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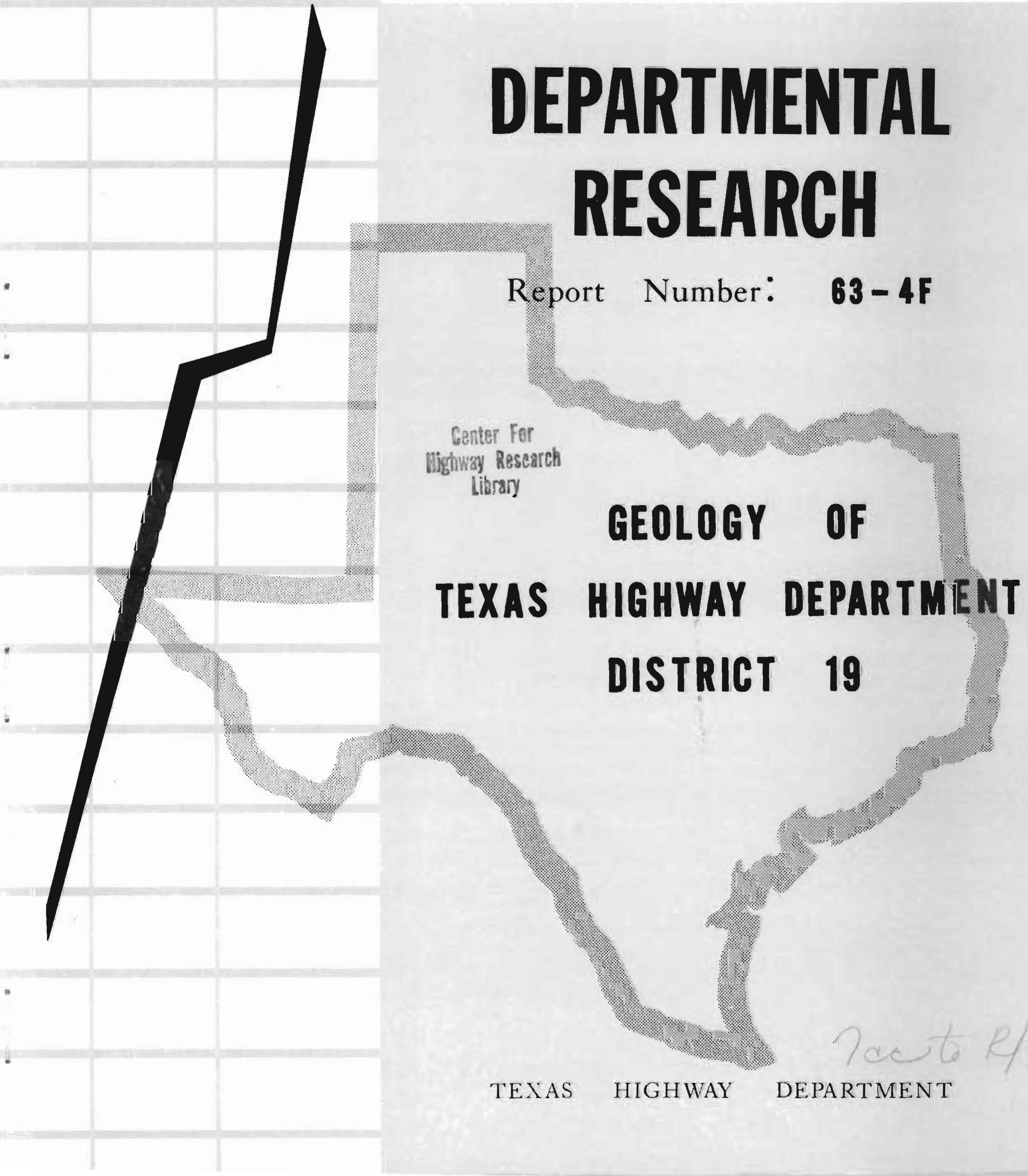

DEPARTMENTAL RESEARCH

Report Number: **63-4F**

GEOLOGY OF TEXAS HIGHWAY DEPARTMENT DISTRICT 19

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TEXAS HIGHWAY DEPARTMENT

GEOLOGY OF
TEXAS HIGHWAY DEPARTMENT DISTRICT 19

by

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Research Report 63-4 F

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2. <u>GEOLOGIC ATLAS OF TEXAS</u> - Tyler Sheet

ACKNOWLEDGMENTS

This work was conducted under the supervision of Mr. Sawyer R. Wimberly, District Design Engineer and the general supervision of Mr. G. A. Youngs, District Engineer of District 19, Atlanta, Texas.

Free access to the reports and other publications of the Bureau of Economic Geology of the University of Texas has been granted and liberally used.

Staff geologists of the Highway Design Division, as well as engineering personnel in District 19, have lent valuable assistance.

PART I. INTRODUCTION

PURPOSE OF REPORT

The purpose of this report is to condense available published information into a usable form so as to acquaint the highway engineer with the geologic conditions past and present in the District. A geologic history and description of geologic features and formations will be given. Secondly, Part III is an attempt by the authors to place into the record knowledge of the correlation existing between the geology and highway construction that has been gleaned by working with the materials in District 19.

Included is a glossary of geologic terms and a bibliography of references used in compiling the report.

LOCATION OF DISTRICT 19

District 19 of the Texas Highway Department is located in the northeast corner of Texas and includes the following counties: Bowie, Camp, Cass, Harrison, Marion, Morris, Panola, Titus, and Upshur.

District Headquarters are located in Atlanta, Texas with the Resident Engineer's Offices in Atlanta, Carthage, Gilmer, Marshall, Mt. Pleasant, and Texarkana.

PHYSIOGRAPHY OF DISTRICT 19

The District is bordered on the north by Red River and is traversed by several major drainage systems. Major streams include the Red, Sulphur, and Sabine Rivers and Big, Little, and Black Cypress Creeks.

Average temperature for the area is about 64° F with average minimum of 47° F and average maximum of 81° F. Average rainfall is 44 inches per year.

Oaks and pines comprise the majority of the timber in the area; however, there are many pecan, bois d'arc, gum, hickory, persimmon, and sassafras trees also found in the area.

PART II. GEOLOGY OF DISTRICT 19

HISTORY OF SEDIMENTATION

The sediments exposed in District 19 range in age from Navarro to Sparta. These units are Upper Cretaceous and Eocene in age. All were deposited under alternating marine and non-marine conditions.

Deposition of these sediments occurred in a geosynclinal basin known as the East Texas Basin. This basin, originally part of the extensive Mississippi Embayment, came into being as a result of the crustal disturbance that formed the Sabine Uplift. History of the beginning of the Sabine Uplift goes back to possibly as early as Lower Cretaceous and continued on into Tertiary time. Subsidence of the East Texas Basin continued as the rise of the Sabine Uplift progressed and as more sediments were deposited in the basin. Final subsidence was at the end of the Miocene deposition and as the whole area of the Mississippi Embayment was being elevated.

The cyclic depositional history of Tertiary sedimentation began after a long period of erosion at the end of Cretaceous time with the eroded upper cretaceous surface as the floor of the East Texas Basin.

The first deposits in the East Texas Basin were the basal Midway sediments. These sediments, dark, steel-gray calcareous shales and shaley clays, bear a great similarity to the late Cretaceous Navarro sediments indicating similar conditions of materials, topography, and climate in their respective source areas. During later Midway deposition, less limey material reached the sea and only finely divided terrigeneous detrital material was deposited. The occurrence of siderite concretions in Upper Midway clays marks the end of the great calcareous depositional cycle of Cretaceous time in the Gulf Coast region and initiates the period of iron deposition that culminated in Claiborne time. The close of Midway deposition came with the end of the crustal stability that had persisted throughout Midway time and had permitted the accumulation of 600 feet of homogenous mud in the slowly and uniformly subsiding basin. Maximum Midway Sea completely submerged the Mississippi Embayment.

A great change in the type of material entering the basin occurred with the renewal of deposition in Wilcox time. The black shaley clays of the Midway were replaced by light gray clays and medium-grained sands. The renewal of an environment conducive to deposition of glauconite, which was so common in the arenaceous Cretaceous sediments, occurred on the sea floor. Volcanic eruptions then contributed a thin layer of volcanic ash to the floor of the Wilcox Sea. This ashy material was altered to the bentonite now found in Wilcox sediments.

Much of the Wilcox sedimentation occurred in lagoonal conditions; therefore, the existence of lignite and carbonaceous clays is common in the section. The maximum Wilcox Sea extended only slightly north of 33° North Lattitude, but non-marine Wilcox was deposited throughout the northern extent of the Mississippi Embayment.

In the East Texas Basin proper, the Wilcox sediments were deposited in a steadily subsiding basin as is indicated by the shallow water nature of the sediments and the increasing thickness of these sediments in the central part of the basin. Filling of the embayment with clastic material, probably a result of decreased subsidence, forced the shore line seaward during late Wilcox time.

Rejuvenation of subsidence in the area occurred after a period of non-deposition at the end of Wilcox and the Carrizo sand was deposited probably in the zone of wave action.

Reklaw sediments covered the Carrizo sand when further subsidence of the embayment occurred. These Reklaw sediments were deposited just beyond the zone of wave action in water not much deeper than 150 feet. Reklaw deposition ended with uplift in the East Texas area and down-warping of the Mississippi Embayment which resulted in a southward retreat of the Gulf boundary.

Landward from the shore line in existence at the close of Reklaw time, the Queen City was being deposited under subaerial and fresh water conditions. As this deposition was occurring landward, the glauconitic marine sedimentation initiated in Reklaw time was continuing.

After 200 feet of Queen City sediments had accumulated in the basin, East Texas was again covered by an encroaching sea. This sea deposited 50 feet or more of glauconitic Weches sediments.

At the close of Weches deposition, a gentle uplift in the floor of the western part of the Mississippi Embayment occurred. On the landward side of the new shore line, a great deposit of white sand accumulated to a depth of 500 feet. This sand deposit is the Sparta Formation.

STRUCTURAL FEATURES - HISTORY AND DESCRIPTION

FAULTS

There are several faults visible on the surface in District 19. The largest and most pronounced is located in Titus and Morris Counties and is associated with the Mexia-Talco Fault System. The down-thrown side of the fault is to the north. The Talco and Pewitt Ranch Oil Fields are on this fault.

Other minor faults are found near Linden, Douglassville, Dalby Springs, Jefferson, Kildare, and Simms, but these are local and have no affect upon the regional geology of the area. However, oil fields occur on several of these faults.

ANTICLINES

SABINE UPLIFT

The crustal disturbance which formed the Sabine Uplift and affected a vast area of North Louisiana, East Texas, South Arkansas, and the entire Coastal Plain of Alabama and Mississippi began in early Cretaceous time. The affected area in Texas, Louisiana, and Arkansas acted as one structural unit throughout Tertiary time.

Final uplift occurred at the end of Micene time resulting in a net difference of 2,000 feet in elevation.

This final upward movement exposed the non-resistant Eocene sediments to erosional forces. Subsequent erosion of the underlying Wilcox and Midway sediments gave the Sabine Uplift its present surface expression as an inlier of Midway and Wilcox surrounded by Claiborne. The uplift is believed to have been caused by movement of molten material deep in the earth crust.

KELSEY ANTICLINE

The Kelsey Anticline is located seven miles west of Gilmer at the town of Kelsey. It is located on the axis of the East Texas Basin and separates what would be a continuous synclinal axis from East Texas northeast into Arkansas.

In Lower Cretaceous time, tilting associated with the upward movement of the Sabine Uplift occurred in Upshur County. At the same time differential movement occurred at Kelsey. This upward movement occurred along a north-south axis and did not affect the present anticline area, as is shown by a normal thickening of the Woodbine and Eagleford formations. This information is derived from drilling in the area.

Slightly differential warping occurred again in Taylor time after normal deposition of Austin sediments occurred, as is shown by the thinning of the Taylor sediments across the Anticline. Again deposition occurred in a normal manner until Wilcox time when more warping thinnned the Wilcox sediments across the Anticline. This movement in Wilcox time finally formed a closed structure.

Subsequent to deposition of Sparta sediments, and probably coincident with final movement of the Sabine Uplift, the whole geologic section was arched into the present Kelsey Anticline. This exposed the sediments to erosional forces. Surface expression is as an inlier of Carrizo, Reklaw, and possibly Wilcox sediments surrounded by Queen City. This outcrop is 15 miles south and 20 miles northwest of the nearest Wilcox.

The area of surface outcrop of the Kelsey Anticline is approximately 150 square miles and an east-west profile across the area shows over 200 feet of uplift above normal position of surface beds.

SYNCLINES

EAST TEXAS EMBAYMENT

Extensive history of development of the embayment is given in the section on History of Sedimentation.

The present surface expression of the embayment is defined by the outcrop of Claiborne sediments in Northeast Texas. Dip of the beds is toward the center of the embayment from either side along with a south component of regional dip.

DESCRIPTION AND LOCATION OF FORMATIONS

During the progress of the work in compiling this report, it was learned that the Tyler and Texarkana sheets of the new Geologic Atlas of Texas being compiled by the Bureau of Economic Geology would be completed before this report. It was felt (and the author's belief has been confirmed) that these sheets would do a more accurate and complete job of mapping and describing the formations encountered in District 19 than they could have attempted. Copies of the sheets are included with each report.

Further descriptions of the formations aimed at helping the highway engineer identify them in the field and delineating their highway engineering properties are given in Part III of this report.

PART III. HIGHWAY ENGINEERING GEOLOGY

INTRODUCTION

Uses of geology by the highway engineer are many and varied. They range from materials location to foundation engineering (a fault unknown in the foundation of a structure could be disastrous) to petrographic studies of aggregates used in concrete attempting to understand, for instance, the weathering process for the concrete.

In District 19 the uses of geology have been limited to materials location and pavement design as related to the foundation of the pavement.

One of the most perplexing problems facing the highway engineer is that of assigning a desirable density or optimum moisture to a soil sample that has been compacted by a contractor. Appendix A contains the results of an attempt to bring geology into play with this problem. This attempt consisted of correlating desired density and optimum moisture to soil constants. The samples were grouped by geologic group in an attempt to decrease the prediction error. Examination of the standard errors and coefficients of determination revealed little if any improvement in the grouped data over the ungrouped data.

The equations are presented herein even though geology appears to offer little improvement in them. It is felt that the data presented may be of some value to readers of this report.

The following description of the geologic formations attempts to add only the authors' opinions of the engineering properties to the geologic descriptions shown on the Texarkana and Tyler sheets of the Geologic Atlas of Texas contained in the back of this report. The reader should note that wherever a range of some test result (triaxial class 4.0 to 5.0) is given for a formation, this range should include 95 per cent of all the material in the formation.

NAVARRO GROUP

Topographically, the Navarro Group is expressed as gently rolling to flat farmland often covered by oak trees. The hilltops are capped by Pleistocene terraces that will be discussed later within this report. Silty clay, chocolate-brown to black, and gray to yellowish soils develop on this group. They are locally highly variable and test triaxially class 5.0 to 5.8. Lime treatment of the subgrade appears to be desirable due to the high variability.

MIDWAY GROUP

Flat to gently rolling prairies characterize the topography of the Midway Group. Trees along streams and low places are primarily oaks. Unweathered exposures are rare except along streams due to the thick soil cover formed.

Triaxially the parent material and the soils developed on it are the worst in District 19. Triaxial tests as poor as 6.2 are common and better than class 5.5 are rare. Plasticity indexes greater than 50 are common.

In low or flat terrain saturated, soft, mucky soils may be encountered to depths of five or six feet. Beneath this muck the compact, shaley clay of the parent material is often relatively dry and hard. Removal of this muck and exposure of the dry clay to available water can create serious swelling problems. Equally serious swelling problems occur with fluctuating moisture contents in the upper soil layers. The undulating surface of the sub-soil (or the highly variable thickness of the surface soil) also creates difficult construction and pavement design problems.

WILCOX GROUP

Topographically, the Wilcox Group is characterized by gently rolling hills with approximately equal amounts of pine and oak trees. Thick beds of sand-clay occur throughout the surface exposure. Triaxially the sand-clays and the soils covering them range from class 3.6 to 4.0. Thick shale beds are also encountered. These shales and the red, yellow, and gray clay soils developed upon them usually test triaxially class 5.0 to 5.7. Locally occurring between these thicker beds are soils that will test anywhere from 4.0 to 5.8 triaxially.

Low relief and the resultant "grass roots" grade lines that are built on this geologic group make the pedologic soil development important to the highway engineer. The locally occurring soils are excellently mapped on the Bowie County Soils Map currently used by District 19 personnel. The other counties (Titus, Harrison, and Panola) traversed by this formation, have only generalized maps available. The thick sand beds mentioned above provide sources for soil cement stabilization and sand-clay subbase. Usually five to eight per cent cement will give 300 psi at seven days and seven to ten per cent will give 500 psi.

The sand layers alternating with the shale (and some lignite) beds are always potential aquifers that may create hydrostatic water problems during construction. Often, opening of highway cuts with time will drain the aquifer. However, under-drains are sometimes required to speed up construction or even for perpetual drainage.

Swelling problems are relatively small considering the vastness of aerial exposure of this group. However, some isolated instances of this problem can be cited in Bowie, Titus, and Panola Counties.

CLAIBORNE GROUP

CARRIZO SAND

This thin formation pinches out along the north and south exposures eastward. Clean white sands develop as soils from the sand-clay parent material. Triaxially, these soils and the parent material test 3.5 to 4.2. Better strengths are obtained with the unleached parent material. This formation may be saturated when lying in position upon the Wilcox shales to perch a water table. It is a potential source of sand-clay subbase or soil cement wherever encountered.

REKLAW FORMATION

Entering the Reklaw from the Wilcox, an observer will first encounter outliers of Reklaw as oak covered hills, and then a pronounced escarpment of these hills. The thinner basal portion of the Reklaw consists of orange to red sandy clay that is often weakly cemented. This portion offers material usable for sand clay subbase - triaxial class 3.6 to 4.0.

Lying directly upon the exposed basal layer, iron-ore gravel top soils derived from the upper Reklaw glauconitic layers can often be found. See Appendix B for a discussion of the quality and usage for this gravel.

The soils and the parent material of the thicker upper portion of the Reklaw range triaxially from class 4.5 to 5.5. Often the layers are saturated and apparently act as an aquifer with the water held in fissures. The parent material forms red to purple soils.

QUEEN CITY FORMATION

This is the largest formation within the Claiborne Group in District 19. As such it contains clay lentils that are quite similar to the Weches and Rekalw formations above and below it. These lentils have similar characteristics to the Reklaw and Weches described herein. Ferruginous sandstone in both ledge form and as gravel occurs only in localized spots. It is not an important building material.

WECHES FORMATION

The Weches topography is hilly and plateau-like with deep V-shaped valleys. Red and mottled red and gray soils develop from the glauconitic sands and clays of the Weches formation. These soils and the parent material are the poorest triaxially to be encountered in the Claiborne Group. They range from class 4.5 to 5.8. Oxidation and weathering converts the glauconitic layers to iron-ore. Subsequent leaching of the clay results in iron-ore top soil producing the best naturally occurring base material found in District 19. The quality and uses for this material are discussed in Appendix B.

Heterogeneous deposition complicated by induration of cross-bedded seams make hydrostatic water problems that are hard to define by drilling both before and after roadway cuts are opened in this formation. During plan preparation it has been found that it is advantageous to anticipate having to place under-drains and make some rock excavation when roadways cut through this formation.

SPARTA SANDS

Capping the Weches hilltops is the Sparta Sand. Deep white to tan, sandy soils form on the parent sand and clay material. Triaxially the soils and parent material test class 3.6 to 4.3, with the leached top soil testing weakest. This material is a potential source for sand clay subbase or soil cement stabilization wherever encountered.

Often a perched water table on the underlying Weches formation is found. Density control of these sands is complicated when the top soils (the leached soils) and the parent sand clays are mixed.

PLEISTOCENE TERRACES

QT-5

This terrace is not mapped as occurring within District 19. However, it has been important to highway construction because of the thousands of yards of gravel hauled from near Foreman, Arkansas. This siliceous gravel generally has greater than 60 per cent retained on the 40 mesh sieve. Plasticity index varies from 6 to probably as high as 40, thereby necessitating thorough testing of any outcrop.

QT-4

In and near Texarkana this terrance has provided sandy to clayey gravel, both as flexible base and as concrete aggregate. The clay content is often quite high. Industrial, commercial and residential development in this area precludes its providing much additional material in the future. Serious hydrostatic problems have occurred in the sands and gravels of this terrace and the underlying basal Wilcox in the Texas side of Texarkana. Basically, the problem is caused by the thick aquifer (±100 feet) of terrace gravel and basal Wilcox sands lying on the impervious Midway.

Little gravel has been found in the remaining mapped terrace. However, a gravel veneer occurs in isolated spots (not mapped) on the Midway north of U. S. Highway 67 and on the Wilcox east of Akin Creek. This veneer has provided most of the flexible base for farm-to-market roads in the area. The terraces in and near Foreman, Arkansas, have been worked extensively for gravel. Recently, this location has provided Processed Gravel, Cement Treated, for use on the shoulders of Interstate Highway 30 near New Boston, Texas. Triaxially, the terrace gravels seldom test better than class 3.0 or worse than class 3.6. However, three to five per cent cement usually gives 500 psi in seven days. For the binders with a higher plasticity index, lime appears to be a satisfactory stabilizer.

QT-3

Two significant features of this terrance should be noted. First, is the extremely flat surface covered with oaks. The soil is an impervious, gray, silty clay that tests triaxially from class 5.5 to 5.8. External and internal drainage is very slow. The second feature is the gradational change at two to six feet into a fine sand. This sand has been used to depths of 20 feet as borrow and subbase. Triaxially, it is about class 4.0.

QT-2

The surface soils and the topography of the area mapped as QT-2 are almost identical as that mapped as QT-3. However, it is not known that the thick sands exist below the surface.

QT-1 AND QAL (in Red River Flood Plain)

These two mapped units make up what is known locally as the Red River bottom. The soils vary from black waxy clays to beach sands. Often the surface soil can be stripped away two to four feet to expose sands to use for borrow and subbase.

These sands seldom test triaxially better than class 4.0.

QT (undivided)

In the Sulphur River drainage basins these terraces are usually clay. Some large deposits of clean sand occur in these terraces on other drainage basins traversing the Claiborne Group.

GOODLAND LIMESTONE (OKLAHOMA)

This Cretaceous formation has provided crushed limestone flexible base for use in northwestern Bowie County. The material of best quality has been the rudistid reef. Some minor freeze damage has occurred in this base and some difficulty occurred in meeting the specifications for Item 248, Type A, Grade Two, Flexible Base. Both difficulties can probably be attributed to an infiltration of the overlying Kiamichi clay into the solution cavities of the Goodland reefs.

GLOSSARY

ALLUVIUM: Soil, sand, gravel, or similar detrital material deposited by running water, especially during recent geologic time.

ANTICLINE: An upfold or arch of stratified rock in which the beds or layers dip in opposite directions from the crest.

ARENACEOUS: Sandy or largely of sand (of the nature of sand) as "arenaceous" limestone.

AXIS: A line following the highest elevation of a ridge or the lowest depth of a depression in the earth's surface.

BASIN: An area in which the strata dip usually from sides toward a center.

BENTONITE: A soft, porous, moisture-absorbing rock, composed essentially of clayey minerals, often of volcanic origin.

CALCAREOUS: Of the nature of calcite or calcium carbonate, consisting of or containing calcium carbonate.

CLASTIC: A rock made up of fragments of pre-existing rocks.

CLOSED STRUCTURE: A structural high or low shown by closed contour lines.

COLUMN: A diagrammatic representation of the chronological order of formations.

CONCRETION: A mass of mineral matter, generally in rock of a composition different from its own, produced by deposition from aqueous solution in the rock.

CROSS-BEDDED: Characterized by a system of minor beds or laminae oblique to the main beds of stratified rock.

CRUST: The exterior portion of the earth, formerly universally supposed to enclose a molten interior. The term is still used to designate the relatively cool outer part of the globe as distinguished from the unknown hotter part within.

DETRITUS: Any loose material that results directly from rock disintegration, especially when composed of rock fragments.

DISTURBANCE: A crustal movement.

EMBAYMENT: An arm or branch extending from a major geosyncline.

ENCROACHING: Invasion of advancing sea.

EXCARPMENT: A slope which is much steeper than normal and extends for a considerable distance.

FAULT: A fracture in the earth's crust accompanied by a displacement of one side of the fracture with respect to the other and in a direction parallel to the fracture.

FERRUGINOUS: Containing iron.

FORMATION: Any sedimentary bed or consecutive series of beds sufficiently homogeneous or distinctive to be regarded as a unit and perhaps given a name.

GEOSYNCLINE: A large depositional basin which subsides as deposition is occurring.

GLAUCONITE: A complex silicate containing iron that weathers to limonite.

GLAUCONITIC: Containing Glauconite.

GROUP: Successive formations, related by lithology or position with reference to unconformities.

HOMOGENEOUS: Uniform in character.

IMMATURE SOIL PROFILE: A pedologic profile which does not contain all of the three normal, A, B, or C zones.

INLIER: A small, isolated area of older beds surrounded by younger.

LAGOONAL: Having the characteristics of a lagoon.

LIGNITE: A soft, black, organic rock.

LITHOLOGY: Referes to the character of the rock, regardless of how or when it was acquired.

MARINE: Derived from the sea.

MATURE SOIL PROFILE: A vertical soil section showing three distinct horizons: (1) the A horizon, (2) the B horizon, and (3) the C horizon or parent material.

MEMBER: Individual parts of a formation.

NON-MARINE: Derived from the land masses.

OUTCROP: Area of exposure of a lithologic unit.

REGIONAL DIP: The major direction of dip for an area.

REGRESSION: Retreat of the sea from a continental area.

REJUVENATION: A renewal process.

RELIEF: Elevation above or below a reference level.

SEDIMENT: A deposition upon the surface of the earth deposited by either wind, water, or ice.

SERIES: A major group of rocks.

SIDERITE: A mineral composed of iron carbonate.

SILICEOUS: Containing silica.

STRUCTURAL CLOSURE: The seal produced by the dip of the rock in all directions away from an anticlinal crest.

SUB-AREIAL: Formed under atmospheric environment.

SUBSIDENCE: Down warping of a depositional basin.

SYNCLINE: A down-warped fold.

TERRACE: Topographic surface which mark former valley floor levels.

TERRIGENOUS: Derived from the erosion of land areas.

TRANSGRESSION: An advancement of the sea upon a continental area.

TRANSITIONAL: Gradual change from one condition to another.

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APPENDIX A

MOISTURE-DENSITY CORRELATIONS

APPENDIX A

MOISTURE-DENSITY CORRELATIONS

The correlation existing between desired moisture and density and various soil constants has been found useful when a quick estimate for Desired Density (D_A) or Estimated Optimum Moisture is needed. It was postulated that this correlation might be better if the samples used in the regression analyses were restricted to one formation. The samples were therefore grouped into those from the Claiborne Group, the Midway-Wilcox Groups, and the Quarternary samples. Although these are rather broad geologic classifications, it would have been difficult to separate the samples further. All test results used were from samples containing 95 per cent or more passing the No. 40 sieve.

Examination of the standard errors of estimate and the coefficients of determination shown in Tables IA and IIA indicates that improvement in correlation was not obtained when the samples are separated into the geologic formations chosen.

Models other than the simple ones shown give better correlation, but any improvement by geologic grouping still seems to be nil.

SYMBOLS

EOM - Estimated Optimum Moisture
BLS - Bar Linear Shrinkage
PI - Plasticity Index
LL - Liquid Limit
D_A - Desired Density
D_D - Dense Density

Note: All test results used in this report were taken from the records of the District 19 Laboratory. All of these test results were obtained using standard Texas Test Methods.

TABLE IA

REGRESSION EQUATIONS FOR DESIRED DENSITY (D_A)

Equation I. $D_A = A + B$ (BLS)

FORMATION	REGRESSION CONSTANT		STANDARD ERROR OF ESTIMATE	COEFFICIENT OF DETERMINATION r^2	NUMBER OF SAMPLES
	A	B			
Quaternary	118.52	-0.81	6.3	0.38	82
Midway-Wilcox	118.55	-0.99	4.8	0.65	204
Claiborne	117.75	-0.96	7.8	0.24	64
All Samples	118.41	-0.95	5.9	0.51	350

Equation II. $D_A = A + B$ (PI)

FORMATION	REGRESSION CONSTANT		STANDARD ERROR OF ESTIMATE	COEFFICIENT OF DETERMINATION r^2	NUMBER OF SAMPLES
	A	B			
Quaternary	118.42	-0.447	6.0	0.42	83
Midway-Wilcox	119.13	-0.518	4.6	0.70	237
Claiborne	118.14	-0.487	6.9	0.39	81
All Samples	118.80	-0.501	5.4	0.59	401

TABLE IA, Cont.

Equation III. $D_A = A + B\ (LL)$

FORMATION	REGRESSION CONSTANT A	REGRESSION CONSTANT B	STANDARD ERROR OF ESTIMATE	COEFFICIENT OF DETERMINATION r^2	NUMBER OF SAMPLES
Quaternary	128.07	-0.482	5.0	0.60	83
Midway-Wilcox	127.86	-0.482	3.7	0.80	237
Claiborne	129.61	-0.526	5.3	0.64	81
All Samples	128.25	-0.490	4.3	0.74	401

Equation IV. $D_A = A + B\ (D_D)$

FORMATION	REGRESSION CONSTANT A	REGRESSION CONSTANT B	STANDARD ERROR OF ESTIMATE	COEFFICIENT OF DETERMINATION r^2	NUMBER OF SAMPLES
Quaternary	-19.74	1.11	3.0	0.85	83
Midway-Wilcox	-46.35	1.33	3.1	0.86	237
Claiborne	-16.59	1.08	3.2	0.87	81
All Samples	-33.09	1.22	3.2	0.85	401

TABLE IA, Cont.

Equation V. $D_A = A + B (D_D) + C (LL)$

FORMATION	REGRESSION CONSTANT A	B	C	STANDARD ERROR OF ESTIMATE	COEFFICIENT OF DETERMINATION r^2	NUMBER OF SAMPLES
Quaternary	19.46	0.352	-0.254	1.2	0.979	83
Midway-Wilcox	21.31	0.838	-0.262	1.0	0.977	237
Claiborne	23.29	0.816	-0.243	1.9	0.954	81
All Samples	21.87	0.832	-0.259	1.4	0.972	401

Equation VI. $D_A = A + B (PI) + C (LL)$

FORMATION	REGRESSION CONSTANT A	B	C	STANDARD ERROR OF ESTIMATE	COEFFICIENT OF DETERMINATION r^2	NUMBER OF SAMPLES
Quaternary	137.81	0.69	-1.08	4.4	0.69	83
Midway-Wilcox	134.19	0.48	-0.88	3.4	0.83	237
Claiborne	140.97	0.86	-1.21	4.1	0.78	81
All Samples	136.49	0.61	-1.00	3.8	0.79	401

TABLE I_A, Cont.

Equation VII. $D_A = A + B\ (PI) + C\ (LL) + D\ (PI)(LL)$

FORMATION	REGRESSION CONSTANT				STANDARD ERROR OF ESTIMATE	COEFFICIENT OF DETERMINATION r^2	NUMBER OF SAMPLES
	A	B	C	D			
Quaternary	137.81	0.67	-1.30	.004	4.3	0.70	83
Midway-Wilcox	135.65	0.43	-0.90	.001	3.4	0.83	237
Claiborne	142.39	0.81	-1.25	.001	4.1	0.88	81
All Samples	138.26	0.56	-1.06	.001	3.8	0.80	401

TABLE IIA

REGRESSION EQUATIONS FOR ESTIMATED OPTIMUM MOISTURE (EOM)

<u>Equation I</u>. EOM = A + B (BLS)

FORMATION	REGRESSION CONSTANT A	REGRESSION CONSTANT B	STANDARD ERROR OF ESTIMATE	COEFFICIENT OF DETERMINATION r^2	NUMBER OF SAMPLES
Quaternary	11.33	0.46	2.5	0.57	83
Midway-Wilcox	11.20	0.51	2.4	0.67	201
Claiborne	11.07	0.69	3.7	0.43	64
All Samples	11.41	0.51	2.8	0.57	348

<u>Equation II</u>. EOM = A+B (PI)

FORMATION	REGRESSION CONSTANT A	REGRESSION CONSTANT B	STANDARD ERROR OF ESTIMATE	COEFFICIENT OF DETERMINATION r^2	NUMBER OF SAMPLES
Quaternary	11.50	0.24	2.3	0.60	84
Midway-Wilcox	10.87	0.27	2.5	0.68	234
Claiborne	11.18	0.32	3.2	0.56	81
All Samples	11.17	0.27	2.6	0.63	399

TABLE IIA, Cont.

Equation III. EOM = A + B (LL)

FORMATION	REGRESSION CONSTANT			STANDARD ERROR OF ESTIMATE	COEFFICIENT OF DETERMINATION r^2	NUMBER OF SAMPLES
	A	B				
Quaternary	6.72	0.25		1.8	0.76	84
Midway-Wilcox	6.46	0.25		2.1	0.77	234
Claiborne	4.35	0.33		2.0	0.82	81
All Samples	6.27	0.26		2.1	0.77	399

Equation IV. EOM = A + B (LL) + C (PI)

FORMATION	REGRESSION CONSTANT			STANDARD ERROR OF ESTIMATE	COEFFICIENT OF DETERMINATION r^2	NUMBER OF SAMPLES
	A	B	C			
Quaternary	3.52	0.45	-0.23	1.6	0.80	84
Midway-Wilcox	4.07	0.40	-0.18	2.0	0.78	234
Claiborne	-0.66	0.63	-0.38	1.4	0.91	81
All Samples	2.70	0.48	-0.26	1.9	0.81	399

TABLE IIA,Cont.

Equation V. $EOM = A + B\ (D_A)$

FORMATION	REGRESSION CONSTANT		STANDARD ERROR OF ESTIMATE	COEFFICIENT OF DETERMINATION r^2	NUMBER OF SAMPLES
	A	B			
Quaternary	60.07	-0.40	1.7	0.78	83
Midway-Wilcox	66.06	-0.46	2.2	0.76	234
Claiborne	71.31	-0.50	2.0	0.82	81
All Samples	65.73	-0.45	2.1	0.77	399

APPENDIX B

SUMMARY OF DISTRICT 19 TESTS ON IRON ORE TOPSOIL

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SUMMARY OF DISTRICT 19 TESTS ON IRON ORE TOPSOIL

These test results are summarized in this report so that they can be readily available to engineers studying the general problem of base material supply for District 19.

Weches Formation

Figure 1 B summarizes the triaxial test results on iron ore topsoil. The graph indicates that the triaxial strengths obtained are in part controlled by the amount of aggregate in the sample. Note that nine of the twenty three Weches samples tested stronger than triaxial class 2.5 and that four of these nine were class one. This indicates that it is possible to obtain strong base material from this formation and points up the necessity of testing each source if this triaxial strength is desired.

Reklaw Formation

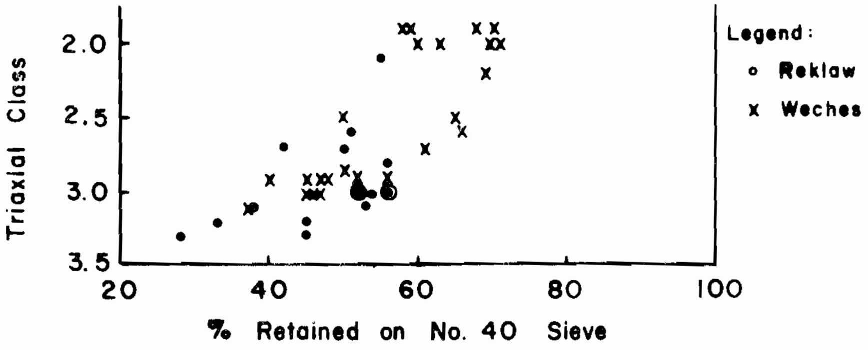
Figure I B also summarizes the triaxial test results on the Reklaw formation. These samples exhibit the same trends as the Weches. Note that no naturally occurring Reklaw samples had more than 56 percent retained on the forty mesh sieve. Also note that only one of the eighteen samples exhibited strengths better than triaxial class 2.6.

Cement Treated Iron Ore Topsoil

Figure II B summarizes tests to date on iron ore gravel treated with portland cement. Note that for the one Weches sample there exists a much higher cohesiometer strength to compressive strength ratio than for the Reklaw samples. Note also that the several Reklaw samples exhibited a fairly constant ratio of cohesiometer to compressive strength. The second point is believed true only because all the Reklaw samples were quite similar in gradation, plasticity, etc.

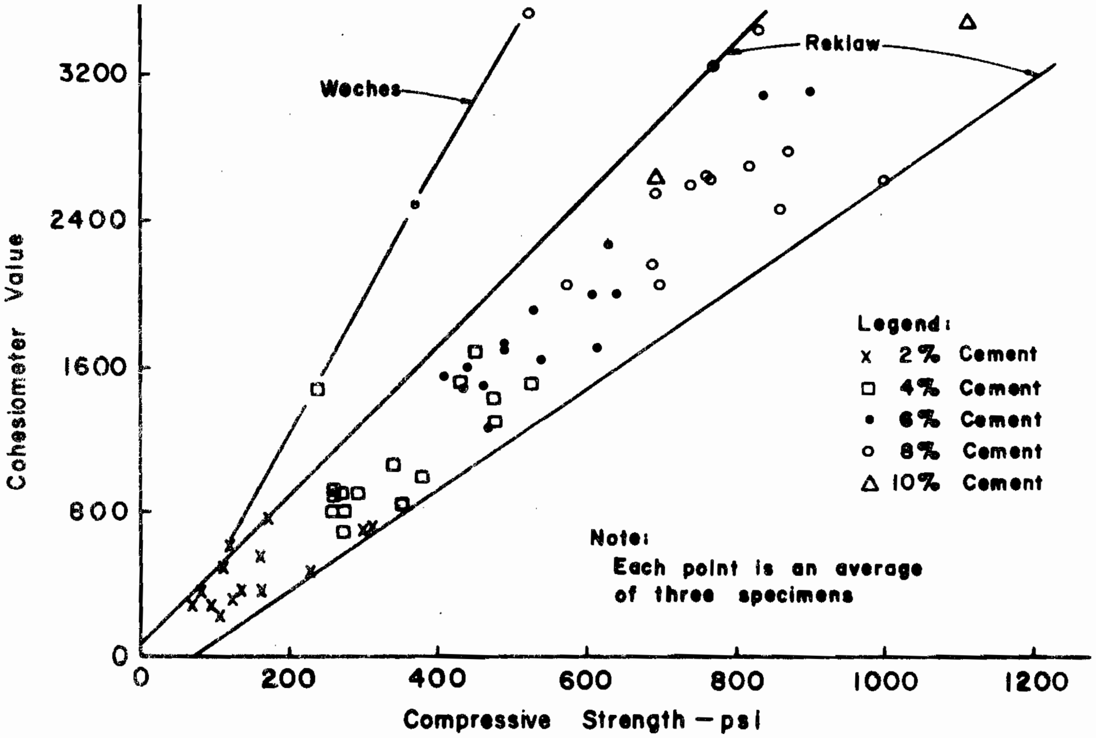
It is believed that the higher cohesiometer strengths for the Weches samples could be largely explained by a lower water-cement ratio. This sample had more aggregate and a denser gradation resulting in both less water at optimum and a greater quantity of cement by volume than is indicated when measured on a percent by weight basis.

At this writing there can be no opinions expressed on the performance of the cement treated iron ore. Its use in District 19 is too new. The untreated material has been used in this area since the time of the first unsurfaced roads. Its use examplifies a Texas Highway Department axiom - "Maximum use of local materials - locally available stone, gravel, shell, or other aggregates - is one essential to low cost roads"; as often stated by Mr. D. C. Greer.



TRIAXIAL TESTS ON IRON ORE TOPSOIL GRAVEL

Figure I B



Note:
Each point is an average of three specimens

COMPRESSIVE STRENGTH VERSUS COHESIOMETER VALUE FOR CEMENT TREATED IRON ORE GRAVEL

Figure II B