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# Stratigraphic Column of the Kope and Fairview Formations, Kentucky 445, Brent, Kentucky

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The Upper Ordovician Kope Formation is exposed over a broad area of southwestern Ohio, southeastern Indiana, and northern Kentucky (Weir and others, 1984). Roadcuts along Ky. 445 near Brent (Figs. 2–3) and adjacent roadcuts along Interstate 275 expose a nearly complete section of the Kope Formation as well as the overlying Fairview Formation (Fig. 1).

The Kope Formation is nearly equivalent to the Latonia Formation or Eden Shale of older literature, but differs in that the contact of the Kope and Fairview Formations is now placed about 3.25 m below the older Latonia-Fairview contact. As currently defined in Ohio, the Kope and Fairview Formations intertongue, such that the main body of the Kope is overlain by the North Bend Tongue of the Fairview, which is overlain by the Wesselman Tongue of the Kope, which is, in turn, overlain by the main body of the Fairview (Fig. 1). Similar relationships can be recognized in Kentucky, although the Wesselman Tongue is regarded there as part of the Fairview Formation. The Latonia of older literature was subdivided into three members on the basis of distinctive bryozoans and lithologic characteristics (Economy, Southgate, and McMicken). These members remain only in informal usage. More recent work has recognized eight informal submembers within the Kope, and all but the basal Fulton submember are exposed in the Ky. 445 composite (Brett and Algeo, 1999a). The Fulton submember is visible nearby in Duck Creek, adjacent to Ky. 1998 and 0.5 mi southeast of the Ky. 445 outcrop.

The Kope Formation consists primarily of three distinctive lithologies. Mudstone comprises the majority of the Kope. Thick mudstone intervals are in detail composed of a series of 2- to 5-cm, graded mudstone beds with thin, slightly silty or shelly bases. Mudstones are generally weakly burrowed and sparsely fossiliferous, but locally contain articulated trilobites and crinoids. Siltstones consist generally of 1- to 10-cm-thick beds of silt-size fossil fragments and quartz with a diversity of trace fossils and physical sedimentary structures, including small-scale hummocky cross lamination, wave-ripple lamination, planar lamination, tool marks, gutter casts, and millimeter-scale "ripples." Bioclastic limestones, chiefly packstone and grainstone, consist of abundant whole to broken skeletal fragments, with erosional bed bases. Many beds of grainstone contain megaripples and large-scale cross-stratification.

The type Cincinnatian Series was deposited in tropical latitudes on a north-dipping, storm-dominated ramp (Tobin, 1982). Some of the best evidence of storm deposition occurs within the Kope Formation, which was deposited in an offshore environment affected only by the strongest storms (Anstey and Fowler, 1969; Hay, 1981; Tobin, 1982). This evidence includes erosional bed bases with bipolar tool marks and gutter casts that indicate strong waves, normally graded beds, wave-ripple lamination, and hummocky cross-stratification. The overlying Fairview Formation also displays abundant evidence of storms, but was deposited in a somewhat shallower environment more frequently affected by storms.

The Kope displays well-developed meter-scale cyclicity (Jennette and Pryor, 1993; Holland and others, 1997; Miller and others, 1997; Brett and Algeo, 1999a, b). Although authors have differed on how such cycles are defined, most recent work suggests that the meter-scale cyclicity is defined by alternations of a proximal storm-bed facies and a distal storm-bed facies. The proximal storm-bed facies is dominated by beds of skeletal packstone and grainstone with only minor amounts of mudstone and siltstone, whereas the distal storm-bed facies is dominated by mudstone with abundant, very thin beds of siltstone and skeletal packstone. Meter-scale cycles have been correlated for tens of miles across the Cincinnati Arch (Jennette and Pryor, 1983; Brett and Algeo, 1999b). Given the approximate 2 m.y. duration of the Kope Formation (Holland and Patzkowsky, 1996), the 50-m-scale cycles in the Kope average 40 k.y. in duration, and thereby offer the potential for very high-resolution correlation.

Arguments over the origin of these meter-scale cycles currently revolve around three hypotheses. In one view, the cycles record no significant change in water depth and were generated by changes in the frequency and intensity of hurricanes as a result of the changing heat budget of tropical oceans during Milankovitch climatic cycles (Holland and others, 1999). A second view is that the cycles reflect substantial changes in water depth, possibly driven by eustatic cycles of sea level (Jennette and Pryor, 1993). A third view argues that the cycles record moderate changes in water depth that controlled the supply of siliciclastic mud to the Cincinnati Arch (Brett and Algeo, 1999b). The origin of these cycles is still debated and may represent a combination of these processes.

These meter-scale cycles show systematic changes in their thickness (Fig. 5), which have been used to define 20-m cycles (Holland and others, 1997). Within each of the four 20-m cycles (C1-1 through C1-4), the lowest meter-scale cycles tend to be thicker than average and rich in distal storm-bed facies, whereas the highest meter-scale cycles tend to be much thinner than average and contain mostly proximal storm-bed facies. Faunal and lithologic changes suggest that the 20-m cycles record changes in water depth, with the upper parts reflecting shallower water conditions than the lower parts. These 20-m cycles have also been correlated for long distances across the Cincinnati Arch (Miller and others, 2001) and have in part led to the informal submembers of the Kope (Brett and Algeo, 1999b).

As a whole, the Kope Formation and part of the basal Fairview Formation represent the C1 sequence of Holland and Patzkowsky (1996). The basal contact of the Kope Formation is inferred to be a surface of subaerial exposure with a significant unconformity. Based on lithologic and faunal changes, approximately the lowest third to quarter of the Kope indicates net deepening upward of the transgressive systems tract, with the remainder reflecting the net shallowing of the highstand systems tract. The contact between the North Bend and Wesselman Tongues is also inferred to be a surface of subaerial exposure with a significant unconformity (Holland and others, 1999).

The Kope contains a highly diverse and well-preserved assemblage of brachiopods, bryozoans, mollusks, trilobites, and crinoids (Holland and others, 2001; Meyer and others, 2002). Multivariate analysis of Kope assemblages has demonstrated their utility in reconstructing changes in water depth (Holland and others, 2001; Miller and others, 2001). In the section at right (Fig. 1), taxa recognized in the Ky. 445 section are sorted from left to right, from shallowest to deepest, based on multivariate ordination (Fig. 4). This multivariate ordination, produced by detrended correspondence analysis, suggests two interpretable axes, the first of which correlates with other indicators of water depth and the second of which appears to reflect substrate consistency (Holland and others, 2001).

Patterns of faunal abundance (Fig. 1) are not random, but reflect systematic up-section changes in water depth. At the coarsest scale, faunal variations record overall shallowing upward within the Kope, from assemblages rich in *Sowerbyella, Flexicalymene,* and *Cryptolithus* in the lower part of the Kope to assemblages dominated by *Rafinesquina, Platystrophia,* and bryozoans near the Kope-Fairview contact. See Holland and others (2001) and Miller and others (2001) for a more definitive description and interpretation of these faunal variations.

At a somewhat finer scale, variations in faunal abundance mirror the 20-m cycles, with the lower shale-rich parts (e.g., Alexandria submember) containing a deeper-water fauna and the upper limestone-rich parts (e.g., Grand Avenue submember) containing a shallower-water fauna. Analysis of meter-scale cycles indicates no relationship between the facies of meter-scale cycles and changes in faunal abundance, however (Webber, 2002).

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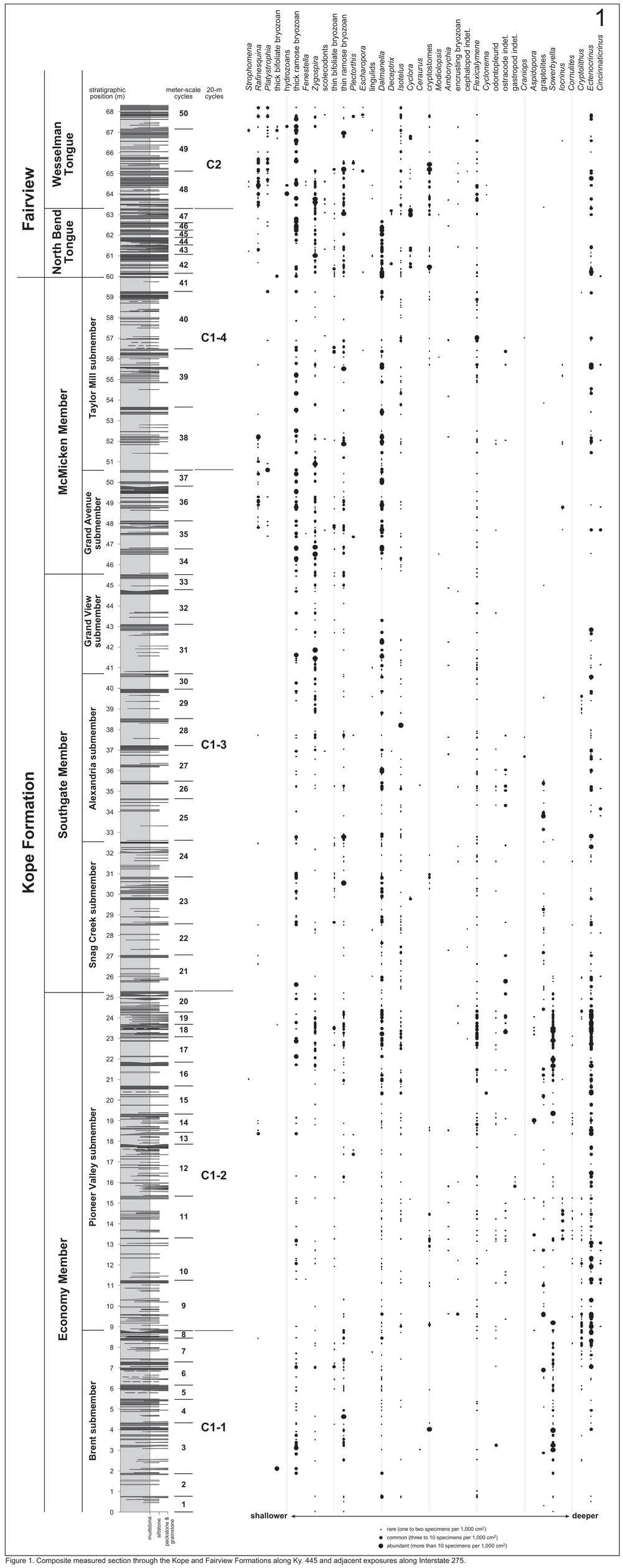


Figure 1. Composite measured section through the Kope and Fairview Formations along Ky. 445 and adjacent exposures along Interstate 275.


Figure 2. The lower part of the Kope Formation exposed on the north side of Ky. 445.

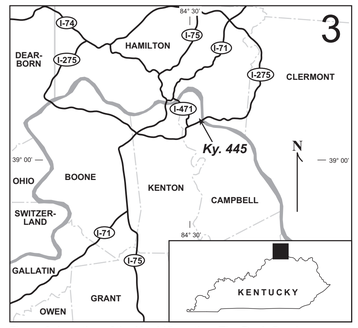


Figure 3. Location of the Ky. 445 section. The Duck Creek exposure mentioned in the text is located at the base of the arrow pointing to the Ky. 445 section.

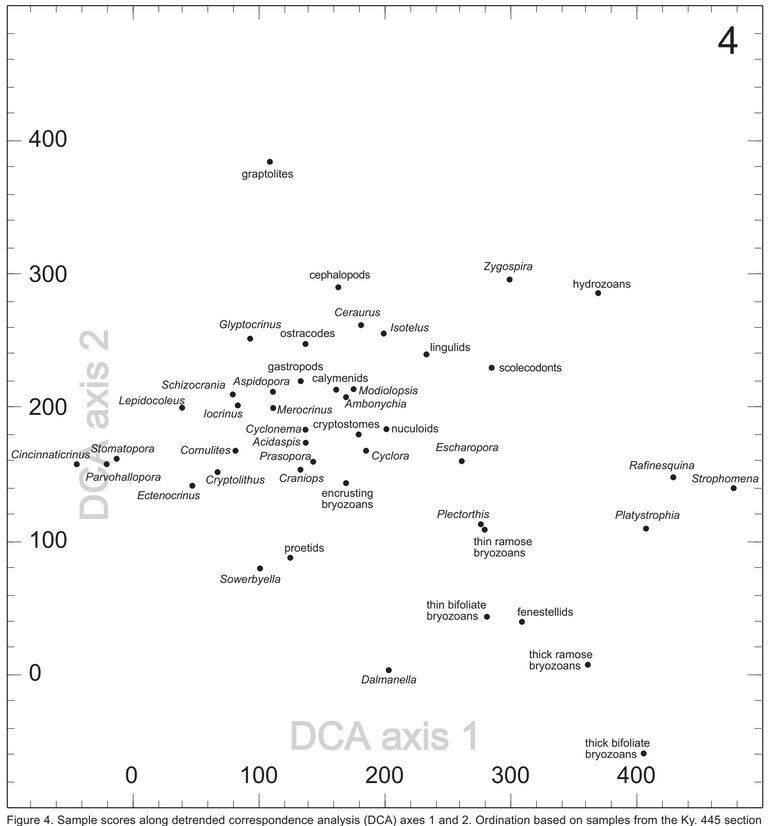


Figure 4. Sample scores along detrended correspondence analysis (DCA) axes 1 and 2. Ordination based on samples from the Ky. 445 section as well as four other sections of the Kope Formation in northern Kentucky, southeastern Indiana, and southwestern Ohio (localities given in Holland and others, 2001). Several taxa shown above did not occur in the Ky. 445 section, and are therefore not indicated in the measured section in Figure 1, but did occur in at least one of the other four studied Kope exposures. Axis 1 has been shown to correlate with water depth; higher values along axis 1 correspond to shallow-water environments and lower values correspond to deeper-water settings (Holland and others, 2001). Axis 2 may reflect substrate consistency; firmer, more stable substrates are at low values of axis 2 and unstable muds are at high values.

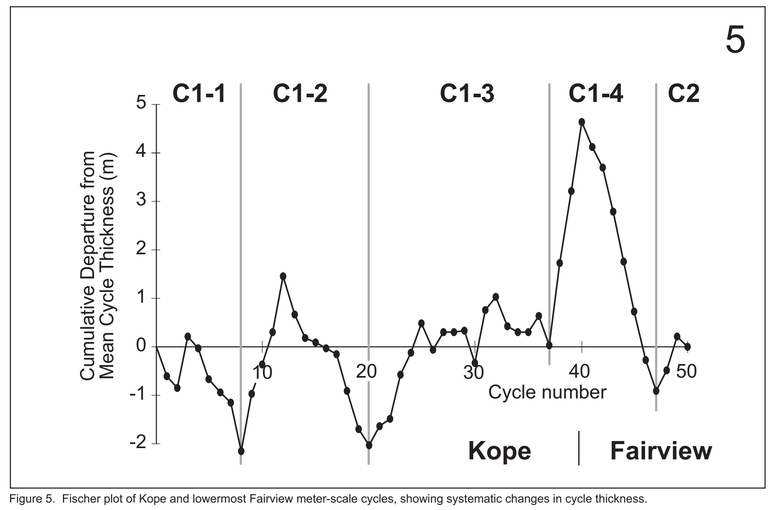


Figure 5. Fischer plot of Kope and lowermost Fairview meter-scale cycles, showing systematic changes in cycle thickness.