River-derived slackwater sediments in caves along Cheat River, West Virginia

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Abstract
The November 1985 Cheat River flood produced overbank, slackwater deposits in caves of the Cheat River canyon. The deposits include loamy silt, loamy sand to very fine sand, and flotsam. Sediments deposited by the November 1985 flood lie within 1 m of the established high water mark and are good indicators of peak stage. Prehistoric overbank, slackwater deposits are present in one cave. These sediments are inferred to be ≥ 400,000 years old and are, therefore, unrelated to the modern Cheat River. Overbank slackwater deposits are poorly preserved in the examined caves, because cave streams actively remove sediments and the warm, moist environment of the caves fosters decay of woody flotsam. Deposits of the 1985 flood are projected to survive at most a few centuries. In contrast, slackwater sediments inferred to be ≥ 400,000 years old are present within a cave shielded from significant runoff and biogenic activity.

Keywords: Cheat River; West Virginia; overbank sedimentation; slackwater deposits; cave sedimentation

1. Introduction
The surficial geology of the Cheat River drainage basin (Fig. 1) in north-central West Virginia includes an incomplete record of very high magnitude floods. The lack of data on very high magnitude floods is critical when we consider events like the catastrophic November 1985 flood, which caused 1.4 billion dollars in damage and claimed many lives across the region (Teets and Young, 1985; Carpenter, 1990). On Cheat River, peak flow during the 1985 flood was a record 100,000 ft³/s (5,384 m³/s), nearly twice the discharge of the previous record flood (Kite and Linton, 1993).

Preparation for very high magnitude floods depends upon determining accurate flood frequency recurrence intervals and developing flood control and siting plans accordingly (Dunne and Leopold, 1978). Within the Cheat River drainage basin, flood records span the last 150 years (Kite and Linton, 1993; Kite and Torres, 1996). Predicting recurrence intervals and planning for very high magnitude floods is complicated by the comparatively short observation span, which allows exceptional events such as the 1985 event to skew annual flood distributions. Elsewhere, the observational record has been extended by recognizing and dating paleofloods using slackwater deposits (Kochel, 1988). A lack of pre-1985 slackwater deposits has made such studies impractical within the Cheat River drainage basin (Linton, 1992).

Caves can offer a unique environment where
stream sediments may be preserved because they can be shielded from weathering, erosion, and biogenic processes (Kochel and Baker, 1988). This paper describes flood-derived sediments found within caves of the Cheat River canyon. The stratigraphy of historical and paleoflood slackwater sediments, sedimentary units within slackwater deposits, and the origins are discussed and compared to surficial slackwater deposits (Linton, 1992; Kite and Linton, 1993) elsewhere along the Cheat River floodplain.

2. Study area

The confluence of Black Fork and Shavers Fork in Parsons, West Virginia (Fig. 1) marks the beginning of Cheat River. The drainage basin is within the unglaciated Allegheny Mountain section of the Appalachian Plateaus Physiographic Province (Hunt, 1974). Bedrock exposed within the basin consists of Upper Paleozoic clastic rocks, thin limestones, and coal. Broad open folds typify the geological structure (Cardwell et al., 1986). The area of the drainage basin upstream of its confluence with the Monongahela River is 3688 km² (U.S. Army Corps of Engineers, 1963).

This study is limited to caves within the Cheat River canyon between the small town of Albright and Lake Lynn (Fig. 1). The canyon is developed where the northward-flowing Cheat River turns northwest across regional strike for approximately 22.5 km (Fig. 1). The gradient of Cheat River through the canyon is 6.7 m/km (Kite and Torres, 1996). The overall gradient of Cheat River from Parsons to Point Marion is 2.06 m/km.

Numerous caves have been discovered within the

![Diagram showing the location of study area and selected locals. Cl denotes lower Coliseum Rapids, Co Cornwell Cave, and Ds Darby Pit and South Side caves.](image-url)
canyon. The most significant of these include Cornwall Cave and the caves of lower Coliseum Rapids. All solutional caves in the canyon are developed in the Mississippian-age Greenbrier Formation which is 46 m thick.

3. Previous research

Slackwater deposits consist of relatively fine-grained sediments (typically fine sand and coarse silt) deposited in sheltered, low-energy floodplain areas by sediment-laden floodwaters (Kochel and Baker, 1988). Within arid portions of the western United States, flood records have been extended along several major rivers by examination of slackwater sediments. Pertinent works include those by Patton and Dibble (1982), Kochel and Baker (1982), and Kochel and Baker (1988).

Linton (1992) and Kite and Linton (1993) examine sediments deposited by the November 1985 flood along Cheat River. Linton (1992) reports that slackwater deposits within sheltered tributary mouths were similar to one another, though the detailed stratigraphy varies from site to site. Linton recognizes four stratigraphic units: a basal gravel and sand, sandy loam, silt loam, and fine sandy loam. Deposits at each site typically contain at least two of the four. The sandy loam is the most common deposit in tributary mouths (Linton, 1992).

Using the Manning equation, Linton (1992) calculates estimates of discharge from the elevations of 1985 slackwater deposits and high water marks. The high water marks are veneers of silt or trash adhering to natural objects or human structures. Most high water marks are destroyed quickly and, therefore, slackwater sediments are often used to calculate discharge. Unfortunately, slackwater sediments typically lie at elevations beneath those of the high water mark and are sources of error in calculating flood discharges. Linton (1992) reports that slackwater sediments along Cheat River underestimate discharge by at least 50% relative to high water marks.

Springer et al. (1996) examine cave development and cave sediments within the Cheat River canyon. They recognize three classes of cave sediments in caves of the canyon: phreatic, vadose, and residual (Table 1). The phreatic sediments are deposited in maze caves with elliptical passage cross-sections. Sediments are fine-grained (sand to clay) and become finer away from Cheat River. Vadose sediments are derived from the overlying valley wall or overbank flooding of the nearby river and are separated from the phreatic facies class by scour surfaces.

4. Overbank sediments

Vadose-deposited, overbank facies in caves of the Cheat River canyon are blanket-like deposits of loamy silt, sand, and organics. Individual deposits

| Table 1 |
|---|---|
| Two of the three facies classes present in caves of the Cheat River canyon. Phreatic facies are associated with anastomotic maze caves. Vadose facies are generally separated from phreatic facies by a scour surface. Modified from Springer et al. (1996) |
| Phreatic facies class: | Vadose facies class: |
| Sediments deposited beneath base level in maze caves. Includes the facies described below | Sediments deposited above base level. Includes the facies described below |
| Diamict: Gleyed, matrix-supported bouldery gravel to loam diamict. Becomes finer away from river | Gravity: Poorly sorted, course colluvial deposits from overlying valley wall. Includes collapse deposits |
| Laminated sand: Laminated sands and sandy loams with cm-thick beds and some silt interbeds | Travertine: Chemically precipitated calcite and aragonite derived from overlying bedrock and soil |
| Silt-clay rhythmite: Silty loams, loamy, silts, and loamy clays displaying rhythmic laminations. Fill elliptical-shaped passages | Overbank: Thin, blanket-like deposits of laminar silt, sand, and organics bounded by scour surfaces. Mudcracks and surge marks present |
| Sandy clay loam: Gleyed, massive sandy clay loams with laminated clay interbeds. Sand trains are frosted and well rounded | Cave stream: Sorted fines and gravels with directional flow indicators or cut and fill features. Associated with discrete input source |
are bounded by scour surfaces and display sedimentary structures not observed in texturally similar phreatic facies sediments. Overbank sediments can be differentiated from cave stream sediments by sedimentary structures, distribution of facies relative to input points, and particle size.

The Cheat River canyon is uninhabited. Modern anthropogenic materials within the caves can be attributed to historic overbank deposition by the river because the towns of Albright and Rowlesburg, upstream of the canyon, were largely destroyed by the 1985 flood and contributed to a recognizable subfacies of overbank flotsam. This flotsam contains a wide diversity of materials (such as housing materials and toys), dissimilar to deposits of beverage containers, styrofoam, and general litter commonly found along major rivers.

Modern and paleoflood overbank deposits were recognized in 10 caves. Loamy silts are the dominant overbank sediment encountered in the caves. Very fine sands were observed in two caves. Large woody debris (flotsam) is volumetrically the largest component of modern overbank deposits in caves near Cheat River.

5. Description of selected overbank deposit localities

Darby Pit: The entrance to this cave is 3 m above Cheat River. The cave is a 45 m long, linear stream passage developed at the same elevation as Cheat River. The cave floor is composed of loamy silts to matrix-supported loamy gravels. The banks of the stream are lined with bioturbated, lenticular deposits of loamy silt deposited by floodwaters from Cheat River. Individual slackwater deposits are indistinguishable.

South Side Cave: The entrance to this cave is a spring located 0.6 m above Cheat River. The cave consists of a short, linear stream passage developed perpendicular to the river. The cave stream is derived from a surface stream sinking on the valley wall. The cave floor is bedrock with short stretches of gravel. Fine sands, 1 to 2 cm thick, are frequently deposited in the cave by flooding of Cheat River. The cave stream removes these deposits in ≤7 days; fine-grained sediments are not preserved in the cave.

Coliseum Rapids: The most extensive deposits of overbank sediments are in caves at lower Coliseum Rapids, a 400 m long, bedrock-lined reach with

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Fig. 2. Caves of lower Coliseum Rapids. FPC is Flotsam Point Cave, RSC Rubber Softball Cave, AH Airtight Hole, and CTC Coliseum Tube Cave. Cheat River is 40 to 60 m wide. Only Tim's Climb Cave was not inundated by the 1985 flood.
boulders up to 8 m in intermediate diameter. Coliseum Rapids is developed atop resistant sandstones of the Price Formation. The downstream end of the rapids is a knickpoint where the sandstones are first exposed along the western limb of an anticline. Eight caves are found in prominent limestone cliffs lining the outside of the river bend (Fig. 2). The majority of the caves are located ≥ 6 m above Cheat River and rarely inundated by the river. The overbank deposits of these caves are discussed below:

*Flotsam Point Cave:* This small cave lies 5 m above Cheat River and contains flotsam deposited by the 1985 flood. Ledges near the entrance and the slopes above the cave are covered by flotsam deposited by the 1985 flood. No clastic sediments in the cave are attributable to flooding by the river.

*Flotsam Rock Cave:* This small cave lies 2-to-5 m above Cheat River and is within the 1 year flood recurrence interval of the Cheat River. The cave contains abundant flotsam deposited atop cobbles, but no fine-grained sediments.

*Rubber Softball and Airtight Hole caves:* These small caves lie ~ 8 m above Cheat River and contain plastic and rubber flotsam deposited by the 1985 flood. No fine-grained sediments are present in either cave.

*Colluvium Breath Cave:* This cave is located 7 m above Cheat River. The southwestern entrance of the cave was inundated by the 1985 flood (Fig. 3). Floodwaters flowing into the cave formed a small logjam 5 m inside the entrance. Beyond the logjam is a blanket-like deposit of sand. Two units are present in the sand deposit (column GS-92-6; Fig. 3): a massive 3-to-8 cm thick very fine sand and an underlying 5 cm thick coarse sandy loam. Macrootic, up to 5 cm long, were deposited atop and within both sands. Beneath these sands is a massive, 20 cm thick sandy loam which contains live roots.
and is otherwise devoid of macroorganics. The upper two sands are separated from the underlying sand by a mat of decomposing macroorganics. This mat is similar to one observed at GS-92-9 in Coliseum Rapids Cave (Fig. 4) and may represent decomposing flotsam from the 1985 flood or leaf litter brought into the cave by resident Appalachian wood rats (*Neotoma sp.*) prior to the flood.

Thin, blanket-like deposits of mud-cracked silts are found in the northern passages of the cave. The silts are laminar to bioturbated and less than 1 cm thick. The silt deposits are present beneath ledges and areas not subject to scour by water entering from the overlying valley wall. The silts contain abundant, macerated organics and were deposited by the 1985 flood.

*Coliseum Rapids Cave:* This cave is 14 m above the river (Fig. 4). The entire cave was inundated by the 1985 flood. A small surface stream flows into the northern part of the cave from a 50 m wide, bedrock-supported terrace. During exceptionally wet periods, the surface stream cascades over a 7 m high waterfall and a portion of the water enters the two southeastern entrances of the cave. Cobbles inside these entrances display imbrication into the cave.

The 1985 flood washed abundant plastic refuse into the cave, along with considerable amounts of macroorganics. The largest piece of woody debris is a 1.3 m long, 0.3 m diameter log found 13 m inside the cave. A 1 m high, 0.6 m wide plastic trash can lies 14 m inside the cave, wedged in a passage constriction. The highest flotsam in the cave is styrofoam balls (2-to-4 mm in diameter) deposited on the cave walls 15 m above Cheat River. These inconspicuous balls are held to the cave walls by water surface tension and thin films of macerated organics and silt. The balls provide the most reliable evidence of water levels during the 1985 flood. Were it not for the balls, the films of macerated organics and silts might otherwise be attributed to vadose flow from the slopes above.

Isolated patches of bioturbated silts (≤ 5.5 cm thick) are observed near GS-92-9 (Fig. 4). The silts are bioturbated by worms and contain abundant macerated organics. The silts are deposited atop sediments of the phreatic facies. A 3 to 5 mm thick mat

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**Fig. 4.** Facies map of Coliseum Rapids and Coliseum Tube caves. Slackwater deposits consist of loamy silts. Stratigraphic column GS-92-9 displays 1985 overbank sediments atop phreatic facies sediments.
of decomposing organics separate the two deposits. The mat is heavily infested by fungal mycelia. Silts are not present were water enters the cave from the terrace, although flotsam is present beneath several of these domes.

Cornwell Cave: This large maze cave lies 38-to-40 m above Cheat River. Overbank sediments consist of unconformity-bounded loamy silts interbedded with clast-supported fine gravels derived from small streams entering the cave via vertical domes (Fig. 5). The silts display inclined laminae bedding. The dip direction of laminae is markedly different across the gravel interbeds. As many as five distinct paleoflood units are present in a single stratigraphic column (Fig. 5).

The loamy silts were deposited during infrequent flooding of Cheat River, and later eroded by vadose streams. Subsequent flooding resulted in parallel accretion of loamy silts on scour surfaces. Parallel accretion is common in the cave environment and is documented only in pipe-full passages.

6. Preservation of sediments

Linton (1992) examines slackwater deposits in the tributary mouths along the Cheat River narrows between Rowlesburg and Albright (Fig. 1). He recognizes 1 m of sediments deposited during the 1985 flood but no deposits definitively assignable to paleofloods. He concludes that the preservation potential of surficial slackwater sediments is low because of biogenic and weathering phenomena.

Slackwater deposits of the 1985 flood are preserved in the caves of the Cheat River canyon; nonetheless the potential for preservation is low. For optimum preservation, the cave must act as an effective shield from water and organisms. All of the caves inundated by the 1985 flood receive water from the overlying valley wall. The caves are generally shallow, lying ≤ 10 m beneath the valley wall. The sediments are not immune from biogenic alteration because they may be penetrated by roots and burrowing organisms and are physically removed from the caves by stream flow.

Of the ten caves inundated by the 1985 flood, six display slackwater sediments. Of the six, only two contain fine-grained slackwater sediments; faunal bioturbation was observed in these sediments. The paucity of fine-grained sediments is attributable to water from the overlying slopes. Fine-grained sediments persist only in sites not subject to scour by water entering via joints in the ceiling. As the small areal extent of overbank deposits in Figs. 3 and 4 suggest, few parts of the caves do not receive water from above. Sediments beneath ledges are not entirely protected. Water entering a dome in Coliseum Rapids Cave from a 1 hr duration, 7.5 cm rainfall event was observed to flow down overhanging cave walls and fall on the sediments of section GS-92-9 (Fig. 4), 1-to-3 m from the edge of a ceiling ledge.

Woody debris, the largest component by volume of the 1985 overbank deposits, is still present beneath domes of Coliseum Rapids Cave because cave stream discharge is ineffective at moving large wood particles (2-to-200 cm in length). Vadose recharge, a relative humidity of ~ 95%, and the constant year-round temperature of ~ 12°C in the cave maintain an environment in which decay of woody flotsam is fostered. Continued decay will probably destroy the wood debris within 25 years of the 1985 flood. Woody flotsam deposited on the surface appears considerably less decayed than that in the cave. The plastic and styrofoam component, however, is largely unaltered and will probably be preserved for centuries.
The poor preservation of 1985 slackwater sediments contrasts with the excellent preservation of paleoflood sediments in Cornwell Cave. Interpolation, using a 59 mm/ka incision rate calculated by Springer (1994) for Cheat River, indicates that the sediments are > 400,000 yr old. The contrasting preservational potential of the two sets of slackwater sediments is a direct product of different geomorphic settings. The majority of Cornwell Cave is overlain by 20-to-30 m of limestone and shale. The caprock limits recharge to the cave and favors preservation of sediments. The caves of lower Coliseum Rapids are overlain by ≤ 10 m of colluvium, alluvium, and bedrock that readily transmit recharge to the caves and, hence, promote erosion of slackwater sediments.

7. Potential use for hydraulic reconstructions

Flood slackwater sediments indicate peak stage from which the discharge of a flood can be calculated using hydraulic reconstruction methods and the Manning equation (Patton et al., 1979). Knowing the cross-sectional area of the peak flow channel, channel gradient, and channel roughness coefficient, flow velocity and discharge may be calculated. Linton (1992) uses this method to independently calculate discharge values based on the maximum heights of slackwater sediments and high water marks. Linton reports that slackwater sediments deposited by the Cheat River flood in tributary mouths are 2.9 to 5.6 m below high water marks. High water marks indicate peak stage water depths of 6 to 11 m. The difference between high water marks and slackwater sediment heights represents a substantial fraction of the total flood depth, therefore, calculations based on 1985 flood slackwater sediments underestimate peak discharge of Cheat River by 50% relative to high water marks. Linton reports that flotsam, the most common high water mark, is an accurate indicator of peak stage, but flotsam is unlikely to be preserved in the geologic record because of decay.

The uppermost slackwater sediments in caves of the Cheat River canyon lie within 1 m of the uppermost flotsam. This narrow gap between the high water mark and slackwater sediments contrasts with elevation differences of greater than 2.9 m observed by Linton (1992). The narrow gap suggests that sediments within the caves of Cheat River canyon are accurate indicators of peak flood stage heights and could be used to more accurately calculate flood discharge values.

Hydraulic reconstructions were not performed using the 1985 slackwater sediments in caves of lower Coliseum Rapids. The hydraulic gradient was significantly steepened at the downstream terminus of Lower Coliseum Rapids during the 1985 flood. This invalidates the slope-area method. Modeling of discharge using the step-backwater method was beyond the scope of this paper.

8. Discussion

The cave overbank facies is composed of three subfacies: loamy silts, very fine sands, and flotsam. In addition to flotsam, Kite and Linton (1993) and Linton (1992) recognize four textural units in sediments deposited by the 1985 flood in the Cheat Narrows: basal gravel and sand, sandy loam, silt loam, and fine sandy loam. The sandy loam (Linton’s unit B) is the most commonly encountered deposit in tributary mouths and is interpreted to represent deposition by the tributary. Linton (1992) reports that of the four units, only the silt loam was deposited by Cheat River. The silt loam observed in caves of lower Coliseum Rapids is similar to the silt loam observed by Linton (1992). Both are blanket-like deposits with abundant organic matter and each is interpreted as a slackwater deposit.

Very fine sands and loamy sands observed in Colluvium Breath Cave are not analogous to Linton’s (1992) sandy loam. Linton reports that the sandy loam thins away from tributary channels and probably represents deposition by tributary floodwaters, prior to ponding of the tributary by Cheat River. The sandy loam observed in Colluvium Breath Cave is not, however, associated with any recharge point except the southwestern entrance of the cave. Therefore, the sandy loam represents deposition by floodwaters of Cheat River. The sands of Colluvium Breath Cave may be analogous to the small sand deposits Linton (1992) found between boulders. Because of different settings, the deposits in the cave are of broader extent.
Except during extreme runoff events, water flow into the caves rarely exceeds rapid drips. During periods of high runoff, much of the runoff bypasses the caves by flowing in surface channels. Water that does reach the caves during high runoff overwhelms the normal flow routes and overflows into subsidiary pathways producing many small drips and waterfalls. The lack of concentrated recharge and a general screening of larger particles results in minimal input of clastic sediments by water from the valley wall. Hence, the three units that Linton (1992) interprets as tributary-derived slackwater sediments are absent in caves of the Cheat River canyon; the fine-grained sediments are primarily river-derived.

To explain the distribution of facies in tributary mouths following the 1985 flood, Kite and Linton (1993) hypothesize that water and sediment discharge peaked in the tributaries before the river. When the river reached peak stage and turbidity, the tributaries were discharging a sediment-poor watermass. A sharp water-mass boundary developed between the turbid river and tributary water-masses and significant deposition occurred only in the Cheat River water-mass. Non-deposition in the relatively sediment-poor, tributary-derived water-masses resulted in no sediments being deposited at the height of peak stage by the tributaries (Kite and Linton, 1993). The turbid peak-stage floodwaters of the 1985 flood penetrated the caves of lower Coliseum Rapids, because the caves of the Cheat River canyon did not discharge significant volumes of water with which to create a water-mass boundary. Therefore, unlike the slackwater sediments examined by Kite and Linton (1993) and Linton (1992), the slackwater sediments in caves of the Cheat River canyon are relatively precise indicators of peak stage.

The deposition of sediments at a height near peak stage within caves of the Cheat River canyon is consistent with the findings of Kochel and Baker (1982), Patton and Dibble (1982), and Patton et al. (1979). Sediments along the Pecos and Devil rivers were deposited by multiple flood events and contained primary structures. Preservation of slackwater sediments appears to be markedly better in the Texas caves than sediments in the Cheat River caves. In this study, only one cave (Cornwell) contains sediments from multiple flood events.

The narrow gap between high water mark and slackwater sediments suggests that calculations of paleoflood discharge along humid rivers, such as Cheat River, are possible. The optimum sites to preserve accurate stage indicators are not tributary mouths, but inactive caves within the valley wall. Humid rivers may be sufficiently turbid to deposit significant slackwater sediments near peak flood inundation levels.

9. Conclusions

Slackwater sediments deposited in caves of the Cheat River canyon are poorly preserved because of geomorphic setting, cave streams, and unfavorable cave environments. Clastic sediments are being removed by scour and altered by biogenic activity. Woody materials decay rapidly because of the moist, warm cave environment and biogenic activity. Sediments in a cave accurately record peak stage of at least one high magnitude flood on Cheat River. The best indicators of peak stage for this historic flood are high water marks composed of small styrofoam balls clinging to cave walls and ceilings. Slackwater sediments lie less than 1 m below the styrofoam balls.

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