TRACE FOSSILS IN THE TIOGA ASH HELP DECIPHER CHANGING PALEOENVIRONMENTAL CONDITIONS IN THE MIDDLE DEVONIAN OF WEST VIRGINIA

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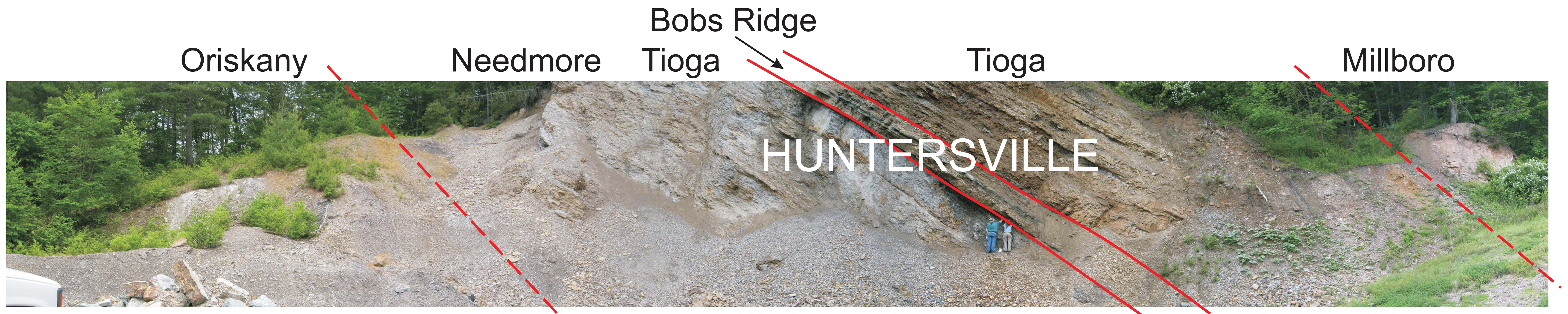
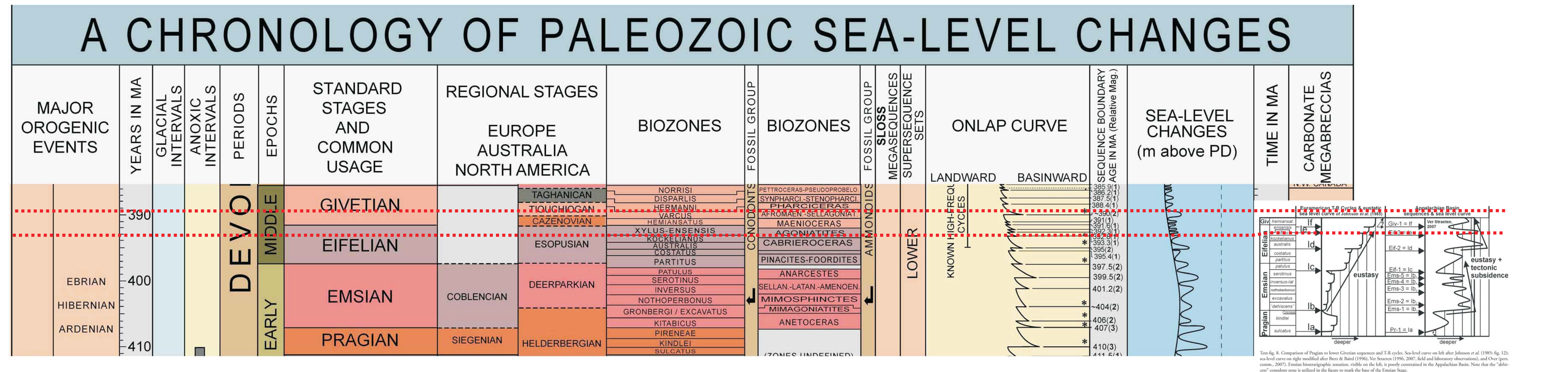
ABSTRACT

The Middle Devonian (mid-Eifelian) Tioga Ash occurs throughout the central Appalachian Basin, both in outcrop and subsurface. In eastern West Virginia, it forms a marker *horizon* comprising multiple, water-lain ashfall episodes spaced closely in time. The Tioga interfingers with the top of the Needmore Shale, a dark grey, organic-rich, marine unit, and is overlain by the Millboro (~ "Marcellus") Shale, a black, organic-rich, marine unit. The Needmore contains a moderately abundant, normal marine fauna of articulate brachiopods and trilobites with diagnostic, intensely bioturbated horizons dominated by *Chondrites* sp. The Millboro, noted for its depauperate fauna, typically contains miniature adult brachiopods, styliolines, and cephalopods; it is nearly devoid of trace fossils. These two shales clearly represent major differences in environmental conditions.

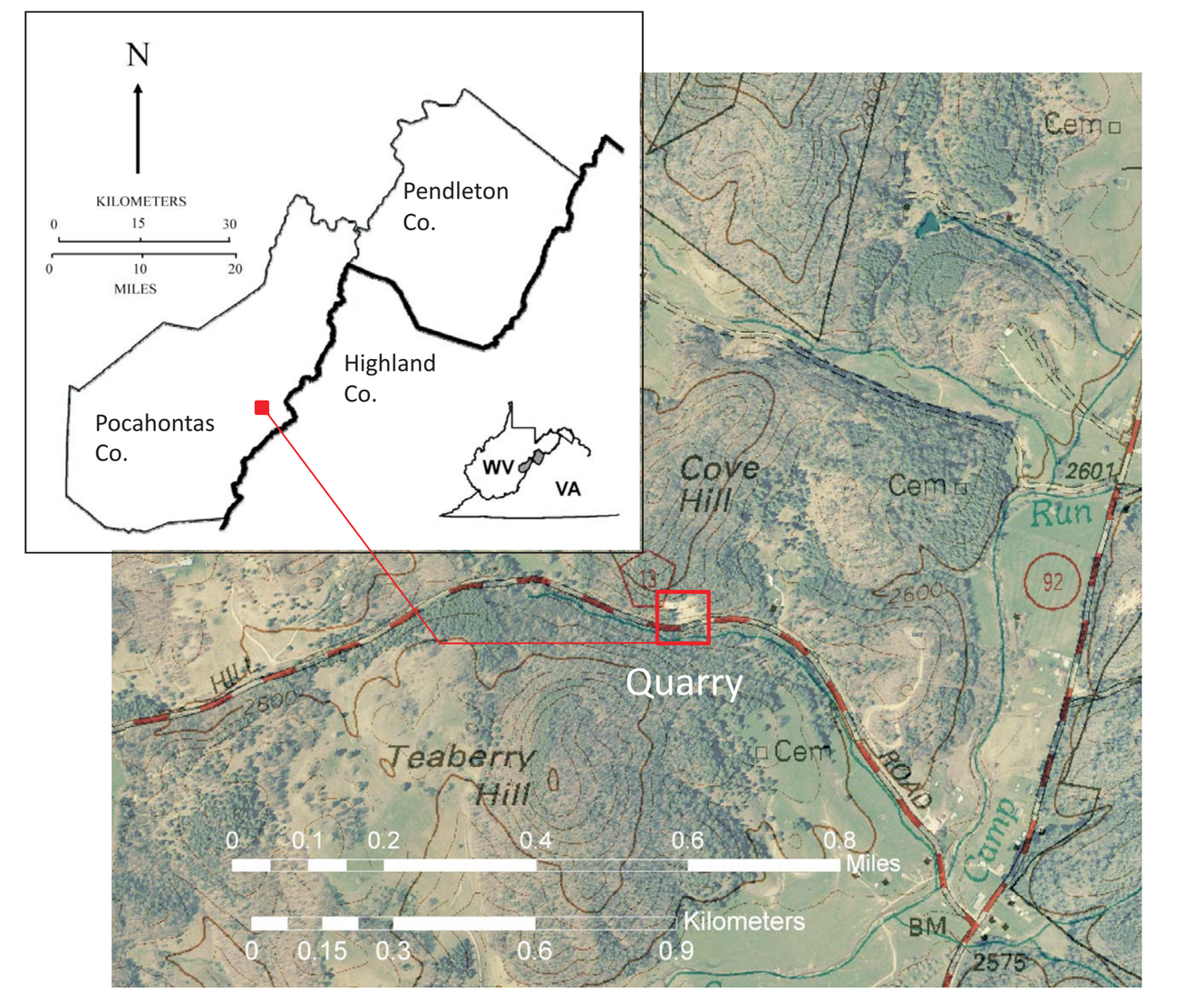
The Tioga falls (literally) between the Needmore and Millboro and should provide insight into the nature of the transition between the shales. Unfortunately, ashfalls are not typically known for abundant paleoenvironmental indicators. At the Cove Hill Quarry in eastern Pocahontas Co., WV, the Tioga also interfingers with a glauconitic sandstone, the Bobs Ridge. Interbeds of the two formations are crosscut by numerous vertical trace fossils (*Arenicolites* sp.) and marked by herringbone crossbedding. Presence of vertical dwelling traces intersecting alternating layer of glauconitic sand and volcanic ash in combination with probable tidal bedding structures implies relatively shallow water, perhaps a few to several ten's of meters in depth, at the end of Needmore deposition. Conversely, Millboro deposition seems to represent deeper water conditions, restriction of circulation, or both. If increasing water depth is responsible, it must have been significant (perhaps hundred's of meters or more) and taken place in a relatively short period following the Tioga Ash event. No major global sea level rise is known for the mid-Eifelian, nor are there any major Appalachian tectonic events at that time. This suggests that changing conditions from Needmore to Millboro may be better explained by restriction of circulation and anoxia associated with organic overproduction.



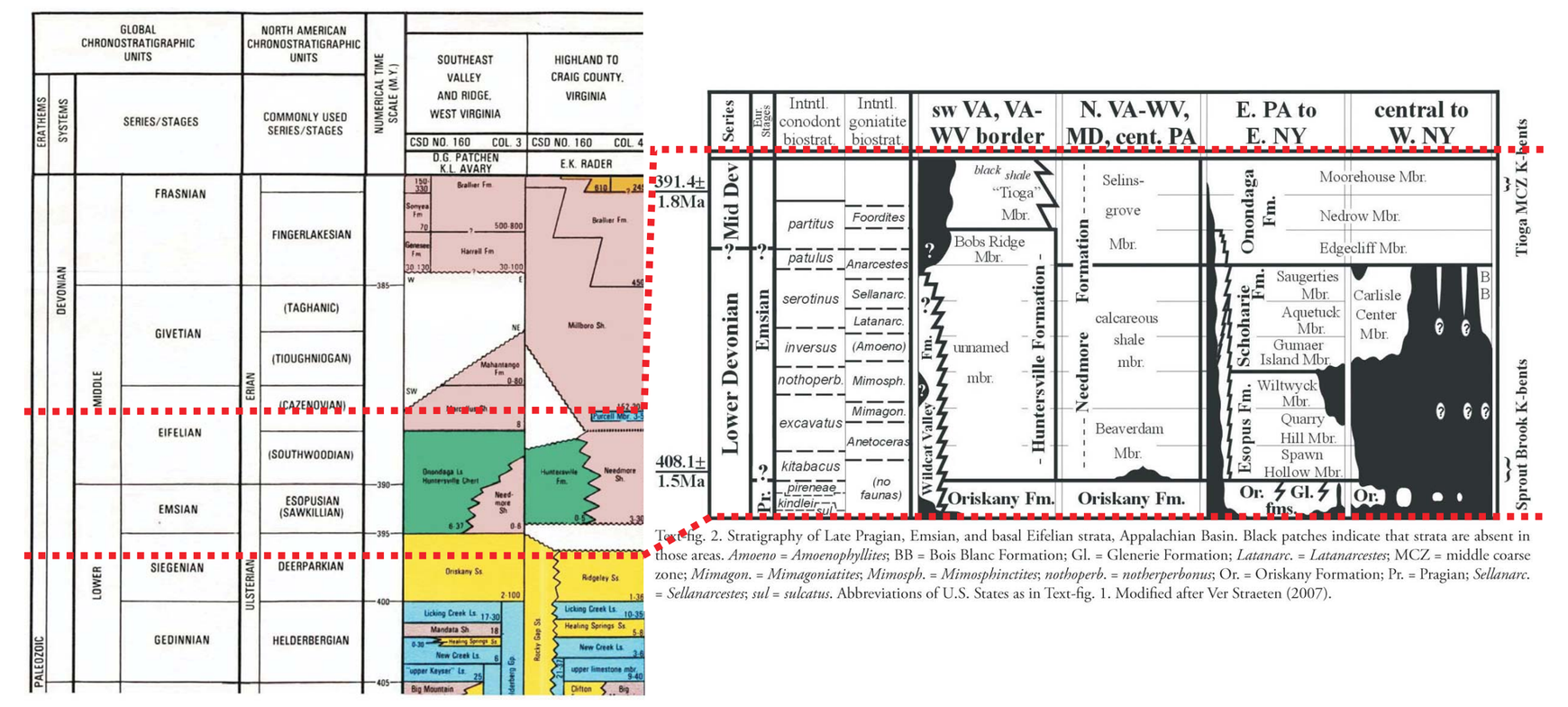
Panoramic view of the Devonian exposure at the Cove Hill Quarry. View is to the north.



A portion of the global sea level chart for the Early and Middle Devonian (Haq and Schutter, 2008) and a more detailed curve centered on the Appalachian region (Ver Straeten, 2009). The red dashed lines delimit the timing of the Tioga Middle Coarse Zone ashfall (Ver Straeten, 2009) - 391.4 ± 1.8 Ma. The shallowing event in the middle of this interval on the Appalachian regional curve may correspond to deposition of the Bobs Ridge glauconitic sandstone exposed at the Cove Hill Quarry.

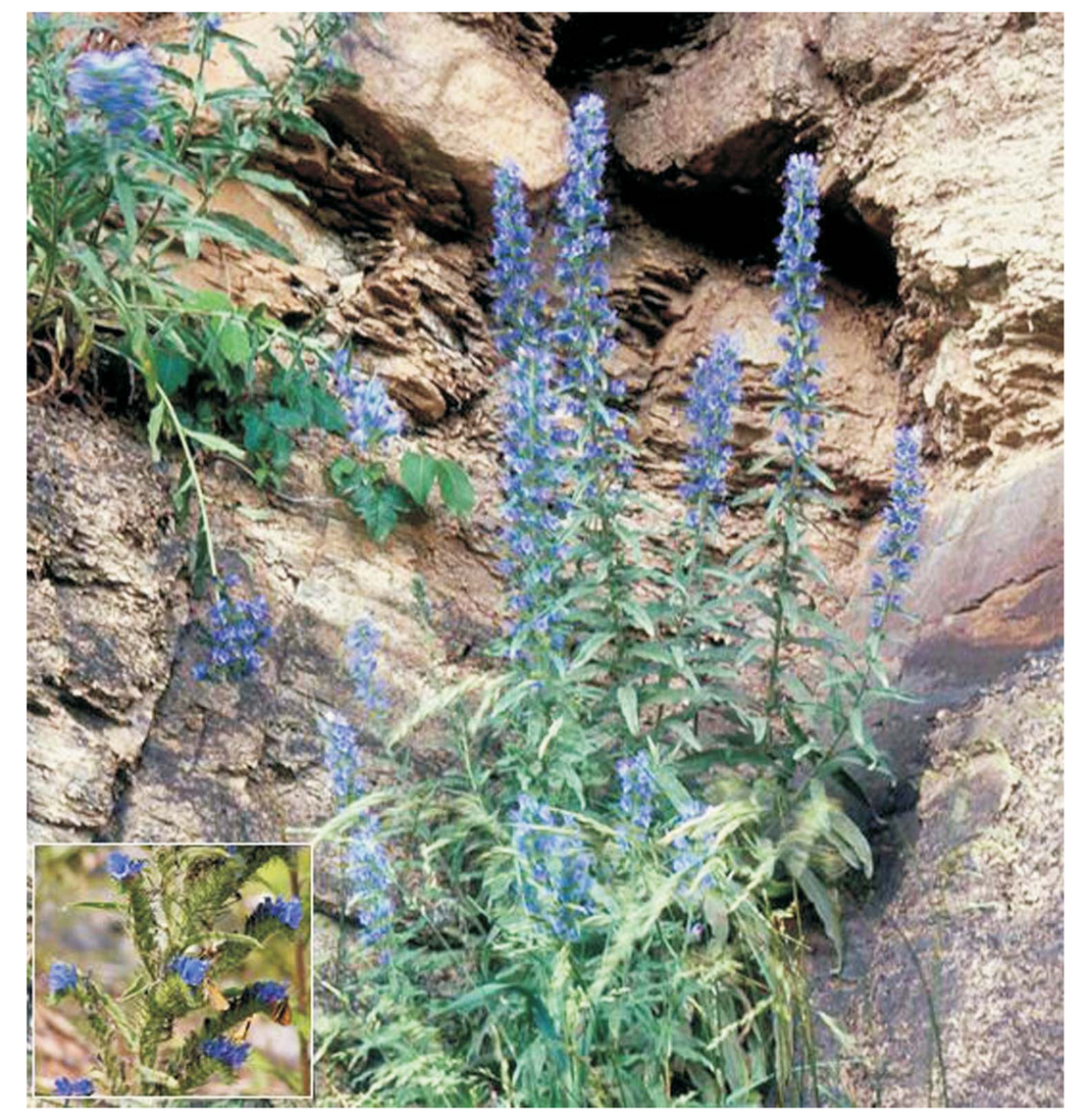


Location of the Cove Hill Quarry in east-central Pocahontas Co., WV.

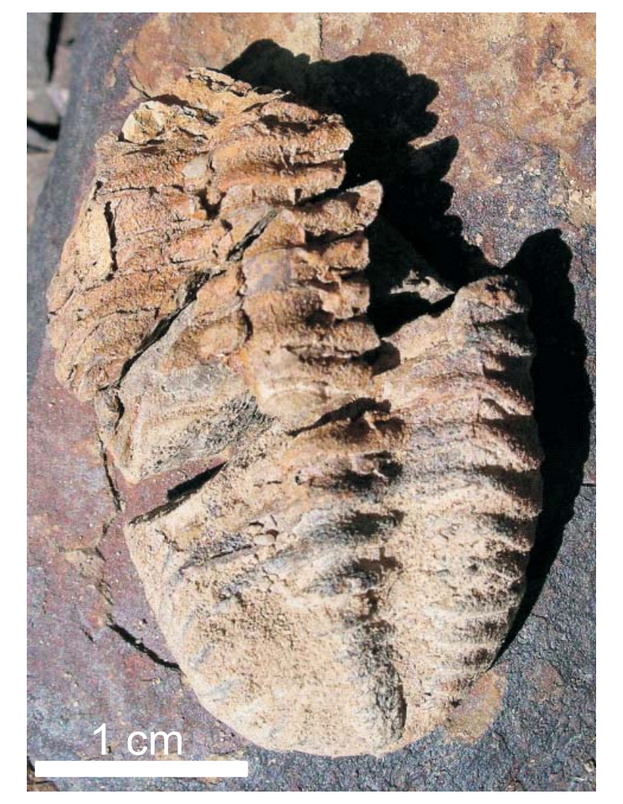


Early to Middle Devonian stratigraphy of southeastern WV and western VA including the Cove Hill Quarry area. Bedrock mapping by the West Virginia Geological and Economic Survey (WVGES) has been ongoing in this region since 1997 under the auspices of the USGS STATEMAP program. On the left, a portion of the COSUNA chart for the Northern Appalachian Region (Patchen and others, 1984); on the right, a more detailed look at the same stratigraphic interval (modified from Ver Straeten, 2009).

NEEDMORE SHALE



Outcrop of Devonian Needmore Shale near Ruddle, WV partially obscured by meter-tall Viper's Bugloss (*Echium vulgare*). Calcareous concretion is visible along the right edge of photo.



Incomplete specimen of *Phacops* sp. from the Needmore south of Petersburg,WV

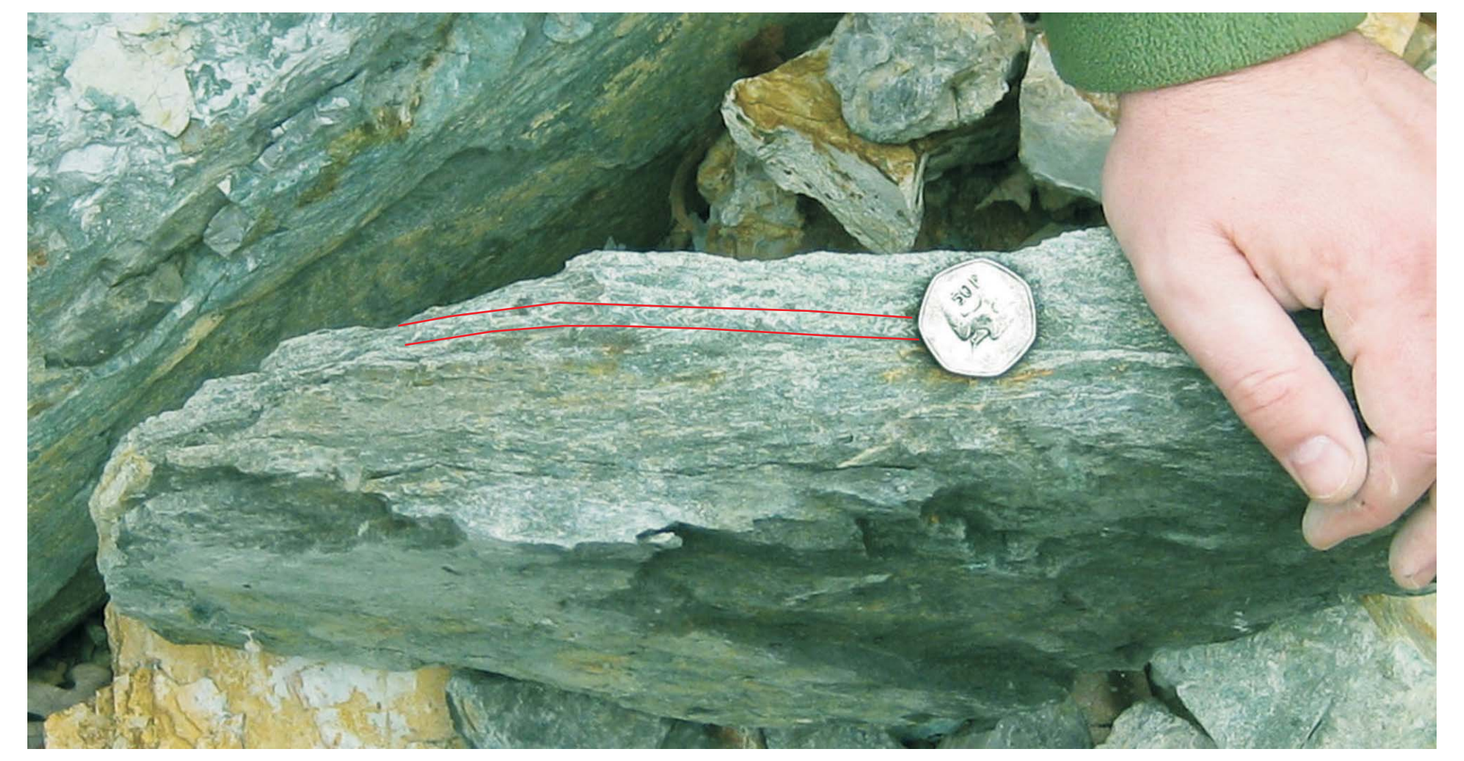
Intensely bioturbated interval in the Needmore east of McDowell, VA. Similar zones dominated by *Chondrites* sp. serve as marker beds when mapping the unit. Coin is 3 cm in diameter.

Probable goniatite cephalopods in the interior of a septarian concretion from the Needmore east of Franklin, WV.

In the study area, the Needmore Shale is a dark grey, locally calcareous shale with irregular to platy fracture. Calcareous concretions up to 0.5 m in diameter, occasionally with well-developed septaria and containing marine body fossils, are present. Two distinct fossil assemblages are encountered within the Needmore: one containing a collection of normal marine body fossils (the *Phacops* Biofacies of Newton) and a second dominated by an abundance of the trace fossil *Chondrites* sp. (Newton's *Planolites-Chondrites* Biofacies). Newton (1978) interpreted these two assemblages to correspond to aerobic vs. dysaerobic conditions in the depositional water column with an associated difference in water depth of a few ten's to a few hundred's of meters.

BOBS RIDGE MEMBER - HUNTERSVILLE FORMATION

Interbedded Tioga Ash and Bobs Ridge glauconitic sandstone from the Cove Hill Quarry crosscut by *Arenicolites* sp. with silicified fills. Walls of individual burrows are marked by a halo of iron mineralization.



Interbedded Bobs Ridge glauconitic sandstone and Tioga Ash from the Cove Hill Quarry marked by herringbone crossbedding of probable tidal origin. Red lines delimit a single set of well-developed crossbeds. Coin is 3 cm in diameter.

Interbedded Bobs Ridge glauconitic sandstone and Tioga Ash from the Cove Hill Quarry crosscut by *Arenicolites* sp. and marked by herringbone crossbedding. The unusual "zebra" coloration is due to the top-down view of individual crosslaminae. Coin is 3 cm in diameter.

In the study area, the Bobs Ridge Member is a dark green, medium-grained, glauconitic sandstone. At the Cove Hill Quarry, the Bobs Ridge is interbedded with white Tioga Ash which implies contemporaneous deposition of the two units. Even more significantly, the Bobs Ridge is marked by herringbone crossbedding suggesting tidal deposition. Finally, the Bobs Ridge is crosscut by numerous specimens of the trace fossil *Arenicolites* sp., all of which are infilled with silicified Tioga Ash. The presence of probable tidal crossbedding in association with *Arenicolites* sp. suggests very shallow water conditions (a few meter's deep). This is in marked contrast to conditions for the underlying Needmore and overlying Millboro shales.

MILLBORO SHALE

Outcrop of Devonian Millboro Shale south of Sugar Grove, WV showing extensive jointing and an example of one of the large calcareous concretions typical of the unit.

A specimen of *Buchiola* sp., a common component of the depauperate fauna present in the Millboro within the study area.

Limonite mineralization associated with intraformational faulting in the Millboro near Brake, WV.

A specimen of *Styliolina* sp., a common component of the depauperate fauna present in the Millboro within the study area.

In the study area, the Millboro Shale is a black, platy shale that is typically pyritiferous. It is frequently marked by the presence of calcareous layers and concretions. These layers may form marker horizons that can be traced for several kilometers, outcrop exposure permitting. The concretions, some of which may exceed 1 m in diameter, weather readily out of exposed bedding surfaces. The Millboro is sparsely fossiliferous and, within the study area, contains a curious depauperate and dwarfed fauna of miniature adult brachiopods, goniatite cephalopods, and styliolines. Trace fossils are even more rare and consist almost exclusively of simple, clay-filled feeding traces. The depositional environment for the lowermost Millboro appears to have been dysaerobic to anerobic based on the nature of the fauna, preserved organic content, and disseminated pyrite. Whether this lack of oxygen was due to water depth (hundred's to thousand's? of meters), stagnation of the water chemistry due to salinity stratification or overproduction of organic matter, or some combination of these factors cannot be determined. At a minimum, the water depth was greater than storm wave base (hundred's of meters).

CONCLUSIONS

Sedimentological features encountered in interbedded Tioga Ash and Bobs Ridge glauconitic sandstone at the Cove Hill Quarry in Pocahontas Co., WV suggest a marked difference in depositional conditions from the two Devonian shale units that bracket the interval. The underlying Needmore Shale may have been deposited in water several ten's to several hundred's of meters deep; the overlying, organic-rich and pyritiferous Millboro Shale may have been deposited in significantly deeper water. Complementary sedimentary structures in the interbedded Bobs Ridge and Tioga - herringbone crossbedding and the trace fossil *Arenicolites* sp. - suggest a tidal depositional system and corresponding water depth of only a few meters. While global sea level curves do not seem to capture this depositional change, the more detailed curve of Ver Straeten (2009) for the Appalachian region indicates a shallowing event at the end of the Eifelian-3 sequence. It's also possible this event is so localized that it is not represented even at the regional scale.

ACKNOWLEDGEMENTS

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