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Gradient analysis of faunal distributions associated with rapid transgression and low accommodation space in a Late Pennsylvanian marine embayment: Biofacies of the Ames Member (Glenshaw Formation, Conemaugh Group) in the northern Appalachian Basin, USA

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Abstract

The Ames Sea, situated in a shallow marine embayment in the Appalachian Basin, was the result of the most extensive marine transgression of the Pennsylvanian in this region. Gradient analysis of the proportional abundance of taxa reveals an environmental continuum across the Ames embayment along which four biofacies were distributed. Biofacies distribution is interpreted to be controlled by salinity, turbidity, and oxygen gradients associated with the geometry of the Ames depositional basin and relative sea-level change.

The eastern portion of the Ames Sea resembled a foredeep trough located on the detrital slope of the recently uplifted Appalachian Highlands. Biofacies 1 and 2 occur exclusively in the eastern part of the Ames depositional basin and are dominated by eurytopic molluscs tolerant of terrigenous influx. Biofacies 3 occurs in both the eastern and western portions of the Ames depositional basin. This biofacies is dominated by the opportunistic brachiopod *Neochonetes*, which would quickly colonize the seafloor in the wake of transgression. Biofacies 4 occurs exclusively in the western part of the Ames depositional basin and is composed primarily of stenotopic crinoids, bryozoans, brachiopods, and epifaunal bivalves that inhabited a clear water, cratonic ramp on the eastern flank of the Cincinnati Arch.

Vertical variations of faunal assemblages in the Ames Member were the result of variations in relative sea level associated with glacio–eustatic cycles. Biofacies 3, dominated by *Neochonetes*, was deposited at the base of the Ames Member during the initial rapid transgression in a mostly dysoxic environment with low turbidity and marine salinity. During the first regression, low-density surface water from eastern sources restricted vertical circulation, established a stratified water column, and promoted estuarine conditions in the Ames Embayment. Well-oxygenated surface waters were unable to circulate to the benthic habitat, which led to periodically dysoxic conditions and the establishment of Biofacies 1 and 2, composed of diminutive eurytopic molluscs. A second, stratigraphically-higher occurrence of Biofacies 3 is interpreted to represent a second transgression. However, unlike the first transgression, lithologic and faunal data suggest that the benthic habitat was well-oxygenated. Above the mid-Ames marine zone occurrence of Biofacies 3, Biofacies 1 and 2 were deposited in the final regressive phase as local terrigenous source areas brought increasing turbidity and fluctuating salinity to the Ames Embayment.

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Previous paleoecological research on the Ames Member cited freshwater and/or clastic influx as the major controls on biotic distribution, but the results of the present study suggest that oxygen availability was also a major control. Stratification of the water column during the Ames sea-level cycle promoted estuarine circulation that prevented well-oxygenated surface waters from reaching the benthic habitat. This led to the deposition of dark gray to black fissile shales that contain fossil assemblages dominated by diminutive molluscs and brachiopods that were tolerant of low-oxygen conditions.

Keywords: Biofacies; Ames member; Conemaugh group; Late Pennsylvanian; Gradient analysis; Appalachian Basin

1. Introduction

Eight thin marine zones are distributed among nonmarine units within the Upper Pennsylvanian Glenshaw Formation in the northern Appalachian Basin (Busch, 1984; Busch and Rollins, 1984; Busch and West, 1987). These marine zones record the distal portions of marine incursions of the Midcontinent Sea onto the high shelf formed by the detrital slope of the Appalachian highlands (Heckel, 1995). The thickest and most extensive of these marine units is the Ames Member, which contains a suite of variable fossil assemblages. The Ames Member was deposited during the most extensive marine event of the Pennsylvanian, and the last major marine event of the Paleozoic in eastern North America. Transgression of the Ames Sea from the southwest resulted in the periodic establishment of a variety of marine facies that have been the subject of several modern paleoecological studies (Donahue and Rollins, 1974; Rollins and Donahue, 1975; Nuhfer, 1979; Al-Qayim, 1983; Brezinski, 1983; Saltsman, 1986; Merrill, 1993). Although these studies have identified biofacies and faunal gradients thought to reflect changing conditions associated with variations in sea level, the role of environmental parameters such as dissolved oxygen, salinity, and turbidity in controlling faunal distribution is not apparent from these studies.

The present study utilizes paleoecologic principles to test two stratigraphic hypotheses: whether the Ames Member of the Glenshaw Formation represents a single transgressive–regressive cycle, or multiple cycles. Each of these alternative hypotheses would make different predictions about the distribution of biofacies within the Ames Member, and both hypotheses were considered during the examination of the spatial and stratigraphic distribution of biofacies. In order to test these hypotheses, lateral and vertical faunal variations in the Ames Member were quantitatively measured in seven outcrops along a general northwest–southeast transect across the northern Appalachian basin. This transect is roughly perpendicular to the depositional axis of the basin, crossing this ancient sea. This provides an opportunity to examine faunal and stratigraphic patterns during the deposition of the most extensive marine event in the Upper Pennsylvanian of this region. Faunal data were analyzed based on how individual taxa may have utilized available resources (e.g., food and habitat) under any given set of environmental conditions (Dodd and Stanton, 1990). The observed faunal patterns were combined with sedimentological data to interpret paleoenvironmental conditions present in the Ames Sea.

2. Stratigraphy and geologic history

The Pennsylvanian System is composed of a single second-order transgressive–regressive unit that begins at the base of the Pennsylvanian and extends to the base of the Permian (Vail et al., 1977). Weller (1930) subdivided Pennsylvanian units in the northern Midcontinent and northern Appalachian Basin into separate packages of lithofacies (Busch and Rollins, 1984). Each package was considered a formation in the Pennsylvanian System, with the specific lithofacies that comprise them classified as members. The cyclically arranged members of these Pennsylvanian formations were thought to represent shifting depositional environments relative to the shoreline during a single transgressive–regressive cycle. Wanless and Weller (1932) used the term cyclothem to describe these formations in Pennsylvanian strata of North America.

The Conemaugh Group includes rocks deposited during the late Middle to Upper Pennsylvanian (Edmunds et al., 1999). Outcrops are located in southeastern Ohio, southwestern Pennsylvania, western Maryland, West Virginia, and eastern Kentucky in an elliptical belt (Fig. 1) with the long axis oriented northeast–southwest. The Conemaugh is divided into two formations (Fig. 2): the Glenshaw Formation, which is distinguished by the presence of many thin marine zones distributed among nonmarine rocks, and the overlying Casselman Formation, which contains two geographically-limited marine zones, the Gaysport and the Skelly (Flint, 1965; Busch, 1984). The boundary between the two formations is located at the top of the uppermost marine zone in the Glenshaw Formation,