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FIGS. 1-3, JUNE, 1962

RELATION OF TEXTURAL (CM) PATTERNS TO DEPOSITIONAL ENVIRONMENT OF ALLUVIAL-FAN DEPOSITS[1,2]

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ABSTRACT

Logarithmic plots of the coarsest 1-percentile grain size (C) and the median grain size (M) of alluvial-fan deposits make distinctive patterns for samples from western Fresno County, Calif. The CM pattern for the tractive-current sediments parallels the limiting line C = M and swings upward where C is about 1500 microns. The mudflow CM pattern is rectilinear and approximately parallels the line C = M. C is about 40 to 80 times M along the axis of the mudflow pattern.

INTRODUCTION

Logarithmic plots of the coarsest 1-percentile grain size (C), and the median grain size (M) of deposits may make patterns characteristic of distinct sedimentary environments, according to Passega (1957). If this is true, the depositional environments of older deposits may be determined partly by CM patterns. The purpose of this article is to show that distinctive CM patterns exist for different types of deposition on alluvial fans.

After the winter rainy seasons of 1956–57 and 1957–58, samples were collected from deposits on 11 alluvial fans in western Fresno County, Calif. Figure 1 shows the outlines of larger alluvial fans and drainage basins of the area studied. The samples were from water-laid (tractive-current) sediments, mudflow deposits, and deposits having properties intermediate between these two. CM patterns for these surface samples were plotted from data obtained from 102 grain-size analyses made by the author.

Core-hole samples were collected from two alluvial fans in western Fresno County by the California Department of Water Resources. Grain-size analyses of these samples were made by the U. S. Geological Survey's Hydrologic Laboratory at Denver, Colo. The CM patterns of the core-hole samples also show a variety of depositional environments.

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[2] Publication authorized by the Director, U. S. Geological Survey. Prepared in cooperation with the California Department of Water Resources.

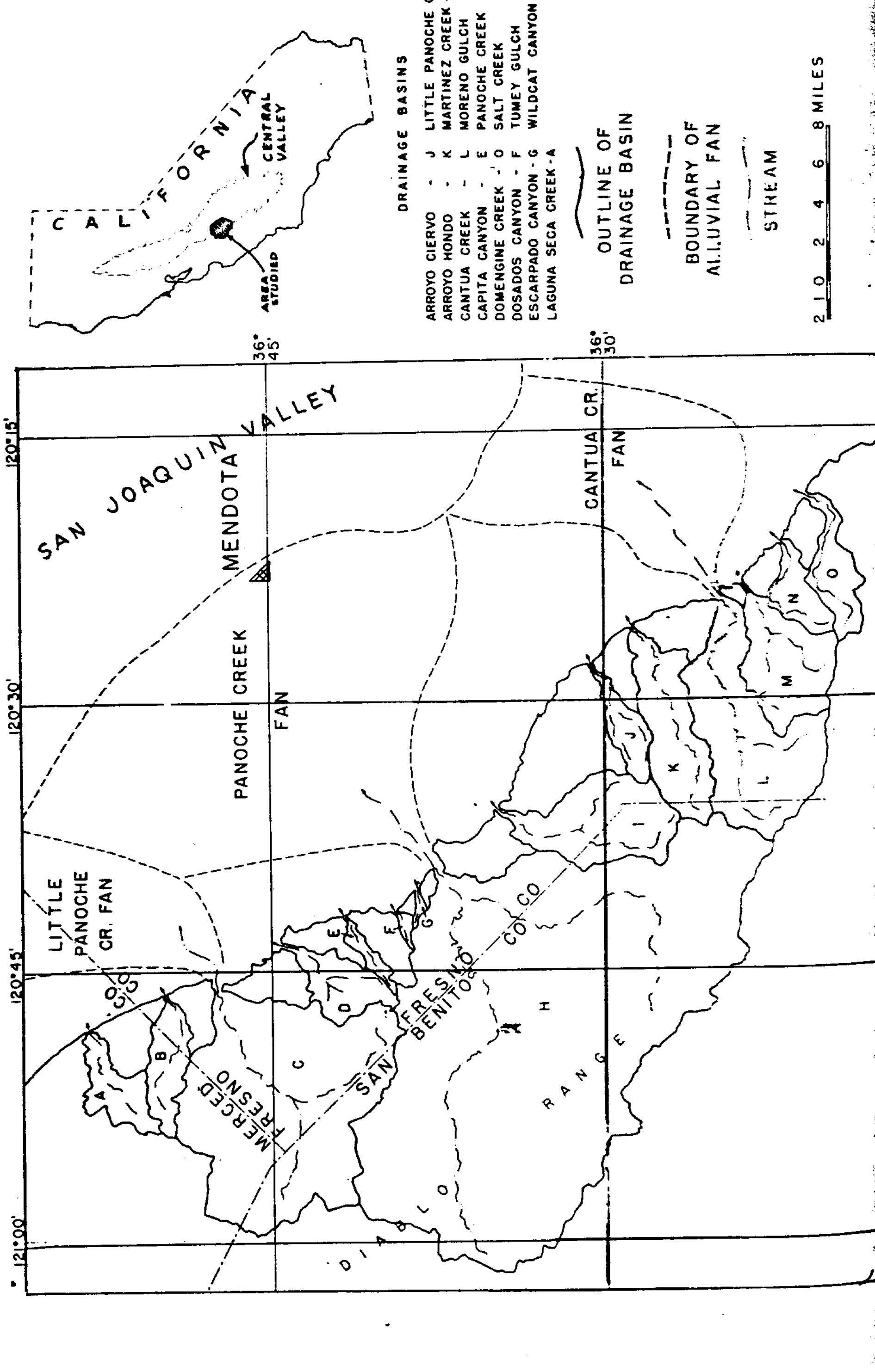
The surface and core-hole samples are believed to be representative of alluvial-fan deposits in western Fresno County and include all known types of alluvial-fan deposition in the area.

The east flank of the Diablo Range consists chiefly of a thick sequence of marine sedimentary rocks dipping toward the San Joaquin Valley (fig. 1). The deformed and slightly metamorphosed shales and graywackes of the Franciscan Formation (Jurassic to Late Cretaceous) comprise the core of the range. Cretaceous mudstone, shale, and sandstone form most of the marine section, and in several places the Cretaceous rocks are more than 20,000 feet thick. Tertiary marine and continental sediments are found mainly in the foothills of the Diablo Range.

The average annual rainfall is 8 to 20 inches for the Diablo Range, and $6\frac{1}{2}$ to 8 inches for the San Joaquin Valley. Daily amounts of rainfall of 3 to 4 inches have been recorded in both the mountains and the San Joaquin Valley.

The vegetative density of most drainage basins is sparse. Hoop tests and estimates indicate that the Arroyo Ciervo basin has an estimated vegetative density of 350 pounds per acre. Other basins such as that of Martinez Creek have much higher vegetative densities caused by stands of shrubs and trees at the higher altitudes.

The streams may be classed as intermittent or ephemeral. The streams in the area studied do not receive enough water from underground sources such as springs and bank storage to sustain a continuous flow from source to mouth during the dry


CALIFORNIA
CENTRAL VALLEY
AREA STUDIED
DRAINAGE BASINS
ARROYO CIERVO - J
ARROYO HONDO - K
CANTUA CREEK - L
CAPITA CANYON - E
DOMENGINE CREEK - O
DOSADOS CANYON - F
ESCARPADO CANYON - G
LAGUNA SECA CREEK - A
LITTLE PANOCHE CREEK - C
MARTINEZ CREEK - N
MORENO GULCH - D
PANOCHE CREEK - H
SALT CREEK - M
TUMEY GULCH - I
WILDCAT CANYON - B
OUTLINE OF DRAINAGE BASIN
BOUNDARY OF ALLUVIAL FAN
STREAM
2 1 0 2 4 6 8 MILES
SAN JOAQUIN VALLEY
MENDOTA
PANOCHE CREEK FAN
CANTUA CR. FAN
LITTLE PANOCHE CR. FAN
MERCED
FRESNO
SAN BENITO
DIABLO RANGE
36° 45'
36° 30'
120°15'
120°30'
120°45'
121°00'

season; consequently, there are no perennial streams. Little Panoche, Panoche, and Cantua Creeks are intermittent streams which receive enough ground water to flow along their entire lengths for a few weeks after most winter rainy seasons. The channels of ephemeral streams such as Arroyo Ciervo and Martinez Creek are always above the water table; therefore, the ephemeral streams flow only in direct response to rainfall.

The ephemeral streams usually have a flash-flood type of flow. The type of flow is controlled by the areal distribution, intensity, and duration of rainfall, and by the vegetative cover, lithology, and slopes of the drainage basin. The resulting flow may range from clear water to viscous mud.

This paper has been prepared from elements of an investigation of deposits susceptible to near-surface subsidence made between 1957 and 1960 by the Ground Water Branch of the U. S. Geological Survey in cooperation with the California Department of Water Resources. The author wishes to thank Dr. George A. Thompson of Stanford University for critically reviewing the article.

GENERAL FEATURES OF A CM PATTERN

Passega (1957) has used two parameters obtained from grain-size distribution curves that he states will produce patterns characteristic of the agent of deposition when plotted on logarithmic graph paper. The parameters are the coarsest 1-percentile grain size (C) and the median grain size (M). He has obtained patterns for deposits of tractive currents, quiet water, beaches, and turbidity currents. C for these materials usually is approximate because of the gentle slope of the cumulative curve in that part of most grain-size graphs. These parameters were selected because the coarse fraction of a sediment is supposed to be more representative of the depositional agent than the fine fraction (Passega, p. 1953). C indicates the upper limit of competence (for the samples analyzed) of a depositional agent, provided that a full range of sizes was available for transport.

Figure 2 shows CM patterns of surface samples of alluvial-fan deposits in western Fresno County. The plot is on logarithmic paper and shows that all the points are scattered to the left of the line C = M. The sorting of a sample between the 50th and the 99th percentile partly determines its plotted position. Thus a sample plotting on the line C = M would be perfectly sorted in its coarser half, but a sample plotting to the left of the line C = M would be characterized by poorer sorting in this size range.

CM PATTERNS OF SURFICIAL ALLUVIAL-FAN DEPOSITS

Two CM patterns are shown in figure 2. A tractive-current pattern is represented by the letters PQRS, which are the letters used by Passega to describe the segments of the pattern. The RS segment apparently does not exist for alluvial-fan sediments and is shown by a dashed line, so that the reader can compare a complete tractive-current pattern with Passega's type example (p. 1954) for the Mississippi River, which was based on data from the U. S. Waterways Experiment Station at Vicksburg, Miss. In Passega's type example, the segments of the CM pattern corresponded with three divisions of the channel. The plot of samples from the main section of the channel were in the segment between P and Q, and the segment between Q and R represented samples from a submerged bank or bar. Samples from a deep, protected part of the channel were represented between R and S.

Thus, the pattern for tractive-current deposits actually consists of three variations of one type of deposition. This relationship is shown by the way the samples from the three sedimentary environments of the Mississippi River channel correspond with the three segments of Passega's CM pattern. PQ represents the coarsest bed material, and a lower limit of 600 microns for C indicated to Passega that particles larger than 600 microns were moved predominantly by traction. In Passega's Mississippi River pattern, QR was parallel to the limit C = M between 350 and 600 microns. Deposits of this segment were probably in suspension part of the time, and sedimentation of the coarser grain sizes produced well-sorted sediments. Passega stated that the RS segment is controlled by bed samples from a deep, protected section of the river channel. The segment parallels the line C = 200 microns,

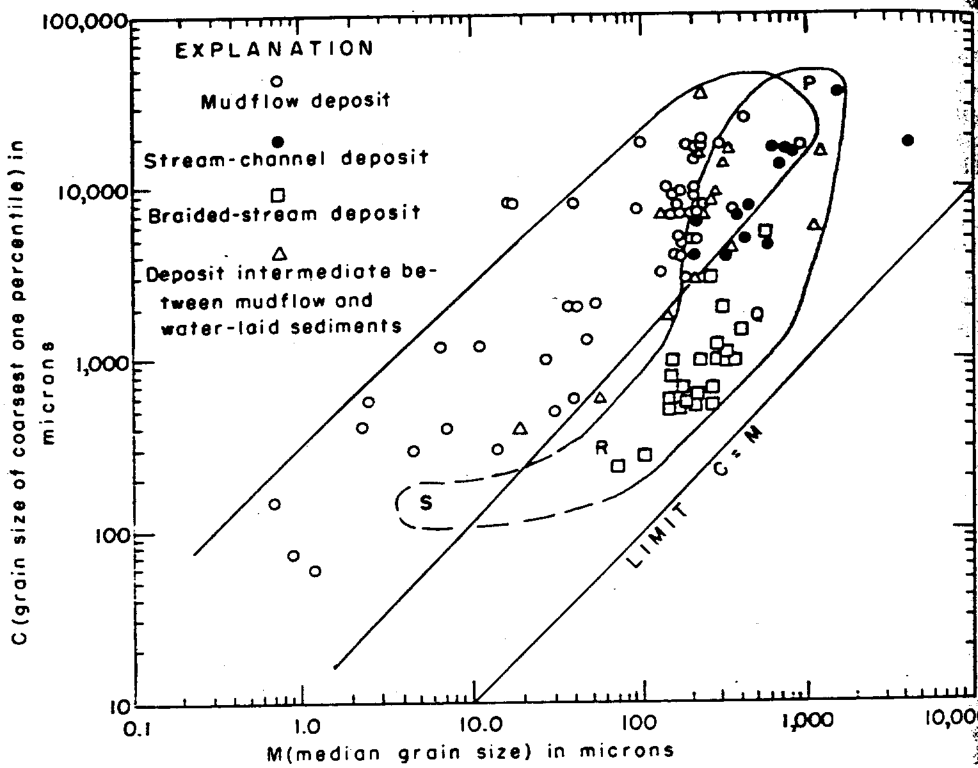


FIG. 2.—CM patterns of surficial alluvial-fan deposits in western Fresno County, California.

which fact, according to Passega, indicates that the Mississippi River is always turbulent enough to carry particles of that size in suspension. Not all tractive-current deposits will show the three segments of the Mississippi River pattern, and Passega's tractive-current patterns from other rivers, bays, and tidal flats commonly have only 2 of the 3 segments. Any segment can be missing.

Two of the three segments of Passega's tractive-current pattern are present in figure 2, but the segment representing the deep protected channel (RS) is not present, suggesting that this type of deposition is not characteristic of alluvial-fan deposits. The stream-channel deposits analyzed are represented in the PQ segment, and the lower limit of 1500 microns for C in this segment may indicate that particles larger than 1500 microns are transported predominantly by traction. The points included within the QR segment represent samples from deposits of shallow braided streams or sheets of water and from sandbars adjacent to the main pa[rt] of a larger stream channel. The segment [is] roughly parallel to the limit C = M, there[-] fore, C is roughly proportional to M. Sed[i-] mentation is mainly from the coarser size[s] and the finer material is carried on down th[e] slope. Thus, C approaches M, and the sedi[-] ments are well sorted.

Some of the water-laid sediments are [a]s well sorted as beach sand. One sand has [a] Trask sorting coefficient (So) of 1.1, a ph[i] standard deviation (σ_ϕ) of 0.48, and a ph[i] quartile deviation (QD_ϕ) of 0.15.

The long rectilinear pattern in figure [2] also is nearly parallel to the limit C = M, bu[t] the axis of the pattern is a considerab[le] distance from the limiting line. The samp[le] points within this pattern represent th[e] poorly sorted mudflow deposits. Most of th[e] particles are carried in suspension, and [a] decrease in velocity and depth of flow ten[ds] to drop some of the coarser material alo[ng] with some of the matrix. The smaller C a[nd]

M values probably represent deposition by more fluid mudflows at a lower velocity than that at which the coarser material is deposited.

The mudflow deposits shown in figure 2 have the following range of sorting: Trask sorting coefficient, 5.0–25: phi standard deviation, 4.1–6.2; and phi quartile deviation, 2.3–4.7. The phi standard deviation could be obtained only for 27 samples: for the other 23 samples the data for the fraction finer than 1 micron is insufficient to determine the sorting.

The CM pattern for the mudflow deposits is of the same type that Passega shows for turbidity currents, which fact may indicate that mudflows are somewhat comparable to dense turbidity currents with respect to their mechanics of deposition. The chief difference between mudflows and most turbidity currents appears to be the density of the currents and the sorting of the deposits. Passega mentions that C for points along the axes of his turbidity-current patterns is 2.3 to 4.2 times M. C for points along the axis of the mudflow CM pattern ranges from about 40 to 80 times M. This poorer sorting probably shows that the mudflows had a much higher density than did the turbidity currents of deposits studied by Passega, or that the mudflows had a greater variety of grain sizes in their source material. The density and sorting of turbidity currents that are more viscous than those of deposits studied by Passega should be similar to some mudflows.

The upper ends of both patterns indicate the approximate maximum competence of the transporting agents for the samples analyzed. Obviously, the degree of competence would be represented better if the samples had contained cobbles or boulders, but the source areas of most fans supply very little material larger than fine gravel. Although some deposits contained cobbles and boulders it was impractical to collect representative samples of these deposits.

The deposits of mudflows and tractive currents studied by the author provide two patterns that illustrate a strong contrast in the types of alluvial-fan deposition. The points representing deposits intermediate between mudflows and water-laid sediments also are plotted in figure 2. As could be expected, the points representing these intermediate deposits fall partly within the patterns for mudflows and water-laid sediments and partly in the area between the patterns.

CM PATTERNS OF ALLUVIAL-FAN DEPOSITS FROM CORE HOLES

The points in figure 2 make distinct patterns only if the depositional environments are differentiated. The scatter of points is due to (1) the complete range of depositional types from water-laid sediments to mudflows and (2) the fact that the samples are from 11 different fans as much as 40 miles apart.

Figure 3 shows CM patterns for core-hole samples from two fans in western Fresno County. The samples should reflect the drainage-basin characteristics and the modes of deposition of each fan.

Ten samples from a 70-foot core hole in the Martinez Creek fan are represented by the points within pattern T in figure 3. Most of the samples are moderately well sorted and form a pattern suggestive of deposition by tractive currents. Again the

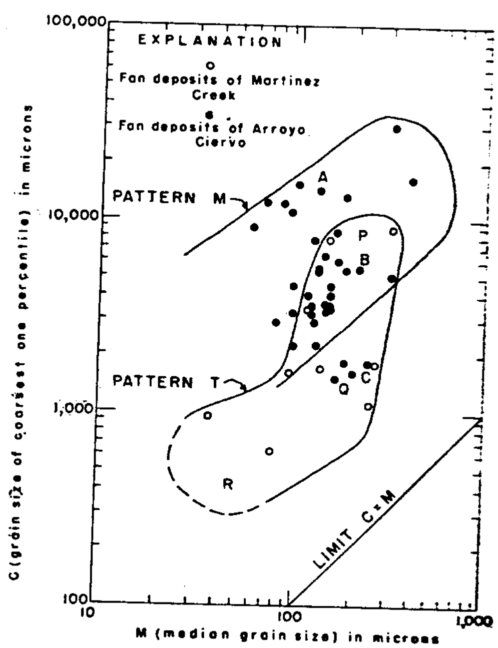


FIG. 3.—CM patterns of alluvial-fan deposits from core holes.

RS segment of Passega's tractive-current pattern is not present.

Forty samples from five core holes in the Arroyo Ciervo fan are represented by the points within pattern M in figure 3. The wide range of sorting between the 50th and the 99th percentile suggests that a mixed depositional environment may be represented. Most of the points are included in the rectilinear mudflow-type pattern.

Points in the vicinity of A probably indicate mudflow deposits, and the four points near C may represent water-laid sediments. The points in the vicinity of B probably represent deposits that are intermediate between mudflows and water-laid sediments. C is about 45 times M at points along the axis of the "mudflow" pattern.

SUMMARY

The parameters C and M from 102 grain-size analyses of samples from surficial alluvial-fan deposits in western Fresno County plot as distinct patterns on logarithmic paper. The tractive-current pattern has a steam-channel deposit segment, PQ, and a braided-stream deposit segment, QR, but the RS segment, or protected-channel deposits of Passega, is not represented by alluvial-fan deposits. The rectilinear mudflow pattern is similar to the turbidity-current patterns of Passega, but the axis is much farther away from the line C = M than the axes of Passega's turbidity-current patterns, suggesting that mudflows are denser and more poorly sorted than the turbidity currents of deposits studied by Passega. The CM pattern for the Martinez fan core-hole samples indicates deposition by tractive currents. The pattern for the Arroyo Ciervo fan core-hole samples suggests a variety of depositional environments that are dominated by a rectilinear pattern suggestive of mudflow deposition.

REFERENCE

Passega, R., 1957, Texture as characteristic of clastic deposition: Am. Assoc. Petroleum Geologists Bull., v. 41, p. 1952–1984.