Reanalysis of the Pyroclastic Fall Deposit from the 18 May 1980 Eruption of Mount Saint Helens, USA.

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Summary

A new analysis of the distal ash-fall deposit from the 18 May 1980 eruption of Mount Saint Helens, Washington, (MSH80) is presented. The removal of fine distal volcanic ash from the atmosphere is complex: From the data presented here, it is clear that atmospheric dynamics and meteorological processes influenced particle sedimentation from the MSH80 cloud. This work improves understanding of volcanic ash dispersion in the atmosphere and distal ash sedimentation. In addition, an extensive database is now available for Volcanic Ash Dispersion and Transport Model (VADTM) validation and development.

Mount St. Helens 18 May 1980 Eruption Chronology

- Magnitude 5.1 earthquake, coincident with the catastrophic failure of the north flank at 08:32 PDT.
- N-directed lateral blast, debris avalanche and density current devastated an area of ~600 km^2 to N of the volcano.
- At ~09:00 PDT, eruption column reached an altitude of >24 km marking start of 9 hour Plinian phase.
- By ~17:00 PDT, eruptive style shifted to pyroclastic flow-dominated activity.

MSH80 Cloud Dispersion and Particle Sedimentation

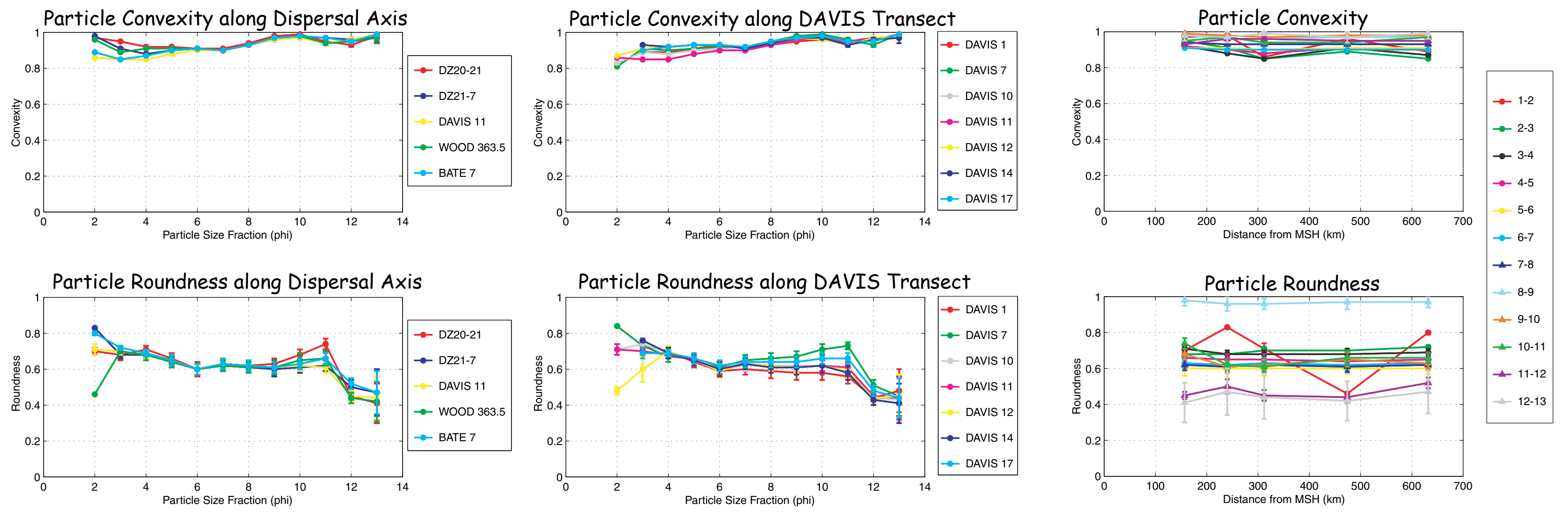
FIGURE 1. LEFT, CENTRE: MSH80 mammatus clouds seen from Ephrata, Washington, on the morning of May 18, 1980 (Photos copyright Douglas Miller); RIGHT TOP: loosely-bound small (0.25-0.5 mm) ash aggregate composed dominantly of fine ash <40 microns, collected at Pullman, WA (Sorem, 1982); RIGHT BOTTOM: Ash aggregate collected in Kennewick, WA, on 18 May 1980 (Rose et al., 1982).

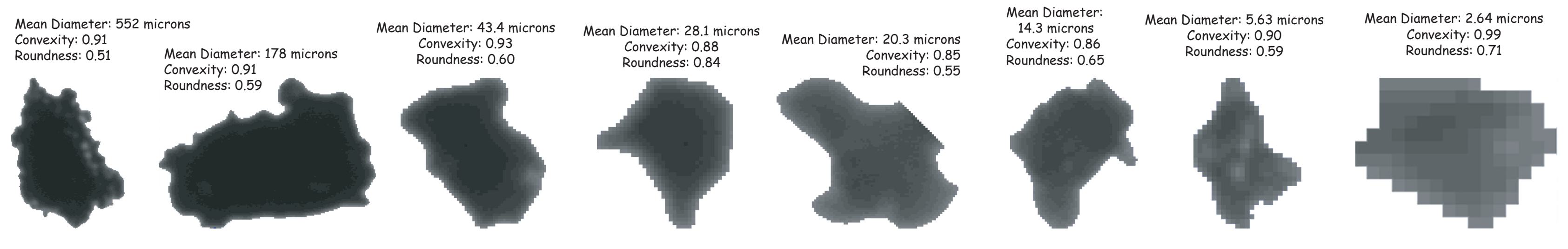
Wind shear in the lower stratosphere converted the eruption column to several horizontally-zoned lateral intrusions, which were dispersed by winds at different altitudes: the upper part was carried W and the lower, much denser part moved E at jet stream velocities. The dominant eastward migration of the MSH volcanic cloud was documented by GOES meteorological satellite images (Sarna-Wojcicki et al., 1981) and National Weather Service (NWS) meteorological radars stationed at Portland, Oregon, and Spokane and Seattle, Washington (Harris et al., 1981). Observations of mammatus clouds were abundant (Figure 1).

An ash-fall layer was deposited at distances greater than 200 km from the volcano. Deposit thickness and mass accumulation was mapped by Sarna-Wojcicki et al. (1981): the ash blanket extended into Montana and exhibited a second thickness maximum centered on Ritzville (Washington). Evidence for ash aggregation in the volcanic cloud includes: (1) fist-sized clumps of loosely-aggregated ash that collided with an aircraft measuring emissions 37 km from the volcano (Hobbs et al., 1981); (2) fallout of ash clusters observed at Pullman, Washington (Sorem, 1982) and at Kennewick, Washington (Rose et al., 1982).

Particle Shape

Particle shape variation was investigated using a Malvern Instruments Pharmavision at the Univeristy of South Florida. During each analysis, the instrument images 100,000s of individual particles and uses image analysis to determine size and shape. Please see Volentik et al. (2006), poster V33B-0651, for more information on this technique.





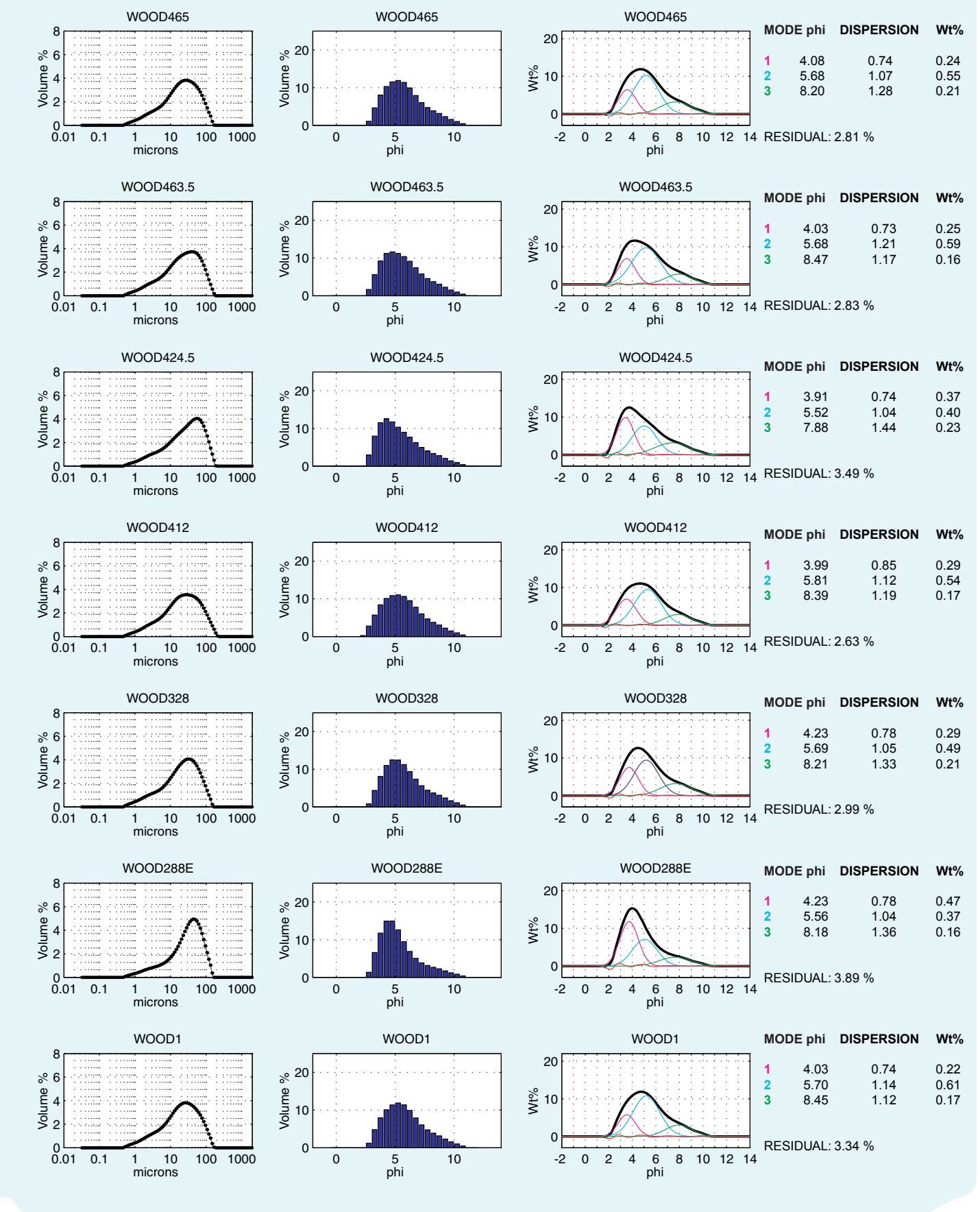
Egs. of particles analysed in DAVIS 11. Convexity = particle area/enclosing area; convex = 1; concave = 0. Roundness = length/width; perfect circle = 1, needle = 0.

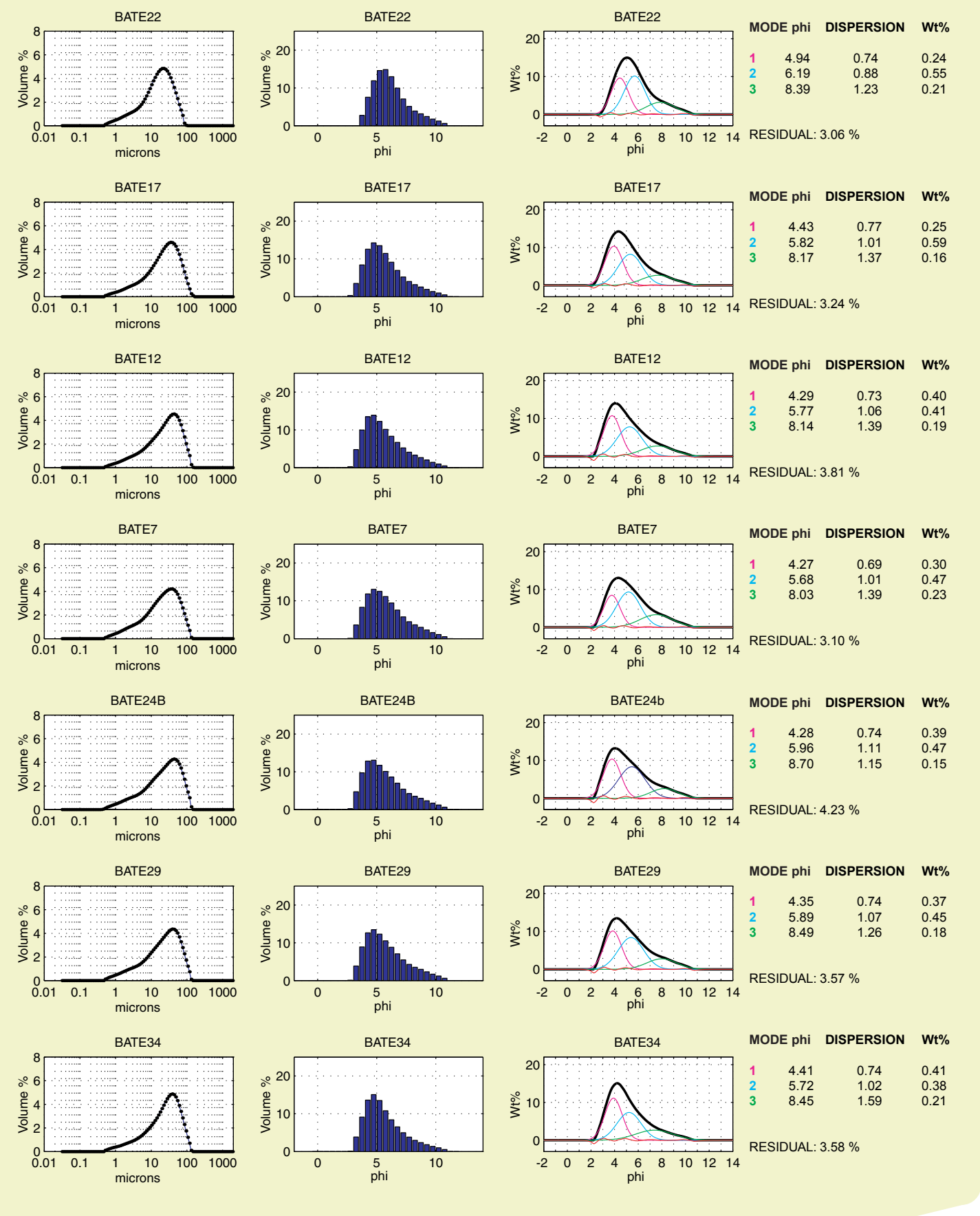
Mount St. Helens 18 May 1980 Eruption Distal Ash Sampling Strategy

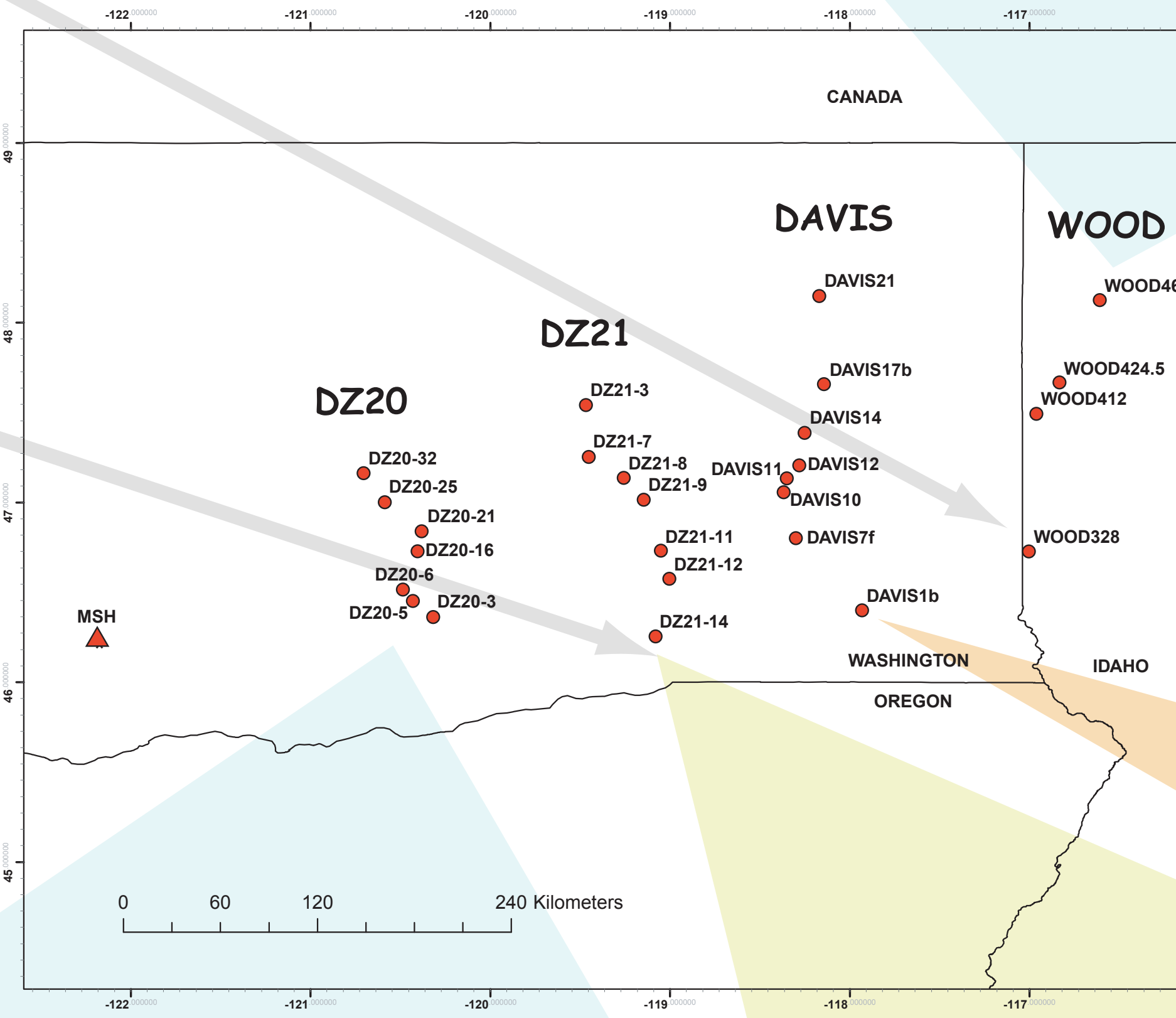
Within hours, teams of investigators started collecting samples along a series of transects running perpendicular to the dispersal axis of the ash-fall deposit. Andrei Sarna-Wojcicki coordinated a team of USGS scientists who carried out several sampling transects at distances up to ~650 km from the volcano. Most traverses were completed between 19-21 May 1980, before rain had fallen on the deposit. Jonathan Davis' traverse was completed between 21-22 May 1980, in part after rain had fallen on part of the deposit.

LALLS Particle Size Analysis

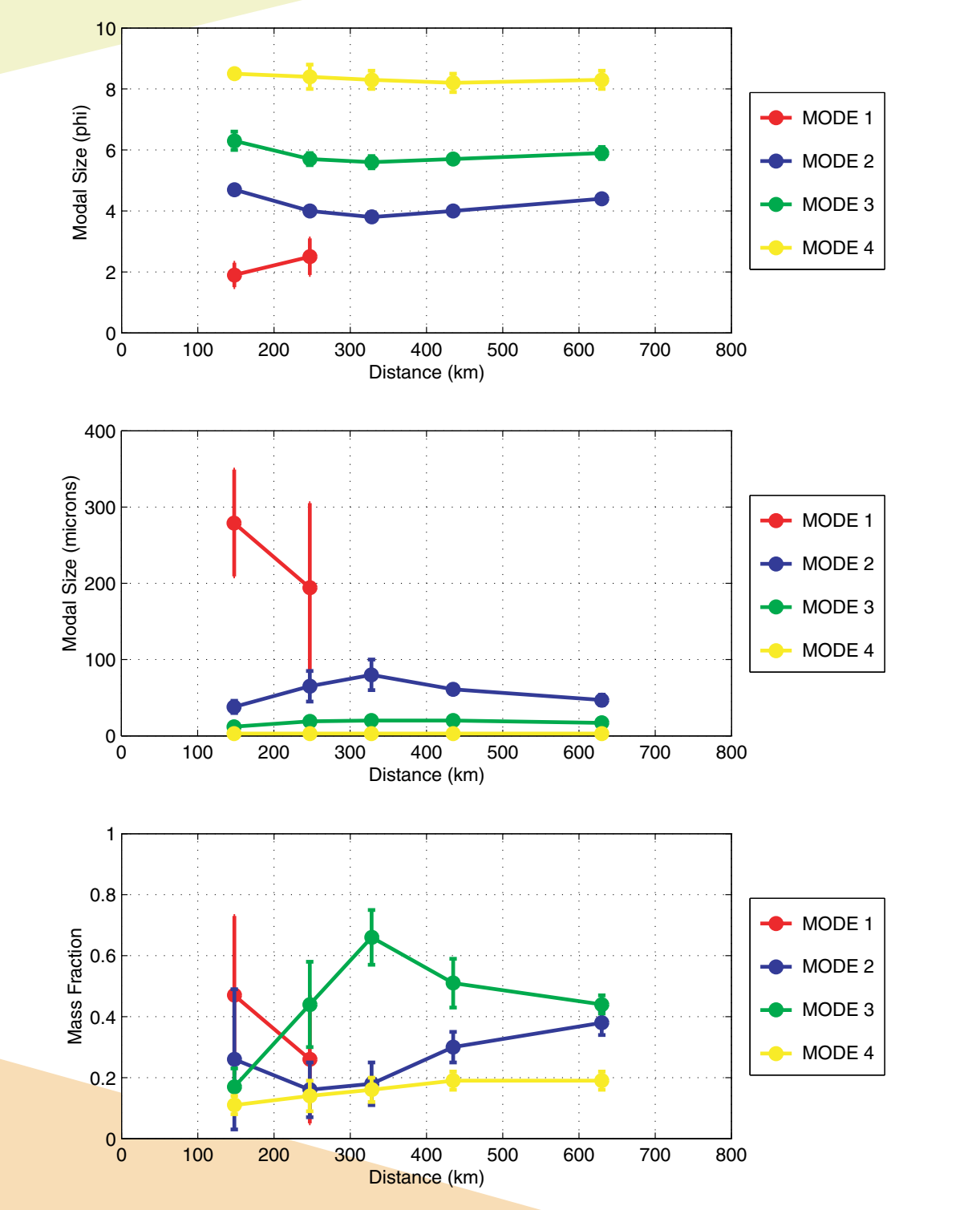
Particle size analysis of original samples of the MSH80 distal ash fall, collected within a few days of deposition, was carried out using a Malvern Instruments Mastersizer 2000. This instrument uses Low Angle Laser Light Scattering (LALLS) to provide a high resolution measurement of particle size between 0.2-2000 microns.

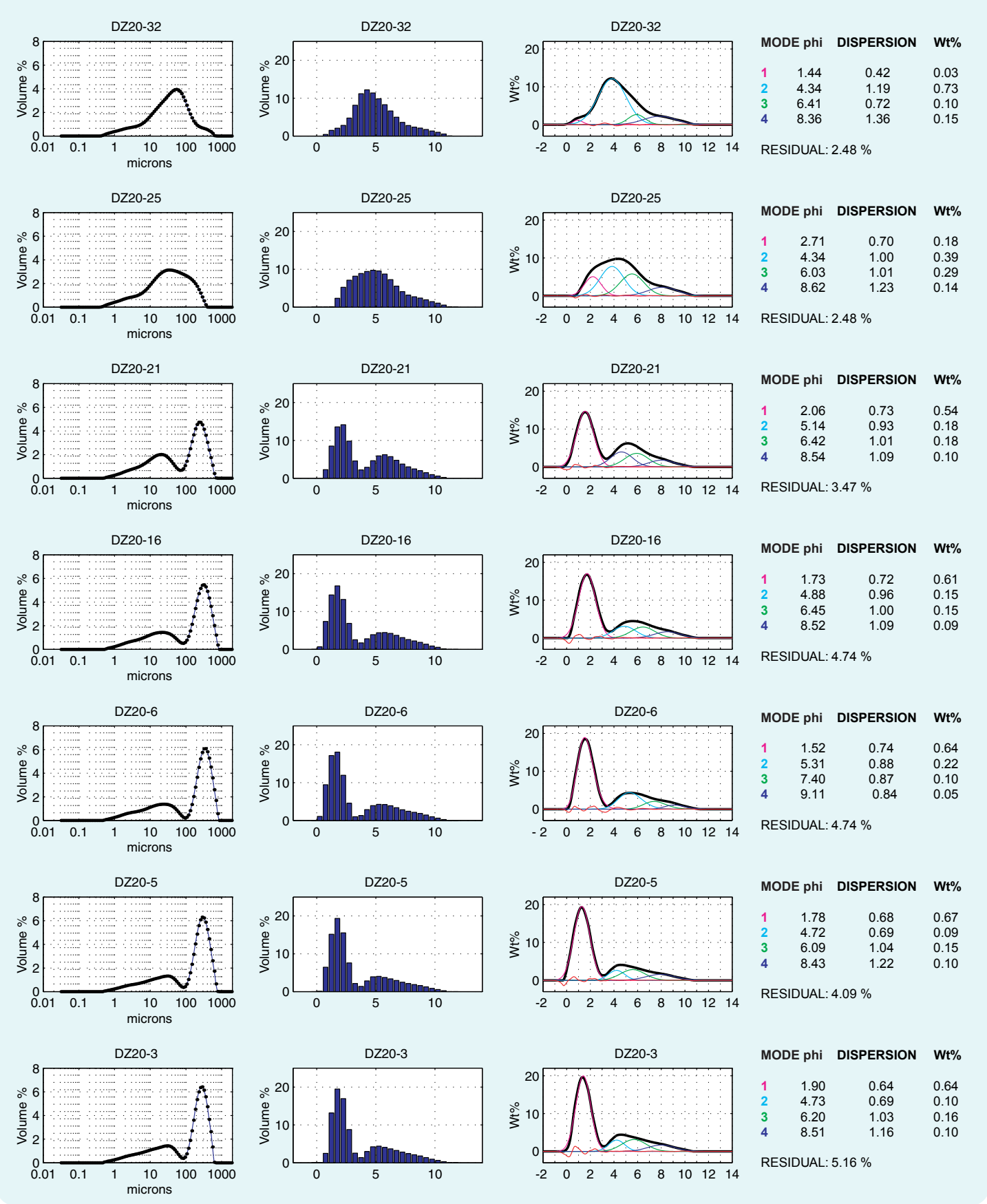

White Bird (ID) to Libby (MT)
Spencer Wood 21 May 1980

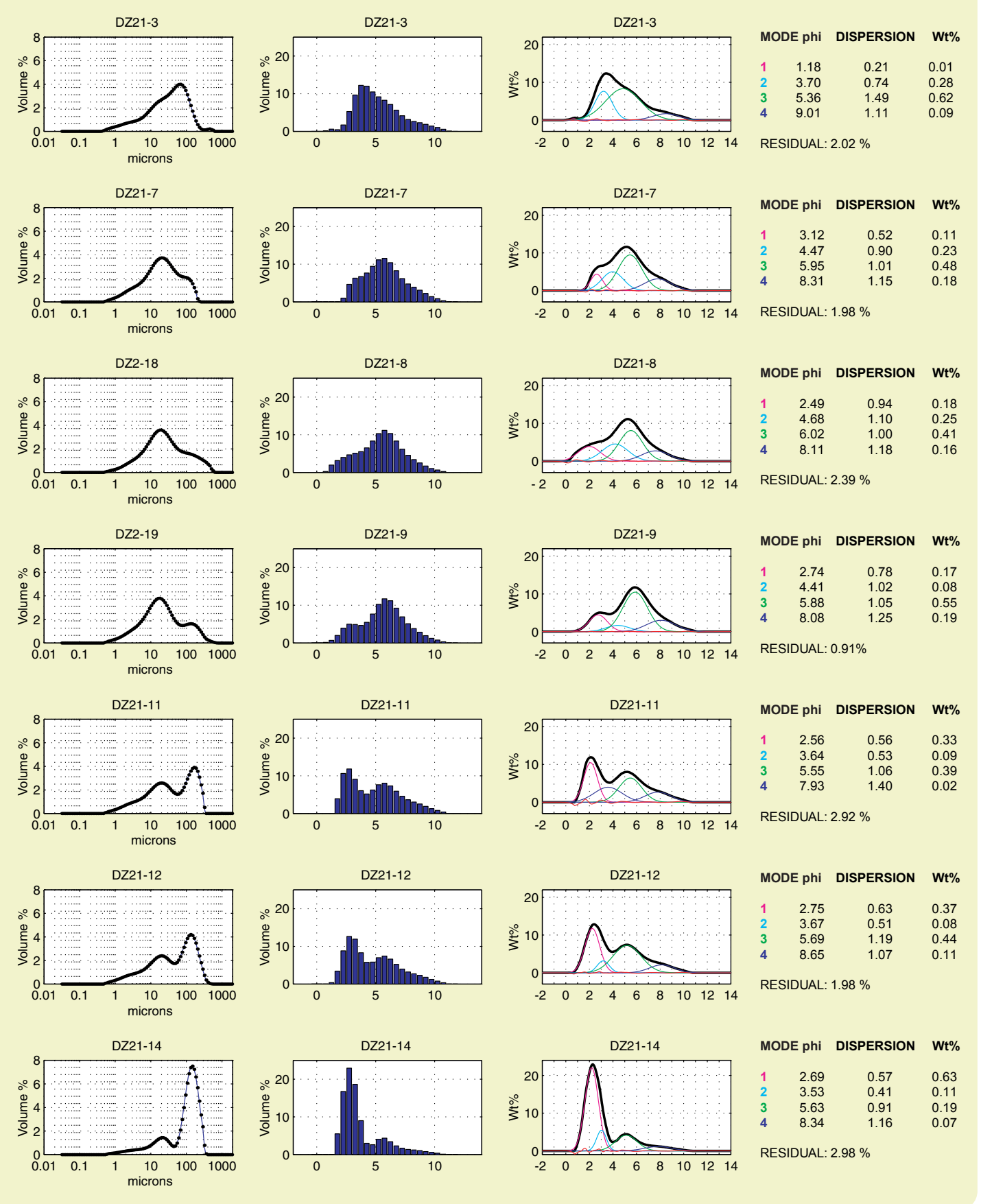

Rose Crossing (MT) to Butte South (MT)
Tom Bateridge 9-21 May 1980

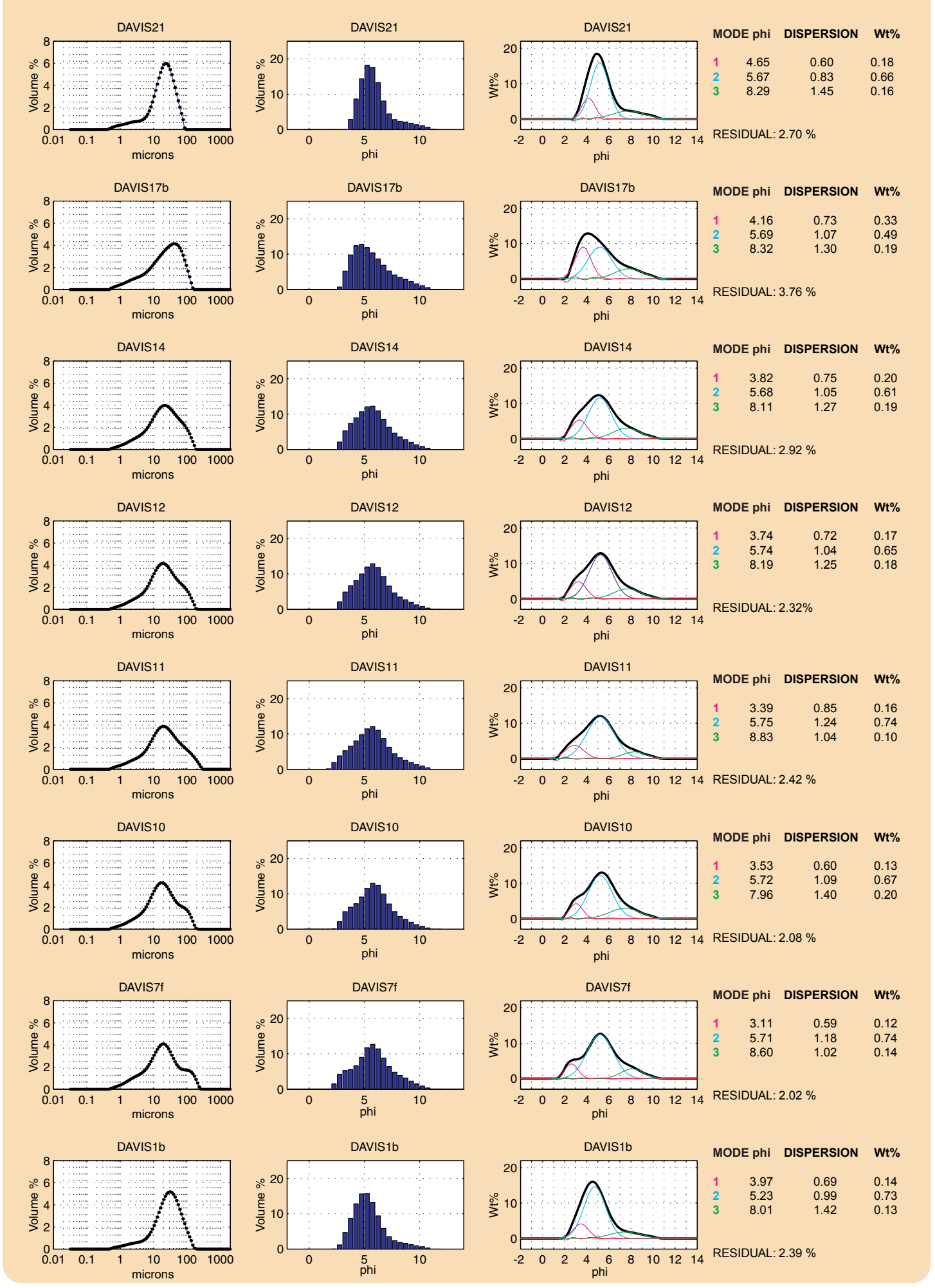


Subpopulation Modes: Transect Averages

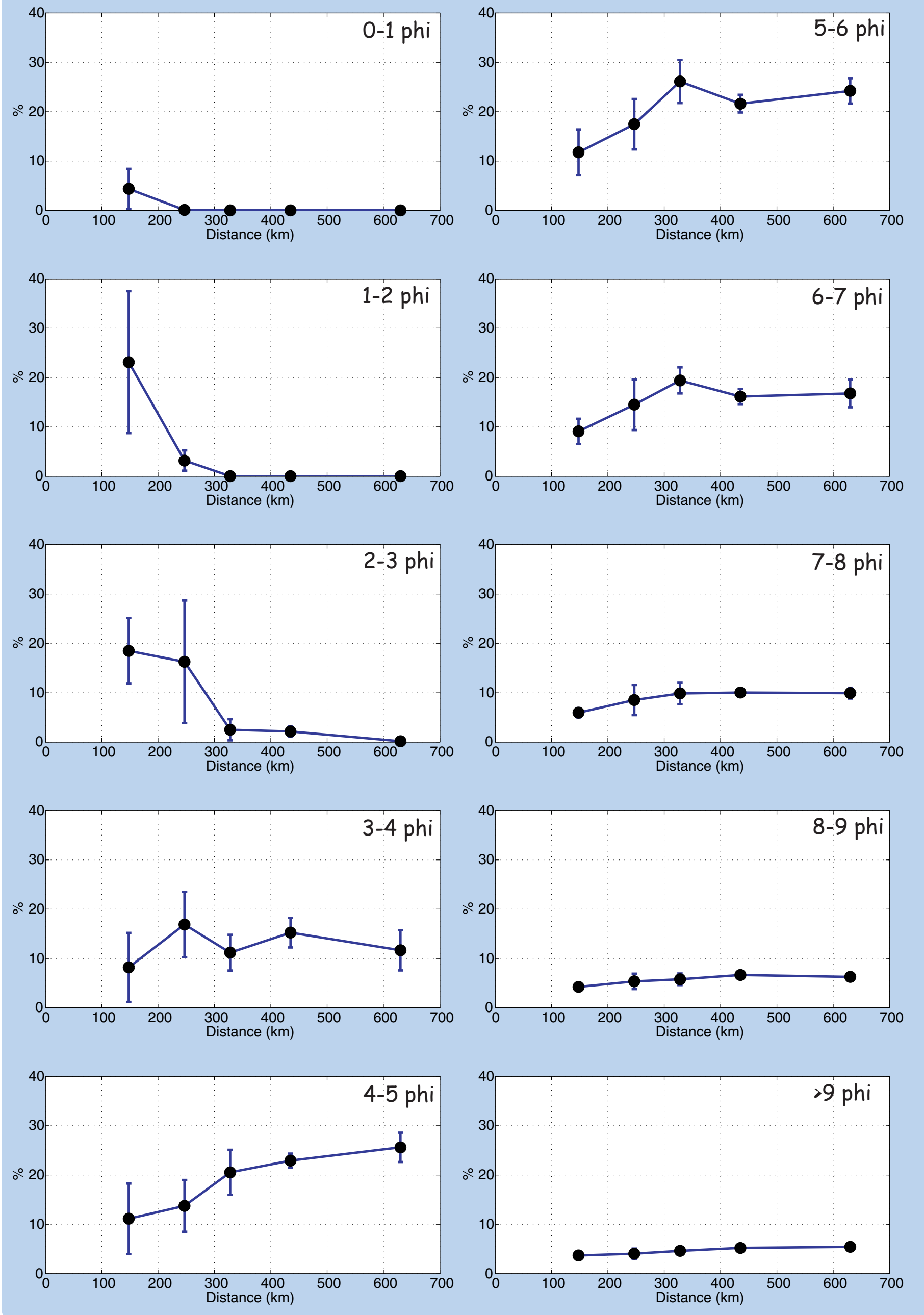



Swauk Prairie (WA) to Kusshi Creek (WA)
Dan Dzurisin 20 May 1980

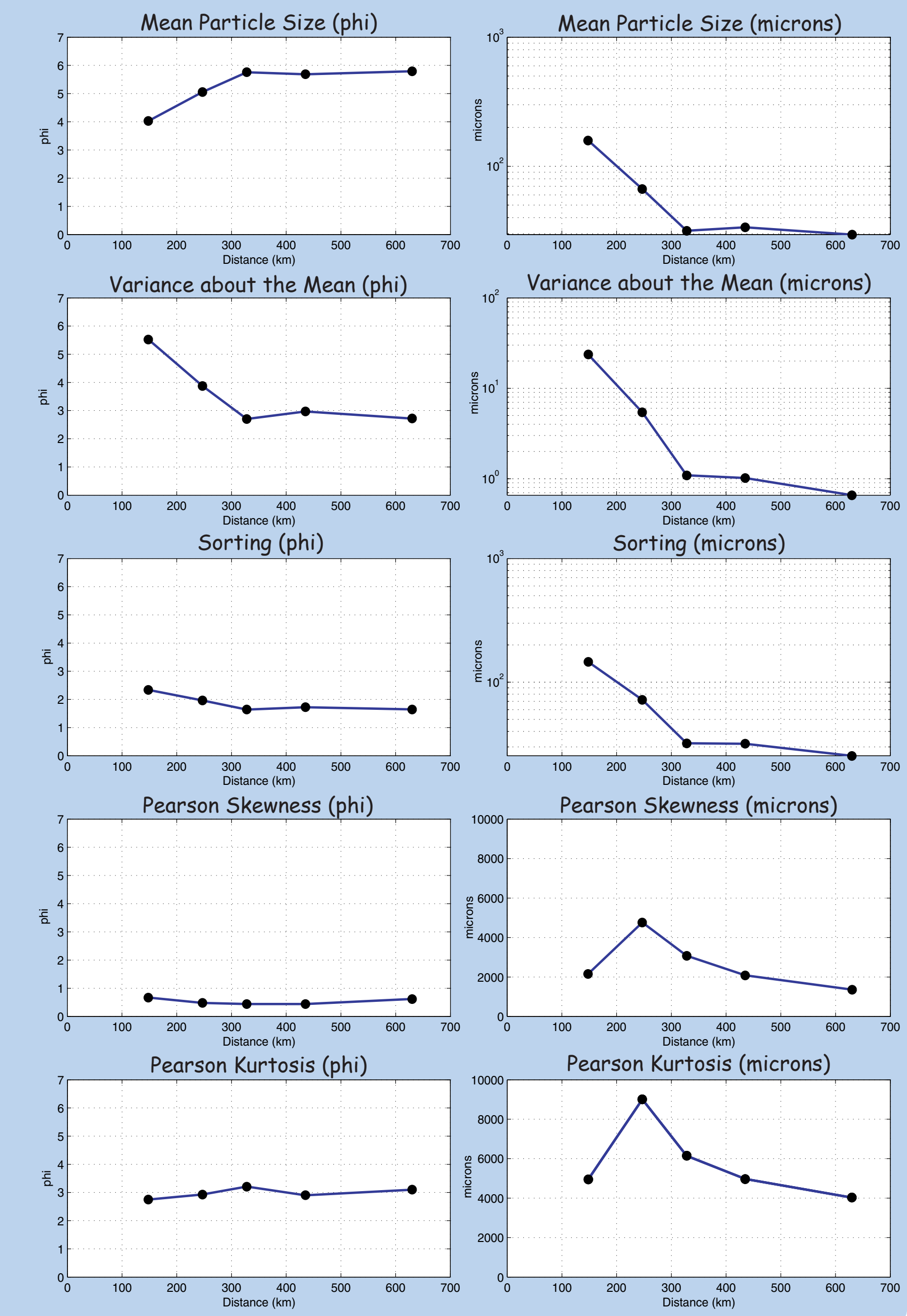

Sims Corner (WA) to Glade (WA)
Dan Dzurisin 21 May 1980


Tucannon (WA) to Louie Creek (WA)
J. Davis 21-22 May 1980

Particle Size Fractions Averaged by Transect



Sedimentological Statistics Averaged by Transect



Discrimination of Grain-size Subpopulations in the MSH80 Distal Ash-fall Deposit

The MSH80 particle size data were analysed to discriminate grain-size distribution subpopulations, following the approach described in Wohletz et al. (1989): the analysis here was performed using KWare Geological Software SFT application, available at http://www.ees1.lanl.gov/Wohletz/SFT.htm.

Hypotheses for the origin of polymodal size distributions: (1) Multiple components (crystals, shards, lithic fragments); determines particle size-weight ratio, characteristic shape, and initial size distribution; (2) Fragmentation mechanisms (magmatic, hydromagmatic, vent erosion, particle collision); (3) Transport mechanisms (eruption plume regimes, atmospheric turbulence, cloud stability, deposit reworking).

Visual investigation of grain-size distributions of the most distal samples suggests that there are 3 subpopulations: for example, see WOOD 463.5. This trend can be identified in more proximal samples. An additional coarse mode appears in samples collected along the DZ20 and DZ21 transects, while the general shape of the finer region of the curve remains similar: for example, see DZ21-3 and DZ21-8. In strongly polymodal samples, accounting for 3 subpopulations in the finer region of the curve provides the best result (i.e. lowest residual): for example, see DZ20-5.

Analysis of results

All individual Malvern analyses were investigated, then average modes were calculated for each transect: there are 4 distinct grain-size subpopulations in the MSH80 distal ash samples. Based on log-normal subpopulations, average modes are located at: (mode 1) 2.2 phi / 237 microns; (mode 2) 4.2 phi / 58 microns; (mode 3) 5.8 phi / 18 microns; and (mode 4) 8.3 phi / 3 microns. The coarsest mode (mode 1) is only present in the closest 2 transects: DZ20 and DZ21.

The proportion of the coarsest mode, mode 1, decreases with distance from MSH, but is not found at distances greater than about 300 km from MSH (beyond DZ21 transect). Modes 2 and 4 show a general increase in proportion with distance from the volcano. The proportion of mode 3 (18 microns) peaks at transect 3 (DAVIS); this location corresponds to the secondary mass deposition maximum and observations of ash aggregate fall-out. Mode 2 (58 microns) shows a corresponding decrease in proportion over the secondary mass deposition maximum region, while, mode 4 (3 microns) appears unaffected, and increases with distance from ~10 % to ~20 % mass fraction over the deposit. This trend was also supported by the LALLS particle size data.

Plots showing proportions of particles as a function of size averaged by transect in specific phi size fractions are presented above. Based on gravitational settling, it would be expected that proportions of fine particles increase with distance. However, enhancements in proportions were observed for particles in the size range 5-7 phi (~8-31 microns) along transect 3 (DAVIS), the region of the secondary maximum in mass deposition.

Discussion

It is inferred here that the subpopulation with mode 3 at 18 microns corresponds to the particle size range preferentially involved in ash aggregation. Sorem (1982) collected and analysed aggregates that settled from the MSH80 ash cloud: the ash clusters measured between 0.25-0.5 mm in diameter and were composed of particles from <1 to >40 microns. Theoretical modelling of turbulence-induced collision and coagulation by Shaw and Rose (unpublished manuscript, 2005) identifies an ash particle distribution with a mode at 20 μm as being most susceptible to inertial collisions. The analysis here may provide a link between the inertial collision mechanism and empirical observations.

Carey and Sigurdson (1982) suggested that ash particles less than 63 microns are aggregated; this corresponds to modes 2 and 3 which both illustrate some variation in proportion over the region of the secondary mass deposition maximum. Sorem (1982) states that, "the porous clusters rafted large ash particles great distances and scavenged particles of all sizes as the wind blew them eastward". The enhancement in mode 2 at greater distances may be related to this process, whereby large irregular particles with aerodynamically low terminal fall velocities are carried to greater distances; finer particle distributions (i.e. mode ~18 microns) form aggregates and settle from the cloud earlier.

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