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SUBAERIAL EXPOSURE FEATURES ASSOCIATED WITH SHOALING FACIES, OZAWKIE LIMESTONE MEMBER OF THE DEER CREEK LIMESTONE (VIRGILIAN), NORTHEASTERN KANSAS

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A report prepared for a graduate-level independent research project in Carbonate Sedimentology. The project was directed by Paul Enos and this manuscript benefited greatly from a review by him and by Rick Abegg.

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ABSTRACT

The Ozawkie Limestone Member of the Deer Creek Limestone Formation (Shawnee Group, Virgilian) exhibits diverse lithologies within northeastern Kansas. Overall, the lithologies and faunas of the Ozawkie suggest an open-marine environment of deposition. Locally, however, in Jefferson, Douglas, and Shawnee Counties, the Ozawkie consists of thick coated-grain and ooid grainstones and packstones, intercalated with dense lime mudstones and wackestones. Paleoflow data collected from these tabular cross-bedded grainstones show a pronounced orientation to the northeast (N 47° E) with a possible second node to the southwest. These lithologies suggest deposition in a high-energy shoal environment, perhaps offshore bars located within a vast, shallow, open-marine region. The shoal lithologies contain paleokarst features and are capped by laminated carbonate crusts.

Silty lime mudstones above the laminated crusts contain numerous features considered diagnostic of paleosols including irregular carbonate nodules (glaebules), circum-granular cracking of coated grains, columnar soil structures (peds) composed of carbonate-cemented autoclastic breccia, and slickensides (stress cutans). The presence of at least two sequences of carbonate shoal lithologies with paleokarst and laminated crusts at their top and overlain by paleosols, suggests that several subaerial exposure events occurred locally within the Jefferson, Douglas, and Shawnee County region during Ozawkie time. Both the carbonate shoal and well-developed paleosols have limited regional extent and appear to be related to a local paleohigh.

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INTRODUCTION

The Ozawkie Limestone Member is the lowermost unit within the Deer Creek Limestone Formation (Upper Pennsylvanian, Virgilian, Shawnee Group). In ascending order, the Deer Creek Limestone, considered a megacyclothem by Moore (1936), consists of the Ozawkie Limestone Member, Oskaloosa Shale Member, Rock Bluff Limestone Member, Larsh-Burroak Shale Member, and the Ervine Creek Limestone Member. Underlying the Deer Creek Limestone is the Tecumseh Shale Formation (Fig. 1).

Rocks of the Shawnee Group, that include the Deer Creek Limestone, crop out along a northeast to southwest belt in eastern Kansas (Merriam, 1963, p. 115). The Ozawkie Limestone Member can be recognized in southeastern Nebraska and into southwestern Iowa (Fagerstrom and Burchett, 1972). Lamoreaux (1983) reports that the Ozawkie grades into impure sandy limestones in north central Coffey County, that resemble sandy intervals within the underlying Tecumseh Shale. This precludes recognition and correlation of the Ozawkie further south, although it has been reported in Shawnee Group outcrops as far south as Chautauqua County, Kansas, near the Oklahoma border (measured sections, Kansas Geological Survey, R. C. Moore, 1929 and 1935 - Appendix A, 1-3). The Deer Creek Limestone is a prominent part of the Pawhuska Formation in Oklahoma, but the Ozawkie Limestone Member is not recognized there.

Lithologies and faunas of the Deer Creek Limestone Formation exposed in northeastern Kansas are generally consistent with cyclic sedimentation models previously postulated (Fig. 2). Virgilian lower limestones are interpreted as being deposited during the initial transgression of a megacyclothem (Moore, 1936). The Ozawkie Limestone Member, identified as a minor cycle by Heckel (1986), actually contains both transgressive and regressive elements. In northeastern Kansas, the lithologies and fauna of the Ozawkie are highly variable. Locally, within Jefferson, Douglas, and Shawnee Counties, it consists of thick coated-grain and ooid grainstone and packstone lithofacies with paleokarst and laminated crusts at their tops. Lime mudstone units contiguous within both the underlying Tecumseh Shale and overlying Oskaloosa Shale Member contain numerous diagnostic paleosol features. This report describes the carbonate shoal lithologies within the Ozawkie Limestone Member that are best developed in association with lithologic and sedimentologic indicators of subaerial exposure.

Previous Work

The lowermost limestone unit within the Deer Creek Formation was originally considered part of the Rock Bluff Limestone Member as defined in Nebraska by Condra (1927). R. C. Moore (1936) established the Ozawkie Limestone Member to include the lowermost unit in Kansas. The name is from

the original town of Ozawkie in Jefferson County, Kansas (Sections 29-32, T. 9 S., R. 18 E., OZAWKIE 7.5' QUAD), now under the waters of Perry Reservoir.

Moore (1936, p. 183) suggested that the Ozawkie Limestone Member may represent a greatly abbreviated cyclothem based on his recognition of a "dense blue facies" in Osage County, that he interpreted as a middle limestone. Bergstrom (1953) used thermoluminescence to demonstrate lateral facies variations within the Ozawkie in northeastern Kansas. Ronca (1959) demonstrated lithologic variability within the Shawnee Group, including the Ozawkie Limestone Member in eastern Kansas. Robb and Michnick (1990) described three distinct carbonate lithologies within the Ozawkie in Jefferson County, Kansas.

Moore (1941) described a bellerophontid gastropod fauna from the Ozawkie in Douglas County. Von Bitter (1972) identified conodont faunas within the Shawnee Group of eastern Kansas, that included a single species (Cavusgnathus sp.) from the Ozawkie.

Moore (1966) interpreted a fusulinid-rich facies within the Ozawkie in northeastern Kansas to represent maximum open-marine conditions and the adjacent algal facies to represent the margins of the retreating sea of that time. In a general interpretation of regional Upper Pennsylvanian paleogeography by Heckel (1980), northeastern Kansas is considered open marine with shoreline facies to the northeast. Fagerstrom and Burchett (1972) discussed Mid-Continent Upper Pennsylvanian paleogeography and shoreline geometry based in part on extensive cryptalgal structures within the Ozawkie Limestone in southeastern Nebraska and southwestern Iowa. By comparison to modern Shark Bay, Western Australia, Fagerstrom and Burchett (1972) suggested a supratidal paleoslope of less than 2 inches per mile and a tide range of at least 8 inches for the southeastern Nebraska-southwestern Iowa region during Ozawkie time.

METHODS

Deer Creek Limestone sections were studied at eighteen widely-spaced localities in northeastern Kansas (Fig. 3 and Appendix B). Sections were measured at select localities in order to demonstrate lateral facies variations (Fig. 4). Measured sections of these localities, except those in Jefferson County illustrated by Robb and Michnick (1990), can be found in Appendix C. Appendix D lists all quarries (some not visited) in Jefferson, Douglas, Shawnee, and Osage Counties where rocks identified as the Ozawkie Limestone are exposed.

Thirty-six paleoflow azimuths were measured from tabular cross-bedded grainstones within the Ozawkie Limestone Member in Jefferson County (localities JF4, JF5, JF6, and JF7). Paleoflow orientation was assumed to be in the dip direction of crossbeds. Measurements were made of in-place foresets and from blocks removed from the section, reoriented, and slabbed to expose apparent dips on perpendicular faces. Apparent dips were converted to true dip asimuths with a stereonet.

LITHOLOGIES

In order to understand the depositional processes that created the Ozawkie Limestone Member, it is important not only to analyze Ozawkie lithologies, but also adjacent lithologic units.

TECUMSEH SHALE

Underlying the Deer Creek Limestone is the Tecumseh Shale. In northeastern Kansas, the upper Tecumseh generally consist of brownish-gray, wavy-bedded, clay-rich, sandy mudstones and shales interbedded with yellowish-gray to dark gray, micaceous siltstones and sandstones near the top. The siltstone and sandstone interbeds, that range in thickness from 0.5 cm to 12.0 cm, become thicker and more abundant in the northeastern portions of the exposure belt in Kansas. The Tecumseh Shale is at least 4.5 meters thick at Locality DH1.

The crests of symmetric, flat-crested, sinuous ripples in a sandy layer of the Tecumseh Shale at Locality JF3 are oriented 285°; indicating flow oriented N 15° E or S 15° W. In addition to flat-crested current ripples, raindrop impressions and sandstone-filled fractures were observed in the Tecumseh at Locality JF7. Mascerated plant detritus and a varied ichnocoenosis also occur within these sandy intervals.

The uppermost 75 cm at Localities DG1 and DG2 consists of an anomalous yellowish-orange, silty lime mudstone that is similar in structure and texture to the lithology at the base of the Oskaloosa Shale Member above the Ozawkie. These features are described in the discussion of the lithology of the Oskaloosa. A similar, but much thinner and less structurally developed interval is present at the top of the Tecumseh in Jefferson County (localities JF4, JF6, & JF7).

OZAWKIE LIMESTONE MEMBER

Within northeastern Kansas, the Ozawkie Limestone Member includes varied carbonate lithologies that intergrade laterally (Fig. 4). The three distinct carbonate units separated by mudstones recognized by Robb and Michnick (1990) within the Ozawkie are limited to Jefferson County. Faunas and sedimentologic features within the Ozawkie are also highly varied. The main lithologies consist of predominantly bioclastic wackestone and packstone, lime mudstone and wackestone, and coated-grain/ooid grainstone and packstone.

Bioclastic Wackestone and Packstone Facies

The thick unbedded bioclastic wackestones and packstones vary considerably in thickness (from 12 cm to 125 cm), sedimentary structure, and color (light to dark gray).

Bioclasts are fragments of brachiopods, pelecypods, cephalopods, crinoids, and foraminifers (fusulinid). Complete fossils are locally common. Locally, silt and clay can make up to approximately 20 percent of the rock.

In Doniphan County, the Ozawkie consists of a single massive (125 cm average thickness) buff gray to yellowish-tan wackestone and packstone bed overlain by a yellowish-orange, silt-rich lime mudstone and wackestone. In Atchison County (Locality AT2), the upper 35 cm and the lower 30 cm are structureless, and the middle 35 cm lithology is a thin (1.0 cm to 4.0 cm thick beds) and wavy-bedded interval. In the southern part of the study area in Osage (OS1 and 2) and Coffey (CF1) Counties, the Ozawkie consists of a single massive (120 cm average thickness) yellowish orange and tan silty wackestone and packstone intercallated by lime mudstone-rich intervals. Foraminifera (fusulines) and brachiopods are abundant in the limestone.

Lime Mudstone and Wackestone Facies

This lithofacies, exists predominantly as a dense lime mudstone along with wackestone, is present most commonly as lenses within other lithofacies of the Ozawkie and can be up to 40.0 cm thick and ten meters in length. This lithology can be wavy bedded, exhibit fenestral fabric, and be locally cherty. It is buff tan fresh and weathers to a dark yellowish tan to light reddish brown. Fossils are uncommon, but include foraminifera (fusilines), brachiopods, and algae.

This lithofacies is most commonly observed intercalated within the lower of the two thick predominantly grainstone and packstone intervals at exposures within Jefferson, Douglas, and Shawnee Counties. It is also present within the predominantly wackestone and packstone lithologies in the northern and southern parts of the study area. In Doniphan County (DH1), it is a yellowish orange interval at least 20 cm thick that contains numerous tapering, spar-filled cavities (cf. rootlets) and overlies the wackestone and packstone lithofacies. In northern Coffey County (CF1), the Ozawkie becomes a tannish-yellow, terrigenous-rich lime mudstone, wackestone, and sometimes packstone that contains foraminifera (fusulines), brachiopods, and uncommonly, syringoporoid corals (cf. Aulopora sp.). In eastern Shawnee County (SH1), the Ozawkie can be predominantly a lime mudstone and wackestone that is less terrigenous rich.

Coated Grain and Ooid Grainstone and Packstone Facies

This lithofacies consists predominantly of thick coated-grain and ooid grainstones and packstones that generally form two distinct units separated by a thin, silty lime mudstones at some localities. The thick grainstone lithologies of this lithofacies consists predominantly of coated grains and ooids that are completely cemented by sparry calcite. Allochems (coated fossils, ooids and

peloids) range in size from 0.5 mm to 6.0 mm and in general are poorly sorted, but fine upward in 1.5 cm to 20.0 cm packages locally.

These predominantly grainstone lithologies contain rounded and angular concretionary lime mudstone, grainstone, and shale intraclasts that can comprise up to 75% of the rock at some locations. The intraclasts are mostly lime mudstone and grainstone in composition, range in size from approximately 1.0 cm to 15.0 cm in diameter, and occur throughout the grainstone facies, but appear to be most concentrated in the upper intervals. These grainstone units, averaging 130 cm or more in combined total thickness, are light buff tan to reddish gray fresh and weather yellow and reddish tan.

The grainstone and packstone lithologies exhibit large cut and fill structures along with tabular cross-bedding at some localities and are the source of all of the Ozawkie paleoflow data presented in this paper. Paleoflow orientation at any particular locality were relatively consistent, but between localities can be highly varied (Fig. 5). The cumulative paleoflow measurements from these localities show a pronounced northeast orientation (N 47° E) with a possible second node to the southwest (Fig. 6).

Bioclast-rich horizons occur within this lithofacies at some localities although fossils are generally sparse. Although uncommon, the fossils within this lithofacies are highly varied, and include gastropods, pelecypods, foraminifera, brachiopods, crinoids, bryozoans, cephalopods, coelenterates, and trace fossils. The most common fossils overall are bellerophontid gastropods.

The coated-grain and ooid grainstone and packstone lithologies occur within the Ozawkie only in Jefferson, Douglas, and Shawnee Counties. Proportionally, superficial ooids (coated grains) are most abundant in southeastern exposures of this lithofacies (e.g., localities JF6, DG1, and DG2), whereas abundance of true ooids increases to the northwest (e.g., locality JF1). Compared to the lithologies in Jefferson and Douglas Counties, those to the northeast in Doniphan and Atchison Counties and those to the southwest in Osage and Coffey Counties (silt-rich lime mudstones and bioclastic wackestones and packstones) contain more abundant open marine forms (brachiopods, crinoids, and foraminifera). Within the grainstone and packstone lithologies of Jefferson, Douglas, and Shawnee Counties, gastropods and pelecypods are the most common fossils.

OSKALOOSA SHALE MEMBER

The Oskaloosa Shale Member consists primarily of a light- to dark-gray, calcareous, silty mudstone and shale. It is a fine-to-medium-laminated and blocky weathering interval that becomes planar and wavy-bedded at the top. Throughout the member fossils are sparse but include

gastropods, bivalves, brachiopods, and plant detritus. Overall, the Oskaloosa Shale Member fines and darkens upward, and including the lower lime mudstone interval, ranges in thickness from 105 cm to over 300 cm within the study area.

Above the carbonate lithologies of the Ozawkie Limestone Member, is a tan to yellowish-orange, silt-rich, lime mudstone interval. This interval, that is lithostratigraphically the base of the Oskaloosa Shale Member, averages 50 cm to 125 cm in thickness. It is thickest and best developed in Jefferson, Douglas, and Osage Counties.

The lower silty lime mudstone interval contains irregular silty lime mudstone nodules that range from less than 0.5 cm to 9.5 cm in diameter. Similar structures have been called caliche nodules (glaebule) by Estaban and Klappa (1983). These nodules occur as isolated structures or in coalesced groups, and are most concentrated in a weakly cemented, cream- yellow, chalky lime mudstone at the base of the Oskaloosa. The base of this lime mudstone as well as the underlying laminated crust (at the top of the Ozawkie) contains carbonate-coated particles consisting of allochems (fossils, ooids, and peloids) as well as rock fragments, including clasts composed of rounded grainstone apparently derived from the underlying carbonate facies. Circum-granular fracturing was observed in coated grains present among the nodular lime mudstone pebbles (glaebules).

DEPOSITIONAL HISTORY

The Deer Creek Limestone occurs between the Tecumseh and Calhoun Shales and exhibits characteristics of a composite or Shawnee type megacyclothem as defined by Moore (1936), but lacks the "super" limestone. Overall, the Deer Creek Limestone is generally interpreted as representing a transgressive-regressive cycle (Fig. 2).

At the lower boundary of the Deer Creek Limestone, the Tecumseh Shale is typically wavy-bedded with thin lensoidal sandstone interbeds. It represents a period of detrital influx that occurred near the beginning of marine transgression. Macerated plant detritus, flat-crested symmetric sinuous ripples, and rain-drop imprints in sandy lenses within the Tecumseh suggest nearshore and occassional subaerial conditions. Paleoflow data collected from symmetric sinuous ripples suggests oscillating northeast-southwest paleocurrents. This matches almost exactly the flow orientation for sandstones within the outside shales of the Kansas City Group in northeastern Kansas reported by Hamblin (1969). Hakes (1976) noted that vertical trace-fossil sequences in the Tecumseh Shale indicate transgressive events that eventually led to Deer Creek deposition. The silty lime mudstones at the top of the Tecumseh in Jefferson and Douglas Counties are interpreted later in the discussion of early diagenetic history.

The lithologies and faunas of the Ozawkie Limestone Member are highly variable within northeastern Kansas. Lithologies in the northern and southern-most parts of the study area support an open marine interpretation and contain an abundant open marine biota including brachiopods, crinoids, and foraminifera. The mud-supported textures at some locations imply deposition in either a protected area or in an area below storm wave base. Although uncommon, algae is present in the lime-mud-rich intervals suggesting deposition within the effective photic zone. The fenestral fabric present in the lime mudstone dominated lithologies of the Ozawkie may be related to algal decay.

An agitated, shoal-water environment of deposition is suggested for the thick cross-bedded grainstone lithologies present locally within the Ozawkie. Based on established Virgilian paleogeography (Heckel, 1980), these shoaling carbonates likely represent a localized offshore bar belt that existed within a vast shallow open-marine sea (Fig. 7). Paleocurrent data (prominant node to the northeast) indicates an prevailing direction of transport for these offshore bars. Ball (1967) describes bedding dips consistently perpendicular to the long axes of shoals from both tidal bars and marine sand belts. This suggests that the shoals may have been oriented northwest to southeast (Fig. 7), parallel to a northern shore. Lithofacies isopachs derived from subsurface data are needed to confirm orientation and lateral extent inferred from essentially two-dimensional data.

Paleoflow orientations are similar to the bimodal distribution (N 52° E and S 42° W) reported by Hamblin (1969) for the Upper Pennsylvanian limestones of the Kansas City Group. Variations in flow orientation between the four closely spaced localities (Fig. 5) suggests very localized currents (Robb and Michnick, 1990) that may have been produced by tidal or channelized currents. Paleoflow data oriented perpendicular to the dominant flow direction (Fig. 5, Localities JF4 and JF5) were collected from foresets that may have formed between channels or sand waves.

Offshore bars, preserved as coated grain and ooid grainstones within the Ozawkie Limestone, may have resulted from the inpingement of wave base on a gently sloping ramp as described by Irwin (1965). The shoaling effects were possibly influenced by localized antecedant paleotopography. A localized paleohigh may have been the result of the depositional thickening of underlying units or possibly structural control. Thompson and Goebel (1968, p.7) illustrate a paleohigh at the top of the Mississippian in southwestern Jefferson and northwestern Douglas County.

EARLY DIAGENESIS

Early Diagenetic Features

Cavities filled with autoclastic breccia and lime mudstone matrix are present within the Ozawkie Limestone Member in Jefferson, Douglas, and Shawnee Counties. These cavities range from 2.0cm to 25.0 cm in maximum relief. The breccia is characterized by angular to subrounded, well-fitted fragments that can be up to 20 cm in maximum dimension. They are most prevalent in the uppermost carbonate unit and are commonly lined by laminated carbonate crusts. In addition, the Ozawkie also contains sediment-filled micro-fractures that traverse lithofacies and may have resulted from root structures.

Throughout northeastern Kansas, a somewhat wavy bedded surface containing relatively flat-bottomed open cavities occurs at the top of the thick carbonate lithologies within the Ozawkie. These features are best developed at the top of the upper grainstone and packstone lithologies in Jefferson, Douglas, and Shawnee Counties. The cavities range from 2.0 cm to 25.0 cm in relief and up to approximately 50.0 cm in diameter and closely resemble the solution pans or rock pools (kamenitzas) described by Esteban and Klappa (1983). Small (up to 0.5 cm diameter) smooth spar-filled fractures or tubes of irregular diameter have been observed predominantly on the basal surfaces of these features and are interpreted to be solution tunnels or fluid escape tubes.

Locally, these solution features as well as the entire upper surface of the Ozawkie are capped with distinct laminated carbonate crusts. These laminated crusts range in thickness from 0.1 cm to 2.5 cm and are composed of fine calcareous and siliceous bands or laminae that alternate from light (translucent spar) to dark (dark brown to black) in color. The laminae range from 0.15 mm to 12.0 mm in thickness and average 0.5 mm thick. Crusts can be composed of a single or multiple laminae. Although numerous dark layers can be present in these calcrete horizons, they do not resemble the charcoal-derived layers that might suggest an ancient burning event. The thickest and most well developed laminated crusts were observed in the Ozawkie at localities within Jefferson (JF6) and Douglas (DG1 and DG2) Counties.

Some of these laminated carbonate crusts appear to have developed in association with thin (<5mm) tapering tubules. Both root tubules and casts are present in the Ozawkie. The most common of these root traces are generally small (1.0 mm diameter average) tapering tubular cavities, empty or spar-filled, and often observed below the laminated carbonate crusts. These traces form a web-like network, resembling alveolar texture in some of the dense lime mudstone and wackestone. In addition, larger scale, downward tapering, cement-lined and sediment-filled structures that are considered root casts are present, most notably near the

top of the packstone and grainstone facies. It appears that the occurrence of these root traces are related to lithologic (? pedogenic) boundaries that may have served as growth and expansion zones for plant root systems. The few trace fossils observed that were not considered root structures consist of sub-vertical burrows that were highly varied in size and filled with host-rock cement or transported grainstone in some cases.

Numerous structural features exist within the calcareous mudstone at the base of the Oskaloosa. Similar, but less well developed features occur in the silty lime mudstones of the Tecumseh at localities DG1 and DG2 and between the thick carbonates of the Ozawkie (at Localities JF6, JF7, DG1, and DG2). These are best developed, however, above the uppermost grainstone lithofacies of the Ozawkie in Jefferson and Douglas Counties, and above the wackestone and packstone lithofacies in northern Osage County.

In Douglas County (DG1 and 2), exceptionally well preserved columnar structures that resemble modern peds are present in the Oskaloosa. These structures are oriented vertically, average 2.5 cm in diameter, and can be up to 25 cm or more in composite height. Excellent autoclastic brecciated texture is displayed within these sub-vertical columnar structures at locality DG2. The sub-rectangular fractures associated with this texture are carbonate filled. Slickensides (stress cutan) were observed within these structures at several localities. Elsewhere (JF6), platy and angular blocky structures exist. Also present within this lime mudstone and questionably within the laminated crusts are small (2 mm average diameter) black pebbles that are similar to those considered by Ettensohn et al. (1988) to be the result of organic matter infusion (cailloux noirs).

Early Diagenetic History

Karstic features, such as the solution pans or rock pools (kamenitzas) and collapse-fill microkarst, present at the top of the thick carbonate lithologies within the Ozawkie, form best in subaerial conditions where local precipitation exceeds evaporation (overall climate is rainy and humid) and carbonate leached from bedrock and soil profile is transported elsewhere. The laminated calcium crusts are the result of carbonate dissolution and reprecipitation. This carbonate may have originated from the underlying host rock or the overlying paleosol. The high permeability and vadose conditions of the shoal lithologies (grainstones) may have promoted carbonate infiltration from the overlying paleosol and served as a lithologic barrier for crust formation.

Walls et al. (1975) suggest the input of wind-blown salt spray as an alternate source of carbonate in crusts. This may have been a source of carbonate in the paleosol that likely was adjacent to open marine waters. If precipitation is insufficient to remove carbonate from the horizon, such as in semi-arid or arid regions, caliche

profiles can develop (Ettensohn et al., 1988). These situations represent climatic end members, and both types of structures as well as various intermediate structures are present either within the Ozawkie or the overlying Oskaloosa.

In addition to the laminated carbonate crusts, the yellowish lime mudstones that surround the carbonate lithologies of the Ozawkie Limestone Member contains numerous features considered diagnostic of a paleosol by Esteban and Klappa (1983) and Retallick (1990). These diagnostic features, present within the Oskaloosa, include irregular carbonate nodules (glaebules), circum-granular cracking in coated grains, columnar soil structures (peds) composed of autobrecciated clasts, and slickensides (stress cutans). Of particular interest are the carbonate filled fractures surrounding the autobrecciated clasts composing the paleosol structures. In combination, these features suggest that one or more drying events occurred locally.

Other less diagnostic features that are present include solution pools and rock ponds (kamenitzas) along with paleokarst at the top of the underlying limestone, small black pebbles (cailloux noirs), and a chalky lime mudstone layer just above a lithologic break. Although the uppermost of these silty lime mudstone intervals is lithostratigraphically the base of the Oskaloosa Shale Member, the presence of these features imply a genetic relation to the Ozawkie sequence. In fact, the features at the top of the carbonate lithologies of the Ozawkie very likely formed under a soil profile as described by Multer and Hoffmeister (1968).

Within Jefferson and Douglas Counties, successive sequences of a paleosol above thick carbonate lithofacies containing karst features and laminated carbonate crusts at their upper surfaces occur within the Ozawkie. This suggests that several subaerial exposure events occurred locally, rather than a single well-developed event (Fig. 8). These events were likely catalyzed by slight sea level eustasy in relation to local paleohighs, and should therefore be correlatable to lateral facies regionally.

Multiple lines of evidence suggest a localized paleohigh in the Jefferson, Douglas, and Shawnee County region during Ozawkie time. First, locally in that region, the Tecumseh contains lithologic features considered diagnostic of paleosols. Second, despite the shoal lithologies, the Ozawkie thickens to the southwest and northeast of this region. Third, the Oskaloosa thins in the Jefferson and Douglas County region to nearly half its thickness in the northern and southern-most parts of the study region. Finally, field observations also reveal that the Rock Bluff Limestone Member thickens to the northeast, possibly the affect of a more sediment starved predepositional area resulting from a seafloor high to the southwest.

CONCLUSIONS

The Ozawkie Limestone Member of the Deer Creek Limestone Formation (Shawnee Group) exhibits diverse lithologies within northeastern Kansas. Bioclastic wackestone and packstone with intercalated lime mudstones and wackestones containing mostly brachiopods, crinoids, and foraminifera in the northern and southern parts of the study area suggest open-marine environments of deposition. In Jefferson, Douglas, and Shawnee Counties, the Ozawkie consists of thick carbonates composed predominantly of coated-grain and ooid grainstones and packstones, intercalated with dense lime mudstones and wackestones. Paleoflow measurements collected from these tabular cross-bedded grainstones show a pronounced orientation to the northeast (N 47° E) with a possible second node to the southwest. A shoaling environment of deposition characterized by offshore bars located within a vast shallow open marine region is suggested for these units.

These carbonates are capped by paleokarst and laminated carbonate crusts. Above the laminated crusts are silty lime mudstone intervals that contain numerous features diagnostic of paleosols including irregular carbonate nodules (glaebules), circum-granular cracking of coated grains, columnar soil structures (peds) composed of carbonate cemented autoclastic breccia, and slickensides (stress cutans). Similar lime mudstone intervals also underlie the shoal lithologies in Jefferson and Douglas Counties. The presence of at least two sequences of carbonate shoals with paleokarst and laminated crusts at their tops, and overlain by paleosols suggests that several subaerial exposure events occured locally during Ozawkie time.

The well-developed paleosols, particularly those beneath the Ozawkie, and the carbonate shoal lithologies of the Ozawkie have limited regional extent and appear to be related to a local paleohigh. The restricted spatial distribution within northeastern Kansas of the varied lithologies of the upper Tecumseh Shale and basal Deer Creek Limestone support the presence of localized paleotopography and the effects of slight sea-level eustasy in deposition. Based on these conclusions, it is possible that this unit represents an abbreviated cyclothem in Moore's terminology. Although the rocks of the Ozawkie Limestone Member exhibit the previously described exceptional characteristics within northeastern Kansas, the remaining lithologies and faunas of the Deer Creek Limestone Formation within the study area are consistent with cyclic sedimentation models previously postulated for this sequence.

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FIGURE CAPTIONS

FIGURE 1. Stratigraphic Column of the Shawnee Group (Virgilian, Upper Pennsylvanian) of Kansas. Position of the Ozawkie Limestone Member indicated by arrow (adapted from Zeller, 1968).

FIGURE 2. Lithologies and interpretation of depositional environments of the Deer Creek Megacyclothem (from Heckel et al., 1979).

FIGURE 3. Outcrop belt of basal Deer Creek Limestone Formation (Shawnee Group) in northeastern Kansas showing study locations. Dashed line shows trend between outcropsindicated by Deer Creek Escarpment (Regional outcrop distribution of basal Deer Creek sediments adapted from Ross et al., 1991).

FIGURE 4. Stratigraphic correlations of measured sections of basal Deer Creek exposures.

FIGURE 5. Frequency roses indicating paleocurrent orientation collected from tabular crossbedded grainstones within the Ozawkie Limestone Member at several localities in Jefferson County, Kansas (class interval = 10^{o}; from Robb and Michnick, 1990).

FIGURE 6. Frequency rose indicating orientation of 36 paleoflow measurements taken from tabular cross-bedded grainstones within the Ozawkie Limestone Member in Jefferson County, Kansas (class interval = 10^{o}; from Robb and Michnick, 1990).

FIGURE 7. Regional paleogeography during Ozawkie time (Generalized facies belts modified from Heckel, 1977).

FIGURE 8. Interpretation of depositional history of lithofacies of the Ozawkie Limestone Member (Deer Creek Limestone Formation) in Douglas County, Kansas.

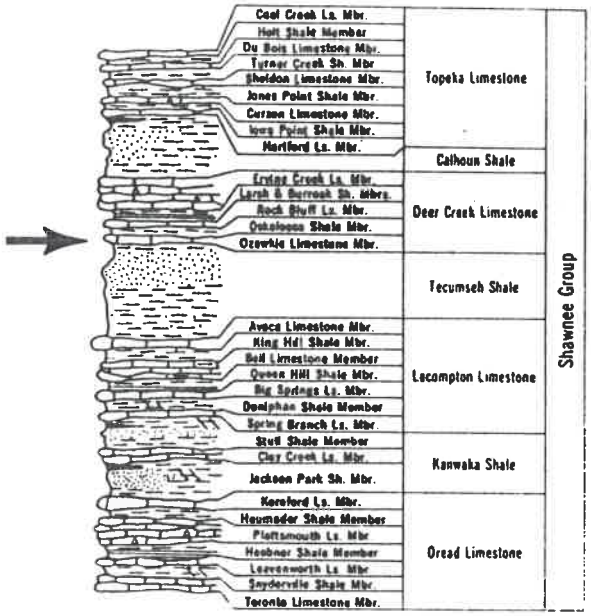

Coal Creek Ls. Mbr.
Holt Shale Member
Du Bois Limestone Mbr.
Turner Creek Sh. Mbr
Sheldon Limestone Mbr.
Jones Point Shale Mbr.
Curzon Limestone Mbr.
Ivan Point Shale Mbr.
Hartford Ls. Mbr.
Topeka Limestone
Calhoun Shale
Ervine Creek Ls. Mbr.
Larsh & Burroak Sh. Mbrs.
Rock Bluff Ls. Mbr.
Oskaloosa Shale Mbr.
Ozawkie Limestone Mbr.
Deer Creek Limestone
Tecumseh Shale
Avoca Limestone Mbr.
King Hill Shale Mbr.
Bell Limestone Member
Queen Hill Shale Mbr.
Big Springs Ls. Mbr.
Doniphan Shale Member
Spring Branch Ls. Mbr.
Lecompton Limestone
Stull Shale Member
Clay Creek Ls. Mbr.
Jackson Park Sh. Mbr.
Kanwaka Shale
Kereford Ls. Mbr.
Heumader Shale Member
Plattsmouth Ls. Mbr
Haskner Shale Member
Leavenworth Ls. Mbr
Snyderville Shale Mbr.
Toronto Limestone Mbr.
Oread Limestone
Shawnee Group

FIGURE 1

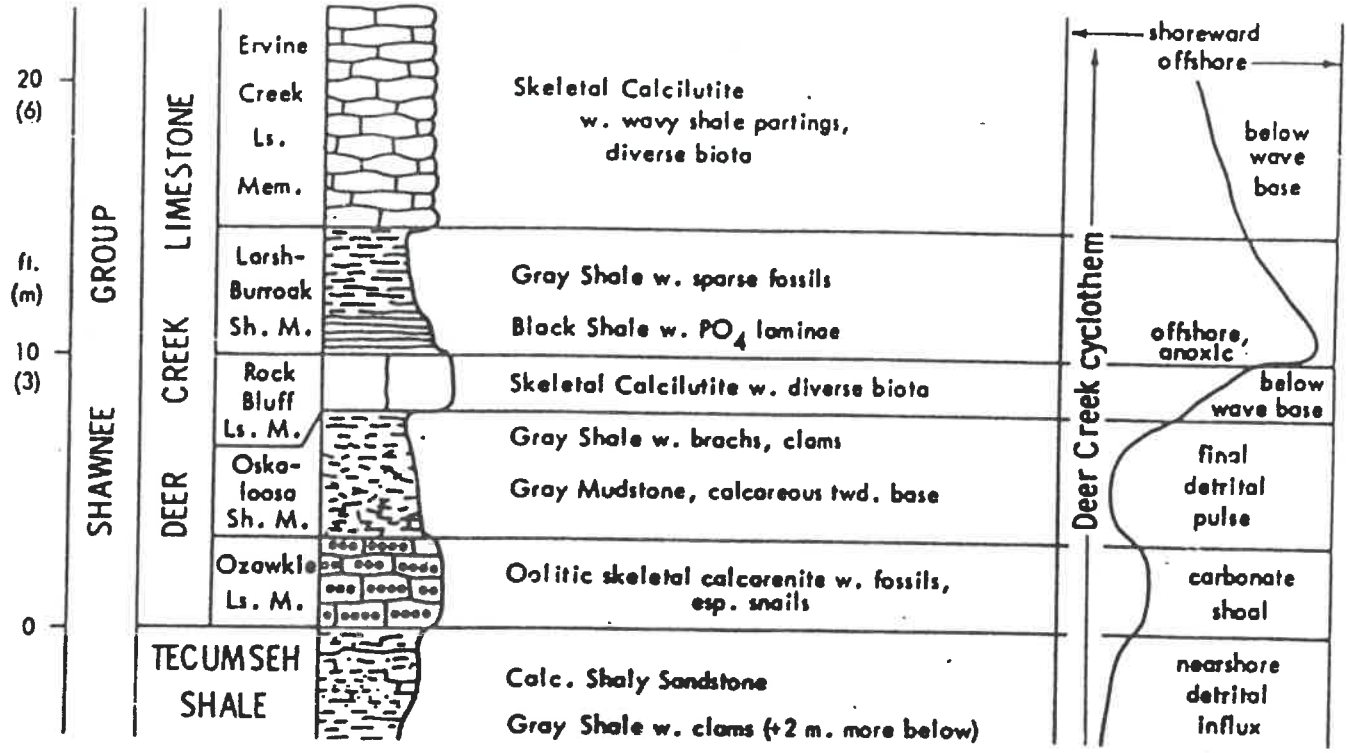

20
(6)
ft.
(m)
10
(3)
0
SHAWNEE GROUP
DEER CREEK LIMESTONE
Ervine Creek Ls. Mem.
Larsh-Burroak Sh. M.
Rock Bluff Ls. M.
Oskaloosa Sh. M.
Ozawkie Ls. M.
TECUMSEH SHALE
Skeletal Calcilutite w. wavy shale partings, diverse biota
Gray Shale w. sparse fossils
Black Shale w. PO4 laminae
Skeletal Calcilutite w. diverse biota
Gray Shale w. brachs, clams
Gray Mudstone, calcareous twd. base
Oolitic skeletal calcarenite w. fossils, esp. snails
Calc. Shaly Sandstone
Gray Shale w. clams (+2 m. more below)
shoreward
offshore
Deer Creek cyclothem
below wave base
offshore, anoxic
below wave base
final detrital pulse
carbonate shoal
nearshore detrital influx

FIGURE 2

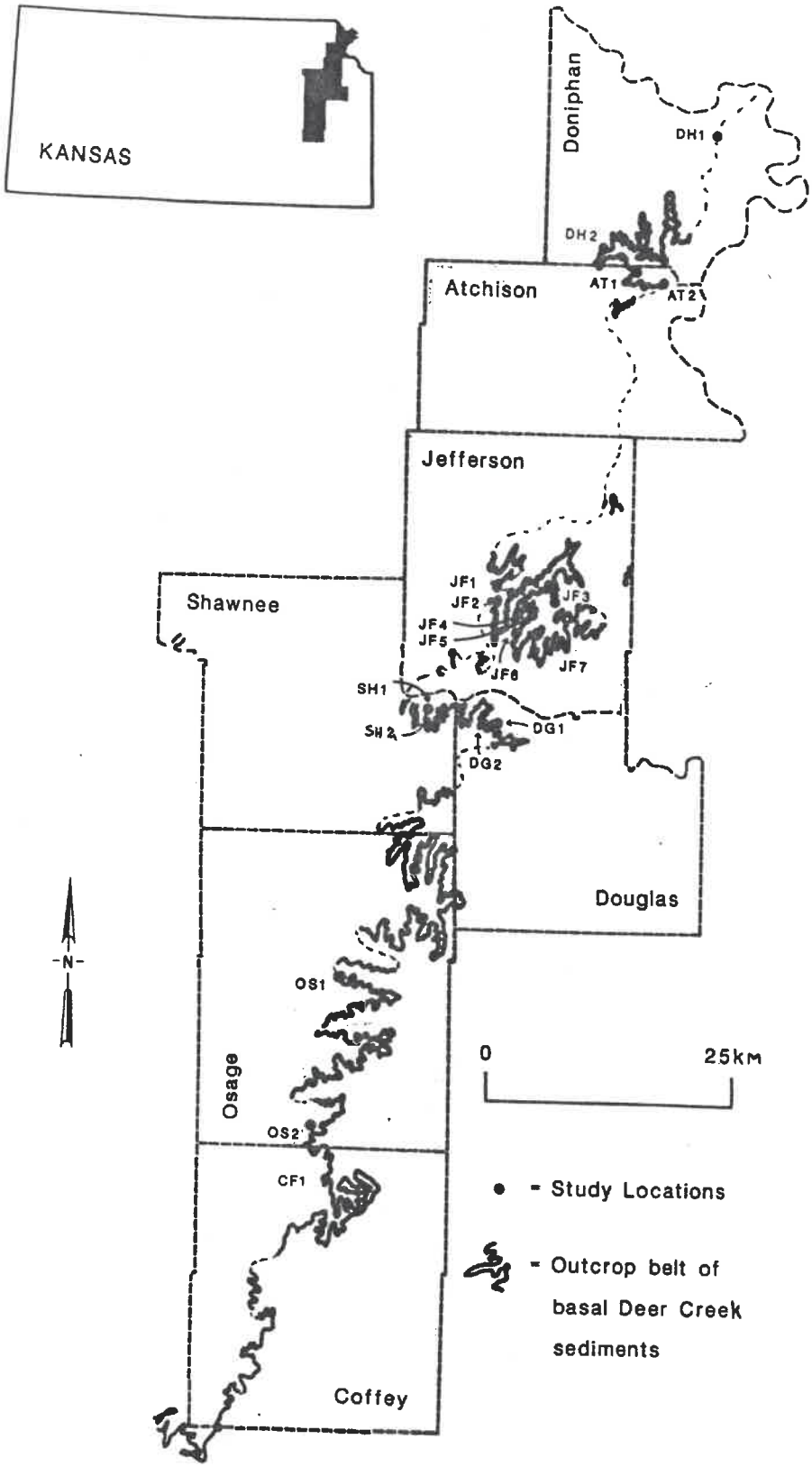

KANSAS
Doniphan
DH1
DH2
Atchison
AT1
AT2
Jefferson
JF1
JF2
JF3
JF4
JF5
JF6
JF7
Shawnee
SH1
SH2
DG1
DG2
Douglas
N
OS1
Osage
OS2
CF1
Coffey
0
25km
• - Study Locations
- Outcrop belt of basal Deer Creek sediments

FIGURE 3

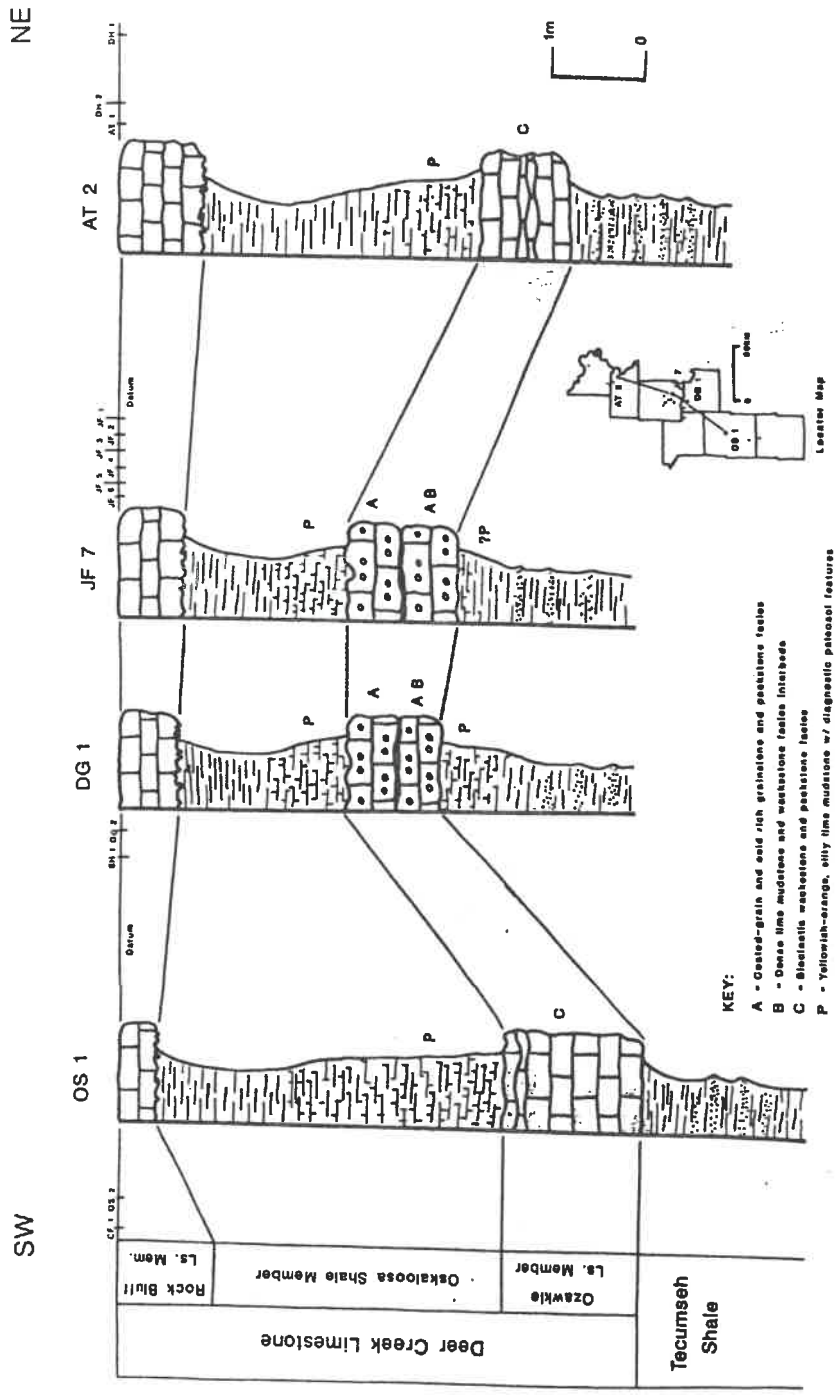

NE
SW
AT 2
JF 7
DG 1
OS 1
1m
0
Datum
Datum
P
C
A
A B
?P
KEY:
A - Coated-grain and mold rich grainstone and packstone facies
B - Dense lime mudstone and wackestone facies interbeds
C - Bioclastic wackestone and packstone facies
P - Yellowish-orange, silty lime mudstone w/ diagnostic paleosol features
Rock Bluff Ls. Mem.
Oskaloosa Shale Member
Ozawkie Ls. Member
Deer Creek Limestone
Tecumseh Shale

FIGURE 4

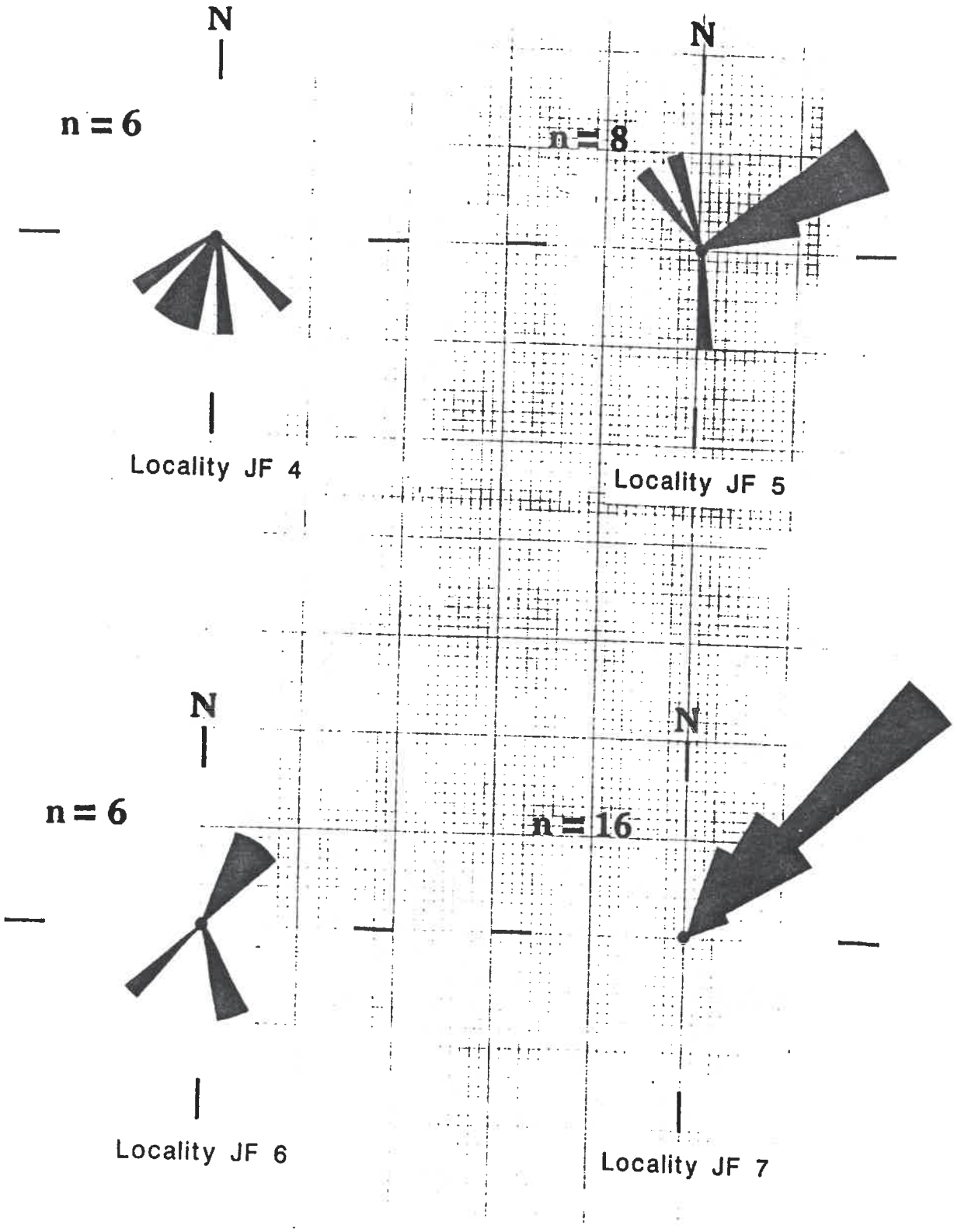

N
n = 6
Locality JF 4
N
n = 8
Locality JF 5
N
n = 6
Locality JF 6
N
n = 16
Locality JF 7

FIGURE 5

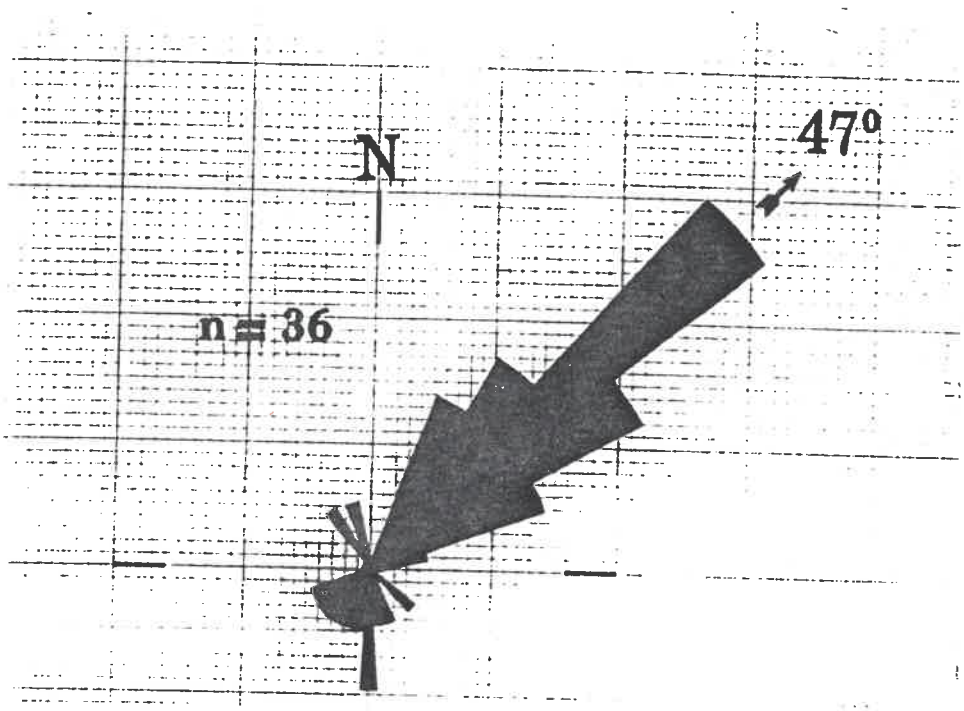


FIGURE 6

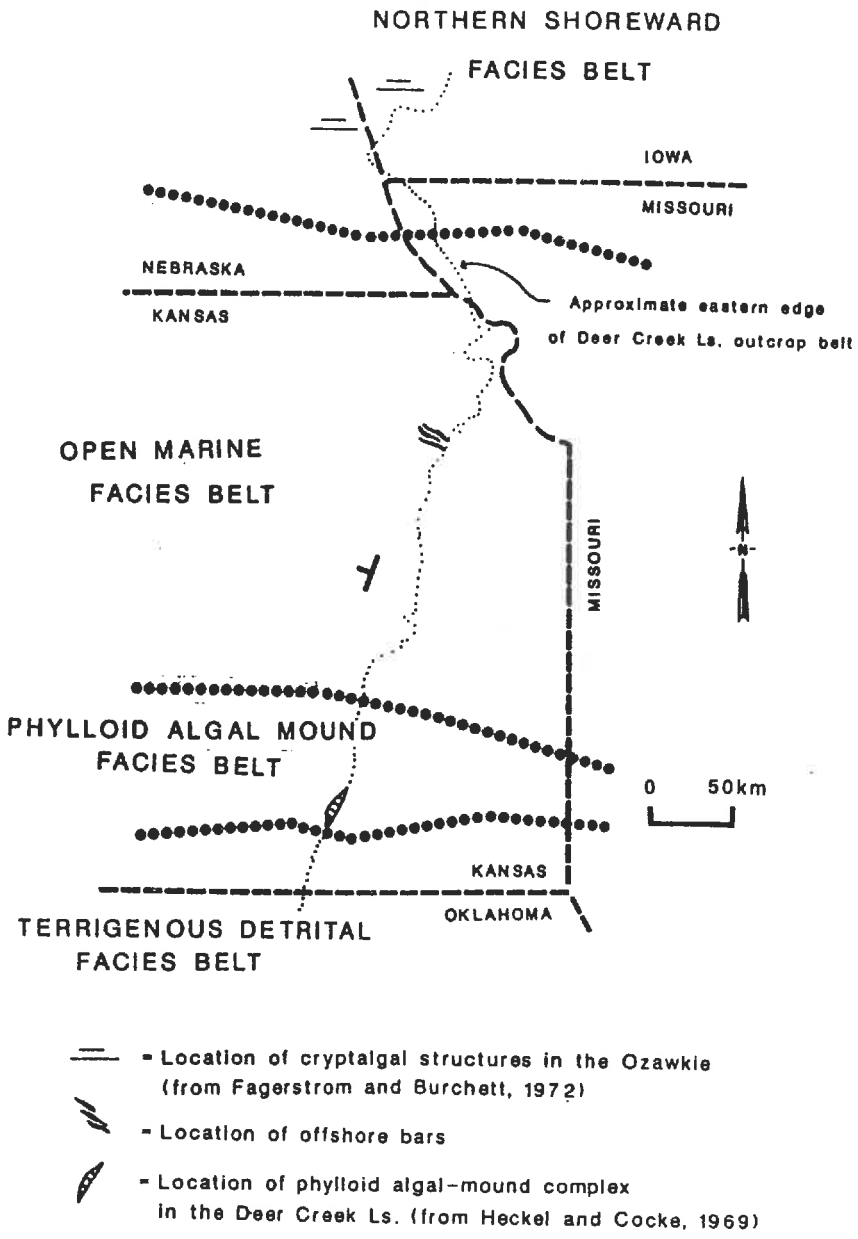

NORTHERN SHOREWARD
FACIES BELT
IOWA
MISSOURI
NEBRASKA
KANSAS
Approximate eastern edge
of Deer Creek Ls. outcrop belt
OPEN MARINE
FACIES BELT
MISSOURI
N
PHYLLOID ALGAL MOUND
FACIES BELT
0 50km
KANSAS
OKLAHOMA
TERRIGENOUS DETRITAL
FACIES BELT
= Location of cryptalgal structures in the Ozawkie
(from Fagerstrom and Burchett, 1972)
= Location of offshore bars
= Location of phylloid algal-mound complex
in the Deer Creek Ls. (from Heckel and Cocke, 1969)

FIGURE 7

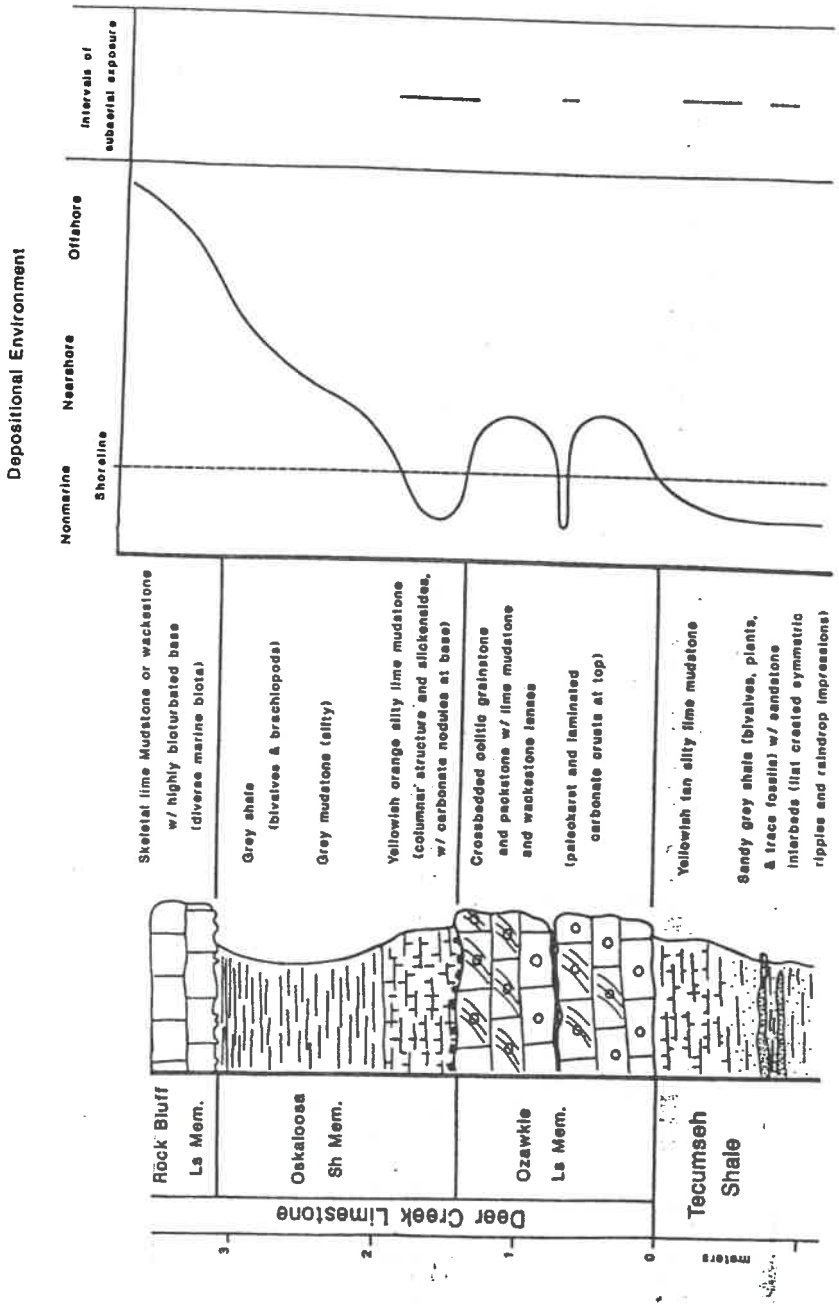
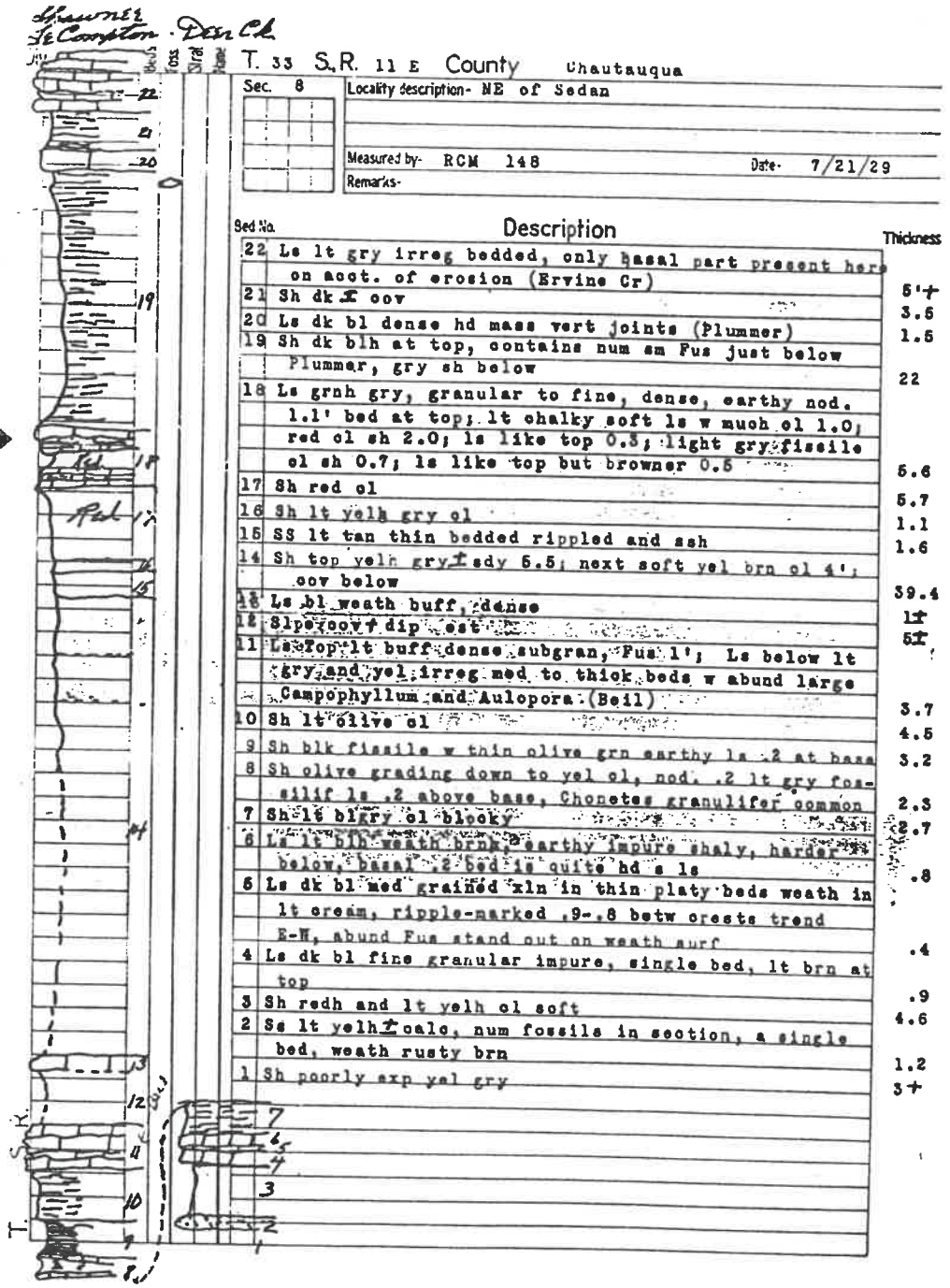

Depositional Environment
Nonmarine
Shoreline
Nearshore
Offshore
Intervals of subaerial exposure
Skeletal lime Mudstone or wackestone w/ highly bioturbated base (diverse marine biota)
Grey shale (bivalves & brachiopods)
Grey mudstone (silty)
Yellowish orange silty lime mudstone (columnar structure and slickensides, w/ carbonate nodules at base)
Crossbedded oolitic grainstone and packstone w/ lime mudstone and wackestone lenses
(paleokarst and laminated carbonate crusts at top)
Yellowish tan silty lime mudstone
Sandy grey shale (bivalves, plants, & trace fossils) w/ sandstone interbeds (flat crested symmetric ripples and raindrop impressions)
Rock Bluff Ls Mem.
Oakalossa Sh Mem.
Ozawkie Ls Mem.
Deer Creek Limestone
Tecumseh Shale
meters
3
2
1
0

FIGURE 8

CHAUTAUQUA COUNTY LOCALITY

Ozawkie
Ls. Mem. →



Hummel & Condon · Dean Ck.

T. 33 S. R. 11 E County Chautauqua

Sec. 8

Locality description- NE of Sedan

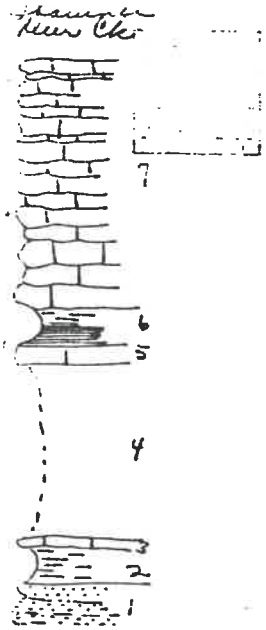
Measured by- RCM 148 Date- 7/21/29

Remarks-

Sed No.	Description	Thickness
22	Ls lt gry irreg bedded, only basal part present here on acct. of erosion (Ervine Cr)	5'+
21	Sh dk ± oov	3.6
20	Ls dk bl dense hd mass vert joints (Plummer)	1.5
19	Sh dk blh at top, contains num sm Fus just below Plummer, gry sh below	22
18	Ls grnh gry, granular to fine, dense, earthy nod. 1.1' bed at top; lt chalky soft ls w much ol 1.0; red ol sh 2.0; ls like top 0.5; light gry fissile ol sh 0.7; ls like top but browner 0.5	5.6
17	Sh red ol	5.7
16	Sh lt yelh gry ol	1.1
15	SS lt tan thin bedded rippled and ssh	1.6
14	Sh top yelh gry ± sdy 5.5; next soft yel brn ol 4'; oov below	39.4
13	Ls bl weath buff, dense	1±
12	Slope oov ± dip est	5±
11	Ls top lt buff dense subgran, Fus 1'; Ls below lt gry and yel irreg med to thick beds w abund large Campophyllum and Aulopora (Beil)	3.7
10	Sh lt olive ol	4.5
9	Sh blk fissile w thin olive grn earthy ls .2 at base	3.2
8	Sh olive grading down to yel ol, nod. .2 lt gry fossilif ls .2 above base, Chonetes granulifer common	2.3
7	Sh lt blgry ol blocky	2.7
6	Ls lt blh weath brnh, earthy impure shaly, harder below, basal .2 bed is quite hd s ls	.8
5	Ls dk bl med grained xln in thin platy beds weath in lt cream, ripple-marked .9-.8 betw crests trend E-W, abund Fus stand out on weath surf	.4
4	Ls dk bl fine granular impure, single bed, lt brn at top	.9
3	Sh redh and lt yelh ol soft	4.6
2	Ss lt yelh ± calc, num fossils in section, a single bed, weath rusty brn	1.2
1	Sh poorly exp yel gry	3+

APPENDIX A — 1

CHAUTAUQUA COUNTY LOCALITY



Ozawkie Ls. Mem. →

o.c.

Sec. 2, T. 35 S., R. 9 E — Chautauqua Co.

1½ mi E of Hewins

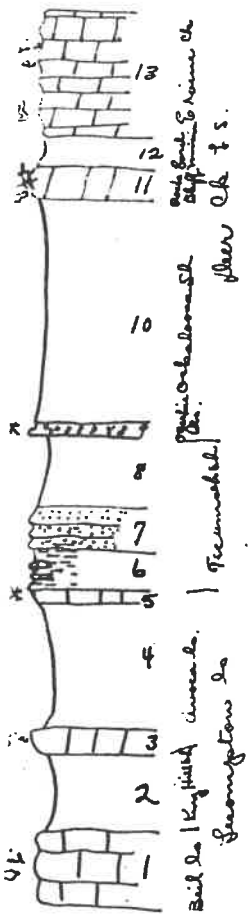
Measured by R. C. M. 189 — Date 7/30/29

7	Ls lt gry mottled brnh, thin irreg beds (Ervine Ck)	20'+
6	Sh, lower pt blk fissile	3'
5	Ls, dk bl dense vert joints (Plummer)	1.2'
4	Sh cov	14'
3	Ls brnh gry fine grained nodular earthy	.7'
2	Sh cov	3'
1	Ss lt tan x bedded	3'+

APPENDIX A — 2

CHAUTAUQUA COUNTY LOCALITY

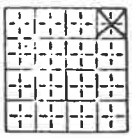
Ozawkie Ls. Mem. →



Sec. 2, T. 35 S., R. 9 — Chautauqua Co.

NE NE 2-35-9
Measured by R. C. Moore 734 — Date 12/9/35

13	Ls lt gry irreg bedded, brachs & abund Cryptozoan Fus not seen	10'
12	Sh dk gry ± weath	2.7'
11	Ls dk bl dense single mass bed vert joints abund irreg "marklets" and scattered few sm Fus	2.2'
10	Sh gry and brn partly cov top 1' ± has Fus Abund free small slender Fus (collection)	18'
9	Lt gry "pebble bed" made up of algal nodules ½"-1" diam top part weathers making a rubble of these pebbles	1'
8	Sh yel brn & cov	5.5'
7	Ss yel brn, irreg bedded, part hard blh calc?	7'
6	Sh yel brn w couple of thin limy sdy plates w small pelecypods	3.5'
5	Yel & lt gry fine irreg ls, algal masses & fragments of shells, sdy fine	.5-1'
4	Sh & cov	10.5'
3	Ls hd bl dense mass layer cryptozoan & few Fus	1.5'
2	Cov	6'
1	Ls lt gry, very mass blocks that separate along joints and slide down hill as unite, pseudo brecciatio fine sdy and lt bl algal masses no Fus ± 1'	6'



APPENDIX A – 3

APPENDIX B - Localities

Doniphan County

DH 1. East side of county road
E 1/2, SE 1/4, NE 1/4, sec. 26, T.2S., R.21E.,
TROY 7.5' QUAD
(U. Tecumseh and partial Deer Creek present, shales partially covered: Ozawkie = wackestone/packstone facies overlain by the lime mudstone and wackestone acies)

DH 2. West side of county road
NE 1/4, NE 1/4, NE 1/4, sec. 36, T.4S., R.19E.,
BENDENA 7.5' QUAD
(Entire Tecumseh and Deer Creek present, shales partially covered: Ozawkie = wackestone/packstone facies)

Atchison County

AT 1. East side of county Road
East edge, SW 1/4, SW 1/4, sec. 9, T.5S., R.20E.,
BENDENA 7.5' QUAD
(Lower Deer Creek present, shales covered: Ozawkie =wackestone/packstone facies)

AT 2. East side of KS 7
West edge, NW 1/4, NW 1/4, sec. 13, T.5S., R.20E.,
ATCHISON W 7.5' QUAD
(U. Tecumseh and entire Deer Creek present, shales mostly covered: Ozawkie = wackestone/packstone facies)

Jefferson County

JF 1. North side of KS 92
NE 1/4, NE 1/4, sec. 31, T.9S., R.18E.,
OZAWKIE 7.5' QUAD (Type Locality)
(? partial Ozawkie exposed, shales covered: Ozawkie = grainstone/packstone facies)

JF 2. North and south side of county road
SW 1/4, SE 1/4, sec. 3, T.10S., R.18E.,
OZAWKIE 7.5' QUAD
(U. Tecumseh and entire Deer Creek present, shales covered: Ozawkie = grainstone/packstone facies)

JF 3. South side of county road
N 1/2, SW 1/4, SE 1/4, sec. 3, T.10S., R.18E.,
OZAWKIE 7.5' QUAD
(U. Tecumseh and entire Deer Creek present, shales covered: Ozawkie = grainstone/packstone facies)

JF 4. Northeast side of county road
midline, E 1/2, SE 1/4, sec. 10, T.10S., R.18E.,
OZAWKIE 7.5' QUAD

(U. Tecumseh and entire Deer Creek present, shales covered: Ozawkie = grainstone/packstone facies)

JF 5. West side of county road
midline,E 1/2, SE 1/4, sec. 10, T.10S., R.18E., OZAWKIE 7.5' QUAD
(U. Tecumseh and entire Deer Creek present, shales covered: Ozawkie = grainstone/packstone facies)

JF 6. East and west side of US 59
midline, W 1/2, W 1/2, sec. 32, T.10S., R.19E., OSKALOOSA 7.5' QUAD
(U. Tecumseh and entire Deer Creek present, shales covered: Ozawkie = grainstone/packstone facies)

JF 7. South side of county road
NE 1/4, NE 1/4, sec. 6, T.10S., R.19E., OSKALOOSA 7.5' QUAD
(U. Tecumseh and entire Deer Creek present, shales covered: Ozawkie = grainstone/packstone facies)

Douglas County

DG 1. North side of Kansas Turnpike (I-70)
NE 1/4, NW 1/4, NW 1/4, sec. 22, T.12S., R.18E., CLINTON 7.5' QUAD
(U. Tecumseh and entire Deer Creek present: Ozawkie = grainstone/packstone facies)

DG 2. North side of Kansas Turnpike (I-70)
SE 1/4, SW 1/4, SE 1/4, sec. 16, T.12 S., R.18E., CLINTON 7.5' QUAD
(U. Tecumseh, Ozawkie, Oskaloosa, and Rock Bluff present: Ozawkie = grainstone/packstone facies)

Shawnee County

SH 1. Along eastern edge of roadcut on north side of Kansas Turnpike (I-70)
SE 1/4, SE 1/4, SW 1/4, sec. 6, T.12S., R.17E., GRANTVILLE 7.5' QUAD
(Entire Deer Creek weathering along drainage, Ozawkie partially covered: Ozawkie = lime mdst/wackestone/packstone/grainstone facies)

SH 2. North face of quarry
NW 1/4, sec. 7, T.12S., R.17E., GRANTVILLE 7.5' QUAD
(U. Tecumseh and entire Deer Creek present, fresh: Ozawkie = packstone/grainstone facies)

Osage County

OS 1.
SW 1/4, SW 1/4, NE 1/4, sec. 7, T.16 S., R.16 E.,

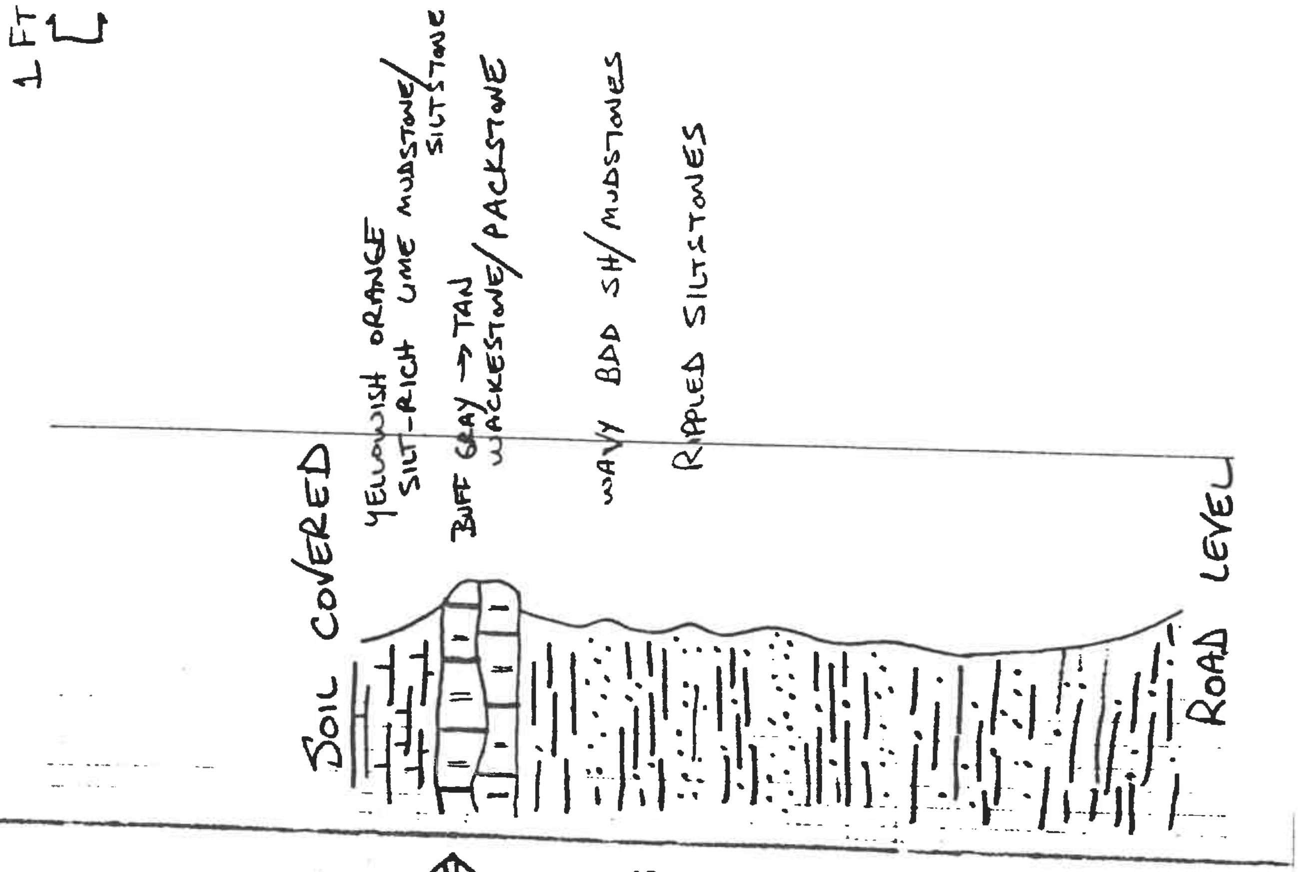
LYNDON NW 7.5' QUAD
(U. Tecumseh and entire Deer Creek present: Ozawkie = wackestone/?packstone facies)

OS 2.
SW 1/4, NW 1/4, sec. 16, T.18S., R.15E., LEBO 7.5' QUAD
(Lower Deer Creek present from U. Ozawkie, shales partially covered: Ozawkie = wackestone/?packstone facies)

Coffey County

CF 1. Along drainage of roadcut east of US 75
West edge, NW 1/4, SW 1/4, sec. 14, T.19S., R.15E., WAVERLY NW 7.5' QUAD
(U. Tecumseh and entire Deer Creek present, shales mostly covered: Ozawkie = wackestone/packstone facies)

LOCALITY DH 1



EAST SIDE OF COUNTY ROAD
E1/2, SE1/4, NE1/4, Sec 26
T2S, R21E, DONIPHAN CO KS
(TROY 7.5' QUAD)

* LOCALITY TAKEN FROM KGS
DONIPHAN COUNTY TOPO MAP

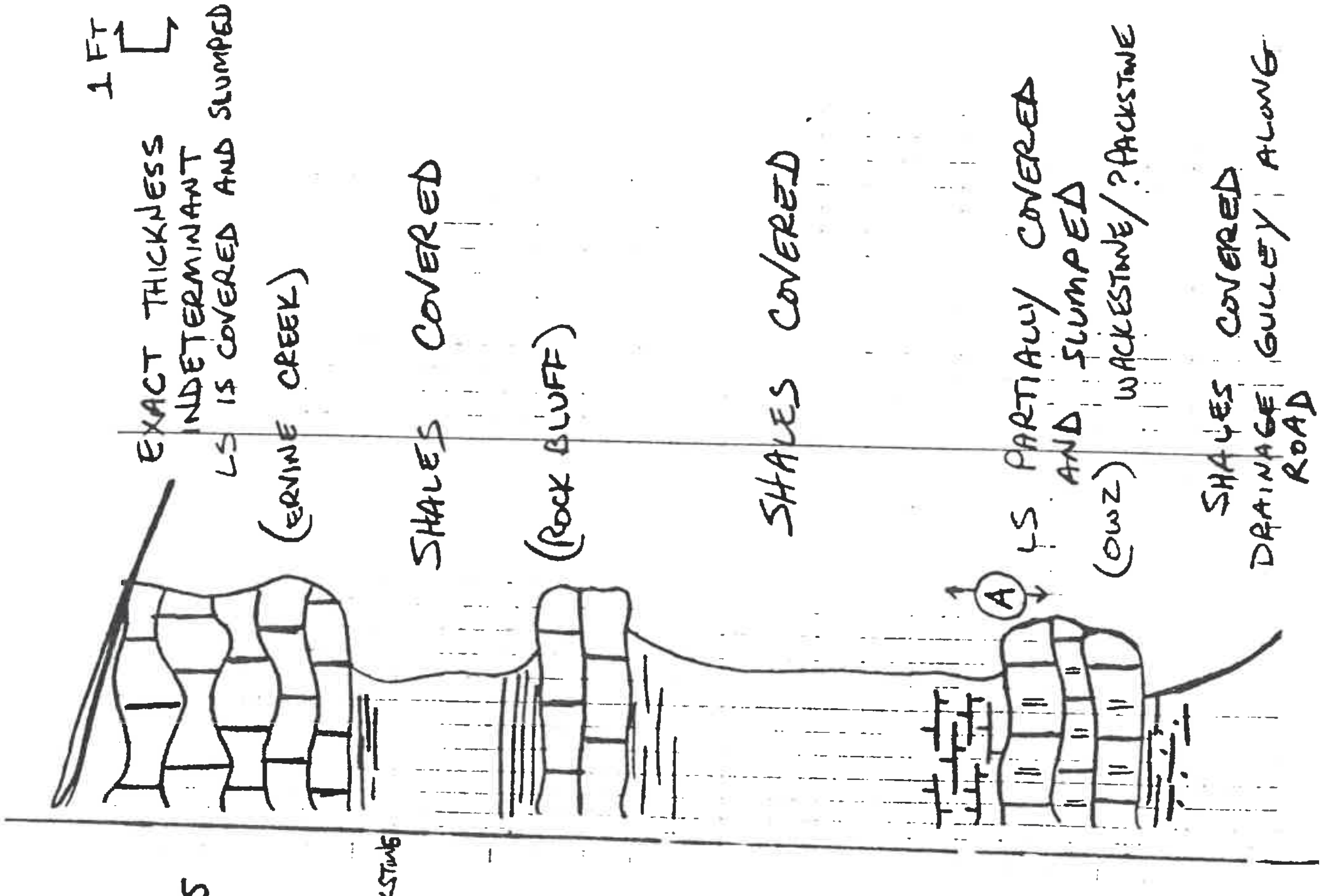
OWZ CONTAINS BRACHIOPODS, OWZ ⇒
FORAMS

TOP OF OWZ IS A YELLOWISH-
ORANGE LIME MUDSTONE
CONTAINING NUMEROUS ROOTLETS
(SPAR-FILLED TAPERING CAVITIES)

* SAMPLES COLLECTED

Transcribed from audio taped field notes

LOCALITY DH 2



WEST SIDE OF COUNTY ROAD
NE 1/4, NE 1/4, NE 1/4, SEC 36
T4S, R19E, DONIPHAN CO., KS
(BENDENA 7.5' QUAD)

OWZ = YELLOWISH TAN WACKESTONE/PACKSTONE

FAUNA = BRACHIOPODS, FORAMS, SHELL DEBRIS

(thin section samples) =

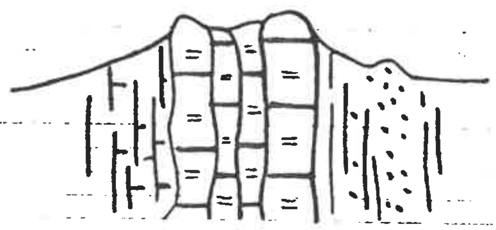
Transcribed from audio taped field notes

LOCALITY AT 1

1 FT

SHALES MOSTLY COVERED

(OWZ) YELLOW TAN GRAY
WACKESTONE / ? PACKSTONE

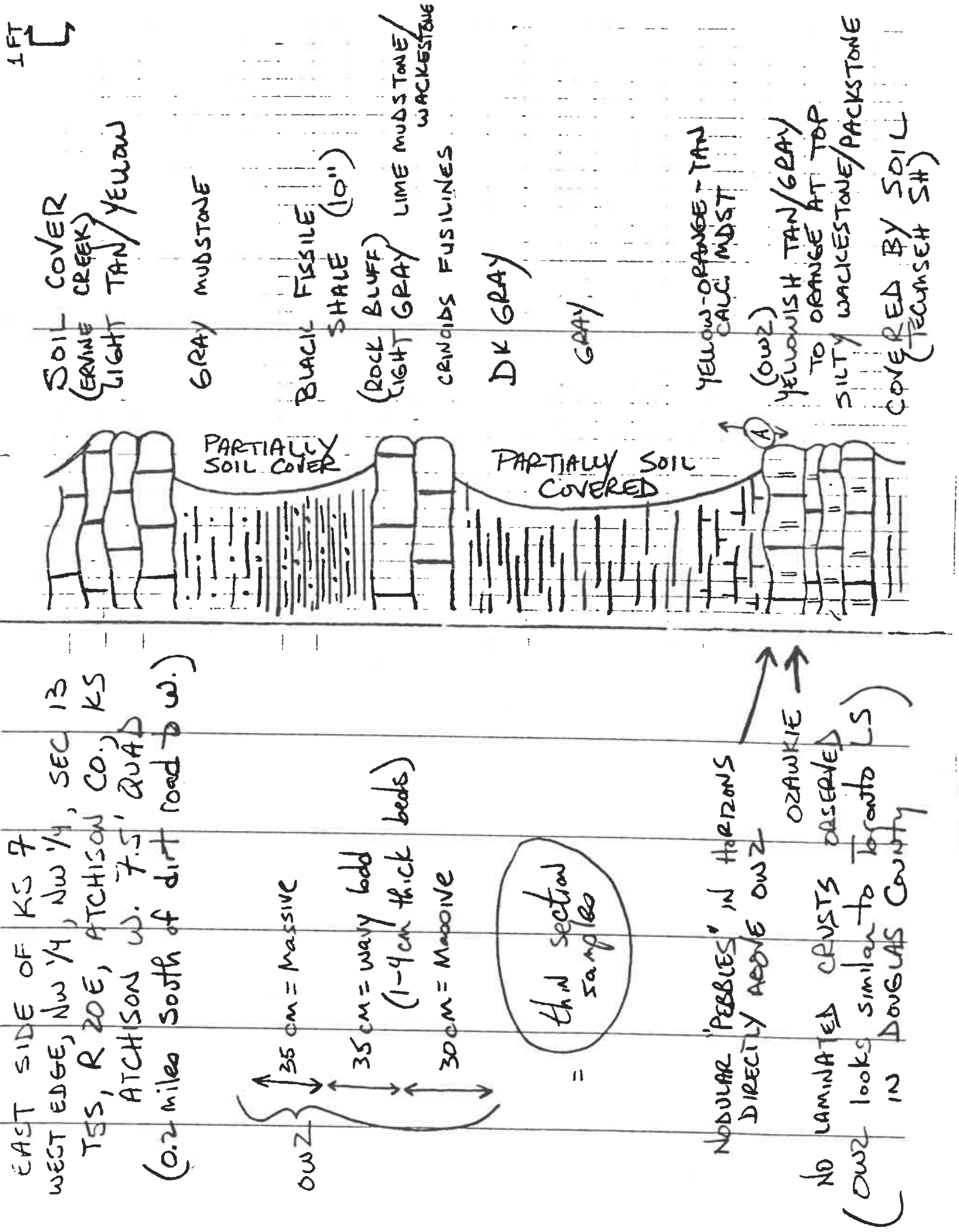


EAST SIDE OF COUNTY ROAD
EAST EDGE, SW/4, SW/4, SEC 9
T.5S, R20E, ATCHISON CO., KS
BENDENA 7.5' QUAD

LS MAY NOT BE IN-PLACE

SAMPLES COLLECTED

LOCALITY AT 2



Transcribed from audio taped field notes

LOCALITY DG 1

ROADCUT, N. SIDE OF KANSAS TURNPIKE (I-70)
NE¼, NW¼, NW¼, SEC 22
T12S, R18E, DOUGLAS COUNTY KS
(CLINTON 7.5' QUAD)

OWZ FAUNA: Bellerophontid gastropods, cephalopods, crinoid frags., pelecypods,

Laminated carbonate crusts at top & both OWZ LS units (1 → 2.5 cm thick)

?Caliche pebbles (1mm → 2" diameter) at top of laminated crusts above OWZ and also less commonly within

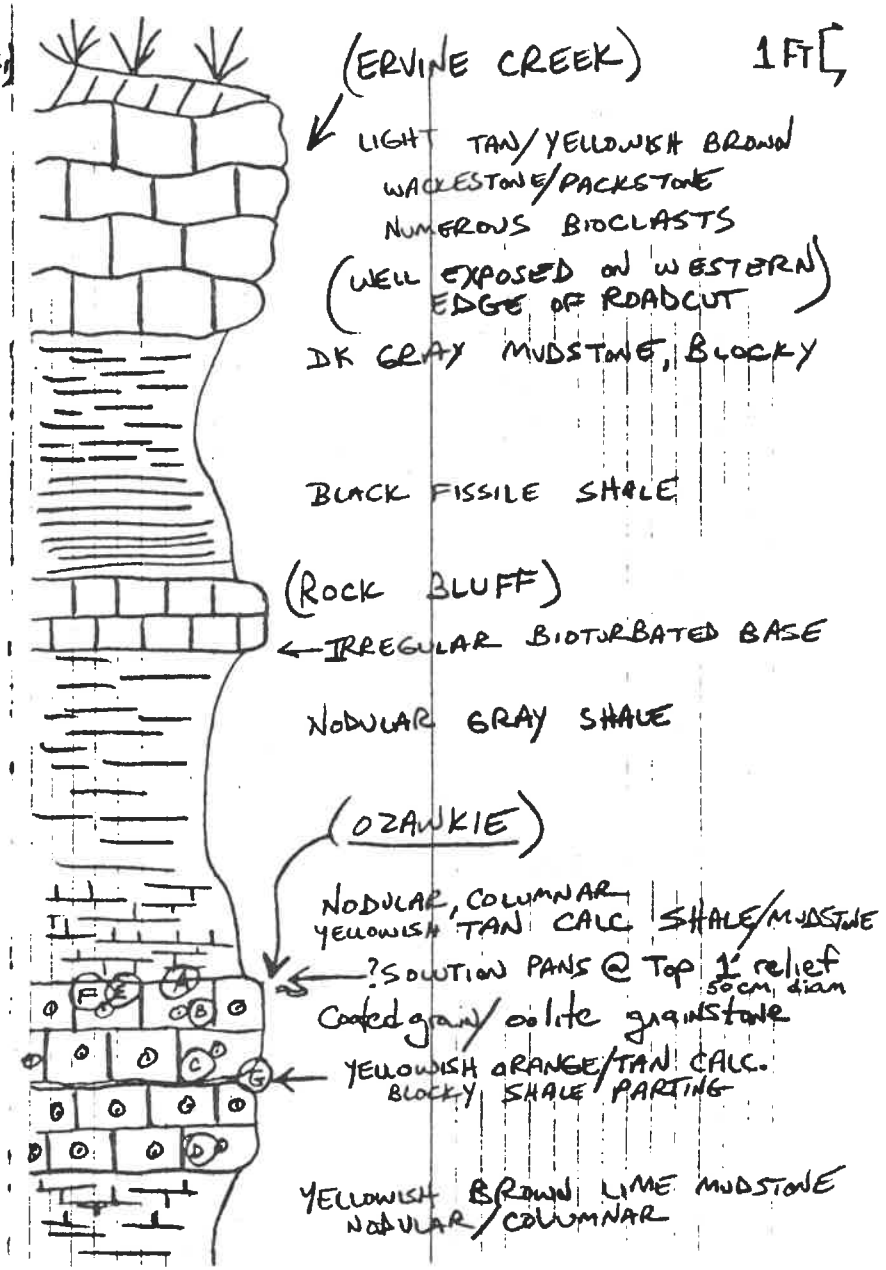
ALLOCHEMS = COATED FOSSILS, OOIDS, PELOIDS
0.5 → 6.0 mm diam, POORLY SORTED
FINE UPWARD (1.5 → 20 cm PACKAGES)

AUTOCLASTIC BRECCIA-FILLED CAVITIES (UP TO 23 CM IN RELIEF)

TAPERING SPAR-FILLED CAVITIES (? ROOT TUBES) 1.mm avg. diam.

OWZ becomes thicker to the North, pinches out towards South ? (large lense configuration)

((MANY Measured Samples collected)) for thin section work = (samples)



ROADCUT, N. SIDE OF KANSAS TURNPIKE (I-70)
SE 1/4, SW 1/4, SE 1/4, SEC 16
T12S, R18E, DOUGLAS CO., KS

FAUNA: BELLEROPHONTID GASTROPODS, PELECYPODS, NAUTILOIDS, CRINOID FRAGS, BRACHS (PRODUCTIDS), FUSULINES, BRYOZOANS, COELENTERATES, TRACES

* GRAINSTONE ? CROSSBEDDED ?
BRECCIA-FILLED MICROKARST &
?SOLN. PANS W/ ESCAPE TUBES
OCCUR AT THE OWZ TOP
(BOTH INTERVALS)

FOSSILS AT TOP ARE COATED W/
IRON ENCRUSTATION

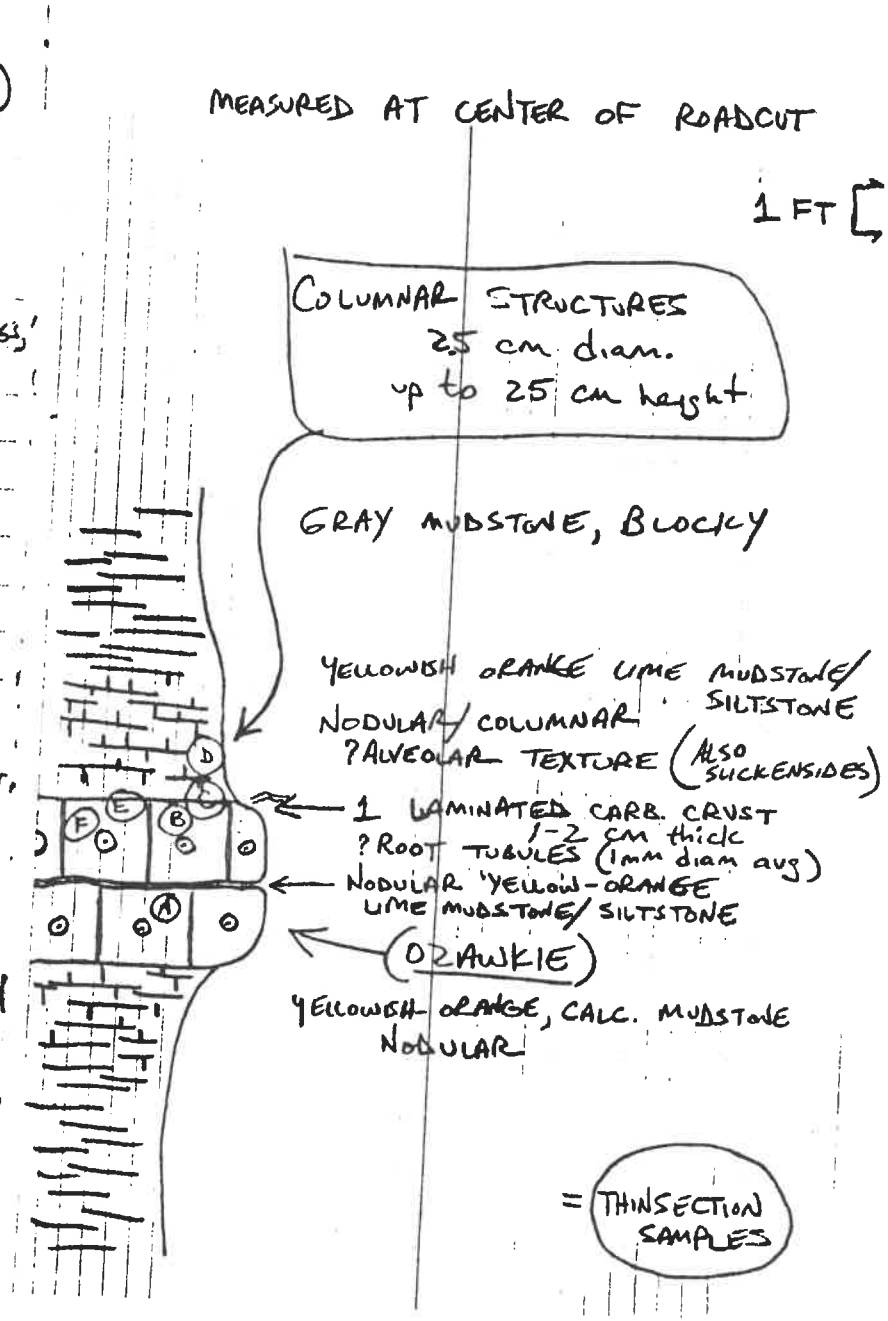
AUTOCLASTIC BRECCIA-FILLED CAVITIES } ?PALEOKARST,
SOLN PAN ALSO OCCURS } 2-25 cm relief
AT BASE OF SHALE PARTING/
TOP OF LOWER INTERVAL OF
OWZ LS

LIME MUDSTONE NODULES (1-15 cm diameter)
OCCUR IN GRAINSTONE FACIES

SMALL black pebbles (2 mm diam) occur
in Oskaloosa IN calc. intervals

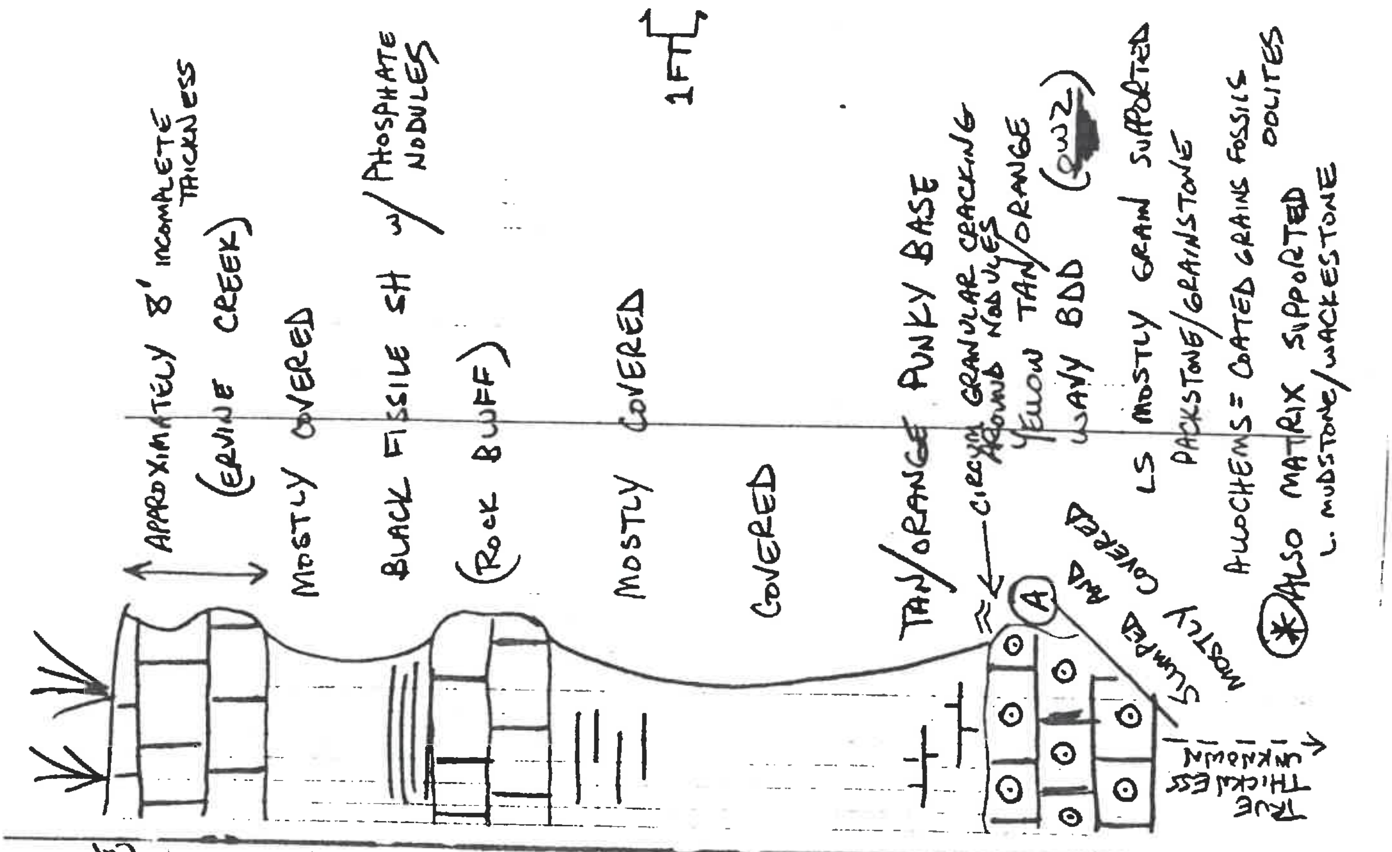
MEASURED AT CENTER OF ROADCUT

1 FT



= THINSECTION SAMPLES

LOCALITY DG 2



EASTERN EDGE OF ROADCUT IN DRAINAGE,
NORTH SIDE OF KANSAS TURNPIKE
SE 1/4, SE 1/4, SW 1/4, SEC 6, T12S, R17E,
SHAWNEE CO., KS
(GRANTVILLE 7.5' QUAD)

= thin section sample

OWZ IS SANDY/CLASTIC-RICH
IN SOME HORIZONS
OWZ CAN ALSO BE LIME MUDSTONE-RICH

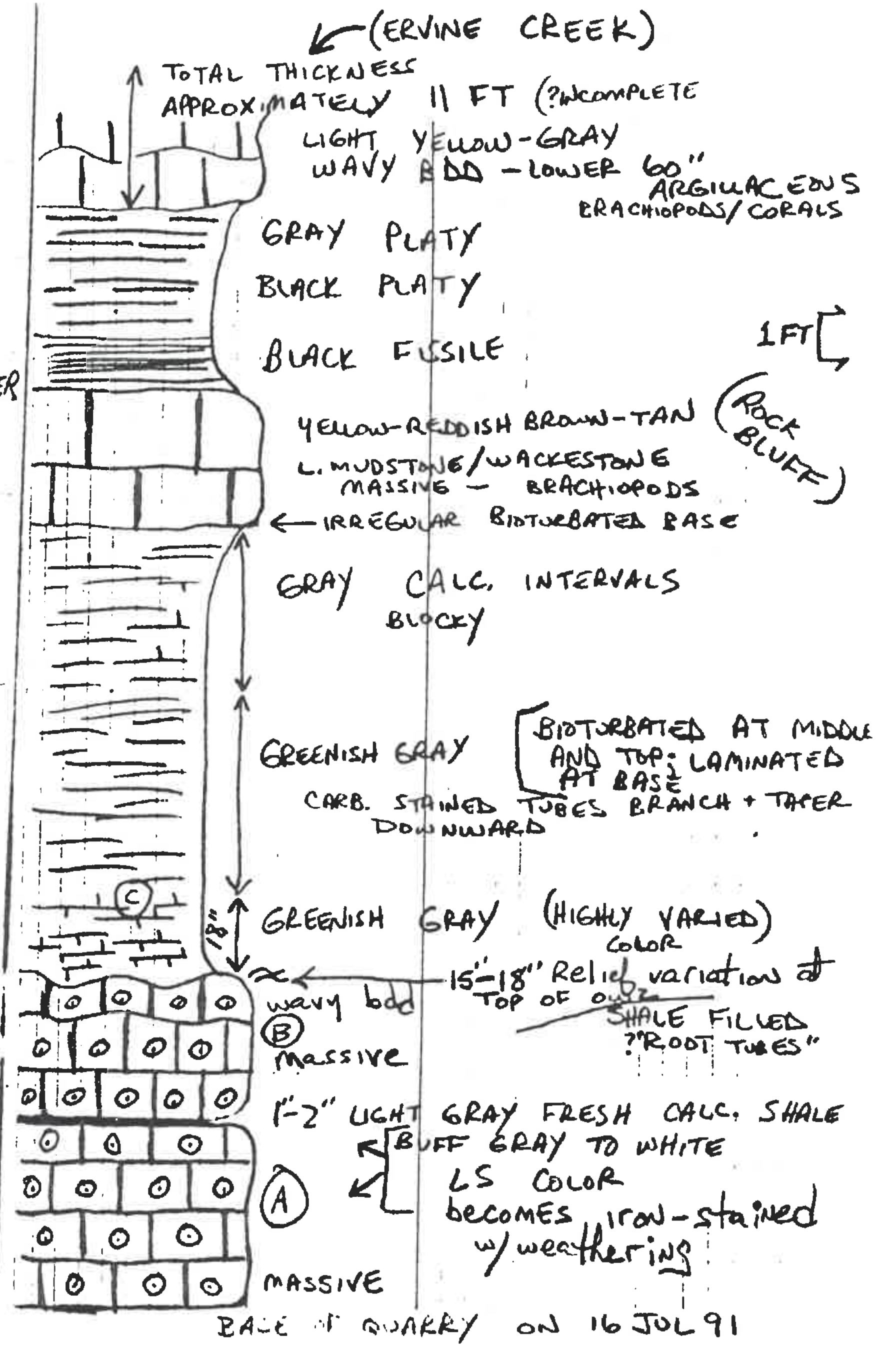
LOCALITY SH 2

NORTH FACE OF QUARRY
NW 1/4 SEC 7 T12S R17E
SHAWNEE COUNTY KS
(GRANTVILLE 7 1/2' QUAD)

- VISITED LOCALITY w/ PAUL ENOS
  VISITATION ARRANGED BY DENNIS BARKER
  QUARRY OPERATED BY
  MARTIN MARIETTA AGGREGATES
  (913) 379-0599

○ = Samples

- BOTH upper + lower OWZ contains
  mud filled solution features
  (? from water infiltration)
  Features seperated by
  shale break ?2 events



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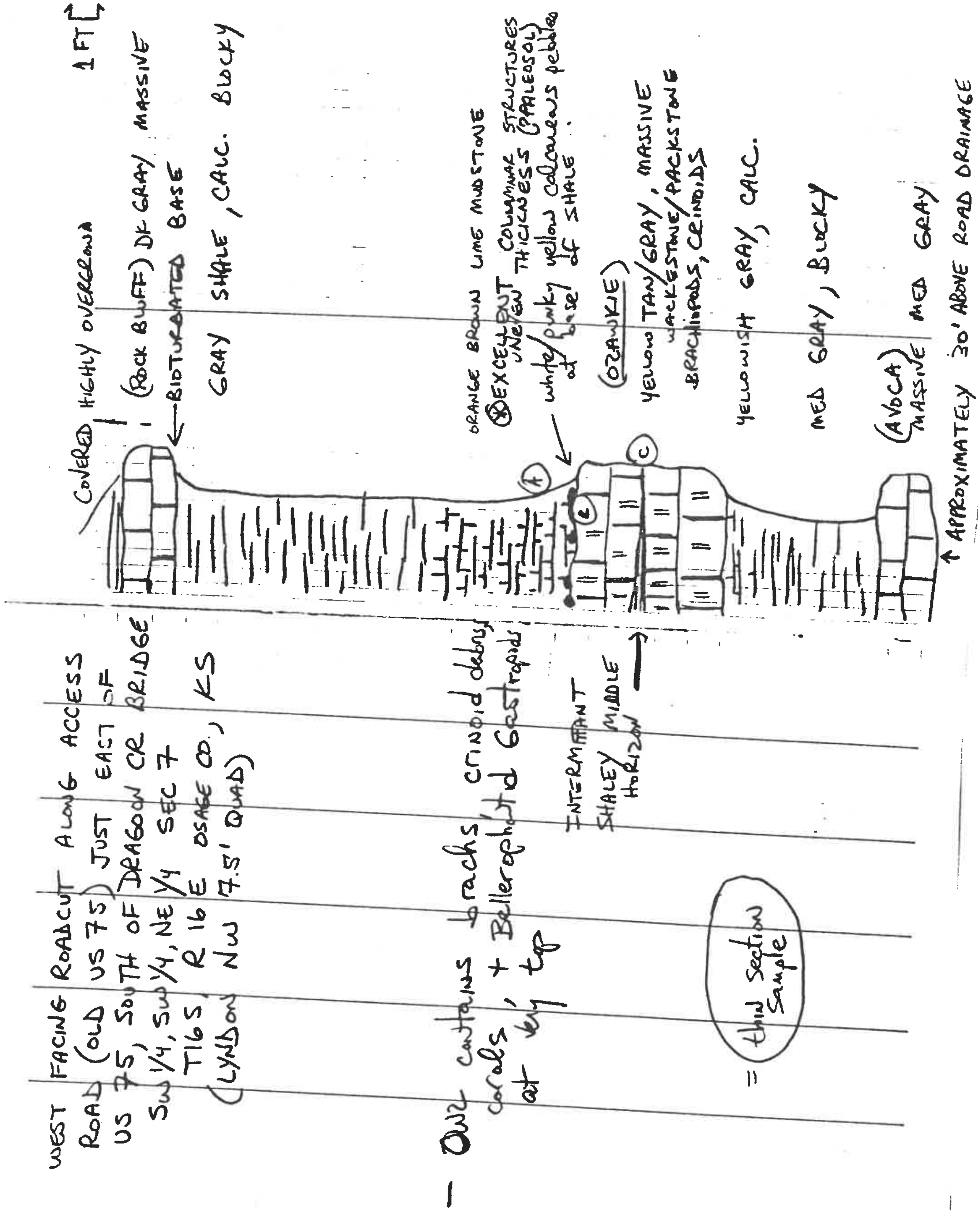
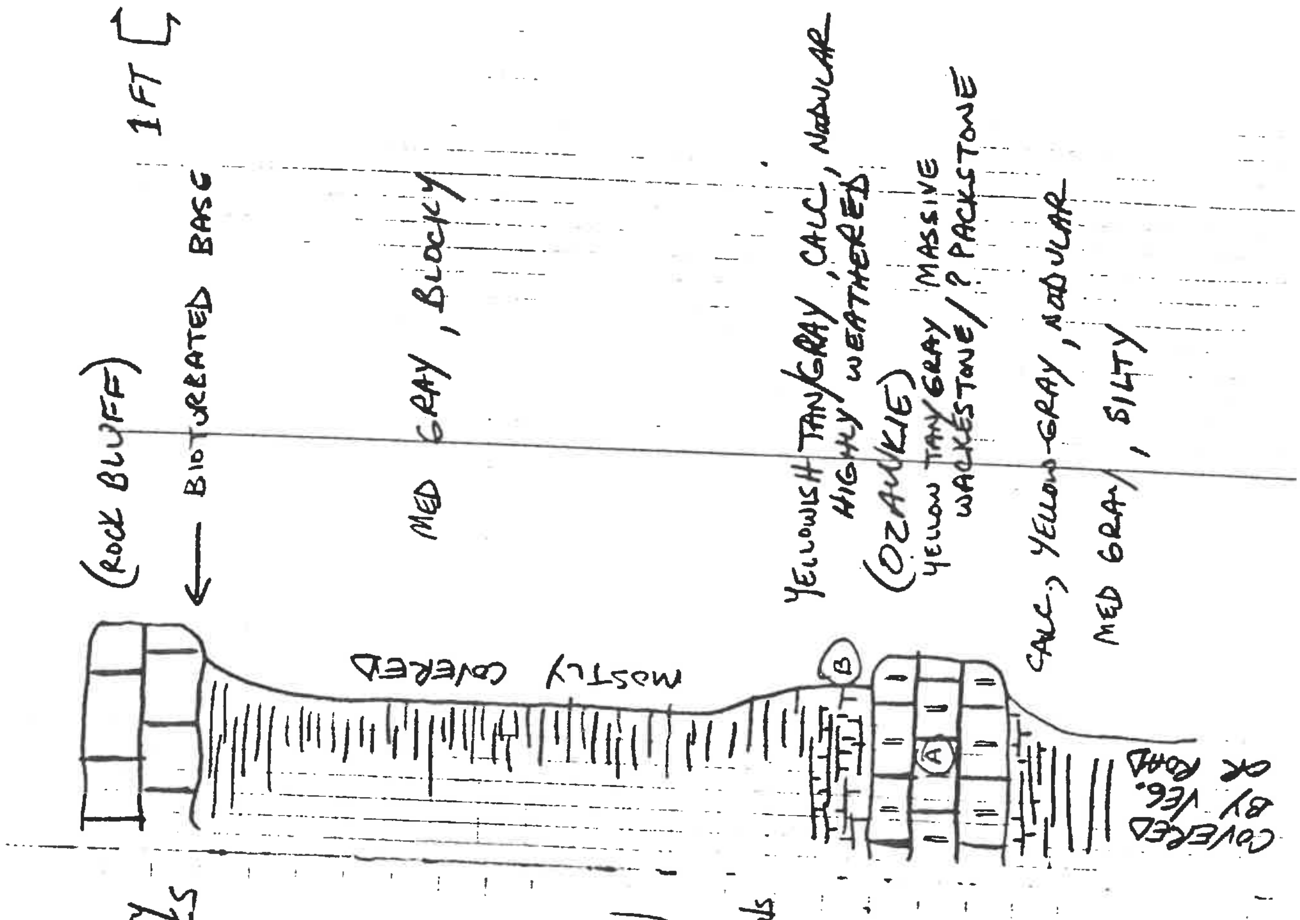
LOCALITY OS 1



Transcribed from audio taped field notes

LOCALITY OS 2

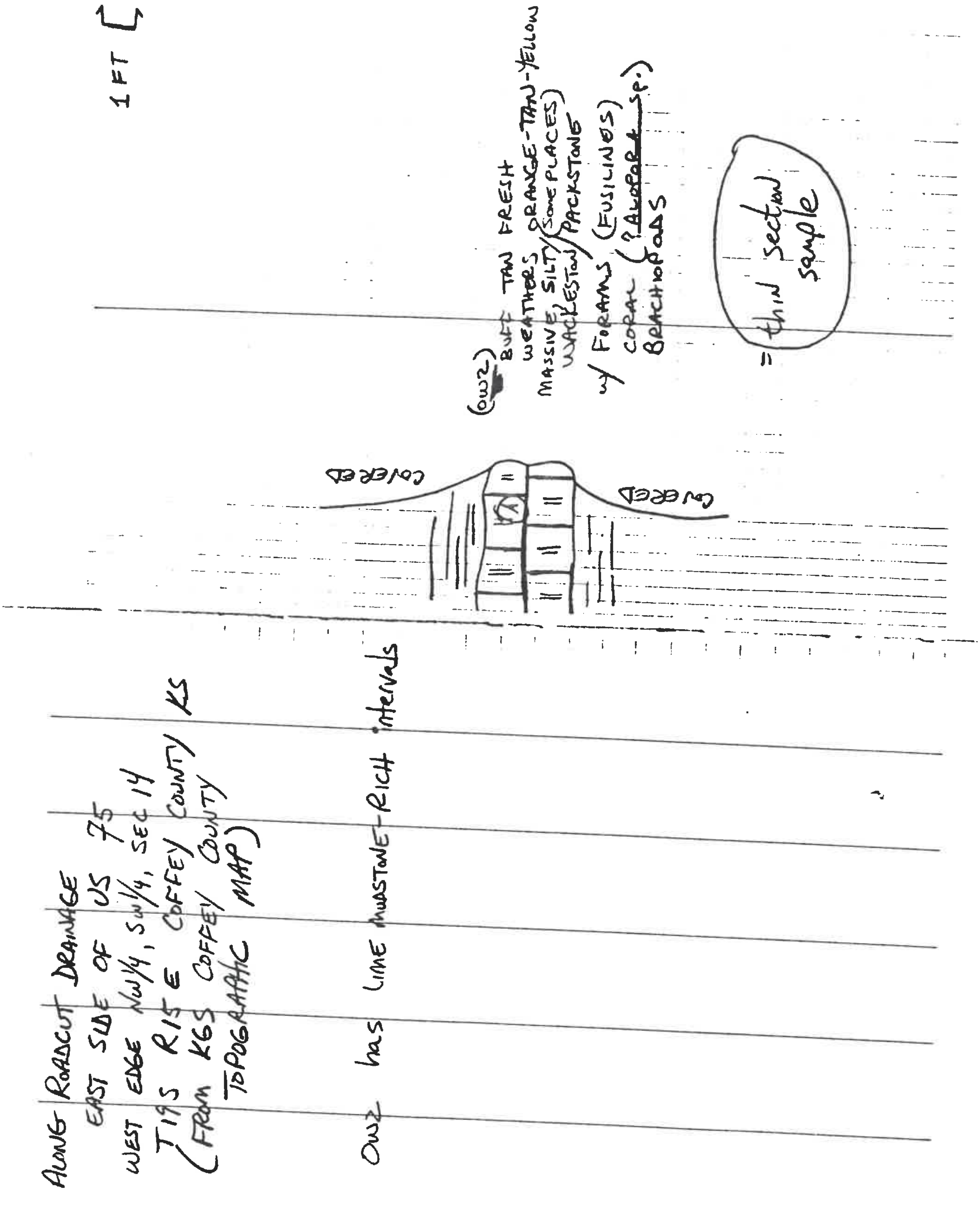


SW 1/4, NW 1/4, SEC 16/17 boundary
T18S, R15E, OSAGE COUNTY, KS
(LEBO 7.5' QUAD)

— BRACHIOPODS, CRINOID DEBRIS common

OW2 has LIME MUDSTONE-RICH intervals

= thin section sample


1 FT
(OWZ) BUFF TAN FRESH
WEATHERS ORANGE-TAN-YELLOW
MASSIVE, SILTY/(SOME PLACES)
WACKESTONE/PACKSTONE
w/ FORAMS (FUSILINIDS)
CORAL (?AULOPORA sp.)
BRACHIOPODS
= thin section sample
COVERED
COVERED
ALONG ROADCUT DRAINAGE
EAST SIDE OF US 75
WEST EDGE NW1/4, SW1/4, SEC 14
T19S R15E COFFEY COUNTY KS
(FROM KGS COFFEY COUNTY
TOPOGRAPHIC MAP)
OWZ has lime mudstone-rich intervals

KANSAS GEOLOGICAL SURVEY

1930 Constant Ave., Campus West
The University of Kansas
Lawrence, Kansas 66046-2598
913-864-3965

MEMORANDUM

TO: AL ROBB

FROM: DAVE GRISAFE

SUBJECT: ACTIVE AND ABANDONED QUARRIES CONTAINING OZAWKIE LS

DATE: APRIL 11, 1991

COUNTY	LOCATION	COMMENTS
DOUGLAS	NONE	
JEFFERSON	NW 05-10-19E	6 FT
	NE 10-11-18E	5 FT
	NW 11-11-18E	NO INFO GIVEN
	16-11-17E	5 FT
	NW 15-11-17E	5 FT ACTIVE QUARRY
	ALSO POSSIBLE: DEER	CREEK FM LISTED FOR
	SW 22-09-17E	9 FT ?ERVINE CK?
	SE 20-09-18E	NO INFO GIVEN
OSAGE	SW 07-16-16E	10-17 FT, LISTED AS OZAW. ?IMPROPER IDENTIFICATION? ERVINE CK?
SHAWNEE	SW 07-12-17E	7.5 FT ACTIVE QUARRY
	NW 18-12-17E	7 FT SAME QUARRY

The above are the only locations listing the Ozawkie Ls in our active and abandoned files. Most of the quarries listing the Deer Ck Fm were for the thicker Ervine Ck Ls Member.

Hope this information willbe useful to you.

APPENDIX D