

Chapter 61

Entrenched Meanders

Meanders are a series of sinuous curves or loops that are found in rivers or streams.¹ The distance around the inside of the meander is less so the current there flows more slowly. It speeds up along the outside of the meander. The outside curve commonly undercuts a bluff and the inside often deposits a point bar or slip off slope (Figure 61.1). An aerial view sometimes shows a widening series of concentric old meandering loops in rivers. The meandering process continues until erosion cuts a shorter path for the water. Eventually, the water runs across the constantly-thinning neck of a meander, and forms an oxbow lake. Eventually, the lake fills with silt and clay. Although the cause of meandering is imperfectly known,^{2,3,4} it is usually associated with a decreased slope and reflects the interaction of flow, slope, and streambed resistance.⁵

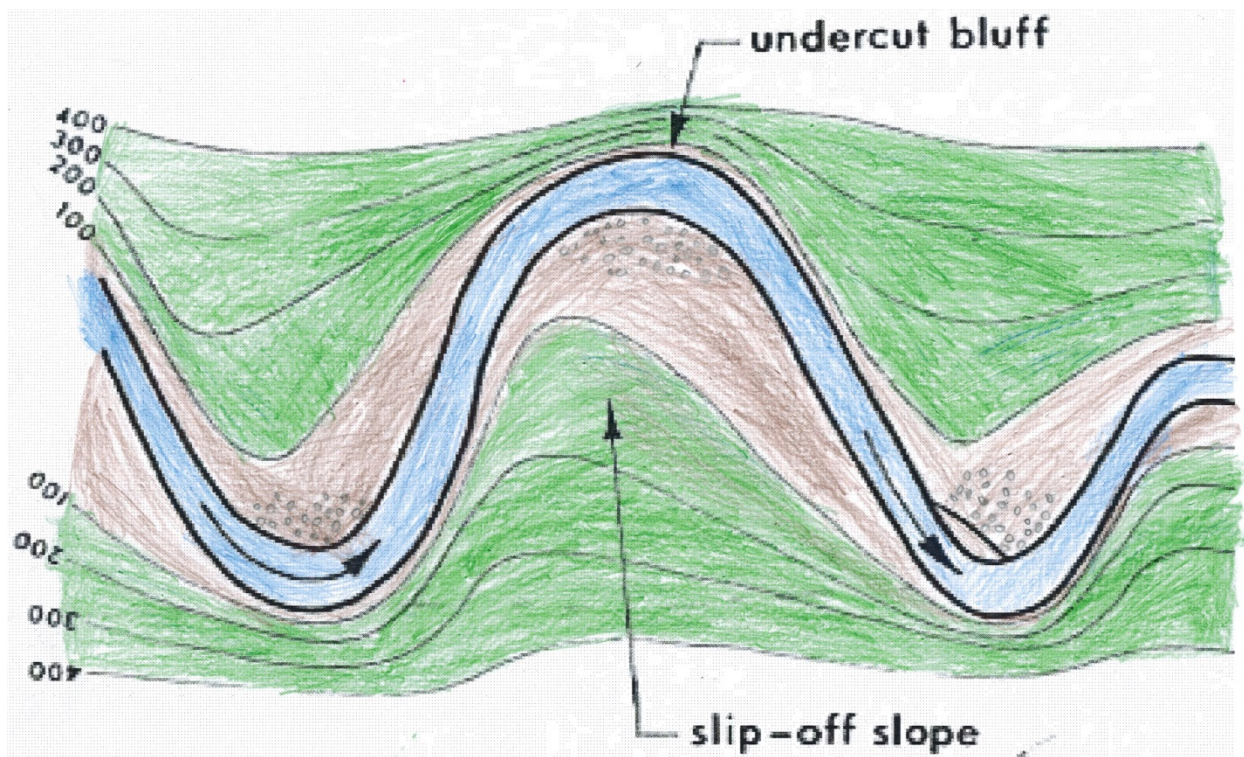


Figure 61.1. Diagram of an incised meander with steep undercut slope on the outside of the meander and a gentle slip-off slope on the inside of the meander. Contours are in hundreds of feet.

¹ Neuendorf, K.K.E., J.P. Mehl, Jr., and J.A. Jackson, 2005. *Glossary of Geology*, Fifth Edition. American Geological Institute, Alexandria, VA, p. 399.

² Parker, G., 1998. River meanders in a tray. *Nature* 395:111-112.

³ Van Dijk, W.M., van de Lageweg, W.I., and Kleinhans, M.G., 2012. Experimental meandering river with chute cutoffs. *Journal of Geophysical Research* 117(F03):1-18.

⁴ Güneralp, I., Abad, J.D., Zolezzi, G., and Hooke, J., 2012. Advances and challenges in meandering channels research. *Geomorphology* 163-164:1-9.

⁵ Pazzaglia, F.J., 2004. Landscape evolution models. In: Gillespie, A.R., S.C. Porter, and B.F. Atwater (editors), *The Quaternary Period in the United States*, Elsevier, New York, NY, p. 251.

When a meander cuts into bedrock it is generally called an incised meander.⁶ There are two types of incised meanders: 1) an ingrown meander which continues to grow *horizontally and vertically*, with an asymmetric slope in its walls (Figure 61.1);⁷ and 2) an entrenched meander with symmetrical, near-vertical walls which cuts downward with *little if any horizontal growth*.⁸ Entrenched, or sometimes spelled “intrenched,” meanders have vertical walls on *both* sides of the channel, indicating there was once a rapid downward cutting without the formation of slip-off slopes on the inside of bends, unlike incised meanders. The presence of slip-off slopes is indicative of an ingrown meander.



Figure 61.2. The Goosenecks of the San Juan River (photo courtesy of Jim Clarke).

Meanders are Common

Meanders seem to be a common feature of watercourses. Today, they form along rivers and streams, especially when the slope is low. Valley meanders are unique since they indicate a considerably larger amount of water formed the valley than what is flowing today (see Chapter 62). The Goosenecks on the San Juan River near Medicine Hat, southeast Utah (Figure 61.2) and Horseshoe Canyon on the Colorado River below Lake Powell, Arizona (Figure 61.3) are two famous examples of entrenched meanders. The first is especially difficult to explain using present day processes since it cuts through the Monument uplift of the Colorado Plateau.

⁶ Neuendorf *et al.*. Ref. 1, p. 323.

⁷ Neuendorf *et al.*. Ref. 1, p. 327.

⁸ Neuendorf *et al.*. Ref. 1, p. 211.



Figure 61.3. Horseshoe Canyon on the Colorado River below Lake Powell, Arizona (photo courtesy of Jim Clarke).

Meanders in Submarine Canyons

Meanders are sometimes found in unusual places like submarine canyons or fans.⁴ In fact, a majority of submarine canyons are sinuous in shape (see Chapter 70). Some even exhibit horseshoe-shaped, cut-off meanders, similar to rivers.^{9,10} The Cap Timiris Canyon on the lower continental slope offshore of Mauritania displays spectacular “gooseneck” meanders and a cut-off meander at about 9,200 feet (2,800 m) below sea level.¹¹ Meanders in submarine canyons could be structurally or fault controlled, but rock structure and faults are responsible for only a small number of meanders.

Extensions from submarine canyons into submarine fans are called fan valleys. The channel of the Monterey fan valley has a horseshoe-shaped entrenched meander called the Shepard Meander (see Figure 72.4).^{12,13} The fact that some submarine fans have sharp meanders (see

⁹ Mitchell, N.C., 2004. Form of submarine erosion from confluences in Atlantic USA continental slope canyons. *American Journal of Science* 304:590-611.

¹⁰ Perkins, S., 2005. Hidden canyons: vast seabed chasms carved by riverlike processes. *Science News* 167:9-11.

¹¹ Krastel, S., T.J.J. Hanebuth, A.A. Antobreh, R. Henrich, C. Holz, M. Kölling, H.D. Schulz, K. Wien, and R.B. Wynn, 2004. Cap Timiris Canyon: a newly discovered channel system offshore of Mauritania. *EOS* 85 (42):417, 423.

¹² McHugh, C.M.G., W.B.F. Ryan, S. Eittreim, and D. Reed, 1998. The influence of the San Gregorio fault on the morphology of Monterey Canyon. *Marine Geology* 146:63-91.

¹³ McHugh, C.M.G. and W.B.F. Ryan, 2000. Sedimentary features associated with channel overbank flow: examples from the Monterey Fan. *Marine Geology* 163:199-215.

Chapter 72) indicates large meanders can be formed underwater. It is likely they formed when the flow was a narrow, fast-moving current.

Meanders in Water Gaps

Water gaps are deep cuts through mountain ridges. Interestingly, meanders are also found in water gaps (see Part XVI for analysis of water gaps). An example is on the Missouri River where it passes through a ridge north of Three Forks, Montana. The ridge itself is up to 800 feet (245 m) above the river yet, the river cuts through its broad saddle. The Missouri River could have flowed more easily around the southern part of the ridge through a lower valley.

In another example, the Bighorn River passes through a water gap in a saddle between the Bighorn and Pryor Mountains. The river flows through a series of entrenched meanders about 1,000 feet (300 m) deep (Figure 61.4).



Figure 61.4. Entrenched meanders on the Bighorn River as it cuts through a water gap in a ridge between the Bighorn and Pryor Mountains.

The Puzzle of Entrenched Meanders

Entrenched meanders are generally rare,¹⁴ but for some reason they are common in the low-sloped reaches of large plateaus, like the Colorado Plateau.^{15,16} A spectacular entrenched valley up to 3,000 feet (900 m) deep meanders through the Columbia River Basalts in the extreme southeastern part of Washington State. The Grand Ronde River runs through this valley.¹⁷

Entrenched meanders of the Colorado and San Juan Rivers on the Colorado Plateau primarily show vertical excavation and very little lateral excavation. They have *no* slip-off slopes; and generally were cut straight down once the meander was established.¹⁸ Since they are deep valley meanders it implies they were formed at the same time as the valley.

The entrenched meanders of the San Joaquin River are a notable exception to low-slope meanders. They cut through hard rocks in the foothills of the Sierra Nevada Mountains¹⁹ and are similar in appearance to the Goosenecks of the San Juan River. The Sierra Nevada entrenched meanders indicate that at one time there must have been a much greater amount of water flowing through the river than we see today (see Chapter 62).

The origin of these and other entrenched meanders is a puzzle for those who are convinced the present is the key to the past since meanders strongly favor low slopes.²⁰

Rapid Uplift and Channelized Flood Erosion May Account for Entrenched Meanders

Uniformitarian scientists believe the valley-scale entrenched meanders were cut during an uplift or fall in the base level.¹⁵ This seems reasonable, but to which base level are they referring—the temporary base level of the Colorado Plateau or the ultimate base level of the ocean surface? Since they consider these tectonic processes took place over millions of years, the meanders should be incised with vertical walls on the outside of the meander and slip-off slopes on the inside bend (Figure 61.1). How is it that instead they have the markings of an entrenched meander?

Entrenched meanders can be explained to have formed during the Channelized Phase of the Flood, when the mountains rose and the ocean basins sank. Rapid channelized flow on generally horizontal or low-sloped surfaces could start the meander by first cutting a shallow channel that deepens as the vertical tectonics continues. There is evidence for meanders forming underwater in submarine canyons and fans.⁴

It is interesting that the meanders seen on the Green River of the Colorado Plateau indicate old meanders were shallowly excavated in the rock around the river before the deeper entrenched meanders were formed.²¹ A similar feature is seen in the water gap saddle between the Bighorn and Pryor Mountains (Figure 61.5). Shallow channels were first cut, showing evidence of the

¹⁴ Dury, G.H., 1977. Underfit streams: retrospect, perspect, and prospect. In, Gregory, K.J. (editor), *River Channel Changes*, John Wiley & Sons, New York, NY, p. 283.

¹⁵ Harden, D.R., 1990. Controlling factors in the distribution and development of incised meanders in the central Colorado Plateau. *GSA Bulletin* 102:233-242.

¹⁶ Twidale, C.R., 2004. River patterns and their meaning. *Earth-Science Reviews* 67:171.

¹⁷ Lupher, R.L., 1942. The Asotin stage of the Snake River Canyon near Lewiston, Idaho. *Journal of Geology* 50:866-881.

¹⁸ Garner, H.F., 1974. *The Origin of Landscapes: A Synthesis of Geomorphology*, Oxford University Press, New York, NY, p. 9.

¹⁹ Huber, N.K., 1981. Amount and timing of Late Cenozoic uplift and tilt of the Central Sierra Nevada, California—evidence from the Upper San Joaquin River Basin. *U. S. Geological Survey Professional Paper 1197*, Washington, D.C.

²⁰ Harden, Ref. 15, p. 241.

²¹ Harden, Ref. 15, p. 233.

first stages of the channelized flow shaped the meanders, before they were rapidly entrenched. Deep entrenchment happened after the Floodwaters drained from the high country and the channelized flow was confined to the original channel. The fact that these entrenched meanders are often 5 to 10 times the size of present river meanders (see Chapter 62) is further indication the entrenched meanders were originally eroded by much greater amounts of water than we see today. The streams and rivers that now flow through these huge meanders are too small for their original channels, and are therefore called “underfit.”



Figure 61.5. Old erosion channels associated with the Bighorn River before the deep entrenched meander formed on the water gap ridge between the Bighorn and Pryor Mountains.