COMPETENCE OF A GLACIAL STREAM

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Short List of Illustrations

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ABSTRACT

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Measurements of particle size and velocity were made in White River below Emmons Glacier, Mt. Rainier, Washington. Boulders up to 1.8 feet in diameter were moved by velocities of 10 fps, less than would be predicted from the sixth power law.

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Size measurements of boulders in transport and measurement of associated velocity were made in White River below the Emmons Glacier, Mount Rainier, Washington, as a part of a study of the processes of valley train formation (Fahnestock, 1960) These measurements provide excellent data for the study of competence because, in White River, all sizes at or near the range of competence are readily available for transport.

Usually the size measurements were made of boulders that were trapped in a wooden-framed sieve with 0.175 foot openings as they moved along the bed. However, some of the largest boulders were caught by hand and rolled onto bars for measurement because they could not be lifted from the water. Most point velocities were determined from about 20-second measurements with a Price Type-A current meter set at 0.6 depth. Because of the size of the particles, this depth setting provided velocity measurements in the immediate vicinity of the moving particles. Surface float velocities adjusted to 0.6 depth were used when current-meter measurements of velocity could not be made. Velocity measurements were made in the reach through which the boulders had been transported.

The graph of particle size and velocity (figure 1) indicates that

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Figure 1. Relation Between Particle Size and Velocity

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the boulders from White River were moving at lower stream velocities than would be predicted from the other data cited. White River data show that boulders up to 1.8 ft in intermediate diameter moved in currents of about 10 fps. For comparison, data that Nevin (1946) selected from Gilbert (1914), the U.S. Waterways Experiment Station (1935), Rubey (1937) and his own traction-tube experiments have been used to define bed velocity and critical traction velocity lines shown in figure 1. Projections of these lines intersect at a velocity of about 10 fps and a particle diameter of about 1 foot. These lines approach each other as the particle size increases and it appears from White River data that for coarse materials the critical traction velocity (velocity measured near the bed or mean velocity in shallow flow, Nevin, p. 665) is closer to the effective velocity than the bed velocity computed with Rubey's formula. The projection of the bed velocity curve is based on the assumption that the size of particles in motion is a function of the square of the effective velocity.

Parts of Hjulstrom's curves (1935, p. 298) which separate the zones of erosion, transportation, and deposition are also shown in figure 1. Data on boulders, in motion, in White River plot in the zone of deposition that is defined by projections of the four curves. However, these curves were based on average velocity and uniform materials.

Hjulstrom's curves, based on Schaffernak's data (1922, p. 14) for uniform materials from 8-70 mm, indicates that size is proportional to the 2.6 power of velocity, which also was the power found by Nevin (1946) using average velocity. Such a line (slope of 2.6) fits the White River data better than one with a slope of 2.0 (the "sixth power law" expressed in terms of linear dimensions). Thus, it is suggested that for materials having intermediate diameters larger than 0.1 foot, streams may have greater competence than some applications of the "sixth power law" would predict.

Most experiments related to erosion and traction velocities have been made in laboratory flumes with uniform materials less than 0.1 foot in diameter; in most cases, in the sand range. The few experiments which have been made with mixed grain sizes show that the mobility of such materials is quite different from that of uniform materials. Gilbert (1914, p. 173) stated:

> "...when such hollows are partly filled by the smaller grains its (the coarser particle's) position is higher and it can withstand less force of current. In other words the larger particles are moved more readily on the smoother bed...The promotion of mobility applies not only to the starting of the grain but to its continuance in motion."

Ippen and Verma (1953) noted a similar effect of bed roughness. Thus because of the large range of particle sizes in the bed and banks of White River channels, the erosion and movement of particles larger than those predicted by formulas based on data for uniform materials can be expected. On the valley train, boulders of all sizes are readily available for movement by any current capable of eroding the finer supporting materials. Boulders on the bed were often set in motion by the blows from other boulders loosened from the banks. Finer materials may be scoured from under boulders setting them in motion. Boulders which are not moved from the bed on one day tumble into the flow from the cut bank of the next day's channel as a result of the rapid cutting and filling that takes place in White River channels.

Studies by White (1940) and Kalinske (1942) emphasized the importance of turbulence in initiation of motion of particles on the bed of natural streams. White (1940, p. 332) stated:

> "If the turbulence extends up to and into the walls, then a speed variation of 2 to 1 implies a stress variation of 4 to 1, and the maximum drag is four times the mean."

Thus, the higher the turbulence the more effective a given mean velocity. White River's high turbulence favors high competence.

In conclusion, boulders up to 1.8 feet in diameter were moved in flows of 10 fps, or less. The movement of these boulders by White River is favored by the large range of particle sizes in the bed and banks and the high turbulence of the flow, as well as the high velocities.

For materials having intermediate diameters larger than 0.1 feet, streams may have more competence than predicted by the "sixth power law."

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