AREAL DISTRIBUTION, THICKNESS, AND VOLUME OF DOWNWIND ASH FROM THE MAY 18, 1980 ERUPTION OF MOUNT ST. HELENS

by

A. M. Sarna-Wojcicki[1/], Susan Shipley[1/], R. B. Waitt[1/], Daniel Dzurisin[2/] W. H. Hays[3/], J. O. Davis[4/], S. H. Wood[5/], and Thomas Bateridge[6/]

U. S. G. S.

Open File Report

No. 80-1078

This report is preliminary and has not been reviewed for conformity with Geological Survey editorial standards

1/ U. S. Geological Survey, Menlo Park, California 94025
2/ U. S. Geological Survey, Hawaiian Volcano Observatory, Hawaii 96718
3/ U. S. Geological Survey, Denver, Colorado 80225
4/ Desert Research Institute, University of Nevada, Reno, Nevada 89507
5/ Boise State University, Boise, Idaho 93752
6/ Geoservices West, Missoula, Montana 59807

Introduction

Isopach and isomass (weight per unit area) maps have been compiled by Susan Shipley and A.M. Sarna-Wojcicki for the May 18, 1980 eruption of Mount St. Helens based on thickness data, samples, and other observations made by Richard B. Waitt, Andrei M. Sarna-Wojcicki, Daniel Dzurisin, Michael Ryan, William H. Hays, all of the U.S. Geological Survey, Jonathan O. Davis, of the Desert Research Institute, University of Nevada, Reno, Spencer H. Wood, of Boise State University, Idaho, and Thomas Bateridge, of Geoservices West, Missoula, Montana. The observers ran one or more traverses along routes approximately normal to the long axis of the downed tephra plume at various distances from the volcano in the states of Washington, northern Idaho, and western Montana. Measurements were made on uncompacted thickness of the ash, and samples were collected from measured areas to determine the weight of material fallen per unit area. Samples were collected from surfaces which were relatively free from ground litter or dust prior to the eruption--for instance, from vehicle hoods or roofs, and other artificial surfaces away from heavily travelled roads. An isochron map compiled by Shipley and Sarna-Wojcicki from NOAA weather satellite photos shows the extent of the airborne tephra plume over a ten hour period at half-hour intervals on May 18, 1980. Volume of tephra erupted is calculated on both a solid-rock basis and on an uncompacted initial-thickness basis.

Isopach map of the May 18 eruption plume

Figure 1 shows the initial uncompacted thicknesses measured in the field. Most of the observations were made after the ash had fallen during the period May 19-21, and before the first rain on May 21. Davis' south-to-north traverse through Ritzville was made on May 21 and 22, partly after the rains had begun to fall, and accounts for the lower uncompacted thickness values compared to the others, as shown by re-entrants in the isopachs (about 60 km) west of Spokane and north of Ritzville, and the higher calculated bulk densities of the ash along this traverse. Sarna-Wojcicki's observations in the proximal area in mid-June showed no compaction, as remeasured at several stations previously occupied by Waitt shortly after the first rain following the eruption. Initial uncompacted thickness measurements were made on representative sites, and replicate measurements were made and averaged for several individual sites.

The low "saddle" in the vicinity of Vantage, and the high thicknesses near Moses Lake and Ritzville are unusual. Such features, to our knowledge, have not been documented for other eruptions. The greater thickness of ash near Ritzville may be an effect of the amount of time which was required to settle most of the particles in the dominant size range within the tephra plume from the average height to which the ash was erupted above the volcano and carried laterally by wind. An alternative interpretation is that the wind speed slowed, reducing its carrying capacity (see below). Perhaps both mechanisms formed the anomalous high in eastern Washington.

Ash along the easternmost traverse through Missoula, Montana was too thin to measure directly in most places. The initial thicknesses for this traverse were estimated by taking an average of three uncompacted thicknesses in Missoula, where the ash was a relatively thick 3.2 mm, and the average of the associated weights per unit area, and calculating what the thickness at the other sampled sites in this traverse would be given the weight per unit area at each site.

Isomass (weight per unit area) map of the May 18 eruption plume

Samples collected from measured areas at each site were weighed, and the weights per unit area were contoured (fig. 2). The isomass map has the same general configuration as the isopach map (fig. 1). Some irregularities on the isopach map, such as reentrants north of Ritzville and east of Spokane, are smoothed in the isomass map, because the differences in relative compaction as a function of observation time are eliminated.

We estimated uncompacted bulk densities at observation sites by dividing the initial uncompacted thicknesses into the weight per unit areas obtained for each site. Average bulk density as a function of distance from the volcano is shown in fig. 3. Density decreases with distance except for the traverse through Ritzville, which was completed after the first rains had compacted the ash at most of the sampling sites along this traverse. This decrease in bulk density reflects the systematic depletion of the heavier crystal and lithic fragments and relative enrichment of the lighter glass and pumice shards in the downwind direction. The way the grains are packed must also play a role in the decrease in bulk density downwind as demonstrated by compaction of the ash with time. Lighter grains will tend to pack more loosely than heavier ones. Also, the angular and irregular shape of glass and pumice shards probably packs more loosely than crystal and lithic grains. The average calculated bulk density at Missoula is very low (0.11 g/cm^3), although the data here are sparse and there is a large error in measuring very thin layers. If this estimated density is anywhere near the true bulk density at this distance, then the ash must consist mostly of highly vesciculated pumice shards, and have been packed very loosely. Analyses of the relative proportions of the different components of this ash are now in progress to better determine these downwind variations.

Isochron map of the airborne tephra plume from the May 18 eruption

An isochron map of the airborne plume from the Mount St. Helens eruption of May 18, 1980 was made using satellite photos obtained from the National Oceanic and Atmospheric Administration (fig. 4). The photos were taken at half-hour intervals, and document the areal extent of the airborne tephra plume during the time interval 8:45 a.m. to 6:15 p.m., PST. Because the eruption began at 8:32 a.m. PST, the coverage began only 13 minutes after the start of the eruption. After 6:15 p.m. there was not enough light in the visible spectrum to track the cloud visually, while available infra-red satellite photos did not have sufficient contrast to show the tephra plume. By the morning of May 19, the airborne plume had become too diffuse and mixed in with local cloud cover to be mapped accurately from satellite photos. During the ten hour period of observation, the leading edge of the ash cloud travelled at an average speed of about 100 km/hr, with some variations in velocity. The plume velocity measured along an approximately maximum velocity trajectory is shown in fig. 5. The plume travel time vs. distance from the volcano, measured along an approximately maximum velocity trajectory, is shown in fig. 5a. The velocity of the plume front vs. the distance from the volcano is shown in fig. 5b.

The velocity of the plume front (fig. 5b) varied from a high of over 180 km/hr to a low of about 60 km/hr, and had a complex, pulse-like pattern that appears to have decayed with distance from the volcano and with time after the beginning of the eruption. The initial, maximum horizontal component of velocity of the leading edge of the plume during the first 13 minutes averaged about 180 km/hr, and the front had travelled over a distance of about 40 km from the volcano. This high velocity probably represents the initial blast propelled by rapidly-expanding gas of the eruption. Initial velocities during the first few minutes of the eruption were probably even higher. The leading edge of the plume continued to slow down, reaching a minimum velocity of about 60 km/hr about 180 km east-north-east of the volcano, about one hour and forty-five minutes after the start of the eruption. A slowing of the wind speed would decrease its carrying capacity, causing ash to settle to lower altitudes. The slower winds at lower altitudes would have even less carrying capacity, and the ash would settle obliquely in the downwind direction. The slowing of the ash plume may thus account for the thick layer of ash deposited near Moses Lake and Ritzville. The leading edge of the plume apparently slowed down again to a minimum velocity of about 60 km/hr between 250 and 350 minutes after the start of the eruption, between about 490 and 560 km from the volcano. We have no firsthand data in the region between our two eastern traverses, consequently, we do not know if a second "high" similar to that at Ritzville lies within this region.

At present, we do not have accurate control on altitude of the ash plume front as it travelled eastward. The base of the leading edge of the plume, the densest part, was reported to be at about 35,000-45,000 feet (about 10,700-13,700 m) along much of its observed route. Diffuse ash was observed to altitudes of 70,000 feet (about 21,300 m) (E. Danielson, oral commun., NASA-Ames, 1980).

Figure 6 is a comparison of the airborne and downed tephra plumes. The latter plume is offset northward relative to the former. This suggests that lower level winds had more of a northward component than the high-level winds. These observations are supported by observations made on the ground and observations of wind velocities and directions for different altitudes made on May 18. The south margin of the downed tephra plume is marked by fairly coarse, relatively well-sorted tephra both at proximal and distal locations, suggesting that finer material was winnowed out and transported north, towards the axis of the lobe. The northern margin of the lobe, to the contrary, is a very diffuse zone: a fine dusting reported far north of the 0.5 mm isopach line in fig. 1 probably represents fines winnowed northward from the main body of the plume.

Volume of downwind ash erupted on May 18, 1980

We have estimated the volume of downwind ash erupted from Mount St. Helens on May 18 using a modified version of the isomass map (fig. 2), with inferred connections of the isolines, as shown in fig. 6. We did not use the isopach map (fig. 1) because the bulk density varied downwind and with time. Areas of each isoline were measured using a LaSico planimeter with digital readout. Each successive area was multiplied by its respective net increment (weight per unit area of each isoline minus the value of the next lower isoline) of weight per unit area, giving a total weight for each increment. All increments were summed to give a total mass of 3.67×10^{14} grams, or 3.67×10^{8} metric tons of total downwind material erupted.

Figure 7 is a plot of mass associated with each area measured for each weight increment, and suggests that there is little mass, perhaps less than a few percent, that lies outside the curve. Consesquently, the error in this estimate is probably small. Another source of error is in the volume of the very fine material which remained suspended and which has been carried far downwind. Consequently, our mass estimate for the downwind tephra is a minimum.

The estimated mass can be converted to volume by dividing the mass by an appropriate density. In fig. 8 we show a curve for converting the measured mass to a volume depending on the density selected, or vice-versa. Converting to an approximate solid-rock density of 2.6, which includes some in-situ fracture porosity, we obtain a small volume of about 0.14 km^3. Using an approximate bulk density of 0.5 g/cm^3 to represent a rough average bulk density of the entire down wind tephra lobe, we obtain a volume of about 0.73 km^3. An estimate of the crater volume representing the volume of material missing from the mountain after the eruption of May 18, based on pre- and post-eruption topographic maps, is 2.6 km^3 (J. Moore, oral commun., 1980). Consequently, most of the volume missing from the summit area must be accounted for by the debris avalanche, mud flows, ash flows, and proximal blast deposits, whereas only a small fraction was erupted and deposited in the downwind plume.

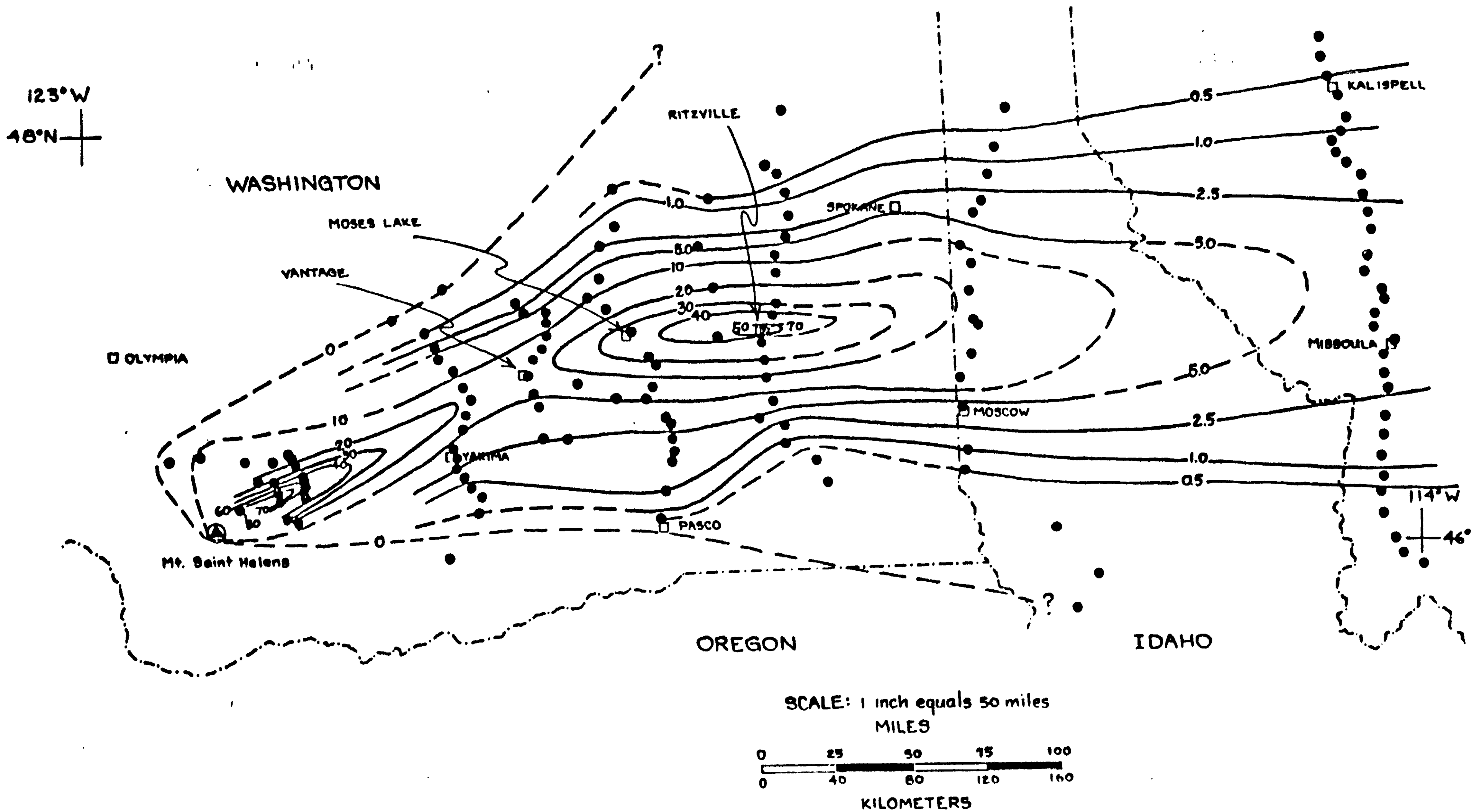


Figure 1. Isopach map of ash erupted from Mount St. Helens on May 18, 1980. Isopach lines represent uncompacted thickness, in millimeters. Dots represent observation stations.

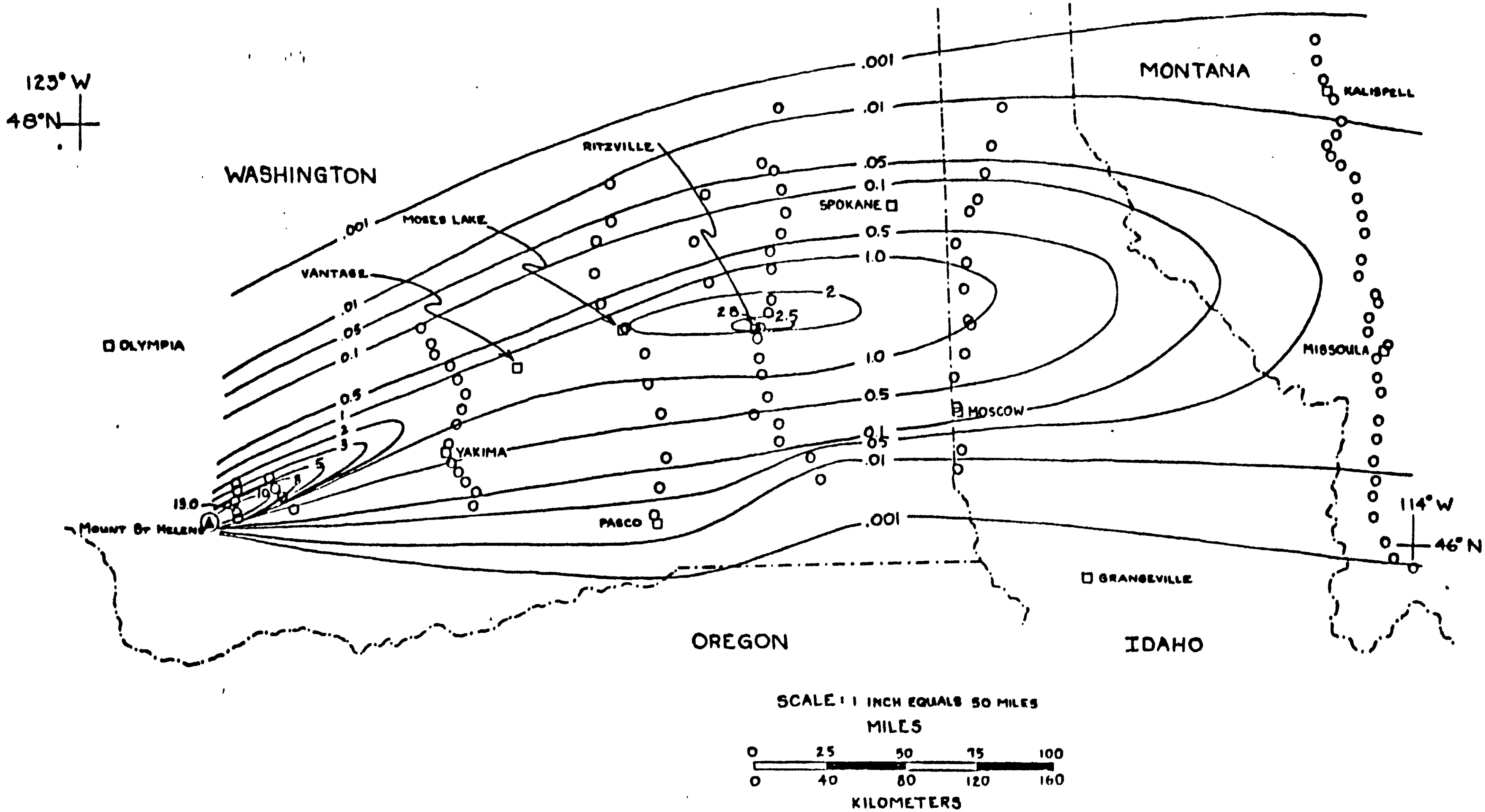


Figure 2. Isomass map of ash erupted from Mount St. Helens on May 18, 1980. Isomass lines represent weight per unit area, in g/cm^2. Open circles represent observation stations.

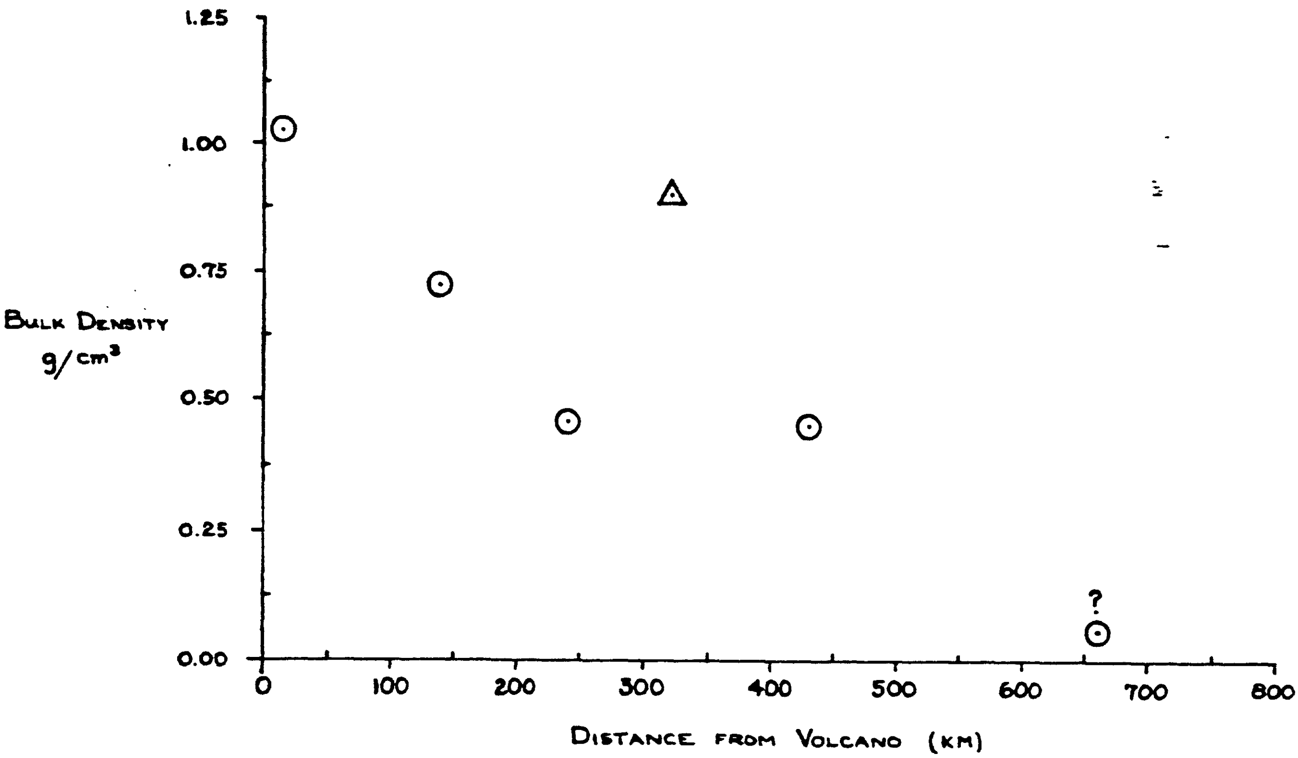


Figure 3. Uncompacted bulk density as a function of distance from the volcano for ash erupted from Mount St. Helens on May 18, 1980. Open circles represent average calculated values from observations made along traverses approximately normal to long axis of downed tephra plume, during the period May 19-21. Triangle represents average calculated value from traverse made after first rains had begun to fall.

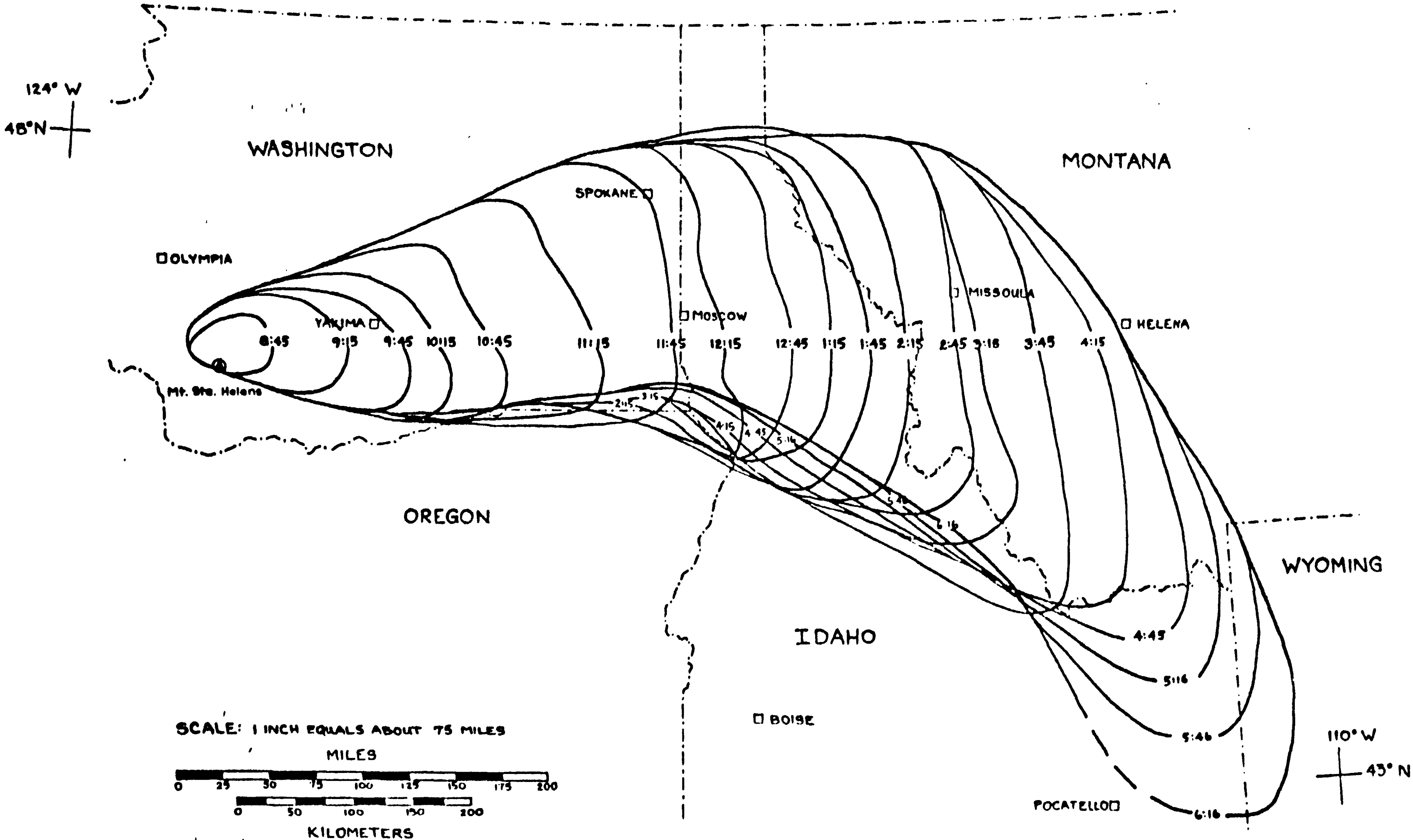


Figure 4. Isochron map of extent of airborne ash plume erupted from Mount St. Helens on May 18, 1980. Map is compiled from NOAA satellite photos taken at half-hour intervals between 8:45 AM and 6:15 PM, PDT , on May 18, 1980.

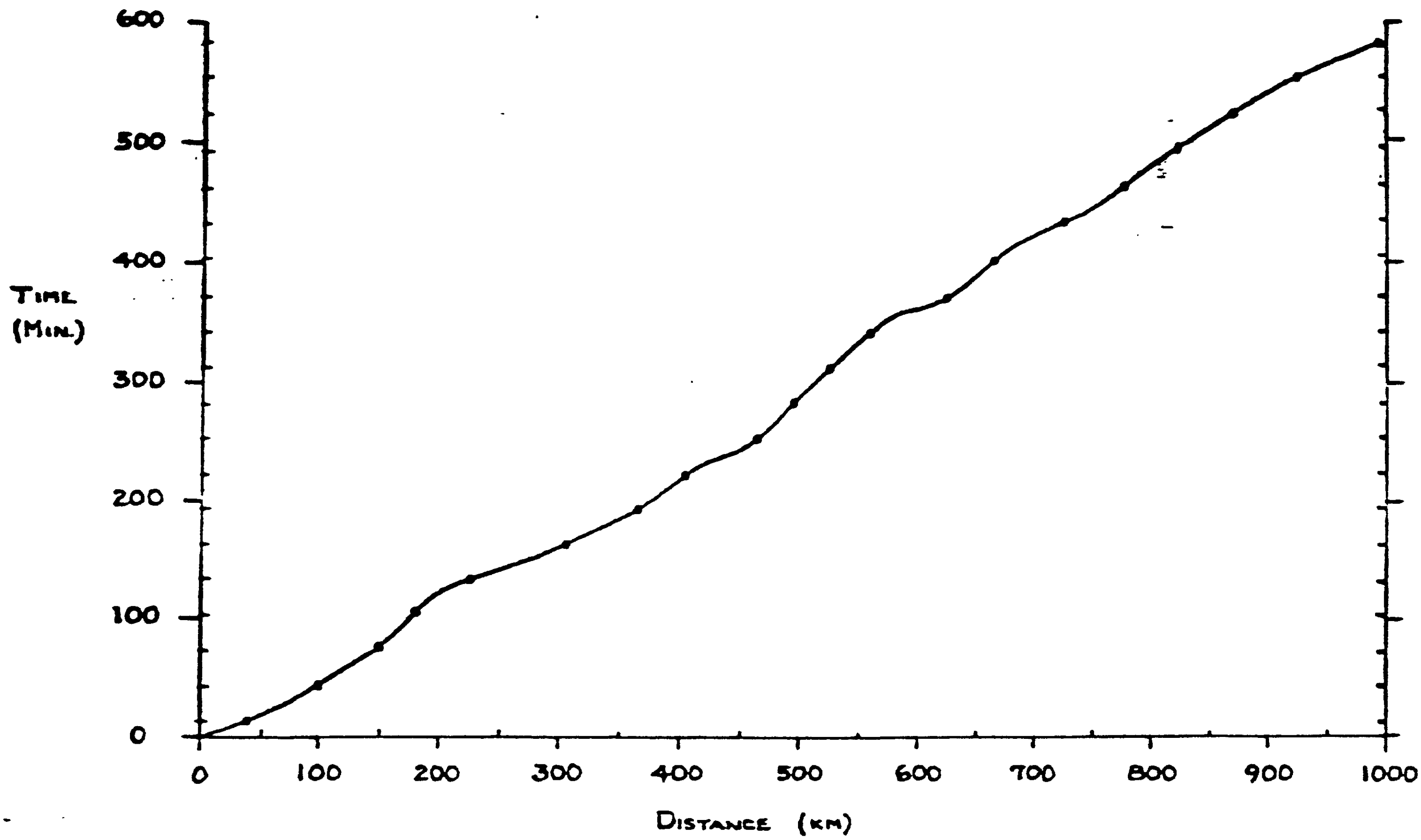
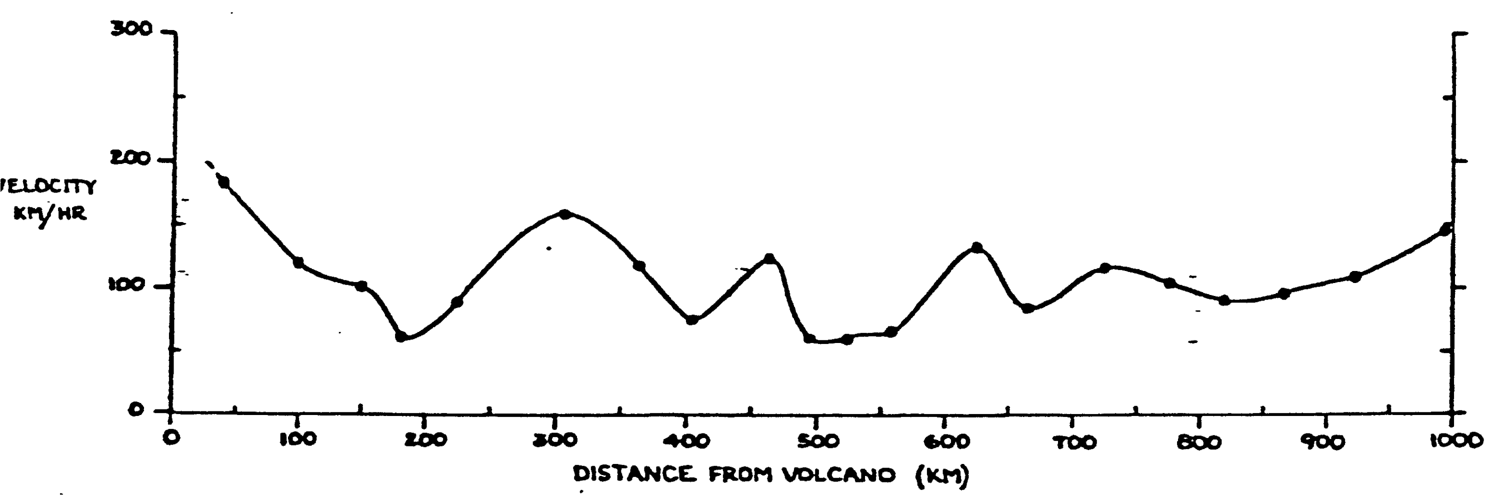


Figure 5a (above). Travel time vs. distance from the volcano of airborne tephra plume from the May 18, 1980 eruption of Mount St, Helens. Travel times were calculated from a trajectory at approximately maximum distances from the volcano, as determined from NOAA satellite photos taken at half-hour intervals on May 18, during the period 8:45 AM - 6:15 PM, PDT.

Figure 5b (below). Velocity of the airborne tephra plume front as a function of the distance from the volcano.



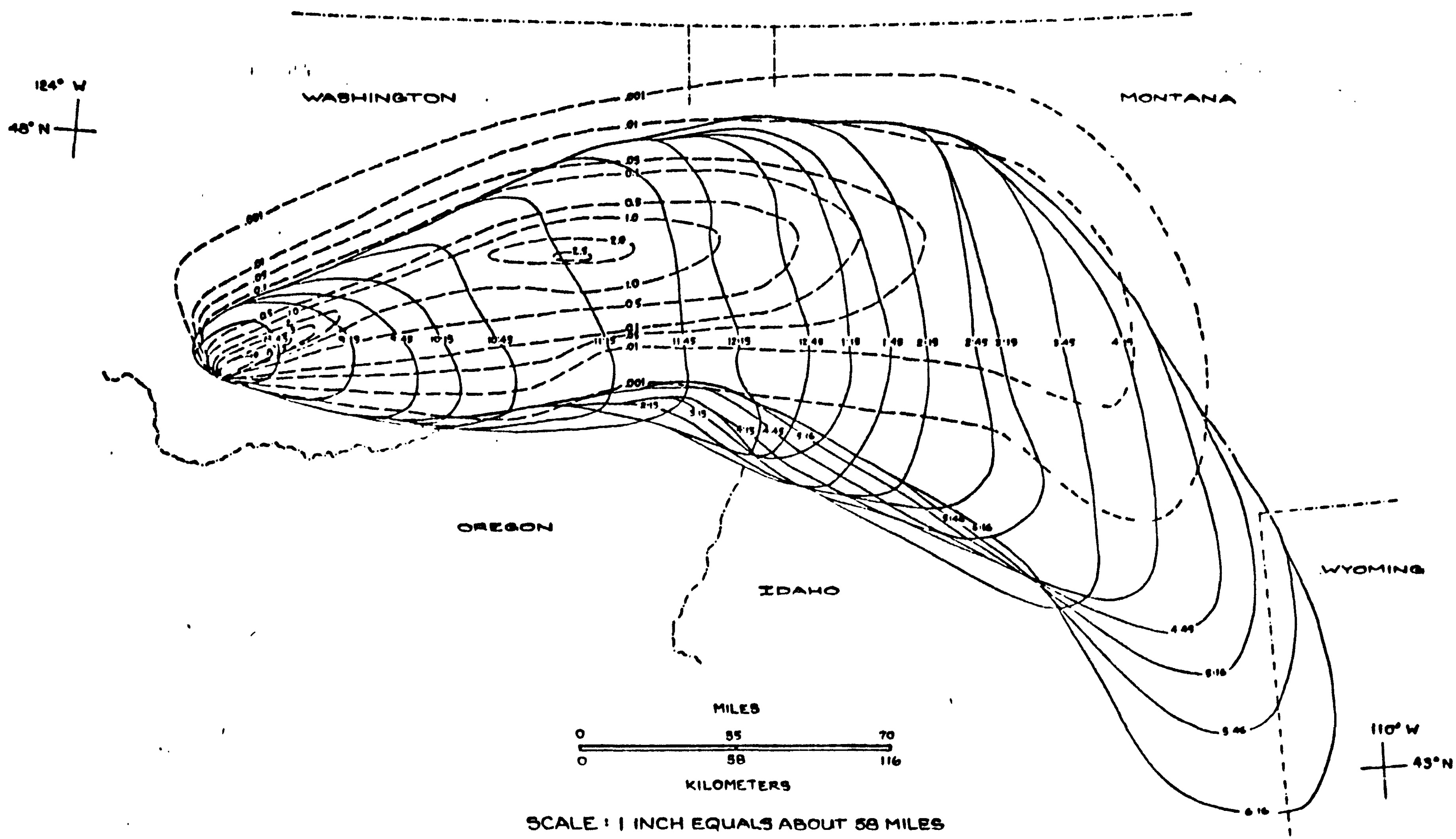


Figure 6. Isochron and isomass (weight per unit area) maps compared. Solid lines, isochrons of airborne tephra plume; dashed lines, isomass lines for downed tephra plume; interrupted dashed lines, inferred positions of isomass lines extended beyond area of control. See figs. 1, 4, and text for further explanation.

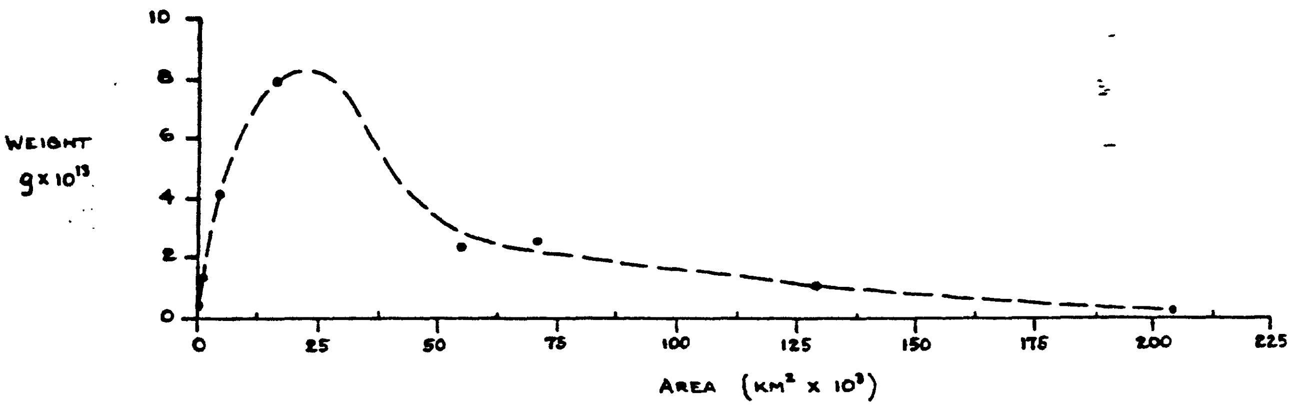


Figure 7. Mass of downwind ash as a function of the size of the area covered.

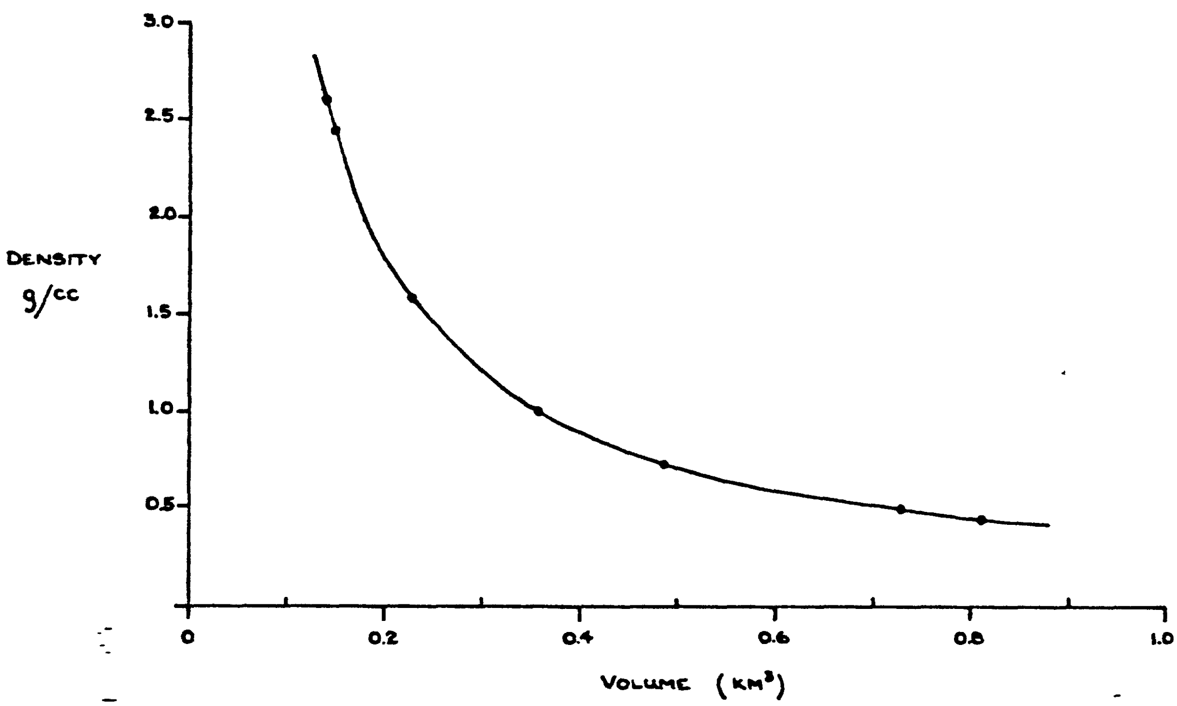


Figure 8. Volume of downwind ash as a function of density, given an eruptive mass of 3.67×10^{14} g.