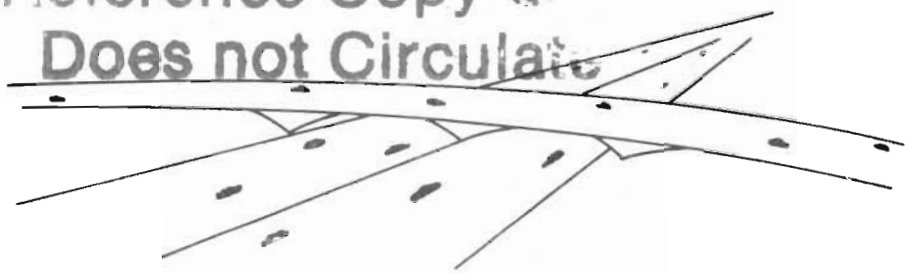

# DEPARTMENTAL RESEARCH

Report Number: 63 – 2

# THE SURFACE GEOLOGY AND RELATED SOILS OF DISTRICT 2



TEXAS HIGHWAY DEPARTMENT

# THE SURFACE GEOLOGY AND RELATED SOILS OF DISTRICT 2

by

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Geologist

Research Report 63-2

Preparation of Geology Information
for use in the Texas Highway Department
Research Project 1-8-63-63


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The opinions, findings, and conclusions expressed in this publication are those of the authors and not necessarily those of the Bureau of Public Roads.

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Particular acknowledgment is given to Dr. Dan E. Faray, Chairman of the Geology Department of Texas Christian University, for the use of his work in Palo Pinto, Jack, and Wise Counties. The writer is indebted to Dr. Daniel Jarvis for suggestions and criticism made during the preparation of this report and Mr. John G. McKenna for his help in mapping the geology of the District.

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## ABSTRACT

The purpose of this report is to provide a reference for personnel of the Fort Worth District of the Texas Highway Department. It is intended that this report be presented in such a manner that personnel with little or no understanding of geology may identify and recognize the geologic materials in their respective areas and operations. This report is not a detailed report of base material pits, physical properties of soils or geological formations, but only a guide to assist in the planning of future highway routes.

# INTRODUCTION

District 2 of the Texas Highway Department is located in the north-central part of the state, approximately 300 miles from the Gulf of Mexico. The district is composed of the following counties: Jack, Wise, Palo Pinto, Parker, Tarrant, Erath, Hood, Somervell, and Johnson. There are 7022 square miles in the district, and elevations range from a low of 500 feet in Tarrant County to a high of 1750 feet in Erath County. The temperature ranges from an average of 45° in January to 85° in July, with an average of 66°.

The surface rock of District 2, with the exception of the gravels and other alluvial deposits, are of two geological ages, the Cretaceous and the Pennsylvanian. The western one-half of the district is primarily Pennsylvanian rock which dips to the northwest at 50 feet per mile. The remaining portion of the district is Cretaceous rock that dips to the southeast at 40 feet per mile. Figures I and IA represent the geologic column found in District 2.

The packet of geology maps included with this report represents the most recent mapping available to the author plus considerable field work. This field work was conducted by walking out the key beds where it was possible. By using a hand level and measuring tape, thicknesses were determined on units exposed in steep escarpments. Much of the work was carried on in the laboratory with the aid of aerial photographs.

For each of the resident offices in District 2 and the District Design Section, there will be issued a colored geologic map. Accompanying these maps will be a generalized soils map that shows the limits of the various soils and how they correspond with the geologic formations.

| EXPLANATION | | | | |
|---|---|---|---|---|
| SYSTEM | SERIES | GROUP | FORMATION | MEMBER |
| CARBONIFEROUS [C] | PENNSYLVANIAN [Cp] | CISCO [Ccs] | HARPERSVILLE [Ccsh] | Saddle Creek Ls [Chsc] |
| | | | THRIFTY [Ccst] | Breckenridge Ls [Cbr] |
| | | | | Shale |
| | | | | Black Ranch Ls |
| | | | | Shale and Sandstone |
| | | | | Ivan Ls |
| | | | | Shale and Sandstone |
| | | | | Avis Sandstone |
| | | | GRAHAM [Ccsg] | Wayland Shale |
| | | | | Gunsight Ls [Cg] |
| | | | | Necessity Shale and Sandstone |
| | | | | Bunger Ls [Cbu] |
| | | | | Gonzales Creek Ls, Sh, SS. [Cgz] |
| | | | | Eastland Sandstone |
| | | | | Gonzales Ls |
| | | | | Finis Shale |
| | | CANYON [Ccn] | CADDO CREEK [Ccncc] | Jacksboro Ls (Jack Co.) [Cj] |
| | | | | Home Creek Ls [Ch] |
| | | | | Sand and Limestone |
| | | | | Hogg Creek Shale |
| | | | | Limestone and Shale |
| | | | BRAD [Ccnb] | Ranger Ls [Crg] |
| | | | | Placid Shale beds; Ls & Sh |
| | | | | (Ventioner beds) |
| | | | GRAFORD [Ccng] | Adams Branch Ls (Jack Co.) [Cab] |
| | | | | Clear Creek Ls |
| | | | | Fusulina bed |
| | | | | (Palo Pinto County) / (Wise County) |
| | | | | Merriman Ls [Cmr] / Devils Den Ls |
| | | | | Wolf Mt. Shale [Cwm] / Chico Ridge Ls |
| | | | | Sand / Jasper Creek Sh |
| | | | | Lime / Rock Hill Ls |
| | | | | Shale / Lake Bridgeport Sh |
| | | | | Wiles Ls [Cw] |
| | | | | Posideon Shale [Cpo] |
| | | | | Palo Pinto Ls [Cpp] |
| | | STRAWN [Cst] | MINERAL WELLS [Cstmw] | Keechi Creek Sh / Willow Point |
| | | | | Shale & Limestone / Bridgeport Coal |
| | | | | Turkey Creek SS / Balsora Ls |
| | | | | Shale & Sand / Sanders Bridge Ls |
| | | | | Salesville Shale / Boone Creek Ls |
| | | | PALO PINTO Wise Co. Jock Co. | Sand, Shale, & Limestone / Shale |
| | | | | Dog Bend Limestone [Cdb] / Martin Lake Ls |
| | | | | Shale & Limestone / Shale |
| | | | | Lake Pinto SS [Clp] / Hudson Bridge Ls [Chb] |
| | | | | Shale |
| | | | | Village Bend Ls [Crb] |
| | | | | East Mt. Shale |
| | | | | Hogg Mt. SS [Chm] |
| | | | GARNER [Cstg] | Brazos River SS [Cbz] |
| | | | | Mingus Shale |
| | | | | Thurber Coal [Ct] |
| | | | MILLSAP LAKE [Cstm] | Grindstone Creek: Goen Ls [Cgo] / Shale / Santo Ls [Cso] / Shale & Sand |
| | | | | Lazy Bend: Brannon Bridge Ls [Cbb] |
| | | | | Steussy Shales |
| | | | | Meek Bend Ls |
| | | | | Hill Creek beds |
| | | | | Dennis Bridge Ls |
| | | | | Kickapoo Falls Ls |
| | | | | Lazy Bend beds |
| | | | | Dickerson beds |

FIGURE I

GEOLOGIC COLUMN

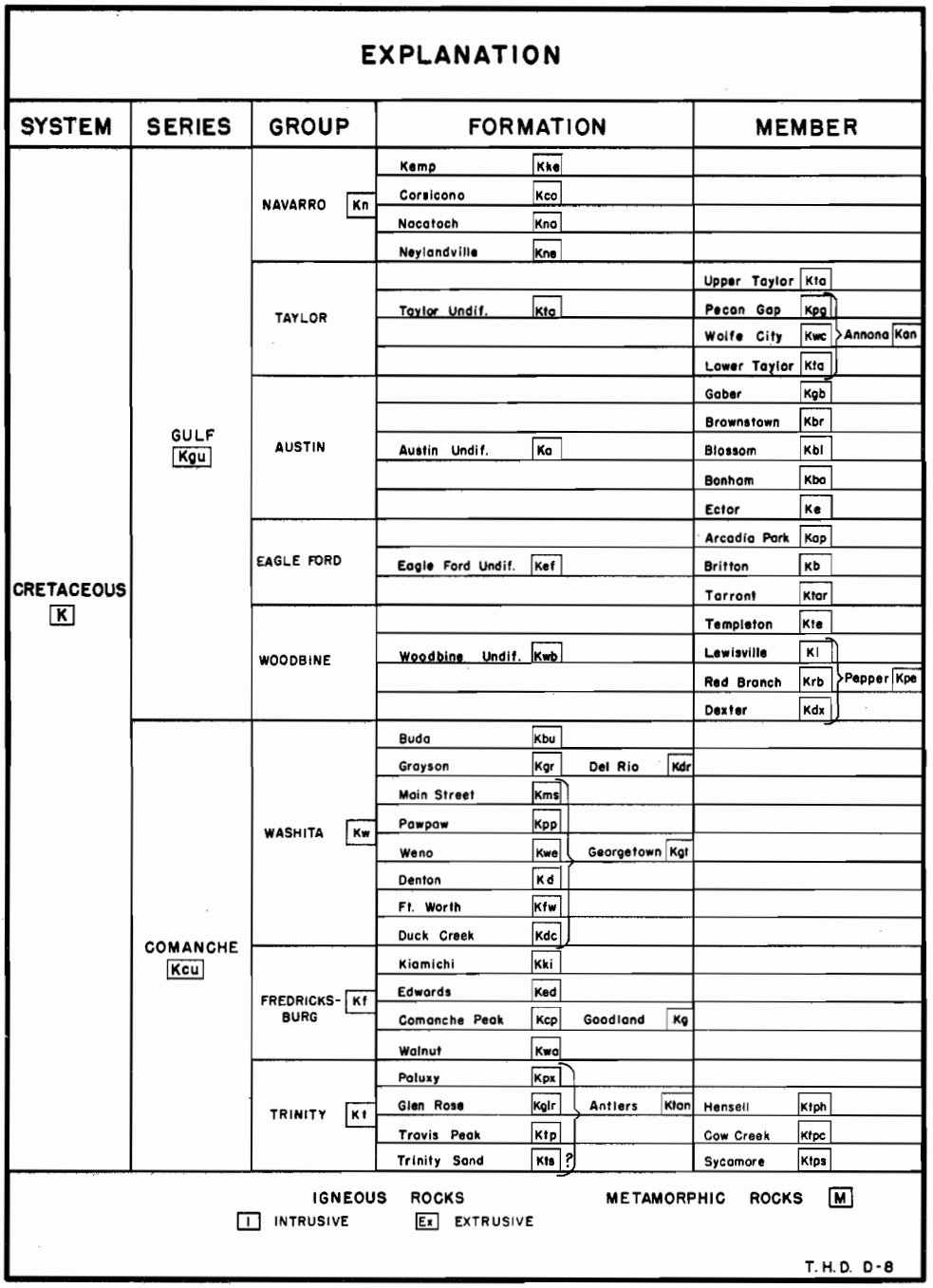


FIGURE IA
GEOLOGIC COLUMN

DESCRIPTION OF GEOLOGICAL
FORMATIONS, ASSOCIATED SOILS,
AND ENGINEERING USES

CARBONIFEROUS SYSTEM

PENNSYLVANIAN SERIES

STRAWN GROUP

MILLSAP LAKE FORMATION

The Millsap Lake formation is exposed in southwestern Parker County, southeast Palo Pinto County, and northern Erath County. The topography ranges from nearly level shale sections to steep escarpments of resistant limestone and sandstones. The Millsap Lake formation has a total thickness of about 600 feet in District 2. This formation is divided into three separate members. These members are the Grindstone Creek, Lazy Bend, and the Dickerson.

Dickerson Member - The Dickerson member is not exposed in District 2, but only mentioned as being part of the Millsap Lake Formation.

Lazy Bend Member - The Lazy Bend member is a series of shales, sandstones, and limestones between the base of the Kickapoo Falls Limestone and the top of the Brannon Bridge Limestone. This member consists of several sub-members and they are as follows: Kickapoo Falls Limestone, Dennis Bridge Limestone, Hill Creek beds, Meek Bend Limestone, Stenssy shales, and the Brannon Bridge Limestone.

Kickapoo Falls Limestone Sub-Member - The Kickapoo Falls Limestone is about 5 feet thick, gray on fresh exposure and weathers to a dull blue gray. It is thick bedded, hard, and fossiliferous. This limestone is very limited in its lateral outcrop extent.

Dennis Bridge Limestone Sub-Member - The Dennis

Bridge Limestone is 10 feet thick, fine-grained, gray on fresh exposure and weathers to a light gray. It is massively bedded in the lower portion and irregularly, thinly bedded in the upper portion.

Hill Creek Beds Sub-Member - Lying directly over the Dennis Bridge Limestone are the Hill Creek beds. This is a series of shales, sandstones, and a few thin limestone layers. The total section of the Hill Creek sub-member is about 80 to 85 feet thick. The shales of the Hill Creek are weathered gray, poorly laminated, and range from pure clay to silty clay. The sandstones are generally poorly bedded, medium to fine-grained, massive noncalcareous bodies. The limestones are usually light gray in color, crystalline, and well bedded in the thicker developed areas. Where it is less than 3 feet thick, it is a brown color and sometimes sandy.

Meek Bend Limestone Sub-Member - The Meek Bend Limestone is a 12 foot thick layer lying directly above the Hill Creek beds. The bedding of this limestone varies from flaggy to massive. The color is gray, with some beds having brown and other varieties of gray and brown. All weather to a light gray.

Stenssy Shale Beds Sub-Member - The Stenssy Shale beds are a series of shales and thin linticular sandstones that are about 180 feet thick. The shales are dark gray and weather to a light gray, poorly laminated, and range from a clayey to a silty shale. Near the middle of the shale beds is a series of sandstones that are 1 to 18 inches thick. The bedding is thick, massive, and the grain size ranges from fine to coarse. The sandstones are noncalcareous.

Brannon Bridge Limestone Sub-Member - The Brannon Bridge Limestone is the top sub-member of the Lazy Bend member. This sub-member actually consists of two limestones that are separated by a shale and

sand body. The lower limestone is about 15 feet thick, fairly pure and crystalline. It is a gray limestone and weathers to a light gray. The bedding surfaces are uneven, and the bedding thickness ranges from 2 to 18 inches. This lower limestone is separated by a shale section of 22 feet. There is a 4 foot thick sandstone present in the shale. It is fine-grained, well sorted, but poorly bedded and lenses out rapidly.

The upper limestone of the Brannon Bridge is 17 feet thick. It is crystalline, the bedding planes are uneven, and the bedding is poor. The thickness of the individual beds ranges from 3 to 24 inches.

Grindstone Creek Member - The Grindstone Creek member is composed chiefly of shales, sands, and thin limestones occurring immediately above the Brannon Bridge Limestone. In this member there are only two sub-members that have been identified and named. These sub-members are the Goen Limestone and the Santo Limestone. There is also a series of beds that are unnamed.

The shales are clayey and poorly laminated, and the sandstones range from medium to coarse-grained, well bedded to massive bedded and usually well sorted.

Santo Limestone Sub-member - The Santo Limestone is 2 to 4 feet thick, and the bedding is irregular to massive. The limestone is gray to brownish-gray on the fresh break and weathers to a light gray, and is fairly pure.

Goen Limestone Sub-member - The Goen Limestone is 1 to 2 feet thick and fossiliferous. It is gray to yellowish-gray in color and weathers to a light gray.

The Darnell and the Renfro soils are the predominant soils derived from the Millsap Lake formation. The Darnell series develops on non-calcareous mostly reddish sandstones.

The color of the surface soil ranges from grayish-brown to brown and is about 5 to 20 inches thick before sandstone bedrock is encountered. The topography is an erosional upland with gradients ranging up to about 15%. The drainage is rapid both internally and externally.

The Renfro series includes soil developed from weakly calcareous clayey red beds. Clays and silts are the principal types of material. The color of the surface, and sub-surface layers ranges from brown to reddish-brown in the Renfro soil series. The topography is undulating erosional upland with gradients of about 2 to 7%. The drainage is rapid from the surface but slow internally.

Except for the Brannon Bridge Limestone, the Millsap Lake formation offers little in the form of road building material. The Brannon Bridge Limestone has in the past, and is now, producing good material for concrete aggregate, hot mix aggregate, and flexible base. The raw Texas Triaxial Class* ranges from 2.3 to Class 1. Hydrated lime has been added to this limestone and the resulting mixtures yielded Texas Triaxial Class 1. The average soil binder is 22% and the average increase of soil binder after the Texas Ball Mill is 9%.

GARNER FORMATION

In District 2 the Garner Formation is exposed in western Parker, northwestern Erath and southwest, south and eastern Palo Pinto Counties. The Garner Formation is expressed topographically as the gentle to undulating prairies of the Mingus Shale and the steep and rugged escarpments of the Brazos River Sandstone.

There are three members that comprise the Garner Formation. These three members are the Brazos River Sandstone, Mingus Shale, and the Thurber Coal.

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*All laboratory test results referred to in this report are standard Texas Test Method results.

Thurber Coal Member - The Thurber Coal is a 2 foot thick seam of black, hard, and fragile coal. This coal seam is the only coal that has been successfully and economically mined in Palo Pinto County.

Mingus Shale Member - The Mingus Shale member ranges in thickness from 145 feet in northwest Erath, thickening to the northeast, to 210 feet in western Parker County. The Mingus Shale is composed of shales that range in color from gray to bluish-gray. It is sandy with a few poorly preserved fossils. There are a few sandstone layers present in the Mingus member. They are from 2 to 19 feet thick. These sandstones are fine-grained, thin bedded (1 to 3 inches), and calcareous. The Mingus Shale is exposed on the broad mesquite covered flats and on the sides of the escarpments supported by the Brazos River Sandstone.

Brazos River Sandstone Member - The Brazos River Sandstone member is composed of lower and upper ledge forming sandstones separated by approximately 40 feet of shale. These two prominent sandstones are light brown, weathering to dark brown, and are fine-grained to very coarse-grained. The upper member is well bedded, while the lower is a massive conglomeratic section. The interval between the two sandstone beds is composed of interbedded gray, green, and purple shale. It is predominantly purple. This member thins from 75 feet in northwestern Erath to 25 to 30 feet in western Parker County.

Soils of the Garner Formation lie within the Darnell-Owens soil area. These soils are interpreted as having been derived mainly from sandstones and shales of Pennsylvanian age. The Darnell-Owens soils are developed from deeply weathered rock material - usually sandstone. The Darnell soils are grayish-brown to brown, friable, slightly acid, 6 to 10 inches thick, over noncalcareous sandstone. The topography is gentle to rolling with 3 to 20% slopes.

The Owens soil is a grayish-brown to olive gray calcareous clay, 5 to 10 inches thick over calcareous clay or shale at 10 to 30 inches beneath the surface. The slopes are

gentle to undulating 2 to 15%.

The Brazos River Sandstone member has been used in District 2 as a base material source with very good results. The sandstone is hard and requires blasting to break it up, but ordinarily a grid roller is sufficient to break the material into its proper size.

MINERAL WELLS FORMATION

The Mineral Wells Formation in District 2 outcrops in northeastern Erath, central and southern Palo Pinto and western Parker Counties. The topography ranges from nearly level to high rugged escarpments.

The Mineral Wells Formation is divided into several members that have a thickness of 400 feet in northeastern Erath and increase in thickness to the northeast of Mineral Wells where it reaches a thickness of 750 to 800 feet. The members comprising the formation are the Keechi Creek Shale, Turkey Creek Sandstone, Salesville Shale, Lake Pinto Sandstone, and the East Mountain Shale which has two sub-members. The two sub-members are the Village Bend Limestone and the Hog Mountain Sandstone.

East Mountain Shale Member - The lowest member of the Mineral Wells Formation is the East Mountain Shale. This member consists primarily of light gray, weathering to light tan, calcareous shale. There are several impure limestone beds found in this member, but they all lens out into the surrounding shale when traced for short distances along the outcrop.

Hog Mountain Sandstone Sub-Member - The Hog Mountain Sandstone is a sub-member of the East Mountain. It is a medium to fine-grained and thin to thick bedded sandstone. It weathers light tan to brown and is about 20 feet thick.

Village Bend Limestone Sub-Member - The Village Bend is a hard, fossiliferous limestone 6 inches to 6 feet thick. It is blue where fresh surfaces are exposed and weathers to a grayish-buff.

Lake Pinto Sandstone Member - The Lake Pinto member lies above the East Mountain and is about 40 feet thick. It primarily consists of light gray to grayish-yellow, fine-grained, thin bedded, ½ to 8 inches thick sandstone. The sandstone is interbedded with thin sandy shale.

Salesville Shale Member - The Salesville extends from the top of the Lake Pinto Sandstone upward to the base of the Turkey Creek Sandstone. It consists of gray, calcareous, sandy shales, with several thin sandstone tongues and near the base a thin impure sandy limestone. The lower portion of the Salesville Shale is gray and fairly well laminated. The upper portion weathers to a light gray and contains thin sand lenses. The average thickness of the shale is about 100 feet.

The limestone near the base of the Salesville is the Dog Bend. It is buff to light gray, fine-grained, thin to medium bedded, and contains very few fossils. This limestone is about 3 to 5 feet thick, but is limited in its lateral extent.

Turkey Creek Sandstone Member - The Turkey Creek Sandstone lies above the Salesville member and directly below the Keechi Creek Shale. This sandstone is a reddish-brown to yellowish-gray, coarse-grained, poorly bedded, and conglomeratic. It exhibits some cross-bedding. The Turkey Creek is 26 feet thick in Palo Pinto County and thins to the northeast to 10 to 12 feet thick in northwest Parker County.

Keechi Creek Shale Member - The Keechi Creek Shale is the uppermost member of the Mineral Wells formation. It is bounded at the base by the Turkey Creek Sandstone and at the top by the Palo Pinto Limestone of the Graford formation. The Keechi Creek is a gray to yellowish-gray calcareous and fossiliferous shale containing several thin sandstone layers.

The dominant soil series developed from the Mineral Wells formation is the Darnell-Owens. The Darnell soil is a

grayish-brown to brown, friable, slightly acid, sandy material usually 6 to 10 inches thick over yellowish-red noncalcareous sandstone. The slopes range from sloping to rolling - usually 3 to 20 per cent.

The Owens soil is a grayish-brown to olive gray calcareous clay. It is 5 to 10 inches thick over olive brown calcareous clay that grades into calcareous shaley clay at 15 to 30 inches beneath the surface. The slope of the soil ranges from gently sloping to undulating.

The Mineral Wells formation offers little in the form of base material for highway construction. There are several limestones that might be exploited for base material; but due to their restricted lateral extent, extensive drilling and testing would be required to determine the exact quantity and quality of the material. The material is hard and would require blasting and crushing to meet the desired particle size.

The sandstonesare also hard and would require blasting to loosen the material, but a grid roller would be sufficient to break the material down to a workable size. The sandstone material is not normally used as a base material in District 2, but it might be used as a foundation course or a select material.

The shales of the Mineral Wells formation are similar to shales in the other formations in that they tend to be unstable when the moisture content is changed.

CANYON GROUP

GRAFORD FORMATION

The Graford formation outcrops in southwestern Palo Pinto, southeastern Jack, western Wise, and northwestern Parker Counties. The topographic features are expressed as low, gently undulating hills of shale and steep rugged escarpments of massive limestones.

The Graford formation is composed of five members that total 400 to 600 feet. These members are the Winchell Limestone, Wolf Mountain Shale, Wiles Limestones, Posideon Shale, and the Palo Pinto Limestone.

Palo Pinto Limestone Member - The Palo Pinto Beds con-

sist of thin to massive bedded; light brown, weathering to gray; fossiliferous limestone with a few thin calcareous clay seams. The Palo Pinto differs from the other limestones of the Canyon Group by containing chert nodules, a stylolithic structure, and thin beds separated by uneven or wavy planes. The Palo Pinto Limestone is 50 feet thick in southern Palo Pinto County and thickens to 100 feet in northeastern Palo Pinto and southwestern Wise.

Posideon Shale Member - The Posideon Shale is a dark gray, sandy to calcareous, fossiliferous, and contains very thin layers of limestone. This member is approximately 50 feet thick.

Wiles Limestone Member - The Wiles Limestone is a gray, hard limestone. It is 3 to 8 feet thick and thin bedded. Actually the Wiles Limestone is more of a limestone bed rather than a member.

Wolf Mountain Shale Member - The Wolf Mountain Shale is predominantly shale throughout the area. Within the shale interval several lenticular sandstone bodies do occur. A few thin limestone lentils also appear in the upper part of the section but none is continuous for any appreciable distance. The Wolf Mountain is a bluish-gray fossiliferous, soft shale containing small brown limonitic concretions.

Winchell Limestone Member - The Winchell Limestone is exposed along its outcrop and dip slope. At Possum Kingdom Dam, in Palo Pinto County, the Winchell is approximately 165 feet thick. From this area the member thins toward Jack County. Northeast in Jack County, near Sparks Spring, the Winchell changes to shale and sandstone, but appears again in the outcrop near the Jack-Wise County line. The Winchell is a gray, massive bedded, highly jointed, resistant, fossiliferous limestone. It averages from 20 to 75 feet thick.

Soils derived from the Graford formation are the Tarrant-Crawford soil series. The Tarrant series is very dark brown to dark grayish-brown, highly calcareous, and friable. Depth to parent material seldom exceeds 12 inches. The

topography is undulating to rolling uplands with gradients of 1 to 20%. The range of 1 to 7% is regarded as normal. The drainage is free to rapid both internally and externally.

The Crawford series is a dark reddish-brown, slightly acid clay 8 to 12 inches thick. Below this is a stiff brown clay, over a hard limestone bedrock. The topography is very gently sloping uplands with gradients of about ½ to 2%. The drainage is slow to moderate from the surface and very slow internally.

The limestones of the Graford formation have produced much of the material for road building in District 2. In the Palo Pinto member the material has been used for concrete and hot mix aggregates, and for base material. This limestone has a raw triaxial class that ranges from 2.6 to 1. Average soil binder is 20 to 25% and increases an average 6 to 10% in the Texas Ball Mill. At the present time there are no crushers set up in this limestone member.

In the Winchell limestone there are several large commercial crushers producing concrete, and hot mix aggregates and base material. In Wise County there are four large commercial crushers and in Palo Pinto there is one large producer. The amount of limestone at these crusher sites is practically unlimited. The raw triaxials range from 2.7 to a class 1. The Texas Ball Mill results average a 6% increase from the original soil binder.

BRAD FORMATION

The Brad formation is exposed in northwest Palo Pinto County, north through southwest, central and northeast Jack County and northwest Wise County. The formation is deeply cut by streams and presents a very rugged, but picturesque topography. The Brad formation has an average thickness of 200 feet and is composed of two separate and distinct lithologic units.

Ranger Limestone Member - The upper member is the Ranger Limestone. This limestone averages 45 feet in District 2.

It is massively bedded in the lower portion of the member and becomes thin bedded in the upper portion. The Ranger Limestone is light gray-tan on fresh exposure and weathers to a blue-gray. The limestone is hard and exhibits considerable jointing.

Placid Shale Bed Member - The lower member is the Placid Shale bed. The Placid Shale is composed of gray, sandy shale with very few fossils. There is a thin limestone 1 to 2 feet thick about midway in the shale. It is a brown, fossiliferous, thin bedded, and hard to medium hard. Also present in the shale are a few thin lentils of brown calcareous sandstones about 3 to 4 feet thick. The total thickness of the Placid Shale is 135 feet.

The dominant soil series of the Brad formation are the Tarrant-Crawford clays. The Tarrant forms primarily on the upper Ranger Limestone. It is very dark brown to grayish-brown, highly calcareous, friable, and is 4 to 8 inches deep. The limestone parent material is less than 12 inches below the surface. The Tarrant Clay forms on slopes of 2 to 20%.

The Crawford Clay usually forms over the Placid Shale. It is dark reddish-brown, and slightly acid. The Crawford is located on nearly level to very gentle slopes of ½ to 3%.

The Ranger Limestone is like most of the Pennsylvanian limestones in District 2. It is in vast almost inexhaustible quantities. The rock could easily be used for highway construction as a base material, concrete and hot mix aggregates. The material is hard and very similar to the Merriman Limestone, but no tests have been performed to determine the engineering characteristics of the rock. Blasting and crushing would be required to work the rock of this formation. Because of the durability of the rock, vertical walls could be cut through the limestone with little concern from slumping and sliding.

The Placid Shale beds provide little or no material suitable for base material. The shales exhibit consider-

able swelling and shrinkage when moisture is introduced. The thin limestone present in the Placid Shale would be too thin to be considered workable.

CADDO CREEK FORMATION

The Caddo Creek formation outcrops in southern, central, and northeastern Jack County; northwestern Wise County; and northwestern Palo Pinto County. Topographically, the Caddo exhibits a rolling undulating to rugged, very steep escarpment. The two members that comprise the Caddo Creek formation are the Home Creek Limestone and the Hogg Creek Shale.

Home Creek Limestone Member - The Home Creek member is the upper unit of the Caddo Creek Formation and is approximately 20 feet thick. The limestone is massive bedded, blue-gray on fresh break, weathers to yellowish-brown, hard, and contains very few fossils. Beginning at Jacksboro and continuing northeast this limestone member consists of four layers separated by shale layers. Beginning with the lowest limestone, all four lens out and are replaced by shales and sands. This can be traced into Montague County where it is covered by cretaceous sediments.

Hogg Creek Shale Member - The Hogg Creek Shale is the lower member of the Caddo Creek formation. It averages about 155 feet thick. This member is quite variable in thickness and composition. In Palo Pinto County it is 155 feet thick with two six foot sandstone beds near its middle. To the northeast in southwestern Jack County, the lower sandstone is about 15 feet thick and increases to 75 feet thick near the community of Cundiff in northeast Jack County. Also, there appears within the Hogg Creek member three limestones near the community of Cundiff. These have thus been given the local name "Cundiff Limestone". Each layer of limestone is one to three feet thick and is separated by about 60 to 70 feet of shale.

The shales of the Hogg Creek are gray to greenish-gray,

usually sandy, thinly laminated, and contain few fossils. The limestones in this member are a gray, hard, and thin bedded rock. The sandstone is fine-grained, thin bedded and a yellowish-gray color.

The soils derived from the Caddo Creek formation are a combination of the Darnell-Owens and Tarrant-Crawford series. The Tarrant soil is found predominantly on the upper Home Creek Limestone. The depth of the soil very rarely if ever exceeds 12 inches to parent rock. The color varies from dark brown to grayish-brown. The topography is undulating to rolling uplands with gradients of 1 to 20%.

The Darnell-Owens series is predominantly located on the lower Hogg Creek Shale. The Darnell develops on non-calcareous mostly reddish sandstones. The drainage is rapid both internally and externally. The Owens series develops on shallow calcareous shales of the Hogg Creek member. The color of the soil ranges from grayish-brown to olive gray. The topography is gentle to strong slopes of 2 to 8%. The drainage is rapid from the surface but very slow internally.

Several pits in the Home Creek Limestone have been used for road building material with good results. The material varies from good to excellent. Only by considerable drilling and testing can the exact quality and quantity be determined. The limestone of the Home Creek has ranged from a Class of 2.5 to Class 1. The soil binder averages 23% and after the Texas Ball Mill Test there is an average increase of about 9%. Because of the massive bedding and the nature of the material, the rock has to be blasted and crushed to its proper size rather than using a grid roller.

The Hogg Creek Shale offers little as a road building material source. The shale has high plasticity index. There is marked swelling and shrinkage with variations in moisture content. Another undesirable characteristic of the shale is the capacity to retain moisture for long periods of time.

CISCO GROUP

GRAHAM FORMATION

The Graham formation outcrops in northwest Palo Pinto County; southwest, central, and northeast Jack County; and northwest Wise County. The topography of the Graham varies from gently rolling to undulating shale beds to very steep escarpments of limestone.

The Graham formation includes all of the beds above the Home Creek Limestone and below the Avis Sandstone. The following members comprise the Graham formation in District 2: Bunger Limestone, Gonzales Creek Shale, Necessity Shale, Gunsight Limestone and the Wayland Shale.

Gonzales Creek Shale Member - The lower member of the Graham formation is the Gonzales Creek Shale and Sandstone. This member consists of sandy shales with two and sometimes three prominent sandstone layers and with one thin coal seam. The lowest sandstone bed can be traced fairly easily because of its uniformity. It consists of fine-grained white, five-foot thick sandstone. The second or middle sandstone bed shows considerable lateral variation. In Jacksboro, it is medium-grained, red, hard sandstone. Three miles northeast of Jacksboro the sandstone is coarse and is made up of chert fragments. The shales of the Gonzales are approximately 116 feet thick, sandy, and are yellow to black and carbonaceous.

Bunger Limestone Member - The Bunger Limestone is 6 feet thick in northwest Palo Pinto County, and thins to the northeast and is only 3 feet thick in western Jack County, and is missing in the northeastern part of the county. The limestone is a grayish-yellow, unevenly bedded, hard, and weathers into small brick like blocks 2 to 6 inches thick.

Necessity Shale and Sandstone Member - Above the Bunger Limestone is the Necessity Shale and Sandstone. This member consists of about 200 feet of shale, sandstone, and one limestone lentil. The shale is sandy, yellow and usually not well exposed. The sandstone lentils

range from fine to coarse-grained, white to yellow in color, with some local cross bedding. The sandstones are 5 to 6 feet thick. The limestone lentil is 2 to 3 feet thick, hard, red in color, ferriginous and very fossiliferous.

Gunsight Limestone Member - The Gunsight Limestone member consists of two gray, fossiliferous limestone beds, both containing large numbers of corals. In part the limestones are relatively soft, and the corals weather out freely and are replaced by clays and sands. In the western part of Jack County the Gunsight is 9 feet thick. The upper 3 feet is red, and the lower part is yellow in color. To the east the limestone thins and where it crosses into Wise County it is only 3 feet thick.

Wayland Shale Member - The upper member of the Graham formation is the Wayland Shale. This member consists of a series of bluish shales with some thin iron-stone partings, interbedded with thin lenticular beds of fossiliferous yellow limestone and some sandstones.

The Tarrant-Crawford and Darnell-Owens are the typically derived soils of the Graham formation. The Tarrant soil forms over the limestones of the Graham and is a dark brown to dark grayish-brown, highly calcareous, 4 to 8 inches thick. The slopes are gentle to hilly with a 2 to 20% grade.

The Crawford is a dark reddish-brown, slightly acid soil which also forms over limestone, but the limestone is usually 2 to 2½ feet deep. The topography of the Crawford ranges from nearly level to gently sloping ½ to 3% slope.

The Darnell-Owens form over the shales and sandstones of the Graham formation. The Darnell is a grayish-brown to brown, friable, slightly acid, 6 to 10 inches thick, over a yellow-red non-calcareous sandstone. The slopes range from 3 to 20%. The Owens soils are grayish-brown to olive gray, calcareous, 5 to 10 inches thick, that grade into calcareous shales about 30 inches beneath the surface. The slopes range from 2 to 15%.

In District 2 there are no known base material pits that are located in the Graham formation. It is possible that the limestones of the Graham formation could produce material satisfactory for highway construction. Only by drilling and testing can the exact quality and quantity of the rock be determined.

The shales of the Graham formation are much like the shales of other formations in that they have a high swell-shrinkage ratio with a change in the moisture content.

THRIFTY FORMATION

The Thrifty formation outcrops in a narrow belt extending from the western central part of Jack County to the northeast part of the county. The topography is a gently sloping to undulating upland.

The lithology of the Thrifty formation consists of a series of sandstones, shales and limestones. At the bottom of the formation is the Avis Sandstone member, and at the top of the formation is the Breckenridge Limestone. Between these two members lie a series of unnamed sandstones and shales.

Avis Sandstone Member - The Avis Sandstone member is a reddish-brown, coarse-grained, cemented together with iron oxide and silica. This member maintains a uniform thickness of 15 to 20 feet throughout Jack County.

Unnamed Shale and Sandstone Member - The Unnamed Shale and Sandstone member consists of shale sections ranging from 4 to 20 feet thick. They are yellow, gray, and blue-gray and poorly laminated. The sandstones are 3 to 8 feet thick, poorly bedded, white to yellow in color, and fine to coarse grain in texture.

Breckenridge Limestone Member - The Breckenridge Limestone member is thin bedded, 3 to 4 feet thick. It is maroon in color, impure, and very sandy. They are also present in this limestone thin seams of gray shale.

The soils derived from the Thrifty formation are the Renfro and an unknown soil series. These soils appear as dark

reddish-brown to brown, friable, slightly acid, 6 to 10 inches thick over dark reddish-brown slightly alkaline clay that grades into a calcareous clay or shale at 30 to 40 inches.

The Breckenridge Limestone could possibly produce material suitable for road building, but only by considerable drilling and testing could exact quantity and quality be determined.

HARPERSVILLE FORMATION

In District 2 the Harpersville formation outcrops only in northeastern Jack County. Topographically, the formation forms gentle to undulating plains. The Harpersville formation is composed of two distinctly different type lithologies.

The upper unit is the Saddle Creek Limestone. This limestone is a hard, gray, evenly bedded, with white specks in the upper part, and is 6 feet thick.

The lower unit is a mass of unnamed shales interbedded with coal and thick conglomerates. The lower 25 to 35 feet of the formation is a blue-gray shale with an 8 inch coal seam near the top. This is followed by a thick conglomeratic sandstone 20 feet thick. Above this sandstone is 30 to 40 feet of shale followed by another coarse sandstone 15 feet thick. Above this second, escarpment forming sandstone, is 260 feet of blue-gray shale containing large amount of iron sulfide material.

The Renfro-Unnamed soil series is formed from the Harpersville formation. The Renfro soil is a dark reddish-brown to brown, friable, slightly acid clay, 6 to 10 inches thick, over dark reddish-brown, slightly alkaline clay that grades into red alkaline to calcareous clay or shale 30 to 40 inches beneath the surface. This soil is formed on the gentle to undulating prairies of the shales and sandstones of the formation.

The Unnamed soils are formed from the limestones of the Harpersville on the steeper slopes. The soil is gray to dark gray, calcareous, 5 to 12 inches thick and develops into a dark gray, compact, heavy clay. The external drainage is slow to moderate, and the internal drainage is very slow.

In District 2 there are no base material pits located in the Harpersville formation. The limestones in the upper part of the formation could possibly be used as a base material, but extensive drilling and testing would be required to prove this.

The shales and sandstones offer little in the form of road building material, except to serve as a subgrade when encountered.

## CRETACEOUS SYSTEM

### COMANCHE SERIES

#### TRINITY GROUP

##### TRAVIS PEAK AND ANTLERS SAND FORMATIONS

The Travis Peak formation is exposed in western Parker, southeast Jack and all parts of Erath Counties, while the Antlers is exposed in northern Wise County. These two formations are topographic expressions of flat to gentle undulating areas.

The Travis Peak formation consists mostly of pure white quartz sands and conglomerates consisting of quartz sands and pebbles. This conglomeratic sand grades upward to a very fine, poorly consolidated, white pack sand and then into sandy clays and limestones of the Glen Rose. The basal member of the Travis Peak is a massive red clay, more predominantly maroon, which derives its color from the oxidation of the iron compounds present in it.

The Antlers sand is of the same composition as the Travis Peak, but the Glen Rose pinches out between the overlying Paluxy sand and the underlying Travis Peak and the sands become indistinguishable. Where these two sands meet, the name Antlers sand has been applied.

Both of the sands are about 100 feet thick and there is much cross bedding present. These sands are both producers of artesian water wells. The Travis Peak is the most prolific water-bearing sand, and large commercial sources obtain water from this formation as far east as Dallas and Fort Worth.

The Winthorst and Stephenville soils are typically developed on the sands of the Travis Peak and Antlers formation. The sand strata of the formation break down and form deep sandy soils which are usually heavily wooded with post oak trees. These soils, because of the lack of cohesion, tend to blow and wash extensively, and much of the land has become denuded. The Stephenville soils consist predominantly of fine sandy

loam which develops on a steeper slope than the Winthorst. The slope for the Stephenville varies between 2 to 10% , has moderate to rapid external drainage, moderate internal drainage and is slightly acid.

The Winthorst soil is usually found on a gentle to moderately sloping upland of 1 to 8% slope. This soil possesses free external and slow internal drainage, and is slightly acid.

In District 2 there is no known base material found in the Travis Peak or the Antlers sands. If there is any base material, it would be in the form of gravel pits, and these probably are very scarce.

The sands, when they can be confined, exhibit excellent subgrade qualities.

GLEN ROSE FORMATION

The Glen Rose formation is exposed in western Wise, northeast and western Parker, northern, western and southeast Hood, central Somervell, eastern Erath, southeast Jack, and western Johnson Counties. This formation is topographically expressed as low, gently undulating to steep escarpments.

The Glen Rose typically consists of thin to medium, but occasional massive, bedded limestones alternating with marls or marly limestones and shales. The Glen Rose decreases in thickness from south to north, and the thinning appears to be caused by the limestones thinning rather than a lensing of the entire formation. The type locality at Glen Rose is 236 feet thick, measured in southern Parker County and found to be 195 feet thick, 25 feet thick in southeast Wise County and is no more than 2½ feet thick west of Decatur in Wise County. As the limestones decrease in a northerly direction, the shales become more prominent and, a few beds of sandy clay begin to appear. Then the shales begin to decrease as the sandy clays increase and sand lenses or beds come in.

In Erath, Hood, Somervell and Parker Counties, the Glen Rose is easily recognized on the hillsides by its terraced or "stair-stepped topography", consisting of well bedded resistant limestones forming the shelves which are separated by the soft receding layers of marl or shale. In Wise County, the Glen Rose is hardly more than a calcareous clay with an occasional hard crystalline limestone ledge. The limestone is light gray-dark gray on the fresh surface and weathers to a blue gray and gives a flaking appearance.

The predominant soils of the Glen Rose are the Brackett, Denton, San Saba and Tarrant. These soils are controlled by the alternating of the limestones and marls. The Denton forms from the marl and clay and normally occurs on gentle slopes. The Tarrant-Denton series occurs more often from the more resistant limestone layers. The San Saba also forms on the limestone. All of these soils are calcareous, and exhibit very rapid to slow external drainage and rapid to slow internal drainage.

The Glen Rose is one of the most widely used sources of base material in the southwestern portion of District 2 because of its wide distribution and abundant quantity. This material varies from very poor to excellent, and only by a series of tests can an exact quantity and quality be determined. The triaxial classification ranges from 3.5 to a Class 1 with the raw sample. The average soil binder is approximately 15% and after the Texas Ball Mill there is an average increase of about 13%. Admixtures of lime and sand have at various instances been used with satisfactory results in most cases.

The Glen Rose formation has a few sand lenses that are water-bearing. Consequently, care must be taken in roadway cuts to prevent landslides, soil creep and slumping of the slopes.

PALUXY SAND FORMATION

The Paluxy formation is exposed in western Wise, western Tarrant, eastern Parker, Western Hood, much of Erath and Somervell, and western Johnson Counties. The Paluxy

sands are usually expressed topographically as low, flat to moderate, or gently sloping plains.

This sand is an artesian water reservoir and consists of alternating layers of poorly consolidated sands and compact clays. The sands are extremely fine-grained and only a very few beds of medium grains are found. The sands are composed almost entirely of quartz and in only a few beds does a clay matrix occur. There seems to be no cementing agent, causing the sands to be soft and friable. The sand bodies range up to 25 feet in thickness. The pure sands are usually white to light gray, whereas the sandy clay and clayey sands are light green to light gray. The Paluxy is about 100 to 150 feet thick in District 2 and thins slightly to the south.

The soils derived from the Paluxy are sandy and deep. Unless properly cared for they erode extensively from the wind and water. The Stephenville-Winthorst soil is the predominant series found on the Paluxy. These soils are neutral to slightly acid, and both form on sand. The Winthorst soil occupies the rolling gentle surfaces, while the Stephenville developes on the slightly steeper slopes. The external drainage is moderate to rapid and internally it is moderate to slow. A rough terrain is developed from the deep erosion.

Any base material for road building purposes would be found in the form of gravel in the Paluxy formation. These gravel deposits are very scarce, and seldom is there enough quantity to warrant using the material.

The sands of this formation, being very fine and clean and having little plasticity and lacking cohesion, make good subgrade. To give any support, the sand must be confined.

Since the formation is water-bearing, clean, cohesionless sand, a rising water table can result in a quicksand or bog condition.

FREDRICKSBURG GROUP

WALNUT FORMATION

The Walnut outcrops in eastern Wise, western Tarrant, much of Erath, eastern Parker, western Johnson, eastern Hood and southern Somervell Counties. This formation gives rise to the low flat areas below the steeply sloping Goodland. The Walnut formation is 25 to 30 feet thick when encountered in the District with remarkable uniformity. This formation is divided into two lithologic units, an upper unit of extremely well consolidated and hard limestone composed largely of shells of oysters, and a lower unit composed of a few thin to medium bedded, fossiliferous limestones and calcareous clays. This lower unit is about 18 to 20 feet thick throughout the District. The Walnut is massively bedded; that is,to say, that there are no bedding planes in most of the outcrops. The upper unit of the Walnut varies in thickness but is generally about four to six feet thick.

On the weathered surface the limestone appears as a dark gray or brownish-gray. The surface of a fresh fracture is light gray to tan in color.

The presence of live oak trees on the Walnut is an outstanding characteristic of this formation. These trees are abundant even in the smallest outliers.

The soils from the Walnut are derived from limestones, marls and clays. The Denton, Brackett, San Saba, and Tarrant soils are all derived from the limestones of the Walnut. The San Saba primarily is formed from the calcareous clays. All of these soils exhibit similar characteristics of shallow soils with moderate to rapid internal and external drainage.

The upper unit of the Walnut has been used as a base material source in District 2 with good results. The oyster shells usually are filled with clay, which may

produce an undesirable plasticity, but with the addition of hydrated lime, good results can usually be obtained. The shell conglomerate has produced a raw triaxial class which has ranged from 3.0 to 2.2. With the addition of lime a triaxial Class of 1 has been produced.

Ordinarily the shell conglomerate can be ripped with a bulldozer or worked with a front end loader. In most all cases the material breaks down satisfactorily under a roller.

COMANCHE PEAK FORMATION

In District 2 the Comanche Peak outcrops in central and northeastern Hood, western Tarrant, western Somervell, western Johnson and north and western Erath Counties. The topographic expression exhibited by the Comanche Peak is gently rolling upland.

The Comanche Peak formation is a chalky-limey facies. In the northern part of the state it continues as the Goodland Limestone even though they both have the same lithology and fossils. Generally this limestone is composed of a series of nodular limestones, thin calcareous clays, and marls. In the outcrops the color is gray to blue-gray on the weathered surface and dull white on the fresh fracture. Like the Goodland, the Comanche Peak is easily recognized by the chalky, nodular appearance.

Soils developed from the Comanche Peak are the Brackett, Denton, and San Saba. These soils form gently sloping to hilly topography with gradients of 5 to 15%. Drainage ranges from rapid to slow externally and moderate to slow internally. The soils are highly calcareous and exhibit moderate to high plasticity. The triaxial class of the Denton soils ranges from 4.6 to Class 5.3. In the San Saba the triaxial class varies between 4.3 and 5.4.

The Comanche Peak has been used in the district as a base material. There are several reasons this material is not used more, one reason being that the material is usually too soft. The soil binder averages 21 to 23% and increases

about 20% after the wet ball mill. Another reason for the infrequent use of the material is that it is shaley and when moisture comes into contact with the rock, it begins to disintegrate and flake off. The Comanche Peak has been triaxially tested and the results range from 3.2 to 2.3.

EDWARDS FORMATION

In District 2 this formation outcrops in southern Johnson County. The Edwards formation is expressed topographically as steep cliff-forming, with broad flat top, massive limestone.

The Edwards formation is composed of layers of hard, white, fossiliferous limestone. The bedding ranges from thin to massive. The limestone contains clay filled voids that were fossils and have been weathered out and replaced with the clay. The Edwards is exposed only in the very southern portion of Johnson County, and then it is only fingers of limestone that are about 15 to 20 feet thick.

Soils derived from the Edwards formation are the Brackett, Crawford, Denton and San Saba. The most abundant soil developed from this limestone is the Crawford. The Crawford series comprises clayey soils of medium depth, developed in smooth well drained areas on hard limestone. The associated San Saba series, which is darker and less reddish, occupies a flatter and more slowly drained area. The Denton, which is highly granular and generally calcareous, is darker than the Crawford.

The Crawford is a dark reddish-brown, slightly acid, plastic, clay. The topography is very gently sloping uplands, with gradients of ½ to 2%. The drainage is slow to moderate on the surface and very slow internally.

The Edwards formation has produced good to excellent base material when it has been encountered in District 2. The few times it has been used, the raw triaxial has ranged from 2.7 to Class 1. The Texas Ball Mill ranges from 24 to 30. Because of the clay filled voids, the plasticity index has been lowered by the use of admixtures of sand

and hydrated lime. Both of the admixes proved successful as they both give Class 1 in the Texas Triaxial Classification.

GOODLAND FORMATION

The Goodland formation is exposed in eastern Wise, western Tarrant, eastern Parker, northeastern Hood, western Somervell, western Johnson, and northwestern Erath Counties. This formation creates the gently rolling topography which is typical of the Goodland.

The Goodland is composed of a series of limestones and marls and clays - all of varying thicknesses. The formation itself varies in thickness from 140 feet in Johnson County to 86 feet in Parker and 117 in Tarrant County. The uppermost limestone is usually 16 to 18 feet of irregularly bedded limestone. Directly below this is 20 to 25 feet of a dark gray or blue-gray shale with alternating limestone layers. Following this is a blue-gray shaley limestone, which is poorly bedded. This limestone is approximately 20 to 25 feet thick.

Below this limestone a marl is encountered. It contains a few thin limestone layers. The marl is also 20 to 25 feet thick and weathers to a yellow color.

All of the limestones of the Goodland appear to be chalky, fossiliferous, fairly well bedded and white in color. Upon weathering the limestones become a chalky white, and tend to flake easily. The Goodland is easily recognized because it forms conspicuous, high escarpments with white faces. These white slopes formed by the outcrop seldom bear much vegetation and are always a prominent topographic feature. Where isolated areas of Goodland occur, they take the form of knobs.

The Goodland when freshly exposed is a rather hard, resistant limestone. When exposed to prolonged weathering this limestone tends to decompose and deteriorate rapidly developing a fractured or knobby appearance.

The soils formed by the Goodland Limestone are Brackett, Denton and San Saba. These soils form gently sloping to undulating, with a slope of 5 to 15%. External drainage ranges from moderate to rapid, while internal drainage is moderate to slow.

The Goodland has been used in the district as a base material. This formation has been tested triaxially at various localities with a raw triaxial class range from 3.2 to 2.3. With the addition of admixes such as a sand or hydrated lime, a triaxial Class of 1 has been obtained. The most objectionable feature of the Goodland is that it is too soft. The Texas Ball Mill averages very close to a 20% increase in this formation. The average soil binder is 23%. After the Texas Ball Mill, the soil binder is raised to about 43%.

## WASHITA GROUP

### KIAMICHI FORMATION

Exposures of Kiamichi are found in southeastern Wise, western Tarrant, western Parker, northern Hood, western Johnson, Somervell and Earth Counties. The Kiamichi forms a thin narrow belt that separates the steep slopes of the underlying Goodland from the Duck Creek above.

The Kiamichi is composed largely of calcareous, silty clays and marls. The clays are dark to bluish-gray on the fresh surfaces, but weather to an olive or yellow color. There are scattered flaggy, silty and nodular limestones in the Kiamichi which are only a few inches thick. The Kiamichi is approximately 30 feet thick, and thickens from south to north.

The Kiamichi is usually exposed only in roadway cuts and stream cuts where the erosion has cut down through the soft clays.

The soils produced from the Kiamichi are similar to those formed on the limestones. They are calcareous and fairly shallow. The external drainage is moderate to slow, and the internal drainage is slow.

The Kiamichi is of little importance as a source of base material because of the lack of limestone beds. As a subgrade material, there is a high plasticity in the clays and a triaxial range of 3.8 to 5.4.

DUCK CREEK FORMATION

This formation is exposed in southern Wise, eastern Parker, west and southwest Tarrant, western Johnson and northern Hood Counties. The Duck Creek forms the caps of the gently rolling hills of the highlands of these counties.

There are two distinct lithologic units composing the Duck Creek. The upper unit is a marl, which lies at the base of the Ft. Worth formation, and forms a gently sloping shelf or terrace. This unit consists of a series of light colored yellow-gray marls and a few thin seams of chalky, clastic limestone only inches thick. The outcrop of this unit is generally found along the rim of the main escarpment. The beds are very susceptible to weathering and break down to form rich soils. These marls often contain perched water tables formed by trapping water from the above beds and in wet weather give rise to seeps and bogs. These same marls give rise to green vegetation in the dry summer months and form a sharp contrast to the dry grasses on either side of the Duck Creek.

The lower unit of the Duck Creek is composed of a series of soft, impure limestones and marls. The limestone is white to light gray when exposed on the fresh surface and the weathered surface is dark gray. This unit is about 20 to 25 feet thick in District 2, and increases to the south to form part of the Georgetown formation near Austin.

The soils of the Duck Creek are Denton, Tarrant, Brackett, and San Saba. The Denton, Tarrant and Brackett are formed from the lower unit of the Duck Creek Limestone. The San Saba primarily is formed from the upper marl. The soils of the Duck Creek are fairly shallow and seldom if ever are there trees present on the undulating to rolling uplands. Prairie grasses predominate.

The shrinkage-swell of the upper Duck Creek, which constitutes the gentler slopes, is high and decreases on the steeper slopes of the lower limestone unit. The formation is strongly calcareous, with a pH of 8.0 to 8.5. The Duck Creek is not usually considered for base material in District 2 because of the lack of limestone and the abundance of clay and marl.

FORT WORTH FORMATION

The Fort Worth formation is exposed in Wise, Tarrant, and Johnson Counties. This formation is characterized by its gently rolling topography and its well known chocolate soil.

This formation is composed of regular alternating limestones in strata 4 inches or 5 inches to 18-20 inches thick, and marls ranging from thin laminae to beds 8 inches or more thick. The limestones are typically soft, chalky, impure, and dull white, and range in color from light gray to brown. The marls are compacted, laminated and highly calcareous and are yellow to brown in color. The Fort Worth formation retains a nearly uniform thickness of 30 feet throughout the district.

The soils of the Fort Worth formation are the Denton, San Saba, Brackett and Tarrant. Generally the same manner of development of these soils, as has previously been mentioned, is characteristic, the Tarrant, Denton, Brackett being formed on the limestones, with the San Saba formed from the marls.

The Fort Worth formation is not used as a base material source due to the relative thin limestone and the high clay or marl content.

DENTON FORMATION

The Denton Marl is exposed in Tarrant and Johnson Counties. This formation forms the broad flat to gently rolling uplands.

The Denton Marl is a moderately shallow water deposit con-

sisting of blue-gray marl and clays which are very shelly in the upper part. For the most part of the formation it is a flaky, laminated, and non-arenaceous material. The lower portion of the Denton is sandy and less fossiliferous. The Denton is uniform 25 feet thick in both Tarrant and Johnson Counties.

The predominant soils of the Denton are the San Saba and Denton. The Denton soil series includes brownish calcareous clay soils of medium depth developed from the calcareous marls of the Denton formation. These soils occur on very gently to moderate sloping areas of 1 to 4% grade. The soil is very dark brown to dark grayish-brown and is either calcareous or neutral, but not acid. The drainage is rapid from the surface but slow to moderate internally. Mainly there are tall bunch grasses in the Denton soil series.

The San Saba soil series is closely associated with the Denton soils. The San Saba is also developed from the marls of the Denton formation; however, it ranges from dark gray to black in color and the drainage is slow from the surface and very slow internally.

The Denton formation is generally not considered a base material because of the lack of limestone. The marls and clays in this formation are high in plasticity, and water seeps are fairly common and cause slippage and slumping on cut slopes.

WENO FORMATION

The Weno is exposed in Tarrant and Johnson Counties. This formation, much like the Denton, forms the broad flat and gently rolling uplands.

The Weno consists of a brownish-yellow, calcareous marl and a few thin limestone seams. This formation thins to the south from 67 feet in Fort Worth to 40 feet at the Brazos River in Johnson County.

The San Saba is the predominant soil formed on the Weno formation. Its color ranges from dark gray to black.

This soil forms on the nearly level to gently sloping (0 to 2%) underlying Weno. The drainage is slow externally and slow to very slow internally. The pH of the upper San Saba is 8.0 with a slight reaction from the hydrochloric acid, and a rather violent reaction in the lower horizon.

In District 2 the limestones of the Weno are not considered to be of sufficient quality or quantity to be exploited for building material. The soils formed on the Weno have moderate to high plasticity and a triaxial range of 4.6 to 5.3.

PAWPAW FORMATION

The Pawpaw is exposed in Tarrant and Johnson Counties. The formation is found on steep slopes, making a narrow but rather distinct exposure.

The Pawpaw consists of a brown-reddish brown sandy clay, which is highly fossiliferous. The prevailing texture is sandy, the clay is acidic, and the vegetation is very sparse. The formation varies in thickness from 27 feet at the Denton-Tarrant County line to 12 feet at the Johnson-Tarrant County line.

The soil developed from this formation is in a transition zone with the Denton-Tarrant above and below it. For all practical purposes we will consider the soil of the Pawpaw to be a Denton-Tarrant type.

The Pawpaw is not a source of base material because there is no limestone present. The clay is moderately high in plasticity, and the raw triaxial class ranges from 5.2 to 4.8.

MAIN STREET FORMATION

The Main Street is exposed in Tarrant and Johnson Counties. This formation forms the flat to gently rolling areas of the Tarrant and Johnson County uplands.

The formation is a series of regularly alternating white,

chalky, or fairly pure limestones interbedded with thin seams of marl. The Main Street is similar to the Fort Worth formation. The beds of the Main Street are little more than a foot in thickness in Tarrant County and thicken in Johnson County to become massive, or exhibit no bedding at all. Often there are hematite or limonite nodules contained in the limestone and on exposure they break down and stain the surrounding rock, giving it a rust color. This formation, unlike those previously mentioned, thickens to the south. It is 30 feet in Tarrant and thickens to 50 feet in Johnson County.

San Saba-Denton soils are formed from the Main Street parent material. The soils are formed on flat to gentle slopes. The soils are very dark gray and strongly calcareous. The drainage is slow both internally and externally.

Base material has been used from this formation. The material ranges from good to poor and the exact quality can be determined only after a series of tests. Raw triaxials range from 4.2 to 2.9, and the Wet Ball Mill averages about a 20% increase from the original soil binder of 26%.

GRAYSON MARL FORMATION

The Grayson is exposed in Tarrant and Johnson Counties. This outcrop forms the usual abrupt escarpment connecting the Woodbine above and the Main Street below. Exposures of this formation are rare because in nearly all places it is covered with overwash and vegetation.

The Grayson consists of soft calcareous marls and clays with a few thin beds of limestone 3 inches to 10 inches thick. The clays and marls vary from yellow to gray in color and are high in fossils, and pyrites and gypsum. The Grayson is 50 feet thick in Tarrant County and thickens to 100 feet in Johnson County.

The San Saba-Tarrant soil is formed from the Grayson marl. This soil is a fairly deep soil with slow and moderate permeability. The soils are slightly calcareous.

There is no base material produced from the Grayson in District 2. The plasticity is moderate to high and raw triaxial class ranges from 5.2 to 4.6 in the Grayson formation.

## GULF SERIES

### WOODBINE GROUP

#### WOODBINE FORMATION

The Woodbine is exposed in Tarrant and Johnson Counties. The outcrop, which covers roughly the eastern third of Tarrant and Johnson Counties, weathers into low rolling hills with open glades and flats of bottom land.

The Woodbine has been divided into two lithologic units, the lower Dexter and the upper Lewisville. The Dexter sands are characterized by highly ferruginous, clayey sands, which are discolored in places by bituminous, laminated clays. The Dexter sands are much like those of the Trinity group, in that they are often unconsolidated, but differ from them by containing more iron. The sands are generally white and very friable, and contain particles of iron sulfides. These oxidize and their solutions consolidate into dark brown silicious "iron ore", which occurs in large quantities in certain locales. Another interesting feature of the Dexter is the lenticular character of the sands. Most of the sands are interbedded with shales and shaley sands and show steep cross-bedding.

The upper unit, the Lewisville, exhibits shale and sand beds that are thinner than the Dexter. The thickness of the Woodbine varies greatly in District 2. In Johnson County the Woodbine is 50 feet thick as compared to 300 feet thick in Tarrant County.

The soils formed from the Woodbine are of the East Cross Timbers. These soils; the Kirvin, Tabor, Edge and Ruston are derived from the ferruginous sands and non-calcareous shales of the Woodbine. They form on nearly level to gently undulating 1 to 3% slopes, have slow-moderately

rapid external drainage and slow internal drainage. Triaxials in these soils have ranged from 6.0 to 4.2.

The Woodbine has produced base material in the form of iron ore and limestone gravels. The materials range from poor to very good, and are limited in amount. Only after drilling and testing can the exact quality and quantity be determined. Raw triaxials have ranged from 4.0 to 2.2, and with the addition of an admixture, a Class 1 may be obtained.

The sands and sandstones of the Woodbine tend to degrade under rolling or traffic. They will not produce base material but have been used as good to excellent borrow sources.

## EAGLEFORD GROUP

### EAGLEFORD FORMATION

The Eagleford formation is exposed in Tarrant and Johnson Counties. The Eagleford makes up the flat to gently rolling uplands of Tarrant and Johnson Counties.

The formation is predominantly blue laminated shale with an occasional thin sandstone bed. The shales are high in bituminous and carbonaceous material. The shales are soft and weather rapidly to a brown-black color. The Eagleford is 300 feet thick in Johnson County and 400 to 450 feet thick in Tarrant County.

The soils derived from the Eagleford are black-brownish, arenaceous, carbonaceous and treeless soils of the Blackland Prairies. The two dominant soils of the Blackland Prairie in Tarrant and Johnson County are the Houston and Houston Black clay.

The Houston clay is a grayish-brown, strongly calcareous and forms on a gently to moderately sloping upland with a slope of 4 to 8%. External drainage is rapid and internal drainage is slow to very slow. This soil is very susceptible to erosion.

The Houston Black clay is very dark gray-black, calcareous and forms on nearly level to gently sloping uplands with a slope of 1 to 4%. External drainage is slow-rapid, and internal drainage is slow to wanting.

There is no source of base material in the Eagleford formation. As a subgrade material the Eagleford can give much trouble due to the high plasticity of the soil. Large volume changes occur with the change in moisture content causing poor pavement performance. During prolonged droughts in the hot summer, crakcs occur to depths of many feet. Triaxial classes range from 6.0 to 4.8 in this formation.

## GLOSSARY

ACID SOIL: A soil that gives an acid reaction (precisely, below pH 7.0, practically, below pH 6.6).

AEOLIAN: Wind transported material.

ALLUVIUM: Fine material, such as sand and mud or other sediments deposited on land by streams.

ARGILLACEOUS: Applied to all rocks or substances composed of clay, or having a notable proportion of clay in their composition, as rotting slate, shale, etc.

BEDDED: Applied to rocks resulting from consolidated sediments, and accordingly exhibiting planes of separation designated as bedding planes.

CALCAREOUS: An adjective applied to rocks containing calcium carbonate or the carbonate of calcium with less than 5% magnesium. A general term applicable to several grades and types.

CONCRETION: A nodular or irregular concentration of certain constituents of sedimentary rocks and tuffs; developed by the localized deposition of material from solution, generally about a central nucleus, and harder than the surrounding rock.

CRYSTALLINE: Of or pertaining to the nature of a crystal, having regular molecular structure.

CROSS BEDDING: The arrangement of laminations of strata transverse or oblique to the main planes of stratification of the strata concerned; inclined, often lenticular beds between the main bedding planes; found only in granular substances.

ESCARPMENT: The steep face of a ridge of high land. In gently inclined strata the abruptly truncated and cliff-like outcrops of the hard beds are called escarpments.

FACIES: Segregated parts of different nature belonging to any genetically related body of sedimentary deposits.

FAULT: A fracture or fracture zone along which there has been displacement of the two sides relative to one another parallel to the fracture. The displacement may be a few inches or many miles.

FERRUGINOUS: Descriptive of rocks of red color but not necessarily abnormal iron content. Containing iron.

FISSILE: Splitting into thin more or less papery, sheets.

FORMATION: Any assemblage of rocks which have some character in common, whether of origin, age, or composition. The ordinary unit of geologic mapping consisting of a large and persistent stratum of some one kind of rock.

FRIABLE: Easily crumbled as would be the case with rocks that are poorly cemented.

GROUP: A local or provincial subdivision of a series, based on lithologic features. It is usually less than a standard series and contains two or more formations.

INDURATED: Rocks that have been hardened not only by heat but also by pressure and cementation.

LAMINA: Unit layer or sheet of a sediment in which the stratification planes are one centimeter or less apart. Lamina need not be parallel to the bedding.

LENTIL: A lens. A lentil has slight geographic extent. The essential feature of a lentil is that it thins out, presumably in all directions.

LIGNITE: A brownish-black coal in which the lateration of vegetal material has proceeded further than in peat but not as far as sub-bituminous coal.

LIMESTONE: A bedded sedimentary deposit consisting chiefly of calcium carbonate ($CaCO_3$) which yields lime when burned. Limestone is the most important and widely distributed of

the carbonate rocks and is the consolidated equivalent of limey mud, calcareous sand, or shell fragments.

MARL: A soft water-deposited material consisting chiefly of calcium carbonate, but containing some sand, clay, organic matter, and other impurities.

MEMBER: A division of a formation, generally of distinct lithologic character or of only local significance.

NODULAR: Having the shape or composition of nodules. A nodule is the general term for a rounded sedimentary body, which can be separated in a discrete mass from the formation in which it occurs.

PERMEABILITY: The capacity of a rock to transmit fluid. Degree of permeability depends on the size and shape of the pores, the size and shape of their interconnections and the extent of the latter.

PHYSIOGRAPHY: Physiography has to do primarily with the surface of the lithosphere and with the relations of air and water to it. Used by American writers as synonymous with physical geography.

PLASTIC: Capable of being molded without rupture.

RELIEF: The elevations or the inequalities, collectively, of a land surface. The difference in elevation between the high and low points of a land surface.

SANDSTONE: A cemented or otherwise compacted transported sediment composed predominantly of quartz grains, the grades of the latter being those of sand.

SERIES: A term applied to a number of related rocks or minerals arranged, or capable of arrangement, in a natural sequence of succession, composition, or other property. The term is applied to the main subdivisions of systems.

SHALE: A laminated sediment, in which the constituent particles are predominantly of the clay grade.

SILICEOUS: Of or pertaining to silica, containing silica, or partaking of its nature.

SLOPE, SOIL: Refers to the incline of the surface of the soil area. Slopes may be defined as single or complex. Slope names and the ranges in slope percent as defined in the Soil Survey Manual are as follows:

| SLOPE RANGE % | SLOPE NAME | SLOPE TYPE |
|---|---|---|
| 0-3 | level | single or complex |
| 1-8 | gently sloping | single |
| 1-8 | undulating | complex |
| 5-16 | sloping | single |
| 5-16 | rolling | complex |
| 10-30 | moderately steep | single |
| 10-30 | hilly | complex |
| 20-65 | steep | single or complex |
| 45-65 | very steep | single or complex |

STRATIFIED: Formed or lying in beds, layers, or strata.

WEATHERED: The physical and chemical disintegration and decomposition of rock and minerals by natural processes.

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