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FINAL REPORT

SEQUENCE STRATIGRAPHY AND ENGINEERING GEOLOGY OF LAWRENCE FORMATION (DOUGLAS GROUP) IN NORTHEASTERN KANSAS

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16 Abstract

Numerous cases of rock and slope instability in the Lawrence Formation (Virgilian Series, Douglas Group) have been encountered in construction, excavation, and highway projects in eastern Kansas (Archer, 1992). This formation consists of a thick interval of shales, mudstones, sands, and local marine limestone (Joeckel, 1994). Because of its heterolithic nature, the factors controlling rock/slope stability will vary throughout this formation. Furthermore, failures that occur following project completion are extremely costly.

The principle objective of this report is to provide a detailed facies characterization of the Lawrence Formation that identifies the sedimentological and depositional properties and their corresponding durability's. In order to identify potential areas that will be the most susceptible to failure, the following tests were conducted: Slake Durability, Jar Slake Index, Chittick ($CaCO_3$ content), water absorption, clay mineralogy (XRD), and petrographic thin sections.

This research will provide a better representation of the spatial distribution of the variability and durability within and between this problematic formation. The results will be useful for both engineers and contractors that encounter the Lawrence Formation in assessing the risk of rock/slope instability for future project developments. This research will not only benefit future project/construction costs, but it will also assist in protecting the safety of people and the environment.

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Final Report

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ABSTRACT

Numerous cases of rock and slope instability in the Lawrence Formation (Virgilian Series, Douglas Group) have been encountered in construction, excavation, and highway projects in eastern Kansas (Archer, 1992). This formation consists of a thick interval of shales, mudstones, sands, and local marine limestone (Joeckel, 1994). Because of its heterolithic nature, the factors controlling rock/slope stability will vary throughout this formation. Furthermore, failures that occur following project completion are extremely costly.

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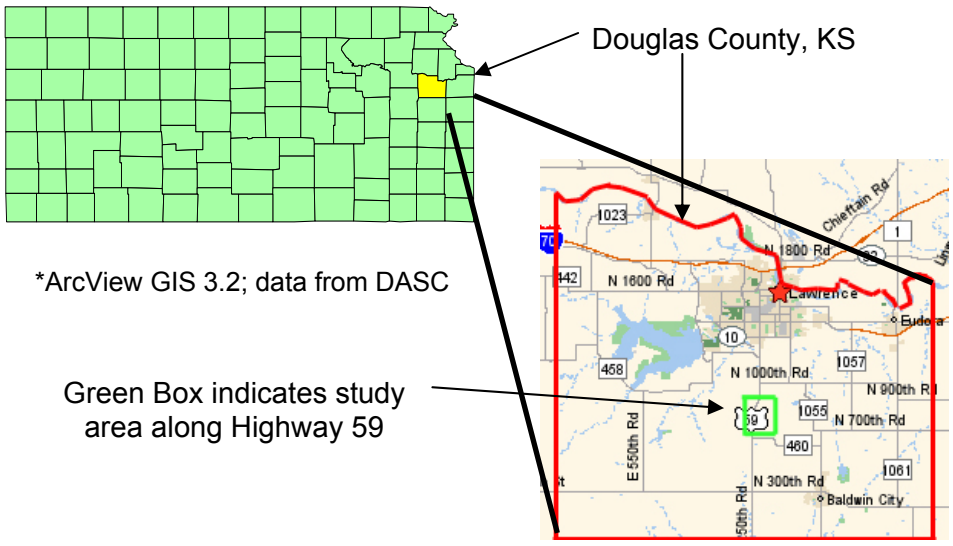
INTRODUCTION

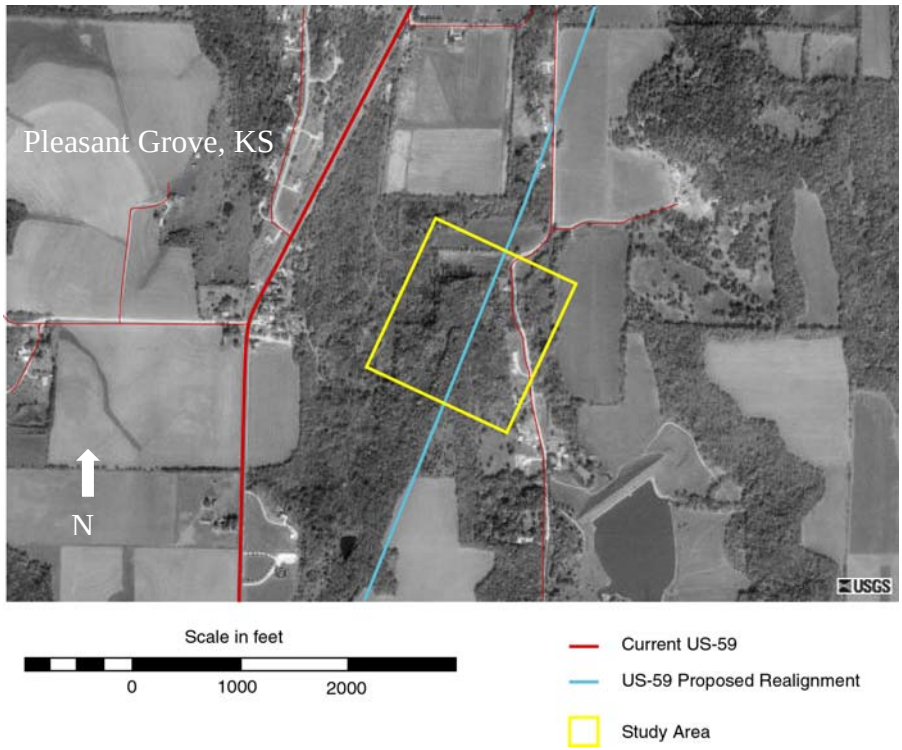
The variability within and among the Lawrence Formation makes it problematic to manage and leads to complex and expensive construction, excavation, and highway projects. In collaboration with the Kansas Department of Transportation (KDOT), the focus for this report is to create a detailed stratigraphic, depositional, and sedimentological description of the Lawrence Formation, relative to its mechanical/durability properties. This has been accomplished by analyzing six cores received from the Kansas Department of Transportation (KDOT). KDOT obtained these cores, for preliminary analysis, for the realignment of Highway 59 from Lawrence, KS, south to Ottawa, KS (KDOT Project Number 59-23 K 7888-01). Currently, this stretch of highway is one of the most dangerous in Kansas. It is a hilly, narrow, two lane highway that has a high traffic volume with many access points to side roads and residential areas. The new highway will be a four lane divided highway that will run parallel to the current Highway 59 and include limited access roads and on/off ramps. The area of interest for this realignment project is located in eastern Kansas (Douglas County) near the town of Pleasant Grove, approximately five miles south of Lawrence, KS (Fig. 1.1, 1.2). This research site was chosen because the projected highway realignment involves excavating into a hillside (Pleasant Grove Hill) and creating road-cuts that will expose approximately seventy-five feet (in height) of the problematic Lawrence Formation.

Figure 1.1 Location of Study Area



www.yahoo.com/maps

Figure 1.2: Aerial View of Study Area



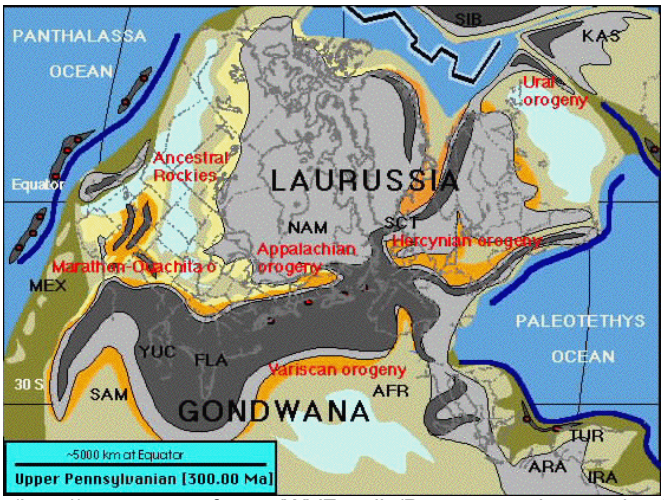
(Aerial photo from www.terraserver-usa.com and projected realignment courtesy of KDOT)

CHAPTER 1: BACKGROUND

Tetonic Setting

The deposition of the Lawrence Formation occurred during the Late Paleozoic Era (543-248 million years ago) in a period known as the Carboniferous (354 to 290 million years ago). During this time the supercontinent of Euramerica, also known as Laurussia, included North America, Greenland, and Europe. This supercontinent collided with Gondwanaland, which included South America, Africa, Antarctica, India, and Australia. The joining of these two supercontinents formed Pangea (Fig. 1.3, 1.4). The collision and suturing of both Laurussia (to the north) and Gondwanaland (to the south) induced the orogenies of the Appalachian (eastern North America), Ouachita (Oklahoma and Arkansas), Marathon, Ural (Russia), Variscan, Hercynian (United Kingdom), and the Ancestral Rockies (in west-central North America). Other tectonic structures that influenced Kansas, besides

Figures 1.3, 1.4: Paleogeographic reconstructions of North America during the Carboniferous.



(http://www.geocraft.com/WVFossils/Penn_tectonic_map.html)

(http://www.geocraft.com/WVFossils/Penn_relief_map.html)

orogenies, were generated by mostly low amplitude vertical movements within the North American craton.

In areas surrounding eastern Kansas, uplift and subsidence were occurring simultaneously. While these uplifted regions provided sources of clasitc sediments, they also generated areas of subsidence which promoted the development of depositional basins. Related to surrounding structural controls within the study region, the Lawrence Shale was deposited in the Forest City basin that extended from central Iowa, through southeastern Nebraska and northeastern Missouri, and into northeastern Kansas. The Forest City Basin is structurally bounded by a variety of geomorphic features. These structural features include (Fig. 1.5): the Canadian Shield and Wisconsin Arch to the north, the Sioux Arch to the northwest, uplifted regions of the failed Mid-Continent Rift (MCR) system from the north through the west (include the St. Croix Horst, Iowa Horst/Thurman-Redfield Structural Zone, and the Nemaha Ridge), the Bourbon Arch and Ouachita Mountains to the south, the Ozark Dome to the southeast, and the Mississippi River Arch to the east.

Sediment Sources and Structural Controls

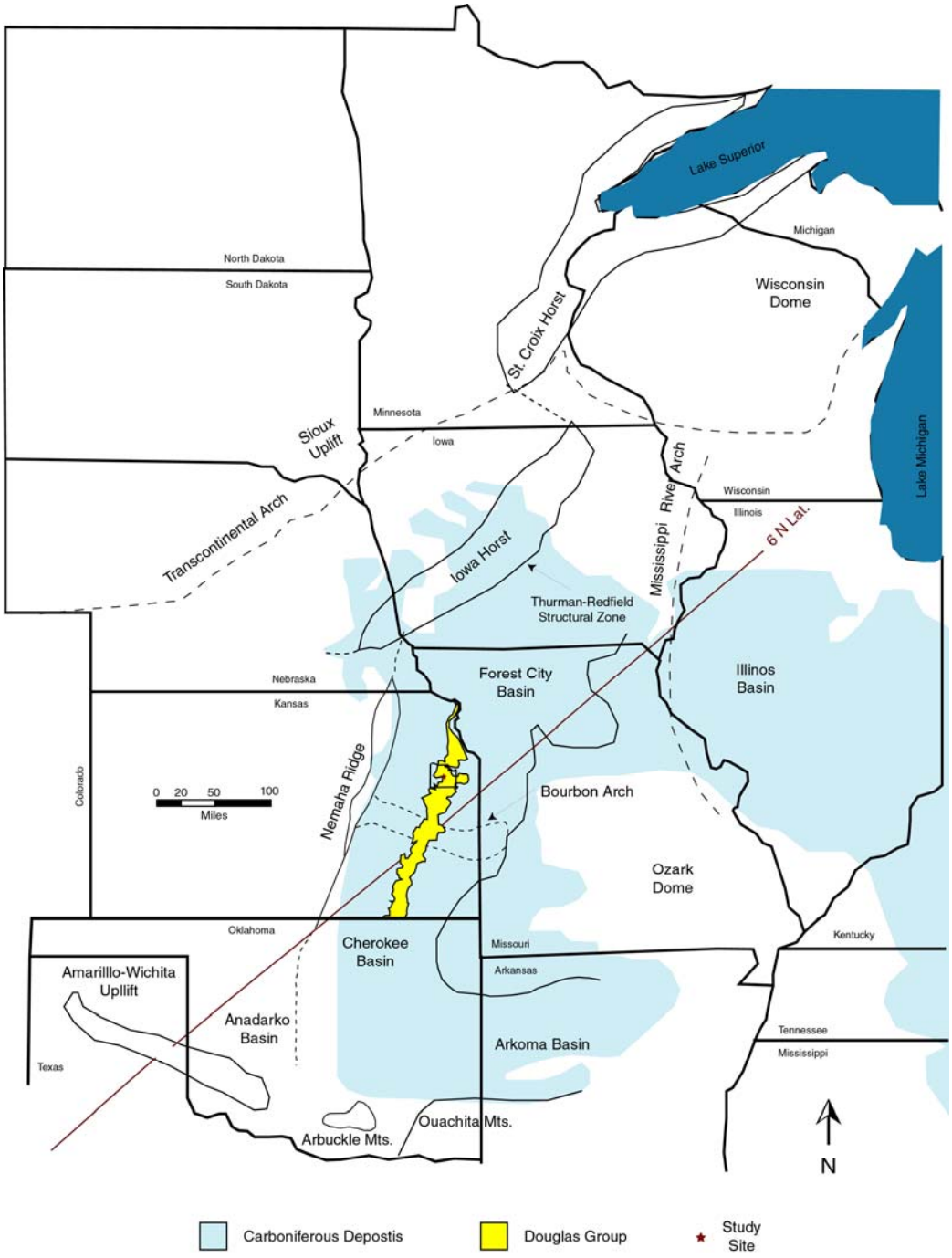
The positive relief structures surrounding the Forest City basin generated major sources of siliciclasitic sediments in northeastern Kansas. Through paleocurrent analyses (Feldman and Archer, 1995), the dominant source of siliciclastic sediments was from the northeast. North of Kansas there were large uplifts that exposed Precambrian basement granites known as the Canadian Shield, in Minnesota, and the Wisconsin Arch, in Wisconsin. Both granitic features provided a source of clastic sediment to surrounding basins.

The Sioux Arch/Ridge extends from southeastern Minnesota into central South Dakota and consists largely of quartzite. The quartzite was metamorphosed from sandstone and claystone that were deposited in a shallow sea approximately 1.7 billion years ago (Southwick, 1986).

The Mid-Continent Rift (MCR) system, also referred to as the Keweenawan Rift, is a 1.1 billion year old failed rift (Anderson and McKay, 1989). The MCR extends southwestward from eastern Lake Superior, across north-central to southwest Iowa, through eastern Kansas, and into central Oklahoma. The cessation of the MCR rifting phase initiated uplift along most of its axis. As the rift became filled with mafic volcanic rocks (basalts), this generated the mid-continent gravity anomaly (MGA). The uplifted region within the MCR consists of the Nemaha Ridge in north-central Kansas, the Iowa Horst in central Iowa, and the St. Croix Horst in Wisconsin (Runkel, 2002).

During the Carboniferous, southern Oklahoma was undergoing its greatest period of mountain building. These orogenic events resulted in the Ouachita, Arbuckle, and Wichita-Amarrillo mountains.

Figure 1.5: Tectonic Framework Surrounding Kansas during the Carboniferous.



(Tectonic framework modified and adapted from Jewett, M., 1951, and Runkel, 2002, Rutan, D., 1975, and Steeples, D., et. al., 1979; the carboniferous deposits were adapted from http://www.paleoportal.org/time_space/period_map.php?period_ id=12; and Douglas Group was adapted from KGS Map M-23)

Geologic Setting

The Carboniferous is separated further into a Lower/Early Carboniferous and an Upper/Late Carboniferous. In North America these subdivisions are known as the Mississippian (354-353 million years ago) and the Pennsylvanian (323-290 million years ago) systems. Most of the Early Paleozoic and into the Early Carboniferous (Mississippian) was a period of expansive shallow epicontinental seas. Throughout this time period, much of the mid-continent United States resulted in predominately thick carbonate deposits. In North America, the Early Carboniferous (Mississippian) is differentiated from the Late Carboniferous (Pennsylvanian) by an unconformity resulting from the regression of the Kaskaskia epieric sea and the transgression of the Absaroka epieric sea. This created a transition from the Early Carboniferous marine environments, in eastern Kansas, to a geologic province consisting of alternating siliciclastic (shale and sandstones), coal, and carbonate (limestone) strata in the Late Carboniferous. These lithologic cycles of repetition, known as cyclothems, are a result of both glacioeustatic fluctuations, due to Gondwanaland ice sheets, and regional tectonic activity (Wanless and Weller, 1932). In 1932, cyclothems were originally applied by Wanless and Weller to the Illinois Basin (Weller, 1964). Moore (1935) continued extensive research in the Illinois Basin and later to the Mid-Continent where he used the concept of megacyclothems. A megacyclothem, according to Heckel (1977), are cyclic repetitions in depositional sequences which are defined as having the outside parts of the cycles consisting of siliciclastic and coal-bearing material while most marine material (limestones and black shales) are designated in the center of the cycles. He interpreted the megacyclothem as the now widely accepted cyclothem model

for Kansas. The depositional environments of the Douglas Group interval, containing the Lawrence Formation, consisted of fluvial, estuarine, and marine facies (Archer and Feldman, 1995).

Figure 1.6: Carboniferous Reconstruction

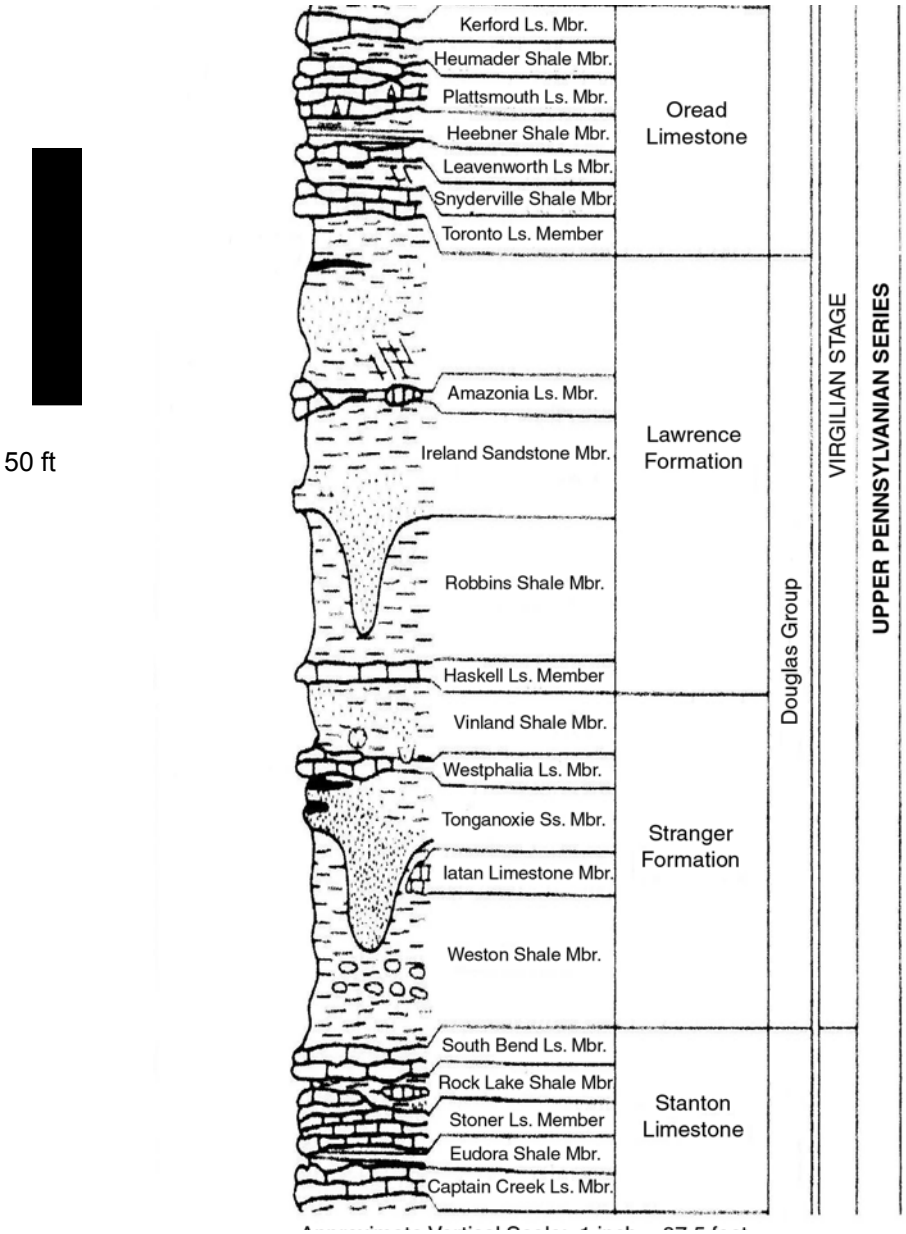
http://hoopermuseum.earthsci.carleton.ca/carbocoal/LIFE3.HTM

The coal-bearing layers, from which the Carboniferous is named, are attributed to the vast amounts of plant material provided by wetlands (e.g., swamps, marshes, and bogs) throughout mid-western and eastern North America, as well as other parts of the world. These stagnant and oxygen deficient wetlands accumulated plant debris with limited decomposition. Periodically, the plant material provided by wetlands were submerged by transgressive seas and buried by sand, clay, and other debris. Over thousands and millions of years, the buried organic material (peat) is altered by increased overburden pressure and temperature to form coal deposits. These coal seams/beds are important stratigraphic markers that are indicative of terrestrial environments. A paleogeographic reconstruction during the Paleozoic locates Kansas near the equator (Fig. 1.5) where tropical and humid conditions prevailed (Archer and Feldman, 1995). Figure 1.6 depicts what Kansas may have looked like during the Carboniferous, where the main biomes were swamps and/or tropical rainforests. Vegetation included a variety of ferns and large tree-like relatives of present-day *Lycopodium*. There were many amphibians, as well as insects, spiders, and other arthropods.

Stratigraphy

The Lawrence Shale is an interval within the Douglas Group that lies in the Virgilian Series of the Upper Carboniferous period (Late Pennsylvanian System). It is important to discuss the stratigraphy of the overlying and underlying lithologies surrounding the Lawrence Formation (Fig. 1.7). This can provide insight into paleoenvironmental conditions and yield key stratigraphic markers used as depth indicators during drilling. The stratigraphy within my study area (Fig. 1.7) includes the Stanton Limestone (Lansing Group) in the Missourian Series and extends upward through the top of the Oread Limestone (Shawnee Group) in the Virgilian Series. Looking at the stratigraphic column in Figure 1.7, there are noticeable similarities and differences within and between the formations. The Oread and Stanton Limestone Formations are similar in that they comprise of the typical Kansas cyclothem with black platy shale members (Eudora and Heebner) and thick, laterally extensive limestones (Heckel, 1977). However, the Douglas Group (Lawrence Shale and Stanton Formation) lack these thick, extensive limestones and black platy shales and primarily consist of siliciclastic facies with locally deep incised valley-filled sandstones. Prominent marker beds exist in the stratigraphic column and can be used to correlate and determine relative stratigraphic position. These marker beds consist of the following: the black fissile Heebner and Eudora Shale, the Upper/Lower Williamsburg Coal, the Ireland and Tonganoxie Sandstone (however in some cases the Ireland may extend into the Tonganoxie and may be hard to determine from one another), and the thick, laterally extensive limestones within the Oread and Stanton Limestone Formations.

Figure 1.7: Generalized Stratigraphy of the Douglas Group and Surrounding Lithologies



(Hagen and Hensiek, 1968)

As defined by O'Connor (1963), the Douglas Group is divided into two formations, the Lawrence Shale and Stranger Formation, which include rocks that were formerly assigned to the Pedee Group. The Lawrence Formation consists of a thick interval of shales, mudstones, sands, and local marine limestone (Joeckel, 1994). Zeller (1968), describes the formation as containing chiefly gray shale and sandstone, which weathers yellowish-gray, minor amounts of red shale, coal (Williamsbrug coal bed), gray limestone, and conglomerate. The Lawrence Formation, which ranges from 140 feet in northern Kansas to 250 feet in southern Kansas (Zeller, 1968), is subdivided into four members that extend from the base of the Haskell Limestone Member to the base of the Toronto Limestone Member (Fig. 1.7). The Haskell Limestone and Robbins Shale members were formerly included in the underlying Stranger Formation. Above the discontinuous Amazonia Limestone Member, an unnamed shale unit (10 to 60 feet thick) consists of gray, green, and red shale, and earthy limestone with minor amounts of siltstone and sandstone and contains the Williamsburg coal bed from Douglas County to Elk County (Zeller, 1968).

Stratigraphic Descriptions and Sampling

Stratigraphic descriptions and laboratory sampling, of the Lawrence Formation, was conducted by analyzing six cores that have were provided by the Kansas Department of Transportation (KDOT). All the cores were obtained using a truck mounted wireline core drilling rig on Pleasant Grove Hill (just east of Pleasant Grove, KS). Cores were hoisted to the surface, through drill rods, in five foot core tubes attached to a wireline. Cores were then taken out of the inner core tube and placed in sequential order in boxes for geological examination.

Detailed measurements, of the various lithologic facies encountered within the cores, were recorded (in feet) along with sedimentological descriptions. These descriptions included: rock type, color (Munsell, 1994), texture, bedding, fractures, and concretions. Using these detailed sedimentological core descriptions, the depositional environments can be determined for the different microfacies. High resolution digital pictures were taken of all the core boxes and materials sampled for testing. Detailed stratigraphic columns and fence diagrams were generated using gINT Professional, which is a software package used for geoenvironmental and/or geotechnical engineering reports. This software allows data to be entered into a relational database system that can generate borehole logs, well logs, fence diagrams, and geotechnical lab testing reports. This software package was used to store and manipulate the data gathered from the core descriptions and laboratory tests to generate graphical representations of the Lawrence Shale using borehole logs and fence diagrams.

Borehole and test pit information with sampling schemes are given in Table 1.1 and 1.2. Figure 1.8 provides an aerial view of Pleasant Grove Hill with borehole locations, while Figure 1.9 displays a profile of Pleasant Grove Hill with borehole information. For testing analysis, representative samples were taken directly from the cores based on lithologic changes within the Lawrence Shale. With these samples, the following tests were conducted to assist in determining durability: slake durability, jar slake, chittick (calcium carbonate content), X-ray diffraction (XRD), and petrographic thin sections.

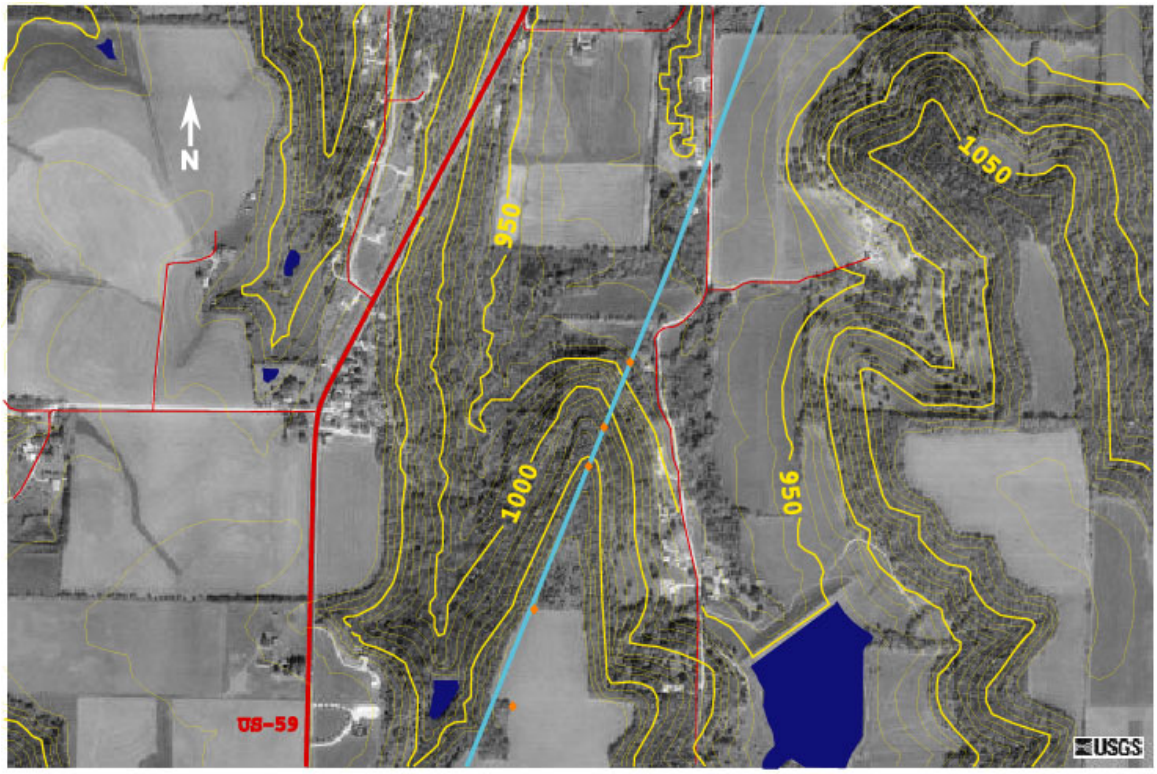
Table 1.1: Borehole Information and Sampling Identification

Station	Location	Surface Elevation (ft)	Completion Depth (ft)	Boxes	Cores	Sample ID
506+36, 200' Rt CL	Top of Pleasant Grove Hill - Deep Hole 1	1083.5	88.2	8	24	DH1
506+36, 200' Rt CL	Top of Pleasant Grove Hill - Deep Hole 2	1083.5	102.8	9	29	DH2
512+00	Northwest corner of soybean field	1082.5	72.5	6	18	SF1
524+25, 25' Lt CL	Back in timber on north face of Pleasant Grove Hill	1058	102.5	9	23	NFH1
526+30, 7' Rt CL	Middle of Pleasant Grove Hill (north face)	1024	62	5	14	MH1
531+50+25' Rt CL	Base of hill (north face)	940	36.5	3	7	BH1

Table 1.2: KDOT Test Pits for Slake Durability Sampling

Station	Sample ID
528+84 CL	P-1-3
530+06 CL	P-2-1
530+06 CL	P-2-3
530+06 CL	P-2-5
527+80, 20 ft Lt CL	P-3-2
527+80, 20 ft Lt CL	P-3-4

Figure 1.8: Contoured Aerial View of Study Area Showing Projected Realignment and Borehole Locations



Scale in feet

0 1000 2000

Contour Interval: 10 feet

Borehole Locations

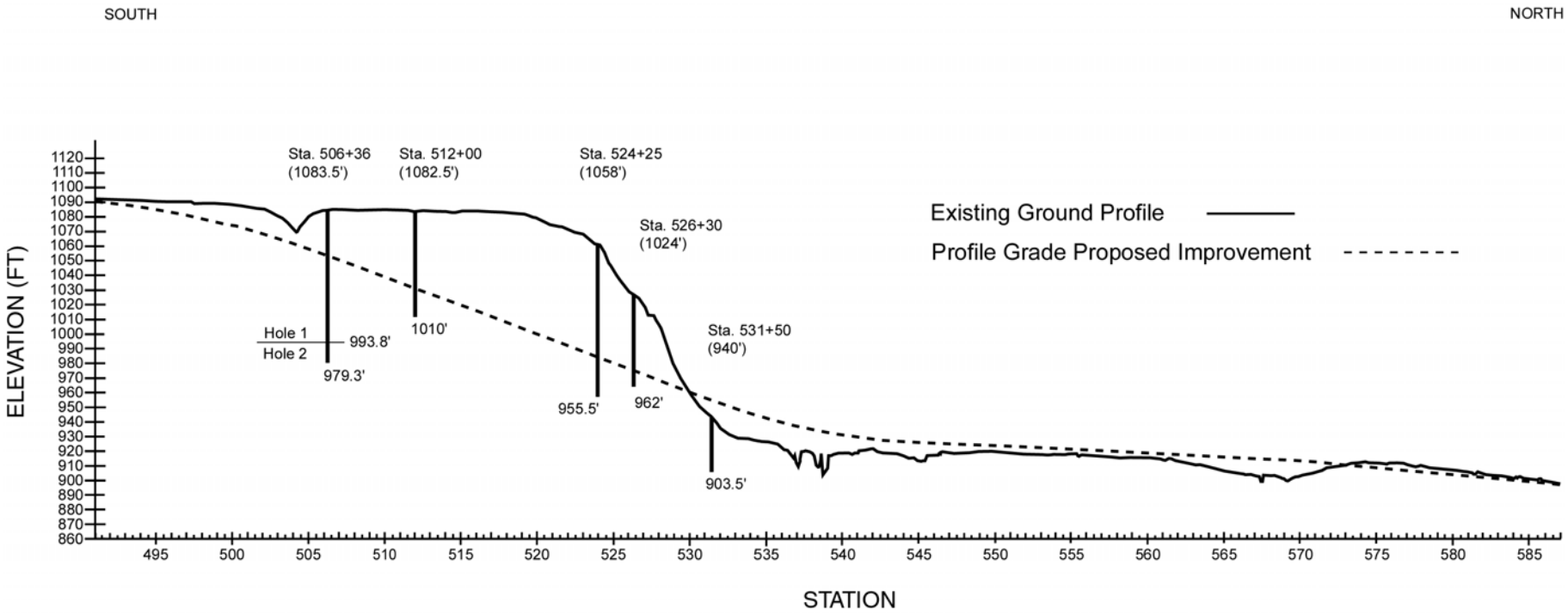
Current US-59

US-59 Proposed Realignment

Water Bodies

Boreholes Identifications from south to north: DH1/DH2 (Sta. 506 + 36, 200' Rt CL)
SF1 (Sta. 512 + 00)
NFH1 (Sta. 524 + 25)
MH1 (Sta. 526 + 30)
BH1 (Sta. 531 +50)

Figure 1.9: Profile of Pleasant Grove Hill with Borehole Locations and Elevations



*Surface elevation (ft) is given in parentheses, while bottom-hole elevation (ft) is not given in parentheses.

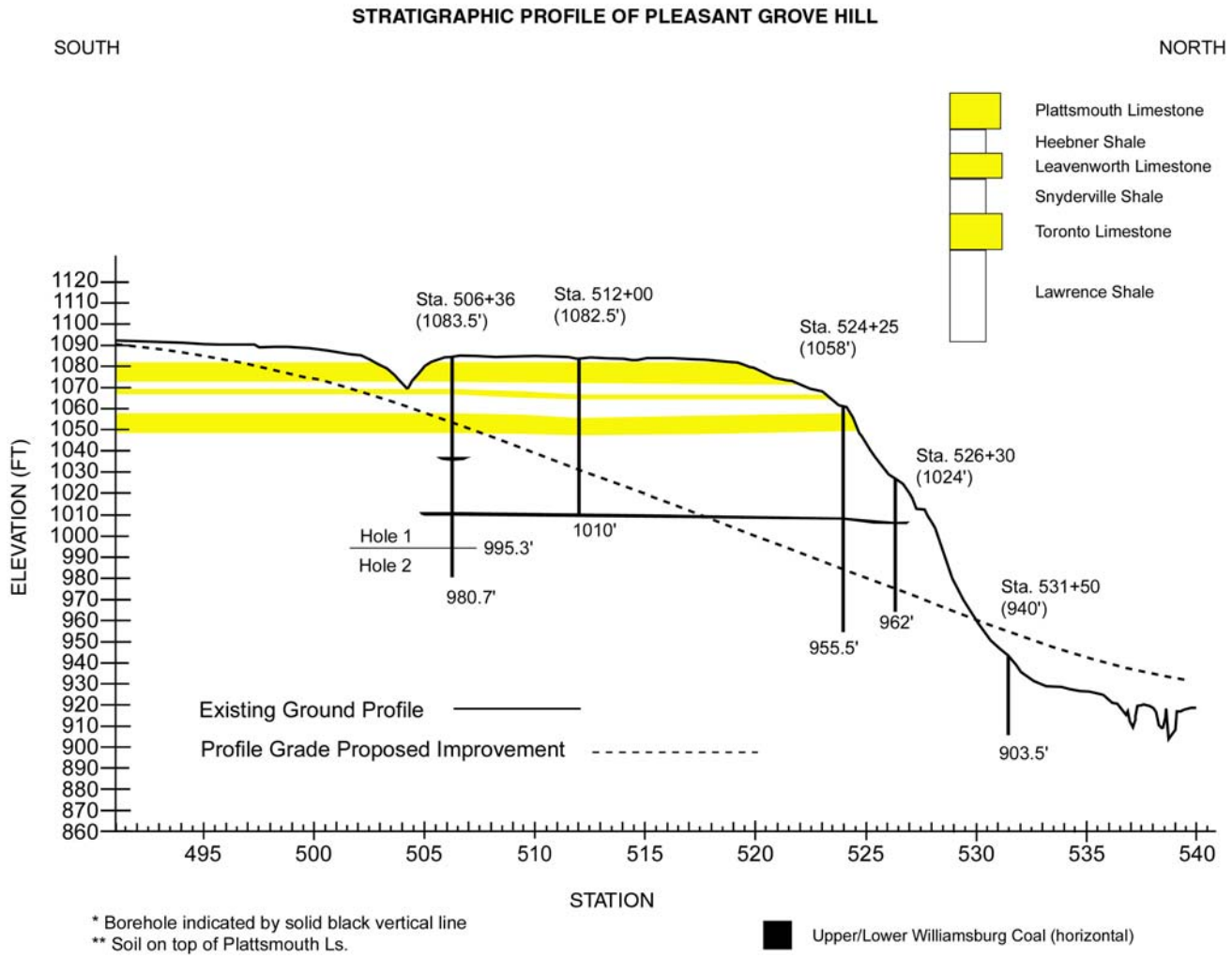
CHAPTER 2: MICROFACIES

Detailed measurements and sedimentological descriptions were recorded for all of the cores received from KDOT. The data were input into gINT Professional to generate graphical borehole logs (Appendix A) as well as identify the sample locations with corresponding durability test results (slake durability, jar slake, and percent calcium carbonate). The general stratigraphy of Pleasant Grove Hill is shown in Figure 2.1.

The tallest road-cut will be approximately seventy-four feet, in height, from Station's 524+25 to 518+250. At most, sixty-six feet (~ 89 %) of the exposure will contain the Lawrence Shale at Station 524+25. Road-cuts containing only the Lawrence Shale will be located on the north face of Pleasant Grove Hill at Station's 524+500' (66' road-cut) to 530 (no road-cut created).

Based on the sedimentological core descriptions within the Lawrence Shale, ten microfacies were defined using primary and secondary sedimentary structures. Based upon an identification of microfacies, an interpretation can be determined regarding its original depositional environment. The microfacies identified include: Churned Shale (biorturbated), Shale, Clayshale, Coal, Paleosol, Carbonate-rich Shale (nodules), Lenticular Shale, Silty/Sandy Shale, and Weathered Shale. A profile of Pleasant Grove Hill with the locations of the microfacies is shown in Figure 2.2. Table 2.1 provides approximate percentages of microfacies encountered during coring within Pleasant Grove Hill.

Figure 2.1: Stratigraphic Profile of Pleasant Grove Hill



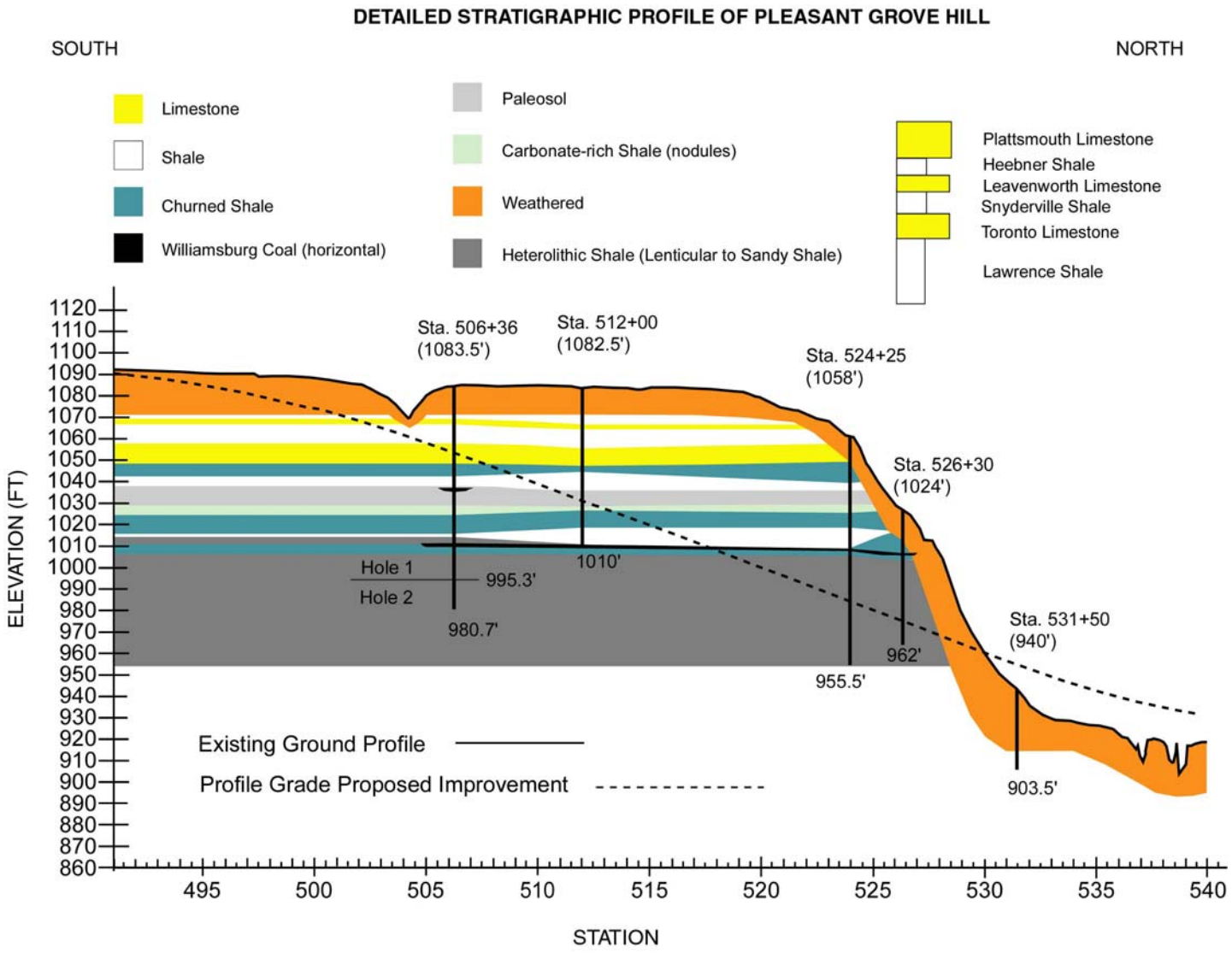


Figure 2.2: Detailed Stratigraphic Profile of Pleasant Grove Hill, with Microfacies

Table 2.1: Approximate Percentages of Lawrence Shale and Microfacies within Pleasant Grove Hill (based on coring).

	Station	506+36, 200' Rt (DH1)	506+36, 200' Rt (DH2)	512+00 (SF1)	524+25, 25' Lt (NFH1	526+30; 7' Rt CL (MH1)	531+50, 25' Rt CL (BH1)
	Lawrence Shale cored	62%	67%	35%	92%	100%	100%
MICROFACIES	**Churned Lenticular Shale**	10%	8%	22%	15%	--	--
	Shale	16%	11%	35%	17%	8%	39%
	Coal	2%	2%	1%	1%	--	--
	Paleosol	11%	12%	17%	7%	--	--
	Churned Shale	17%	16%	17%	1%	--	--
	Carbonate-rich Shale	13%	7%	7%	2%	--	--
	Claystone	1%	1%	1%	1%	--	--
	Lenticular Shale	25%	29%	--	21%	28%	--
	Silty/Sandy Shale	5%	14%	--	35%	42%	--
	Weathered Shale	--	--	--	--	22%	61%
	SUM	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**

Microfacies #1: Churned Shale

Description: Light Greenish Gray (5GY 8/1) to Greenish Gray (5G 8/1) shale that was identified by disruption or reformation of the primary sedimentary bedding features. The churned shales were identified at three localites within the Lawrence Shale:

1) Beneath the Toronto Limestone, the churned shale was comprised of very fine sand to silty, isolated lenticels. The lenticels were irregularly shaped and deformed due

to bioturbation. The more resistant, coarser lenticels protruded from the less resistant shale/mud creating a “ribbed” appearance on the surface of the core (Fig. 2.3a).

2) Underlying the carbonate-rich (nodular) shale microfacies, was a fossiliferous shale containing bivalves. The presence of the bivalves and disruptive bedding (“ribbed”) were indications of bioturbation (Fig. 2.3b).

3) Beneath the lower Willamsburg coal a churned shale was identified with disrupted bedding, wisps on the outside of the core, and plant fossils. The whisps are good indication of root penetration, and correlates well with the presence of plant fossils. Underlying a coal seam, this churned shale may represent a weakly developed paleosol.

Figure 2.3: Churned Shale
a) Very thin, isolated silty to sandy lenticels/ripples. The more resistant silty/sandy ripples protrude out from the weaker (less resistant) shale generating a ribbed appearance on the surface of the core. The ripple morphology is not well defined due to alteration by bioturbation.
b) Shale displaying ribbed appearance on the surface of the core due to bioturbation. Bivalves within the bedding plane are associated with this shale.
Scale in both core photos is 1/10'.

a) Churned Shale; Lenticular/Streaked Bedding

b) Churned Shale; Bivalves

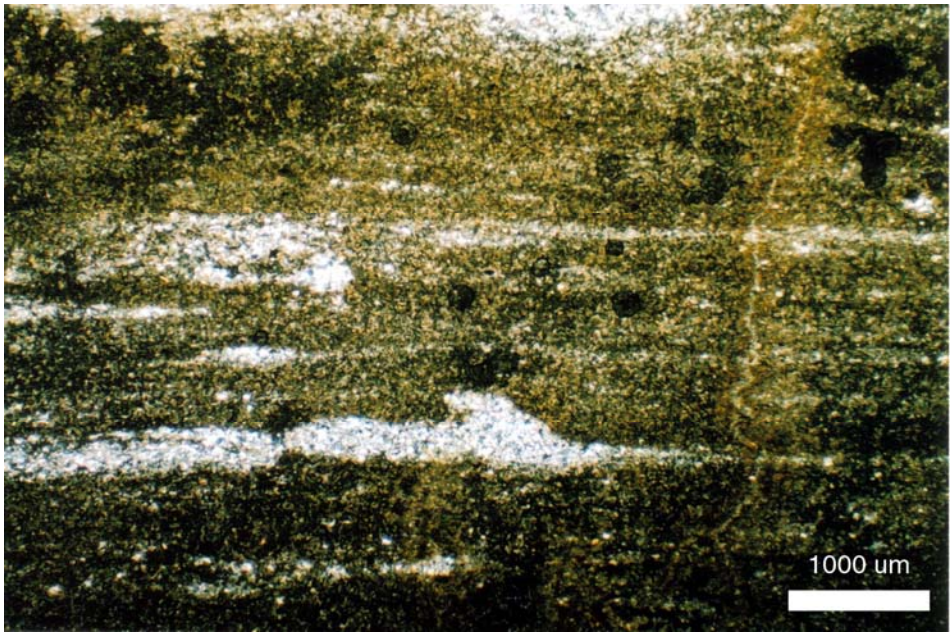
Figure 2.4: Churned Shale microfacies
a) silty streaked to lenticular shale with disturbed bedding caused by abundant bioturbation.
b) rotated 45°, the clay orientation is identified by the high birefringence. Disrupted silty lenticel and bedding due to bioturbation.
Frame length in both photomicrographs is 6650 μm (6.65 mm).

(a) cross-polarized; 5x total magnification

(b) cross-polarized; 5x total magnification; rotated 45°

Figure 2.5: Churned Shale microfacies
a) silty shale with burrow filled with coarser silt (spreites).
b) lenticular shale with disturbed bedding generated by bioturbation; root (right) and disrupted silty lense in upper left.
Frame length in both photomicrographs is 6650 μm (6.65 mm).

(a) cross-polarized; 5x total magnification



(b) cross-polarized; 5x total magnification

Interpretation: The term “churned” is referring to the agitation or deformation of the primary bedding structure, due to bioturbation. The churned shales are located in three regions within the Lawrence Shale. Directly beneath the Toronto Limestone lies a light greenish gray churned lenticular shale. Because of its proximity to limestone, it suggests transgressive sequence where marine bioturbation has disrupted the silty/sandy lenticles within the shale. Another sequence of this microfacies is located beneath the carbonate-rich shale, where the shale has been churned by bivalves. The final churned shale microfacies was located in proximity to coal seams, with root wisps/traces, which indicate terrestrial influence.

Microfacies #2: Shale

Description: Light Gray (N7) to Medium Dark Gray (N4) lithified clay/mud that breaks (platy to slabby) parallel to horizontal bedding plane. A majority of the shales were clay-rich (Fig. 2.6a), displaying irregular partings along bedding plane due to the presence of expandable clays (shrink/swell).

Figure 2.6: Shale Core Photographs.
a) Light gray clay-rich shale with abundant fractures that are irregular (shrink/swell) and parallel to the horizontal bedding plane.
b) Medium gray shale that lacks the irregular fractures (shrink/swell clay) as in (a), with flat, parallel fractures along horizontal bedding plane. Scale is 1/10" in core photos.

a) Clay-rich Shale

b) Shale

Interpretation: Low energy, open marine environment below wave base allowing fall out from suspension.

Microfacies #3: Clayshale

Description: Light Gray (N7) to Light Olive Gray (5Y 6/1) fat/slick clay with very thin laminations. Predominately occurs in isolated, small beds, no thicker than 0.5 feet. Typically creates sharp contacts with the underlying and overlying materials. Clayshale is very weak/soft clay-rich material with abundant fractures (irregular). Because of its high plasticity, the material is compressed and deformed easily (expandable clays).

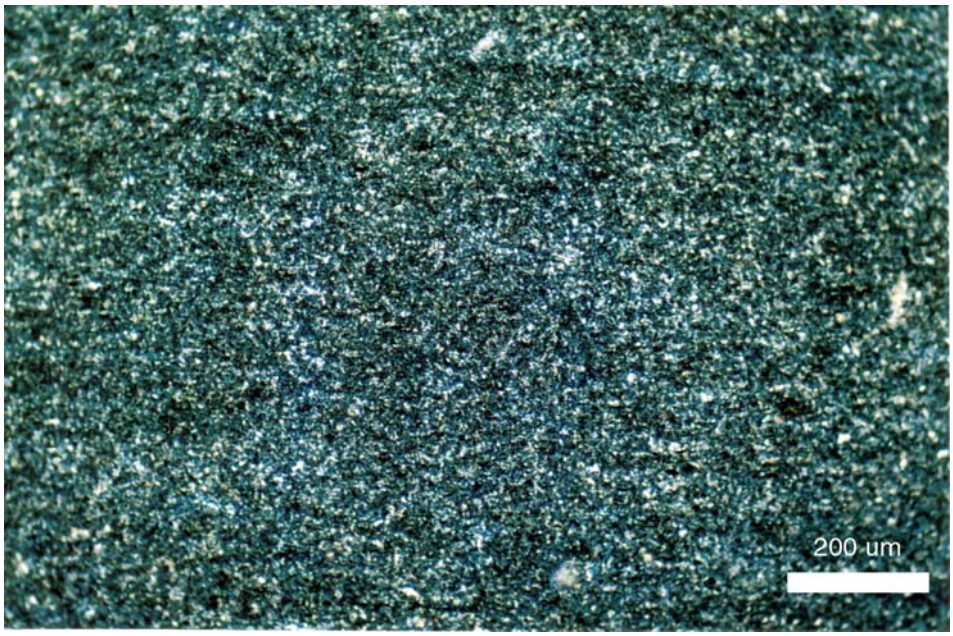
Figure 2.7: Displays the abundance of irregular fractures through out the friable clayshale.
Fig. 3.10: Due to the high plasticity of the material, finger prints were preserved on the surface of the core during core retrieval.
Fig. 3.11*:* Light gray clayshale showing the thinly laminated structure within the core. Scale in all core photos is 1/10'.

A: Clayshale

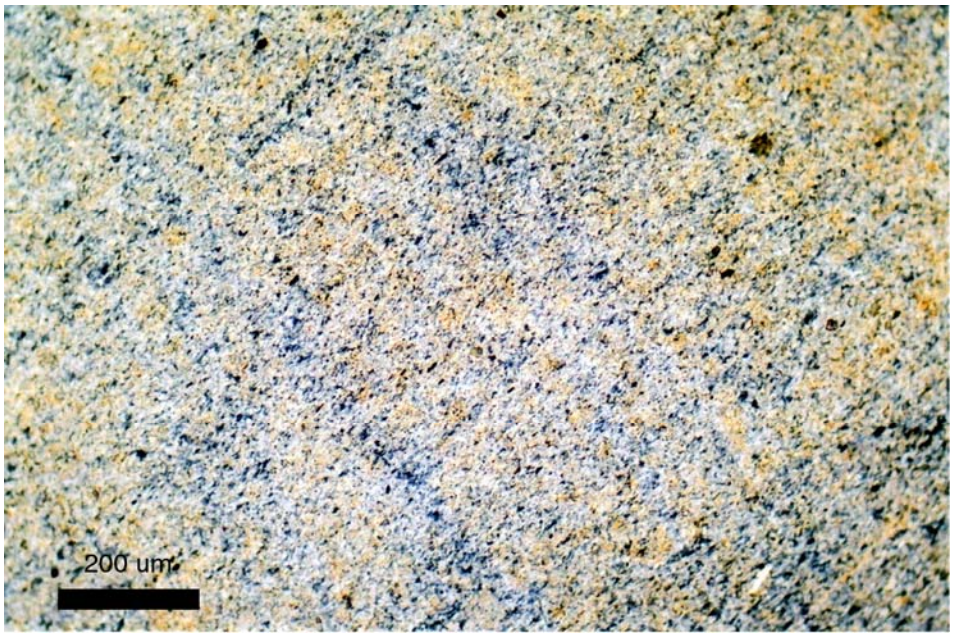
B: Clayshale

C: Clayshale

Figure 2.8: Clayshale Photomicrographs
a) contains abundant clay.
b) rotated 45°, the high birefringence of the oriented clays displays the bistrial b-fabric (micromass) where two intersecting sets of oriented clays can be seen.
Frame length in both photomicrographs is 1330 μm (1.33 mm).



(a) crossed polarized; 25x total magnification



(b) crossed polarized; 25x total magnification; rotated 45°

Interpretation: The extremely high clay content suggests a very low energy environment of deposition. The isolated pod-like and irregular lateral distribution of this facies indicates that the paleoenvironmental conditions were highly variable laterally. Similar shales occur in the roof rocks of coal mines in Indiana and Illinois (A. Archer, pers. comm., 2006). The various features of these shales could be interpreted as having formed within areas of ponded water, such as lagoons or abandoned tidal creeks and channels. Such features are common in areas of laterally extensive tidal flats which develop only poor drainage conditions.

Microfacies #4: Coal

Description: Two coal seams exist within the Lawrence Shale, the Upper and Lower Williamsburg Coal. The Lower Williamsburg Coal, located at ~1010', is more laterally extensive than the Upper Williamsburg Coal, located at ~1038' (Fig. 2.2). The coal beds are thin (0.1'-0.4' thick) and mostly consist of Dark Gray (N3) to Black (N1), brittle, bituminous coal. Gradations exist where the coal becomes very thinly interlaminated with shale or becomes carbonaceous shale.

Interpretation: The coal beds are attributed to highly reducing environments where vast amounts of plant material existed with little biodegradation. Environments include waterlogged regions or wetlands (e.g. swamps, marshes, and bogs) that were quickly submerged by transgressive oceans, burying the organic matter with sediments before it could be decomposed.

Microfacies #5: Paleosol

Description: The paleosols are located at an elevation of 1038' to 1030'. The color ranges from Light Gray (N7) to Medium Dark Gray (N4), and Greenish Gray (5G 6/1).

Occasional there are shades of Pale Red (10R 6/2) to Grayish Red (5R 4/2), and Grayish Red Purple (5RP 4/2). Paleosols are identified by post-depositional sedimentary structures and fossils. Post-depositional structures include mostly platy mudstone “clods”, with few columnar mudstone “clods”. Other post-depositional sedimentary features include the presence of shrink/swell cracks (slickensides), carbonate nodules, and root traces.

Figure 2.9: Paleosol Core Photographs
a) Purplish-gray, fine platy, paleosol with an angled shear plane (A) containing slickensides. Bottom of core becomes finely mottled with yellow drab-haloed root traces (B).
b) Close-up of yellow drab-haloed root traces within grayish red purple paleosol.
c) Gray clay-rich paleosol with desiccation cracks (shrink/swell). Bottom of core displays its columnar ped structure.
1/10’ scale in all core photos.

a) Paleosol

b) Paleosol

c) Paleosol

Figure 2.10: Paleosol Core Photographs
a) Light greenish gray paleosol containing a recrystalized, pale brown, calcite root cast (A).
b) Indurated churned shale to weak paleosol with irregularly distributed wisps on the side of the core. These wisps represent root traces causing minor disorientation of the bedding. Shear planes (with slickensides) on the top and bottom of the core.
c) Paleosol with red clay coated slickenside (angled shear plane).
All scales in core photos are 1/10'.

a) Paleosol

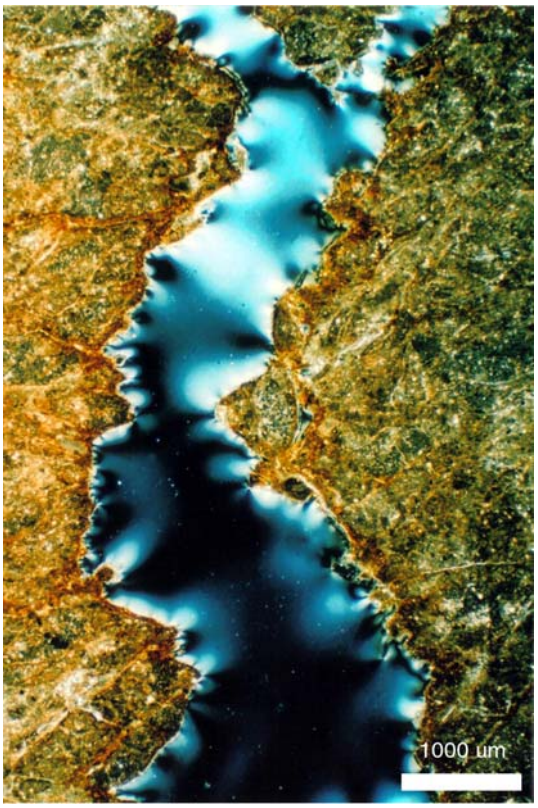
b) Paleosol

c) Paleosol - slickenside

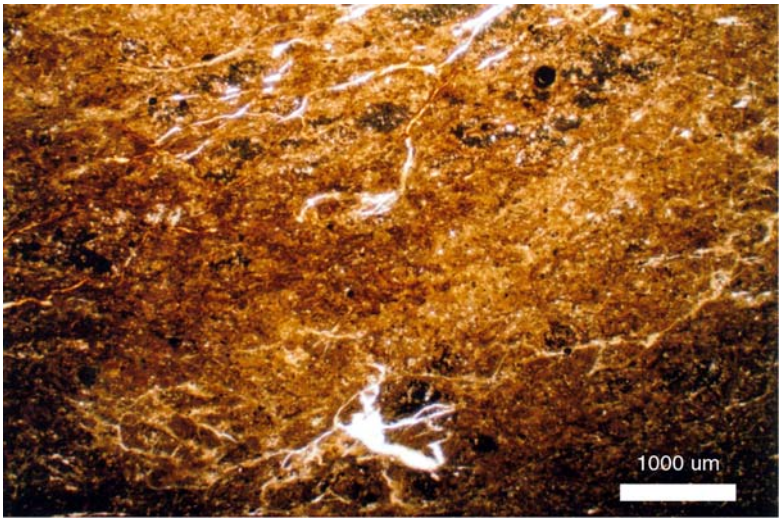
Figure 2.11: Paleosol Microfacies

a) dendritic root channel with abundant rootlets branching into clay/silt matrix. Root traces lined with a red clay coating (ferri-argillan).
b) root channel with fine branching rootlets with ferri-argillans.
c) abundant root traces, within clay/silt matrix, with ferri-argillans.
Frame length in all photmicrographs is 6650µ (6.65 mm).

(a) cross-polarized; 5x total magnification

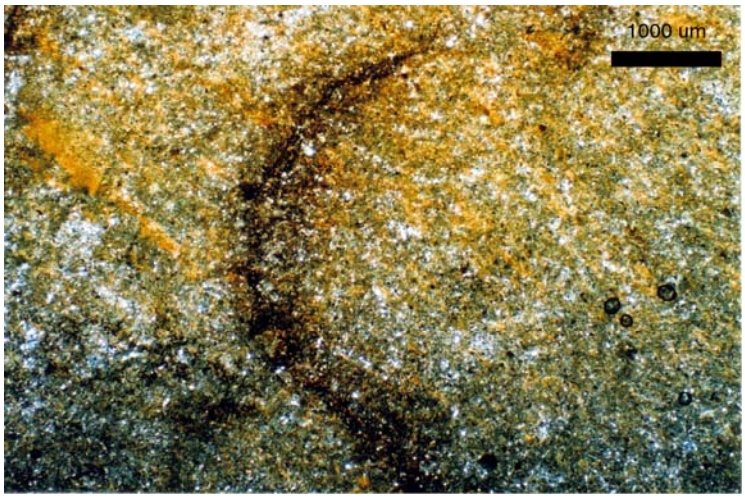


(b) cross-polarized; 5x total magnification

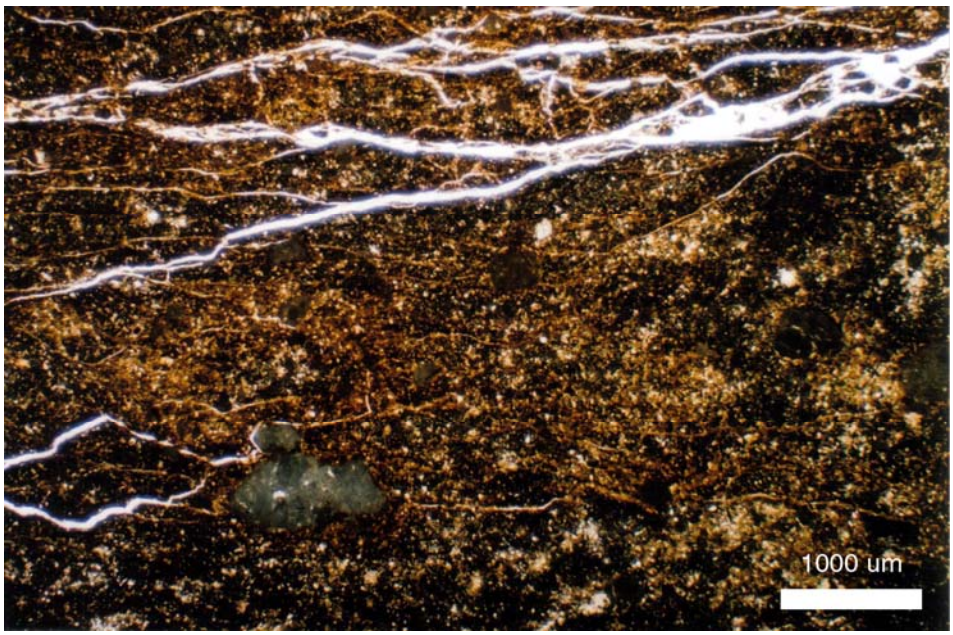


(c) plane-polarized; 5x total magnification

Figure 2.12: Paleosol microfacies
a) dark, iron oxidized root trace (center) with illuviated clay (high birefringence) throughout the clay/silty matrix.
b) abundant root traces within clay/silt matrix with chert sand grains. Finer root traces lined with ferri-argillans (red).
Frame length in all photomicrographs is 6650 μm (6.65 mm).



(a) cross-polarized; 5x total magnification



(b) plane-polarized; 5x total magnification

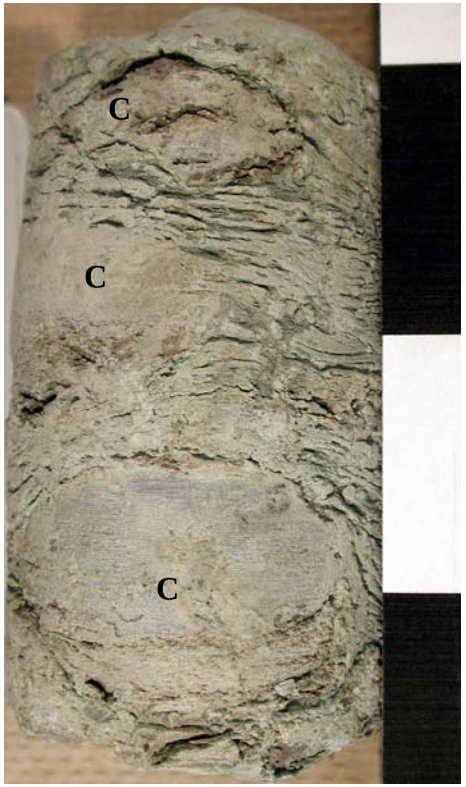
Interpretation: Paleosols are relicts of ancient soils that represent the conditions present during soil formation. Paleosols can be distinguished by the presence of ped structure, root traces, and fossils. Any one of these characteristics, for this study, is interpreted as a paleosol forming from weathering and pedogenic (soil-forming) processes during subaerial exposure.

Few paleosols for this project exhibit red to purplish red color indicating oxidizing environments. The gray to greenish gray color dominating the paleosols within the Lawrence Shale indicates environments with reducing conditions, such as waterlogged regions (swamp, marshes, or bogs). Jockel (1994) suggests the paleosols show a strong resemblance to modern Vertisols.

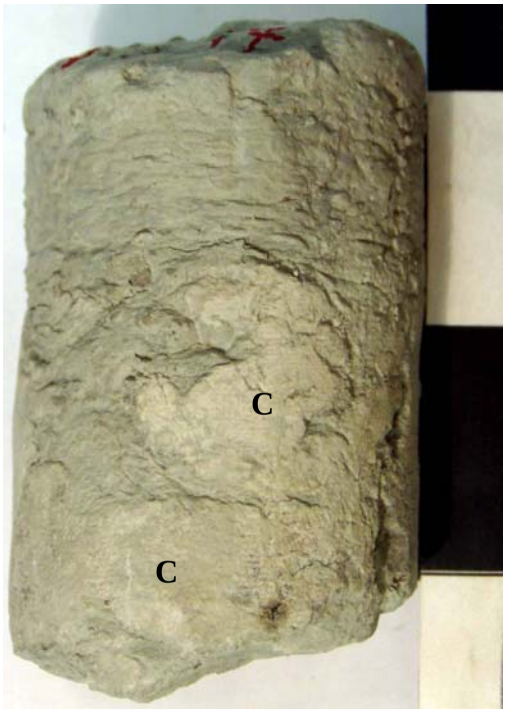
Microfacies #6: Carbonate-Rich Shale; Nodules

Description: The shales containing these hard/dense carbonate nodules are usually Light Greenish Gray (5G 8/1) to Greenish Gray (5G 6/1). There are two noticeable types of carbonate-rich shales: 1. contains hard limey nodules with sharp contacts between the shale/carbonate interface (Fig. 2.13 a,b), and 2. carbonate nodules consisting of a diffuse (or gradational) contact within the shale (Fig. 2.13 c). The shales in which the carbonates are contained are also calcareous.

a) Carbonate-rich Shale



b) Carbonate-rich Shale

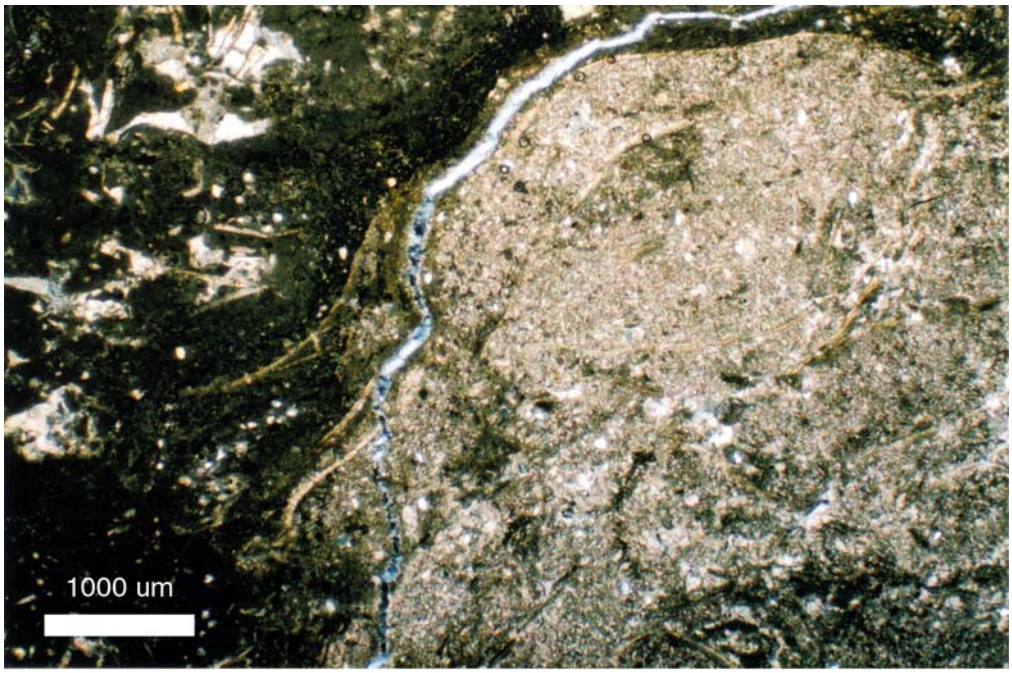


c) Carbonate-rich Shale

Figure 2.13) Carbonate-rich Core Photographs. a,b) Carbonate-rich shale consisting of hard/dense carbonate nodules (C). *c)* Pebble-like carbonate nodules within the shale. Scale in all core photos is 1/10'.

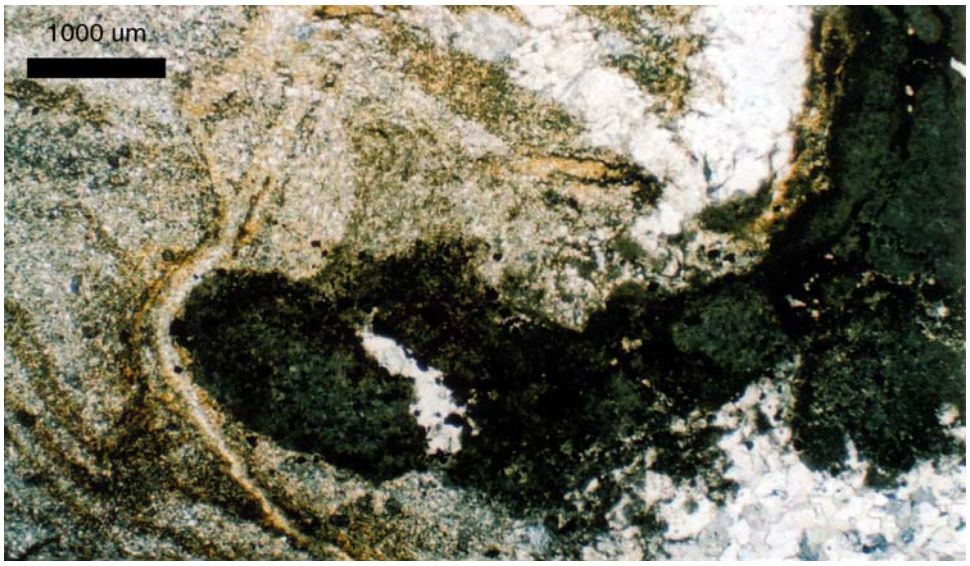
Figure 2.14: Carbonate-Rich Shale microfacies
a) micrite calcite skeletal shell fragments.
b) micrite nodule, with shell fragments, surrounded by micritic matrix; notice how fractures occur at matrix and nodule interface.
Frame length in all photomicrographs is 6650 μm (6.65 mm).

(a) cross-polarized; 5x total magnification

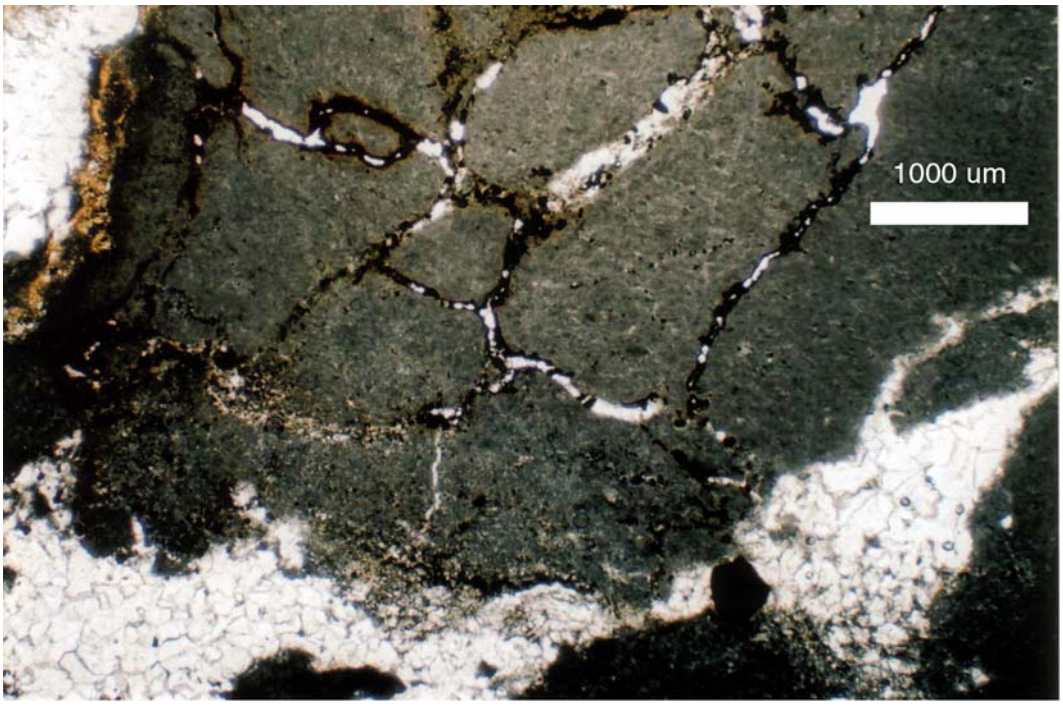


(b) cross-polarized; 5x total magnification

Figure 2.15: Carbonate-rich Shale microfacies
a) Fine micritic matrix with clay lined root trace (left); fractured micrite nodule, due rooting; calcite-spar filled vughes.
b) Linear voids within micrite nodule due to root penetration. Linear voids lined/filled with both clay and calcite. Larger vughes filled with calcite.
Frame length in all photomicrographs is 6650 μm (6.65 mm).



(a) cross-polarized; 5x total magnification



(b) plane-polarized; 5x total magnification

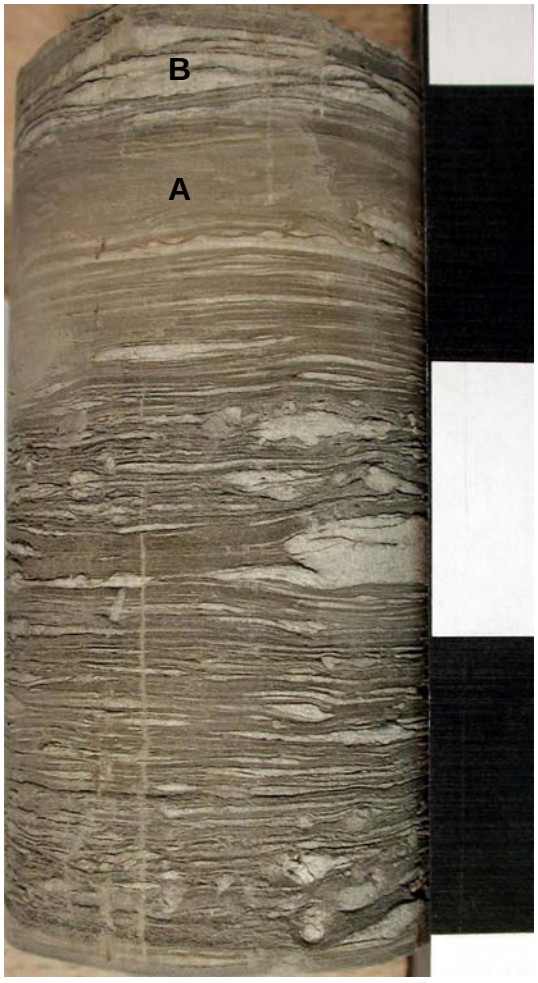
Interpretation: The nodular carbonate concretions within the Lawrence Shale are believed to have at least two origins, both marine and pedogenic. Joekel (1994) suggested that the carbonate, underlying the paleosols, is entirely related to pedogenic prcesses (caliche-like nodules). However, further work by Feldman and Archer (1995) identified shell fossils within some of these carbonate nodules, which indicates original deposition of marine limestone. The limestone is suggested as being the discontinuous Amazonian Limestone that was subaerially exposed due to a fall in sea level. This resulted in paleosol development on top of the Amazonian Limestone, which incorporated pedogenic carbonate and limestone fracturing within the facies.

Microfacies #7: Lenticular Shale

Description: Lenticular shales consist of parallel laminated, White (N9) to Light Gray (N8) very fine sandstone to siltstone lenses/ripples that are incorporated in a Medium Dark Gray (N4) to Light Gray (N7) mud (Fig. 2.16). In a few areas the clay is Light Greenish Gray (5G 8/1). The fine grained sandstone/siltstone lenticels form sharp, flat to irregular contacts with the surrounding shale. Based on the morphology of the lenticels, lentiuclar bedding is separated into two categories; either isolated (starved) lenses or connected lenses. According to Reineck and Singh (1980), the criteria for classification depend on whether 75% of the sandstone lenses are continuous or isolated in the horizontal and vertical direction. Further subdivision can be determined by whether the lenticels are thick (length/height ratio <20) or flat (length/height ratio >20). Both lenticular categories exist within the Lawrence Shale, however, most contain flat, discontinuous lenticels. Foreset laminae of current/wave

ripples are preserved within some of the thicker lenticels. Secondary bedding features are exhibited in the forms of load structures and disturbed bedding (mud flow/slump).

Figure 2.16: Lenticular Shale Core Photograph
a) Lenticular Shale displaying very thin, isolated sandstone lenticels/ripples. Sand lenticels become more continuous toward the top of the core (A) with siderite cementation. Becoming for sandy at top with flaser bedding (B).
b) Lenticular Shale displaying more continuous sandstone lenticels (C). Bedding slightly disturbed (loading or bioturbation). Notice in both figures how the shale fractures along the sandstone/mud interface.
Scale in both core photos is 1/10'.



a) Lenticular Shale

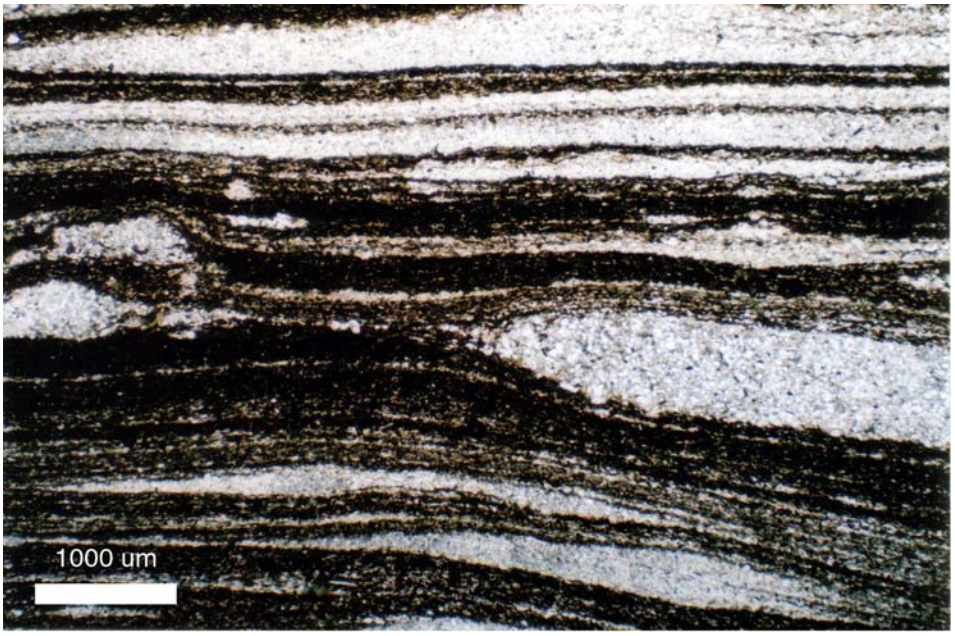
b) Lenticular Shale

Figure 2.17: Deformed Lenticular Shale; Soft Sediment Deformation
a) Lenticular shale displaying convolute bedding; related to sandy mudflow or slumping activity.
b) Lenticular Shale displaying vertical bedding; consisting of very fine sand to silt, wavy/crenulated laminations. Sandstone lenticels (C). Bedding slightly disturbed (loading or bioturbation).
Scale in both core photos is 1/10'.

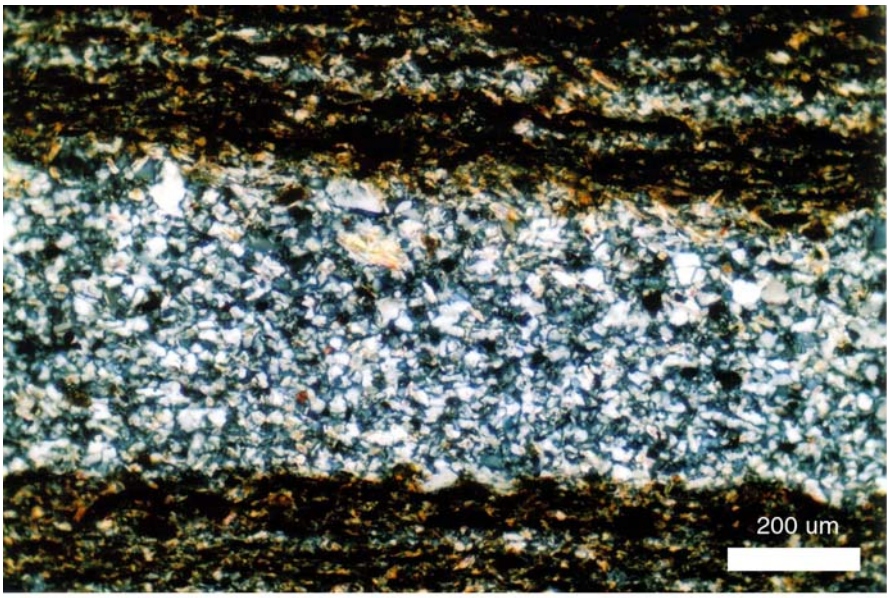
a) Lenticular Shale; Deformed

b) Lenticular Shale; Deformed

Figure 2.18: Lenticular microfacies
a) Alternating dark, organic rich clay laminae with coarser grained lenticels (isolated and connected). Frame length is 6650 μm
b) Lenticels primarily consist of very fine sand to silt sized, sub-angular to sub-rounded quartz grains. Grains are well sorted and display equigranular sutured/mosaic-like internal fabric. There is a sharp, prominent contact between the organic-rich clay and sand/silt interface. Notice the parallel orientation (perpendicular to overburded stresses) of the organic matter.
The frame length is 1330 μm (6.65 mm).

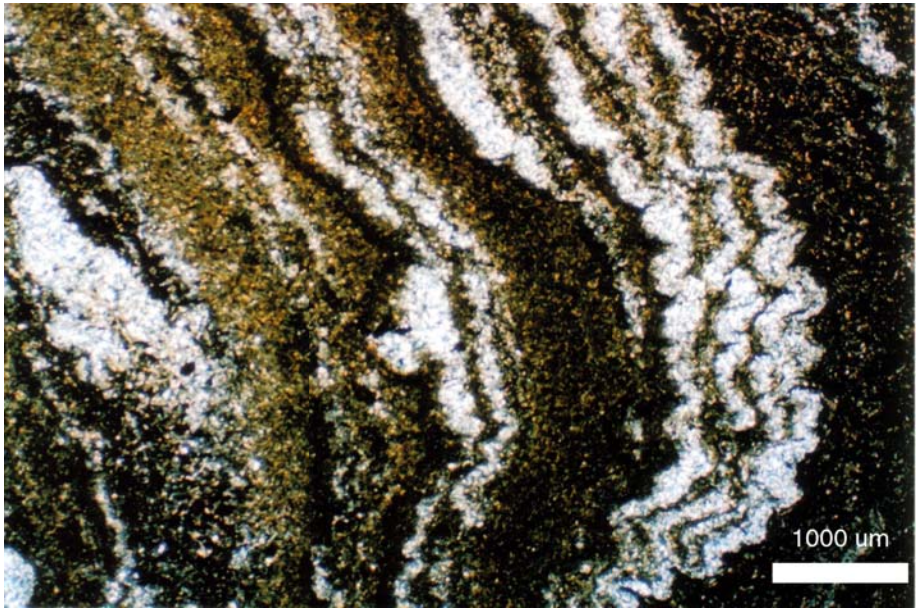


(a) plane-polarized light; 5x total magnification



(b) crass-polarized light; 25x total magnification

(a) cross-ploarized; 5x total magnification



(b) cross-ploarized; 5x total magnification

Figure 2.19: Lenticular Shale Microphotographs
a) Vertical bedding of lenticular shale due to mud flow/slumping activity. Quartz-rich, very fine sand to silt lenticels consist of a sharp undulating boundary with the surrounding dark, organic rich clay. Frame height is 6650 *µm* (6.65 mm).
b) More vertical lenticular bedding with undulating morphology. Few lenticels displaying crenulated/crinkled laminae.
Frame length is 6650 *µm* (6.65 mm).

Interpretation: The incomplete or starved ripples are generated by an insufficient supply of sand with conditions favoring the deposition and preservation of mud. The formation of these lenticular shales depends upon alternating periods of both high energy (turbulent water) and low energy (slack water) depositional events. The sand ripples are deposited on a muddy substratum, during limited intervals of current or wave action, and preserved by mud deposition from slack water suspension fallout.

The main environments of this occurrence are subtidal zones (Reineck 1963 a; Reineck et al. 1968), intertidal zones (Hantzschel 1936 a; van Straaten 1954 a), and mid tidal flats (deVries Klein, 1977). Similar bedding was reported in Carboniferous rocks deposited in Indiana by Kvale and Archer (1990) and subsequently in Kansas by Archer (1994).

Microfacies #8: Sandy/Silty Shale

Description: The silty/sandy shale facies consists of a Light Gray (N7) to Medium Light Gray (N6) heterogeneous mixture of sand, silt and clay with massive bedding. There are abundant amounts of mica and black organic debris/particles. Associated with some of these rocks are slightly connected to isolated ball-and-pillow strucutres (or "sunken/starved" ripples) consisting of very fine sandstone. The pillows themselves may be structureless or display curved or deformed laminations (Fig. 2.20 a). These very fine sandstone pillows form a sharp, contoured contact with the surrounding mud matrix. Other bedding features include soft sediment deformation (Fig. 2.20 b)This microfacies provides more resistant cores with very few fractures. This microfacies is often found interbedded with lenticular shale.

Figure 2.20: Sandy/Silty Shale Core Photographs
a) Massive gray, sandy shale/siltstone with an isolated sandstone load structure (A) in the middle of the core.
b) Massive, light gray, silty/sandy shale with fine sandstone ball-and-pillow structure (B) and contorted soft sediment deformation (C). Notice how resistant the cores are in both figures, with very few fractures.
c) Abundant sand, mica, and macroscopic organics within sandy/silty shale.
Scale in all core photos is 1/10'.

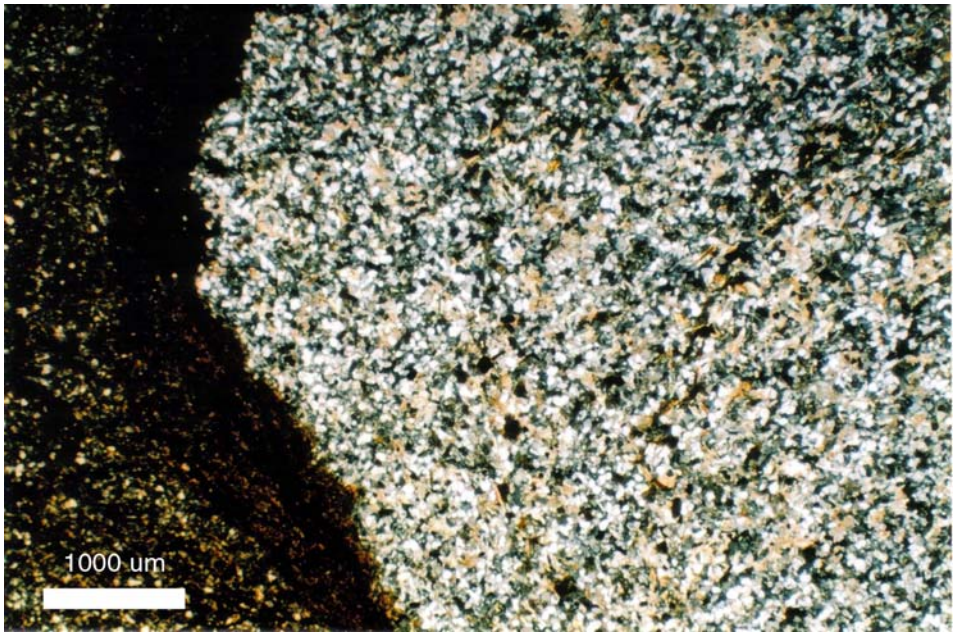
a): Sandy/Silty Shale **b)** Sandy/Silty Shale **c)** Sandy/Silty Shale

Figure 2.21: Silty/Sandy Shale Photomicrographs
a) heterogeneous mixture of clay, silt and very fine sand; dominate minerals are quartz and muscovite mica; abundant black organic debris/particles
b) well sorted, very fine sand "sunken" pillow preserved within very fine sand, silt, and clay matrix with abundant black organic debris.
Frame length in both photomicrographs is 6650 μm (6.65 mm).

(a) cross-polarized light; 5x total magnification

(b) cross-polarized light; 5x total magnification

Figure 2.22: Silty/Sandy Shale Photomicrographs
a) large “sunken” pillow consisting of predominately well sorted and sutured quartz grains (very fine sand to silt); thick, dark, organic-rich clay film (left) accumulated around pillow as it sank through the silty/sandy clay matrix.
b) soft sediment deformation within silty/sandy clay matrix related to mudflow or slumping prior to deposition.
Frame length in both photomicrographs is 6650 *μ*m (6.65 mm).



(a) cross-polarized light; 5x total magnification

(b) cross-polarized light; 5x total magnification

Interpretation: The ball-and-pillow structure is generated by a disturbance within the deposit (e.g. applied shock, loading or slumping activity) that results in the overlying sandy layers to be broken into “pillows”. These sandy pillows then sink into the underlying mud. In some cases, rather than being broken into pillows, a larger portion of the sandy layer is vertically displaced causing contorted/convolute bedding to develop (Fig. 2.20 b).

Along with the ball-and-pillow and contorted structures, the heterogeneous composition of very fine sand, silt, and clay, implies rapid sedimentation. The presence of abundant very fine sand and macroscopic organic debris indicates the deposition is proximal to continental or marginal marine environments (near-shore, fluvial-deltaic to estuarine).

Microfacies #9: Weathered Shale

Description: The shale consists of oxidized Grayish Orange (10YR 7/4) to Pale Yellowish Orange (10YR 8/6) sandy/silty shale. Besides the color, the most distinguishing feature of this microfacies was the abundant fractures and presence of modern roots. A significant portion of the fractures were vertical, with black manganese or red iron oxidation on the fracture surfaces. The weathered silty/sandy shale is found along the backslope, or toe, of Pleasant Grove Hill. The weathered portion thickens (~ 30’) toward the toe and base of the hill where it grades into Light Gray (N7) to Medium Gray (N5) sandy/silty shale microfacies.

Figure 2.23: Weathered Sandy/Silty Shale Core Photographs
a) Weathered and fractured shale.
b) Orangish-Gray weathered shale with shear plane (A) in the middle of the core.
c) Weathered shale exhibiting prominent vertical fractures.
d) Modern root development within weathered shale; notice the drabe halos (light green) forming around the rootlets.
1/10' scale on all core photos.

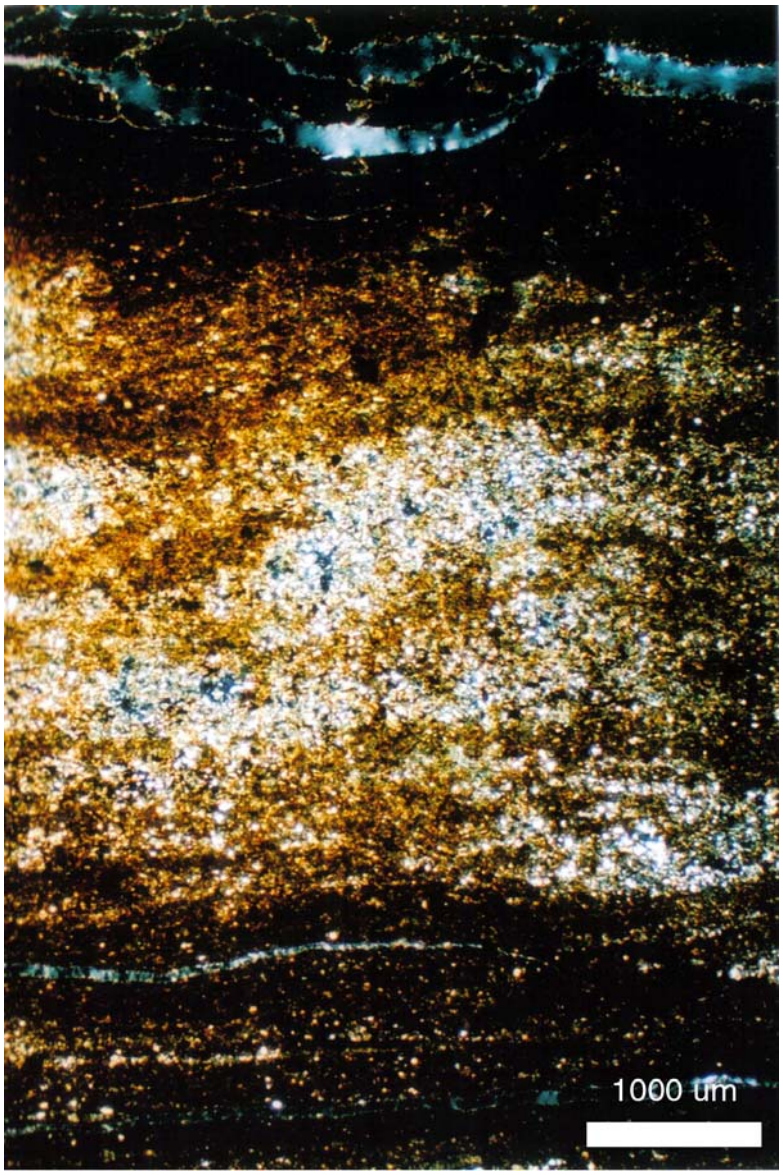
a) Weathered Shale

c) Vertical Fractures

d) Modern Roots

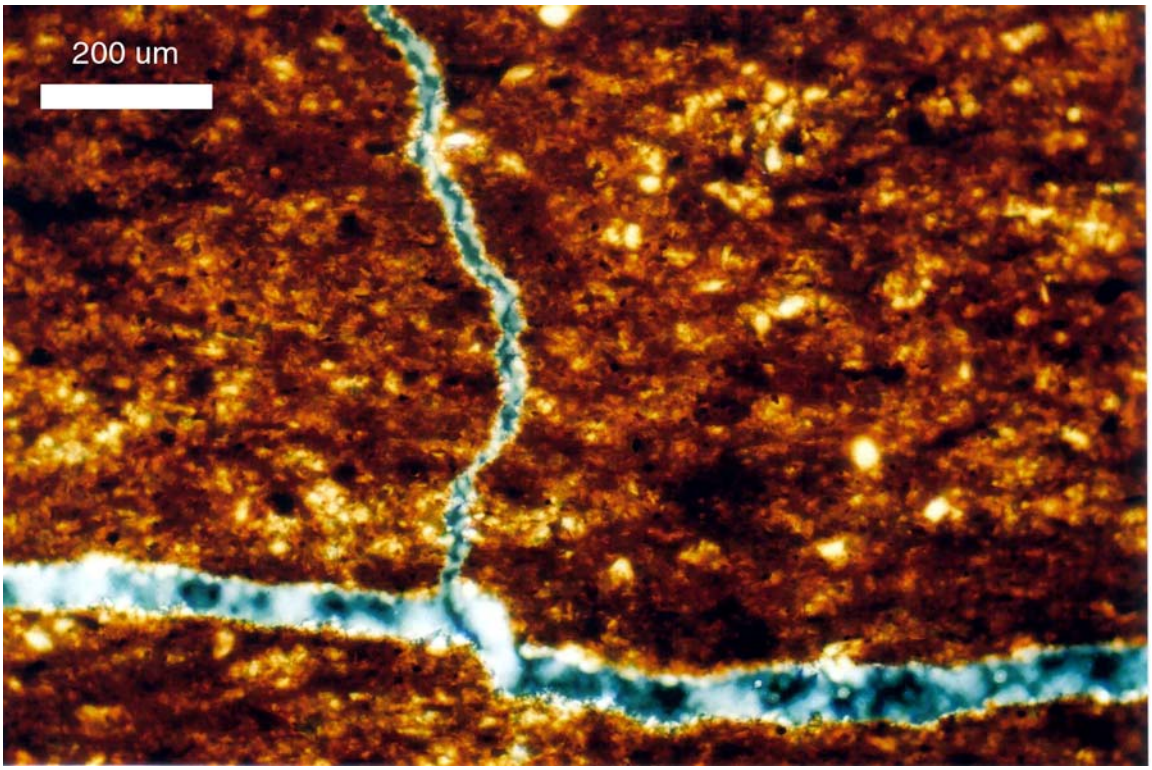
b) Weathered Shale

Figure 2.24: Weathered Sandy/Silty Shale Photomicrograph
Highly oxidized and iron rich silty/sandy shale with numerous voids and fractures. Frame height in photomicrograph is 6650 μm (6.65 mm).



Cross-polarized; 5x total magnification

Figure 2.25: Weathered Shale Photomicrograph
Highly oxidized and iron rich silty shale with numerous voids and fractures.
Frame length in photomicrograph is 1330 μm (1.33 mm).



Cross-polarized; 25x total magnification

Interpretation: The relic lithofacies, superimposed by weathering and pedogenic alteration, is the same silty/sandy shale found at depth within Pleasant Grove Hill. Weathering and pedogenic process within the Lawrence Shale are influenced by the overlying material and the slope of the hill. The top of the hill is heavily vegetated and capped by approximately forty feet of overlying material, including three laterally extensive limestones (Plattsmouth Ls., Leavenworth Ls, and Toronto Ls.). This overlying material prevents percolating water and root penetration from reaching the Lawrence Shale. However, on the slopes and base of the hill, where the Lawrence

Shale is exposed in close proximity to the surface, the weathering and pedogenic effects can be seen. The highest degree and extent of weathering and pedogenisis is located near the base or toe of Pleasant Grove hill. Surface runoff, generated from the steeper slopes of the hill, accumulates and percolates into the ground due to the low relief at the base of the hill. This results in more water infiltration/percolation and vegetative growth. The depth, or extent, of weathering diminishes on the slopes of the hill. This is primarly due to both higher surface runoff on slopes and reduced vegetation cover on slopes.

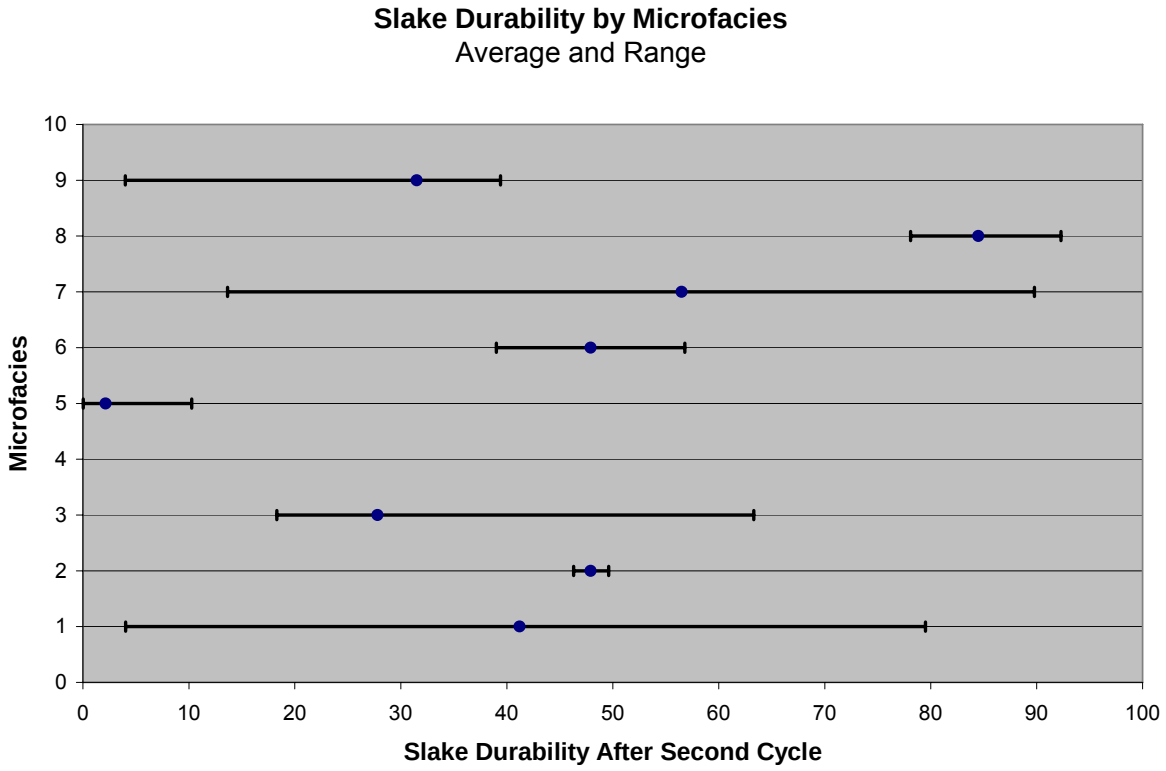
CHAPTER 3: TEST RESULTS

Slake Durability

The slake durability procedure proved to be the most useful in terms of determining the materials durability within the Lawrence Formation. A total of sixty-five test were conducted on samples taken from cores received by KDOT at the six borehole locations. Using slake durability classification schemes proposed by Deo (1975), Gamble (1971), Franklin and Chandra (1972), and Dick and Shakoor (1995), the Lawrence Formation contains predominately low durability materials in the orders of: 61-65% Low Durability, 15-31% Medium Durability, and 8-23% High Durability. Dick and Shakoor (1995) also developed a slope classification scheme based on the materials slake durability after two cycles. Within the Lawrence Shale, 62% of the materials tested were classified as "probable" indicators for slump or debris flow (with "probable" excess erosion: 5-10 cm/yr of undercutting), while 31% resulted in "potential" indicators (with "unlikely" excess erosion: 3-5 cm/yr of undercutting), and 8% unlikely of failure (with "unlikely" excess erosion: 2-3 cm/yr of undercutting).

Arranging the data in order of increasing slake durability, there is a strong relationship between the microfacies within the Lawrence Shale. Based on the slake durability results, after two cycles, the paleosols are designated as being the least durable (Id = 0-10.7) and thus most susceptible to rock/slope failure. The sandy/silty shales represent the microfacies that are more resistant to slaking and are located at greater depths. Figure 3.1 provides slake durability results by microfacies.

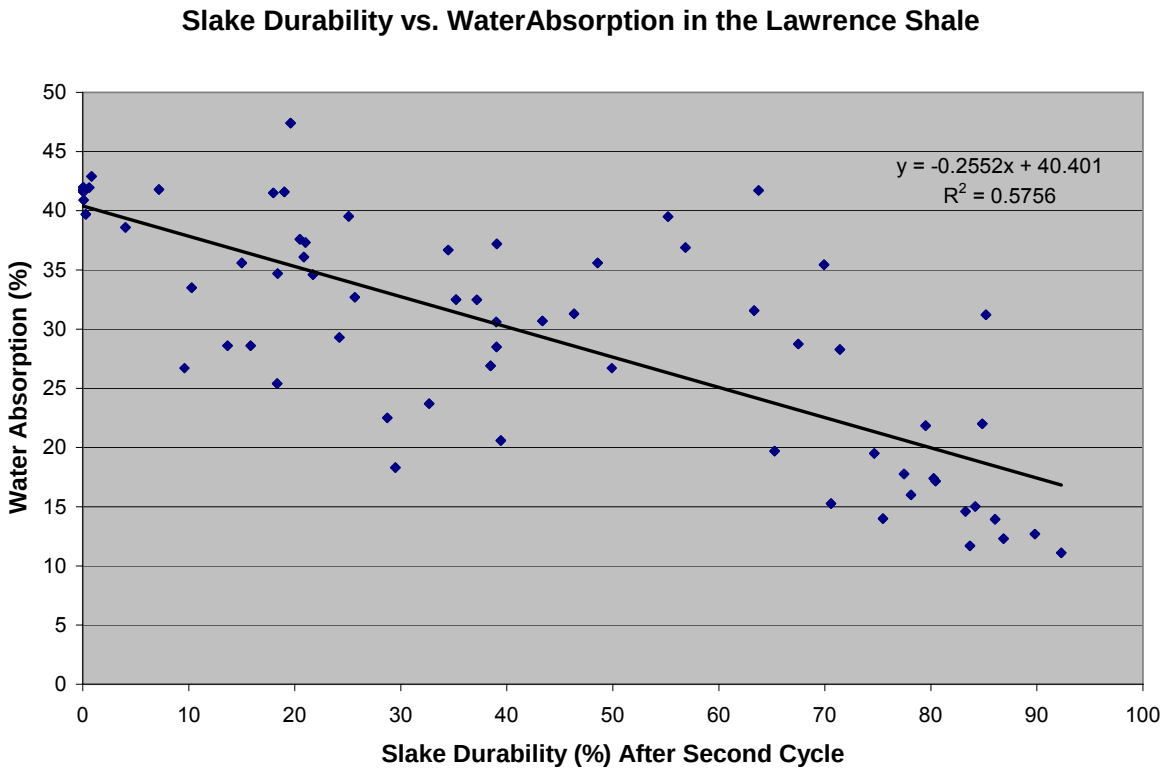
Figure 3.1: Slake Durability by Microfacies; average and range values



Jar Slake Test

The Jar Index is a simple and fast test to identify the effects of submersing a rock sample in water. As a secondary procedure to the jar index, water absorption can be calculated. There is an adequate relationship between the slake durability and water absorption within the Lawrence Formation. As water absorption increases, the durability of the material is reduced (Fig. 3.2).

Figure 3.2: Slake Durability vs. Water Absorption in the Lawrence Shale



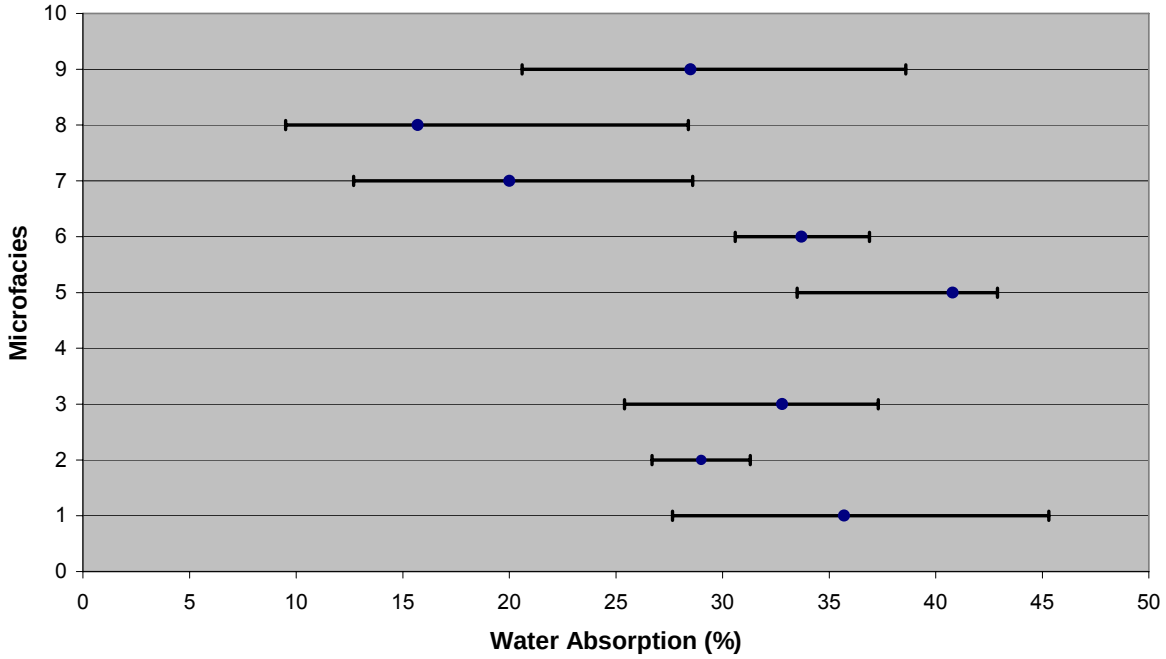
Using the Jar Slake classification in Table 3.1, 63% of the Lawrence Shale tested consists of low durability, 22% medium durability, and 14% high durability. These percentages correlate well with the slake durability classification results: Low: 61-65%, Medium: 15-31%, and High: 8-23%.

Table 3.1: Jar Slake Classification

Durability Classification	Jar Index	Behavior
Low	1	Degrades into a pile of flakes or mud
	2	Breaks rapidly and/or forms many chips
	3	Breaks rapidly and/or forms few chips
Medium	4	Breaks slowly and/or develops several fractures
High	5	Breaks slowly and/or develops few fractures
	6	No Change

The relationship between microfacies and water absorption is provided in Figure 3.3.

Figure 3.3: Percent Water Absorption by Microfacies; average and range values



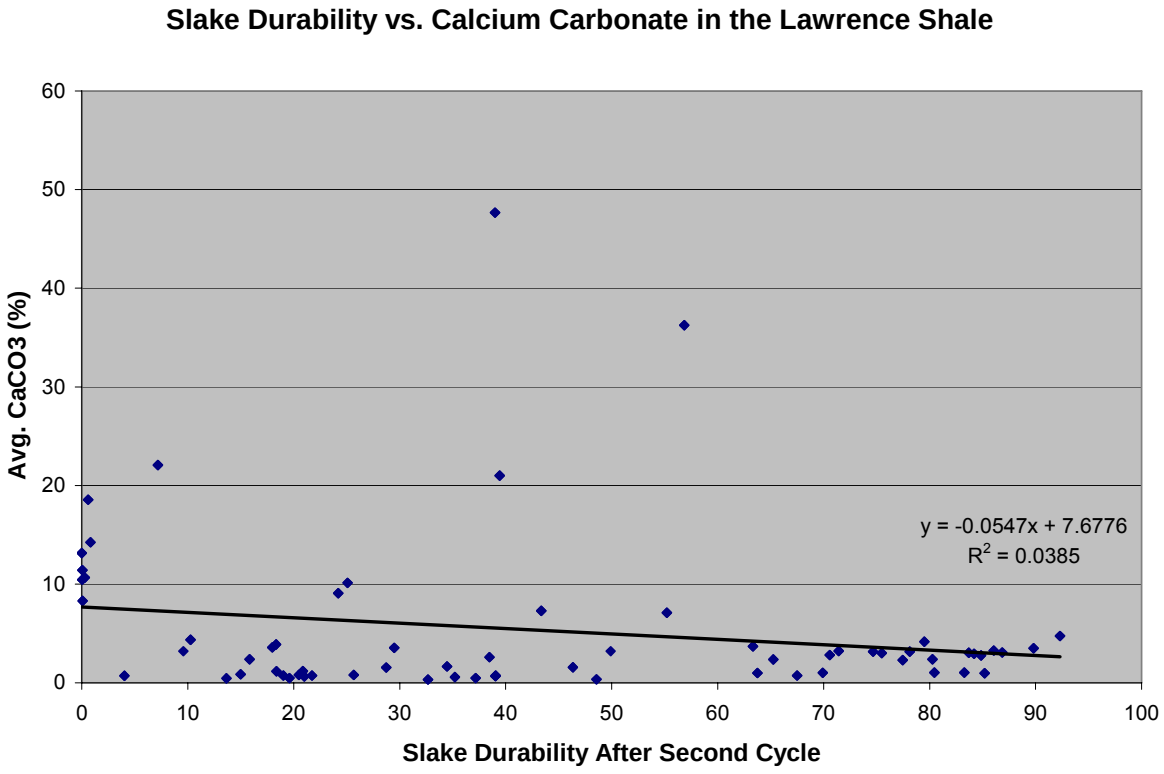
* Microfacies: (1) Churned Shale; (2) Shale; (3) Clayshale; (4) Coal (N/A); (5) Paleosol; (6) Carbonate-rich Shale; (7) Lenticular Shale; (8) Sandy/Silty Shale; (9) Weathered Shale. Average and range of percent calcium carbonate are indicated by a circle and whiskers.

Calcium Carbonate Content (Chittick)

The calcium carbonate ($CaCO_3$) content within the Lawrence Shale was determined using the chittick test. Calcium carbonate is a cementing agent in sedimentary rocks and can give insight into the durability of the material. Shown below in Figure 3.4, the chittick results consist of predominately low concentrations of calcium carbonate throughout the Lawrence Formation. According to Miller & McCahon (1997), calcium carbonate content < 35% will likely have low durability, while content > 35% will

likely have medium to high durability. In relation to durability, there is no correlation between calcium carbonate content and slake durability within the Lawrence Formation (Fig. 3.4).

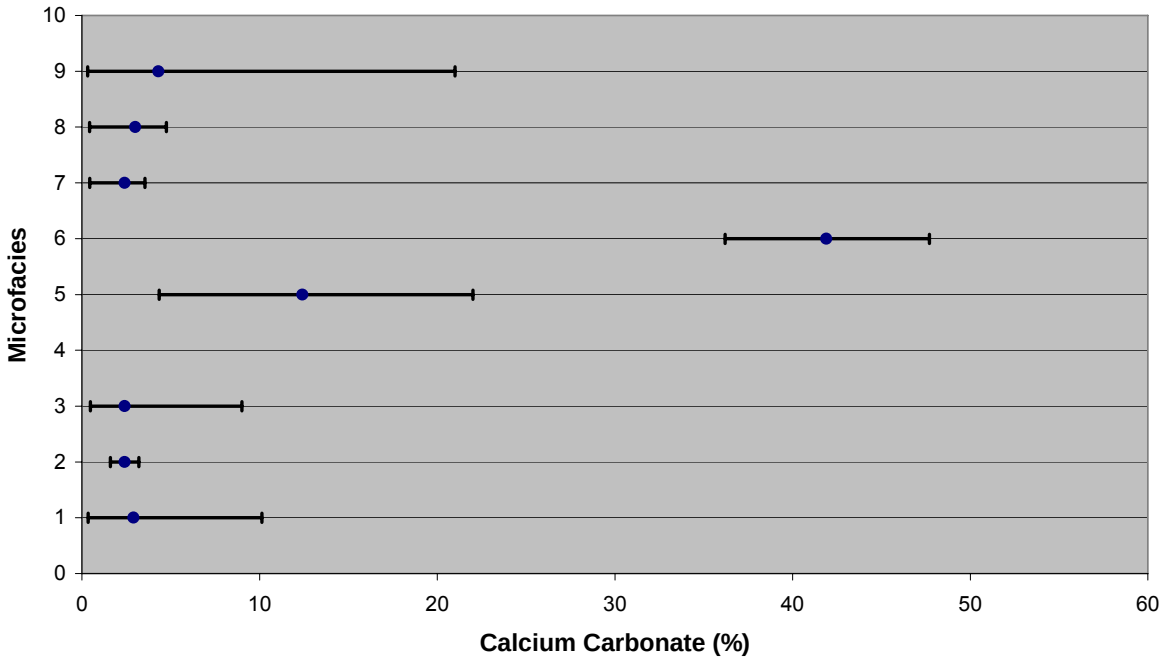
Figure 3.4: Slake Durability vs. Calcium Carbonate in the Lawrence Shale



The high "outliers" in Figure 3.4 are due to the high concentration of calcium carbonate in the Carbonate-rich Shale and Paleosol microfacies.

The relationship between microfacies and calcium carbonate is provided in Figure 3.5.

Figure 3.5: Percent Calcium Carbonate by Microfacies; average and range values



* Microfacies: (1) Churned Shale; (2) Shale; (3) Clayshale; (4) Coal (N/A); (5) Paleosol; (6) Carbonate-rich Shale; (7) Lenticular Shale; (8) Sandy/Silty Shale; (9) Weathered Shale. Average and range of percent calcium carbonate are indicated by a circle and whiskers.

Mineralogy – Clay and Silt

Mineralogy of both the silt and clay fraction was identified using X-ray diffraction (XRD) of the major microfacies (Table 3.2). Fractionation results (Table 3.3) show that all of the microfacies are dominated by the silt fraction (50.2% – 58.2%), with the exception of the paleosol being influenced by higher concentrations of clay (55.9%). The lenticular, sandy/silty, and weathered shales consist of higher sand concentrations that are associated with significantly lower amounts of clay.

Table 3.2: Identification for XRD Analysis

XRD Sample ID	Microfacies	Location	Elevation (ft)
1	Lenticular Shale	DH2-12	1001.1 – 1000.5
2	Churned Shale	DH1 Box 3 Core 10	1047.7 – 1047.62
3	Sandy/Silty Shale	NFH1-4	1032.8 - 1032
4	Shale	BH1-7	905.4 – 904.4
5	Weathered Shale	BH1-2	926.3 – 925.9
6	Carbonate-rich Shale	NFH1-5	1029.8 – 1028.8
7	Paleosol	SF1-4	1035.2 – 1034.1
8	Clayshale	DH1 Box 4 Core 12	1039.7 – 1039.55

Table 3.3: Fractionation Results During XRD Preparation

XRD Sample	Microfacies	Clay (%)	Silt (%)	Sand (%)
1	Lenticular	17.8	51.2	31.0
2	Churned Shale	35.6	57.0	7.4
3	Sandy/Silty Shale	23.9	56.7	19.4
4	Shale	42.3	57.2	0.5
5	Weathered Shale	27.9	58.2	13.9
6	Carbonate-rich Shale	36.7	57.9	5.4
7	Paleosol	55.9	43.2	0.9
8	Clayshale	47.6	50.2	2.2

Analyzing the XRD patterns of the silt fractions, all of the microfacies contained quartz, albite, orthoclase, calcite and 2:1 layered silicates (Table 3.4). Dolomite was identified only in the lenticular shale.

Table 3.4: XRD Silt Mineralogy

1	2	3	4	5	6	7	8
Quartz Albite Orthoclase Calcite Dolomite	Quartz Albite Orthoclase Calcite	Quartz Albite Orthoclase Calcite	Quartz Albite Orthoclase Calcite	Quartz Albite Orthoclase Calcite	Quartz Albite Orthoclase Calcite	Quartz Albite Orthoclase Calcite	Quartz Albite Orthoclase Calcite
2:1	2:1	2:1	2:1	2:1	2:1	2:1	2:1

The identification of the clay mineralogy, using the X-ray diffractograms, was determined using procedures by Jackson (1975). The clay mineral species and their relative amounts were characterized by analyzing the peak geometry and peak intensities produced on the X-ray diffractograms. The various chemical and heating treatments used in preparation for XRD, assisted in identifying clay mineral species.

Kaolinite was characterized by a 7.1 Å (d_{001}) peak with both K and Mg cation saturations and heat treatments of K-25°C and K-350°C. However, the same peak is absent after heating to 550°C as the structure of kaolinite collapses.

Clay mica (Illite) was identified by 10 Å (d_{001}), 5 Å (d_{002}) and 3.3 Å (d_{003}) peaks using the Mg-25°C treatment. The 10 Å peak remained persistent through all of the chemical and heat treatments.

Like chlorite, hydroxy interlayered 2:1 mineral (HIM) was identified by a 14 Å peak that remained throughout the entire chemical and heat treatments. Upon heating at K-550°C, the 7 Å peak disappeared from all of the diffractograms indicating the presence of HIM. If the 7 Å peak remained at K-550°C, this supports the presence of chlorite.

Chlorite and other 2:1 layered silicates were identified by a 14 Å (d_{001}) peak using Mg-25°C. Both chlorite and kaolinite are characterized by a 7 Å peak. However, upon heating to 550°C, the presence or absence of this 7 Å peak differentiates either chlorite or kaolinite. Kaolinite is characterized by a collapse of the 7 Å peak, while chlorite is recognized by the presence of the 7 Å peak upon heating to 550°C. All of the microfacies X-ray diffractograms generated no 7 Å peaks at 550°C, thus indicating kaolinite is present and not chlorite.

The absence of the 7 Å peak at 550°C, in combination with the presence of the 14 Å peak with Mg-25°C, now suggests either 2:1 layered silicate, hydroxy interlayer, or a interstratification of 2:1 and hydroxyl interlayer. Within the Lawrence Shale, it is important to identify the presence of vermiculite and/or smectite. Both vermiculite and smectite are expandable 2:1 layer silicates that cause rock/slope stability problems due to their shrink/swell capabilities. The presence of vermiculite is characterized by a 14-15 Å (d_{001}) peak with both EG and GLY treatments. Upon heating, the 2:1 layered structure of vermiculite collapses to 10 Å (d_{001}) and remains constant throughout the remaining heat treatments. Smectite is identified by its expansive response to both Eg and GLY treatments. With the Mg-EG, smectite was identified by a 17 Å (d_{001}) peak, and by an 18 Å (d_{001}) peak with Mg-GLY treatment. Upon treating with K-25°C, smectite is recognized by a 12 Å (d_{001}) peak. With further heating (K-350°C and K-550°C), both smectite and vermiculite generated a peak at 10 Å (d_{001}).

Randomly interstratified clay minerals were determined by diffraction peaks becoming broad and weak upon Mg-EG and K-25 treatments (Gunal, 2001). Broad peaks were identified between 14 Å and 10 Å. Because these peaks are characteristic of smectite, vermiculite, HIM, and clay mica, it was established that randomly interstratified hydroxy/2:1 expandable clay was present. In the case of a distinct 14 Å peak persisting upon heating to 550 °C, this is interpreted as the presence of more crystalline HIM.

Analyzing the peak geometries and peak intensities produced on the X-ray diffractograms, a semi-quantitative analysis was performed to determine the relative distribution of clay mineral species, within each microfacies (Table 3.5). Kaolinite and

clay mica dominated the clay fractions in all of the microfacies. To a lesser extent, 2:1 expanding clays and HIM existed in most of the microfacies. Both smectite and vermiculite were recognized within the microfacies. Vermiculite was the most dominant expandable clay mineral, with the exception of the clayshale microfacies (XRD #8) where smectite and vermiculite relative concentrations were approximately the same.

Table 3.5: Clay minerals and relative quantitative abundance. See Table 3.7 for rating explanation.

	Clay Minerals				
XRD Sample	**Quartz**	**Kaolinite**	**Clay Mica**	**Expandable Clays**	**Hydroxy Interlayered 2:1**
1	TRACE	XXXX	XXX	XXX	XX
2	X	XXXX	XXX	XXX	X
3	X	XXXX	XXX	XX	X
4	TRACE	XXXX	XXX	XX	XX
5	TRACE	XXXX	XXXX	XXX	--
6	X	XXXX	XXXX	XX	XX
7	X	XXX	XXXX	XX	XX
8	X	XXX	XXXX	XXX	X

Table 3.6 Rating system for quantitative abundance.

		Approximate Corresponding %
Very Strong	XXXXX	> 50
Strong	XXXX	30-50
Medium	XXX	15-30
Weak	XX	5-15
Very Weak	X	0-5
Trace	Trace	Trace

The origin of the clay minerals within these sedimentary rocks is interpreted as inherited (detrital) from parent materials, with the exception of the paleosol microfacies. During the Carboniferous, tropical conditions prevailed which resulted in abundant rainfall and increased rates of erosion and clastic sedimentation. Sources of clastic sediments, as discussed previously, originated from the northeast where the craton was subaerially exposed to weathering and pedogenic processes. This highly weathered

environment is consistent with the abundance of kaolinite that was inherited within the microfacies. Also, associated with the Carboniferous are the vast coal deposits indicating waterlogged regions. These wetlands provide an acidic environment for organic debris and the formation of HIM's. Other than the origin of these clay minerals being inherited by weathering on the surface of the craton, pedogenic processes formed additional clay minerals in-situ. The parent material of the paleosol, presumably shale or alluvium (consisting of inherited clay minerals), was superimposed/masked by pedogenic process that formed additional clay minerals. Upon subaerial exposure, weathering of these paleosols would have contributed additional clay minerals that would later be deposited/inherited within the microfacies of the Lawrence Shale. The depositional environments in which these clays were inherited include: near shore (fluvial-deltaic to estuarine), subtidal to intertidal flats, and marginal/open marine.

CHAPTER 4: SUMMARY

In northeastern Kansas, the Lawrence Formation (Virgilian Series, Douglas Group) was deposited, within the Forest City Basin, during the Upper Carboniferous (Pennsylvanian) Period approximately 320 million years ago. Numerous cases of rock and slope instability within the Lawrence Shale were encountered in pervious highway, excavation, and construction projects. The Kansas Department of Transportation is planning a realignment of Highway 59, that will be exposing 75 foot road-cuts of this problematic formation, within Pleasant Grove Hill. Detailed sedimentological descriptions and geotechnical tests were preformed to identify the areas that might be most susceptible to failure.

Figure 4.1 provides the relative paleoenvironments during the late Carboniferous Period. The microfacies of the Lawrence Shale, within Pleasant Grove hill, have been identified with corresponding depositional processes and environments (Table 4.1).

Figure 4.1: The Lawrence and Stranger Formations are dominated by non-mairne/clastic environments, unlike the marine/carbonate-rich environments of the Oread and Stanton Limestones.

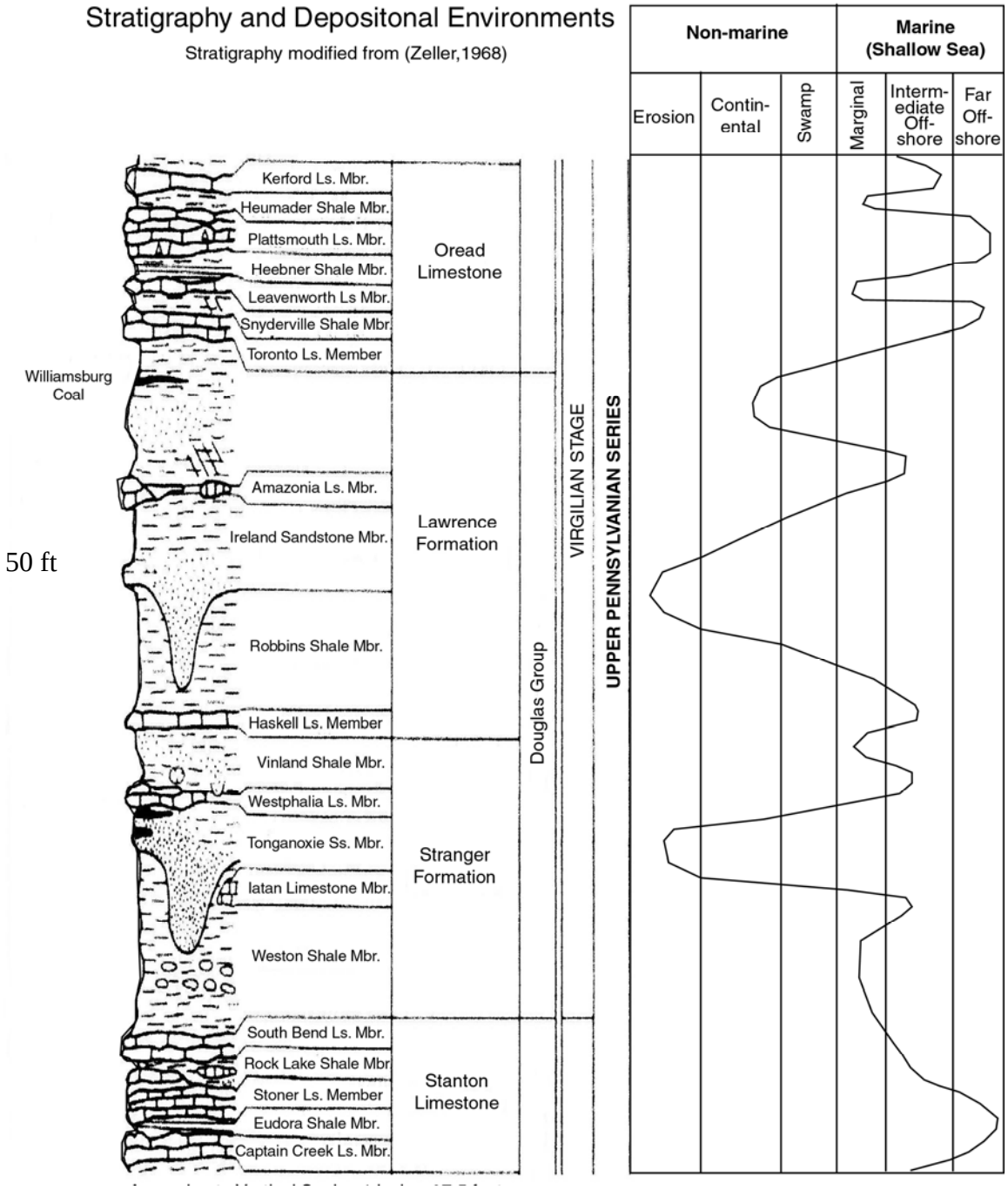


Table 4.1: Depositional Processes and Interpretations of the Lawrence Shale Microfacies

Microfacies	Depositional Process	Depositional Interpretation
Churned Shale	Disruption or reformation of the primary sedimentary bedding due to bioturbation	Marginal marine (bivalves); continental (root whisps and plant fossils)
Shale	Low energy, sediment fall out	open marine environment below wave base
Clayshale	Suspension fall out	Ponded water (lagoons or abandoned tidal creeks and channels)
Coal	Peat accumulation and coalification	Wetland
Paleosol	Weathering and pedogenesis of pre-existing facies in reducing environments	Waterlogged soil
Carbonate-rich Shale	Both marine and pedogenic processes	Subaerially exposed limestone with overlying soil development
Lenticular Shale	Alternating periods of high energy (turbulent water) and low energy (slack water)	Subtidal, intertidal, or mid-mud flat
Sandy/Silty Shale	High energy with rapid sedimentation	Near-shore, fluvial-deltaic to estuarine
Weathered Silty/Sandy Shale	High energy with rapid sedimentation; churned and altered by modern pedogeneisis	Near-shore, fluvial-deltaic to estuarine; altered by modern weathering and pedogenesis

A summary of all microfacies test results is given in Table 4.2.

Table 4.2: Summary of Microfacies Durability Results

Micro-facies	1	2	3	4	5	6	7	8	9
	Churned Shale	Shale	Clayshale	Coal	Paleosol	Carbonate-rich Shale	Lenticular Shale	Sandy/ Silty Shale	Weathered Shale
Slake Range	4.03 - 79.5	46.3 - 49.6	18.3 - 63.34	---	0 - 10.27	39 - 56.8	13.65 - 89.8	78.1 - 92.3	4 - 39.4
Slake Avg.	41.2	47.9	27.8	---	2.15	47.9	56.5	84.5	31.5
Water Abs. Range	19.5 - 47.4	26.7 - 31.3	25.4 - 37.3	---	33.5 - 42.9	30.6 - 36.9	12.7 - 28.6	9.5 - 28.4	20.6 - 38.6
Water Abs. Avg.	35.7	29	32.8	---	40.8	33.7	20	15.7	28.5
$CaCO_3$ Range	0.35 - 10.13	1.6 - 3.2	0.48 - 9	---	4.35 - 22	36.2 - 47.7	0.44 - 3.55	0.43 - 4.75	0.32 - 21
$CaCO_3$ Avg.	2.9	2.4	2.4	---	12.4	41.9	2.4	3	4.3

The slake durability results proved to be the most useful/reliable in terms of determining the materials resistance/durability. Of the materials tested, ~ 65% of the Lawrence Shale was classified as soil-like with low durability. The slake durability of the microfacies, in terms of increasing durability, is as follows: paleosols < weathered shale < clay shale < churned shale $\leq$ shale < carbonate-rich shale < lenticular shale < silty/sandy shale. The least resistant facies was identified as the paleosols (Id = 0-10.7), located at elevation of ~1038' – 1029'. The sandy/silty shales are the most durable (Id2 = 74.7-92.3) and are located near the base of Pleasant Grove Hill. Slake durability values are inversely proportional to the materials water absorption and proportional to the amount of sand content. No durability relationship was identified for the amount of calcium carbonate (used as a cementing agent) within the rock material.

Using X-ray diffraction, kaolinite and clay mica were the most abundant clay minerals within all of the microfacies. More importantly, within the clay fraction was the presence of 2:1 expandable layer silicates that are characterized by their ability to shrink/swell. Vermiculite was the dominant expandable 2:1 layer silicate within most of the microfacies. Relative quantities of smectite and vermiculite were approximately the same in the clayshale microfacies.

CHAPTER 5: CONCLUSION

Overall, the concerns associated with rock and slope instability within the Lawrence Shale are attributed to the material's predominately low durability (soil-like), and the presence of 2:1 expandable clays. The microfacies that pose the most potential for rock/slope failure are the paleosols, clayshale, weathered shale, lenticular shales, and the interface between the more durable heterogeneous shales and the overlying less resistant materials. The microfacies that are potentially the most susceptible threat of rock/slope failure are as follows: Paleosol (High Concern), Weathered Shale and Clayshale (High-Medium Concern), and Lenticular Shale (Moderate Concern).

The paleosols are the most susceptible microfacies for potentially inducing rock/slope failure. The slake durability average was 2.15% with a range of 0-10.27%. The paleosols contain abundant ancient root traces/channels and angled shear planes with slickensides. The root traces/channels provide conduits for water to infiltrate into the paleosol and result in the high water absorption values (33.5 – 42.9), supported by the Jar Slake test. The water disrupts the thin platy ped structure of the paleosols causing the material to disintegrate into a pile of flakes, as indicated by the slake durability results. Throughout the paleosol, numerous angled shear planes, with slickensides, occur at various directions and angles. The shear planes were generated by either one or a combination of the following processes: pedogenisis, compactional/overburden forces, or shrink/swell. Most of the angled shear planes were identified as having smooth, striated, and thinly coated clay surfaces which create numerous planes of weakness within the paleosol.

The weathered shale microfacies is classified as high-medium concern for rock/slope instability as the slake durability average was 31.5% with a range of 4-39.4%. This microfacies was originally a member of the more resistant sandy/silty shale microfacies, found toward the base of Pleasant Grove Hill. However, because the material is located at the toe of the back slope and with close proximity to the ground surface, modern weathering and pedogenic processes have altered the material to its weathered shale microfacies. The effects of weathering and pedogenic processes, on rock materials close to the surface, are most extensive at the base or toe of the hill. Abundant fractures and oxidation of the Lawrence Shale is a result of the high amounts of water accumulation/percolation, due to surface runoff from hill slopes, and more vegetative growth (root penetration). Along the slopes of the hill, the degree and extent of weathering and pedogenisis is less. The most distinguishing feature throughout the weathered shale microfacies was the abundant vertical fractures. This will not only lead to rock/slope stability problems when exposed on the road-cut, but it may also cause problems beneath the subgrade of the new highway. It is recommended to consider removing the interval of weathered shale where exposed during road-cut excavation.

The clayshale microfacies is classified as high-medium concern for rock/slope instability with an average slake durability of 21.8%. This microfacies occurred randomly throughout the Lawrence Shale in thin, isolated beds. Compared to the other microfacies, the clay mineralogy indicated that there were higher relative quantities of smectite. Smectite's ability to shrink/swell exceeds that of vermiculite. Because of this, not only is the clayshale durability of concern, but also the stability of the material both above and below this more notably expandable microfacies.

Although the lenticular shale microfacies performed moderately well in the slake durability (avg. Id_2 = 56.5) and water absorption (20%) tests, the fabric and structure of the material poses moderate concern for rock/slope failure. The lenticular shale microfacies contains alternating silty/sandy lenticels (isolated or connected) that abruptly overlie clay and organic rich layers. Because of the materials heterolithic nature, the geotechnical behavior of the lenticular shale is complex. The coarser grained lenticels allow water to infiltrate the lenticular shale. With the presence of expandable clays, exposure of this material to seasonal conditions (wetting and drying cycles) will generate fractures, due to shrinking and swelling, along the abrupt interface between the clay and sand/silt lenticels. In addition to fracturing, the saturated clays become very slick, due to reduced friction/cohesion between the sand/silt-shale laminae interface, and may lead to rock/slope failure. One factor that may be influencing the durability of the lenticular shale is the amount of organic material within the clay. The lenticular shales that lie at great depths, within Pleasant Grove Hill, contain black shale with alternating white sand/silt lenticels. The black color implies reducing conditions as well as abundant organic material. Organic matter is characterized as having very high surface charge areas, which might in turn impede the shrink/swell capabilities of the expandable clays. Organic matter significantly increases the liquid and plastic limits of clay.

Within the geologic profile of Pleasant Grove Hill lie potential planes of weakness between the interface of durable and nondurable microfacies that might promote slope failure. For example, there may be a potential plane of weakness both above and below the interface between the less durable paleosol. Other interfaces that might be

susceptible to slope failure include: sandy/silty shale and lenticular shale, lenticular shale and overlying shale, and the Toronto Limestone and upper Lawrence Shale.

Identifying these areas most susceptible to rock/slope failure, engineers may take preventative measures to manage slope stabilization. Slope stabilization efforts may include: regrading and benching of slopes to reduce their steepness (slope angle), reduce water abosorption by installing drainage and runoff channeling structures, vegetate slope, and/or construct retaining walls, sunken pylons, and backfilled supports. Although repair of slopes can be performed following slope failure, the economic consequences far outweigh the initial remedial costs, even in a short period of time.

APPENDIX A: METHODS AND MATERIALS FOR SAMPLE PREPERATION

SAMPLE PREPARATION FOR SLAKE DURABILITY

The slake durability test method and procedures below follows the American Society for Testing and Materials (ASTM) Standards (ASTM D 4644). Slake Durability is a geotechnical testing method that determines the durability of shales and other similar weak rocks after two drying and wetting cycles with abrasion. Results are given in terms of how the material is retained (Type I-III) and by calculating a slake durability index after the second cycle.

SAMPLE PREPARATION FOR JAR SLAKE

The Jar Index test (FHWA, 1977) is a fast and simple method to determine how dry samples of rock material respond when immersed in water. A rock sample of ~20g is oven dried and immersed in distilled water. The resulting behavior of the sample is then observed after 2 hours of being immersed and assigned a jar index value according to specific criteria (Table 2.8).

Table 2.8: Jar Index values and descriptions

Jar Index	Behavior
1	Degrades into a pile of flakes or mud
2	Breaks rapidly and/or forms many chips
3	Breaks rapidly and/or forms few chips
4	Breaks slowly and/or develops several fractures
5	Breaks slowly and/or develops few fractures
6	No Change

(FHWA, 1977)

Water absorption (Abs. %) is determined as a secondary procedure during the jar index tests. Samples were weighed prior to and after oven drying and then after

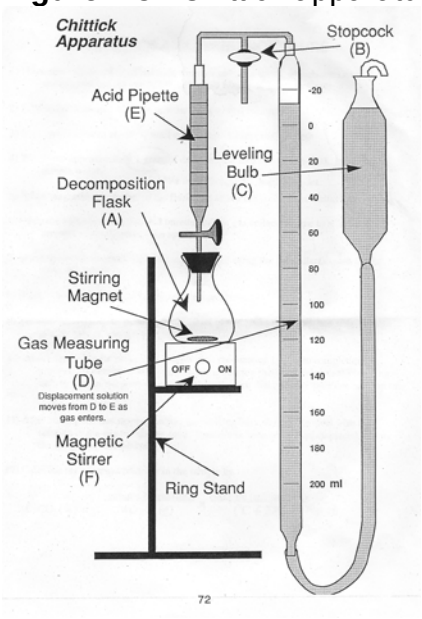
immersion during the jar index test. The percentage of water absorbed, by weight, is then obtained from this equation:

$$\% \text{ Abs.} = \frac{\text{Saturated weight (after immersion)} - \text{Oven dry weight (post Jar test)}}{\text{Saturated weight (after immersion)}} \times 100$$

SAMPLE PREPARATION FOR CHITTICK

The principles and procedures for the Chittick Analysis, follows that given by Machette (1986). The purpose of the Chittick Analysis is to provide a relatively quick and inexpensive method of measuring calcium and magnesium carbonate in rock/soil material. The amount of calcium carbonate is determined by dissolving the sample material in hydrochloric acid and measuring the volume of carbon dioxide gas produced by the reaction. Calcium carbonate is a common cementing agent in shale rock types. A useful predictor of durability is calculating the percentage of carbonate in the sample material by using the Chittick apparatus (Fig. 2.5). The volume of carbon dioxide is proportional to the amount of calcium carbonate.

Figure 2.5: Chittick apparatus



(Machette, 1986)

In a previous study by Miller and McCahon (1997), the % $CaCO_3$ was found to increase with slake durability index (I_d2) values. Samples with >35% calcium carbonate have medium to high durability.

METHODS FOR CLAY/SILT MINERALOGY

Identification of clay mineralogy involves variable pre-treatments of the rock samples in order to get accurate and recognizable X-ray diffraction (XRD) patterns (diffractograms). Analysis of the rock samples was done by determining the peaks, generated on the XRD patterns, and comparing them to XRD patterns of known minerals. The XRD pretreatments and procedures used for identifying clay and silt mineralogy follows that given by Jackson (1975).

MICROFABRIC ANALYSIS USING PHOTOMICROGRAPHY

For selected microfacies, petrographic thin sections were made by a commercial laboratory in order to analyze the microfabric and sedimentary bedding features. In order to identify bedding features, all thin sections were prepared vertically, most at a size of 1” x 2” (25 x 45 mm) and a few at 2” x 3” (51 x 75 mm). Thin sections were examined using a Nikon Optiphot-Pol petrographic microscope with the Nikon UFX camera system attachment. Photomicrographs were taken under both plane-polarized and crossed-polarized light. The terminology used to describe the micromorphology of the thin sections was from Stoops (2003).

APPENDIX B

STRATIGRAPHIC BORE LOGS OF PLEASANT GROVE HILL

APPENDIX B-1: STATION 506+36, 200’ RT CL - DEEP HOLE # 1 - DH1

DEPARTMENT OF GEOLOGY — Kansas State University

Project Number: 59-23 K-7888-01

Project Name: Realignment of Hwy. 59, south of Lawrence, KS

Site: Pleasent Grove, KS in Douglas County

Surface Elevation: 1083.5'

Location: Sta. 506 + 36 200' Rt

Material Description			Graphic Log	Depth (ft)	Sample Type	RQD	FIELD DATA: Moisture %	Liquid Limit	Plastic Limit	Plasticity Index	Unconfined Compression	LABORATORY DATA: Jar Index	CaCO3 %	Slake Durability Index	Slake Type
Not recovered															
	2.3	1081.2													
PLATTSMOUTH LIMESTONE.: Very Pale Orange (10YR 8/2) to White (N9) and stained Dark Yellowish Orange (10YR 6/6) dense hard limestone. Few calcite filled fractures (vertical/angled). Grayish Brown (5YR 3/2) claystone interbeds at 2.3' - 2.5' and 3.2' - 3.3'.				5											
	8.7	1074.8													
HEEBNER SHALE: Light Tan Gray to Grayish Orange (10YR 7/4) with Dark Yellowish Orange (10YR 6/6), Moderate Brown (5YR 3/4) and Grayish Black (N2) staining/oxidation. Horizontal, vertical, and step fractures.	9.8	1073.7													
Medium Light Gray (N6) to Grayish Black (N2) silty shale with horizontal fractures. Becomes more resistant and darker downward. Light Tan Gray to Grayish Orange (10YR 7/4) shale band at 10.1' - 10.2'. Very Light Gray (N8) silty starved ripple near base.	11.5	1072.0		10											

Remarks:

Hole #1, near Pleasant Grove, KS in Douglas County.

Completion Depth: 88.2'
Date Started: 06/29/04
Date Completed: 06/29/04
Drilled By:
Logged By:

Slake Type 1: Retained pieces virtually unchanged.
Slake Type 2: Retained material consists of large and small pieces
Slake Type 3: Retained material is exclusively small fragments.

JAR INDEX

1.Degrades into pile of flakes or mud
2.Breaks rapidly and/or forms many chips
3.Breaks rapidly and/or forms few chips
4.Breaks slowly and/or develops several fractures
5.Breaks slowly and/or develops few fractures
6.No change

CaCO3 %

High to Medium Durability > 35%

BORING LOG LAWREN~1.GPJ KANSAS STATE.GDT 5/1/06

DEPARTMENT OF GEOLOGY — Kansas State University

Project Number: 59-23 K-7888-01

Project Name: Realignment of Hwy. 59, south of Lawrence, KS

Site: Pleasent Grove, KS in Douglas County

Surface Elevation: 1083.5'

Location: Sta. 506 + 36 200' Rt

Material Description			Graphic Log	Depth (ft)	Sample Type	RQD	Moisture %	Liquid Limit	Plastic Limit	Plasticity Index	Unconfined Compression	Jar Index	CaCO3 %	Slake Durability Index	Slake Type
			FIELD DATA				LABORATORY DATA								
Grayish Black (N2) well indurated (resistant) shale with abundant horizontal fractures. Sparse lenticular bedding and bioturbation/root traces. Moderate Yellowish Brown (10YR 5/4) shale bands near top with Very Light Gray (N8) sandy layers beneath them (some with more resistant concretions). White (N9) to Very Light Gray (N8) more resistant fine sandy to silty interbed at 13' (<0.1' thick). *Continued Next Page*	14.2	1069.3													
LEAVENWORTH LIMESTONE: Medium Gray (N5) to White (N9) and Light Brownish Gray(5YR 6/1) limestone. Small recrystalized calcite shells. Stained Dark Yellowish Orange (10YR 6/6). Bottom 0.4' Dark Yellowish Orange (10YR 6/6) to Pale Yellowish Brown (10YR 6/2) less indurated limestone with White (N9) carbonate inclusions/sunken ripples. Sharp contact at base.	16.1	1067.4		15											
SNYDERVILLE SHALE: Pale Blue (5B 6/2), Greenish Gray (5GY 6/1), to Medium Light Gray (N6) paleosol. Top (0.6') is less resistant and irregularly fractured while the bottom (0.6') is more resistant and contains White (N9) carbonate concretions (rhizoconcretions), root traces, and irregular fractures.	18.7	1064.8													
Similar paleosol as above but Greenish Gray(5G 6/1) with more White (N9) carbonate (powdery) rhizoconcretions. Irregular fractures and shear planes with pedogenic slicks (shrink/swell). Shear planes at 20.2' (~40°), 20.6' (~40°), 21' (~20°).				20											
	23.7	1059.8													

Remarks:

Hole #1, near Pleasant Grove, KS in Douglas County.

Completion Depth: 88.2'
Date Started: 06/29/04
Date Completed: 06/29/04
Drilled By:
Logged By:

Slake Type 1: Retained pieces virtually unchanged.
Slake Type 2: Retained material consists of large and small pieces
Slake Type 3: Retained material is exclusively small fragments.

JAR INDEX

1.Degrades into pile of flakes or mud
2.Breaks rapidly and/or forms many chips
3.Breaks rapidly and/or forms few chips
4.Breaks slowly and/or develops several fractures
5.Breaks slowly and/or develops few fractures
6.No change

CaCO3 %

High to Medium Durability > 35%

BORING LOG LAWREN-1.GPJ KANSAS STATE.GDT 5/1/06

DEPARTMENT OF GEOLOGY — Kansas State University

Project Number: 59-23 K-7888-01

Project Name: Realignment of Hwy. 59, south of Lawrence, KS

Site: Pleasent Grove, KS in Douglas County

Surface Elevation: 1083.5'

Location: Sta. 506 + 36 200' Rt

Material Description			Graphic Log	Depth (ft)	Sample Type	RQD	Moisture %	Liquid Limit	Plastic Limit	Plasticity Index	Unconfined Compression	Jar Index	CaCO3 %	Slake Durability Index	Slake Type
			FIELD DATA				LABORATORY DATA								
Similar paleosol as above but weaker zone with abundant irregular fractures at 23.9' to 24.7' and then becoming more resistant and very carbonate rich (white). Sharp contact at base. *Continued Next Page*	24.9	1058.6		25											
TORONTO LIMESTONE: More resistant White (N9), Light Greenish Gray (5GY 8/1), and Moderate Olive Brown (5Y 4/4) diagenetically altered shaley limestone. Small clay/mud filled vughs. Vertical fracture at 25.6' to 26'.	26.7	1056.8													
Yellowish Gray (5Y 7/2) to White (N9) fossiliferous limestone with Pale Olive (10Y 6/2) to Light Gray (N7) clay filled vughs and drapes. Dark Yellowish Orange (10YR 6/6) to Moderate Brown (5YR 3/4) staining. Vertical fracture at 27.5' to 28'.	28.7	1054.8													
Limestone with Medium Light Gray (N6) clay drapes and filled vughs/inclusions. More abundant at top (~0.8') with Dark Yellowish Orange (10YR 6/6) staining. Bottom (~0.7') is a transition zone that grades into a Greenish Gray (5G 6/1) silty shale with abundant carbonate filled bioturbation toward the top (~0.4') of the transition zone.				30											
Lawrence Shale: Greenish Gray (5G 6/1) silty shale with faint streaked bedding. More resistant silty to very fine sand streaks lenticels stand out from the core giving a ribbed appearance. Thin to very thinly bedded.	33.7	1049.8		35								1	0.34	48.55	1

Remarks:

Hole #1, near Pleasant Grove, KS in Douglas County.

Completion Depth: 88.2'
Date Started: 06/29/04
Date Completed: 06/29/04
Drilled By:
Logged By:

Slake Type 1: Retained pieces virtually unchanged.
Slake Type 2: Retained material consists of large and small pieces
Slake Type 3: Retained material is exclusively small fragments.

JAR INDEX

1. Degrades into pile of flakes or mud
2. Breaks rapidly and/or forms many chips
3. Breaks rapidly and/or forms few chips
4. Breaks slowly and/or develops several fractures
5. Breaks slowly and/or develops few fractures
6. No change

CaCO3 %

High to Medium Durability > 35%

BORING LOG LAWREN-1.GPJ KANSAS STATE.GDT 5/1/06

DEPARTMENT OF GEOLOGY — Kansas State University

Project Number: 59-23 K-7888-01

Project Name: Realignment of Hwy. 59, south of Lawrence, KS

Site: Pleasent Grove, KS in Douglas County

Surface Elevation: 1083.5'

Location: Sta. 506 + 36 200' Rt

Material Description			Graphic Log	Depth (ft)	Sample Type	RQD	Moisture %	Liquid Limit	Plastic Limit	Plasticity Index	Unconfined Compression	Jar Index	CaCO3 %	Slake Durability Index	Slake Type
			FIELD DATA				LABORATORY DATA								
of core. Some woody/plant debris is smooth, slick, and shiny/glossy; other organic debris is oxidized black to deep red maroon	48.7	1034.8													
N/A*Continued Next Page*															
More resistant Medium Light Gray (N6) to Greenish Gray(5GY 6/1) paleosol with root traces and angled shear planes with slickensides at 48' (~30°) and 48.4' (~30°). Grades to more clay-rich paleosols with abundant irregular fratures (shrink/swell deccication). Columnar ped structure. Similar paleosol as above (irregular angled fractures). Pale Reddish Brown (10R 5/4) oxidation along fractures at base. Becomes more resistant towards base with sharp contact.	50.0	1033.5		50											
	52.0	1031.5										1	13.3	0	3
Pale Green (5G 7/2) to Pale Yellowish Green (10GY 7/2) shale with resistant carbonate nodules/lenses (1"-4" thick).												3	34.5	56.84	2
				55											
Soft/weak fractured zone (clay rich) at 55.6' (0.3' thick).															
Thin (~0.1') limey lenses at 55.8', 56.6', 56.8'.															
	58.9	1024.6													
Grades into churned shale with bivalve fossils with no carbonate concretions/lenses. Grayish Orange (10YR 7/4) dense/hard limestone with clacite filled bioturbation at				60											

Remarks:

Hole #1, near Pleasant Grove, KS in Douglas County.

Completion Depth: 88.2'
Date Started: 06/29/04
Date Completed: 06/29/04
Drilled By:
Logged By:

Slake Type 1: Retained pieces virtually unchanged.
Slake Type 2: Retained material consists of large and small pieces
Slake Type 3: Retained material is exclusively small fragments.

JAR INDEX

1.Degrades into pile of flakes or mud
2.Breaks rapidly and/or forms many chips
3.Breaks rapidly and/or forms few chips
4.Breaks slowly and/or develops several fractures
5.Breaks slowly and/or develops few fractures
6.No change

CaCO3 %

High to Medium Durability > 35%

BORING LOG LAWREN~1.GPJ KANSAS STATE.GDT 5/1/06

DEPARTMENT OF GEOLOGY — Kansas State University

Project Number: 59-23 K-7888-01

Project Name: Realignment of Hwy. 59, south of Lawrence, KS

Site: Pleasent Grove, KS in Douglas County

Surface Elevation: 1083.5'

Location: Sta. 506 + 36 200' Rt

Material Description			Graphic Log	Depth (ft)	Sample Type	RQD	Moisture %	Liquid Limit	Plastic Limit	Plasticity Index	Unconfined Compression	Jar Index	CaCO3 %	Slake Durability Index	Slake Type
			FIELD DATA				LABORATORY DATA								
60.2	60.2' (0.2' thick) with sharp basal contact. Contains aundantly horizontal fractured Medium Gray (N5) and Brownish Gray (5YR 4/1) shale with slickensides. Grades into a finley interlaminated shale (~0.3' thick) with sooty coal laminations.	1023.3													
60.9	Very fine to fine wavy to lenticular bedding of coal organic rich (sooty) layers with Medium Bluish Gray (5B 5/1) to Light Gray (N7) mud at top (0.5'). Grades to thin wavy bedded Greenish Gray (5G 6/1) shale that is finely mottled Brownish Gray (5YR 4/1). Leafy plant fossils and other plant/organic debris.	1022.6													
				65								2	1	63.75	2
66.2	Medium Gray (N5) to Greenish Gray (5GY 6/1) finely laminated shale with plant/leafy debris. Abundant fractures along horizontal bedding plane. Some areas with lenticular to flaser bedding towards the bottom.	1017.3													
67.7	Soft/weak clay rich zone at ~65.6 and ~66.5' (~0.1' thick). Plant and root fossils.	1015.8													
68.7	Medium Gray (N5) to Medium Dark Gray (N4) shale with thin lenticular to streaked bedding with White (N9) very fine sand to silt lenticels. Few areas with flaser bedding. Very thinly laminated and fractures along horizontal bedding plane.	1014.8													
	Similar to above but with more lenticular bedding with few areas of flaser bedding. Micaceous with few organic debris. Few areas with dense hard ironstone bands (cementation) and concretions. Soft/weak clay rich zone at 71.6' (0.2' thick). Sharp basal contact.			70								3.5	3.8	71.42	1

Remarks:

Hole #1, near Pleasant Grove, KS in Douglas County.

Completion Depth: 88.2'
Date Started: 06/29/04
Date Completed: 06/29/04
Drilled By:
Logged By:

Slake Type 1: Retained pieces virtually unchanged.
Slake Type 2: Retained material consists of large and small pieces
Slake Type 3: Retained material is exclusively small fragments.

JAR INDEX

1.Degrades into pile of flakes or mud
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3.Breaks rapidly and/or forms few chips
4.Breaks slowly and/or develops several fractures
5.Breaks slowly and/or develops few fractures
6.No change

CaCO3 %

High to Medium Durability > 35%

BORING LOG LAWREN~1.GPJ KANSAS STATE.GDT 5/1/06

DEPARTMENT OF GEOLOGY — Kansas State University

Project Number: 59-23 K-7888-01

Project Name: Realignment of Hwy. 59, south of Lawrence, KS

Site: Pleasent Grove, KS in Douglas County

Surface Elevation: 1083.5'

Location: Sta. 506 + 36 200' Rt

Material Description			Graphic Log	Depth (ft)	Sample Type	RQD	Moisture %	Liquid Limit	Plastic Limit	Plasticity Index	Unconfined Compression	Jar Index	CaCO3 %	Slake Durability Index	Slake Type
	72.6	1010.9													
Grayish Black (N2) to Black (N1) sooty coal bed with few root traces. Thin mud interbed toward top (~ 0.1' thick) . Grades into carbonaceous shale with sooty coal material debris. Grades to shale with plant organic debris. Gradational contact at base.	74.0	1009.5													
Greenish Gray (5G 6/1) silty churned shale with plant/organic debris and Moderate Yellowish Brown (10YR 5/4) to Dark Yellowish Orange (10YR 6/6) oolitic ironstone concretions (2mm-3"). Bottom contains isolated, thin sandy streakes and becomes darker - Medium Dark Gray (N4).				75								1	1.6	85.19	1
	77.0	1006.5													
Abrupt sharp transition to Medium Dark Gray (N5) heterolithic shale with well preserved lenticular bedding of White (N9) fine sand lenticles. Some Orangish Gray ironstone banding cementation.												6	4.4	89.82	1
	79.2	1004.3													
Silty, micaceou shale with abundant black organic particles. Soft sediment deformation and starved/sunken ripples (load structures) present. Good resistant core with gradational basal contact. Minor amounts of very fine sand.	80.4	1003.1		80								6	6.5	92.3	1
Medium Gray (N5) to Medium Dark Gray (N4) heterolithic, micaceous shale with abundant lenticular bedding and minor amounts of flaser bedding. White (N9) to Very Light Gray (N8) very fine sand to silt lenticels. Few areas with deformation/load structures.															
	83.5	1000.0													

Remarks:

Hole #1, near Pleasant Grove, KS in Douglas County.

Completion Depth: 88.2'
Date Started: 06/29/04
Date Completed: 06/29/04
Drilled By:
Logged By:

Slake Type 1: Retained pieces virtually unchanged.
Slake Type 2: Retained material consists of large and small pieces
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JAR INDEX

1.Degrades into pile of flakes or mud
2.Breaks rapidly and/or forms many chips
3.Breaks rapidly and/or forms few chips
4.Breaks slowly and/or develops several fractures
5.Breaks slowly and/or develops few fractures
6.No change

CaCO3 %

High to Medium Durability > 35%

BORING LOG LAWREN~1.GPJ KANSAS STATE.GDT 5/1/06

DEPARTMENT OF GEOLOGY — Kansas State University

Project Number: 59-23 K-7888-01

Project Name: Realignment of Hwy. 59, south of Lawrence, KS

Site: Pleasent Grove, KS in Douglas County

Surface Elevation: 1083.5'

Location: Sta. 506 + 36 200' Rt

Material Description			Graphic Log	Depth (ft)	Sample Type	RQD	Moisture %	Liquid Limit	Plastic Limit	Plasticity Index	Unconfined Compression	Jar Index	CaCO3 %	Slake Durability Index	Slake Type
84.4	Micaceous and organic rich silty shale with soft sediment deformation and sunken ripples (load structures) at 83.5' to 84.4'. *Continued Next Page*	999.1													
85.7	Much thinner interlaminations consisting of lenticular to pinstripe bedding with minor amounts of flaser bedding. Fractures along shale and sandy lenticle interface.	997.8		85											
86.2	Sandy shale at 85.7' to 86.2' with White (N9) starved ripples load structures.	997.3													
	Similar heterolithic shale with thin lenticular pinstripe bedding as above. Micaceous and organic debris present.											5	3	70.58	2
88.2		995.3		90											
				95											

FIELD DATA | LABORATORY DATA

Remarks:

Hole #1, near Pleasant Grove, KS in Douglas County.

Completion Depth: 88.2'
Date Started: 06/29/04
Date Completed: 06/29/04
Drilled By:
Logged By:

Slake Type 1: Retained pieces virtually unchanged.
Slake Type 2: Retained material consists of large and small pieces
Slake Type 3: Retained material is exclusively small fragments.

JAR INDEX

1.Degrades into pile of flakes or mud
2.Breaks rapidly and/or forms many chips
3.Breaks rapidly and/or forms few chips
4.Breaks slowly and/or develops several fractures
5.Breaks slowly and/or develops few fractures
6.No change

CaCO3 %

High to Medium Durability > 35%

BORING LOG LAWREN-1.GPJ KANSAS STATE.GDT 5/1/06

DEPARTMENT OF GEOLOGY — Kansas State University

Project Number: 59-23 K-7888-01

Project Name: Realignment of Hwy. 59, south of Lawrence, KS

Site: Pleasent Grove, KS in Douglas County

Surface Elevation: 1083.5'

Location: Sta. 506 + 36 200' Rt

Material Description			Graphic Log	Depth (ft)	Sample Type	RQD	Moisture %	Liquid Limit	Plastic Limit	Plasticity Index	Unconfined Compression	Jar Index	CaCO3 %	Slake Durability Index	Slake Type
			FIELD DATA				LABORATORY DATA								
Same as above but with more areas with streaked starved bedding downward of Light Olive Gray (5Y 6/1) to Very Light Gray (N8) fine sand/silt. Sharp contact at base.															
14.2		1069.3													
Leavenworth Limestone: Top 0.2' is same black shale as above with a sharp contact at base. Very Light Gray (N8) to Medium Gray (N5) fossiliferous limestone with long calcite filled vertical fractures. Pale Yellowish Orange (10YR 8/6) staining. Sharp contact at base.				15											
16.2		1067.3													
Snyderville Shale: Pale Olive (10Y 6/2) to Greenish Gray (5GY 6/1) resistant (few fractures) paleosol with root traces. Soft weak (clay rich) zone with irregular fracture (calcite filled) at 17' (~0.1' thick).															
18.4		1065.1													
Same paleosol as above but with sparse White (N9) powdery carbonate concretions that increase downward. Bottom 0.6' abundant carbonate concretions zone (1mm - 2").				20											
22.9		1060.6													
Greenish Gray (5G 6/1) paleosol with abundant White (N9) carbonate concretions (1mm - 1").															
24.0		1059.5													

Remarks:

Hole #2, near Pleasant Grove, KS in Douglas County.

Completion Depth: 102.8'
Date Started: 06/30/04
Date Completed: 06/30/04
Drilled By:
Logged By:

Slake Type 1: Retained pieces virtually unchanged.
Slake Type 2: Retained material consists of large and small pieces
Slake Type 3: Retained material is exclusively small fragments.

JAR INDEX

1.Degrades into pile of flakes or mud
2.Breaks rapidly and/or forms many chips
3.Breaks rapidly and/or forms few chips
4.Breaks slowly and/or develops several fractures
5.Breaks slowly and/or develops few fractures
6.No change

CaCO3 %

High to Medium Durability > 35%

BORING LOG LAWRENCE SHALE 1.GPJ KANSAS STATE.GDT 4/26/06

APPENDIX B-2: STATION 506+36, 200’ RT CL - DEEP HOLE # 2 - DH2

DEPARTMENT OF GEOLOGY — Kansas State University

Project Number: 59-23 K-7888-01

Project Name: Realignment of Hwy. 59, south of Lawrence, KS

Site: Pleasent Grove, KS in Douglas County

Surface Elevation: 1083.5'

Location: Sta. 506 + 36 200' Rt

Material Description			Graphic Log	Depth (ft)	Sample Type	RQD	Moisture %	Liquid Limit	Plastic Limit	Plasticity Index	Unconfined Compression	Jar Index	CaCO3 %	Slake Durability Index	Slake Type
			FIELD DATA				LABORATORY DATA								
Greenish Gray (5G 6/1) paleosol with abundant White (N9) carbonate concretions (1mm - 1").	24.9	1058.6													
Same shale as above but with much more weathering staining of Pale Yellowish Orange (10YR 8/6) to Light Brown (5YR 5/6).	25.5	1058.0		25											
Same stained shale as above but more resistant and contains small Grayish Yellow Green (5GY 7/2) clay filled vughs/rootcasts. Sharp contact at base.	26.1	1057.4													
Toronto Limestone: Hard resistant Yellowish Gray (5Y 7/2) fossiliferous limestone with Dark Yellowish Orange (10YR 6/6) staining. Few small clay filled vughes at top. Few biogenic traces.															
	28.8	1054.7													
Same fossiliferous limestone as above but with no vughs. More biogenic traces and staining downward. Grades at base.				30											
	33.8	1049.7													
				35											

Remarks:

Hole #2, near Pleasant Grove, KS in Douglas County.

Completion Depth: 102.8'
Date Started: 06/30/04
Date Completed: 06/30/04
Drilled By:
Logged By:

Slake Type 1: Retained pieces virtually unchanged.
Slake Type 2: Retained material consists of large and small pieces
Slake Type 3: Retained material is exclusively small fragments.

JAR INDEX

1.Degrades into pile of flakes or mud
2.Breaks rapidly and/or forms many chips
3.Breaks rapidly and/or forms few chips
4.Breaks slowly and/or develops several fractures
5.Breaks slowly and/or develops few fractures
6.No change

CaCO3 %

High to Medium Durability > 35%

Slake Type 3: Retained material is exclusively small fragments.

CaCO3 %

High to Medium Durability > 35%

BORING BORING LOG LAWRENCE SHALE 1.GPJ KANSAS STATE.GDT 4/26/06

DEPARTMENT OF GEOLOGY — Kansas State University

Project Number: 59-23 K-7888-01

Project Name: Realignment of Hwy. 59, south of Lawrence, KS

Site: Pleasent Grove, KS in Douglas County

Surface Elevation: 1083.5'

Location: Sta. 506 + 36 2(

FIELD DATA | LABORATORY DATA

Materia

Lawrence Shale: Pale G
Greenish Gray (5G 6/1) s
irregular "pockets" of fine
structures?). Slightly res
bedding/starved ripples, l
irregularly shaped pocket
churning bioturbation. M
lenticles stand out from tl
ribbed apperance. Minor
bedding. Some Dark Yel
(10YR 6/6) staining arou

Very soft/weak clay rich
thick).*Continued Next Pag*

39.5

Less resistant Medium Li
Medium Gray (N5) shale
fine sand to silt streaked
Deformed lenticels due to
Abundant horizontal to s
Soft/weak clay rich zones
fractures at 39.5' (~0.2' th
thick), 40.9' (~0.1' thick).

43.4

Same shale as above but
indurated/resistant with f
streaks. Very thinly lami

45.2

Medium Light Gray (N6)
Gray (N4), and Moderate
to medium platy ped stru
and plant debris. Carbon
with sooty coal spars at 4

47.3

Remarks:

Hole #2, near Pleasant Grove,

BORING LOG LAWRENCE SHALE 1.GPJ KANSAS STATE.GDT 4/26/06

DEPARTMENT OF GEOLOGY — Kansas State University

Project Number: 59-23 K-7888-01

Project Name: Realignment of Hwy. 59, south of Lawrence, KS

Site: Pleasent Grove, KS in Douglas County

Surface Elevation: 1083.5'

Location: Sta. 506 + 36 200' Rt

FIELD DATA | LABORATORY DATA

Material Description	Graphic Log	Depth (ft)	Sample Type	RQD	Moisture %	Liquid Limit	Plastic Limit	Plasticity Index	Unconfined Compression	Jar Index	CaCO3 %	Slake Durability Index	Slake Type
Bedding becomes inclined (~10°). Organic particles present. Grades into horizontally bedded shale with sharp contact at base.*Continued Next Page*													
73.4 / 1010.1													
73.8 / 1009.7 Black (N1) glossy to vitreous, sooty and brittle coal seam. Low density and sharp contact at base.													
Medium Light Gray (N6) churned shale to weak paleosol with organics plant debris near top (black) and root traces. Grayish Red (5R 4/2) to Dark Yellowish Orange (10YR 6/6) root casts and traces. Pedogenic slickensides.										1	.74	19.02	2
75.2 / 1008.3		75											
Light Gray (N7) to Greenish Gray (5G 6/1) heterolithic shale with thin lenticular to streaked bedding; minor amounts of flaser bedding. Bedding is faint at the top and becomes more abundant downward with (very thin and long) White (N9) very fine sand to silt lenticels. Slight disturbed bedding toward top. Sparse, very fine oolitic ironstone concretions (weak paleosol?)										4	1.02	80.45	1
79.2 / 1004.3													
Light Olive Gray (5Y 6/1) to Light Gray (N7) micaceous sandy shale with black organic particles. Top 0.6' contains hard dense White (N9) sandstone, with soft sediment deformation due to slump or bioturbation. Bottom is sandy shale with		80											
80.9 / 1002.6 few sandy sunken starved ripples (load structures) - some forsets seen.													
Heterolithic shale with lenticular bedding; few interlaminated White (N9), fine grained, dense hard sandstones. Silty to very fine sandy lenticels contain aboundant mica and black organic particles. Some areas of deformation and organic-rich (black) laminae.										5	3.01	75.49	1
83.3 / 1000.2													

Remarks:

Hole #2, near Pleasant Grove, KS in Douglas County.

Completion Depth: 102.8'
Date Started: 06/30/04
Date Completed: 06/30/04
Drilled By:
Logged By:

Slake Type 1: Retained pieces virtually unchanged.
Slake Type 2: Retained material consists of large and small pieces
Slake Type 3: Retained material is exclusively small fragments.

JAR INDEX

1.Degrades into pile of flakes or mud
2.Breaks rapidly and/or forms many chips
3.Breaks rapidly and/or forms few chips
4.Breaks slowly and/or develops several fractures
5.Breaks slowly and/or develops few fractures
6.No change

CaCO3 %

High to Medium Durability > 35%

BORING LOG LAWREN~1.GPJ KANSAS STATE.GDT 5/1/06

DEPARTMENT OF GEOLOGY — Kansas State University

Project Number: 59-23 K-7888-01

Project Name: Realignment of Hwy. 59, south of Lawrence, KS

Site: Pleasent Grove, KS in Douglas County

Surface Elevation: 1083.5'

Location: Sta. 506 + 36 200' Rt

Material Description	Graphic Log	Depth (ft)	Sample Type	RQD	Moisture %	Liquid Limit	Plastic Limit	Plasticity Index	Unconfined Compression	Jar Index	CaCO3 %	Slake Durability Index	Slake Type
FIELD DATA					LABORATORY DATA								
Similar heterolithic shale as above, but with much finer/thinner lenticular/pinstripe bedding. Some cross bedding seen in the few larger lenses present. *Continued Next Page*		85								4	2.3	77.47	1
92.9 990.6		90											
Medium Light Gray (N6) silty/sandy, micaceous shale with black organic particles/debris. Some biogenic traces toward top. Micaceous sandstone at 93.1' (0.5' thick) with soft sediment deformation of sunken/starved ripples (load structure). Same silty/sandy, micaceous shale as above with black organic debris and plant fragments. Organic debris and mica decrease downward.													
94.2 989.3		95								4	2.9	84.18	1

Remarks:

Hole #2, near Pleasant Grove, KS in Douglas County.

Completion Depth: 102.8'
Date Started: 06/30/04
Date Completed: 06/30/04
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4.Breaks slowly and/or develops several fractures
5.Breaks slowly and/or develops few fractures
6.No change

CaCO3 %

High to Medium Durability > 35%

BORING LOG LAWREN-1.GPJ KANSAS STATE.GDT 5/1/06

DEPARTMENT OF GEOLOGY — Kansas State University

Project Number: 59-23 K-7888-01

Project Name: Realignment of Hwy. 59, south of Lawrence, KS

Site: Pleasent Grove, KS in Douglas County

Surface Elevation: 1083.5'

Location: Sta. 506 + 36 200' Rt

Material Description			Graphic Log	Depth (ft)	Sample Type	RQD	Moisture %	Liquid Limit	Plastic Limit	Plasticity Index	Unconfined Compression	Jar Index	CaCO3 %	Slake Durability Index	Slake Type
			FIELD DATA				LABORATORY DATA								
Same silty/sandy, micaceous shale as above with black organic debris and plant fragments. Organic debris and mica decrease downward. *Continued Next Page*															
	97.7	985.8													
98.0 Similar to above shale but little organic debris and less mica. More indurated Light Gray (N7) to Medium Gray (N5) shale with areas of abundant mica and organic debris; becomes more sandy downward.		985.5										4	3.5	86.05	1
	100.4	983.1		100											
Medium Light Gray (N6) heterolithic shale with mostly very thin fine lenticular bedding. Minor amounts of flaser bedding. Abundant mica and black organic particles.															
	102.8	980.7													
				105											

Remarks:

Hole #2, near Pleasant Grove, KS in Douglas County.

Completion Depth: 102.8'
Date Started: 06/30/04
Date Completed: 06/30/04
Drilled By:
Logged By:

Slake Type 1: Retained pieces virtually unchanged.
Slake Type 2: Retained material consists of large and small pieces
Slake Type 3: Retained material is exclusively small fragments.

JAR INDEX

1.Degrades into pile of flakes or mud
2.Breaks rapidly and/or forms many chips
3.Breaks rapidly and/or forms few chips
4.Breaks slowly and/or develops several fractures
5.Breaks slowly and/or develops few fractures
6.No change

CaCO3 %

High to Medium Durability > 35%

BORING LOG LAWREN-1.GPJ KANSAS STATE.GDT 5/1/06

DEPARTMENT OF GEOLOGY — Kansas State University

Project Number: 59-23 K-7888-01

Project Name: Realignment of Hwy. 59, south of Lawrence, KS

Site: Pleasent Grove, KS in Douglas County

Surface Elevation: 1083.5'

Location: Sta. 506 + 36 200' Rt

Material Description			Graphic Log	Depth (ft)	Sample Type	RQD	Moisture %	Liquid Limit	Plastic Limit	Plasticity Index	Unconfined Compression	Jar Index	CaCO3 %	Slake Durability Index	Slake Type
							FIELD DATA					LABORATORY DATA			
Same green shale as above but without carbonate concretions, churned bedding with bivavle fossils. *Continued Next Page*												3	4.71	79.51	1
62.3		1021.2													
Top 0.1' is interlaminated coaly/sooty material that grades to Light Gray (N7) to Medium Dark Gray (N4) and Greenish Gray(5G 6/1) churned shale (weak paleosol?) with irregular fractures (clay-rich). Grayish Orange (10YR 7/4) limestone nodules (3mm-2").															
63.5		1020.0													
Greenish Gray(5G6/1), Medium Dark Gray (N4), and Brownish Gray (5YR 4/1) finely mottled silty churned shale with abundant plant and leafy material debris. Grayish Orange (10YR 7/4) limestone interbeds (discontinous erosional?) at 55.5' (~0.1' thick) and 64.1' (~0.2' thick with black plant debris) - both Ls. interbeds have sharp contacts (undulating bottom).				65								2	.48	37.16	2
64.5		1019.0													
Finely mottled Medium Gray (N5) and Greenish Gray (5G 6/1) churned shale. Discontinuous Grayish Orange (10YR 7/4) limestone interbed at 64.6' (~0.1' thick). Lose mottling downward and becomes more sandy/silty.															
67.5		1016.0													
Heterolithic shale with lenticular and some flaser bedding. Medium Dark Gray (N4) shale with White (N9) to Very Light Gray (N8) fine sandy lenses. Mostly very finely bedded.															
68.6		1014.9													
68.9	More resistant sandstone with mud drapes	1014.6													
69.1	and 69.1' (~0.1' thick).	1014.4													
69.2	Heterolithic shale with lenticular and some	1014.3													
69.4	flaser bedding. Medium Dark Gray (N4) shale with White (N9) to Very Light Gray (N8) fine sandy lenses. Mostly very finely bedded.	1014.1		70											
More resistant sandstone with mud drapes and 69.1' (~0.1' thick).															
Heterolithic shale with lenticular and some flaser bedding. Medium Dark Gray (N4) shale with White (N9) to Very Light Gray (N8) fine sandy lenses. Mostly very finely bedded.															
71.4		1012.1										3	.72	67.5	2

Remarks:

Hole #2, near Pleasant Grove, KS in Douglas County.

Completion Depth: 102.8'
Date Started: 06/30/04
Date Completed: 06/30/04
Drilled By:
Logged By:

Slake Type 1: Retained pieces virtually unchanged.
Slake Type 2: Retained material consists of large and small pieces
Slake Type 3: Retained material is exclusively small fragments.

JAR INDEX

1.Degrades into pile of flakes or mud
2.Breaks rapidly and/or forms many chips
3.Breaks rapidly and/or forms few chips
4.Breaks slowly and/or develops several fractures
5.Breaks slowly and/or develops few fractures
6.No change

CaCO3 %

High to Medium Durability > 35%

BORING LOG LAWREN-1.GPJ KANSAS STATE.GDT 5/1/06

DEPARTMENT OF GEOLOGY — Kansas State University

Project Number: 59-23 K-7888-01

Project Name: Realignment of Hwy. 59, south of Lawrence, KS

Site: Pleasent Grove, KS in Douglas County

Surface Elevation: 1083.5'

Location: Sta. 506 + 36 200' Rt

Material Description			Graphic Log	Depth (ft)	Sample Type	RQD	Moisture %	Liquid Limit	Plastic Limit	Plasticity Index	Unconfined Compression	Jar Index	CaCO3 %	Slake Durability Index	Slake Type
48.3	Grayish Green (5GY 6/1) to Medium Gray (N5) paleosol with top 0.5' resistant and the rest weaker with irregular fractures. Bottom 0.2' Grayish Red Purple (5RP 4/2) oxidized paleosol. *Continued Next Page*	1035.2													
49.8	Same Grayish Red Purple paleosol as above and mottled Greenish Gray (5GY 6/1), Medium Light Gray (N6), and stained root traces of Moderate Yellow (5Y 7/6) to Dark Yellowish Orange (10YR 6/6). Some biogenic traces. Angled (40°) shear plane with slicks at 49'.	1033.7		50								1	14.24	.83	3
	Grades to Greenish Gray (5G 6/1) angular blocky paleosol with Light Olive Brown (5Y 5/6) root traces.											1	18.56	.6	3
53.5		1030.0													
	Pale Yellowish Green (10GY 7/2) to Light Greenish Gray (5G 8/1) silty shale with White (N9) carbonate inclusions (2mm-3"). Near base inclusions are replaced by few White (N9) powdery carbonate concretions zones. Minor amounts of lenticular bedding near base. Bivalve fossils and biogenic trace fossils.			55								2	10.13	25.08	2
58.0		1025.5													
	Same green shale as above but without carbonate concretions, churned bedding with bivavle fossils.			60											

FIELD DATA | LABORATORY DATA

Remarks:

Hole #2, near Pleasant Grove, KS in Douglas County.

Completion Depth: 102.8'
Date Started: 06/30/04
Date Completed: 06/30/04
Drilled By:
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JAR INDEX

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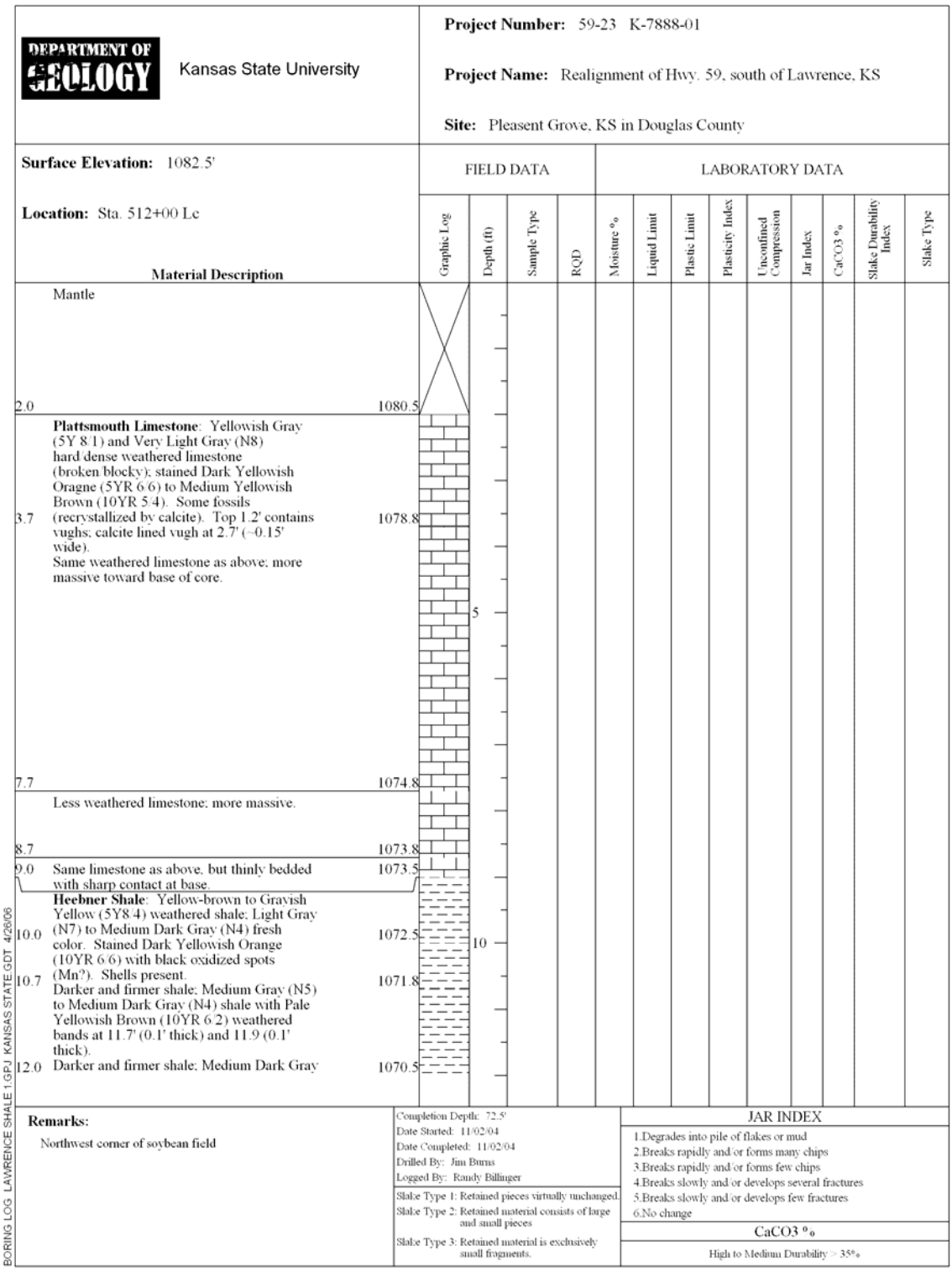
2.Breaks rapidly and/or forms many chips
3.Breaks rapidly and/or forms few chips
4.Breaks slowly and/or develops several fractures
5.Breaks slowly and/or develops few fractures
6.No change

CaCO3 %

High to Medium Durability > 35%

BORING LOG LAWRENCE SHALE 1.GPJ KANSAS STATE.GDT 4/26/06

APPENDIX B-3: STATION 512+00 CL - SOYBEAN FIELD AT TOP OF HILL -SF1



DEPARTMENT OF GEOLOGY — Kansas State University

Project Number: 59-23 K-7888-01

Project Name: Realignment of Hwy. 59, south of Lawrence, KS

Site: Pleasent Grove, KS in Douglas County

Surface Elevation: 1082.5'

Location: Sta. 512+00 Lc

FIELD DATA | LABORATORY DATA

Material Description			Graphic Log	Depth (ft)	Sample Type	RQD	Moisture %	Liquid Limit	Plastic Limit	Plasticity Index	Unconfined Compression	Jar Index	CaCO3 %	Slake Durability Index	Slake Type
Mantle															
	2.0	1080.5													
Plattsmouth Limestone: Yellowish Gray (5Y 8/1) and Very Light Gray (N8) hard dense weathered limestone (broken blocky); stained Dark Yellowish Oragne (5YR 6/6) to Medium Yellowish Brown (10YR 5/4). Some fossils (recrystallized by calcite). Top 1.2' contains vughs; calcite lined vugh at 2.7' (~0.15' wide). Same weathered limestone as above; more massive toward base of core.	3.7	1078.8		5											
	7.7	1074.8													
Less weathered limestone; more massive.															
	8.7	1073.8													
Same limestone as above, but thinly bedded with sharp contact at base.	9.0	1073.5													
Heebner Shale: Yellow-brown to Gravish Yellow (5Y8/4) weathered shale; Light Gray (N7) to Medium Dark Gray (N4) fresh color. Stained Dark Yellowish Orange (10YR 6/6) with black oxidized spots (Mn?). Shells present.	10.0	1072.5		10											
Darker and firmer shale; Medium Gray (N5) to Medium Dark Gray (N4) shale with Pale Yellowish Brown (10YR 6/2) weathered bands at 11.7' (0.1' thick) and 11.9 (0.1' thick).	10.7	1071.8													
Darker and firmer shale; Medium Dark Gray	12.0	1070.5													

Remarks:

Northwest corner of soybean field

Completion Depth: 72.5'
Date Started: 11/02/04
Date Completed: 11/02/04
Drilled By: Jim Burns
Logged By: Randy Billinger

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Slake Type 2: Retained material consists of large and small pieces
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JAR INDEX

1.Degrades into pile of flakes or mud
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3.Breaks rapidly and/or forms few chips
4.Breaks slowly and/or develops several fractures
5.Breaks slowly and/or develops few fractures
6.No change

CaCO3 %

High to Medium Durability > 35%

BORING LOG LAWRENCE SHALE 1.GPJ KANSAS STATE.GDT 4/26/06

DEPARTMENT OF GEOLOGY — Kansas State University

Project Number: 59-23 K-7888-01

Project Name: Realignment of Hwy. 59, south of Lawrence, KS

Site: Pleasent Grove, KS in Douglas County

Surface Elevation: 1082.5'

Location: Sta. 512+00 Lc

Material Description			Graphic Log	Depth (ft)	Sample Type	RQD	Moisture %	Liquid Limit	Plastic Limit	Plasticity Index	Unconfined Compression	Jar Index	CaCO3 %	Slake Durability Index	Slake Type
(N4) to Dark Gray (N3) shale. Darker and dense hard fissile shale with high organic content (carbonaceous). Dark Gray (N3) to Grayish Black (N2) shale with very thin (1-2mm) crystalline gypsum interbeds lenses from 10.6' to11'. Lenticular (single thin lenses of fine silt) beds near base of core. White (N9) to Very Light Gray (N8) sandy zone (~0.1' thick) that is wavy bedded at 13.4'.	13.7	1068.8													
Same dense, black (carbonaceous), fissile shale as above, but with no gypsum interbeds lenses. Abundant horizontal fractures. Sharp contact at base. Very minor amounts of lenticular bedding (single thin lenses). Sandy interbeds pillows at 14.2' (0.1' thick), 14.8' (0.1' thick), and 15.5' (~0.1' thick- wavy).	15.5	1067.0		15											
Leavenworth Limestone: Very Light Gray (N8) to Medium Light Gray (N6) thickly bedded and hard dense fossiliferous limestone. Some Dark Yellowish Orange (10YR 6/6) staining. Sharp contact at base.	17.5	1065.0													
Snyderville Shale: Greenish Gray (5GY 6/1) to Medium Bluish Gray (5B 5/1) firm calcareous paleosol with a shear plane (with slicks) at 17.8' (40°). Root or burrow trace.	18.2	1064.3													
Same Greenish Gray (5GY 6/1) firm paleosol, with root/burrow traces, that becomes more green (Greenish Gray 5G 6/1) downward. Irregular fractures and shear planes. Angled shear planes (with slicks) at 18.4' (~25°), 19' (~45°), 19.2' (~20°), 19.9' (~45°), 20.5' (~40°), 22.2' (~40°). White (N9) calcitic concretions appear toward bottom of core. White (N9) powdery calcitic zones at 20.9' (~0.15' thick), 21.9' (~0.1' thick).				20											
	23.1	1059.4													

Remarks:

Northwest corner of soybean field

Completion Depth: 72.5'
Date Started: 11/02/04
Date Completed: 11/02/04
Drilled By: Jim Burns
Logged By: Randy Billinger

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Slake Type 2: Retained material consists of large and small pieces
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JAR INDEX

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3.Breaks rapidly and/or forms few chips
4.Breaks slowly and/or develops several fractures
5.Breaks slowly and/or develops few fractures
6.No change

CaCO3 %

High to Medium Durability > 35%

BORING LOG LAWREN-1.GPJ KANSAS STATE.GDT 5/1/06

DEPARTMENT OF GEOLOGY — Kansas State University

Project Number: 59-23 K-7888-01

Project Name: Realignment of Hwy. 59, south of Lawrence, KS

Site: Pleasent Grove, KS in Douglas County

Surface Elevation: 1082.5'

Location: Sta. 512+00 Lc

Material Description			Graphic Log	Depth (ft)	Sample Type	RQD	Moisture %	Liquid Limit	Plastic Limit	Plasticity Index	Unconfined Compression	Jar Index	CaCO3 %	Slake Durability Index	Slake Type
Same calcitic paleosol as above with shear planes at 23.4' (~35°), 23.7' (45°), and 24.4' (~35°). More silty; Bottom 1' becoming more calcitic (White N9 concretions) and lighter green (Light Greenish Gray 5G 8/1 to Pale Blue Green 5GB 7/2) downward. *Continued Next Page*	25.2	1057.3		25											
Same calcitic, silty, paleosol as above, but with Light Brownish Gray (5YR 6/1) dense hard limey inclusions. Very hard dense limey beds zones at 25.4' (0.1' thick) and 25.9' (0.2' thick). Bottom 0.1' is very soft clay rich with sharp contact at base.	26.2	1056.3													
Toronto Limestone: Weathered Pale Yellowish Orange (10YR 8/6) dense hard medium bedded blocky limestone with vughs toward the top. Stained Dark Yellowish Orange (10YR 6/6). Shaley limey interbed at 27' (0.1' thick) with sharp undulating contact.	27.5	1055.0													
Less weathered, more indurated and massive limestone. White (N9) to Medium Light Gray (N6)	28.1	1054.4													
Same Light Gray (N7) dense hard, massive to blocky limestone as above. Shale breaks at 29.2' (0.1' thick) and 29.9 (0.1' thick) all with sharp contacts.	30.0	1052.5		30											
More weathered dense hard limestone. Top 0.6' is very muddy limestone with clay filled vughs and mud drapes. Fewer vughs and drapes downward. Mud break with limey inclusions (1-3mm) at 32.1' (~0.1' thick). Vertical (~70°) fracture plane at 32.4'-32.8'.															
Weahtered limestone with Dark Yellowish Orange (10YR 6/6) staining. Abundant bioturbation (calcite filled-White N9) and limey/sandy inclusions (1mm-7cm). Sharp contact at base.	33.1	1049.4													
	34.5	1048.0		35											

Remarks:

Northwest corner of soybean field

Completion Depth: 72.5'
Date Started: 11/02/04
Date Completed: 11/02/04
Drilled By: Jim Burns
Logged By: Randy Billinger

Slake Type 1: Retained pieces virtually unchanged.
Slake Type 2: Retained material consists of large and small pieces
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JAR INDEX

1.Degrades into pile of flakes or mud
2.Breaks rapidly and/or forms many chips
3.Breaks rapidly and/or forms few chips
4.Breaks slowly and/or develops several fractures
5.Breaks slowly and/or develops few fractures
6.No change

CaCO3 %

High to Medium Durability > 35%

BORING LOG LAWRENCE SHALE 1.GPJ KANSAS STATE.GDT 4/26/06

DEPARTMENT OF GEOLOGY — Kansas State University

Project Number: 59-23 K-7888-01

Project Name: Realignment of Hwy. 59, south of Lawrence, KS

Site: Pleasent Grove, KS in Douglas County

Surface Elevation: 1082.5'

Location: Sta. 512+00 Lc

Material Description	Graphic Log	Depth (ft)	Sample Type	RQD	Moisture %	Liquid Limit	Plastic Limit	Plasticity Index	Unconfined Compression	Jar Index	CaCO3 %	Slake Durability Index	Slake Type
Lawrence Shale: Greenish Gray (5G 8/1) to Light Bluish Gray (5B 7/1) shale. Top 0.6' is sandy heterolithic shale with lenticular bedding (thin, single lenses of very fine sand) and starved ripples. Bioturbation disrupts the bedding and deforms the very fine sand to silt lenticles. 35.1'-36.9' firm sandy greenish gray shale with irregularly fractures (swelling = clayey). *Continued Next Page*				98						1	0.79	20.47	2
37.8 1044.7													
38.6 Same silty shale as above but with heterolithic bedding; faint bedding at top that becomes more visable toward bottom. Lenticular bedding (single, flat lenses of fine sand). Flaser at bottom of core. 1043.9													
Greenish Gray (5GY 6/1) to Medium Light Gray (N6) silty shale. Clay rich with abundant irregular horizontal fractures (swelling). Very finely laminated with faint lenticular bedding (fine, single, flat lenses). Bedding more visable downward becoming lenticular/wavy flat connecting lenses. Becoming more gray towards bottom. Bottom 0.8' has low inclined bedding (~ 5°).		40		93						2	0.79	25.67	2
42.9 1039.6													
Medium Bluish Gray (5B 5/1) to Medium Gray (N5) clayey shale with low inclined bedding (~5°). Weak/soft clay rich zone at 44.2'-44.7' with irregular fractures (swelling).		45											
45.3 1037.2													
Darker shale; Medium Dark Gray (N4) to Medium Gray (N5) low inclined shale with Dark Yellowish Orange (10YR 6/6) weathered bands at 45.3' (~0.1'), 45.6' (~0.1'), 46.1' (~0.1'), and 46.2' (~0.1'). Clay rich zone at 45.6' (0.3' thick) with a angled fracture at ~50°. Sharp contact at base with slickensides and possible root cast (columnar) protruding out bottom.				67						3	1.57	46.33	2
46.5 1036.0													
				0						1	11.42	0.07	3

Remarks:

Northwest corner of soybean field

Completion Depth: 72.5'
Date Started: 11/02/04
Date Completed: 11/02/04
Drilled By: Jim Burns
Logged By: Randy Billinger

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Slake Type 2: Retained material consists of large and small pieces
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JAR INDEX

1.Degrades into pile of flakes or mud
2.Breaks rapidly and/or forms many chips
3.Breaks rapidly and/or forms few chips
4.Breaks slowly and/or develops several fractures
5.Breaks slowly and/or develops few fractures
6.No change

CaCO3 %

High to Medium Durability > 35%

BORING LOG LAWRENCE SHALE 1.GPJ KANSAS STATE.GDT 4/26/06

DEPARTMENT OF GEOLOGY — Kansas State University

Project Number: 59-23 K-7888-01

Project Name: Realignment of Hwy. 59, south of Lawrence, KS

Site: Pleasent Grove, KS in Douglas County

Surface Elevation: 1082.5'

Location: Sta. 512+00 Lc

Material Description		Graphic Log	Depth (ft)	Sample Type	RQD	Moisture %	Liquid Limit	Plastic Limit	Plasticity Index	Unconfined Compression	Jar Index	CaCO3 %	Slake Durability Index	Slake Type
		FIELD DATA				LABORATORY DATA								
60.4	1022.1													
Dense hard Dark Greenish Gray (5G 4/1 to 5GY 4/1) limey mudstone.														
61.0	1021.5													
Same shale as in 58.2'; Grayish Green (5G 5/2) sitly shale with few limestone inclusions (~0.1') toward base. Top 0.2' is														
61.7	1020.8													
61.9 weak crumbly.	1020.6													
Grayish Black (N2) organic rich (carbonaceous) shale (some sooty/coaly and vitreous areas with minor amounts of yellow					90						2	1.18	20.85	3
62.9 sulfur present.	1019.6													
Medium Gray (N5) to Medium Dark Gray (N4) clayey shale with irregular fractures. Soft/weak material with woody/planty/leafy debris.														
Flaggy to slabby Medium Light Gray (N6) to Medium Gray (N5) shale with horizontal bedding planes with abundant fractures (poor shale). Becoming silty to sandy at ~65'. Very soft/clay rich zones at 64.6'-65.5', 66.1' (~0.1'), 66.7' (0.1'). Weak/broken zones at 63.8' (~0.1'thick), 63.9' (0.1' thick), 64.3' (0.1' thick)			65		0						2	4.35	10.27	3
68.0	1014.5													
Same shale as above core, but with lesser amounts of soft/clay rich and crumbly zones. Wavy heterolithic bedding (very thinly laminated) with White (N9) sandy interbed and becoming finer/faint downward. Abundant fractures along bedding planes (poor shale). Becoming sandy to silty at ~70'. Moderate Yellowish Brown (10YR 5/4) dense/hard limey mudstone at 71.6' (0.1' thick).			70											

Remarks:

Northwest corner of soybean field

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5.Breaks slowly and/or develops few fractures
6.No change

CaCO3 %

High to Medium Durability > 35%

BORING LOG LAWREN~1.GPJ KANSAS STATE.GDT 5/1/06

DEPARTMENT OF GEOLOGY — Kansas State University

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Material Description	Graphic Log	Depth (ft)	Sample Type	RQD	Moisture %	Liquid Limit	Plastic Limit	Plasticity Index	Unconfined Compression	Jar Index	CaCO3 %	Slake Durability Index	Slake Type
	FIELD DATA				LABORATORY DATA								
72.5 1010.0		75											
		80											

Remarks:

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CaCO3 %

High to Medium Durability > 35%

BORING LOG LAWRENCE SHALE 1.GPJ KANSAS STATE.GDT 4/26/06

DEPARTMENT OF GEOLOGY — Kansas State University

Project Number: 59-23 K-7888-01

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			FIELD DATA				LABORATORY DATA								
48.3	Greenish Gray (5GY 6/1) to Medium Dark Gray (N4) calcareous paleosol that gets lighter downward (Medium Gray N5). Root casts traces with black some black organic debris. Weak crumbly zone at 47.2 (0.2' thick). Irregular and angled fractures (with slicks). Shear planes at 46.9' (~30°), 47.2' (~30°), 47.3' (~25°), 47.9' (~40°), 48.1' (~30°), and 48.3' (30°). *Continued Next Page*	1034.2													
49.1		1033.4				65						1	8.3	0.09	3
50.4	Same calcareous paleosol as above with high angle shear plane at 48.5' (~40°) and 49.1' (~40°) with slickensides. Root traces.	1032.1		50											
	Grades into finely mottled Grayish Red Purple (5RP 4/2) calcareous paleosol with angled shear planes at 49.3' (30°), 49.6' (20°), and 49.9' (20°); Moderate Yellow (5Y 7/6) fine drab-haloed root traces; finely mottled Medium Light Gray (N6). Grades into a Greenish Gray (5GY 6/1), Grayish Purple (5P 4/2), and Medium Light Gray (N6) mottled calcareous with yellow drab-haloed root traces. Sharp contact at base.					65						1	10.67	0.28	3
52.8		1029.7													
53.5	Greenish Gray (5G 6/1) calcareous clayey paleosol with abundant irregular and shear fractures. Limestone inclusion lense at 49.5' (~0.1') and 50' (0.1' thick) with sharp contacts. Shear plane at 51' (~30), 51.4' (~55°), 51.7' (~30°), 51.9' (~15°), 52' (~50°), 52.2' (~60°), 52.3' (~60°), 52.4' (~40°). Becoming more calcitic downward.	1029.0		55											
55.5	Grades into Pale Green (5G 7/2) to Light Greenish Gray (5G 8/1) shale with abundant White (N9) to Brownish Gray (5YR 4/1) limestone nodules (1mm-0.1'). Wavey bedding. Shear plane at 53' (~30°)	1027.0													
	Similar to above shale, but lighter green and softer (more clay rich). Light Greenish Gray (5G 8/1) shale with White (N9) to Brownish Gray (5YR 4/1) limestone inclusions (2mm-0.2'). 54.5'-55.2' limestone nodules are small pebble like anglular to subrounded.					74						1	7.11	55.21	2
58.2	Pale Yellowish Green (10GY 7/2) to Pale Green (5G 7/2) silty sandy shale with shells.	1024.3													
	Grayish Green (5G 5/2) to Pale Green (10G 6/2) silty shale (weakly calcreous) with few limestone inclusions (~0.1'). Dense resistant limey shale at 58.6' (0.2' thick).			60											

Remarks:

Northwest corner of soybean field

Completion Depth: 72.5'
Date Started: 11/02/04
Date Completed: 11/02/04
Drilled By: Jim Burns
Logged By: Randy Billinger

Slake Type 1: Retained pieces virtually unchanged.
Slake Type 2: Retained material consists of large and small pieces
Slake Type 3: Retained material is exclusively small fragments.

JAR INDEX

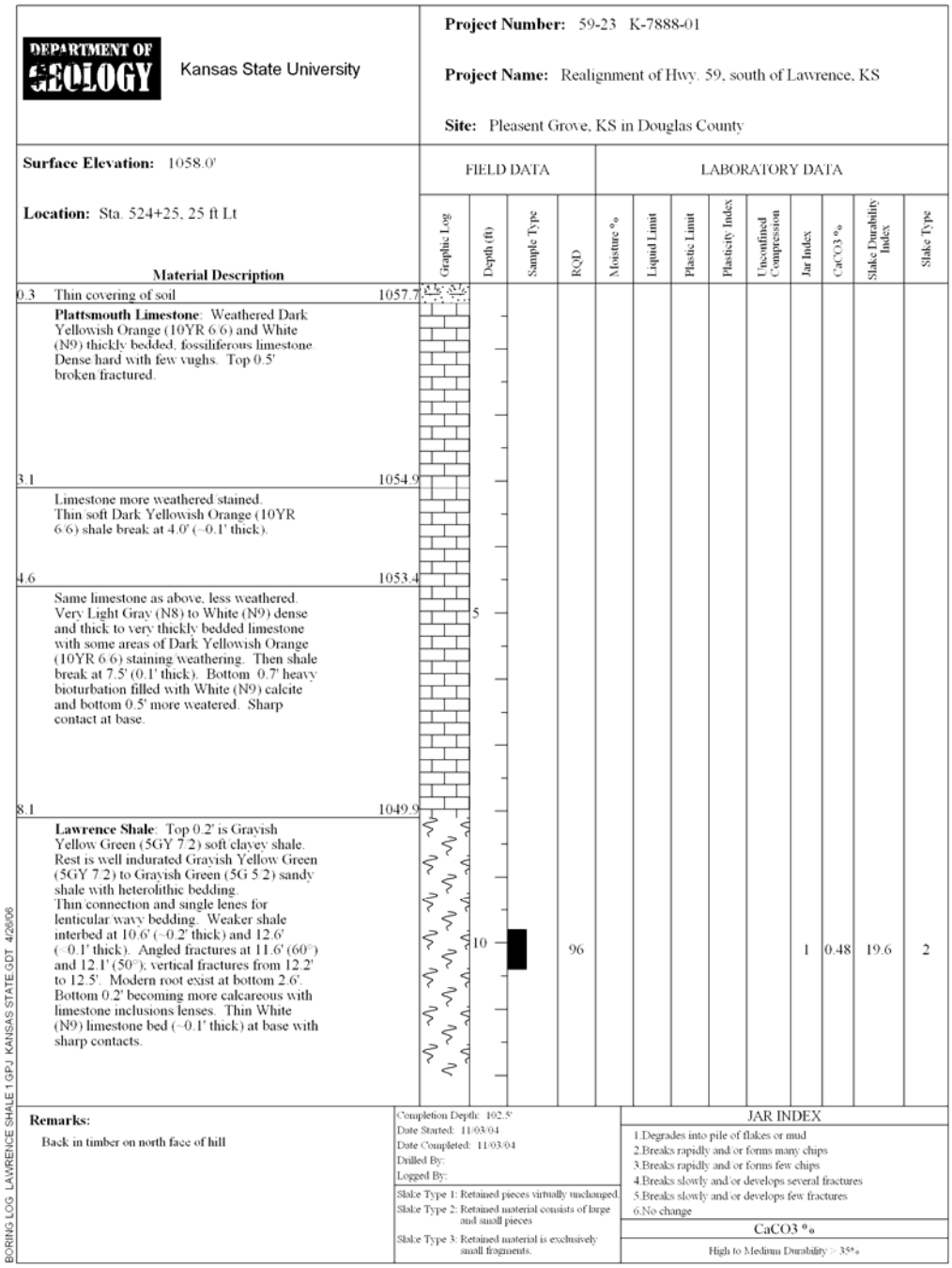
1.Degrades into pile of flakes or mud
2.Breaks rapidly and/or forms many chips
3.Breaks rapidly and/or forms few chips
4.Breaks slowly and/or develops several fractures
5.Breaks slowly and/or develops few fractures
6.No change

CaCO3 %

High to Medium Durability > 35%

BORING LOG LAWRENCE SHALE 1.GPJ KANSAS STATE.GDT 4/26/06

APPENDIX B-4: STATION 524+25, 25’ LT CL - NORTH FACE OF HILL - NFH1



DEPARTMENT OF GEOLOGY — Kansas State University

Project Number: 59-23 K-7888-01

Project Name: Realignment of Hwy. 59, south of Lawrence, KS

Site: Pleasent Grove, KS in Douglas County

Surface Elevation: 1058.0'

Location: Sta. 524+25, 25 ft Lt

Material Description		Graphic Log	Depth (ft)	Sample Type	RQD	Moisture %	Liquid Limit	Plastic Limit	Plasticity Index	Unconfined Compression	Jar Index	CaCO3 %	Slake Durability Index	Slake Type
0.3 Thin covering of soil	1057.7													
Plattsmouth Limestone: Weathered Dark Yellowish Orange (10YR 6/6) and White (N9) thickly bedded, fossiliferous limestone. Dense hard with few vughs. Top 0.5' broken fractured.														
3.1	1054.9													
Limestone more weathered/stained. Thin soft Dark Yellowish Orange (10YR 6/6) shale break at 4.0' (~0.1' thick).														
4.6	1053.4													
Same limestone as above, less weathered. Very Light Gray (N8) to White (N9) dense and thick to very thickly bedded limestone with some areas of Dark Yellowish Orange (10YR 6/6) staining/weathering. Then shale break at 7.5' (0.1' thick). Bottom 0.7' heavy bioturbation filled with White (N9) calcite and bottom 0.5' more weatered. Sharp contact at base.			5											
8.1	1049.9													
Lawrence Shale: Top 0.2' is Grayish Yellow Green (5GY 7/2) soft clayey shale. Rest is well indurated Grayish Yellow Green (5GY 7/2) to Grayish Green (5G 5/2) sandy shale with heterolithic bedding. Thin connection and single lenes for lenticular wavy bedding. Weaker shale interbed at 10.6' (~0.2' thick) and 12.6' (~0.1' thick). Angled fractures at 11.6' (60°) and 12.1' (50°); vertical fractures from 12.2' to 12.5'. Modern root exist at bottom 2.6'. Bottom 0.2' becoming more calcareous with limestone inclusions/lenses. Thin White (N9) limestone bed (~0.1' thick) at base with sharp contacts.			10		96						1	0.48	19.6	2

FIELD DATA | LABORATORY DATA

Remarks:

Back in timber on north face of hill

Completion Depth: 102.5'
Date Started: 11/03/04
Date Completed: 11/03/04
Drilled By:
Logged By:

Slake Type 1: Retained pieces virtually unchanged.
Slake Type 2: Retained material consists of large and small pieces
Slake Type 3: Retained material is exclusively small fragments.

JAR INDEX

1.Degrades into pile of flakes or mud
2.Breaks rapidly and/or forms many chips
3.Breaks rapidly and/or forms few chips
4.Breaks slowly and/or develops several fractures
5.Breaks slowly and/or develops few fractures
6.No change

CaCO3 %

High to Medium Durability > 35%

BORING LOG_LAWRENCE SHALE 1.GPJ_KANSAS STATE.GDT 4/26/06

DEPARTMENT OF GEOLOGY — Kansas State University

Project Number: 59-23 K-7888-01

Project Name: Realignment of Hwy. 59, south of Lawrence, KS

Site: Pleasent Grove, KS in Douglas County

Surface Elevation: 1058.0'

Location: Sta. 524+25, 25 ft Lt

Material Description			Graphic Log	Depth (ft)	Sample Type	RQD	Moisture %	Liquid Limit	Plastic Limit	Plasticity Index	Unconfined Compression	Jar Index	CaCO3 %	Slake Durability Index	Slake Type
			FIELD DATA				LABORATORY DATA								
13.1		1044.9													
Greenish Gray (5GY 6/1) to Medium Light Gray (N6) calcareous sandy shale with heterolithic bedding (lenticular/wavy). Top 0.3' White (N9) calcitic lenses/beds. breaks easy on horizontal beding planes, flaggy to slabby. Few shells.															
15.1		1042.9		15											
Light Gray (N7) sandy shale with heterolithic bedding (thin lenticular/pinstripe). Higher clay content than above producing more irregular/vertical/angled fractures. At 17.2' becomes Light Bluish Gray (5B 7/1) clayey shale with vertical/angled fractures and lose the sand/heterolithic bedding.						90						3	0.72	21.72	2
18.0		1040.0													
Light Gray (N7) weak/high clay content (shrink/well) shale. Top 0.3' crumbly/broken and soft shale (very poor). Low inclined bedding (~6°).															
19.3		1038.7													
Medium Gray (N5) clayey shale becoming with stained Moderate Yellowish Brown (10YR 5/4) mud cracks at 19.5'. Becomes firmer downward. Irregular fractures. Very thin (~0.1') carbonaceous shale (organic rich) with black sooty break at 21.4' with some vitreous areas.				20											
21.4		1036.6													
Medium Gray (N5) weak paleosol development with irregular fractures (clay rich) and shear planes (with slicks). Brownish Gray (5YR 5/1) root traces. Bottom 0.2' broken, angular blocky paleosol.						78						1	10.53	N/A	N/A
22.5		1035.5													

Remarks:

Back in timber on north face of hill

Completion Depth: 102.5'
Date Started: 11/03/04
Date Completed: 11/03/04
Drilled By:
Logged By:

Slake Type 1: Retained pieces virtually unchanged.
Slake Type 2: Retained material consists of large and small pieces
Slake Type 3: Retained material is exclusively small fragments.

JAR INDEX

1.Degrades into pile of flakes or mud
2.Breaks rapidly and/or forms many chips
3.Breaks rapidly and/or forms few chips
4.Breaks slowly and/or develops several fractures
5.Breaks slowly and/or develops few fractures
6.No change

CaCO3 %

High to Medium Durability > 35%

BORING LOG LAWRENCE SHALE 1.GPJ KANSAS STATE.GDT 4/26/06

DEPARTMENT OF GEOLOGY — Kansas State University

Project Number: 59-23 K-7888-01

Project Name: Realignment of Hwy. 59, south of Lawrence, KS

Site: Pleasent Grove, KS in Douglas County

Surface Elevation: 1058.0'

Location: Sta. 524+25, 25 ft Lt

	Material Description		Graphic Log	Depth (ft)	Sample Type	RQD	Moisture %	Liquid Limit	Plastic Limit	Plasticity Index	Unconfined Compression	Jar Index	CaCO3 %	Slake Durability Index	Slake Type
							FIELD DATA					LABORATORY DATA			
24.5	More indurated and well developed paleosol; Top 0.5' same broken angular blocky paleosol as above. Greenish Gray (5GY 6/1) paleosol with shear planes at 24.2' (40°) and 24.6' (30°). Becoming Medium Light Gray (N6) and Grayish Purple (5RP 4/2) at 24.9' with oxidized Moderate Yellow (5Y 7/6) to Light Olive Brown (5Y 5/6) root traces. *Continued Next Page*	1033.5		25		96						1	10.45	.05	3
27.3	Top 0.3' same Grayish Purple (5RP 4/2) paleosol as above then grades to Medium Light Gray to Pale Blue 5B 6/2 paleosol. Shear planes (with slicks) at 24.9' (20°), 25.4' (40°), 25.5' (20°), 26.6' (20), 26.8' (25), 26.9' (25), 27.1' (40), 27.3' (30).	1030.7													
28.1	Dark Greenish Gray (5GY 4/1) weak paleosol with shear planes at 27.5' (30°) and 27.6' (40°). Grades to Light Greenish Gray (5G 8/1) shale paleosol with Medium Gray (N5), Brownish Gray (5Y 4/1), to White (N9) calcareous inclusions (chips) concretions (0.2mm-0.1') - rhizozone? roots?	1029.9				66						2	47.66	.39	2
30.5	Same Light Greenish Gray (5G 8/1) shale with abundant White (N9) to Brownish Gray (5YR 4/1) limestone inclusions pebbles throughout. Very hard/dense limestone lenses at 28.8' (0.1' thick) with bioturbation. Broken zone with abundant pieces of limestone at 29.4' (0.2' thick). Very hard/dense limestone lenses with shale breaks (sharp contacts) at 29.8' (<0.1'), 29.9' (~0.1' w/ biotrubation), 30' (<0.1 w/ bioturbation), 30.3' (~0.1'), and 30.5' (<0.1' w/ bioturbation/shell). Sunken pieces of weathered limestone?	1027.5		30		66						2	3.58	17.98	2
32.9	Greenish Gray (5GY 6/1) to Light Greenish Gray (5G 8/1) heterolithic shale becoming more sandy downward. Wavy/Lenticular (thin, single/connecting lenses) bedding.	1025.1													
33.4	White (N9) to Grayish Orange (10YR 7/4) limestone inclusion at 31.5' (0.4' thick) with stromatolite growth (weathered limestone included into shale?). Thin (3mm) White (N9) sandy stringer at 32.4' and a thin (4mm) hard/dense limey White (N9) and Brownish Gray (5YR 4/1) stringer at 32.5'. Better shale than above (in core 8).	1024.6													
	Greenish Gray (5G 6/1) silty, firm shale with few Yellowish Gray (5Y 8/1) sandy starved ripples near top of core. Breaks easily along horizontal bedding planes.			35								2		43.35	2

Remarks:

Back in timber on north face of hill

Completion Depth: 102.5'
Date Started: 11/03/04
Date Completed: 11/03/04
Drilled By:
Logged By:

Slake Type 1: Retained pieces virtually unchanged.
Slake Type 2: Retained material consists of large and small pieces
Slake Type 3: Retained material is exclusively small fragments.

JAR INDEX

1. Degrades into pile of flakes or mud
2. Breaks rapidly and/or forms many chips
3. Breaks rapidly and/or forms few chips
4. Breaks slowly and/or develops several fractures
5. Breaks slowly and/or develops few fractures
6. No change

CaCO3 %

High to Medium Durability > 35%

BORING LOG LAWRENCE SHALE 1.GPJ KANSAS STATE.GDT 4/26/06

DEPARTMENT OF GEOLOGY — Kansas State University

Project Number: 59-23 K-7888-01

Project Name: Realignment of Hwy. 59, south of Lawrence, KS

Site: Pleasent Grove, KS in Douglas County

Surface Elevation: 1058.0'

Location: Sta. 524+25, 25 ft Lt

	Material Description		Graphic Log	Depth (ft)	Sample Type	RQD	Moisture %	Liquid Limit	Plastic Limit	Plasticity Index	Unconfined Compression	Jar Index	CaCO3 %	Slake Durability Index	Slake Type
36.2	Sharp contact at base.	1021.8													
36.5	Same shale as above, but less firm and more clay rich. Weak/soft zones (shrink/swell w/ larger irregular fractures) at 33.7' (0.1' thick), 34.2' (0.1' thick), 34.6' (0.1' thick), 35' (~0.2' of broken/crumbly shale). *Continued Next Page*	1021.5													
37.3	Grayish Black coal seam at 36.2' - 36.5' coal seam (top 0.1' is more of a Medium Dark Gray (N4) carbonaceous shale) with sharp contact at base.	1020.7													
	Medium Light Gray (N6) to Medium Gray (N5) and Greenish Gray (5G 6/1) clay rich shale. Top 0.9' is Greenish Gray (5G 6/1) and Medium Gray (N5) shale with a Dark Yellowish Orange sandy starved ripple at 37.8' (0.1'). 38.4' - 40.5' shale becomes more flaggy to slabby and breaks easily on horizontal planes (swelling shale).											2		14.99	3
40.5		1017.5		40											
	Shale becomes more sandy with very thin flat connecting lenses of White (N9) fine sand/silt for lenticular bedding. White (N9) starved sandy ripples at 40.5'-40.6'. Grayish Orange (10YR 7/4) dense/hard calcitic band at 41' (0.1' thick) with lenticular bedding of thin/connecting lenses. Thin Wavy bedding at 40.6' -41', 41.2' (0.1' thick) 40.5' (0.1' thick).														
42.7		1015.3													
	Medium Light Gray (N6) to Medium Bluish Gray (5B 5/1) clay rich, swellling shale. Abundant soft clay rich zones (clayshale) with irregular fractures from 43.5' to the base of the core. Dense/hard sandsone at 42.9'-43.3' with the top 0.1' being Light Olive Gray (5Y 6/1) finely interlaminated with low inclined bedding (~3°) and bioturbation. Rest of the sandstone is White (N9) with few mud drapes. Dense/hard Grayish Orange dolomitic beds/inclusions towards base at 44.3' (0.1' thick), 45.7' (<0.1'), and 46.2' (broken ~0.1') with sharp contacts.			45								3		24.2	2
46.2		1011.8													
46.6	Black (N1) brittle, sooty, and vitreous coal seam with sharp contacts.	1011.4													
	Bluish Gray (5B 5/6) to Medium Light Gray (N6) paleosl with black organic debris and root traces and oxidized resistant root casts. Grades to Light Bluish Gray (5G 7/1) downward.														
47.8		1010.2													

Remarks:

Back in timber on north face of hill

Completion Depth: 102.5'
Date Started: 11/03/04
Date Completed: 11/03/04
Drilled By:
Logged By:

Slake Type 1: Retained pieces virtually unchanged.
Slake Type 2: Retained material consists of large and small pieces
Slake Type 3: Retained material is exclusively small fragments.

JAR INDEX

1.Degrades into pile of flakes or mud
2.Breaks rapidly and/or forms many chips
3.Breaks rapidly and/or forms few chips
4.Breaks slowly and/or develops several fractures
5.Breaks slowly and/or develops few fractures
6.No change

CaCO3 %

High to Medium Durability > 35%

BORING LOG LAWRENCE SHALE 1.GPJ KANSAS STATE.GDT 4/26/06

DEPARTMENT OF GEOLOGY — Kansas State University

Project Number: 59-23 K-7888-01

Project Name: Realignment of Hwy. 59, south of Lawrence, KS

Site: Pleasent Grove, KS in Douglas County

Surface Elevation: 1058.0'

Location: Sta. 524+25, 25 ft Lt

Material Description			Graphic Log	Depth (ft)	Sample Type	RQD	Moisture %	Liquid Limit	Plastic Limit	Plasticity Index	Unconfined Compression	Jar Index	CaCO3 %	Slake Durability Index	Slake Type
		FIELD DATA					LABORATORY DATA								
Medium Gray (N5) shale with three dense hard Grayish Orange (10YR 7/4) dolostone lenses at 47.5' (~0.1'), 47.7' (~0.1'), and 47.9' (~0.1') with sharp contacts. Greenish Gray (5G 6/1) sandy, interlaminated shale. Lenticular to wavy bedding with thin connecting lenses of White (N9) fine sand/silt. Few Dark Yellowish Orange (10YR 6/6) sandy inclusions with some minor deformation. Bottom 0.5' is sandy shale. *Continued Next Page*	51.8	1006.2		50								5		83.26	1
Top 0.5' is same sandy shale as in bottom of core 12 with few small starved ripples and flaser bedding at bottom 0.1'.	52.8	1005.2													
Medium Light Gray (N6) to Medium Dark Gray (N4) sandy micaceous interlaminated shale with lenticular/wavy bedding. 55.1' (0.2' thick) interlaminated sandy shale with lenticular/wavy bedding that has major deformation/disruption. Dense hard sandstone White (N9) sandstone bed at 55.3' (0.1' thick) with mud drapes. Very sandy shale to sandstones at 54.5' (~0.5' thick with starved sand ripples near base), 56.6' (0.2' thick), 57' (~0.2' thick) with sharp contacts.	57.3	1000.7		55											
Same interlaminated lenticular/wavy shale; few lenses show crossbedding. Very thin/long White (N9) lenses of fine sand/silt (some resemble pinstripe bedding). Weak crumbly zone at 57.7' (0.1' thick). Dense hard sandstone at 58' (0.2' thick) with few mud drapes at top and becoming interlaminated at bottom.	58.6	999.4		60											

Remarks:

Back in timber on north face of hill

Completion Depth: 102.5'
Date Started: 11/03/04
Date Completed: 11/03/04
Drilled By:
Logged By:

Slake Type 1: Retained pieces virtually unchanged.
Slake Type 2: Retained material consists of large and small pieces
Slake Type 3: Retained material is exclusively small fragments.

JAR INDEX

1.Degrades into pile of flakes or mud
2.Breaks rapidly and/or forms many chips
3.Breaks rapidly and/or forms few chips
4.Breaks slowly and/or develops several fractures
5.Breaks slowly and/or develops few fractures
6.No change

CaCO3 %

High to Medium Durability > 35%

BORING LOG LAWRENCE SHALE 1.GPJ KANSAS STATE.GDT 4/26/06

DEPARTMENT OF GEOLOGY — Kansas State University

Project Number: 59-23 K-7888-01

Project Name: Realignment of Hwy. 59, south of Lawrence, KS

Site: Pleasent Grove, KS in Douglas County

Surface Elevation: 1058.0'

Location: Sta. 524+25, 25 ft Lt

Material Description	Graphic Log	Depth (ft)	Sample Type	RQD	Moisture %	Liquid Limit	Plastic Limit	Plasticity Index	Unconfined Compression	Jar Index	CaCO3 %	Slake Durability Index	Slake Type
					FIELD DATA					LABORATORY DATA			
Same interlaminated lenticular/wavy shale with White (N9) fine sand silt lenses; some areas resemble thin pinstripe bedding. More resistant sandy shale at 60.5' (0.1' thick),60.9' (0.2' thick) with few small sandy sunken pillows inclusions (1-2cm wide), and 62.2' (0.1' thick). Breaks easily along horizontal bedding planes. Green mineralization of sand grains at 59.6'.*Continued Next Page*										3		28.72	2
62.3 995.7													
Same shale, but much thinner interlaminations with pinstripe lenticular/wavy bedding of White (N9) fine sand/silt. Few sunken pillows/ripples. Thin White (N9) sandstone lenses at 65.4' (<0.1), 65.5' (<0.1'), and 65.6' (<0.1'). Breaks easily along horizontal bedding planes.		65								4		65.26	2
67.3 990.7													
Top 0.4' is the same interlaminated shale as above; then lose bedding downward. Medium Gray (N5) sandy shale with clay rich (soft) zone at 68.5' (0.1' thick with sharp contact). Breaks easily along horiozontal bedding planes. Bottom 0.7' is more resistant Light Gray (N7) to Medium Gray (N 5) sandy micaceous shale to shaley sandstone with black organic debris.		70								5		83.69	1
69.6 988.4													

Remarks:

Back in timber on north face of hill

Completion Depth: 102.5'
Date Started: 11/03/04
Date Completed: 11/03/04
Drilled By:
Logged By:

Slake Type 1: Retained pieces virtually unchanged.
Slake Type 2: Retained material consists of large and small pieces
Slake Type 3: Retained material is exclusively small fragments.

JAR INDEX

1.Degrades into pile of flakes or mud
2.Breaks rapidly and/or forms many chips
3.Breaks rapidly and/or forms few chips
4.Breaks slowly and/or develops several fractures
5.Breaks slowly and/or develops few fractures
6.No change

CaCO3 %

High to Medium Durability > 35%

BORING LOG LAWRENCE SHALE 1.GPJ KANSAS STATE.GDT 4/26/06

DEPARTMENT OF GEOLOGY — Kansas State University

Project Number: 59-23 K-7888-01

Project Name: Realignment of Hwy. 59, south of Lawrence, KS

Site: Pleasent Grove, KS in Douglas County

Surface Elevation: 1058.0'

Location: Sta. 524+25, 25 ft Lt

Material Description			FIELD DATA				LABORATORY DATA								
			Graphic Log	Depth (ft)	Sample Type	RQD	Moisture %	Liquid Limit	Plastic Limit	Plasticity Index	Unconfined Compression	Jar Index	CaCO3 %	Slake Durability Index	Slake Type
72.3	Top 0.7' is the same resistant sandy micaceous shale as above, but with little no black orngic debris. 70.3'-70.7' sandy shale becomes less resistant, breaks easily along horizontal bedding planes. 70.7-72.3 shale becomes very sandy micaceous with black organic particles debris. No noticable bedding planes and is more dense resistant than above (good core); few sunken pillows of White (N9) fine sand. *Continued Next Page*	985.7													
	Same dense resistant very sandy micaceous shale to shaley sandstone with no bedding planes. Black (N1) and Grayish Red (5R 4/2) organic debris. Good core. Large White (N9) sandy starved ripples/pillows at 72.8' (~1cm-0.2' wide). Hard dense White (N9) sandstone at 75.1' (~0.1' thick with mud drapes). 75.2'-77.2' becomes sandy micaceous shale with black organic debris. Thinly interlaminated sandy shale with lenticular pinstripe bedding of fine sand			75											
77.2	from 75.8' (0.4' thick). White (N9) medium grained sandstone interbed (~0.1' thick). Sandy pillows (1cm-0.1' wide) near base.	980.8													
	Medium Light Gray (N6) to Medium Dark Gray (N4) very sandy micaceous shale with Black (N1) orgnic debris particles. Little to no bedding features present. Inclined bedding of ~20° from 77.9'-78.1'. Dense hard White (N9) to Very Light Gray (N8) sandstone from 78.2' to 79.1' with mud drapes and black organic debris. Sandstone has sharp cotacts. Thin White (N9) sandstone interbed at 79.3' (~0.1' thick). Thinly interlaminated sandy shale with lenticular pinstripe bedding of White (N9) fine sand at 80.4'.			80											
81.8		976.2													
	Dense good core; Top 0.6' is Medium Gray to Medium Dark Gray sandy micaceous shale like above. disturbed deformed-convolute pillows/starved ripples.) Bottom														
82.9	0.4' is inclined lenticular bedded shale (~10°).	975.1													

Remarks:

Back in timber on north face of hill

Completion Depth: 102.5'
Date Started: 11/03/04
Date Completed: 11/03/04
Drilled By:
Logged By:

Slake Type 1: Retained pieces virtually unchanged.
Slake Type 2: Retained material consists of large and small pieces
Slake Type 3: Retained material is exclusively small fragments.

JAR INDEX

1.Degrades into pile of flakes or mud
2.Breaks rapidly and/or forms many chips
3.Breaks rapidly and/or forms few chips
4.Breaks slowly and/or develops several fractures
5.Breaks slowly and/or develops few fractures
6.No change

CaCO3 %

High to Medium Durability > 35%

BORING LOG LAWRENCE SHALE 1.GPJ KANSAS STATE.GDT 4/26/06

DEPARTMENT OF GEOLOGY — Kansas State University

Project Number: 59-23 K-7888-01

Project Name: Realignment of Hwy. 59, south of Lawrence, KS

Site: Pleasent Grove, KS in Douglas County

Surface Elevation: 1058.0'

Location: Sta. 524+25, 25 ft Lt

Material Description			Graphic Log	Depth (ft)	Sample Type	RQD	Moisture %	Liquid Limit	Plastic Limit	Plasticity Index	Unconfined Compression	Jar Index	CaCO3 %	Slake Durability Index	Slake Type
			FIELD DATA				LABORATORY DATA								
Shale interbedded with White (N9) fine sandy layers (pinstripe) with major deformation of convolute and vertical bedding (good core/dense).*Continued Next Page*	84.9	973.1		85											
Medium Light Gray (N6) to Medium Dark Gray (N4) sandy/micaceous shale with some black organic debris.	87.9	970.1													
Same sandy/micaceous shale/siltstone (no bedding visable) with black organic debris. Less resistant sandy shale with visable wavy/lenticular bedding Gray sandy, siltstone (good solid core with only one break); leaf and plant fossils.	92.9	965.1		90											
Same sandy/micaceous shale/siltstone with black organic debris. Sandy siltstone with only one fracture; good core.	94.5	963.5													
Medium Light Gray (N6) to Medium Gray (N5) silty/sandy shale with black organic debris; gets slightly darker downward. Good core.				95											

Remarks:

Back in timber on north face of hill

Completion Depth: 102.5'
Date Started: 11/03/04
Date Completed: 11/03/04
Drilled By:
Logged By:

Slake Type 1: Retained pieces virtually unchanged.
Slake Type 2: Retained material consists of large and small pieces
Slake Type 3: Retained material is exclusively small fragments.

JAR INDEX

1.Degrades into pile of flakes or mud
2.Breaks rapidly and/or forms many chips
3.Breaks rapidly and/or forms few chips
4.Breaks slowly and/or develops several fractures
5.Breaks slowly and/or develops few fractures
6.No change

CaCO3 %

High to Medium Durability > 35%

BORING LOG LAWRENCE SHALE 1.GPJ KANSAS STATE.GDT 4/26/06

DEPARTMENT OF GEOLOGY — Kansas State University

Project Number: 59-23 K-7888-01

Project Name: Realignment of Hwy. 59, south of Lawrence, KS

Site: Pleasent Grove, KS in Douglas County

Surface Elevation: 1058.0'

Location: Sta. 524+25, 25 ft Lt

Material Description	Depth (ft)	Graphic Log	Sample Type	RQD	Moisture %	Liquid Limit	Plastic Limit	Plasticity Index	Unconfined Compression	Jar Index	CaCO3 %	Slake Durability Index	Slake Type
		FIELD DATA			LABORATORY DATA								
Medium Light Gray (N6) to Medium Gray (N5) silty/sandy shale with black organic debris; gets slightly darker downward. Good core. *Continued Next Page*													
97.6 960.4													
Light Olive Gray (5Y 6/1) to Medium Gray (N5) sandy shale with black organic debris; no bedding features visable; good solid core. Thin/long interlaminations of lenticular lenses of White (N9) fine sand/silt; inclined (10°) bedding at bottom 0.1'.	100									5		86.84	1
102.5 955.5	105												

Remarks:

Back in timber on north face of hill

Completion Depth: 102.5'
Date Started: 11/03/04
Date Completed: 11/03/04
Drilled By:
Logged By:

Slake Type 1: Retained pieces virtually unchanged.
Slake Type 2: Retained material consists of large and small pieces
Slake Type 3: Retained material is exclusively small fragments.

JAR INDEX

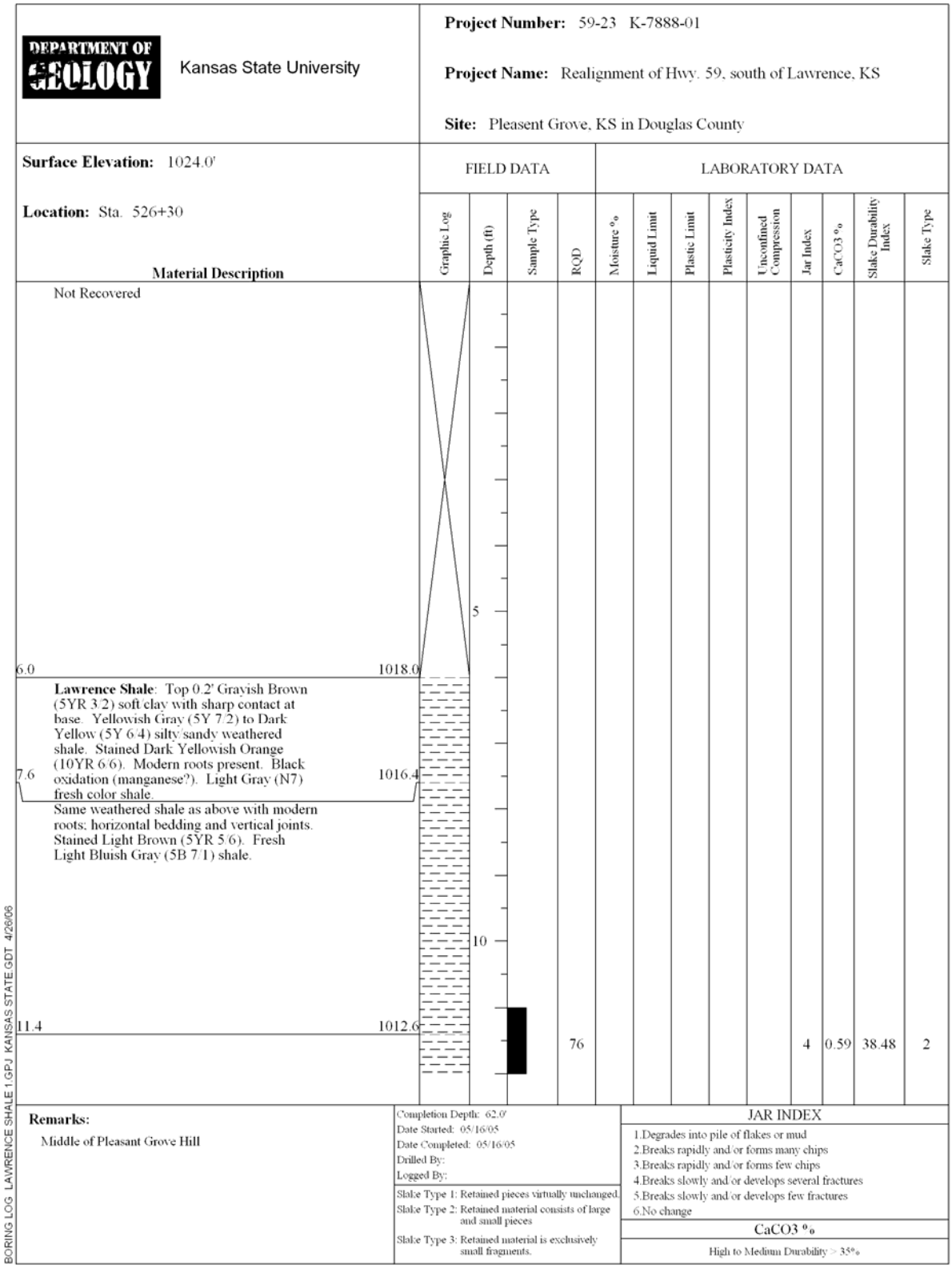
1.Degrades into pile of flakes or mud
2.Breaks rapidly and/or forms many chips
3.Breaks rapidly and/or forms few chips
4.Breaks slowly and/or develops several fractures
5.Breaks slowly and/or develops few fractures
6.No change

CaCO3 %

High to Medium Durability > 35%

BORING LOG LAWRENCE SHALE 1.GPJ KANSAS STATE.GDT 4/26/06

APPENDIX B-5: STATION 526+30, 7’ RT CL - MIDDLE OF HILL - MH1



DEPARTMENT OF GEOLOGY — Kansas State University

Project Number: 59-23 K-7888-01

Project Name: Realignment of Hwy. 59, south of Lawrence, KS

Site: Pleasent Grove, KS in Douglas County

Surface Elevation: 1024.0'

Location: Sta. 526+30

Material Description	Graphic Log	Depth (ft)	Sample Type	RQD	Moisture %	Liquid Limit	Plastic Limit	Plasticity Index	Unconfined Compression	Jar Index	CaCO3 %	Slake Durability Index	Slake Type
					FIELD DATA					LABORATORY DATA			
Medium Gray (N5) sandy micaceous shale with White (N9) sandy sunken ripples. Top 0.5' contains faint lenticular to flaser bedding and becoming more distinct downward. Bottom 0.4' flaser bedding. *Continued Next Page*		25								5	3.55	29.49	2
27.5 996.5													
Medium Dark Gray (N4) to Medium Gray (N5) sandy micaceous shale with abundant black organic particles. Top 0.5' lenticular bedding becoming faint/none downward. 28.1'-29.1' clay rich; bottom 0.5' flaser lenticular.													
29.5 994.5													
Medium Light Gray (N6) to Medium Gray (N5) lenticular shale (very thinly laminated) with black organic particles. Top 0.2' sandy shale with starved/sunken ripples. 29.7'-30' flaser beding; inclined/disturbed bedding at 31.4'.		30											
32.4 991.6													
Medium Gray (N5) sandy micaceous shale with lenticular bedding of White (N9) to Light Olive Gray (5Y 6/1) fine sand/silt lenses. Becoming faint very fine downward while black organic debris increases. Flaser zones at 36.7' (~0.1' thick) and 36.8' (~0.3' thick).		35		86						5	2.38	15.84	2

Remarks:

Middle of Pleasant Grove Hill

Completion Depth: 62.0'
Date Started: 05/16/05
Date Completed: 05/16/05
Drilled By:
Logged By:

Slake Type 1: Retained pieces virtually unchanged.
Slake Type 2: Retained material consists of large and small pieces
Slake Type 3: Retained material is exclusively small fragments.

JAR INDEX

1.Degrades into pile of flakes or mud
2.Breaks rapidly and/or forms many chips
3.Breaks rapidly and/or forms few chips
4.Breaks slowly and/or develops several fractures
5.Breaks slowly and/or develops few fractures
6.No change

CaCO3 %

High to Medium Durability > 35%

BORING LOG LAWRENCE SHALE 1.GPJ KANSAS STATE.GDT 4/26/06

DEPARTMENT OF GEOLOGY — Kansas State University

Project Number: 59-23 K-7888-01

Project Name: Realignment of Hwy. 59, south of Lawrence, KS

Site: Pleasent Grove, KS in Douglas County

Surface Elevation: 1024.0'

Location: Sta. 526+30

Material Description			Graphic Log	Depth (ft)	Sample Type	RQD	Moisture %	Liquid Limit	Plastic Limit	Plasticity Index	Unconfined Compression	Jar Index	CaCO3 %	Slake Durability Index	Slake Type
			FIELD DATA				LABORATORY DATA								
Weathered shale becoming more sandy/micaceous with black orgnic debris. Very thinly laminated with lenticular bedding. *Continued Next Page*	12.6	1011.4													
Dusky Yellow (5Y 6/4) weathered shale; stained Dark Yellowish Orange (10YR 6/6) to Moderate Brown (5YR 4/4). Fresh Light Gray (N7) to Light Bluish Gray (5B 7/1). Top 0.6' heterolithic shale with lenticular bedding; thinly laminated.	13.5	1010.5													
Light Bluish Gray (5B 7/1) shale with black organic fragments/debris.				15		58						4	21.38	39.43	2
	17.3	1006.7													
Vitreous coal with sharp contact.	17.5	1006.5													
Light Bluish Gray (5B 7/1) to Light Gray (N7) silty churned shale/paleosol?	18.6	1005.4													
Sandy/silty micaceous shale	19.0	1005.0													
Light Gray (N7) to Medium Light Gray (N6) silty/sandy micaceous shale with White (N9) lenticular lenses of fine sand/silt. Minor amounts of distrubed bedding.				20								4	0.79	13.65	2
	21.6	1002.4													
Very sandy/micaceous shale with soft sediment deformation. Bottom 0.3' starved ripples and black organic particles.	22.5	1001.5				0						4	0.79	N/A	N/A
Medium Gray (N5) sandy/micaceous shale with White (N9) sandy sunken ripples. Top 0.5' contains faint lenticular to flaser bedding and becoming more distinct downward. Bottom 0.4' flaser bedding.															

Remarks:

Middle of Pleasant Grove Hill

Completion Depth: 62.0'
Date Started: 05/16/05
Date Completed: 05/16/05
Drilled By:
Logged By:

Slake Type 1: Retained pieces virtually unchanged.
Slake Type 2: Retained material consists of large and small pieces
Slake Type 3: Retained material is exclusively small fragments.

JAR INDEX

1.Degrades into pile of flakes or mud
2.Breaks rapidly and/or forms many chips
3.Breaks rapidly and/or forms few chips
4.Breaks slowly and/or develops several fractures
5.Breaks slowly and/or develops few fractures
6.No change

CaCO3 %

High to Medium Durability > 35%

BORING LOG LAWREN-1.GPJ KANSAS STATE.GDT 5/1/06

DEPARTMENT OF GEOLOGY — Kansas State University

Project Number: 59-23 K-7888-01

Project Name: Realignment of Hwy. 59, south of Lawrence, KS

Site: Pleasent Grove, KS in Douglas County

Surface Elevation: 1024.0'

Location: Sta. 526+30

Material Description	Graphic Log	Depth (ft)	Sample Type	RQD	Moisture %	Liquid Limit	Plastic Limit	Plasticity Index	Unconfined Compression	Jar Index	CaCO3 %	Slake Durability Index	Slake Type
					FIELD DATA					LABORATORY DATA			
37.2 / 986.8													
Top 0.2' flaser to lenticular bedding. Mud drapes at top 0.3'. Wavy/disrupted bedding of White (N9) sandy ripples. 39.5'-40.3' Light Gray (N7) to White (N9) dense hard fine grained micaceous sandstone; sharp contacts. 40.3'-40.6' sandy micaceous shale with black organic debris.										4	2.38	80.27	1
40.6 / 983.4		40											
Medium Gray (N5) and Medium Light Gray (N6) to Light Olive Gray (5Y 6/1) sandy micaceous shale with black organic debris. Becoming more micaceous downward. Sandy sunken ripples at base (~1cm thick). Well indurated (good core).										5	3.15	78.12	1
41.9 / 982.1													
Medium Light Gray (N6) to Medium Gray (N5) sandy micaceous shale with black organic debris and minor amounts of leafy debris. 43.6'-44.2' sunken pillows of White (N9) fine sand (~0.1' -0.2' thick) with deformation. 45'-45.4' sunken ripples (0.1'-0.3' thick). 46' sandy sunken ripple (0.3' thick). Angled fracture at 43.8' (~40°).		45											
46.8 / 977.2													
Medium Gray (N5) sandy micaceous shale with black plant debris/particles.													

Remarks:

Middle of Pleasant Grove Hill

Completion Depth: 62.0'
Date Started: 05/16/05
Date Completed: 05/16/05
Drilled By:
Logged By:

Slake Type 1: Retained pieces virtually unchanged.
Slake Type 2: Retained material consists of large and small pieces
Slake Type 3: Retained material is exclusively small fragments.

JAR INDEX

1.Degrades into pile of flakes or mud
2.Breaks rapidly and/or forms many chips
3.Breaks rapidly and/or forms few chips
4.Breaks slowly and/or develops several fractures
5.Breaks slowly and/or develops few fractures
6.No change

CaCO3 %

High to Medium Durability > 35%

BORING LOG LAWRENCE SHALE 1.GPJ KANSAS STATE.GDT 4/26/06

DEPARTMENT OF GEOLOGY — Kansas State University

Project Number: 59-23 K-7888-01

Project Name: Realignment of Hwy. 59, south of Lawrence, KS

Site: Pleasent Grove, KS in Douglas County

Surface Elevation: 1024.0'

Location: Sta. 526+30

Material Description		Graphic Log	Depth (ft)	Sample Type	RQD	Moisture %	Liquid Limit	Plastic Limit	Plasticity Index	Unconfined Compression	Jar Index	CaCO3 %	Slake Durability Index	Slake Type
~~48.1~~	~~975.9~~													
Same shale as above, but more sandy with lenticular bedding of White (N9) fine sand/silt lenses.					100						4	4.55	N/A	N/A
49.2	974.8													
Sandy shale; interbedded sandstone and shale zones at 50.7' (~0.2' thick), 51.1' (~0.1' thick), and 51.3' (~0.1' thick).			50											
51.5	972.5													
Silty/sandy micaceous shale with few starved ripples of White (N9) fine sand. Becoming more micaceous and sandy downward. Near base of core black organic debris appears. Flaser at bottom 0.1'.														
52.7	971.3													
Medium Light Gray (N6) and Medium Gray (N5) silty/sandy micaceous shale. Inclined flaser lenticular zone at 54' (~0.2' thick). 56.5'-56.9' weak highly fractured shale (clay rich) with fracture spacing of 1-2mm.					77						6	2.77	84.84	1
			55											
57.2	966.8													
Medium Gray (N5) sandy micaceous shale. Low inclined bedding at 59.8'-60.7'; wavy bedding at 60.5'-60.7'. Wavy/distrubed lenticular zone of White (N9) sand lenses at 61.3' (~0.1' thick).														
			60											

FIELD DATA | LABORATORY DATA

Remarks:

Middle of Pleasant Grove Hill

Completion Depth: 62.0'
Date Started: 05/16/05
Date Completed: 05/16/05
Drilled By:
Logged By:

Slake Type 1: Retained pieces virtually unchanged.
Slake Type 2: Retained material consists of large and small pieces
Slake Type 3: Retained material is exclusively small fragments.

JAR INDEX

1.Degrades into pile of flakes or mud
2.Breaks rapidly and/or forms many chips
3.Breaks rapidly and/or forms few chips
4.Breaks slowly and/or develops several fractures
5.Breaks slowly and/or develops few fractures
6.No change

CaCO3 %

High to Medium Durability > 35%

BORING LOG LAWRENCE SHALE 1.GPJ KANSAS STATE.GDT 4/26/06

DEPARTMENT OF GEOLOGY — Kansas State University

Project Number: 59-23 K-7888-01

Project Name: Realignment of Hwy. 59, south of Lawrence, KS

Site: Pleasent Grove, KS in Douglas County

Surface Elevation: 1024.0'

Location: Sta. 526+30

Material Description	Graphic Log	Depth (ft)	Sample Type	RQD	Moisture %	Liquid Limit	Plastic Limit	Plasticity Index	Unconfined Compression	Jar Index	CaCO3 %	Slake Durability Index	Slake Type
				FIELD DATA				LABORATORY DATA					
Medium Gray (N5) sandy micaceous shale. Low inclined bedding at 59.8'-60.7'; wavy bedding at 60.5'-60.7'. Wavy distrubed lenticular zone of White (N9) sand lenses at 61.3' (~0.1' thick).*Continued Next Page*				90						4	3.16	74.66	1
62.0 962.0		65											
		70											

Remarks:

Middle of Pleasant Grove Hill

Completion Depth: 62.0'
Date Started: 05/16/05
Date Completed: 05/16/05
Drilled By:
Logged By:

Slake Type 1: Retained pieces virtually unchanged.
Slake Type 2: Retained material consists of large and small pieces
Slake Type 3: Retained material is exclusively small fragments.

JAR INDEX

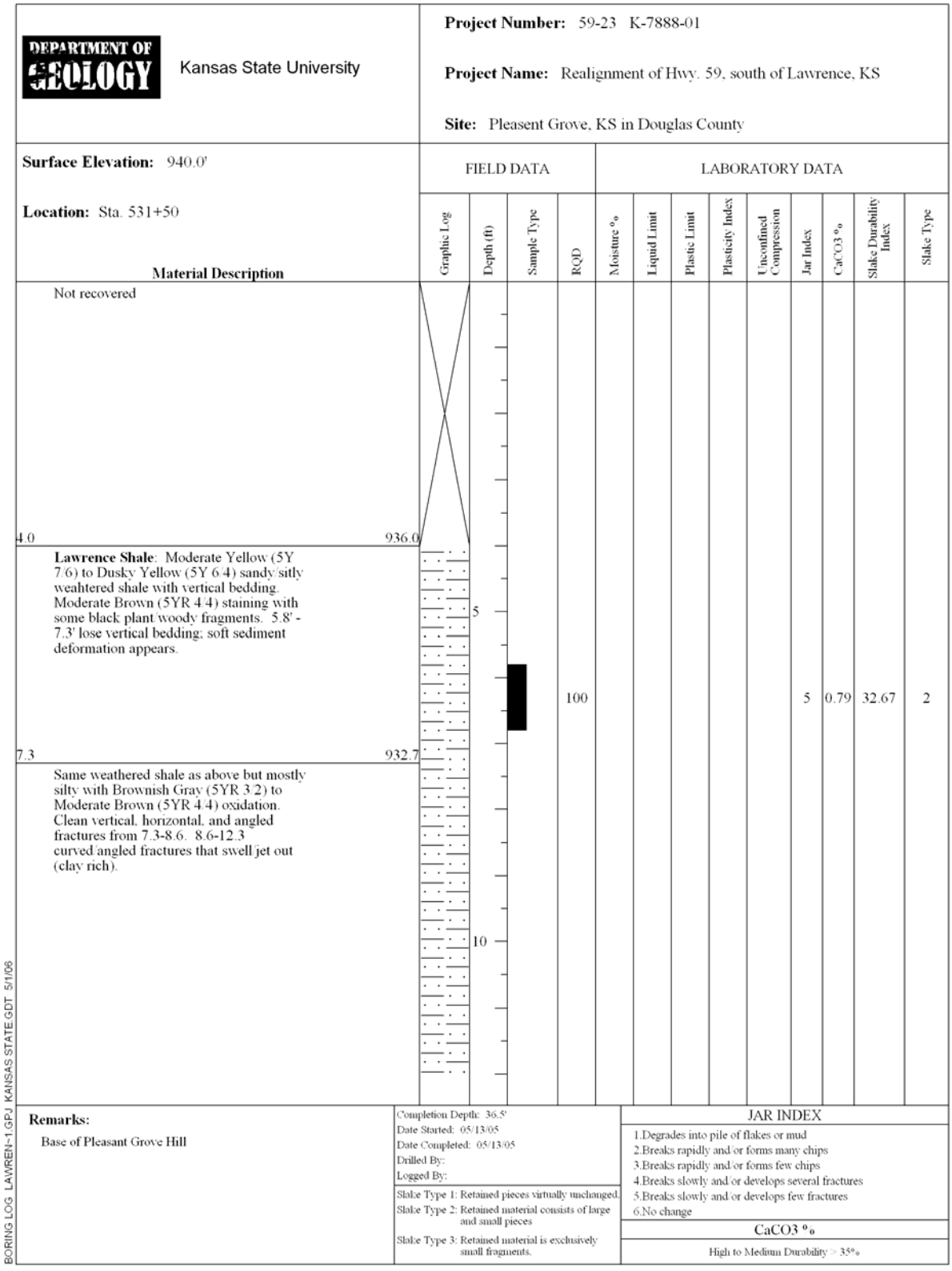
1.Degrades into pile of flakes or mud
2.Breaks rapidly and/or forms many chips
3.Breaks rapidly and/or forms few chips
4.Breaks slowly and/or develops several fractures
5.Breaks slowly and/or develops few fractures
6.No change

CaCO3 %

High to Medium Durability > 35%

BORING LOG LAWRENCE SHALE 1.GPJ KANSAS STATE.GDT 4/26/06

APPENDIX B-6: STATION 531+20', 25' RT CL - BASE OF HILL - BH1



DEPARTMENT OF GEOLOGY — Kansas State University

Project Number: 59-23 K-7888-01

Project Name: Realignment of Hwy. 59, south of Lawrence, KS

Site: Pleasent Grove, KS in Douglas County

Surface Elevation: 940.0'

Location: Sta. 531+50

Material Description	Graphic Log	Depth (ft)	Sample Type	RQD	Moisture %	Liquid Limit	Plastic Limit	Plasticity Index	Unconfined Compression	Jar Index	CaCO3 %	Slake Durability Index	Slake Type
Not recovered													
4.0 / 936.0													
Lawrence Shale: Moderate Yellow (5Y 7/6) to Dusky Yellow (5Y 6/4) sandy/sitly weahtered shale with vertical bedding. Moderate Brown (5YR 4/4) staining with some black plant/woody fragments. 5.8' - 7.3' lose vertical bedding; soft sediment deformation appears.		5		100						5	0.79	32.67	2
7.3 / 932.7													
Same weathered shale as above but mostly silty with Brownish Gray (5YR 3/2) to Moderate Brown (5YR 4/4) oxidation. Clean vertical, horizontal, and angled fractures from 7.3-8.6. 8.6-12.3 curved/angled fractures that swell jet out (clay rich).		10											

Remarks:

Base of Pleasant Grove Hill

Completion Depth: 36.5'
Date Started: 05/13/05
Date Completed: 05/13/05
Drilled By:
Logged By:

Slake Type 1: Retained pieces virtually unchanged.
Slake Type 2: Retained material consists of large and small pieces
Slake Type 3: Retained material is exclusively small fragments.

JAR INDEX

1.Degrades into pile of flakes or mud
2.Breaks rapidly and/or forms many chips
3.Breaks rapidly and/or forms few chips
4.Breaks slowly and/or develops several fractures
5.Breaks slowly and/or develops few fractures
6.No change

CaCO3 %

High to Medium Durability > 35%

BORING LOG LAWREN~1.GPJ KANSAS STATE.GDT 5/1/06

DEPARTMENT OF GEOLOGY — Kansas State University

Project Number: 59-23 K-7888-01

Project Name: Realignment of Hwy. 59, south of Lawrence, KS

Site: Pleasent Grove, KS in Douglas County

Surface Elevation: 940.0'

Location: Sta. 531+50

Material Description	Depth (ft)	Sample Type	RQD	Moisture %	Liquid Limit	Plastic Limit	Plasticity Index	Unconfined Compression	Jar Index	CaCO3 %	Slake Durability Index	Slake Type
Weathered Pale Olive (10Y 6/2) shale; fresh Medium Light Gray (N6) to Medium Gray (N5) and stained Moderate Brown (5YR 5/4). Vertical bedding at 22.3-24.1 (darker gray shale), 24.3-24.7. Convolute distrubed bedding at 25.4-25.8.*Continued Next Page*	25		50						2	.81	4.03	3
			50						3	.99	39.06	2
27.1 / 912.9												
Medium Light Gray (N6) to Medium Gray (N5) silty shale wit abundant horizontal fractures on surface of core. Top 0.5' is oxidized Light Brown (5YR 5/6) with vertical joints bedding.	30								3	3.96	18.34	3
32.0 / 908.0												
Same shale as above but with fewer fractures.	35		70						3	3.16	49.59	2

Remarks:

Base of Pleasant Grove Hill

Completion Depth: 36.5'
Date Started: 05/13/05
Date Completed: 05/13/05
Drilled By:
Logged By:

Slake Type 1: Retained pieces virtually unchanged.
Slake Type 2: Retained material consists of large and small pieces
Slake Type 3: Retained material is exclusively small fragments.

JAR INDEX

1.Degrades into pile of flakes or mud
2.Breaks rapidly and/or forms many chips
3.Breaks rapidly and/or forms few chips
4.Breaks slowly and/or develops several fractures
5.Breaks slowly and/or develops few fractures
6.No change

CaCO3 %

High to Medium Durability > 35%

BORING LOG LAWRENCE SHALE 1.GPJ KANSAS STATE.GDT 4/26/06

DEPARTMENT OF GEOLOGY — Kansas State University

Project Number: 59-23 K-7888-01

Project Name: Realignment of Hwy. 59, south of Lawrence, KS

Site: Pleasant Grove, KS in Douglas County

Surface Elevation: 940.0'

Location: Sta. 531+50

Material Description	Graphic Log	Depth (ft)	Sample Type	RQD	Moisture %	Liquid Limit	Plastic Limit	Plasticity Index	Unconfined Compression	Jar Index	CaCO3 %	Slake Durability Index	Slake Type
				FIELD DATA					LABORATORY DATA				
12.3 927.7 Same weathered silty shale as above. Vertical bedding/fractures at 13.4-15.1.				90						3	.99	39.03	2
15.1 924.9 Same weathered silty shale as above. Vertical bedding/fractures at 15.4-16.4 and 17-17.3becoming broken/blocky shale.		15		90						3	.70	35.21	2
17.3 922.7 Yellowish Gray (5Y 7/2) weathered silty/sandy shale stained Dark Yellowish Orange (10YR 6/6) with Moderate Reddish Brown (10YR 4/6) iron cementation. Fresh Light Gray (N8) shale. 18.3-22.3 more weathered with vertical bedding/fractures (bad shale).		20											
22.3 917.7 Weathered Pale Olive (10Y 6/2) shale; fresh Medium Light Gray (N6) to Medium Gray (N5) and stained Moderate Brown (5YR 5/4). Vertical bedding at 22.3-24.1 (darker gray shale). 24.3-24.7. Convolute/distrubed bedding at 25.4-25.8.													

Remarks:

Base of Pleasant Grove Hill

Completion Depth: 36.5'
Date Started: 05/13/05
Date Completed: 05/13/05
Drilled By:
Logged By:

Slake Type 1: Retained pieces virtually unchanged.
Slake Type 2: Retained material consists of large and small pieces
Slake Type 3: Retained material is exclusively small fragments.

JAR INDEX

1.Degrades into pile of flakes or mud
2.Breaks rapidly and/or forms many chips
3.Breaks rapidly and/or forms few chips
4.Breaks slowly and/or develops several fractures
5.Breaks slowly and/or develops few fractures
6.No change

CaCO3 %

High to Medium Durability > 35%

BORING LOG LAWREN-1.GPJ KANSAS STATE.GDT 5/1/06

DEPARTMENT OF GEOLOGY — Kansas State University

Project Number: 59-23 K-7888-01

Project Name: Realignment of Hwy. 59, south of Lawrence, KS

Site: Pleasent Grove, KS in Douglas County

Surface Elevation: 940.0'

Location: Sta. 531+50

Material Description	Graphic Log	Depth (ft)	Sample Type	RQD	Moisture %	Liquid Limit	Plastic Limit	Plasticity Index	Unconfined Compression	Jar Index	CaCO3 %	Slake Durability Index	Slake Type
36.5 903.5		40											
		45											

Remarks:

Base of Pleasant Grove Hill

Completion Depth: 36.5'
Date Started: 05/13/05
Date Completed: 05/13/05
Drilled By:
Logged By:

Slake Type 1: Retained pieces virtually unchanged.
Slake Type 2: Retained material consists of large and small pieces
Slake Type 3: Retained material is exclusively small fragments.

JAR INDEX

1.Degrades into pile of flakes or mud
2.Breaks rapidly and/or forms many chips
3.Breaks rapidly and/or forms few chips
4.Breaks slowly and/or develops several fractures
5.Breaks slowly and/or develops few fractures
6.No change

CaCO3 %

High to Medium Durability > 35%

BORING LOG LAWRENCE SHALE 1.GPJ KANSAS STATE.GDT 4/26/06

REFERENCES

American Association of State Highway and Transportation Officials (AASHTO), 1984, T-208-70: Method of Sampling and Testing, p. 755-758.

Anderson, Raymond R., and McKay, Robert M., 1989, Clastic Rocks Associated with the Midcontinent Rift System in Iowa, Strategic and Critical Minerals in the Midcontinent Region, United States, U.S. Geologcial Survey Bulletin 1989, 44 pg.

Annual Book of American Society for Testing and Materials Standards, 1990, section 4: Soil and Rock; Dimension Stone; Geosynthetics: American Society for Testing and Materials, Philadelphia, p. 863-865.

Archer, Allen W., 1994, Extaction of Sedimentological Information Via Computer-based Image Analyses of Gray Shales in Carboniferous Coal-Bearing Sections of Indiana and Kansas, USA, Mathematical Geology, v. 26, p. 47-65.

Archer, Allen W., 1992, Analysis of Microfabric and its Relationships to Mineralogy and Structural Failure: Final Report K-TRAN Project KSU-91-6: Kansas Department of Transportation, 58 pg.

Archer, W.A., and Feldman, H.R., 1995, Incised Vallys and Estuarine Facies of the Douglas Group (Virgilian): Implications for Similar Pennsylvanian Sequences in the U.S. Mid-Continent, *in* Hyne, Norman, Sequence Stratigraphy of the Mid-Continent: Tulsa Geological Society, p. 119-145.

Deo, P., 1972, Shales as embankment materials, Joint Highway Research Project, Purdue University, W. Lafeyette, Ind.

Dick, J.C. and Shakoor, A., 1995, Characterizing durability of mudrocks for slope stability purposes. In: Haneberg, W.C. and Anderson, S.A. (eds.), Clay and Shale Slope Instability, Geological Society of America, Reviews in Engineering Geology, v. 10, p. 121-130.

Federal Highway Administration (FHWA), 1977, Design and Construction of Compacted Shale Embankments, vol. 3, Slaking Indexes for Design, Interim Report No. FHWA-RD-77-1: Federal Highway Administration, Offices of Research and Development, Washington, D.C.

Feldman, Howard A., and Archer, Allen W., 1995, Virgilian (Upper Pennsylvanian) Paleosols in the Upper Lawrence Formation (Douglas Group) and in the Snyderville Shale Member (Oread Formation, Shawnee Group) of the Northern Midcontinent, USA: Pedologic Contrasts in a Cyclothem Sequence – Discussion, Journal of Sedimentary Research, vol. A65, No. 4, p. 712-718.

Franklin, J., A. and Chandra, R., 1972, “The Slake Durability Test”. Int. J. Rock Mech. Min. Sc. Vol. 9, pp.325-341.

Gamble, J.C., 1971, Durability-plasticity classification of shales and other argillaceous rocks, Ph.D. thesis, University of Illinois at Urbana-champaign.

Gunal, Hikmet, 2001, Clay Illuviation and Calcium Carbonate Accumulation Along a Precipitation Gradient in Kansas, Ph.D. Thesis, Department of Agronomy, Kansas State University.

Hagen, S., and Hensiek, L., 1968, Classification of Rocks in Kansas, in Zeller, Doris E., 1968, The Stratigraphic Succession in Kansas, Kansas Geological Survey, Bulletin 189, Plate 1.

Heckel, P.H., 1977, Origin of phosphatic black shale facies in Pennsylvanian cylcothems of mid-continent North America: AAPG Bulletin, v. 61, p. 1045-1068.

Jackson, M.L., 1975, Soil chemical analysis - advanced course. 2nd Edition. Published by the author, Madison, Wisconsin. 895p.

Jewett, John M., 1951, Geologic Structures in Kansas, Kansas Geological Survey Bulletin 90, Part 6, pp. 105-172. (http://www.kgs.ku.edu/Publications/Bulletins/90_6/index.htm)

Joeckel, R.M, 1994, Virgilian (Upper Pennsylvanian) Paleosols in the Upper Lawrence Formation (Douglas Group) and in the Snyderville Shale Member (Oread Formation, Shawnee Group) of the Northern Midcontinent, USA: Pedologic Contrasts in a Cyclothem Sequence: Journal of Sedimentary Research, vol. A64, no. 4, p. 853-866.

KGS Map M-23, Geologic Map of Kansas, http://www.kgs.ku.edu//General/Geology/state23.html.

Kvale, E.P., and Archer, A.W., 1990. Tidal deposits associated with low-sulpher coals, Brazil FM. (Lower Pennsylvanian), Indiana. *Journal of Sedimentary Petrology*, v. 60:4, pp. 563-574.

Machette, M.N., 1986, Laboratory Methods; Calcium and Magnesium Carbonates, *in*: Singer, M.J. and Janitzky, P., Field and laboratory procedures used in a soil chronosequence study: U.S. Geological Bulletin, no. 1648, p. 30-33.

Miller, K.B., and McCahon, T.J., 1997, Sedimentologic and Mechanical Analysis of Uppermost Pennsylvannian and Permian Mudstones in Northeast Kansas: Final Report K-TRAN Project KSU-97-5: Kansas Department of Transportation.

Moore, R.C., 1935, Stratigraphic classification of the Pennsylvanian rocks of Kansas. Kansas Geological Survey, Bulletin 22, 256 p.

Munsell, 1994, Munsell Soil Color Charts, revised edition: Macbeth Division of Kollmorgen Instruments Corp., New Windson, N.Y.

O'Connor, H.G., 1963, Changes in Kansas stratigraphic nomenclature: AAPG Bulletin, v. 47, p. 1873-1877.

Runkel, A.C., 2002, Contributions to the Geology of Wabasha County, Minnesota: Minnesota Geological Survey Report of Investigations 59, 41 p.

Rutan, Debra, 1975, The Petrology and Depositional Environments of the Pennsylvanian Lawrence Formation in Eastern Kansas, M.S. Thesis, Department of Geology, University of Kansas, 118 p.

Steeples, Don W., DuBois, Susan M., and Wilson, Frank W., 1979, Seismicity, faulting, and geophysical anomolies in Nemaha County, Kansas: Relationship to Regional Structures, Geology, vol. 7, no. 3, pp. 134-138.

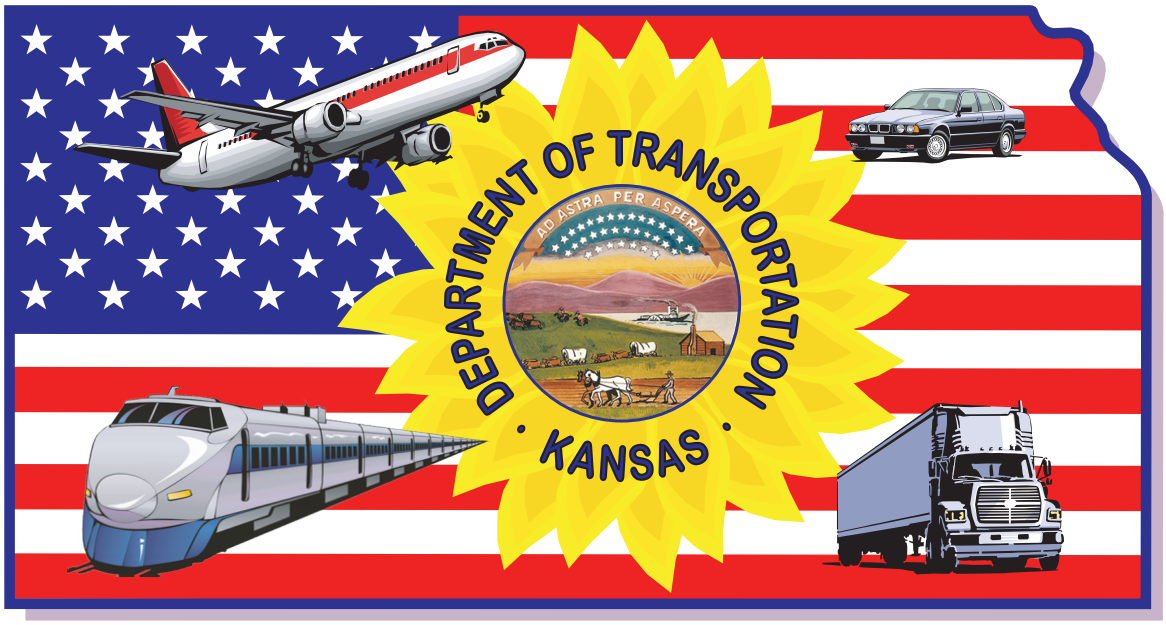
Stoops, Georges, 2003, Guidelines for Anaysis and Description of Soil Regolith Thin Sections: Soil Science Society of America, Madison, WI, 184 p.

Southwick, D.L, Morey, G.B., and Mossler, J.H., 1986, Fluvial Origin of the Proterozoic Sioux Quartzite, Southwestern Minnesota, Geological Society of America Bulletin, vol. 97, no. 12, pp. 1432-1441.

Wanless, H.R., and Weller, J.M., 1932, Correlation and extent of Pennsylvanian cyclothems. GSA Bulletin, v. 43, p. 1177-1206.

Weller, J., 1964, The concept of cyclic sedimentation, in Symposium on Cyclic Sedimentation, D.F. Merriam, ed., Kansas Geological Survey, Bulletin 169, v. 2, p. 607-621.

Zeller, Doris E., 1968, The Stratigraphic Succession in Kansas: Kansas Geological Survey Bulletin, v. 189, p. 34-35.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