SECTION B, GEOLOGY

Why Streams Meander[1]

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A number of theories have appeared in the literature to explain why streams meander. They are, for the most part, the outgrowth of field studies by geologists and geographers, who had not the facilities to isolate the variables of flow, such as velocity, volume, slope, load, angle of attack against the banks and type of rock through which any given stream meandered. It is not surprising that the opinions of these men were so divergent or that they were correct only under certain circumstances.

Men sent in reports of streams that meandered only after attaining some size, whereas others meandered from their very inception. There were meandering streams that degraded their channels, those that aggraded them, and still others that did neither. It seemed that no matter what the circumstances were streams meandered. However, some did not meander and some, once having produced meanders, set about trying to eliminate them (Matthes, 1943).

Streams meander as intricately in salt-water swamps as in fresh-water ones. Goldthwait (1937) studied the meanders of streams subject to tidal action. Cockfield (1921) took note of the meanders of streams flowing in perennially frozen ground where debris froze to the channel bottom unless it was removed as soon as it accumulated. Geologists saw other streams that produced their curving loops in an area floored by gravel, muck, sand, volcanic ash and ground ice (Cockfield, 1921), in glacial (Bostock, 1936) and in auriferous gravels (Spurr, 1898). They

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reported that streams meandered through cobbles and boulders (Miser, 1924) (Matthes, 1941), but that others serpentined only in soft sediments of uniform size. Some geologists studied streams that meandered less frequently in soft rock areas than in hard. Moore (1926) found that this correlation between rock hardness and ability to meander held good for small streams, but not for large ones. Gregory (1938) and Gregory and Moore (1931) found that streams of the Colorado Plateau have their meanders almost entirely confined to the harder rocks where the channel is narrowest, the stream gradient the steepest, and the velocity the greatest.

Eakin (1911) proposed that the earth's rotation was the answer to the question as to why streams meander. He was followed by Lacey (1923) and Chatley (1938) who favored the same theory. They were English engineers who worked on streams and canals in India. However, in 1940 Chatley stated that the process of meandering is initiated by any slight inequality of flow, asymmetry of channel, or the entrance of a tributary. In 1943 Quraishy put forward the theory that the earth's rotation is responsible for the meandering of streams.

Shulits (1936) stated that a stream would meander if its gradient exceeded that required to transport fine-grained material. The stream flattens its slope by lengthening its course, that is, by meandering. As a rule serpentining starts at a bar that has been formed along one bank and crowds the stream over to the other. He cited Schoklitsch (1930) in support of his statement. The view that excessive slope and energy cause a river to meander was held by von Engeln (1942). Maythaler (1903), who studdied the upper Rhine, held the concept that a stream with fine sediment load would tend to meander, if it had a small slope.

Reclus (1888) offered the explanation that the fluctuations between flood and low water shifted the stream current from one side of the channel to the other, and so initiated meandering. Russell (1936) introduced the concept of "effective stage difference" coupled with fineness of sediment to explain the meandering of streams in Louisiana. This stage difference involves a ratio between actual difference and the amount of water in the channel. The "effective stage difference" would be inconsequential along the lower Mississippi, he stated, but it would be effective on smaller streams, especially tidal inlets.

Griggs (1906) found the best developed meanders on the Buffalo River in its upper course where it had its greatest velocity. He considered load to be of great importance in the formation of meanders. Griggs stated that meandering is dependent upon the ratio of down cutting to lateral cutting and also on the relative load carried. He said that meandering belongs to the middle stage of loading, that a stream, if overloaded, does not meander, and that a swift stream will meander if it has a heavy load.

Smith (1929) stated that the saturation of a stream by eroded bank material may affect its flow, but that it is not the total cause of its meandering. A flowing stream of water constantly seeks a straight course from its source to its mouth, and will not change its course unless resistance makes it do so. Early in its downward course a stream encounters a greater resistance from one bank than from the opposite one: the result is a succession of bends. This, Smith stated, is the case whether or not the banks are of solid rock and the water clear (apparently) or the banks are of sand and the water overloaded with silt.

The meanderings of alluvial rivers in India has been attributed to a fixed law (Claxton, 1927). In the Punjab terminology, action at the banks is called erosion, and that over the bed, scour. Scour enters but little into the competition in meander formation, whereas erosion is important. On a river, whose width is enormous, stream load cannot pass across it. Debris torn from one bank is deposited downstream on the same side of the river. This action explains the behavior of rivers in general, and their meandering in particular. In 1936 Russell stated that available load seemed to be a factor that distinguished the meandering from the braided stream. He concluded that in general agrading streams flowing through floodplains composed chiefly of clay and fine silt are not easily overloaded and, as a consequence tend to meander, rather than to anastomose or braid.

Friedkin (1945) stated that meandering results primarily from local bank erosion and consequent overloading and deposition by the river of bed load. He found that in alluvial streams every phase of meandering represents a changing relationship among three closely related variables which, though striving to reach a balance never do. These variables are: (1) the flow and hydraulic properties of the channel, (2) the amount of debris moving along the stream bed, and (3) the rate of bank erosion. In his laboratory experiments he found four types of channels developed on alluvial rivers. In the first type, with banks entirely resistant to erosion, a deep narrow channel developed with extremely flat slopes. In the second type, slowly eroding banks resulted in a slowly meandering and relatively deep channel with fairly flat slopes. In the third type, which had easily eroded banks, a wide shallow channel with fairly steep slopes developed. The fourth type, with extremely erodible banks, resulted in a braided stream pattern. Side slopes were extremely steep. There is an intermediate type of channel between the braided and the meandering. This is the reach type. Its wide and shallow channel is fairly straight and its flow is divided by only a few islands or bars.

The complexity of meandering prevents the formulation of set rules concerning it. It permits no more than a knowledge of the tendencies and countertendencies brought about by changes in each of the variables. Changes in one variable are opposed or limited by changes in another. They form a circle of dependency.

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