Journal of the Arkansas Academy of Science

Volume 48 Article 18

1994

Storm Dominated Channel Sequences on a Shallow Marine Shelf: Morrowan of Northwest Arkansas

Kimberley R. Jones
University of Arkansas, Fayetteville

Doy L. Zachry
University of Arkansas, Fayetteville

Storm Dominated Channel Sequences on a Shallow Marine Shelf: Morrowan of Northwestern Arkansas

Kimberly R. Jones and Doy L. Zachry
Department of Geology
University of Arkansas
Fayetteville, AR 72701

Abstract

The Brentwood Member of the Bloyd Formation (Morrowan, Pennsylvanian) in northwestern Arkansas contains stratigraphic sequences deposted by tropical storms in middle shelf environments. The deposits are confined to shallow channels incised by strong unidirectional currents into an interval of shale deposited during fair weather conditions. Complete storm sequences reflect initial bottom currents of high competency that declined through time and were succeeded by wave generated oscillatory activity. The storm succession consists of an erosion surface followed by a basal pebble conglomerate, massive grainstone and packstone, whole-fossil wackestone, hummocky cross-strata and a swell lag of platy crinoid calyxes. As storm activity ceased, fairweather deposits of middle shelf clay blanketed the storm sequences.

Introduction

In recent years modern storm event shave caused storm deposits to be recognized as a normal part of the stratigraphic record. It is assumed that ancient storms would systematically effect coastal areas and adjacent continental shelves, and that these storm deposits would interrupt normal fairweather marine deposition. An understanding of storm processes has heightened the interest in ancient storm deposits and led to more frequenct recognition of such deposits in recent years.

Morrowan strata within the Bloyd Formation of northwest Arkansas contain depositional characteristics that can not be attributed to normal open marine, inner shelf depositional processes, but are compatible with storm depositional processes.

Geologic Setting.--Accumulation of early Morrowan sediment in northwest Arkansas occurred in a variety of marine and nonmarine environments on an inner shelf depositional surface inclined to the south at less than .01 degrees. A deeper outer shelf and slope marine environment lay to the south in central and southern Arkansas. Marine strata composed of shale, sandstone, and limestone were deposited in inner and middle shelf settings and dominate the Morrowan sequence.

The Hale and Bloyd Formations compose the Morrowan Series in northwest Arkansas (Fig. 1). The Hale Formation rests unconformably on rocks of Mississippian age. The Bloyd Formation conformably overlies the Hale. It is divided in ascending order into the Brentwood Member, the middle Bloyd sandstone, the Dye Shale Member and the Kessler Limestone Member (Fig. 1). All are marine deposits except for the middle Bloyd sandstone, a fluvial interval deposited by braided streams.

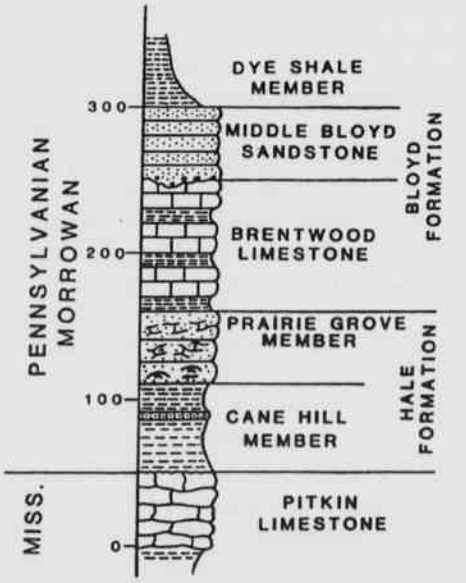

Fig. 1. Stratigraphic column of lower Pennsylvanian (Morrowan) strata of Madison County, Arkansas. Storm channel deposits occur in the upper Brentwood Member.

The Brentwood Member is composed of alternating beds of limestone and shale and ranges to 50 feet in thickness (Zachry, 1977). It conformably succeeds the Prairie Grove Member of the Hale Formation. The Prairie Grove accumulated in high-energy, inner shelf environments succeeded by transgression and the deposition of middle shelf shale and limestone beds of the Brentwood Member in slightly deeper water. Deposits believed to be of storm origin have been identified in the upper part of the Brentwood Member (Fig. 1). They were deposited on an erosion surface formed on the middle shelf during maximum storm intensity and accumulated as storm current and wave intensity declined.

During the early Carboniferous, the southern part of North America was south of the equator. Arkansas was approximately 20 degrees south of the equator and bounded by an open sea and continential shelf (Smith et. al., 1981). Reconstructions suggest that the shelf was in a belt effected by tropical storm events.

Location.--The storm channel deposits are in the upper part of the Brentwood Member and are exposed along the east side of Highway 23 approximately 15 miles south of the city of Huntsville in central Madison County (T15N, R26W, Sec. 25; Fig. 2.). Exposures containing storm deposits range from 12 to 15 feet in thickness and extend for a distance of 432 feet.

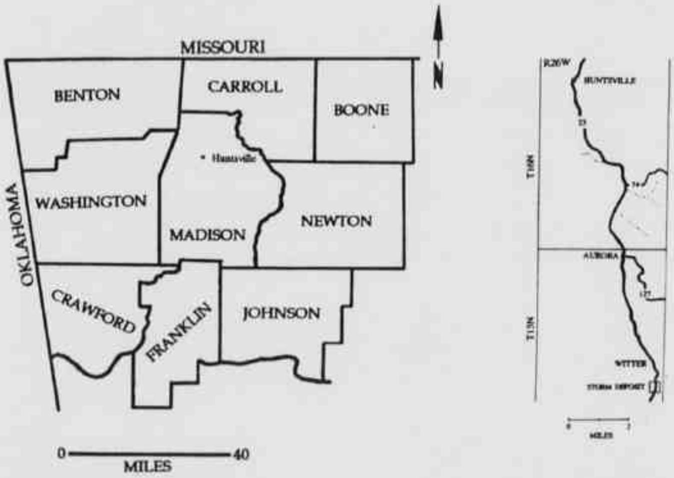

Fig. 2. Geographic locality map of the study area. Storm channel deposits occur along Highway 23, south of Huntsville in central Madison County.

Materials and Methods

Outcrop sections were measured with a Jocobs staff and measuring tape. Slabs and thin sections were prepared from outcrop samples collected from each unit, and detailed descriptions of sedimentary structures and lithic characteristics were made. X-ray diffraction analyses were conducted to compare the compositions of selected facies.

Discussion

Storm Facies.--Five storm facies are defined within the storm sequence that is confined above and below by fair-weather shale deposits. In ascending order they are the pebble conglomerate facies, the packstone facies, the wackestone facies, the hummocky corss-stratified facies, and the swell lag facies (Figs. 3 and 4).

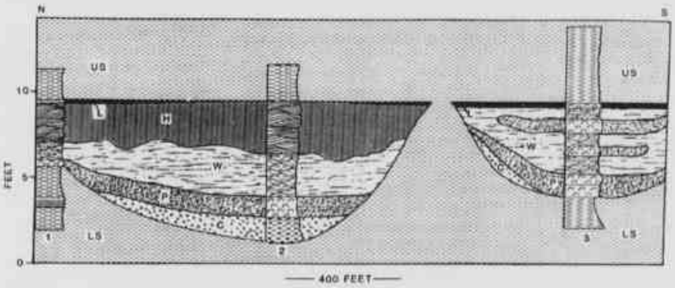

Fig. 3. Cross-section view of storm deposits and channel system. Measured sections include fair weather facies involving the lower shale (LS) and upper shale (US) and storm facies including the basal pebble conglomerate facies (C), athe packstone facies (P), the wackestone facies (W), the hummocky cross-stratification facies (H), and the swell lag facies (L).

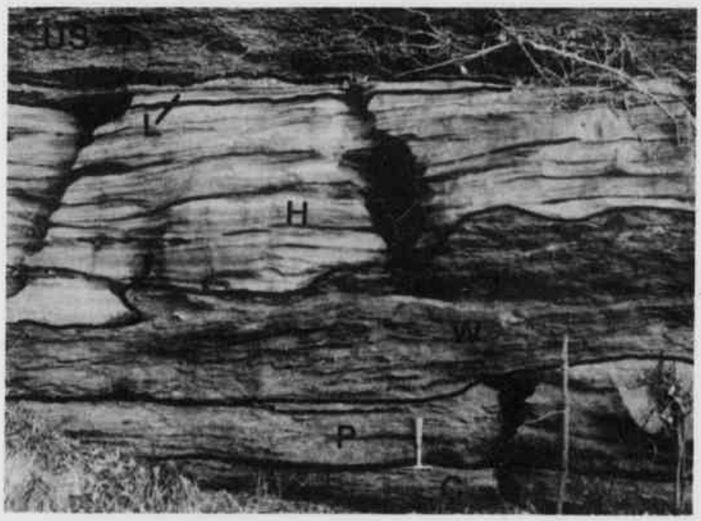

Fig. 4. Photograph of measured section 2 (Fig. 3) displaying the complete storm interval. Abbreviations same as in Fig. 3.

Storm deposits of the lower Brentwood are unconformably underlain throughout the outcrop area by an interval of black, fissile shale containing several thin beds of iron oxide cemented siltstone and ironstone concretions. The siltston beds are trucated by the erosion surface (Fig. 5). The shale is dominantly composed of illite and chlorite and is not calcareous.

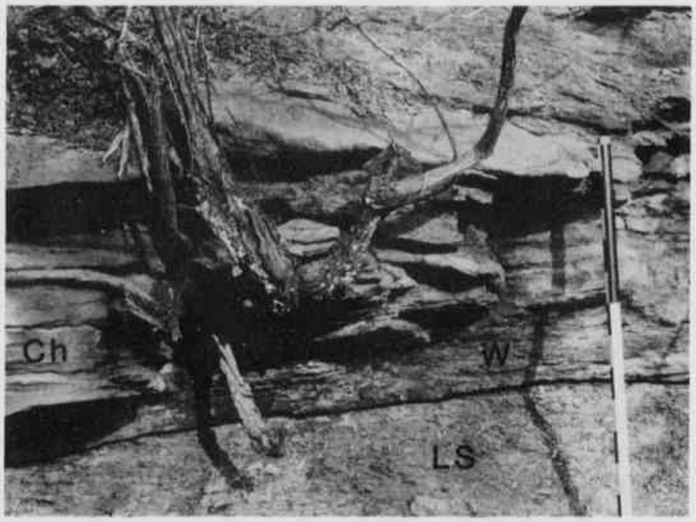

Fig. 5. Truncation of the lower shale unit by the storm channel erosion surface. The surface is indicated by the solid line with the lower shale (LS) below and the wackestone (W) and hummocky facies (Ch) above.

The pebble conglomerate facies rests on the erosion surface cut on the lower shale unit. It is composed of clay ironstone pebbles and cobbles from one to four inches in length. The particles are embedded in a matrix of course skeletal bioclasts (Fig. 6). The matrix is composed of subrounded crinozoan fragments (24%), ramose bryozoans (2%), and brachiopods (1%). Pebble and cobble clasts form 65% of the conglomerate. The remaining constituents are quartz sand (2%) and clay (6%). The facies ranges from 0.5 to three feet in thickness. The stratigraphic position of the pebble conglomerate suggests that the clasts were derived from the lower shale and formed during scouring of the channels.

Beds of the packstone facies directly overlie the pebble conglomerate. The facies consists of a lower bed of limestone composed of massive, ungraded grainstone. Fragments of coarse to very coarse, rounded crinozoan fragments (74%) are the dominate constituent (Fig. 7). Bryozoans (7%) and brachiopods (3%) are also present. Clay matrix (4%) and calcite cement (7%) occur in intergranular areas (Fig. 7).

The lower bed is overlain by a second limestone bed composed of massive, crinoid and bryozoan packstone. Crinozoans fragments compose 18% of the rock whereas various kinds of bryozoans form 65% of the rock. Skeletal fragments are horizontally to subhorizontally oriented. Clay matrix (24%) is pervasive in intergranular areas and calcite cement is absent.

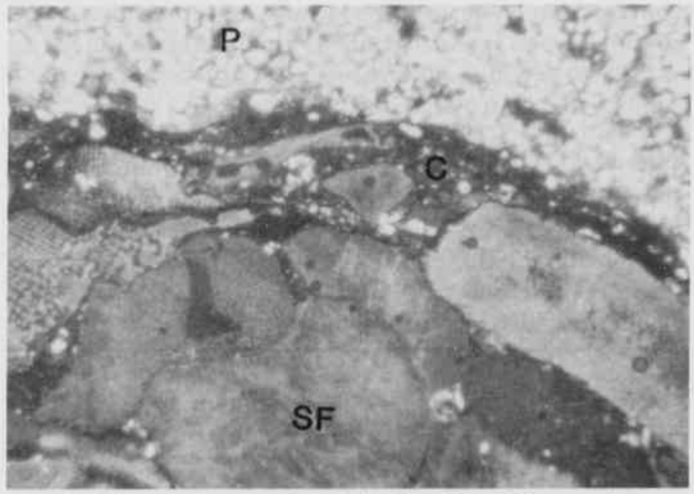

Fig. 6. Photomicrograph of the basal pebble conglomerate. The pebble (P) interpenetrates the crinoid skeletal fragments (SF). A thin layer of clay occurs between the pebble and crinoid fragment.

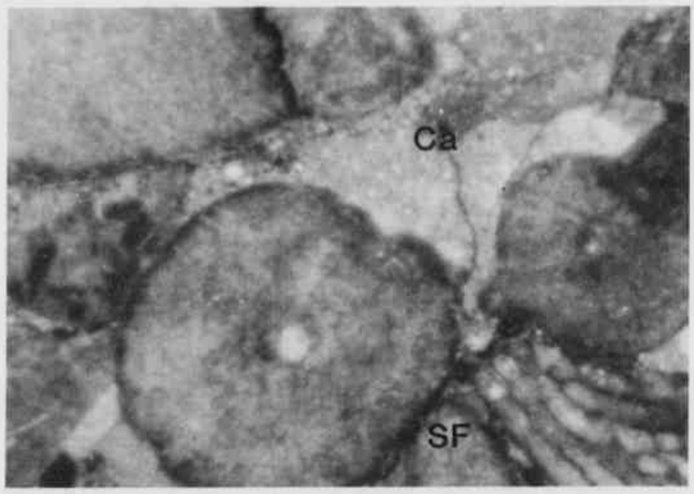

Fig. 7. Photomicrograph of the packstone facies with calcite cement (Ca) between skeletal fragments (SF).

Beds of the packstone facies are overlain by strata assigned to the wackstone facies (Figs. 3 and 4). Beds of the facies are gray and have a shaley appearance related to the presence of platy skeletal grains. Coarse to very coarse, articulated crinoid stems ranging to eight inches in length are common. Platy fenestrate bryozoan fronds and occasional brachiopod valves are present. Calcite cement occurs, but most intergranular areas contain terrigenous clay.

The hummocky facies directly overlies beds of the wackestone facies and consists of sets of cross-strata from three to 8.5 feet in length and from four to 14 inches in thickness (Fig. 8). Foreset laminae dip less than 10 degrees and are clearly defined by oriented fenestrate bryozoan fronds along foreset boundaries (Fig. 8). A single hummocky set was collected from a wackestone interval. Polished slabs display foresets inclined from 5 - 15 degrees and composed of crinozoan and bryozoan fragments. Large tabulate coral fragments from 4 - 24 mm in diameter are scattered throughout the set. Intergranular terrigenous clay composes 27 - 30% of the rock. Micrite and calcite cement are essentially absent.

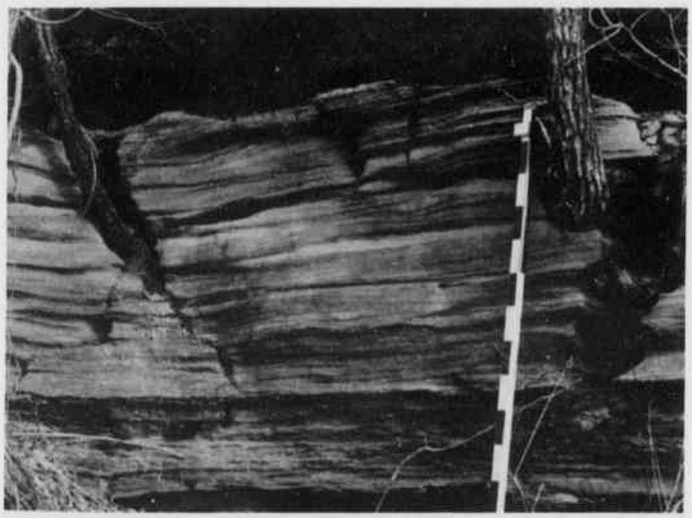

Fig. 8. Hummocky cross-stratification facies in the storm sequence. Note well defined foreset strata and inclination to the north (left).

Strata of the hummocky facies are overlain by a thin veneer of crinozoan calyx plates from two to three inches thick (Figs. 3 and 4). Individual plates are oriented with their convex side up. Other fossil fragments are absent. This veneer is assigned to the swell lag facies and is the uppermost facies in the storm sequence. The swell lag facies is overlain by black, fissile shale of the upper shale unit. This shale is not calcareous and fossil fragments are absent.

Outcrop Stratigraphy.--Storm deposits of the Brentwood Member fill two shallow channels in the outcrop area (Fig. 3). The channels are incised into the lower shale interval and have erosional relief of up to four feet. Complete storm sequences include the pebble conglomerate facies at the base of a channel succession followed by the packstone, wackestone, hummocky cross-stratification, and swell lag facies. This succession is bounded above by the upper shale unit (Figs. 3 and 4). A sharp contact exists between the top of the storm sequence and the upper shale.

Results and Conclusions

Depositional Synthesis.--Early Carboniferous paleographic interpretation by Smith et al., (1981) placed southern North America south of the equator with Arkansas at 15 degrees south latitude (Fig. 9) and bounded to the south and southeast by shelf, slope and oceanic basin environments. The area was a prime location for hurricanes and tropical storms that are capable of extensive shoreline erosion and sediment transport in shallow, marine depositional settings (Duke, 1985). Wind and pressure gradients generate wave and current forces operating far below fairweather wave base that erode and transport bottom sediment during storm events (Kreisa, 1981, Aigner, 1982; 1985 Snedden and Nummedal, 1991). Water driven onto inner shelf and coastal areas creates coastal buildups and generates high energy, seaward-directed return currents (Dot and Bourgeois, 1982; Hobday and Morton, 1984). As storm energy wanes unidirectional currents are gradually supplanted by wave processes that produce oscillatory flow (Leckie and Krystinik, 1989). Sediment is reworked under these conditions but sediment "migration" does not occur (Hunter and Clifton, 1881). Hummocky cross-stratified sets of reworked sediment are formed under these conditions (Snedden and Nummedel, 1991).

Onshore directional storm currents initially scoured channels into the lower shale unit on the middle shelf during the early phases of storm activity. These bottom currents transported sediment from a carbonate-dominated inner shelf to an outer shelf where terrigenous clay and silt had accumulated during fairweather conditions. Mass quantities of skeletal debris were moved from the inner shelf and combined with clay pebbles eroded from middle sheld clays during channel formation. This sediment was funnelled through and deposited in the shallow channel system. The basal claystone pebble conglomerate accumulated at the base of channels during the most competent phases of return current flow. The skeletal-rich packstone facies was depostied from waning but still competent return current systems. During the last phases of unidirectional flow from return currents, mass transport and deposition of poorly sorted sediment rich in skeletal fragments and terrigenous mud formed the wackestone facies. During transport, boulder-sized bryozoan and cobble-sized tabulate coral fragments were suspended in a matrix of finer skeletal fragments and terrigenous clay.

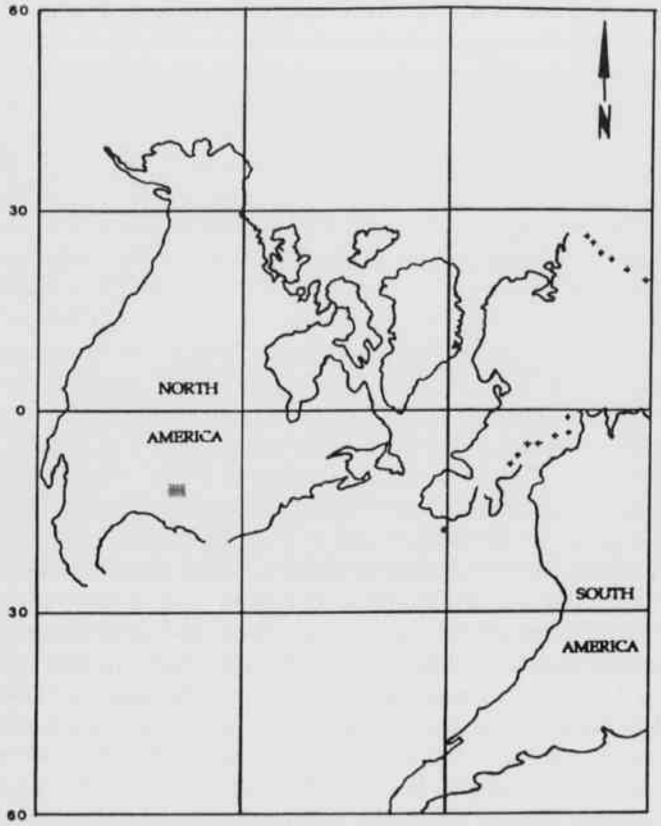

Fig. 9. Paleogeographic map of North America during early Carboniferous time (modified from Smith et al., 1981). Rectangle represents the position of the northwestern Arkansas and the study area during this time.

As storm intensity subsided wave activity replaced unidirectional currents as the dominant process in the water column. Oscillatory movement driven by waves impinged on the bottom and reworked the skeletal and terrigenous sediment of the wackestone facies forming hummocky corss-stratification. Platy calyx plates from crinoids remained suspended in the oscillatory regime after more spherical fragments were deposited and ultimately accumulated as a swell lag on the hummocky sets to complete storm deposition. Outer shelf clays blanketed the storm sequence with the return of fairweather conditions. Facies within the Brentwood storm sequence document phases of storm activity observed in modern coastal areas and indicate that mass transport of inner shelf carbonate sediment to middle-shelf environments during storms is a normal sedimentologic event.

Literature Cited

Aigner, T. 1985. Storm Depositional Systems. Springer-Verlag, Berlin, 157 pp.

Duke, W.L. 1985. Hummocky cross-stratification, tropical hurricanes and intense winter storms. Sedimentology 32: 167-194.

Dott Jr., R.H. and **J. Bourgeois.** 1982. Hummocky stratification: significance of its variable bedding sequences. Bull. Geol. Soc. Amer. 93: 6632-6680.

Hobday, D.K. and **R.A. Morton.** 1984. Lower Cretaceous shelf storm deposits, northwest Texas. Jour. Sed. Petrology 55: 205-213.

Hunter R.E. and **Clifton, H.E.** 1981. Cyclic deposits and hummocky cross-stratification of probable storm origin in upper Cretaceous rocks of the Cape Sebastian area, southwestern Oregon. J. Sed. Petrology 52: 127-143.

Kreisa, R.D. 1981. Storm generated sedimentary structures in subtidal marine facies with examples from the Middle and Upper Ordovician of southwest Virginia. J. Sed. Petrology 51: 823-848.

Leckie, D.A. and **Lee F. Krystinik.** 1989. Is there evidence for geostropic currents preserved in the sedimentary record of inner to middle shelf deposits. J. Sed. Petrology 59: 862-870.

Smith, A.G., A.M. Hurley and **J.C. Briden.** 1981. Phannerozoic Paleocontinental World Maps. Cambridge Univ. Press, London, 102 pp.

Snedden, J.W. and **D. Nummedal.** 1991. Origin and geometry of storm deposited sand beds in modern sediments of the Texas continental shelf. Int. Assoc. Sedimentologists. Special Pub. 14: 283-308.

Zachry, D.L. 1977. Stratigraphy of middle and upper Bloyd strata (Pennsylvanian, Morrowan) northwestern Arkansas. Oklahoma Geol. Surv. Guidebook 18: 61-66.