EUSTACY IN CYCLOTHEMS IS MASKED BY LOSS OF MARINE BIOFACIES WITH INCREASING PROXIMITY TO A DETRITAL SOURCE: AN EXAMPLE FROM THE CENTRAL APPALACHIAN BASIN, U.S.A.

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ABSTRACT

In cyclothsms of the Midcontinent basin in the central United States, eustatic sea level changes are recorded in a distinctive biofacies sequence developed through each transgressive-regressive cycle. Cyclothsms of the Appalachian basin have been found to contain few marine biofacies, so this line of evidence has not been used to support glacial eustacy in the eastern basin. Recent paleontological and stratigraphic analyses of one eastern cyclothem, the Magoffin Member of the Four Corners Formation, reveal a stratigraphic sequence of biofacies analogous to that seen in midcontinent cyclothsms. The complete transgressive to regressive package of biofacies in the Magoffin Member is developed over a thin interval in the northern part of the basin, indicating regression independent of sediment aggradation, a characteristic of eustatic sea level fall. Moving across the axis of the Appalachian basin toward the Alleghenian orogenic belt to the southeast, the Magoffin becomes increasingly dominated by a thick, coarsening-upward sequence, which begins progressively lower in the cyclothem approaching the detrital source. Only the lowermost biofacies, developed above the flooding surface, is present at all localities throughout the basin. Late transgressive and early regressive biofacies that otherwise would have developed through the T-R cycle were overwhelmed by the earlier arrival of prodeltaic sediments and are lost toward the southeast. This demonstrates that rapid progradation of deltas can inhibit the development of all, but early transgressive biofacies, suggesting that eustatic sea level fall in marine cyclothsms in the Appalachian basin may commonly be masked by thick coarsening-upward sequences of detrital sediments.

INTRODUCTION

In the eastern United States, Upper Carboniferous strata of the central Appalachian basin (Fig. 1) occur as cyclothemic packages dominated by sandstones and mudrock and bounded by coals that are often overlain by relatively thin intervals of marine or paralic shales (Chesnut 1981). Several Appalachian cyclothsms are regionally extensive marine intervals that document episodes of widespread transgression and regression throughout the basin. In the Middle Pennsylvanian Beithitt Group of eastern Kentucky, four thick, widespread marine members have been identified (Fig. 2). Of these four major marine members, the Magoffin Member is the most widespread, having been reported from across eastern Kentucky and into Virginia and West Virginia (D.R. Chesnut Jr., unpub. compil., Rice et al. 1994).

Although open marine environments can be established for many Appalachian basin marine intervals based on the presence of stenohaline invertebrate taxa (Chesnut 1981), it is usually difficult to interpret their significance relative to changing sea level because fossiliferous intervals tend to be thin and to consist of a limited number of distinctive biofacies (Bennington 1995, Brezinski, 1983, Chesnut 1981, Donahue and Rollins 1974, Donahue et al. 1972, Martino 1994, White
progradation of deltaic and terrestrial depositional systems (Boardman II et al. 1984, Heckel 1977, 1984, 1991, 1994). Biofacies provide evidence that the core shale interval of Midcontinent cyclothem systems, with its distinctive, central, fissile, black shale, represents the establishment of dysoxic conditions followed by sustained benthic anoxia beneath a thermocline developed during maximum transgression at water depths in excess of 50 metres (Bisnutt and Heckel 1996, Heckel 1977, Heckel 1994). The transition from maximum transgression in the fissile black shale to regression in the overlying grey shale and limestone is developed without significant sediment accumulation, indicating active sea level fall. Evidence for rapid, widespread transgression, development of deep water environments, and active sea level fall are key observations in the model arguing for glacio-eustatic control of the development of Midcontinent cyclothem systems (Heckel 1994).

It has been previously proposed that the stratigraphic pattern developed during a glacio-eustatic sea level cycle might be obscured by the lesser diversity of facies developed in detrital-dominated strata (Heckel et al. 1998). This paper demonstrates such an effect by examining geographic changes in the stratigraphic sequence of biofacies within the marine Magoffin Member. A sequence of transgressive to regressive biofacies analogous to that seen in midcontinent cyclothem systems is present in the Magoffin Member cyclothem in the northern part of the central Appalachian basin. Toward the southeast, in the direction of the axis of the depositional basin, earlier arrival of deltaic clastic sediment progressively eliminates the regressive biofacies observed in the northwest, masking the evidence for active sea level fall and glacio-eustacy.

Figure 2. Stratigraphic column for Breathitt Group and correlative strata in the Appalachian basin showing major marine members. After Chesnut (1996) and Rice et al. (1994).

and Martino 1992, Williams 1960). For this reason, many authors (Dennis and Lawrence 1979, Fahrer and Heckel 1992, Fern 1974, Merrill 1993, Stevens 1971, Tankard 1986) have interpreted most Appalachian basin marine facies to represent nearshore, 'bay' environments, developed during maximum transgression in relatively shallow water. In contrast, Upper Carboniferous cyclothem systems of the Midcontinent basin (Fig. 1) exhibit a characteristic suite of marine lithofacies and biofacies (summarized in Fig. 3) that track the change upsection from transgression to development of relatively deep water, offshore environments, to subsequent regression, and the eventual
Methods

Stratigraphic sections of the Magoffin Member were measured in outcrop at 19 localities along 4 transects in eastern Kentucky, southwestern Virginia, and western West Virginia (Fig. 4). All outcrops are highway roadcuts permitting sampling of the marine strata from the flooding surface overlying coal or carbonaceous shale through the capping non-marine, fluvio-deltaic sediments. Sedimentary facies were described and fossiliferous intervals were sampled and disaggregated to obtain invertebrate macrofauna and microfauna. Stratigraphic diagrams showing major lithologies and biofacies types were drafted and correlated along a series of four transects. These transects were positioned on an isopach map for the stratigraphic interval from the Kendrick member to the Magoffin Member (Rice et al. 1979) to determine their positions relative to the axial trend of the depositional basin. This work was carried out as part of an ongoing study of the stratigraphy and paleoecology of the Magoffin and other marine members of the Breathitt Group in the central Appalachian basin.

Results

The Magoffin Member cyclothem in the northern region of the study area consists of seven distinct facies types. Terrestrial or marginal marine facies (facies 1, Fig. 3) such as coal and Lingula-bearing silty shales, siltstone and sandstone with comminuted plant debris, and cross-beded, burrowed sandstone occur directly below the base of the marine strata at all localities in the Magoffin. These facies are overlain by a thin, argillaceous, bioclastic packstone (facies 2, Fig. 3) containing an abundant and diverse open-marine fauna consisting mostly of articulate brachiopods (productoids and spiriferoids) and crinoids. This basal limestone has a gradational upper contact with overlying dark grey shales (facies 3, Fig. 3) bearing a molluscan fauna dominated by the bivalve Pleurophorella and several genera of gastropods, predominantly Trepospora. This fauna disappears upsection as the shale becomes black and finely fissile (facies 4, Fig. 3), with a monospecific fauna consisting of the thin-shelled bivalve Posidonia. Above the fissile black shale there is a transition to moderately bioturbated dark
grey shale (facies 5, Fig. 3) with a mollusk-dominated fauna consisting of nuculoid bivalves such as *Nuculeoida*, *Nuculopsis* and *Phestia* and small gastropods such as *Glabrocinulum* and *Trepospiga*. At the top of facies 5 a color change from dark grey to medium grey shales (facies 6, Fig. 3) marks a transition from a mollusk-dominated fauna to a brachiopod-crinoid fauna dominated by *Antracospirifer* and *Desmoinesia* (a small productoid). This fauna becomes abundant in a shell bed encompassing or located within facies 6, which is dense enough at some localities to form a second argillaceous packstone. Above facies 6 is an abrupt transition to a sparsely fossiliferous to unfossiliferous coarsening upward sequence consisting of shales, siltstones, and sandstones with common nodules and layers of siderite (facies 7, Fig. 3). At some localities this coarsening sequence is truncated by an unconformity surface, having been eroded away by subsequent fluvial incision (Benningen 1996).

Stratigraphic sections bearing facies types 1 through 7 are present at the northern localities located along the transect A' - A (Fig. 5). The fissile black shale and subjacent dark shale (facies 4 and 3) are restricted to localities in the centre of the transect. In West Virginia, at locality W74, the faunas associated with facies 3 through 5 are absent, but a dark shale equivalent in lithology to facies 3 and 5 is present at the same stratigraphic position. At all localities along transect A' - A the upper brachiopod-crinoid biofacies (facies 6) is overlain by a coarsening upward sequence (facies 7) with the onset of unfossiliferous layers marked by the presence of diagenetic siderite. Although the overall sequence of facies is consistent between localities, the thickness of the interval bearing facies 2 through 6 and the thicknesses of individual facies intervals are highly variable from locality to locality.

Southeastward, toward the axis of the depositional basin (Fig. 4), transect B' - B (Fig. 6) includes three localities, two of which (M 56 and M28) contain the complete sequence of Magoffin facies. At locality M33, which is the closest of the three to the basin axis, the basal fossiliferous limestone (facies 2) is directly overlain by a fossiliferous mollusk-dominated shale (facies 5), which is capped by a thick coarsening upward sequence (facies 7). This pattern becomes the rule farther southeast, along transect C' - C (Fig. 7), which includes eight similar localities with thin basal fossiliferous intervals consisting of facies 2 and a highly condensed facies 5 overlain by a thick, sideritic, coarsening interval (facies 7). Facies 6, the upper, brachiopod-crinoid shale, is only present at the top of the Magoffin Member at two adjacent localities (M9 and M10) where the upper part of the coarsening interval becomes non-sideritic.

Transect D - D' (Fig. 8) trends perpendicular to the axis of the basin and includes the most basin-marginal and basin-central localities in the study area (M38 and M67, respectively). Along this transect the total thickness of the Magoffin Member more than triples approaching the basin axis due to the increasingly thick development of the coarsening sequence (facies 7). At locality M38 brachiopod-crinoid limestones (facies 2 and 6) are present, separated by a thin layer of dark grey shale with branching horizontal burrows and a sparse fauna of orthoconic nautiloids. At M37 a similar sequence of facies is present, but with a mollusk-dominated shale (facies 5) developed between the brachiopod-dominated limestones (facies 2 and 6). At the next locality southeast along the transect (M14) the upper brachiopod-crinoid limestone (facies 6) disappears, leaving the mollusk-dominated shale (facies 5) overlain by a thick coarsening sequence (facies 7). At locality M67, near the axis of the basin, only the basal fossiliferous interval (facies 2) remains below the sideritic shales at the base of the coarsening upward sequence (facies 7). The overall trend from the margin of the basin to the basin axis is one of progressive loss of the upper brachiopod-crinoid biofacies, followed by the loss of the mollusk biofacies, accompanied by a progressive increase in the thickness of the unfossiliferous upper coarsening sequence (Fig. 9).

### Discussion

**Analogy to Midcontinent Cyclothem**

In the northwestern region of the Central Appalachian basin, the Magoffin Member consists of a stratigraphic sequence of marine facies that is directly analogous to the sequence characteristic of midcontinent cyclothem (Fig. 3). Of particular relevance is the presence of a core shale interval (facies 3-5 in Fig. 3) “sandwiched” between lower and upper open marine, fossiliferous facies (facies 2 and 6 in Fig. 3). The core shale in the Magoffin contains a succession of invertebrate faunas that is remarkably similar to the succession present in midcontinent

![Figure 6. Transect B' - B of stratigraphic columns for Magoffin localities in the central region of the study area. Lithofacies and biofacies symbols as in Figure 3.](image)
core shales (Boardman II et al. 1984) as well as other characteristics that have been argued to indicate relatively deep water deposition during maximum flooding in midcontinent cyclothem (Heckel 1977, Heckel 1994). These include: 1) the widespread occurrence of the Magoffin core shale, which is present across the entire outcrop belt in eastern Kentucky and West Virginia; 2) the position of a fissile black shale with a low diversity fauna at a midpoint of symmetry between upper and lower bioturbated, mollusk-dominated core shale and basal and upper brachiopod-dominated limestone / calcareous mudstone deposits; 3) the condensed nature of the core shale, particularly in the southwestern region of the Breathitt outcrop belt where it contains abundant conodonts and small phosphate nodules; and 4) the condensed, undisturbed nature of the fissile black shale, with fine, clay laminations, a lack of demonstrably benthic fauna, and horizons containing accumulations of the thin-shelled bivalve Posidonia, a possibly epipelagic species associated with deep water, oxygen deficient environments (Boardman II et al. 1984, Stanley 1970, Wignall 1990). The lower core shale facies (facies 3) and the fissile black shale facies (facies 4) are localized within the north central region of the study area, suggesting localized development of benthic anoxia. Elsewhere, the core shale is manifested as a thin, densely fossiliferous dark grey shale with a dysaerobic fauna of
small nuculoid bivalves and gastropods characteristic of facies 5. However, this interval has been found to contain specimens of Posidonia and Pleurophorella and thus may represent a highly condensed amalgamation of the core shale facies 3, 4, and 5.

The transition from the basal, fossiliferous limestone to the thin, fissile black shale in the northern localities of the Magoffin Member shows deepening in the absence of significant clastic influx. The reverse transition upsection from fissile black shale to dark grey, mollusk-dominated shales to medium grey, brachiopod-dominated shales shows a shallowing of the Magoffin seaway. The thickness of this regressive interval is highly variable from locality to locality (for example, compare locality M24 with adjacent locality M78 in transect A' - A, Fig. 5), in spite of the overall consistency of the facies sequence and corresponding suite of lithologies. The fact that stratigraphic thickness varies by as much as a factor of four without affecting facies development in the regressive part of the sequence suggests that water depth was changing independent of sediment aggradation, a characteristic of eustatic sea level fall (Posamentier et al. 1992).

**Figure 8.** Transect D - D' of Magoffin localities trending perpendicular to the axis of the basin. Lithofacies and biofacies symbols as in Figure 3.  

**Figure 9.** Cartoon diagram showing the pattern of facies developed through deposition of the Magoffin Member from the northwestern basin margin to the southeastern basin center. Sea level curves show the position within the Magoffin transgressive-regressive cycle of the onset of deltaic sedimentation. This occurs progressively earlier in the cycle approaching the axis of the basin and the Appalachian orogen to the southeast. Lithofacies and biofacies symbols as in Figure 3.

**The Effect of Detrital Influx on the Facies Pattern**

The Magoffin Member is unique in being the only marine cyclothem in the Appalachian basin to preserve a symmetrical sequence of biofacies developed through transgression and subsequent regression. However, within the Magoffin Member the complete biofacies cycle is only present across the northern margin of the basin. Elsewhere, the symmetrical pattern is lost as fewer and fewer biofacies are recorded within the Magoffin stratigraphic sequence. This is clearly shown by the basin-crossing transect (D - D', Fig. 8) in which the number of preserved biofacies drops from three to one approaching the axis of the basin. There is also variability in the thickness and lithology of each fossiliferous facies in the Magoffin Member within basin-parallel transects Figs. 5 - 7). The transgressive-regressive stratigraphic interval recorded by facies 2 through 6, which includes the core shale, thickens and thins markedly from locality to locality. Transect A' - A shows progressive thickening of the core shale (facies 3 through 5) eastward from locality M37 to M24 and then thinning again continuing from M24 to M77. Where the core shale is thin the upper brachi-
pod-crinoid facies 6 is developed as a thin limestone; where the core shale is thick facies 6 is a calcareous shale. This pattern is most parsimoniously explained by changing proximity to a detrital source. Where and when clastic influx is greater the core shale is thicker and the upper, regressive brachiopod-crinoid facies develops as a calcareous shale due to dilution of the bioclastic carbonate by clay mud. Away from any detrital source the core shale is thinner and the upper, regressive brachiopod-crinoid facies develops as a bioclastic limestone. Consistent with this pattern, moving closer to the axis of the basin and the source of detrital sediments, the core shale attains its thickest development at locality M28 (transect B'-B, Fig. 6) which includes a correspondingly thick overlying calcareous shale with a brachiopod-crinoid fauna (facies 6).

At almost all localities, the uppermost fossiliferous facies is overlain by sideritic-bearing shales at the base of the thick coarsening upward sequence (facies 7), which indicate the arrival of prodelta clastics (Woodland and Stenstrom 1979) at relatively high sediment accumulation rates (Frank and Tyson 1995). These sideritic sediments are unfossiliferous, probably because the rate of sediment influx was too high to permit sustained colonization of the benthos by invertebrates. One recent study of the Magoffin Member in the vicinity of locality M14 (transect C'-C, Fig. 7) found intervals of ebb tidal rhythms in the sandy upper part of the coarsening sequence that record accumulation rates of 30 cm per day (Adkins and Ekirsson 1998), suggesting that, twice daily, significant quantities of sediment may have rained down on the benthos in the vicinity of the prograding delta front. As sea level rise slowed through the Magoffin transgression and then reversed, delta progradation would have commenced as fluvial systems draining the orogen to the southeast built out from the shoreline. Approaching the axis of the basin to the southeast, the Magoffin Member should record the initiation of rapid deltaic sedimentation progressively earlier in time and, therefore, lower in the stratigraphic sequence of facies. This is the pattern that is shown by this study (Fig. 9). At all localities along transect C'-C (Fig. 7), brachiopod-crinoid shales (facies 6) are replaced above the core shale (facies 5) by sideritic shales at the base of the coarsening upward sequence. Only at two localities, M10 and M3 (Fig. 7), is an upper brachiopod-crinoid shale (facies 6) present, and it occurs near the top of the Magoffin Member, above a thick interval of sideritic shale. The return of the fauna at these localities occurs upsection of the last siderite bed, suggesting that, sometime after the initiation of deltaic sedimentation, a reduction in the rate of influx allowed invertebrates to recolonize the benthos. Note that, in spite of the accumulation of over 5 meters of sideritic shale at locality M10, the mollusk-dominated core shale biofacies present at the start of deltaic deposition returns when deltaic deposition is reduced. This fauna transitions to a brachiopod-dominated fauna characteristic of facies 6 over several metres of section. The symmetrical pattern of brachiopod-dominated biofacies surrounding a mollusk-dominated core shale biofacies present in the northern localities is maintained along transect C'-C, in spite of being significantly thickened by a higher influx of clastic sediments closer to the basin axis.

Farther to the southeast, at locality M67 (transect D - D', Fig. 8) sideritic shales directly overlie the thin, argillaceous packstone characteristic of the base of the Magoffin Member (facies 2). At this locality, 50 kilometres closer to the clastic source than the localities along transect C'-C, there is no development of a core shale (facies 2 - 5) nor the overlying regressive, fossiliferous facies 6. This suggests that deltas began building out from the shoreline during the waning stage of transgression and that they reached the vicinity of locality M67 prior to the development of maximum water depth in the Magoffin seaway (Fig. 9), preventing the formation of a core shale, which in midcontinent cyclothems is the distinctive marker for the maximum transgressive interval of the eustatic cycle (Heckel 1991).

**Tectonic vs Eustatic Contributions to the Biofacies Pattern**

Transgressive-regressive cycles in marine strata can result from either eustatic sea level fluctuations, cycles of tectonic subsidence and uplift, or subsidence combined with varying rates of sedimentation (Yang *et al.* 1998). Based on the number of transgressive-regressive cycles in the Four Corners Formation and the overall duration of the Middle Pennsylvanian, Chesnutt and Cobb (1989) estimate the duration of Appalachian basin cyclothems to be approximately 400 ka. The existence of the high frequency cycles of tectonic subsidence and uplift that would be required to generate sea level cycles of this duration is controversial (Klein and Kupperman 1992) and doubted by most (*e.g.* Heckel 1986, Posamentier *et al.* 1988). Because of their proximity to an active orogenic belt, some authors have attributed transgressive-regressive cycles within the Appalachian basin to pulses of subsidence generated by episodic thrust loading of the orogen, followed by progradational filling of the basin by clastics (Tankard 1986, Klein and Willard 1989). Certainly, substantial tectonic subsidence was occurring during deposition of the Magoffin Marine Member, creating the accommodation space needed to preserve the Magoffin sediments. Transect D - D' (Fig. 8) shows that the Magoffin Marine Member thickens from the basin margin toward the basin axis, demonstrating higher rates of subsidence southeastward toward the basin axis and the orogen. This pattern is typical for actively subsiding foreland basins (Posamentier and Allen 1993). It is also apparent that the rate of clastic influx into the basin during Magoffin deposition varied through time and from place to place. This is shown by the variability in thickness of individual biofacies from one locality to the next. The important question is, can the stratigraphic patterns developed through the Magoffin transgression and regression be explained solely by the interaction of subsidence and clastic supply, or is it necessary to invoke eustatic sea level change as a major control on the development of Magoffin biofacies?
The transgressive interval of the Magoffin Member consists of a basal bioclastic limestone overlain by fossiliferous core shales. The maximum transgressive deposit is a paper-fissile black shale deposited under conditions of benthic anoxia within the core shale. The core shale is thicker at localities along transects A - A’ (Fig. 5) and B - B’ (Fig. 6) toward the northwestern margin of the basin and very condensed at localities along transect C - C’ (Fig. 7) toward the centre of the basin. However, the transgressive biofacies are substantially similar at all localities, except for the maximum transgressive fissile black shale, which did not develop at localities near the center of the basin. If the Magoffin transgression was generated by a pulse of tectonic subsidence, then the axis of the basin should have developed greater water depths for longer periods of time than basin-marginal regions. However, the uniformity of the thin limestone deposited at the base of the Magoffin argues against any significant difference in the magnitude or duration of the transgression across the study region. Furthermore, the core shale biofacies are thicker and more completely developed away from the basin centre, which is the opposite of what would be expected if greater water depths were attained along the axis of the basin. In contrast, a eustatic sea level rise would have resulted in a comparable rate of sea level rise and increase in water depth across the basin during transgression, with moderate depth increases controlled by regional topographic lows. The more condensed nature of the core shale in the southeastern localities is indicative of sediment starvation caused by their position near the basin centre. Northwestern localities likely received some clastic influx from the northwestern margin of the basin as the rate of sea level rise slowed during late transgression, resulting in better preservation of environments developed during maximum transgression.

The most compelling evidence for eustatic sea level change in the Magoffin Member is found in the northeastern localities (transects A - A’, Fig. 5, and B - B’, Fig. 6) where an apparent forced regression is preserved. Forced regressions occur when there is shallowing independent of sediment flux, in contrast to normal regressions where shallowing is caused primarily by the accumulation of sediment at a faster rate than the creation of accommodation space (Posamentier et al. 1992). The decoupling of shallowing and sedimentation in the Magoffin Member is observed in the northeastern localities where the regressive transition from the mollusk-dominated core shale upsection to a brachiopod-dominated calcareous shale is developed over greatly different thicknesses from locality to locality. For example, at locality M24 (Fig. 5) the regressive interval from biofacies 5 to biofacies 6 is three times as thick as the comparable interval at locality M78 (Fig. 5), less than 5 km to the east. Given that the lithology of the facies is the same at both localities and assuming that the facies transition occurred at the same depth at both localities, subsidence rates across less than 5 km of the basin would have to differ by a factor of three to account for the observed thickness differences, assuming a normal regression. This great a difference in subsidence rates is not supported by the overall amount of subsidence recorded in the basin through the Kendrick to Magoffin Member stratigraphic interval (Fig. 4). Likewise, at locality M10 (Fig. 7) deposition of biofacies 5 is interrupted by an influx of deltaic sediment indicated by the appearance of sideritic shales and siltstones. Four metres upsection deltaic deposition stops, as shown by a loss of siderite nodules and a return to deposition of bioturbated silty shales, and the fauna that reappears is the mollusk-dominated assemblage characteristic of the core shale (biofacies 5). In spite of the deposition of a relatively thick interval of sediment, shallowing was insufficient to affect the transition from biofacies 5 to biofacies 6. Again, the lack of correlation between the timing of facies changes due to shallowing and the thickness of sediment deposited is characteristic of a forced regression, which is the product of a eustatic sea level fall. A normal regression is only observed in the Magoffin Member after the onset of persistent deltaic sedimentation, when the high rate of sediment influx precludes the development of regressive biofacies and rapidly fills the available accommodation space.

Conclusions

Recognition of metre-scale transgressive-regressive cycles caused by eustatic fluctuations in sea level depends on the preservation of distinctive sequences of lithofacies and associated biofacies. In both midcontinent cyclothsms and in the Magoffin Member, a complete eustatic cycle is expressed in the stratal pattern of a transgressive limestone overlain by a mollusk-dominated core shale with a central maximum-transgressive fissile black shale bounded above by a brachiopod-dominated limestone or calcareous shale. Where some or most of these biofacies are not developed due to overwhelming clastic influx, the eustatic pattern is masked by an aggradational coarsening sequence. This is clearly demonstrated in the Magoffin by the progressive top-down truncation of the fossiliferous facies sequence southwest toward the source of prograding deltas (Fig. 9). The pattern of progressive cycle truncation with increasing proximity to a detrital source seen in the Magoffin Member has been noted in Upper Carboniferous cyclothsms from other depositional basins. In Upper Carboniferous cyclothsms of the Midcontinent basin, cycles traced southward into the foreland basin region of Oklahoma show thinning and then loss of the regressive limestone facies as it is overwhelmed by prograding detrital sediments (Heckel 1994). Metre-scale cycles delineated on the basis of transgressive limestone - core shale - regressive limestone packages in north-central Texas gradationally disappear shoreward as carbonate deposition is overwhelmed by nearshore siliciclastic deposition (Yang et al. 1998). The proximity of the Appalachian basin to an active orogen during the Upper Carboniferous allowed delta progradation to progress rapidly following transgressive flooding of the basin, causing most marine environments to be rapidly inundated with detrital sediments. This resulted in most Appalachian marine cyclothsms developing clastic-dominated stratigraphic sequences with.
fewer marine biofacies than midcontinent cyclothems, but these differences do not of themselves imply different genetic mechanisms for cycle development. Closer to the northwestern margin of the Appalachian basin the Magoffin Member preserves a eustatically generated facies sequence that is masked to the southeast, suggesting that a similar eustatic signal may be masked by the basin-filling coarsening sequences of other Appalachian marine cyclothems.

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