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TITLE: ORIGIN OF ACCRETIONARY LAPILLI FROM THE POMPEII AND AVELLINO DEPOSITS OF VESUVIUS

AUTHOR(S) M. F. Sheridan
K. H. Wohletz

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Los Alamos National Laboratory
Los Alamos, New Mexico 87545

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ORIGIN OF ACCRETIONARY LAPILLI FROM THE POMPEII AND AVELLINO DEPOSITS OF VESUVIUS

M.F. Sheridan and K.H. Wohletz

Accretionary lapilli from the Pompeii and Avellino Plinian ash deposits of Vesuvius consist of centimeter-sized spheroids composed of glass, crystal, and lithic fragments of submillimeter size. The typical structure of the lapilli consists of a central massive core surrounded by concentric layers of fine ash with concentrations of larger clasts and vesicles and a thin outer layer of dust. Clasts within the lapilli larger than 125 μm are extremely rare. The median grain-size of the fine ash is about 50 μm and the size-distribution is well sorted. Most constituent particles of accretionary lapilli display blocky shapes characteristic of grains produced by phreatomagmatic hydroexplosions.

Spheroids of accretionary ash have been long recognized in the geologic literature[1-3]. Modern references have noted their occurrence in ash-fall and base-surge deposits of

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M.F. Sheridan is at Arizona State University (Department of Geology), Tempe, AZ 85287; K.H. Wohletz is at Los Alamos National Laboratory (Earth and Space Science Division), Los Alamos, NM 87545.

phreatomagmatic origin.[4-6]. No recent detailed studies using modern techniques have been published on accretionary lapilli. We have used the scanning electron microscope (SEM) in conjunction with energy dispersive spectral analysis (EDS) to investigate the textural and chemical variation along traverses from the core to the rim of lapilli from Vesuvius.

Method

The accretionary lapilli were collected from hydromagmatic ash deposits produced by the last two major catastrophic eruptions of Vesuvius. Avellino (3,500 years b.p.) samples were taken from stratigraphic sections measured at Cave l'Amendolare, Ottaviano, Palmenetto, and Vallegrande. Pompeii (A.D. 79) samples came from sections at Pompeii-Castellemare and Oplontis. At all locations the accretionary lapilli were dispersed within the fine-ash of surge deposits that rest above thick (greater than 2 m) Plinian pumice-fall beds.

Photographs (~1000X magnification) were taken at discrete intervals from the core to the rim of epooxy-impregnated thin sections of the lapilli. Grain-size measurements were made directly from these photographs by visual inspection of approximately 1000 grains using a hand magnifier.

Bulk chemical analyses were made of 2700 μm^2 areas

(200 s count, 15 keV beam potential) at four selected intervals from the core to the rim. Spectra were quantitatively analysed using an internal standard with a ZAF correction routine (KEVEX). Precision was checked by repeated analysis of the same area as well as by changing the size of the analysed area.

Results

Accretionary lapilli from both the Avellino and Pompeii deposits have three distinct structural zones (Fig. 1): a massive (structureless) core (3 to 6 mm diameter) of fine ash, an intermediate zone with bands of bubbles and larger clasts, and a fine-grained rim (0.3 to 1.8 mm thick). Patches of bubbles (50 to 300 μm in diameter) occur in the cores of some lapilli as well as bands and patches between the cores and the rims. The distribution of larger clasts (greater than 50 μm in diameter) in the zone between the cores and the rims is either random or concentrated in one or two concentric bands. A matrix of fine dust (less than 1 μm in diameter) has an irregular distribution, but in some lapilli it occurs as distinct layers.

Only a small fraction of the clasts from the accretionary lapilli have vesicles: for Pompeii lapilli about 2% and for Avellino lapilli about 5%. Most clasts are blocky with delicate projections; many corners have acute angles (Fig. 2). The median grain size ranges from

3.7 to 5.4 ϕ (77 to 24 μm); the most common mode is about 45 μm. The sorting is good (σ_ϕ = 1.0). The size and shape of these grains are characteristic of pyroclasts produced by hydroexplosions[6,7].

Considerable chemical data exists for the ash deposits containing these lapilli. Major element analyses were made on bulk ash samples collected throughout the entire stratigraphic thickness (Plinian fall through overlying surge beds) of the Pompeii deposit[8]. In addition, pumice from the Avellino and Pompeii deposits as well as representative lavas of the post-caldera stage of Vesuvius have been analysed[9]. Thus the original magmatic composition is well known.

The fine-ash horizon above the pumice-fall bed of the Pompeii deposit has a significant change in composition[8] that reflects a general increase in contamination of the ash with carbonate xenolithic materials (Fig. 3). The general model for the Plinian eruptions of Vesuvius is based on the assumption that the carbonate walls of the magma chamber disintegrate allowing pulses of water to enter the chamber creating hydroexplosions[9,10]. The coupled wall-rock disintegration and water/magma interaction produces finer-grained products in an eruption plume that becomes progressively enriched in water (liquid and vapor) relative to magma. The compositions of analyzed pumice and lava give an approximation to that expected for uncontaminated ash. Fig. 3 shows a linear decrease of CaO and MgO when plotted against SiO_2 that reflects the contamination trend for the Pompeii deposit.

If simple mixing of pyroclasts with comminuted wall-rock were true for the accretionary lapilli, their analyses should plot on a line that parallels the slope of the Pompeii surge ash analyses. This trend is in fact true for the spot analyses of the Avellino and Pompeii accretionary lapilli. However, the analyses plot above the line defined by the surge samples (Fig. 3). In addition, spot analyses from the core to the rim of individual lapilli also define lines that are parallel to the general trend.

Conclusions and discussion

Several conclusions may be drawn from textural evidence. (1) The structureless cores of the lapilli accreted rapidly in a zone of the eruption plume that did not experience appreciable turbulence. (2) Grain-size layering in the intermediate zone suggests rotation of the lapilli during their accretion in a portion of the eruption cloud containing grains of variable size. (3) The outer rim of fine dust suggests final accretion in a relatively low-energy environment. (4) The dispersal of lapilli throughout the fine-grained surge deposit suggests that they fell into a laterally-moving surge cloud as discrete particles rather than as a pulsating rain that would have formed individual beds. (5) The unbroken spheroids show that they remained coherent during transport and deposition within the surge deposits of ash.

The bubbles provide evidence for local temperature and humidity conditions during growth of the lapilli. The presence of bubbles suggests either that water adhering to the particles was vaporized by the hot core or that the condensed water on the surface of lapilli was incorporated with a spherical shape due to surface tension. In either case, bubbles indicate that abundant water was present when the temperature in the cloud decreased below the vaporation point.

Chemical data provide additional constraints on the model of lapilli formation. (1) The chemical trend (CaO, MgO, and SiO_2) for the lapilli is parallel to that for the Plinian (lapilli-fall plus surge) deposit as a whole. (2) The accretionary laplilli analyses fall above those of the associated surge deposit. (3) The Avellino lapilli analyses plot in a higher position than do the Pompeii lapilli. (4) Generally the rims of the lapilli are enriched in carbonate (MgO and CaO) components. Sample 14, however, had the reverse trend. (5) The maximum amount of carbonate included is about 20 percent.

Model for Formation

The above data and conclusions are compatible with a model for formation of the lapilli by rapid accretion of the cores in a high-temperature (above 100° C) volcanic plume. This produced a massive core without bubbles. The core composition near that of the last-erupted magma is consistent with the hot central zone of the plume that is enriched in magmatic components and poorer in water vapor and xenolithic dust. As the lapilli move outward from the zone of laminar flowage in the central part of the erupted plume into the turbulent margins, the layered zone is accreted. The presence of bubbles in this zone indicates that the incorporated air from the atmosphere had cooled the vapor to the saturation temperature so that water could condense. This part of the plume also contains more carbonate (CaO plus MgO), as would be expected from the increased load of chamber-wall clasts towards the margins of the conduit and hence in a corresponding position within the plume above. Little accretion occurs after the lapilli move out of the turbulent plume. Only a thin veneer of fine carbonate-rich dust deposited as a rim before the lapilli plunged down into the avalanching surge clouds. The plot of the lapilli analyses above those of the surge deposits in Fig. 3 suggests that the lapilli are enriched in glass (or depleted in crystals) relative to the base-surge clouds.

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Figure captions

Fig. 1. Accretionary lapillus from Avellino deposit at Cave l'Amendolare, Vesuvius. Note three concentric zones: (1) massive core without bubbles, (2) intermediate zone with concentric bands of bubbles and larger clasts, and (3) outer rim composed of fine dust.

Fig. 2. Detail of texture in rim zone of lapillus from the Avellino deposit at Vallegrande, Vesuvius. Note extremely angular clasts, fine dust matrix, and bubble voids. Backscatter immage mode distinguishes crystals (bright) from glass (gray).

Fig. 3. Plot of ($CaO + CaCO_3 + MgO$) vs. SiO_2 for Plinian-fall and surge deposts (circles) and accretionary lapilli from Pompeii (squares) and Avellino (triangles) deposits. Whole numbers refer to lapilli from single level at specific locality. Decimal numbers indicate number of analyses in average of several areas on single lapillus. Error bars about these points represent standard deviation.

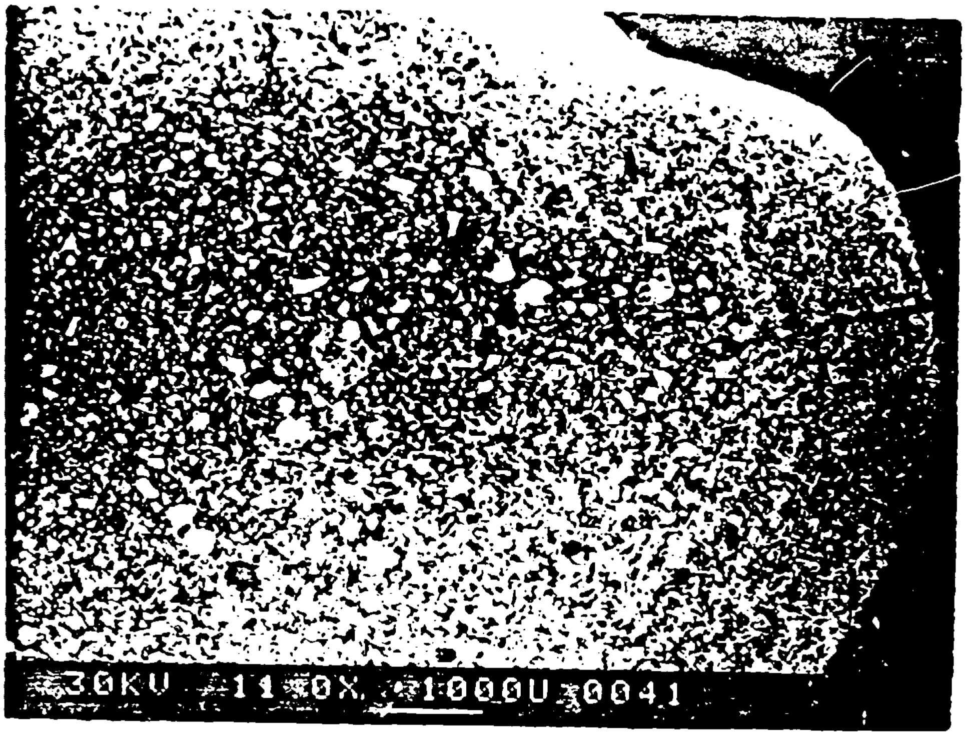


Fig 1

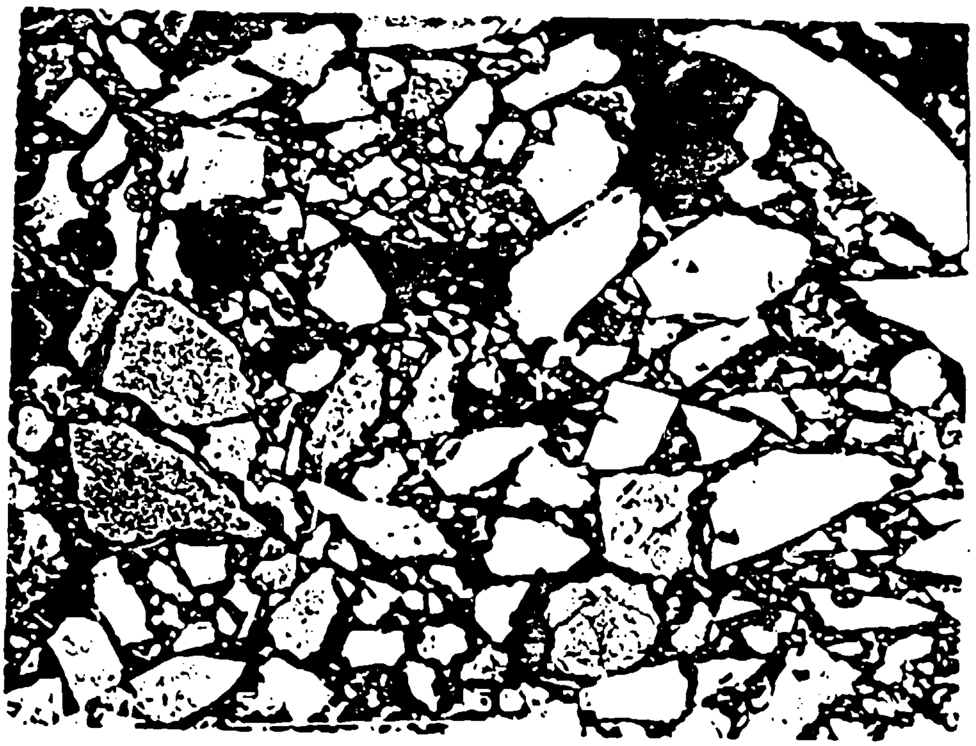
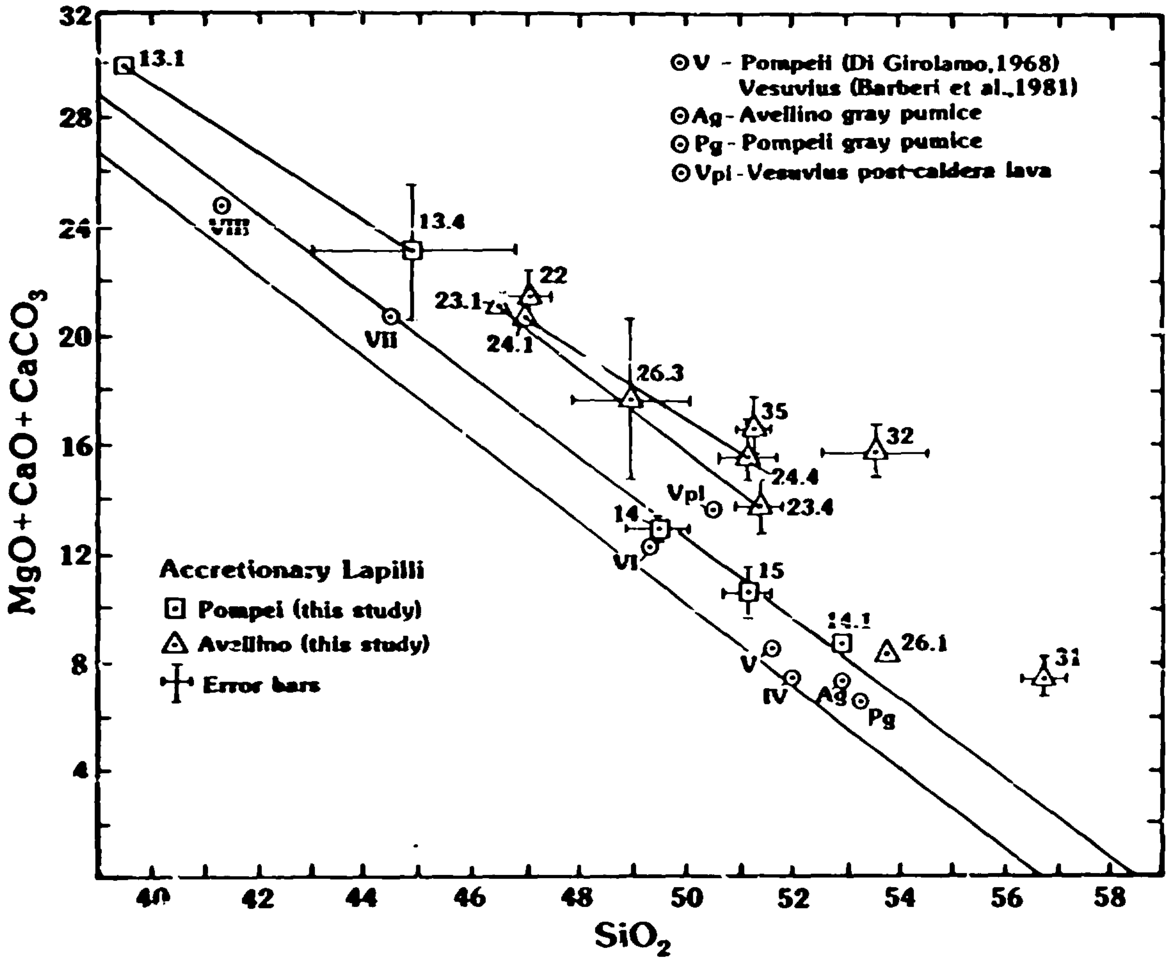


Fig 2



⊙V - Pompeii (Di Girolamo,1968)
Vesuvius (Barberi et al.,1981)
⊙Ag - Avellino gray pumice
⊙Pg - Pompeii gray pumice
⊙Vpl - Vesuvius post-caldera lava
Accretionary Lapilli
Pompei (this study)
Avellino (this study)
Error bars
MgO+CaO+CaCO3
SiO2