Location-dependent sediment sorting in gravelly megaripples from the Rio Grande, central New Mexico

David W. Love, James T. Boyle, Sylveen Robinson, and Mark P. Hemingway

New Mexico Geology, v. 7, n. 2 pp. 26-30, Print ISSN: 0196-948X, Online ISSN: 2837-6420.
https://doi.org/10.58799/NMG-v7n2.26

New Mexico Bureau of Geology & Mineral Resources
New Mexico Institute of Mining & Technology
801 Leroy Place
Socorro, NM 87801-4796

https://geoinfo.nmt.edu

This page is intentionally left blank to maintain order of facing pages.

Location-dependent sediment sorting in gravelly megaripples from the Rio Grande, central New Mexico

by *David W. Love*, *James T. Boyle*, *Sylveen Robinson*, and *Mark Hemingway*, New Mexico Bureau of Mines and Mineral Resources, Socorro, NM

Introduction

An ongoing study of modern fluvial sediments in New Mexico has revealed that grain-size sorting in streams is dependent on sample location within portions of bedforms and on bedform position within downstream progressions of similar forms. These results have many potential geologic applications.

One of the sets of bedforms studied is straight-crested, gravelly megaripples of the Rio Grande conveyance channel near Socorro, New Mexico. Megaripples are ripple-shaped bedforms having wavelengths larger than 60 cm and a range in amplitudes larger than ripples. In streams, megaripples form under lower-flow-regime conditions and migrate downstream by progressive deposition along their slip faces (Fig. 1). The purposes of this paper are to relate grain-size distributions to the form and location of megaripples and troughs left by waning flow along the conveyance channel, to determine whether a megaripples's position within a progression may be located by analyzing its grain-size distribution, and to determine sorting mechanisms taking place along megaripples.

Description of channel conditions

The conveyance channel east of Socorro is about 23 m wide at the top and 4 m deep, with an average gradient of 0.016 (Fig. 2). During the week of April 8, 1984, flow averaged an estimated 86 m^3/sec (based on flow estimation techniques of Williams, 1978). On April 14, flow in the conveyance channel was diverted back into the Rio Grande channel upstream. During the next four days, the flow dropped to an estimated 3 m^3/sec, so that the channel was approximately 10 m wide and 0.2 m deep. Flow was maintained in part by seepage from the banks. On April 19, the water was clear and the tops of some of the megaripples were near the surface of the water when surveying and sampling were conducted (Fig. 3). Little sediment was in suspension. Sand was transported only where megaripples were eroded by flow in the thalweg. Most parts of the megaripples were no longer migrating downstream.

Straight-crested megaripples with wavelengths averaging 2.8 m were measured and sampled along a 30 m long reach where reworking by a low-flow thalweg had not altered the bedform configuration. After sampling was completed, the reach was surveyed using a Leitz TM 20 theodolite and a rod measuring to the nearest hundredth of a foot (about 3 mm). The megaripples had long, low-angle stoss sides, steep lee sides (at the angle of repose), and crests about 12 cm above the adjacent troughs downstream (Fig. 4). No ripples occurred on the stoss

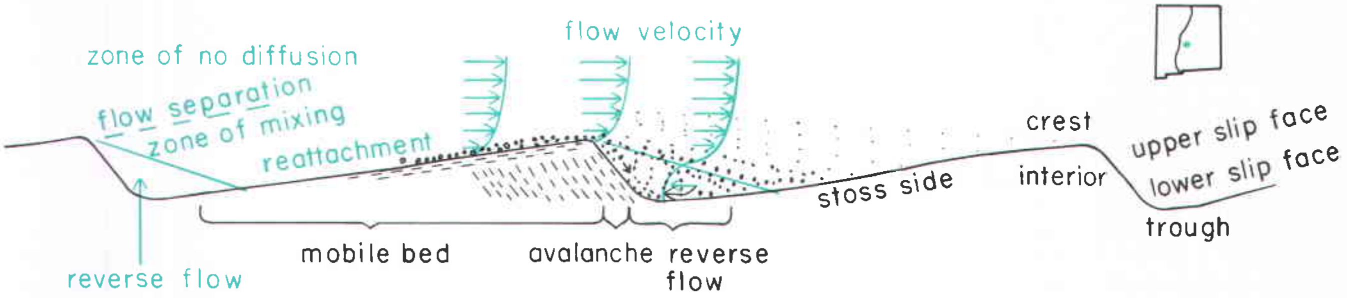

FIGURE 1—Anatomy of megaripples, water flow (in blue), and sediment movements (in black) involved in sorting processes. Modified from Jopling (1963) and Reineck and Singh (1980). Index map shows approximate study location.

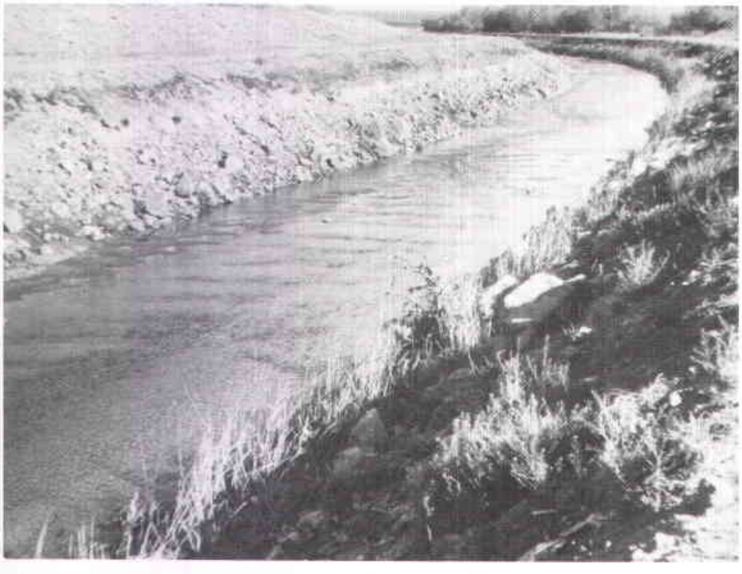

FIGURE 2—Low flow in conveyance channel of Rio Grande near Socorro on April 19, 1984. Note tops of megaripples near water surface. Channel is approximately 10 m wide.

FIGURE 3—Megaripples in conveyance channel of Rio Grande. Thalweg in lower middle portion of picture is reworking sand and obliterating megaripples.

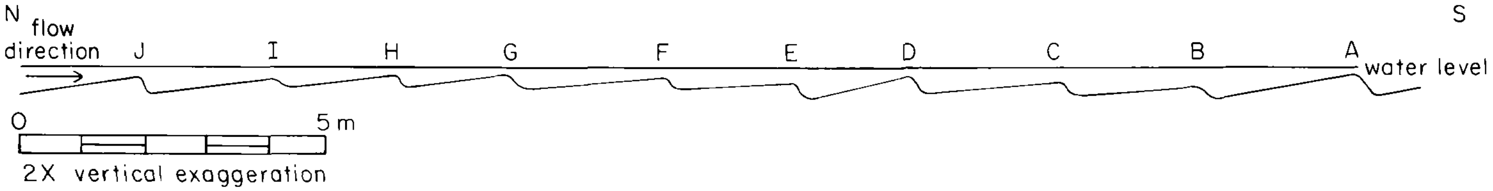

FIGURE 4—Longitudinal profile of megaripples and water surface.

sides of the megaripples, except in the thalweg, where the megaripples were beginning to be reworked and fine sand was being transported. The exact timing of deposition of the megaripples is not known, but probably the formation and preservation of the bedforms lagged behind flow conditions (cf. Allen, 1982). The slip faces probably were deposited just before flow waned to the point of no sediment transport, whereas the interior portions of the megaripples were deposited during active transport conditions. Although the timing and conditions for deposition of the megaripples remain partially undetermined, the fact that they were preserved during waning flow suggests that similar sedimentary structures in geologic contexts may be examined and interpreted in a similar manner.

Sample treatment

Samples were taken from the megaripples by sampling portions of bedforms progressively upstream so that the samples remained undisturbed and uncontaminated by sediments agitated during the sampling process. Thus, troughs downstream from each megaripple were sampled first, then the lower slip faces, upper slip faces, the armor at the crest of the megaripples, and, finally, the interior portion of each megaripple. Not all megaripples within the sequence were sampled, primarily because they were all very similar in overall characteristics. We were not convinced that differences would be found between adjacent megaripples, and, therefore, we expected only slight differences between the upstream and downstream ends of the sequence. Where the megaripples were dominated by gravel, about 1 kg samples were taken in an area of 200–400 cm^2. The uppermost few cm were scooped by hand into a large plastic bag. The interiors of megaripples were sampled by clearing away all surface clasts from a broader area and then scooping the sample from the megaripple by hand. The dominantly sandy slip faces were sampled using film canisters that hold about 40 g of sand when full; one to two canisters of sand were taken from each of the upper and lower slip faces.

Sediments forming the megaripples and troughs were extremely loosely packed. While walking across the channel, a 65-kg (143 lb) person could sink up to 60 cm into the uncompacted sandy sediments. Although slip faces were present on the lee sides of the megaripples, no internal sedimentary structures were seen during sampling, probably because slumping occurred immediately after samples were taken, and because of the lack of differentiation of grain sizes into discrete laminae. Unfortunately, time and expense did not allow more sophisticated techniques for sampling cross sections of sedimentary structures (such as taking epoxy box cores) to be used.

In the lab, the samples were dried and sieved using sieve sizes listed in Table 1. The entire sample was sieved to a size of 1 mm in order to have an adequate sample of large clasts. Samples with abundant portions of sand less than 1 mm were split to about 50 g and sieved. Then the proportion of the total was calculated. Duplicate splits of some samples were sieved to test the adequacy of this procedure.

Mass-frequency diagrams were plotted following Bagnold's (1941) procedures. In the diagrams that illustrate grain-size distributions (Figs. 5–9), both axes are logarithmic because of the wide ranges in grain size and mass percentages. The irregular intervals between sieves are standardized by dividing the mass percent in each size class by the difference between logarithms of the diameters of the largest and smallest grains in the size class. The diagrams show the mass frequency of different-size grains in such a way that proportions of one population may remain similar even though other populations are added or subtracted from the total in other parts of the distribution. In the plots that follow, some sieves caught consistently less mass than the sieves adjacent to them because of deviations in aperture size. For example, the 0.5-mm sieve nearly always had less sand in it than did the 0.43-mm sieve, indicating that some apertures of the 0.5-mm sieve are too large and let too many grains through to the 0.43-mm sieve. These inconsistencies have not been corrected in the plots, but are clearly apparent as a V-shaped depression in the grain-size curves at 0.5 mm. Some curves are discontinuous at the coarse end because no clasts were caught on some sieves.

Results

The grain-size distributions from the megaripples depend on where samples were taken within each megaripple and associated trough downstream, and on the location of the megaripple and trough set within the sequence. The differences in grain size are reflected in the overall distributions at a given location within each megaripple, in trends downstream along each megaripple/trough sequence, and in proportions of gravel fractions and various sand fractions within individual megaripples and along the entire sequence. The grain-size data are organized in Figs. 5–9 for each location along megaripples/troughs, and the data are "stacked" from upstream to downstream to illustrate any longitudinal shifts. More subtle trends are revealed by comparing adjacent parts of megaripples/troughs for different populations/line slopes and by examining relative percentages of different parts of the populations. These differences and trends are summarized below.

TABLE 1—Sieve aperture sizes in mm used in sediment analyses.

38.05	1.00
26.67	0.85
18.35	0.71
13.33	0.605
9.52	0.500
8.00	0.430
6.30	0.355
5.66	0.303
4.76	0.250
4.00	0.212
3.35	0.180
2.83	0.150
2.36	0.125
2.00	0.107
1.68	0.090
1.40	0.075
1.18	0.063
	0.045

Distributions from analogous portions of megaripples

As shown in Fig. 5, troughs show a broad, skewed peak between 0.25 and 8–10 mm, a decrease in grains larger than about 10 mm, a paucity of grains between 0.075 and 0.180 mm, and a second peak at 0.063 mm. Grains between 0.85 and 8 mm increase in mass percent downstream, whereas grains between 0.355 and 0.85 mm decrease in mass percent downstream.

Grains armoring the crest of megaripples have distributions somewhat similar to troughs, because they have a general broad peak from 0.25 to 8 mm and a small peak at about 0.063 mm (Fig. 6). The broad peak greater than 0.25 mm tends to be flatter (more of a plateau) than the broad peak of the troughs, and it tends to show slightly lesser amounts of the coarser clasts (curve has a negative slope at coarser sizes). Grains between 1.4 and 4.76 mm decrease in mass percent downstream, whereas grains between 0.25 and 1.4 mm increase in mass percent downstream, with the last megaripple having a definite peak between 0.5 and 1.18 mm (this peak may be due in part to sampling the underlying megaripple interior). No trend is apparent in the amount of fine sand forming the peak at about 0.063 mm.

Samples from the interiors of megaripples show a similar broad peak from 0.25 to 6.3 mm and a precipitous decline in the amount

☞

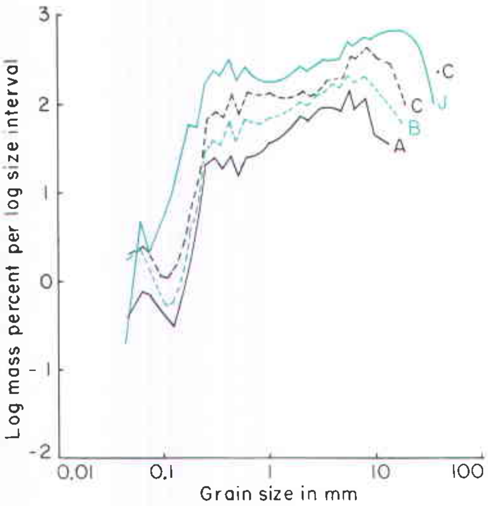

FIGURE 5—Grain-size distributions of troughs located downstream from megaripples A, B, C, and J. For clarity, curves B, C, and J have been offset vertically by the respective addition of 0.3, 0.6, and 0.9 to their Y-values.

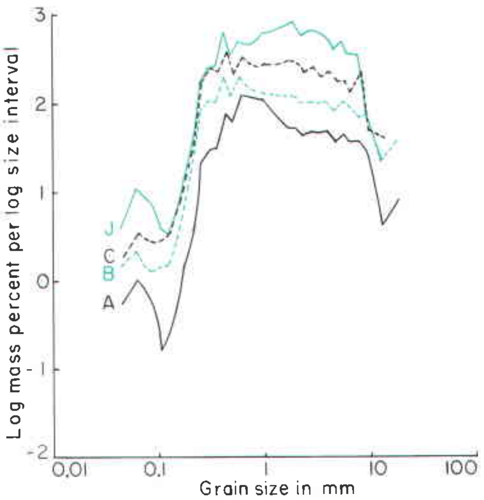

FIGURE 6—Grain-size distributions of crest armor of megaripples A, B, C, and J. For clarity, curves B, C, and J have been offset vertically by the respective addition 0.3, 0.6, and 0.9 to their Y-values.

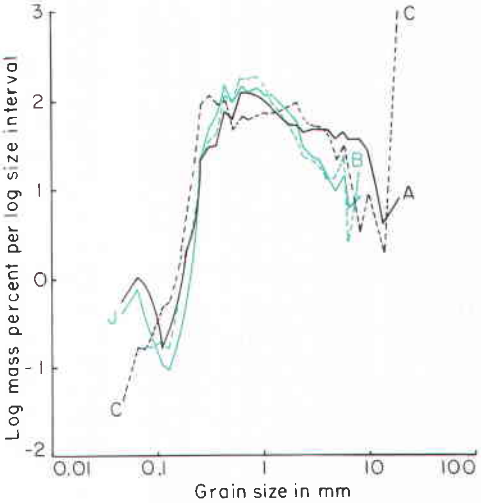

FIGURE 7—Grain-size distributions of megaripple interiors. No curves have been offset. Curve A is the same as that for crest armor A because no separate sample was obtained.

of sand less than 0.25 mm (Fig. 7). In comparison with samples of crest armor, interiors have fewer clasts larger than 6.3 mm. There appears to be a decrease in fine sand fraction downstream, but secondary peaks at 0.107 or 0.063 mm or both occur in all interior samples.

Upper slip faces have a narrower range of grain sizes, commonly exhibiting a peak between 0.25 and 1 mm (Fig. 8). From the upstream megaripple (J) to the next to the last megaripple (B) in the sequence, the distribution shifts to a finer peak (from 0.605–0.85 to 0.303–0.43 mm), but the last megaripple (A) is similar to the first. Moreover, samples from different parts of the upstream megaripple (active and inactive) are quite different in proportions of coarse and fine grains (Fig. 8: Ja, active, and Jb, inactive).

Lower slip faces are much better sorted than either the troughs or the rest of the megaripple locations. They have a single, relatively narrow peak, slightly skewed toward the fine side (Fig. 9). The peak of the distribution shifts downstream from 1.18–1.4 to 0.71–0.85 mm. The amount of grains between 0.063 and 0.71 mm increases downstream, affecting the slope of the fine side of the distribution, but no separate peak of fine sand occurs. Grains between 1.4 and 2.83 mm decrease downstream, but the last lower slip face (A) has an increase in granules between 3.35 and 4 mm.

Progressive downstream changes in distributions from adjacent portions of megaripples

Downstream progressions along individual megaripples also reveal trends in the following sequence: 1) trough to 2) megaripple crest to 3) interior to 4) upper slip face to 5) lower slip face to 6) trough. As Figs. 5–9 show, distributions become better sorted and unimodal in progressions from troughs to lower slip faces. The coarse modes (>8 mm) of troughs decrease in crests and interiors and are not present in slip faces. Secondary modes at 0.063 mm also decrease from troughs to slip faces. In two of the progressions from lower slip faces to troughs, the troughs have a deficiency of clasts in the range of the peak of the lower slip faces.

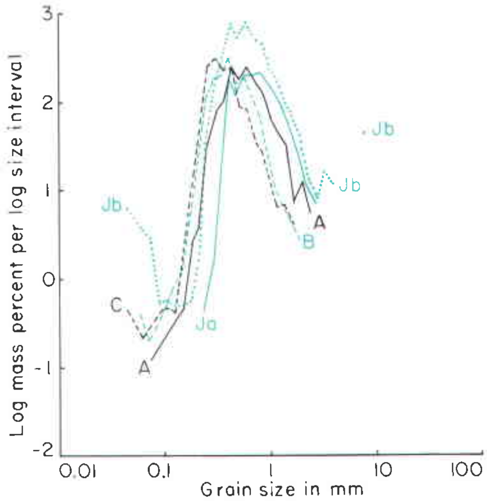

FIGURE 8—Grain-size distributions of upper slip faces of megaripples A, B, C, and J. Curves A, B, C, and Ja are not offset; Jb is offset by 0.5 Y-units to avoid overlap. Ja is from active slip face in thalweg; Jb is from inactive slip face 2 m from thalweg.

Other locational indicators

In comparing curves, it was noted that points where two curves cross (termed crossover points) may shift significantly depending on location within the megaripple sequence. For example, the crossover points between crest armor and adjacent trough range downstream from 5.66 mm at J to 4.76 mm at C to 2.36 mm at B to 1.4–1.68 mm at A. Similarly, the amount of mass in certain size intervals may show trends downstream. As Table 2 shows, the mass of clasts larger than 2 mm in troughs decreases downstream, but the mass of all clasts larger than 0.6 mm in troughs shows no significant differences downstream. The lower slip faces contain progressively less mass greater than 0.605 mm downstream, but other megaripple portions do not show significant trends.

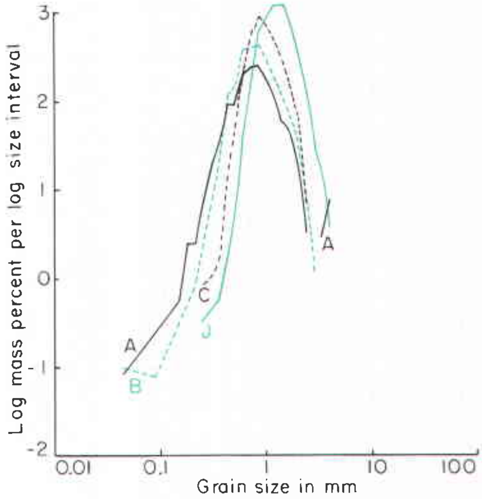

FIGURE 9—Grain-size distributions of lower slip faces of megaripples A, B, C, and J. Curves B, C, and J are offset vertically by the respective addition of 0.2, 0.4, and 0.6 to their Y-values.

Discussion

Rather than merely comparing grain-size distributions of adjacent samples, discussion of the above results focuses on the sorting mechanisms responsible for producing the distributions and on interpreting the distributions based on the proposed sorting mechanisms.

Sorting mechanisms

Numerous factors determine the grain size and sedimentary structures within each reach of a stream. In general, dominant grain size along stream beds and character of flow (such as velocity, depth, stream power, and shear stress) determine bedforms. For example, stream beds with a preponderance of grains larger than 0.6–0.7 mm do not develop rip-

TABLE 2—Examples of longitudinal ranges in weight percent of selected large clast sizes from portions of megaripples along the conveyance channel of the Rio Grande; *armor and interior sampled together in megaripple A; **b**, only Jb, inactive upper slip face, represented here.

megaripple	percent > 2 mm in troughs	percent > 0.6 mm in troughs	lower slip	upper slip	armor	interior
J	75.3	83.3	99.8	57.3^b	83.7	71.4
C	75.1	91.3	97.7	12.8	75.4	65.6
B	73.6	91.8	86.4	28.7	76.5	77.2
A	72.2	91.3	81.9	52.3	83.0*	

ples; rather, as flow is increased, such beds progress from being stationary to planar mobile beds to megaripples to upper-flow-regime plane beds, and finally to antidunes (as summarized in Reineck and Singh, 1980). Under lower-flow-regime conditions of water and sediment discharge, sediment transport and sorting mechanisms in gravelly megaripples depend primarily on 1) mobile-bed phenomena such as armor development and overpassing, and on 2) flow separation at the brink of the bedforms (Fig. 1).

As a result of fluid shear stress along the bed, mobile (i.e., all grains move episodically and cannot be considered lag) gravelly beds develop an armor or pavement at the bed–water interface that results in nearly equal transport rates for all sizes of clasts in the bedload (Andrews, 1983; Parker and Klingeman, 1982); winnowing of finer sizes by differential bedload transport apparently does not take place. Grains larger than about 4–5 times the median diameter of the bedload are most exposed to shear stress and tend to overpass the bed (Everts, 1973; Allen, 1983; Andrews, 1983). Fine grains may also overpass, but they are more likely to become transported in partial or full suspension. As grains are remobilized from the pavement, other grains drop into the "holes" and become less mobile. Andrews (1983) and Parker and Klingeman (1982) imply that grain-size distributions of pavement should reflect nearly equal amounts of a large range in sizes of grains. Parker and Klingeman (1982) noted that in gravelly streams with plane beds, bedload and subpavement grain-size distributions tend to be similar, while the pavement at the interface is coarser. However, with megaripple bedforms other sorting mechanisms appear to influence the grain-size distributions of the subpavement so that it is no longer similar to the bedload.

Flow separation at the brink of megaripples takes some grains beyond the brink to settle through zones of differential turbulence to the trough or stoss side of the next megaripple downstream (Jopling, 1964). Grains settling beyond the brink are sorted according to forward momentum, settling velocity, and strength of turbulence. Small grains are carried away in suspension. Grains near the bed in the zone of differential turbulence may be caught in a zone of reverse flow, being transported toward the slip face of the megaripple upstream. Other grains are deposited at the brink and avalanche down the slip face. Grains caught in avalanches are sorted by differential shearing and relative dispersive pressure, as well as by turbulent suspension of smaller grains.

Interpretations of distributions based on sorting mechanisms

These mechanisms of grain movement in megaripples suggest that the interiors of the bedforms should be made up of upper and lower slip faces, and that pavement on crests and stoss sides of megaripples should be derived in part from reworking megaripple interiors along with addition of grains that passed over previous bedforms. These implied relations appear to be substantiated by the grain-size distributions illustrated in Figs. 5–9.

The interiors of megaripples appear to be made up of sediments from the slip faces, although some clasts coarser than those of the slip faces also occur. These coarse clasts in the interior of the megaripples may be due to flow conditions at an earlier time of deposition; the sampled slip faces formed later during waning flow. Megaripple interiors C and J are similar to upper slip faces, whereas A and B appear to contain components of both upper and lower slip faces. In part, this may be a problem of sampling at equal depths or at equivalent positions in adjacent megaripples.

The excellent degree of sorting of the lower slip faces is unexpected considering the proposed mechanism of intermittent avalanching of grains down the slip face. In bedforms studied in other streams, the lower slip faces are the least well sorted locations. If avalanching was the chief sorting mechanism, coarser grains should be expected at the base of the slip face. Instead, the shape of the grain-size distributions suggests sorting during unidirectional flow similar to that of sand in ripples and plane beds. Therefore, the sand of the lower slip face may be resorted and accumulated by reverse flow in the wake of the megaripples. Under this mechanism, avalanching coarse grains either may be trapped occasionally at the base of the slip face or may roll to the trough and continue downstream. The medium to coarse sand, on the other hand, may accumulate at the base of the slope where the reverse currents begin to rise. Finer sand would continue in suspension or perhaps would be deposited on the upper slip face.

Armor could have been derived either by 1) reworking megaripple interiors, removing large amounts of finer clasts, and accumulating coarser clasts as lag, or by 2) additions of coarser clasts in a mobile bed that moved over the troughs and up stoss sides of the megaripples. The nearly flat "plateaus" between 0.25 and 8 mm of the grain-size distributions of the armor (Fig. 6) could indicate either that clasts in that size range were equally mobile because of equal shear stress to move all sizes (cf. Andrews, 1983) or that the grains were differentially exposed to shear stress depending on size and placement of surrounding grains (Parker and Klingeman, 1982). The plateaus of nearly equal amounts of grains are much wider (8 mm is 32 times as big as 0.25 mm) than predicted by Andrews (roughly 14 times from 0.3xd50 to 4.2xd50). This discrepancy may indicate that the larger grains are moving under a nearly constant low value of critical dimensionless shear stress. Lower shear stress in troughs would force accumulation of otherwise mobile large grains, accounting for the slight "hump" in the mass of coarse grains (Fig. 5).

If megaripples and troughs migrate, stoss sides of megaripples must be progressively eroded away as the form shifts downstream. The differences between crest armor and trough armor may be explained either by progressive accumulation (lag) of coarse grains or by additions of coarse grains in transit from upstream. Based on the results of Andrews (1983) and Parker and Klingeman (1982), armor is not due to lag. Therefore, the coarse grains must come from upstream, probably from erosion and overpassing of stoss sides of megaripples. The relative abundance of coarse grains in troughs compared to crests may be due to the relatively weak overall currents in the zone of reattachment (Fig. 1). Large grains may not be moved out of this area as readily as smaller grains.

The abrupt decrease in mass percent of grains less than 0.25 mm in the armor of crests and troughs suggests an efficient sorting process such as suspension of finer grains, but secondary peaks commonly occur at 0.090–0.107 and 0.063 mm in the armor of the troughs and crests. This sorting of secondary modes takes place despite the fact that no ripples form along beds with average grain size larger than about 0.6 mm. Bridge (1981) explored the production of grain-size distributions with abrupt decreases in the amount of fine grains due to suspension. Most of his theoretical distributions show an abrupt decrease in amounts of grains finer than a given size determined by the strength of bed shear stress. For example, Bridge's calculated grain-size distribution for a mean shear stress of 4 dynes/cm^2 yields a curve that abruptly declines in mass of grains less than 0.21 mm in diameter.

Bridge (1981) proposed two alternatives to explain the presence of fine grains in gravelly deposits. He suggested that some fines may be present due to entrapment and infiltration between larger grains, particularly as flow wanes, and other fines may be present due to mechanical crushing of some clasts between larger clasts. Mechanical crushing to produce fines in the range of the grains seen in the megaripples appears to be extremely unlikely. Some trapping of fines may occur because the bedforms are loosely packed. However, if one assumes that the 0.25 mm grains (the smallest grains in great abundance) control the size of interstices between

☞

grains, the largest space between grains would be about 0.100 mm with cubic packing and 0.039 mm for close rhombohedral packing (derived from formulae in Pettijohn, 1957). Under rhombohedral packing, void fillers could be between 0.104 and 0.056 mm in size, but the void-filling grains could not filter between grains. In any case, smaller grains should be favored over larger grains in an entrapment process, and such definite peaks at about 0.063 mm should not be expected. Therefore, some sorting process of fine sand along the bed must be taking place. The mechanism appears to take place during mobile conditions rather than after movement of all coarse grains has ceased because some subpavement samples exhibit secondary peaks. Fine grains may be sorted into secondary peaks by reverse flow up the slip face, but this mechanism would not explain secondary peaks in armor. The small modes of fine sand in armor suggest that secondary currents sort fine sand moving between larger grains, but the nature of the sorting processes producing secondary peaks of sand remains to be examined further.

The downstream trends in grain-size distributions from analogous portions of megaripples along such a relatively short reach are difficult to explain, but may be considered in terms of 1) changes in flow conditions, 2) pulses of sediment, and 3) relative mobility of grains. The actual explanation may be a combination of these factors. Deposition (and erosion) at each point along each megaripple/trough must be controlled by local flow conditions and availability of grains. The sampled reach is only a small portion of the conveyance channel containing megaripples. No obvious changes in channel geometry or size of bedforms occur along the reach, so changes in average flow conditions along the reach appear to be unlikely causes of changes in sediment sorting. However, the reach is in a gently curving portion of the channel (Fig. 2) and flow could change along the curve. Possibly the waning stages of deposition changed progressively downstream so that deposition, particularly along slip faces, continued downstream after it had ceased upstream.

The uniformity or periodicity of sediment transport cannot be assessed without measurements of flow and sediment discharge during formation of the megaripples. Different pulses of grains may have reached different portions of megaripples at different times during deposition, providing more coarse grains to upstream megaripples than to downstream megaripples, or providing more grains in the range of 0.85–8 mm to downstream troughs after passing upstream bedforms.

The trough farthest downstream contains all but the coarsest clasts, so most sizes of grains have been transported through the reach. The largest grains must be less mobile than smaller grains so that movement of large grains from trough to trough is slowed. Therefore, upstream troughs should have more large clasts than downstream troughs, until large clasts have migrated throughout the reach to achieve equal rates of movement from bedform to bedform. The possibility of larger-scale periodicity in deposition along the conveyance channel cannot be evaluated.

Conclusions

In gravelly megaripples along the conveyance channel of the Rio Grande, grain-size distributions and some of their derivative parameters can be used to locate samples within a longitudinal sequence of bedforms. Each part of a megaripple (crest, interior, upper slip face, lower slip face, or trough) has a diagnostic grain-size distribution. Distributions from each portion of megaripples change slightly downstream so that locating a sample within a train of megaripples is possible. Along a reach of only 10 megaripples, the crests, lower slip faces, and troughs of upstream megaripples are coarser than their downstream counterparts. Similarly, the crossover points between grain-size curves of crests and troughs shift to finer sizes downstream. Although the mass percent of all clasts larger than 0.6 mm in troughs shows no significant trends downstream, the mass percent of clasts larger than 2 mm does decrease downstream. In lower slip faces, the mass of clasts larger than 0.6 mm decreases downstream.

Sorting mechanisms that produce different grain-size distributions along megaripples apparently are related to mobile-bed formation of armor along troughs, stoss sides, and crests and to flow separation, avalanching, and reverse flow along slip faces. Suspension of fines less than 0.25 mm appears to take place from troughs to crests of megaripples. Fine sand is also sorted into secondary modes that may indicate the presence of secondary currents between larger gravel clasts. The reasons for trends in distributions downstream over a distance of only 30 m may include changes in flow conditions, pulses of sediment, and/or relative mobility of the largest grains.

The grain-size distributions illustrated above show the importance of knowing the location of samples with respect to bedforms. Only the grain-size distributions of the lower slip faces appear to have relatively simple probability distributions. The variation in grain-size distributions along bedforms demonstrates that many fundamentally different distributions occur in fluvial deposits.

The technique of relating grain-size distributions to location within bedforms suggests several potential directions for further study. Where grain-size data are gathered from different bedforms formed under known flow conditions, it may be possible to relate the distributions to flow conditions more quantitatively. Alternatively, more data may demonstrate that several sets of flow conditions can produce similar distributions or that one set of flow conditions can produce dissimilar distributions. If quantification of flow conditions is possible using grain-size distributions from similar bedforms, it also may be possible to determine what entire bedforms were like from the portions that are preserved in geologic sections as well as their relative longitudinal position within a progression of bedforms.

ACKNOWLEDGMENTS—We are grateful to the New Mexico Bureau of Mines and Mineral Resources for supporting this study. We thank Ron Broadhead, John MacMillan, and Steve Cather for their helpful comments and criticisms. We thank Cherie Pelletier for drafting the figures. We are especially thankful to Deb Shaw for editing and reducing the length of the manuscript, and for helping to produce the figures.

References

Allen, J. R. L., 1982, Computational models for dune time-lag—calculations using Stein's rule for dune height: Sedimentary Geology, v. 20, pp. 165–216.

Allen, J. R. L., 1983, Gravel overpassing on humpback bars supplied with mixed sediment—examples from the lower Old Red Sandstone, south Britain: Sedimentology, v. 30, pp. 285–294.

Andrews, E. D., 1983, Entrainment of gravel from naturally sorted river-bed material: Geological Society of America, Bulletin, v. 94, pp. 1225–1231.

Bagnold, R. A., 1941, The physics of blown sand and desert dunes: Methuen, London, 265 pp.

Bridge, J. S., 1981, Hydraulic interpretation of grain-size distributions using a physical model for bedload transport: Journal of Sedimentary Petrology, v. 51, pp. 1109–1124.

Everts, C. H., 1973, Particle overpassing on a flat granular boundary: American Society of Civil Engineers, Proceedings, Journal of the Waterways, Harbors, and Coastal Engineering Division, v. 99, no. WW4, Paper 10125, pp. 425–438.

Jopling, A. V., 1963, Hydraulic studies on the origin of bedding: Sedimentology, v. 2, pp. 115–121.

Jopling, A. V., 1964, Laboratory study of sorting processes related to flow separation: Journal of Geophysical Research, v. 16, pp. 3403–3418.

Parker, G., and Klingeman, P. C., 1982, On why gravel bed streams are paved: Water Resources Research, v. 18, pp. 1409–1423.

Pettijohn, F. J., 1957, Sedimentary rocks: Harper and Row, New York, 718 pp.

Reineck, H. E., and Singh, I. B., 1980, Depositional sedimentary environments: Springer-Verlag, New York, 549 pp.

Williams, G. P., 1978, Bank-full discharge of rivers: Water Resources Research, v. 14, pp. 1141–1154. □

Richard H. Jahns fellowship in field geology at Stanford

Richard H. Jahns was Professor of Geology and Dean (1965–79) and Professor of Geology and Applied Earth Sciences (from 1979 until his death in December 1983) at Stanford University. Gifts received in his name will be placed in the Richard H. Jahns Fellowship in Field Geology fund and will always be so designated. The fund income, but no part of the principal or any appreciation in it, will be used for graduate fellowships to support earth-science research that involves substantial observation and mapping of geologic relationships in the field. Fellowships from the fund will only be awarded to students who have completed their basic graduate coursework and who have proposed a detailed research project; fellowships will be restricted further to students who bear substantial, independent responsibility for the conception and conduct of their research and priority will be given to doctoral candidates. Fellowships from the fund will be awarded by the Dean of the Earth Sciences School in amounts reasonably necessary for completion of the supported research.