only along the extreme northern edge of the Study Area on the upthrown side of fault A-A beneath a thin mantle of the Navarro. The Taylor attains a maximum thickness of about 315 feet at Lackland AFB.

The Navarro group is a sandy, silty clay shale and, in most cases, exhibits jointing, fracturing, and weathering features to a depth of 70 to 80 feet below the ground surface (Figure 1). The Navarro immediately underlies the overburden in the southern one-third of the Study Area, within a small portion of the Hospital Complex area, and beneath almost all of Kelly AFB. The maximum thickness of the Navarro within the Study Area is approximately 450 feet.

The Midway group underlies the northern two-thirds of the base, with the exception of the area underlain by the Navarro in the Hospital Complex area. This structural discontinuity in the hospital area is a result of faulting. The Midway is divided into upper and lower members to better define structural conditions in the area. The lower member, approximately 60 feet thick, consists of glauconitic clay with glauconitic sandstone beds up to 5 feet thick. A relatively pure bentonite bed from 2 to 5 feet thick is present in the Lower Midway, approximately 8 feet above the Midway-Navarro contact. This horizon appears to be a good marker, as it has been identified in core logs at both Lackland and Medina bases. The upper member consists of a highly plastic, montmorillonitic clay shale. Generally speaking, all cores from the Upper and Lower Midway within the Study Area show extensive jointing, fracturing, and weathering (oxidation) to a depth of approximately 50 feet below natural ground surface. Maximum thickness of the combined Upper and Lower Midway at Lackland AFB is 250 feet. This interval is located in the northeast section of the base.

Structure

The strike of these Cretaceous and Tertiary strata is approximately N30°E and they have a general dip of approximately 3 degrees to the north. As evidenced by the dip of the beds, it appears that Lackland AFB is located on the north flank of a small anticline that is oriented in an east-west direction with the crest located a short distance south of the base. This structure is possibly associated with the Culebra anticline, discussed earlier. The geology at Lackland AFB has also been greatly influenced by faulting. Three major faults have been located and are identified as faults A-A, B-B, and I-I on plate 7. Two of these faults, A-A and B-B, occur in the hospital area and are discussed in detail under "Structure of the Hospital Complex Area." The third fault, I-I, is located near the southern boundary of the base and strikes approximately east-west. The fault is downthrown to the south and has a maximum displacement of 180 feet at Military Highway. The displacement decreases toward the west, as shown on plates 8, 9, and 10. The fault brings a thin, narrow section of Lower Midway to the surface, as evidenced by glauconitic clays which were noted in logs of test borings made at the Kelly AFB Security Building site. A minor fault, G-G, located in the central part of the base, strikes N38°E, and is downthrown toward the north. Maximum displacement is 75 feet at the west boundary of the reservation and the throw decreases rapidly to the east. This feature is probably an asset as it concerns structure foundations since it reduces the areal extent of the bentonitic Upper Midway within the base. Other minor faults, designated F-F and H-H, were found in the Study Area, and their locations and extent are as shown on plate 7. Three geologic sections have been developed depicting the subsurface geology for the Study Area. Plate 8 shows section A-A' along the western boundary of the base, plate 9 shows section B-B' along Military Drive in the center of the reservation, and plate 10 shows section C-C' along the eastern boundary of the base. These sections were further developed into the isometric fence diagram, presented on plate 11.

Ground Water

An effort was made to obtain water level readings in each boring drilled during the subsurface investigations to establish the water table condition throughout the Study Area. After the first few NX fishtail borings had been completed, attempts to obtain ground-water readings were unsuccessful. Without exception all of the borings "bridged over" generally near the top of the primary strata. In some cases it was necessary to re-enter and condition the borings before electric logs could be run. A perched water table is present throughout the Study Area, but no pattern could be developed. It appears reasonable to assume that the free water generally found in the gravel stratum is recharged from the surface, and is dependent on local precipitation and watering practices. Additional ground-water data were obtained during the investigation of the Hospital Complex area and are discussed in detail under that portion of the report.

GEOLOGY OF WILFORD HALL HOSPITAL COMPLEX AREA

Location

The Hospital Complex is located in the north-northeast corner of the Lackland reservation, as shown on plates 7 and 12. At present, the only buildings in the Complex are the multistory Wilford Hall Hospital, MacKown Dental Clinic, a medical laboratory, and the boiler plant. Future construction will include additions to the hospital and a number of permanent type medical support buildings.

Previous Investigations

Previous investigations conducted in the Hospital Complex area included drilling a number of auger and core borings for design studies of the hospital, dental clinic, boiler plant, and medical laboratory. The depth of these borings ranged from 10 to 80 feet below the then existing ground surface.

Post construction structural distress noted at the MacKown Dental Clinic was investigated by a series of auger and core borings. The results of these studies and recommendations for repair were covered in detail in a report titled "Lackland Air Force Base, Dental Clinic, Final Report," published by U. S. Army District, Fort Worth, Corps of Engineers, 15 November 1966.

Subsurface Investigations

The drilling program for the geological study at the Hospital Complex was laid out to grid the area on 600-foot centers. Twenty-six holes were drilled and included thirteen 3-1/8-inch fishtail type borings drilled to an average depth of 300 feet. Electrical resistivity logs were run in all fishtail borings and gamma-ray logs were run in most of these holes to develop back-up data. Thirteen 6-inch core borings were drilled in conjunction with the program and served a dual purpose in that they were used for geological studies as well as test borings for foundation design studies for the proposed hospital additions. All core holes were electric logged with the exception of 8A6C-20. Representative samples were taken from boring 6DC-22 for mineralogical examination and testing. Samples were also selected from the overburden materials and from the Midway and Navarro strata for laboratory testing. Upon completion of these investigations, an isometric fence diagram was prepared (plate 13), depicting the subsurface conditions for the Hospital Complex area.

Two 30-inch diameter calyx holes were drilled for the purpose of inspecting two fault zones encountered during subsurface explorations. However, due to ground-water problems and caving condition in the holes, both in the overburden and in the primary materials, the holes were deemed unsafe for entry and detailed inspection. A total of 4,655 feet of fishtail and 900 feet of 6-inch core drilling was completed during this phase of the investigation. The location and designation of the above borings are shown on plate 7.

Seismic Survey

A test seismic survey was performed to facilitate correlation between the core borings and to further develop the subsurface structural geology. It had been anticipated that it would be difficult to delineate any structural anomalies by this method because of the homogeneous nature of the primary strata. The paucity of correlative data is reflected in the consultant's report which states, in part: "The information determined by this survey is very limited. The unconsolidated nature of the subsurface material results in a very low velocity and produces a very high rate of attenuation of the seismic energy." The consultant's recommendation for obtaining better results was to utilize a much larger detonation charge to get the seismic energy necessary to travel the required distances. This was not possible due to the proximity of permanent structures and in-use parking facilities. His report stated further "that the record obtained through the use of these measures might not provide much additional information." The entire report is presented in Appendix C.

Topography

The general topography around the Hospital Complex area is relatively flat and is interrupted only to the east and south where surface drainage has eroded deep ravines through the overburden materials and into primary strata. These ravines drain toward Leon Creek approximately one-half mile to the east.

Stratigraphy

Overburden in the Hospital Complex area generally consists of from 2 to 5 feet of black, highly plastic clay or topsoil, 10 to 13 feet of tan, silty, and limy clay, and approximately 5 feet of clayey gravel.

The Taylor and Navarro groups of the Cretaceous system and the Midway group of the Tertiary system comprise the primary formations at the Hospital Complex. The Taylor is present in the extreme northwest corner of the area and has a maximum thickness of 315 feet. The Navarro underlies most of the remaining area and reaches a maximum thickness of 450 feet. All foundation piers for existing permanent buildings within the Hospital Complex area are founded within the Navarro. The Lower Midway is fault controlled and is present only under the northwestern half of the Hospital building. Its maximum thickness here is approximately 15 feet. The Upper Midway is present on the downthrown side of the major fault, B-B, which is located just south of the dental clinic. Plate 7 shows the location and the areal extent of these stratigraphic units. Within this report the Upper and Lower Midway lithologic units and the Navarro have been described as a bentonitic clay shale and as a sandy, silty clay shale, respectively. This description has been based entirely on visual examination. Mineralogical analyses performed on core samples, using X-ray diffraction techniques, reveals the Midway to be essentially a claystone (or shale) with approximately 70 percent Ca-montmorillonite (expansive clay) and the Navarro to be a calcareous siltstone or fine sandstone with approximately 30 percent or less Ca-montmorillonite. Since the mineralogy of these primary strata appears to bear significantly on the problems resulting in the use of these materials as a foundation medium, this subject is discussed later in detail under "Summary of Mineralogical Analyses." The consultant's report, based on his mineralogical analyses, is presented in Appendix D.

Structure

Foundation rocks in the subject area are intensely faulted and fractured. Two major displacements have been delineated which bracket the Hospital Complex. One is located 1200 feet east-northeast from the center of Wilford Hall. It is identified on plate 13 as A-A, is a normal fault which strikes N50°E, and is downthrown to the southeast. Total displacement appears to be about 400 feet. This fault has been noted in previous geologic reports and has been traced for 17 miles in southwest Bexar County. This is also the fault mentioned earlier that had been confirmed by surface geology studies. The other major fault is a normal fault, designated B-B, and is located 800 feet due south of Wilford Hall hospital. It strikes N80°E and is downthrown to the south, exhibiting a maximum throw of 180 feet just south of the Dental Clinic, with decreasing slip or displacement toward the east. This fault intersects fault A-A just west of Military Highway. Within this area the fault brings the Navarro in contact with the Upper Midway on the downthrown side. A minor fault, C-C, striking N45°E and dipping to the north, exhibits approximately 30 feet of displacement. This fault zone passes beneath the center of the hospital and accounts for the thin section of Lower Midway under the northwestern half of the building. Three other small faults have been located within this area. Their location and position relative to the major structural features are graphically depicted on plate 13.

Ground Water

The ground-water table at Lackland AFB presents an unusual situation in that it appears that a true perched water table exists in the granular materials at the base of the overburden. Ground-water levels in the Upper Midway and Navarro strata which are independent of the perched water, have been investigated by installing 11 open tube well-point type piezometers in the general vicinity of the Hospital Complex. The depth of piezometer intake points ranges from 10 to 80 feet below the ground surface. The piezometer tubes are sealed so that they will reflect only the water pressure at the intake point. Locations of the piezometers are shown on plate 7. Subsurface profiles with ground-water information are shown on plates 17 and 18. Generally, the perched water is encountered in drill holes at depths between 5 and 15 feet below the ground surface, and piezometers set within this zone reflect this water level. Piezometers set at depths of 30-50 feet below the ground surface and below the zone of perched water do not indicate the perched water level but show a deficit head of as much as 25 feet below the known elevation of the perched water table. Piezometers with tips set approximately 75 to 80 feet below the ground surface have remained dry for a period of several months. One exception, piezometer No. 8, with the intake set 35-39 feet below the ground surface, reflects the piezometric head of the perched water table which, at this location, is 11.0 feet below the ground surface. The piezometers have been checked several times by filling the tubes to the ground surface and observing the rate of fall to the point of equilibrium. From the investigations it is concluded that, at some point below approximately 25 feet, there is a deficiency in water pressure and this deficiency increases until, at some point below approximately 40 feet, the head in a piezometer becomes zero. Field measurements of negative pressures have not been made, but laboratory tests indicate negative pore pressure (or suction forces) greater than 200 psi exist in strata of the Upper Midway and Navarro groups.

ENGINEERING PROPERTIES OF FOUNDATION MATERIALS

Sampling Procedures

Samples of the overburden and primary formations were obtained for laboratory testing from selected borings drilled at Lackland AFB. The locations of borings from which samples were taken are shown on plate 7. The samples were chosen to be representative of the overburden and the Upper and Lower Midway and the Navarro. The samples of overburden were obtained with an earth auger and Denison barrel sampler; samples of the primary strata were obtained by using a 6-inch core barrel. Samples were protected from disturbance and moisture changes by placing them in sealed containers during transfer to the testing laboratory.

Identification Tests

Liquid and plastic limits tests and hydrometer grain size analyses were conducted on samples representative of the subsurface materials encountered. Typical test results showing the range of values for liquid limits and plastic indices for the various materials are shown on plate 19. Particles smaller than 0.002 millimeters ranged from 20 percent in the Navarro to 60 percent in the Upper Midway.

Even though the percent of colloidal sizes showed a relatively wide range for the various materials, the activity index, as defined by Seed,[20*] lies generally between 1.5 and 2.0 for all the materials. This indicates that the colloids are probably of the same general mineral type and, according to mineralogical analyses conducted on these materials, are of the montmorillonite group. For further information on mineralogical studies, see "Summary of Mineralogical Studies" on page 17.

---

* Raised numerals refer to similarly numbered entries in the Bibliography at the end of the main report.

Moisture Content and Density Tests

Moisture content and density tests were conducted on undisturbed samples obtained from the selected borings. Correlation of moisture and density test results with respect to depth are shown on plates 20 through 23 for each of the materials investigated. The effective overburden pressure-depth correlation for Upper and Lower Midway and Navarro materials are shown on plate 24. Since the water table encountered at approximately 10 feet appears to be a perched water table, the moist unit weight has been used in determining effective pressures.

Shear, Compression, and Consolidation Tests

Direct shear, confined and unconfined compression, triaxial shear, and consolidation tests were conducted on specimens from each of the three primary formations. Results of strength tests are tabulated in tables 1 through 3. In those samples which showed jointing, the compression tests were conducted in a triaxial chamber with the chamber pressure equal to effective overburden pressure. The compressive strength was taken to be the value of $\sigma_1 - \sigma_3$. This would correspond to recommended test procedures for stiff, fissured clays. Correlation of compressive strengths with respect to depth is shown on plate 25 for the three formations.

Direct shear tests were conducted on samples of the Upper and Lower Midway and the Navarro, with tests conducted on pre-split specimens; that is, specimens with a pre-formed failure plane. It has been noted by some observers that the shear strength derived by this test procedure represents the long term shear strength of a material having fissures. However, the use of these test values has not been evaluated for use in design of building foundations which consist of deeply embedded piers.

Results of typical consolidation test results are shown on plates 26 through 28. It should be noted that these tests are subject to a great deal of interpretation. Settlement analyses for this report were conducted using these test values with the only interpretation being that they represent results of tests conducted on highly overconsolidated clays. The influence of sampling procedures, changes in environment, changes in electrolyte in pore water, and other changes from in situ conditions have not been evaluated in this report. It is believed that each of these changes increases the amount of apparent consolidation indicated for each test load increment and reduces the potential expansion pressures.

Bearing Capacities

Bearing capacity with respect to shear strength and permissible settlement has been determined using typical values. In determining comparable allowable bearing capacities from data obtained in this study, certain assumptions were made:

Depth of Footing - Thirty-five feet below ground surface. This would place the footings some 20 feet into the primary formation.

Size and Shape Footing - Circular bell having a 4-foot diameter.

Soil-Shaft Friction - No skin friction on shaft. This implies that the total load is transmitted to the bell and is effective both in shear and consolidation.

Shear Strength - Test procedures accurately defined in situ shear strength.

Consolidation - Material is overconsolidated clay, and test procedure accurately defined the compression index.

Using these assumptions, a comparative analysis of the allowable bearing capacities for the three formations is shown below.

Formation	Allowable Bearing Capacity, TSF		
	Unconfined Compression	Shear	Settlement
Upper Midway	12	9	5
Lower Midway	6	25	7
Navarro	20	32	20

The allowable bearing capacity with respect to settlement allows a maximum predicted settlement of 1.0 inch and a possible differential settlement of 0.5 inch. The allowable bearing capacity with respect to strength includes an adequate factor of safety.

SUMMARY OF MINERALOGICAL ANALYSES

Lackland Air Force Base Samples

Representative samples of the three primary strata (Upper and Lower Midway and Navarro) and of the black, fat clay overburden were subjected to X-ray diffraction analysis. The principal minerals identified in the primary materials were montmorillonite, mica (illite), chlorite, quartz, and feldspar. Montmorillonite, quartz, gypsum, and calcite were the principal minerals found in the overburden soils. Montmorillonite, illite, and chlorite are recognized as the primary clay-forming minerals. Of the clay-forming minerals found in the subject materials, montmorillonite is recognized as having the least desirable engineering characteristics because of its potential volume change. Results of the mineralogical analyses are presented in Appendix D.

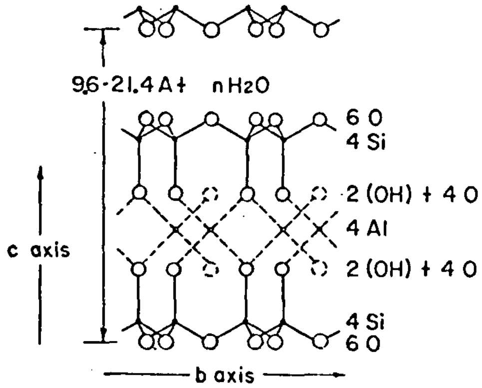
Definition of Clay and Montmorillonite

The term clay as it is commonly used carries with it three implications: (1) a naturally occurring material with plastic properties, (2) an essential composition of particles of very fine grain size (less than 2 microns), and (3) an essential composition of crystalline fragments of minerals that are essentially hydrous aluminum silicates or occasionally hydrous magnesium silicates. The term implies nothing regarding origin but is based on properties, texture, and composition.

Montmorillonites are defined as a group of clay minerals having a definite structure. Their formulas may be divided by substitution in the general formula $Al_4(SiO_4\ O_{10})_2(OH)_4xH_2O$ with deficiencies in charge in the tetrahedral and octahedral positions balanced by the presence of cations, most commonly Ca and Na, subject to ion exchange. They are characterized by swelling in water due to introduction of inter-layer water in the direction of the C-axis.

Properties of Montmorillonites

The montmorillonite structures has layers consisting of one aluminum-hydroxyl unit sandwiched between two (Si_4O_{10}) sheets; these layers are stacked one above the other in the "c" axis direction, with water molecules between them. The interlayer bond is an oxygen-to-oxygen bond which results in a weak structural connection. A characteristic feature of montmorillonite is the high variable water content, which is reflected in the basal spacing, ranging from 9.6 Angstroms in a dehydrated material to 21.4+ Angstroms when the mineral approaches water saturation. Montmorillonite is therefore said to have an expanding lattice.



Schematic of Montmorillonite Structure
$Al_4(Si_4O_{10})_2(OH)_4 \cdot xH_2O$

The characteristic swelling of the primary strata at Lackland AFB is due to their montmorillonite content. As shown by the mineralogical analysis, the clay samples in their natural state had a basal spacing of 17.7A and that of an air-dried sample was 14.2A. This represents a volume change of 25 percent. This value of 25 percent volume change is a minimum, and values of 25 to 50 percent probably occur.

The analyses indicate the composition of the Midway is relatively constant with approximately 70 percent Ca-montmorillonite. The Navarro contains considerably less Ca-montmorillonite, approximately 30 percent a maximum down to a trace.

Recognition of Expansive Clays

Most of the research on expansive clays has been conducted on remolded or manufactured materials. The problems associated with testing undisturbed materials are greatly multiplied because of variations in density, moisture content, and stress history. Skempton[22] proposed a fairly simple index to delineate "active" materials. This index is defined as the ratio Plasticity Index/clay fraction. More recent investigations by Seed[19], using results of controlled laboratory experiments, have more closely defined this value to be equal to the ratio PI/(clay fraction - 10%). Skempton[22] and others have identified "active" clays as those having an activity index greater than 1.25, and the higher the number the more active the clay.

Tests conducted on materials from Lackland AFB indicate an activity index ranging from 1.5 to 3.5. It can therefore be concluded that, in general, the subsurface materials at Lackland AFB range from active to very active. An exception to this was found in material from boring 6D-22 below a depth of 80 feet. Samples obtained from this stratum did not show any montmorillonite. It is of interest that this material was also below the zone of jointing. Whether the jointing is due to the presence of montmorillonite or the montmorillonite is a product of weathering or the occurrence is coincidental has not been resolved. The first possibility is considered the more probable. The expansive properties of the clay minerals are currently being investigated by both laboratory procedures and field performance. The findings of these investigations will be reported in "Building Foundations in Expansive Clays," to be published by the Fort Worth District.

SUMMARY OF CASE STUDIES

Scope

Results of field investigations and engineering analysis of a detailed study of selected existing structures in the Southwestern part of San Antonio, Texas, are presented in this section. Structures on both military reservations and private property were included in the study.

Purpose

The purpose of the case study was to examine buildings constructed at military installations and on adjacent private property to determine if a correlation could be made between building distress and (a) the foundation material, (b) the foundation design, (c) the superstructure design, and (d) the building location. Buildings showing no distress were also examined to determine what, if any peculiarity in foundation material, foundation design, superstructural design, or locality might offer clues for successful design, construction and service.

Design Assumptions

Until recently, foundation and design engineers assumed that most of the foundation problems in the San Antonio area were caused by swelling clays. They used deep footings, structurally supported floor slabs over void or crawl spaces, voids beneath grade beams, and reinforcing steel in pier shafts to attempt to overcome the effect of these swelling soils.

Distress was still experienced in many buildings even where these design features were included. Where this occurred, the distress was attributed to differential settlement of the foundation material beneath the supporting pier footings. However, detailed surveys on at least two major buildings showing distress, together with interviews with several prominent design engineers who have had wide experience in foundation design in the Study Area, led to the conclusion that heaving rather than settlement may be the primary cause of building distress. Further, since many of the more recently constructed buildings have foundations isolated from the swelling surface soils, it must be concluded that the swelling or heaving is occurring within the deeper soil strata and primary clay shale foundation materials. This reaction may be taking place against the pier shafts, the base of the footings, or a combination of reaction in both areas.

Geology of the Case Study Areas

Generally, the geologic formations involved in the case study survey areas are as follows:

a. Lackland AFB - Northern half, Midway group; southern half, Navarro group.

b. Kelly AFB - Navarro group.

c. Brooks AFB - Wilcox group.

d. Shopping Center and Junior High School west of Lackland AFB - Midway group.

e. Elementary schools north of Lackland AFB - Taylor marl.

f. St. Mary's University - Taylor marl.

Identification of the above geologic groups, with the exception of those at Lackland AFB, is based on information derived from the Bexar County geologic map. A detailed geological investigation would be required at each site to positively identify the geologic formation in which the footings for each building were bottomed. The overburden material at each site is a high plasticity clay (CH). A chert and limestone gravel is usually encountered immediately above the clay shale primary formation and varies in depth and thickness at each building site.

Areas of Investigation

The areas selected for the case study survey include Lackland, Kelly, and Brooks Air Force Bases, commercial and public school buildings just north and west of Lackland AFB, and St. Mary's University campus, which is located approximately 5 air miles northeast of Wilford Hall Hospital, Lackland AFB. Locations of buildings examined at Lackland AFB are shown on plate 29, those at Kelly AFB on plates 30 and 31, those at Brooks AFB on plate 32, and nonmilitary buildings examined are shown on plate 33. Military base locations with respect to San Antonio are shown on plate 1. The building numbers shown on these plates refer to the building numbers on the Case Study Survey Data Sheets for each respective area.

Lackland Air Force Base - Most buildings at Lackland AFB are temporary, wood frame, asbestos shingle structures constructed during the late 1940's and the early 1950's. These buildings can take a considerable amount of differential foundation movement without showing signs of distress in the superstructure. The most recently constructed buildings are rigid frame (steel) with masonry exterior walls and plaster interior walls. These structures show signs of distress with only a small amount of foundation movement. This difference in type of construction is believed to be of major importance in attempting to analyze and correlate the distress found in each structure.

Eight of the temporary buildings were examined, six of which had drilled and underreamed pier foundations about 20 feet below ground surface in weathered clay shales. Another had the same type of footing landed in gravel about 6 feet below ground surface. The eighth building had a foundation consisting of a turned down edge slab on overburden. Swelling soil beneath the building on the turned down edge slab had broken the slab and perimeter beams to such an extent that it resulted in distress to the building superstructure. The building founded on drilled and underreamed footings on gravel showed no signs of distress. Five of the six buildings on drilled and underreamed piers were founded on the Midway clay shales, the other on the Navarro clay shales. The building on the Navarro showed distress due to foundation movement, as did three of the five buildings on the Midway. All buildings with drilled and underreamed foundations had a design footing load of 3.0 KSF.

Six buildings with rigid frame structure were examined, five of which were founded on drilled and underreamed footings founded in clay shales. The other building was constructed on spot footings landed on gravel. This building has shown no distress. The two buildings founded on Navarro clay shales are the hospital and the dental clinic. The hospital is a multistory building with footings landed at depths from 50 to 67 feet below ground surface. Design footing loadings varied from 8.0 to 16.0 KSF. Footings for the single story dental clinic are 35 feet below ground surface with a design loading of 6.0 KSF. Distress that developed in these buildings has been the subject of considerable field and laboratory investigations with the conclusion that the distress was caused by swelling materials around the pier shafts and/or beneath the footings, causing upward movement of the footings.

The middle one of three recruit training and housing buildings constructed in 1962 has shown distress. These buildings were of identical design with drilled and underreamed footings landed in the Midway clay shale at a depth of 30 feet below ground surface. During drilling of the pier holes for the middle building, some of the pier holes became flooded from surface runoff and water remained in them for several days. This could have caused the foundation stratum to swell then reconsolidate or to swell after the building load was added.

The other two rigid frame structures examined, both with footings landed in Midway clay shale about 35 feet below ground surface, have footing design for about 6.0 KSF. One has shown distress while the other has not. Pertinent data sheets for all structures inspected at Lackland AFB are shown on pages 33 to 47.

Kelly Air Force Base - For this report, Kelly AFB has been divided into two areas: Main Kelly and the "2000 Area." Main Kelly includes all structures located to the east of the main N-S runway, and the "2000 Area" is a small area adjacent to Highway 13 southeast of Lackland AFB and southwest of Main Kelly (see plates 30 and 31). Buildings at Main Kelly and the "2000 Area" are permanent structures which were constructed between the early 1940's to the early 1960's.

Buildings examined at Main Kelly included six rigid frame structures, three of which were founded on drilled and underreamed piers at depths of from 35 to 57 feet below ground surface in Navarro clay shales. The other three were founded in dense gravel on dug or drilled footings ranging from 10 to 20 feet below ground surface. Allowable bearing pressures on the clay shale ranged from 4.0 to 5.0 KSF and on the gravel from 6.0 to 10.0 KSF. No evidence of distress was found in these structures.

Seven buildings were inspected in the "2000 Area" of Kelly AFB, six of which were found to have experienced severe foundation movement. The Chapel, which does not reflect any foundation movement, is a wood-frame structure founded on shallow continuous footings bottomed in gravel.

The Communications Security Services building is a three-story structure with a reinforced concrete frame and reinforced concrete block, plaster, or glazed tile construction. The foundation consists of drilled and underreamed piers bottomed in unweathered Navarro shale some 95 feet below the natural ground surface. The crawl space beneath the first floor is approximately 4 feet in depth. The floor is thickened at pier locations to act as a pier cap, with the pier being connected directly to the cap with no intervening pedestal. The piers and exterior walls do not show any signs of distress but the floors show warping, and the interior partitions have numerous cracks, indicating differential vertical movement.

The mess hall is a wood frame structure with asbestos siding walls founded on drilled and underreamed piers bottomed 32 feet below the ground surface. Although the wood frame does not reflect any foundation movement, the grade beam is cracked, reflecting foundation movement. Photograph 1, figure 2, shows one of the cracks resulting from this movement.

The other four buildings have rigid frame structures with concrete block walls and are founded on drilled and underreamed piers bottomed in clay shale of the Navarro group approximately 35 feet below the ground surface. All the buildings are supported over a crawl space. Each of these buildings has experienced severe foundation movement. In one of the buildings approximately 75 percent of the pedestals connecting the pier to the floor beams were fractured and have since been repaired. Numerous cracks have appeared in the interior and exterior walls. Examination of the buildings showed that cracks which were once repaired have reopened, indicating a continuing movement. Pertinent data sheets for all structures inspected at Kelly AFB are shown on pages 49 to 62.

Brooks Air Force Base - Most of the buildings at Brooks AFB are permanent type structures constructed in the late 1950's and 1960's. The school of Aero-Space Medicine occupies some ten newly constructed buildings in the northwest corner of the base. The permanent structures are of both steel or concrete frame and load bearing wall construction. The building foundations consist of drilled and underreamed piers bottomed in clay shales of the Wilcox group. Depth of footings varies from 25 to 35 feet below the natural ground surface and the footings are generally sized for an allowable bearing capacity of 5.0 KSF.

Four permanent type buildings were inspected and they have floor slabs which are structurally supported; three over a crawl space and one over 6-inch cardboard carton forms. Buildings with floor slabs placed over a crawl space showed no distress. The building with the floor slab placed on carton forms has suffered severe distress which is reflected both in the floor slab and interior walls. The cause of this distress was determined to be uplift pressure from expansive overburden material. This material became wet and swelled beyond the limits of the 6-inch void formed by the carton forms. Water lines were placed beneath the structure in the expansive soil. Expensive forces broke or disjointed many of these water lines which accelerated and increased the swelling of the overburden material. A 3-foot deep by 3-foot wide trench was constructed beneath and in the center of the structure to free the water lines. In addition, this trench probably acts as a semi-void area beneath the floor slab. No additional disturbance has been noted in the building since the trench was constructed and repairs made.

It is of interest that at least two of the buildings in the School of Aero-Space Medicine are situated across two known faults. Foundation materials varied from one side of the fault to the other, and footing depth and size were adjusted to accommodate the change of material. These buildings have performed satisfactorily. Pertinent data sheets for all structures inspected at Brooks AFB are shown on pages 63 to 67.

Commercial and Public School Buildings - The Valley-Hi Shopping Center, Sam Rayburn Junior High School, Westwood Terrace and Mary Hull Elementary Schools, John F. Kennedy High School, and several buildings on St. Mary's University campus were inspected. Locations of these buildings are shown on plate 33. The buildings are rigid frame (steel) with plaster interior walls and masonry exterior walls. The buildings on St. Mary's campus were constructed in the late 1950's. The other buildings were constructed between 1960 and 1964. The building foundation designs are variable, some being drilled and underreamed piers and some a raft (mat) type foundation.

The Valley-Hi Shopping Center and Sam Rayburn High School are located between Loop 410 and Lackland AFB. The shopping center is of concrete block type construction. The foundation is drilled and underreamed piers bottomed 35 feet below natural ground in shaly clay (Midway formation) with the floor slab placed on a gravel fill. The school is steel frame masonry construction with concrete blocks exposed as interior walls. The foundation for the school is the same as the shopping center, except that the floor is structurally supported. Foundation movement has occurred at both buildings with resultant distress to the superstructures. Photograph 2, figure 2, and photograph 3, figure 3, show typical distress experienced at the buildings. The distress occurred almost immediately after completion of construction and was so severe that the interior architectural features of both buildings were revised to allow for foundation movement.

Two elementary schools located just north of Highway 90 (see plate 33) were inspected and found to be in good condition. These buildings are steel frame with masonry walls and are founded on mat type slabs. The interior walls are masonry but carry no roof load. The slabs were placed on 24 inches of caliche gravel and heavily reinforced. At each steel column, the beams are spread to act as a spot footing. This type foundation design has been very successful for one-story structures with steel columns and girders.

The John F. Kennedy High School, located just north of the entrance to Kelly AFB, is a two-story structure with full basement. The building has reinforced concrete columns and girders with masonry exterior walls and plaster interior walls. Foundation for the structure is pier and beam, with piers extending approximately 50 feet below natural ground into unweathered Navarro shale. The building has very heavy column loads, is in very good condition, and shows no evidence of foundation movement.

Buildings on the campus of St. Mary's University were inspected to determine behavior of structures founded on the Taylor group marls and clay shales. It was obvious from visual inspection that many of these buildings have foundation problems but, due to the lack of construction and design data, only two are discussed. One of these buildings, used for classrooms, is a three-story reinforced concrete frame structure with plaster interior walls and masonry exterior walls. The foundation is drilled and underreamed piers bottomed 35 feet below natural ground in shaly clay. The first floor slab is structurally supported over a crawl space. Many large diagonal cracks are visible in all three stories of the interior walls. Typical distress cracks are shown on photographs 5 and 6, figure 4. This building has suffered severe distress from foundation movement. The other building, a men's dormitory, is also a three-story, reinforced concrete frame structure. The foundation for this building is the same as the classroom structure except that the top 25 feet of the pier shaft has a 3-inch layer of pea gravel around it to act as a friction reducing medium. In addition, an underground drainage system was installed completely around the perimeter of the building extending from the ground surface to the top of a naturally occurring gravel stratum which overlies the primary formation. The purpose of the drainage system was to intercept ground water which might otherwise infiltrate the pea gravel surrounding the piers and funnel down the pier shaft to the base of the footings. Since the building shows signs of foundation movement, it does not appear that the special design incorporated in this building was entirely effective. Photograph 4, figure 3, shows distress to the building. Pertinent data sheets for all nonmilitary structures are shown on pages 69 to 76.

Interviews with Engineers

Several prominent engineers were interviewed to determine what methods private foundation engineers were using in the San Antonio area to overcome the expansive soil and/or foundation problem. Most of the engineers interviewed felt that pea gravel or similar so-called friction reducing material was not suitable to place around pier shafts. They felt that this created a funnel for water to reach the base of the pier shafts. The engineers who were interviewed believed that the primary material has a moisture deficiency to the base of weathering. One engineer casually remarked that he had experienced the most severe problems with piers that are poured in a dry hole; that piers placed in wet borings performed satisfactorily. Because of this moisture deficiency the engineers believed that the pea gravel funnel would create more problems than it would solve in that the gravel would provide access of water to the zone of moisture deficiency.

The current practice of most engineers is to extend the drilled piers well into the unweathered shale and to design against uplift by adding more reinforcing steel in the pier shafts. The uplift forces were assumed to be expansion forces from the overburden soils and weathered primary strata. Some of the engineers believed that the uplift forces were very large; therefore, the required ratio of reinforcing steel to concrete should be approximately 5 percent. Some engineers place the pier shafts in compression before the superstructure load is applied, the theory being that the piers in pre-compression can resist a certain amount of tensional force from the material in which it is embedded before the pier itself is placed in tension. Construction of this type pier is very expensive.

Other types of foundations have been considered by private engineers but are not used for various reasons. Driven friction pile foundations are not used due to the initial construction cost and, also, due to the uplift forces that would be assumed to act on the piles if the foundation materials swelled. Raft or mat-type foundations are rarely used for large structures, primarily because there is no simple way to design them properly. Engineers who use this type foundation rely chiefly on experience to determine size and depth of the finished mat. Raft-type foundations that have proved to be successful are made very rigid by placing heavily reinforced interior stiffener beams 15 feet on center. This type foundation design is used on buildings in which architectural features allow some movement.

In summary, the current practice is to keep pier shafts as small as practical, add 3 to 5 percent reinforcing steel in the shafts and extend the footings to a material that is believed to be moisture sufficient.

Results of Case Study Survey

Based on the case studies, certain broad generalizations can be made with regard to building distress in the Study Area.

With reference to foundation materials, no distress was found in any buildings founded on dense gravel strata at any of the localities investigated. Foundation design on gravel strata included drilled piers, spot footings, and continuous footings, so it appears that the foundation medium proved satisfactory regardless of the foundation design. No building founded on the Wilcox group clay shales at Brooks AFB or on the Navarro clay shales at Kelly AFB showed any evidence of foundation distress. These formations appear to contain less montmorillonite than other clay shales investigated in the Study Area. Building distress appeared to be most common in buildings founded on Navarro and Upper Midway clay shales, both at Lackland AFB and located immediately adjacent to Lackland AFB. These strata were found to contain the highest percentage of montmorillonite. No correlation could be made between distress and depth of footings in these formations.

Apparently there is not much correlation between superstructure design and distress except that distress was less apparent in wood frame compared to rigid frame structures. It could not be determined that superstructure design had caused building distress; therefore it was assumed the distress was caused by foundation movement.

No evidence could be developed that correlated building distress to locality. Distress has occurred to buildings irregularly located at both Lackland and Kelly Air Force Bases. Also, distress could not be correlated with topography or structural geology features, such as fault or shear zones.

Finally, correlation could not be made between foundation design and building foundation distress. Distress was evident in buildings founded both on shallow and deep drilled and underreamed piers and on spot or continuous footings, while other buildings with the same foundation designs in the same foundation media showed no sign of distress. It was found that all buildings with slab or grade construction evidenced some form of distress.

CONCLUSIONS AND RECOMMENDATIONS

1. The Study Area, and the Hospital Complex in particular, are located in areas of significant faulting. It is probable that not all of the faults or shear zones were found in the course of investigations for this study; however, the most significant features are believed to have been located. Smaller faults with minor displacements of from 5 to 10 feet should be anticipated within areas between the major faults.

2. No evidence was uncovered to indicate active faulting or mass movement of the foundation materials is the cause of building foundation distress. Vertical or horizontal movements of surface features such as concrete pavement, utility poles, sewer and utility lines, etc., give no evidence to support this possibility. However, fault and shear zones should be avoided for building locations if at all possible. Footings landed in or through these zones can settle or be distressed because of the broken nature of the foundation materials. Also, fault and shear zones may furnish conduits or seepage paths for water to reach moisture deficient clay shales which may swell and heave appreciably when they take on even a small amount of water. The montmorillonite content of these clay shales compounds this problem.

3. Lightly loaded buildings founded on piers, spot, or continuous ootings constructed on the active surface soils have invariably shown gns of distress. These soils also have an adverse effect on water

lines and floor slabs; however, this problem can be controlled to some extent by placing floor slabs over a crawl space and creating a void beneath the grade beams.

4. Dense gravel strata which occur at some localities in the Study Area have been used for pier footings without developing any sign of distress to the foundation piers, grade beams, or superstructures. Design loads on this material have been in the order of 5 to 10 KSF. This material is considered to be the most desirable foundation medium in the Study Area.

5. A zone of rather severe weathering occurs in the primary Navarro and Upper and Lower Midway clay shales beneath the overburden materials throughout the Study Area. This zone usually extends to at least 30 feet and sometimes as much as 60 to 70 feet below the ground surface. Clay shales are very heavily stained, jointed, and fractured in this zone. Drilling and underreaming piers in this material is usually difficult and frequently hazardous. Settlement can take place beneath the footings, particularly when the clay shales are severely broken and jointed. Conversely, when water becomes available to these clay shales, probably through the joints and fractures, they can swell and heave significantly, thus transmitting upward forces to pier shafts and footings.

6. Beneath the severely weathered zone and above the unweathered primary material is a 20 to 40-foot thick zone of mildly weathered clay shale which is chemically weathered but not severely jointed and fractured. This is considered a reasonably good foundation material if moderately loaded and protected from intrusion of water. This material is montmorillonitic and can swell significantly if allowed to take on moisture.

7. Unweathered primary clay shales capable of supporting rather heavy loads generally occur 60 to 70 feet below ground surface. These materials are usually montmorillonitic, moisture deficient, and can develop high swell pressures when free moisture is made available to them. Generally speaking, it appears that building foundation problems have occurred in these materials when footings in them were too lightly loaded or when free moisture was allowed to reach the footing area.

8. Measures presently being taken to separate building foundations from the influence of shallow swelling surface soils have apparently been successful. However, no suitable measures have been developed to separate ier shafts and/or footings from the influence of potentially active eeper soils and weathered clay shales. Friction reducing media such as ea gravel or vermiculite have been used for this purpose with little success. These materials can have an adverse effect on foundation materials that they can provide a path for surface water to reach the footing ea and thus cause more trouble than the questionable benefits derived

from them. More research needs to be done in development of a suitable, water tight, friction reducing medium to separate pier shafts from surrounding soil and weathered clay shale strata.

9. Tests currently being conducted on another research project by the Fort Worth District indicate that, as has long been suspected, building probably have not been sufficiently loaded to overcome the reaction of shallow soil and primary materials on the pier shafts. In effect, piers have not been loaded in end bearing but rather have been supported by skin friction and therefore influenced by movement of these materials. Serious consideration should be given to increasing footing loadings and decreasing the size of pier footings.

10. Every effort should be made to minimize environmental change in the foundation medium during construction. Surface water and ground water from gravel strata at the base of overburden should be prevented from entering pier holes either during or after construction. Consideration should be given to spraying the drilled and underreamed pier holes with asphalt to minimize the amount of moisture change allowed to take place in foundation materials during and following construction.

11. Greater use should be made of mat type foundation for small, lightly loaded, single story structures with the following features included in the mat design:

a. Perimeter and interior beams should extend not less than 30 inches below grade.

b. Interior stiffeners should be spaced not more than 15 feet center to center.

c. Intersection of perimeter and interior beams should be stiffened with extra reinforcing steel.

d. The top 24 inches of subgrade material should be removed and replaced with nonexpansive soil.

e. Expansion joints should be placed on 25-foot centers in the walls of the superstructures.

12. Based on results of the case history study, it does not appear that generalizations can be made for building foundation design criteria in a given area at a base or for an entire base except that buildings can be founded on the dense gravel strata on piers, spot, or continuous footings. Each building foundation must be carefully investigated and designed to assure successful performance. In design of a building superstructure, particularly those constructed on drilled and underreamed piers, every effort should be made to design as much flexibility as practicable into the superstructure so as to minimize distress which may develop from foundation movement.

13. Geological, soils, and mineralogical data presented in this report should be constantly revised and updated as new building foundations are investigated, designed, and constructed. A better understanding of clay mineralogy and the effect of even a small change in moisture content in foundation materials may aid materially in building foundation design considerations. Quoted strength values for foundation materials presented under "Engineering Properties of Foundation Materials" are not proposed for use in foundation design for any particular building but are presented as values to be considered in future design. Significantly, these values are considerably higher than allowable bearing pressures heretofore used for design in the Lackland AFB area.

14. Laboratory test data, geology, mineralogy, ground water, and foundation moisture conditions are all factors which must be considered in a building foundation design. The design cannot be made based on data from only one of these factors. The final design solution must be that one which achieves the greatest compatibility considering all of these factors.

BIBLIOGRAPHY

1. Arnow, Ted, 1959, Ground-Water Geology of Bexar County, Texas: Texas Board of Water Engineers, Bulletin 5911.

2. Arnow, Ted, 1963, Ground-Water Geology of Bexar County, Texas: Geological Survey Water Supply Paper, 1588.

3. Deussen, Alexander, 1924, Geology of the Coastal Plain of Texas West of Brazos River: U. S. Geological Survey, Professional Paper 126.

4. Follett, C. R., 1956, Records of Water Level Measurements in Bexar County, Texas: Texas Board of Water Engineers, Bulletin 5606.

5. Geologic Map of Texas, 1937: U. S. Geologic Survey.

6. Grim, R. E.,(1953), Clay Mineralogy, McGraw-Hill, N.Y.

7. Guyton, W. F., in collaboration with White, W. N., 1953, Ground Water Available from Trinity Sands in San Antonio Area: San Antonio Water Board, manuscript report.

8. Jones, Richard A., 1936, Report on a Mineral Resource Survey of Bexar County, Texas: The University of Texas Bureau of Economic Geology Mineral Resource Survey, Circular No. 2.

9. King, Philip B., 1940, Clay Deposits of the San Antonio Area and Morris County, Texas: U. S. Geological Survey, Bulletin 901.

10. Lang, J. W., 1954, Ground-Water Resources of the San Antonio Area, Texas: Texas Board of Water Engineers, Bulletin 5412.

11. Lang, J. W., 1953, Ground Water in the Trinity Group in the San Antonio Area, Texas: U. S. Geological Survey and Texas Board of Water Engineers, manuscript report.

12. Livingston, Penn, 1947, Ground-Water Resources of Bexar County, Texas: Texas Board of Water Engineers, mimeographed report.

13. Livingston, Penn; Sayre, A. N.; and White, W. N., 1936, Water Resources of the Edwards Limestone in the San Antonio Area, Texas: U. S. Geological Survey Water-Supply, Paper 773-B.

Lonsdale, John T., 1927, Igneous Rocks of the Balcones Fault Region of Texas: The University of Texas, Bulletin 2744.

15. Parkinson, G. A., and Barnes, V. E., 1946, Grinding Pebble Deposits of Western Gulf Coastal Plain of Texas: The University of Texas, Publication 4301.

16. Pettit, B. M., Jr., and George, W. O., 1955, Ground-Water Resources of the San Antonio Area, Texas: U. S. Geological Survey and Texas Board of Water Engineers, manuscript report.

17. Pettit, B. M., Jr., and George, W. O., 1956, Ground-Water Resources of the San Antonio Area, Texas: Texas Board of Water Engineers, Bulletin 5608.

18. Potter, A. C., and McKnight, David, Jr., 1931, The Clays and the Ceramic Industries of Texas: The University of Texas, Bulletin 3120.

19. Seed, H. B.; Woodward, R. J., Jr.; and Lundgren, R., Clay Mineralogical Aspects of Atterberg Limits, ASCE Journal, Soil Mechanics and Foundations Division, June 1962.

20. Seed, H. B.; Woodward, R. J., Jr; and Lungren, Raymond, Reduction of Swelling Potential for Compacted Clays, ASCE Journal,Soil Mechanics and Foundations Division, June 1962.

21. Sellards, E. H., 1919, The Geology and Mineral Resources of Bexar County: The University of Texas, Bulletin 1932.

22. Skempton, A. W., The Colloidal "Activity of Clays, 1953, 3rd International Conference on Soil Mechanics and Foundation Engineers, Vol. 1, pp. 57-61.

23. Structural Map of Texas, 1946: The University of Texas Bureau of Economic Geology.

24. Topographic Map of Texas, 1937: U. S. Geological Survey.

References:

1. Electric logs of 75 wells in the county.
2. Drillers' logs of more than 50 wells.
3. U. S. Geological Survey and Corps of Engineers topographic maps of the area with surface contours.
4. Stereoscopic aerial photograph coverage of Bexar County.
5. Miscellaneous geologic maps and data, U. S. Geological Survey and Texas Board of Water Engineers.

PERTINENT DATA SHEETS
LACKLAND AIR FORCE BASE BUILDINGS

CASE STUDY SURVEY

1. Owner: Lackland Air Force Base - Building #1
2. Type of Structure: Reinforced concrete frame with concrete exterior walls.
3. Location: Highway 90 and Military Highway.
4. Function of Structure: Hospital.
5. Dimensions: Varies - 1 to 13 story and basement.
6. Foundation
   a. First floor support: Structurally supported over crawl space.
   b. Structural support: Drilled and underreamed piers bottomed 50 to 67 feet below natural ground.
   c. Supporting stratum: Shale - Navarro formation.
   d. Foundation design: 8,000 to 16,000 psf
   e. Percent reinforcing steel: 0.5%
7. Dates of construction: 1954 to 1957, 1958 to 1960, and 1962 to 1963.
8. Distress
   a. Description: Broken interior walls, broken water lines within building, broken floor beams, and inoperative doors. A total of 5 inches and a differential of 3 inches upward (vertical) movement has been measured within the building.
   b. Causes: Movement of primary material in which the building is ounded, causing differential heave in the foundation piers.
   c. When first noted: 1957.

CASE STUDY SURVEY

1. Owner: Lackland Air Force Base - Building #2
2. Type of Structure: Steel frame with masonry walls.
3. Location: 300 feet southeast of Lackland Hospital
4. Function of Structure: Dental Clinic
5. Dimensions: 100' x 140', one-story
6. Foundation
   a. First floor support: Structurally supported over crawl space.
   b. Structural support: Drilled and underreamed piers bottomed 35 feet below natural ground.
   c. Supporting stratum: Shaly clay - Navarro formation
   d. Foundation design: 6,000 psf
   e. Percent reinforcing steel: 0.75%
7. Dates of construction: 1963 to 1964
8. Distress
   a. Description: Broken plints beneath floor slab. Large cracks in exterior and interior walls. West grade beam broken. A total of 4.0 inches and a differential of 4.0 inches upward vertical movement has been measured within the building.
   b. Causes: Movement in primary strata beneath the level of the base
f the footings, causing differential heave in the foundation piers.
ements of ground-water levels beneath footing indicated water deficiency
zone beneath footings was being diminished.
. When first noted:

CASE STUDY SURVEY

1. Owner: Lackland Air Force Base - Building #3

2. Type of Structure: Wood Frame with Asbestos Siding

3. Location: Harmon Drive and Lowry Court

4. Function of Structure: Office and Mess Hall

5. Dimensions: 100 x 300 feet - Two-story.

6. Foundation

   a. First floor support: Structurally supported over crawl space.

   b. Structural support: Drilled and underreamed piers bottomed 20 feet below natural ground.

   c. Supporting stratum: Clay - Navarro formation

   d. Foundation design: 3000 psf

   e. Percent reinforcing steel: 0.3%

7. Dates of construction: Early 1950

8. Distress

   a. Description: Many small diagonal cracks in interior sheetrock wall and grade beam. Due to type of structure, the distress does not visibly appear to be highly severe, but it is obvious from difference in floor slab elevations and movement of structural joints that considerable movement has occurred.

   b. Causes: Foundation movement - whether upheaval or settlement is not known.

   c. When first noted: Unknown

CASE STUDY SURVEY

1. Owner: Lackland Air Force Base - Building #4
2. Type of Structure: Wood Frame with Asbestos Siding
3. Location: Shaw Drive and Circle Drive
4. Function of Structure: Office, PX, and Cleaners
5. Dimensions: 75 X 300 Feet - One-Story.
6. Foundation
   a. First floor support: Structurally supported over crawl space.
   b. Structural support: Drilled and underreamed piers bottomed 20 feet below natural ground.
   c. Supporting stratum: Clay - Midway Formation.
   d. Foundation design: 3000 psf
   e. Percent reinforcing steel: 0.3%
7. Dates of construction: Early 1950
8. Distress
   a. Description: None noted.
   b. Causes: N/A
   c. When first noted: N/A

CASE STUDY SURVEY

1. Owner: Lackland Air Force Base - Building #5

2. Type of Structure: Wood frame with asbestos siding.

3. Location: Circle and Shaw Drives

4. Function of Structure: Classrooms

5. Dimensions: "T" shaped, 100 X 300 feet, two-story.

6. Foundation

   a. First floor support: Structurally supported over crawl space.

   b. Structural support: Drilled and underreamed piers bottomed 12 feet below natural ground.

   c. Supporting stratum: Clay - Midway Formation.

   d. Foundation design: 3000 psf

   e. Percent reinforcing steel: 0.3%

7. Dates of construction: Early 1950.

8. Distress

   a. Description: No visible distress. Building being remodeled. Distress reported by occupants of building.

   b. Causes: Foundation movement.

   c. When first noted: Unknown.

CASE STUDY SURVEY

1. Owner: Lackland Air Force Base - Building #6

2. Type of Structure: Reinforced concrete frame with masonry walls.

3. Location: Ent Circle and Hughes Avenues

4. Function of Structure: Chapel

5. Dimensions: 100 x 100 feet - One-story; High steep roof.

6. Foundation

   a. First floor support: Structurally supported

   b. Structural support: Shallow spot footings bottomed 6 feet below natural ground.*

   c. Supporting stratum: Dense gravel

   d. Foundation design: 4,000 psf

   e. Percent reinforcing steel: 1%

7. Dates of construction: 1965

8. Distress

   a. Description: None

   b. Causes: N/A

   c. When first noted: N/A

*Contractor was given option to machine drill or hand excavate spot footings.

CASE STUDY SURVEY

1. Owner: Lackland Air Force Base - Building #7

2. Type of Structure: Wood frame with asbestos walls.

3. Location: Metzger and Kingsly Drive

4. Function of Structure: Classrooms (Femoyer Hall)

5. Dimensions: "T" shaped, 100 X 200 X 400 feet - Two-story.

6. Foundation

   a. First floor support: Structurally supported over crawl space.

   b. Structural support: Drilled and underreamed piers bottomed 12 feet below natural ground.

   c. Supporting stratum: Clay - Midway Formation.

   d. Foundation design: 3000 psf

   e. Percent reinforcing steel: 0.3%

7. Dates of construction: Early 1950.

8. Distress

   a. Description: Major cracks in grade beam and interior wall.

   b. Causes: Foundation movement.

   c. When first noted: N/A

CASE STUDY SURVEY

1. Owner: Lackland Air Force Base - Building #8

2. Type of Structure: Steel frame with concrete block walls.

3. Location: Metzger and Luke Drive

4. Function of Structure: Squadron Headquarters

5. Dimensions: 30 X 90 feet - One-Story.

6. Foundation

   a. First floor support: Structurally supported over crawl space.

   b. Structural support: Drilled and underreamed piers bottomed 36 feet below finished floor.

   c. Supporting stratum: Shaly clay - Midway Formation.

   d. Foundation design: 6000 psf

   e. Percent reinforcing steel: 1%

7. Dates of construction: 1963

8. Distress

   a. Description: Many large cracks in concrete block wall. Distress worse in center of building.

   b. Causes: Foundation movement.

   c. When first noted: One year after construction completed.

CASE STUDY SURVEY

1. Owner: Lackland Air Force Base - Building #9.

2. Type of Structure: Steel frame with concrete block walls.

3. Location: Metzger and Louisiana Drives

4. Function of Structure: Office (Headquarters Building)

5. Dimensions: 30 X 110 feet - One-Story

6. Foundation

   a. First floor support: Structurally supported over 6" cartons.

   b. Structural support: Drilled and underreamed piers bottomed 35 feet below natural ground.

   c. Supporting stratum: Shaly clay - Midway Formation.

   d. Foundation design: 5500 psf

   e. Percent reinforcing steel: 1%

7. Dates of construction: 1961

8. Distress

   a. Description: None

   b. Causes: N/A

   c. When first noted: N/A

CASE STUDY SURVEY

1. Owner: Lackland Air Force Base - Building #10

2. Type of Structure: Combination steel frame w/metal panel walls and reinforced concrete frame w/masonry walls.

3. Location: Connally and Hughes Streets.

4. Function of Structure: Dorm (Recruit Housing and Training) See note*

5. Dimensions: "Z" shaped, 170 x 150 x 170 feet - Three-Story.

6. Foundation

   a. First floor support: Structurally supported over crawl space.

   b. Structural support: Drilled and underreamed piers bottomed 30 feet below natural ground.

   c. Supporting stratum: Shaly clay - Midway Formation.

   d. Foundation design: 6000 psf

   e. Percent reinforcing steel: 1%

7. Dates of construction: 1962

8. Distress

   a. Description: Large cracks in interior and exterior walls on south end of center building. Cracks appear on all three floors and in stairway and corridor. The two outer buildings have shown no appreciable distress.

   b. Causes: Foundation movement.

   c. When first noted: 1964

*This complex consists of three buildings which are identical except for orientation.

CASE STUDY SURVEY

1. Owner: Lackland Air Force Base - Building #11

2. Type of Structure: Wood frame with asbestos siding.

3. Location: Hughes and Truemper Streets

4. Function of Structure: Personnel Office

5. Dimensions: Varies -- See Layout -- 1-and 2-story.

6. Foundation

   a. First floor support: Slab on grade

   b. Structural support: Turned down edge slab

   c. Supporting stratum: Clay overburden

   d. Foundation design: 2000 psf

   e. Percent reinforcing steel: 2-3/4" ∅ bars top and bottom

7. Dates of construction: Early 1950

8. Distress

   a. Description: Many vertical cracks in perimeter beams. Floor slab broken at one corner. Different wings of building have separated from each other. Cracks in interior wall.

   b. Causes: Foundation movement.

   c. When first noted: Unknown.

CASE STUDY SURVEY

1. Owner: Lackland Air Force Base - Building #12

2. Type of Structure: Wood frame with asbestos siding.

3. Location: Selfridge Drive and Randolph Lane

4. Function of Structure: Classrooms (Academic Building)

5. Dimensions: 100 X 210 feet - Two-Story.

6. Foundation

   a. First floor support: Structurally supported over crawl space.

   b. Structural support: Drilled and underreamed piers bottomed 20 feet below natural ground.

   c. Supporting stratum: Clay - Midway Formation

   d. Foundation design: 3,000 psf

   e. Percent reinforcing steel: 0.3%

7. Dates of construction: Early 1950

8. Distress

   a. Description: None

   b. Causes: N/A

   c. When first noted: N/A

CASE STUDY SURVEY

1. Owner: Lackland Air Force Base - Building #13

2. Type of Structure: Wood frame with wood siding

3. Location: Arizona and Gary Street

4. Function of Structure: Warehouse

5. Dimensions: 100 X 400 feet.

6. Foundation

   a. First floor support: Slab on fill with structurally supported dock.

   b. Structural support: Drilled and underreamed piers to top of gravel.

   c. Supporting stratum: Gravel.

   d. Foundation design: 3000 psf

   e. Percent reinforcing steel: 0.5%

7. Dates of construction: Completed in 1951.

8. Distress

   a. Description: None

   b. Causes: N/A

   c. When first noted: N/A

CASE STUDY SURVEY

1. Owner: Lackland Air Force Base - Building #14

2. Type of Structure: Wood frame with asbestos siding

3. Location: Foulois and Olmsted Streets

4. Function of Structure: Mess Hall

5. Dimensions: 75 x 250 feet - One story

6. Foundation

   a. First floor support: structurally supported with basement on overburden.

   b. Structural support: Drilled and underreamed piers bottomed 20 feet below natural ground.

   c. Supporting stratum: Clay - Midway formation

   d. Foundation design: 3,000 psf

   e. Percent reinforcing steel: 0.5%

7. Dates of construction: Early 1950

8. Distress

   a. Description: Horizontal movement of basement. Cracks in basement floor and wall. Grade beam cracked. Center of building has heaved.

   b. Causes: Foundation movement.

   c. When first noted: Unknown

PERTINENT DATA SHEETS

KELLY AIR FORCE BASE BUILDINGS

CASE STUDY SURVEY

1. Owner: Kelly Air Force Base - Building #1

2. Type of Structure: Reinforced Concrete Frame with Concrete Walls.

3. Location: "2000 Area" Kelly

4. Function of Structure: Communications Security Building

5. Dimensions: "H" Shaped - 240 x 20 x 300 x 70 feet. (See Plate 30)

6. Foundation

   a. First floor support: Floor supported over 4-foot crawl space.

   b. Structural support: Drilled and underreamed piers bottomed 95± feet below natural ground surface.

   c. Supporting stratum: Unweathered shale - Navarro formation

   d. Foundation design: Unknown - Estimated 10.0 KSF.

   e. Percent reinforcing steel: 1%

7. Dates of construction: Circa 1954

8. Distress

   a. Description: Interior walls and partitions have long horizontal and diagonal cracks. Floor slabs appear to have been warped or twisted. Some differential vertical movement noted at expansion joints.

   b. Causes: Not known - suspected uplift from pier shafts.

   c. When first noted: Soon after occupancy.

CASE STUDY SURVEY

1. Owner: Kelly Air Force Base - Building #2

2. Type of Structure: Steel frame with concrete block wall.

3. Location: 2000 Area, Kelly Air Force Base

4. Function of Structure: Cryptographic Building

5. Dimensions: 200 x 400 feet - One Story

6. Foundation

   a. First floor support: Slab on grade (Floating Slab)

   b. Structural support: Drilled and underreamed piers bottomed 26 feet below natural ground.

   c. Supporting stratum: Silty clay - Navarro formation

   d. Foundation design: 3,500 psf

   e. Percent reinforcing steel: 0.5%

7. Dates of construction: Early 1950's

8. Distress

   a. Description: Concrete block walls have many major cracks.

   b. Causes: Uncertain - suspected heave of supporting stratum.

   c. When first noted: Unknown

CASE STUDY SURVEY

1. Owner: Kelly Air Force Base - Building #3

2. Type of Structure: Wood frame with asbestos siding.

3. Location: 2000 Area, Kelly AFB - 3rd Street And Avenue "A".

4. Function of Structure: Mess Hall

5. Dimensions: 100 x 150 feet - Single story

6. Foundation

   a. First floor support: Structurally supported over crawl space.

   b. Structural support: Drilled and underreamed piers bottomed 32 feet below natural ground.

   c. Supporting stratum: Clay shale - Navarro formation

   d. Foundation design: 2,000 psf. Basement placed on 6" of gravel.

   e. Percent reinforcing steel: 0.7%

7. Dates of construction: Early 1950's.

8. Distress

   a. Description: Southeast end of building has basement. Basement floor bowed up. Basement wall severely cracked. Grade beam severely cracked.

   b. Causes: Uncertain - suspected heave of supporting stratum.

   c. When first noted: Unknown

CASE STUDY SURVEY

1. Owner: Kelly Air Force Base - Building #4.

2. Type of Structure: Wood frame with wood siding.

3. Location: 2000 Area Kelly - 4th Street and Avenue "B".

4. Function of Structure: Chapel.

5. Dimensions: 30 X 100 feet with Two 50 x 60 feet additions.

6. Foundation

   a. First floor support: Structurally supported over crawl space.

   b. Structural support: Continuous footings.

   c. Supporting stratum: Gravel

   d. Foundation design: Uncertain-1500 psf estimated 18" below grade.

   e. Percent reinforcing steel:

7. Dates of construction: Early 1950's.

8. Distress

   a. Description: None

   b. Causes: N/A

   c. When first noted: N/A

CASE STUDY SURVEY

1. Owner: Kelly Air Force Base - Building #5

2. Type of Structure: Steel frame with concrete block walls.

3. Location: 2000 Area, Kelly AFB - Avenue "B" and 3rd Street

4. Function of Structure: Personnel Office

5. Dimensions: 100 x 150 feet - One Story

6. Foundation

   a. First floor support: Structurally supported over crawl space.

   b. Structural support: Drilled piers bottomed 30 feet below natural ground.

   c. Supporting stratum: Sandy clay - Navarro formation

   d. Foundation design: 5,000 psf

   e. Percent reinforcing steel: 0.7%

7. Dates of construction: 1953

8. Distress

   a. Description: Many large diagonal cracks in walls which have been repaired. Complete failure of 75% of pedestals beneath floor slab. (Very similar to the Dental Clinic at Lackland Air Force Base.)

   b. Causes: Unknown - suspected heave of supporting stratum.

   c. When first noted: Failure of plinths noted first in April 1965. Cracks in superstructure had occurred a considerable period of time before this was noted.

CASE STUDY SURVEY

1. Owner: Kelly Air Force Base - Building #6

2. Type of Structure: Reinforced concrete frame with concrete block walls.

3. Location: 2000 Area Kelly - 2nd Street and Avenue "A".

4. Function of Structure: Airmen's Dormitory

5. Dimensions: 40' X 225' - Three-Story.

6. Foundation

   a. First floor support: Structurally supported over 4" carton voids.

   b. Structural support: Drilled and underreamed piers bottomed 30 feet below natural ground.

   c. Supporting stratum: Sandy clay - Navarro Formation

   d. Foundation design: 5000 psf

   e. Percent reinforcing steel: 0.7%

7. Dates of construction: 1953

8. Distress

   a. Description: None. Few very minor cracks in concrete block walls.

   b. Causes: N/A

   c. When first noted: N/A

CASE STUDY SURVEY

1. Owner: Kelly Air Force Base - Building #7

2. Type of Structure: Reinforced concrete frame with concrete block walls.

3. Location: 2000 Area Kelly

4. Function of Structure: Airmen's Dormitory

5. Dimensions: 40' X 225' - Three-Story.

6. Foundation

   a. First floor support: Structurally supported over 4" void.

   b. Structural support: Drilled and underreamed piers bottomed 30 feet below natural ground.

   c. Supporting stratum: Sandy clay - Navarro Formation

   d. Foundation design: 5000 psf

   e. Percent reinforcing steel: 0.7%

7. Dates of construction: 1953

8. Distress

   a. Description: None.

   b. Causes: N/A

   c. When first noted: N/A

CASE STUDY SURVEY

1. Owner: Kelly Air Force Base - Building #8

2. Type of Structure: Concrete frame with concrete walls.

3. Location: 100 feet east of Gilmore and Lombard Streets.

4. Function of Structure: Officers' Quarters and Mess Hall.

5. Dimensions: "C" Shaped - 150' x 315' X 200' - Three Story.

6. Foundation

   a. First floor support: Structurally supported over crawl space.

   b. Structural support: Drilled and underreamed piers bottomed 57 feet below natural ground.

   c. Supporting stratum: Blue shale - Navarro Formation.

   d. Foundation design: N/A but footings were relatively small for structural load.

   e. Percent reinforcing steel: 1%

7. Dates of construction: 1941

8. Distress

   a. Description: None

   b. Causes: N/A

   c. When first noted: N/A

CASE STUDY SURVEY

1. Owner: Kelly Air Force Base - Building #9.

2. Type of Structure: Steel frame with masonry walls.

3. Location: Wagner Drive and Andrews Road

4. Function of Structure: Dispensary (Occupational Health & Military)

5. Dimensions: 200' X 200' - One-Story.

6. Foundation

   a. First floor support: Structurally supported over crawl space.

   b. Structural support: Drilled and underreamed piers bottomed 10 feet below natural ground.

   c. Supporting stratum: Dense gravel

   d. Foundation design: 6000 psf

   e. Percent reinforcing steel: 1%

7. Dates of construction: 1966

8. Distress

   a. Description: None

   b. Causes: N/A

   c. When first noted: N/A

CASE STUDY SURVEY

1. Owner: Kelly Air Force Base - Building #10.

2. Type of Structure: Reinforced concrete frame with concrete block walls.

3. Location: 600' N of Lackland Road and Nostrand Road

4. Function of Structure: Warehouse

5. Dimensions: 400' X 1700 ' - One Story

6. Foundation

   a. First floor support: Slab on Grade.

   b. Structural support: Drilled and underreamed piers bottomed 10 to 20 feet below natural ground.

   c. Supporting stratum: Dense gravel.

   d. Foundation design: 10,000 psf

   e. Percent reinforcing steel:

7. Dates of construction: Early 1950's.

8. Distress

   a. Description: None. Very good condition.

   b. Causes: N/A

   c. When first noted: N/A

CASE STUDY SURVEY

1. Owner: Kelly Air Force Base - Building #11.

2. Type of Structure: Steel frame with masonry walls

3. Location: See plate 32.

4. Function of Structure: Maintenance Shop.

5. Dimensions: 72' X 175' - One Story.

6. Foundation

   a. First floor support: Structurally supported over 8" cardboard forms.

   b. Structural support: Drilled and underreamed piers bottomed 40 feet below natural ground.

   c. Supporting stratum: Shaly clay - Navarro Formation.

   d. Foundation design: 5000 psf

   e. Percent reinforcing steel:

7. Dates of construction: Early 1960.

8. Distress

   a. Description: None.

   b. Causes: N/A

   c. When first noted: N/A

CASE STUDY SURVEY

1. Owner: Kelly Air Force Base - Building #12.

2. Type of Structure: Reinforced Concrete Frame with Concrete Block Walls.

3. Location: Jackson Road and East Apron.

4. Function of Structure: Office Building

5. Dimensions: 400' X 400' - One-Story.

6. Foundation

   a. First floor support: Slab on Grade

   b. Structural support: Drilled and underreamed piers bottomed 35 feet below natural ground.

   c. Supporting stratum: Clay - Navarro Formation

   d. Foundation design: 4,000 psf.

   e. Percent reinforcing steel: 1%

7. Dates of construction: 1956

8. Distress

   a. Description: None

   b. Causes: N/A

   c. When first noted: N/A

CASE STUDY SURVEY

1. Owner: Kelly Air Force Base - Building #13.

2. Type of Structure: Reinforced concrete frame with concrete block walls.

3. Location: South of Kelly Golf Course

4. Function of Structure: Office (Originally Warehouse)

5. Dimensions: 400' X 1100' - One-Story

6. Foundation

   a. First floor support: Slab on Fill

   b. Structural support: Hand dug piers bottomed 16 feet below natural ground.

   c. Supporting stratum: Gravel.

   d. Foundation design: Not known.

   e. Percent reinforcing steel:

7. Dates of construction: 1941

8. Distress

   a. Description: None

   b. Causes: N/A

   c. When first noted: N/A

PERTINENT DATA SHEETS
BROOKS AIR FORCE BASE BUILDINGS

CASE STUDY SURVEY

1. Owner: Brooks Air Force Base - Building #1

2. Type of Structure: Steel frame with masonry wall

3. Location: South of Military Drive and East of Aerospace Court

4. Function of Structure: Dining Hall

5. Dimensions: 100 X 100 feet.

6. Foundation

   a. First floor support: Structurally supported over crawl space.

   b. Structural support: Drilled and underreamed piers bottomed 32 feet.

   c. Supporting stratum: Shaly clay - Wilcox Formation

   d. Foundation design: 5000 psf

   e. Percent reinforcing steel: 1%

7. Dates of construction: 1962

8. Distress

   a. Description: Small vertical crack in grade beam at every corner. Not noticeable in interior of building.

   b. Causes: Appears to be structural failure of concrete.

   c. When first noted: N/A

CASE STUDY SURVEY

1. Owner: Brooks Air Force Base - Building #2

2. Type of Structure: Steel frame with masonry walls.

3. Location: 10th Street and Outer Circle

4. Function of Structure: Service Club

5. Dimensions: "T" Shaped - 114 X 133 feet.

6. Foundation

   a. First floor support: Structurally supported over crawl space.

   b. Structural support: Drilled and underreamed piers bottomed 25.0 feet below natural ground.

   c. Supporting stratum: Brown shaly clay - Wilcox Formation

   d. Foundation design: 5,000 psf

   e. Percent reinforcing steel: 1%

7. Dates of construction: 1962

8. Distress

   a. Description: None

   b. Causes: N/A

   c. When first noted: N/A

CASE STUDY SURVEY

1. Owner: Brooks Air Force Base - Building #3
2. Type of Structure: Steel frame with metal siding
3. Location: 18th Street and Westgate Road
4. Function of Structure: Military and Professional Training Facility.
5. Dimensions: 245 X 160 feet.
6. Foundation
   a. First floor support: (a) Classroom - Structurally supported over crawl space; (b) Training Area - Slab on grade.
   b. Structural support: Drilled and underreamed piers bottomed 31.0 feet below natural ground.
   c. Supporting stratum: Shaly clay - Wilcox Formation.
   d. Foundation design: 5000 psf
   e. Percent reinforcing steel: 1%
7. Dates of construction: 1964
8. Distress
   a. Description: None
   b. Causes: N/A
   c. When first noted: N/A

CASE STUDY SURVEY

1. Owner: Brooks Air Force Base - Building #4

2. Type of Structure: Steel frame with masonry wall.

3. Location: South of Military Drive and east of Aerospace Center.

4. Function of Structure: Officers' Quarters

5. Dimensions: 90 x 291 feet - Three-story

6. Foundation

   a. First floor support: Structurally supported on cardboard carton forms.

   b. Structural support: Drilled and underreamed piers bottomed 30 feet below natural ground.

   c. Supporting stratum: Clay - Wilcox formation

   d. Foundation design: 5,000 psf

   e. Percent reinforcing steel: 1%

7. Dates of construction: 1962

8. Distress

   a. Description: Horizontal cracks in first floor walls.

   b. Causes: Swelling of surface soils. Broken water line caused such severe swelling that the 6" void was depleted, allowing swelling soil to come in ntact with floor slab.

   c. When first noted: 1964 - Two years after completion.

Base C.E. dug 3' x 3' trench down center of building beneath and
nt to first floor. The water lines were broken and rerouted down
ench. No additional distress has been noticed.

PERTINENT DATA SHEETS
COMMERCIAL AND PUBLIC SCHOOL BUILDINGS

CASE STUDY SURVEY

1. Owner: San Antonio School District - Building #1

2. Type of Structure: Concrete columns with masonry walls.

3. Location: 0.8 mile SW of pier test site, Lackland AFB

4. Function of Structure: Sam Rayburn Junior High School

5. Dimensions: 400' x 400' with 150' x 150' center patio

6. Foundation

   a. First floor support: Structurally supported over crawl space.

   b. Structural support: Drilled and underreamed piers bottomed 20-30' below finished floor grade.

   c. Supporting stratum: Clay shale - Midway formation

   d. Foundation design: 4,000 psf

   e. Percent reinforcing steel: 1%

7. Dates of construction: 1962

8. Distress

   a. Description: Utility lines broken, basement slab broken, concrete block wall cracked, grade beam raised 3", and hairline cracks in floor beams.

   b. Causes: Swelling of subsurface materials. Subgrade beneath structure is now saturated with water, but no water was encountered during construction. Whether the water is from natural sources or from broken water lines was not determined.

   c. When first noted: Several months after construction was completed.

CASE STUDY SURVEY

1. Owner: Valley H. Developing Company - Building #2

2. Type of Structure: Concrete columns with concrete block walls.

3. Location: 0.8 mile SW of Pier Test Site, Lackland AFB

4. Function of Structure: Shopping Center

5. Dimensions: Approximately 500' x 500'

6. Foundation

   a. First floor support: Slab on fill with piers supporting walls.

   b. Structural support: Drilled and underreamed piers - 30 feet below natural ground.

   c. Supporting stratum: Clay shale - Midway formation

   d. Foundation design: 4,000 psf - Pea gravel around pier shafts.

   e. Percent reinforcing steel: 1%

7. Dates of construction: 1962

8. Distress

   a. Description: Buckling of floor slab. Raising up of grade beams resulting in numerous large cracks in walls, glass in doors and windows, and large mirror on wall broken due to foundation movement.

   b. Causes: Uplift due to subsurface material.

   c. When first noted: Soon after construction was completed.

CASE STUDY SURVEY

1. Owner: San Antonio School District - Building #3

2. Type of Structure: Steel Frame and Masonry Walls.

3. Location: 7300 Remuda - 2 miles NW of Lackland Hospital

4. Function of Structure: Mary Hull Elementary School

5. Dimensions: Approximately 300 X 300 feet.

6. Foundation

   a. First floor support: Slab on grade.

   b. Structural support: Mat type slab - Exterior beams 30" deep.

   c. Supporting stratum: Clay overburden underlain by Taylor Formation.

   d. Foundation design: 2000 psf - 24" gravel beneath slab.

   e. Percent reinforcing steel: Heavily reinforced.

7. Dates of construction: 1963

8. Distress

   a. Description: None

   b. Causes: N/A

   c. When first noted: N/A

CASE STUDY SURVEY

1. Owner: San Antonio School District - Building #4

2: Type of Structure: Steel Frame with Masonry Walls.

3. Location: 7600 Bronco - 1.5 miles NW of Lackland Hospital.

4. Function of Structure: Westwood Elementary School

5. Dimensions: 200- X 200-feet with patio in center.

6. Foundation

   a. First floor support: Slab on grade

   b. Structural support: Mat type slab - Perimeter beam 30" deep.

   c. Supporting stratum: Clay overburden - Underlain by Taylor Formation.

   d. Foundation design: 2000 psf - 24" gravel beneath slabs.

   e. Percent reinforcing steel: Heavily reinforced

7. Dates of construction: 1961

8. Distress

   a. Description: Minor cracking in brick wall.

   b. Causes: N/A

   c. When first noted: N/A

CASE STUDY SURVEY

1. Owner: San Antonio School District - Building #5

2. Type of Structure: Concrete frame with concrete walls.

3. Location: General McMullen Drive and Thompson Place , 3/4 mile N of Kelly main gate.

4. Function of Structure: John F. Kennedy High School

5. Dimensions: 307 x 240 foot - Two Story Building and has full basement.

6. Foundation

   a. First floor support: Structurally supported over crawl space.

   b. Structural support: Drilled and underreamed piers bottomed 56 feet below basement grade.

   c. Supporting stratum: Blue shale - Navarro Formation

   d. Foundation design: 20,000 psf with pea gravel around shaft

   e. Percent reinforcing steel: 1%

7. Dates of construction: 1963

8. Distress

   a. Description: None

   b. Causes: N/A

   c. When first noted: N/A

CASE STUDY SURVEY

1. Owner: St. Mary's University - Building #6

2. Type of Structure: Steel frame with masonry exterior and plaster interior walls.

3. Location: Main campus, St. Mary's University, approximately 5 miles NE of Lackland Hospital.

4. Function of Structure: Classrooms (Science Building)

5. Dimensions: 200 x 200-feet - Three-Story

6. Foundation

   a. First floor support: Structurally supported over crawl space.

   b. Structural support: Drilled and underreamed piers bottomed 35 feet below natural ground.

   c. Supporting stratum: Sandy clay - Taylor Formation.

   d. Foundation design: Unknown,but footing sizes vary from 3' - 8' diameter.

   e. Percent reinforcing steel: Varies - 2% to 2.5%

7. Dates of construction: 1950

8. Distress

   a. Description: Many diagonal, vertical, and horizontal cracks of major size in walls of all three stories. This building is under major distress.

   b. Causes: Foundation movement - uplift.

   c. When first noted: Unknown.

CASE STUDY SURVEY

1. Owner: St. Mary's University - Building #7

2. Type of Structure: Steel frame with masonry exterior and plaster interior walls.

3. Location: Main campus, St. Mary's University.

4. Function of Structure: Men's Dormitory.

5. Dimensions: 42 X 350 feet - Three-Story.

6. Foundation

   a. First floor support: Structurally supported over crawl space.

   b. Structural support: Drilled and underreamed piers bottomed 35' below natural ground.

   c. Supporting stratum: Sandy clay - Taylor Formation.

   d. Foundation design: Unknown. Footing sizes vary from 3 to 7 feet diameter.

   e. Percent reinforcing steel: 2%

7. Dates of construction: 1958

8. Distress

   a. Description: Cracks in interior plaster walls of major size.

   b. Causes: Foundation movement - Uplift.

   c. When first noted: Unknown

TABLES

Table 1
Strength Test
Upper Midway Group
Lackland Air Force Base

Boring No.	Depth (Ft)	Moisture Content	Density	Compression		Direct Shear	
				σ_3	σ_1	Ø	c,TSF
8A6C-46	17.1-21.9	27.9	95	1.2	3.5		
	40.9-44.9	28.4	96	2.5	11.7	11.0	0.9
						(10.2	0.9)
						(pre-split)	
	43.3-47.5	28.3	97				
8A6C-47	32.7-37.6	29.3	94	2.0	7.9		
	37.6-42.0	28.0	94			8.6	0.9
						(7.8	0.0)
						(pre-split)	
8A6C-48	18.0-22.6	27.2	96	1.2	5.5		
	22.6-27.1			1.7	4.3		
	44.9-51.2	28.6	96	3.0	11.6		

Table 2
Strength Test
Lower Midway Group
Lackland Air Force Base

Boring No.	Depth (Ft)	Moisture Content	Density	Compression $\sigma 3$	Compression $\sigma 1$	Triaxial Compression Ø	Triaxial Compression c,tsf	Direct Shear Ø	Direct Shear c,tsf
6DC-22	43.3-44.2	23.9	100					35.0	0.2
	51.5-52.4	20.1	106	0.0	6.0				
6DC-39	9.0-11.0	31.2	89	0.6	1.6				
8A6C-41	24.9-25.8	24.0	103	1.6	6.2				
	30.6-31.6	18.5	116	2.0	10.5				
8A6C-43	25.9-26.9	23.1	105	1.7	5.8				
6DC-45	11.0-13.0	16.4	114	0.3	3.6				
6DC-207	17.0-19.0	29.7	96			0.9	1.4		
	19.0-21.0	27.6	96	0.0	1.3				
	25.0-27.0	25.9	99	0.0	1.2				
	27.0-29.0	29.8	93			4.0	1.5		
	29.0-31.0	33.1	91	0.0	1.3				
	31.0-33.0	28.5	95	0.0	2.3				
	44.8-45.7	24.8	95			2.5	4.8		
	49.9-50.8	23.9	96					25.1	0.6
	54.4-55.3	24.5	101	0.0	3.5				
	63.8-64.7	25.1	104	0.0	3.4				
	77.5-78.4	48.1	74	0.0	13.9				
	95.4-96.3	25.2	101	0.0	14.8				

Table 2 (Contd)
Strength Test
Lower Midway Group
Lackland Air Force Base

Boring No.	Depth (Ft)	Moisture Content	Density	Compression		Triaxial Compression		Direct Shear	
				σ_3	σ_1	Ø	c,tsf	Ø	c,tsf
8A6C-209	50.0-50.8	25.1	90	0.0	3.2				
6DC-211	28.4-29.3	31.4	90	0.0	1.1				
	33.1-34.0	24.5	100					25.5	0.6

Table 3
Strength Test
Navarro Group
Lackland Air Force Base

Boring	Depth	Moisture		Compression		Direct Shear	
No.	(Ft)	Content	Density	σ_3	σ_1	Ø	c,TSF
8A6C-20	25.5-26.5	21.2	107	1.5	11.1		
	36.0-36.8	18.7	109	2.2	13.0		
	48.9-49.8	18.5	110	2.9	7.4		
	59.6-60.6	17.0	113	0.0	13.5		
	71.8-72.7	20.3	111	4.3	17.4		
	86.8-87.6	19.9	111	5.2	22.4		
8A6C-21	35.0-36.0	20.2	109	2.1	11.3		
	71.2-72.2	24.7	104	4.3	11.6		
	89.2-90.2	16.8	115	0.0	11.7		
6DC-22	43.3-44.2	23.0	103			35.0	0.2
	63.0-64.0	16.7	114	4.0	20.3		
	75.0-76.0	17.0	115			36.0	0.4
	88.6-89.5	14.3	118	5.3	13.2		
6DC-24	29.8-30.5	18.1	103			26.4 (26.0	1.1 0.0)
						(pre-split	)
	44.7-45.7	15.8	113	2.7	19.7		
	66.6-67.0	20.1	109	4.0	15.8		
	83.7-84.6	17.5	111	5.0	16.4		

Table 3 (Contd)
Strength Test
Navarro Group
Lackland Air Force Base

Boring No.	Depth (Ft)	Moisture Content	Density	Compression		Direct Shear	
				σ_3	σ_1	∅	c,TSF
8A6C-25	27.0-28.0	19.0	110	1.6	8.3		
	64.3-65.1	21.9	105	3.9	10.3		
	85.7-86.7	16.5	117	0.0	7.9		
6DC-39	39.5-40.5	17.5	111	2.6	19.1		
	64.7-65.7	15.0	116	4.2	19.9		
	71.6-72.3	20.8	108	4.7	13.6		
6DC-40	23.0-24.0	16.5	116	1.5	16.9		
	49.2-50.2	19.4	110	3.2	12.3		
8A6C-41	49.2-50.2	16.7	115	3.2	20.7		
8A6C-43	36.8-37.8	19.1	110	2.4	12.2		
6DC-44	25.1-26.1	22.3	104	1.7	7.6		
	42.0-43.0	19.8	109	2.7	9.6		
6DC-45	24.7-25.5	26.1	98	1.6	3.1		
	53.6-54.4	27.1	98	3.5	10.6		
	60.7-61.7	26.0	98	3.9	11.4		
	77.0-78.0	24.1	103	5.0	14.9		

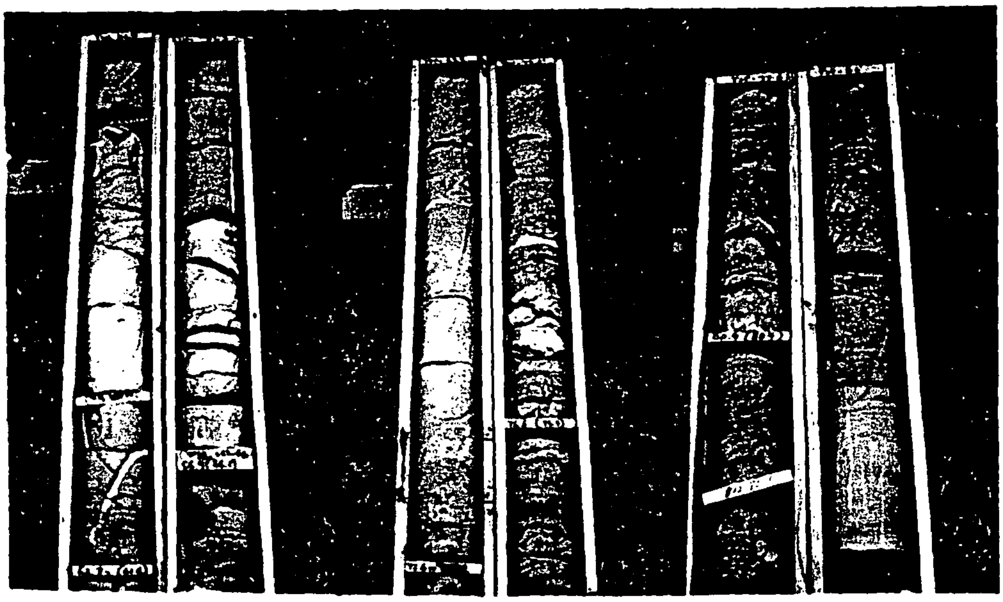
FIGURES

BORING 8A6C-20

NORTH SIDE OF WILFORD HALL HOSPITAL

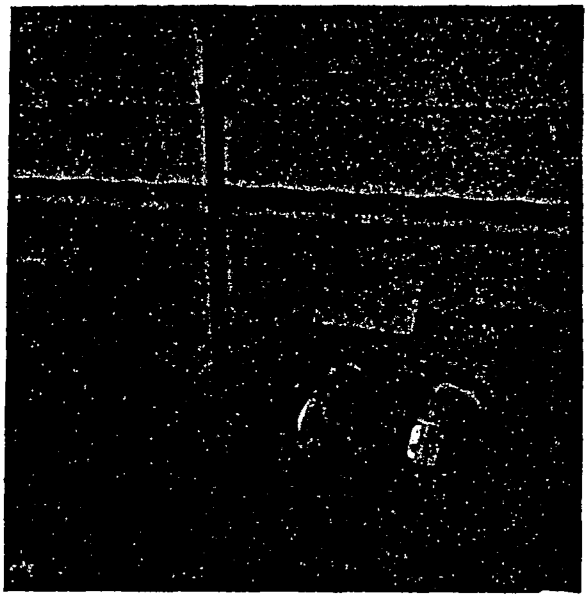
MIDWAY & NAVARRO FOUNDATION

12.8' TO 23.8'   23.8' TO 35.5' MID/NAV. 24.7   35.5' TO 46.0'   46.0' TO 56.9'



56.9' TO 67.5'   67.5' TO 77.6'   77.6' TO 88.6 (T.D.)

FIGURE 1



PHOTOGRAPH NO. 1

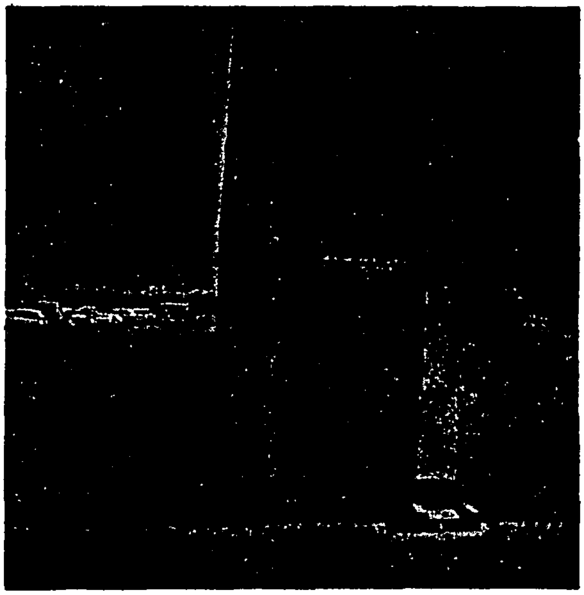
KELLY AIR FORCE BASE - "2000 AREA"
MESS HALL - BUILDING # 3

VIEW WEST - HORIZONTAL AND DIAGONAL CRACK IN EAST GRADE BEAM AND BASEMENT WALL

PHOTOGRAPH NO. 2

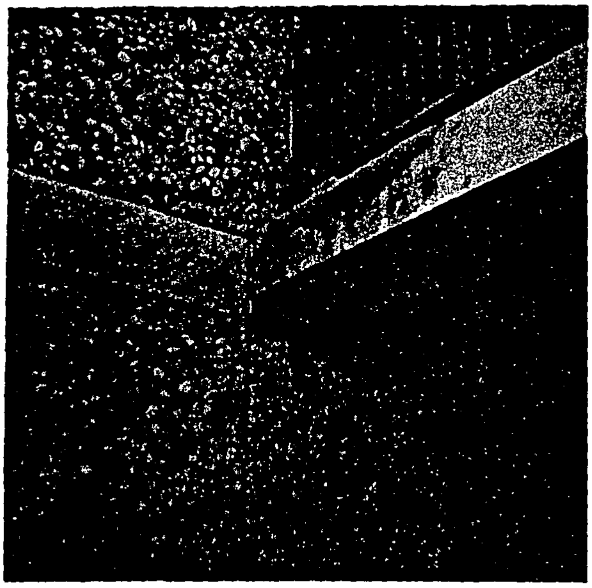
VALLEY HI SHOPPING CENTER
BUILDING # 2

VIEW NORTH - CRACK IN CONCRETE BLOCK EXTERIOR WALL - SOUTHEAST CORNER



UNIVERSITY OF UTAH
RESEARCH INSTITUTE
EARTH SCIENCE LAB.

FIGURE 2



PHOTOGRAPH NO 3

SAM RAYBURN JR. HIGH SCHOOL

BUILDING # 1

VIEW WEST FROM CENTER PATIO-
MOVEMENT OF SECOND FLOOR GRADE
BEAM DUE TO HEAVING OF STEEL
COLUMN.

PHOTOGRAPH NO. 4

ST MARY'S UNIVERSITY

FACULTY DORMITORY

VIEW WEST- CRACK IN EXTERIOR
MASONRY WALL

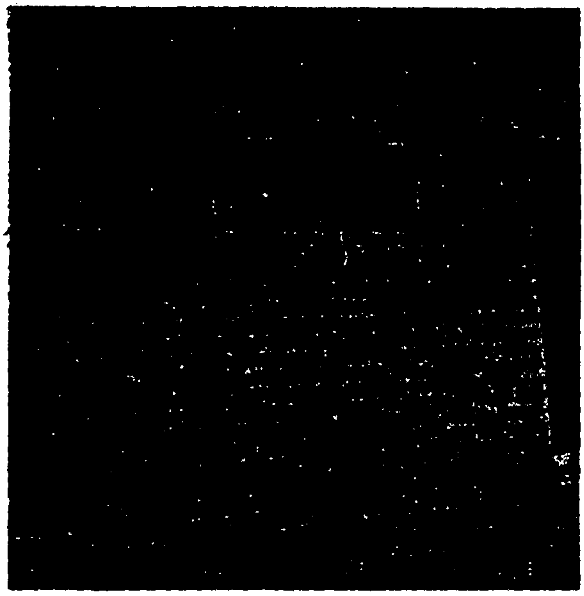
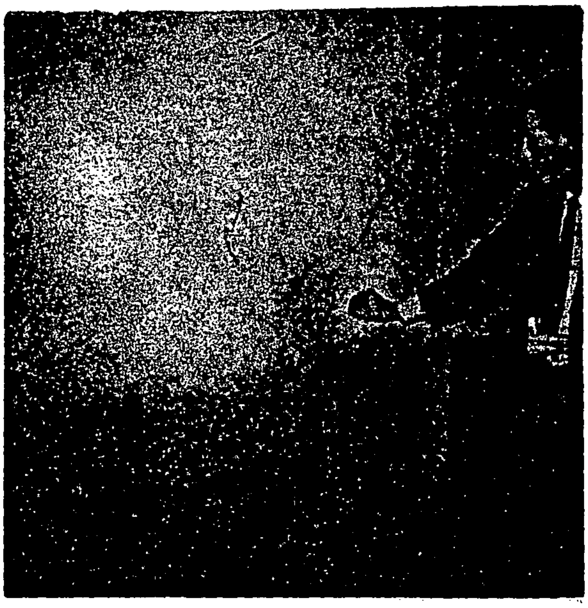


FIGURE 3



PHOTOGRAPH NO. 5

ST. MARY'S UNIVERSITY

SCIENCE BUILDING # 6

VIEW FROM CENTER CORRIDOR- FIRST FLOOR. DIAGONAL CRACK IN CORRIDOR WALL

PHOTOGRAPH NO. 6

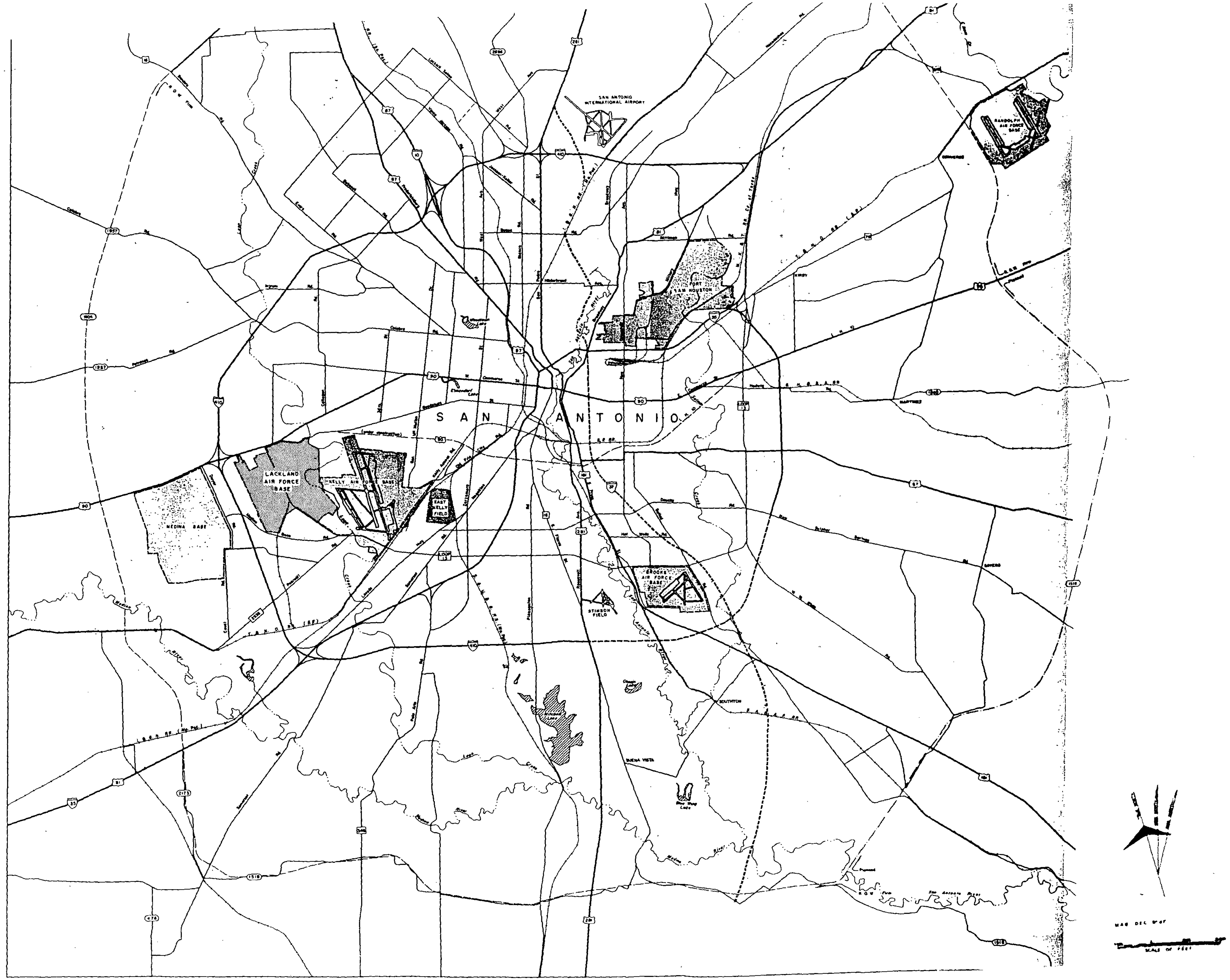
ST. MARY'S UNIVERSITY

SCIENCE BUILDING # 6

VIEW FROM CENTER CORRIDOR- SECOND FLOOR. DIAGONAL CRACK IN CORRIDOR WALL-CRACK EXTENDS FROM WINDOW TO CORRIDOR FLOOR

FIGURE 4

PLATES

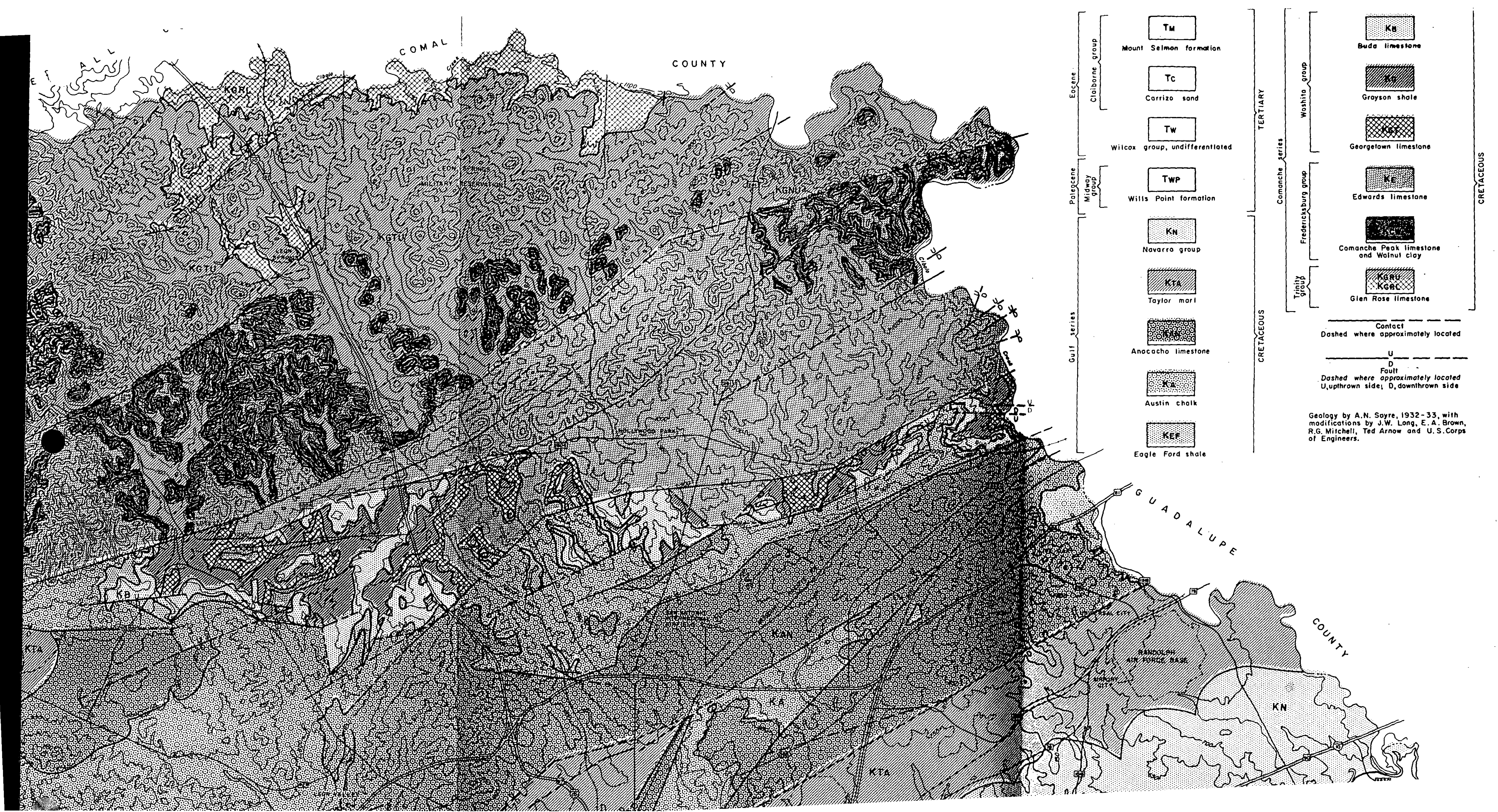


LACKLAND AIR FORCE BASE
SAN ANTONIO, TEXAS

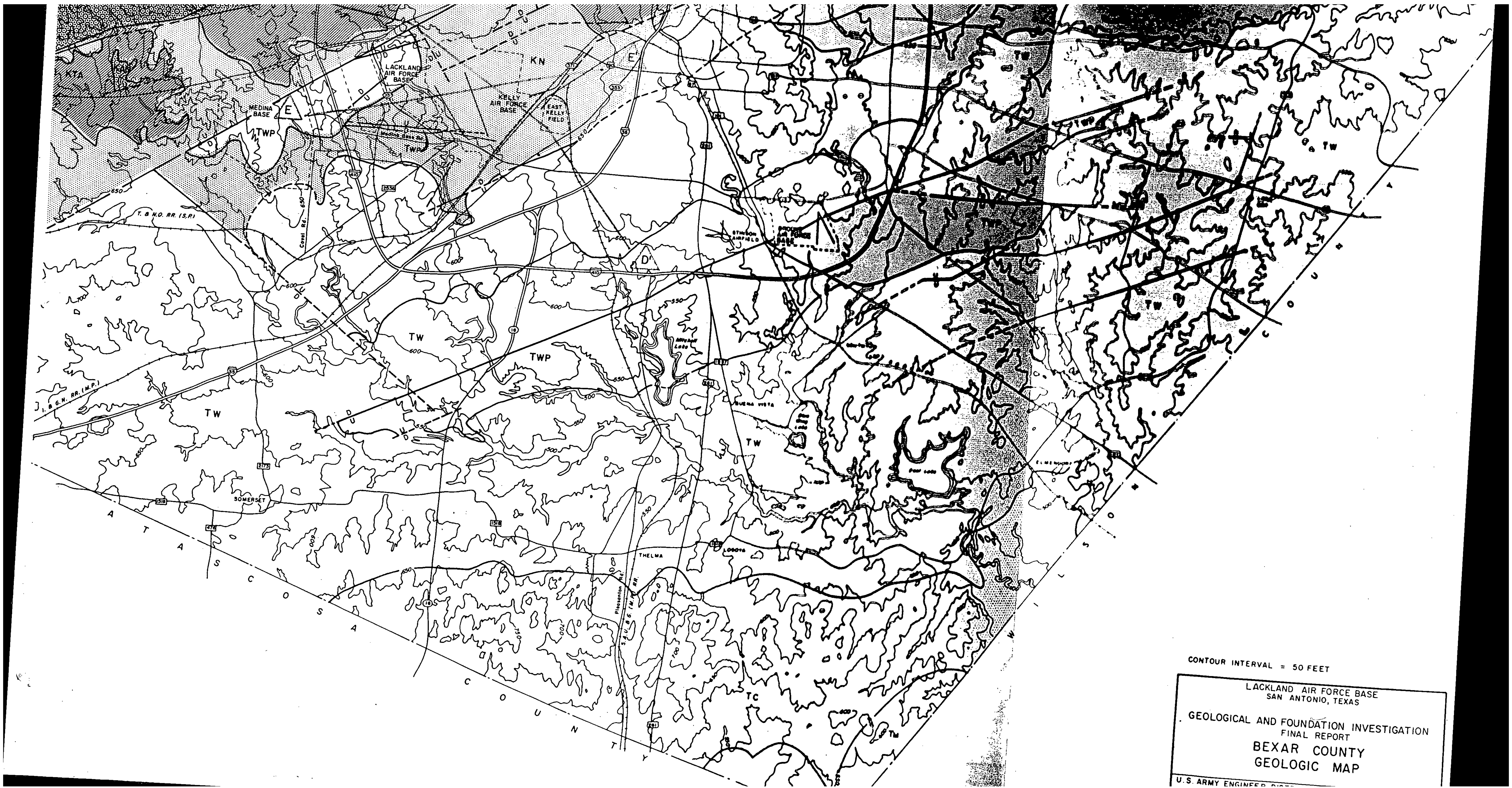
GEOLOGICAL AND FOUNDATION INVESTIGATION

VICINITY MAP

U.S. ARMY ENGINEER DISTRICT, FORT WORTH



Geology by A.N. Sayre, 1932-33, with modifications by J.W. Long, E.A. Brown, R.G. Mitchell, Ted Arnow and U.S. Corps of Engineers.



CONTOUR INTERVAL = 50 FEET

LACKLAND AIR FORCE BASE
SAN ANTONIO, TEXAS

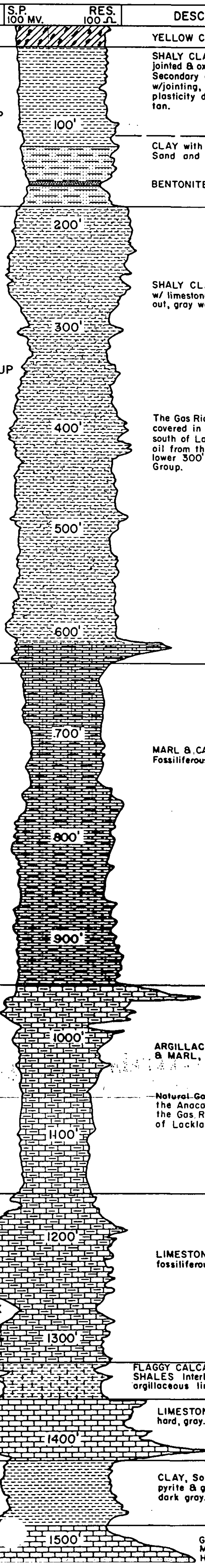
GEOLOGICAL AND FOUNDATION INVESTIGATION
FINAL REPORT

BEXAR COUNTY
GEOLOGIC MAP

U.S. ARMY ENGINEER

LACKLAND A.F.B.

GEOLOGICAL COLUMN FROM ELECTRIC LOG ON WATER WELL NO. 3 LOCATED ON LUKE DRIVE AT MILITARY HWY.

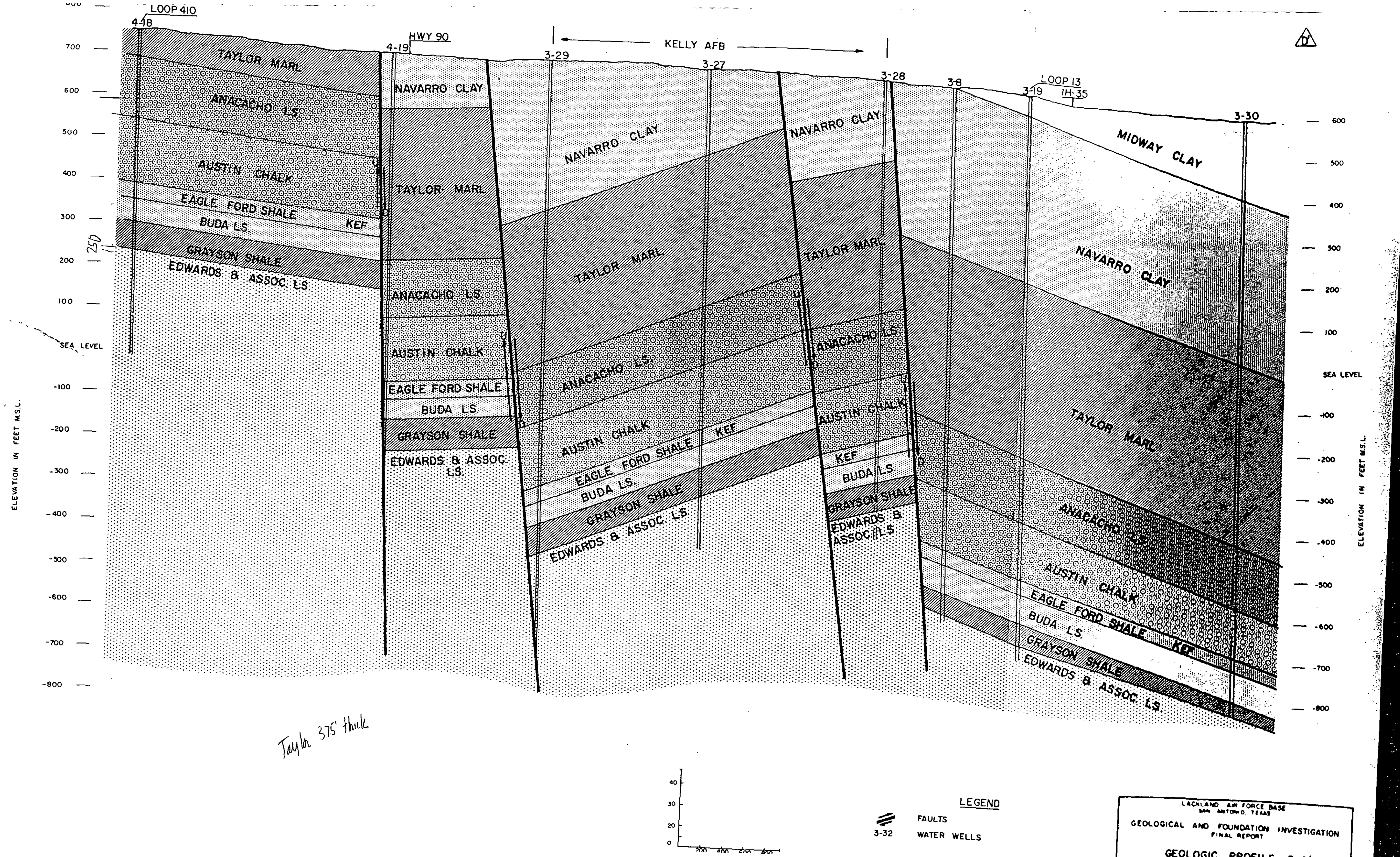


SYSTEM	SERIES	FORMATION	S.P. 100 MV. RES. 100 Ω	DESCRIPTION
TERTIARY	RECENT	ALLUVIUM 20		YELLOW CLAY W/GRAVEL
	PALEOCENE	MIDWAY GROUP (160')		SHALY CLAY: Sandy, silty jointed & oxidized to 75'. Secondary gypsum associated w/jointing, bentonitic, high plasticity dk. gray weathers tan. CLAY with GLAUCONITIC Sand and Silt. BENTONITE 2' thick
CRETACEOUS	GULF	NAVARRO GROUP (450')		SHALY CLAY: Sandy and silty w/ limestone concretions thru-out, gray weathers tan. The Gas Ridge Oil Field discovered in 1912 & located just south of Lackland produces oil from thin sand lenses in lower 300' of the Navarro Group.
		TAYLOR MARL (315')		MARL & CALCAREOUS SHALE Fossiliferous bluish gray.
		ANACACHO LIMESTONE (212')		ARGILLACEOUS LIMESTONE & MARL, Fossiliferous, gray. Natural Gas was produced from the Anacacho Limestone in the Gas Ridge Field south of Lackland A.F.B.
		AUSTIN CHALK (166')		LIMESTONE, Soft, argillaceous, fossiliferous, gray.
		EAGLE FORD SHALE (36')		FLAGGY CALCAREOUS & SANDY SHALES Interbedded w/ hard argillaceous limestone, dark gray.
	COMANCHE	BUDA LIMESTONE (61')		LIMESTONE, Fine grain, dense, hard, gray.
		GRAYSON SHALE (DEL RIO CLAY) (65')		CLAY, Soft fossiliferous, pyrite & gypsum through-out dark gray.
		EDWARDS		GEORGETOWN MEMBER-LIMESTONE Hard, massive w/few

LACKLAND AIR FORCE
SAN ANTONIO, TEX
GEOLOGICAL AND FOUNDATION
FINAL REPORT

GEOLOGICAL CO

U.S ARMY ENGINEER DISTRICT, FORT WORTH



Taylor 375' thick

LEGEND

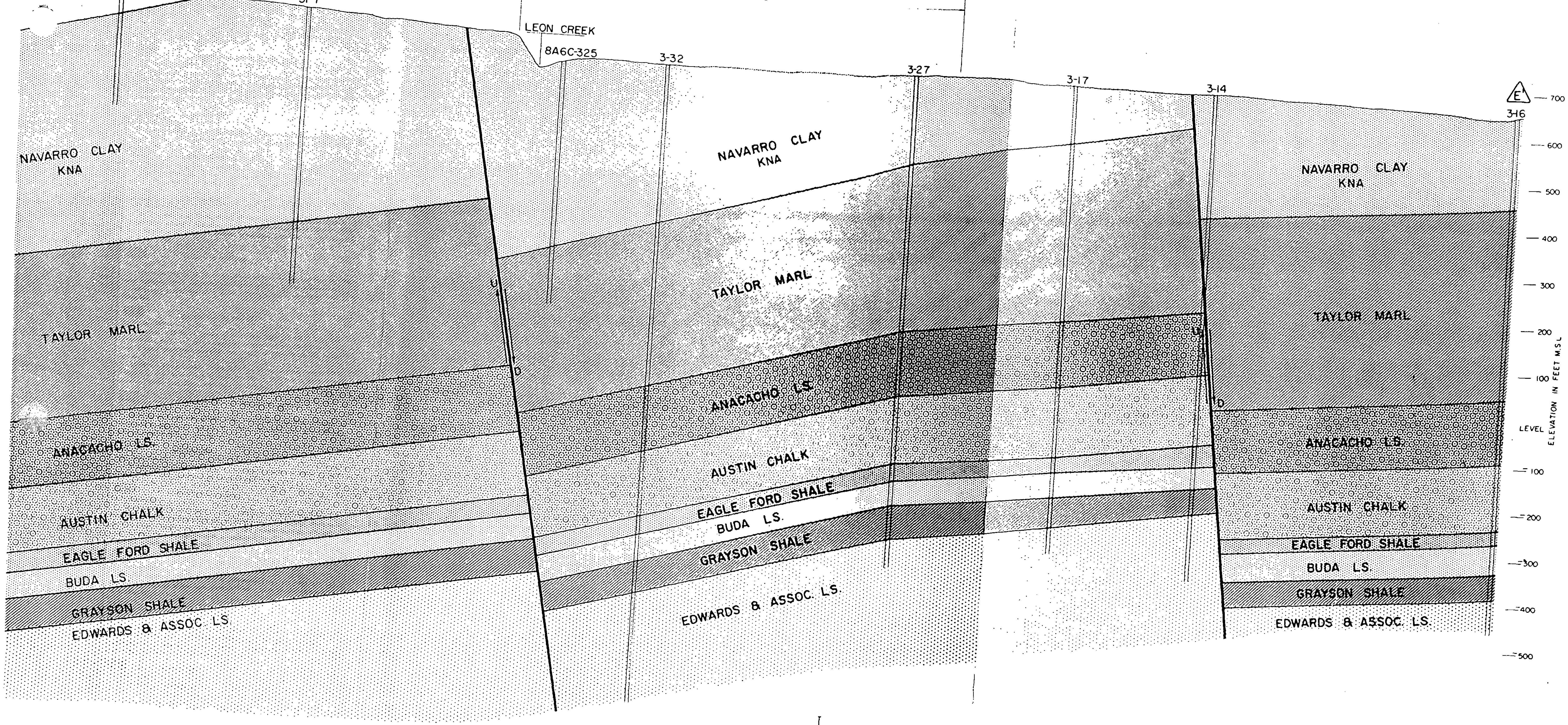
FAULTS

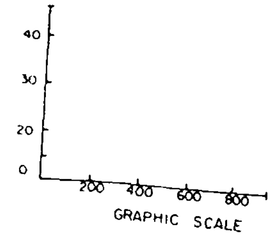
3-32 WATER WELLS

LACKLAND AIR FORCE BASE
SAN ANTONIO, TEXAS

GEOLOGICAL AND FOUNDATION INVESTIGATION
FINAL REPORT

GEOLOGIC PROFILE D-D'





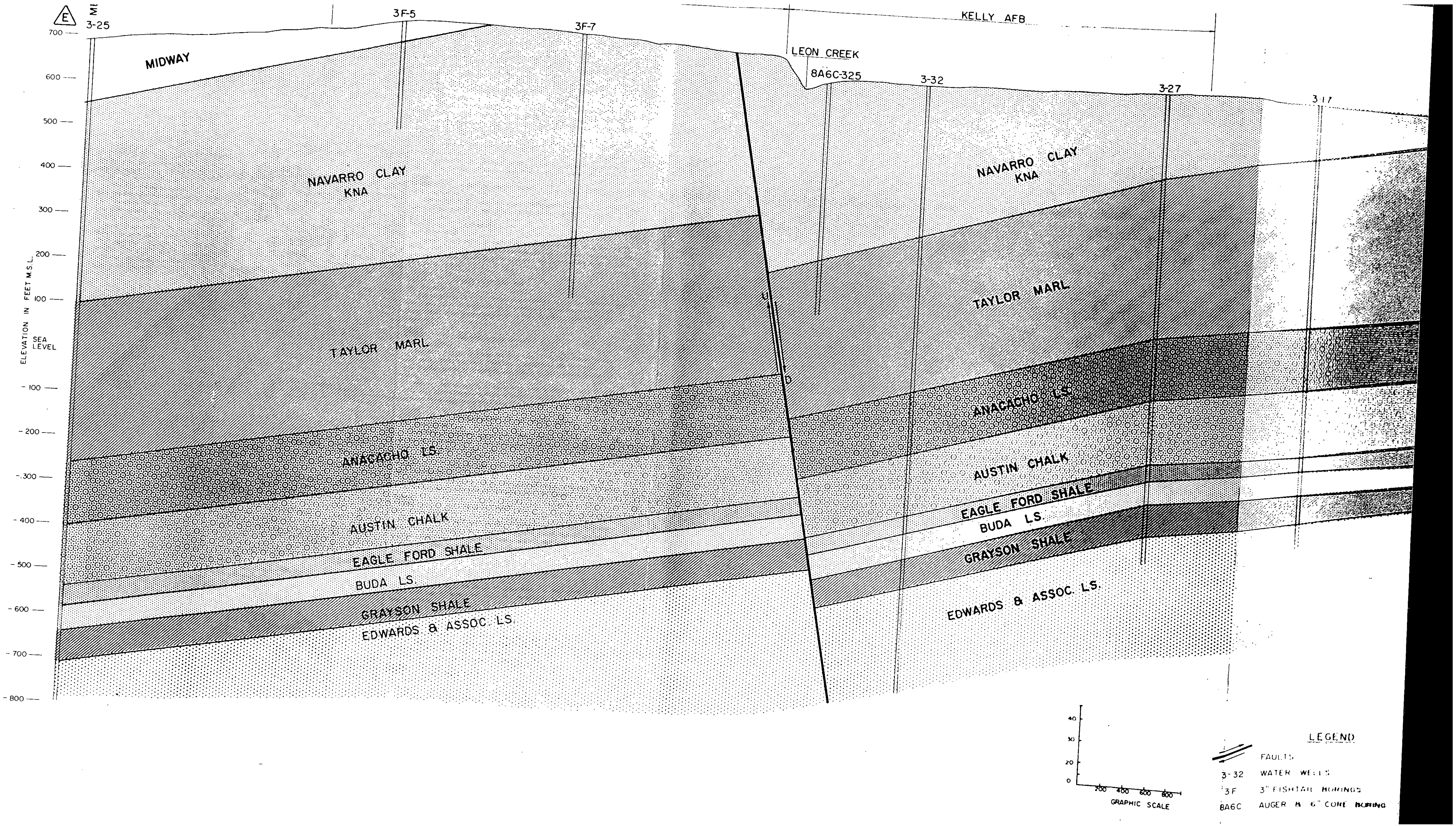
LEGEND

⇄	FAULTS
3-32	WATER WELLS
3F	3" FISHTAIL BORINGS
8A6C	AUGER & 6" CORE BORING

LACKLAND AIR FORCE BASE
SAN ANTONIO, TEXAS

GEOLOGICAL AND FOUNDATION INVESTIGATION
FINAL REPORT

GEOLOGIC PROFILE E-E'

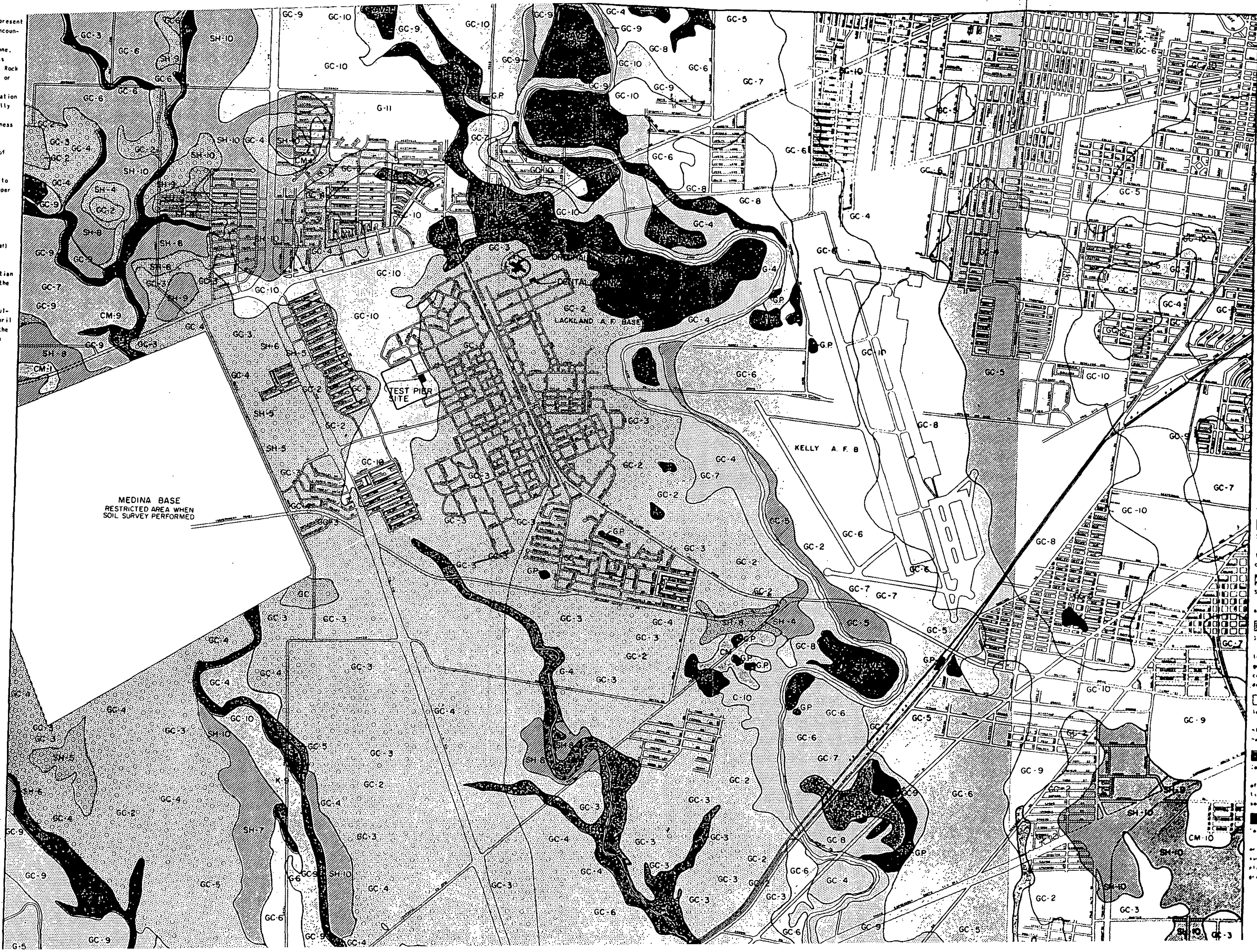

E
3-25
3F-5
3F-7
KELLY AFB
LEON CREEK
8A6C-325
3-32
3-27
3-17
MIDWAY
NAVARRO CLAY
KNA
TAYLOR MARL
ANACACHO LS.
AUSTIN CHALK
EAGLE FORD SHALE
BUDA LS.
GRAYSON SHALE
EDWARDS & ASSOC. LS.
U
D
ELEVATION IN FEET M.S.L.
700
600
500
400
300
200
100
SEA LEVEL
- 100
- 200
- 300
- 400
- 500
- 600
- 700
- 800
40
30
20
0
200
400
600
800
GRAPHIC SCALE
LEGEND
FAULTS
3-32 WATER WELLS
3F 3" FISHTAIL BORINGS
8A6C AUGER & 6" CORE BORING

The following symbols are used to represent the kinds of rock or substrata material encountered below the soil horizon:

- R Hard rock, such as limestone, sandstone, chalk, or other rock having a hardness rating of 2.5 or more, Mohr's Scale. Rock is hard enough to require jackhammers or dynamite to excavate.
- G Gravel of sufficient size or concentration to hamper excavation operations; usually exceeds 25 percent of volume.
- CM Chalk, marl, or caliche having a hardness of 2.5 or less, Mohr's Scale. Can be excavated with ditching equipment.
- SH Shale or shaly clays having hardness of 2.5 or less, Mohr's Scale. Can be excavated using excavating equipment.
- GC Gravelly clay having approximately 12 to 25 percent gravel by volume. Will hamper small excavating equipment.
- GP Gravel pit.

Arabic number following the above symbols indicates to the nearest foot the depth to bedrock or other "not-soil" materials, such as gravel. (Example GC-5 = Gravelly Clay at 5 feet)

The data presented on this map and the descriptions used were compiled from the "Soil Handbook for Soil Survey of Metropolitan Area, San Antonio, Texas," as developed by the Soil Conservation Service, USDA, under a cooperative agreement with the city of San Antonio in cooperation with the Texas Agricultural Experiment Station and published in April of 1964. For a more detailed treatment of the soils data shown on this plate, reference is made to the above publication.



SOIL LEGEND

▨ **HOUSTON BLACK CLAY**

Soil Description

Approximately 48 inches of slowly permeable calcareous clays ove marly clays, marl, or chalk. Profile contains less than 7 percent

☐ **HOUSTON BLACK CLAY, TERRACE**

Soil Description

Approximately 3 to 5 feet of clay underlain by clayey alluvium w grades to gravelly alluvium at about 6 to 12 feet; solum contains slickensides below about 15 inches.

☐ **HOUSTON BLACK GRAVELLY CLAY**

Soil Description

A gravelly clay having 8 to 15 percent gravel in the upper horiz with gravelly clay horizons occuring in some profiles between 24 to inches; clay extends to 50 to 95 inches over marly clays; gravel var from 1/2 to over 3 inches in diameter.

▨ **HOUSTON CLAY**

Soil Description

Approximately 28 inches of slowly permeable calcareous clays over marly clays, chalk, or marls; less than 7 percent gravel in profile.

▨ **HOUSTON-SUMPTER CLAYS**

Soil Description

Approximately 28 inches of slowly permeable calcareous clays over marly clays, chalk, or marl; less than 7 percent gravel in profile.

☐ **KNIPPA CLAYS**

Soil Description

Approximately 30 to 50 inches of moderately crumbly clays grading thick loamy alluvial sediments; rounded calcium carbonate concretions soft masses occur below 30 inches; gravel may underlie the soil at de of 5 to 12 feet.

▨ **FRIO SILTY CLAY LOAM**

Soil Description

Approximately 16 to 50 inches of calcareous silty clay loam to loa over loamy alluvial sediments positioned on high bottom above normal flood stage; gravel may occur below 5 feet in depth; some gravel is cemented.

■ **BRACKETT-AUSTIN COMPLEX**

Soil Description

Brackett - 12 to 20 inches of clay loam, loam, or silty clay loam over chalk, marl, and soft limestone, interbedded and many feet thick; some angular gravel or fragments are common on the surface and in the solum.

Austin - Approximately 20 to 45 inches of calcareous, very crumbly silty clay over altered chalk which usually is soft and thinbedded with vertical thickness; occasional hard strata occur within 4 to 3 feet.

☐ **GRAVELLY ROUGH LAND AND CALICHE OUTCROPS**

Soil Description

Mapping unit includes gravel pits, areas having caliche outcrops du to mining of gravel, with a few soil areas included; very mixed; 85 percent of mapping unit is not soil.

▨ **GULLIED LAND**

Soil Description

Streambank escarpments and gullied areas along streambanks; of loamy alluvial sediments underlain at variable depths by gravel.

▨ **LEWISVILLE CLAY LOAM**

Soil Description

Approximately 3 to 5 feet of very crumbly calcareous clay loam over loamy alluvial sediments which may be stratified with lighter and heavier gravels occurring between 3 to 12 feet; hard rounded calcium carbonate concretions occur throughout with a concentration of white calcium deposits around 35 to 45 inches.

☐ **FRIO CLAY LOAM (OCCASIONALLY FLOODED)**

Soil Description

Approximately 35 to 40 inches of calcareous clay loam underlain in places with beds of gravel and loamy soil materials; gravel beds may be many feet thick.

▨ **CLAYEY ALLUVIAL LAND**

Soil Description

This mapping unit is composed of several clayey soils having texture of clay, gravelly clay, and gravelly clay loam 1 to 5 feet deep over limestone, shale, chalk, and marly clays. They are stratified with loamy sediments, frequently to occasionally flooded.

■ **PATRICK SOILS**

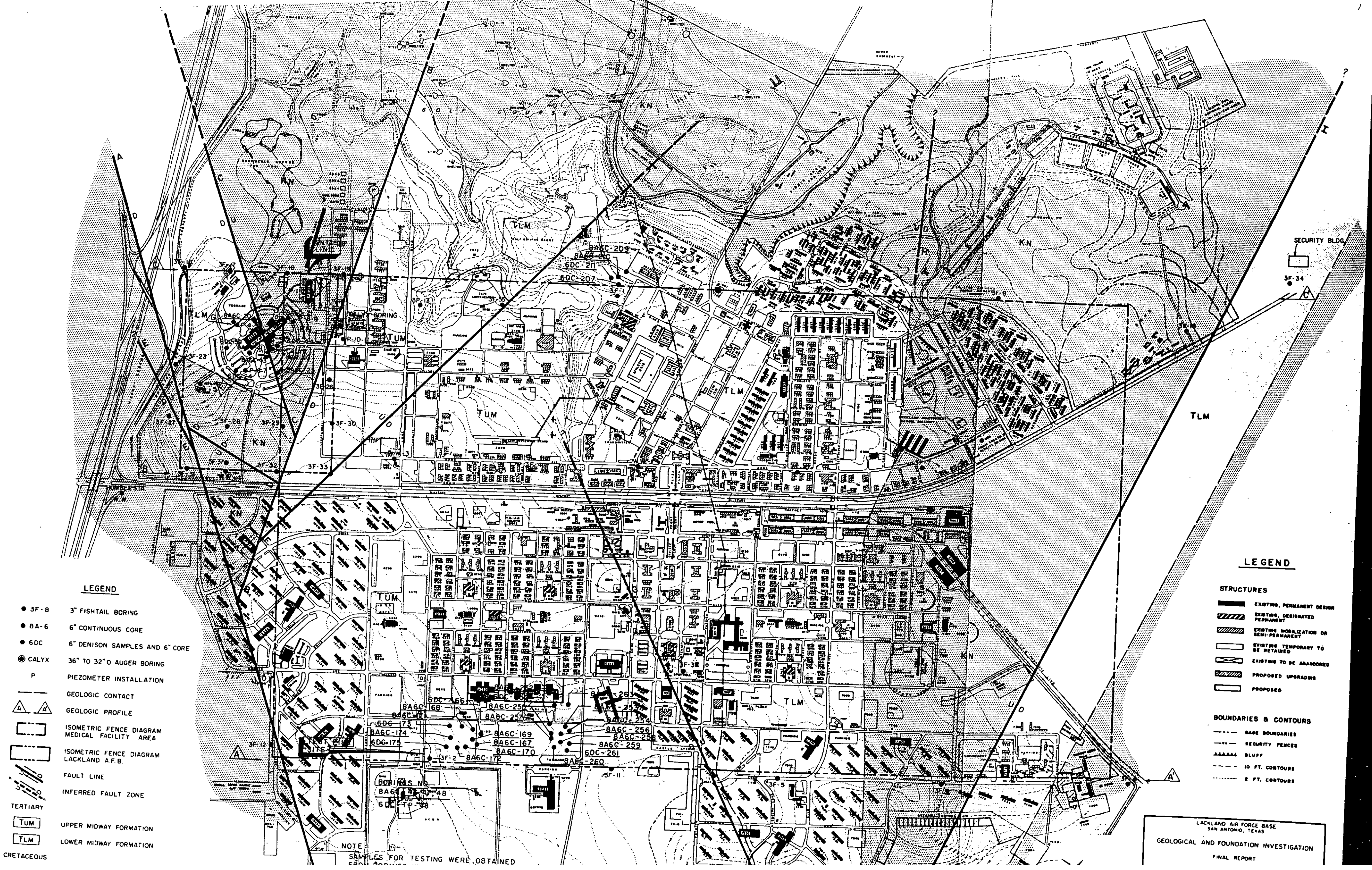
Soil Description

Range from 10 to about 30 inches of clay loam, loam, silty clay loam, or light clay over porous beds of gravel that occur within 3 feet of the surface; gravel is commonly cemented in upper 3 to 4 inches and, in places, several feet in thickness; contains both limestone and chert gravels 1/4 to over 3 inches in diameter.

LACKLAND AIR FORCE BASE
SAN ANTONIO, TEXAS

GEOLOGICAL AND FOUNDATION INVESTIGATION

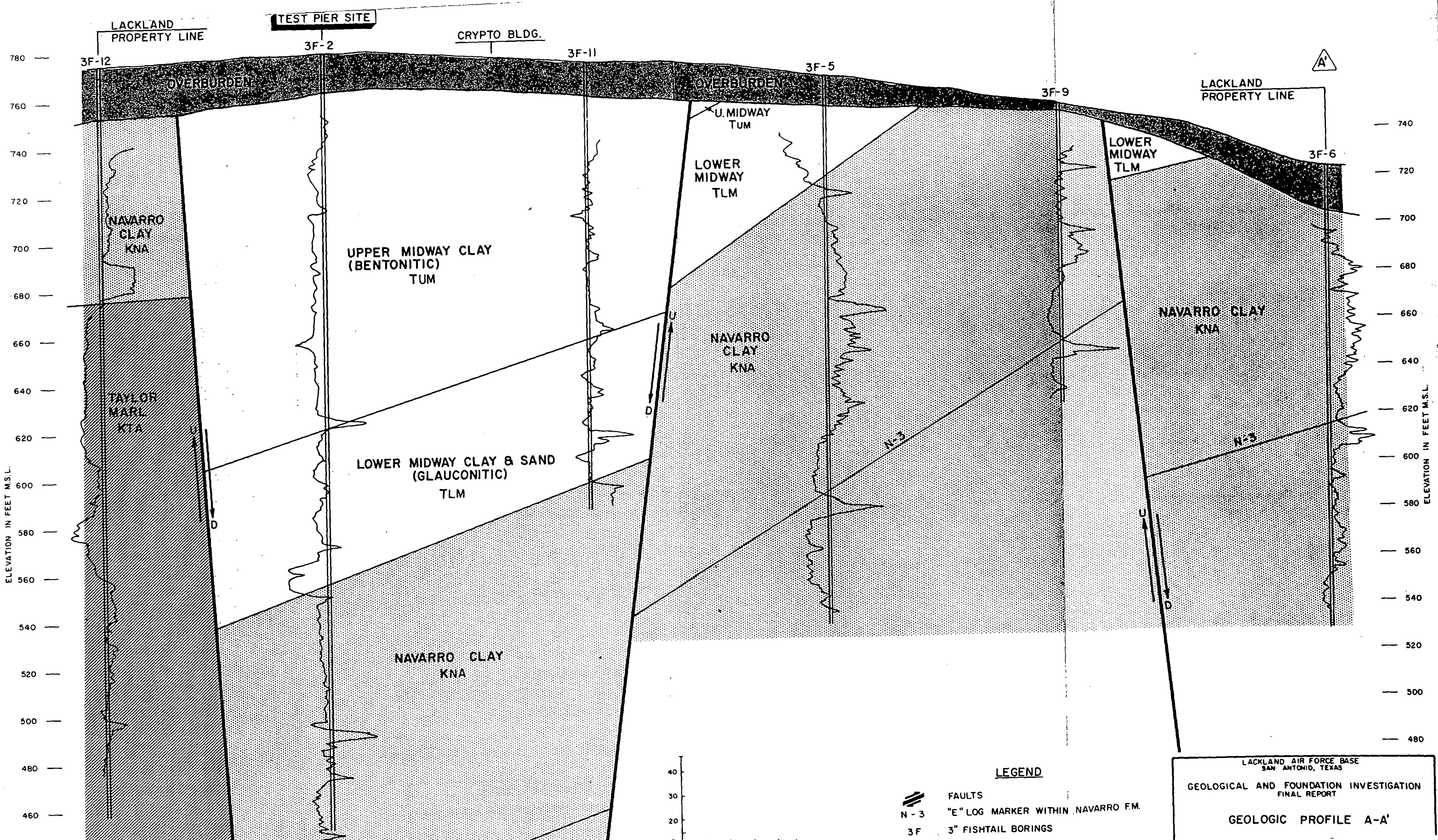
FINAL REPORT



LACKLAND AIR FORCE BASE
SAN ANTONIO, TEXAS

GEOLOGICAL AND FOUNDATION INVESTIGATION

FINAL REPORT



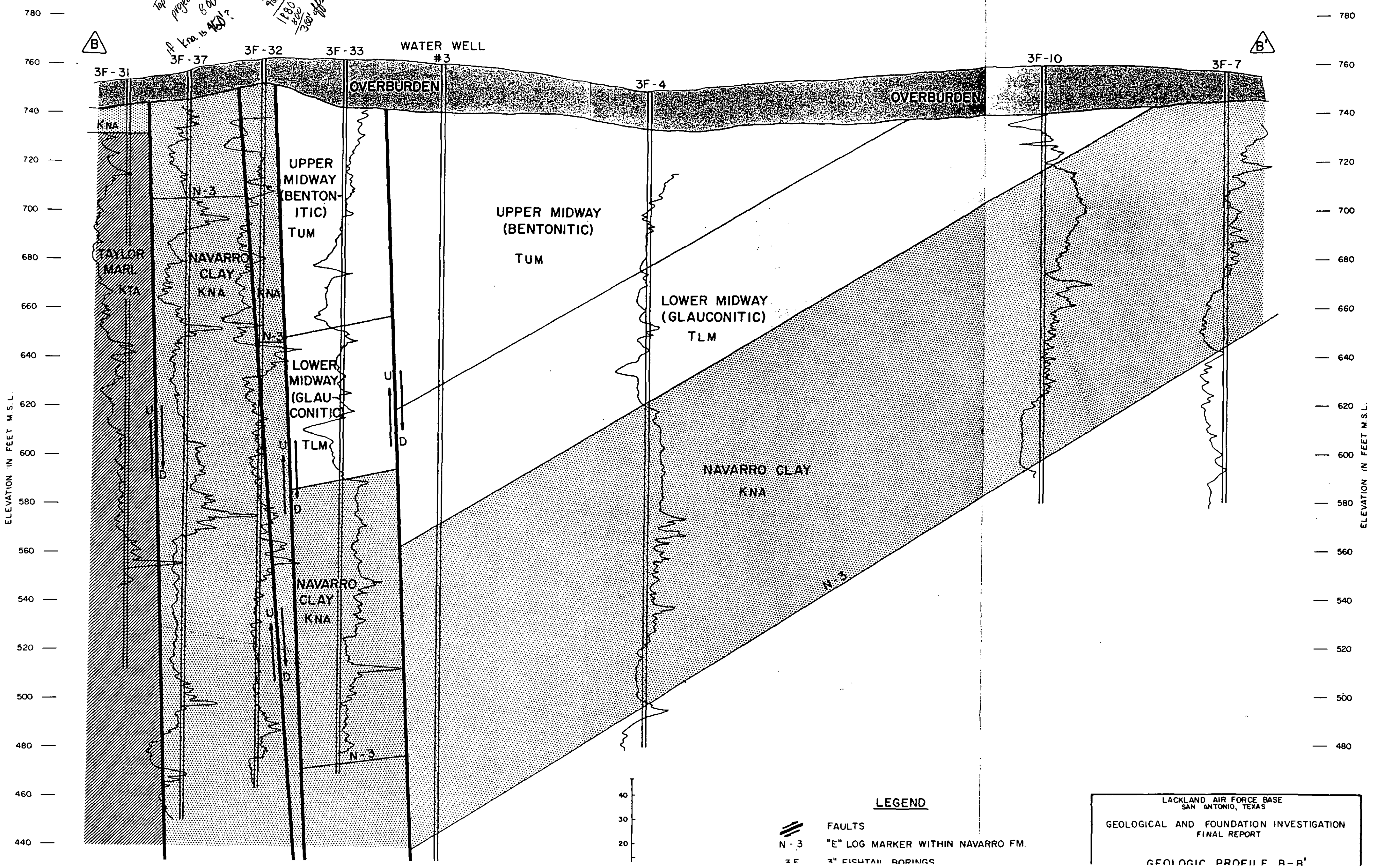
LACKLAND AIR FORCE BASE
SAN ANTONIO, TEXAS

GEOLOGICAL AND FOUNDATION INVESTIGATION
FINAL REPORT

GEOLOGIC PROFILE A-A'

Top Nav... projects ... 800' (?)
If Kna is 450'?

730
950
1880
800
380' offset



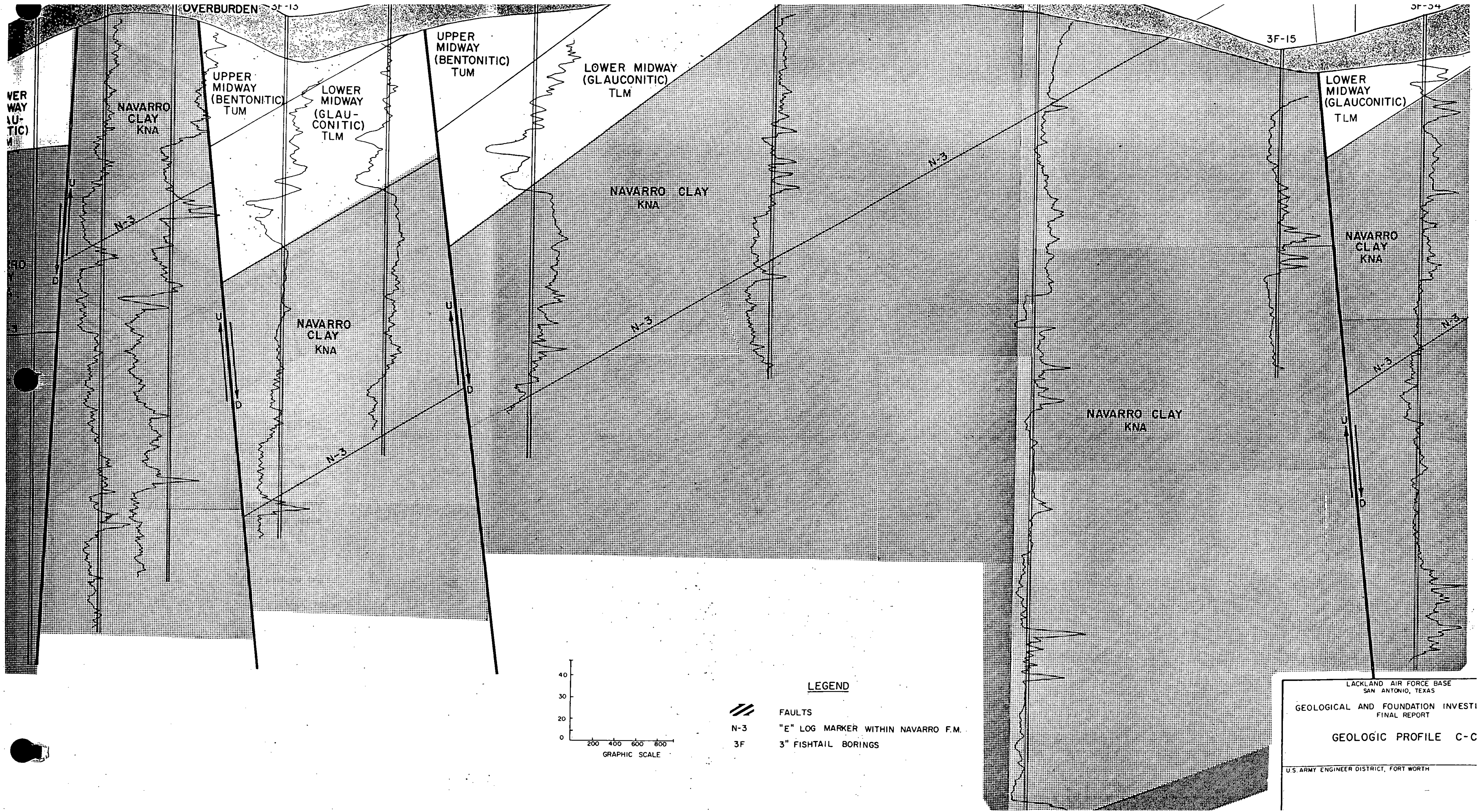
LEGEND

⫽	FAULTS
N - 3	"E" LOG MARKER WITHIN NAVARRO FM.
3F	3" FISHTAIL BORINGS

LACKLAND AIR FORCE BASE
SAN ANTONIO, TEXAS

GEOLOGICAL AND FOUNDATION INVESTIGATION
FINAL REPORT

GEOLOGIC PROFILE B-B'



LEGEND

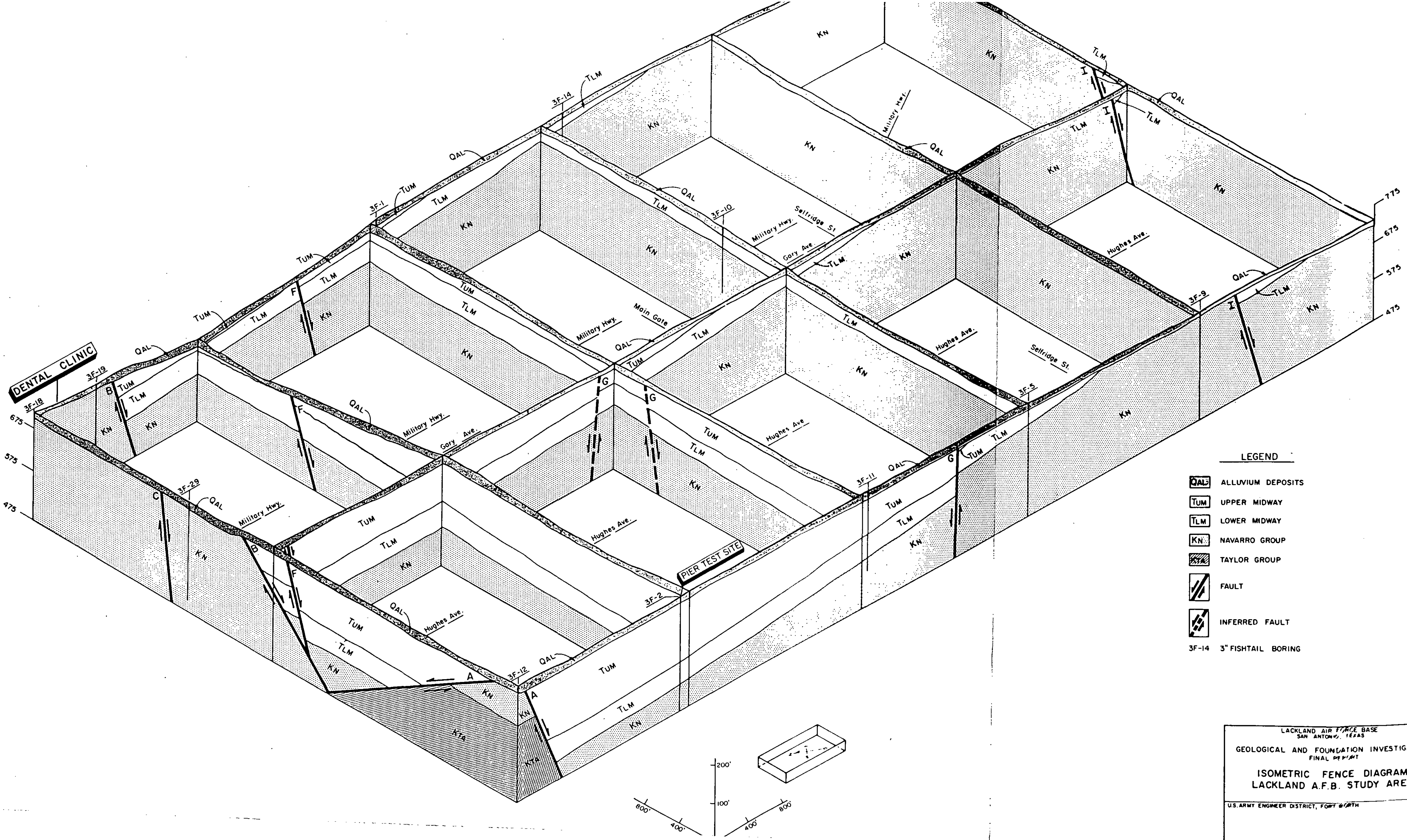
▨	FAULTS
N-3	"E" LOG MARKER WITHIN NAVARRO F.M.
3F	3" FISHTAIL BORINGS

LACKLAND AIR FORCE BASE
SAN ANTONIO, TEXAS

GEOLOGICAL AND FOUNDATION INVESTI
FINAL REPORT

GEOLOGIC PROFILE C-C

U.S. ARMY ENGINEER DISTRICT, FORT WORTH

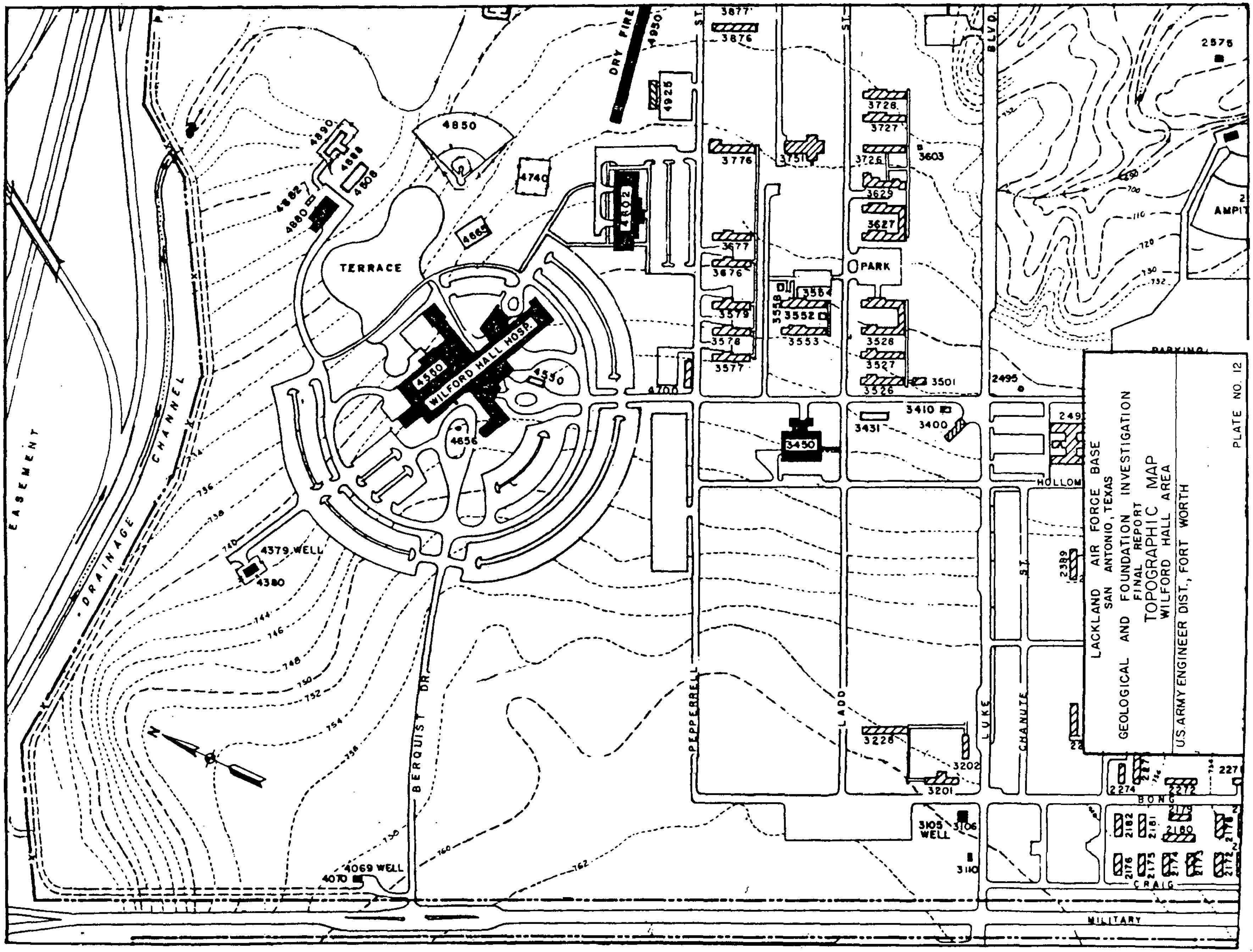


LACKLAND AIR FORCE BASE
SAN ANTONIO, TEXAS

GEOLOGICAL AND FOUNDATION INVESTIGATION
FINAL REPORT

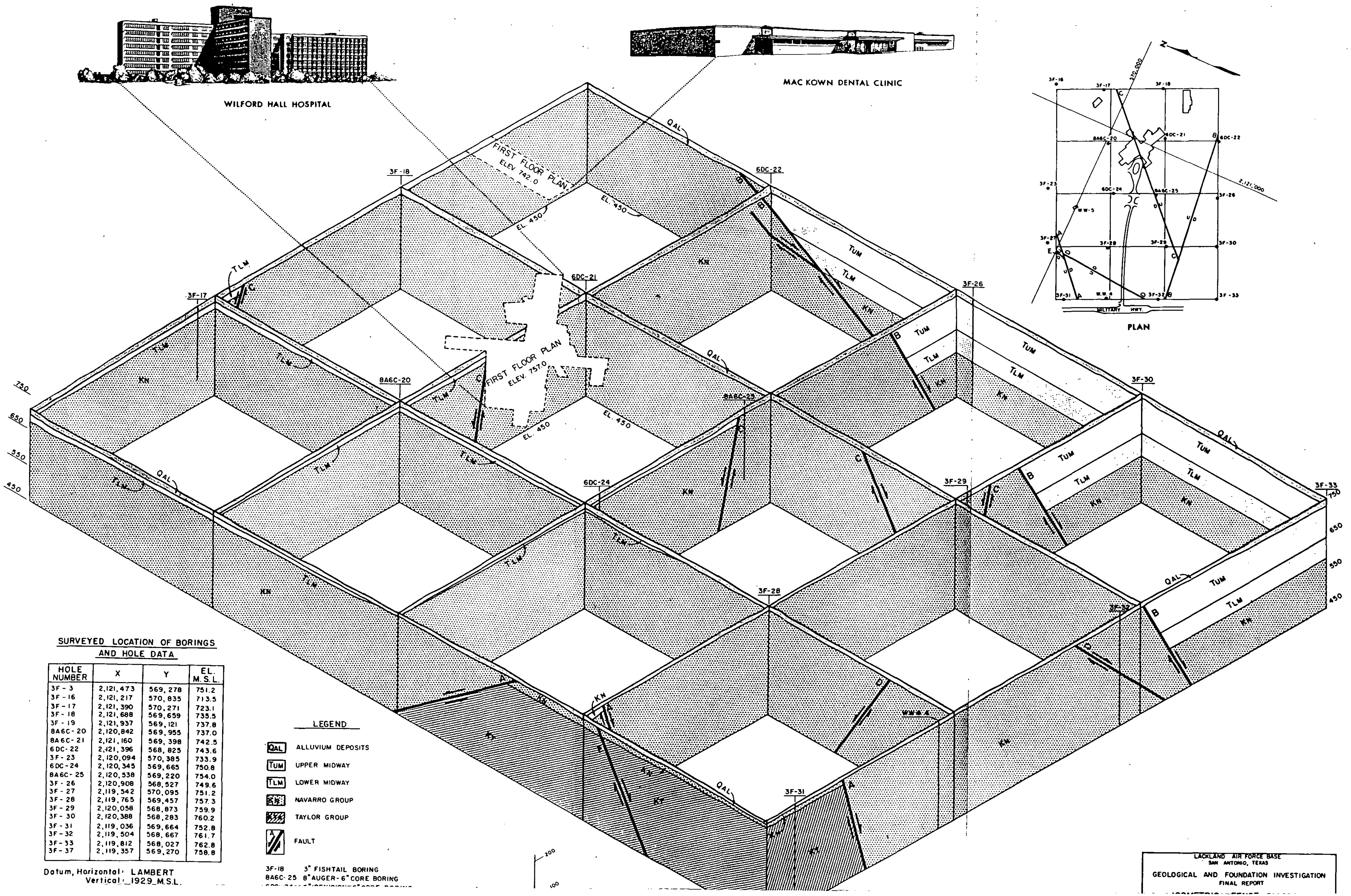
ISOMETRIC FENCE DIAGRAM
LACKLAND A.F.B. STUDY AREA

U.S. ARMY ENGINEER DISTRICT, FORT WORTH



LACKLAND AIR FORCE BASE
SAN ANTONIO, TEXAS
GEOLOGICAL AND FOUNDATION INVESTIGATION
FINAL REPORT
TOPOGRAPHIC MAP
WILFORD HALL AREA
U.S. ARMY ENGINEER DIST., FORT WORTH

PLATE NO. 12



SURVEYED LOCATION OF BORINGS AND HOLE DATA

HOLE NUMBER	X	Y	EL. M.S.L.
3F - 3	2,121,473	569,278	751.2
3F - 16	2,121,217	570,835	713.5
3F - 17	2,121,390	570,271	723.1
3F - 18	2,121,688	569,659	735.5
3F - 19	2,121,937	569,121	737.8
8A6C- 20	2,120,842	569,955	737.0
8A6C- 21	2,121,160	569,398	742.5
6DC- 22	2,121,396	568,825	743.6
3F - 23	2,120,094	570,385	733.9
6DC - 24	2,120,345	569,665	750.8
8A6C- 25	2,120,538	569,220	754.0
3F - 26	2,120,908	568,527	749.6
3F - 27	2,119,542	570,095	751.2
3F - 28	2,119,765	569,457	757.3
3F - 29	2,120,058	568,873	759.9
3F - 30	2,120,388	568,283	760.2
3F - 31	2,119,036	569,664	752.8
3F - 32	2,119,504	568,667	761.7
3F - 33	2,119,812	568,027	762.8
3F - 37	2,119,357	569,270	758.8

Datum, Horizontal: LAMBERT
Vertical: 1929 M.S.L.

LEGEND

QAL	ALLUVIUM DEPOSITS
TUM	UPPER MIDWAY
TLM	LOWER MIDWAY
KN	NAVARRO GROUP
KT	TAYLOR GROUP
A	FAULT

3F-18 3" FISHTAIL BORING
8A6C-25 8" AUGER-6" CORE BORING

LACKLAND AIR FORCE BASE
SAN ANTONIO, TEXAS

GEOLOGICAL AND FOUNDATION INVESTIGATION
FINAL REPORT

HOLE NO. 6DC-TP-47

DEPARTMENT OF THE ARMY

DIVISION Southwestern

INSTALLATION Ft. Worth

DRILLING LOG

1. PROJECT Lackland A.F.B. - Top Pegs — SHEET 1 OF 2
2. LOCATION (Coordinates or Station)
3. DRILLING AGENCY Corps of Engineers
4. HOLE NO. (As shown on drawing title and file number) 6DC-TP-47
5. NAME OF DRILLER Tanner
6. DIRECTION OF HOLE ☒ VERTICAL ☐ INCLINED — DEGREES FROM VERTICAL
7. THICKNESS OF OVERBURDEN 14.5'
8. DEPTH DRILLED INTO ROCK 36.5'
9. TOTAL DEPTH OF HOLE 51'
10. SIZE AND TYPE OF BIT 8" Flight Auger, 6" Carbon
11. DATUM FOR ELEVATION SHOWN (TBM or MSL) MSL
12. MANUFACTURER'S DESIGNATION OF DRILL Failing 1500
13. TOTAL NO. OF OVERBURDEN SAMPLES TAKEN — DISTURBED 8 — UNDISTURBED —
14. TOTAL NO. CORE BOXES 7
15. ELEV. GROUND WATER
16. DATE HOLE — STARTED 7 Jan. 66 — COMPLETED 10 Jan. 66
17. ELEV. TOP OF HOLE
18. TOTAL CORE RECOVERY FOR BORING 100 %
19. SIGNATURE OF INSPECTOR James L. Christie

ELEVATION | DEPTH | LEGEND | CLASSIFICATION OF MATERIALS (Description) | % CORE RECOVERY | BOX OR SAMPLE NO. | REMARKS (Drilling time, water loss, depth of weathering, etc., if significant)

Classification of materials:

0.0' to 2.8'
Clay, calc., stiff, moist.
0.0' to 1.5' - Black.
1.5' to 2.8' - Dk. Gray.

2.8' to 14.5'
Gravel, clay & "caliche" binder, augers medium, water. Bearing @ 6.8'.

14.5' to 18.8'
Clay, shaley - See Description below.

— No Refusal w/ Auger —
— Start 6" Core @ 18.8' —

18.8' to 51' - [redacted]
Clay, shaley, non-calc., hard (Pen. + 4.5), Hi-angle joints throughout, healed to moderately healed, tan & gray

19.9' to 23'. Continuous near-vertical joint, med. healed.

22.3' to 25' - This piece shows many slickensides.

29.3' to 33.1' - Do

37.5' to 38'. 60° fractures showing well-healed brecciation.

Core recovery / sample no.: 8' Auger — samples 1–8; 18.8 | 18.8; 22.1' | 1; 23.3; 25' | 2; 28.1'; 29.5' | 3; 32.7'; 33.1' | 4; 37.5' | 37.6 | 5

Remarks:

*1.) Water Information -
a.) Hole drilled to 49' w/ casing intact to see if primary matl was water bearing. - No water in hole on 11 Jan. -
b.) Water level in overburden was 6.8'. -

2.) Jar Samples
1. 0.0 to 1.5
2. 1.5' to 2.8'
3. 2.8' to 4.5'
4. 4.5' to 6.8'
5. 6.8' to 10'
6. 10' to 11'
7. 11' to 14.5'
8. 14.5' to 18.8'

3.) No samples taken of primary Carlos Clay

4.) Core wrapped & preserved

5.) 18' of 8" casing set to 17.7'

6DC-TP-47

@ 41.5' - Thin zone of pelecypod casts

@ 44.5' - Oval, 1" dia. concretionary calcareous siltstone -

46.2' to 46.5 - Limestone, m. hard, stained red in lower 0.2'.

— T.D. - 51' —

Core recovery / sample no.: 40.9 | 42'; 6; 45.2; 46.8; 7; 51' | 51'

— Wrapped to T.D.

ENG FORM 1836 (EM 1110-1-1801) TRANSLUCENT — PREVIOUS EDITION MAY BE USED UNTIL EXHAUSTED. — PROJECT Lackland A.F.B. — HOLE NO. 6DC-TP-47

Hole No. BAGC-10

DRILLING LOG — DIVISION Southwestern — INSTALLATION Ft. Worth — SHEET 1 OF 3 SHEETS

1. PROJECT Lackland A.F.B.
2. LOCATION (Coordinates or Station) Dental Clinic
3. DRILLING AGENCY C. of E.
4. HOLE NO. (As shown on drawing title and file number) BAGC-10
5. NAME OF DRILLER Stanford
6. DIRECTION OF HOLE ☑ VERTICAL ☐ INCLINED ____ DEG. FROM VERT.
7. THICKNESS OF OVERBURDEN 16.5'
8. DEPTH DRILLED INTO ROCK 258.5'
9. TOTAL DEPTH OF HOLE 275'
10. SIZE AND TYPE OF BIT 6" Carboloy and 3½"
11. DATUM FOR ELEVATION SHOWN (TBM or MSL)
12. MANUFACTURER'S DESIGNATION OF DRILL Failing 1500
13. TOTAL NO. OF OVERBURDEN SAMPLES TAKEN 6 — DISTURBED 6 — UNDISTURBED
14. TOTAL NUMBER CORE BOXES 22
15. ELEVATION GROUND WATER *
16. DATE HOLE — STARTED 9 March 1966 — COMPLETED 21 March 1966
17. ELEVATION TOP OF HOLE
18. TOTAL CORE RECOVERY FOR BORING 98%
19. SIGNATURE OF INSPECTOR James L. Christie

ELEVATION | DEPTH | LEGEND | CLASSIFICATION OF MATERIALS (Description) | % CORE RECOVERY | BOX OR SAMPLE NO. | REMARKS (Drilling time, water loss, depth of weathering, etc., if significant)

Classification of materials:

0.0' to 8.5'
Clay -
0.0' to 5.1' - Stiff, moist, calc., black.
5.1' to 8.5'. Stiff, moist, calc., tan.

8.5' to 16.5'
Gravel, clayey, medium to dense, saturated from 11.6'. —

16.5' - 22.1'
Clay, shaley, calc., sl. moist, tan.

— Start 6" core @ 22.1' —

22.1 to 123' - Navarro Fm.
Clay, shaley, calc. -
Stiff w/ gray mottling - m. hard, unbedded, tan & gray.

38.5' - 0.2' thick calc. lamina

40.4' to 40.6' - Limestone -

41.9' - 0.2' thick calcareous siltstone limestone

45.5' to 45.8' - calc. & marly
46.0 to 48' Do
48.5' to 49.0' Do

@ 50' - Gravel increase in % of sand, also @ 51' found fine-grained phosphate staining to BAGC-26B at same marker —

Siltstone seams averaging 0.02 thickness at following depths:
51.7', 53.9', 56.6', 66.2', 66.5', 66.8', 67.5', 67.8.

Limestone @ following depths
56.0' to 60.5' - marly
76' to 76.5' - m. hard
80.5' to 80.75 - m. hard
86' to 86.5' - marly
98.8' to 99.3' - marly
117.9' to 118.6' - marly
119' to 119.6' - m. hard

77' to 77.4' - sandy, very fossiliferous -
86.5' to 86.8' - Do —

Note - Unweathered. Black shaley clay shows many pyrite nodules avg. ⅛" dia.

Sand seams @ following depths:
85.5' to 85.8' - Partially cemented
88.8' to 88.5' - cemently
90.2' to 90.25' - "
60.4' to 60.5' - "
78' to 78.6' - Partially cemented
85.5', 86.5', 86.8', 91.6', 91.9', 93.6' } 0.02' thick
96.8 to 97.1 - cemented -

Core recovery / sample no.: A; 5.1; B; 7'; C; 8.5'; D; 11.2'; E; 16.5'; F; 22' | 22'; 1 | L. 0.7 | 26.9; 2 | L. 0.6 | 29 | 6. 0.6 | 29.9; 3 | L. 0.2 | 36.9; 4 | 6. 0.7 | 39 | L. 0.0 | 41.9; 5 | L. 0.8 | 46.9; 6; 7 | L. 0.1 | 52.9' | L. 0.1; 8 | 57.4' | 6. 0.1 | 62'; 9 | L. 0.1 | 66'; 10 | L. 0.6 | 69'; 11 | L. 0.6 | 71.4'; 12 | 6. 0.1 | 77.8' | L. 0.6 | 81.4'; 13 | 6. 0.9 | 84.9'; 14 | L. 1.1 | 89; 15 | L. 0.1 | 91.9; 16 | L. 0.0 | 96.9 | 6. 0.4 | 99

Remarks:

*1.) W.L. after augering was 11.6'

2.) 8" casing set to 22'

3.) Jars
A. 0.0' to 5.1'
B. 5.1' to 7'
C. 7' to 8.5'
D. 8.5' to 11.2'
E. 11.2' to 16.5'
F. 16.5' to 22'

4.) All core wrapped and preserved in wax.

* Possible marker bed.

— Base of weathering @ 69' —

* Possible marker bed

BAGC-10

119.6' to 121.6' - marly

119 to 119.6 - Limestone, m. hard

123 to 123' - Sandy, very fossiliferous -

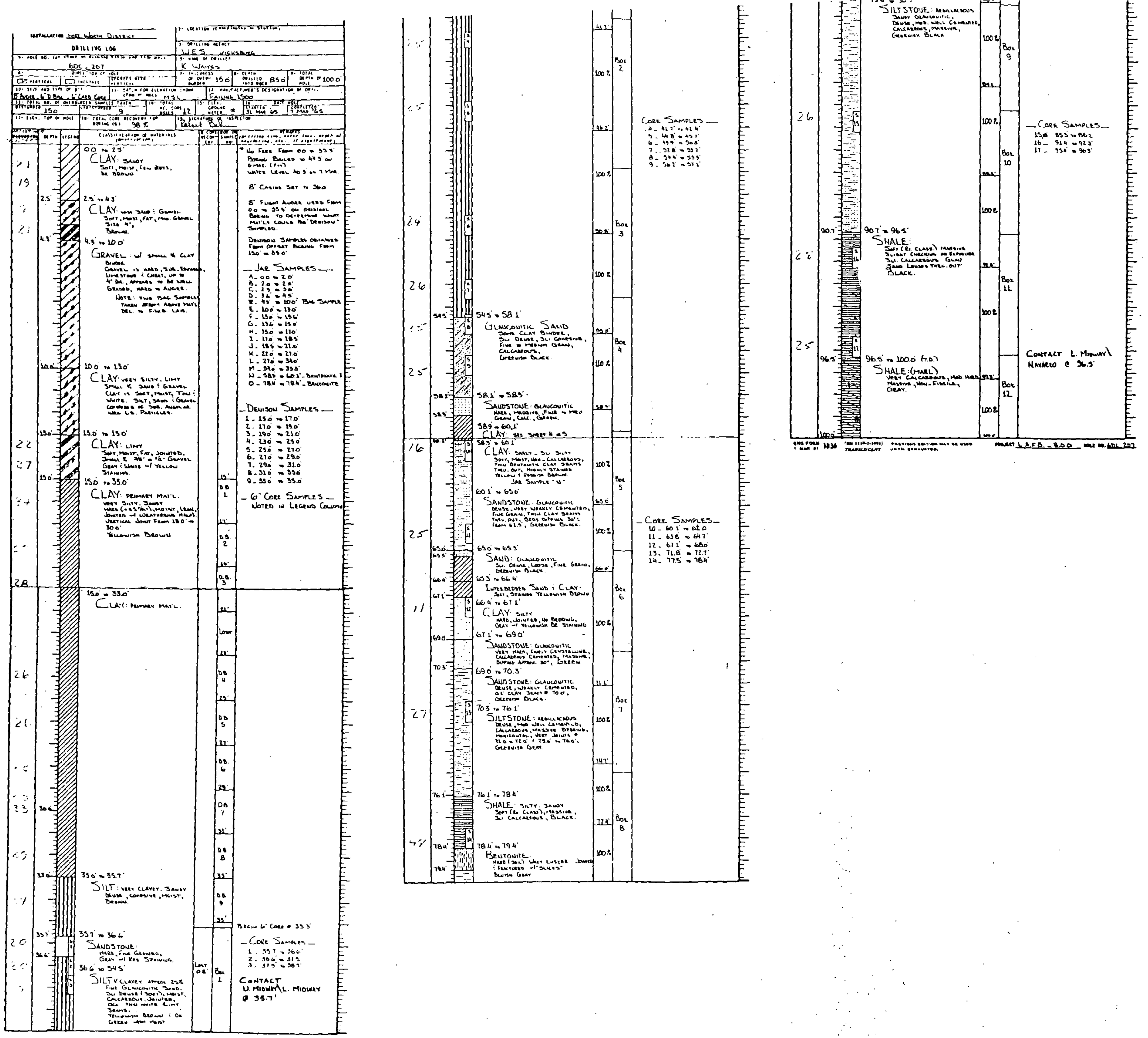
Logged & cleaned out from 123' to 130' - Set 3½" casing to 130' - No core or E log from this 7 ft. interval —

145' Fish'g & E Log

Core recovery / sample no.: 17 | L 0.0 | 101.1'; 18 | L 0.0 | 107.1' | L 0.0 | 109'; 19 | L 0.0 | 111'; 20 | L 0.1 | 117'; 21 | L 0.1 | 121' | L 0.0; 123' | 123'; 130' | 130'; 275'

* Possible marker bed

ENG FORM 1836 — PREVIOUS EDITIONS MAY BE USED — PROJECT Lackland A.F.B. — HOLE NO. BAGC-10 3



INSTALLATION Fort Worth District

DRILLING LOG

2. LOCATION (Coordinates or Station)

3. DRILLING AGENCY WES VICKSBURG

4. HOLE NO. 6DC - 207

5. NAME OF DRILLER K. Waites

6. DIRECTION OF HOLE ☐ VERTICAL ☐ INCLINED DEGREES FROM VERTICAL

7. THICKNESS OF OVERBURDEN 15.0

8. DEPTH DRILLED INTO ROCK 85.0

9. TOTAL DEPTH OF HOLE 100.0

10. SIZE AND TYPE OF BIT 8" Auger, 6" D Bbl., 6" Card Core

11. DATUM FOR ELEVATION SHOWN (TBM or MSL) MSL

12. MANUFACTURER'S DESIGNATION OF DRILL Failing 1500

13. TOTAL NO. OF OVERBURDEN SAMPLES TAKEN DISTURBED 15 UNDISTURBED 9

14. TOTAL NO. CORE BOXES 12

15. ELEV. GROUND WATER *

16. DATE HOLE STARTED 31 Mar 65 COMPLETED 7 Mar 65

17. ELEV. TOP OF HOLE

18. TOTAL CORE RECOVERY FOR BORING 98 %

19. SIGNATURE OF INSPECTOR Robert B...

ELEVATION	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS (Description)	% CORE RECOVERY	BOX OR SAMPLE NO.	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant)
21 19			0.0 to 2.5' CLAY: Sandy Soft, Moist, Few Roots, Dk Brown			* No Free From 0.0 to 35.5' Boring Bailed to 44.5' on 6 Mar. (PM) Water Level At 5 on 7 Mar. 8" Casing Set to 36.0' 8" Flight Auger used From 0.0 to 35.5' on Original Boring to Determine what Mat'ls Could Be "Denison" Sampled. Denison Samples obtained From Offset Boring From 15.0' to 35.0'
7 21	2.5'		2.5' to 4.3' CLAY: with Sand & Gravel Soft, Moist, Fat, Max. Gravel Size 4", Brown.			
	4.3'		4.3' to 10.0' GRAVEL: w/ small % Clay Binder Gravel is Hard, Sub-Rounded, Limestone & Chert, up to 4" Dia., Appears to Be Well Graded, Hard to Auger. Note: Two Bag Samples Taken From Above Mat'l Del. to F.W.D. Lab.			— Jar Samples — A. 0.0 to 2.0' B. 2.0 to 2.6' C. 2.5 to 3.6' D. 3.6' to 4.5' E. 4.5' to 10.0' Bag Sample E. 10.0 to 13.0' F. 13.0 to 13.6' G. 13.6 to 15.0' H. 15.0 to 17.0' I. 17.0 to 18.5' J. 18.5 to 21.0' K. 22.0 to 27.0' L. 27.0 to 34.0' M. 34.0 to 35.5' N. 58.9 to 60.1' Bentonitic ? O. 78.4 to 79.4' Bentonite
	10.0'		10.0 to 13.0' CLAY: Very Silty, Limy Small % Sand & Gravel Clay is Soft, Moist, Tan & White. Silt, Sand & Gravel Composed of Sub. Angular Ls. Particles.			— Denison Samples — 1. 15.0 to 17.0' 2. 17.0 to 19.0' 3. 19.0 to 21.0' 4. 23.0 to 25.0' 5. 25.0 to 27.0' 6. 27.0 to 29.0' 7. 29.0 to 31.0' 8. 31.0 to 33.0' 9. 33.0 to 35.0'
22 27	13.0'		13.0 to 15.0' CLAY: Limy Soft, Moist, Fat, Jointed, Small % 1/8" to 1/4" Gravel Gray & White w/ Yellow Staining.			
	15.0'		15.0 to 35.0' CLAY: Primary Mat'l. Very Silty, Sandy Hard (1.5 T/ft²), Moist, Lean, Jointed w/ Weathering Halos. Vertical Joint From 18.0' to 30.0' Yellowish Brown		15' D.B. 1 17' D.B. 2 19' D.B. 3	— 6" Core Samples — Noted in Legend Column
28			15.0 to 35.0' CLAY: Primary Mat'l.		21' Lost 23' D.B. 4 25' D.B. 5 27' D.B. 6 29' D.B. 7 31' D.B. 8 33' D.B. 9 35'	
26 21 33 45	30.0					
	33.0		33.0' to 35.7' SILT: Very Clayey, Sandy Dense, Cohesive, Moist, Brown.			Begin 6" Core @ 35.5'
20	35.7'		35.7' to 36.6' SANDSTONE: Hard, Fine Grained, Gray w/ Red Staining.			— Core Samples — 1. 35.7 to 36.6' 2. 36.6 to 37.5 3. 37.5' to 38.5'
	36.6'		36.6 to 54.5' SILT: V. Clayey Approx. 25% Fine Glauconitic Sand. Sl. Dense (Soft), Moist, Calcareous, Jointed, Occ. Thin White Limy Seams. Yellowish Brown & Dk Green when Moist	Lost 0.8'	Box 1	Contact U. Midway\L. Midway @ 35.7'
				41.7' 100 % 46.2' 100 % 50.8' 100 %	Box 2 Box 3	Core Samples — 4. 41.7' to 42.4' 5. 44.8' to 45.7' 6. 49.9' to 50.8' 7. 52.8 to 53.7' 8. 54.4' to 55.5' 9. 56.2' to 57.1'
24 26	54.5'		54.5' to 58.1' GLAUCONITIC SAND Some Clay Binder, Sl. Dense, Sl. Cohesive, Fine to Medium Grain, Calcareous, Greenish Black.	55.8' 100 %	Box 4	
25	58.1'		58.1' to 58.5' SANDSTONE: Glauconitic Hard, Massive, Fine to Med Grain, Calc., Green.	58.7'		
	58.5'		58.9 to 60.1' CLAY: See Sheet 4 & 5			
16	60.1'		58.9 to 60.1' CLAY: Shaly, Sl. Silty Soft, Moist, Non-Calcareous, Thin Bentonitic Clay Seams Thru-out, Highly Stained Yellow & Reddish Brown. Jar Sample "N"	100 %	Box 5	
25			60.1' to 65.0' SANDSTONE: Glauconitic Dense, Very Weakly Cemented, Fine Grain, Thin Clay Seams Thru-out, Beds Dipping 30°± From 61.5', Greenish Black.	65.0 100 %		— Core Samples — 10. 60.1' to 61.0 11. 63.8 to 64.7' 12. 67.1' to 68.0' 13. 71.8 to 72.7' 14. 77.5 to 78.4'
	65.0 65.5'		65.0 to 65.5' SAND: Glauconitic Sl. Dense, Loose, Fine Grain, Greenish Black.	66.0'		
	66.4'		65.5 to 66.4' Interbedded Sand & Clay. Soft, Stained Yellowish Brown		Box 6	
11	67.1'		66.4' to 67.1' CLAY: Silty Hard, Jointed, No Bedding, Gray w/ Yellowish Br. Staining	100 %		
	69.0		67.1' to 69.0' SANDSTONE: Glauconitic Very Hard, Finely Crystalline, Calcareous Cemented, Massive, Dipping Approx. 30°, Green			
	70.3'		69.0' to 70.3' SANDSTONE: Glauconitic Dense, Weakly Cemented, 0.1' Clay Seam @ 70.0', Greenish Black.	71.1'	Box 7	
27			70.3' to 76.1' SILTSTONE: Argillaceous Dense, Mod. Well Cemented, Calcareous, Massive Bedding, Horizontal, Vert. Joints @ 71.0 to 72.0' & 73.0' to 74.0', Greenish Gray.	100 % 74.7' 100 %		
	76.1'		76.1' to 78.4' SHALE: Silty, Sandy Soft (Rx Class), Massive, Sl. Calcareous, Black.	77.4'	Box 8	
45	78.4' 79.4'		78.4' to 79.4' BENTONITE Hard (Soil) Waxy Luster Jointed & Fractured w/ "Slicks" Bluish Gray	100 %		
			SILTSTONE: Argillaceous Sandy Glauconitic, Dense, Mod. Well Cemented, Calcareous, Massive, Greenish Black	100 %	Box 9	
26				84.1 100 % 88.3' 100 %	Box 10	— Core Samples — 15. 85.3 to 86.2 16. 91.4 to 92.3' 17. 95.4' to 96.3'
22	90.7'		90.7' to 96.5' SHALE: Soft (Rx Class) Massive Slight Checking on Exposure Sli. Calcareous Glau Sand Lenses Thru-out Black.	92.8' 100 %	Box 11	
25	96.5'		96.5' to 100.0' (T.D.) SHALE: (MARL) Very Calcareous, Mod. Hard, Massive, Non-Fissile, Gray.	97.5' 100 %	Box 12	Contact L. Midway\Navarro @ 96.5'
	100.0'			100.0		

ENG FORM 1 MAR 61 1836 (EM 1110-2-1801) TRANSLUCENT PREVIOUS EDITION MAY BE USED UNTIL EXHAUSTED. PROJECT L.A.F.B. - B.O.Q. HOLE NO. 6DC-207

LACKLAND AIR FORCE BASE
SAN ANTONIO, TEXAS

GEOLOGICAL AND FOUNDATION INVESTIGATION
FINAL REPORT

TYPICAL CORE LOG

U.S. ARMY ENGINEER DISTRICT, FORT WORTH

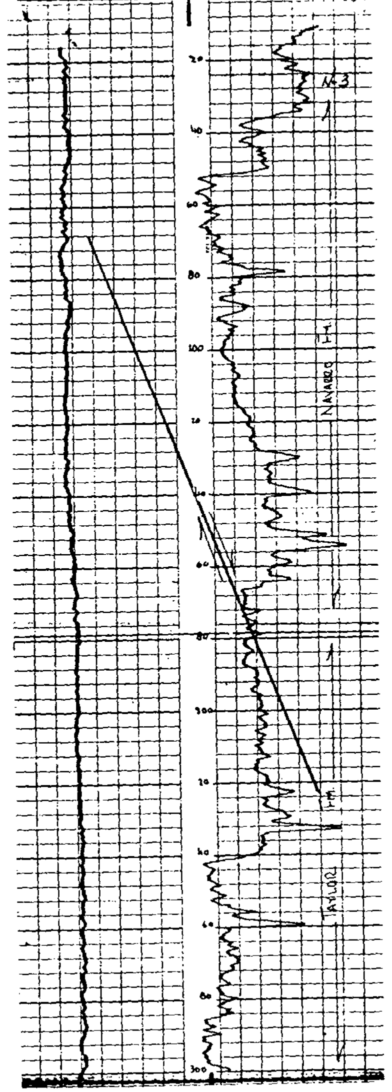
..ELL RECONNAISSA..CE
INCORPORATED
P. O. Box 1483 Dallas, Texas

Geo-Log

COMPANY Corps of Engineers
WELL 3F-23
FIELD Lackland AFB
LOCATION 400' W of WW # 5
COUNTY Bexar STATE Texas
ELEVATION
D. F.
G. L. 736'
K. B.

DATE 14 Sept. 66
RUN NO. One MUD NATURE Natural
DEPTH REACHED 300' BOTTOM, DRILLER 300'
OPERATOR Christie
REMARKS: Depth Primary .. 8'
Depth Weathering .. 90'±

Gamma Ray - Casing Collars
SENSITIVITY SECONDS FT/MIN
Self Potential DEPTH *Resistance*
— MV + 100 OHMS 100



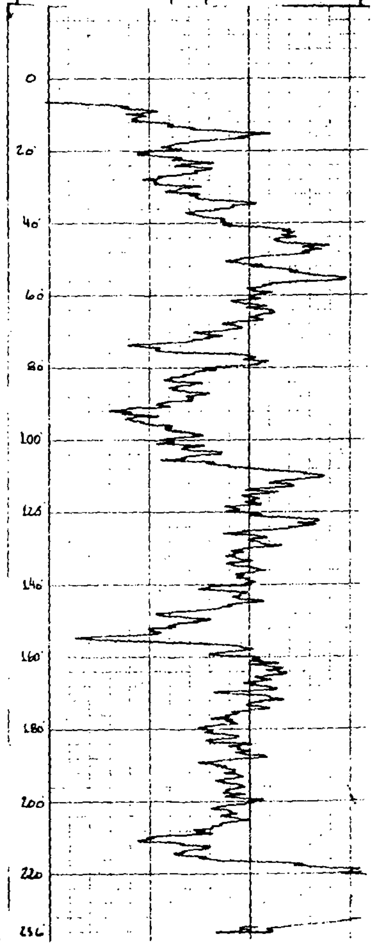
WELL RECONNAISSANCE
INCORPORATED
P. O. Box 1483 Dallas, Texas

Geo-Log

COMPANY Corps of Engineers
WELL 3F-23
FIELD Lackland AFB
LOCATION 400' W of W.W. #5
COUNTY Bexar STATE Texas
ELEVATION
D. F.
G. L. 736'
K. B.

DATE 16 Sept. '66
RUN NO. One MUD NATURE Natural
DEPTH REACHED 236' BOTTOM, DRILLER 300'
OPERATOR Follett - U.S.G.S. Austin
REMARKS: Res. Log Ran on 14 Sept 66
Depth to Primary .. 6'
Depth of Weathering - 90'±

Gamma Ray - Casing Collars
SENSITIVITY .0025 SECONDS 5 FT/MIN 20
Self Potential DEPTH *Resistance*
— MV + OHMS



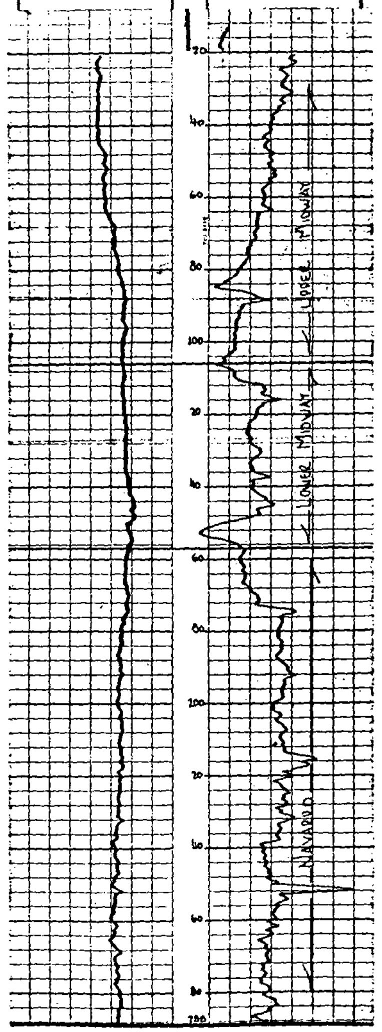
WELL RECONNAISSANCE
INCORPORATED
P. O. Box 1483 Dallas, Texas

Geo-Log

COMPANY Corps of Engineers
WELL 3F-33
FIELD Lackland AFB
LOCATION 800' NW of WW # 3
COUNTY Bexar STATE Texas
ELEVATION
D. F.
G. L. 763'
K. B.

DATE 7 Sept. '66
RUN NO. One MUD NATURE Natural
DEPTH REACHED 288' BOTTOM, DRILLER 301'
OPERATOR Christie
REMARKS: Depth to Primary = 21'
Depth of Wea. = 78'

Gamma Ray - Casing Collars
SENSITIVITY SECONDS FT/MIN
Self Potential DEPTH *Resistance*
— MV + 100 OHMS 100



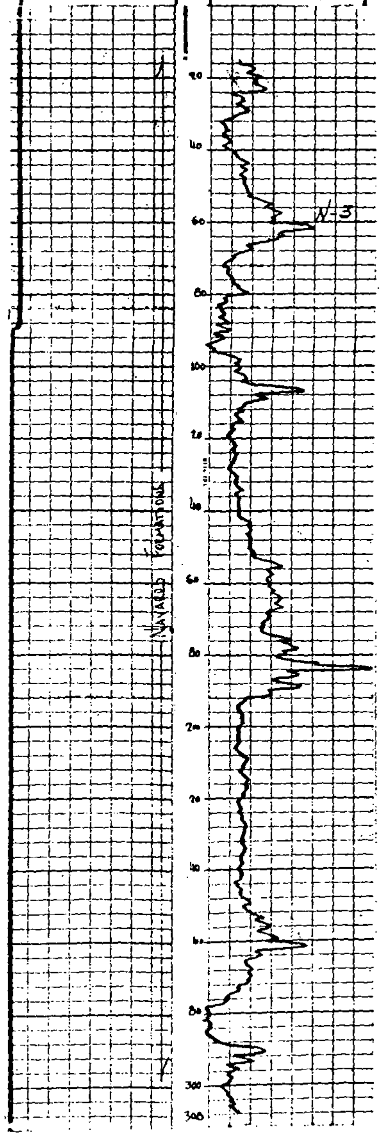
WELL RECONNAISSANCE
INCORPORATED
P. O. Box 1483 Dallas, Texas

Geo-Log

COMPANY Corps of Engineers
WELL 3F-37
FIELD Lackland AFB
LOCATION Adj. to W.W. #4
COUNTY Bexar STATE Texas
ELEVATION
D. F.
G. L. 758'
K. B.

DATE 19 Sept. 66
RUN NO. One MUD NATURE Natural
DEPTH REACHED 308' BOTTOM, DRILLER 310'
OPERATOR Christie
REMARKS: Depth to Primary ... 12'
Depth of Weathering .. 80'±

Gamma Ray - Casing Collars
SENSITIVITY SECONDS FT/MIN
Self Potential DEPTH *Resistance*
— MV + OHMS 100

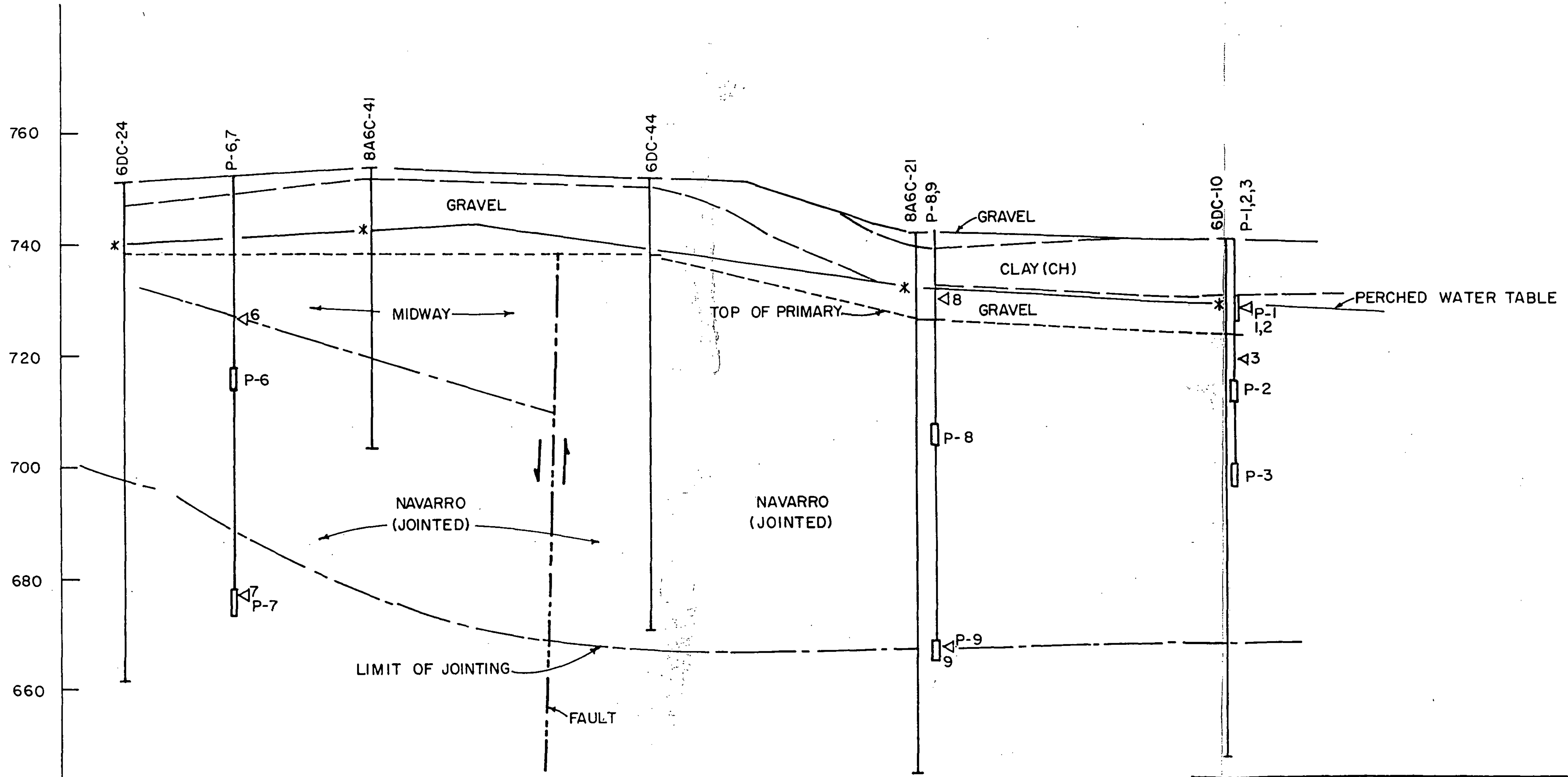


LACKLAND AIR FORCE BASE
SAN ANTONIO, TEXAS

GEOLOGICAL AND FOUNDATION INVESTIGATION
FINAL REPORT

TYPICAL ELECTRIC LOGS
RESISTIVITY & GAMMA RAY

U.S. ARMY ENGINEER DISTRICT, FORT WORTH



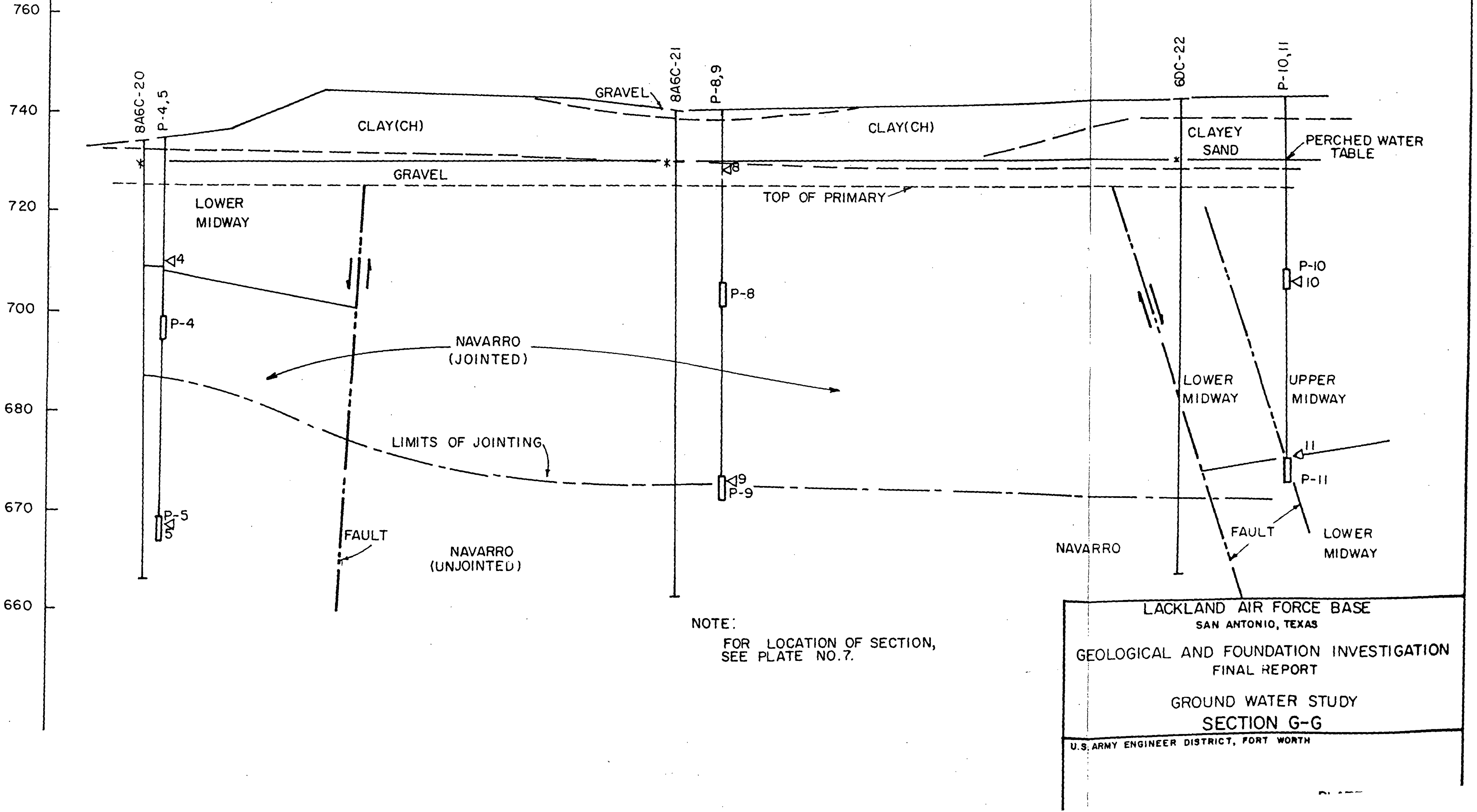
NOTE:
FOR LOCATION OF SECTION,
SEE PLATE NO. 7.

LACKLAND AIR FORCE BASE
SAN ANTONIO, TEXAS

GEOLOGICAL AND FOUNDATION INVESTIGATION
FINAL REPORT

GROUND WATER STUDY
SECTION F-F

U.S. ARMY ENGINEER DISTRICT, FORT WORTH



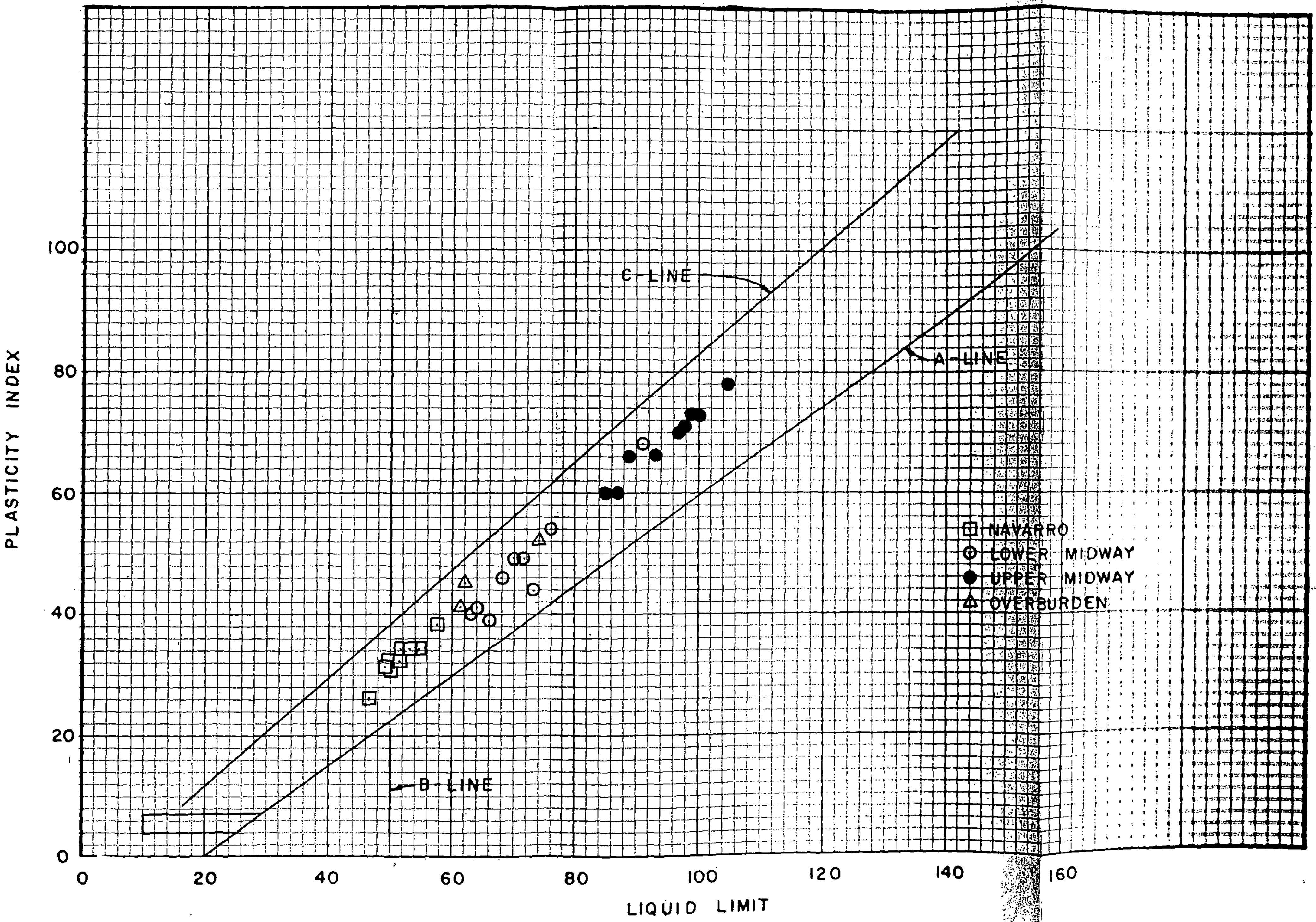
NOTE:
FOR LOCATION OF SECTION, SEE PLATE NO.7.

LACKLAND AIR FORCE BASE
SAN ANTONIO, TEXAS

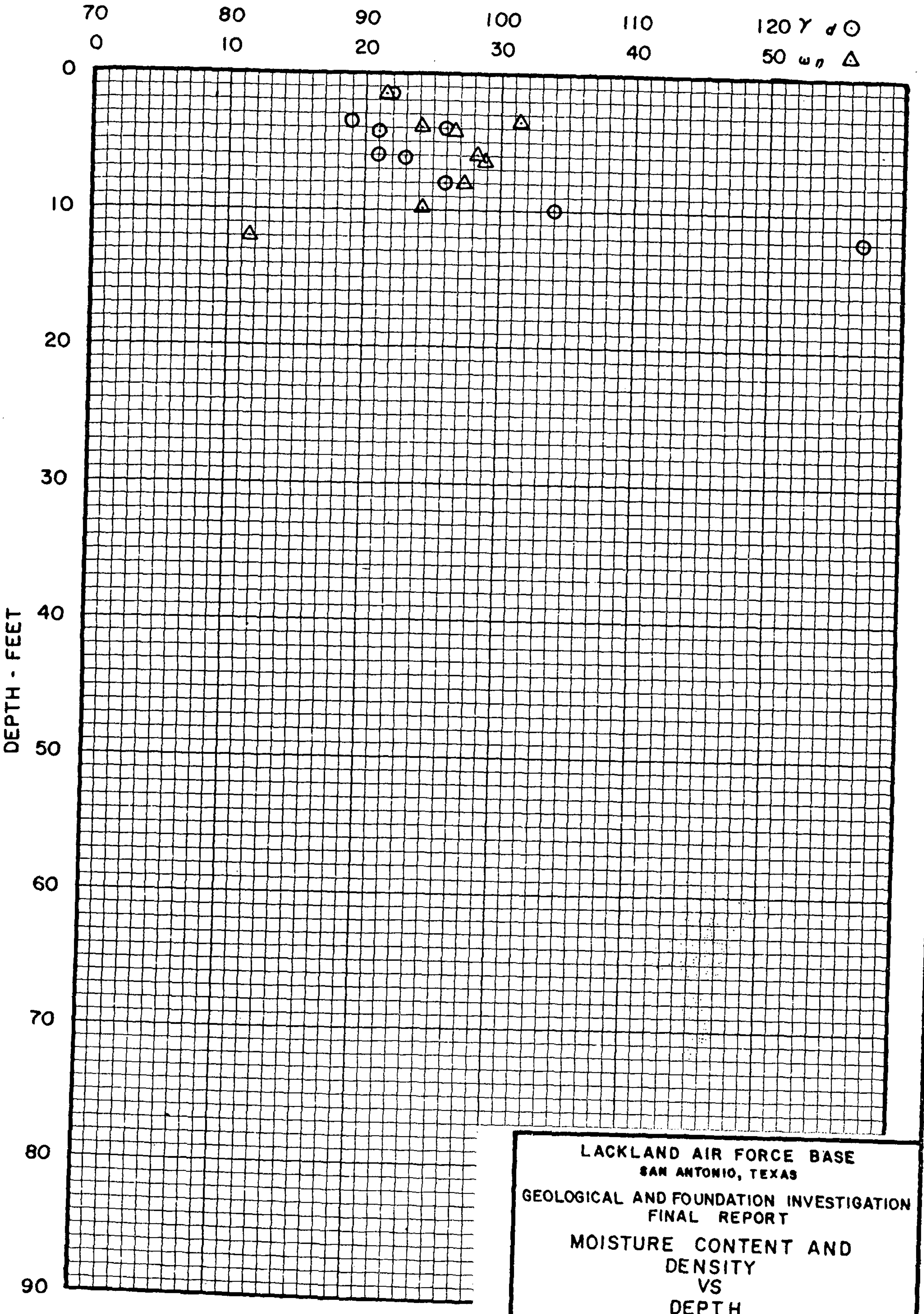
GEOLOGICAL AND FOUNDATION INVESTIGATION
FINAL REPORT

GROUND WATER STUDY
SECTION G-G

U.S. ARMY ENGINEER DISTRICT, FORT WORTH



LACKLAND AIR

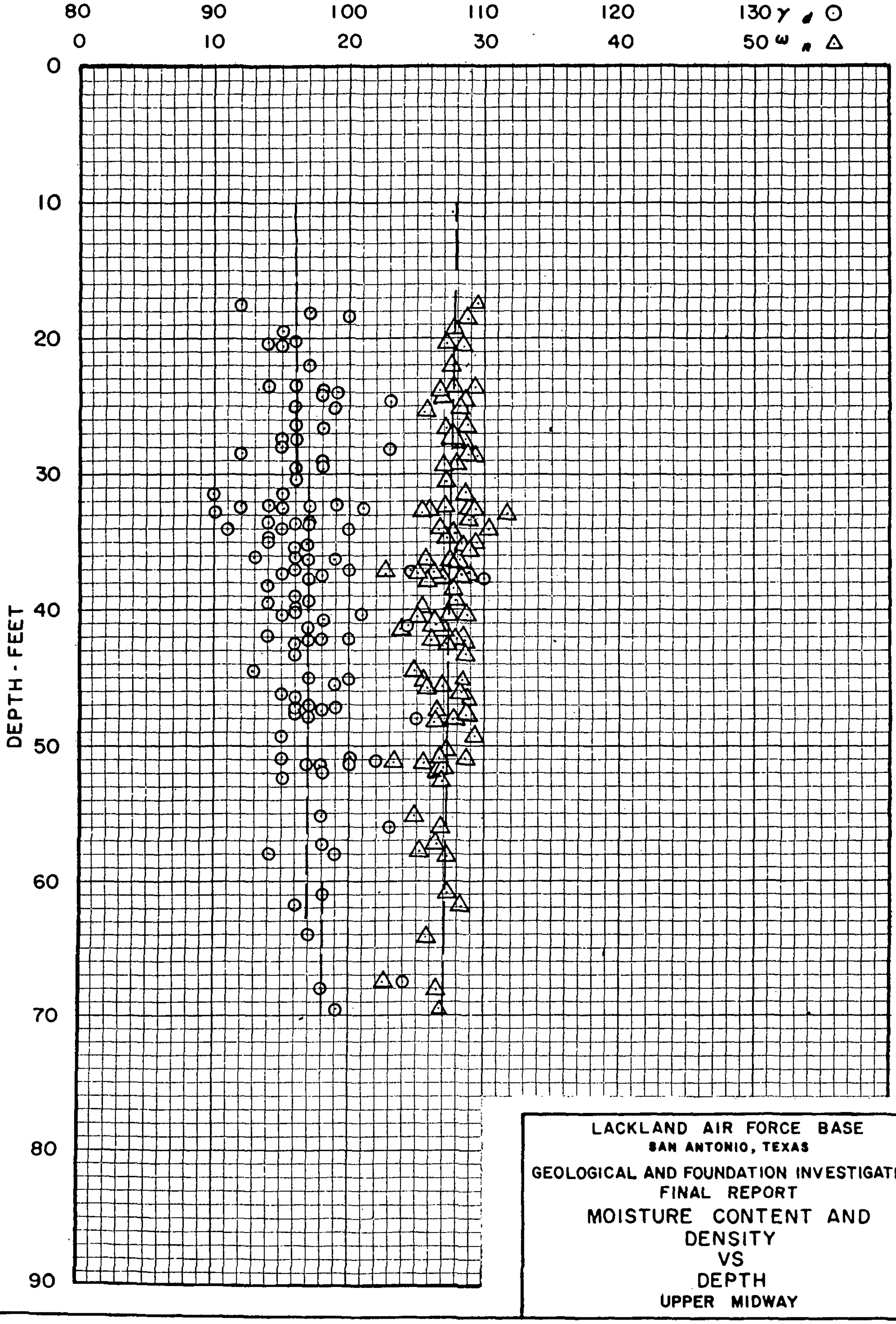


LACKLAND AIR FORCE BASE
SAN ANTONIO, TEXAS

GEOLOGICAL AND FOUNDATION INVESTIGATION
FINAL REPORT

MOISTURE CONTENT AND
DENSITY
VS
DEPTH
OVERBURDEN

PLATE NO.20



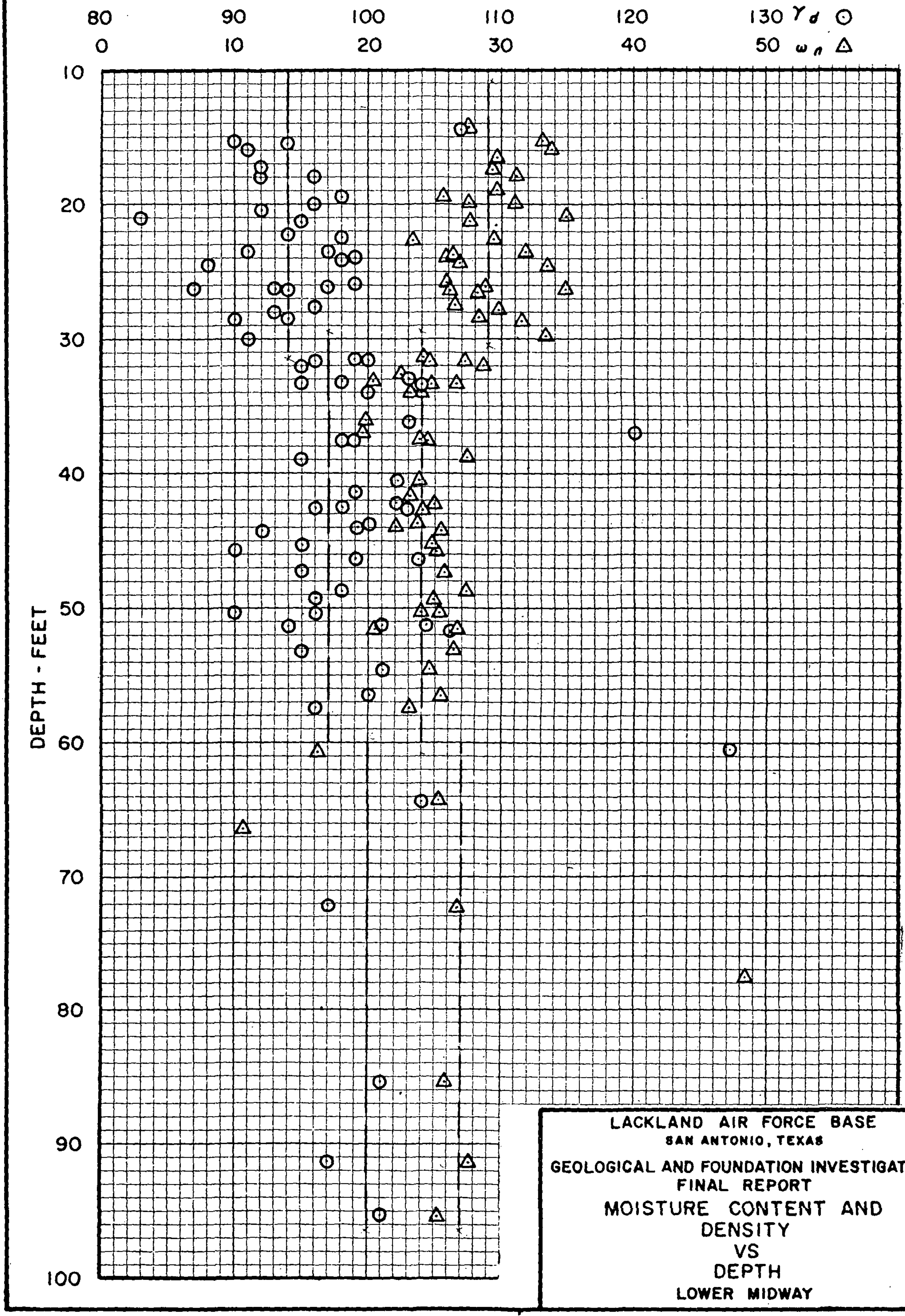
LACKLAND AIR FORCE BASE
SAN ANTONIO, TEXAS

GEOLOGICAL AND FOUNDATION INVESTIGATION
FINAL REPORT

MOISTURE CONTENT AND DENSITY VS DEPTH

UPPER MIDWAY

PLATE NO. 21



LACKLAND AIR FORCE BASE

SAN ANTONIO, TEXAS

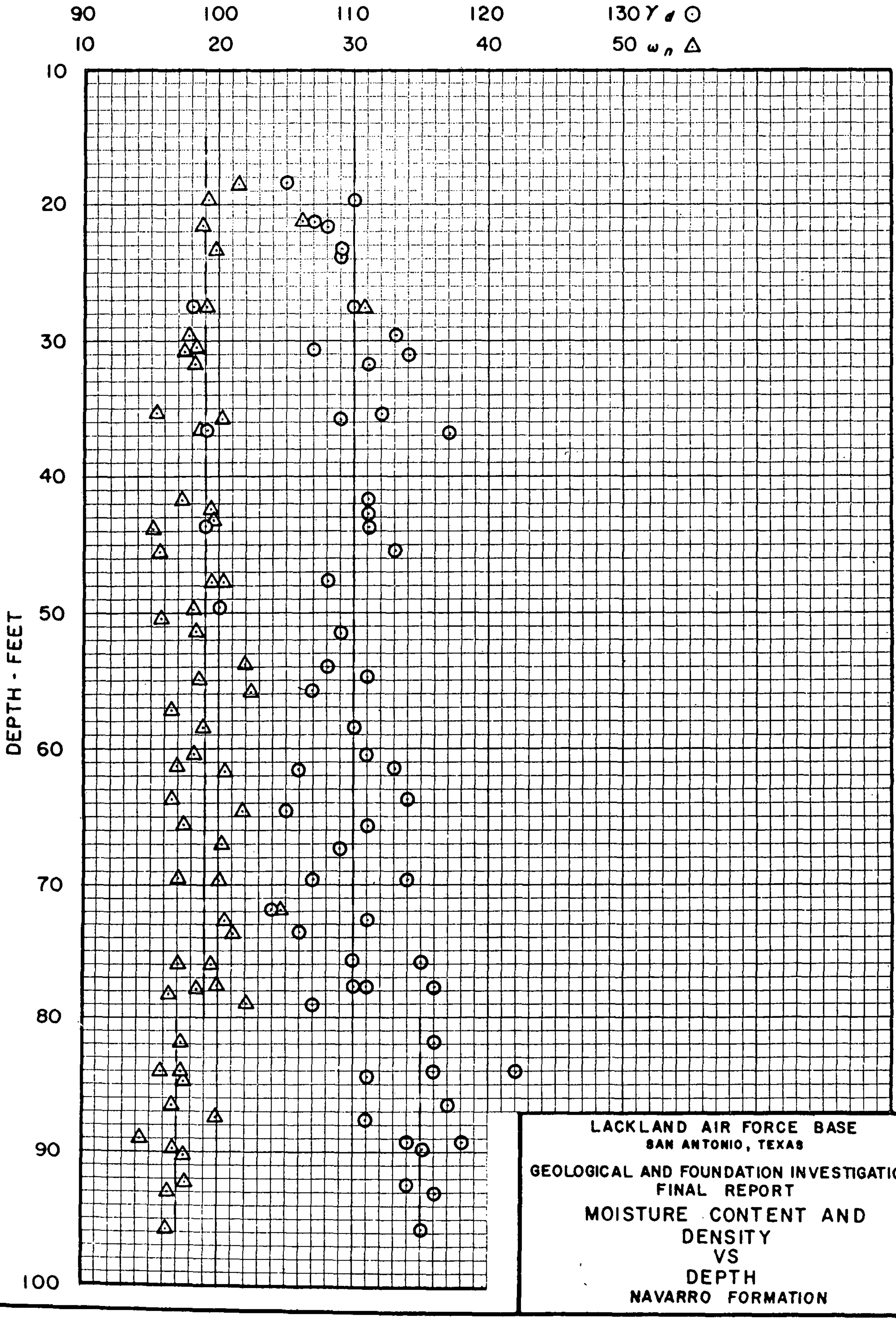
GEOLOGICAL AND FOUNDATION INVESTIGATION

FINAL REPORT

MOISTURE CONTENT AND DENSITY VS DEPTH

LOWER MIDWAY

PLATE NO. 22

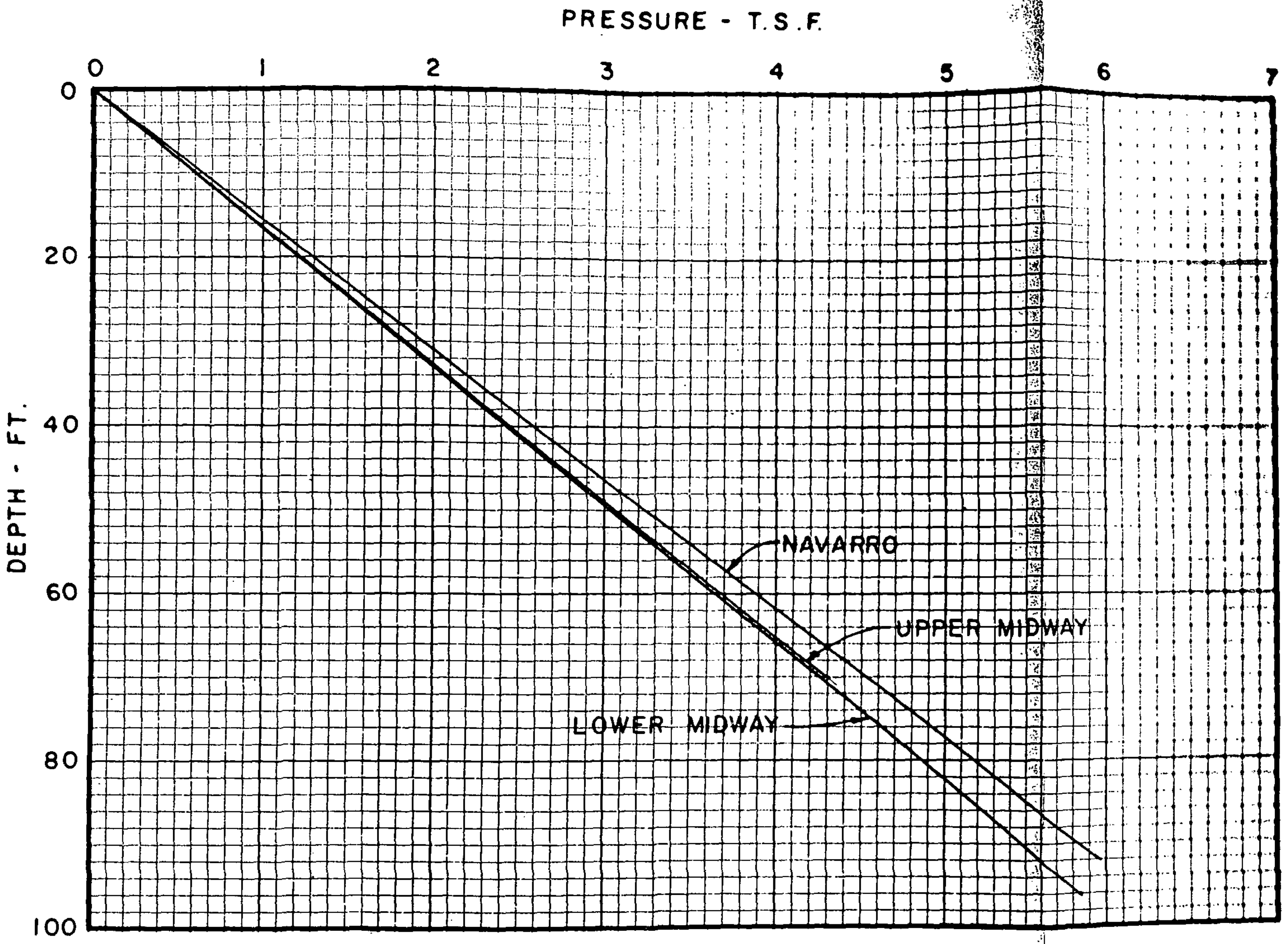


LACKLAND AIR FORCE BASE
SAN ANTONIO, TEXAS

GEOLOGICAL AND FOUNDATION INVESTIGATION
FINAL REPORT

MOISTURE CONTENT AND
DENSITY
VS
DEPTH
NAVARRO FORMATION

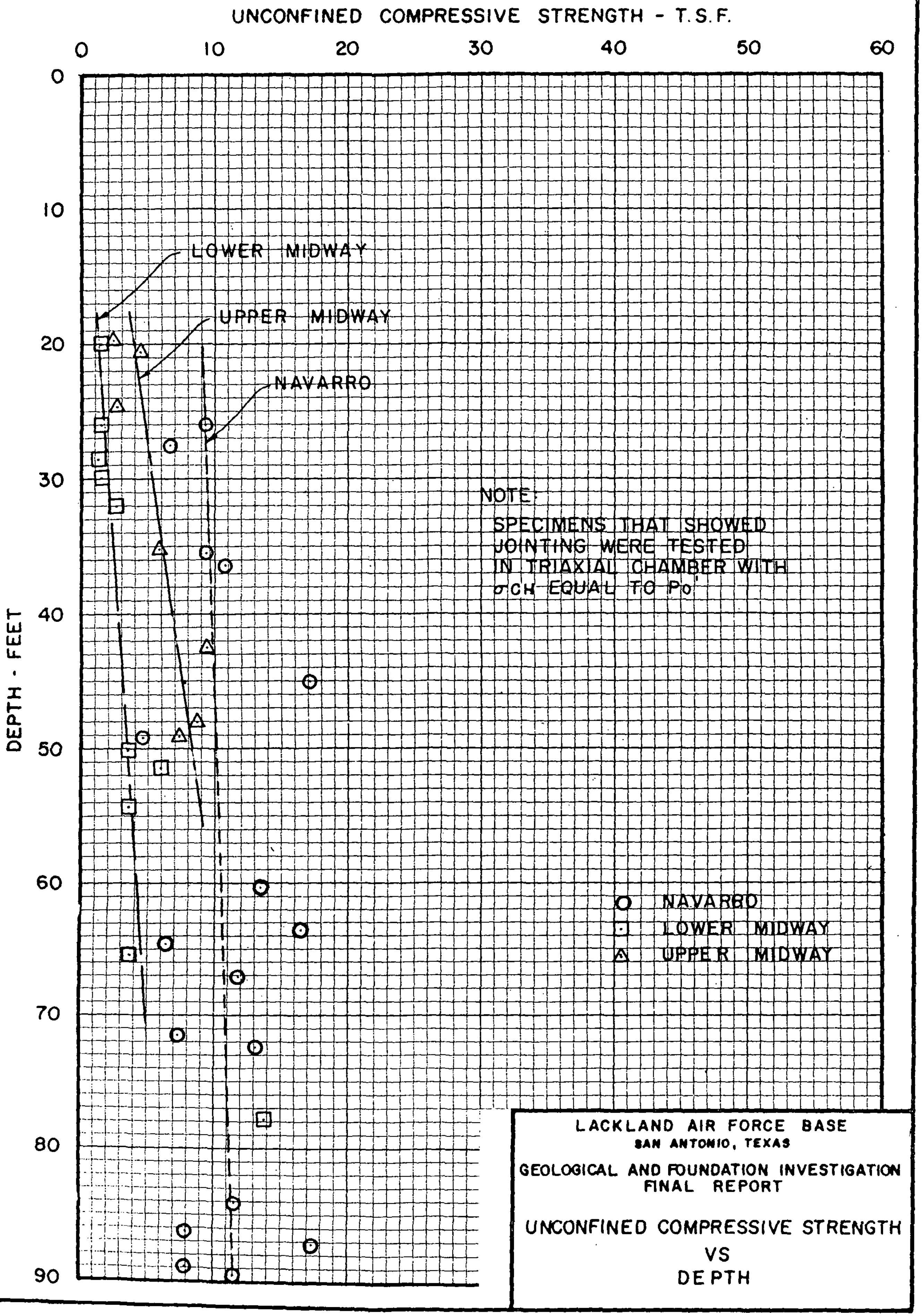
PLATE NO. 23



LACKLAND AIR FORCE BASE
SAN ANTONIO, TEXAS

GEOLOGICAL AND FOUNDATION INVESTIGATION
FINAL REPORT

EFFECTIVE PRESSURE
VS



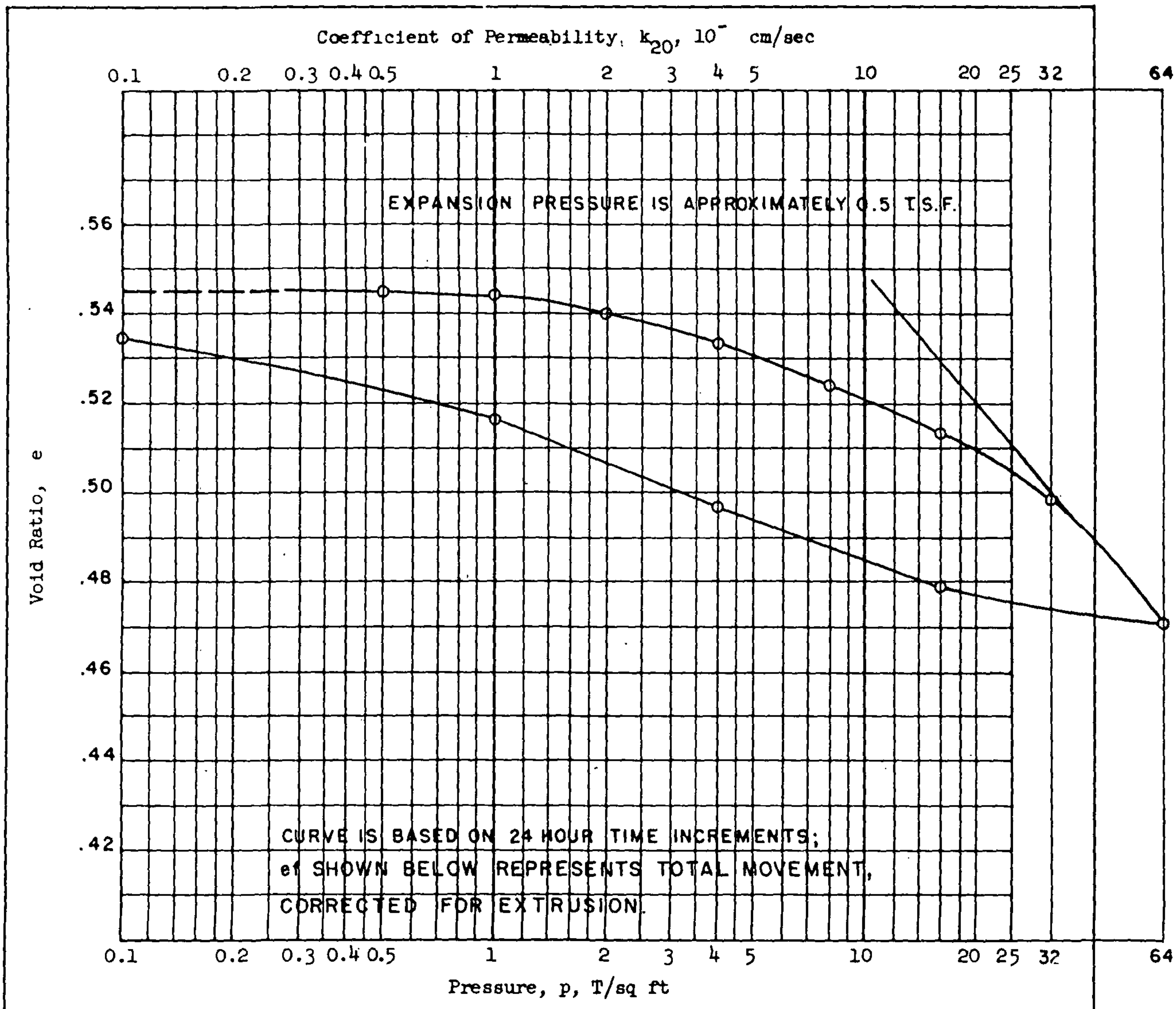
NOTE:
SPECIMENS THAT SHOWED JOINTING WERE TESTED IN TRIAXIAL CHAMBER WITH σCH EQUAL TO Po

LACKLAND AIR FORCE BASE
SAN ANTONIO, TEXAS

GEOLOGICAL AND FOUNDATION INVESTIGATION
FINAL REPORT

UNCONFINED COMPRESSIVE STRENGTH
VS
DEPTH

PLATE NO.25



EXPANSION PRESSURE IS APPROXIMATELY 0.5 T.S.F.

CURVE IS BASED ON 24 HOUR TIME INCREMENTS; ef SHOWN BELOW REPRESENTS TOTAL MOVEMENT, CORRECTED FOR EXTRUSION.

Type of Specimen	UNDISTURBED		
Diam 4.44 in.	Ht 2H = 1.00 in.		
Overburden Pressure, p_o	2.3 T/sq ft		
Preconsol. Pressure, p_c	32 T/sq ft		
Compression Index, C_c	0.10		
Classification	SHALE, CLAYEY		
LL 52	G_s 2.72		
PL 18	D_{10}		

	Before Test		After Test
Water Content, w_o	18.8 %	w_f	19.6 %
Void Ratio, e_o	.546	e_f	.535
Saturation, S_o	94 %	S_f	100 %
Dry Density, γ_d	109.9 lb/ft^3		

k_{20} at e_o = × 10^{-} cm/sec

Remarks

Project LACKLAND AFB

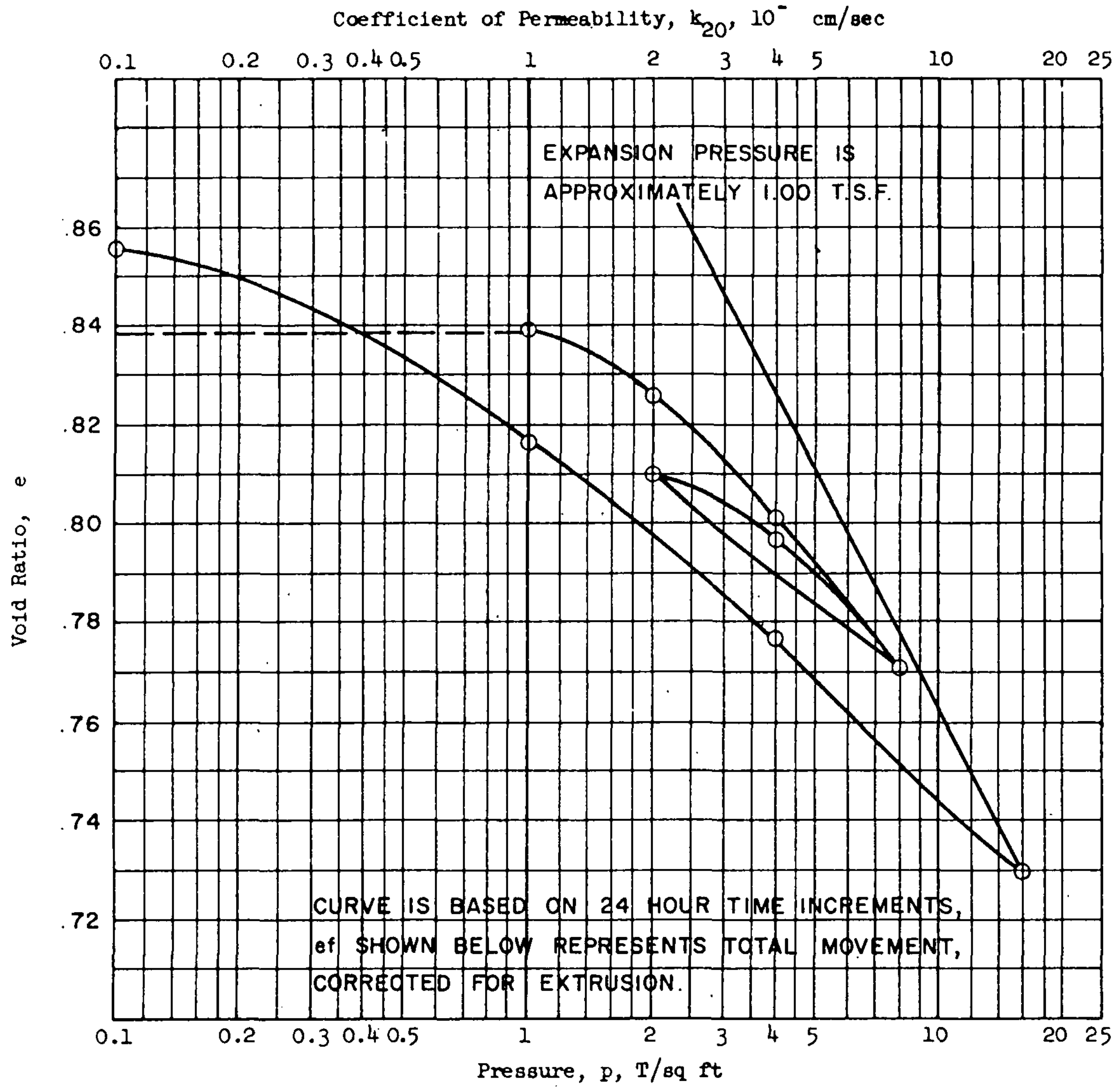
NAVARRO FORMATION

Area FOUNDATION MATERIAL

Boring No. 8A6C - 20	Sample No. TYPICAL
Depth 42.7 - 43.7	Date JAN 67

CONSOLIDATION TEST REPORT

ENG FORM 1 MAY 63 2090 PREVIOUS EDITIONS ARE OBSOLETE. *(TRANSLUCENT)*



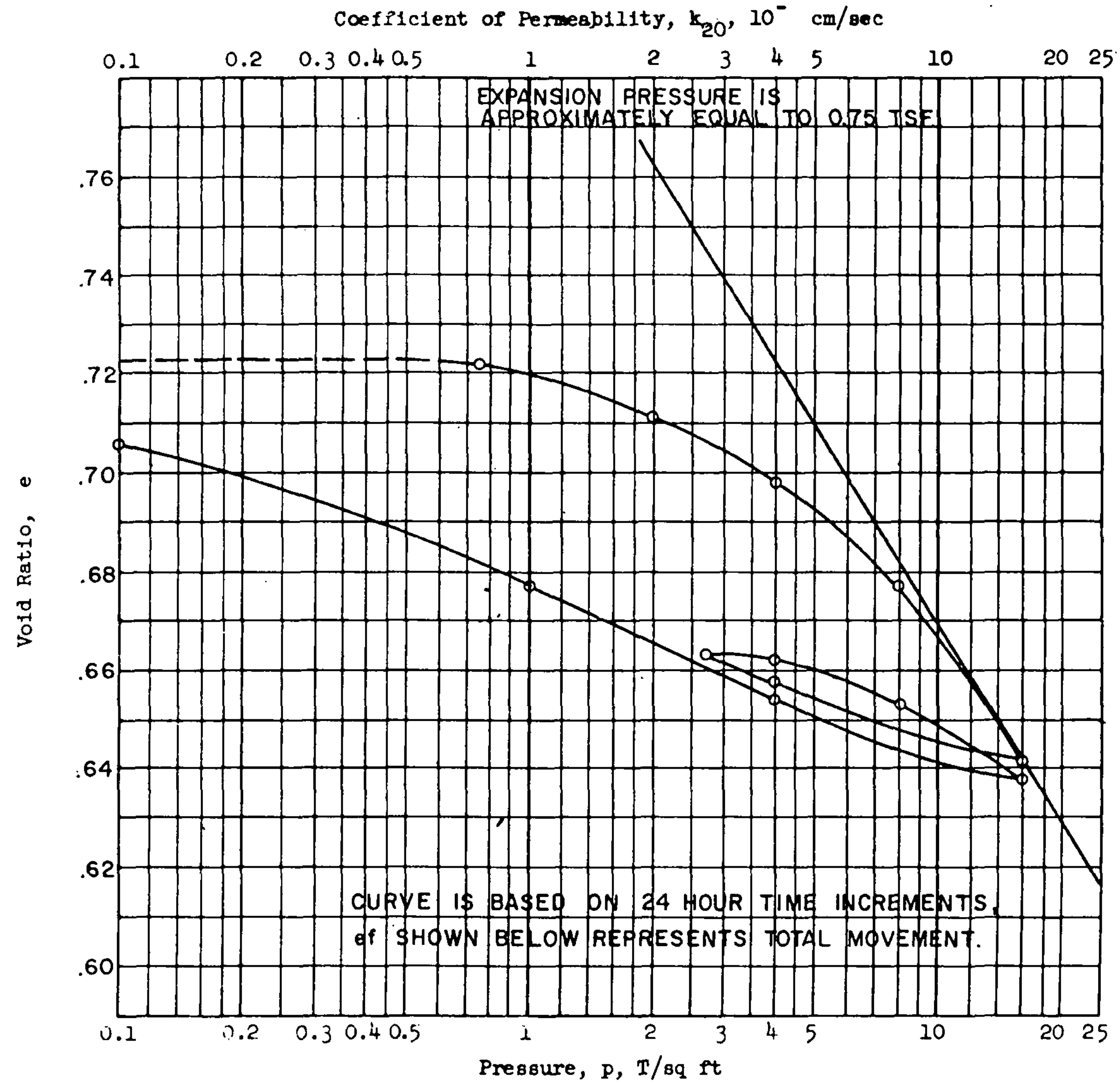
EXPANSION PRESSURE IS APPROXIMATELY 1.00 T.S.F.

CURVE IS BASED ON 24 HOUR TIME INCREMENTS, ef SHOWN BELOW REPRESENTS TOTAL MOVEMENT, CORRECTED FOR EXTRUSION.

Type of Specimen UNDISTURBED		Before Test		After Test	
Diam 4.45 in.	Ht 2H = 1.00 in.	Water Content, w_o	29.6 %	w_f	31.2 %
Overburden Pressure, p_o 2.1 T/sq ft		Void Ratio, e_o	.840	e_f	.862
Preconsol. Pressure, p_c T/sq ft		Saturation, S_o	96 %	S_f	99 %
Compression Index, C_c - 0.16		Dry Density, γ_d	93 lb/ft^3		
Classification CLAY (CH)		k_{20} at e_o = × 10⁻ cm/sec			
LL 99	G_s 2.74	Project LACKLAND A.F.B.			
PL 26	D_{10}	UPPER MIDWAY FORMATION			

Remarks SAMPLE CUT FROM	Area FOUNDATION MATERIAL	
34.3' - 34.5'	Boring No. 8A-6C-48	Sample No. TYPICAL
	Depth SEE REMARKS 31.8 - 36.4	Date MAR. 66

CONSOLIDATION TEST REPORT



Type of Specimen UNDISTURBED		Before Test		After Test	
Diam 4.44 in.	Ht 2H = 1.00 in.	Water Content, w_o	22.0 %	w_f	25.4 %
Overburden Pressure, p_o 3.0 T/sq ft		Void Ratio, e_o	.722	e_f	.702
Preconsol. Pressure, p_c T/sq ft		Saturation, S_o	83 %	S_f	99 %
Compression Index, C_c 0.34		Dry Density, γ_d	99.5 lb/ft^3		
Classification CLAY, SANDY (CH)		k_{20} at e_o = × 10^{-} cm/sec			

LL 68	G_s 2.74
PL 22	D_{10}

Remarks

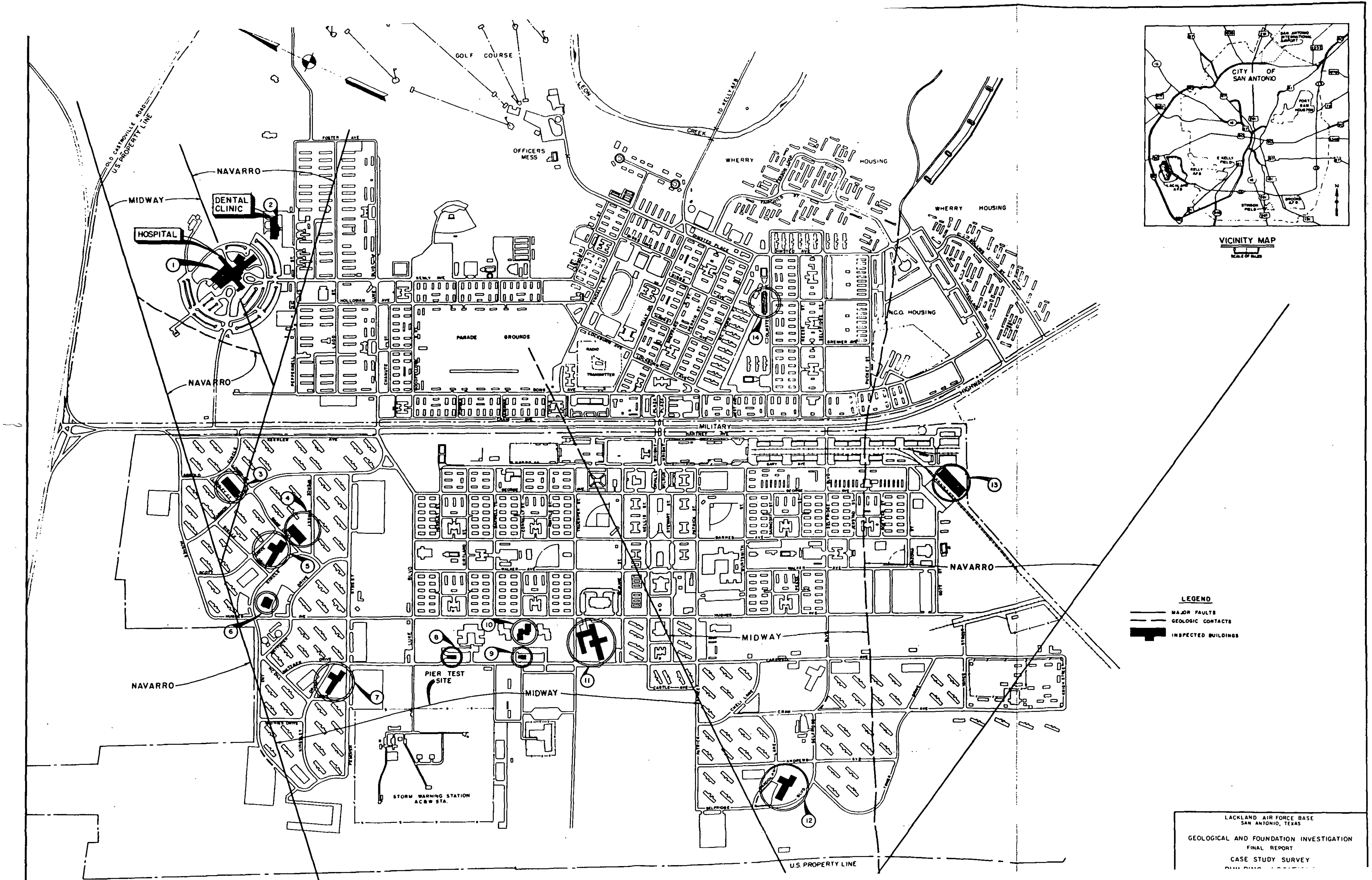
Project LACKLAND AIR FORCE BASE

LOWER MIDWAY FORMATION

Area FOUNDATION MATERIAL

Boring No. 6DC - 207	Sample No. TYPICAL
Depth 44.8 - 45.7	Date AUG. 65

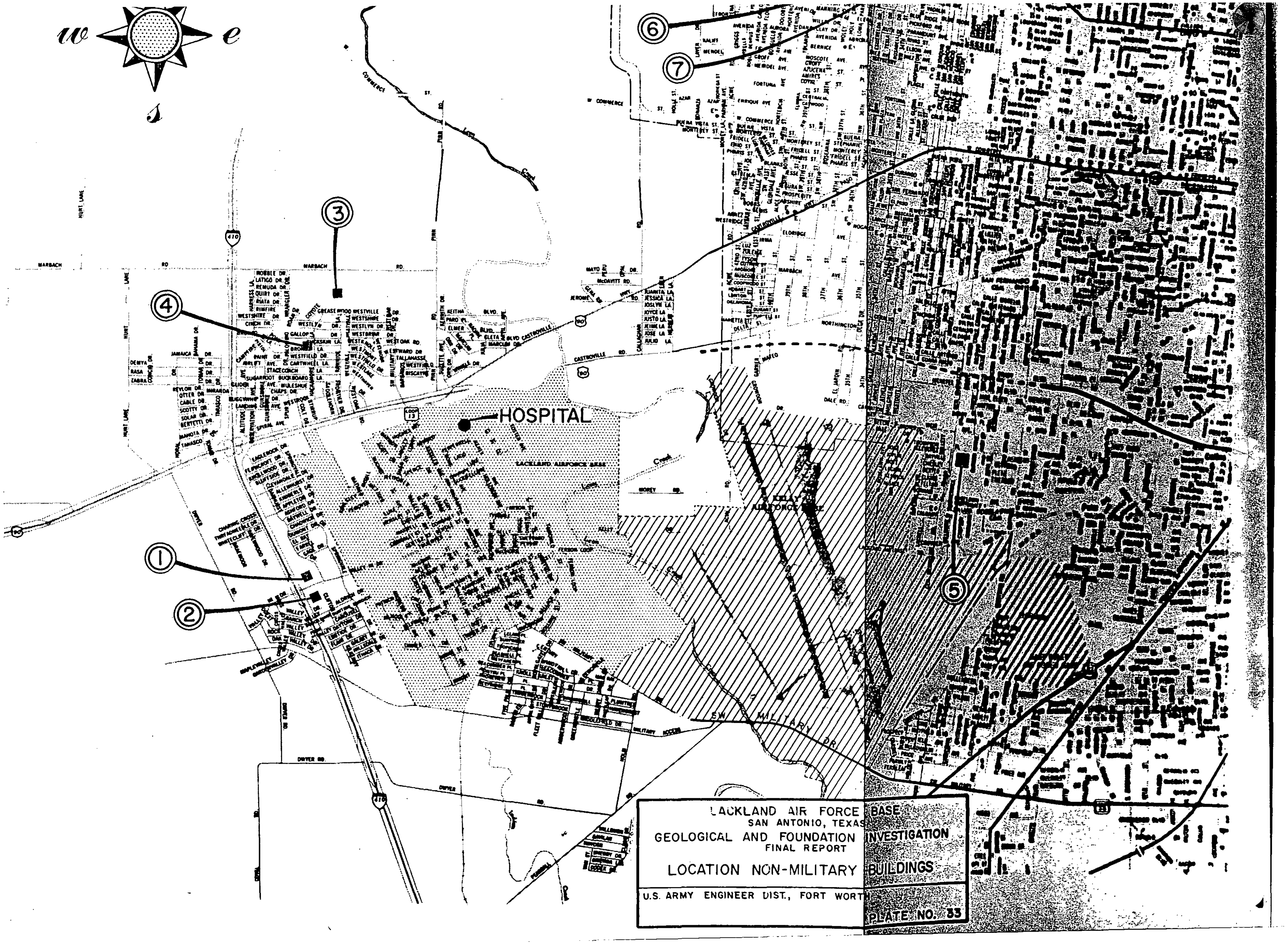
CONSOLIDATION TEST REPORT



LACKLAND AIR FORCE BASE
SAN ANTONIO, TEXAS

GEOLOGICAL AND FOUNDATION INVESTIGATION
FINAL REPORT

CASE STUDY SURVEY

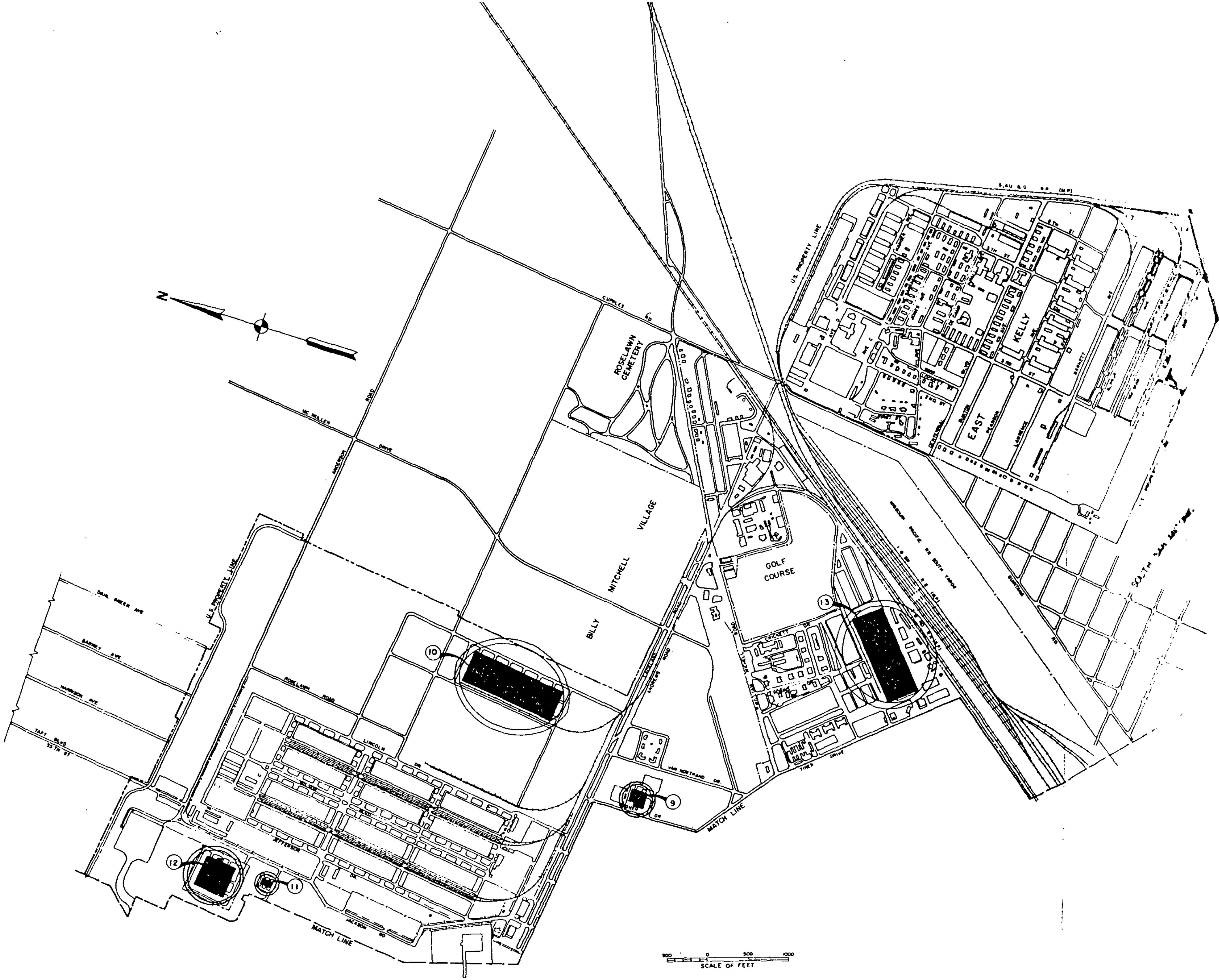


LACKLAND AIR FORCE BASE
SAN ANTONIO, TEXAS
GEOLOGICAL AND FOUNDATION INVESTIGATION
FINAL REPORT

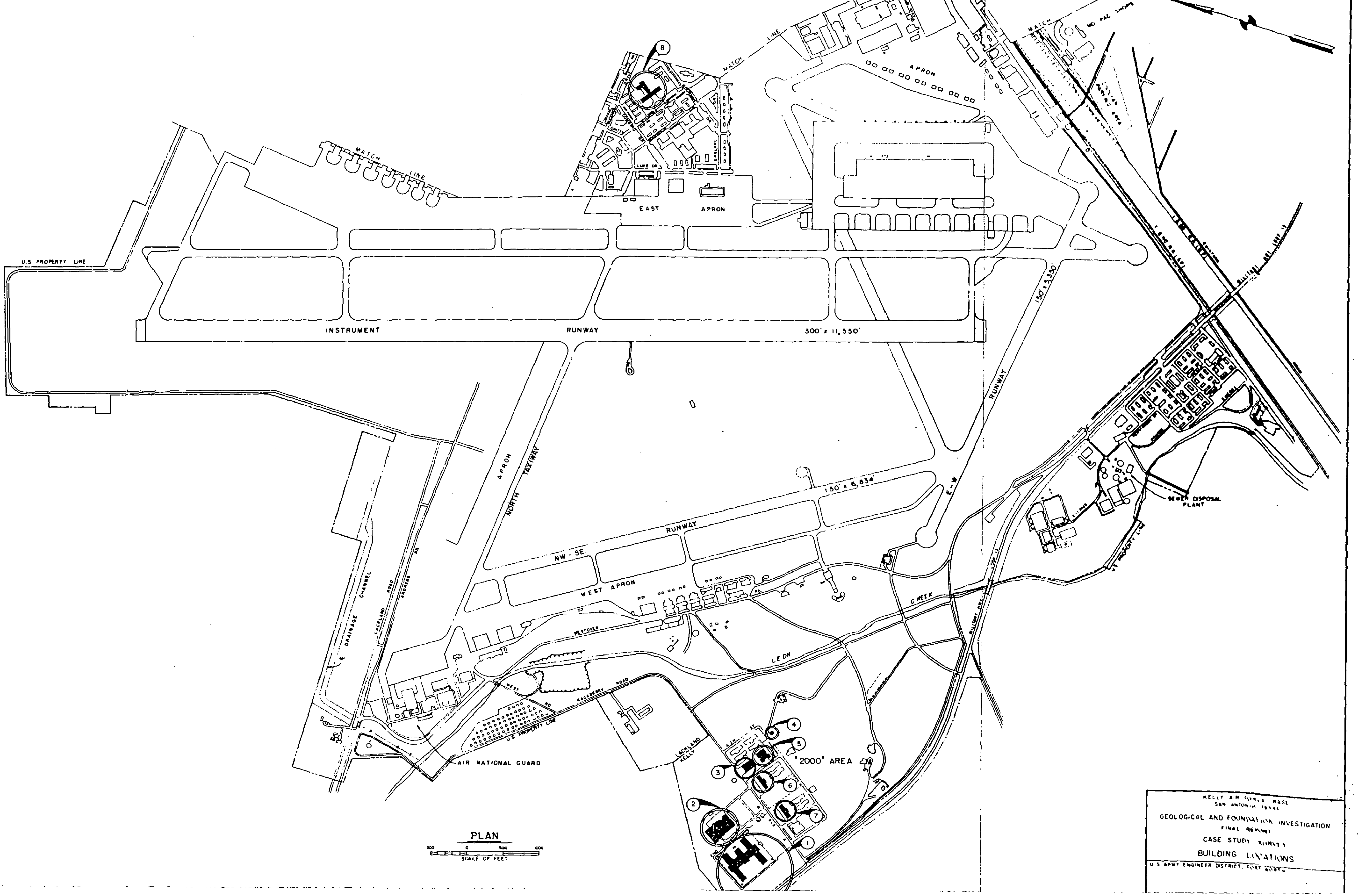
LOCATION NON-MILITARY BUILDINGS

U.S. ARMY ENGINEER DIST., FORT WORTH

PLATE NO. 33



[illegible]
[illegible]
[illegible]
BUILDING LOCATIONS
[illegible]



PLAN

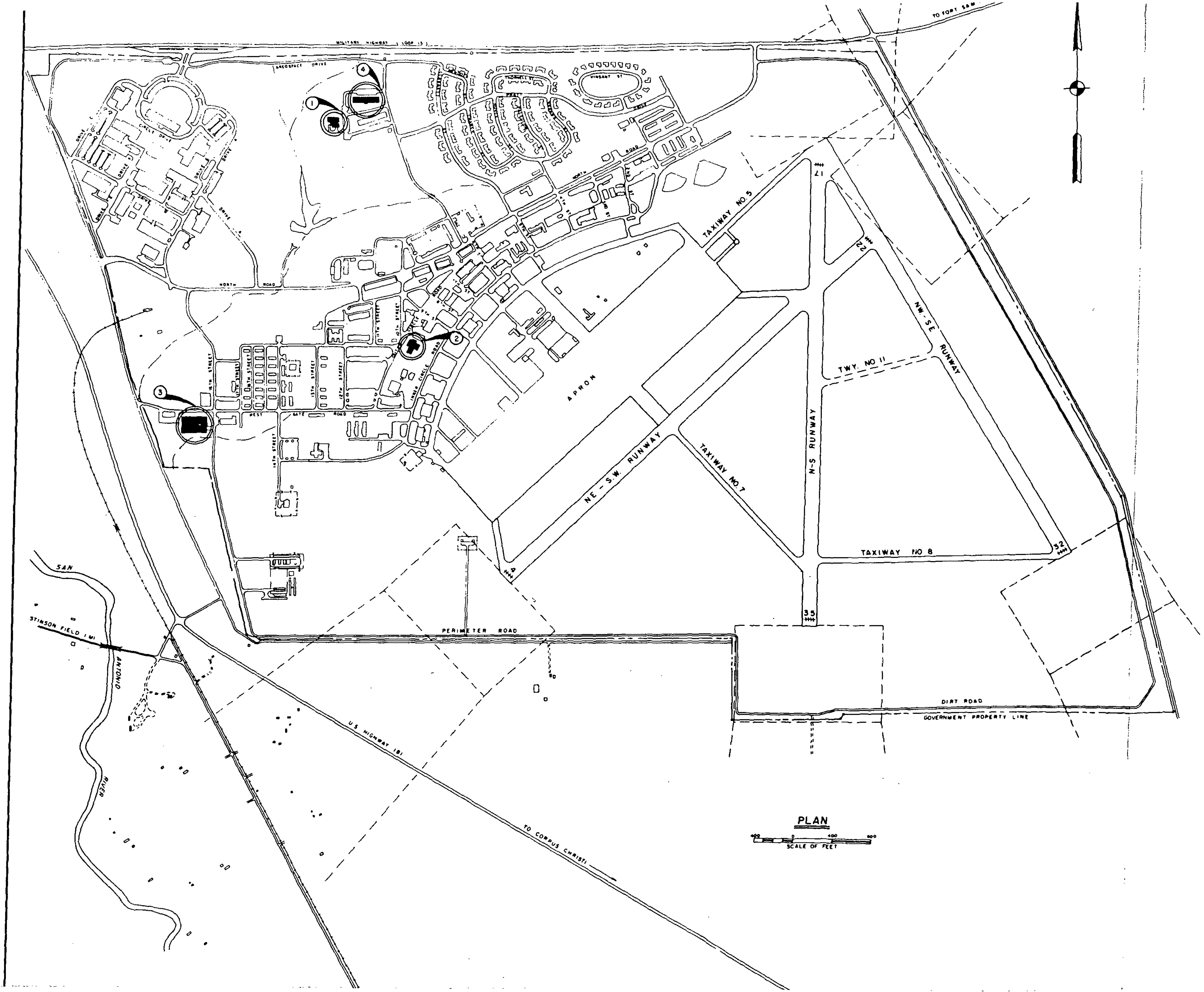
KELLY AIR FORCE BASE
SAN ANTONIO, TEXAS

GEOLOGICAL AND FOUNDATION INVESTIGATION
FINAL REPORT

CASE STUDY SURVEY

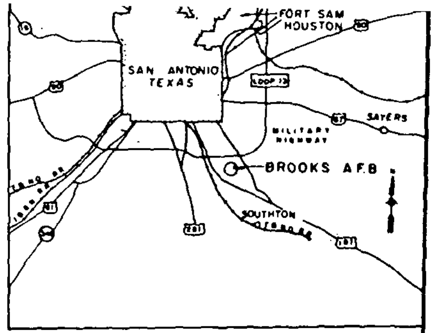
BUILDING LOCATIONS

U S ARMY ENGINEER DISTRICT, FORT WORTH



PLAN

SCALE OF FEET



VICINITY MAP

SCALE IN MILES

BROOKS AIR FORCE BASE
SAN ANTONIO, TEXAS

GEOLOGICAL AND FOUNDATION INVESTIGATION
FINAL REPORT

CASE STUDY SURVEY

BUILDING LOCATIONS

U S ARMY ENGINEER DISTRICT, FORT WORTH

APPENDIXES

APPENDIX A

PARTICIPANTS IN THE INVESTIGATION

CONTENTS

U. S. GEOLOGICAL SURVEY
AND
TEXAS WATER DEVELOPMENT BOARD

Mr. A. G. Winslow, Chief of Projects, and Mr. C. R. Follett, Engineer, of the Geological Survey, and Mr. Richard C. Peckham, Director of the Ground Water Division for the Texas Water Development Board, were very helpful with their invaluable suggestions and assistance during the course of this investigation. Their cooperation in making their logging unit available for this study facilitated development of information useful in checking subsurface data which had been obtained from other sources. Their services and equipment were furnished at no cost. A letter of appreciation has been furnished to each agency for this assistance, and a copy of this letter is included in this Appendix.

DRILLING CONTRACTORS

The Highway Drilling Company of Route 9, Box 590A, San Antonio, Texas, was the drilling contractor for the two exploratory calyx borings drilled for this investigation. This company furnished a crane-mounted foundation auger rig and all the necessary supporting equipment to drill, case, and backfill a 30-inch x 100-foot auger boring. Mr. Dale Williams supervised this operation.

CONSULTANTS

Mr. Porter A. Montgomery of Montgomery Stratigraphic Services was retained for micro-paleontological studies of the primary formation within the study area.

Mr. Will R. Clack of Bedford, Texas, was retained to perform a seismic survey of the Hospital Complex area.

Dr. Arthur J. Ehlmann, Associate Professor of Geology, Texas Christian University, Fort Worth, Texas, was retained to perform mineralogical analyses on selected samples of the Midway and Navarro formations.

Core Laboratories, Incorporated, of Midland, Texas, was retained to run a gamma log for correlation purposes on the core from boring 8A6C-10.

LETTERS OF APPRECIATION

DEPARTMENT OF THE ARMY
FORT WORTH DISTRICT, CORPS OF ENGINEERS
P. O. BOX 17300
FORT WORTH, TEXAS 76102

IN REPLY REFER TO
SWFED-F

2 December 1966

Mr. Trigg Twichell, District Chief
U. S. Geological Survey
Federal Building
300 East 8th Street
Austin, Texas 78701

Dear Mr. Twichell:

The Fort Worth District Corps of Engineers wishes to express its appreciation for the assistance of the Ground Water Division of the U. S. Geological Survey in logging water wells and exploratory borings for the Lackland Air Force Base Geological Investigation being performed by our District for the United States Air Force. This service was invaluable in determining the detailed subsurface conditions for the proposed area for the Wilford Hall Hospital Complex and resulted in obtaining structural information useful to both agencies.

Our special thanks go to Mr. A. G. Winslow, Chief of Projects, and Mr. C. R. Follett, Engineer, for their excellent cooperation and invaluable suggestions during this investigation.

It is understood that the logging equipment in service by the U.S.G.S. is a cooperative unit with the Texas Water Development Board, with expenses shared equally by these two agencies. We would also like to express our appreciation to the Texas Water Development Board and Mr. Richard C. Peckham, Director of the Ground Water Division, for their cooperation in this study.

Sincerely yours,

C. F. SWENSON
Chief, Engineering Division

Copies furnished:
See next page

Copies furnished:
Mr. John J. Vandertulip
Chief Engineer
Texas Water Development Board
Sam Houston State Office Building
P. O. Box 12386
Austin, Texas 78711

Mr. Joe G. Moore, Jr.
Executive Director
Texas Water Development Board
Sam Houston State Office Building
P. O. Box 12386
Austin, Texas 78711

APPENDIX B

PALEONTOLOGICAL, STRATIGRAPHIC, AND STRUCTURAL NOTES ON LACKLAND AIR FORCE BASE, SAN ANTONIO, TEXAS

FOR

U. S. ARMY ENGINEER DISTRICT, FORT WORTH, TEXAS

BY

PORTER A. MONTGOMERY
MONTGOMERY'S STRATIGRAPHIC SERVICE
1517 MILAM BUILDING
SAN ANTONIO, TEXAS

MONTGOMERY'S STRATIGRAPHIC SERVICE
MILAM BUILDING / SAN ANTONIO, TEXAS
PORTER MONTGOMERY
CA 3-9861

MAY 23, 1966

MR. WAYNE MCINTOSH
UNITED STATES CORPS OF ENGINEERS
100 WEST VICKERY
FORT WORTH, TEXAS

DEAR MR. MCINTOSH:

ENCLOSED IS A REPORT ON THE MICROPALEO WORK DONE ON GEOLOGIC SAMPLES FROM CORE HOLES ON LACKLAND AIR FORCE BASE AND SURFACE WORK IN THE AREA.

INCLUDED ARE A FEW EXTRA NOTES IN ADDITION TO THE REQUESTED PALEO WORK BECAUSE THEY HAVE A BEARING ON YOUR PROBLEM.

VERY TRULY YOURS,

Porter Montgomery

PORTER A. MONTGOMERY

PAM:BP

PALEONTOLOGICAL, STRATIGRAPHIC AND STRUCTURAL NOTES

ON LACKLAND AIR FORCE BASE

SAN ANTONIO, TEXAS

A GEOLOGIC REPORT PREPARED FOR
UNITED STATES CORPS OF ENGINEERS
FORT WORTH, TEXAS

BY PORTER MONTGOMERY
MONTGOMERY'S STRATIGRAPHIC SERVICE
1517 MILAM BUILDING
SAN ANTONIO, TEXAS

CONTENTS

MONTGOMERY'S STRATIGRAPHIC SERVICE
MILAM BUILDING / SAN ANTONIO, TEXAS
PORTER MONTGOMERY
CA 3-9861

PURPOSE OF REPORT

THE PURPOSE OF COLLECTING GEOLOGIC SAMPLES FROM SURFACE OUTCROPS AND CORE HOLES AND STUDYING THE FOSSIL FORAMINIFERA WAS TO IDENTIFY THE GEOLOGIC FORMATIONS AND TO SEE IF THESE COULD BE ZONED IN DETAIL. THE GEOLOGIC INFORMATION GAINED IS TO BE USED WITH THE CORE DRILL PROGRAM SET UP TO STUDY FOUNDATION PROBLEMS ON LACKLAND AIR FORCE BASE.

CONCLUSIONS

TWO GEOLOGIC FORMATIONS, THE MIDWAY AND THE NAVARRO, HAVE BEEN PENETRATED WITH THE FIVE CORE HOLES EXAMINED. THICKNESS ESTIMATES OF THE GEOLOGIC SECTIONS PENETRATED ARE 129' OF MIDWAY AND 107' OF NAVARRO. THIS IS NOT THE COMPLETE THICKNESS OF EITHER FORMATION IN THIS AREA. A WATER WELL IN THE AREA ALLOWS AN ESTIMATE OF 465' OF THE NAVARRO FORMATION. NO ADDITIONAL NEARBY MIDWAY DATA WAS EXAMINED.

THE MIDWAY FORMATION WAS PRESENT IN THREE CORE HOLES. THE UPPER 68' OF THE FORMATION WAS NON-GLAUCONITIC. FURTHER ZONATION OF THIS PART OF THE MIDWAY DOES NOT SEEM TO BE POSSIBLE ON THE LIMITED DATA AT THIS TIME. THE FORMATION IS VERY GLAUCONITIC IN THE LOWER 61'. AT LEAST A PART OF THIS LOWER SECTION IS EXPOSED AT THE SURFACE AND A VISUAL EXAMINATION INDICATES A POSSIBILITY OF ZONING BASED ON LITHOLOGY AND PROBABLY FORAMINIFERA. YOUR LOG ON 6UC-207 IS NOT FAR FROM THE OUTCROP AND SHOWS THE VARIATION IN LITHOLOGIES IN THE GLAUCONITIC ZONE FROM 35.7' TO 96.5'.

IF OTHER CORE HOLES ARE AVAILABLE IN THIS INTERVAL, LITHOLOGIC CORRELATIONS SHOULD BE ATTEMPTED TO SEE IF THE BEDS ARE EXTENSIVE OR VERY LOCAL.

THE NAVARRO FORMATION WAS EXAMINED IN TWO CORE HOLES. A ZONE OF SHALE CONTAINING ABUNDANT FORAMINIFERA AND RED-BROWN ROUNDED POLISHED FISH BONES AND PEBBLES OCCURS IN BOTH WELLS. IT IS LIKELY THAT THESE TWO OCCURRENCES ARE THE SAME GEOLOGIC ZONE, AND IF SO CAN BE USED FOR CORRELATION IN THE FIELD BECAUSE THE ZONE CAN BE PICKED ON CLOSE VISUAL EXAMINATION. IN THE DEEPER TEST, TWO ADDITIONAL ZONES OF SMALL WATER-WORN OYSTER SHELLS, 30' AND 70' BELOW THE FISH BONE BED, MIGHT BE SECONDARY CORRELATIVE ZONES. VISUALLY THEY APPEAR THE SAME, BUT THE UPPER ZONE CONTAINED A FORAMINIFERA, GYROIDINA DEPRESSA, NOT SEEN IN THE LOWER BED.

THE LIMITED NUMBER OF FORAMINIFERA, PROBABLY BECAUSE OF WEATHERING, THROUGH MOST OF THE SECTION EXAMINED TO DATE AND LONG RANGING FORAMS MAKES A DETAILED FORAMINIFERAL ZONATION DIFFICULT AND SUBJECT TO QUESTION. HOWEVER, NO DIFFICULTY WAS EXPERIENCED IN DISTINGUISHING THE NAVARRO FAUNA FROM THE MIDWAY FORAMS EXCEPT FOR ONE INSOLUBLE FORAM OCCURRING IN BOTH FORMATIONS.

THE SAMPLE EXAMINATION ALSO SHOWED THAT SOME OF THE SEDIMENTS WERE WEATHERED AND SOME WERE NOT. THIS WEATHERING IS POSSIBLY CAUSED BY WATER PERCOLATING THROUGH FRACTURES DUE TO FAULTING AND FOLDING. THE DEPTH OF WEATHERING MAY BE RELATED TO ELEVATION OF SURFACE DRAINAGE ON LEON AND MEDIO CREEK. THIS WEATHERING MAY BE A FACTOR IN THE FOUNDATION PROBLEM.

STRUCTURE WAS NOT STUDIED IN DETAIL BUT A DOWN-TO-COAST FAULT (SEE ENCLOSURE #2) WITH AT LEAST 230' OF THROW (MISSING SECTION) AND TRENDING NORTH

60 DEGREES EAST IS PRESENT ALONG THE NORTH EDGE OF LACKLAND AIR FORCE BASE. AN ANTICLINE WITH APPROXIMATELY 265' OF NORTHWEST DIP TRENDS THROUGH SOUTH CENTRAL LAFB APPROXIMATELY PARALLEL WITH THE FAULT. THE AMOUNT OF DIP SHOULD BE CONSIDERED IN SPACING CORE HOLE LOCATIONS SO THAT THE LOGS MAY BE CORRELATED.

WORK METHODS

THE INITIAL SAMPLES, AT APPROXIMATELY FIVE FOOT INTERVALS, WERE SELECTED FROM CORES OF TEST HOLES 8A6C-268 AND 6DC-262 STORED AT LAFB. THESE CORE CHIPS WERE PROCESSED TO FREE THE FORAMINIFERA FROM THE MATRIX AND A SEPARATE MICRO-PALEONTOLOGICAL SLIDE OF EACH INTERVAL WAS MADE TO DETERMINE IF THE GEOLOGIC SECTION COULD BE ZONED IN ANY DETAIL. MOST OF THE SAMPLES CONTAINED VERY FEW FORAMINIFERA AND MANY WERE POORLY PRESERVED. SOMETIMES ONLY THE INSOLUBLE FORMS WERE PRESENT.

THE FORMATION IDENTIFICATIONS, BASED ON THE FORAMS, WERE MADE AND MR. ROBERT BEHM WAS NOTIFIED BY TELEPHONE.

LATER SAMPLES FROM THREE MORE CORE HOLES, WHICH HAD BEEN STORED AT CANYON DAM, WERE BROUGHT IN BY MR. BEHM AND THESE WERE PROCESSED IN THE SAME MANNER. THE CORES ON 8A6C-8 WERE VISUALLY EXAMINED A SECOND TIME AT LAFB TO DETERMINE IF THE FISH BONE BED FOUND IN CORE HOLE 8A6C-268 HAD BEEN MISSED ON THE FIRST SAMPLING DONE AT FIVE FOOT INTERVALS. MR. BEHM HAD RECORDED THIS BED IN HIS NOTES. A SAMPLE WAS TAKEN OF THIS INTERVAL WHICH CONFIRMED THE PRESENCE OF THIS BONE BED. IT WAS THIN ENOUGH TO BE MISSED AT THE FIVE FOOT SAMPLE INTERVAL.

A SURFACE COLLECTION WAS MADE ON LAFB ALONG LEON CREEK BY MR. BEHM AND MY-

SELF. LATER MR. BEHM AND I EXTENDED THE SURFACE GEOLOGICAL WORK TO CLARIFY STRUCTURAL AND GEOLOGIC RELATIONSHIPS TO THE NORTH AND SOUTH ALONG LEON CREEK AND ON MEDIO CREEK ON MEDINA BASE. A SMALL AMOUNT OF MATERIAL, PREVIOUSLY COLLECTED BY ME IN THE AREA AND SOME PREVIOUS SUBSURFACE WORK, FURNISHED BACK~~B~~GROUN~~G~~D INFORMATION. THESE LOCATIONS ARE NUMBERED AND ARE PREFIXED WITH THE LETTERS "PM" ON THE TWO MAPS TO DISTINGUISH THEM FROM THE CORE HOLES ON LAFB.

THE ENCLOSED LOGS GRAPHICALLY PRESENT A PARTIAL LIST OF THE KEY FORAMINIFERA FOUND IN CORE HOLES AT LAFB.

SURFACE GEOLOGY

THE OUTCROP PATTERN ON LAFB IS INFLUENCED BY FAULTING, FOLDING, EROSION AND NORMAL SOUTHEAST REGIONAL DIP.

IN THIS AREA, THE SURFACE GEOLOGICAL FORMATIONS FROM THE LOWER-MOST UPWARD ARE TAYLOR SHALE, NAVARRO SHALE, MIDWAY SHALE AND QUATERNARY GRAVELS AND CLAYS. SURFACE COLLECTIONS WERE MADE ONLY OF THE FIRST THREE FORMATIONS.

THE LOCATION AND GEOLOGIC AGE OF THE SAMPLES ARE INDICATED BY COLORED CIRCLES, PLOTTED ON ENCLOSURE #1 AND #2 AND COMMENTS ON EACH ARE MADE AT APPROPRIATE PLACES IN THIS REPORT.

TAYLOR FORMATION

THE TAYLOR FORMATION (SEE ENCLOSURE #2), UNDERLYING THE NAVARRO AND OLDEST OF THE GEOLOGIC INTERVALS EXAMINED, HAS NOT BEEN PENETRATED IN ANY OF THE CORE HOLES EXAMINED, NOR HAS IT BEEN FOUND OUTCROPPING ON LAFB, ALTHOUGH IT MIGHT BE NEAR THE SURFACE IN THE NORTHWEST CORNER OF LAFB. THIS FORMATION IS SHALE WITH A SMALL AMOUNT OF SILT AND IS APPROXIMATELY 290' THICK

IN A WATER WELL AT PM-22. IT IS FOUND ON THE SURFACE ON LEON CREEK NORTH OF HIGHWAY 90 (PM-35) AND AGAIN WEST OF LOOP 410 ON HIGHWAY 90 (PM-20) AND SLIGHTLY TO THE NORTH PM-19, 39 AND 40.

IT IS PROBABLE THAT THE TAYLOR OUTCROP SWINGS SOUTHWARD DOWN MEDIO CREEK AND IS PRESENT 5' TO 10' BELOW STATION PM-36 AND PM-37, BUT IS NOT EXPOSED. A SMALL AMOUNT OF SHOVEL WORK SHOULD EXPOSE THE TAYLOR FORMATION AT PM-37 IN THE MEDIO CREEK BANK.

NAVARRO FORMATION

THE OUTCROP OF THE NAVARRO (SEE ENCLOSURE #2) IS INFLUENCED ON THE NORTH BY A DOWN-TO-COAST FAULT "A", TRENDING NORTHEAST, IN THE CENTER BY AN ANTICLINE TRENDING PARALLEL WITH THE FAULT, ON THE SOUTHEAST BY REGIONAL DIP AND A DOWN-TO-COAST FAULT BETWEEN PM-33 AND PM-29.

THE COMPLETE NAVARRO SECTION HAS NOT BEEN PENETRATED IN THE CORE HOLES EXAMINED. IT CONSISTS OF SHALE WITH A SMALL AMOUNT OF SILT. THE THICKNESS CAN BE ESTIMATED AT ABOUT 465' BY COMPARING THE ELECTRIC LOG OF LAFB WATER WELL #3 WITH THE SAMPLE LOG OF A WATER WELL LABELED PM-22. THE UPPER SAMPLES ARE POOR, SO AN EXACT TOP OF NAVARRO CAN NOT BE PICKED BUT COMPARISON OF THIS SAMPLE LOG WITH THE ELECTRIC LOG ON WATER WELL #3 SUGGESTS THE TOP OF NAVARRO TO BE AT 180' AND THE BOTTOM TO BE AT 645'.

STARTING AT LEON CREEK ON THE NORTH SIDE OF THE ANTICLINE (ENCLOSURE #2); PM-2 IS A POOR EXPOSURE OF WEATHERED SHALE WITH A TRACE OF NAVARRO FORAMS; PM-1 IS AN EXPOSURE AT THE DRAINAGE DITCH ALONG HIGHWAY 90 AND CONTAINS A TRACE OF WEATHERED NAVARRO FORAMS; PM-15 IS A CORE HOLE IN HIGHWAY 90 MEDIAN,

LOCATION IS APPROXIMATE, BY TEXAS HIGHWAY DEPARTMENT. SAMPLE COLLECTED FROM THIS CORE HOLE AT 32' BY MR. JAMES CHRISTIE APPEARS TO BE WITHIN A FEW FEET (5'-10') OF THE BASE OF THE NAVARRO; PM-41 HAS A FEW NAVARRO FORAMS; PM-36 IS AN EXOGYRA COSTATA ZONE LOCATED IN A PIT ON MEDINA BASE, THIS IS WITHIN A FEW FEET OF THE BASE OF THE NAVARRO; PM-37 IS THE SAME HORIZON BUT ON MEDIO CREEK, IT IS LIKELY THAT A SMALL AMOUNT OF SHOVEL WORK WOULD EXPOSE THE TAYLOR SHALE AT THIS POINT.

THE ANTICLINE BRINGS THE NAVARRO TO THE SURFACE AGAIN ALONG LEON CREEK AT PM-12, PM-9, AND PM-6, 7 & 8. PM-16 HAS A BONE BED POSSIBLY EQUIVALENT TO THE ONE FOUND IN CORE HOLE 8A6C-8 AT 55'. PM-17 AND PM-18 ARE STILL SURFACE OUTCROPS CONTAINING NAVARRO FORAMS. PM-29, 30 AND 31 ARE NAVARRO SHALE. ACROSS THE GULLY FROM PM-29 ARE MIDWAY GREEN SANDS. THIS INDICATES A DOWN-TO-COAST FAULT ALTHOUGH THE FAULT PLANE ITSELF WAS NOT OBSERVED. PM-26, 27 AND 28 ARE NAVARRO SHALE WITH A FEW WEATHERED FORAMS.

MIDWAY FORMATION

THE SURFACE OUTCROPS OF THE MIDWAY (ENCLOSURE #2) ON THE NORTH SIDE OF THE ANTICLINE ALONG LEON CREEK ARE PM-34, A GLAUCONITIC SHALE WITH MIDWAY FORAMS; PM-3, A GLAUCONITIC SHALE WITH MIDWAY FORAMS; PM-4, A GLAUCONITIC MIDWAY SHALE WITH FORAMS AND ABOUT ONE FOOT ABOVE THE NAVARRO CONTACT; PM-11, A GLAUCONITIC MIDWAY SHALE; PM-13, A GLAUCONITIC MIDWAY SHALE THREE FEET ABOVE NAVARRO CONTACT; PM-10, GLAUCONITIC MIDWAY; WESTWARD ON MEDIO CREEK, PM-38, A GLAUCONITIC MIDWAY SHALE; PM-21, A WEATHERED MIDWAY SHALE; PM-22, A WATER WELL WHICH STARTED IN MIDWAY SHALE, SOUTH OF THE ANTICLINE ON LEON CREEK; PM-33, A GLAUCONITIC MIDWAY SHALE ON THE DOWN SIDE OF A FAULT SEPARATING IT FROM NAVARRO AT PM-29. PM-32 IS ALSO GLAUCONITIC MIDWAY SHALE.

SUBSURFACE GEOLOGY

TWO GEOLOGIC PERIODS ARE REPRESENTED IN THE SUBSURFACE MATERIAL EXAMINED (ENCLOSURE #1). THE PALEOCENE MIDWAY FORMATION AND THE CRETACEOUS NAVARRO FORMATION. BOTH CONSIST OF CLAY AND A SMALL AMOUNT OF SILTY CLAY AND SILT WITH THE LOWER PART OF THE MIDWAY BEING VERY GLAUCONITIC. ONLY A FEW LITHOLOGIC NOTES WERE MADE FOR THIS HAS BEEN ADEQUATELY STUDIED BY THE UNITED STATES CORPS OF ENGINEERS. THE FORMATIONS WERE DIFFERENTIATED BY THIS WRITER ON THE BASIS OF PALEONTOLOGY. THE FORAMINIFERA, WITH FEW EXCEPTIONS, BEING DISTINCTIVE IN THE TWO FORMATIONS.

THE TAYLOR FORMATION HAS NOT BEEN PENETRATED IN ANY CORE HOLES EXAMINED BUT IT HAS BEEN REACHED IN WATER WELLS ON LAFB AND VICINITY.

NAVARRO

LAFB WATER WELL #5, ELECTRIC LOG CONTROL, FIRST READING AT 112', CORRELATION WITH LAFB WATER WELL #3 SUGGESTS THE WELL STARTS 10' TO 20' BELOW THE TOP OF NAVARRO, INDICATING APPROXIMATELY 500' OF NAVARRO FORMATION AT THIS POINT. ELECTRIC LOG CORRELATION SHOWS A FAULT WITH 230' OF MISSING SECTION AT APPROXIMATELY 1,020' AND TOP OF GEORGETOWN AT 1,100' (-358'). SAMPLE AT DEPTH 32' IN PM-15 IS PROBABLY NEAR (5'-10') THE BASE OF THE NAVARRO. IF THIS INTERPRETATION IS CORRECT, IT IS ON THE HIGH-SIDE AND FAULT SEPARATED FROM WATER WELL #5.

HUMBLE OIL & REFINING COMPANY SERVICE STATION WELL AT HIGHWAY 90 AND LOOP 13, ELECTRIC LOG CONTROL SUGGESTS BASE OF THE NAVARRO AT APPROXIMATELY 50'. THIS AND DATUM RELATIONSHIP AT TOP OF THE GEORGETOWN AT 876' (-125') INDICATES HUMBLE WATER WELL IS ON THE HIGH-SIDE AND FAULT SEPARATED FROM WATER

WELL #5.

LAFB WATER WELL #4, ELECTRIC LOG CONTROL, FIRST READING AT 285', LAST READING AT 1,251', CORRELATION INDICATED WELL STARTED ABOUT 50' BELOW TOP OF THE NAVARRO. THE WELL IS FAULTED AT 1,140', DISPLACEMENT UNKNOWN. PROJECTED TOP OF THE GEORGETOWN 1,250' (-492').

SAMPLES AT PM-36 AND PM-37 ARE NAVARRO AND PROBABLY A FEW FEET (5'-10') ABOVE THE TOP OF THE TAYLOR.

THESE POSTULATIONS INDICATE THAT ON THE HIGH-SIDE OF THE FAULT THERE IS A SMALL AMOUNT OF DOWNWARPING INTO THE FAULT WITH A RELATIVELY THIN REMMANT OF NAVARRO OVERLYING THE TAYLOR ON THE NORTH SIDE OF FAULT "A".

ON THE SOUTH SIDE OF THE FAULT, THE NAVARRO HAS BEEN FOUND IN CORE HOLE 8A6C-8, WATER WELL #5, WATER WELL #4, AND WATER WELL #3. CORE HOLE 8A6C-8 WAS IN NAVARRO AT THE FIRST SAMPLE AT 21' AND AT THE LAST SAMPLE AT 127.8'. WATER WELL #5, AS NOTED ABOVE, PROBABLY STARTS 10' TO 20' BELOW TOP OF THE NAVARRO AND THE BASE OF THE NAVARRO IS AT 490'. THE SECTION IS SLIGHTLY THICKER BECAUSE OF DOWNWARPING INTO THE FAULT.

WATER WELL #3, ELECTRIC LOG CONTROL, FIRST READING AT 85', LAST READING AT 1,548', CORRELATION WITH SAMPLE LOG PM-22, SUGGESTS THAT 180' OF MIDWAY IS PRESENT. TOP? OF NAVARRO AT 180', BASE? OF NAVARRO AT 640'. THICKNESS IS ESTIMATED TO BE 460'. TOP OF GEORGETOWN IS AT 1,475' (-708').

CORE HOLE 6DC-207, ON THE NORTH FLANK OF THE ANTICLINE, FOUND THE NAVARRO AT 96' AND PENETRATED FOUR FEET OF THE FORMATION.

IT WAS ALSO FOUND ON THE ANTICLINE IN CORE HOLE 8A6C-268, FIRST SAMPLE AT

23' AND LAST SAMPLE AT 70' WERE IN NAVARRO.

MIDWAY

THE MIDWAY FORMATION, YOUNGEST MARINE FORMATION IN THE LAFB AREA, IS PRESERVED IN THE DOWN FAULTED BLOCK ADJACENT TO THE DOWN-TO-COAST FAULT "A" AND HAS BEEN REMOVED BY EROSION OVER THE ANTICLINE. IT HAS NOT BEEN FOUND SOUTH OF THE ANTICLINE ON LAFB, BUT HAS BEEN FOUND SOUTH OF LAFB ON LEON CREEK WHERE IT IS AGAIN PRESERVED ON THE DOWN-SIDE OF A DOWN-TO-COAST FAULT, LABELED FAULT "B".

A WELL ABOUT 12 MILES SOUTH OF WILFORD HALL HOSPITAL ON LAFB HAS 280' OF MIDWAY SHALE OF WHICH ABOUT 110' AT THE BOTTOM IS GLAUCONITIC. THE FORMATION THICKENS GULFWARD, SO THE LAFB AREA WOULD HAVE HAD A SLIGHTLY THINNER SECTION. EROSION PROBABLY HAS REMOVED A SUBSTANTIAL PART OF THAT MIDWAY ORIGINALLY DEPOSITED OVER LAFB AND A COMPLETE SECTION IS PROBABLY NOT PRESERVED IN THE DOWN FAULTED BLOCK.

THERE WAS NOT SUFFICIENT CORE HOLE DATA ON LAFB TO GIVE A FULL SECTION OF THE MIDWAY PRESENT, ALTHOUGH IT IS POSSIBLE TO ESTIMATE A MINIMUM THICKNESS PRESENT OF 106'. THE CORE HOLE 6DC-262 PENETRATED 45' OF NON-GLAUCONITIC MIDWAY FROM 23' (FIRST SAMPLE) TO TOTAL DEPTH OF 68'. CORE HOLE 6DC-207 PENETRATED 61' OF GLAUCONITIC MIDWAY, THUS GIVING THE MINIMUM THICKNESS NOTED ABOVE.

THE MIDWAY FORMATION WAS PENETRATED IN THREE OF THE CORE HOLES EXAMINED.

CORE HOLE 8A6C-225 IS ON THE DOWN SIDE OF FAULT "A" AND THE MIDWAY IS IN THE FIRST SAMPLE AT 25' AND THE LAST SAMPLE AT 65'. WEATHERED GLAUCONITE

IS PRESENT.

CORE HOLE 6DC-207 IS ON THE NORTH FLANK OF THE ANTICLINE. THE FIRST SAMPLE AT 35' IS GLAUCONITIC MIDWAY AND THE TOP OF THE NAVARRO IS AT 95'.

CORE HOLE 6DC-262, ALSO BETWEEN THE ANTICLINE AND FAULT "A", HAD NON-GLAUCONITIC MIDWAY FROM FIRST SAMPLE AT 23' TO LAST SAMPLE AT 68'.

MIDWAY ZONATION

THE MIDWAY FORMATION OF WHICH 106' HAS BEEN PENETRATED IS DOMINANTLY CLAY WITH A SMALL AMOUNT OF SILT. THE UPPER 68' OF MIDWAY PENETRATED IN THE CORE HOLES WAS NON-GLAUCONITIC AND APPEARED TO BE BENTONITIC. MOST OF THE FAUNA WAS LEACHED OUT AND FURTHER ZONATION OF THIS UPPER PART DOES NOT SEEM POSSIBLE. IF ANY ADDITIONAL HIGHER MIDWAY SECTION, PROBABLY PRESENT NEAR FAULT "A", IS PENETRATED THIS MIGHT FURNISH ADDITIONAL DATA.

THE BOTTOM PART OF THE FORMATION IS GLAUCONITIC SILT AND SHALE. THE CORPS OF ENGINEERS' LOG ON CORE HOLE 6DC-207 IN CONJUNCTION WITH THE PALEO INDICATES THE MINIMUM THICKNESS OF THE GLAUCONITIC ZONE. IT SHOWS THE FIRST 15' TO BE REWORKED MATERIAL, THEN PRIMARY CLAY AND SILT TO 35.7', A SAND STONE 35.7' TO 36.6' WITH RED STAIN (POSSIBLY FROM WEATHERED GLAUCONITE); 36.6' TO 96.5' GLAUCONITIC CLAY, SILT AND SAND; 96.5' TO 100' SHALE - MARL. THIS INDICATES THE MIDWAY TO BE GLAUCONITIC FROM 35.7' TO 96.5', SO WE HAVE USED THE FIGURE OF 61' FOR THE GLAUCONITIC ZONE.

THE SAMPLE INTERVALS EXAMINED BY THE WRITER ON THIS CORE HOLE WERE 35', 49', 61', 71', 80', 90' AND 100'. THE FIRST SAMPLE AT 35' THROUGH 90' CONTAINED MIDWAY FORAMS AND GLAUCONITE IN VARYING ABUNDANCE. THE LAST SAMPLE AT 100'

CONTAINED A FEW NAVARRO FORAMS.

THE MIDWAY SURFACE OUTCROP ON THE WEST SIDE OF LEON CREEK IN THE VICINITY OF KELLY ROAD CONTAINS ABUNDANT GLAUCONITE AND VARYING LITHOLOGIES. IT MAY BE POSSIBLE TO ZONE THIS EXPOSED INTERVAL OF MIDWAY AND A CHECK WOULD BE TO CORRELATE THE LOG OF 6DC-207, WHICH SHOWS VARIATIONS IN LITHOLOGY, WITH THE SURFACE OUTCROP AND WITH OTHER CORE HOLES PENETRATING THE LOWER MIDWAY.

NAVARRO ZONATION

TWO CORE HOLES WERE EXAMINED WHICH HAD A LONG NAVARRO SECTION, 8A6C-8 AND 8A6C-268.

THREE POSSIBLE ZONES MIGHT BE CORRELATABLE OVER THE AREA. THE UPPERMOST IS A RELATIVELY THIN ZONE OF SHALE CONTAINING ROUNDED POLISHED RED-BROWN BONE FRAGMENTS AND PEBBLES. THE OTHER TWO ZONES ARE SHALES WITH SMALL THIN WATER-WORN OYSTER SHELLS. VISUALLY THESE APPEAR TO BE VERY SIMILAR AND MIGHT NOT BE GOOD MARKERS, ALTHOUGH THE UPPER BED HAD A FORAM NOT SEEN IN THE LOWER OYSTER BED. ADDITIONAL DATA IS NEEDED, FOR THESE TWO LOWER ZONES WERE PENETRATED IN ONLY ONE CORE HOLE.

CORE HOLE 8A6C-8, ALL NAVARRO

FIFTEEN SAMPLES WERE EXAMINED, 21', 30.5', 41.9', 50.9', 56.7', 60', 69' 78', 87', 96.8', 106', 115', 119.5', 124' AND 127'. ALL WERE FROM THE NAVARRO.

SAMPLE FROM 56.7' TO 57.5' - A ZONE OF RED-BROWN ROUNDED FISH BONES, TEETH AND PEBBLES WAS FOUND. THIS POSSIBLY COULD BE USED AS A MARKER BED FOR IT CAN BE IDENTIFIED IN THE FIELD.

SAMPLE AT 87' - SMALL WATER-WORN BORED OYSTER SHELLS. THIS MIGHT BE A SECOND HORIZON IDENTIFIABLE IN THE FIELD. IT HAS THE

FORAM GYROIDINA DEPRESSA. THIS IS THE ONLY PLACE IT HAS BEEN FOUND TO DATE.

SAMPLE AT 127.8' - A SIMILAR OYSTER SHELL ZONE, BUT IT DID NOT HAVE THE GYROIDINA DEPRESSA.

THE ZONE OF RED-BROWN ROUNDED FISH BONES AND PEBBLES ALSO WAS FOUND AT THE SURFACE AT LOCATION PM-16 AND IN CORE HOLE SA6C-268 AT 60'. THIS CORE HOLE DID NOT GO DEEP ENOUGH TO CHECK THE OCCURRENCE OF THE TWO OYSTER SHELL BEDS NOTED ABOVE. SAMPLES WERE EXAMINED ON A WATER WELL (PM-22) A SHORT DISTANCE FROM THE SOUTHWEST CORNER OF LAFB AND FISH BONES AND OYSTER SHELLS WERE SCATTERED THROUGH THESE SAMPLES. THE QUALITY OF THE SAMPLES DID NOT PERMIT SATISFACTORY ZONATION. HOWEVER THE PRESENCE OF THIS MATERIAL IN THIS WELL AND AT PM-16 SUGGESTS THAT THE THREE ZONES PROBABLY ARE PRESENT OVER LAFB.

STRUCTURE

THE GEOLOGIC STRUCTURE WAS NOT STUDIED IN DETAIL AT THIS TIME BY ME. PREVIOUS RECONNAISSANCE WORK IN CONJUNCTION WITH THE PRESENT WORK ARE THE BASIS FOR THESE NOTES AND MIGHT HELP IN INTERPRETATION OF THE CORE HOLE DATA. STRUCTURAL FEATURES APPARENT ARE AT LEAST TWO DOWN-TO-COAST FAULTS (SEE ENCLOSURE #2), A SOUTHWESTWARD PLUNGING ANTICLINE AND NORMAL REGIONAL GULFWARD DIP.

AT LEAST ONE DOWN-TO-COAST FAULT, TRENDING APPROXIMATELY NORTH, 60 DEGREES EAST, IS ALONG THE NORTH SIDE OF THE LAFB PROPERTY. THIS FAULT "A" WAS INTERPRETED FROM DATUM RELATIONSHIPS ON TOP OF THE GEORGETOWN IN VARIOUS WATER WELLS IN THE AREA AND FORMATIONS FOUND AT THE SURFACE. A FAULT WAS FOUND IN WATER WELL #4 AND WATER WELL #5 BY USE OF THE ELECTRIC LOGS IN THE THREE LAFB WATER WELLS, #3, #4 AND #5. THIS FAULT COULD BE INTERPRETED TO BE THE

REGIONAL FAULT MENTIONED ABOVE OR TO BE A CROSS FAULT SEPARATING WATER WELL #5 AND WATER WELL #4. TOP OF THE GEORGETOWN DATA, BASED PRIMARILY ON DRILLER LOGS IN THE AREA, SUGGEST ADDITIONAL FAULTING MAY BE PRESENT.

IN WATER WELL #5, THIS FAULT CUT WITH 230' OF MISSING SECTION IS FOUND AT 1,020'. WATER WELL #4 HAS A FAULT CUT AT 1,140'+-, BUT THE AMOUNT OF MISSING SECTION CAN NOT BE DETERMINED BECAUSE THE LOG ENDS AT 1,251'. THE TWO WELLS ARE NOT ON THE SAME SIDE OF THIS FAULT AT THE GEORGETOWN DATUM RELATIONSHIPS. NO FAULTING IS APPARENT IN WATER WELL #3.

FURTHER EVIDENCE OF FAULT "A" IS SHOWN ON THE NORTHEAST BY PRESENCE OF TAYLOR AT PM-35 AND MIDWAY AT PM-34, ALSO BY DATUM RELATIONS ON TWO WATER WELLS TWO TO THREE MILES FARTHER NORTHEAST.

ADDITIONAL FAULT CONTROL ON THE SOUTHWEST IS SHOWN BY PM-37, WHERE TAYLOR IS POSTULATED TO BE 10' BELOW THE NAVARRO AND PM-38 HAS MIDWAY GREEN SANDS PRESENT. LOCATION PM-38 COULD ONLY BE APPROXIMATED BECAUSE A MEDINA BASE MAP WAS NOT AVAILABLE.

THE PRESENCE OF GLAUCONITIC MIDWAY AT PM-34 AND CORE HOLE 8A6C-225 CAN BE EXPLAINED BY A COMBINATION OF PRESERVATION AGAINST THE FAULT AND A GREATER FAULT THROW AT THIS POINT THAN AT PM-1. A SIMILAR EXPLANATION CAN BE MADE FOR THE GLAUCONITIC MIDWAY AT PM-38 BEING ADJACENT TO POSTULATED TOP OF THE TAYLOR AT PM-37. THIS WOULD REQUIRE ABOUT 475' OF DISPLACEMENT AT PM-38. WATER WELL #5 HAS 230' OF DISPLACEMENT (MISSING SECTION).

ANOTHER WAY OF STATING THIS INTERPRETATION IS THAT THERE IS A LOCAL STRUCTURAL "HIGH" ON THE DOWN SIDE AND ADJACENT TO THE FAULT IN THE VICINITY OF

PM-1 TO PM-2. THIS WOULD ALLOW THE EROSION OF MIDWAY ON THE "HIGH" AND STILL ALLOW THE PRESERVATION OF THE REMAINDER OF THE MIDWAY AT PM-34, PM-38 AND PM-3 AND IN THE SUBSURFACE ON THE DOWN SIDE OF THE FAULT AND NORTH OF THE ANTICLINE.

AN ANTICLINE IN SOUTH CENTRAL LAFB, PROBABLY ASSOCIATED WITH THE FAULTING, HAS PREVIOUSLY BEEN MAPPED USING SCANTY WATER WELL CONTROL. THIS ANTICLINE TRENDS APPROXIMATELY PARALLEL TO FAULT "A" WITH THE ANTICLINAL CREST NEAR PM-16 TO PM-28. THERE IS AT LEAST 265' OF NORTHWEST DIP FROM THE CREST TOWARD THE FAULT, THE NORMAL REGIONAL GULFWARD DIP FORMS THE SOUTHEAST FLANK OF THE ANTICLINE. THIS DIP SHOULD BE TAKEN INTO CONSIDERATION IN SPACING THE CORE HOLES.

FAULT "B" IS SOUTH OF LAFB AND IS EVIDENCED BY NAVARRO PM-29 AND GLAUCONITIC MIDWAY PM-33 BEING AT THE SAME ELEVATION, ONE ON EACH SIDE OF THE SMALL CANYON. ADDITICNAL CONTROL IS NECESSARY TO DETERMINE THE STRIKE.

IT IS PROBABLE THAT ADDITIONAL SMALL FAULTS ON LAFB WILL BE FOUND WITH THE CORE HOLE DATA.

WEATHERING

IN THE PREVIOUS PRELIMINARY NOTES ATTENTICN WAS CALLED TO WEATHERING OF THE SHALES AND TO THE SCARCITY OF FORAMINIFERA IN SOME OF THE SAMPLES. THESE TWO ITEMS ARE PROBABLY RELATED, AT LEAST IN PART, BECAUSE SOME FIRM SHALE SAMPLES STILL HAVE MOLDS OF THE FORAMS WHICH HAVE BEEN REMOVED BY SOLUTION. THIS INDICATES THAT THESE WERE DISSOLVED OUT RELATIVELY NEAR THE SURFACE FOR A HEAVY OVERBURDEN WOULD PROBABLY COLLAPSE THE PLASTIC CLAY INTO THE SOLUTION CAVITIES.

THE FAULTING AND FOLDING PROBABLY HAVE PRODUCED ABUNDANT FRACTURES WHICH ALLOWED WATER TO CIRCULATE THROUGH THE SHALES. THIS WATER COULD COME UP THE FAULT PLANE FROM THE EDWARDS BECAUSE OF ARTESIAN PRESSURE, OR COULD ENTER FROM LEON CREEK OR BE FROM RAINFALL. WHEN THE PERCOLATING WATER REACHED GROUND WATER TABLE, INFLUENCED BY THE ELEVATION OF LEON CREEK AND MEDIO CREEK, IT FLOWED OUTWARD CARRYING CALCIUM CARBONATE AND POSSIBLY OTHER MINERALS IN SOLUTION. THE SHALE BELOW GROUND WATER LEVEL POSSIBLY HAS FEWER FRACTURES AND LIMITED CIRCULATION OF GROUND WATER AND HENCE HAS NOT BEEN SUBJECT TO WEATHERING BY PERCOLATING GROUND WATER.

THIS IS MAINLY SPECULATION AND ADDITIONAL CORE HOLE DATA SHOULD BE CONSIDERED BEFORE VALID CONCLUSIONS CAN BE DRAWN.

THIS WEATHERING IS POSSIBLY RELATED TO THE FOUNDATION PROBLEM AND IS THE REASON THIS IS MENTIONED.

PORTER A. MONTGOMERY, JR.
MONTGOMERY'S STRATIGRAPHIC SERVICE

PAM:BP

THE FOLLOWING NOTES ARE BRIEF COMMENTS ON THE SAMPLES. THIS IS ALSO PRESENTED GRAPHICALLY ON THE ENCLOSED LOG STRIPS WHICH ARE PLOTTED ON THE SAME SCALE AS THE ELECTRIC LOGS OF THE CORE HOLE, $\frac{1}{2}$" = 10'. THE LOG STRIPS WILL BE MORE CONVENIENT TO USE IN CORRELATIVE WORK THAN THE WRITTEN DESCRIPTION. THE WRITER HAS SEEN YOUR CORE DESCRIPTION LOG OF 6DC-207 AND THIS LOOKS ADEQUATE TO TAKE CARE OF ANY LITHOLOGIC NEEDS.

CORE HOLE 8A6C-8 - ALL NAVARRO FORMATION

FIFTEEN SAMPLES, 21', 30.5', 41.9', 50.9', 56.7', 60', 69', 78', 87', 96.8', 106', 115', 119.5', 124' AND 127' WERE EXAMINED. THE FIRST TO THE LAST SAMPLES WERE FROM THE NAVARRO.

SAMPLE AT 21' - A LIGHT GREY BUFF SILTY SLIGHTLY LIMONITE STAINED BENTONITIC SHALE WITH A SMALL NAVARRO FAUNA

30.5' - SHALE IS WASHED OUT. SLIGHTLY LARGER FAUNA

41.9' - SAME AS FIRST SAMPLE WITH TRACE OF FISH BONES. SMALL NAVARRO FAUNA

50.9' - LITHOLOGY SAME AS FIRST SAMPLE. SMALL NAVARRO FAUNA

56.7' TO 57.5' - LITHOLOGY IS SAME BUT CONTAINS ABUNDANT RED-BROWN BROKEN ROUNDED POLISHED FISH BONES, TEETH, PEBBLES AND A MODEST NAVARRO FAUNA.

THIS ZONE MIGHT BE CORRELATED IN THE FIELD OVER THE AREA FOR A SIMILAR ZONE OCCURS IN CORE HOLE 8A6C-268.

60.1' - A SIMILAR LITHOLOGY TO THE FIRST SAMPLE BUT A VERY MEAGER NAVARRO FAUNA

69.1' - AN UNWEATHERED GREY BENTONITIC CLAY WITH ONLY A TRACE OF FORAMS

78.3' - SAME

87.8' - A SIMILAR LITHOLOGY BUT HAS ABUNDANT SMALL BORED GREY OYSTER SHELL FRAGMENTS AND A SMALL NAVARRO FAUNA. THIS MIGHT BE A POINT WHICH CAN BE CORRELATED. IT CONTAINS THE FORAM GYROIDINA DEPRESSA, THE FIRST AND ONLY OCCURRENCE OF THE FOSSIL WHICH MAY POSSIBLY BE USED TO DISTINGUISH THIS OYSTER SHELL BED FROM THE ONE OCCURRING AT 127.8'.

96.7' - A GREY SILTY SHALE, VERY ABUNDANT FINE PYRITE AND A TRACE OF FORAMS

106.1' - SAME

115' - SAME

119' - SAME

124' - GREY SHALEY SILTY WITH A SMALL NAVARRO FAUNA

127.8' - GREY SILTY SHALE WITH OYSTER SHELL FRAGMENTS AND MODEST NAVARRO FAUNA

CORE HOLE 8A6C-268 - ALL NAVARRO FORMATION

NINE SAMPLES, 28', 33', 38', 43.3', 48.5', 54', 60', 65.5', AND 70.1' WERE EXAMINED. THE FIRST SAMPLE WAS IN NAVARRO AND THE LAST SAMPLE HAD A MEAGER FAUNA BUT PROBABLY WAS STILL IN NAVARRO.

SAMPLE AT 28' - A LIGHT YELLOW GREY CLAY WITH FINE LIMONITE STAIN. IT HAS A SMALL NAVARRO FAUNA.

33' - AN INCREASE IN LIMONITE STAIN WITH A SMALL AMOUNT OF DARK GREY MATERIAL AS NOTED IN SAMPLE 38.1' IN CORE HOLE 6DC-262. IT HAS A MEAGER FAUNA WITH ABUNDANT INSOLUBLE HAPLOPHRAGMOIDES.

38' - SAME SHALE WITH SMALL NAVARRO FAUNA

43.3' - SAME

48.5' - SAME

54' - SAME WITH A FEW SMALL BONE FRAGMENTS

60' - SAME WITH ABUNDANT ROUNDED POLISHED RED-BROWN BONE FRAGMENTS AND MODEST NAVARRO FAUNA.

65.5' - A LIGHT YELLOW SHALE WITH ABUNDANT LIMONITE WITH TRACE NAVARRO FORAMS

70.1' - BUFF SILT WITH LIMONITE TRACE OF FORAMS, PROBABLY NAVARRO.

CORE HOLE 6DC-207 - MIDWAY WITH NAVARRO NEAR BOTTOM .

SEVEN SAMPLES, 35', 49', 61', 71', 80', 90' AND 100' WERE EXAMINED. THE FIRST SIX WERE FROM THE MIDWAY AND THE LAST SAMPLE AT 100' WAS IN NAVARRO.

SAMPLE AT 35' - ABUNDANT GLAUCONITE WITH COPROLITES, FISH TEETH, ROUNDED POLISHED BONE FRAGMENTS AND PEBBLES AND A NUMBER OF MIDWAY SPECIES, BUT NOT ABUNDANT IN QUANTITY.

49' - ABUNDANT GLAUCONITE WITH COPROLITES AND A LARGE NUMBER OF MIDWAY FORAMS.

61' - A GLAUCONITIC SAND LIGHTLY CEMENTED WITH FEW MIDWAY FORAMS.

71' - A GREY SHALEY SILT WITH FEW FORAMS, PROBABLY MIDWAY.

80' - A GREY SHALEY SILT WITH GLAUCONITE, A FEW SMALL PYRITE NODULES AND A FEW MIDWAY FORAMS.

90' - A GREY CLAY WITH GLAUCONITE AND AN ABUNDANT MIDWAY FAUNA

100' - A GREY SILTY SHALE WITH A SMALL NAVARRO FAUNA.

CORE HOLE 8A6C-225 - ALL MIDWAY

FOUR SAMPLES, 25', 50', 60' AND 65' WERE EXAMINED. ALL FOUR SAMPLES CONTAINED A MEAGER FAUNA.

SAMPLE AT 25'	- A MEAGER FAUNA WITH THE RELATIVELY INSOLUBLE HAPLOPHRAGMOIDES AND AMMODISCUS AND IS ASSIGNED TO MIDWAY BECAUSE OF STRATIGRAPHIC POSITION.
50'	- A TRACE OF MIDWAY FAUNA AND WEATHERED GLAUCONITE AND INTERGLAUCONITE MATRIX.
60'	- HAPLOPHRAGMOIDES, LIMONITE, WEATHERED, GLAUCONITE, INTERNAL PYRITE ALTERED TO LIMONITE MOLDS OF MINUTE FOSSILS.
65'	- STILL HAD A TRACE MIDWAY FAUNA. DEEP WEATHERING POSSIBLY WAS RESPONSIBLE FOR THE SCARCITY OF FOSSILS AND WEATHERING OF THE GLAUCONITE AND PYRITE TO LIMONITE.

IT IS POSSIBLE THAT THE SAMPLE AT 25' AND CERTAINLY THE REMAINING THREE SAMPLES AT 50', 60' AND 65' WERE GLAUCONITIC AND POSSIBLY EQUIVALENT TO THE GLAUCONITIC ZONE IN THE 6DC-207 CORE TEST AND SURFACE OUTCROP.

CORE HOLE 6DC-262 - ALL MIDWAY

NINE SAMPLES, 22.5', 28.9', 33', 38.1', 45.1', 49', 53', 62' AND 68' WERE EXAMINED. ALL WERE FROM THE MIDWAY.

SAMPLE AT 22.5' - A BENTONITIC CLAY WITH FINE LIGHT SPECKLED LIMONITE STAINING AND NO FORAMINIFERA.

28.9' - A SIMILAR LITHOLOGY WITH A TRACE OF THE INSOLUBLE HAPLOPHRAGMOIDES.

33' - AN ABUNDANT LIMONITE, ABUNDANT HAPLOPHRAGMOIDES AND A TRACE OF CHRYSALOGONIUM GRANTI, A MIDWAY FORAM.

38.1' - AN ABUNDANT LIMONITE AND DARK GREY MATERIAL OF SIMILAR TEXTURE AND AN ABUNDANT MIDWAY FAUNA.

45.1' - A LIMONITE AND BLACK MATERIAL AS NOTED ABOVE AND A SMALLER MIDWAY FAUNA.

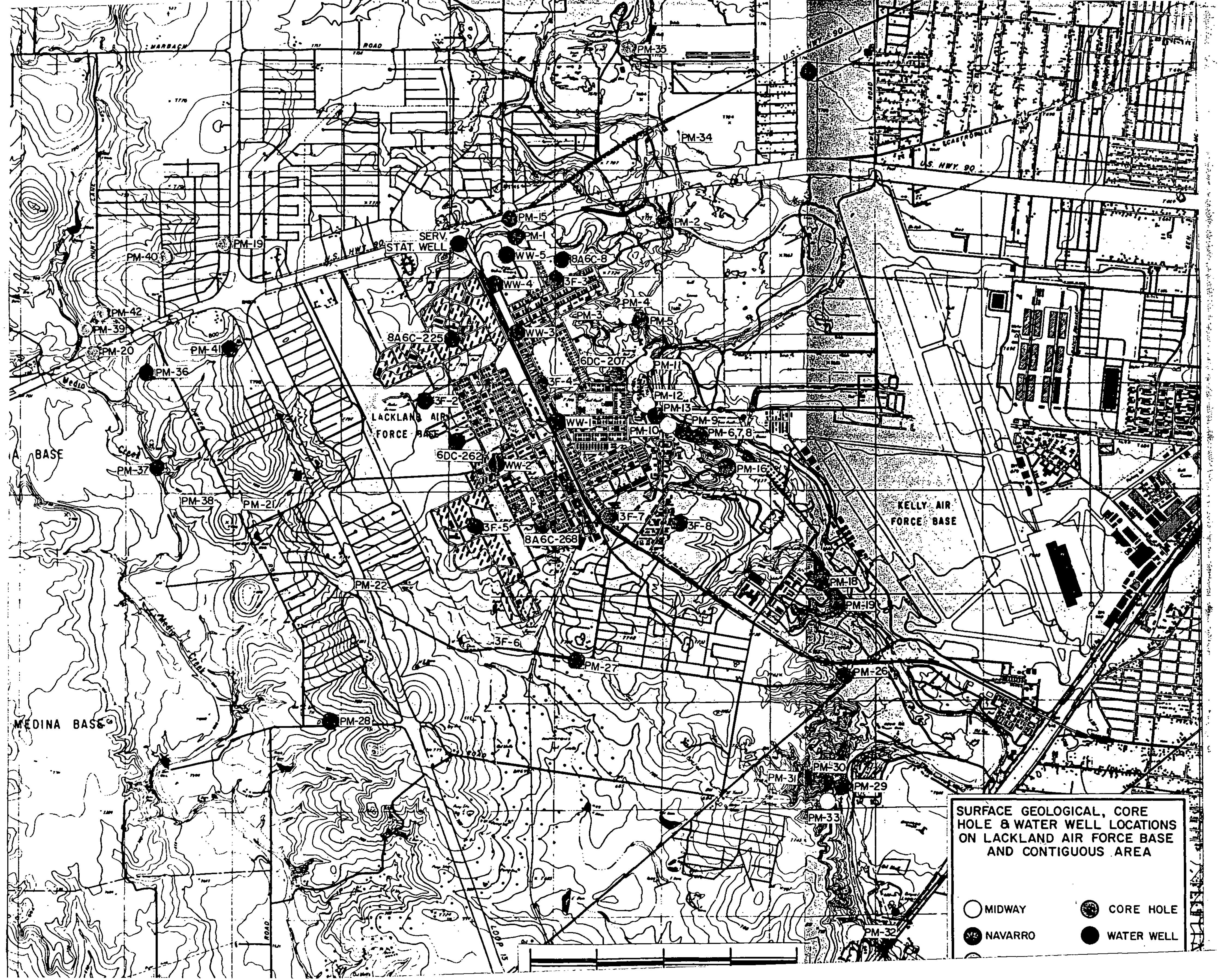
49' - A LIMONITE AND HEMATITE WITH MIDWAY FAUNA.

53' - A SMALL AMOUNT OF LIMONITE AND HEMATITE WITH A MIDWAY FAUNA.

62' - A SMALL AMOUNT OF LIMONITE AND HEMATITE WITH A MIDWAY FAUNA

68' - CHANGED FROM A LIGHT GREY, LIGHTLY LIMONITE STAINED BENTONITIC CLAY WITH BUFF FORAMINIFERA TO A GREY CLAY WITH GREY FORAMINIFERA WITH SMALL AMOUNT OF PYRITE AND A SMALL MIDWAY FAUNA.

THERE IS NO EVIDENCE THAT THE GLAUCONITIC ZONE OF THE OUTCROPPING MIDWAY WAS ENCOUNTERED.



SURFACE GEOLOGICAL, CORE HOLE & WATER WELL LOCATIONS ON LACKLAND AIR FORCE BASE AND CONTIGUOUS AREA

APPENDIX C

SEISMIC SURVEY
WILFORD HALL HOSPITAL COMPLEX AREA
LACKLAND AIR FORCE BASE

FOR

U. S. ARMY ENGINEER DISTRICT, FORT WORTH, TEXAS

BY

WILL R. CLACK
P. O. BOX 111
BEDFORD, TEXAS

SEISMIC SURVEY OF
WILFORD HALL HOSPITAL COMPLEX AREA
SAN ANTONIO, TEXAS

PURPOSE:

This survey was performed to assist in developing correlation between existing borings in order to develop the subsurface structural geology of the area. For drill hole location see Figure 1.

PROCEDURE:

This seismic survey was performed in two phases. The first phase consisting of four profiles from southwest to northeast. These profiles were performed with a geophone spacing of ten feet with a distance of 100 feet betwee shot points. These profiles are designated lines A, B, E, and D. See figure 2.

Phase two of the project was performed with a spacing of 50 ft. between geophones and a distance of 500 ft. between shot points. These profiles consist of lines S, T, U, V, W, X, Y, AA, and BB. See Figure 3.

The energy for all shots was supplied by explosives. The 100 ft. spreads used a cap and a water works booster. For the spreads of 500 ft. a cap and one-half lb. 60% dynamite were used. All shots were placed 12 to 18 inches below the surface and tamped.

RECORDS:

Records were made on direct print paper and later made permanent by chemical processing. Time base on the records is 20 inches per second allo ing timing accuracy of ± .5 m.s. There are 24 signal traces and one time break trace on each record. Only 12 traces were used on some records because of the traffic in the area. Arrival times were determined and plotted scale 1 in.= 10 ft. and 1 in.= 10 milliseconds (MS) for spreads of 100 ft. and o a scale of 100 ft. = 1 inch and 100 MS = 1 inch for 500 ft. spreads.

The records are of good technical quality; however, because of the excessively high rate of attenuation of the energy in subsurface, the time bre are not as sharp as might be desired. The records of the 100 ft. spreads representative of near subsurface conditions, however the records of the 5 ft. spreads do not show the arrival of the energy through the subsurface b the first 200 ft.

The arrival times marked on the records in most cases are for the of the sound wave through the air.

Figure 4 shows the representative rate of attenuation of the energy in the subsurface. This attenuation is considerably greater than is normally experienced, even in areas of poorly consolidated materials.

DATA DETERMINED FROM INVESTIGATION:

The depths to the velocity horizons determined from the records of the 100 ft. spreads are listed in Table 1.

Since very few seismic arrivals could be determined for the longer spread, no computation for deeper horizons could be determined from the records of the 500 ft. spreads.

CONCLUSION:

The information determined by this survey is very limited. The unconsolidated nature of the subsurface material results in a very low velocity and produces a very high rate of attenuation of the seismic energy. From the graph of attenuation shown in Figure 4 we see that at 10 ft. the seismogram trace amplitude is only about .4 inch and at 10 ft. the trace amplitude is only about .03 inch. In order to get seismic energy out to a distance of 500 ft. to the geophone the explosive charges would have to be at least ten times as large, or about five pounds of dynamite. Detonation of this size charge would certainly blow material from the hole for a considerably distance from the shot and perhaps cause damage to buildings and automobiles in the vicinity. Drilling deep shot holes would reduce the possibility of the holes blowing, but the expense was not included in the original cost.

The mentioned procedures are commonly used to improve the record quality; however, it is felt by the contractor that the records obtained through the use of these measures might not provide much additional information because of the low velocity and lack of any large changes in velocity between the various depths.

TABLE 1: SEISMIC HORIZONS

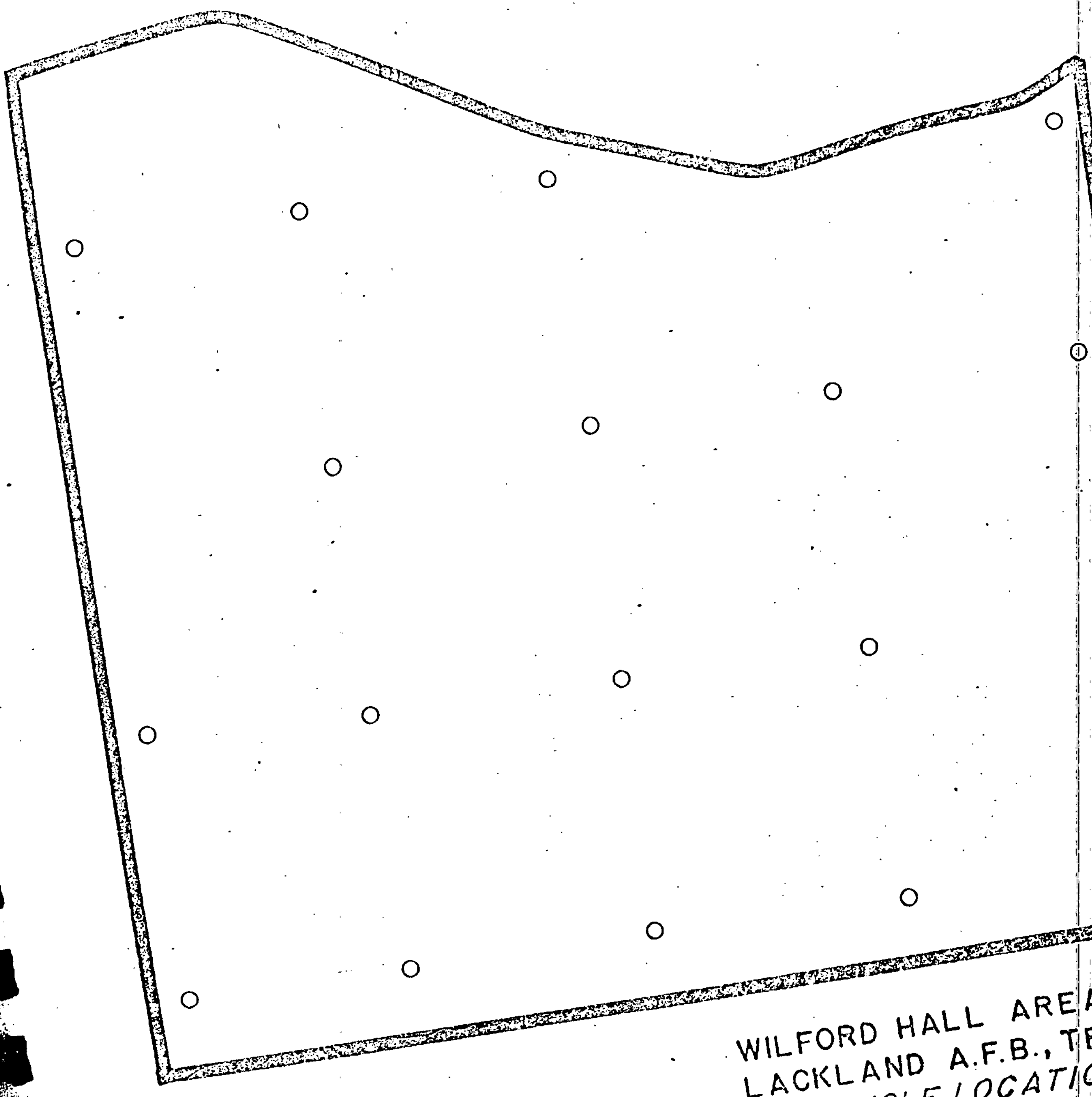
Shot Point	Depth Interval (Feet)	Velocity (Feet per Second)	Spread (Feet
A-1	0-10 ft. 10 -	1,200 fps 2,100	100 ft.
A-2	-	3,000	100 ft.
A-3	0-10 10-	800 2,100	100 ft.
A-4	Surface	1,300	100 ft.
A-5	0-8 8-	875 1,750	100 ft.
A-6	Surface	1,000	100 ft.
A-7	0-19.5 19.5-	1,000 2,700	100 ft.
A-8	0-17.5 17.5-	1,300 2,450	100 ft.
A-9	-	-	100 ft.
A-10	0-32.0 32.0-	1,400 5,000	100 ft.
A-11	Surface	1,350	100 ft.
A-12	-		100 ft.
A-13	-		100 ft.
A-14	Surface	1,200	100 ft.
A-15	0-11.5 11.5-	1,100 1,825	100 ft.
A-16	Surface	1,300	100 ft
A-17	Surface	1,300	100 f
A-18	0-15.0 15.0-	1,175 2,750	100

Shot Point	Depth Interval (Feet)	Velocity (Feet per Second)	Spread (Feet)
A-19	0-22.0	1,200	100 ft.
	22.0-	2,150	
A-20	Surface	1,250	100 ft.
A-21	0-10.0	1,100	100 ft.
	10.0-		
A-22	0-4.8	1,400	100 ft.
	4.8-	2,250	
A-23	0-10.0	1,100	100 ft.
	10.0		
A-24	0-6.5	1,300	100 ft.
	6.5	2,300	
A-25	0-11.0	1,500	100 ft.
	11.0-	2,400	

Shot Point	Depth Interval (Feet)	Velocity (Feet per Second)	Spread (Feet)
B-1	0-7.0	700	100 ft.
	7.0-	3,500	
B-2	0-7.0	800	100 ft.
	7.0-	2,600	
B-3	0-6.5	1,300	100 ft.
	6.5-	2,400	
B-4	0-7.0	750	100 ft.
	7.0	2,600	
B-5	0-4.5	900	100 ft.
	4.5-	2,700	
B-6	0-5.8	600	100 ft.
	5.8-	3,700	
B-7	0-6.8	1,700	100 ft.
	6.8-	3,500	
B-8	0-2.0	1,500	100 ft.
	2.0-	2,250	

Shot Point	Depth Interval (Feet)	Velocity (Feet per Second)	Spread (Feet)
E-1	0-6.3	1,400	100 ft.
	6.3	4,500	
E-2	0-7.2	700	100 ft.
	7.2	5,500	
E-3	0-13.0	1,100	100 ft.
	13.0-	5,200	
E-4	0-8.0	1,000	100 ft.
	8.0-	3,000	
E-5	0-7.5	800	100 ft.
	7-5	3,500	
E-6	0-7.0	700	100 ft.
	7.0-	4,200	
E-7	0-10.5	950	100 ft.
	10.5-	4,250	
E-8	0-6.0	700	100 ft.
	6.0-	2,800	
E-9	0-4.0	800	100 ft.
	4.0-	3,800	
E-10	0-5.5	900	100 ft.
	5.5-	3,800	

Shot Point	Depth Interval (Feet)	Velocity (Feet per Second)	Spread (Feet)
D-1	0-6.0 6.0-	700 6,000	100 ft.
D-2	0-9.0 9.0-	640 8,500	100 ft.
D-3	-	-	100 ft.
D-4	-	-	100 ft.
D-5	0-10.0 10.0-	800 1,800	100 ft.
D-6	-	-	100 ft.
D-7	0-5.0 5.0	1,000 3,500	100 ft.
D-8	-	-	100 ft.
D-9	0-4.75 4.75-	900 3,000	100 ft.
D-10	0-6.5 6.5-	1,000 3,250	100 ft.
D-11	0-5.0 5.0-	1,000 4,000	100 ft.
D-12	0-9.0 9.0	850 2,700	100 ft.
D-13	0-6.5 6.5	650 3,100	100 ft.
D-14	-	-	100 ft.
D-15	0-5.5 5.5	1,000 2,500	100 ft.
D-16	0-9.0 9.0-	800 3,400	100 ft
D-17	-	-	100 f



WILFORD HALL ARE
LACKLAND A.F.B., TE
BORE HOLE LOCATI

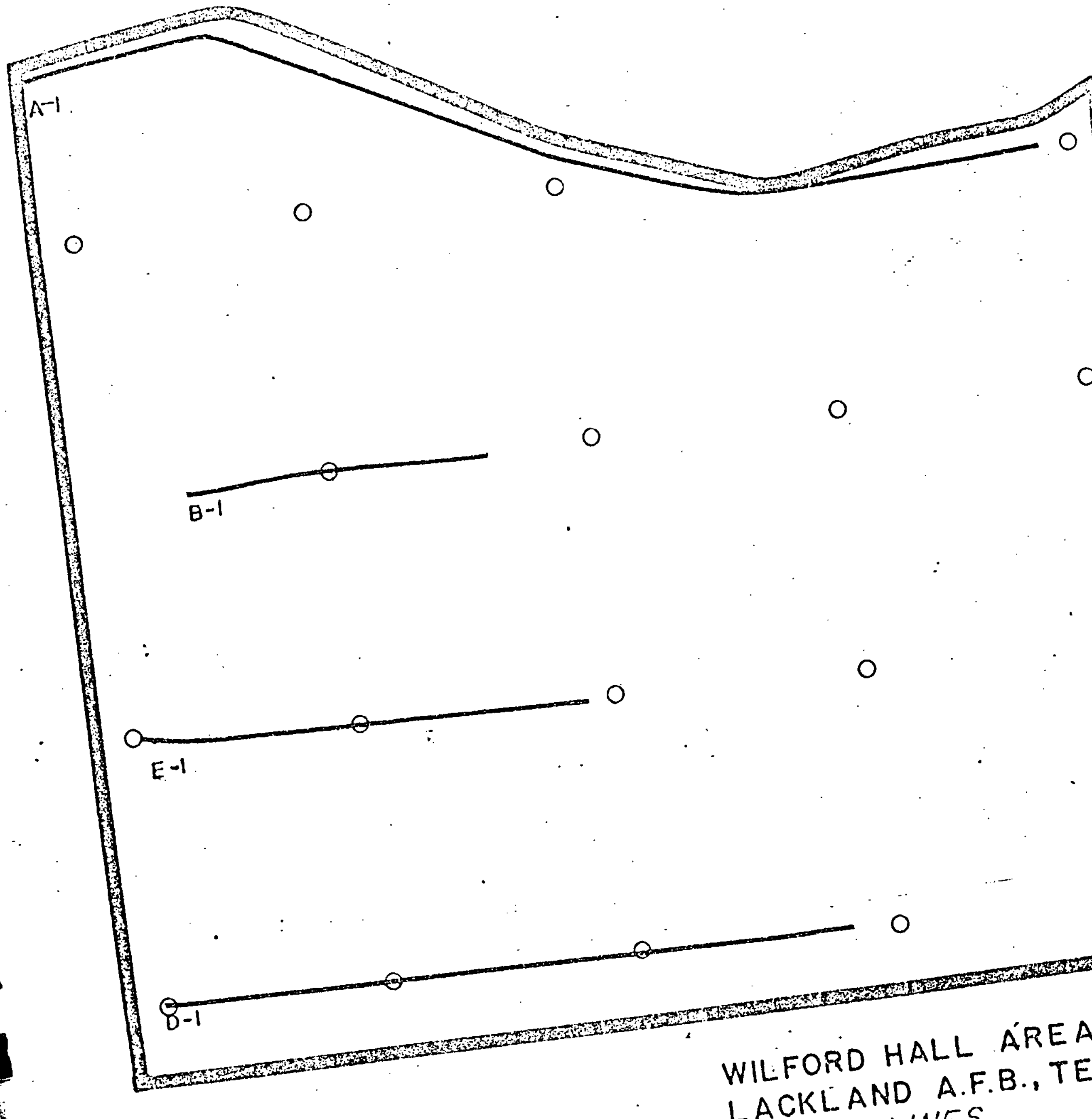
N

scale 1in.=400 ft.

○ *bor*

report by
WILL R. CLACK

FIGU



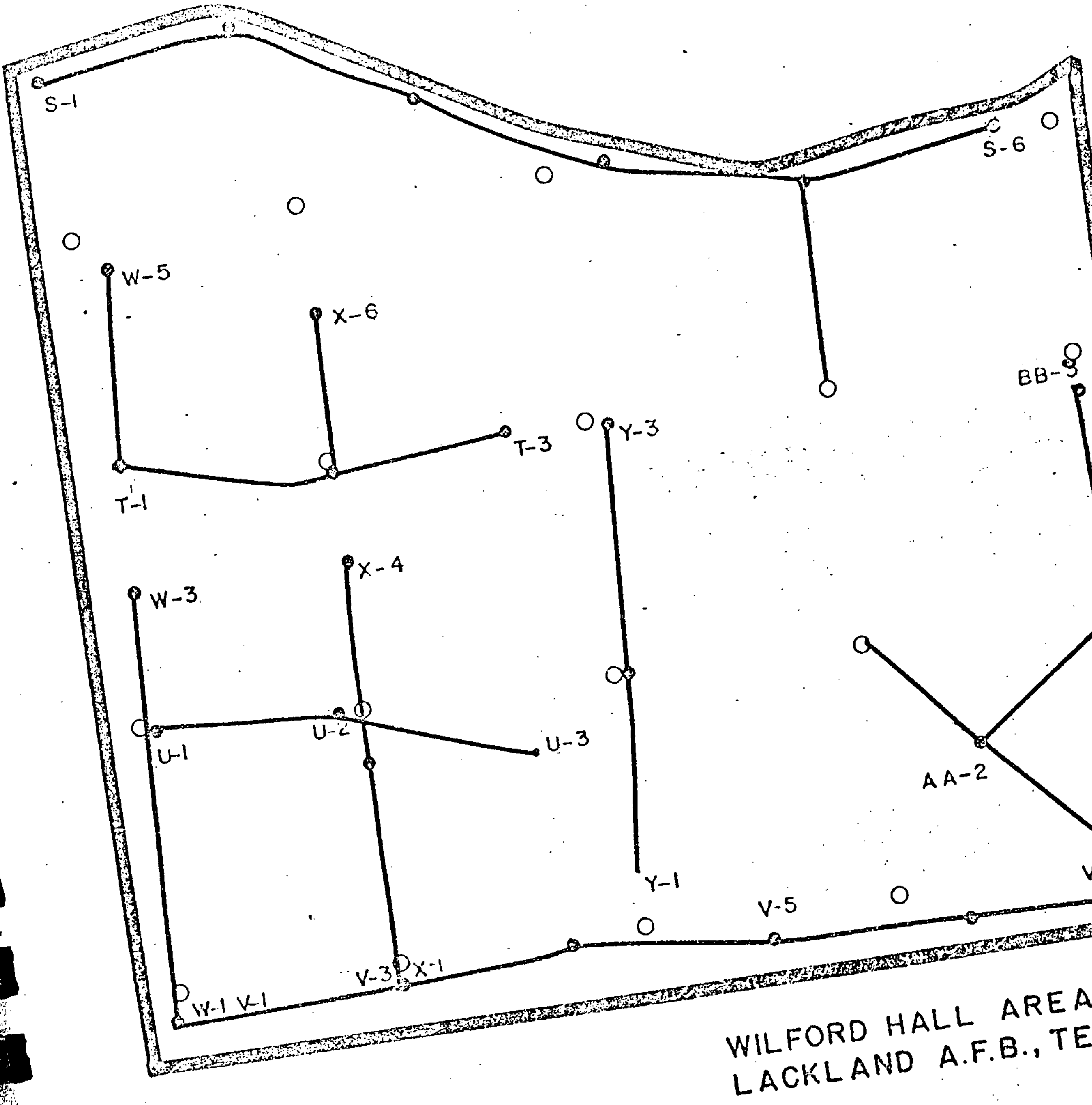
WILFORD HALL AREA
LACKLAND A.F.B., TE
SEISMIC LINES
100 ft. SPACING

○ bo
— sc

scale 1in.=400 ft.

report by
WILL R. CLACK

F



WILFORD HALL AREA
LACKLAND A.F.B., TE

SEISMIC LINES
500 ft SPACING
scale 1in.= 400 ft.

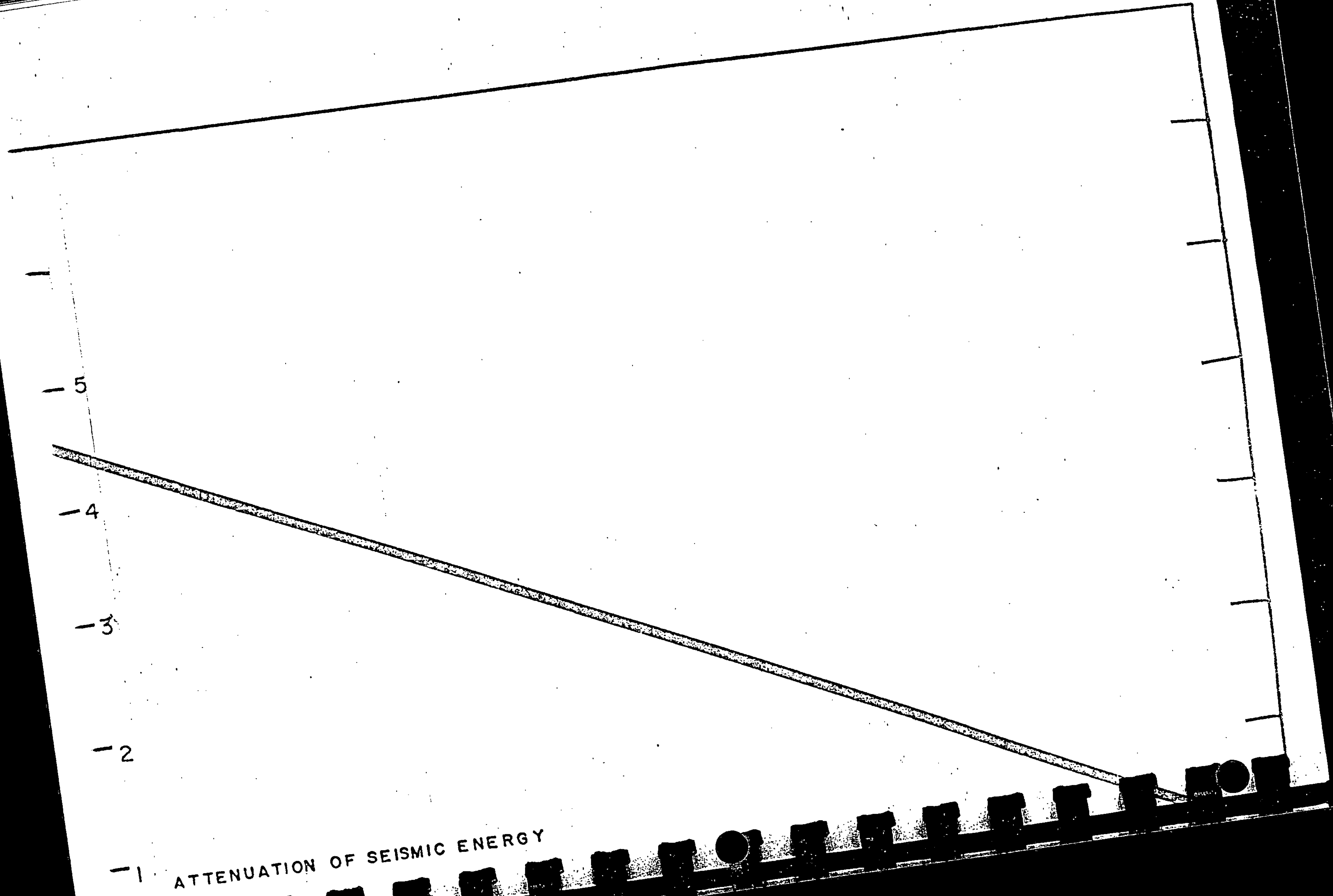
N

⊙ *bo*

● *s*

report by
WILL R. CLACK

FIGURE 3


5
4
3
2
1
ATTENUATION OF SEISMIC ENERGY

APPENDIX D

MINERALOGICAL ANALYSES
SUBSURFACE MATERIALS
LACKLAND AIR FORCE BASE, SAN ANTONIO, TEXAS

FOR

U. S. ARMY ENGINEER DISTRICT, FORT WORTH, TEXAS

BY

DR. ARTHUR J. EHLMANN
ASSOCIATE PROFESSOR OF GEOLOGY
TEXAS CHRISTIAN UNIVERSITY
FORT WORTH, TEXAS

LACKLAND AIR FORCE BASE ANALYSIS

Cores which were delivered to TCU in closed containers (jars, plastic bags and paraffin) were analyzed by X-ray diffraction (1) in the natural state and (2) after drying at room temperatures for three days. The material analyzed in the natural state was damp and could be plastically molded into the sample holders with a spatula. For the analyses after drying, the samples were normally ground to a powder in mortar and pestle and powder mounts were made.

The basal spacing of the natural state clays was found to be 17.7 A and that of the dried clays, to be 14.2 A. This represents a volume change of approximately 25%. The volume change occurs relatively rapidly as is indicated by the table of data given entitled "Lackland Clay Drying Tests". These data were obtained by weighing an original 11.900 grams of plastic, crumbled clay and be reweighing after the indicated number of hours. It is seen that after 3 days the clay is essentially at equilibrium with the temperature and humidity of the laboratory. It is conceivable and in fact probable that under mid-summer humidity and temperature in San Antoni the dehydration would be greater. The value of 25% volume change is a minimum, therefore, and values of 25-50% probab occur.

The clay occurring most abundantly in the cores is Ca-montmorillonite although some minor percentage of mica (or illite) and chlorite occur along with other non-clay constituents (see tables of analyses). The analyses indicate the composition of the Midway is relatively constant with approximately 70% Ca-montmorillonite. The Midway, therefore, should be a severely troublesome substratum to foot a pier. The Navarro contains considerably less montmorillonite (approximately 30% a maximum down to a trace) and, therefore, should be less troublesome as a substratum to foot a pier. The Midway is essentially a claystone (or shale) whereas the Navarro is essentially a calcareous siltstone or fine sandstone.

One of the near surface samples contains gypsum which is undoubtedly a caliche deposit (see Pier 2, #5).

The orientation of the particles is generallyparallel to bedding planes but because of the high plasticity of the clay can be (and is frequently) reoriented by lateral slippage and even by coring devices. The gummy nature of the Midway prevents taking completely undisturbed cores. The Navarro, in contrast, having a greater framework of quartz, feldspar and calcite tends to retain bedding orientation more easily.

If additional information on these samples is needed, fell free to call on me.

Arthur J. Ehlmann
Assoc. Prof. of Geology
Geology Department
Texas Christian Univers
Fort Worth, Texas 7612

LACKLAND CLAY DRYING TESTS

TIME (hrs)	CLAY Wt.	% of Original
0	11.900	100.0
1	11.830	99.4
3	11.660	98.0
4	11.550	97.1
6	11.355	95.4
11	11.050	92.9
24	10.400	87.3
26	10.350	87.0
28	10.230	86.0
31	10.205	85.8
71	9.865	82.9
95	9.730	81.8
143	9.720	81.7

6DC - 22

Depth		Mineralogy	Estimated %
21		Montmorillonite	75
		Quartz	10
		Mica	5
		Chlorite	5
		Feldspar	5
26.8		Montmorillonite	70
		Quartz	10
		Mica	5
		Chlorite	5
		Feldspar	10
31.6		Montmorillonite	80
		Quartz	10
		Mica	5
		Feldspars (2)	5
41		Montmorillonite	90
		Quartz	5
		Mica	5
		Calcite	(trace)
50		Montmorillonite	65
		Quartz	10
		Feldspars (2)	20
		Mica	5
60		Montmorillonite	80
		Quartz	10
		Gypsum	5
		Feldspar (1)	5
	Midway		
65	Navarro	Quartz	30
		Calcite	20
		Feldspar (1)	20
		Montmorillonite	25
		Mica	5

Depth		Mineralogy	Estimated %
70		Quartz	30
		Feldspar (1)	20
		Calcite	15
		Montmorillonite	30
		Mica	5
75		Quartz	30
		Feldspar (1)	20
		Calcite	15
		Montmorillonite	30
		Mica	5
80	Chl.	Quartz	30
		Feldspar (1)	20
		Calcite	10
		Montmorillonite	30
		Mica	5
		Chlorite	5
85		Quartz	30
		Calcite	30
		Feldspar (1)	20
		Mica	10
		Chlorite	10
90		Quartz	35
		Calcite	35
		Feldspar (1)	10
		Mica	10
		Chlorite	10
94		Quartz	30
		Calcite	30
		Feldspar (1)	20
		Mica	10
		Chlorite	10

Pier #2

Sample #	Depth (ft)	Mineralogy	Estimated %
1	0 - 1	Montmorillonite	75
		Quartz	25
5	4 - 5	Montmorillonite	60
		Quartz	15
		Gypsum	15
		Calcite	10
9	16 - 17	Montmorillonite	70
		Quartz	10
		Mica	10
		Chlorite	10
15	21.5-22.5	Montmorillonite	65
		Quartz	10
		Mica	10
		Chlorite	5
		Feldspars(2)	10
21	27.5-28.5	Montmorillonite	65
		Quartz	10
		Mica	10
		Chlorite	10
		Feldspars (2)	5
27	33.5-34	Montmorillonite	70
		Quartz	10
		Mica	10
		Chlorite	5
		Feldspars (tr)	5
32	38.5-39.5	Montmorillonite	70
		Quartz	10
		Mica	10
		Chlorite	5
		Feldspars (tr)	5

8AGC - 46

Sample No.	Depth	Mineralogy	Estimated %
M - 17522	39.7-40	Montmorillonite	70
		Quartz	10
		Mica	10
		Chlorite	5
		Feldspar	5
M - 17524	44.9-45.2	Montmorillonite	70
		Quartz	10
		Mica	10
		Chlorite	5
		Feldspar	5
M - 17525	50.3-50.7	Montmorillonite	70
		Quartz	10
		Mica	10
		Chlorite	5
		Feldspar	5

30 A - 283

Sample No.	Depth (ft)	Mineralogy	Estimated %
A of A	24	Montmorillonite	70
		Quartz	10
		Mica	10
		Chlorite	5
		Feldspar	5