140-8

RECONSTRUCTING PALEOCURRENT DIRECTION IN THE CHADAKOIN AND GIRARD FORMATIONS IN NORTHWESTERN PENNSYLVANIA

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Abstract

Extensive exposures of late Devonian Chadakoin and Girard Formation (Conneaut Group) are exposed in Fourmile, Sixmile, Twentymile, Elk, and Walnut Creeks, Erie County, Pennsylvania. Both formations consist of medium-gray shale interbedded with 5–20 cm thick siltstone lenses. The relatively low energy marine environment of these formations allowed for the creation and preservation of ripple marks in the fine sand and silt lenses. Ripple crests are transverse sinuous in phase and out of phase. Average grain size of ripple mark sediment was 0.03 cm. Ripple heights rang from <0.5–3.25 cm (avg=0.95 cm) (std(h)=0.74 cm) and wavelengths from 6–31 cm (avg=12.88 cm) (std(λ)=5) (n=103). Ripple marks were documented throughout Fourmile, Sixmile, Twentymile, Elk, and Walnut Creeks and mapped stratigraphically to reconstruct paleocurrent direction through time. Paleocurrent directions and changes in time were identified using rose diagrams and stratigraphy. During the transition from the Girard Formation to the Chadakoin Formation, asymetrical ripple crests record a shift in current direction from the northeast to the northwest with trend in flow direction at N10°E and S90°W. The shift in paleocurrent direction is hypothesized to be due to a change in dominant current forces of deep water bottom currents flowing parallel to the continental margin of the Catskill Sea (N-NE) to basinal turbidite flows parallel to these currents (W-SW). Prograding continental slope during the transition from the Girard Shale to the Chadakoin Formation is one hypothesis explaining the observed changes in ripple current direction. Future work will consist of mapping ripple marks throughout all of Northwestern Pennsylvania along with using techniques developed by Diem (1985), Immenhauser (2009), and Okoro etal (2010) to reconstruct paleo-water depth based on ripple height, ripple spacing, and grain size.

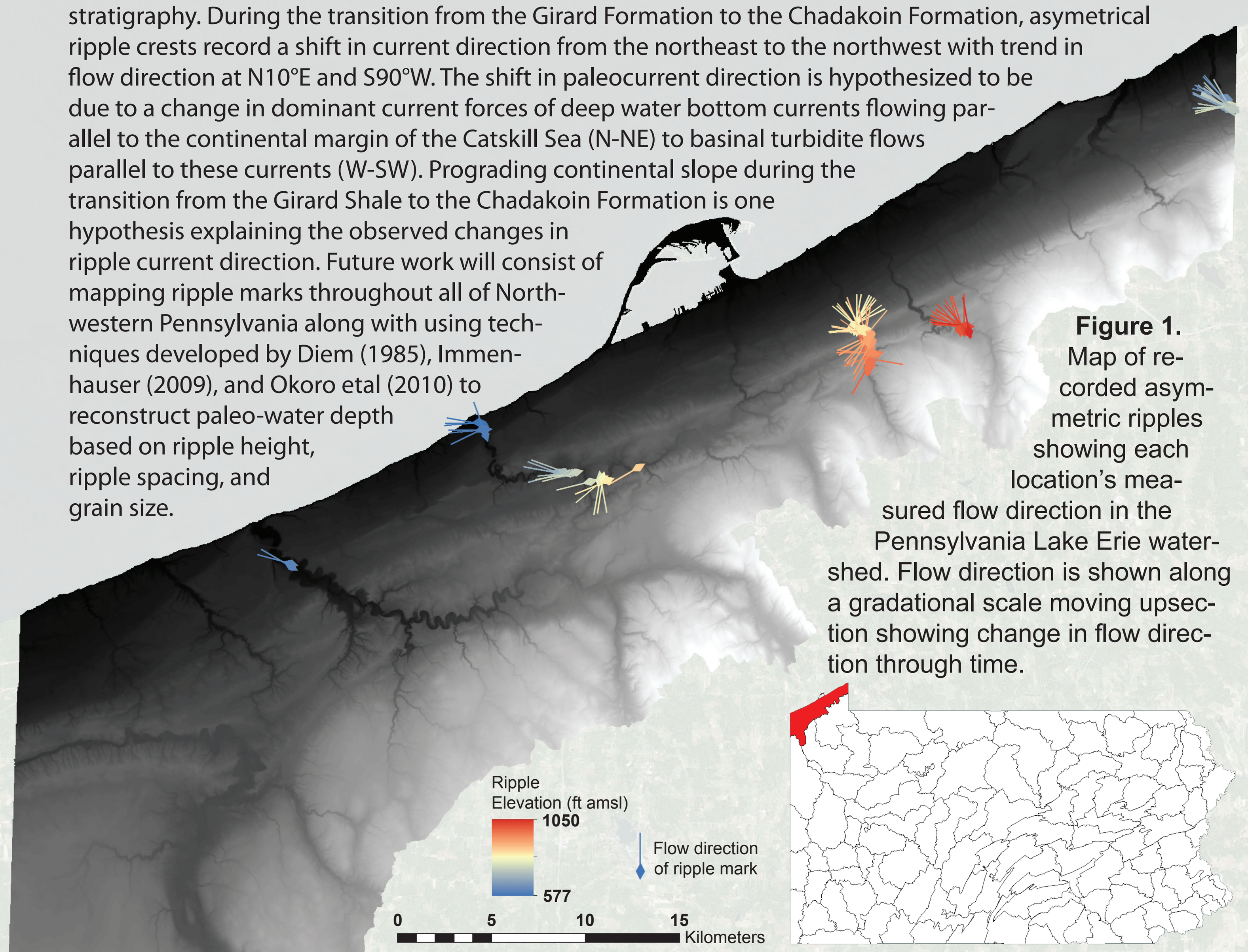


Figure 1. Map of recorded asymmetric ripples showing each location's measured flow direction in the Pennsylvania Lake Erie watershed. Flow direction is shown along a gradational scale moving upsection showing change in flow direction through time.

Background

The Late Devonian stratigraphic section in western Pennsylvania is characterized by a westward prograding delta system associated with the Acadian Orogeny, part of the overall Appalachian Orogeny (Harper 1999). The Catskill delta complex begins approximately halfway across (east to west) Pennsylvania (Figure 6) forming a typical delta fed basin complex (Figure 7). The Girard Shale and Chadakoin Formation (Conneaut Group) (Figure 5) consist of medium-gray shales interbedded with thin tabular fine-grained sandstone lenses, ripple marks and are void of fossils. These features are consistent with Harper's (1999) interpretations of the region as part of a delta-fed submarine ramp. Both the Girard and Chadakoin were deposited in the Late Devonian (Harper 1999) and are specifically associated with basinal deposits of the Catskill Sea (Woodrow 1985). Lundgard et al. (1985) used sole marks to map paleocurrents of Late Devonian turbidites in the Appalachian basin showing a mean slope direction of the basin as S87°W with a standard deviation of 32° (Figure 4). Murphy (1973) and Woodrow and Isley (1983) interpret these deposits as part of a marine transgression, causing coarse clastic sediment to be trapped on the landward end of the coastal plain, only allowing fine-grained clastic sediment to reach the basin margin. The transgression of the basin margin also led to well-oxygenated water to be replace by denser, anaerobic water, leading to a great reduction in diversity and abundance of marine fauna (Murphy 1973). This study hopes to further the understand what depositional processes and environmental conditions led to the formation of the Girard and Chadakoin formations during the Late Devonian of northwestern Pennsylvania.

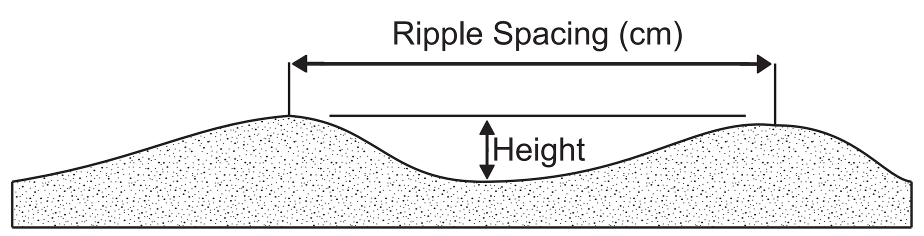


Figure 2. Diagram of asymmetric ripples and defined ripple spacing and ripple height.

Methods

Ripple marks were located in shale deposits incised and exposed by Twenty Mile, Six Mile, Fourmile, Walnut, and Elk Creeks, in Erie County, PA (Figure 3). Locations were collected using a survey grade Trimble GPS and paper map. Average measurements of ripple spacing, height, symmetry, morphology, strike, dip, and orientation were recorded for each ripple set (Table 1) and recorded in stratigraphic order (Figure 1). Samples were taken from four locations for thin sections to determine average grain size. Paleocurrent direction based on ripple mark orientation was plotted on a set of rose plots (Figure 4). All data was entered into an Excel database for analysis and compared to previous studies.

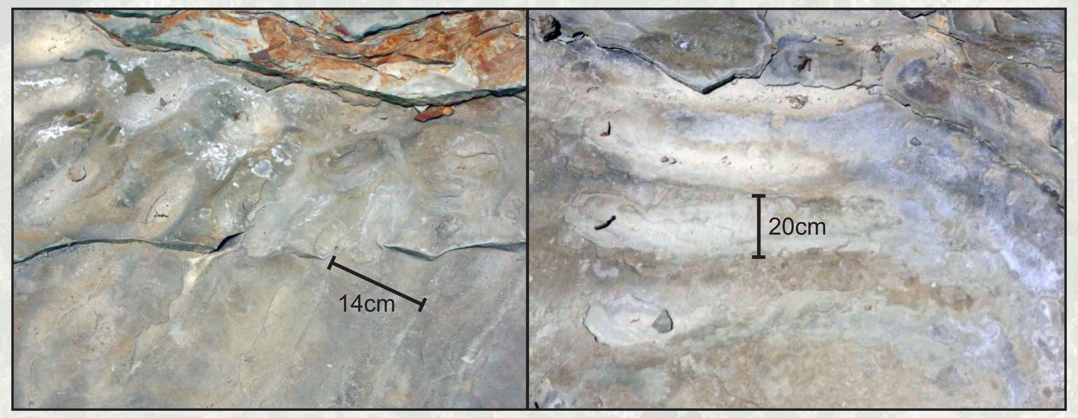


Figure 3. Examples of asymmetric ripples and ripple spacing from Fourmile Creek, Erie, PA.

Discussion

- Asymmetric ripple marks exposed in Erie County, PA show a mean flow direction of N68°W.
- Flow direction fluctuates between S83°W – N42°W through time.
- Grain size for ripple marks range 0.2–0.4 mm with clays between particles.
- The majority of ripple marks are asymmetrical and range 0.2–4.5 cm tall (Table 1), indicating weak currents for their formation.
- No fossil fauna are found in deposits containing ripple marks but are found above and below these strata along with increased grain size.
- Wavelength between ripple crests range 6–31 cm (Table 1).
- Ripple flow direction's match at the same elevations between seperate creeks, indicating flat lying bedrock of the Girard and Chadakoin formations.
- Due to a predominantly NW flow direction, it is postulated ripple marks trending northwest are likely formed during low-density basin edge turbidity currents.

Figure 4. Paleocurrent map of Late Devonian turbidites in the Appalachian basin by Lundegard et al. (1985). Data are from sole marks and have a mean trend of S87°W with a standard deviation of 32°. Location of observed asymmetric ripple mark flow direction in Erie County, PA (n=103) are shown in red and have a mean trend of N68°W.

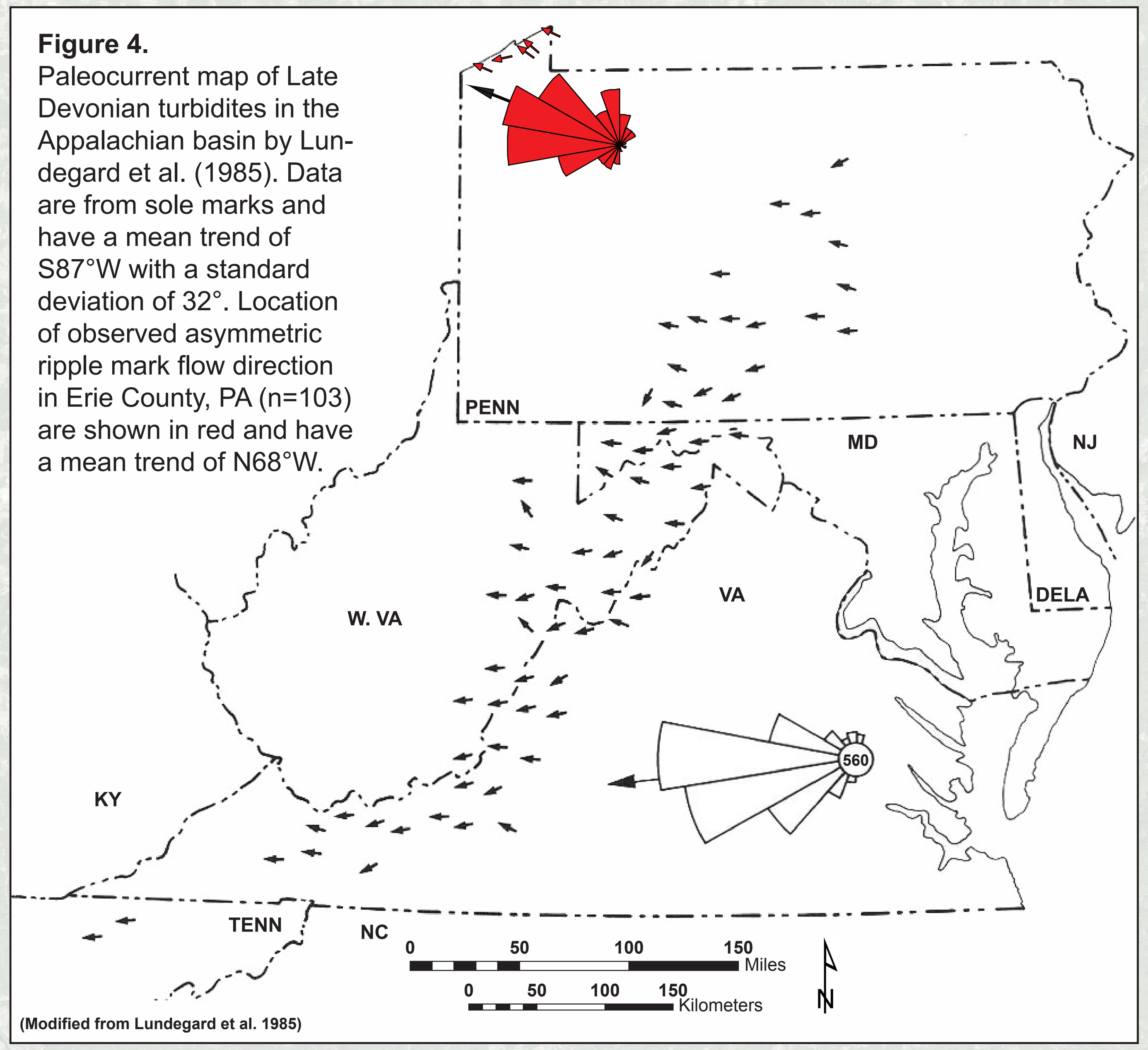


Figure 5. Stratigraphic units of the Upper Devonian.

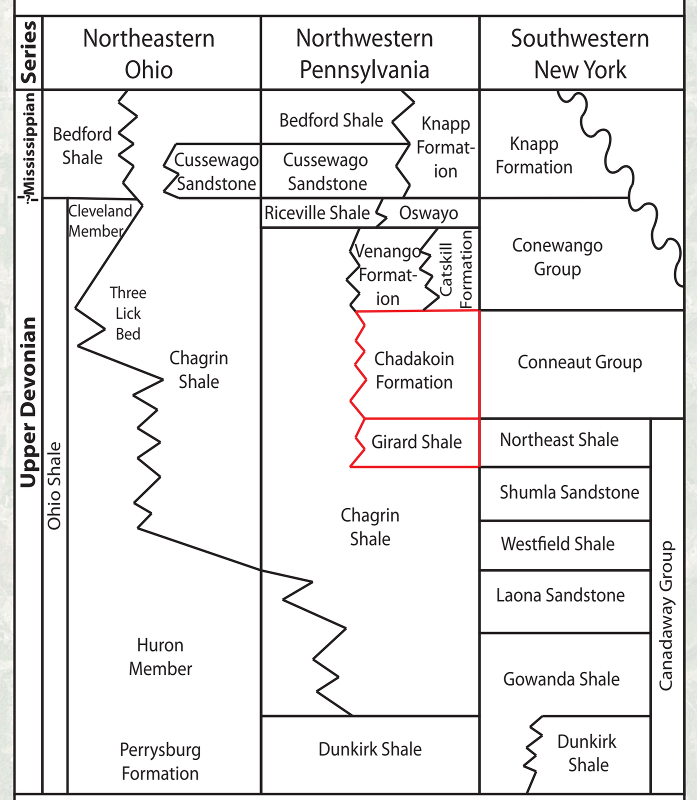


Table 1. Ripple Spacing and Height Frequencies and Ripple Spacing vs. Height over time.

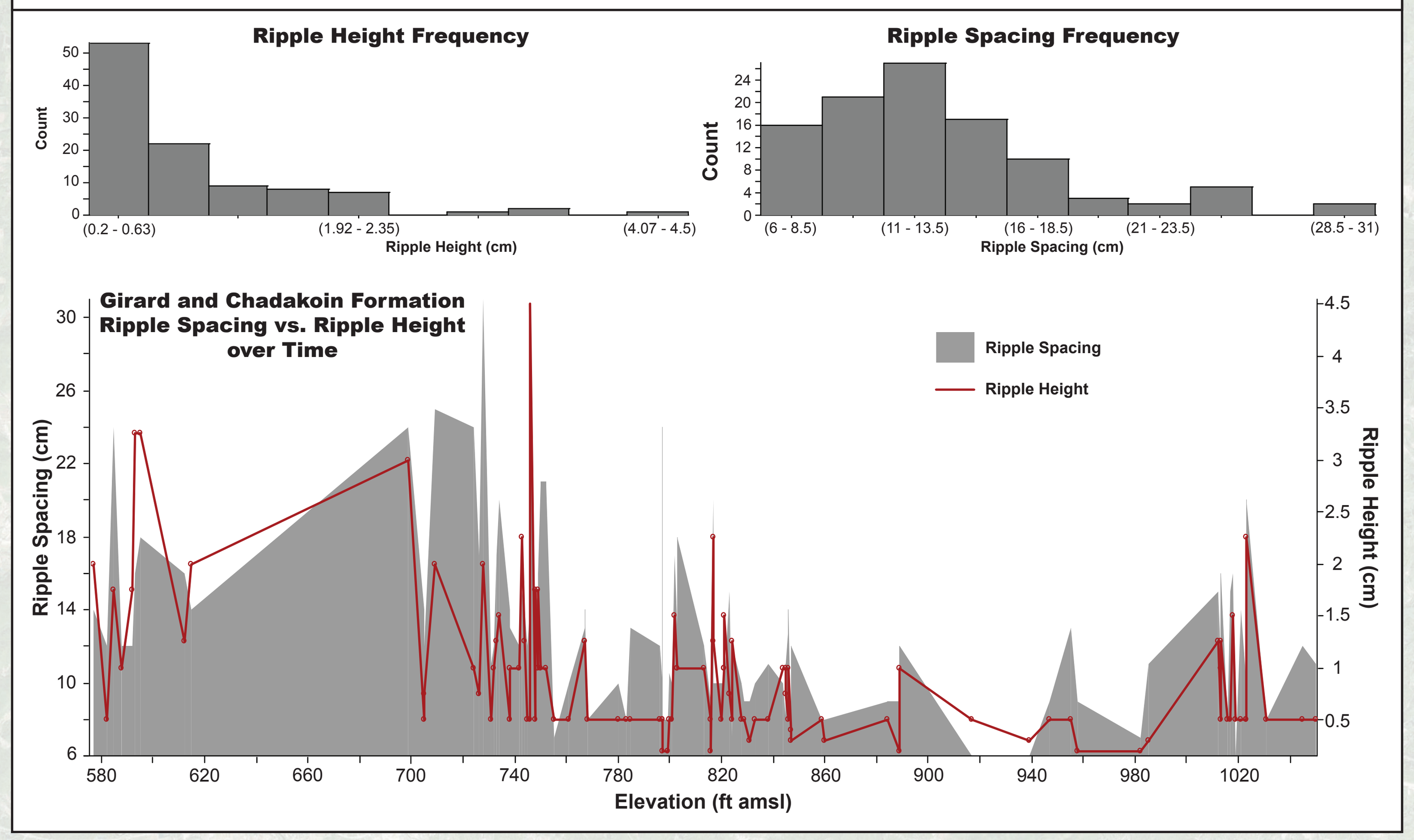
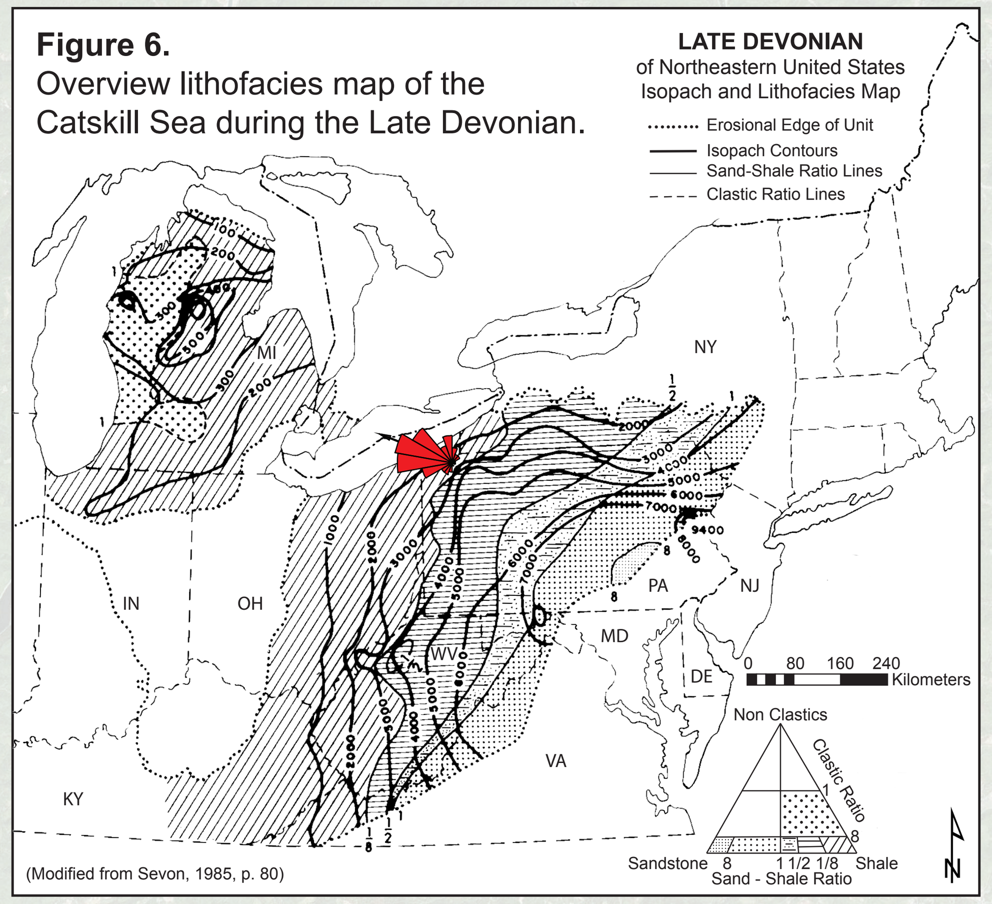


Figure 6. Overview lithofacies map of the Catskill Sea during the Late Devonian.



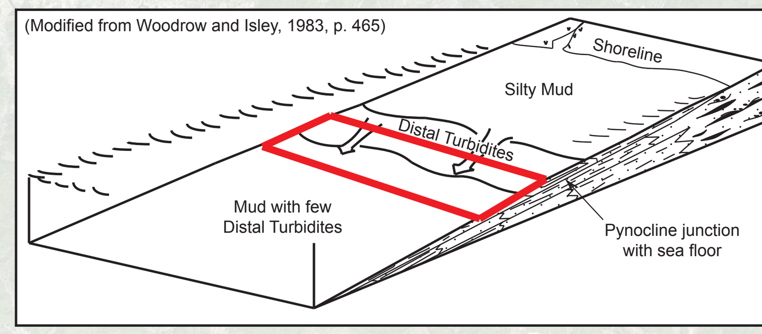


Figure 7. Model of deposition in the Catskill Sea during a marine transgression. Depositional environment of the Girard and Chadakoin Formations highlighted in red.

Conclusions

The ripple marks are distributed with a mean current flow direction of N68°W (Figure 4). This is hypothesized to be due to basinal turbidite flows perpendicular to the Catskill Basin coastline (Figure 7). Stratigraphically, the observed ripple marks show a fluctuating mean flow direction ranging from S83°W – N42°W (Figure 1), indicating a relatively regular output of sediment along a distal slope (Figure 7). The lack of marine fauna, predominance of fine sand and clay shales, and small ripple marks in the lower portion of the Chadakoin and the Girard Formations indicate a marine transgression during this time (Figure 7). This data agrees with Woodrow and Isley (1983) who hypothesized a marine transgression during the late Devonian of the Catskill Sea, allowing for a reduction in sand-laden turbidity currents and a shift in oxygenated water zones. This would cause a shift in marine faunal populations to more oxygenated zones upslope.

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