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Figs. 1–4, June, 1970

INTERFERENCE RIPPLE MARKS FORMED BY EPHEMERAL STREAMS[1]

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ABSTRACT

Interference ripple marks form during floods along many ephemeral streams. Cuspate (linguoid) ripples form first when flood water in the channel is deep enough to flow over marginal and channel sand bars. As the water level falls, downstream currents are refracted shoreward over the marginal sand bars and linear ripple sets are formed on the tops and flanks of the bars. The linear ripples are oriented at right angles to the cuspate ripples and commonly form interference sets with them. Refracted waves and changing water level over the irregular bottom can complicate further the patterns of asymmetric ripple marks and other directional structures.

On the basis of study of modern ephemeral streams, we conclude that paleocurrent patterns of fluvial deposits are probably more complex than has been generally recognized. Still, the distribution of directional structures in modern streams is, in general, unimodal and the dominant inclinations of foreset laminae are downstream.

INTRODUCTION

Ephemeral streams in semi-arid and arid regions are natural flumes in which a variety of fluvial sedimentary structures are formed (High and Picard, 1968; Picard and High, 1969). Each flood is a separate "experiment" and for each flood significant variables can be measured or estimated. By investigating streams of diverse characteristics, some control and understanding of the variables is possible.

Interference ripple marks are common sedimentary structures in many rock sequences. That the two ripple sets record more than one paleocurrent direction is apparent. The mechanics of formation of interference ripple marks is less clear, however. In particular, do interference ripple marks record a one-stage or a two-stage event? Were both sets formed nearly simultaneously by a single process, or are the separate ripple sets essentially unrelated? Finally, of what interpretive significance are interference ripple marks?

RECENT OCCURRENCES

The interference ripple marks described here were noted first on sand bars in Ashley Creek, north of Vernal, Utah, in northeastern Utah. We have since found interference ripple marks of the same type in other ephemeral streams in the Uinta Basin, indicating that they are more than a local feature. Quite similar interference ripple marks also are present in the Green River Formation (Eocene) of the southeastern Uinta Basin, Utah.

Although Ashley Creek is a permanent stream, the section near Vernal is ephemeral inasmuch as most of the flow is diverted for irrigation. Significant flow is attained only during flood and near-flood stages. For much of its length, the bed of Ashley Creek has been modified for flood control. Gravel in the stream bed has been pushed to the sides to form levees and to protect the banks. However, in wider reaches, the stream has re-established its braided pattern and has constructed sand and gravel bars that are undisturbed and reflect sedimentary processes during brief periods of flow.

In sandy areas composed of medium and coarse sand-size material, cuspate (linguoid) ripple marks are the dominant structure (fig. 1). Commonly, the areas between and along the flanks of sand bars are covered with cuspate ripples. The tops of bars are less commonly rippled. In general, the cuspate ripples are asymmetric downstream, although where currents are refracted around bars other orientations of asymmetric ripple marks are present. Despite anomalous current directions, the cuspate ripple marks approximate the ideal unimodality of fluvial current patterns.

Younger sets of linear ripple marks also are formed on the sand bars. These ripples are characterized by long subparallel crests and differ markedly from the cuspate ripples. The younger sets of ripples are restricted to the crests and upper flanks of bars. Where cuspate and linear sets are both present, interference

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sets are found. Generally, the younger sets are confined mainly to the troughs of the larger cuspate ripples (fig. 2), but some sets continue across the crests of cuspate ripples (fig. 3). These smaller sets of linear ripples originate later than the cuspate ripples.

In contrast to the cuspate ripple marks, the linear ripples are oriented with their crests parallel with the banks. The steep faces of linear ripples are shoreward and foreset laminae are inclined shoreward. These relationships are true both for interference sets on bar flanks and for extensive sets of linear ripples that are developed on bar crests.

FIG. 2.—Interference ripple marks formed by cuspate and linear ripples. Linear ripples are largely confined to troughs of cuspate ripples. Dominant downstream current from top to bottom of picture. Refracted current from left to right. Quarter for scale.

DESCRIPTION OF RIPPLE MARKS

Table 1 compares the morphology of the cuspate and linear ripple marks. The linear ripples are smaller and are more symmetrical than the cuspate ripples. It is also apparent that the morphology of the linear ripples is more uniform than that of the cuspate ripples.

In size and shape, the cuspate ripples are similar to those ripples that commonly are found along stream beds in arid and semi-arid regions. In plan view, the ripples are discontinuous, doubly-plunging, and strongly curved. The curvature of the crests is concave downstream. The internal structure of the cuspate ripples is obscured frequently by a lack of sediment differentiation, but foreset laminae can be seen. The cuspate ripples described here commonly are called "current ripples." Although these ripple marks are the result of current flow, we prefer the descriptive name cuspate. Various kinds of currents can produce ripple marks that differ in morphologic characteristics.

In addition to their dimensions and symmetry, the two ripple sets differ markedly in general appearance. The crests of the cuspate ripples are curved and discontinuous; those of the linear ripples are parallel and subparallel and are continuous. The internal structure of the linear ripples is well-developed, and in places concentrations of organic matter define the lamination. Although they are nearly symmetrical in ripple form, the linear ripples possess definite foresets that are inclined shoreward. The linear ripples belong to a morphological class generally termed "wave ripples." This genetic terminology is inappropriate, however, which was noted long ago (Evans, 1941 and 1949; van Straaten, 1953 and 1954). As we have discussed in more detail elsewhere (Picard, 1967 a,b; Picard and High, 1968, p. 417), wave ripples encompass at least two different types; ripple forms produced by oscillatory waves and ripple forms produced

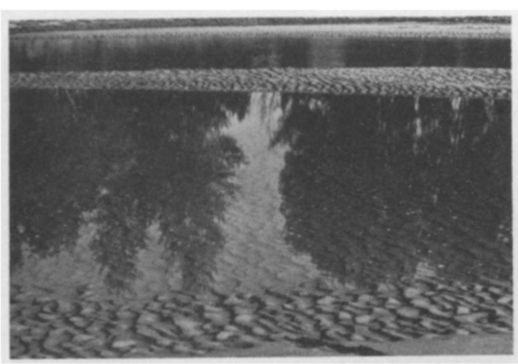

FIG. 1.—Cuspate ripple marks in channel-bar complex. Ripple marks cover channel bottom and flanks of bars marginal to the channel. Bar in middleground is lower than marginal bars (foreground and background) and is covered by ripple marks. Current from right to left.

FIG. 3.—Interference ripple marks. Linear ripples locally override cuspate ripples. Dominant downstream current from left to right. Refracted current from bottom to top. Quarter for scale.

TABLE 1.—*Cuspate and linear ripple marks, Ashley Creek, Vernal, Utah.* (15 *measurements*)

	Cuspate			Linear		
	Mean	Standard Deviation	Range	Mean	Standard Deviation	Range
Length	17.3 cm	3.8	9.0 to 24.0	2.0 cm	0.1	1.7 to 2.4
Height	1.8 cm	0.3	1.5 to 2.5	0.48 cm	0.05	0.40 to 0.55
Ripple Index	10.0	2.7	4.5 to 17.7	4.3	0.7	3.4 to 5.2
Ripple Symmetry Index	4.1	1.2	2.2 to 7.5	1.6	0.25	1.1 to 2.1

by translatory waves. To lump the two types under one term is to ignore basic differences. Thus, we prefer the descriptive terms.

The means of the ripple index (length/height) and the ripple symmetry index (trough-to-crest/crest-to-trough) of the cuspate ripple marks (table 1) plot in the field of "current" ripples of a chart prepared by Tanner (1967, p. 97). The means of the same two ratios of the linear ripple marks occur in the "wave" ripple field of Tanner's chart. On the basis of several parameters, Tanner (1967) believes that he can distinguish wave, current, wind, and swash ripple marks in Recent settings. As just noted, we believe at this time that genetic classification is premature.

FORMATION OF RIPPLE MARKS

The interference ripple marks were noted first after a flood in May 1969. Subsequently, the formation of similar ripples was observed during several floods in June 1969. No significant differences were noted between the ripples formed by different floods.

Cuspate ripple marks are formed by unidirectional currents within the channel. During floods, sediment is transported and at the appropriate flow conditions, ripples form in the sandy areas. The rather wide range in size and shape of individual ripple marks is the result of varying flow conditions that prevail at different times during the flood and at different sites within the channel-bar complex.

Most tracts of cuspate ripple marks observed at Ashley Creek probably are high-energy current ripples (Harms, 1969, p. 365; also, see plate 2). Cuspate forms were more abundant, however, than Harms illustrates (1969, plate 2) or than he implies is characteristic. Small dunes, which form at higher energies (Harms, 1969, p. 366; Simons and others, 1965), were not noted where the interference ripple marks had formed. The cuspate ripples were formed in the lower part of the lower-flow regime (Simons and others, 1965; Harms and Fahnestock, 1965; Harms, 1969) and are indicative of relatively low hydraulic energy and slow transport of sand.

The formation of the linear ripple marks (wave ripples of Harms, 1969) was more complex than that of the cuspate ripple marks. Near the marginal sand bars the dominant downstream waves were refracted shoreward (fig. 4), and at shallow depths (generally less than two inches of water) the refracted waves produced the linear ripples in the lower part of the lower-flow regime. Extensive sets of linear ripples formed on areas, such as crests of bars,

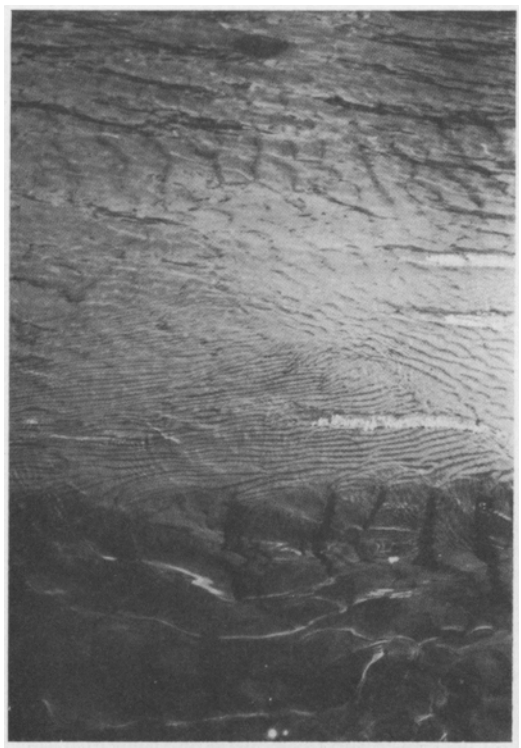

FIG. 4.—Refracted waves and resulting linear ripple marks on bar crest. View toward center of stream. Dominant current from right to left. Refracted current from top to bottom. Note cuspate ripples on flanks of bar.

that were too shallow for the formation of further cuspate ripples after the flood began to recede. Interference sets also formed on bar flanks during recession of the flood. The cuspate ripples were formed first, when water in the channel was deep enough to maintain downstream flow over marginal and channel sand bars. As the water level fell, bar flanks were progressively exposed to refracted wave patterns. Water velocities, therefore, were much less during formation of the linear ripples than during formation of the cuspate ripples.

Cuspate ripples can be partially reworked or, in the case of Ashley Creek, finer sediment can be deposited in the cuspate troughs and rippled. Because the direction of the refracted waves changed as the water level fell in the irregular channel of Ashley Creek, separate sets of linear ripple marks were not parallel. Nevertheless, the steep faces of linear ripples were generally shoreward for bars on the channel margin and toward the middle of bars within the channel.

Other ripple orientations also are present in ephemeral streams. At one locality, we observed five separate wave sets: initial downstream, refracted onshore (onbank), reflected offshore, and refracted downstream and upstream (longshore currents of refracted oblique wave sets). Subsequent studies by Picard of other ephemeral streams indicate that ripple marks are formed by the reflected offshore and the refracted downstream and upstream wave sets but they are rare compared with initial downstream and generally onshore ripple marks.

The interference ripple marks described here are the result of only one of the possible mechanisms of formation. In addition to illustrating the formation of this particular structure, this paper is intended to call attention to the complex current patterns that exist in ephemeral streams and the different orientations of asymmetric ripple marks that are formed. An understanding of these relationships will be useful in interpreting paleocurrent patterns of fluvial deposits.

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