SPECIFIC GRAVITY CHARACTERISTICS OF RECENT VOLCANICLASTIC SEDIMENT: IMPLICATIONS FOR SORTING AND GRAIN SIZE ANALYSIS

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ABSTRACT

Specific gravity of water-saturated, surface-dried individual grains and bulk, sieved samples of pumice lapilli, ash, and slightly vesiculated rock fragments produced by recent eruptions at Mount St. Helens, Washington, as well as the composition of sediment derived from this material, indicate two major departures in the character of volcaniclastics from more familiar quartzo-feldspathic sediment. These are: (1) a three-to-five-fold variation in the specific gravity of volumetrically important detrital grains, as opposed to a less than 5% variation in 99% of the volume of average quartzo-feldspathic sandstone; and (2) significant variation in specific gravity that is inversely related to grain size within clast populations of the same composition. This latter observation is attributed to the larger volume of vesicles, particularly non-interconnected vesicles, with increasing grain size. Sorting in volcaniclastic sediment, therefore, is not only a function of depositional process, environment, and post-depositional modification but also of sediment composition. Statistical analysis of sieve grain size data on weight-percent basis is inappropriate for evaluation of volcaniclastic sediments.

INTRODUCTION

The purpose of this paper is to evaluate the specific gravity characteristics of water-laid volcaniclastic sediment. The range of specific gravity exhibited in a sediment sample influences hydrodynamic evaluation of its grain-size distribution. Interpretation of the statistical measures obtained from sieve grain-size data (Folk 1968), particularly sorting, is based on study of quartzo-feldspathic sediment in which, on average, more than 99% of the sediment exhibits less than a 5% variation in specific gravity (Blatt et al. 1980). The presence of vesiculated fragments in volcaniclastic sediments introduces a low-density population whose influence on sorting is familiar, qualitatively, to anyone who has observed sediment composed of pumice lapilli and dense lithics or crystals.

Because the average sandstone is composed of grains with nearly equitable specific gravity, the degree of sorting is interpreted typically only in terms of depositional process and environment and post-depositional modifications. For instance, poorly sorted sediments are generally interpreted to be the result of rapid deposition of a wide range of grain sizes with limited reworking, infiltration of small grains into interstices between larger grains, mixing by bioturbation, or diagenetic production of clay-size matrix around framework grains.

Modern sediments surrounding presently active Mount St. Helens, Washington and Neogene, nonmarine volcaniclastic rocks adjacent to the Cascade Range in Oregon and Washington are commonly poorly to very poorly sorted. In part, the poor sorting reflects rapid deposition of sediment during floods as indicated by bed thickness, sedimentary structures (Smith and Smith 1983) and, in some cases at Mount St. Helens, observation of the sedimentation event (Dinehart in press, Pierson and Scott in press). But it is to be expected that sorting parameters also reflect the mixing of sediment having variable specific gravity: e.g., pumice, vesiculated and non-vesiculated volcanic lithic fragments, feldspar and quartz, and heavy minerals.

This paper attempts to quantify the differences in specific gravity between volcaniclastic and quartzo-feldspathic sediment and to evaluate an interpretation of volcaniclastic sediment texture made using the methodology standardly applied to quartzo-feldspathic material.
SETTING AND DESCRIPTION OF SEDIMENTS

The 1980 explosive eruptions of Mount St. Helens, Washington, blanketed several drainage basins over a 600 km² area with three types of fragmental material. These are: (1) porphyritic ash and pumice lapilli from Plinian eruption plumes; (2) porphyritic, dense to vesiculated, “blast dacite” rock fragments, texturally gradational to the pumice lapilli, that represent a recently solidified intrusion disrupted by the phreatic-magmatic lateral blast of May 18 (Hoblitt et al. 1981); and (3) crystals of plagioclase, pyroxene, hornblende, and magnetite ejected as Plinian tephra derived from explosive fragmentation of the dacite intrusion or liberated from the pumice lapilli and blast dacite by water-transport abrasion.

Within the area devastated by the lateral blast, hillslope erosion has produced alluviation of adjacent stream valleys by sediment composed of these three juvenile components mixed with varying proportions of Tertiary bedrock clasts (Smith 1984). Pumice and blast dacite are present in about equal abundance, plagioclase and minor quartz represent up to 25%, and heavy minerals (pyroxene, hornblende, magnetite) up to 15% of the size fraction 1/16 mm to 16 mm (J. Carpenter, unpub. data). Sieve analysis and modal analysis of grain mounts show that the overall sediment composition and texture surrounding Mount St. Helens is similar to that observed in Neogene volcaniclastic sedimentary rocks throughout the Pacific Northwest (J. Carpenter and G. Smith unpub. data).

METHODS

An essential assumption in sieve analysis, because weight not volume is measured, is that the sediment is of uniform specific gravity. Thus the influence of specific gravity on the statistical measures of the grain size distribution cannot be evaluated from sieve analysis data, but it may be considerable if the sediment is composed of particles with a wide range in density.

Samples of pumice lapilli and blast dacite grains were collected within the lateral blast zone near Mount St. Helens and hand-seived to minimize abrasion to pumice, at 1 phi size intervals (phi = −log₂d, d = grain diameter). Specific gravity characteristics were measured utilizing ASTM D854-58 Standard Test Method for Specific Gravity of Soils (ASTM 1983, p. 212−214). These data were used to evaluate the grain size characteristics of sediments exhibiting traction-produced sedimentary structures; therefore grains were saturated with water at one atmosphere pressure to fill interconnected vesicles with water, thus simulating the assumed density of the grains during bedload transport. Pumice lapilli that continued to float after a two-week period were not considered. Surface water was blotted from the samples during their rapid transfer from the water-filled storage containers to the water-filled volumetric flask used for specific gravity determination. Mean specific gravity was measured for bulk samples of pumice lapilli, ash, and blast dacite at 1 phi size intervals and for individual pumice lapilli with a nominal diameter (Wadell 1932) larger than 5 mm. Determinations were reproducible to within 5%.

RESULTS

Specific gravity of individual water-saturated, surface-dried pumice lapilli with nominal diameters between 5 mm and 17 mm varied widely from just above 1.00 to 1.95 (fig. 1). Measurement of bulk samples averaged the variation illustrated in figure 1 and allowed consideration of the average specific gravity of grains too small to accurately measure individually. An inverse relationship of grain size to mean specific gravity of bulk samples of pumice lapilli and ash is clearly represented in figure 2.

The specific gravity of bulk samples of blast dacite also exhibit a general inverse re-

![Graph](https://via.placeholder.com/150)
GEOLOGICAL NOTES

2.00 -

r = -0.92
p = < 0.01

1.75

1.50

1.25 -

1.00

I

I

I

I

I

<1

0

-1

-2

-3

-4

SIEVE DIAMETER (PHI)

FIG. 2.—Plot of bulk specific gravity versus sieve diameter of Mount St. Helens pumice lapilli and ash sieve fractions: r = correlation coefficient; p = probability value of significance test.

1.00

2.00

2.50

3.00

3.50

4.00

SIEVE DIAMETER (PHI)

FIG. 3.—Plot of bulk specific gravity versus sieve diameter of Mount St. Helens blast dacite sieve fractions: r and p as in figure 2.

The specific gravity characteristics of volcaniclastic sediment depart in two fundamental ways from those of quartzo-feldspathic sediment. First, and not unexpected, the density of different clast types is highly variable. Unlike quartzo-feldspathic sediments, where virtually all grains are within the narrow specific gravity range 2.55-2.65 with less than 1% heavy minerals, the volcaniclastic sediments studied here contain volumetrically important constituents in several specific gravity ranges: 1.00-2.00 (pumice and ash), 2.20-2.40 (blast dacite), 2.53-2.65 (plagioclase and quartz, Hughes 1982), 3.20-3.40 (pyroxene and hornblende, Hughes 1982), and greater than 5.0 (magnetite, Hughes 1982). Second, there is a highly significant negative correlation of mean specific gravity with grain size within grain populations of the same composition. This is the most important difference in specific gravity characteristics of volcaniclastic material compared to quartzo-feldspathic sediment. The specific gravity of single-crystal detrital grains (e.g., quartz and feldspar) is an intrinsic property independent of the size of the grain.

The inverse relationship between mean specific gravity and grain size of pumice and dacitic rock fragments (figs. 2 and 3) is caused mainly by vesicles within the grains. Ash and pumice lapilli owe their size, shape, and specific gravity to the size and distribution of vesicles developed during explosive disruption of the parent magma. For vesicles of a given size the ratio of solid volume to vesicle space increases as grain size diminishes and contributes to the observed specific gravity variation. The specific gravity of the finest fraction probably best approximates the specific gravity of the erupted material without voids (Fisher 1965).

Intra-grain permeability is also a major factor determining specific gravity and may be more important than total porosity. When dry, Mount St. Helens pumice lapilli and ash were put into water-filled storage containers, grains less than 1 mm in diameter sank immediately, 1-4 mm grains sank within a few minutes, 4-8 mm grains within hours, and several grains over 8 mm in diameter did not sink in the two-week period allotted. Increased buoyancy with increasing grain size is probably a result of internal vesicles not filling with water because of impermeability. The larger the lapillus, the larger the volume of non-interconnected vesicles.

Variation in specific gravity for the blast dacite is also a function of vesicularity. The dacite fragments contain fewer vesicles than pumice lapilli, and they are rarely interconnected. Thus, most vesicles probably remained air-filled during this experiment.

Other than the general inverse relationship
between grain size and mean specific gravity, it is unlikely that a rigorous mathematical relationship can be defined to relate these two parameters by consideration of vesicle geometry. Figure 1 demonstrates that, even for a given grain size, specific gravity is variable. This probably reflects the variable nature of permeability, as defined by the proportion of interconnected vesicles and, perhaps to a lesser degree, variation in the type and proportion of phenocryst minerals in the pumice. The problem is further compounded by the variable degree of vesiculation and abundance of phenocrysts in ejecta from different eruptions, so that these Mount St. Helens data are only qualitatively applicable to other pyroclastic sediments.

CONCLUSIONS

Because of the variation in specific gravity of volcaniclastic sediments discussed above, statistical evaluation of sieve grain size data on a weight percent basis may not be meaningful. Settling tube techniques are also inappropriate because, even in the fine sand range, vesiculated ash behaves in a non-Stokian fashion as a result of buoyancy induced by air-filled vesicles (Fisher 1965).

The observations reported here indicate that sorting in volcaniclastic sediment is not only a function of depositional processes and post-depositional modification but also a function of particle properties. Not only should one expect a given pumice fragment to be in hydraulic equilibrium with lithic fragments and crystals of a smaller size, but also with other, smaller pumice grains. Because of the wide range in specific gravity exhibited by lithic and crystal populations in volcaniclastic sediment, the quality of sorting can be evaluated only after extensive study of the specific gravity of grains within the sediment sample being investigated. In evaluating ancient sediment this laborious task is made virtually impossible by the extensive diagenesis characteristic of volcaniclastic rocks, which alters the specific gravity characteristics of the grains, may preclude disaggregation, and often produces a clay-size matrix. Sorting alone, therefore, is not as useful a sedimentological tool as it is in quartzo-feldspathic sandstones, and textural evaluation of volcaniclastic sediment containing vesiculated material should not rely on the same principles and procedures that have been developed to describe quartzo-feldspathic sediments.

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