Olsen, P. E., 1985, Distribution of organic-rich lacustrine rocks in the early Mesozoic Newark Supergroup: U.S. Geological Survey Circular 946, p. 61-64.

10. DISTRIBUTION OF ORGANIC-MATTER-RICH LACUSTRINE ROCKS IN THE EARLY MESOZOIC NEWARK SUPERGROUP

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Most major, relatively fine grained Newark Supergroup sequences show a pattern of recurring lithologies making up sedimentary cycles (Van Houten, 1969, 1977; Olsen, 1980a, 1984a,b; Manspeizer and Olsen, 1981). These cycles consist of a strongly asymmetrical sequence of lithologically identifiable units that record the transgression, high stand, regression, and low stand of lakes. I propose that these cycles in the Newark Supergroup be termed "Van Houten cycles" for the worker who first recognized them. Each Van Houten cycle can be divided into three lithologically defined divisions (fig. 10.1), which have already been described for a number of Newark sequences (Olsen, 1981; Hentz, 1981). (I include division 4 of Towaco cycles (Olsen, 1980) within division 3 of Van Houten cycles.) In this paper I will focus on division 2, which has the greatest percentage of total organic carbon (TOC).

Division 1 is a relatively thin, platy to massive siltstone to conglomerate, which generally has a higher TOC (0.5–1.0 percent) than division 3 of the preceding cycle and shows fewer signs of desiccation. Current bedding, algal tufa, pisolites, oncolites, root zones, and reptile footprints are sometimes present.

Division 2 is commonly a laminated to microlaminated (laminae less than 1 mm) black siltstone, claystone, or carbonate showing few or no signs of desiccation, which commonly is rich in organic carbon (TOC locally more than 20 percent). In its most extreme form, division 2 contains abundant and well-preserved fossil fish, reptiles, arthropods, and sometimes plants. In its least developed form, division 2 consists of a red laminated siltstone that has desiccation cracks and is much better bedded than surrounding divisions 1 and 3.

Division 3 is generally thicker than the other two divisions. It consists of a massive, commonly red mudstone grading to a coarsening upwards sequence of sandy tilted beds showing current bedding and structures indicating deceleration of flow or to a fining upwards sequence with high-flow-regime structures at the base and low-flow-regime structures near the top. Desiccation structures are pervasive, commonly obliterating most bedding. Root and burrow zones and reptile footprints are common.

Both division 2 and the entire Van Houten cycle can be usefully thought of as varying along four independent lithologic axes (three of which are shown in fig. 10.2), which are (1) the desiccation-bioturbation axis, which reflects the amount of exposure to air and oxygenated water (largely a function of lake depth);

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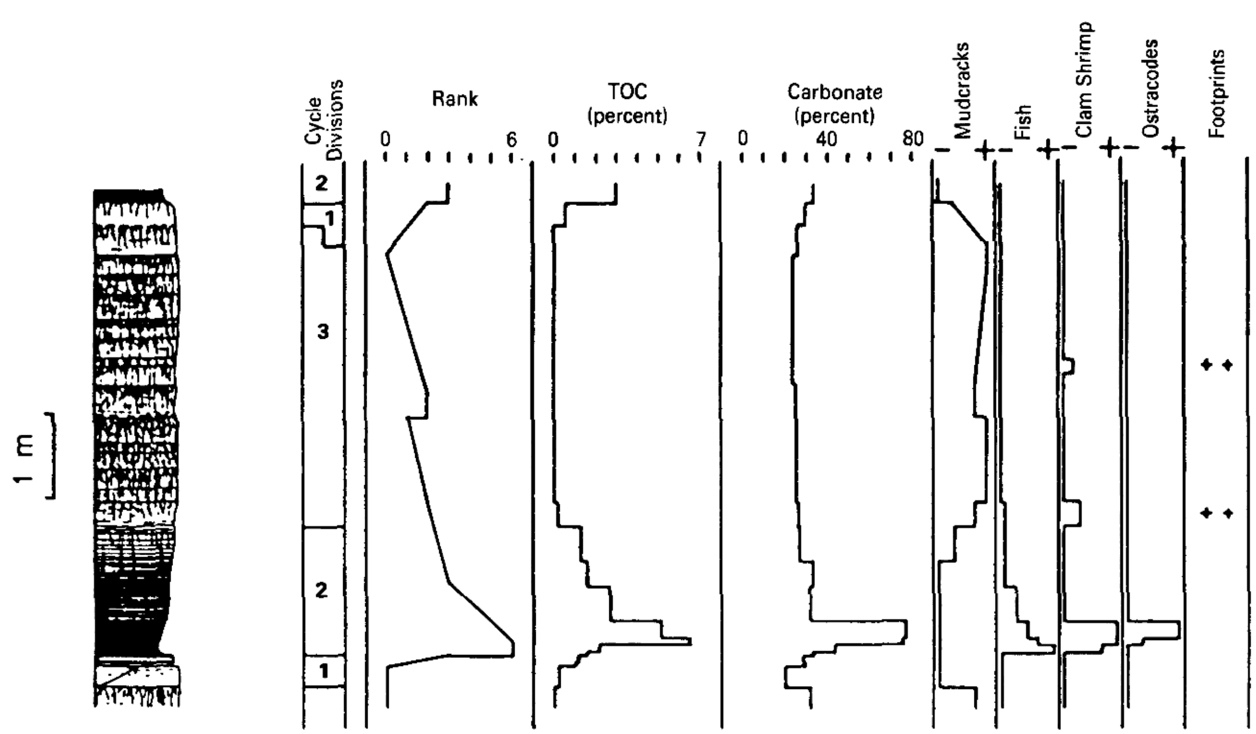

FIGURE 10.1.—Measured section through a single Van Houten cycle comprising the Skunk Hollow fish bed in the Lockatong Formation, showing common characteristics of a cycle near the microlaminated side of the desiccation-bioturbation axis (from Olsen, 1984a). Closeness of horizontal lines in the lithologic section indicates degree of lamination; solid black indicates microlamination. Irregular near-vertical lines indicate the density and depth of desiccation cracks. Rank is an indication of the position of *single beds* along the desiccation-bioturbation axis in figure 10.2; rank 6 indicates a microlaminated unit showing no signs of bioturbation or desiccation.

(2) the thickness axis, which is a measure of net sedimentation rate; (3) the coarseness axis, which reflects proximity to the basin edge; and (4) the chemical axis, which in part reflects the salinity of the lake water. At one end of the desiccation-bioturbation axis are beds showing very little or no signs of desiccation or bioturbation, while at the other end the sediments are massively disrupted by desiccation cracks and (or) bioturbation. For division 2, one end member along this axis is a microlaminated siltstone containing complete fish, while the opposite end member is a mud-cracked siltstone containing *Scoyenia*, roots, and reptile footprints. Extremes in the thickness axis are about 2 cm to 15 m for division 2 and 1 m to more than 50 m for the whole cycle. The coarseness axis for division 2 ranges from siltstone sequences containing thin conglomerate beds and abundant sandy graded beds (interpreted as turbidites) to claystones. Finally, along the chemical axis, division 2 ranges from a nearly pure limestone or dolomite to a noncalcareous claystone.

In a single Van Houten cycle, percentages of TOC are always highest in division 2. Within a single cycle, organic-matter content is closely related to the desiccation-bioturbation axis, increasing in beds as disturbance decreases. This relationship also holds for comparisons between cycles in single formations and suites of related formations in single basins, but it does not hold for comparisons between units in different basins. There also seems to be no correlation between increasing thickness of a cycle and increasing TOC. There is a general trend to have substantially greater TOC contents in more southern basins, however. Within the Triassic Lockatong Formation (late Carnian age) in the Newark basin, calcareous microlaminated portions of division 2 contain the most organic carbon (TOC 2.5–8.0 percent). Other cycles of the Lockatong in which division 2 is not microlaminated are not as rich in organic carbon. In contrast, the Cumnock Formation (Late Triassic, middle Carnian) in the Deep River (Sanford) basin contains no microlaminated sediments or beds producing whole fish, and Van Houten cycles there are quite thin (about 2 m). Many of the laminated siltstones of division 2, however, contain much more organic carbon (TOC 5–30 percent) than most other parts of the Newark Supergroup. The interbeds of coal (Cumnock and Gulf seams) low in the section are within division 2 and contain the same aquatic fossils as the overlying black siltstones.

Visual examination of kerogen from organic-matter-rich parts of division 2 commonly shows a large amorphous fraction made up of possible fecal pellets (E.I. Robbins, oral commun., 1984) and what is presumably algal and bacterial matter. Small amounts of pollen and spores and even smaller amounts of leaf cuticle and wood tracheids are also present. However, woody matter can become the dominant component, as in some lacustrine Newark coals. The kerogen in divisions 1 and 3 is, in contrast, almost always dominated by pollen, spores, cuticle, and wood tracheids.

The organic-carbon-rich parts of division 2 generally are a small fraction of the total volume of formations. However, this fraction is substantially larger in the Cumnock Formation, the lower 500 m of the Lockatong Formation, much of the Portland Formation (Early Jurassic, Hettangian to Toarcian) in the Hartford basin, and the Waterfall Formation (Early Jurassic, Hettangian to ?Sinemurian) in the Culpeper basin. Some formations have very thick Van Houten cycles, and, since the thickness of division 2 correlates strongly with total cycle thickness, the organic-matter-rich examples of division 2 can be quite thick. The Richmond basin section (Late Triassic, middle Carnian) seems to have very thick transgressive-regressive cycles, which may fall within a broad definition of Van

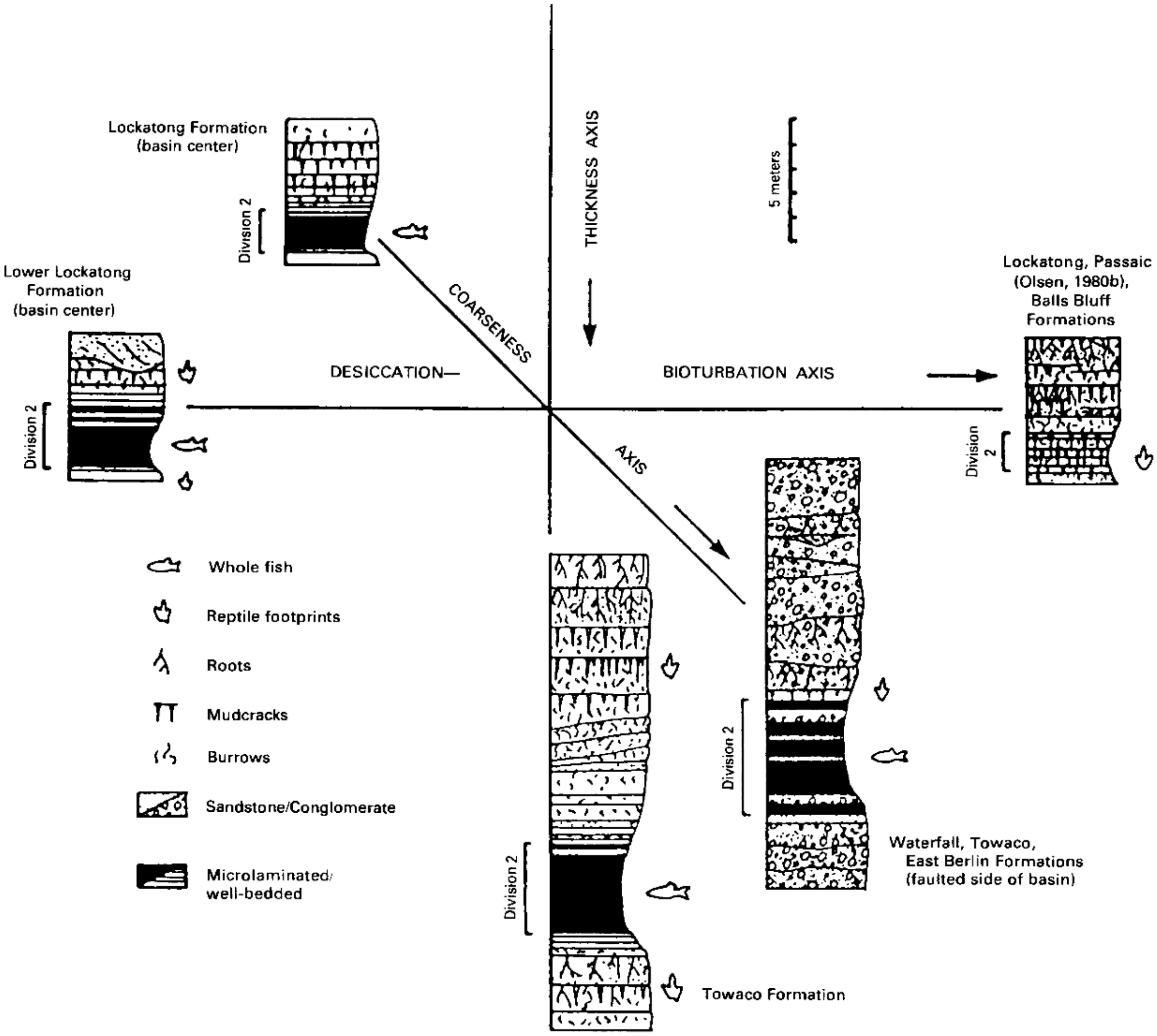

FIGURE 10.2.—Diagram of the relationship between the desiccation-bioturbation axis, the thickness axis, and the coarseness axis of Van Houten cycles and specific examples of classes of cycles from various Newark Supergroup formations in various basins. Division 2 is marked by brackets to the left of the columns.

Houten cycles (B. Cornet, oral commun., 1984). The deep-water parts of these cycles can be more than 15 m thick and consist of microlaminated black siltstones containing whole fish (TOC in the range of 10 percent) interbedded with sandstone beds showing no signs of desiccation. Similarly, the Towaco Formation (Early Jurassic, Hettangian) in the Newark basin has Van Houten cycles with a mean thickness of 25 m on the western side of the basin. Division 2 of these cycles is commonly as much as 5 m thick and contains more than 1.5 percent TOC.

Cycles in the Fundy basin commonly contain a conspicuous eolian and evaporitic component, substantially different from cycles in the other exposed Newark Supergroup basins. However, some can still be broadly classed as Van Houten cycles. The Blomidon Formation (Late Triassic, late Carnian to Norian) is made up of thin cycles (about 1.5 m thick), which consist mostly of a lower fissile red siltstone and an upper, highly disrupted siltstone or sandstone apparently containing eolian sand. The upper parts of these cycles seem to have been disrupted by evaporite crystal growth and possibly by efflorescent salt crusts (Smoot and Olsen, chapter 6, this volume). The overlying Scots Bay Formation (Early Jurassic) seems to consist of at least two 3-m-thick transgressive-regressive cycles, which are made up almost entirely of white and green limestone and chert. The coeval McCoy Brook Formation resembles the older Blomidon Formation, except that bioturbation seems more important than the evaporite-disrupted fabric in the upper parts of cycles and the sequences have much more fluvial sediment. Apart from some very thin beds just below the North Mountain Basalt, there are no organic-carbon-rich beds in the Fundy basin. The deepest water deposits, even those that are finely laminated and contain complete fish and invertebrates, have no carbonaceous organic matter.

Even Van Houten cycles that are otherwise rich in organic carbon can have very low TOC's near sills and other plutons where the sediments are metamorphosed. The most dramatic changes in the TOC occur within 50 m of the intrusive bodies, well within their zone of metamorphic alteration.

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