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RAPID ADJUSTMENT OF THE RIO PUERCO TO MEANDER CUTOFF: IMPLICATIONS FOR EFFECTIVE GEOMORPHIC PROCESSES, CROSSING THRESHOLDS AND TIMING OF EVENTS

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Abstract—A meander loop of the upper Rio Puerco of the east experienced a neck cutoff during the late winter–early spring of 1988, temporarily changing the gradient of the stream from 0.003 (m/m) to 0.25. Observations before, during and after the cutoff document (1) that cutoff was not a major disruption for the stream, (2) that timing, order and duration of events are important in crossing geomorphic thresholds and subsequent adjustments, (3) that the threshold for cutoff was lowered considerably by erosion and humans in preceding years, (4) that breaching was thwarted temporarily by low-flow processes, (5) that initial breaching took place during moderate flow, and (6) that subsequent large flows in 1988 caused both width and gradient to be fully adjusted with upstream and downstream values within one flow season. The steep gradient of the breach did not propagate upstream as a headwall; rather the slope increased slightly upstream and extended until the former gradient was reached.

INTRODUCTION

Landscapes change as geomorphic processes cross thresholds, but geomorphic analyses of these adjustments are subject to several recurrent problematic issues (Ritter, 1988). First, it is commonly difficult to recognize a significant threshold and when it has been crossed. Perceived significance of events is dependent on spatial and temporal scales (Schumm, 1985). Second, the effectiveness of geomorphic events is not well understood in terms of time needed for adjustment or recovery after an initial disruption. Third, components of a geomorphic system have different thresholds and temporal responses, so effectiveness depends on which components are active. Fourth, actual timing and duration of events and intervals between events commonly are more important than their estimated statistical recurrence; geomorphic effectiveness and its control on landscape stability is partially dependent on order and timing of events (Beven, 1981). Fifth, responses in surficial systems may be strongly controlled by spatial characteristics existing within the geomorphic setting. These issues may be examined by looking at adjustments made by an ephemeral stream, Rio Puerco of the east, to a major meander cutoff. It might be assumed that the effectiveness of channel-adjustment processes would be relatively less or at least slower in ephemeral streams compared to perennial streams, that threshold-crossings might be caused by large, infrequent events, and that threshold-crossings might produce significant long-lasting changes in channel morphology. However, the sequence of events documented in this case shows that none of the assumptions is warranted, precisely because of the issues outlined above.

The Rio Puerco of the east drains 18,892 km^2 in west-central New Mexico east of the Continental Divide (Love, 1986). The course of the 200-km-long stream is predominantly south from the northern Nacimiento Mountains and eastern San Juan Basin through the Albuquerque Basin to the Rio Grande. Almost the entire drainage occupies major valleys that eroded during the past 1 Ma. The modern channel is entrenched 6 to 14 m in Holocene alluvium throughout most of its course (Elliott, 1979), and many of its tributaries are deep, narrow arroyos as well. The Rio Puerco flows 53% of the year near Cabezon, with discharge as large as 196.5 m^3/sec, but only 20% near its mouth, with discharge as large as 1015 m^3/sec (Popp et al., 1983).

The Rio Puerco has numerous reaches of well-developed sinuous meanders that are entrenched. Migration occurs both laterally (swing) and down-valley (sweep) at rates on the order of 2 to 8 m/yr (Wells et al., 1982). Based on historic (the past 50 years) aerial photographs covering reaches of grouped meanders several kilometers long, meander cutoffs through entrenched meanders occur only once or twice per century.

CHRONOLOGY OF A MEANDER CUTOFF NEAR CUBA

A typical meandering reach is 14.6 km south of Cuba adjacent to Highway 44 (Fig. 1). The chronology of events leading to cutoff and subsequent adjustment of one meander loop and adjacent upstream and downstream reaches is based on casual observations by geologists-passersby (Love photographs, 1982, 1984–1989; R. Shepherd, personal comm. 1985; R. Wright-Dunbar, personal comm. 1986, 1988; R. Hadley, personal comm. 1986) and recorded by aerial photographs and maps (1935, 1954, 1965, 1986, 1989). Stream-flow records are taken from the U.S. Geological Survey water-stage recorder near Cabezon, 40 km downstream, where the drainage is approximately 1088 km^2 (U.S. Geological Survey Water-Data Reports; Fig. 2).

The high arroyo wall of the meander neck collapsed between 1982 and 1984, leaving only the downstream bank as a neck abutment (Fig. 3A). When cutoff appeared imminent, the vicinity of the meander was surveyed (10 April 1987) with the help of several students. The following spring the neck was breached before 22 March 1988 (R. Wright-Dunbar, personal comm. 1988), and qualitative observations were made in 1988 and 1989 until the reach was resurveyed (30 June 1989).

In 1987, before cutoff, the gradient around the meander loop was 0.003 (m/m), and the drop across the neck was 1.7 m in 7 m (.25 m/m; Figs. 4 and 5). Bank height on the upstream side of the neck at extremely low flow (sandbar exposed adjacent to neck) was 0.06 to 0.8 m. Someone had dug a small, crude, shovel-width trench causing some flow across the neck in 1986, but the stream had deposited a sandbar against the neck on the upstream side, shifting the channel to the north away from the bank before 10 April 1987.

The date of the initial breach of the neck is unknown, but because flows in summer and fall of 1987 were particularly low to nonexistent (Fig. 2), and occasional observers did not see changes until 1988, the most likely time was during a moderate flow recorded downstream on 29 February 1988. It is likely that when cutoff occurred in early 1988, the low artificial channel was the initial course across the neck. By 23 April 1988, the breach was at least 5 m wide (Figs. 3B, 6A, 7A), and the channel had noticeably entrenched at least 170 m upstream. No headwall of erosion was evident; rather, erosion into the older valley-fill clay layers was along a steeper gradient (about 0.01), and the exposed layers were fluted. A sand plug had built across the downstream end of the cutoff meander loop, and an attached sandbar developed immediately downstream from the neck on the east side of the channel (Fig. 6A). Water only occurred in the lower part of the oxbow and was relatively clear, presumably from seepage through sand at both ends of the meander loop. Channel bedforms were preserved "high and dry" in the oxbow and adjacent channel at the upstream end of the meander



FIGURE 1. Aerial photograph of the meander loop taken 29 April 1986 (courtesy New Mexico Highway and Transportation Department).

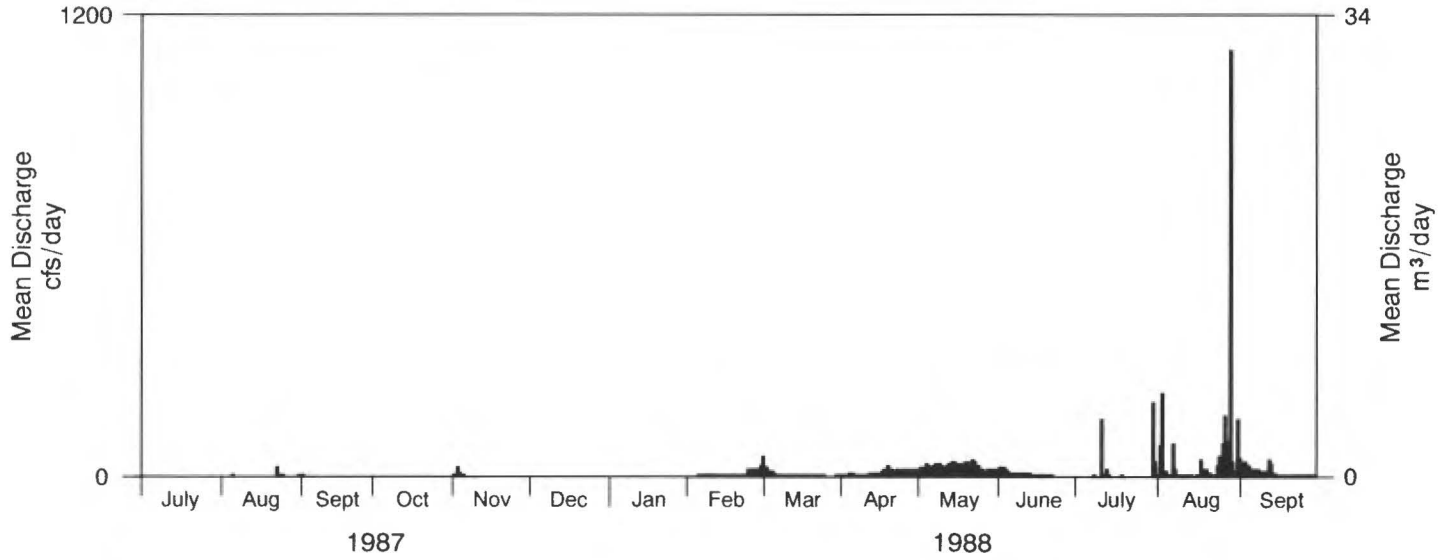


FIGURE 2. Mean instantaneous discharge per day, July 1987 through September 1988, at U.S. Geological Survey gage "Rio Puerco Above Arroyo Chico, Near Guadalupe."

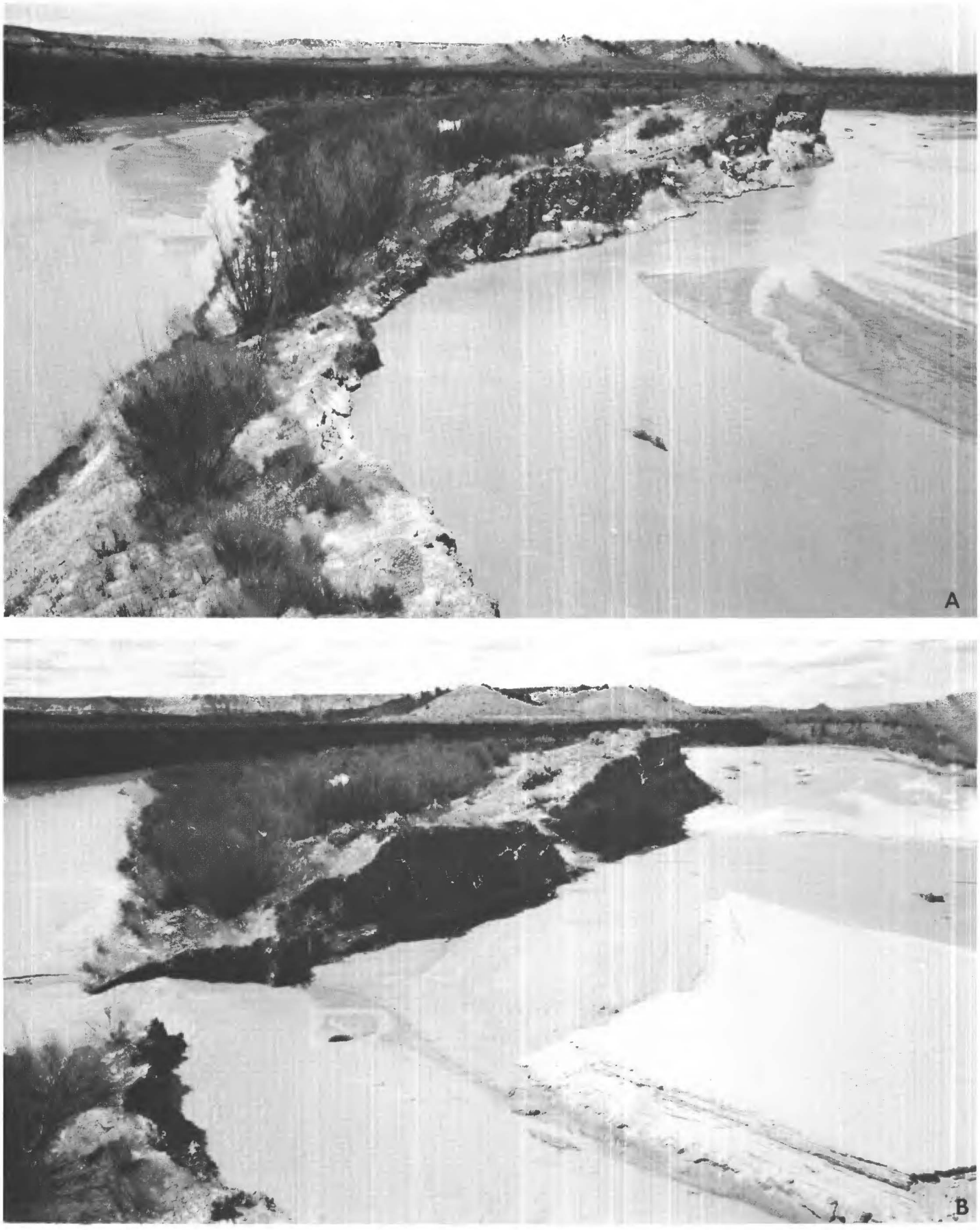


FIGURE 3. A, Neck of meander loop, 6 May 1986; B, Neck cutoff and abandoned upper side of meander loop, 23 April 1988.

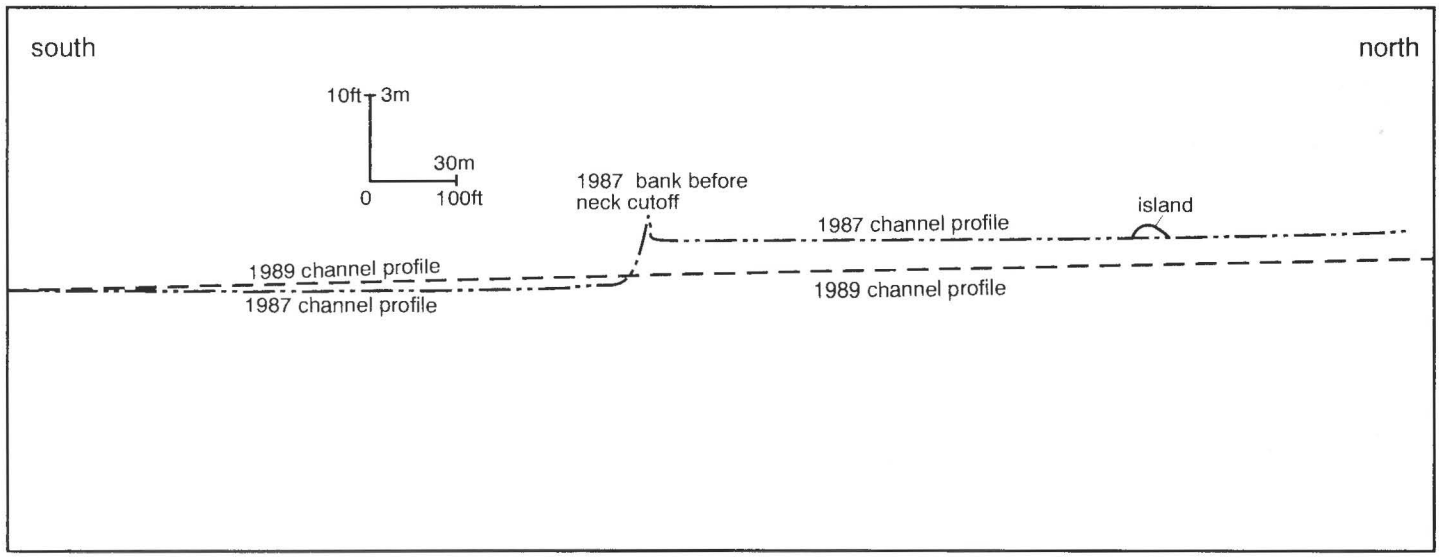


FIGURE 4. Profiles across neck of meander loop before and after cutoff.

loop, beyond where flow suddenly had been diverted across the neck (Fig. 3B).

Although low flows continued in this reach until July, the overall appearance remained similar to photographs taken in April. Several moderate to large floods (149 m^3/sec at gage) occurred in July and August 1988 (reportedly an El Niño year). A large amount of erosion and rearrangement of sediments took place during these floods. The largest flood overtopped the former pointbar upstream from the cutoff, flowed into the oxbow, and must have been at least 2 m deep and 41 m wide upstream from the former pointbar. The cutoff gap was eroded to 46 m wide across the former neck (measured diagonally across the new channel; Figs. 5, 6B). The channel upstream from the cutoff was enlarged laterally to a width of 30 m (Fig. 7B). The gradient both upstream and downstream from the cutoff became 0.003. The channel immediately downstream from the cutoff actually aggraded slightly (up to 0.65 m; Figs. 4, 5). A sand plug developed across the former channel at the upstream end of the oxbow, and the sand plug at the downstream end aggraded 1.6 m above the former channel and extended into the oxbow itself for more than 75 m (Figs. 5, 8). The attached bar opposite the downstream sand plug expanded both laterally and vertically and consisted of coarse sand and gravel. The form of the channel remained about the same until sometime after the resurvey was done (30 June 1989). Low flows had obliterated all flood-related bedforms, so the active channel consisted of low-relief anastomosing channels and bars. Even ripples were not preserved along the floor of the channel.

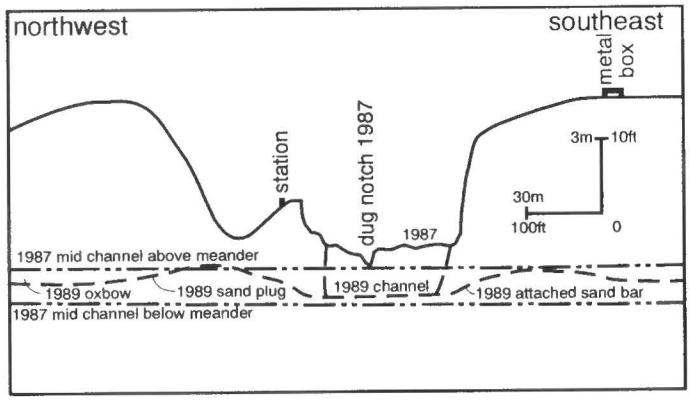


FIGURE 5. Profiles along meander loop channel segments and neck before and across channel after cutoff.

DISCUSSION AND CONCLUSIONS

The rapid adjustment of this reach of the Rio Puerco has implications for the geomorphological issues introduced above. First, breaching the threshold across the neck of the meander appears to be less significant to the stream than it was to the anticipatory observers. Even under low-flow conditions, the stream adjusted its gradient to the breach within a few months. Adjustment of the width to an equilibrium threshold comparable to the reaches upstream and downstream required either larger discharge (which happened to occur) or more time (meandering low flows within the channel eventually may have increased the width). Full development of attached bars and sand plug required higher flows.

Second, the threshold for breaching the neck of the meander essentially followed the shape of the profile across the neck, decreasing through time from a very high plateau, while the valley floor remained part of the neck, to the colluvial slope and bank of the downstream reach of the stream, and finally to the combination of the low-flow sandbar and slightly elevated crude trench across the former downstream bank.

Third, the Rio Puerco provided a complete surprise to observers by depositing a sandbar against the inner bank adjacent to the neck, where all common meander models would predict scour to be most active. This sandbar provided a slight buffer against breaching the meander neck in 1986 and 1987. Such deposition could only have occurred during low flows, when the active channel meandered on a much shorter wavelength.

Fourth, the initial breach of the neck took place during a moderate-flow event, not during a major flood. This demonstrates that as a threshold for change in erosion rates is lowered by everyday processes (including possible interference by humans), major events are not required to trigger the change.

Fifth, the timing and duration of events was important to threshold crossing and rates of adjustment to new thresholds. If major flows had occurred in 1987 (or as early as 1984), the neck probably would have been breached earlier. If no major flows had occurred in 1988 after the initial breach, adjustments of stream width in the breach would have been prolonged at least until major flows occurred or until low flows had produced similar results. Aggradation of the sand plugs and bars to the level of the former stream banks would require large flows in any case.

Finally, as an aside to arroyo aficionados, the meander-neck breach has implications for arroyo entrenchment too. The Rio Puerco of the east has been noted by several generations of explorers and geomorphologists as a premier example of gully erosion in the semiarid West. Descriptive models of forming arroyos by progressive headward erosion

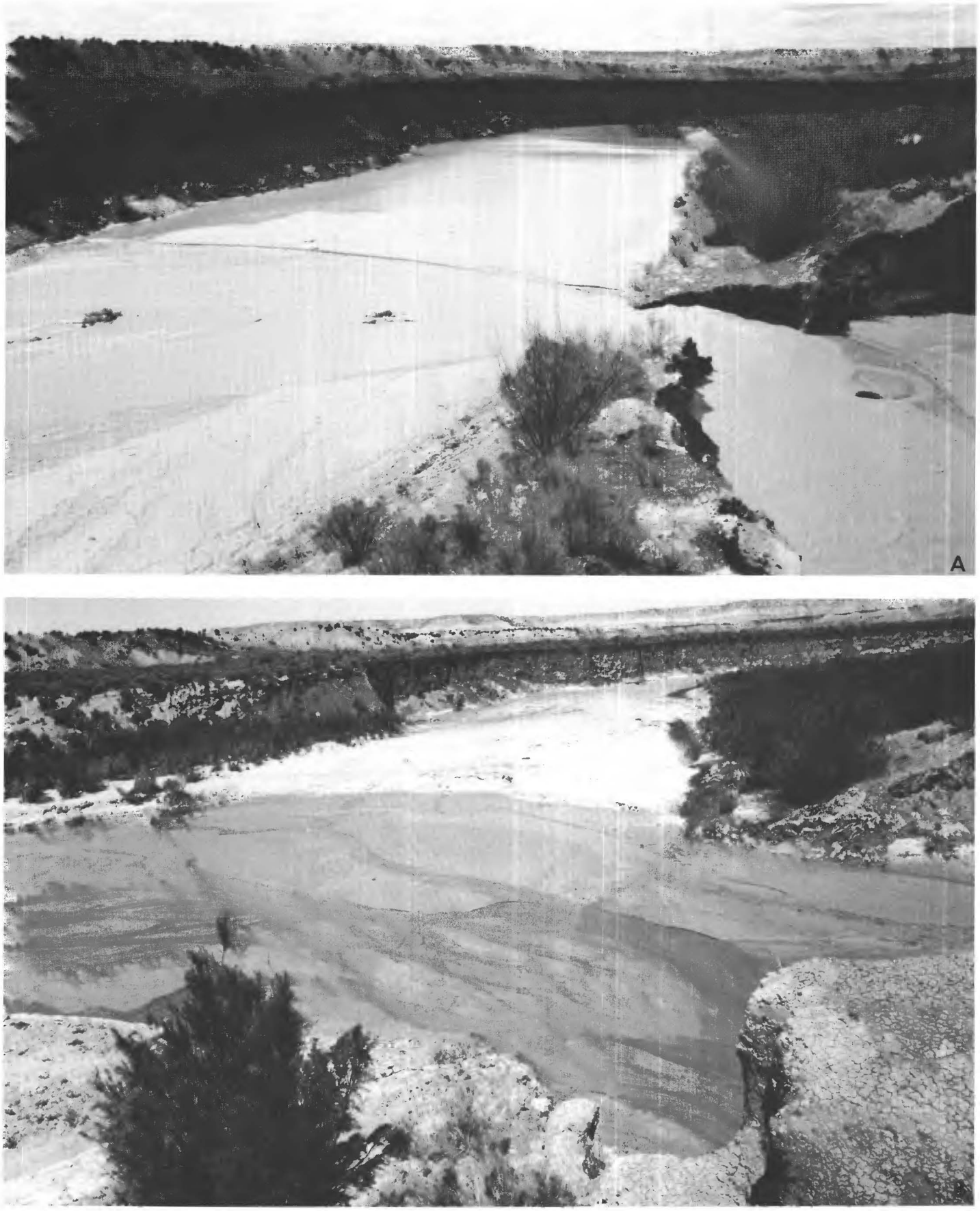


FIGURE 6. A, Neck cutoff and lower meander loop with oxbow, sand plug and sandbars on opposite sides of new channel (23 April 1988); B, Channel across former neck and sand plug-oxbow complex (16 June 1989).



FIGURE 7. A, Incised channel and neck cutoff from upstream (23 April 1988); B, Channel and neck cutoff from upstream (30 June 1989).



FIGURE 8. Channel and neck cutoff from downstream high bank (30 June 1989).

of valley-fill alluvium and incised-channel evolution have been based upon observations along the Rio Puerco and its tributaries (e.g., Bryan, 1928; Elliott, 1979). Headwall erosion analogies based on observations of smaller drainages and scale models may not apply to drainages larger than some threshold. A stream the size of the upper Rio Puerco (with flow about 53% of the year and magnitudes up to 196.5 m^3/sec) practically requires a continuous channel. The present breach probably formed a headwall at the neck initially, but it was not maintained even for a few months or even for a few hundred meters upstream during low flows. The lack of a headwall may be due in part to the form of the channel base and loose sediment, but less erodible clay layers were evident at the base of the channel and could have maintained a headwall if the stream had not developed an alternative form after the initial breach. This implies that incised meanders along the Rio Puerco probably formed by eroding the base of a previously established meandering channel (cf., Leighly, 1936), rather than by headwall migration progressing diagonally back and forth across an unchanneled valley floor.

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REFERENCES

Beven, K., 1981, The effect of ordering on the geomorphic effectiveness of hydrologic events; *in* Davies, T. R. H. and Pearce, A. J., eds., Erosion and sediment transport in Pacific Rim steeplands: International Association of Hydrological Sciences, Publication 132, p. 510–526.

Bryan, K., 1928, Historic evidence of changes in the channel of the Rio Puerco, a tributary of the Rio Grande, New Mexico: Journal of Geology, v. 36, p. 265–282.

Elliott, J. G., 1979, Evolution of large arroyos: the Rio Puerco of New Mexico [M.S. thesis]: Fort Collins, Colorado State University, 106 p.

Leighly, J., 1936, Meandering arroyos of the dry Southwest: Geographical Review, v. 26, p. 270–282.

Love, D. W., 1986, A geological perspective of sediment storage and delivery along the Rio Puerco, New Mexico; *in* Hadley, R. F., ed., Drainage basin sediment delivery: International Association of Hydrological Sciences, Publication 159, p. 305–322.

Popp, C. J., Hawley, J. W. and Love, D. W., 1983, Radionuclide and heavy metal distribution in recent sediments of major streams in the Grants mineral belt: Final Report to Office of Surface Mining, U.S. Department of the Interior, 130 p.

Ritter, D. F., 1988, Landscape analysis and the search for geomorphic unity: Geological Society of America Bulletin, v. 100, p. 160–171.

Schumm, S. A., 1985, Explanation and extrapolation in geomorphology: seven reasons for geologic uncertainty: Japanese Geomorphological Union, Transactions, v. 6, p. 1–18.



Exposures of the Paleocene Nacimiento Formation in Kutz Canyon with Angel Peak at center. Angel Peak is a resistant spire of the basal Cuba Mesa Member of the lower Eocene San Jose Formation. Photograph taken the evening of 11 April 1992. Copyright © Paul L. Sealey, 1992.