UVIAL FAN ORIGIN FOR TERRACE DEPOSITS OF THE SOUTHEAST PRENTISS QUADRANGLE, NEAR OTTO, NORTH CAROLINA

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ABSTRACT

Lithologies and structures in unconsolidated terrace gravels, sands, and silts, as exposed along U.S. Highway 23-441 near Otto, North Carolina, suggest an alluvial fan. Deposits at one no-longer-extant exposure included extensive sheets of massive, poorly sorted, matrix-supported sandstone interbedded with channel-filling cross-bedded sands, and tabular beds of homogenous or poorly plane-laminated fine sands and silts. One lent fine-sand interval exhibited a red oxidized lower portion grading into a white horizon. The white interval had a distinctive vertical micritic structure strongly reminiscent of natic or salic horizons of arid alluvial fans. These deposits are interpreted as debris flow, alluvial channel, and lake deposits (with some arid paleosol development) on local alluvial fans. Although this exposure no longer exists, several other exposures in the area contain some of these same features. The record of episodic sedimentation and climate change implied by the lithologies, structures, color, and the pedogenic features, is consistent with recent sedimentological, geomorphic, and climatological studies elsewhere in the southern Blue Ridge, which have noted that climate may vary significantly on time scales approaching the mean recurrence interval of sedimentation episodes on the fan. This record also has implications for the climatic interpretation of alluvial fan sequences. The western Prentiss quadrangle is a promising area for investigating the Pleistocene-Holocene geomorphic history of the southern Blue Ridge.

INTRODUCTION

The Quaternary geomorphology and paleoclimate of the southern Appalachians are not well understood. As Clark (1979) noted, "the Appalachian Quaternary record is characterized by its occurrence in discontinuous, widely-ted depositional sites." A variety of sedimentary deposits have been utilized in geomorphic and paleoclimatological studies. Lake, pond, bog, and marsh sediments have yielded valuable evidence of Quaternary vegetational and climatic changes (e.g., H. Delcourt, 1979, 1985; P. Delcourt, 1985; Delcourt and Delcourt, 1987). Geomorphic evidence for and against hypotheses of alpine glaciation in the southern Appalachians also has been a topic of considerable recent debate (Raymond, 1977, 1979; Raymond and Cadwell, 1980; Haselton, 1973, 1976, 1980). Some types of sedimentary deposits, however, have not yet been exploited for their potential record of Appalachian geomorphology and climate. Clark (1979) suggests: "Sites that may have promise for future gation include blockfields and blockstreams and the blocky/bouldery colluvial sediments of piedmont coves." Some such deposits have been the...
of recent reports (e.g., Mills, 1981, 1982a,b, 1983), but studies of the
limatic and geomorphological significance of southern Appalachian fluvial
deposits have not yet begun in earnest.

In the course of field studies of bedrock weathering in the southern Blue
in the early 1980's, the author encountered several sedimentologically
exposures of terraces bordering the Little Tennessee River. One of these
ires contained a particularly rich variety of sedimentary and pedogenic
s, and was photographed for future reference. This exposure exhibited a
of features with potential geomorphic and paleoclimatological significance;
se features are similar to features at other recently described localities
n southern Appalachians. Unfortunately, the sedimentary material has since
omoved (presumably for fill). The purpose of this note is to present the
g record of the Asbury terrace exposure as a datum point for regional studies
ival fan and paleopedogenic features, and as a reference point for more
local studies of nearby similar (and possibly correlative) exposures which
il available for study.

FACIES DESCRIPTION

The terrace deposit described here was formerly exposed on the west side of
highway 23-441, less than a kilometer north of Asbury Cemetery, near Otto,
olina. Although the terrace was a number of meters above the present
of the Little Tennessee River, topographic maps of the area show a broad low:
the foot of the nearby hills, with no topographic expression of fan
ology on the scale of the 20 foot topographic contour interval. The roadcut
photographs of Figures 1-4 was a north-south face; the viewer is facing west,
s the hills which form the western boundary of the Little Tennessee River.
This view is transverse to the inferred depositional axis of the alluvial fan
; flow was towards the viewer.

From bottom to top, the outcrop consisted of six units, each consisting of one
ithofacies. These units are here classified using a facies classification
ology similar to that of Miall (1978, 1985) for units of sand and finer grain

Unit I. Buried saprolite. This *in situ* residuum of weathered of crystalline
is the “basement” on which the terrace was deposited. The saprolite was
inantly dark yellow-orange, and preserved clearly the schistosity and
sitional banding of its parent material. There is no evidence indicating
er the alteration of the crystalline rock to saprolite occurred before or after
otion of the overlying sediment.

Unit II. Facies Dmm - Massive matrix-supported conglomerate. This unit
conformably upon the underlying saprolite, with a sharp, broadly irregular
. Figures 1-3 suggest that the large-scale shape of the contact is a channel
the north (right) end of the outcrop. This unit is 30-40 cm thick, and
rs to line, rather than completely fill, the channel in the underlying material.
glomerate is poorly sorted; clast size ranges from sand to coarse cobble
clasts are subangular to subrounded. There is no discernable internal
structure, or textural grading. This unit is distinguishable from its
acent counterpart (unit IV, below) by the fact that the cobbles of unit II are
Figure 1. A. Photograph and B. interpretive sketch of Asbury terrace outcrop. Unit numbers are roman numerals; facies classification (following Miall, 1977, 1985, Shultz, 1984) for each unit is in parantheses. Unit I - Buried saprolite (mostly red). Unit II (Dmm) - Massive matrix-supported conglomerate. Unit III (Se) - sandy cross-stratified sand with concave-up lower contact. Unit IV (Dmm) - fine matrix-supported conglomerate. Unit V (Fl & P) - Red homogenous or plane-laminated fine sands, with bleaching and prismatic structure at top. Unit VI (Fl) - Homogenous or poorly plane-laminated fine sands.
Figure 2. A. Photograph and B. interpretive sketch: close-up of right-center portion of Figure 1. See Figure 1 caption for unit and facies definitions.
Figure 3. A. Photograph and B. interpretive sketch: close-up of upper five units (II - VI). See Figure 1 caption for unit and facies definitions.
with a manganese-oxide- or desert-varnish-like stain.

III. Facies Se - Weakly cross-stratified sand with concave-up lower (interpreted as erosional scour-fill). A lenticular body of poorly cross-stratified, well-sorted medium to coarse sand thickens towards the north, that is, the presumed axis of the channel. The channel axis itself was not traced in the outcrop. A second, smaller channel or scour-fill containing well-sorted sand with weakly-developed cross-stratification occurs at the southern part of the larger channel-fill (Figures 1 & 4). Where not covered by loose material, the contact with the underlying conglomerate (and its matrix) is sharp and horizontal. The scoured surface of the underlying unit is stained black; in contrast, the channel-filling sands are yellow-orange.

IV. Facies Dmm - Massive matrix-supported conglomerate. This bed extends the entire length of the outcrop, maintaining a uniform thickness of about 65 cm. The contact with the underlying sands (unit III, facies Se) is sharp and horizontal. The clasts are poorly sorted; clast size ranges from sand to coarse cobble size, and are subangular to subrounded. There is no discernable internal fabric, textural grading. This bed is distinguishable from its subjacent part (unit II, facies Dmm) by the absence of any manganese-oxide- or desert-varnish-like stain.

V. Facies Fl & P - Red, homogenous or poorly plane-laminated fine sand with (paleopedogenic?) bleaching and prismatic structure at top. This bed extends the entire length of the outcrop, and is approximately 75 cm thick. Faint subhorizontal (cross?) lamination of the fine sands is present in the half of the bed (facies Fl). The color grades rapidly upward from a dull pale red not seen in any other unit of this outcrop, into a white fine sand with well-developed vertical prismatic structure (facies P). The color change may be to bleaching via remobilization of iron pigments, or it may be due to loss of the red color by white fine-grained precipitates (such as evaporite efflorescences, which are common in certain types of arid soils).

VI. Facies Fl - Homogenous or poorly plane-laminated fine sands. The meter of the outcrop consists of a tabular bed of fine sand, similar in color to the underlying sand (unit V) bed, but with a yellow-orange color. The bed, with the underlying unit is probably non-erosive; the thickness of the prismatic interval in unit V is uniform across the entire length of the bed. This suggests that deposition of the yellow fine sands of unit VI did not disrupt the previously developed prismatic structure.

FACIES INTERPRETATIONS

The two most informative features of the Asbury terrace exposure are the two main units of the Asbury terrace exposure are the unorganized (lacking internal structure or clast fabric) matrix-supported conglomerates (units II and IV), and unit V, the reddish fine sand capped by the lower conglomerate with vertical prismatic structure.

The unorganized matrix-supported conglomerates are interpreted as debris flows. According to Rust and Koster (1984, p. 59), “commonly preserved features” of ancient debris flows “include a lack of internal stratification and differentiation, and a sheet-like form, in contrast with the common channel forms of...
Figure 4. A. Photograph and B. interpretive sketch: close-up of units II - IV, near center of Figure 1 and left-center portion of Figure 2. See Figure 1 caption for unit facies definitions.
laid deposits." Uniformity of thickness, and sheet-like form, which
characterize unit IV, are widely but not universally accepted as characteristics of
flow deposits. Bull (1972) notes that "because the bulk of fan deposits are
treated as sheets and lobes, uniform thickness for a given bed is common in most
places, particularly for debris-flow deposits." Similarly, Wasson (1977) finds
debris flow deposits consist of thin, laterally extensive sheets, parallel or
parallel with each other, and with the depositional surface. The channel-lining,
supported conglomerate (unit II) is similar in its lithology and distribution
to a debris flow deposit from Wasson's (1977) Windy Point Fan (his Figures 4 and
5). The Windy Point deposit was apparently a debris flow confined to a pre-
existing channel on the Windy Point Fan surface.

Gloppen and Steel (1981) interpret clast- and matrix-supported, poorly
organized conglomerates as debris flows, "despite the common lack of
large amounts of clay or silt-sized matrix." (p.51) Lack of erosion between
channelized features shared by the Asbury terrace fan, is cited as evidence favoring the
flow interpretation. The Asbury terrace conglomerates strongly resemble
aerial debris flows of Gloppen and Steel's (1981) classification.

Shultz (1984) infers that massive matrix-supported conglomerate (facies
1 in his classification) is deposited from plastic debris flows, which are
terminated by high yield strength, laminar flow, and viscous (rather than grain-
collision) interactions. Like Wasson (1977), Shultz (1984) also notes that
clasts associated with channeling do not imply that the debris flow caused the
channeling; the debris flow might simply have followed and/or filled pre-existing
channels.

Wells (1984), following Bull (1972), distinguishes between sheetfloods,
flows, and debris flows, and discusses diagnostic criteria for evaluating
of different types of flows. Wells suggests that unorganized mud-
k) supported conglomerates are deposited from turbulent unchanneled
flows, whereas unorganized clast-supported conglomerates are deposited by
debris flows. It is likely, however, that the mechanism of the support
k x vs. clast) depends not only on the depositional mechanism, but also on the
of particles which are available in the source materials of the gravity flow.

Bull (1972) and Nilsen (1982) observe that debris flows form where (i) slopes
are stable (due to steepness and lack of vegetation), (ii) abundant water is made
available over short periods of time at irregular or seasonal intervals, and (iii)
ent sources provide abundant muddy material to form the matrix. This last
in particular stresses the significance of the source material in determining
availability of matrix-size material (and, presumably, coarse clasts as well) to
determine gravity flow. Wells' conglomerates were deposited under a cool, wet
climate with local perennial snowbanks. Such an environment favors
vation of coarse clastic material, allowing coarse clasts to dominate, for
example, clast-supported debris flows. However, the climate of the southern Blue
facilitates vigorous chemical weathering of rocks and minerals; this is borne
by the presence of weathering profiles so thick and well developed that, even
under humid-temperate conditions (like the present) which favor intense chemical
weathering, the deep weathering profiles on nearby slopes must have taken many
hundreds of thousands of years to form (e.g., Velbel, 1985). It is possible
debris flows in the southern Blue Ridge are derived from source materials that
not contain sufficient coarse clasts to form clast-supported debris flow deposits as discussed by Wells. If so, the conglomerates of the Asbury terrace may be sheet debris flow deposits, despite the fact that they are matrix-, not clast-, supported. DeCelles and others (1987), Wells and Harvey (1984), and Blair (1987) have all recently stressed the importance of source materials (especially the availability of fine-grained materials) in determining the mechanisms and styles of alluvial fan sedimentation, particularly the occurrence of debris flows.

The fine sand bed (unit V, Facies Fl & P), with the red lower portion and the upper portion with a vertical prismatic structure, is interpreted as an arid soil developed on a fine-grained fluvial deposit. Similar bleaching of shallow horizons could result from other processes, such as kaolinization of feldspar, or development of a podzol-like A horizon. However, both of these alternatives are consistent with the dehydrated state of the associated iron minerals, which is indicated by the color of unit V, facies Fl (discussed below). Silts in beds 20 cm to 1 m thick, interstratified with sheet gravels, occur in stratigraphically similar sequences in Quaternary deposits of Spain (Harvey, 1984); the Spanish silts are cemented, reddish, and contain only occasional weak horizontal bedding. Key (1984) interprets these sediments to be either flood deposits, or clast-free flows. The prismatic structure is a diagnostic property of natric soil horizons (Survey Staff, 1975, p. 28 & Plate 4B). Such structures are commonly related to soils from arid and semi-arid zones, and in regions with a pronounced dry season (Burird, 1970; Birkeland, 1984). Because the outcrop no longer exists, and there are no samples, it is not possible to analytically characterize these horizons. However, the fact that the bright red color of the fine clastic material (facies Fl) is lost in facies P, possibly due to masking by rite mineral efflorescences, supports (although it cannot prove) the natric character of the horizon in question.

The reddish color of the parent material (unit V, facies Fl) supports the hypothesis that the white prismatic horizon formed under the influence of an arid, arid, or seasonally desiccated climate. Following Schwertmann (1985, p. 79), the reddish color suggests that hematite rather than goethite dominates iron-oxide mineralogy of unit V. The dominance of hematite, in turn, favors hypothesis of a relatively warm and/or dry climate during the formation of unit V. Furthermore, however, the fact that only unit V exhibits red color, whereas the saprolite and other fine clastic materials are yellow-orange, suggests that unit V was the unit in the sequence deposited under such warm and/or dry conditions. The other “redbeds” (e.g., Walker, 1967), age of the iron-oxide material is not the controlling factor in this example, because units both above and below the red interval are yellow-orange. Residual and transported materials with red and yellow-orange colors are widely exposed in the immediate vicinity of the Asbury terrace exposure. Therefore, unlike questions of the character and age of the “natric” horizon, which cannot be tested unless another occurrence is discovered, hypotheses regarding the relationship between color and iron oxide mineralogy, and the relationship between iron oxide mineralogy and controlling factors like climate, can be tested. This work is in progress.
DEPOSITIONAL SYNTHESIS

The sediments exposed in the Asbury terrace exposure were deposited on an alluvial fan. Many of the sedimentary and pedogenic features of these deposits are recognized in alluvial fan sequences. Among these features are the matrix-supported conglomerates (units II and IV), and unit V, the fine sand capped by the whitened interval with vertical prismatic structure. Features that the Asbury exposure shares with alluvial fans include; lithology to source (the Asbury terrace locality is less than one-half kilometer to the west of the Little Tennessee River Valley), vertical and lateral facies variations, colors characteristic of oxidized sands, channels, depositional bodies containing soil profiles, and possible salts (of Nilsen, 1982). The channeled, cross-stratified sands (unit III) and the sands of units V and VI are amenable to a variety of interpretations, but are consistent with alluvial fan deposition.

The dominance of debris-flow deposits in the lower part of the section (units II and IV) suggests a proximal-fan origin for these units; Bull (1972) states that “the fraction of debris flow deposits decreases downfan from the apex in those fans where both water-laid and debris-flow deposits are present.” (p. 81). According to en and Steel (1981), mass-flows indicate deposition on proximal portions of a fan. Similarly, Shultz (1984) finds that his facies Dmm conglomerates are proximal in proximal-fan settings. The presence of cut-and-fill structures (unit III) suggests a proximal origin for the lower part of the section (Bull, 1972). The fine sand layer with its paleosol (unit V) cannot be easily placed into a proximal framework, but its lithology, color, and paleosol features are again consistent with an alluvial fan model.

DISCUSSION

Most studies of alluvial fans and their deposits are based on examples from actively active, arid geologic settings (e.g., western North America; Bull, 1972; Nilsen, 1982; Rust and Koster, 1984). Recently, however, alluvial fans and their deposits have been discovered and studied in other geologic and/or climatic settings, including Quaternary and ancient cold-humid and periglacial settings (e.g., Nilsen, 1977; Harvey, 1984; Wells, 1984; Wells and Harvey, 1987; Blair, 1987). Recent studies have found, described, and interpreted alluvial fan deposits in a tonically stable, humid-temperate setting of the southern Appalachians (e.g., and Bartholomew, 1977).

The deposits of the Asbury terrace deposit, and the sedimentological retention of those deposits, are similar to other alluvial fan deposits found in the southern Appalachians. For example, Mills (1981, 1982a,b, reported numerous examples in the Great Smoky Mountains of fan-like deposits consisting largely of matrix-supported diamicton, which he interprets to be debris flows. The debris flows are thought by Mills to have originated via recent (post-glacial?) high-magnitude episodic (catastrophic) erosion/sedimentation events. Acknowledging that definitive evidence is lacking, suggests that episodic erosion/sedimentation in the Great Smoky Mountains have been caused by climate change associated with Holocene post-glacial
ic evolution, although physiographic and autocyclic factors may play an
gnore significant role.

Kochel and Johnson (1984) recognized that the tectonic and climatic setting
which the generic alluvial fan facies models were developed are not
rsal. They defined “The Virginia Humid-Temperate Alluvial Fan Model”
on their studies of fan deposits in Nelson County, Virginia. These authors
that humid-temperate fans experience periods of depositional activity at
als on the order of thousands of years. Many fan surfaces are presently
ed, which suggests an absence of recent depositional activity. Some portions
surfaces, however, were reactivated by sedimentation and transport caused
intense precipitation which accompanied Hurricane Camille in 1969.
n County fan sequences are less than 110 m thick; most are about 20 m thick.
the most resistant rock types making up conglomerate clasts are subangular
inded. Thin (<2 m thick) matrix-supported boulder facies are most common
ximal portions of the fans; Kochel and Johnson (1984) interpret these to be
flow deposits; in fact, they conclude (p. 119) that “the major depositional
ss on the Nelson County alluvial fans appears to be debris flow and debris
ches triggered by intense rainfall.” Channel-fills consisting of cross-bedded
also occur locally. The Nelson County alluvial fan deposits are
ogically, sedimentologically, and stratigraphically similar to the Asbury
e deposit.

Kochel and Johnson (1984) dated several of their depositional units by
carbon, and found three discrete episodes of high-magnitude sedimentation in
han four meters of sediment, representing approximately ten thousand years.
se basis of their radiocarbon data, Kochel and Johnson (1984) estimate a
ence interval for fan sedimentation events on the order of three to six
and years. Deposits of the Camille flood (1969) are clearly distinguishable
older deposits by their unweathered nature. Discrete sediment units within
idual stratigraphic columns of the Nelson County deposits differ from one
her in their weathering characteristics, a finding similar to that of Mills (1981,
s supports Mills’ (1982b) inferences that debris-flow dominated alluvial fan
its of the southern Appalachians originated via relatively recent (post-glacial)
magnitude episodic erosion/sedimentation events, possibly influenced by
change associated with Holocene post-glacial climatic evolution.

The similarities between the fan deposits discussed above and the Asbury
e deposit are striking. All share evidence of brief episodic sedimentation at
regular time intervals, although only Kochel and Johnson’s (1984) study
its quantification of the time intervals between sedimentation events.
The Asbury terrace study illustrates the need for further careful and multi-
ded studies of alluvial fan/terrace deposits of the southern Appalachians. The
of the southern Appalachians are not tectonically controlled like those in more
tectonic settings (e.g., Decelles and others, 1987; Nichols, 1987). Instead,
te is a major controlling factor. Even in other climatic and tectonic settings
y thin fan deposits may result from minor climatic changes and represent
positional intervals during long periods of erosion” (Nilsen, 1982, p. 54).
workers (e.g., Mills, 1981, 1982a,b, 1983; Kochel and Johnson, 1984) in the
ern Appalachians have noted the importance of debris flows in the
raphic evolution of the region, and the possible role of climate in driving the sedimentational episodes. Debris avalanching is increasingly recognized as an important geomorphic process in the southern Appalachians (Grant, 1983; 1986; Neary and others, 1986).

Recent work has suggested, however, that even climate may not play the central role in determining the style of alluvial fan sedimentation. Mills has suggested that intrinsic geomorphic thresholds within fan settings have a greater influence than climatic triggering on sedimentation. Wells and Harvey (1973) note that “the humid fans of the Howgill Fells (their study area) have characteristics which occur in arid-land fans and which have been attributed to climatic fluctuations during the Quaternary.” Like Blair (1987), they suggest that this similarity in sedimentary deposits reflects primarily the similarity of intrinsic geomorphic thresholds, related to physiographic properties of source areas and fan surfaces. Climatic fluctuations exert only secondary influences over the major sedimentary facies on any individual fan. The work of (1983), Wells and Harvey (1987) and Blair (1987) suggests that source and landscape and lithology, and autecyclic (intrinsic) factors, can combine in humid settings to give sedimentary facies assemblages which are usually similar to arid fan processes. Their work suggests that such factors may be as important as climate in controlling the nature of alluvial fan sedimentation.

To say that facies architecture may not be as strongly dependent on climate as previously thought does not, however, mean that these sediments are poorer records of climate. The stratigraphically controlled color changes in the Asbury deposit strongly suggest that the hydration state of the pigment-causing iron minerals was determined approximately at the time of deposition, and has not been modified by later diagenesis of the deposits. This clearly demonstrates that color does not uniformly redden with age, as is widely assumed in relative age dating of surficial deposits. It also suggests that the paleosol features, and the color and mineralogy of the sediment pigments, may provide a record of recent climatic and geomorphic history in the southern Appalachians. The work components of terrace deposits may also contain such information; (in press) for a discussion of the climatic and source-area morphic influences on composition of modern sands in the area.) The bound distribution of iron oxide/oxyhydroxide pigment in the Asbury terraces indicates that unit V was affected by greater dehydration than any of the other units. Color is a useful index of the hydration state of iron oxyhydroxides in soils; reddish colors indicate the dehydrated form, which in turn indicates drier conditions (Schwertmann, 1985). The fact that subjacent and superjacent units were not similarly subjected to dehydration suggests that the time interval between the deposition of units V and VI represents a temporary but significant excursion to drier climatic conditions. The yellow-orange color of the bulk of the sediments suggests that most of the deposition on the Asbury terrace took place under conditions of temperature and humidity more conducive to the present (conditions under which yellow-orange goethite is forming; Velbel, 1984, 1985) rather than under warmer or wetter conditions. Irrespective of the primary control, alluvial fan terrace deposits therefore provide an important source of information on magnitude/frequency relations, geomorphic history, and possibly the climatic history, of the southern...
Ridge landscape and its episodic sediment gravity flows. The Asbury terrace deposit thus illustrates another important point in the formation of alluvial fan facies models. Rust and Koster (1984) are correct in pointing out that "Red colouration and evaporitic paleosols occur in several ancient fan deposits, and point to a semi-arid paleoclimate" (p. 59). However, as noted above, it can take many thousands of years to deposit a few meters of sediment (Kochel and Johnson, 1984). This interval of time almost certainly passes climatic changes, possibly significant ones. It is therefore dangerous to attribute a specific paleoclimate to an entire stratigraphic interval of alluvial fan deposits, because climate may vary significantly on time scales approaching the recurrence interval of sedimentation episodes on the fan.

Although the Asbury terrace deposit no longer exists, there are several other examples of terrace deposits which contain at least some of the features noted by the Asbury exposure, and which may be correlative with it and with another (Velbel and Grantham, 1985). If the Asbury deposit is any indication, alluvial terrace deposits in the southern Blue Ridge may contain valuable and valuable information about the climatic and geomorphic history of the southern Ridge Mountains.

CONCLUSIONS

The Asbury terrace deposit consisted of massive matrix-supported conglomerate, weakly cross-stratified scour-filling sand, and several homogenous orly laminated fine sands, including a distinctive red interval with white color and prismatic structure at the top. Conglomerates are interpreted to be products of debris flows; both sheet-like forms with uniform thickness, and deposits which fill existing channels occur. The red and white interval capped by prismatic structure is interpreted to be an arid paleosol developed on a fine-grained fluvial fan. Color differences among different strata are of primary, rather than inherent, origin, and are probably caused by differences in the relative abundance of ethite and hematite. Similar color and mineralogical differences in other outcrops may therefore prove useful in elucidating aspects of climate in the region. The channeled and cross-stratified sand is of fluvial origin.

The sedimentary facies of the Asbury terrace deposit indicate deposition on an alluvial fan, under variable climatic conditions. Debris flows, the yellow (goethitic) color of most units, and the young age and regional climatic setting suggest that the bulk of the sediments were deposited under temperate conditions much like the present. One sedimentary unit (unit V), however, indicates arid conditions by its red (hematitic?) pigment and the natric soil features. The existence of alluvial fan deposits in this instance is more likely influenced by climate rather than by fault-block or thrust-fault tectonism, because climatic variations took place on a time-scale approaching the recurrence interval of sedimentation episodes on the fan.
ACKNOWLEDGMENTS

Jeremy H. Grantham (now of Petrostar Energy), Danita Brandt (Eastern Michigan University), and the Michigan State University Department of Geological Sciences Alumni Fund all provided assistance at various stages of this investigation. Jeffrey J. Gryta (Kent State University) provided many helpful comments on the manuscript. Preparation of this paper was facilitated by NSF BSR-8514328.

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