Guidebook 33

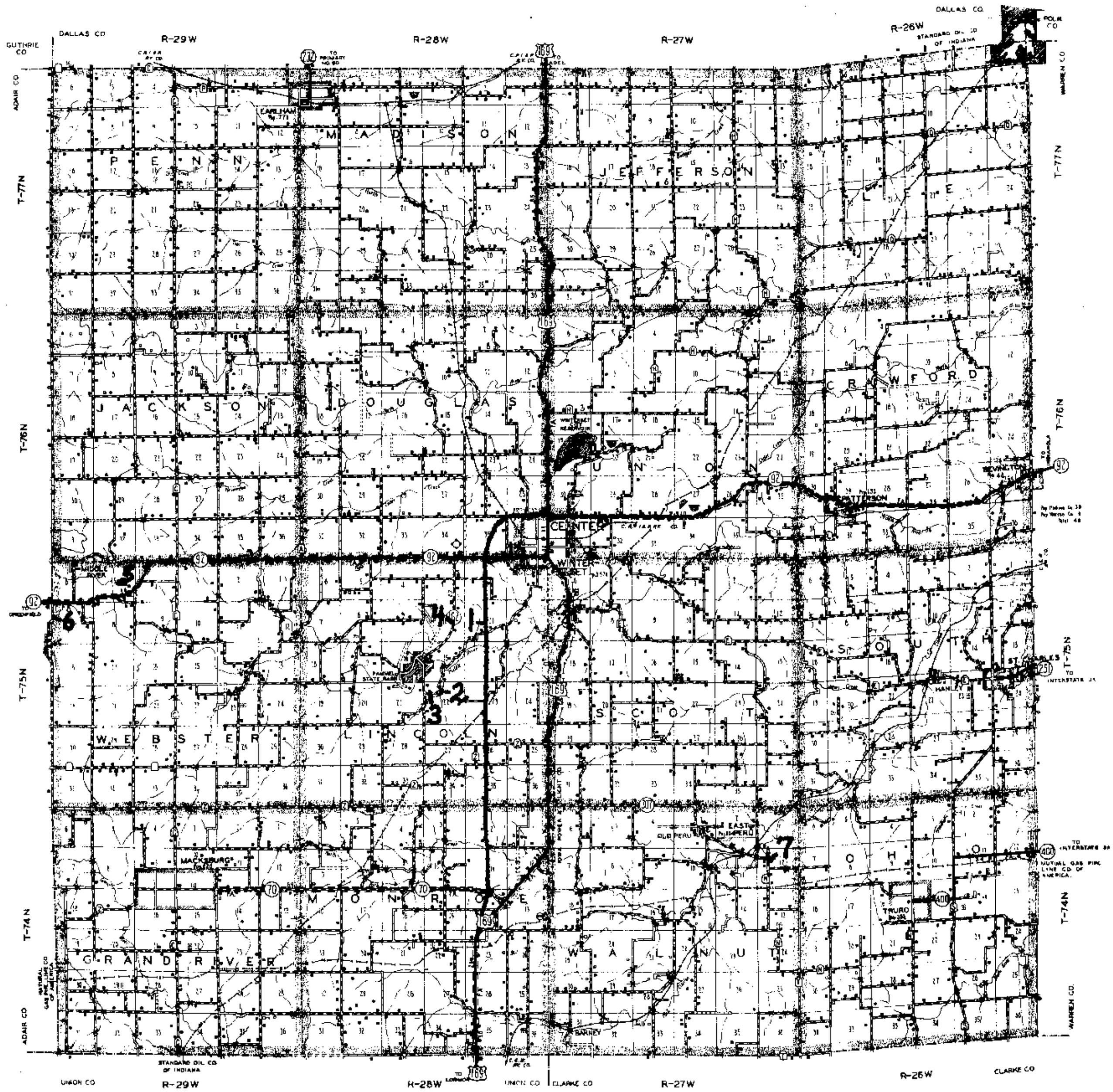
FIELD GUIDE

TO

UPPER PENNSYLVANIAN CYCLOTHEMS

IN

SOUTH-CENTRAL IOWA



A field trip along the Middle River Traverse, Madison County, Iowa

April 20, 1980

Led by P. H. Heckel, Department of Geology, The University of Iowa

Sponsored by the Geological Society of Iowa

Iowa City, Iowa

FIELD GUIDE TO UPPER PENNSYLVANIAN CYCLOTHEMS IN SOUTH-CENTRAL IOWA

Philip H. Heckel
Department of Geology
The University of Iowa, Iowa City

INTRODUCTION

Nearly 12 years have elapsed since the last formal field trip (Welp et al., 1968) visited the Upper Pennsylvanian rocks along the "Middle River Traverse" of south-central Iowa. Since then, systematic mapping of outcrops in this area (Stark, 1973) has increased confidence in local correlation and identification of most of the sequence exposed in the Madison County portion of the traverse. Also, progress has been made in understanding both the vertical cyclic lithic sequence of Midcontinent Upper Pennsylvanian deposits and the regional lateral variations of the units along the entire outcrop. As a result, their depositional history has been interpreted in terms of a succession of sedimentary environments that are reasonable in light of modern processes of deposition (Heckel and Baesemann, 1975; Heckel, 1977; Heckel, 1980). Recent field trips to the Pennsylvanian outcrop of eastern Kansas and southeastern Nebraska have illustrated these depositional interpretations of the vertical sequence for many Upper Pennsylvanian units in those areas (Heckel, 1978; Heckel et al., 1979). The present trip will visit all formations of the Missourian Stage (lower division of the Upper Pennsylvanian Series) along the Middle River Traverse in the vicinity of Winterset, Madison County, Iowa, in order to show application of the modern depositional interpretations to the vertical cyclic sequences exposed in this area.

GEOLOGIC SETTING

Upper Pennsylvanian bedrock geology of south-central Iowa is characterized by an alternation of laterally persistent limestones from 3 to 10 m thick and containing thin shale beds, with laterally persistent thicker sandy shales from 2 to 10 m thick and containing local sandstones and coals. These rocks strike generally south-north near the Missouri border, and swing toward the northwest around Winterset to an east-west strike westward toward Council Bluffs (Fig. 1A). Regional dip is toward southwestern Iowa.

Several problems have complicated understanding of Pennsylvanian stratigraphy and structure of south-central Iowa: 1) Most exposures are so isolated from one another by thick Pleistocene cover that stratigraphic relations typically are impossible to determine without drilling to discover more of the local vertical sequence. 2) So many of the formations resemble one another so closely in vertical lithic sequence that it is difficult to distinguish one from another in isolated exposures. 3) Local variations in dip and strike known for some time (e.g. in northeastern Adair County; see Welp and others, 1968, p. 4-1) have confounded attempts to correlate between nearby isolated exposures by means of projecting elevations. The combination of all these problems has led to a large number of questionable and controversial correlations, which are just beginning to be resolved. In fact, even in as long studied an area as the Middle River Traverse, a long-standing misidentification of the Stanton Formation for the Oread Formation (lower Virgilian Stage, above the Missourian) in western Madison County has only recently been corrected through detailed study of conodonts (von Bitter and Heckel, 1978).

THE BEDFORD CORE

A long core through the lower two-thirds of the Upper Pennsylvanian sequence, including the entire Missourian Stage, was taken near Bedford, Taylor County, Iowa, just north of the Missouri border, by the State Highway Commission. Recently acquired by the Iowa Geological Survey, this core affords the most complete sequence of Upper Pennsylvanian rocks known from this part of the Midcontinent outcrop. It is now under intensive study by the Department of Geology of The University of Iowa, in cooperation with the Iowa Geological Survey, in order to establish a standard reference section for Upper Pennsylvanian rocks of south-central Iowa and adjacent regions. Detailed studies of the vertical lithic sequence and its depositional interpretation, in conjunction with studies of the succession of conodont and fusulinid faunas, are expected to form a basis for sorting out correlations of isolated exposures in south-central Iowa and for resolving possible miscorrelations between the better known complete sequences of southeastern Nebraska and eastern Kansas (see Heckel and others, 1979, p. 52). A graphic measured section of the lower half of the Bedford core, with probable correlations to the standard Kansas sequence indicated by formation and member names, is shown in Figure 1B.

NOMENCLATURE

Most nomenclature of formations and members of the Iowa Upper Pennsylvanian is derived from the better known sequence of eastern Kansas for the Missourian Stage and from both eastern Kansas and southeastern Nebraska for the uppermost Missourian and overlying Virgilian Stage. Of the two names derived from Iowa, the Winterset Limestone is correlated southward with confidence, but the type Westerville Limestone of Iowa is correlated much less certainly with what is called Westerville in Kansas. The basic scheme of nomenclature was fashioned by R. C. Moore (1936) in Kansas to accomodate both the remarkable vertical repetition of certain distinctive limestone and shale units throughout most of the sequence and the remarkable lateral persistence of many of these units, some of them members less than 1 m thick, for hundreds of miles along outcrop from eastern Kansas to Iowa and Nebraska.

CYCLOTHEMS

The vertical repetition of distinctive lithologies in a definite sequence was recognized in Kansas by Moore (1931) and incorporated into his (1936) nomenclatural scheme in terms of cyclothems and megacyclothems. Moore's ideas on cyclothems in Kansas have been summarized by Heckel and others (1979, p. 11-13), and the voluminous literature on interpretation of Midcontinent Pennsylvanian cyclothems in general has been summarized by Heckel (in press) for the recent Ninth International Carboniferous Congress. The basic "Kansas cyclothem" of Heckel (1977) is interpreted as a single transgressive-regressive sequence nucleated around the limestone formations and is applicable also to the Iowa section. It comprises the following ascending vertical sequence (Fig. 2): 1) thick nearshore sandy ("outside") shale (top of underlying shale formation, 2) thin transgressive ("middle") limestone, 3) thin offshore ("core") shale (typically with phosphatic black facies), 4) thick, regressive ("upper") limestone, and 5) thick, nearshore sandy shale again (base of overlying shale formation). The "lower" limestone of Moore's old megacyclothem classification is known only from the Shawnee Group of the lower Virgilian. His "super" limestone is in most cases a shoal-water facies of the regressive limestone separated from the "upper" limestone by a fortuitous shale bed. In a few cases (e.g., South Bend on Fig. 1B), the "super" limestone is part of a higher cycle separated by an abnormally thin nearshore shale.

A. Midcontinent Missourian Outcrop Belt

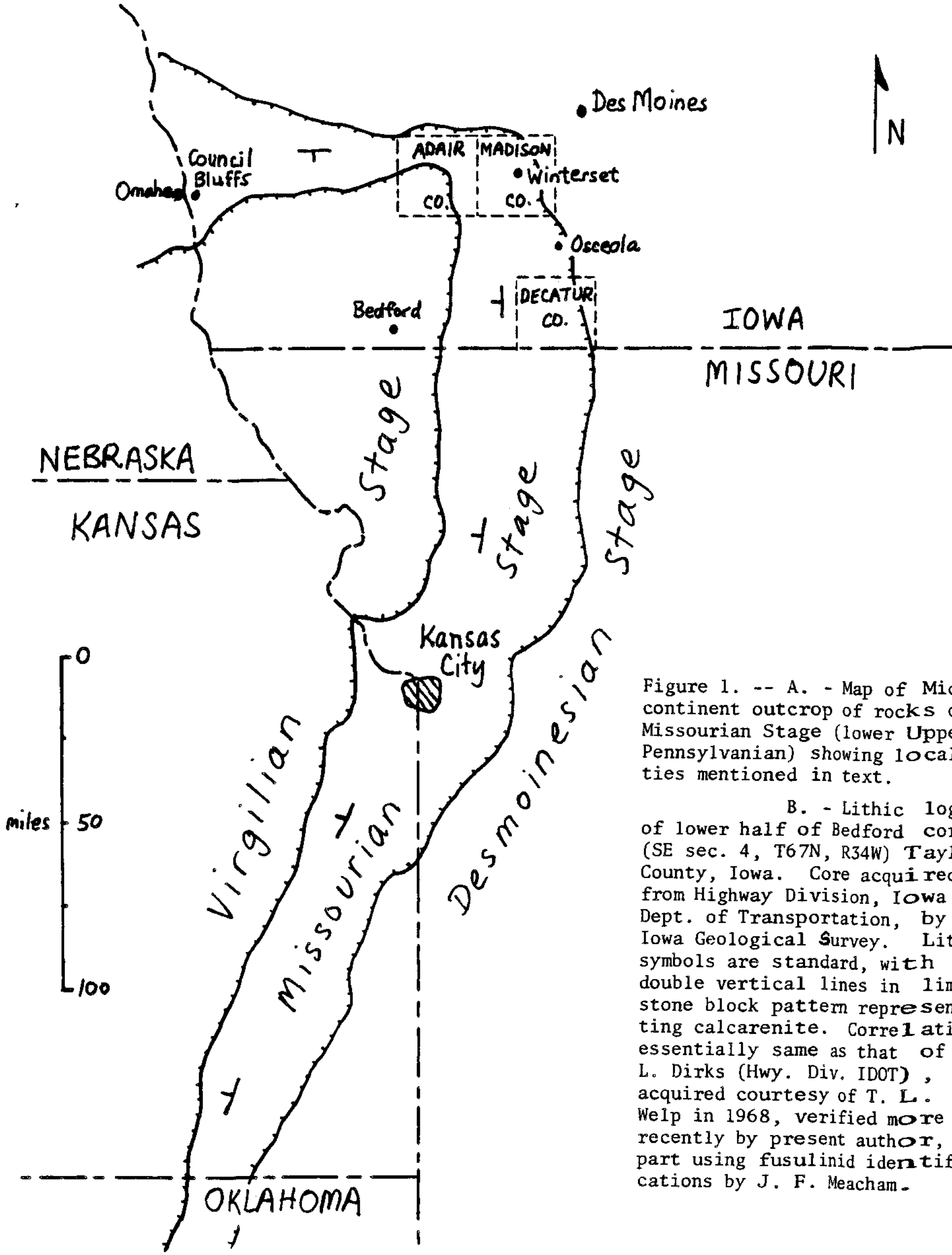
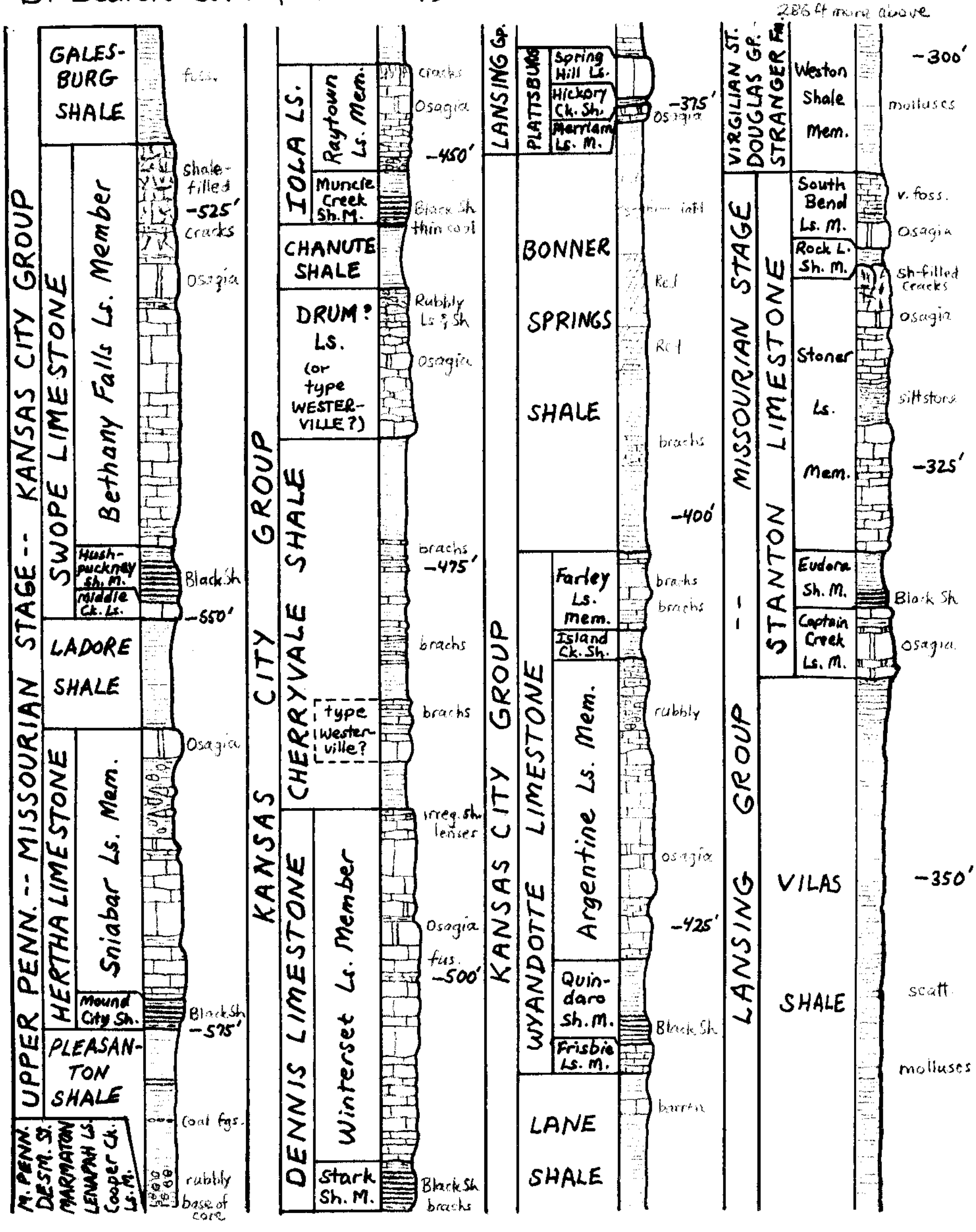


Figure 1. -- A. - Map of Midcontinent outcrop of rocks of Missourian Stage (lower Upper Pennsylvanian) showing localities mentioned in text.

B. - Lithic log of lower half of Bedford core (SE sec. 4, T67N, R34W) Taylor County, Iowa. Core acquired from Highway Division, Iowa Dept. of Transportation, by Iowa Geological Survey. Lithic symbols are standard, with double vertical lines in limestone block pattern representing calcarenite. Correlation essentially same as that of K. L. Dirks (Hwy. Div. IDOT), acquired courtesy of T. L. Welp in 1968, verified more recently by present author, in part using fusulinid identifications by J. F. Meacham.

B. Bedford core (lower half)



ENVIRONMENTAL INTERPRETATION OF CYCLOTHEMS

Depositional environments are interpreted for the basic Kansas cyclothem of Heckel (1977), with comments on major facies changes observed along the Midcontinent outcrop belt (Fig. 3).

Nearshore shales. -- Nearshore shales are the shale formations that alternate with limestone formations in the cyclic sequence. Because these shale formations lie "outside" the "bundles" of limestones and thin shales that constitute the limestone formations, these shale portions of the cyclothem were termed "outside shales" in a positional sense before their depositional significance was thoroughly established.

Nearshore shales are typically sandy and variable in thickness. Although some are thin (1 to 2 m), particularly in Iowa and Nebraska, most are generally thick, often attaining 10 m and locally 40 m in Kansas. Commonly they contain thin layers of siltstone and sandstone carrying macerated plant fragments and only a sparse marine fauna of low diversity. They locally contain deposits that are demonstrably nonmarine, such as coals with underclays, shales with well preserved land plant fossils, and channel sandstones, all lacking marine fossils. They are the units within which Wanless and his co-workers (e.g., 1970) have mapped many deltaic sequences in the Midcontinent.

A deltaic depositional model of abundant detritus prograding into the shallow sea readily accounts for the characteristics of most of these shales. Each delta lobe eventually became abandoned as new distributaries formed shorter routes to the sea and started prograding younger lobes in different places. Variations in thickness of the nearshore shales reflect the local nature of each delta lobe. The nonmarine deposits record the subaerial deltaic plain. The rocks with sparse marine fossils of low diversity record prodelta environments where rapid deposition, increased turbidity, and fluctuating salinity reduced both abundance and diversity of marine organisms.

Southward, nearshore shales tend to thin over thickened portions of underlying limestones; then most thicken substantially in the Kansas-Oklahoma border region where they constitute proportionally greater amounts of the sequence (Fig. 3) as they approach a major deltaic detrital source in Oklahoma.

Most nearshore shales tend to thin northward into Iowa and Nebraska away from the major directions of detrital influx. Parts of some become more abundantly and diversely fossiliferous, reflecting a marine environment with less detrital influx and attendant unstable conditions. Others become unfossiliferous blocky mudstone, sometimes with a thin overlying coal, and appear to represent soil profiles either within a deltaic sequence or directly upon the underlying limestone. Some of these are red in color, which indicates long enough subaerial exposure for complete oxidation and dehydration of iron minerals, as seen in the Bedford core (Bonner Springs shale) and on outcrop (Vilas Shale).

Transgressive limestones. -- Transgressive limestones are the thin (0.1 to 1.0 m), dense, dark skeletal calcilutites denoted as the "middle" limestone of Moore's megacyclothem. They carry a diverse and a relatively abundant marine biota comprising all the major phyla, including algae, although fossils do not seem abundant on outcrop because of the denseness of the rock and lack of shale partings. Fine grain size and diverse biota indicate deposition in the open marine environment far enough offshore to be below effective wave base, but above effective base of the photic zone. Where shoal-water facies are present with the skeletal calcilutite, they are only at the base, as seen in the basal calcarenite of the Stanton Formation in the Bedford core.

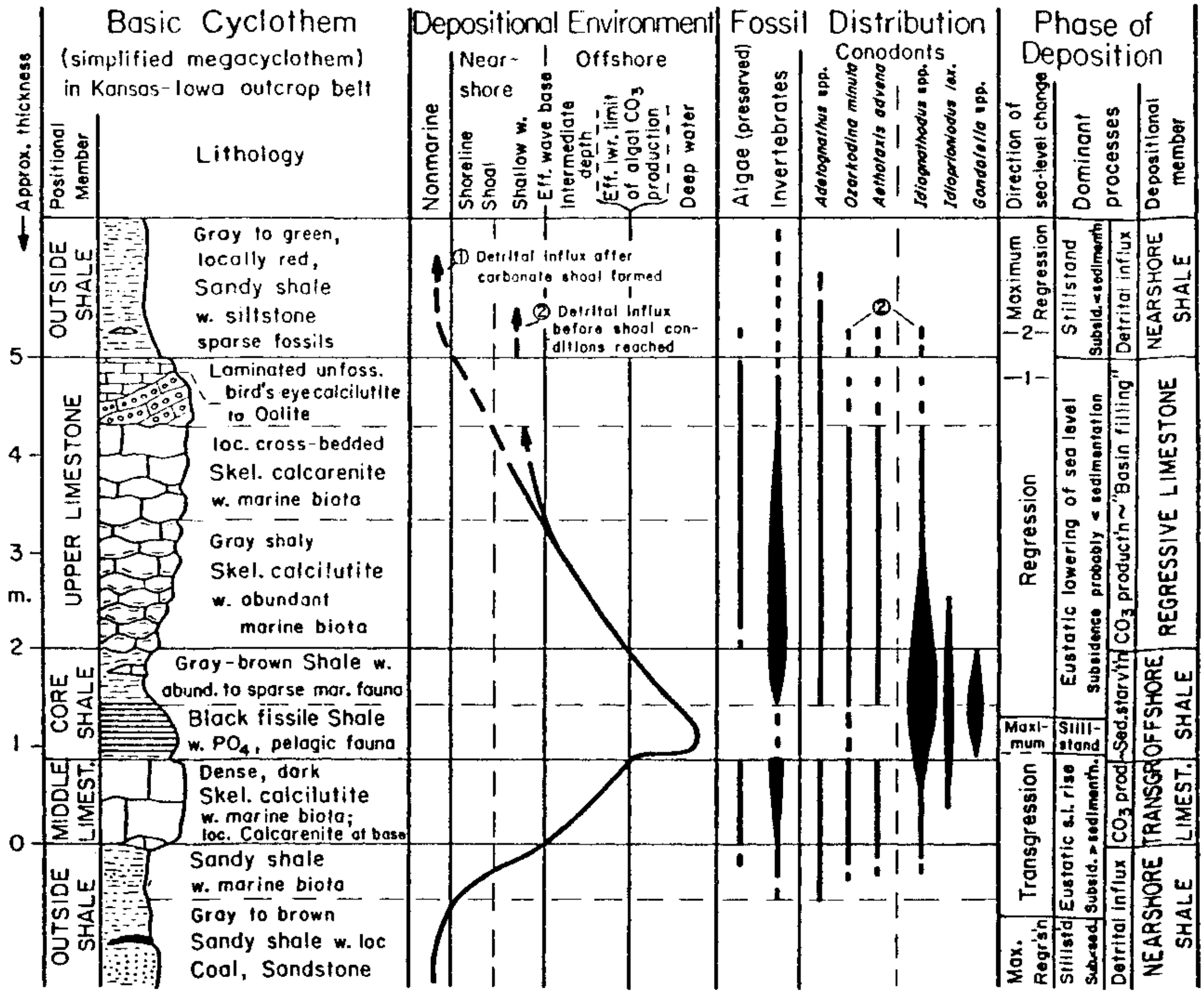


Fig. 2. -- Basic vertical sequence of individual "Kansas cyclothem," the transgressive-regressive depositional unit characterizing, with only minor modification, most of the Missourian and lower Virgilian sequence of the Midcontinent Pennsylvanian. Positional terms derive from Moore (1936) for limestones and Heckel and Baesemann (1975) for shales. Conodont faunas conspicuously differentiate the two shale members. (From Heckel, 1977, Fig. 2).

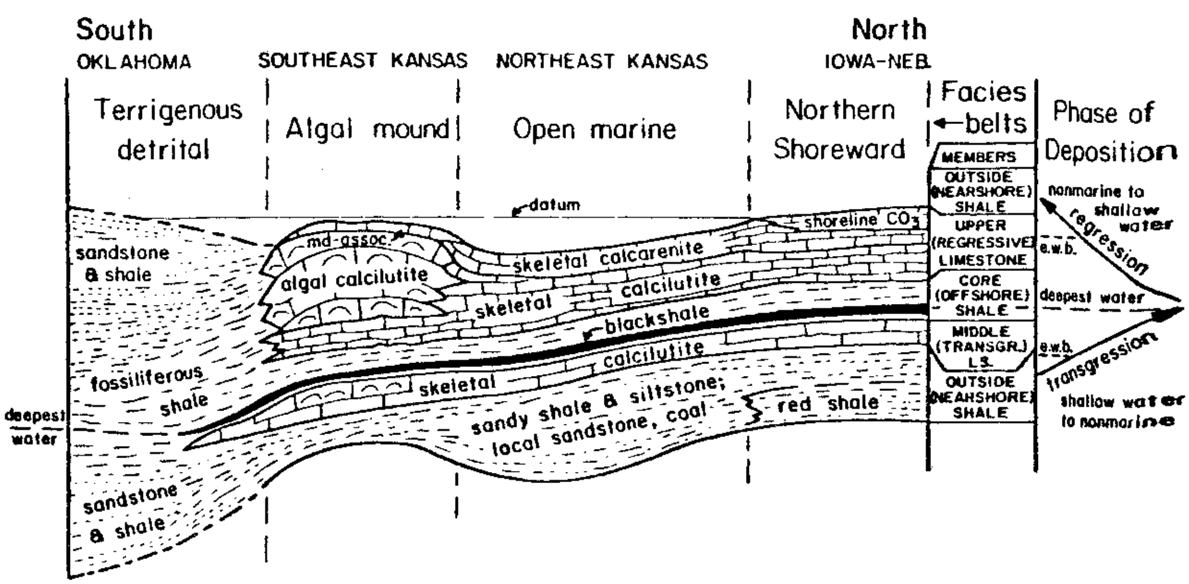


Fig. 3. -- Basic pattern of facies change within Kansas cyclothem across facies belts along Midcontinent Pennsylvanian outcrop (Fig. 1A). Datum is interpreted sea level when increased detrital influx ended deposition of regressive limestone. (From Heckel, 1977, Fig. 4).

Aside from a few that thicken with increase in phylloid algae content in southeastern Kansas, transgressive limestones undergo little lateral facies change, yet several extend laterally for hundreds of miles along outcrop. Thus transgressive limestones generally record widespread marine inundation of the Midcontinent, with carbonate sedimentation mainly at depths below effective wave base where minor variations in topography on the underlying delta lobes had little influence over facies. Absence of transgressive limestones in certain cycles in Iowa (Fig. 1) indicate that the thin blanket of lime mud was not as continuous in these cycles as in others.

Offshore shales. -- Offshore shales are the thin (0.3 to 2.0 m), laterally persistent, nearly nonsandy, gray to black marine shales that lie between the "middle" and "upper" limestone members within limestone formations. These were termed "core shales" by Heckel and Baesemann (1975) because of their central position within the megacyclothem. The typical black fissile facies is rich in organic matter and generally contains nodules and laminae of nonskeletal phosphorite and relatively high concentrations of certain heavy metals. The black facies lacks definitely benthic fossils, carrying mainly conodonts in great abundance, fish remains, orbiculoid brachiopods and a few other fossils reasonably inferred to have been pelagic or epipelagic. The gray facies typically carries only a sparse macrofauna of several benthic invertebrate groups, including echinoderms and articulate brachiopods, often in addition to those fossils found in the black facies. Only away from the black facies do offshore shales carry abundant and diverse macrofossils. Like transgressive limestones, offshore shales also change laterally very little along the entire length of the outcrop. Those that lose the black facies laterally, in general retain phosphate nodules and abundant conodonts in the otherwise sparsely fossiliferous gray facies (e.g. in the Iola and Stanton above thickened underlying units in southeastern Kansas).

Thinness in conjunction with great lateral persistence, fineness of detrital grain size, presence of marine fauna, great abundance of conodonts and conspicuous nonskeletal phosphorite all point to very slow sedimentation away from detrital influx, far offshore in deeper water. Presence of abundant organic matter along with lack of benthic fossils indicates anoxic bottom conditions for the black facies. Lack of bottom oxygen in conjunction with very high concentrations of phosphate and heavy metals is explained as the result of a two-layered quasi-estuarine circulation cell in the Midcontinent sea (Fig. 4), established when water became deep enough for a thermocline to form above the bottom and prevent replenishment of bottom oxygen by vertical circulation. Surface water blown out of the sea by prevailing Pennsylvanian trade winds (Fig. 5) was replaced by upwelling of deeper phosphate-rich water of the oxygen-minimum zone, drawn in below the thermocline from intermediate depths of the open ocean. Nutrients brought into the photic zone by this upwelling promoted immense blooms of plankton, which settled back into the incoming lower water layer. Decay of this phytoplankton depleted the bottom water of already low oxygen, continually enriched it in phosphate (as well as heavy metals that organisms concentrate), and ultimately caused deposition of unoxidized organic matter and conspicuous phosphorite on the sea bottom, along with little other sediment, to produce the phosphatic black facies.

Similar circulation that enriched phosphate but did not deplete all bottom oxygen accounts for the sparsely fossiliferous gray facies with phosphorite nodules. Merely far offshore deposition, probably below the effective limit of algal production of carbonate mud, but without persistent establishment of the oxygen-depleting quasi-estuarine circulation cell, accounts for the more abundantly and diversely fossiliferous gray facies of the offshore shale.

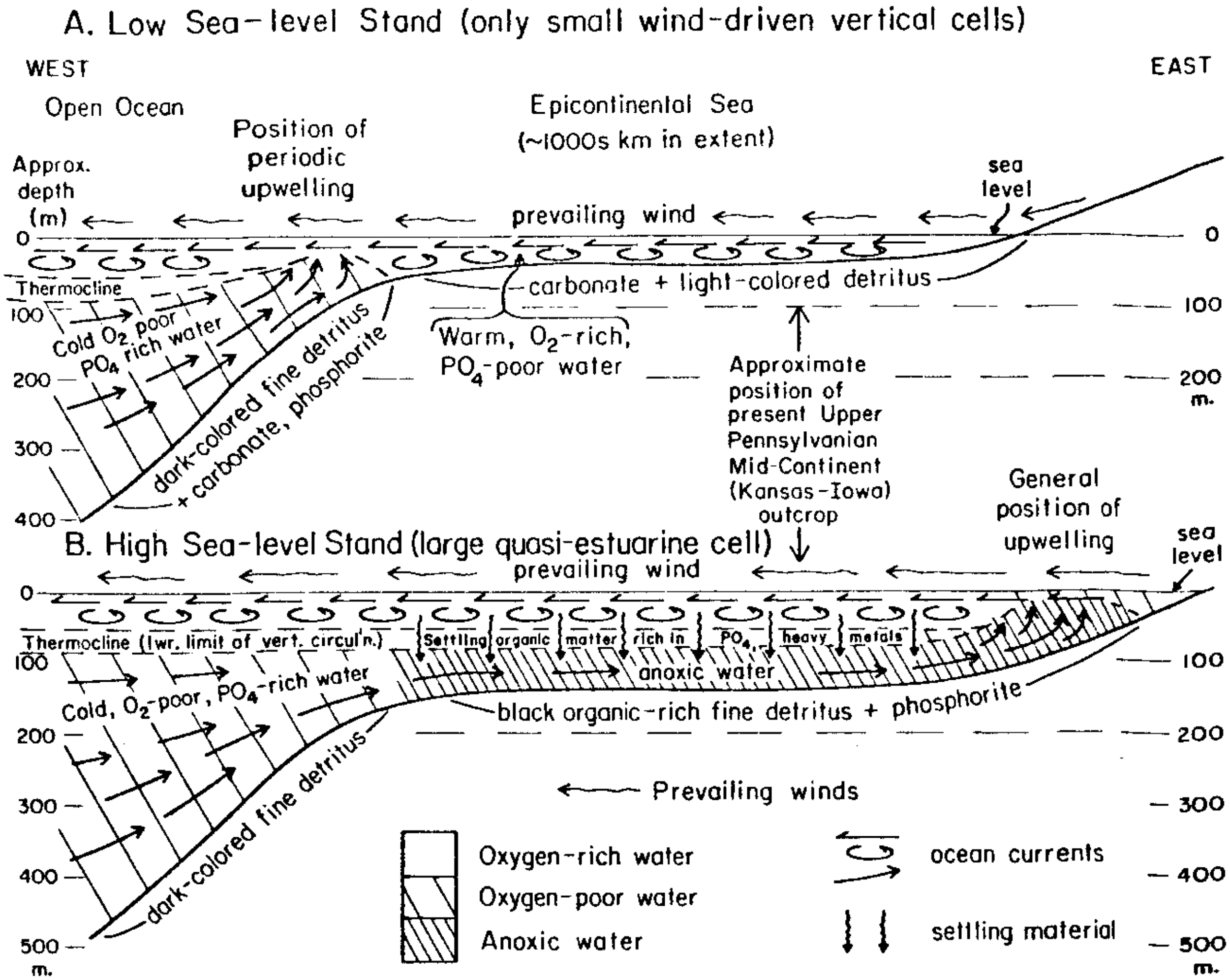


Fig. 4. -- Expected patterns of vertical circulation in west-facing tropical epicontinental sea: A, Low sea-level stand when vertical circulation and algal photosynthesis maintain bottom oxygen; B, High sea-level stand when thermocline allows prevailing trade winds to establish large quasi-estuarine circulation cell, which results in depletion of bottom oxygen and concentration of phosphate. (From Heckel, 1977, Fig. 5).

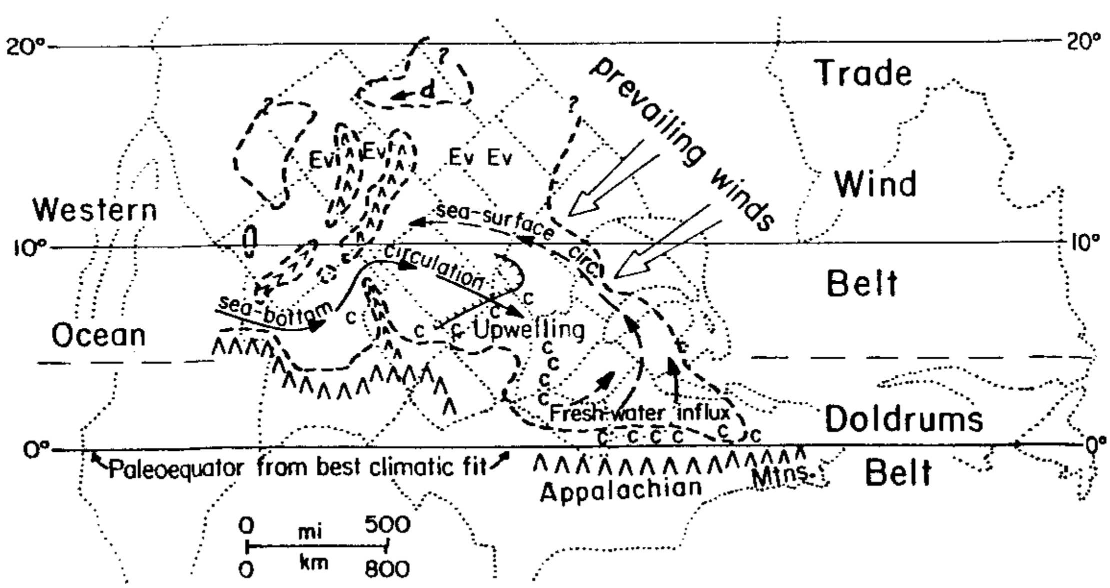


Fig. 5. -- Pennsylvanian paleogeography of North America based on distribution of major coals (c) in ancient doldrums belt, evaporites (Ev) and dune sands (d) in ancient trade-wind belt, and paleomagnetic data. Dashed lines mark maximum transgression when quasi-estuarine cell was operating. (From Heckel, 1977, Fig. 6).

Regressive limestones. -- Regressive limestones comprise the "upper", sometimes with the "super", limestone members of Moores' megacyclothem. They are generally thicker (up to 8 m) than transgressive limestones and contain a greater variety of facies, several of which were described in more detail by Heckel (1968).

The lower parts of regressive limestones consist largely of wavy-bedded, shale-parted to locally shaly, skeletal calcilutite with an abundant and diverse marine biota consisting of all major phyla. Lateral persistence of this facies along outcrop in conjunction with fine-grained lithology and diverse biota indicates that this part of regressive limestones, like most of the transgressive limestones, was deposited offshore below effective wave base but above the lower limit of algal carbonate production.

The upper parts of regressive limestone members display the most conspicuous lateral segregation of facies along the Midcontinent outcrop belt (Fig. 3), as would be expected in shallow water where minor differences in bottom topography produce conspicuous lateral changes in facies.

In northeastern Kansas most regressive limestones grade upward into capping skeletal calcarenites that contain various proportions of abraded algal and invertebrate debris, grains with "osagia" (algal-foraminiferal) coatings, and grains with "micrite envelopes" resulting from algal boring. Although this vertical succession records increasing water agitation and light penetration with time as water shallowed above effective wave base, this facies still records a relatively open marine environment, which defines this portion of the outcrop belt as the "open marine facies belt" (Fig. 3), where such conditions persisted longest during deposition of the regressive limestone.

Northward, nearly all regressive limestones grade upward through osagia-dominated shoal-water calcarenites into unfossiliferous laminated, dolomitic calcilutite, locally with mudcracks, birdseye, and root molds, often filled with overlying shale. This facies records a tidal-flat environment followed by subaerial exposure and plant growth. It defines the "northern shoreward facies belt", which is best developed in Iowa and Nebraska. This facies is present at the tops of most regressive limestones in the Bedford core (Fig. 1B), and can be observed at some exposures on the field trip.

In southeastern Kansas, most regressive limestones thicken as they grade upward into phylloid algal mound facies (Heckel and Cocke, 1969), which defines the facies belt of that name. Mounds consist primarily of algae-dominated skeletal calcilutite, in which large blades of phylloid red and green algae characteristically shelter spar-filled voids. Mound-associated facies, particularly cross-bedded, abraded-grain skeletal calcarenite and oolite, overlie and flank some of the mound facies. These reflect shoaling water over and around the buildups during later stages of regression. Phylloid algae are found in Iowa only in scattered horizons in the skeletal calcilutite facies of regressive limestones.

Southward in southernmost Kansas and Oklahoma, most regressive limestones grade into shales and sandstones, which define the "terrigenous detrital facies belt" and represent a wide range of offshore to nearshore and deltaic environments dominated by terrigenous clastics from the Oklahoma detrital source.

SEQUENCE AND CONTROL OF DEPOSITION

Typical Kansas cyclothems were initiated during relatively low stands in sea level. In areas still submerged, rapid detrital influx from nearby deltaic shorelines formed the thicker prodeltaic to deltaic facies. In areas that had become emergent, residual soils formed on whatever sediment was exposed, ranging from deltaic plains to tops of the underlying regressive limestone.

Then transgression deepened the water over submerged areas and reinundated emergent areas. This progressively stranded detrital influx farther away from the Midcontinent outcrop. Initially, thin gray shale with only local shoal-water carbonate sands were deposited on parts of the irregular deltaic surface. Eventually, a thin layer of relatively pure carbonate mud accumulated relatively uniformly over most parts of the inundated delta lobes in deeper water below effective wave base, to form the calcilutitic transgressive limestone.

When water became deep enough to inhibit benthic algal activity and to establish a thermocline (perhaps as little as 100 m near the mouth of the sea: Heckel, 1977, p. 1057), a quasi-estuarine circulation cell was set up. This drew in phosphate-rich, oxygen-poor water from the open ocean, and, through upwelling and the concomitant nutrient-concentrating organic-decay trip, depleted bottom oxygen to various degrees to form both the gray and black phosphatic facies of the offshore shale.

Then lowering of sea level destroyed the thermocline and broke up the quasi-estuarine cell. This allowed significant reoxygenation of the bottom and eventual reestablishment of benthic algal carbonate production to initiate formation of the regressive limestone. Continued lowering of sea level through the photic zone to above effective wave base allowed development of the regressive limestone into shoal water, lagoons, and locally tidal flats. Greater amounts of fine terrigenous material from distal ends of progressively encroaching deltas account for the greater abundance of shaly partings and beds in most regressive limestones.

Deposition of the regressive limestone ceased where still submerged, when it was overwhelmed by terrigenous detrital influx of prograding delta lobes that initiated development of the succeeding nearshore shale. In areas where tidal carbonate facies became emergent, soil formation often produced the succeeding nearshore shale without deltaic influx. The cycle then repeated with another sea level rise.

Although transgression can occur with an increase in basinal subsidence, and regression can occur by sedimentary basin filling during a slowdown in subsidence, the extremely widespread nature of Upper Pennsylvanian transgressions, in conjunction with water depth changes on the order of 100 m indicated by the black phosphatic offshore shales, suggest that eustatic rise and fall of sea level was the basic cause of cyclic deposition in the Midcontinent Pennsylvanian. First proposed by Wanless and Shepard (1936), glacial eustatic control of Pennsylvanian sea level changes is now strongly supported by identification and dating of Mississippian through Permian glacial deposits in Gondwanaland by Crowell (1978). Both the depth variation (100-200 m) and the frequency of Pennsylvanian cyclothems (about 400,000 years) are on the same orders of magnitude as those of Pleistocene glaciation (Heckel, 1980). Nevertheless, the sedimentary cyclic controls of delta-lobe formation and abandonment, proposed by several authors to explain Pennsylvanian cyclic deposits in the Appalachians and Texas, were also at play in the Midcontinent whenever the shoreline was nearby, and minor delta-lobe cycles of this origin are present in some nearshore shales and regressive limestone sequences.

REFERENCES

Crowell, J. C., 1978, Gondwanan glaciation, cyclothems, continental positioning, and climate change: Amer. Jour. Science, v. 278, p. 1345-1372.

Heckel, P. H., 1968, Limestone facies in the Kansas City and Lansing Groups (Missourian, Upper Pennsylvanian) in southwestern Iowa: Geol. Soc. America N. Cent. Sec. Ann. Mtg. Field Trip Gdbk., Iowa City, p. 4-29 to 4-41.

Heckel, P. H., 1977, Origin of phosphatic black shale facies in Pennsylvanian cyclothems of Mid-continent North America: A.A.P.G. Bull., v. 61, p. 1045-1068.

Heckel, P. H., 1978, Field guide to Upper Pennsylvanian cyclothemic limestone facies in eastern Kansas: Kansas Geol. Survey Gdbk. Ser. 2, p. 1-69, 76-79.

Heckel, P. H., 1980, Paleogeography of eustatic model for deposition of Mid-continent Upper Pennsylvanian cyclothems: in Paleozoic Paleogeography of West-Central U.S., ed. by T. D. Fouch & E. R. Magathan. Rocky Mtn. Sec. SEPM: W.-Cent. U.S. Paleoz. Paleogeog. Symp.1, p.

Heckel, P. H., in press, Changing concepts of Midcontinent Pennsylvanian cyclothems, North America: Rept. 9th Internat. Cong. Carboniferous Strat. & Geol. Urbana, Ill.

Heckel, P. H., and Baesemann, J. F., 1975, Environmental interpretation of conodont distribution in Upper Pennsylvanian (Missourian) megacyclothems in eastern Kansas: A.A.P.G. Bull., v. 59, p. 486-509.

Heckel, P. H., and Cocke, J. M., 1969, Phylloid algal-mound complexes in outcropping Upper Pennsylvanian rocks of Mid-Continent: A.A.P.G. Bull., v. 53, p. 1058-1074.

Heckel, P. H., and others, 1979, Field guide to Pennsylvanian cyclic deposits in Kansas and Nebraska: Kansas Geol. Survey Gdbk. Ser. 4, p. 1-60.

Moore, R. C., 1931, Pennsylvanian cycles in the northern Mid-Continent region: Illinois Geol. Survey Bull. 60, p. 247-257.

Moore, R. C., 1936, Stratigraphic classification of the Pennsylvanian rocks of Kansas: Kansas Geol. Survey Bull. 22, 256 p.

O'Brien, D. E., 1977, Stratigraphy, petrology, and depositional sequence of the Marmaton, Pleasanton and lowermost Kansas City Groups (late Middle-early Upper Pennsylvanian) in a core from south-central Iowa: Unpub. M.S. thesis, Univ. of Iowa, 120 p.

Stark, M. P., 1973, The geology of the Winterset and St. Charles Quadrangles, Madison County, Iowa: Unpub. M.S. thesis, Iowa State Univ., 86 p.

von Bitter, P. H., and Heckel, P. H., 1978, Differentiation of black "core" shales in Missourian and Virgilian cyclothems (Pennsylvanian) in Iowa and Kansas, using conodonts [abst.]: Geol. Soc. America Abstracts w. Prog., v. 10, p. 510.

Wanless, H. R., and Shepard, F. P., 1936, Sea level and climatic changes related to late Paleozoic cycles: Geol. Soc. America Bull., v. 47, p. 1177-1206.

Wanless, H. R., and others, 1970, Late Paleozoic deltas in the central and eastern United States: SEPM Spec. Pub. 15, p. 215-245.

Welp, T. L. and others, 1968, GSA Field Trip No. 4, Middle River Traverse: Geol. Soc. America N. Cent. Sec., Ann. Mtg. Field trip Gdbk., Iowa City, p. 4-1 to 4-26. (This is only slightly modified from an undated guidebook to the Middle River Traverse by the same authors published by the Geological Society of Iowa in 1967.)

ACKNOWLEDGMENTS

I wish to express appreciation to the following persons who helped make this field trip and guidebook possible: Greg Ludvigson of the Iowa Geological Survey invited me to lead the trip and took care of arrangements; Jean Prior, also of the Iowa Survey, arranged for printing of the guidebook. Ted Welp, formerly a geologist with the Highway Division, Iowa Dept. of Transportation, introduced me to the Iowa Pennsylvanian, in terms of both exposures and cores, in 1967; Ken Isenberger, also of the Highway Division, shared more recent information with me. Iowa University geology graduate students Rex Price, Steve Schutter, John Mitchell and Bob Ravn provided thesis information on several of the outcrops. Jane Ries of the Department of Geology typed the guidebook. The following landowners of Madison County kindly allowed access to their property for several of the stops: Carol Selsor, Stop 2; Paul Bruett, Stop 4; Dennis Schildberg, Stop 5; and Eugene Drake, Stop 6.

DESCRIPTION OF FIELD TRIP STOPS

Leave parking lot near corner of N. Buxton and E. Euclid Sts. on east side of Simpson College Campus, Indianola, at 8:30 A.M.

Drive about 28 miles (south to Iowa Rte. 92, west to western outskirts of Winterset and south on U.S. Rte. 169 to 1.7 mile south of junction where Rte. 92 turns west) (40 min.)

STOP 1: U.S. 169 ROADCUT SOUTHWEST OF WINTERSET: DENNIS FM. (60 min.)
Location: E line NE¼ SW¼ sec. 11, T75N, R28W

This stop shows the Dennis cyclothem, which has a lenticular transgressive limestone, a black shale and a well-developed regressive limestone. PLEASE STAY ON WEST SIDE OF HIGHWAY.

Top of Bethany Falls Member, regressive limestone of underlying Swope cyclothem, is exposed down the road ditch.

Blocky Galesburg shale has a coal (Davis City) at the top in Decatur County 30 to 50 miles south of here, and probably represents a soil profile here as well. Dark fossiliferous shale at the top represents the early part of the Dennis marine transgression.

Lenticular Canville Limestone, transgressive limestone of Dennis cyclothem, has not been found on west side of highway. This skeletal calcilutite was laid down in local patches later during transgression.

Black phosphatic Stark Shale has been traced from Iowa to Nebraska and southern Kansas and represents maximum marine transgression of the Dennis cyclothem, when upwelling caused anoxic bottom conditions and phosphorite deposition. Both the Stark and underyling Galesburg Shales are presently under doctoral study by S. R. Schutter of Iowa University.

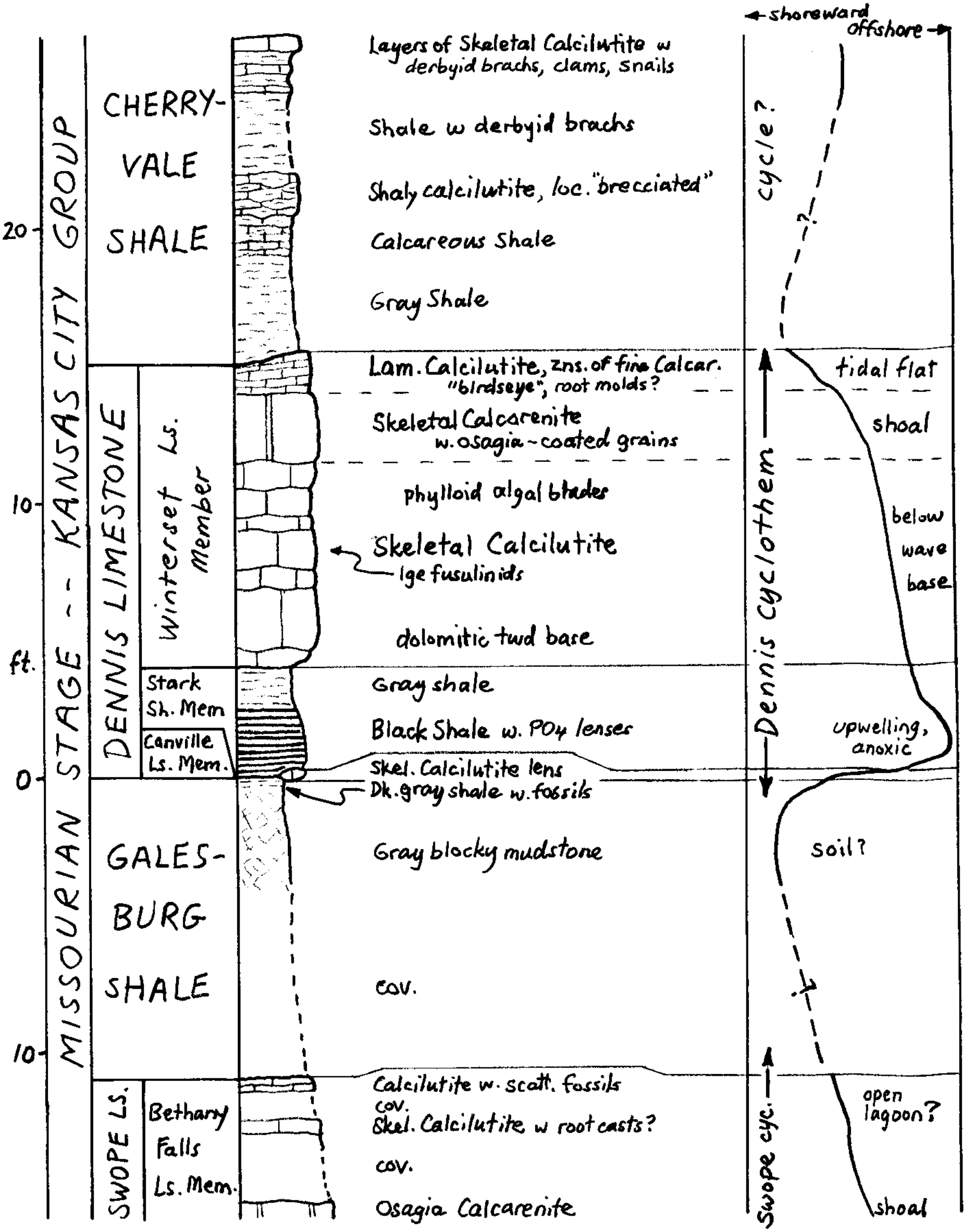
Winterset Limestone, regressive limestone of Dennis cyclothem, is named from this area and is traced into nearby states along with the underlying Stark Shale. Lower two thirds is skeletal calcilutite with a diverse fauna, which was deposited during early regression below effective wave base. Above this is "osagia" calcarenite, which represents a shoal developed during later regression where minute algae and encrusting forams (together termed "osagia") coated sand-size skeletal grains in an agitated environment where mud was winnowed out. Top toward north is muddy, with sparry spots and lines. Capping bed exposed also toward north is laminated calcilutite with zones of fine-grained calcarenite probably representing storm-washed debris on a tidal flat. Small spots here and in muddy top of underlying bed are termed "birdseye" and probably represent trapped gas bubbles and/or small root casts. This distinct shallowing sequence of carbonate lithologies is characteristic of regressive limestones in Iowa.

Overlying Cherryvale Shale contains a number of thin limestone beds but is generally poorly exposed in most places along outcrop. It lacks a well defined cyclic sequence and seems to represent mainly a series of shallow marine environments, which may have resulted from an intermediate sea level stand that never achieved very deep water. The Cherryvale is presently under master's investigation by C. J. Siebels of Iowa University.

Leave Stop 1 at 10:10 A.M.

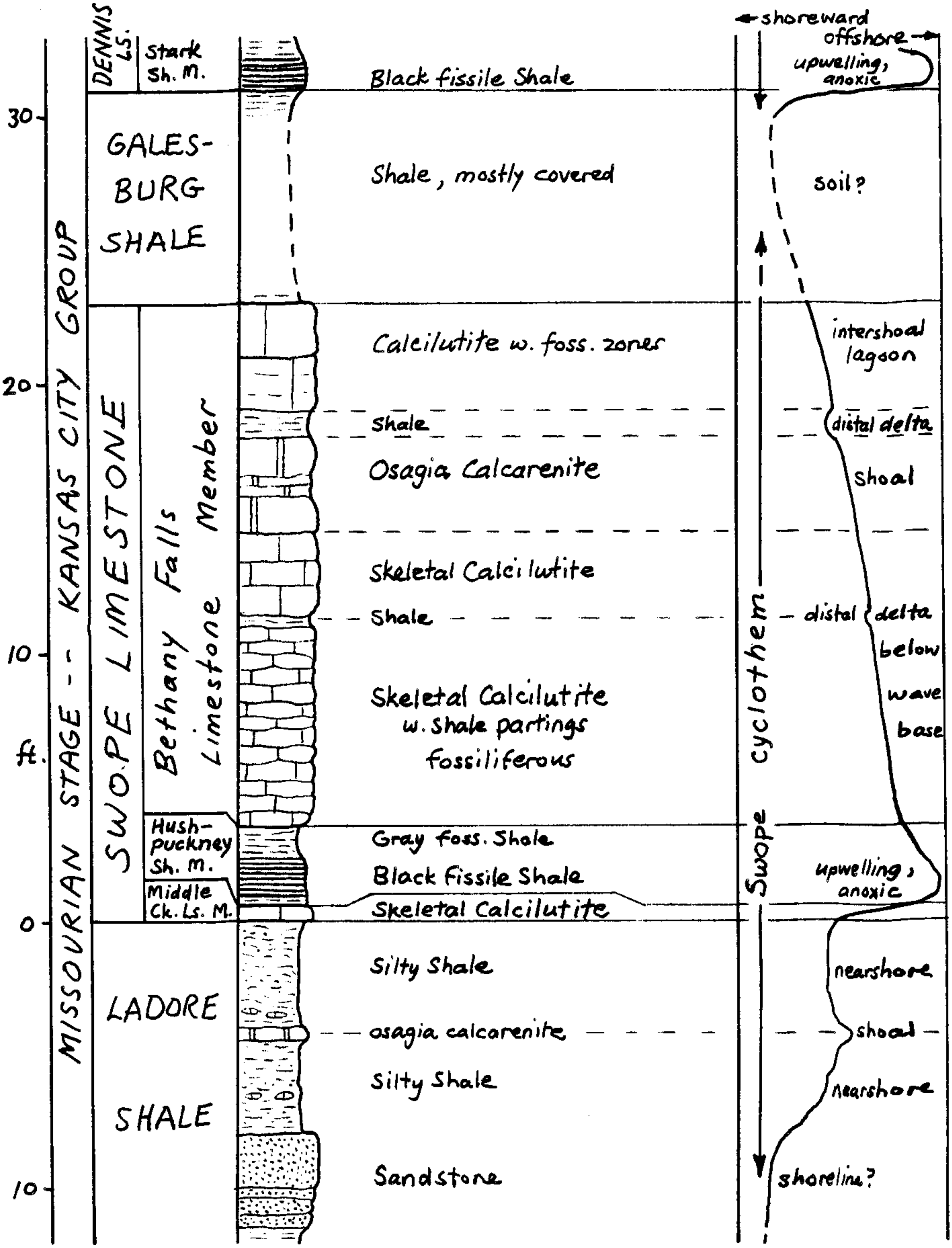
Drive 2.5 miles (south 0.1 mile to gravel road, then west up valley of Middle River to south-facing cliff around bend from new house) (10 minutes)

STOP 1: U.S. 169 ROADCUT S.W. OF WINTERSET



meas. by R.C. Price, 1977, & P.H. Heckel, 1980

STOP 2: STREAMBANK CLIFF S.E. OF PAMMEL PARK



Section sli. modified from Welp et. al, 1968, p. 4-10 by P.H. Heckel

STOP 2: STREAMBANK CLIFF SOUTHEAST OF PAMMEL PARK: SWOPE FM. (40min.)
Location: center E half NW¼ sec. 22, T75N, R28W

This stop shows the Swope cyclothem, which has a thin transgressive limestone as well as a black shale and well developed regressive limestone. We will look mainly at the lower part of the sequence. PLEASE BE CAREFUL HERE AS RATTLESNAKES ARE REPORTED TO INHABIT THIS AREA IN GREAT ABUNDANCE.

Ladore Shale at base comprises a variety of rock types, including sandstone, shale, and limestone, which represent various nearshore to perhaps nonmarine environments developed at a low stand of sea level. The thin osagia calcarenite may have been a nearshore shoal or beach.

Middle Creek Limestone, the transgressive limestone of the Swope cyclothem, is a thin skeletal calcilutite that is traced both to Nebraska and southern Kansas. It represents a thin layer of lime mud that settled out over an immense area later during transgression when the sea bottom was below effective wave base.

Black Hushpuckney Shale also has been traced to Nebraska and southern Kansas, and represents the maximum marine transgression of the Swope cyclothem, when upwelling caused anoxic bottom conditions, as for the analogous Stark Shale in the Dennis cyclothem.

Thick Bethany Falls Limestone, regressive limestone of the Swope cyclothem, is one of the most important quarried units along the Iowa outcrop. Like the analogous Winterset in the Dennis cyclothem, the lower two-thirds is skeletal calcilutite with a diverse fauna, which was deposited below effective wave base during early regression. Above is osagia calcarenite deposited as shoals developed during later regression. The capping ledge is again calcilutite, but with several fossiliferous zones representing more open marine conditions than in the capping bed of the Winterset. The top of the Swope probably represents quieter intershoal areas with fairly good interchange with the open sea, rather than tidal flats like the top of the Dennis. Prominent shale horizons in the Bethany Falls represent distal ends of deltas that encroached farther into the Midcontinent as sea level fell.

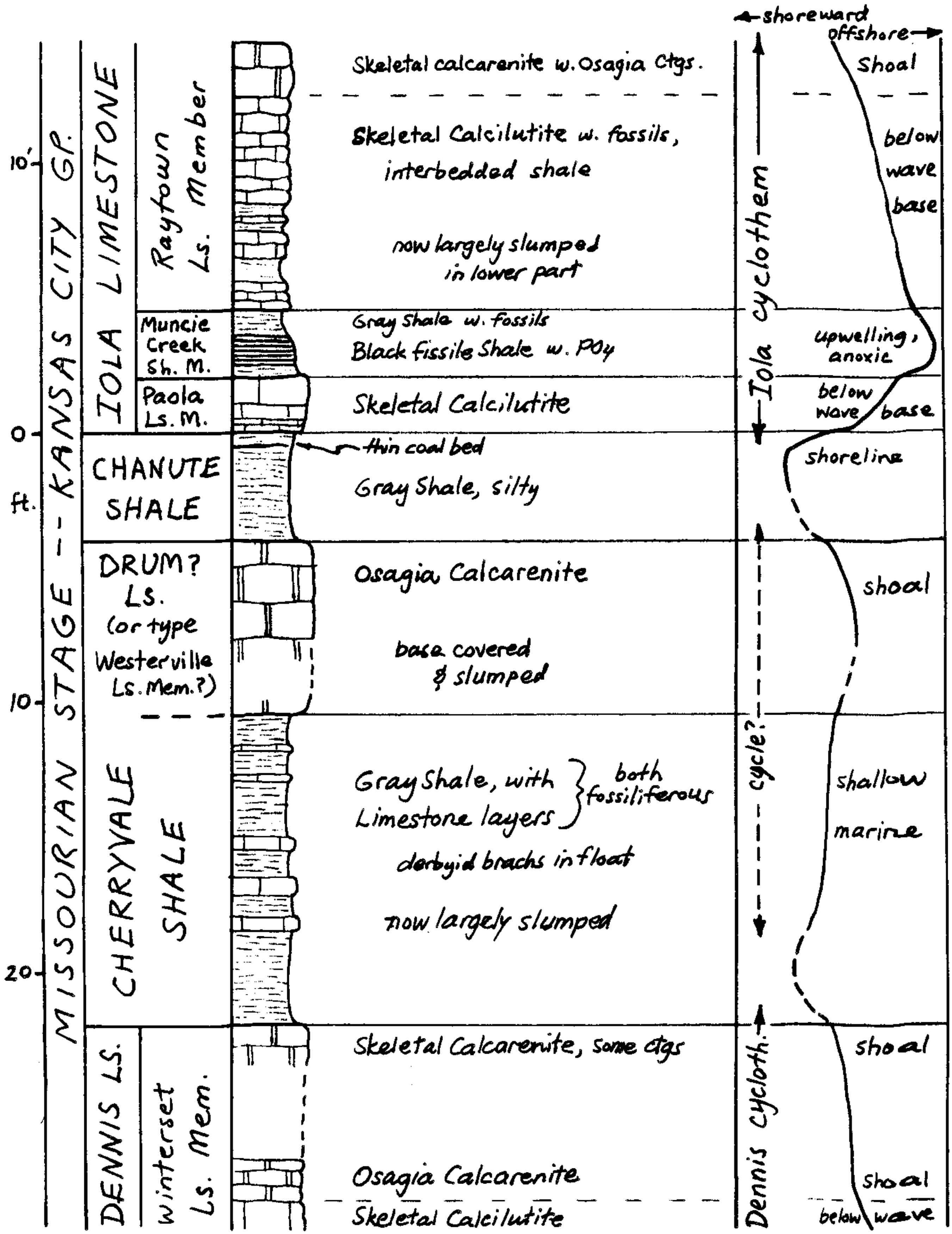
Overlying Galesburg Shale probably represents a soil horizon, as explained previously, which formed during the withdrawal of the sea that terminated the Swope cyclothem.

Dennis Formation, not completely shown on the measured section, is essentially the same as at Stop 1.

Leave Stop 2 at 11:00 A.M.

Drive 0.5 mile (continue west on gravel road, then north at intersection to partway up hill on another gravel road) (5 min.)

STOP 3: ROADCUT SOUTH OF PAMMEL PARK



section sli. modified from Welp et al, 1968, p. 4-12 by J.C. Mitchell & P.H. Heckel, 1980

STOP 3: ROADCUT SOUTH OF PAMMEL PARK: IOLA, CHERRYVALE FMS. (25 min.)
Location: NE side of road in SW¼ NW¼ sec. 22, T75N, R28W

This stop shows the Iola cyclothem, which has both transgressive and regressive limestones and an intervening black shale, and also affords another look at the Cherryvale and associated units. The Iola is presently under doctoral investigation by J. C. Mitchell of Iowa University.

Top of Winterset Limestone is the lowest unit in the road ditch on the east side. Skeletal calcilutite and overlying calcarenite are partially exposed, but it is not known if overlying tidal flat calcilutite seen at Stop 1, about 3 miles to northeast, is absent or merely covered.

Cherryvale Shale is badly slumped now, but the description in Welp and others (1968, p. 4-12) shows that it is shale with thin, abundantly fossiliferous limestones like those exposed near the top of the section at Stop 1.

Nomenclature of the overlying Drum-Westerville? Limestone is questioned because: 1) the type Drum Limestone, which occupies this stratigraphic position in southeastern Kansas, is poorly exposed northward, undergoes abrupt facies changes in places, and is possibly lenticular along outcrop; and 2) the type Westerville, named from Decatur County Iowa just 30 miles south of here, is possibly at the same stratigraphic horizon. Both units are recognized as discrete limestones at Kansas City, Drum above Westerville separated by Quivira Shale, but correct identification of this unit in Iowa awaits restudy of type Westerville. In any case this unit in Iowa does not display a well-developed cyclic sequence; rather it is mainly osagia calcarenite which represents an agitated shoal, probably deposited toward the end of the intermediate sea level stand responsible for the underlying Cherryvale sequence.

Chanute Shale, mostly covered here, is silty shale with a thin coal near the top and represents withdrawal of the sea prior to the Iola inundation.

Paola Limestone, transgressive limestone of the Iola cyclothem, is skeletal calcilutite representing deposition below effective wave base during late transgression.

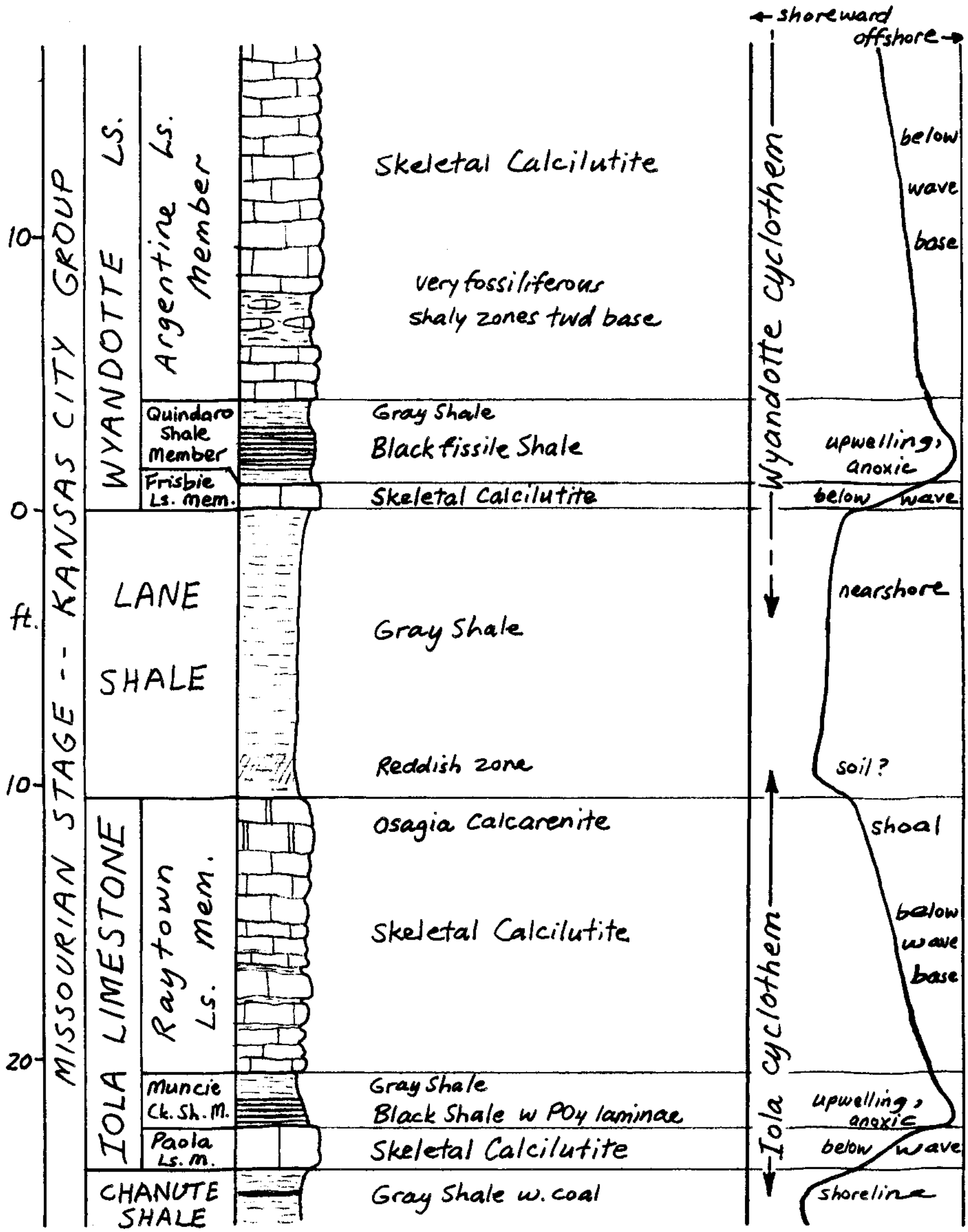
Muncie Creek Shale is the black phosphatic shale (fairly weathered here) that represents maximum marine transgression in the Iola cyclothem, when upwelling caused anoxic bottom conditions.

Raytown Limestone, regressive limestone of the Iowa cyclothem, is thinner and shalier than most other regressive limestones, but it displays the typical shallowing upward sequence of shaly calcilutite (now largely slumped) overlain by skeletal calcarenite (exposed only at the north end of the outcrop) in which many grains are osagia-coated. The top is not exposed, so that presence of capping shoreline facies, as observed in cores to the west by J. C. Mitchell is not determined.

Leave Stop 3 at 11:30 A.M.

Drive 2.6 miles (continue north on gravel road through Pammel Park, through tunnel cut in Hushpuckney and Ladore Shales below the Bethany Falls cliff, across Middle River and onto paved road to small valley beyond second gentle curve to left) (10 minutes)

STOP 4: STREAMBANK NORTH OF PAMMEL PARK



section sli. modified from Welp et al, 1968, p. 4-15, by P.H. Heckel, 1968 (Iola)

STOP 4: STREAMBANK NORTH OF PAMMEL PARK: LOWER WYANDOTTE FM. (30 min.)
Location: NE¼ SW¼ NE¼ sec. 10, T75N, R28W

This stop shows the lower part of the Wyandotte cyclothem, the next cyclothem above the Iola. Go west over fence across field north of creek. The Wyandotte is a well developed cyclothem with transgressive and regressive limestones and intervening black shale in Iowa, Nebraska and northern Missouri, but mounds up into algal mound facies in the Kansas City area and grades abruptly southward into shale in east-central Kansas. All other well developed Missourian cyclothems persist into southeastern Kansas before grading southward into shale toward the Oklahoma deltaic detrital source.

All three members of the Iola Limestone are exposed in the streambank east of the road, but the Muncie Creek and lower Raytown are badly slumped here now. Because the Iola was observed at the previous stop, we will not visit it here.

Lane Shale is badly slumped in this area now, but was reported by Welp and others (1968) to have a reddish zone in the lower part. It represents the detrital nearshore to well-drained nonmarine deposits that terminated the Iola cyclothem.

Frisbie Limestone is exposed in the small cutbank on the first major northeastward meander northwest of the road culvert across the creek. The transgressive limestone of the Wyandotte cyclothem, it is a thin skeletal calcilutite that represents deposition below effective wave base during later transgression.

Quindaro Shale, exposed above the Frisbie Limestone in the same cut bank, is the black shale that represents maximum marine transgression of the Wyandotte cyclothem, when upwelling caused anoxic bottom conditions.

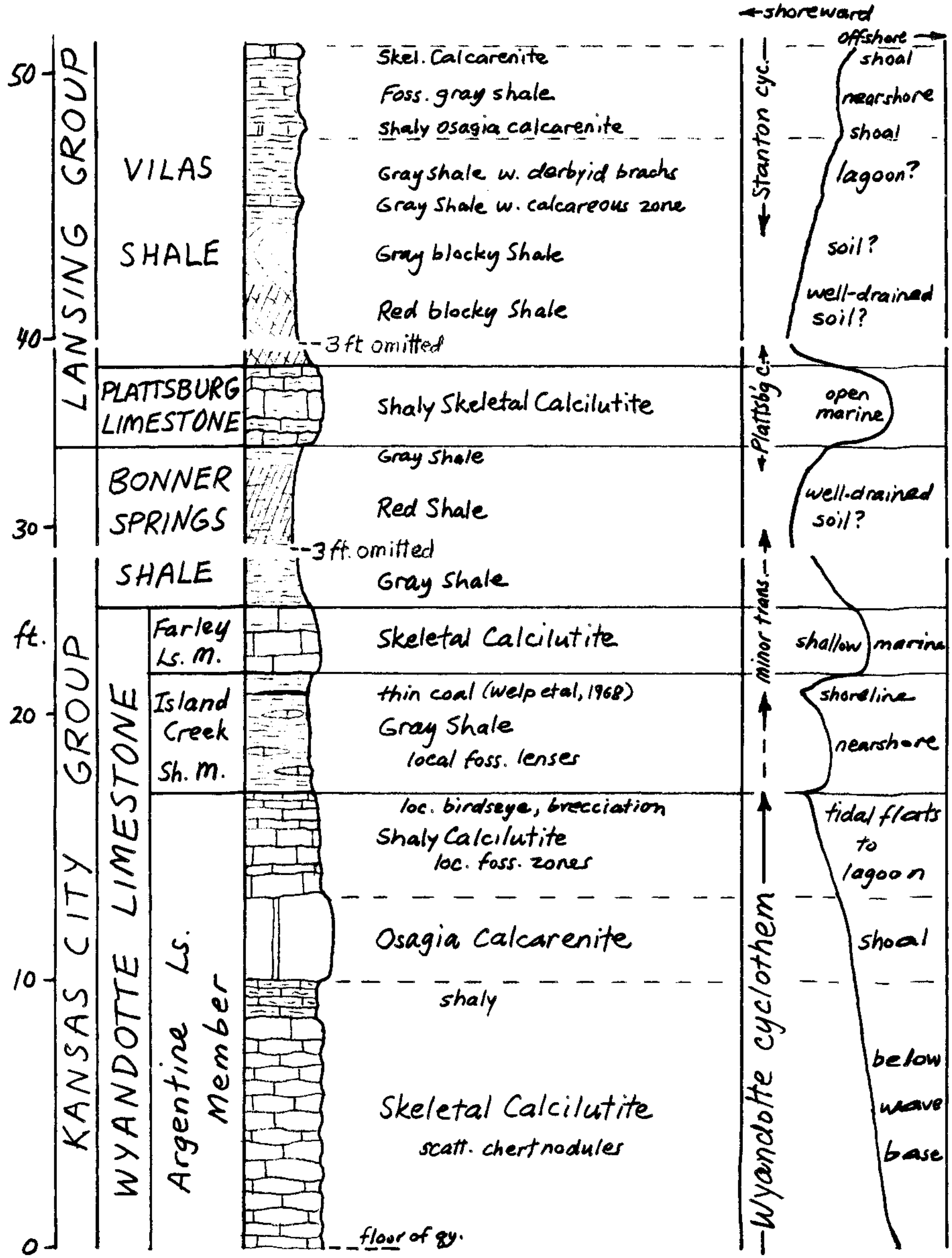
Argentine Limestone, the regressive limestone of the Wyandotte cyclothem, is exposed in and along the stream bed northwest of the cutbank exposing the two lower members. The lower part exposed here is skeletal calcilutite deposited below effective wave base during early regression. The upper part, which displays shallower water facies, is well exposed at the next stop.

Leave Stop 4 at 12:10 P.M.

Drive 10 miles (continue north on paved road a little over 1 mile to Rte. 92, then west a little over 8 miles to quarry entrance on right along bend in highway around to right; drive through entire quarry to new pit in northeast end) (20 minutes)

(Those who did not bring a lunch to eat in the quarry can go east on Rte. 92, across US 169 into Winterset, where drive-ins should be open on the main north-south street in the east side of town; they can then rejoin the trip at the quarry at Stop 5 where the trip will remain until 1:50 P.M.)

STOP 5: SCHILDBERG'S STANZEL QUARRY



section meas. by P. H. Heckel, 1967 near south end of old east wall near entrance road.

STOP 5: SCHILDBERG'S STANZEL QUARRY: WYANDOTTE & PLATTSBURG FMS. (80 min.)
Location: SW¼ NE¼ sec. 5, T75N, R29W

This stop shows the upper part of the Wyandotte cyclothem, the entire Plattsburg cyclothem, and affords a good view of parts of two "outside" shales. PLEASE WEAR YOUR HARDHATS & BE VERY CAREFUL IN THIS QUARRY. Those who brought lunches will eat them here (but please leave no trash).

Argentine Limestone, regressive member of the Wyandotte cyclothem, is another of the important quarried units along the Iowa outcrop. Several feet of its base is left as the floor of the quarry above the maximum transgressive Quindaro Shale, which we saw at the previous stop. The lower Argentine exposed in the quarry is skeletal calcilutite with a variety of fossils, which represents deposition below wave base during early regression. The overlying ledge of osagia calcarenite represents shallowing to shoal-water conditions during later regression. Above this, the thinner bedded marly calcilutite with few fossils, except in certain zones, probably represents a protected lagoon developed even later, perhaps partly behind the osagia shoal. Brecciated fabric with "birdseye" features noted locally at the top probably represent disturbance of semi-indurated sediment with trapped gas bubbles on a tidal flat that developed near the end of regression.

Overlying Island Creek Shale represents increased detrital influx that may or may not be from the same delta lobe as the type Island Creek Shale of the Kansas City area. Although fossil lenses noted in the south end of the quarry suggest slight marine inundation, perhaps as general subsidence of the region exceeded both sea-level drop and sediment accumulation, a thin coal smut near the top reported by Welp and others (1968, p. 4-16) indicates that shoreline again prograded over this area.

Farley Limestone is the "super" limestone of the Wyandotte cyclothem. Rather than merely a shoal-water facies of the regressive limestone (as many super limestones are), the Farley appears to represent a minor transgression of the sea, which may be regional, as the Farley appears as a distinct marine unit above shallow-water Argentine and nearshore Island Creek in the Kansas City area as well.

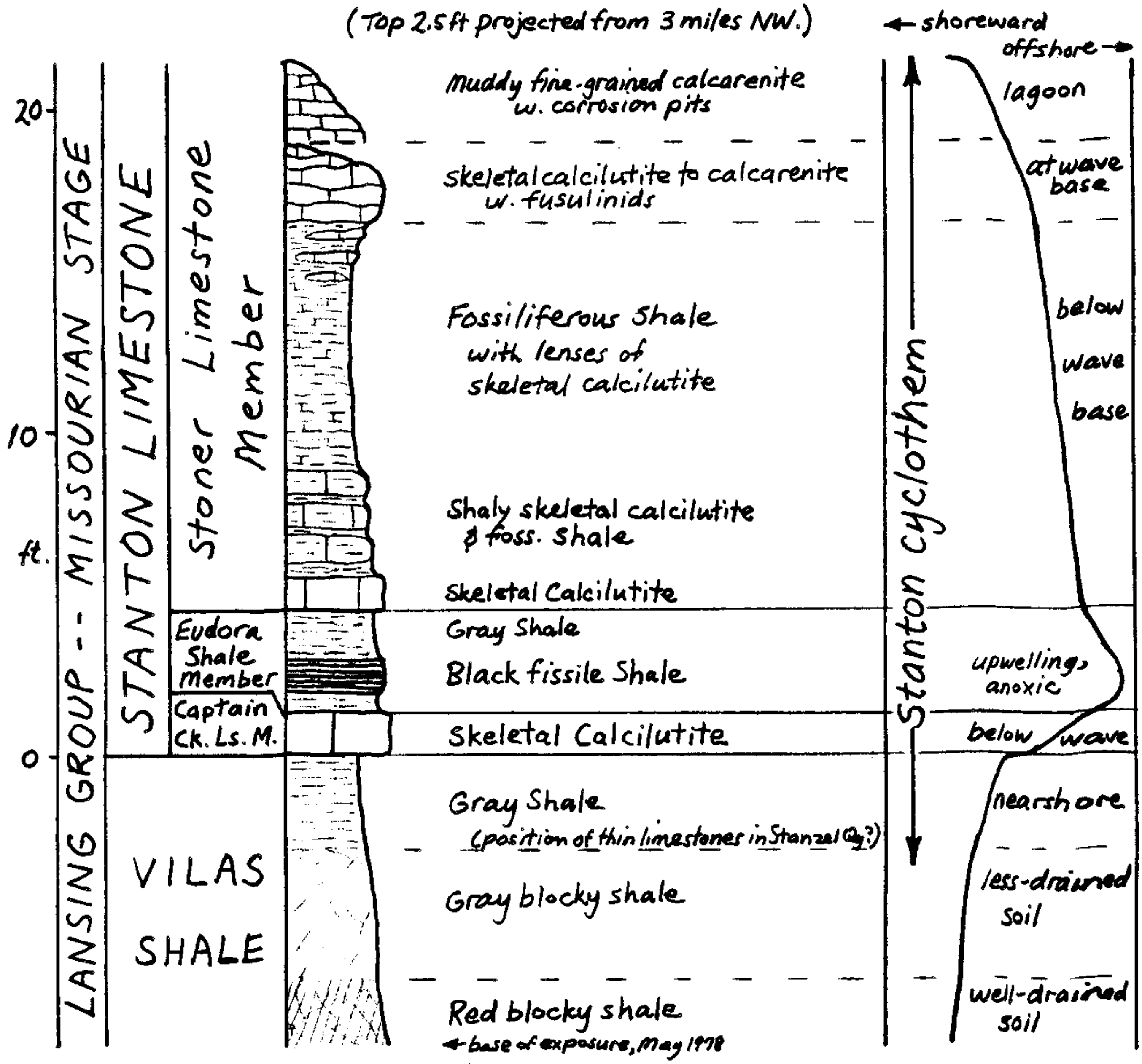
Bonner Springs Shale finally terminates the Wyandotte cyclothem with a well drained alluvial plain in which iron minerals dehydrated to hematite, the mineral responsible for the red color of part of this shale.

Thin Plattsburg Limestone is a complete cyclothem with transgressive and regressive limestones separated by an offshore shale in the Kansas City region. Absence of black facies in the offshore shale along outcrop suggests that this marine inundation did not get as deep as the others, which have black offshore shale facies even in Iowa. Thinness and shaliness of the limestone here, along with no definite development of offshore shale, suggest greater nearness to shoreline throughout this inundation here and provide further support for generally lesser depths at maximum transgression for the Plattsburg cyclothem.

Vilas Shale represents termination of the Plattsburg cyclothem with a well-drained alluvial plain as in the Bonner Springs below. Limestones at the top in the south end of the old quarry may represent early transgressive phases of the Stanton cyclothem, which will be observed at the next stop.

Leave Stop 5 at 1:50 P.M.

STOP 6: STREAMBANK NEAR MADISON-ADAIR CO. LINE



section meas. by P.H. Heckel, 1978; same as Welp et al, 1968, p. 4-17, termed Oread

Drive 2.5 miles (return to Rte. 92, then go west about 1.7 miles to county line, south on gravel road 0.4 mile, just across bridge) (10 minutes)

STOP 6: STREAMBANK NEAR MADISON-ADAIR COUNTY LINE: STANTON FM. (40 minutes)
Location: SW¼ SW¼ NW¼ sec. 7, T75N, R29W

This stop shows most of the Stanton cyclothem, the youngest complete cyclothem of the Missourian Stage. For years this exposure has been misidentified as part of the Oread Formation (although questioned by Welp et al., 1968, p. 4-14). The Oread is the lowest cyclothem of the Shawnee Group of the overlying Virgilian Stage, and is separated from the Stanton by the Douglas Group, a relatively thick detrital sequence consisting largely of "outside" shales. Collection and identification of conodonts from the black shale here by P. von Bitter of the Royal Ontario Museum (written commun. 1973) showed presence of Gondolella sublanceolata, which is found elsewhere in the Stanton but not in the Oread (see von Bitter and Heckel, 1978). In 1979, I measured a partly exposed cyclothem, previously identified as Oread, about 3 miles to the northwest (SE¼ SW¼ sec. 26, T76N, R30W), and it appears nearly identical to the Stanton exposed here; its black shale is presently being processed for conodonts for further confirmation. Higher beds from the top of this more northwestern locality are added to the measured section for this stop because they show a younger facies.

Vilas Shale is the outside shale developed during low sea level stand with a well-drained alluvial plain indicated by the red color of the blocky shale visible at the base of the exposure (at least in May 1978). The overlying gray blocky shale may represent an alluvial plain with a higher water table developed during the earliest stages of transgression, which prevented dehydration of the iron oxides to red hematite. The capping chippy gray shale probably represents the initial stages of marine inundation in this area. The thin limestones observed 3 to 9 feet above the red Vilas at the top of the section exposed at the south end of the Stanzel Quarry in 1967 may be lenticular facies of the upper Vilas here, two miles to the west-southwest.

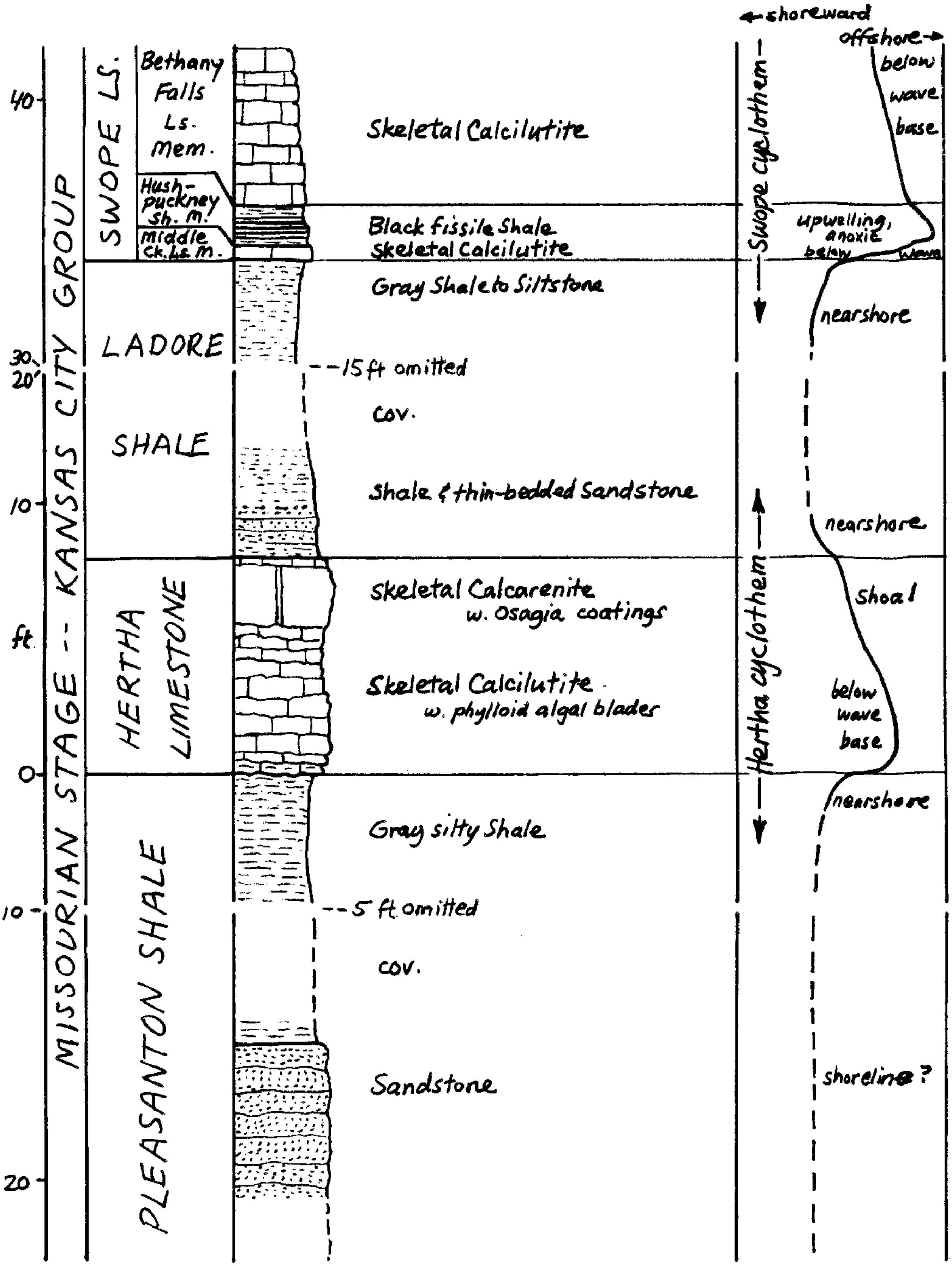
Overlying Captain Creek Limestone is the transgressive limestone of the Stanton cyclothem, which has been traced from southeastern Nebraska to southeastern Kansas, where it is one of the few transgressive limestone to thicken into a phylloid algal mound complex. The thin layer of skeletal calcilutite here represents deposition below effective wave base during later transgression.

Eudora Shale represents maximum marine transgression of the Stanton cyclothem when upwelling caused anoxic bottom conditions. Its black facies is continuous from Nebraska to east-central Kansas, where the underlying Captain Creek thickens southward to greater than 10 feet. Phosphate nodules persist in the gray Eudora above thick Captain Creek, and the black facies reappears over thinned Captain Creek in topographic lows around the mounds (Heckel, 1978). Both the Eudora and Vilas Shales are presently under doctoral study by S. R. Schutter of Iowa University.

Stoner Limestone is the regressive limestone of the Stanton cyclothem with skeletal calcilutite and fossiliferous shale through most of the exposure representing deposition below effective wave base. More calcarenitic fusulinid limestone at the top of the exposure here represents shallowing to effective wave base. The poorly fossiliferous fine-grained muddy calcarenite with corrosion pits a few feet higher (projected from the top of the exposure 3 miles to the northwest) represents a restricted shoreline lagoon followed by subaerial exposure.

Leave Stop 6 at 2:40 P.M.

STOP 7: ROADCUT EAST OF EAST PERU



section meas. by R.L. Ravn, 1979

Drive about 25 miles (return north to Rte. 92, then east across new US 169 into Winterset to old U.S. 169 (where road you are on ends), then go south about 6 miles, turn east on paved road through East Peru to high roadcut where road turns south at east end of town) (40 minutes)

STOP 7: ROADCUT EAST OF EAST PERU: HERTHA, LOWER SWOPE FMS. (40 mins.)
Location: W line, E½ NW¼ sec. 12, T74N, R27W

This stop shows the Hertha cyclothem, the oldest cyclothem of the Missourian Stage, and the lower part of the Swope cyclothem, well exposed, but nearly inaccessible at the top of the cut. You have now seen as complete a traverse of Missourian rocks in south-central Iowa as is possible in a few closely spaced exposures.

Pleasanton Shale is a nearshore detrital unit developed during low sea level stand, with locally prominent sandstone bodies at places along outcrop through Missouri into southeastern Kansas. A rubbly limestone reported by R. L. Ravn some distance below the sandstone in the ravine to the north is probably the Cooper Creek Limestone, equivalent to the Lenapah Limestone of Kansas and the youngest Middle Pennsylvanian (Desmoinesian) cyclothem in the Midcontinent. The Middle-Upper Pennsylvanian (Desmoinesian-Missourian) contact occurs within the detrital unit here classified as Pleasanton Shale, and is traditionally placed at the base of the sandstone body in the belief that the sandstone overlies a regional unconformity, a belief that is not yet definitely established.

Hertha Limestone is not differentiated into members at this exposure. Presently under doctoral study by R. L. Ravn of Iowa University, the Hertha is only irregularly developed into members along its entire outcrop. In a core from the vicinity of Osceola, just 15 miles south of here, a thin dark phosphatic shale at the base (O'Brien, 1977) represents the offshore shale deposited at maximum marine transgression of the Hertha cyclothem. Such a shale has not been observed in this exposure, which thus must have been closer to the edge of the depositional limits of this cyclothem where either carbonate (lower Hertha) or light gray clastics (top of Pleasanton) were deposited during maximum transgression. The position of maximum transgression, typically marked by a zone of abundant conodonts, has not yet been determined at this exposure. The lower Hertha here is skeletal calcilutite deposited below effective wave base, probably mostly during early regression, as the offshore shale, when present, is at or near the base of the limestone. The upper Hertha here is skeletal calcarenite with osagia coatings and represents shallowing above wave base to shoal conditions during later regression. Lack of shoreline carbonate facies at the top suggests that carbonate deposition was overwhelmed by detrital influx in the marine environment.

Ladore Shale represents nearshore to shoreline detrital influx during the low sea level stand that terminated the Hertha cyclothem.

Middle Creek Limestone, Hushpuckney Shale and lower part of Bethany Falls Limestone represent transgression and early regression of the Swope cyclothem as outlined at Stop 2.

Leave Stop 7 at 4:00 P.M.

Continue south on paved road, then east in less than 1 mile on paved road through Truro to I-35, about 10 miles away.

END OF TRIP