UNIVERSITY OF OKLAHOMA

GRADUATE COLLEGE

AN ICEHOUSE DUST RECORD FROM THE UPPER PALEOZOIC (ASSELIAN-ARTINSKIAN, MOSCOVIAN) AKIYOSHI LIMESTONE (JAPAN)

A THESIS

SUBMITTED TO THE GRADUATE FACULTY

in partial fulfillment of the requirements for the

Degree of

MASTER OF SCIENCE

By

XIAO QI
Norman, Oklahoma
2016

Downloaded from SHAREOK. Persistent Handle URL: https://hdl.handle.net/11244/44224

AN ICEHOUSE DUST RECORD FROM THE UPPER PALEOZOIC (ASSELIAN-ARTINSKIAN, MOSCOVIAN) AKIYOSHI LIMESTONE (JAPAN)

A THESIS APPROVED FOR THE
CONOCOPHILLIPS SCHOOL OF GEOLOGY AND GEOPHYSICS

BY

_____
Dr. Gerilyn S. Soreghan, Chair

_____
Dr. Hiroyoshi Sano

_____
Dr. Michael J. Soreghan

© Copyright by XIAO QI 2016
All Rights Reserved.

Acknowledgements

The work presented here is Xiao Qi's M.S. degree under the supervision of G. S. Soreghan, M. J. Soreghan and Hiroyoshi Sano. This work was funded by a grant from the U. S. National Science Foundation Earth-Life Transitions (ELT) program under grant number EAR-1338331. I am extremely thankful to my advisor Lynn Soreghan for her guidance, advice, support and encouragements in research and study throughout these two years. I am equally thanks to Mike Soreghan and Dr. H. Sano for their advice and support in every aspect of my work. I would like to thank Dr. H. Sano and Ms. Honoka Makino for their extensive help in the fieldwork, and Dr. Masayuki Fujisawa (Akiyoshidai Museum of Natural History) for his arrangement of permission for the fieldwork. I am grateful to Dr. Linda Hinnov and Dr. Ueno for the intellectual aid they supplied on my thesis. Thank you to the undergraduate students, Amy Bailey, Kathleen Baczkowski and Cassidy Wion, for helping me with the many hours of lab work. Thanks to Young Ji Joo and Carlos Carvajal for their times and helps on instruments and lab work. Thank you to Dr. Preston Larson and Curtis Smith with their guidance, support and help in SEM. Thanks for Dr. Roger Slatt for allowing me to use the XRF instrument and thanks to Bryan Turner for his training and help in XRF measurement. Thanks to Alyssa Wickard for her assistance with microscope training and support. Thank you to Robert Turner with his assistance in sample preparation and lab work. A special thanks to my family, friends and fiancé Chijun Sun, for your love and accompany, understanding and support all the time.

Table of Contents

Acknowledgement ..... **iv**

Table of Contents ..... **v**

List of Figures ..... **vii**

List of Tables ..... **viii**

Abstract ..... **ix**

1. Introduction **1**

2. Geologic Background **3**

2.1 Tectonic Setting and Paleogeographic Position of the Akiyoshi Terrane **3**

2.2 Paleoclimatic Setting **4**

2.3 Stratigraphic Setting **5**

3. Methods **7**

3.1 Field Data Collection and Age Determinations **7**

3.2 Petrographic and Compositional Analysis (Whole Rock, and Dust Fraction) .. **7**

3.3 Extraction of the Silicate Mineral (Dust) Fraction **8**

3.4 Grain-Size Analysis **9**

4. Results11

4.1 Facies Analysis **11**

Bioclastic grainstone 11

Bioclastic packstone 12

Chaetetes wackstone 12

Bioclastic mud/wackestone 13

Brachiopod wackestone 13

4.2 Features of Subaerial Exposure **13**

4.3 Fusulinodean Biostratigraphy **15**

4.4 Sequence- and Cyclostratigraphy **15**

4.4 Size, Composition and Stratigraphic Distribution of the Dust Component **17**

5. Discussion **20**

5.1 Origin and Provenance of the Dust Contribution **20**

5.2 Atmosphere Dust Loading from Carboniferous-Permian time **24**

Dust variability in the LPIA Icehouse 24

Dust variability on a glacial-interglacial scale 25

6. Conclusions **27**

Figure Captions 29

References 47

Appendix 1. Stratigraphic section field notes from the Akiyoshi Limestone 56

Appendix 2. D10, D50, D90, maximum, volume weighted mean , standard deviation (μm) and percentage of (<10 μm, 10<x<63 μm, >63 μm, <20 μm, >20 μm) and Ratio of (<20 μm)/(>20 μm) 67

Appendix 3. Modes of upper Asselian, upper Artinskian and middle-upper Moscovian sections..... 75

Appendix 4. Mophologi G3 CE diameter (volume distribution) report 80

List of Figures

Figure 1. Location of Akiyoshi accretionary complex 33

Figure 2. Generalized geologic map of the Akiyoshi Limestone Plateau 34

Figure 3. Paleogeographic locations of the Akiyoshi atoll in the equatorial Panthalassic Ocean during Carboniferous to Permian time 35

Figure 4. Stratigraphic logs of study sections 36

Figure 5. Detailed topographic map of study area showing locations of measured sections (contour interval: 10 m) 37

Figure 6. Illustrations of grain aggregates 38

Figure 7. Photomicrographs of depositional facies 39

Figure 8. Stratigraphic column of upper Asselian-upper Artinskian (GH3) section and middle-upper Moscovian (UHA) section 40

Figure 9. Photomicrographs of features documenting subaerial exposure 41

Figure 10. Smear slide photomicrographs of representative dust samples 42

Figure 11. SEM images of representative non-volcanic quartz grains 43

Figure 12. SEM image and EDX spectrum of andesitic volcanic grains 44

List of Tables

Table 1. Summary of depositional facies 45

Table 2. Average mean, maximum, and standard deviation of dust amount and D(10), D(50), D(90), mode, maximum, volume weighted mean, standard deviation, and volume percentages (vol %) of different size classes (<10 µm, 10<x<63 µm, >63 µm, <20 µm, >20 µm) and ratio of (<20 µm)/(>20 µm) 46

Abstract

The Akiyoshi terrane in southwest Japan consists of a subduction-generated accretionary complex of shallow-marine limestone and deep-water spicular chert, underlain by ocean island-type basalt, all of which was obducted in late Permian (Capitanian-Wuchiapingian) time. The limestone and chert formed as atoll carbonates and slope deposits on and around a basaltic seamount during Viséan to Guadalupian time of the Late Paleozoic Ice Age (LPIA) in the open ocean realm of the Panthalassic ocean. This unusual paleogeography indicates that the Akiyoshi atoll formed isolated from continental terrigenous input excepting that related to eolian delivery. Thus, the detrital fraction preserved in the limestone archives a record of atmospheric dust.

Two stratigraphic sections recording the upper Asselian disconformably overlain by the upper Artinskian and the middle-upper Moscovian of the Akiyoshi Limestone exhibit facies ranging across wackestone, packstone, grainstone and boundstone fabrics, recording shallow marine deposition. Lithofacies variations in all three intervals commonly record repeated upwardly shallowing successions. The Moscovian and Asselian intervals preserve subaerial exposure surfaces interpreted to reflect glacioeustatic lowstands formed during more intense glaciations of the LPIA, whereas the Artinskian interval lacks evidence for subaerial exposure surfaces, consistent with formation at a time when the LPIA was waning.

The dust fraction extracted from the study sections comprises both clay and subrounded to subangular, very fine silt- to fine sand-sized quartz, indicating a

long-transport, continentally sourced eolian dust. Selected horizons contain relatively coarse-grained angular volcanic fragments recording discrete explosive volcanism from differentiated arc sources. The dust content (weight percentage) varies over two orders of magnitude, reflecting greater dust input during the Moscovian and Asselian in general, and during glacials relative to interglacials. Thus, atmospheric dust loading covaries positively with ice volume of the LPIA in general, and at the Milankovitch glacial-interglacial time scale. The most proximal source for the andesitic volcanic input is arc magmatism of the North China block. Furthermore, the grain size mode of the Moscovian dust is much finer (34.50 μm) than that of the Artinskian (139.41 μm), This shift is interpreted to reflect a provenance shift, form arid regions of western equatorial Pangaea to those of eastern equatorial Pangaea.

1. Introduction

Atmospheric dust has been recognized as a key component of the climate system, as it influences Earth's energy balance directly and indirectly. Dust can directly scatter and absorb solar and long-wave radiation, and influence cloud nucleation that can subsequently reflect, scatter or absorb radiation (e.g. Tegen et al., 1996; Sassen et at, 2003; Mahowald et al., 2011). Furthermore, eolian dust deposits form high-resolution archives of climate changes (Muhs et al., 2012), and have been extensively used to aid climate reconstructions of Earth's recent (late Cenozoic) icehouse climate mode. For the Quaternary, dust recovered from marine, lacustrine, and ice core records show that atmospheric dust loading was generally higher during glacial phases relative to interglacial phases, possibly owing to higher wind intensity and glaciogenic dust production, aridity, decreased vegetation and lowered sea level (e.g., Yung et al., 1996; Mahowald et al., 1999; Muhs and Bettis, 2003; Mahowald et al., 2006; Sugden et al., 2009).

Analogous to the late Cenozoic, the late Paleozoic was also an icehouse period, with repeated, high-magnitude, high-frequency glacial-interglacial climate shifts on the 10^5-yr scale, as well as longer-term fluctuations consisting of several-My intervals with more ice separated by intervals of less ice (e.g., Isbell et al., 2003; Jones and Fielding, 2004; Montanez et al., 2007; Fielding et al., 2008). Furthermore, paleo-loess deposits, as well as dust recovered from isolated epeiric sea carbonates that accumulated far removed from fluvial-deltaic influx constitute good potential archives of paleoclimate;

recent research on these types of deposits generally suggests a dustier atmosphere during glacial phases relative to interglacial phases (G. Soreghan et al., 2008, 2015). However, most studies on Carboniferous-Permian paleo-loess/dust deposits are from tropical western Pangea (e.g., Soreghan et al., 2002, 2008; Sweet et al., 2013). An expansion of the Carboniferous-Permian paleoclimate data set is needed to construct more global records of atmospheric dustiness, at both glacial-interglacial and longer resolutions, and thus to understand spatial and temporal patterns of dust distribution regionally to globally, and their climatic implications.

This research focuses on constructing a late Paleozoic ice age (LPIA) dust record for part of the Akiyoshi limestone (Japan) (Fig. 1)—an oceanic carbonate buildup that formed isolated from all terrigenous input, excepting that delivered by atmospheric transport (dust). The Akiyoshi Limestone records deposition in an atoll in the low-latitude Panthalassic Ocean, and thus includes a record of atmospheric dustiness in a truly oceanic setting. This research expands the growing dataset on dust of the Carboniferous-Permian greatly in space, to the far reaches of the Panthalassic, to shed light on global atmospheric dust loading during this interval in general, and at the glacial-interglacial resolution specifically, and to assess possible dust transport pathways, and climatic implications.

2. Geologic Background

2.1 Tectonic Setting and Paleogeographic Position of the Akiyoshi Terrane

The Akiyoshi terrane, located in southwest Japan, composes a subduction-generated accretionary complex consisting of unmetamorphosed Carboniferous to Permian terrigenous and oceanic assemblages (Fig. 1: Kanmera et al., 1990; Sano and Kanmera, 1991). The oceanic assemblage comprises middle Visean to upper Guadalupian shallow-marine limestone and deep-marine spicular chert underlain by basaltic rocks, and the terrigenous assemblage consists of Guadalupian to lower Wuchiapingian trench-fill turbidites (Fig. 2). The oceanic assemblage is inferred to record deposition on and around a volcanic seamount, in the equatorial realm of the Panthalassic Ocean (Fujiwara, 1971; Sano and Kanmera, 1988; Tatsumi et al., 2000; Fig. 3). The shallow-marine limestone succession designated as the Akiyoshi Limestone Group is approximately 1000 m thick (Kanmera and Nishi, 1983; Sano and Kanmera, 1988) and interpreted to record atoll top/flank sedimentation, whereas the deep-water spicular chert is interpreted to record lower seamount-flank and surrounding basinal deposition (Sano and Kanmera, 1988). These shallow-marine and deep-water associations along with trench-fill sediments accreted to an eastern continental margin of Asia in latest Middle to Late Permian time (Kanmera et al., 1990; Sano and Kanmera, 1991).

The Akiyoshi terrane is one of many tectonic units of southwest Japan; these allochthonous units young southwards, reflecting collision and accretion as terranes

and seamounts progressed northward by subduction (Morinaga et al., 1989). The isolated oceanic setting of the Akiyoshi Limestone is inferred on the basis of both the tectono-sedimentary association (described above), and the observation that the limestone grades basinward into siliceous pelagic strata (Kanmera and Nishi, 1983); the terrigenous component appears only in the late Permian, coincident with the obduction event. Early paleomagnetic results from a Pennsylvanian tuff of the Akiyoshi complex suggested deposition in low northern latitudes (reported inclination of 27° for a paleolatitude ~13° N Fujiwara, 1967), and such equatorial results are also reported for the Carboniferous-Permian of other reef-bearing (paleo-atoll) terranes of central Japan (Fujiwara, 1967; Hattori and Hirooka, 1979; Hirooka et al., 1983). However, later paleomagnetic work specifically on the Akiyoshi Limestone (Morinaga et al., 1989) demonstrated pervasive Cretaceous remagnetization of these rocks that preclude a paleolatitudinal determination. Here, we use paleomagnetic results from Permian reef-bearing terranes located north (Mino terrane; inclinations of -16 to 9°; Hirooka et al., 1983) and south (inclination of -24°; Kirschvink et al., 2015) of the Akiyoshi terrane to constrain the paleolatitude to approximately 8°S and 8°N (Fig. 3). This placement also agrees with determinations using biogeography of the fusulinid fauna (Kasuya et al., 2012).

2.2 Paleoclimatic Setting

The Akiyoshi atoll archives climatic and eustatic changes that occurred during

Carboniferous-Permian time (Sano et al., 2004; Nakazawa and Ueno, 2004; Sano, 2006), an interval spanning the onset, peak, and demise of the Late Paleozoic Ice Age (LPIA). The Gondwanan glaciation characterizing the LPIA was first comprehensively investigated in the 1970s (Frakes and Crowell, 1969, 1970; Frakes et al., 1971; Crowell, 1978). Early researchers suggested that a large, long-lived ice sheet covered much of the high-latitude Gondwanan continent extending from Mid-Carboniferous to Early Permian times, with icehouse conditions maximizing around the Carboniferous-Permian boundary (e.g., Veevers and Powell, 1987; Crowell, 1999). More recent work from, in particular, the Australian record suggests the occurrence of several My-long episodes of more- and less-intense icehouse conditions (e.g., Isbell et al., 2003; Fielding et al., 2008). Contemporaneous far-field records in epeiric marine strata exhibit evidence for glacioeustatic variations that appear to similarly record differences in magnitude interpreted to reflect the intensity of icehouse conditions (Rygel et al., 2008). For example, strata from latest Carboniferous-early Permian time exhibit evidence for very large magnitude (> 100 m) glacioeustasy (Soreghan and Giles, 1999) whereas strata from later Permian time record relatively small magnitude (< 25 m) variations (Osleger, 1998).

2.3 Stratigraphic Setting

This study focuses on two sections of the Akiyoshi Limestone: one that includes late Asselian and late Artinskian (early Permian) time intervals separated by a

disconformity surface (GH3 section, named for a nearby guest house), and one spanning part of the middle-upper Moscovian (late Carboniferous) (UHA section, named for the nearby village of Uehata), in the eastern part of the Akiyoshidai Plateau in southwest Japan (Fig. 1). The Asselian falls into one of the proposed icehouse maxima phases of the Permian (P1) defined by Fielding et al. (2008) and Frank et al. (2015), whereas the late Artinskian falls between major glacial intervals according to these authors. The middle Moscovian falls near the end of the last icehouse maxima of the Carboniferous (C4) and before the first maxima of the Permian (P1) defined by Fielding et al. (2008) (Fig. 4).

3. Methods

3.1 Field Data Collection and Age Determinations

Exposures on the Akiyoshidai Plateau consist of pinnacles of massive (predominantly unbedded) limestone, presenting challenges to identifying and measuring age-specific intervals. Published fusulinoidean biostratigraphy (Ueno, 1989) sheds light on the structure of the plateau exposures, and indicates that the entire Akiyoshi Limestone section is overturned (Ueno, 1989), albeit essentially unmetamorphosed. This previous work was used to identify the approximate target sections in the field, and rare exposures of discrete bedding planes were used to assess bedding attitude necessary for measuring the sections using a compass and Jacob's Staff. The target sections were logged and sampled (GH3—22.5m, UHA—16.1m) at decimeter (10-20 cm) resolution (Fig. 5) for petrography, geochemical analyses, and extraction of the silicate mineral (dust) fraction. In the lab, fusulinoidean biostratigraphic analysis (conducted by K. Ueno, 2016) was used for more precise dating to further constrain ages of each section.

3.2 Petrographic and Compositional Analysis (Whole Rock, and Dust Fraction)

Field facies descriptions were supplemented by examination of polished slabs from which thin sections (n=66) were made for detailed description and determination of representative facies and diagenetic attributes. The silicate mineral fraction was examined using smear slide analysis for gross determinations of composition, and

representative samples were examined using an FEI Quanta 250 Scanning Electron Microscope (SEM) for both micromorphology (using secondary electron imaging) and compositional analysis (using Energy-Dispersive X-ray Spectroscopy-- EDS) under accelerating voltage of 20 kV, working distance of ~ 10 mm and spot size of 5.

3.3 Extraction of the Silicate Mineral (Dust) Fraction

For extraction of the silicate mineral fraction (SMF), samples were cleaned of external debris by a 30-second immersion in 1 N HCl followed by physical brushing to remove any debris. Cleaned samples were crushed to gravel size using a rock crusher and washed to remove any adhering small particles. Approximately 300 g of gravel-sized material was then subjected to carbonate dissolution in 2 N HCl. Fresh acid was added every 24 hours until complete dissolution occurred. The insoluble residue was rinsed and then combusted at 500°C for 24 hours for removal of organic matter and oxidation of pyrite iron. Finally, the citrate–bicarbonate–dithionite (CBD) process was used to remove any iron oxides (Sur et al. 2010a). Residues were then checked using a reflected-light microscope and any authigenic silica was removed by hand. At this point the residue is considered to represent detrital (allochthonous) dust. The dust components of representative samples were examined using smear slides as a secondary check for authigenic contaminants, and for rapid assessment of mineralogy (e.g. clay, quartz, rock fragments, others). See Sur et al. (2010a) for detailed methodology.

3.4 Grain-Size Analysis

The commonly small volumes of extracted dust precluded use of a laser particle-size analyzer; hence, grain size was measured using a Malvern Morphologi3 unit. Alcohol evaporation was used to prepare samples dominated by larger grains (>20 μm). For this method, 1-2 ml of 91% alcohol was added into dry sample material and the sample was sonicated for 1 minute. Subsequently, 3-5 drops of this sample slurry were dropped on a glass slide and air dried prior to scanning using the Morphologi G3 instrument. For samples composed of very fine grains (<20 μm), modification was necessary to ensure adequate grain dispersion. For these samples, 10 drops of isooctane were added to 0.5 mg dry sample, to which 1-2 drops of 0.1% lecithin solution (dissolved in isooctane) were added as a surfactant. Samples were then sonicated for 1 minute, and placed onto a glass slide. Samples were then analyzed using the Malvern Morphologi G3 after evaporation of the isooctane.

The Morphologi G3 unit consists of a petrographic microscope with automated stage to enable (2D) size and shape analysis of each particle. Particles are backlit and the silhouettes are auto-scanned to measure a variety of parameters such as circle equivalent (CE) diameter, length, width, perimeter, and area; data analysis then enables calculation of grain size in terms of, e.g. circle equivalent (CE) volume. For samples reported here, the Morphologi3 analyzed 10^3-10^5 grains for each sample (>20,000 grains were analyzed for 65% (upper section) to 80% (lower section) of samples). Filters of elongation (> 0.5), solidity (< 0.8) and convexity (< 0.88) were applied to the

results to eliminate contaminants (e.g. fibers, bubbles) and aggregates (Fig. 6). Grain images were then checked manually to eliminate aggregates and contaminants that were not automatically eliminated. Because the Morphologi3 measures individual particles, data were transformed to volume-weighted circular-equivalent (CE) diameter, as this most closely approximates the output of laser particle-size analysis. For several test samples, sediment size distribution was measured using both the Malvern Morphologi3 (expressed in volume-weighted CE diameter) and the Malvern Multisizer 3000 laser particle-size analyzer (LPSA) to enable direct comparison of the results from these different particle measurement techniques. The comparison indicates that the results for coarser fractions (>20 μm) are similar for both measurement techniques. However, for finer fractions (<20 μm), the Morphologi3 unit yields an average order-of-magnitude coarser result for D10, D50 and D90, than that from the Multisizer 3000 LPSA. Similarly, the volume percent of grains < 10 μm is 2-3 times larger using the Multisizer 3000 LPSA relative to the Morphologi unit, and the volume percent of grains between 10 μm and 63 μm is 2-3 times larger using the Morphologi unit relative to the LPSA.

4. Results

4.1 Facies Analysis

Both study sections represent strata of an atoll-top assemblage of the Akiyoshi Limestone Group, and include wackestone, packstone, grainstone and boundstone fabrics, defined using Dunham's (1962) classification. As noted, all the rocks are massive, predominantly lacking bedding. All microfacies are described and interpreted below and summarized in Table 1.

Bioclastic grainstone

Bioclastic grainstone makes up 45-50% of the studied sections and consist of light grey grainstone (with local packstone pockets) in exposures 0.5-3 m thick. Predominant components comprise fusulinoideans, crinoids, *Tubiphytes*, phylloid algae, bryozoa, ostracods, gastropods, *Donezella* dasycladacean algae and microbrecciated fabrics (Fig. 7A), and ~20% of the grains have either micritized rims or oolitic coatings (Fig. 7B). This facies is commonly associated stratigraphically with the bioclastic packstone facies above and below.

Interpretation-- The well-washed and well-sorted grainstone fabric and presence of micritized to oolitic coatings on allochems that commonly include photozoans record deposition in a high-energy, agitated, shallow-subtidal environment within the photic zone and above wave base. This is interpreted to be the shallowest-water facies documented in the study sections.

Bioclastic packstone

The bioclastic packstone makes up 20-30% of the sections in stratigraphic intervals 0.5-2 m thick, and consists of crinoid fragments, fusulinids, *Tubiphytes*, and phylloid algae, with subordinate bryozoa, ostracods, gastropods, and intraclasts, all set in the sparse lime mud matrix (Fig. 7C). A facies variant occurs containing abundant phylloid algae and dasycladacean algae (Fig. 7D). This facies commonly occurs in vertical association (above and below) with the bioclastic grainstone facies.

Interpretation-- The presence of abundant fragmented allochems that include photozoans indicates deposition in a shallow subtidal (photic) environment under conditions of moderate wave energy.

Chaetetes wackstone

This facies consists of grey, massive wackestone of 0.5-2.5 m thick, and makes up ~15% of the sections. Abundant, large (cm-scale) *Chaetetes* body fossils are visible in polished slabs and thin sections, and common allochems include foraminifera (including fusulinids), and fragmental crinoids, molluscs, bryozoa, phylloid algae, and intraclasts (Fig. 7E).

Interpretation-- The high diversity of allochems that includes photozoans, together with evidence of pervasive microbial activity suggest deposition in a shallow subtidal, mound-core environment within the photic zone.

Bioclastic mud/wackestone

The bioclastic mud/wackestone makes up 5-10% of the sections in occurrences up to 1 m thick, and contains various allochems including fragments of crinoids, phylloid algae, foraminifera and *Tubiphytes*. Facies variants occur consisting of comminuted debris of crinoid and phylloid algae (Fig. 7F) or fusulinids (Fig. 7G). This facies commonly is overlain by bioclastic packstone.

Interpretation-- The normal marine assemblage and high mud content record deposition in a subtidal environment; however, the fragmentation of much skeletal material, and presence of abundant photozoans suggests high-energy conditions within the photic zone.

Brachiopod wackestone

The brachiopod wackestone makes up 2-3% of the section and consists of light grey, massive wackestone with abundant brachiopod spines (Fig. 7H), in occurrences ~20 cm thick. This facies commonly grades upward into the bioclastic packstone facies.

Interpretation-- The abundance of the lime mud matrix, and presence of only heterozoan skeletal debris imply deposition in a low-energy, subtidal environment.

4.2 Features of Subaerial Exposure

In outcrop, selected horizons exhibit blackened crusts and irregular areas of brown

calcite similar to features described from other Pennsylvanian cyclic strata (e.g. Goldstein, 1988; Rankey et al., 1990) and interpreted to record exposure and incipient pedogenesis. Additionally, associated with these horizons, possible *Microcodium* and several vadose diagenetic features occur that document subaerial exposure of the Akiyoshi atoll. In all cases, these features are evident from thin section analysis, as described below. These features occur only in limited horizons within the Asselian and Moscovian sections (Fig. 8), and do not occur in the Artinskian interval.

In thin section, small scale (~200 μm), elongated fan-like blades of brown calcite occur locally (Figs. 9C), and are interpreted as possible incipient *Microcodium*. *Microcodium* more typically appears as elongate, petal-shaped brown calcite prisms, <1 mm in length aggragated into radial clusters (Esteban and Klappa, 1983), and is well documented from upper Moscovian to upper Kasimovian strata of the Akiyoshi Limestone (Sano et al., 2004). *Microcodium* is widely recognized as a sign of emergence, possibly related to fungal or microbial activity (e.g., Klappa, 1978; Kabanov et al., 2008). Features of vadose-zone diagenesis include pendant cements, meniscus cements, and vadose silt (Esteban and Klappa, 1983). Dogtooth meniscus cements form crystal rim overgrowths at or near grain contacts in the positions a water meniscus would occupy (Esteban and Klappa, 1983; Fig. 9B). Pendant cements are recognized as crescent-shaped cements that thicken on the (stratigraphically) lower surfaces of allochems (Esteban and Klappa, 1983; Figs. 9A, B). Vadose silt is a crystal silt deposited as internal sediment in voids (Fig. 9A), interpreted as an indicator of

subaerial exposure and vadose diagenesis (Dunham, 1969).

4.3 Fusulinodean Biostratigraphy

For the GH3 section, most schwagerinids from the lowermost (0-3.5 m) section are *Pseudofusulina firma*, typical of late Asselian and early Sakmarian ages. Above this (5.5-22.3 m above base), *Chalaroschwagerina exilis* and *C. inflate*? were found, which are characteristic of the lower Yakhtashian interval (=early late Artinskian) in the Akiyoshi region.

For the UHA section, we relied upon previous biostratigraphic work conducted by V. Davydov (see Patterson, 2011). Presence of *Kanmeraia eopulchra*, *K. Pulchra*, *Beedeina aff. Elshanica*, *B. distenta* (= *B. akiyoshiensis*), *B. mosquensis*, *B. siviniensis* and *B. quasicylindrica* indicate the UHA section belongs to the upper Podolskian through upper Mychkovian (= middle-upper Moscovian) of the Moscow Basin (Davydov et al., 2010)

4.4 Sequence- and Cyclostratigraphy

The studied sections of the middle-upper Moscovian, upper Asselian, and upper Artinskian intervals exhibit facies variations that record apparent shifts in relative sea level, e.g. from muddy heterozoan-dominant units, recording deposition below wave base, to grainy photozoan-dominant units, containing lithofacies recording deposition within the photic zone. Within the Asselian and Moscovian intervals, evidence for

subaerial exposure (described above) occurs at discrete horizons (Figs. 8); in contrast, within the Artinskian section, alternations of facies recording upward shallowing and abrupt deepening occur, but no signs of subaerial exposure.

Previous authors have also documented apparent facies cyclicity and subaerial exposure features that record water depth changes within intervals of the Akiyoshi Limestone (e.g., Nakazawa and Ueno, 2004; Sano et al., 2004; Sano, 2006; Nakazawa et al., 2011, 2015), and attributed them to late Paleozoic glacioeustasy, but suggested that the Akiyoshi Limestone was less sensitive to high frequency, 10^5 yr glacial-interglacial cyclicity rather than relatively long-term (10^6 yr) changes (Sano et al., 2004). The motif of high-frequency sequences attributed to glacioeustasy is common to other carbonate-mound systems of the late Paleozoic that formed in relatively low latitudes (e.g., Texas-Saller et al., 1994; Tengiz platform- Kenter et al., 2006). Some of the minor facies variations can be attributed to the existence of facies mosaics and random facies migrations within these shallow marine carbonate regions (cf. Kenter et al., 2006). More significant changes are recorded by the presence of subaerial exposure features formed atop subtidal facies, and abrupt, significant facies deepening (e.g. from a near-emergent grainstone to a heterozoan wackestone), although these types of changes occur only in the Asselian and Moscovian sections.

All facies in the studied sections record subtidal deposition. Accordingly, features of subaerial exposure record “abnormal subaerial exposure” in the sense that peritidal facies recording normal progradation are missing, indicating an allogenic forcing, a

common observation in shallow-water carbonates of icehouse intervals (e.g., Wright, 1992; Soreghan, 1997; Read, 1998; Rankey et al, 1999; Burgess, 2016). These surfaces are thus interpreted as high-frequency sequence boundaries that record glacioeustatic lowstands, likely operating at the 10^5-yr scale (Sano et al., 2004). As noted, these abnormal exposure features are limited to the Moscovian and Asselian sections.

4.4 Size, Composition and Stratigraphic Distribution of the Dust Component

The dominant modal grain sizes within the upper Artinskian and upper Asselian sections are fine sand-size (141 μm) and very fine sand-size (90 μm), respectively, whereas coarse silt-size (35 μm) predominates within the middle Moscovian section. Within the Asselian and Artinskian intervals, 30% of the samples exhibit bimodal distributions with a modal average in the fine sand (124 μm) and very fine sand (87 μm) sizes, whereas 48% of samples in the Moscovian section exhibit bimodality with averages modes of 35 μm and 49 μm (Table 2, Appendix 3). Additionally, the proportion of grains finer than 20 μm relative to the amount coarser than 20 μm within the middle Moscovian section is an order of magnitude higher than that within the upper Asselian and upper Artinskian sections (Table 2).

Petrographic studies (reflected light, transmitted light, SEM, EDX) of the dust component from all sections reveal that the dominant components are quartz and clay (Figs. 10A-H), followed by plagioclase, muscovite and biotite, in order of decreasing abundance. Most medium silt- to fine sand-sized quartz grains are subrounded to

subangular in shape (Figs. 11B, 12A, C), with some grains exhibiting clay or muscovite coatings (Figs. 11B, D). Rounded fine sand-sized quartz (Fig. 11A) and angular fine silt-sized quartz (Figs. 11E, F) also occur. Angular quartz grains in the coarse silt to very fine sand size (63-125 μm) also occur, but are not common, and their size, and angularity indicate a volcanic origin (cf. Smythe et al., 2008; Sur et al., 2010b). Authigenic quartz characterized by doubly terminated crystals (> 200 μm) occurs in only one sample. Owing to their abundance in this sample, this data point was eliminated from the dust amount analysis and interpretation. The abundance may reflect an input of highly reactive siliceous material, such as volcanic dust (cf. Sur et al., 2010b). Large (up to 5 mm), angular to subangular rock fragments (quartz and plagioclase, with accessory Fe-Ti phases Fig. 12) were found at 3 horizons in the study sections (Fig. 8). The size, angularity, and composition (andesitic) of these rock fragments indicate an explosive volcanic origin for this material.

In an effort to focus on the possible climatic significance of the non-volcanic dust component, the dust fractions from the three horizons exhibiting an obvious volcanic contribution are eliminated from the stratigraphic analysis. After eliminating these samples, the amount (weight percent; wgt %) of dust in the study sections varies over more than 2 orders of magnitude, ranging from below detection limits to 0.170 wgt % (Fig. 8), and exhibits a non-uniform stratigraphic distribution. The Artinskian section exhibits the lowest dust concentrations ($\bar{\chi} = 0.0018\%$), whereas the Asselian section is twice as dusty ($\bar{\chi} = 0.0040\%$), and the Moscovian section archives a mean dust

content ($\bar{\chi} = 0.0119\%$) an order of magnitude higher than the other two. Details of these dust contents appear in Table 2. The middle-upper Moscovian section exhibits a weight percent mean and maximum of 0.0119% and 0.1685% (detailed in Table. 2). Dust spikes (without a visible volcanic component) of 0.01-0.045 wgt % appear within the upper Asselian and upper Artinstkian sections (Fig. 8) whereas the middle-upper Moscovian section exhibits spikes of 0.03-0.17 wgt % (Fig. 8). For the Asselian and Moscovian sections, the dust fraction increases at or near (within ~50 cm) inferred high-frequency sequence boundaries, marked by evidence for vadose diagenesis (Fig. 8).

5. Discussion

5.1 Origin and Provenance of the Dust Contribution

The paleogeographic setting of the Akiyoshi Limestone as a paleo-atoll implies that this system developed far removed from any source of detrital (fluvial, deltaic) siliciclastic input excepting that delivered by eolian transport. Additionally, the facies observed all record atoll-top, shallow-marine deposition bathymetrically far above possible slope and basinal turbidite flow. Thus, the siliciclastic input can be taken to record atmospheric dust additions to this system. However, the dust data reveal two distinct sources for the atmospheric input: a volcanically derived mineral dust, and a non-volcanic (continental) mineral dust.

Localized (3) occurrences of angular clasts of intermediate-felsic (andesitic) composition, and angular quartz indicate derivation from a volcanic source that incorporated continental (differentiated) material. All previous work places the Akiyoshi paleoatoll in low latitudes of the western Panthalassic Ocean (e.g., Fujiwara, 1967; Sano et al., 2004; Kasuya et al., 2012), with the nearest continental blocks (North China, South China, and IndoChina) located farther west and south, bordering the Paleo-Tethys Ocean. For Pennsylvanian (Moscovian) time, the placement of the North China microcontinent varies, with some authors depicting an equatorial-southern equatorial position (Cocks and Torsvik., 2013), and others depicting a position in low- to low-mid northern latitudes (e.g. Metcalfe, 2006; Boucot et al., 2013). Regardless, continental arc subduction and associated volcanism is well documented associated

with the (northern margin of the) North China craton against terranes of Mongolia (Xiao et al., 2003; Cope et al., 2005; Zhang et al., 2011) for Carboniferous-Permian time, as well as the southern margin as well for Permian time (Eizenhofer et al., 2014; Zhang, 2007; Zhang et al., 2011; Qing et al., 2012). Data also document both Carboniferous and Permian volcanism associated with ocean-continent subduction along the northern margin of Indochina associated with its convergence with South China (Kamvong et al., 2014; Manaka et al., 2014).

In contrast to this volumetrically minor explosive volcanic component, most samples of the dust fraction from the Asselian-Artinskian section consist of subangular-subrounded quartz (some with clay coatings) and plagioclase grains, with circular-equivalent modal grain sizes within the very fine to fine sand fraction (average modal range of 86-141 μm). The Moscovian (and to lesser degree, Asselian) sections record more voluminous dust input composed of quartz, plagioclase and clay-sized materials, but finer grain sizes (average modal range of 34-49 μm) than the Artinskian section (86-141 μm). This fraction reflects a felsic contribution interpreted to record deposition from predominantly non-volcanic continental regions capable of sourcing dust. Assessment of possible dust sources requires consideration of the positions of the paleo-atoll through the time slices sampled, to gauge distances to continental regions, as well as consideration of whether those regions were sufficiently arid to source dust.

As previously established, we know that the Akiyoshi terrane ultimately collided

with South China in Wuchiapingian time (260 Ma; Kanmera et al., 1990; Sano and Kanmera, 1991), and previous paleolatitudinal arguments place the terrane at low (<10°) northern latitudes at time of collision (Kanmera et al., 1990; Sano and Kanmera, 1991). The Akiyoshi atoll was part of a seamount chain that migrated north-northwest (Maruyama, 1997; Kasuya et al., 2012), analogous to the motions determined for similarly aged paleoatolls of the Panthalassic that accreted to Japan (Kirschvink et al., 2015). Hence, using an average plate motion of 5 cm/yr, and taking the age of the (upper) Artinskian study section as ~280-283 Ma yields ~1000 km of plate motion from late Artinskian to Wuchiapingian time, and another 1250-1500 km of plate motion from mid-late Moscovian (~308-311 Ma) to Artinskian time. These approximations guided the positions depicted on Figure 3, which show the north-northwest trajectory of the Akiyoshi atoll from Moscovian to Artinskian time.

The position of the Akiyoshi atoll within the low-latitude western Panthalassic Ocean throughout the ~25 My interval places it within the equatorial easterlies in a zonal climate system, with the nearest continental regions to the east located in western Pangaea, a distance of 10,000-12,000 km. For Moscovian time, arid regions existed in low (<5°) northern latitudes and relatively low (15-30°) southern latitudes of equatorial Pangaea (Boucot et al., 2013). Thus, dust transport from these regions would require very long transport distances, but modern examples exist of deposition of long-transport, fine-grained (<20 μm) siliciclastic dust hosted on, e.g. basaltic oceanic islands (e.g. Beget et al., 1993; Mizota and Mtsuhisa, 1995; Maher et al., 2010). In

some cases, even rare associated “giant” grains (>>20 μm) can be transported long (>2000-10,000 km) distances (e.g. Beget et al., 1993; Arimoto et al., 1997; Maher et al., 2010; Jeong et al., 2014). Prospero (1999) noted that dusts tranported long distances are characterized by a substantial fraction of material in the fine (<10 μm) size range. A long transport distance is consistent with the very fine-grained character of dust in the Moscovian section.

In contrast, the dust of the Artinskian section exhibits much coarser sizes, yet the northwestward trajectory of the Akiyoshi terrane would have placed it farther from dust sources of western Pangaea from Moscovian to Artinskian time. This significant shift in size modes suggests a more proximal source, but the nearest continental fragments to the west were South China and North China, and Indochina to the south (Fig. 3). However, for Carboniferous (Bashkirian) to late Permian times, the North and South China blocks and Indochina block contain sedimentary paleoclimate indicators of ever-wet conditions (e.g., bauxite, coal), or were submerged (marine shale/carbonate; Liu, 1990; Shangyou, 1991; Fontaine and Workman, 1978; Boucot et al., 2013). Paleoclimate indicators from the North China block include both humid and some arid indicators beginning in Artinskian time (Liu, 1990; Cope et al., 2005; Boucot et al., 2013). Cope et al. (2005) attributed the loss of coal-bearing deposits in North China in mid-late Permian time to aridification associated either with uplift, or northward migration of North China into the arid belt. Hence, it is possible that parts of the North China block could have supplied dust to the Akiyoshi atoll by Artinskian time.

Alternatively, arid regions pervaded subtropical-tropical latitudes of western and eastern Pangaea by the Artinskian, such that arid regions located northwest of the Paleo-Tethys (Fig. 3), ~5000-7000 km west of the Akiyoshi, could have also supplied dust, albeit such long-transport dust should be very fine grained. Whether the source was North China, or eastern equatorial Pangaea, dust from these regions requires westerly transport at equatorial latitudes.

5.2 Atmosphere Dust Loading from Carboniferous-Permian time

Dust variability in the LPIA Icehouse

The overall dust amount and the proportions of non-volcanic coarse grains vary among the three sections, with the Moscovian section significantly dustier than the younger sections, and the Asselian dustier than the upper Artinskian section, albeit the Asselian section contains limited data. Yet all three time intervals contain very shallow-water, photic-zone facies, so the differences cannot be attributed to significant differences in depositional environment, and thus rates of carbonate accumulation. Furthermore, all three developed in a paleo-atoll setting, far from continental dust sources, so fluctuations in dust source distances driven by changes in shoreline positions (eg. glacial-interglacial) should have been minimal as well. We thus interpret these differences in dust content to reflect real differences in atmospheric dust loading. The Moscovian section exhibits evidence for abnormal subaerial exposure recorded by vadose diagenetic features and rare macroscopic evidence for subaerial exposure (eg.

blackened crusts), which are absent in the upper Artinskian section. These subaerial exposure surfaces reflect a significant influence of glacioeustatic forcing, consistent with the inference that (at least part of) the Moscovian records a time of more marked icehouse conditions, with larger-magnitude glacioeustatic variations, than the global climatic conditions of the Artinskian (Isbell et al., 2003; Fielding et al., 2008). The overall (average) higher dust amount within the middle-upper Moscovian section is interpreted to reflect generally dustier atmospheric conditions during this colder interval of the LPIA.

Dust variability on a glacial-interglacial scale

In addition to recording generally dustier conditions overall, the middle-upper Moscovian interval, which exhibits significant evidence for abnormal subaerial exposure (Fig. 9) interpreted to record glacial lowstands (Fig. 8), also records a glacial-interglacial variability in dustiness. The stratigraphic distribution of the dust fraction indicates peak dust input at or near sequence boundaries, which reflect lowstand (glacial) phases, and thus dustier glacials relative to interglacials. This general relationship of higher atmospheric dustiness during glacials is well documented from the Quaternary (Thompson et al., 1995; Harrison et al., 2001; Anderson et al., 2006; Maher et al., 2010). Possible drivers for this could include the increased intensity of aridity, dust production, thermal gradients (driving winds), and exposure of potential dust source areas, and decreased vegetation and lowered sea level during glacial

intervals (e.g., Yung et al., 1996; Mahowald et al., 1999; Broecker and clark, 2002; Muhs and Bettis, 2003; Mahowald et al., 2006; Sugden et al., 2009; McGee et al., 2010; Muhs et al., 2012). For the past 500,000 years, heightened glacial-stage dustiness is even documented for the remote regions of the modern equatorial Pacific and in Antarctica (Winckler et al., 2008), suggesting that dust loading correlated with global ice volume, and records an interhemispheric response to glacial-interglacial climate change.

6. Conclusions

(1) The silicate mineral fraction extracted from shallow marine carbonate strata of the middle Moscovian, upper Asselian and upper Artinskian intervals within the Akiyoshi Limestone record input of atmospheric dust of both volcanic and non-volcanic (continental) sources.

(2) The significantly higher dust fractions present within the middle Moscovian section relative to the Artinskian interval indicates dustier conditions overall in the Moscovian relative to the Artinskian. This correlates to more intense icehouse conditions and may reflect the greater ice volume and thus generally more arid atmospheric conditions during Moscovian time.

(3) The presence of subaerial exposure features developed on subtidal carbonates in the Moscovian (and Asselian) sections record glacial lowstands associated with glacioeustasy. The coincidence of dust peaks in proximity to intervals of exposure indicates that glacial phases were characterized by increased atmospheric dustiness relative to interglacials, even in this remote tropical oceanic region.

(4) During the late Carboniferous-Permian, volcanism associated with ocean-continent subduction took place 3000-4000 km west of the Akiyoshi atoll associated with the North China block, South China block and Indochina block. This is the nearest possible source for the angular volcanic debris of intermediate composition recovered from the Akiyoshi system that records explosive volcanic activity.

(5) The nearest sources for the non-volcanic dust must be continental areas that

were a) emergent, and b) characterized by (paleo)climatic conditions that would promote emission of siliciclastic dust. The nearest continental blocks of North China, South China and Indochina were either submerged or humid for late Carboniferous to late Permian times, implying that the non-volcanic dust component was most likely sourced from arid regions of western equatorial Pangaea for the Moscovian, which is characterized by a generally very fine grained dust fraction, and eastern Pangaea for the Artinskian, which is characterized by a much coarser-grained dust contribution.

Figure Captions

Figure 1. Location of the Akiyoshi accretionary complex in Yamaguchi Prefecture, southwest of Japan (modified from Nakazawa et al., 2015).

Figure 2. Generalized geologic map of the Akiyoshi Limestone Plateau (modified from Nakazawa et al., 2015, and Kanmera and Nishi, 1983). Location of study area highlighted in black rectangle.

Figure 3. Carboniferous-Permian paleogeographic maps with position of the Akiyoshi atoll (solid and open stars). Dashed arrow shows the trajectory of the Akiyoshi atoll from Moscovian to Artinskian time (see text for explanation of position and motion of the atoll over the time interval studied). The Akiyoshi atoll accreted to the eastern continental margin of the South China (SC) block in Capitanian-Wuchiapingian time (Fujiwara, 1967; Sano and Kanmera, 1988; Tatsumi et al., 2000). Arc subduction is documented within the northern and southern margins of the North China (NC) block for Carboniferous-Permian time. The SC block subducted beneath the Indochina (IC) block associated with volcanism during late Carboniferous-middle Permian time (see text for additional explanation). A) Late Carboniferous (Bashkirian-Moscovian) time interval. Arrows indicate zonal easterlies. Solid star indicates the position of the Akiyoshi atoll in middle-late Moscovian time. B) Middle-late Permian (Artinskian-Lopingian) time interval. Arrows indicate inferred westerlies (see text for

explanation). Open star indicates the position of the Akiyoshi atoll in late Artinskian time. Base maps of continental positions and climate belts are modified from Boucot et al., 2013.

Figure 4. Stratigraphic framework of the Carboniferous-Permian Akiyoshi Limestone, with study sections highlighted (GH3: upper Asselian and upper Artinskian sections; UHA: middle Moscovian section). Ages of upper Asselian-upper Artinskian section and middle Moscovian section rely on fusulinid biostratigraphy conducted by K. Ueno (2016) and V. Davydov (2011), respectively. Timescale is from stratigraphy.org.

Figure 5. A) Detailed topographic map of study area showing locations of measured sections (contour interval: 10 m). GH3 section (22.5 m) is named for a nearby guest house; UHA section (16.1 m) is named for the nearby village of Uehata. B,C) Field photos of outcrops of GH3 (upper Asselian and upper Artinskian) and UHA (middle-upper Moscovian) sections.

Figure 6. Grain aggregate images taken using the Morphologi3 measurement. Filters of elongation (>0.5), solidity (<0.8) and convexity (<0.88) were applied before manually checking the grain images and eliminating aggregates and other contaminants.

Figure 7. Photomicrographs of depositional facies. A) Brachiopod wackestone facies. B, C) Bioclastic mud/wackestone facies of two variants consisting of crinoid and phylloid algae debris or fusulinids. D) Chaetetes wackestone facies. Note the large

Chaetetes body fossils. E, F) Two variants of the bioclastic packstone facies. A facies variant occurs containing aboundant phylloid algae and dasycladacean algae. G, H) Bioclastic grainstone facies. Note the micritized rims and oolitic coatings in H.

Figure 8. Measured stratigraphic sections of the upper Asselian, upper Artinskian and middle-upper Moscovian intervals. Columns illustrate dust weight percent. Inferred sequence boundaries are indicated, based on occurrence of macroscopic and (more commonly) microscopic signs of exposure. Occurrences of angular, giant volcanic grains are marked in red. Dust weight percent, grain size, ratio of grains (<20 μm)/(>20 μm) appear beside each stratigraphic column. Examples of volume-based grain size distributions are shown at right.

Figure 9. Photomicrographs of vadose diagenesis features indicating subaerial exposure. A) Pendant cements (p) and vadose silt (vs). B) Meniscus cements (m) between two grains and pendant cement. C) Elongated fan-like blades of brown calcite, possible Microcodium (mi). D) Isopachous rim cement of bladed calcite.

Figure 10. SEM images of representative grains. A) Rounded fine sand size quartz grain B) Subrounded-subangular very fine sand size quartz grain C) Subangular very fine sand size quartz grain with clay coating. D) Subrounded quartz grain with muscovite coating. E, F) Angular fine silt-size quartz.

Figure 11. SEM image and EDX spectrum of an angular volcanic rock fragment. The

EDX spectrum from three points reveals different minerals (1- calcic plagioclase; 2- Mg-silicate (amphibole?); 3- quartz), indicating an intermediate (andesitic) rock composition.

Figure 12. Smear slide photos of representative dust. A, C, E, G were taken in plane light and B, D, F, H are the corresponding cross-polarized views. A, B, C, D) Angular-subangular quartz and plagioclase grains from the upper Artinskian section; E, F, G, H) Subangular-subrounded quartz and plagioclase grains with clay particles from the middle-upper Moscovian section. A, C, E, G) Quartz grains are transparent with no cleavage, and plagioclase grains are light brown under plane-polarized light, reflecting significant alteration. Note very fine-grained dust faintly (especially) visible in E.

Figure 1. Location of Akiyoshi accretionary complex

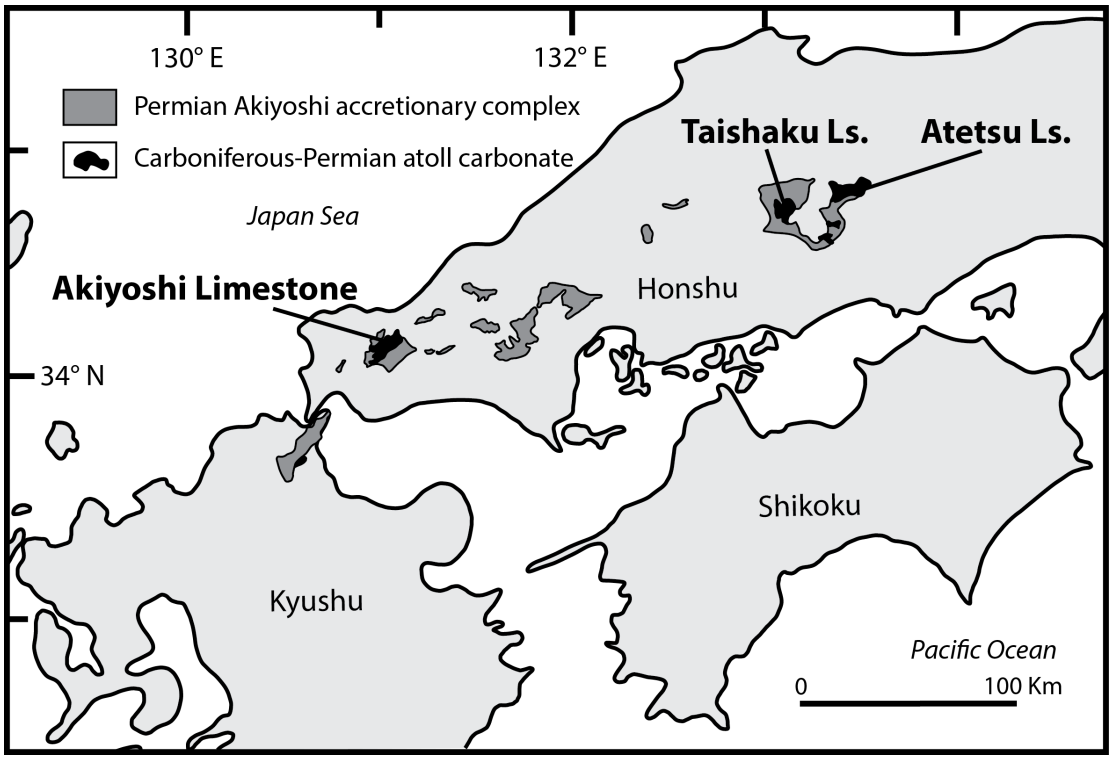


Figure 2. Generalized geologic map of the Akiyoshi Limestone Plateau

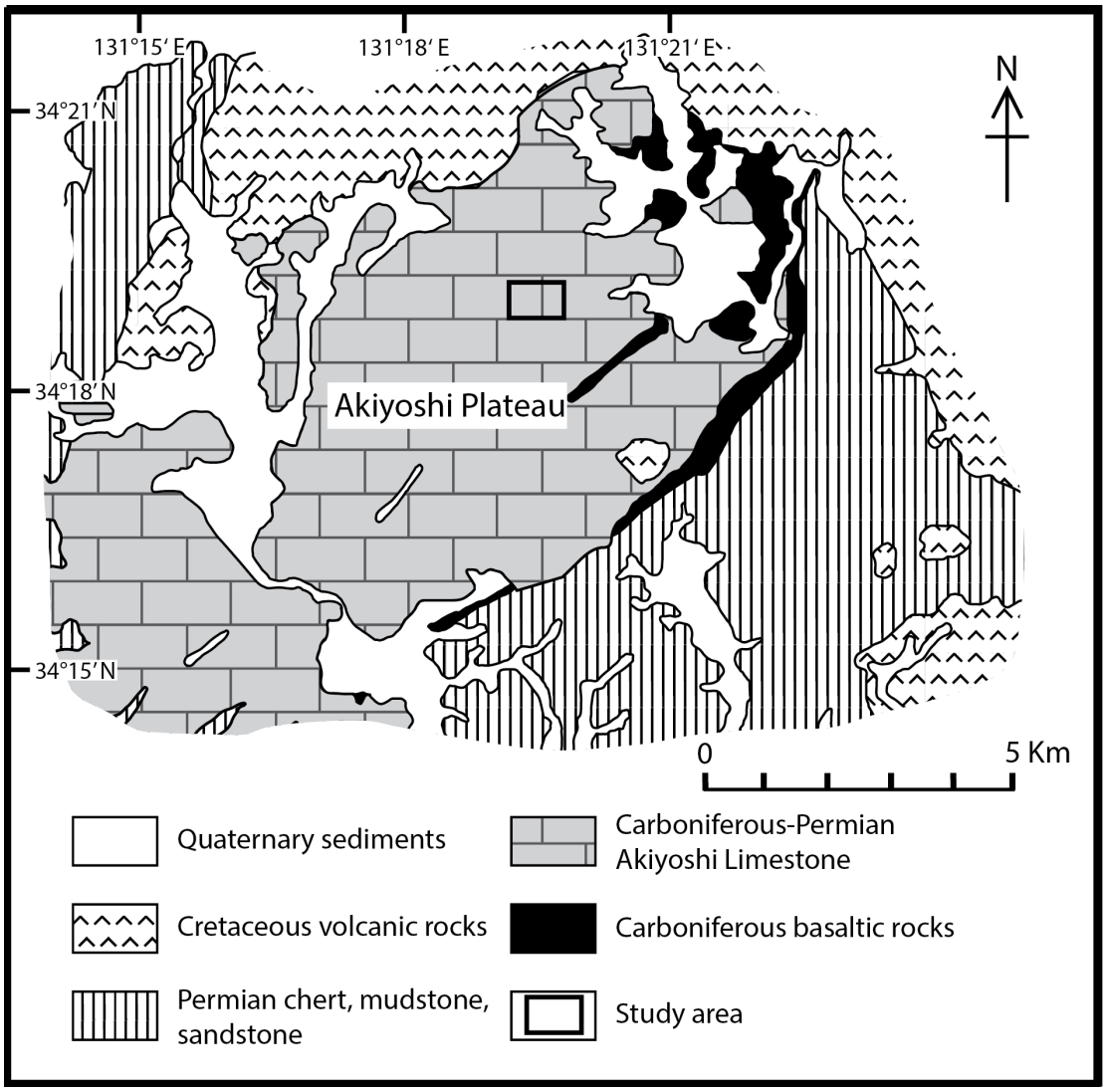


Figure 3. Paleogeographic locations of the Akiyoshi atoll in the equatorial Panthalassic Ocean during Carboniferous to Permian time

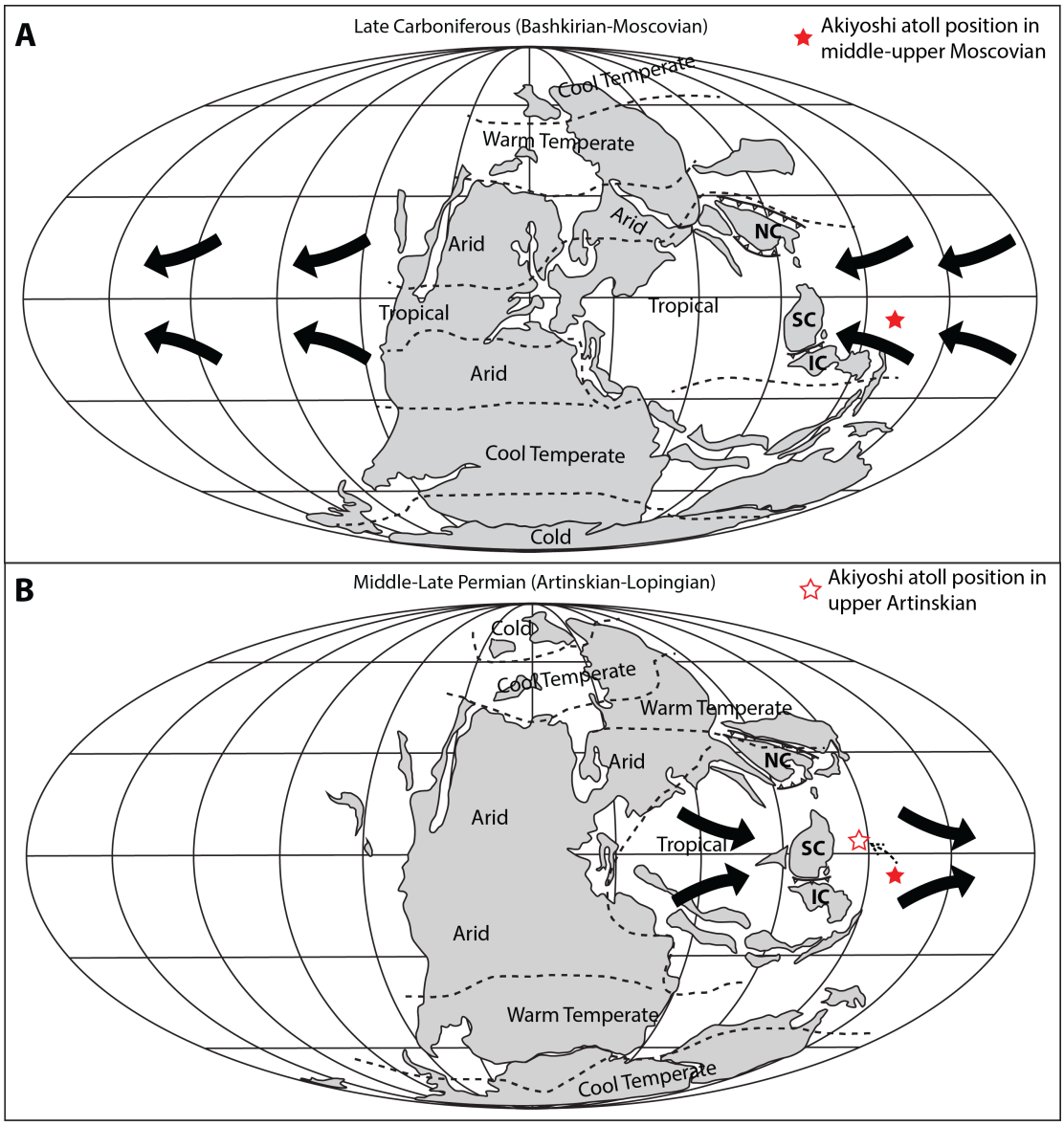


Figure 4. Stratigraphic logs of study sections

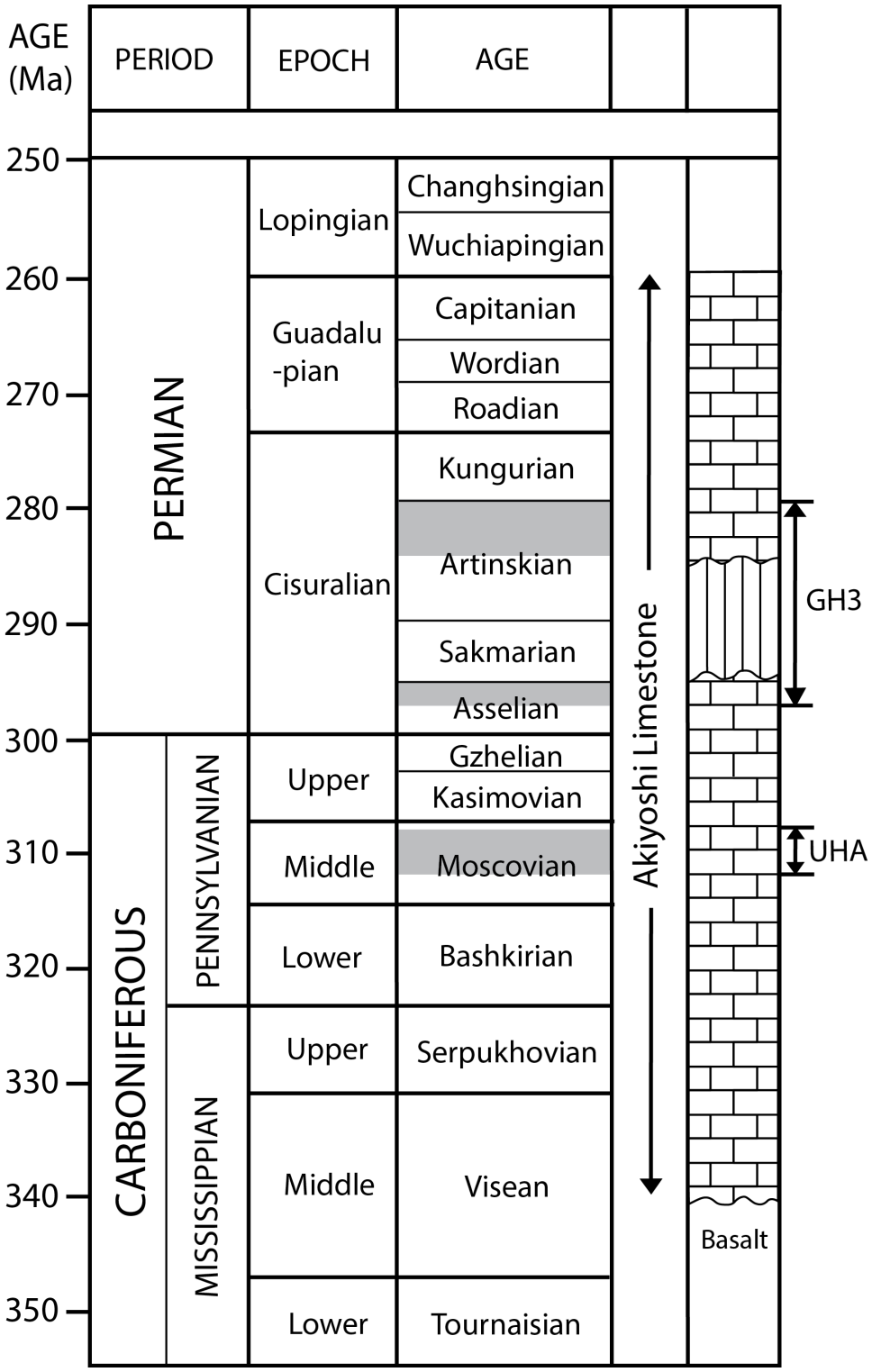


Figure 5. Detailed topographic map of study area showing locations of measured sections (contour interval: 10 m)

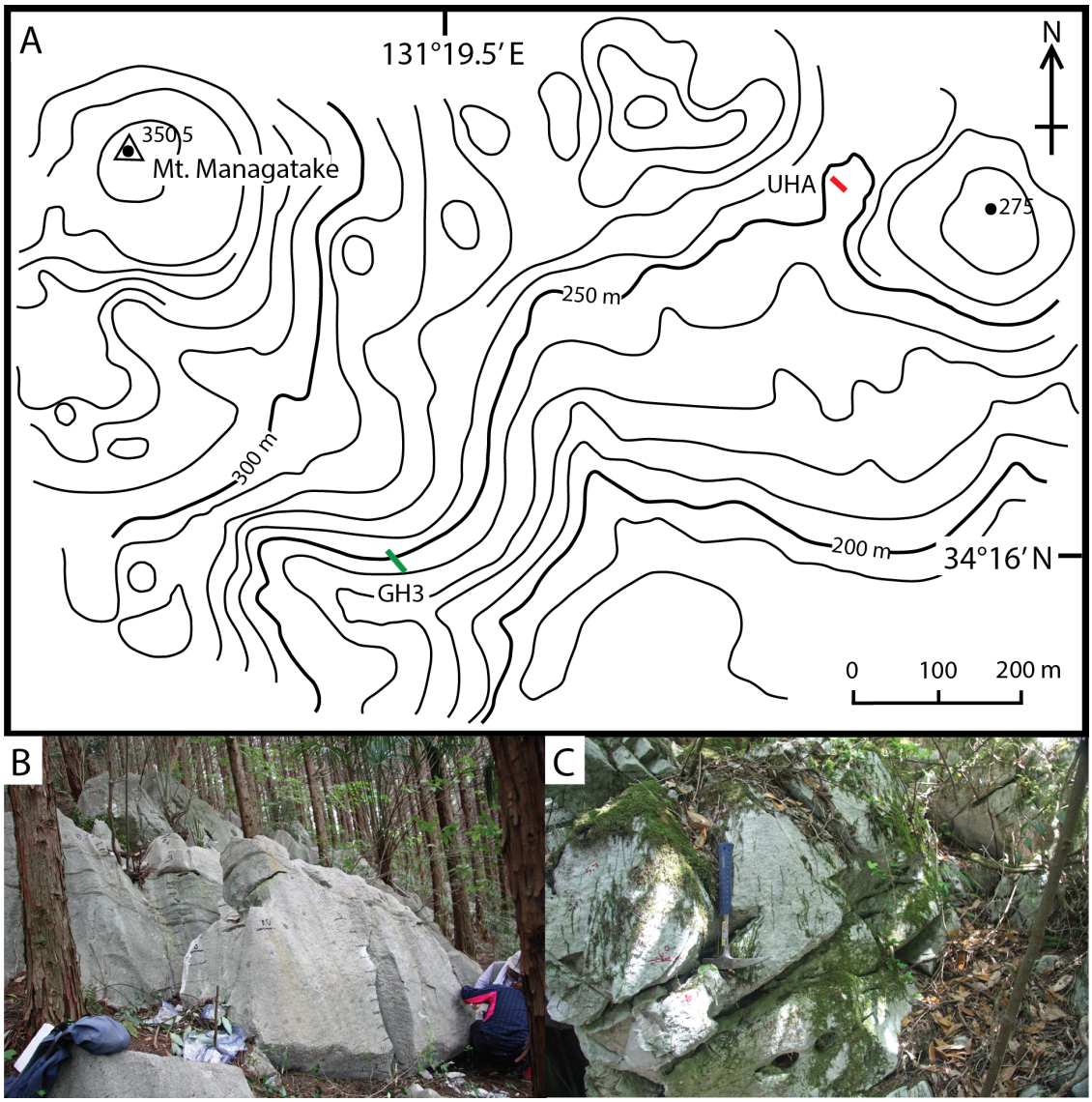


Figure 6. Illustrations of grain aggregates

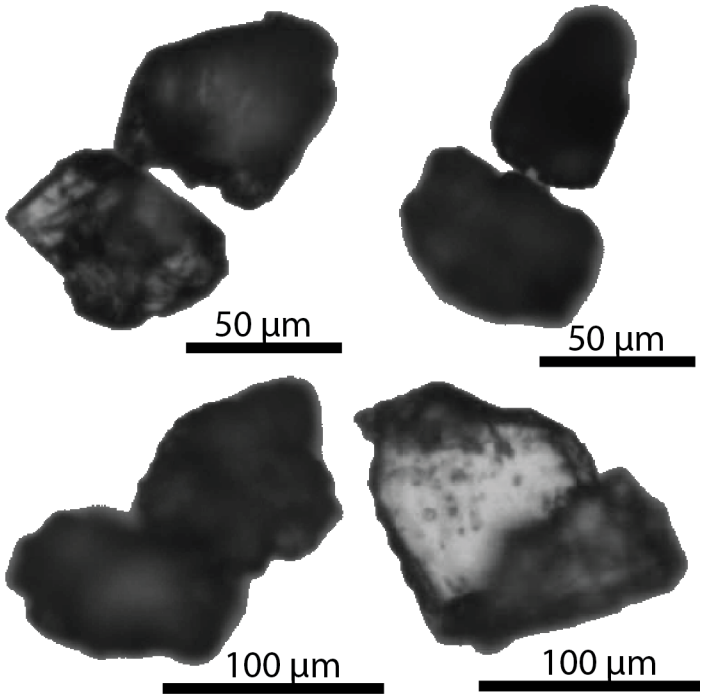


Figure 7. Photomicrographs of depositional facies

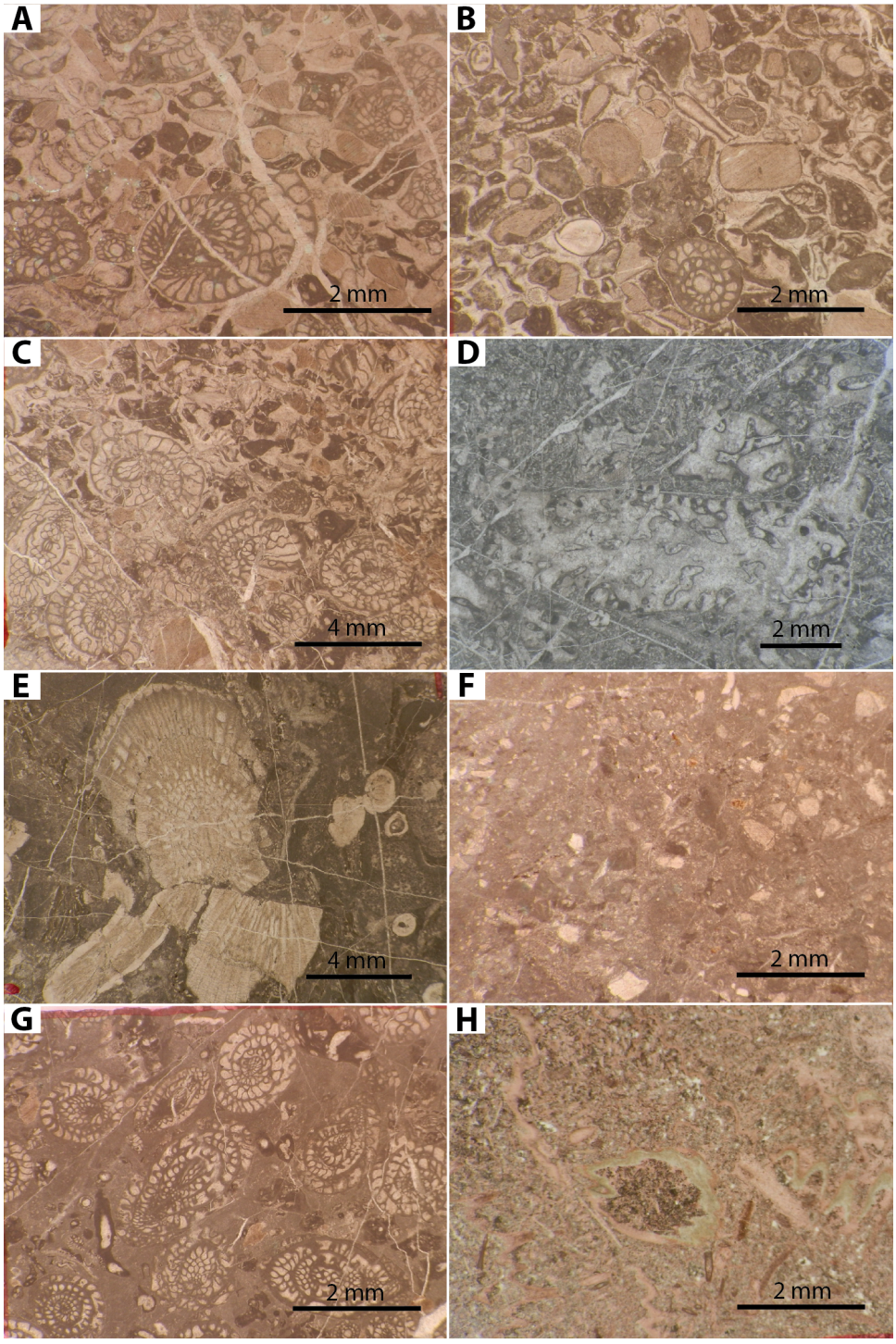


Figure 8. Stratigraphic column of upper Asselian-upper Artinskian (GH3) section and middle-upper Moscovian (UHA) section

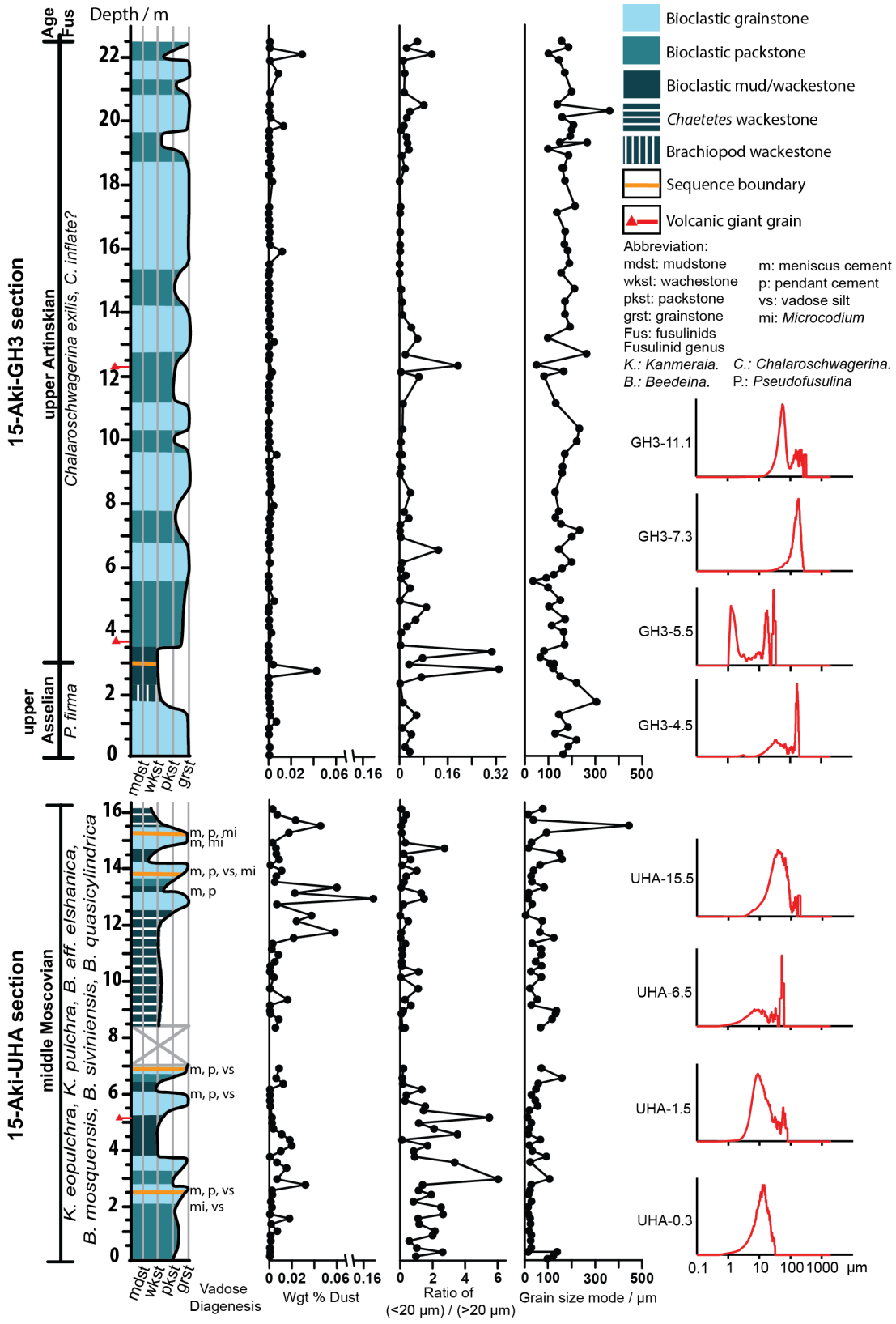


Figure 9. Photomicrographs of features documenting subaerial exposure

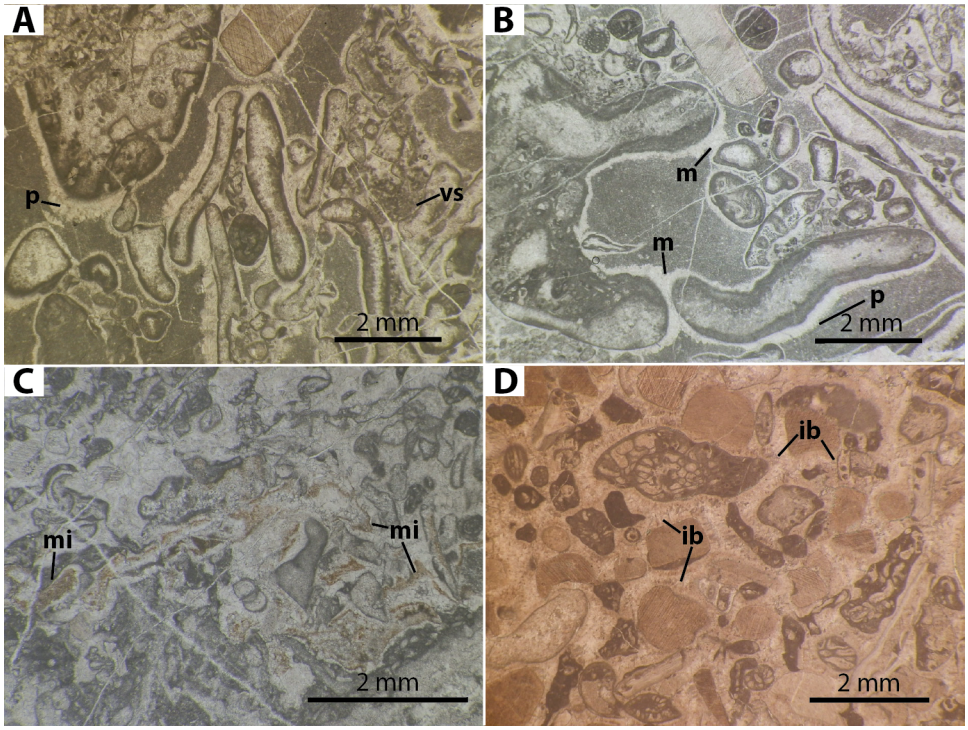


Figure 10. Smear slide photomicrographs of representative dust samples

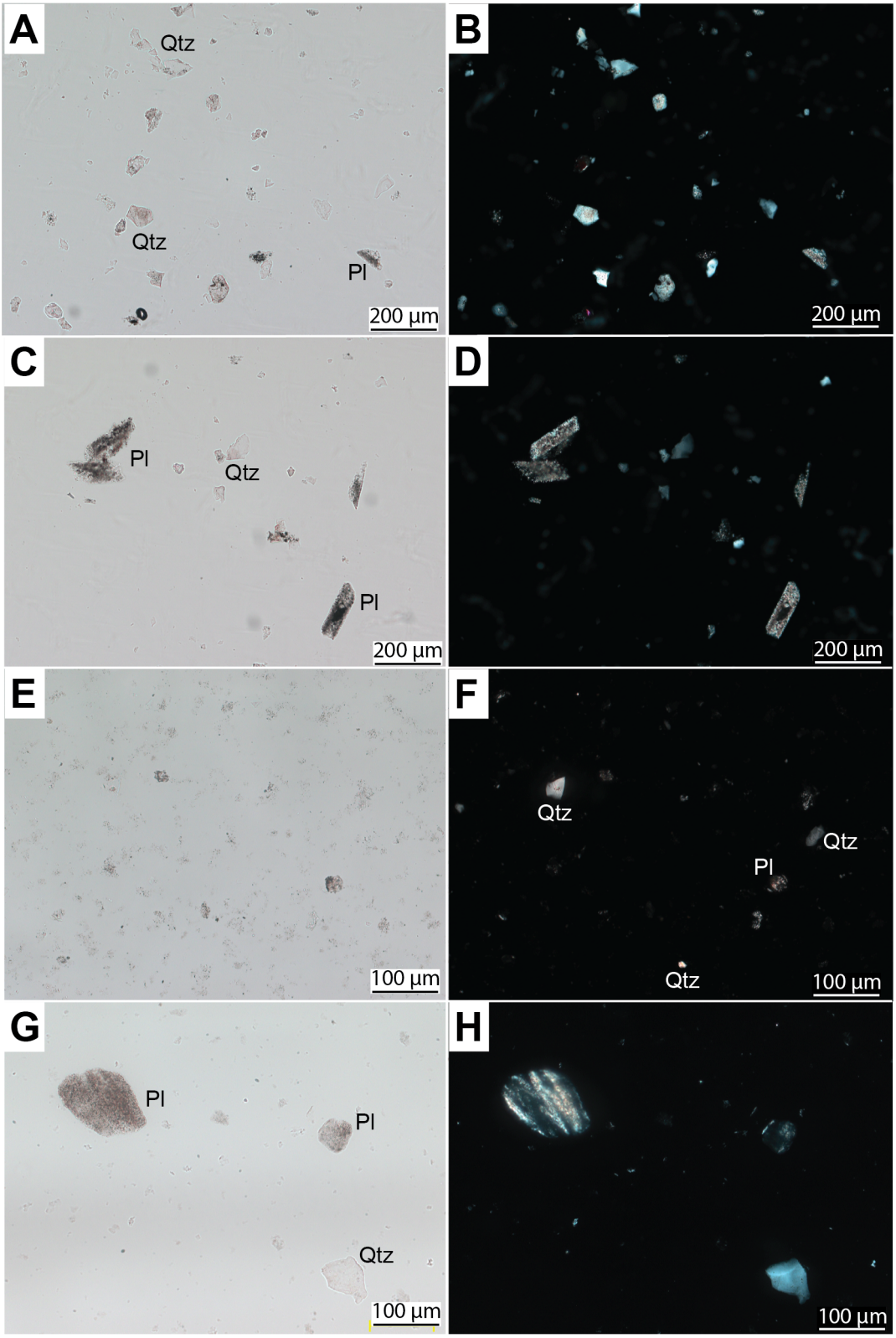


Figure 11. SEM images of representative non-volcanic quartz grains

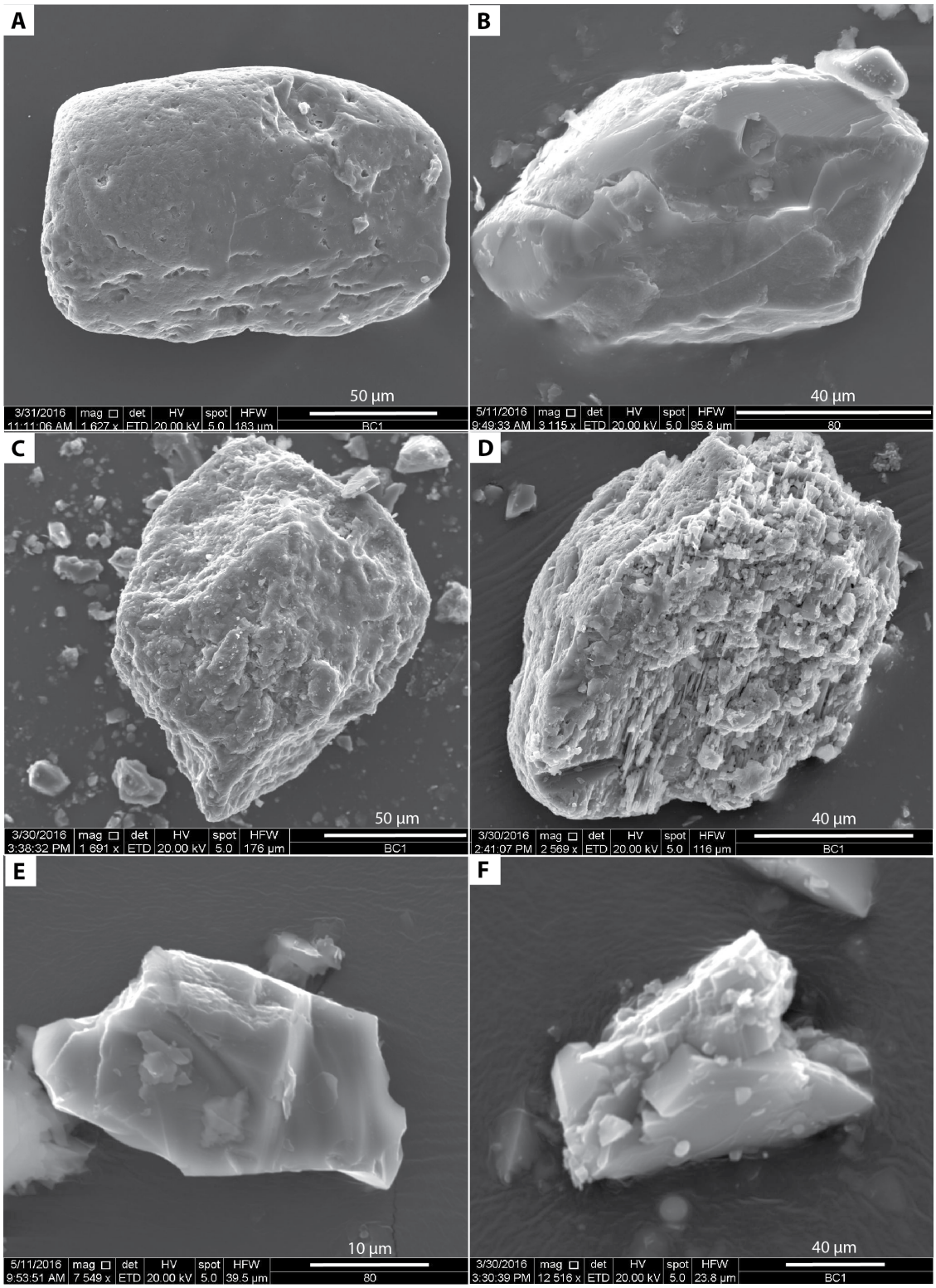


Figure 12. SEM image and EDX spectrum of andesitic volcanic grains

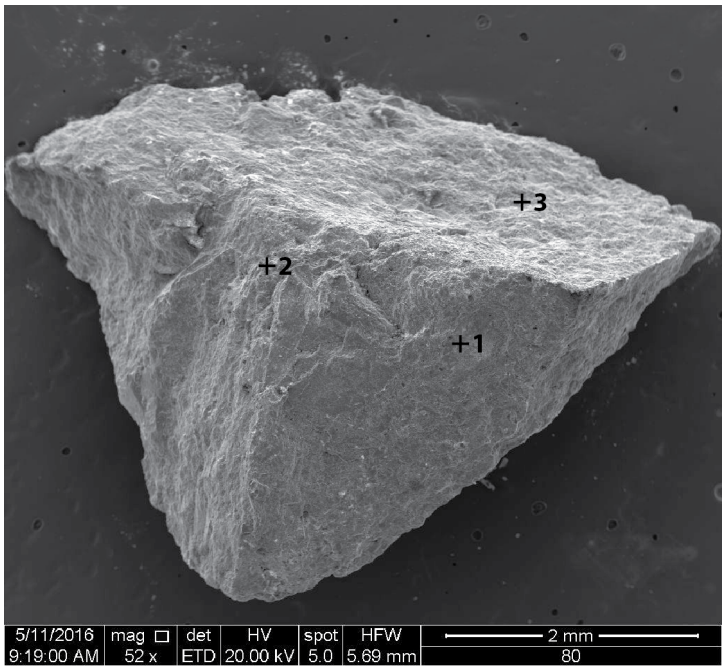


Table 1. Summary of depositional facies

Facies name	Grain type	Structure	Environment	Association
Brachiopod wackestone	Abundant brachiopod spines; common forams	Massive	Low energy, restricted shallow subtidal	Subjacent with bioclastic mud/wackstone facies above through gradational contact
Bioclastic mud/wackestone	Abundant fragments of crinoids, phylloid algae, foraminifera and Tubiphytes. Facies variants occur consisting of comminuted debris of crinoid and phylloid algae or fusulinids	Massive;	Higher energy and photic zone conditions	Subjacent with bioclastic packstone facies
Chaetetes wackestone	Abundant, large (cm-scale) Chaetetes; common foraminifera (including fusulinids), and fragmental crinoids, molluscs, bryozoa, phylloid algae, and intraclasts	Massive	Shallow subtidal, mound-core environment within the photic zone	Subjacent with bioclastic packstone facies
Bioclastic packstone	Common crinoids, fusulinids, Tubiphytes, phylloid algae; subordinate bryozoa, ostracods, gastropods, calcispheres.	Massive	Moderate energy shallow subtidal (photic) environment	Sub- and superjacent with bioclastic grainstone facies
Bioclastic grainstone	Fusulinids, crinoids, *Tubiphytes*, phylloid algae, bryozoa, ostracods, gastropods, *Dvinella* and/or *Donezella* algae. ~20% grains exhibit either micritized rims or oolitic coatings	Massive;	High-energy, agitated, shallow-marine environment within the photic zone and above wave base	Sub- and superjacent with bioclastic packstone facies below and above

Table 2. Average mean, maximum, mode range and standard deviation of dust amount and D(10), D(50), D(90), mode, maximum, volume-weighted mean, standard deviation, and volume percentages (vol %) of different size classes (<10 µm, 10<x<63 µm, >63 µm, <20 µm, >20 µm) and ratio of (<20 µm)/(>20 µm) particles

Dust Weight %	Mean	σ	Maximum
Artinskian	0.0018	0.0039	0.0299
Asselian	0.0040	0.0108	0.0426
Moscovian	0.0119	0.0233	0.1685

Average grain size	D (10) /µm	D (50) /µm	D (90) /µm	Average mode /µm	Maximum /µm	Volume weighted mean/ µm	σ	vol % <10 µm	vol % 10-63 µm	vol % >63 µm	vol % <20 µm	vol % >20 µm	ratio of (<20µm)/(>20µm)
Artinskian	47.13	110.67	182.34	141.33	211.92	113.61	8.12	2.65	24.06	73.30	6.18	93.82	0.15
Asselian	41.32	101.85	165.56	90.20	176.80	104.39	4.39	9.06	24.55	66.39	16.56	83.44	0.68
Moscovian	8.23	23.53	50.83	34.93	66.62	26.89	2.32	29.23	61.17	10.26	54.91	45.09	5.04

References

Anderson, R., Fleisher, M. and Lao, Y., (2006). Glacial–interglacial variability in the delivery of dust to the central equatorial Pacific Ocean. *Earth and Planetary Science Letters*, 242(3), 406-414.

Arimoto, R., Ray, B., Lewis, N., Tomza, U. and Duce, R., (1997). Mass-particle size distributions of atmospheric dust and the dry deposition of dust to the remote ocean. *Journal of Geophysical Research: Atmospheres*, 102(D13), 15867-15874.

Begét, J.E., Keskinen, M. and Severin, K., (1993). Mineral particles from Asia found in volcanic loess on the island of Hawaii. *Sedimentary Geology*, 84(1), 189-197.

Boucot, A.J., Chen, X. and Scotese, C.R., (2013). Phanerozoic paleoclimate: an atlas of lithologic indicators of climate, Society for Sedimentary Geology (SEPM) Concepts in Sedimentology and Paleontology, No.11, Tulsa, Oklahoma, 478 pp.

Broecker, W.S. and Clark, E., (2002). Carbonate ion concentration in glacial‐age deep waters of the Caribbean Sea. *Geochemistry, Geophysics, Geosystems*, 3(3), 1-14.

Burgess, P.M., (2016). Identifying ordered strata: evidence, methods, and meaning. *Journal of Sedimentary Research*, 86(3), 148-167.

Cocks, L.R.M. and Torsvik, T.H., (2013). The dynamic evolution of the Palaeozoic geography of eastern Asia. *Earth-Science Reviews*, 117, 40-79.

Cope, T., Ritts, B.D., Darby, B.J., Fildani, A. and Graham, S., (2005). Late Paleozoic sedimentation on the northern margin of the North China block: implications for regional tectonics and climate change. *International Geology Review*, 47(3), 270-296.

Crowell, J.C., (1978). Gondwanan glaciation, cyclothems, continental positioning, and climate change. *American Journal of Science*, 278(10), 1345-1372.

Crowell, J.C., (1999). Pre-Mesozoic ice ages: their bearing on understanding the climate system, Geological Society of America, Memoir 192, Boulder, Colorado, 106 pp.

Davydov, V.I., Crowley, J.L., Schmitz, M.D. and Poletaev, V.I., (2010). High-precision U-Pb zircon age calibration of the global Carboniferous time scale and Milankovitch band cyclicity in the Donets basin, eastern Ukraine. *Geochemistry, Geophysics, Geosystems*, 11(2).

Dunham, R.J., (1962). Classification of carbonate rocks according to depositional textures. In: W.E. Ham (Editor). Classification of Carbonate Rocks: A Symposium,

American Association of Petroleum Geologists, Memoir 1, Tulsa, Oklahoma, 108-121.

Dunham, R.J., (1969). Early vadose silt in Townsend mound (reef), New Mexico. In: G.M. Friedman (Editor). Depositional Environments in Carbonate Rocks, Society for Sedimentary Geology (SEPM), Tulsa, Oklahoma, Special Publication 14. 139-181.

Eizenhöfer, P.R., Zhao, G., Zhang, J. and Sun, M., (2014). Final closure of the paleo-Asian ocean along the Solonker suture zone: Constraints from geochronological and geochemical data of Permian volcanic and sedimentary rocks. *Tectonics*, 33(4), 441-463.

Esteban, M. and Klappa, C.F., (1983). Subaerial exposure environment. In: P.A. Scholle, D.G. Bebout and C.H. Moore (Editors). Carbonate Depositional Environments, American Association of Petroleum Geologists, Memoir 33, Tulsa, Oklahoma, pp. 1-54.

Fielding, C.R., Frank, T.D., Birgenheier, L.P., Rygel, M.C., Jones, A.T. and Roberts, J., (2008). Stratigraphic imprint of the Late Palaeozoic Ice Age in eastern Australia: a record of alternating glacial and nonglacial climate regime. *Journal of the Geological Society, London*, 165, 129-140.

Fontaine, H. and Workman, D., (1978). Review of the geology and mineral resources of Kampuchea, Laos and Vietnam. In P. Nutalaya (Editor). Third Regional Conference on Geology and Mineral Resources of Southeast Asia, Bangkok, Thailand, pp. 541-603.

Frakes, L.A. and Crowell, J.C., (1969). Late Paleozoic glaciation: I, South America. *Geological Society of America Bulletin*, 80(6), 1007-1042.

Frakes, L.A. and Crowell, J.C., (1970). Late Paleozoic glaciation: II, Africa exclusive of the Karoo basin. *Geological Society of America Bulletin*, 81(8), 2261-2286.

Frakes, L.A., Matthews, J.L. and Crowell, J.C., (1971). Late Paleozoic glaciation: Part III, Antarctica. *Geological Society of America Bulletin*, 82(6), 1581-1604.

Frank, T.D., Shultis, A.I. and Fielding, C.R., (2015). Acme and demise of the late Palaeozoic ice age: A view from the southeastern margin of Gondwana. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 418, 176-192.

Fujiwara, Y., (1967). Palaeomagnetism of upper Carboniferous rocks in Akiyoshi province, SW Honshu, Japan. *Journal of the Faculty of Science, Hokkaido University. Series 4, Geology and Mineralogy*, 13(4), 395-399.

Fujiwara, Y., (1971). Palaeomagnetism of Upper Carboniferous Rocks in Akiyoshi

Province, S. W. Honshi, Japan. *Journal of the Faculty of Science, Hokkaido University. Series 4, Geology and Mineralogy*, 4, 395-399.

Goldstein, R.H., (1988). Cement stratigraphy of Pennsylvanian Holder Formation, Sacramento Mountains, New Mexico. *American Association of Petroleum Geologists Bulletin*, 72(4), 425-438.

Harrison, S.P., Kohfeld, K.E., Roelandt, C. and Claquin, T., (2001). The role of dust in climate changes today, at the last glacial maximum and in the future. *Earth-Science Reviews*, 54(1), 43-80.

Hattori, I. and Hirooka, K., (1979). Paleomagnetic results from Permian greenstones in central Japan and their geologic significance. *Tectonophysics*, 57(2), 211-235.

Hirooka, K., Nakajima, T., Sakai, H., Date, T., Nittamachi, K. and Hattori, I., (1983). Accretion tectonics inferred from paleomagnetic measurements of Paleozoic and Mesozoic rocks in central Japan. In: M. Hashimoto. and S. Uyeda. (Editors). Accretion tectonics in the circum-Pacific regions, Terra Publications, Tokyo. pp. 179-194.

Isbell, J.L., Miller, M.F., Wolfe, K.L. and Lenaker, P.A., (2003). Timing of late Paleozoic glaciation in Gondwana: Was glaciation responsible for the development of Northern Hemisphere cyclothems? In: M.A. Chan and A.W. Archer (Editors). Extreme Depositional Environments: Mega End Members in Geologic Time, Geological Society of America Special Paper 370, Boulder, Colorado, pp. 5-24.

Jeong, G., Kim, J., Seo, J., Kim, G., Jin, H. and Chun, Y., (2014). Long-range transport of giant particles in Asian dust identified by physical, mineralogical, and meteorological analysis. *Atmospheric Chemistry and Physics*, 14(1), 505-521.

Jones, A.T. and Fielding, C.R., (2004). Sedimentological record of the late Paleozoic glaciation in Queensland, Australia. *Geology*, 32(2), 153-156.

Kabanov, P., Anadón, P. and Krumbein, W.E., (2008). Microcodium: an extensive review and a proposed non-rhizogenic biologically induced origin for its formation. *Sedimentary Geology*, 205(3), 79-99.

Kamvong, T., Zaw, K., Meffre, S., Maas, R., Stein, H. and Lai, C.-K., (2014). Adakites in the Truong Son and Loei fold belts, Thailand and Laos: Genesis and implications for geodynamics and metallogeny. *Gondwana Research*, 26(1), 165-184.

Kanmera, K. and Nishi, H., (1983). Accreted oceanic reef complex in southwest Japan. In: M. Hashimoto and S. Uyeda (Editors). Accretion Tectonics in the Circum-Pacific Regions, Terra Publications, Tokyo. pp. 195-206.

Kanmera, K., Sano, H. and Isozaki, Y., (1990). Akiyoshi terrane. Pre-Cretaceous Terranes of Japan. Osaka City Univ, 224, 49-62 pp.

Kasuya, A., Isozaki, Y. and Igo, H., (2012). Constraining paleo-latitude of a biogeographic boundary in mid-Panthalassa: Fusuline province shift on the Late Guadalupian (Permian) migrating seamount. *Gondwana Research*, 21(2), 611-623.

Kenter, J., Harris, P., Collins, J., Weber, L., Kuanysheva, G. and Fischer, D., (2006). Late Visean to Bashkirian platform cyclicity in the central Tengiz buildup, Precaspian Basin, Kazakhstan: Depositional evolution and reservoir development. In: P.M. Harris and L.J. Weber (Editors). Giant Hydrocarbon Reservoirs of the World: From Rocks to Reservoir Characterization and Modeling, Tulsa, Oklahoma, AAPG Memori 88. pp. 7-54.

Kirschvink, J.L., Isozaki, Y., Shibuya, H., Otofuji, Y.-i., Raub, T.D., Hilburn, I.A., Kasuya, T., Yokoyama, M. and Bonifacie, M., (2015). Challenging the sensitivity limits of paleomagnetism: Magnetostratigraphy of weakly magnetized Guadalupian–Lopingian (Permian) Limestone from Kyushu, Japan. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 418, 75-89.

Klappa, C.F., (1978). Biolithogenesis of Microcodium: elucidation. *Sedimentology*, 25(4), 489-522.

Liu, G., (1990). Permo-Carboniferous paleogeography and coal accumulation and their tectonic control in the North and South China continental plates. *International Journal of Coal Geology*, 16(1), 73-117.

Maher, B., Prospero, J., Mackie, D., Gaiero, D., Hesse, P. and Balkanski, Y., (2010). Global connections between aeolian dust, climate and ocean biogeochemistry at the present day and at the last glacial maximum. *Earth-Science Reviews*, 99(1), 61-97.

Mahowald, N., (2011). Aerosol indirect effect on biogeochemical cycles and climate. *Science*, 334(6057), 794-796.

Mahowald, N., Kohfeld, K., Hansson, M., Balkanski, Y., Harrison, S.P., Prentice, I.C., Schulz, M. and Rodhe, H., (1999). Dust sources and deposition during the Last Glacial Maximum and current climate: A comparison of model results with paleodata from ice cores and marine sediments. *Journal of Geophysical Research: Atmospheres* 104(D13), 15895-15916.

Mahowald, N.M., Muhs, D.R., Levis, S., Rasch, P.J., Yoshioka, M., Zender, C.S. and Luo, C., (2006). Change in atmospheric mineral aerosols in response to climate: Last glacial period, preindustrial, modern, and doubled carbon dioxide climates.

Journal of Geophysical Research, 111(D10), 22, doi:10.1029/2005JD006653.

Manaka, T., Zaw, K., Meffre, S., Vasconcelos, P.M. and Golding, S.D., (2014). The Ban Houayxai epithermal Au–Ag deposit in the Northern Lao PDR: Mineralization related to the Early Permian arc magmatism of the Truong Son Fold Belt. *Gondwana Research*, 26(1), 185-197.

Maruyama, S., Isozaki, Y., Kimura, G. and Terabayashi, M., (1997). Paleogeographic maps of the Japanese Islands: plate tectonic synthesis from 750 Ma to the present. *Island Arc*, 6(1), 121-142.

McGee, D., Broecker, W.S. and Winckler, G., (2010). Gustiness: The driver of glacial dustiness? *Quaternary Science Reviews*, 29(17), 2340-2350.

Metcalfe, I., (2006). Palaeozoic and Mesozoic tectonic evolution and palaeogeography of East Asian crustal fragments: the Korean Peninsula in context. *Gondwana Research*, 9(1), 24-46.

Mizota, C. and Matsuhisa, Y., (1995). Isotopic evidence for the eolian origin of quartz and mica in soils developed on volcanic materials in the Canary Archipelago. *Geoderma*, 66(3), 313-320.

Montanez, I.P., Tabor, N.J., Niemeier, D., DiMichele, W.A., Frank, T.D., Fielding, C.R., Isbell, J.L., Birgenheier, L.P. and Rygel, M.C., (2007). CO_2-forced climate and vegetation instability during Late Paleozoic deglaciation. *Science*, 315(5808), 87-91.

Morinaga, H., Inokuchi, H., Domen, H., Yaskawa, K. and Kawano, M., (1989). Paleomagnetism of the Akiyoshi limestone. Evidence for secondary magnetization. *Journal of Geomagnetism and Geoelectricity*, 41(1), 89-99.

Muhs, D.R. and Bettis, E., (2003). Quaternary loess-paleosol sequences as examples of climate-driven sedimentary extremes. In: M.A. Chan and A.W. Archer (Editors). Extreme Depositional Environments: Mega End Member in Geologic Time, Geological Society of America Special Paper 370, Boulder, Colorado, pp. 53-74.

Muhs, D.R., Simmons, K.R., Schumann, R.R., Groves, L.T., Mitrovica, J.X. and Laurel, D., (2012). Sea-level history during the Last Interglacial complex on San Nicolas Island, California: implications for glacial isostatic adjustment processes, paleozoogeography and tectonics. *Quaternary Science Reviews*, 37, 1-25.

Nakazawa, T. and Ueno, K., (2004). Sequence boundary and related sedimentary and diagenetic facies formed on Middle Permian mid-oceanic carbonate platform: core observation of Akiyoshi Limestone, Southwest Japan. *Facies*, 50(2), 301-311.

Nakazawa, T., Ueno, K., Kawahata, H. and Fujikawa, M., (2011). Gzhelian–Asselian Palaeoaplysina–microencruster reef community in the Taishaku and Akiyoshi limestones, SW Japan: Implications for Late Paleozoic reef evolution on mid-Panthalassan atolls. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 310(3), 378-392.

Nakazawa, T., Ueno, K., Nonomura, N. and Fujikawa, M., (2015). Microbial community from the Lower Permian (Artinskian–Kungurian) paleoclimatic transition, mid-Panthalassan Akiyoshi atoll, Japan. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 420, 116-127.

Osleger, D.A., (1998). Sequence architecture and sea-level dynamics of Upper Permian shelfal facies, Guadalupe Mountains, southern New Mexico. *Journal of Sedimentary Research*, 68(2), 327-346

Patterson, E.M., (2011). Fluctuating dust in the late Paleozoic ice house: records from an oceanic atoll, Akiyoshi, Japan. M.S. Thesis Thesis, University of Oklahoma, 150 pp.

Prospero, J.M., (1999). Long-range transport of mineral dust in the global atmosphere: Impact of African dust on the environment of the southeastern United States. *Proceedings of the National Academy of Sciences*, 96(7), 3396-3403.

Qing, M., Tang, M., Ge, L., Han, X., Feng, J., Yuan, S. and Zhao, Y., (2012). LA-ICP-MS zircon U-Pb age, geochemistry of andesite in Bilihe goldfield, Suniteyouqi, Inner Mongolia and its tectonic significance. *Acta Petrologica Sinica*, 28(2), 514-524.

Rankey, E.C., Bachtel, S.L. and Kaufman, J., (1999). Controls on stratigraphic architecture of icehouse mixed sarbonate-siliciclastic systems: A case study from the Holder Formation (Pennsylvanian, Virgilian), Sacramento Mountains, New Mexico. In: P.M. Harris, A.H. Saller and J.A. Simo (Editors). Advances in Carbonate Sequence Stratigraphy: Application to Reservoirs, Outcrops and Models, Society for Sedimentary Geology (SEPM), Special Publication 63, Tulsa, Oklahoma, pp. 127-150.

Read, J.F., (1998). Phanerozoic carbonate ramps from greenhouse, transitional and ice-house worlds: clues from field and modelling studies. *Geological Society, London, Special Publications*, 149(1), 107-135.

Rygel, M.C., Fielding, C.R., Frank, T.D. and Birgenheier, L.P., (2008). The magnitude of Late Paleozoic glacioeustatic fluctuations: a synthesis. *Journal of Sedimentary Research*, 78(8), 500-511.

Saller, A.H., Dickson, J. and Boyd, S.A., (1994). Cycle stratigraphy and porosity in

Pennsylvanian and Lower Permian shelf limestones, eastern Central Basin Platform, Texas. *American Association of Petroleum Geologists Bulletin*, 78(12), 1820-1842.

Sano, H., (2006). Impact of long-term climate change and sea-level fluctuation on Mississippian to Permian mid-oceanic atoll sedimentation (Akiyoshi Limestone Group, Japan). *Palaeogeography, Palaeoclimatology, Palaeoecology*, 236(3-4), 169-189.

Sano, H., Fujii, S. and Matsuura, F., (2004). Response of Carboniferous–Permian mid-oceanic seamount-capping buildup to global cooling and sea-level change: Akiyoshi, Japan. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 213(1-2), 187-206.

Sano, H. and Kanmera, K., (1988). Paleogeographic reconstruction of accreted oceanic rocks, Akiyoshi, southwest Japan. *Geology*, 16(7), 600-603.

Sano, H. and Kanmera, K., (1991). Collapse of ancient oceanic reef complex—what happened during collision of Akiyoshi reef complex?—Broken limestone as collapse products. *Journal of the Geological Society of Japan*, 97, 217-229.

Sassen, K., DeMott, P.J., Prospero, J.M. and Poellot, M.R., (2003). Saharan dust storms and indirect aerosol effects on clouds: CRYSTAL‐FACE results. *Geophysical Research Letters*, 30(12), doi:10.1029/2003GL017371

Shangyou, N., (1991). Paleoclimatic and paleomagnetic constraints on the Paleozoic reconstructions of South China, North China and Tarim. *Tectonophysics*, 196(3), 279-308.

Smyth, H.R., Hall, R. and Nichols, G.J., (2008). Cenozoic volcanic arc history of East Java, Indonesia: the stratigraphic record of eruptions on an active continental margin. In: A.E. Draut, P.D. Clift and D.W. Scholl (Editors). Formation and applications of the sedimentary record in arc collision zones, Geological Society of America, Special Paper 436, Boulder, Colorado, pp. 199-222.

Soreghan, G.S., (1997). Walther's law, climate change, and upper Paleozoic cyclostratigraphy in the ancestral Rocky Mountains. *Journal of Sedimentary Research*, 67(6), 1001-1004.

Soreghan, G.S. and Giles, K.A., (1999). Facies character and stratal responses to accommodation in Pennsylvanian bioherms, western Orogrande Basin, New Mexico. *Journal of Sedimentary Research*, 69(4), 893-908.

Soreghan, G.S. and Soreghan, M.J., (2002). Atmospheric dust and algal dominance in the late Paleozoic: a hypothesis. *Journal of Sedimentary Research*, 72(4), 457-461.

Soreghan, M.J., Soreghan, G.L. and Hamilton, M.A., (2002). Paleowinds inferred

from detrital-zircon geochronology of upper Paleozoic loessite, western equatorial Pangea. *Geology*, 30(8), 695-698.

Soreghan, G.S., Soreghan, M.J. and Hamilton, M.A., (2008). Origin and significance of loess in late Paleozoic western Pangaea: A record of tropical cold? *Palaeogeography, Palaeoclimatology, Palaeoecology*, 268(3-4), 234-259.

Soreghan, G.S., Heavens, N.G., Hinnov, L.A., Aciego, S.M. and Simpson, C., (2015). Reconstructing the dust cycle in deep time: the case of the late Paleozoic icehouse In: P.D. Polly, J.J. Head and D.L. Fox (Editors). Earth-Life Transitions: Paleobiology in the Context of Earth System Evolution, The Paleontological Society Papers, 21. pp. 83-120.

Sugden, D.E., McCulloch, R.D., Bory, A.J.-M. and Hein, A.S., (2009). Influence of Patagonian glaciers on Antarctic dust deposition during the last glacial period. *Nature Geoscience*, 2(4), 281-285.

Sur, S., Soreghan, M.J., Soreghan, G.S. and Stagner, A.F., (2010a). Extracting the Silicate Mineral Fraction from Ancient Carbonate: Assessing the Geologic Record of Dust. *Journal of Sedimentary Research*, 80(8), 763-769.

Sur, S., Soreghan, G.S., Soreghan, M.J., Yang, W. and Saller, A.H., (2010b). A Record of Glacial Aridity and Milankovitch-Scale Fluctuations in Atmospheric Dust from the Pennsylvanian Tropics. *Journal of Sedimentary Research*, 80(12), 1046-1067.

Sweet, A.C., Soreghan, G.S., Sweet, D.E., Soreghan, M.J. and Madden, A.S., (2013). Permian dust in Oklahoma: source and origin for middle Permian (Flowerpot-Blaine) redbeds in western tropical Pangaea. *Sedimentary Geology*, 284, 181-196.

Tatsumi, Y., Kani, T., Ishizuka, H., Maruyama, S. and Nishimura, Y., (2000). Activation of Pacific mantle plumes during the Carboniferous: evidence from accretionary complexes in southwest Japan. *Geology*, 28(7), 580-582.

Tegen, I., Lacis, A.A. and Fung, I., (1996). The influence on climate forcing of mineral aerosols from disturbed soils. *Nature*, 380(6573), 419-422.

Thompson, L.G., Mosley-Thompson, E., Davis, M.E., Lin, P.-N., Henderson, K.A., Cole-Dai, J., Bolzan, J.F. and Liu, K.-B., (1995). Late glacial stage and Holocene tropical ice core records from Huascaran, Peru. *Science*, 269(5220), 46-50.

Ueno, K., (1989). Carboniferous and Lower Permian foraminiferal biostratigraphy in the Akiyoshi limestone group studies of the upper Palaeozoic foraminifers in the Akiyoshi limestone group, Southwest Japan; Part 1. *Bulletin of the Akiyoshi-Dai*

Museum of Natural History 24, 1-39.

Veevers, J.J. and Powell, C.M., (1987). Late Paleozoic glacial episodes in Gondwanaland reflected in transgressive-regressive depositional sequences in Euramerica. *Geological Society of America Bulletin*, 98(4), 475-487.

Winckler, G., Anderson, R.F., Fleisher, M.Q., McGee, D. and Mahowald, N., (2008). Covariant glacial-interglacial dust fluxes in the equatorial Pacific and Antarctica. *Science*, 320(5872), 93-96.

Wright, V., (1992). Speculations on the controls on cyclic peritidal carbonates: ice-house versus greenhouse eustatic controls. *Sedimentary Geology*, 76(1), 1-5.

Xiao, W., Windley, B.F., Hao, J. and Zhai, M., (2003). Accretion leading to collision and the Permian Solonker suture, Inner Mongolia, China: termination of the central Asian orogenic belt. *Tectonics*, 22(6).

Yung, Y.L., Lee, T., Wang, C.-H. and Shieh, Y.-T., (1996). Dust: A diagnostic of the hydrologic cycle during the Last Glacial Maximum. *Science*, 271(5251), 962-963.

Zhang, S.-H., Zhao, Y., Song, B. and Yang, Y.-H., (2007). Zircon SHRIMP U–Pb and in-situ Lu–Hf isotope analyses of a tuff from Western Beijing: evidence for missing Late Paleozoic arc volcano eruptions at the northern margin of the North China block. *Gondwana Research*, 12(1), 157-165.

Zhang, X., Wilde, S.A., Zhang, H. and Zhai, M., (2011). Early Permian high-K calc-alkaline volcanic rocks from NW Inner Mongolia, North China: geochemistry, origin and tectonic implications. *Journal of the Geological Society*, 168(2), 525-543.

Appendix 1. Stratigraphic section field notes from the Akiyoshi Limestone

The 15-AKI-GH3 section was measured on the southeast site of Managatake Mountain, and named for the nearby guesthouse. This section contains late Asselian and late Artinskian time intervals. The 15-AKI-UHA section was measured on the east site of Managatake Mountain and west of the town of Uehata (named for this town). This section is of Moscovian age.

Bedding attitudes were difficult to determine in both sections owing to the massive character of the Akiyoshi Limestone. Strike and dip were measured where bedding was found. General strike and dip of the study area were used when bedding was obscure. The Akiyoshi Limestone is overturned so both sections were measured upsidedown and backwards. The study area is pinnacle-like karstified terrane, thus both sections were measured pinnacle-to-pinnacle and the shifts between pinnacles were noted. In most cases, section was continuous, but if gaps occurred, these are noted in the logs.

Abbreviations of the notes:

grst: grainstone

pkst: packstone

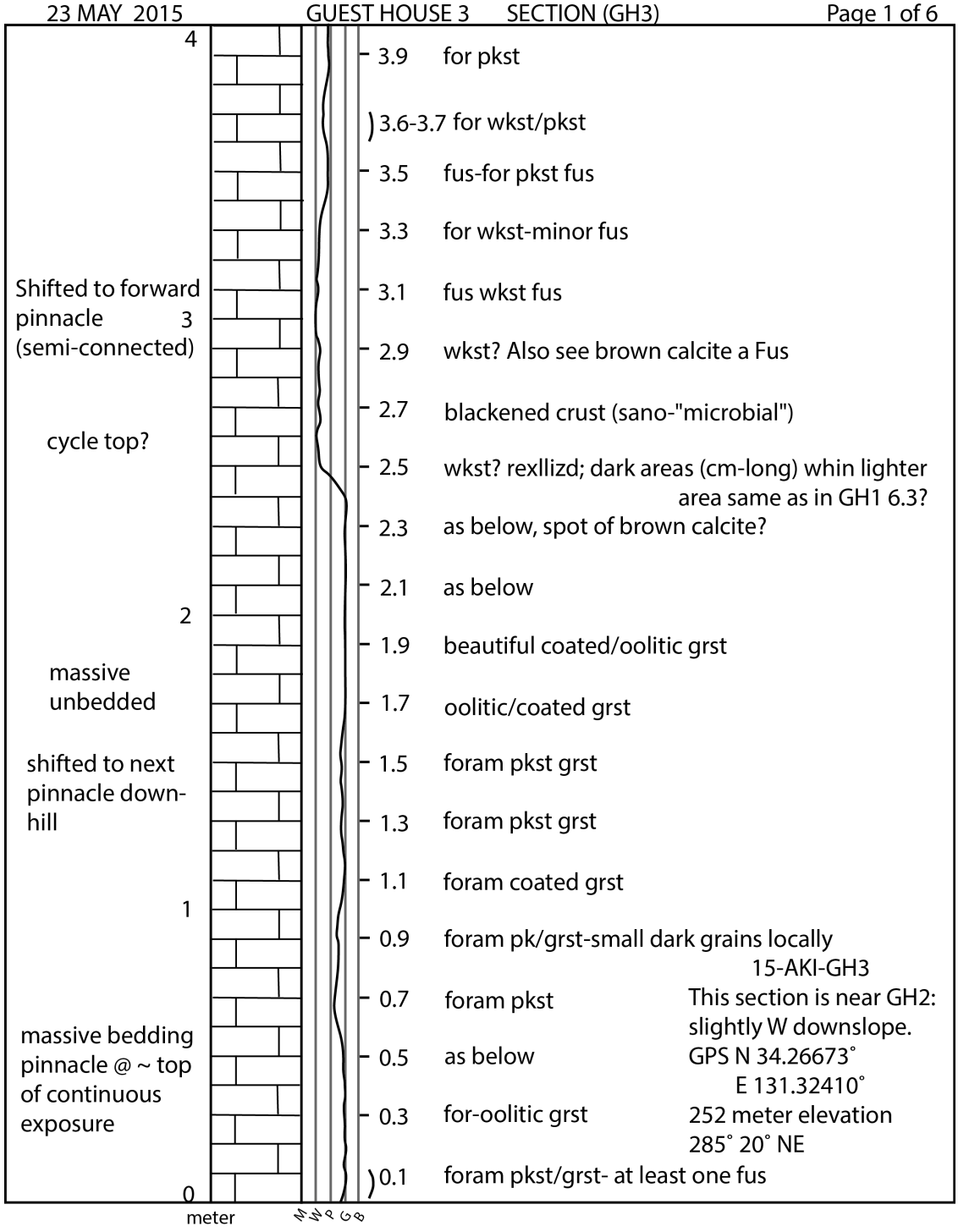
wkst: wackestone

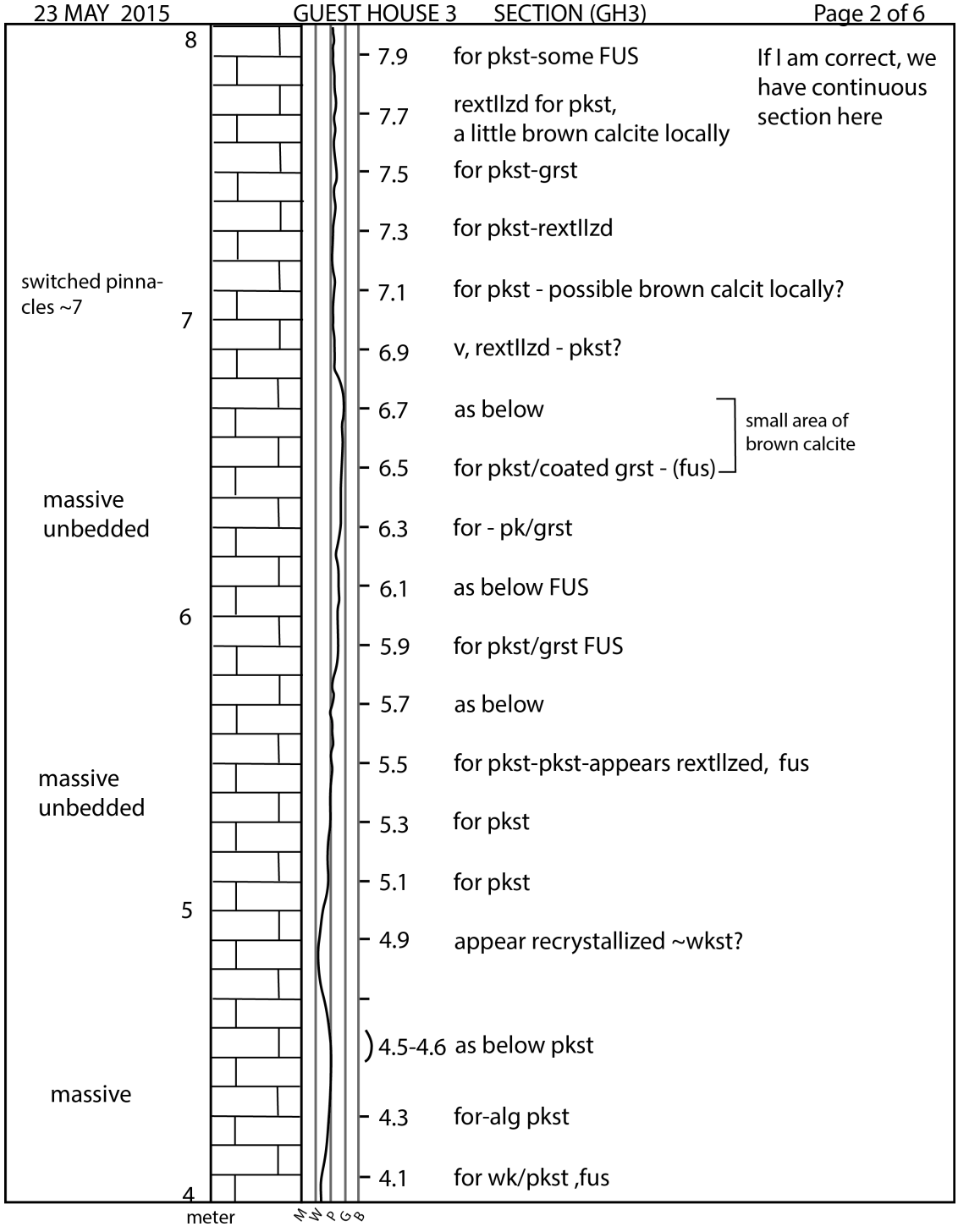
fus: fusulinid

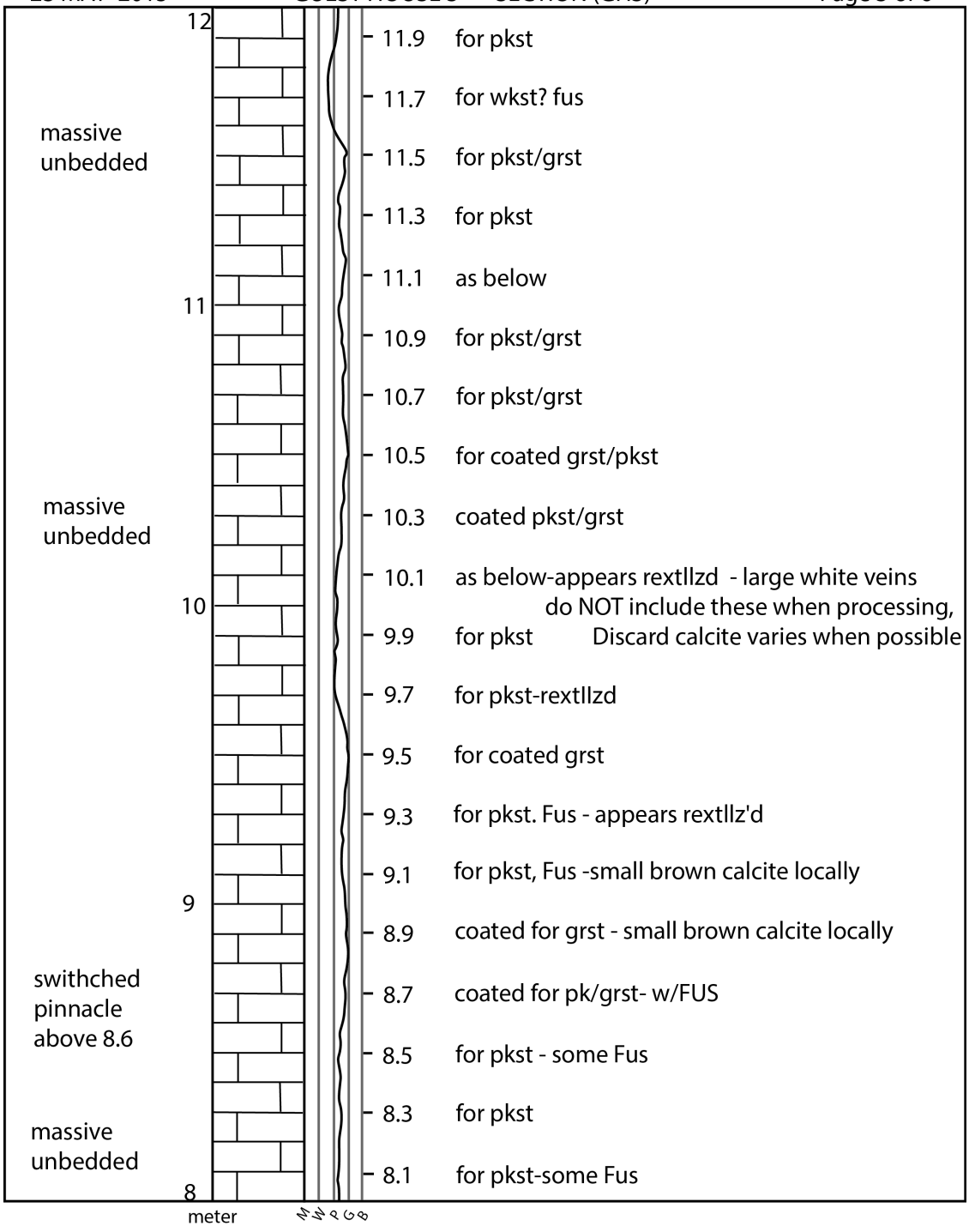
for: (non-fusulinid) forams

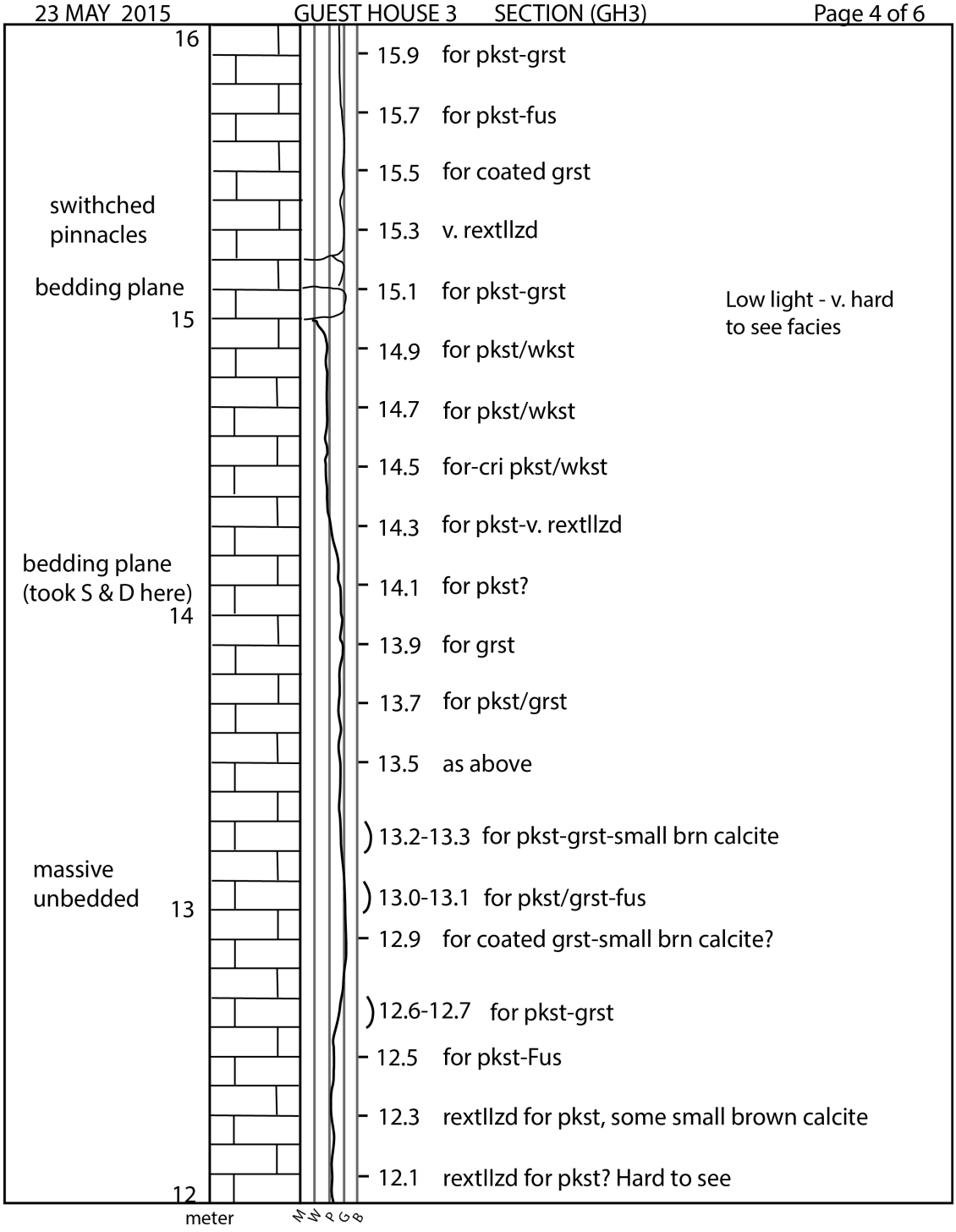
alg: algae

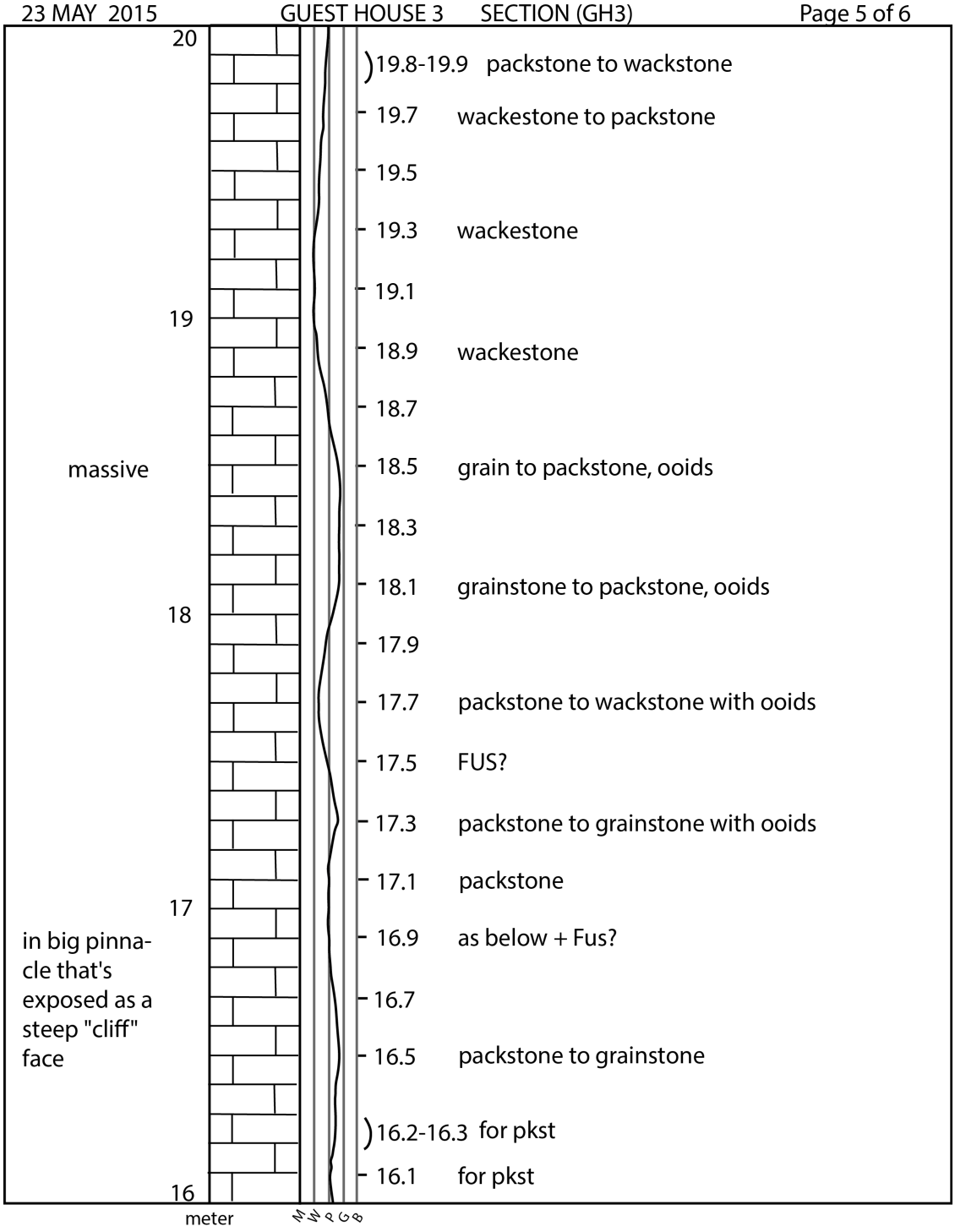
rextllzed: recrystallized

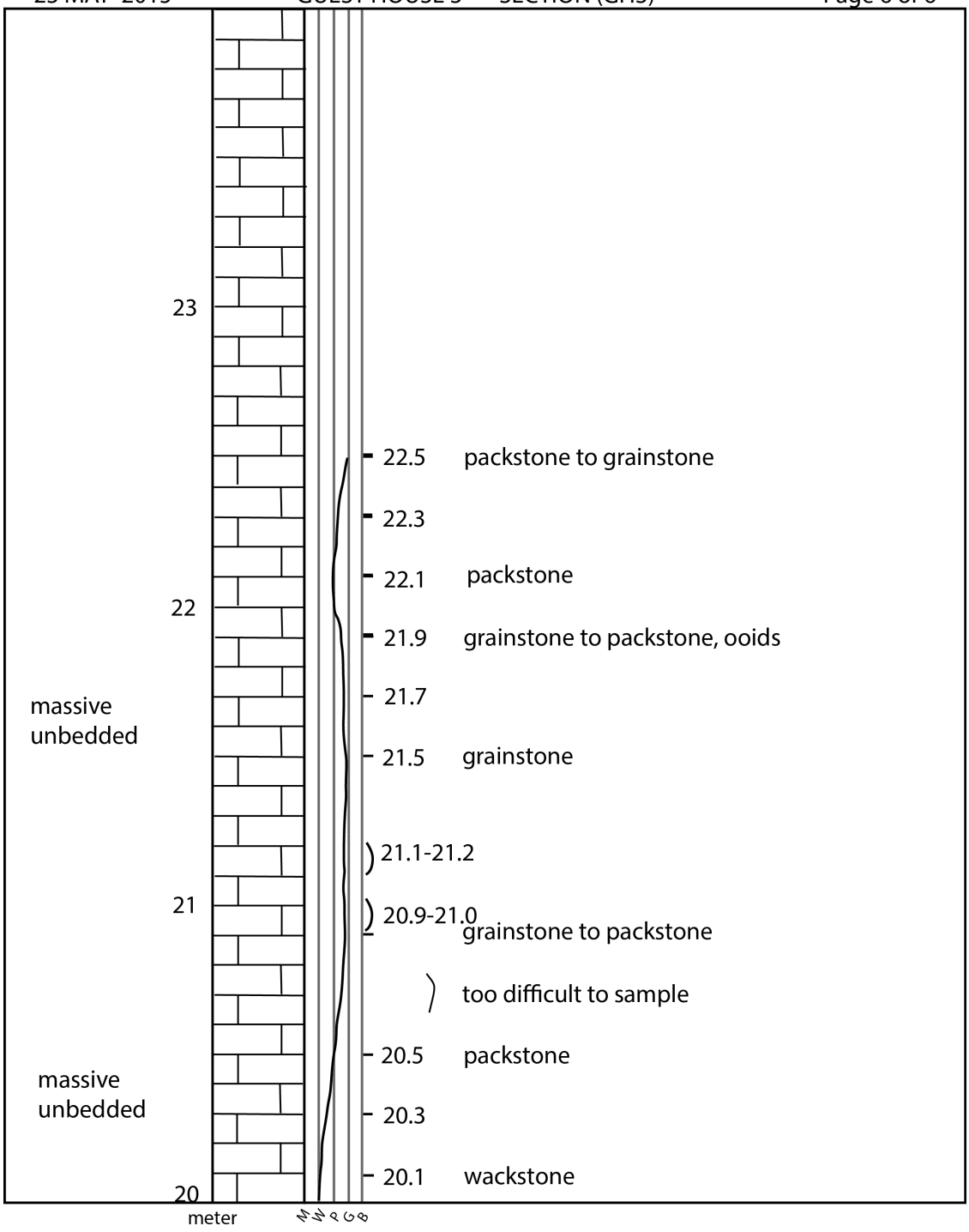

4
3
2
1
0
meter
Shifted to forward pinnacle (semi-connected)
cycle top?
massive unbedded
shifted to next pinnacle down-hill
massive bedding pinnacle @ ~ top of continuous exposure
3.9 for pkst
3.6-3.7 for wkst/pkst
3.5 fus-for pkst fus
3.3 for wkst-minor fus
3.1 fus wkst fus
2.9 wkst? Also see brown calcite a Fus
2.7 blackened crust (sano-"microbial")
2.5 wkst? rexllizd; dark areas (cm-long) whin lighter area same as in GH1 6.3?
2.3 as below, spot of brown calcite?
2.1 as below
1.9 beautiful coated/oolitic grst
1.7 oolitic/coated grst
1.5 foram pkst grst
1.3 foram pkst grst
1.1 foram coated grst
0.9 foram pk/grst-small dark grains locally
0.7 foram pkst
0.5 as below
0.3 for-oolitic grst
0.1 foram pkst/grst- at least one fus
15-AKI-GH3
This section is near GH2: slightly W downslope.
GPS N 34.26673˚
E 131.32410˚
252 meter elevation
285˚ 20˚ NE
M W P G B

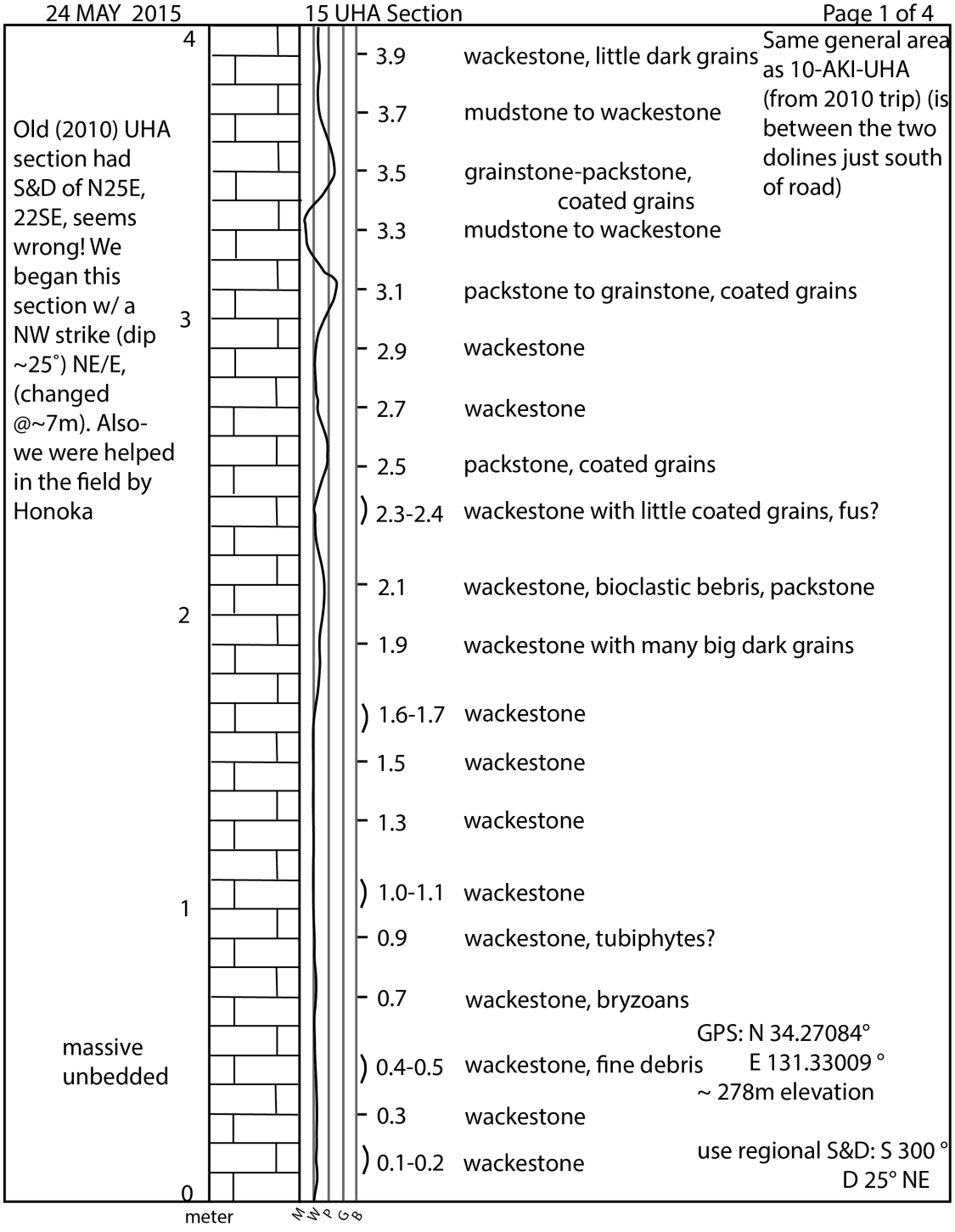

8
7
6
5
4
meter
M W P G B
7.9 for pkst-some FUS
7.7 rextllzd for pkst, a little brown calcite locally
7.5 for pkst-grst
7.3 for pkst-rextllzd
7.1 for pkst - possible brown calcit locally?
6.9 v, rextllzd - pkst?
6.7 as below
6.5 for pkst/coated grst - (fus)
6.3 for - pk/grst
6.1 as below FUS
5.9 for pkst/grst FUS
5.7 as below
5.5 for pkst-pkst-appears rextllzed, fus
5.3 for pkst
5.1 for pkst
4.9 appear recrystallized ~wkst?
4.5-4.6 as below pkst
4.3 for-alg pkst
4.1 for wk/pkst ,fus
If I am correct, we have continuous section here
small area of brown calcite
switched pinna-cles ~7
massive unbedded
massive unbedded
massive

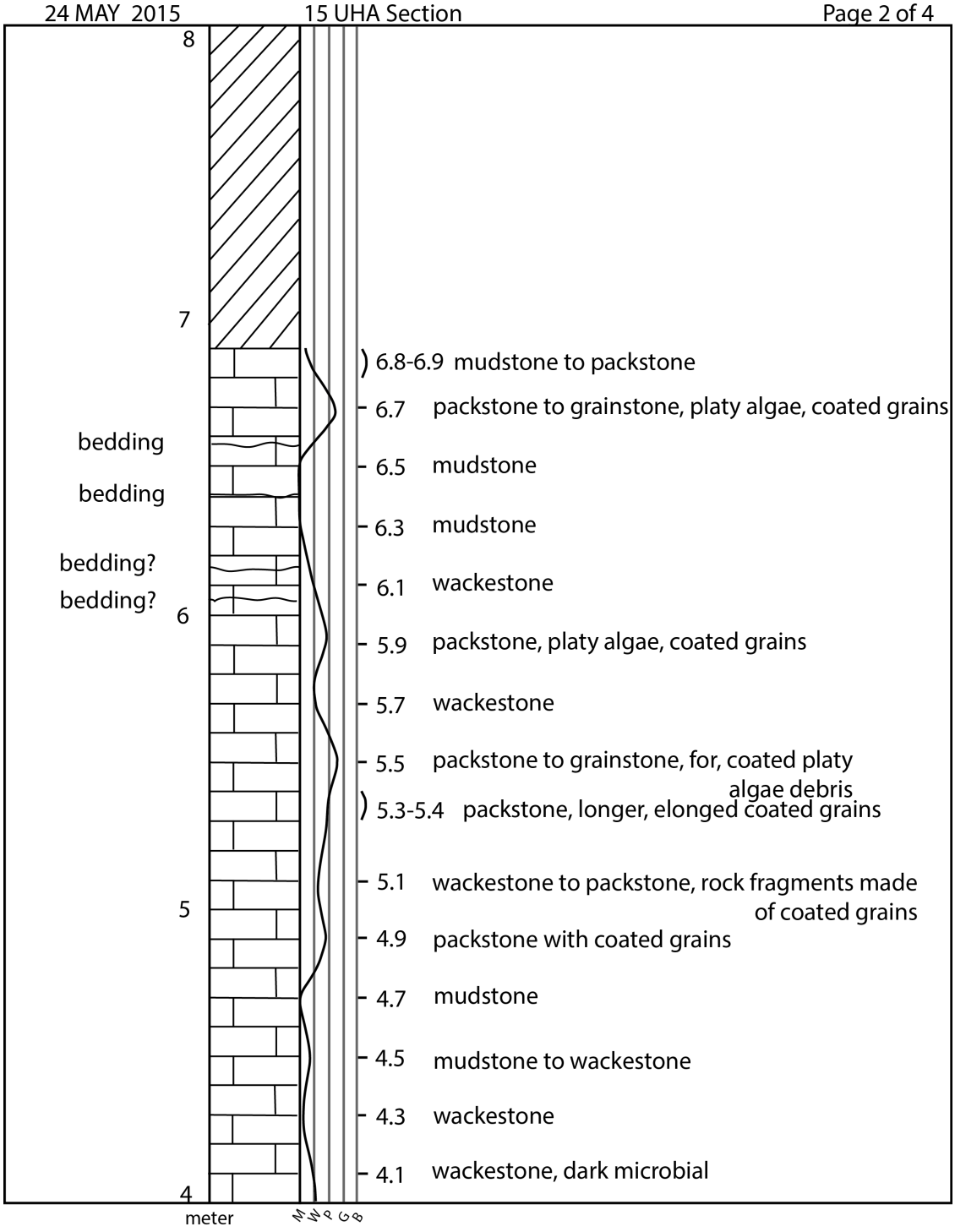

12
11
10
9
8
meter
M W P G B
massive unbedded
massive unbedded
swithched pinnacle above 8.6
massive unbedded
11.9 for pkst
11.7 for wkst? fus
11.5 for pkst/grst
11.3 for pkst
11.1 as below
10.9 for pkst/grst
10.7 for pkst/grst
10.5 for coated grst/pkst
10.3 coated pkst/grst
10.1 as below-appears rextllzd - large white veins
do NOT include these when processing,
9.9 for pkst Discard calcite varies when possible
9.7 for pkst-rextllzd
9.5 for coated grst
9.3 for pkst. Fus - appears rextllz'd
9.1 for pkst, Fus -small brown calcite locally
8.9 coated for grst - small brown calcite locally
8.7 coated for pk/grst- w/FUS
8.5 for pkst - some Fus
8.3 for pkst
8.1 for pkst-some Fus

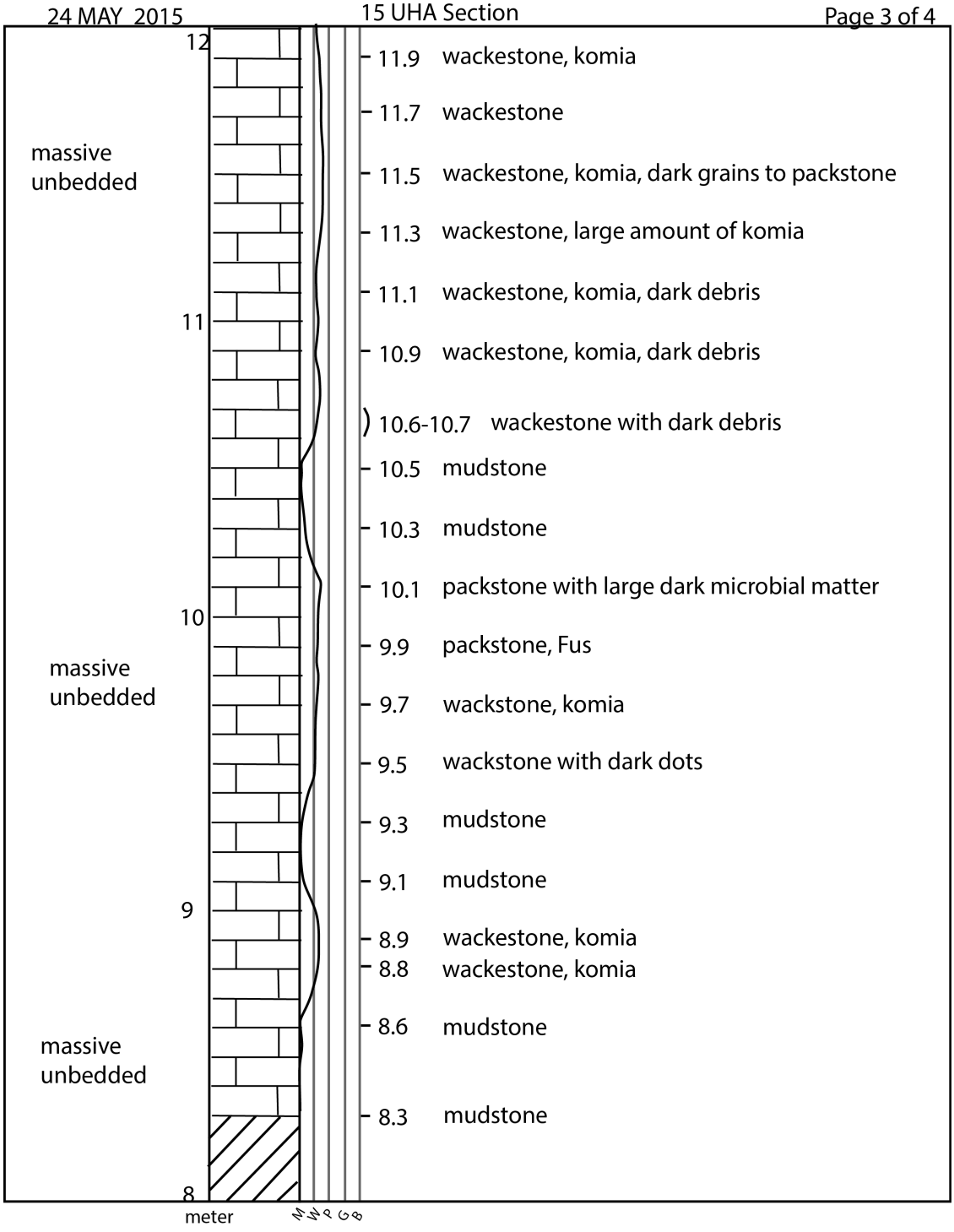

16
15
14
13
12
meter
M W P G B
15.9 for pkst-grst
15.7 for pkst-fus
15.5 for coated grst
swithched pinnacles
15.3 v. rextllzd
bedding plane
15.1 for pkst-grst
Low light - v. hard to see facies
14.9 for pkst/wkst
14.7 for pkst/wkst
14.5 for-cri pkst/wkst
14.3 for pkst-v. rextllzd
bedding plane (took S & D here)
14.1 for pkst?
13.9 for grst
13.7 for pkst/grst
13.5 as above
13.2-13.3 for pkst-grst-small brn calcite
massive unbedded
13.0-13.1 for pkst/grst-fus
12.9 for coated grst-small brn calcite?
12.6-12.7 for pkst-grst
12.5 for pkst-Fus
12.3 rextllzd for pkst, some small brown calcite
12.1 rextllzd for pkst? Hard to see

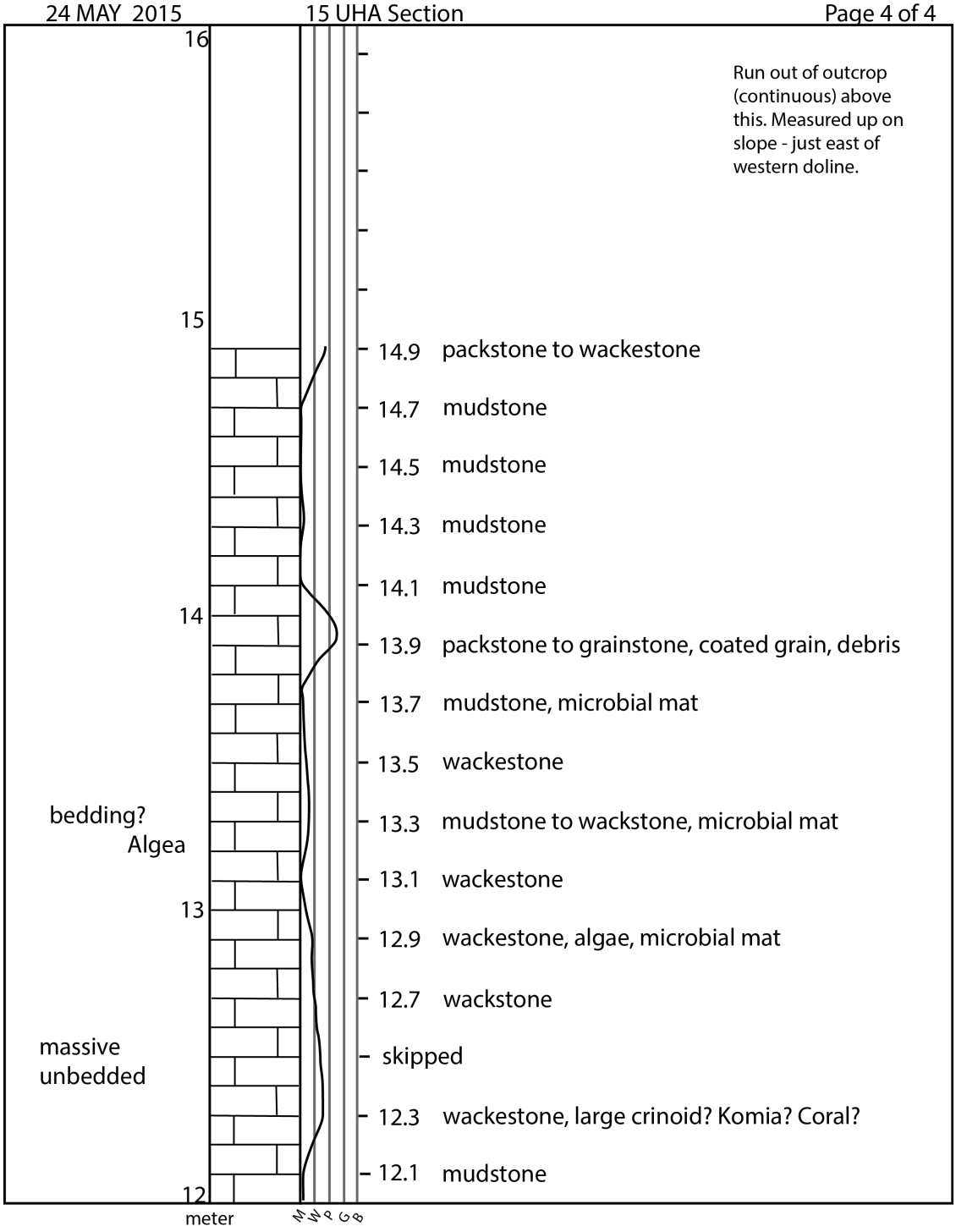

20
19
18
17
16
meter
M W P G B
19.8-19.9 packstone to wackstone
19.7 wackestone to packstone
19.5
19.3 wackestone
19.1
18.9 wackestone
18.7
18.5 grain to packstone, ooids
18.3
18.1 grainstone to packstone, ooids
17.9
17.7 packstone to wackstone with ooids
17.5 FUS?
17.3 packstone to grainstone with ooids
17.1 packstone
16.9 as below + Fus?
16.7
16.5 packstone to grainstone
16.2-16.3 for pkst
16.1 for pkst
massive
in big pinna-
cle that's
exposed as a
steep "cliff"
face


23
22
21
20
meter
massive
unbedded
massive
unbedded
M W P G B
22.5 packstone to grainstone
22.3
22.1 packstone
21.9 grainstone to packstone, ooids
21.7
21.5 grainstone
21.1-21.2
20.9-21.0 grainstone to packstone
too difficult to sample
20.5 packstone
20.3
20.1 wackstone


4
3
2
1
0
meter
M W P G B
3.9 wackestone, little dark grains
3.7 mudstone to wackestone
3.5 grainstone-packstone, coated grains
3.3 mudstone to wackestone
3.1 packstone to grainstone, coated grains
2.9 wackestone
2.7 wackestone
2.5 packstone, coated grains
2.3-2.4 wackestone with little coated grains, fus?
2.1 wackestone, bioclastic bebris, packstone
1.9 wackestone with many big dark grains
1.6-1.7 wackestone
1.5 wackestone
1.3 wackestone
1.0-1.1 wackestone
0.9 wackestone, tubiphytes?
0.7 wackestone, bryzoans
0.4-0.5 wackestone, fine debris
0.3 wackestone
0.1-0.2 wackestone
Same general area as 10-AKI-UHA (from 2010 trip) (is between the two dolines just south of road)
Old (2010) UHA section had S&D of N25E, 22SE, seems wrong! We began this section w/ a NW strike (dip ~25˚) NE/E, (changed @~7m). Also- we were helped in the field by Honoka
massive unbedded
GPS: N 34.27084° E 131.33009 °
~ 278m elevation
use regional S&D: S 300 ° D 25° NE


8
7
6
5
4
meter
M W P G B
bedding
bedding
bedding?
bedding?
6.8-6.9 mudstone to packstone
6.7 packstone to grainstone, platy algae, coated grains
6.5 mudstone
6.3 mudstone
6.1 wackestone
5.9 packstone, platy algae, coated grains
5.7 wackestone
5.5 packstone to grainstone, for, coated platy algae debris
5.3-5.4 packstone, longer, elonged coated grains
5.1 wackestone to packstone, rock fragments made of coated grains
4.9 packstone with coated grains
4.7 mudstone
4.5 mudstone to wackestone
4.3 wackestone
4.1 wackestone, dark microbial


12
11
10
9
8
meter
M W P G B
massive unbedded
massive unbedded
massive unbedded
11.9 wackestone, komia
11.7 wackestone
11.5 wackestone, komia, dark grains to packstone
11.3 wackestone, large amount of komia
11.1 wackestone, komia, dark debris
10.9 wackestone, komia, dark debris
10.6-10.7 wackestone with dark debris
10.5 mudstone
10.3 mudstone
10.1 packstone with large dark microbial matter
9.9 packstone, Fus
9.7 wackstone, komia
9.5 wackstone with dark dots
9.3 mudstone
9.1 mudstone
8.9 wackestone, komia
8.8 wackestone, komia
8.6 mudstone
8.3 mudstone


16
15
14
13
12
meter
M W P G B
Run out of outcrop (continuous) above this. Measured up on slope - just east of western doline.
14.9 packstone to wackestone
14.7 mudstone
14.5 mudstone
14.3 mudstone
14.1 mudstone
13.9 packstone to grainstone, coated grain, debris
13.7 mudstone, microbial mat
13.5 wackestone
13.3 mudstone to wackstone, microbial mat
13.1 wackestone
12.9 wackestone, algae, microbial mat
12.7 wackstone
skipped
12.3 wackestone, large crinoid? Komia? Coral?
12.1 mudstone
bedding?
Algea
massive
unbedded

Appendix 2. D10, D50, D90, maximum, volume weighted mean , standard deviation (µm) and percentage of (<10 µm, 10<x<63 µm, >63 µm, <20 µm, >20 µm) and Ratio of (<20 µm)/(>20 µm)

Upper Asselian-upper Artinskian (GH3) section

Sample #	D(10)	D(50)	D(90)	Max	Mean	σ	<10 μm	10<x<63	>63 μm	<20 μm	>20 μm	Ratio
0.0-0.1	55.52	130.80	170.80	175.53	1.76	2.62	1.97	11.48	86.55	3.02	96.98	0.03
0.3	47.08	169.10	282.90	306.94	2.95	5.88	0.58	14.52	84.90	2.40	97.60	0.02
0.5	59.59	178.20	281.70	349.89	4.91	8.27	0.86	9.76	89.37	3.51	96.49	0.04
0.7	37.43	91.78	139.40	156.85	2.79	4.73	1.94	19.44	78.62	4.43	95.57	0.05
0.9	42.86	75.12	196.30	197.52	4.56	10.09	0.35	25.05	74.60	1.68	98.32	0.02
1.3	23.10	84.78	152.80	169.62	3.70	6.06	1.59	35.83	62.58	7.53	92.47	0.08
1.7	133.00	223.10	312.10	315.31	1.27	2.24	0.64	2.74	96.62	0.82	99.18	0.01
2.3	99.87	155.30	233.80	273.77	2.17	9.04	0.04	1.38	98.59	0.07	99.93	0.00
2.5	3.98	22.16	76.43	77.03	2.21	1.79	29.02	55.38	15.60	46.12	53.88	0.86
2.7-2.8	3.51	25.53	109.40	110.65	1.87	1.40	23.72	44.53	31.75	44.12	55.88	0.79
2.9	30.44	124.90	250.80	253.04	2.67	3.92	3.06	17.96	78.98	6.51	93.49	0.07
3.1	21.64	46.59	70.61	85.47	1.88	3.12	2.80	76.77	20.43	8.36	91.64	0.09
3.3	9.39	66.11	81.44	82.38	1.55	1.30	10.77	22.75	66.49	19.48	80.52	0.24
3.5	65.77	129.60	182.20	183.95	1.62	4.54	0.15	8.27	91.58	0.43	99.57	0.00
3.9	55.46	125.80	177.60	209.04	2.79	6.98	0.26	13.04	86.70	0.86	99.14	0.01
4.1	31.88	75.06	175.90	177.14	2.31	3.68	1.22	32.86	65.93	3.06	96.94	0.03
4.3	24.61	144.10	279.60	281.52	2.82	4.08	1.61	30.39	68.00	6.44	93.56	0.07
4.7	24.57	74.11	102.20	103.31	1.64	1.54	4.54	42.62	52.84	8.34	91.66	0.09
4.9	90.79	154.90	217.20	281.52	5.16	18.82	0.03	2.67	97.30	0.10	99.90	0.00
5.3	34.19	90.60	133.80	142.86	1.87	4.07	0.78	25.27	73.95	3.13	96.87	0.03
5.5	1.33	15.76	37.44	37.86	1.42	0.63	39.72	60.28	0.00	60.70	39.30	1.54
5.6	53.71	95.37	150.50	167.48	1.74	4.90	0.18	12.97	86.85	0.53	99.47	0.01
5.7	50.76	126.60	160.80	162.59	1.59	3.28	0.59	10.68	88.73	1.91	98.09	0.02

Upper Asselian-upper Artinskian (GH3) section

Sample #	D(10)	D(50)	D(90)	Max	Mean	σ	<10 μm	10<x<63	>63 μm	<20 μm	>20 μm	Ratio
5.9	70.72	134.20	168.80	171.25	1.77	5.18	0.14	5.14	94.72	0.46	99.54	0.00
6.1	68.81	142.80	193.50	214.94	4.09	11.17	0.17	8.15	91.68	0.98	99.02	0.01
6.5	16.47	69.49	155.10	157.75	2.86	4.13	3.10	45.23	51.67	14.16	85.84	0.16
6.9	75.38	163.90	235.80	241.57	3.88	12.46	0.07	6.87	93.06	0.46	99.54	0.00
7.1	82.50	141.70	250.90	253.48	3.45	13.53	0.03	2.94	97.02	0.15	99.85	0.00
7.3	85.30	160.10	211.90	238.03	8.53	22.91	0.05	3.99	95.96	0.29	99.71	0.00
7.5	38.44	124.80	174.70	176.96	7.93	12.93	0.58	21.35	78.07	3.23	96.77	0.03
7.7	57.92	134.00	190.50	213.45	4.24	9.94	0.40	10.56	89.04	1.60	98.40	0.02
8.3	33.32	87.05	173.80	175.54	2.47	5.44	1.02	30.30	68.68	3.81	96.19	0.04
8.9	71.77	132.50	203.70	248.67	4.87	14.65	0.07	6.00	93.94	0.25	99.75	0.00
9.1	83.97	162.40	211.30	229.38	10.27	21.67	0.12	6.79	93.09	0.60	99.40	0.01
9.5	99.95	155.10	233.70	273.74	2.24	9.64	0.03	1.36	98.61	0.07	99.93	0.00
9.9	101.50	164.70	237.70	287.74	7.83	19.18	0.18	3.11	96.71	0.53	99.47	0.01
10.3	99.81	181.80	241.70	244.77	5.09	13.33	0.11	6.72	93.16	0.87	99.13	0.01
11.1	41.22	133.40	177.00	181.24	4.67	11.42	0.16	25.45	74.39	1.21	98.80	0.01
11.9-12.0	21.96	68.07	142.10	151.01	4.26	7.60	1.03	44.18	54.78	6.87	93.13	0.07
12.1	72.53	154.50	193.50	216.32	5.01	14.33	0.11	6.39	93.50	0.47	99.53	0.00
12.3	12.23	39.31	85.92	124.48	4.42	5.20	6.68	70.98	22.34	21.31	78.69	0.27
12.6-12.7	35.33	107.50	201.80	204.78	7.70	12.41	0.61	27.83	71.56	2.63	97.37	0.03
13.1-13.2	23.21	56.53	98.23	111.35	5.19	8.10	1.89	53.40	44.72	7.54	92.46	0.08
13.5	34.46	89.10	208.00	209.44	4.82	7.82	1.46	29.23	69.31	4.74	95.26	0.05
13.9	35.31	76.59	178.90	183.36	8.33	15.30	0.13	38.22	61.65	1.08	98.92	0.01
14.3	35.29	76.58	178.90	183.48	8.77	15.70	0.13	38.28	61.59	1.06	98.94	0.01

Upper Asselian-upper Artinskian (GH3) section

Sample #	D(10)	D(50)	D(90)	Max	Mean	σ	<10 μm	10<x<63	>63 μm	<20 μm	>20 μm	Ratio
14.7	58.60	140.60	225.10	229.45	5.19	13.25	0.15	11.85	88.00	0.73	99.27	0.01
15.2	97.90	147.50	201.40	212.28	17.07	37.48	0.01	2.49	97.50	0.05	99.95	0.00
15.5	93.23	152.00	200.40	232.08	21.68	41.48	0.01	2.58	97.41	0.06	99.94	0.00
15.9	82.03	165.60	246.40	270.52	12.79	27.05	0.02	7.11	92.87	0.27	99.73	0.00
16.1	56.55	144.40	207.90	236.73	20.02	30.88	0.01	12.35	87.64	0.22	99.78	0.00
16.5	68.13	133.10	192.40	227.56	22.32	33.36	0.01	8.13	91.86	0.28	99.72	0.00
17.2	123.90	148.00	202.50	203.70	11.13	29.91	0.03	0.71	99.25	0.19	99.81	0.00
17.3	77.44	181.60	238.40	240.62	14.79	28.84	0.03	7.21	92.76	0.37	99.63	0.00
18.1	76.01	149.80	268.40	331.66	42.85	46.57	0.01	4.81	95.19	0.08	99.92	0.00
18.5	54.74	106.40	193.10	224.10	11.83	21.48	0.10	14.79	85.11	0.74	99.26	0.01
18.9	93.93	169.00	214.90	242.29	7.29	17.31	0.18	4.41	95.41	0.78	99.22	0.01
19.1	33.43	71.31	135.60	170.84	3.58	7.45	0.92	37.87	61.21	3.30	96.70	0.03
19.3	41.52	132.20	302.10	306.37	4.26	8.64	0.70	17.73	81.57	2.80	97.20	0.03
19.5	34.59	92.78	209.90	227.36	4.09	8.55	0.68	27.74	71.58	2.81	97.19	0.03
19.7	70.83	156.00	206.40	215.40	10.41	22.23	0.09	7.77	92.15	0.50	99.50	0.01
19.8-19.9	81.40	183.10	267.70	314.28	3.74	7.91	0.54	6.89	92.56	1.68	98.32	0.02
20.1	41.24	109.50	311.00	315.53	3.92	7.49	1.04	22.45	76.51	2.90	97.10	0.03
20.3	33.99	80.79	359.20	360.63	3.73	6.86	1.27	32.43	66.30	3.79	96.22	0.04
20.5	21.77	84.88	175.00	185.79	3.95	6.29	2.29	35.56	62.15	8.56	91.44	0.09
20.9	62.08	146.20	207.10	227.15	4.79	11.01	0.35	9.75	89.90	1.73	98.27	0.02
21.5	47.78	154.10	249.70	300.51	4.46	8.78	0.68	13.56	85.75	2.57	97.43	0.03
21.9	43.20	128.10	250.40	312.34	4.24	9.29	0.36	20.36	79.27	1.65	98.35	0.02
22.1	18.73	72.37	144.00	163.33	5.76	7.82	2.19	41.64	56.17	11.25	88.75	0.13

Upper Asselian-upper Artinskian (GH3) section

Sample #	D(10)	D(50)	D(90)	Max	Mean	σ	<10 μm	10<x<63	>63 μm	<20 μm	>20 μm	Ratio
22.3	50.38	145.60	219.90	223.99	3.62	7.94	0.72	14.19	85.09	2.05	97.95	0.02
22.5	34.78	138.90	216.40	221.54	2.13	3.82	2.40	11.89	85.71	5.89	94.11	0.06

Middle-upper Moscovian (UHA) section

Sample #	D(10)	D(50)	D(90)	Max	Mean	σ	<10 μm	10<x<63	>63 μm	<20 μm	>20 μm	Ratio
0.0-0.2	6.44	14.64	94.86	95.69	1.98	2.54	26.10	56.96	16.94	67.05	32.95	2.03
0.3	4.24	11.33	21.63	30.62	1.44	1.66	41.22	58.78	0.00	86.64	13.36	6.49
0.4-0.5	6.67	20.04	63.87	64.93	1.48	2.06	18.75	68.08	13.17	48.66	51.34	0.95
0.7	10.09	23.96	56.20	98.22	1.87	2.95	9.72	83.66	6.62	37.59	62.41	0.60
0.9	5.06	11.34	28.88	65.74	1.74	2.10	41.20	54.99	3.81	79.93	20.07	3.98
1.0-1.1	6.22	13.85	88.01	90.51	2.16	2.72	29.14	51.55	19.31	66.85	33.15	2.02
1.3	4.23	9.75	19.92	33.21	1.52	1.73	50.99	49.01	0.00	89.78	10.22	8.78
1.5	5.48	12.05	41.12	71.70	2.44	2.75	39.28	58.89	1.83	71.03	28.97	2.45
1.6-1.7	6.88	15.16	29.68	41.99	1.66	2.39	22.37	77.63	0.00	70.93	29.07	2.44
1.9	3.90	10.24	25.49	47.34	1.67	1.78	48.03	51.97	0.00	83.52	16.48	5.07
2.1	6.20	14.17	25.50	52.38	2.04	2.71	28.30	71.70	0.00	75.64	24.36	3.11
2.3-2.4	4.29	11.25	27.81	49.93	1.57	1.79	43.51	56.49	0.00	76.50	23.50	3.26
2.5	5.49	14.82	30.99	60.40	1.76	2.24	27.78	72.22	0.00	70.31	29.69	2.37
2.7	4.97	13.64	31.02	44.10	1.88	2.21	33.57	66.43	0.00	69.14	30.86	2.24
2.9	2.75	6.03	11.13	25.76	1.36	1.29	85.21	14.79	0.00	98.81	1.19	83.10
3.5	3.61	8.70	21.88	36.28	1.69	1.72	57.15	42.85	0.00	86.63	13.37	6.48
3.7	6.06	14.19	89.67	90.66	1.67	2.17	29.34	50.85	19.82	60.93	39.07	1.56
3.9	5.62	14.44	34.76	50.55	1.90	2.34	31.23	68.77	0.00	64.16	35.84	1.79
4.1	4.32	9.39	19.54	38.51	1.97	2.09	53.68	46.32	0.00	90.31	9.69	9.32
4.3	11.58	48.51	71.78	72.97	1.56	2.67	7.36	56.54	36.10	21.86	78.14	0.28
4.5	3.20	7.03	14.69	31.46	1.61	1.57	71.77	28.23	0.00	97.25	2.75	35.43
4.7	4.36	10.31	22.96	58.13	1.76	1.97	47.63	52.37	0.00	84.10	15.90	5.29
4.9	4.24	9.45	22.88	39.65	1.63	1.84	52.70	47.30	0.00	85.37	14.63	5.84

Middle-upper Moscovian (UHA) section

Sample #	D(10)	D(50)	D(90)	Max	Mean	σ	<10 μm	10<x<63	>63 μm	<20 μm	>20 μm	Ratio
4.9	4.24	9.45	22.88	39.65	1.63	1.84	52.70	47.30	0.00	85.37	14.63	5.84
5.1	3.50	7.72	19.98	44.09	1.83	1.80	63.39	36.61	0.00	89.54	10.46	8.56
5.3-5.4	6.56	17.48	32.27	45.20	2.54	3.15	21.51	78.49	0.00	59.66	40.34	1.48
5.5	5.08	11.35	36.59	58.34	2.52	2.67	42.04	57.96	0.00	76.71	23.29	3.29
5.7	12.03	46.16	88.78	89.82	1.29	1.99	7.70	72.65	19.65	20.73	79.27	0.26
5.9	10.78	26.31	43.37	49.54	1.92	3.02	9.17	90.83	0.00	28.06	71.94	0.39
6.1	4.77	12.38	25.61	31.59	1.77	2.07	37.47	62.53	0.00	73.93	26.07	2.84
6.3	9.37	39.19	99.44	114.58	2.07	3.23	11.14	58.10	30.76	27.45	72.55	0.38
6.5	3.18	13.57	56.24	56.74	1.24	1.20	39.98	60.02	0.00	58.50	41.50	1.41
6.8-6.9	3.36	9.66	20.06	24.75	1.39	1.43	51.27	48.73	0.00	89.31	10.69	8.35
8.3	7.70	15.36	30.10	30.42	2.09	3.15	18.56	81.44	0.00	61.17	38.83	1.58
8.6	7.19	29.92	67.84	68.85	1.78	2.45	19.82	65.26	14.92	41.17	58.83	0.70
9.1	8.64	21.72	43.33	46.47	2.42	3.48	12.52	87.48	0.00	42.99	57.01	0.75
9.3	5.55	15.10	44.93	45.20	1.15	1.38	24.76	75.24	0.00	65.17	34.83	1.87
9.7	5.85	20.22	58.07	58.84	2.17	2.58	23.65	76.35	0.00	48.80	51.20	0.95
10.1	6.87	58.30	58.75	58.87	1.46	1.90	16.41	83.59	0.00	30.28	69.72	0.43
10.5	16.65	43.34	78.01	79.17	1.16	1.73	4.70	64.55	30.75	14.90	85.10	0.18
10.6-10.7	4.52	16.50	48.29	48.83	1.34	1.51	28.03	71.97	0.00	56.32	43.68	1.29
10.9	3.51	11.45	21.73	23.81	1.34	1.42	43.03	56.97	0.00	88.15	11.85	7.44
11.1	3.11	21.33	31.06	31.41	1.11	1.05	22.69	77.31	0.00	47.07	52.93	0.89
11.3	8.07	32.24	43.62	49.63	1.25	1.68	13.15	86.85	0.00	29.32	70.68	0.41
11.5	17.70	70.24	92.64	93.38	1.29	2.23	3.47	29.55	66.97	10.44	89.56	0.12
11.7	15.71	48.20	63.00	69.60	1.56	2.82	4.93	79.34	15.73	15.99	84.01	0.19

Middle-upper Moscovian (UHA) section

Sample #	D(10)	D(50)	D(90)	Max	Mean	σ	<10 μm	10<x<63	>63 μm	<20 μm	>20 μm	Ratio
12.7	17.14	33.74	48.26	67.09	1.18	2.05	4.25	90.75	5.01	12.75	87.25	0.15
12.9	4.62	12.04	39.91	55.81	1.80	2.09	41.17	58.83	0.00	70.10	29.90	2.34
13.1	6.59	15.80	31.62	58.21	1.89	2.56	23.47	76.53	0.00	64.61	35.39	1.83
13.3	44.91	85.34	140.80	142.32	1.78	3.93	2.44	17.80	79.75	4.82	95.18	0.05
13.5	17.85	32.44	50.21	72.67	2.73	5.35	2.91	93.36	3.73	12.00	88.00	0.14
13.7	13.94	26.55	39.56	51.14	1.52	2.71	6.00	94.00	0.00	21.15	78.85	0.27
13.9	4.78	13.68	52.44	95.91	1.76	1.98	34.78	60.02	5.20	65.17	34.83	1.87
14.1	16.53	52.95	85.70	95.19	2.33	4.56	3.78	64.03	32.18	13.29	86.71	0.15
14.3	6.22	22.79	172.90	173.93	1.97	2.33	21.87	31.91	46.22	47.56	52.44	0.91
14.5	9.24	56.80	162.70	164.44	1.83	2.67	11.12	43.60	45.28	22.66	77.34	0.29
14.7	3.23	9.72	25.84	36.24	1.41	1.44	50.78	49.22	0.00	79.09	20.91	3.78
14.9	12.21	34.51	75.64	76.38	1.30	2.10	7.57	67.89	24.54	18.49	81.51	0.23
15.2-15.3	17.88	62.81	130.50	162.58	2.20	4.28	3.72	45.91	50.38	11.62	88.38	0.13
15.5	13.96	38.87	84.54	179.09	3.37	5.30	5.43	72.11	22.46	17.84	82.16	0.22
15.7	10.92	38.81	63.08	64.18	2.09	3.70	8.41	76.87	14.72	20.82	79.18	0.26
15.9	2.58	12.00	20.87	21.09	1.08	1.01	41.07	58.93	0.00	85.40	14.60	5.85
16.1	12.82	96.03	96.47	97.33	1.09	1.14	8.78	5.89	85.33	13.28	86.72	0.15

Appendix 3. Modes of upper Asselian, upper Artinskian and middle-upper Moscovian sections

Upper Asselian-upper Artinskian (GH3) section

Sample #	Single mode	Bi-/Multiple modes		
		Mode 1	Mode 2	Mode 3
0.05		161.65	128.719602	
0.30		194.15	137.959591	80.019392
0.50		215.43	117.743087	
0.70		128.72	77.676949	
0.90	68.97			
1.30	114.30			
1.70		291.40	205.018521	
2.30	127.45			
2.50	15.93			
2.75		109.86	92.834777	15.6144
2.90	124.34			
3.10	59.45			
3.30		40.81	20.604123	9.422644
3.50		162.45	83.252899	
3.90		160.05	93.758732	
4.10	120.70			
4.30		163.26	33.473768	
4.70	47.81			
4.90	191.29			
5.30		90.12	144.96296	
5.50		28.57	1.225069	17.759825
5.60		122.50	68.973108	
5.70	122.50			
5.90	163.26			
6.10	173.25			
6.50		146.41	56.021943	
6.90	163.26			
7.10		113.17	215.426064	
7.30	174.98			
7.50		135.25	118.914947	
7.70	116.58			
8.30		174.98	68.973108	
8.90	126.20			
9.10	191.29			
9.50	166.52			

Upper Asselian-upper Artinskian (GH3) section

Sample #	Single mode	Bi-/Multiple modes		
		Mode 1	Mode 2	Mode 3
9.90	150.82			
10.30	178.48			
11.10		55.47	193.191012	
11.95		81.62	54.381988	22.749111
12.10	152.32			
12.30	40.40			
12.65	108.77			
13.15		96.59	58.285736	
13.50		131.29	75.403077	
13.90	135.25			
14.30	57.14			
14.70	241.42			
15.15	168.18			
15.50	147.86			
15.90	166.52			
16.10		197.06	71.760246	
16.50	168.18			
17.30	205.02			
18.10	163.26			
18.50	143.53			
18.90	176.72			
19.10	77.68			
19.30	149.33			
19.50	144.96			
19.70	174.98			
19.85	178.48			
20.10		144.96	109.857119	91.919926
20.30		76.91	113.169995	
20.50	104.03			
20.90	209.12			
21.50	158.48			
21.90	208.09			
22.10		135.25	23.204195	
22.30		185.69	114.296341	
22.50		156.92	101.489232	

Middle-upper Moscovian (UHA) section

Sample #	Single mode	Bi-/Multipal modes		
		Mode 1	Mode 2	Mode 3
0.05	12.31			
0.30	12.68			
0.45		64.35	24.869881	
0.70		25.12	52.269814	
0.90		9.71	37.326386	
1.05		12.19	61.244548	
1.30		9.71	30.317564	
1.50		8.88	56.579512	
1.65	15.61			
1.90		13.86	42.036669	
2.10	16.90			
2.35	21.87			
2.50		17.07	56.579512	
2.70	18.66			
2.90	6.34			
3.50		8.53	21.225466	
3.70		10.30	28.287013	
3.90	31.54			
4.10	9.71			
4.30	69.32			
4.50		6.40	28.287013	
4.70		8.04	25.619863	
4.90	7.88			
5.10		5.92	44.170615	
5.35	20.00			
5.50		8.97	56.579512	
5.70	45.73			
5.90		26.39	45.502634	
6.10	19.80			
6.30	42.88			
6.50		52.53	8.704915	
6.85	18.12			
8.30		27.73	13.728147	
8.60		48.77	13.458909	
9.10		27.19	38.073079	

Upper Asselian-upper Artinskian (GH3) section

Sample #	Single mode	Bi-/Multiple modes		
		Mode 1	Mode 2	Mode 3
9.30		32.17	14.860046	
9.70	21.65			
10.10		100.49	213.303124	
10.50		75.03	40.005817	
10.65		45.96	15.308169	
10.90	75.03			
11.10		70.35	31.542668	
11.30	38.83			
11.50		101.99	68.293405	19.034694
11.70	64.35			
12.70	34.14			
12.90		53.32	8.121894	
13.10		16.41	52.79004	
13.30		81.62	130.000708	
13.50	30.62			
13.70	27.19			
13.90		13.46	42.877589	
14.10	59.45			
14.30	15.01			
14.50	61.85			
14.70	9.80			
14.90		71.41	35.876645	
15.25	84.50			
15.50		38.07	193.191012	
15.70	59.16			
15.90	107.70			
16.10	14.93			

Appendix 4. Mophologi G3 CE diameter (volume distribution) report

CE Diameter Report - Volume Distribution

Malvern

Measurement Details

Sample Name: GH3-0.0-0.1

SOP Name: Xiao Qi-Japan 2015-new.vsop

User Name: itscdl

Date: Tuesday, March 29, 2016 4:40:14 PM

Edited: True

Edited On: Thursday, May 19, 2016 5:43:03 PM

Analysis

SOP Analysis: 3.0

SOP Segmentation: None

SOP Optic(s) used: 5x, 20x

SOP Fill Holes: True

SOP Trash Size: 10

Result

CE Diameter Minimum (µm): 0.54

CE Diameter Maximum (µm): 175.53

CE Diameter D[4,3] (µm): 122.5

CE Diameter D[3,2](µm): 59.92

Particles Counted: 286237

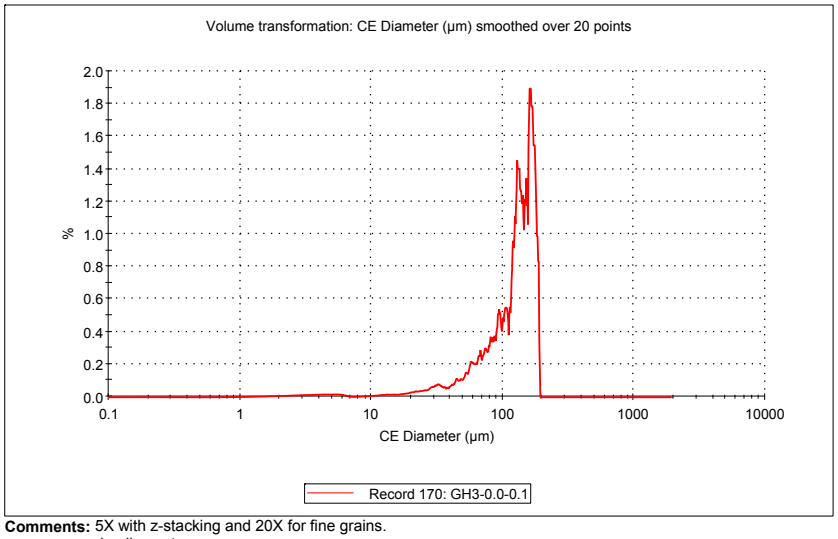
CE Diameter D[v, 0.1]: 54.51

CE Diameter D[v, 0.5]: 130.1

CE Diameter D[v, 0.9]: 170.9

CE Diameter STDV (µm): 2.56

CE Diameter RSD (%): 145.71



Comments: 5X with z-stacking and 20X for fine grains.
dry disperste

CE Diameter Report - Volume Distribution

Malvern

Measurement Details

Sample Name: 15-AKI-GH3-0.3

SOP Name: Xiao Qi-Japan 2015.vsop

User Name: itscdl

Date: Wednesday, January 20, 2016 4:23:14 PM

Edited: True

Edited On: Thursday, May 19, 2016 5:16:24 PM

Analysis

SOP Analysis: 1.0

SOP Segmentation: None

SOP Optic(s) used: 10x, 20x

SOP Fill Holes: True

SOP Trash Size: 50

Result

CE Diameter Minimum (µm): 1.13

CE Diameter Maximum (µm): 222.53

CE Diameter D[4,3] (µm): 123.3

CE Diameter D[3,2](µm): 61.34

Particles Counted: 108466

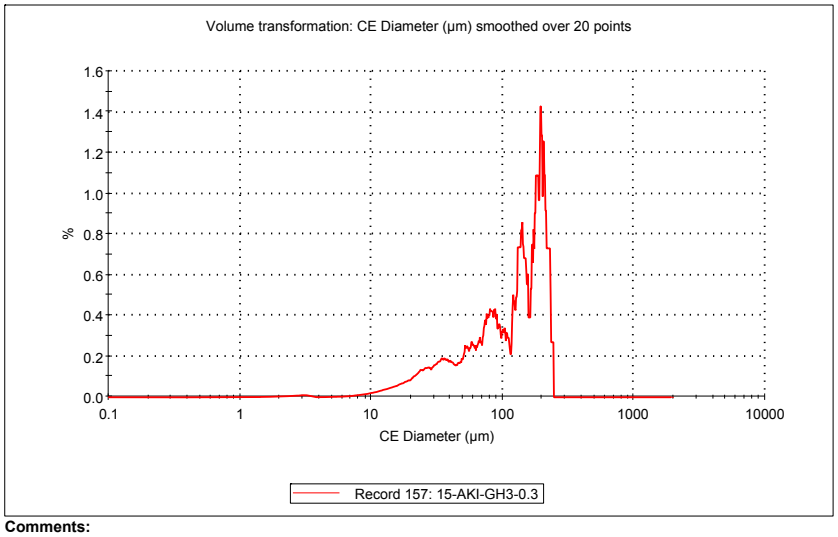
CE Diameter D[v, 0.1]: 30.27

CE Diameter D[v, 0.5]: 129.1

CE Diameter D[v, 0.9]: 208.9

CE Diameter STDV (µm): 4.92

CE Diameter RSD (%): 172.63



Comments:

CE Diameter Report - Volume Distribution

Malvern

Measurement Details

Sample Name: 15-AKI-GH3-0.5 [1 of 4]

SOP Name: Xiao Qi-Japan 2015.vsop

User Name: itscdl

Date: Wednesday, January 20, 2016 5:24:38 PM

Edited: True

Edited On: Thursday, May 19, 2016 5:21:14 PM

Analysis

SOP Analysis: 1.0

SOP Segmentation: None

SOP Optic(s) used: 10x, 20x

SOP Fill Holes: True

SOP Trash Size: 50

Result

CE Diameter Minimum (µm): 1.13

CE Diameter Maximum (µm): 244.81

CE Diameter D[4,3] (µm): 147.1

CE Diameter D[3,2](µm): 71.09

Particles Counted: 74367

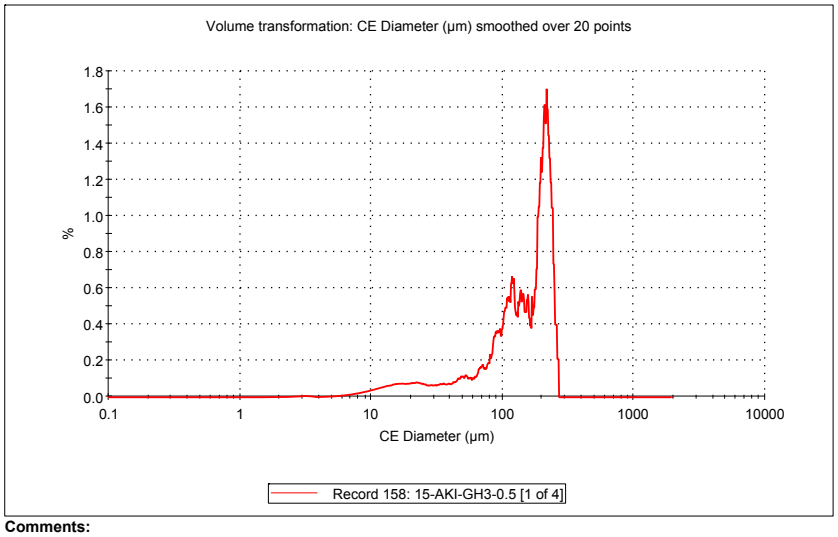
CE Diameter D[v, 0.1]: 34.92

CE Diameter D[v, 0.5]: 151.8

CE Diameter D[v, 0.9]: 224.7

CE Diameter STDV (µm): 6.91

CE Diameter RSD (%): 148.06



Comments:

CE Diameter Report - Volume Distribution

Malvern

Measurement Details

Sample Name: GH3-0.7

SOP Name: Xiao Qi-Japan 2015-new.vsop

User Name: itscdl

Date: Wednesday, March 30, 2016 10:48:12 AM

Edited: True

Edited On: Thursday, May 19, 2016 5:47:51 PM

Analysis

SOP Analysis: 3.0

SOP Segmentation: None

SOP Optic(s) used: 5x, 20x

SOP Fill Holes: True

SOP Trash Size: 10

Result

CE Diameter Minimum (µm): 0.54

CE Diameter Maximum (µm): 141.63

CE Diameter D[4,3] (µm): 85.08

CE Diameter D[3,2](µm): 43.96

Particles Counted: 39497

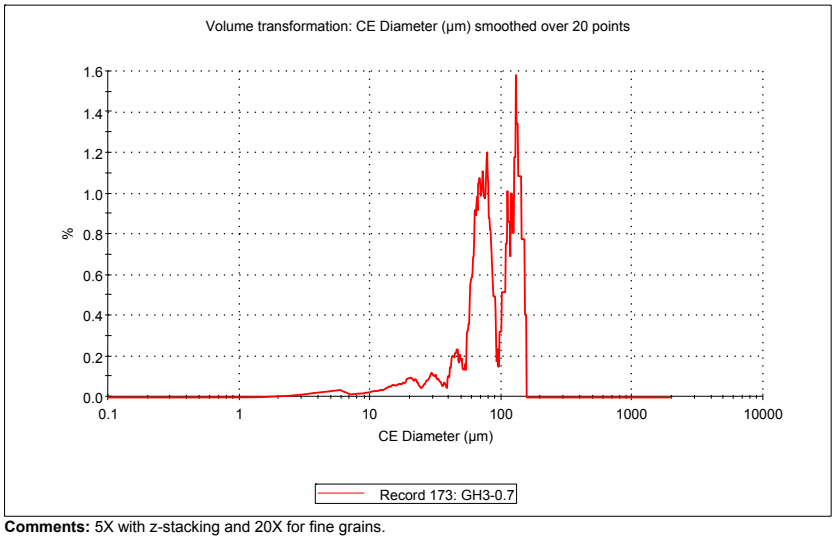
CE Diameter D[v, 0.1]: 28.75

CE Diameter D[v, 0.5]: 78.02

CE Diameter D[v, 0.9]: 136.2

CE Diameter STDV (µm): 3.79

CE Diameter RSD (%): 144.11



Comments: 5X with z-stacking and 20X for fine grains.

CE Diameter Report - Volume Distribution

Malvern

Measurement Details

Sample Name: 15-AKI-GH3-0.9

SOP Name: Xiao Qi-Japan 2015.vsop

User Name: itscdl

Date: Wednesday, January 20, 2016 6:05:20 PM

Edited: True

Edited On: Thursday, May 19, 2016 5:22:29 PM

Analysis

SOP Analysis: 1.0

SOP Segmentation: None

SOP Optic(s) used: 10x, 20x

SOP Fill Holes: True

SOP Trash Size: 50

Result

CE Diameter Minimum (µm): 1.13

CE Diameter Maximum (µm): 111.56

CE Diameter D[4,3] (µm): 65.47

CE Diameter D[3,2](µm): 51.69

Particles Counted: 3667

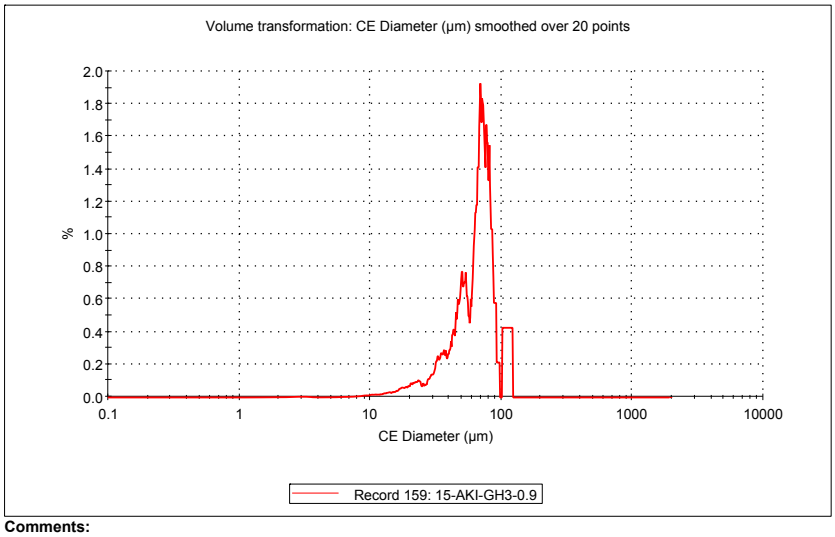
CE Diameter D[v, 0.1]: 34.42

CE Diameter D[v, 0.5]: 66.81

CE Diameter D[v, 0.9]: 87.95

CE Diameter STDV (µm): 8.53

CE Diameter RSD (%): 204.05



Comments:

CE Diameter Report - Volume Distribution

Malvern

Measurement Details

Sample Name: 15-AKI-GH3-1.3

SOP Name: Xiao Qi-Japan 2015.vsop

User Name: itscdl

Date: Wednesday, January 20, 2016 6:46:03 PM

Edited: True

Edited On: Thursday, May 19, 2016 5:24:37 PM

Analysis

SOP Analysis: 1.0

SOP Segmentation: None

SOP Optic(s) used: 10x, 20x

SOP Fill Holes: True

SOP Trash Size: 50

Result

CE Diameter Minimum (µm): 1.13

CE Diameter Maximum (µm): 169.62

CE Diameter D[4,3] (µm): 72.42

CE Diameter D[3,2](µm): 33.2

Particles Counted: 40333

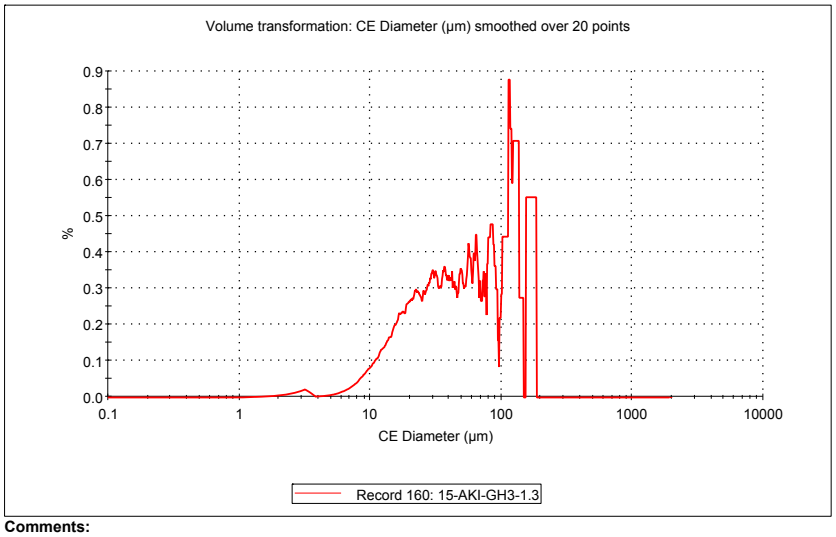
CE Diameter D[v, 0.1]: 15.91

CE Diameter D[v, 0.5]: 58.84

CE Diameter D[v, 0.9]: 166.6

CE Diameter STDV (µm): 4.79

CE Diameter RSD (%): 139.56



Comments:

CE Diameter Report - Volume Distribution

Malvern

Measurement Details

Sample Name: GH3-1.7

SOP Name: Xiao Qi-Japan 2015-new.vsop

User Name: itscdl

Date: Tuesday, March 29, 2016 6:40:26 PM

Edited: True

Edited On: Thursday, May 19, 2016 5:45:31 PM

Analysis

SOP Analysis: 3.0

SOP Segmentation: None

SOP Optic(s) used: 5x, 20x

SOP Fill Holes: True

SOP Trash Size: 10

Result

CE Diameter Minimum (µm): 0.54

CE Diameter Maximum (µm): 315.31

CE Diameter D[4,3] (µm): 223.9

CE Diameter D[3,2](µm): 120.6

Particles Counted: 209524

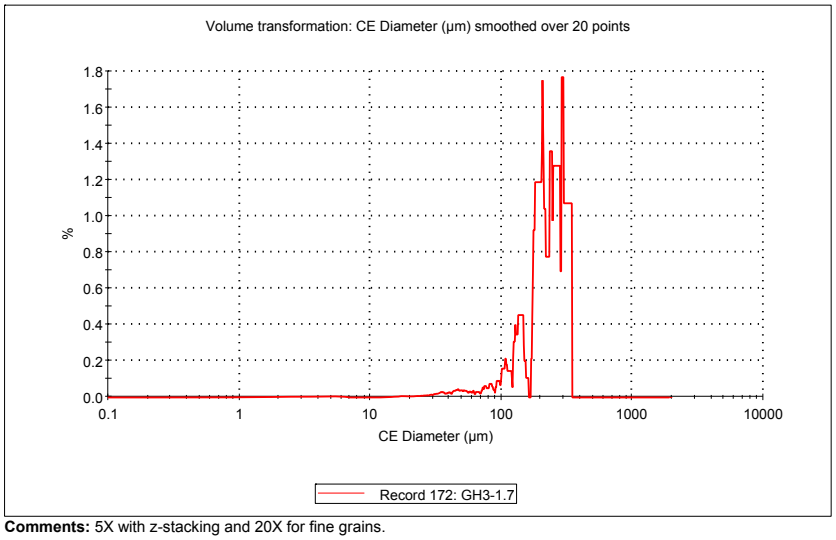
CE Diameter D[v, 0.1]: 132.8

CE Diameter D[v, 0.5]: 222.5

CE Diameter D[v, 0.9]: 312.3

CE Diameter STDV (µm): 2.12

CE Diameter RSD (%): 167.59



Comments: 5X with z-stacking and 20X for fine grains.

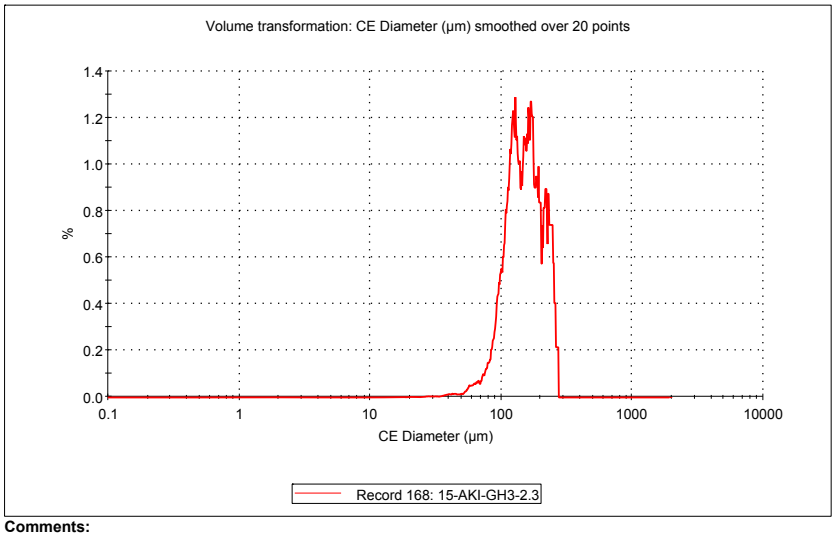
CE Diameter Report - Volume Distribution

Malvern

Measurement Details	
Sample Name: 15-AKI-GH3-2.3	
SOP Name: Xiao Qi-Japan 2015.vsop	**Edited:** True
User Name: itscdl	**Edited On:** Thursday, May 19, 2016 5:40:30 PM
Date: Thursday, January 21, 2016 11:36:32 PM	

Analysis	
SOP Analysis: 1.0	**SOP Fill Holes:** True
SOP Segmentation: None	**SOP Trash Size:** 50
SOP Optic(s) used: 10x, 20x	

Result	
CE Diameter Minimum (µm): 1.13	**CE Diameter D[v, 0.1]:** 98.38
CE Diameter Maximum (µm): 247.50	**CE Diameter D[v, 0.5]:** 150.1
CE Diameter D[4,3] (µm): 155.1	**CE Diameter D[v, 0.9]:** 227
CE Diameter D[3,2](µm): 134	**CE Diameter STDV (µm):** 8.28
Particles Counted: 37875	**CE Diameter RSD (%):** 396.74



Comments:

CE Diameter Report - Volume Distribution

Malvern

Measurement Details

Sample Name: 15-AKI-GH3-2.5

SOP Name: Xiao Qi-Japan 2015.vsop

User Name: itscdl

Date: Monday, January 11, 2016 4:15:31 PM

Edited: True

Edited On: Thursday, May 19, 2016 11:28:03 AM

Analysis

SOP Analysis: 1.0

SOP Segmentation: None

SOP Optic(s) used: 10x, 20x

SOP Fill Holes: True

SOP Trash Size: 50

Result

CE Diameter Minimum (µm): 1.13

CE Diameter Maximum (µm): 36.83

CE Diameter D[4,3] (µm): 11.14

CE Diameter D[3,2](µm): 6.062

Particles Counted: 35268

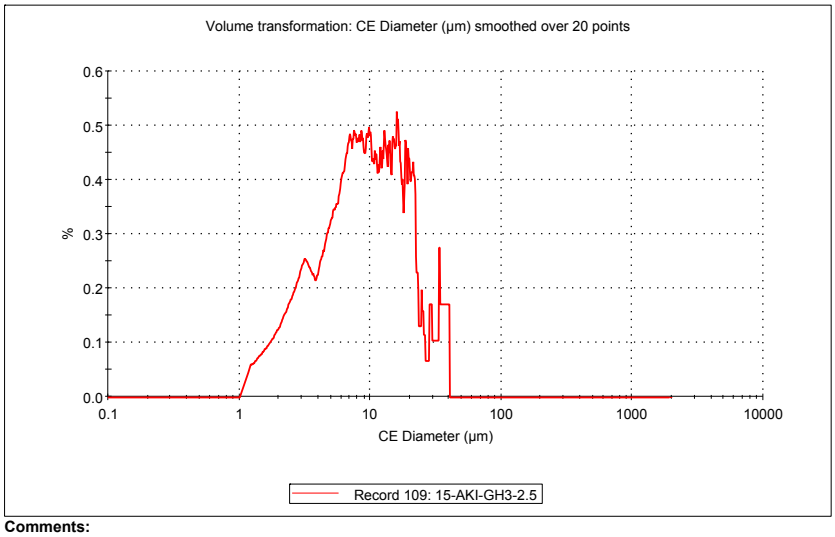
CE Diameter D[v, 0.1]: 2.707

CE Diameter D[v, 0.5]: 8.833

CE Diameter D[v, 0.9]: 21.06

CE Diameter STDV (µm): 1.56

CE Diameter RSD (%): 71.25



Comments:

CE Diameter Report - Volume Distribution

Malvern

Measurement Details

Sample Name: 15-AKI-GH3-2.7-2.8

SOP Name: Xiao Qi-Japan 2015.vsop

User Name: itscdl

Date: Monday, January 11, 2016 5:44:12 PM

Edited: True

Edited On: Thursday, May 19, 2016 11:30:44 AM

Analysis

SOP Analysis: 1.0

SOP Segmentation: None

SOP Optic(s) used: 10x, 20x

SOP Fill Holes: True

SOP Trash Size: 50

Result

CE Diameter Minimum (µm): 1.13

CE Diameter Maximum (µm): 110.65

CE Diameter D[4,3] (µm): 47.78

CE Diameter D[3,2](µm): 9.51

Particles Counted: 113341

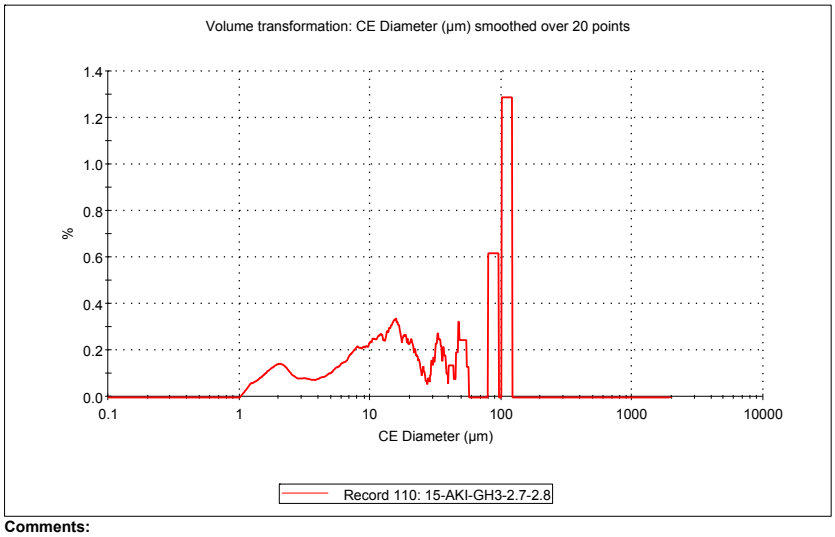
CE Diameter D[v, 0.1]: 2.97

CE Diameter D[v, 0.5]: 24.43

CE Diameter D[v, 0.9]: 109.4

CE Diameter STDV (µm): 1.31

CE Diameter RSD (%): 70.44



Comments:

CE Diameter Report - Volume Distribution

Malvern

Measurement Details

Sample Name: 15-AKI-GH3-2.9

SOP Name: Xiao Qi-Japan 2015.vsop

User Name: itscdl

Date: Monday, January 11, 2016 6:28:32 PM

Edited: True

Edited On: Thursday, May 19, 2016 11:41:14 AM

Analysis

SOP Analysis: 1.0

SOP Segmentation: None

SOP Optic(s) used: 10x, 20x

SOP Fill Holes: True

SOP Trash Size: 50

Result

CE Diameter Minimum (µm): 1.13

CE Diameter Maximum (µm): 168.80

CE Diameter D[4,3] (µm): 94.47

CE Diameter D[3,2](µm): 39.16

Particles Counted: 87208

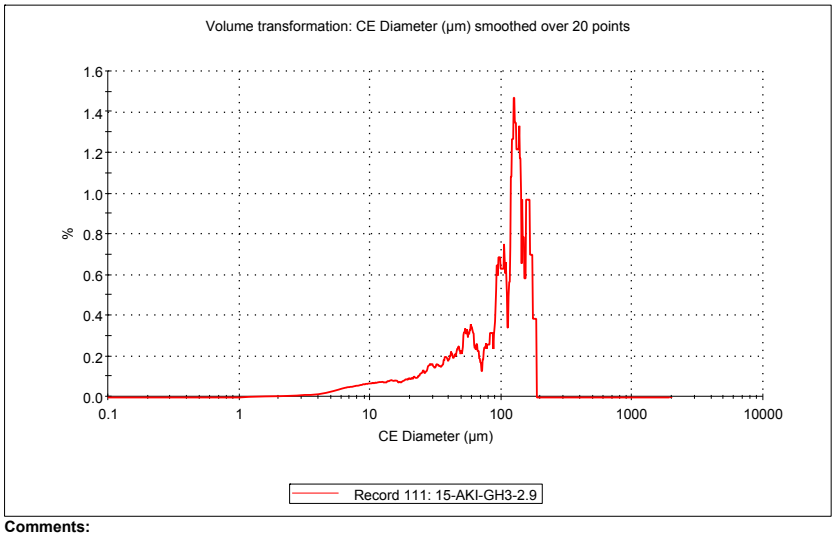
CE Diameter D[v, 0.1]: 18.87

CE Diameter D[v, 0.5]: 99.86

CE Diameter D[v, 0.9]: 156.2

CE Diameter STDV (µm): 3.51

CE Diameter RSD (%): 133.27



Comments:

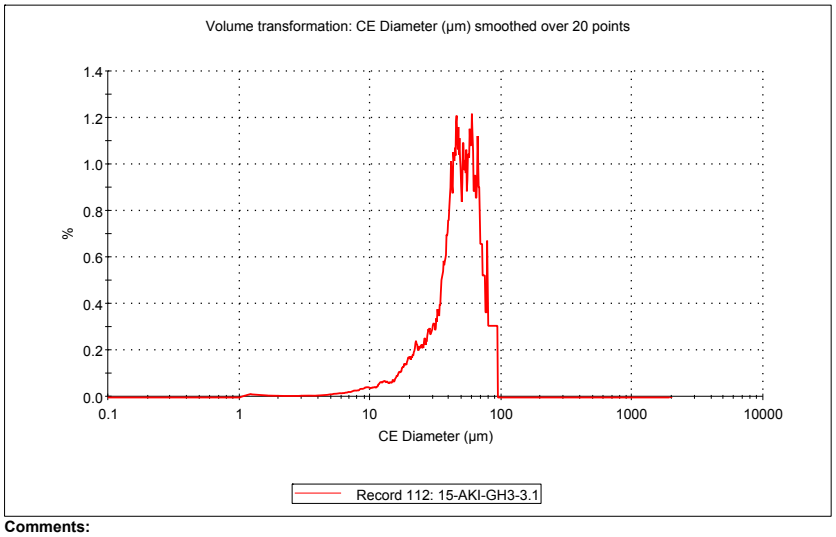
CE Diameter Report - Volume Distribution

Malvern

Measurement Details	
Sample Name: 15-AKI-GH3-3.1	
SOP Name: Xiao Qi-Japan 2015.vsop	**Edited:** True
User Name: itscdl	**Edited On:** Thursday, May 19, 2016 11:47:49 AM
Date: Monday, January 11, 2016 8:51:40 PM	

Analysis	
SOP Analysis: 1.0	**SOP Fill Holes:** True
SOP Segmentation: None	**SOP Trash Size:** 50
SOP Optic(s) used: 10x, 20x	

Result	
CE Diameter Minimum (µm): 1.13	**CE Diameter D[v, 0.1]:** 20.93
CE Diameter Maximum (µm): 85.47	**CE Diameter D[v, 0.5]:** 46.81
CE Diameter D[4,3] (µm): 47.54	**CE Diameter D[v, 0.9]:** 70.92
CE Diameter D[3,2](µm): 30.33	**CE Diameter STDV (µm):** 2.92
Particles Counted: 29644	**CE Diameter RSD (%):** 158.29



Comments:

Morphologi
Malvern Instruments Worldwide
www.malvern.com

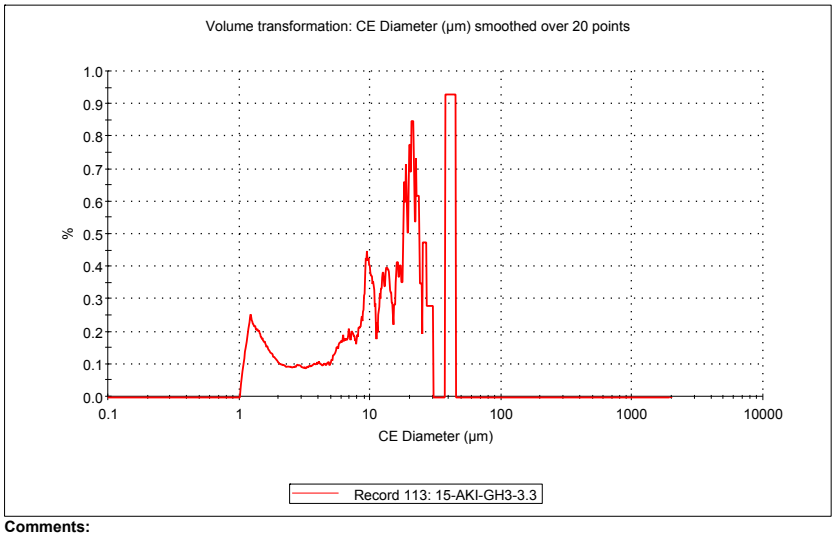
CE Diameter Report - Volume Distribution

Malvern

Measurement Details	
Sample Name: 15-AKI-GH3-3.3	
SOP Name: Xiao Qi-Japan 2015.vsop	**Edited:** True
User Name: itscdl	**Edited On:** Thursday, May 19, 2016 11:49:23 AM
Date: Monday, January 11, 2016 9:35:20 PM	

Analysis	
SOP Analysis: 1.0	**SOP Fill Holes:** True
SOP Segmentation: None	**SOP Trash Size:** 50
SOP Optic(s) used: 10x, 20x	

Result	
CE Diameter Minimum (µm): 1.13	**CE Diameter D[v, 0.1]:** 1.814
CE Diameter Maximum (µm): 41.13	**CE Diameter D[v, 0.5]:** 15.53
CE Diameter D[4,3] (µm): 17.77	**CE Diameter D[v, 0.9]:** 40.58
CE Diameter D[3,2](µm): 6.261	**CE Diameter STDV (µm):** 1.02
Particles Counted: 18561	**CE Diameter RSD (%):** 66.51



Comments:

Morphologi
Malvern Instruments Worldwide
www.malvern.com

Morphologi Ver. 8.20
Serial Number : MAL1115686

File name: GH3-final data with additional samples.vmes
Record Number: 113
20 May 2016 4:01:47 PM

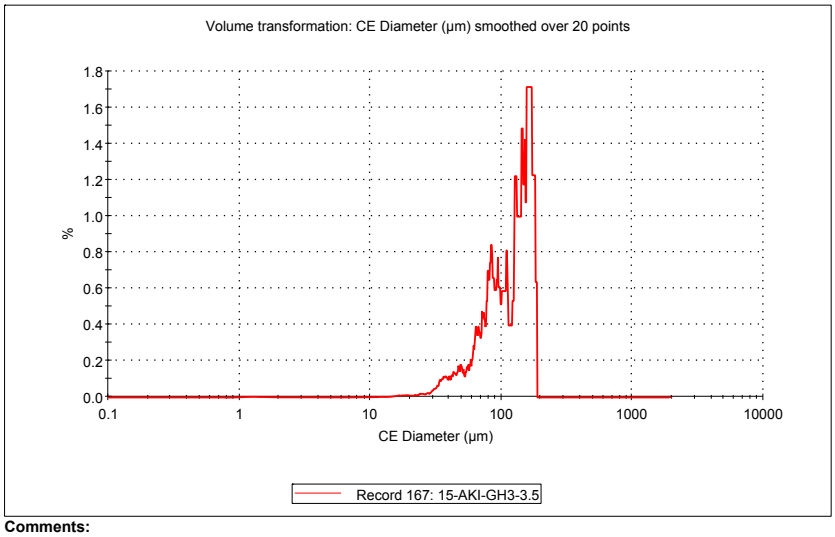
CE Diameter Report - Volume Distribution

Malvern

Measurement Details	
Sample Name: 15-AKI-GH3-3.5	
SOP Name: Xiao Qi-Japan 2015.vsop	**Edited:** True
User Name: itscdl	**Edited On:** Thursday, May 19, 2016 5:38:42 PM
Date: Thursday, January 21, 2016 10:55:50 PM	

Analysis	
SOP Analysis: 1.0	**SOP Fill Holes:** True
SOP Segmentation: None	**SOP Trash Size:** 50
SOP Optic(s) used: 10x, 20x	

Result	
CE Diameter Minimum (µm): 1.13	**CE Diameter D[v, 0.1]:** 60.9
CE Diameter Maximum (µm): 169.96	**CE Diameter D[v, 0.5]:** 131.6
CE Diameter D[4,3] (µm): 118.7	**CE Diameter D[v, 0.9]:** 168.5
CE Diameter D[3,2](µm): 87.59	**CE Diameter STDV (µm):** 4.00
Particles Counted: 25083	**CE Diameter RSD (%):** 253.27



Comments:

Morphologi
Malvern Instruments Worldwide
www.malvern.com

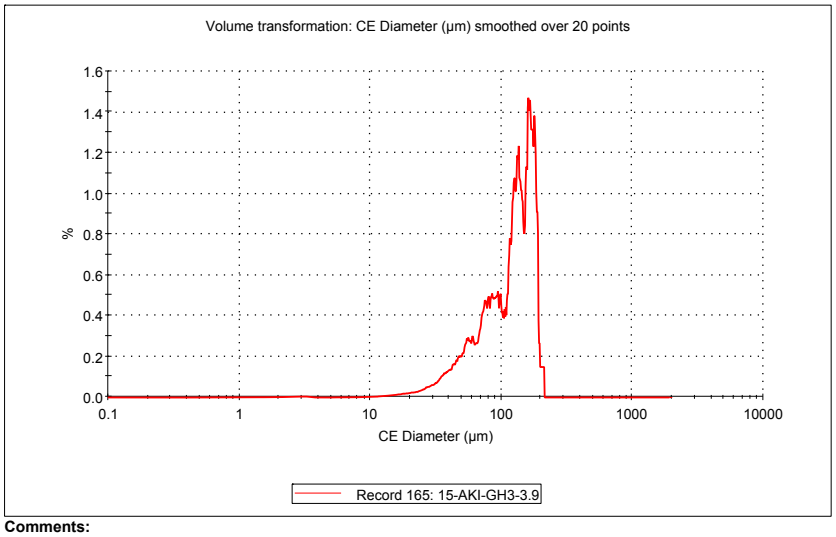
CE Diameter Report - Volume Distribution

Malvern

Measurement Details	
Sample Name: 15-AKI-GH3-3.9	
SOP Name: Xiao Qi-Japan 2015.vsop	**Edited:** True
User Name: itscdl	**Edited On:** Thursday, May 19, 2016 5:36:43 PM
Date: Thursday, January 21, 2016 7:37:39 PM	

Analysis	
SOP Analysis: 1.0	**SOP Fill Holes:** True
SOP Segmentation: None	**SOP Trash Size:** 50
SOP Optic(s) used: 10x, 20x	

Result	
CE Diameter Minimum (µm): 1.13	**CE Diameter D[v, 0.1]:** 51.17
CE Diameter Maximum (µm): 194.46	**CE Diameter D[v, 0.5]:** 124.5
CE Diameter D[4,3] (µm): 119.2	**CE Diameter D[v, 0.9]:** 172.7
CE Diameter D[3,2](µm): 84.01	**CE Diameter STDV (µm):** 6.39
Particles Counted: 64005	**CE Diameter RSD (%):** 236.27



Comments:

CE Diameter Report - Volume Distribution

Malvern

Measurement Details

Sample Name: 15-AKI-GH3-4.1

SOP Name: Xiao Qi-Japan 2015.vsop

User Name: itscdl

Date: Friday, January 22, 2016 12:17:21 AM

Edited: True

Edited On: Thursday, May 19, 2016 5:41:01 PM

Analysis

SOP Analysis: 1.0

SOP Segmentation: None

SOP Optic(s) used: 10x, 20x

SOP Fill Holes: True

SOP Trash Size: 50

Result

CE Diameter Minimum (µm): 1.13

CE Diameter Maximum (µm): 125.50

CE Diameter D[4,3] (µm): 68.41

CE Diameter D[3,2](µm): 37.95

Particles Counted: 25630

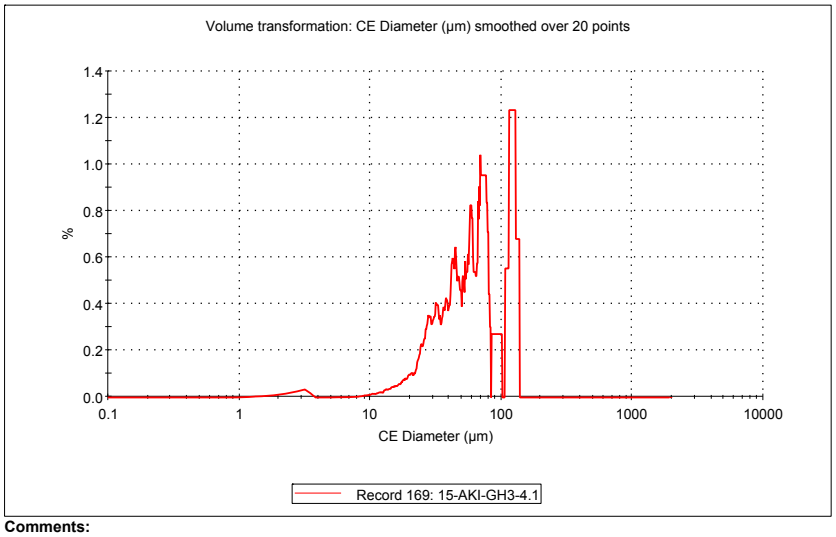
CE Diameter D[v, 0.1]: 26.37

CE Diameter D[v, 0.5]: 61.84

CE Diameter D[v, 0.9]: 124

CE Diameter STDV (µm): 3.25

CE Diameter RSD (%): 142.92



Comments:

Morphologi
Malvern Instruments Worldwide
www.malvern.com

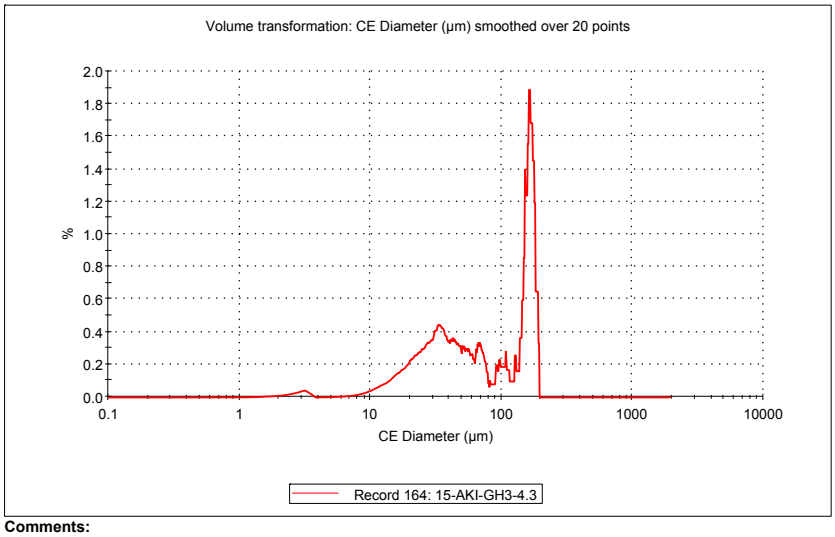
CE Diameter Report - Volume Distribution

Malvern

Measurement Details	
Sample Name: 15-AKI-GH3-4.3	
SOP Name: Xiao Qi-Japan 2015.vsop	**Edited:** True
User Name: itscdl	**Edited On:** Thursday, May 19, 2016 5:35:00 PM
Date: Thursday, January 21, 2016 6:57:10 PM	

Analysis	
SOP Analysis: 1.0	**SOP Fill Holes:** True
SOP Segmentation: None	**SOP Trash Size:** 50
SOP Optic(s) used: 10x, 20x	

Result	
CE Diameter Minimum (µm): 1.13	**CE Diameter D[v, 0.1]:** 19.31
CE Diameter Maximum (µm): 177.15	**CE Diameter D[v, 0.5]:** 67.56
CE Diameter D[4,3] (µm): 90.58	**CE Diameter D[v, 0.9]:** 172.2
CE Diameter D[3,2](µm): 35.59	**CE Diameter STDV (µm):** 3.64
Particles Counted: 118840	**CE Diameter RSD (%):** 131.19



Comments:

Morphologi
Malvern Instruments Worldwide
www.malvern.com

Morphologi Ver. 8.20
Serial Number : MAL1115686

File name: GH3-final data with additional samples.vmes
Record Number: 164
20 May 2016 4:05:10 PM

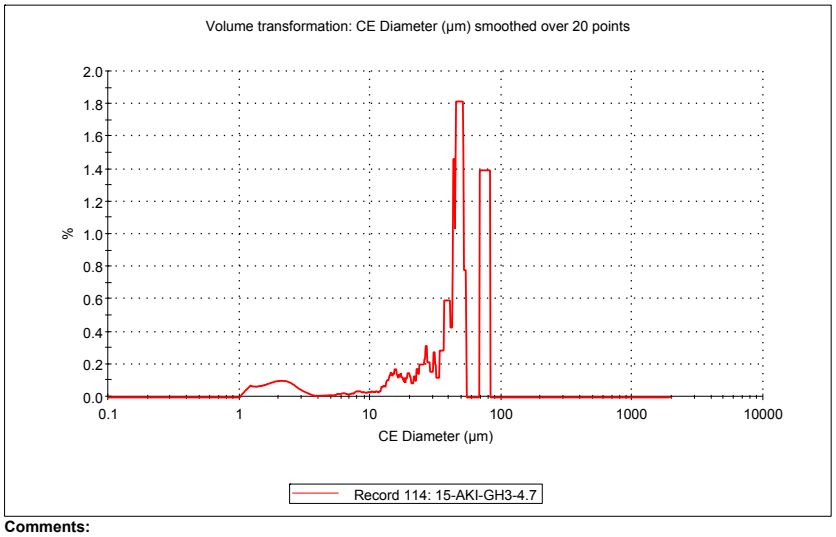
CE Diameter Report - Volume Distribution

Malvern

Measurement Details	
Sample Name: 15-AKI-GH3-4.7	
SOP Name: Xiao Qi-Japan 2015.vsop	**Edited:** True
User Name: itscdl	**Edited On:** Thursday, May 19, 2016 11:53:54 AM
Date: Monday, January 11, 2016 10:18:48 PM	

Analysis	
SOP Analysis: 1.0	**SOP Fill Holes:** True
SOP Segmentation: None	**SOP Trash Size:** 50
SOP Optic(s) used: 10x, 20x	

Result	
CE Diameter Minimum (µm): 1.13	**CE Diameter D[v, 0.1]:** 7.875
CE Diameter Maximum (µm): 75.00	**CE Diameter D[v, 0.5]:** 46.57
CE Diameter D[4,3] (µm): 44.98	**CE Diameter D[v, 0.9]:** 74.38
CE Diameter D[3,2](µm): 13.82	**CE Diameter STDV (µm):** 1.17
Particles Counted: 28780	**CE Diameter RSD (%):** 72.37



Comments:

Morphologi
Malvern Instruments Worldwide
www.malvern.com

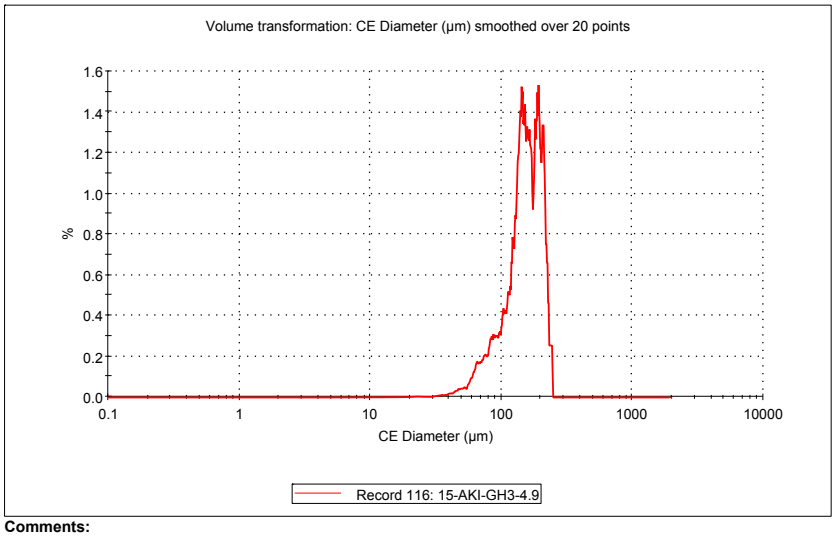
CE Diameter Report - Volume Distribution

Malvern

Measurement Details	
Sample Name: 15-AKI-GH3-4.9	
SOP Name: Xiao Qi-Japan 2015.vsop	**Edited:** True
User Name: itscdl	**Edited On:** Thursday, May 19, 2016 12:05:58 PM
Date: Monday, January 11, 2016 11:02:29 PM	

Analysis	
SOP Analysis: 1.0	**SOP Fill Holes:** True
SOP Segmentation: None	**SOP Trash Size:** 50
SOP Optic(s) used: 10x, 20x	

Result	
CE Diameter Minimum (µm): 1.13	**CE Diameter D[v, 0.1]:** 87.66
CE Diameter Maximum (µm): 225.69	**CE Diameter D[v, 0.5]:** 150.8
CE Diameter D[4,3] (µm): 151.6	**CE Diameter D[v, 0.9]:** 204.4
CE Diameter D[3,2](µm): 132.1	**CE Diameter STDV (µm):** 17.32
Particles Counted: 11028	**CE Diameter RSD (%):** 363.67



Comments:

CE Diameter Report - Volume Distribution

Malvern

Measurement Details

Sample Name: 15-AKI-GH3-5.3 [1 of 4]

SOP Name: Xiao Qi-Japan 2015.vsop

User Name: itscdl

Date: Tuesday, January 12, 2016 3:47:14 PM

Edited: True

Edited On: Thursday, May 19, 2016 12:11:20 PM

Analysis

SOP Analysis: 1.0

SOP Segmentation: None

SOP Optic(s) used: 10x, 20x

SOP Fill Holes: True

SOP Trash Size: 50

Result

CE Diameter Minimum (µm): 1.13

CE Diameter Maximum (µm): 142.86

CE Diameter D[4,3] (µm): 83.68

CE Diameter D[3,2](µm): 45.03

Particles Counted: 26307

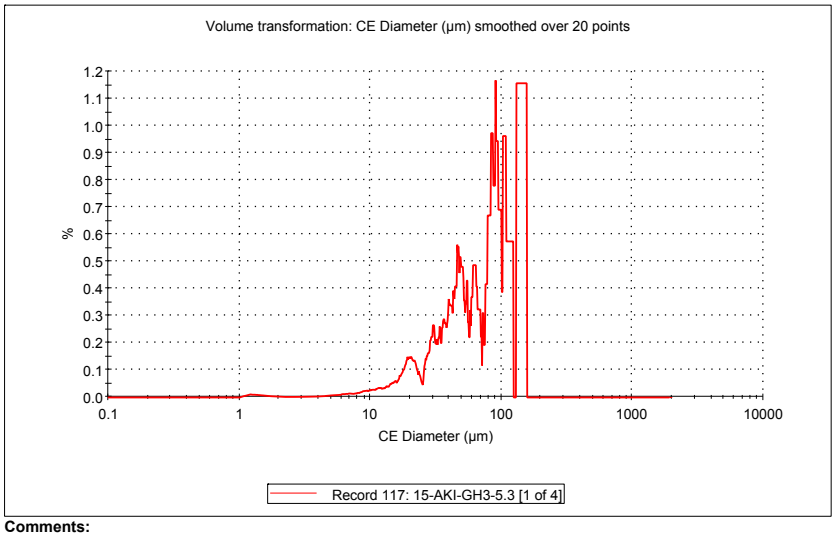
CE Diameter D[v, 0.1]: 28.13

CE Diameter D[v, 0.5]: 85.05

CE Diameter D[v, 0.9]: 141.5

CE Diameter STDV (µm): 2.88

CE Diameter RSD (%): 169.30



Comments:

Morphologi
Malvern Instruments Worldwide
www.malvern.com

Morphologi Ver. 8.20
Serial Number : MAL1115686

File name: GH3-final data with additional samples.vmes
Record Number: 117
20 May 2016 4:02:11 PM

CE Diameter Report - Volume Distribution

Malvern

Measurement Details

Sample Name: 15-AKI-GH3-5.5

SOP Name: Xiao Qi-Japan 2015.vsop

User Name: itscdl

Date: Tuesday, January 12, 2016 4:40:10 PM

Edited: True

Edited On: Thursday, May 19, 2016 12:14:34 PM

Analysis

SOP Analysis: 1.0

SOP Segmentation: None

SOP Optic(s) used: 10x, 20x

SOP Fill Holes: True

SOP Trash Size: 50

Result

CE Diameter Minimum (µm): 1.13

CE Diameter Maximum (µm): 30.37

CE Diameter D[4,3] (µm): 11.08

CE Diameter D[3,2](µm): 3.049

Particles Counted: 36892

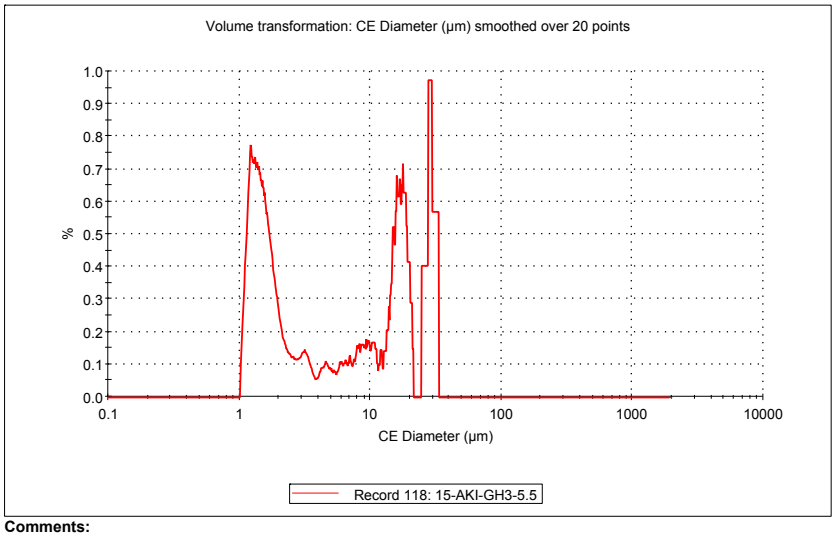
CE Diameter D[v, 0.1]: 1.257

CE Diameter D[v, 0.5]: 6.827

CE Diameter D[v, 0.9]: 30.04

CE Diameter STDV (µm): 0.54

CE Diameter RSD (%): 38.27



Comments:

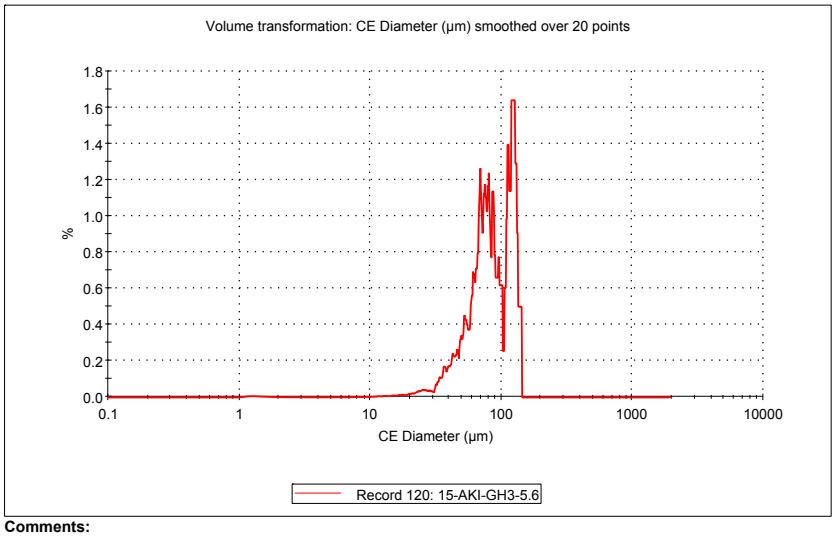
CE Diameter Report - Volume Distribution

Malvern

Measurement Details	
Sample Name: 15-AKI-GH3-5.6	
SOP Name: Xiao Qi-Japan 2015.vsop	**Edited:** True
User Name: itscdl	**Edited On:** Thursday, May 19, 2016 12:24:19 PM
Date: Tuesday, January 12, 2016 5:23:39 PM	

Analysis	
SOP Analysis: 1.0	**SOP Fill Holes:** True
SOP Segmentation: None	**SOP Trash Size:** 50
SOP Optic(s) used: 10x, 20x	

Result	
CE Diameter Minimum (µm): 1.13	**CE Diameter D[v, 0.1]:** 47.53
CE Diameter Maximum (µm): 130.41	**CE Diameter D[v, 0.5]:** 81.12
CE Diameter D[4,3] (µm): 86.64	**CE Diameter D[v, 0.9]:** 121.2
CE Diameter D[3,2](µm): 63.2	**CE Diameter STDV (µm):** 3.25
Particles Counted: 28418	**CE Diameter RSD (%):** 210.24



Comments:

Morphologi
Malvern Instruments Worldwide
www.malvern.com

CE Diameter Report - Volume Distribution

Malvern

Measurement Details

Sample Name: 15-AKI-GH3-5.7

SOP Name: Xiao Qi-Japan 2015.vsop

User Name: itscdl

Date: Tuesday, January 12, 2016 6:07:29 PM

Edited: True

Edited On: Thursday, May 19, 2016 12:32:57 PM

Analysis

SOP Analysis: 1.0

SOP Segmentation: None

SOP Optic(s) used: 10x, 20x

SOP Fill Holes: True

SOP Trash Size: 50

Result

CE Diameter Minimum (µm): 1.13

CE Diameter Maximum (µm): 162.59

CE Diameter D[4,3] (µm): 121.2

CE Diameter D[3,2](µm): 83.11

Particles Counted: 21340

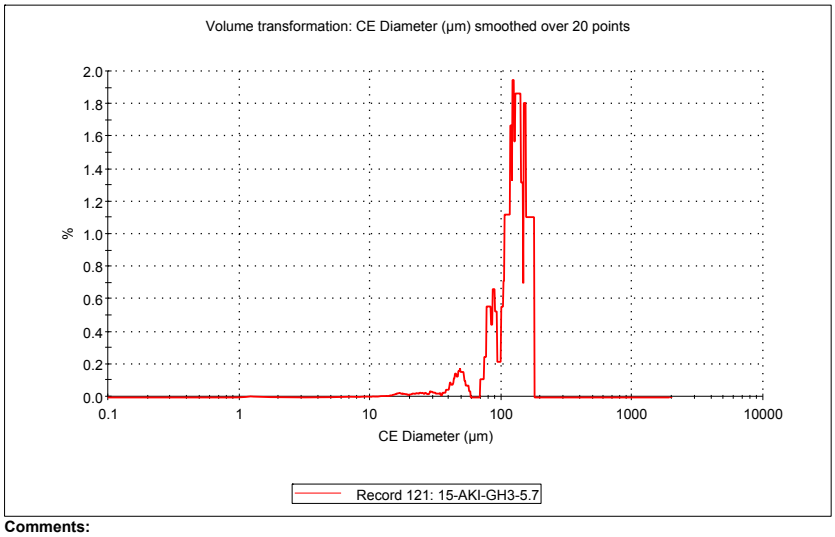
CE Diameter D[v, 0.1]: 80.1

CE Diameter D[v, 0.5]: 127

CE Diameter D[v, 0.9]: 160.9

CE Diameter STDV (µm): 3.04

CE Diameter RSD (%): 199.17



Comments:

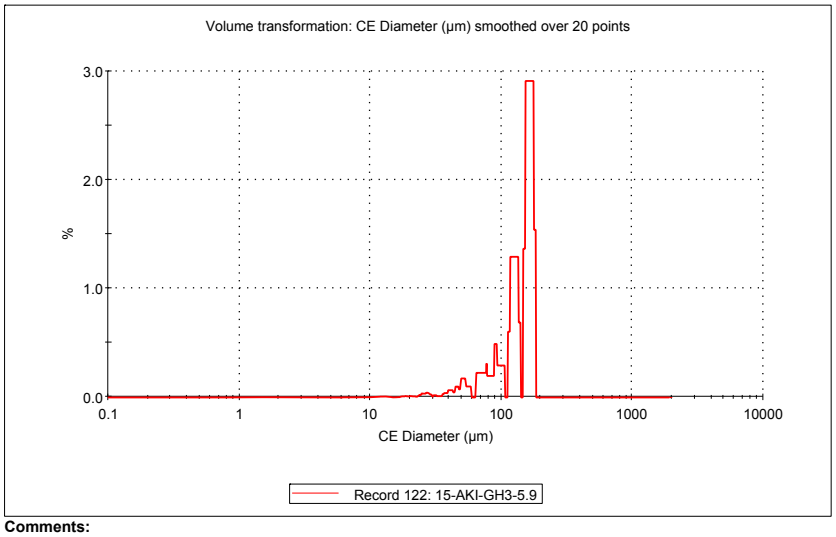
CE Diameter Report - Volume Distribution

Malvern

Measurement Details	
Sample Name: 15-AKI-GH3-5.9	
SOP Name: Xiao Qi-Japan 2015.vsop	**Edited:** True
User Name: itscdl	**Edited On:** Thursday, May 19, 2016 12:37:17 PM
Date: Tuesday, January 12, 2016 7:11:59 PM	

Analysis	
SOP Analysis: 1.0	**SOP Fill Holes:** True
SOP Segmentation: None	**SOP Trash Size:** 50
SOP Optic(s) used: 10x, 20x	

Result	
CE Diameter Minimum (µm): 1.13	**CE Diameter D[v, 0.1]:** 70.08
CE Diameter Maximum (µm): 168.15	**CE Diameter D[v, 0.5]:** 158.8
CE Diameter D[4,3] (µm): 136.4	**CE Diameter D[v, 0.9]:** 166
CE Diameter D[3,2](µm): 99.26	**CE Diameter STDV (µm):** 3.67
Particles Counted: 10186	**CE Diameter RSD (%):** 227.65



Comments:

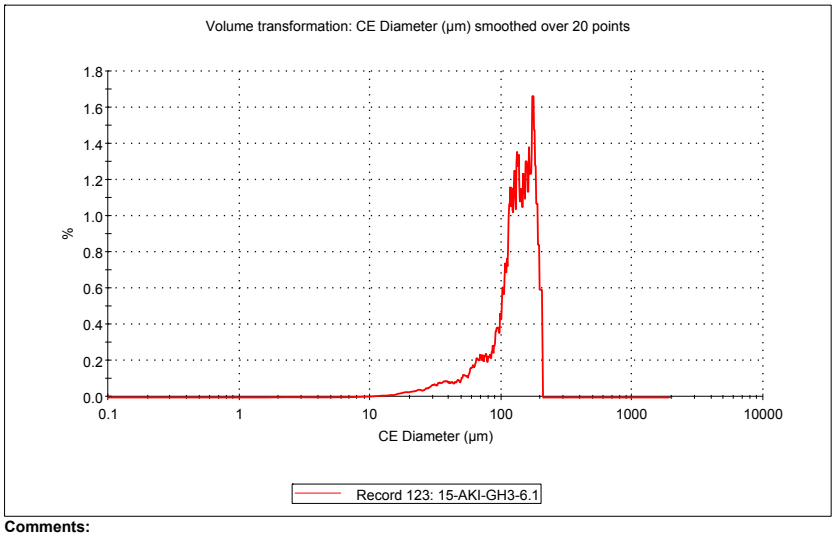
CE Diameter Report - Volume Distribution

Malvern

Measurement Details	
Sample Name: 15-AKI-GH3-6.1	
SOP Name: Xiao Qi-Japan 2015.vsop	**Edited:** True
User Name: itscdl	**Edited On:** Thursday, May 19, 2016 12:46:19 PM
Date: Tuesday, January 12, 2016 7:55:31 PM	

Analysis	
SOP Analysis: 1.0	**SOP Fill Holes:** True
SOP Segmentation: None	**SOP Trash Size:** 50
SOP Optic(s) used: 10x, 20x	

Result	
CE Diameter Minimum (µm): 1.13	**CE Diameter D[v, 0.1]:** 61.32
CE Diameter Maximum (µm): 188.57	**CE Diameter D[v, 0.5]:** 133.6
CE Diameter D[4,3] (µm): 128.7	**CE Diameter D[v, 0.9]:** 184.3
CE Diameter D[3,2](µm): 95.44	**CE Diameter STDV (µm):** 9.93
Particles Counted: 10853	**CE Diameter RSD (%):** 259.55



Comments:

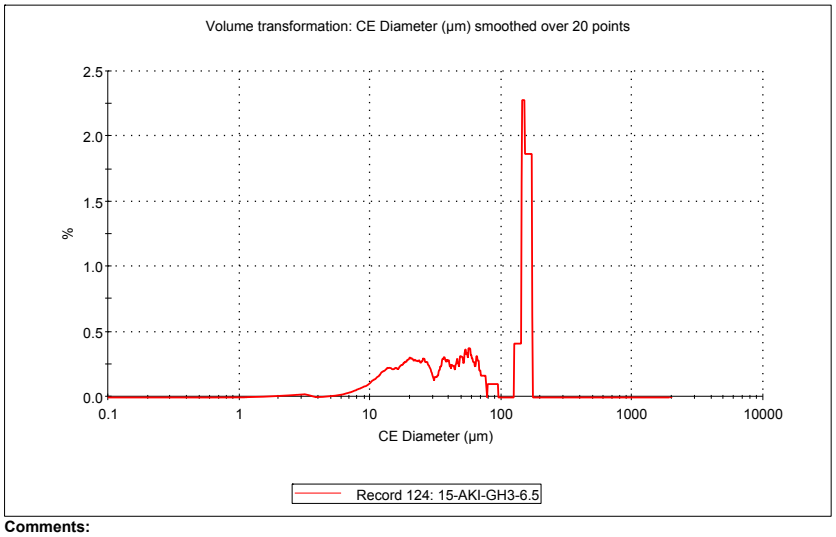
CE Diameter Report - Volume Distribution

Malvern

Measurement Details	
Sample Name: 15-AKI-GH3-6.5	
SOP Name: Xiao Qi-Japan 2015.vsop	**Edited:** True
User Name: itscdl	**Edited On:** Thursday, May 19, 2016 12:54:52 PM
Date: Tuesday, January 12, 2016 8:39:14 PM	

Analysis	
SOP Analysis: 1.0	**SOP Fill Holes:** True
SOP Segmentation: None	**SOP Trash Size:** 50
SOP Optic(s) used: 10x, 20x	

Result	
CE Diameter Minimum (µm): 1.13	**CE Diameter D[v, 0.1]:** 13.38
CE Diameter Maximum (µm): 157.75	**CE Diameter D[v, 0.5]:** 60.89
CE Diameter D[4,3] (µm): 85.35	**CE Diameter D[v, 0.9]:** 155.6
CE Diameter D[3,2](µm): 29.8	**CE Diameter STDV (µm):** 3.52
Particles Counted: 55653	**CE Diameter RSD (%):** 129.59



Comments:

Morphologi
Malvern Instruments Worldwide
www.malvern.com

CE Diameter Report - Volume Distribution

Malvern

Measurement Details

Sample Name: 15-AKI-GH3-6.9

SOP Name: Xiao Qi-Japan 2015.vsop

User Name: itscdl

Date: Tuesday, January 12, 2016 9:23:00 PM

Edited: True

Edited On: Thursday, May 19, 2016 1:03:46 PM

Analysis

SOP Analysis: 1.0

SOP Segmentation: None

SOP Optic(s) used: 10x, 20x

SOP Fill Holes: True

SOP Trash Size: 50

Result

CE Diameter Minimum (µm): 1.13

CE Diameter Maximum (µm): 241.57

CE Diameter D[4,3] (µm): 148.6

CE Diameter D[3,2](µm): 109

Particles Counted: 17619

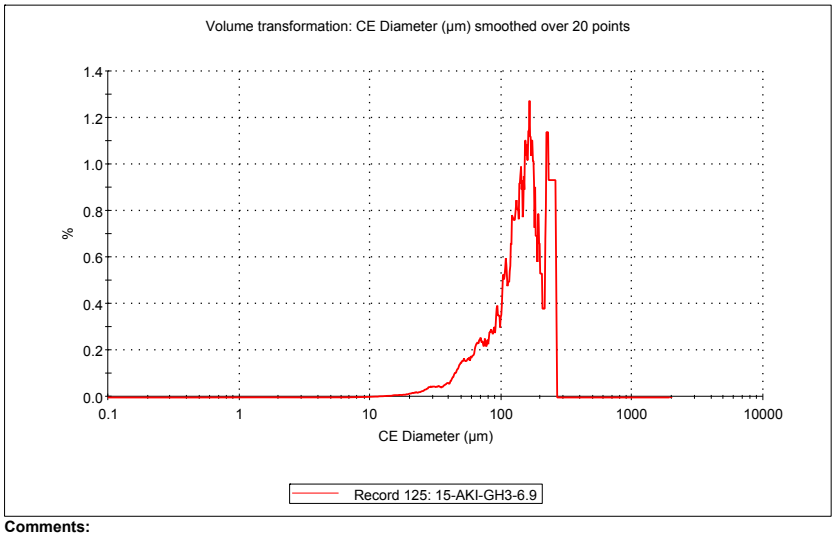
CE Diameter D[v, 0.1]: 63.74

CE Diameter D[v, 0.5]: 148.9

CE Diameter D[v, 0.9]: 236.3

CE Diameter STDV (µm): 10.41

CE Diameter RSD (%): 302.07



Comments:

Morphologi
Malvern Instruments Worldwide
www.malvern.com

CE Diameter Report - Volume Distribution

Malvern

Measurement Details

Sample Name: GH3-7.1

SOP Name: Xiao Qi-Japan 2015-new.vsop

User Name: itscdl

Date: Tuesday, May 17, 2016 3:27:49 PM

Edited: True

Edited On: Thursday, May 19, 2016 7:33:26 PM

Analysis

SOP Analysis: 3.0

SOP Segmentation: None

SOP Optic(s) used: 5x, 20x

SOP Fill Holes: True

SOP Trash Size: 10

Result

CE Diameter Minimum (µm): 0.54

CE Diameter Maximum (µm): 222.51

CE Diameter D[4,3] (µm): 123

CE Diameter D[3,2](µm): 41.56

Particles Counted: 306379

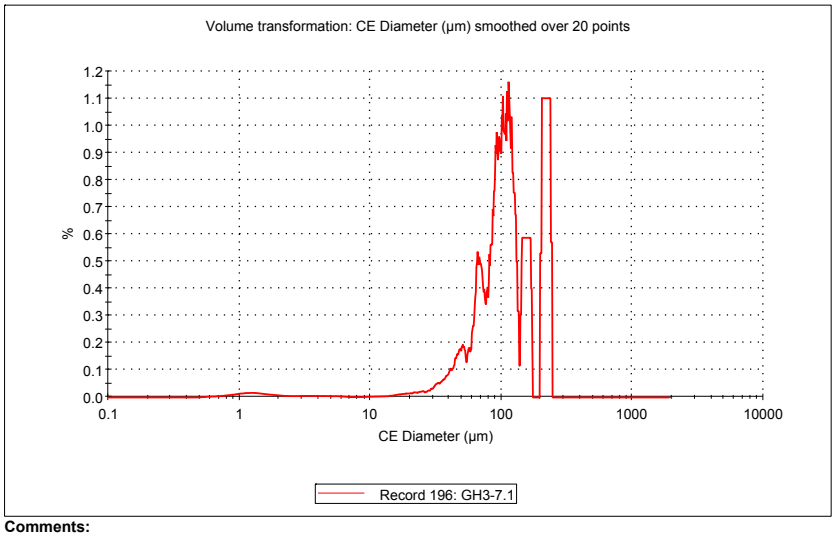
CE Diameter D[v, 0.1]: 54.32

CE Diameter D[v, 0.5]: 108.9

CE Diameter D[v, 0.9]: 219.9

CE Diameter STDV (µm): 0.95

CE Diameter RSD (%): 99.10



Comments:

Morphologi
Malvern Instruments Worldwide
www.malvern.com

CE Diameter Report - Volume Distribution

Malvern

Measurement Details

Sample Name: GH3-7.3 [1 of 4]

SOP Name: Xiao Qi-Japan 2015-new.vsop

User Name: itscdl

Date: Monday, May 16, 2016 11:17:59 PM

Edited: True

Edited On: Thursday, May 19, 2016 7:10:44 PM

Analysis

SOP Analysis: 3.0

SOP Segmentation: None

SOP Optic(s) used: 5x, 20x

SOP Fill Holes: True

SOP Trash Size: 10

Result

CE Diameter Minimum (µm): 0.54

CE Diameter Maximum (µm): 243.83

CE Diameter D[4,3] (µm): 147.9

CE Diameter D[3,2](µm): 117.5

Particles Counted: 7811

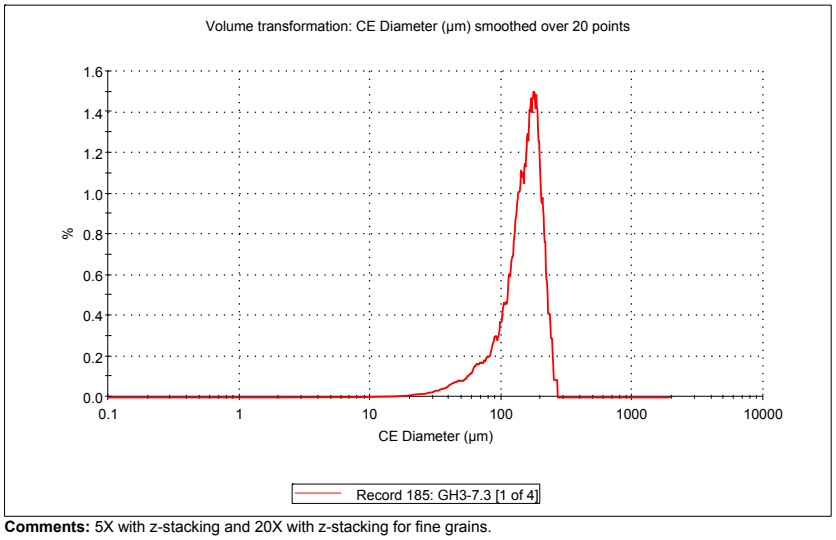
CE Diameter D[v, 0.1]: 76.61

CE Diameter D[v, 0.5]: 152.5

CE Diameter D[v, 0.9]: 202.5

CE Diameter STDV (µm): 16.23

CE Diameter RSD (%): 261.66



Comments: 5X with z-stacking and 20X with z-stacking for fine grains.

Morphologi
Malvern Instruments Worldwide
www.malvern.com

CE Diameter Report - Volume Distribution

Malvern

Measurement Details

Sample Name: GH3-7.5

SOP Name: Xiao Qi-Japan 2015-new.vsop

User Name: itscdl

Date: Tuesday, May 17, 2016 2:50:15 PM

Edited: True

Edited On: Thursday, May 19, 2016 7:32:21 PM

Analysis

SOP Analysis: 3.0

SOP Segmentation: None

SOP Optic(s) used: 5x, 20x

SOP Fill Holes: True

SOP Trash Size: 10

Result

CE Diameter Minimum (µm): 0.54

CE Diameter Maximum (µm): 234.52

CE Diameter D[4,3] (µm): 117.2

CE Diameter D[3,2](µm): 78.49

Particles Counted: 10022

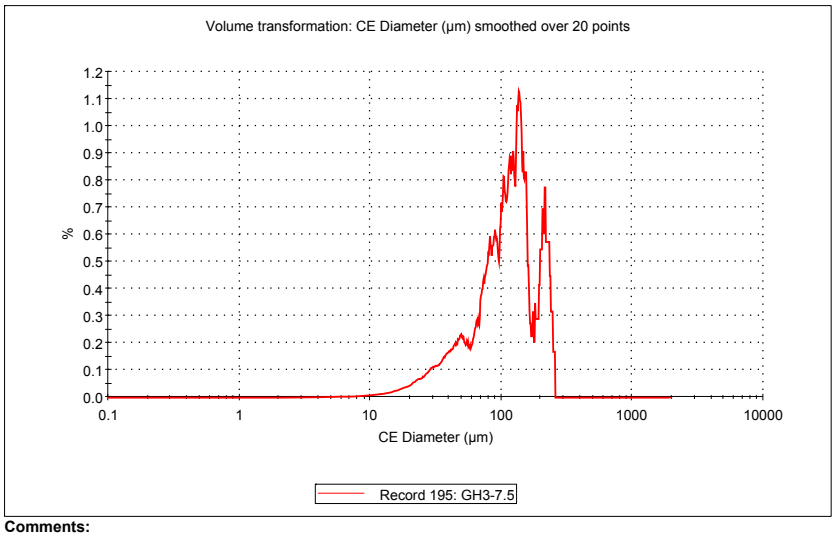
CE Diameter D[v, 0.1]: 42.04

CE Diameter D[v, 0.5]: 111.7

CE Diameter D[v, 0.9]: 209.9

CE Diameter STDV (µm): 12.61

CE Diameter RSD (%): 197.83



Comments:

CE Diameter Report - Volume Distribution

Malvern

Measurement Details

Sample Name: 15-AKI-GH3-7.7

SOP Name: Xiao Qi-Japan 2015.vsop

User Name: itscdl

Date: Wednesday, January 13, 2016 2:36:48 PM

Edited: True

Edited On: Thursday, May 19, 2016 3:24:24 PM

Analysis

SOP Analysis: 1.0

SOP Segmentation: None

SOP Optic(s) used: 10x, 20x

SOP Fill Holes: True

SOP Trash Size: 50

Result

CE Diameter Minimum (µm): 1.13

CE Diameter Maximum (µm): 192.14

CE Diameter D[4,3] (µm): 122.7

CE Diameter D[3,2](µm): 84.39

Particles Counted: 18277

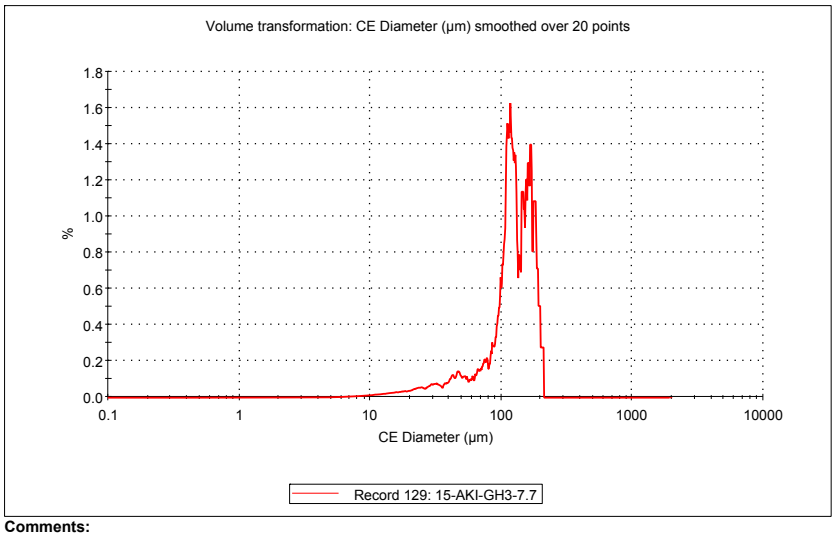
CE Diameter D[v, 0.1]: 50.7

CE Diameter D[v, 0.5]: 119.6

CE Diameter D[v, 0.9]: 173.1

CE Diameter STDV (µm): 8.49

CE Diameter RSD (%): 216.85



Comments:

Morphologi
Malvern Instruments Worldwide
www.malvern.com

CE Diameter Report - Volume Distribution

Malvern

Measurement Details

Sample Name: 15-AKI-GH3-8.3

SOP Name: Xiao Qi-Japan 2015.vsop

User Name: itscdl

Date: Wednesday, January 13, 2016 4:39:28 PM

Edited: True

Edited On: Thursday, May 19, 2016 3:27:27 PM

Analysis

SOP Analysis: 1.0

SOP Segmentation: None

SOP Optic(s) used: 10x, 20x

SOP Fill Holes: True

SOP Trash Size: 50

Result

CE Diameter Minimum (µm): 1.13

CE Diameter Maximum (µm): 175.54

CE Diameter D[4,3] (µm): 98.72

CE Diameter D[3,2](µm): 56.9

Particles Counted: 17789

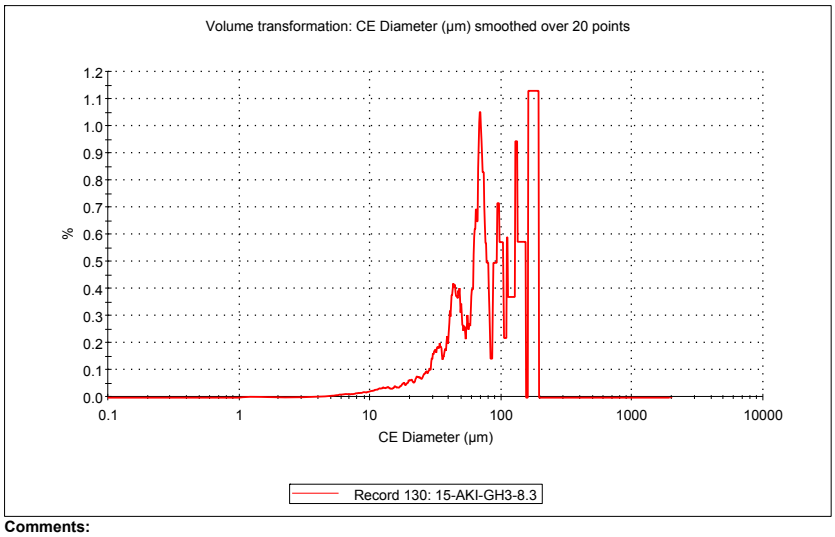
CE Diameter D[v, 0.1]: 34.14

CE Diameter D[v, 0.5]: 92.9

CE Diameter D[v, 0.9]: 174.2

CE Diameter STDV (µm): 4.48

CE Diameter RSD (%): 204.12



Comments:

CE Diameter Report - Volume Distribution

Malvern

Measurement Details

Sample Name: 15-AKI-GH3-8.9

SOP Name: Xiao Qi-Japan 2015.vsop

User Name: itscdl

Date: Thursday, January 21, 2016 5:34:19 PM

Edited: True

Edited On: Thursday, May 19, 2016 5:29:53 PM

Analysis

SOP Analysis: 1.0

SOP Segmentation: None

SOP Optic(s) used: 10x, 20x

SOP Fill Holes: True

SOP Trash Size: 50

Result

CE Diameter Minimum (µm): 1.13

CE Diameter Maximum (µm): 231.50

CE Diameter D[4,3] (µm): 129

CE Diameter D[3,2](µm): 105.8

Particles Counted: 26016

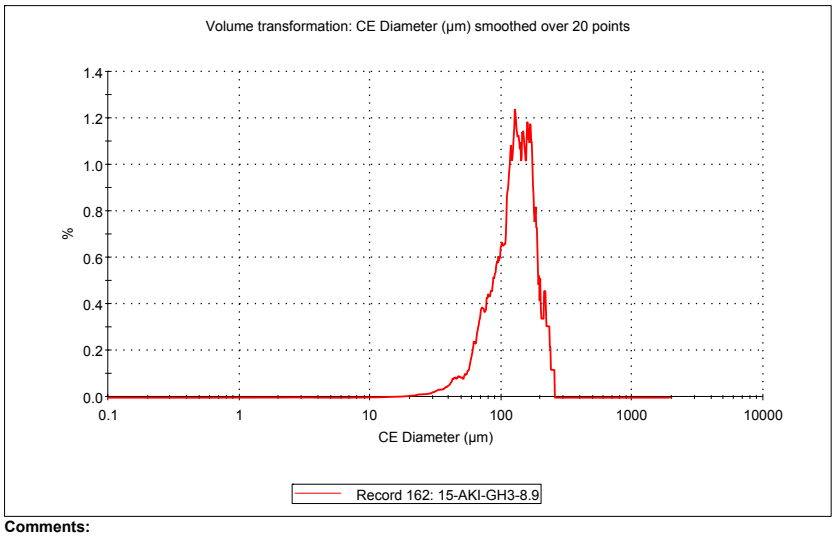
CE Diameter D[v, 0.1]: 70.04

CE Diameter D[v, 0.5]: 126.5

CE Diameter D[v, 0.9]: 180.1

CE Diameter STDV (µm): 13.37

CE Diameter RSD (%): 295.90



Comments:

Morphologi
Malvern Instruments Worldwide
www.malvern.com

CE Diameter Report - Volume Distribution

Malvern

Measurement Details

Sample Name: GH3-9.1

SOP Name: Xiao Qi-Japan 2015-new.vsop

User Name: itscdl

Date: Tuesday, May 17, 2016 4:57:33 PM

Edited: True

Edited On: Thursday, May 19, 2016 7:35:42 PM

Analysis

SOP Analysis: 3.0

SOP Segmentation: None

SOP Optic(s) used: 5x, 20x

SOP Fill Holes: True

SOP Trash Size: 10

Result

CE Diameter Minimum (µm): 0.54

CE Diameter Maximum (µm): 353.22

CE Diameter D[4,3] (µm): 197.5

CE Diameter D[3,2](µm): 139.4

Particles Counted: 4130

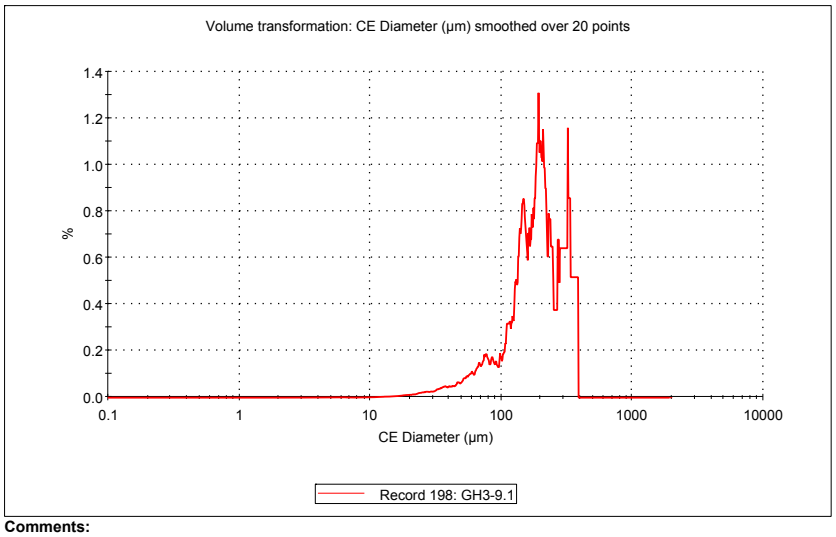
CE Diameter D[v, 0.1]: 81.65

CE Diameter D[v, 0.5]: 188.8

CE Diameter D[v, 0.9]: 304.6

CE Diameter STDV (µm): 14.64

CE Diameter RSD (%): 280.30



Comments:

Morphologi
Malvern Instruments Worldwide
www.malvern.com

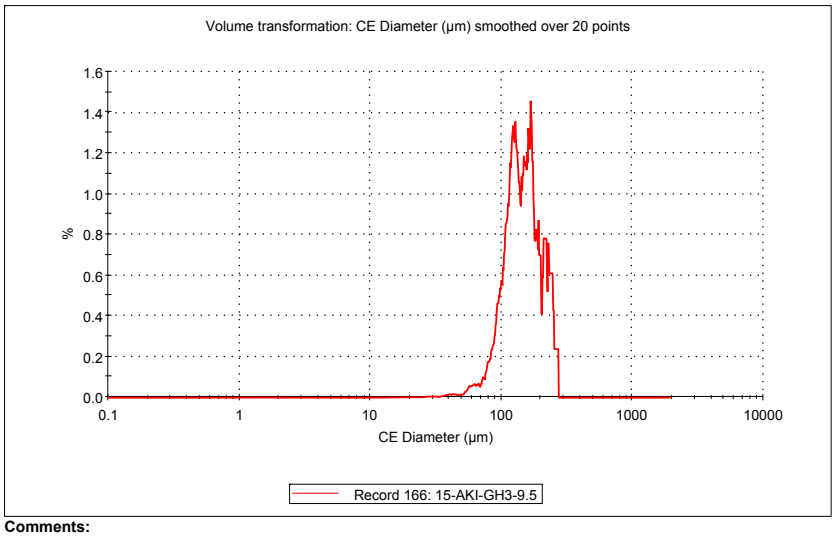
CE Diameter Report - Volume Distribution

Malvern

Measurement Details	
Sample Name: 15-AKI-GH3-9.5	
SOP Name: Xiao Qi-Japan 2015.vsop	**Edited:** True
User Name: itscdl	**Edited On:** Thursday, May 19, 2016 5:38:03 PM
Date: Thursday, January 21, 2016 10:14:45 PM	

Analysis	
SOP Analysis: 1.0	**SOP Fill Holes:** True
SOP Segmentation: None	**SOP Trash Size:** 50
SOP Optic(s) used: 10x, 20x	

Result	
CE Diameter Minimum (µm): 1.13	**CE Diameter D[v, 0.1]:** 97.77
CE Diameter Maximum (µm): 247.52	**CE Diameter D[v, 0.5]:** 143.5
CE Diameter D[4,3] (µm): 150.9	**CE Diameter D[v, 0.9]:** 222.9
CE Diameter D[3,2](µm): 131.2	**CE Diameter STDV (µm):** 8.47
Particles Counted: 33522	**CE Diameter RSD (%):** 403.61



Comments:

Morphologi
Malvern Instruments Worldwide
www.malvern.com

CE Diameter Report - Volume Distribution

Malvern

Measurement Details

Sample Name: GH3-9.9

SOP Name: Xiao Qi-Japan 2015-new.vsop

User Name: itscdl

Date: Tuesday, May 17, 2016 6:16:10 PM

Edited: True

Edited On: Thursday, May 19, 2016 7:42:25 PM

Analysis

SOP Analysis: 3.0

SOP Segmentation: None

SOP Optic(s) used: 5x, 20x

SOP Fill Holes: True

SOP Trash Size: 10

Result

CE Diameter Minimum (µm): 0.54

CE Diameter Maximum (µm): 291.87

CE Diameter D[4,3] (µm): 131.6

CE Diameter D[3,2](µm): 94.97

Particles Counted: 7050

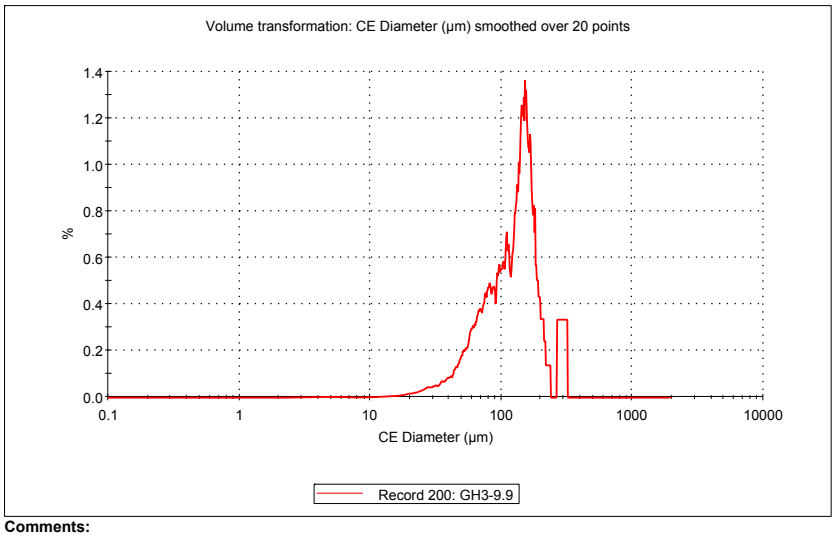
CE Diameter D[v, 0.1]: 57.91

CE Diameter D[v, 0.5]: 131.6

CE Diameter D[v, 0.9]: 196.1

CE Diameter STDV (µm): 11.90

CE Diameter RSD (%): 243.57



Comments:

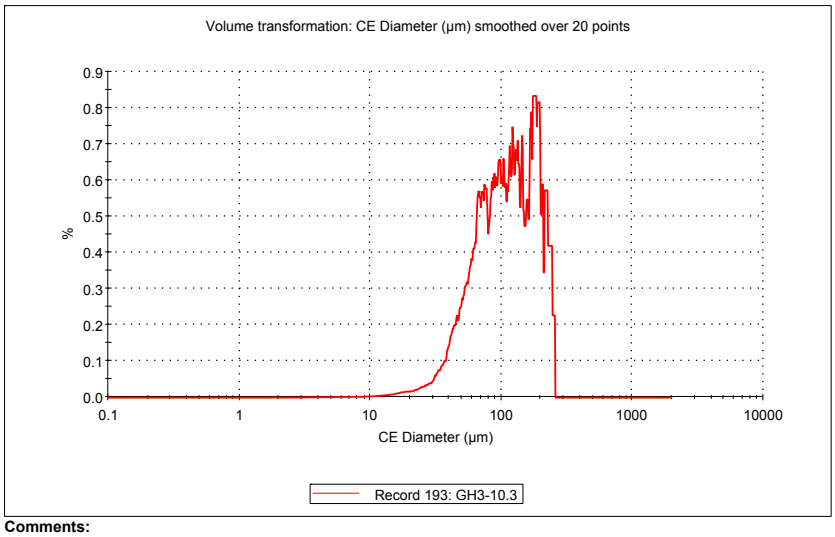
CE Diameter Report - Volume Distribution

Malvern

Measurement Details	
Sample Name: GH3-10.3	
SOP Name: Xiao Qi-Japan 2015-new.vsop	**Edited:** True
User Name: itscdl	**Edited On:** Thursday, May 19, 2016 7:27:38 PM
Date: Tuesday, May 17, 2016 12:38:36 PM	

Analysis	
SOP Analysis: 3.0	**SOP Fill Holes:** True
SOP Segmentation: None	**SOP Trash Size:** 10
SOP Optic(s) used: 5x, 20x	

Result	
CE Diameter Minimum (µm): 0.54	**CE Diameter D[v, 0.1]:** 51.64
CE Diameter Maximum (µm): 234.89	**CE Diameter D[v, 0.5]:** 110.7
CE Diameter D[4,3] (µm): 120.7	**CE Diameter D[v, 0.9]:** 203.6
CE Diameter D[3,2](µm): 87.39	**CE Diameter STDV (µm):** 12.38
Particles Counted: 6107	**CE Diameter RSD (%):** 273.20



Comments:

Morphologi
Malvern Instruments Worldwide
www.malvern.com

Morphologi Ver. 8.20
Serial Number : MAL1115686

File name: GH3-final data with additional samples.vmes
Record Number: 193
20 May 2016 4:08:49 PM

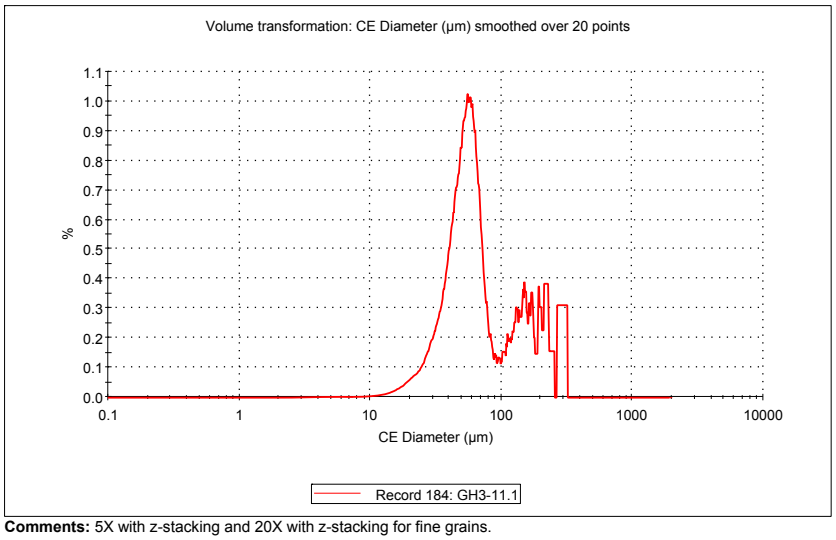
CE Diameter Report - Volume Distribution

Malvern

Measurement Details	
Sample Name: GH3-11.1	
SOP Name: Xiao Qi-Japan 2015-new.vsop	**Edited:** True
User Name: itscdl	**Edited On:** Thursday, May 19, 2016 6:12:45 PM
Date: Monday, May 16, 2016 10:19:54 PM	

Analysis	
SOP Analysis: 3.0	**SOP Fill Holes:** True
SOP Segmentation: None	**SOP Trash Size:** 10
SOP Optic(s) used: 5x, 20x	

Result	
CE Diameter Minimum (µm): 0.54	**CE Diameter D[v, 0.1]:** 34.35
CE Diameter Maximum (µm): 291.88	**CE Diameter D[v, 0.5]:** 59.77
CE Diameter D[4,3] (µm): 93.68	**CE Diameter D[v, 0.9]:** 208.1
CE Diameter D[3,2](µm): 57.34	**CE Diameter STDV (µm):** 13.00
Particles Counted: 21723	**CE Diameter RSD (%):** 184.60



Comments: 5X with z-stacking and 20X with z-stacking for fine grains.

CE Diameter Report - Volume Distribution

Malvern

Measurement Details

Sample Name: 15-AKI-GH3-11.9-12.0

SOP Name: Xiao Qi-Japan 2015.vsop

User Name: itscdl

Date: Wednesday, January 13, 2016 10:53:02 PM

Edited: True

Edited On: Thursday, May 19, 2016 3:43:54 PM

Analysis

SOP Analysis: 1.0

SOP Segmentation: None

SOP Optic(s) used: 10x, 20x

SOP Fill Holes: True

SOP Trash Size: 50

Result

CE Diameter Minimum (µm): 1.13

CE Diameter Maximum (µm): 122.98

CE Diameter D[4,3] (µm): 57.68

CE Diameter D[3,2](µm): 35.65

Particles Counted: 10178

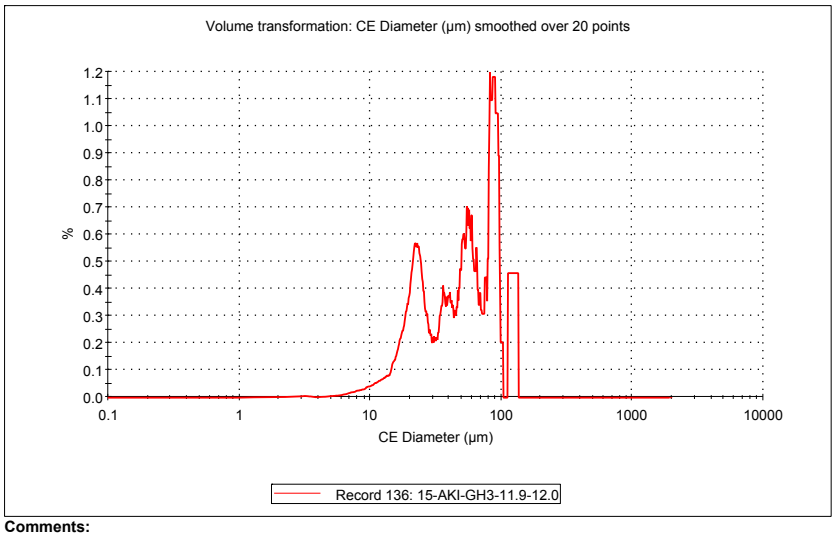
CE Diameter D[v, 0.1]: 19.11

CE Diameter D[v, 0.5]: 53.11

CE Diameter D[v, 0.9]: 93.45

CE Diameter STDV (µm): 6.56

CE Diameter RSD (%): 164.69



Comments:

Morphologi
Malvern Instruments Worldwide
www.malvern.com

CE Diameter Report - Volume Distribution

Malvern

Measurement Details

Sample Name: GH3-12.1

SOP Name: Xiao Qi-Japan 2015-new.vsop

User Name: itscdl

Date: Tuesday, May 17, 2016 7:59:38 PM

Edited: True

Edited On: Thursday, May 19, 2016 7:50:49 PM

Analysis

SOP Analysis: 3.0

SOP Segmentation: None

SOP Optic(s) used: 5x, 20x

SOP Fill Holes: True

SOP Trash Size: 10

Result

CE Diameter Minimum (µm): 0.54

CE Diameter Maximum (µm): 259.65

CE Diameter D[4,3] (µm): 122.2

CE Diameter D[3,2](µm): 80.47

Particles Counted: 133694

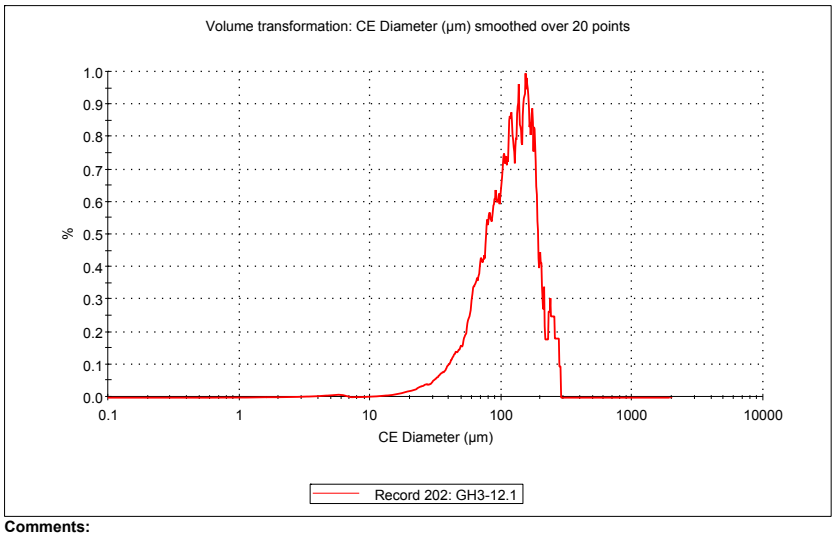
CE Diameter D[v, 0.1]: 55.84

CE Diameter D[v, 0.5]: 117.6

CE Diameter D[v, 0.9]: 187.3

CE Diameter STDV (µm): 4.26

CE Diameter RSD (%): 247.18



Comments:

CE Diameter Report - Volume Distribution

Malvern

Measurement Details

Sample Name: 15-AKI-GH3-12.3

SOP Name: Xiao Qi-Japan 2015.vsop

User Name: itscdl

Date: Friday, January 15, 2016 2:21:46 PM

Edited: True

Edited On: Thursday, May 19, 2016 4:11:30 PM

Analysis

SOP Analysis: 1.0

SOP Segmentation: None

SOP Optic(s) used: 10x, 20x

SOP Fill Holes: True

SOP Trash Size: 50

Result

CE Diameter Minimum (µm): 1.13

CE Diameter Maximum (µm): 106.02

CE Diameter D[4,3] (µm): 39.48

CE Diameter D[3,2](µm): 22.89

Particles Counted: 113539

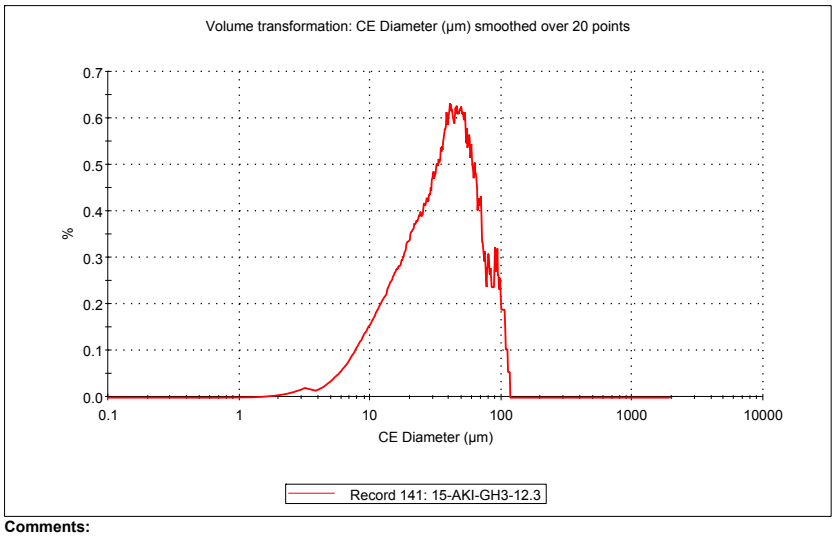
CE Diameter D[v, 0.1]: 11.26

CE Diameter D[v, 0.5]: 35.33

CE Diameter D[v, 0.9]: 73.15

CE Diameter STDV (µm): 4.98

CE Diameter RSD (%): 113.92



Comments:

CE Diameter Report - Volume Distribution

Malvern

Measurement Details

Sample Name: GH3-12.6-12.7

SOP Name: Xiao Qi-Japan 2015-new.vsop

User Name: itscdl

Date: Tuesday, May 17, 2016 2:13:22 PM

Edited: True

Edited On: Thursday, May 19, 2016 7:30:32 PM

Analysis

SOP Analysis: 3.0

SOP Segmentation: None

SOP Optic(s) used: 5x, 20x

SOP Fill Holes: True

SOP Trash Size: 10

Result

CE Diameter Minimum (µm): 0.54

CE Diameter Maximum (µm): 229.89

CE Diameter D[4,3] (µm): 86.79

CE Diameter D[3,2](µm): 53.42

Particles Counted: 18211

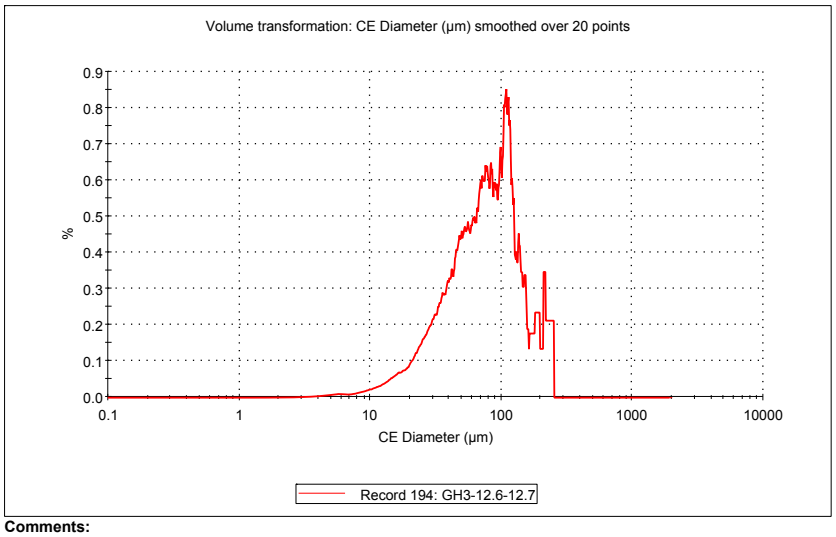
CE Diameter D[v, 0.1]: 28.75

CE Diameter D[v, 0.5]: 76.93

CE Diameter D[v, 0.9]: 147.8

CE Diameter STDV (µm): 9.33

CE Diameter RSD (%): 176.39



Comments:

CE Diameter Report - Volume Distribution

Malvern

Measurement Details

Sample Name: 15-AKI-GH3-13.1-13.2

SOP Name: Xiao Qi-Japan 2015.vsop

User Name: itscdl

Date: Friday, January 15, 2016 12:18:11 PM

Edited: True

Edited On: Thursday, May 19, 2016 3:51:12 PM

Analysis

SOP Analysis: 1.0

SOP Segmentation: None

SOP Optic(s) used: 10x, 20x

SOP Fill Holes: True

SOP Trash Size: 50

Result

CE Diameter Minimum (µm): 1.13

CE Diameter Maximum (µm): 106.54

CE Diameter D[4,3] (µm): 56.04

CE Diameter D[3,2](µm): 33.87

Particles Counted: 10700

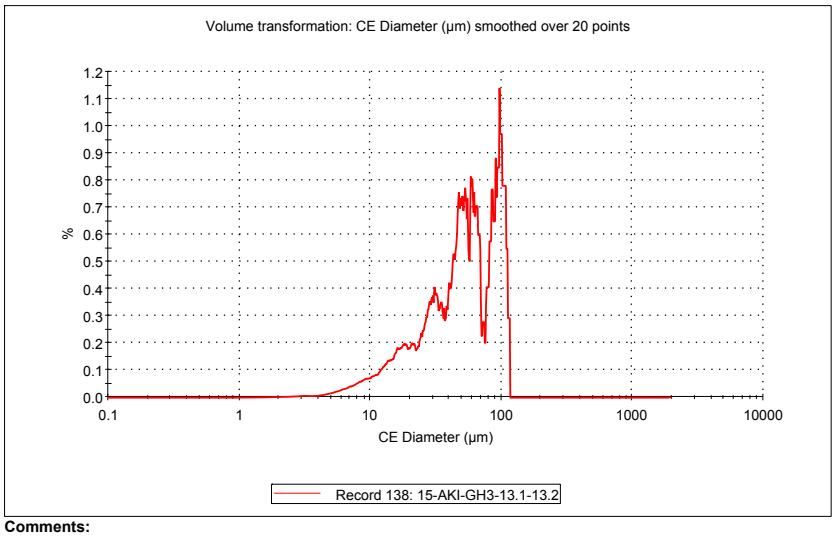
CE Diameter D[v, 0.1]: 16.78

CE Diameter D[v, 0.5]: 51.41

CE Diameter D[v, 0.9]: 100.6

CE Diameter STDV (µm): 6.31

CE Diameter RSD (%): 139.99



Comments:

Morphologi
Malvern Instruments Worldwide
www.malvern.com

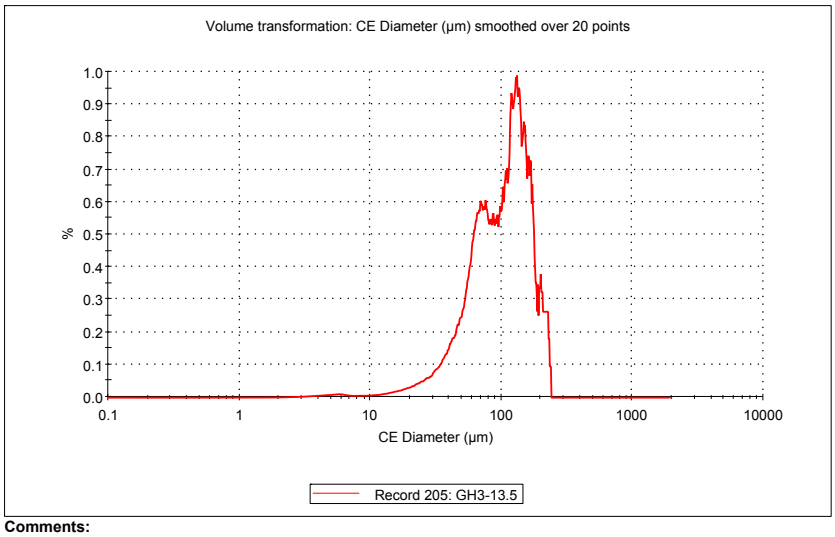
CE Diameter Report - Volume Distribution

Malvern

Measurement Details	
Sample Name: GH3-13.5	
SOP Name: Xiao Qi-Japan 2015-new.vsop	**Edited:** True
User Name: itscdl	**Edited On:** Thursday, May 19, 2016 7:59:39 PM
Date: Tuesday, May 17, 2016 9:58:36 PM	

Analysis	
SOP Analysis: 3.0	**SOP Fill Holes:** True
SOP Segmentation: None	**SOP Trash Size:** 10
SOP Optic(s) used: 5x, 20x	

Result	
CE Diameter Minimum (µm): 0.54	**CE Diameter D[v, 0.1]:** 46.43
CE Diameter Maximum (µm): 219.18	**CE Diameter D[v, 0.5]:** 105.5
CE Diameter D[4,3] (µm): 107.6	**CE Diameter D[v, 0.9]:** 171.6
CE Diameter D[3,2](µm): 71.88	**CE Diameter STDV (µm):** 7.56
Particles Counted: 31921	**CE Diameter RSD (%):** 212.17



Comments:

Morphologi
Malvern Instruments Worldwide
www.malvern.com

Morphologi Ver. 8.20
Serial Number : MAL1115686

File name: GH3-final data with additional samples.vmes
Record Number: 205
20 May 2016 4:10:41 PM

CE Diameter Report - Volume Distribution

Malvern

Measurement Details

Sample Name: GH3-13.9

SOP Name: Xiao Qi-Japan 2015-new.vsop

User Name: itscdl

Date: Tuesday, May 17, 2016 10:34:56 AM

Edited: True

Edited On: Thursday, May 19, 2016 7:24:06 PM

Analysis

SOP Analysis: 3.0

SOP Segmentation: None

SOP Optic(s) used: 5x, 20x

SOP Fill Holes: True

SOP Trash Size: 10

Result

CE Diameter Minimum (µm): 0.54

CE Diameter Maximum (µm): 254.52

CE Diameter D[4,3] (µm): 106.2

CE Diameter D[3,2](µm): 52.6

Particles Counted: 34170

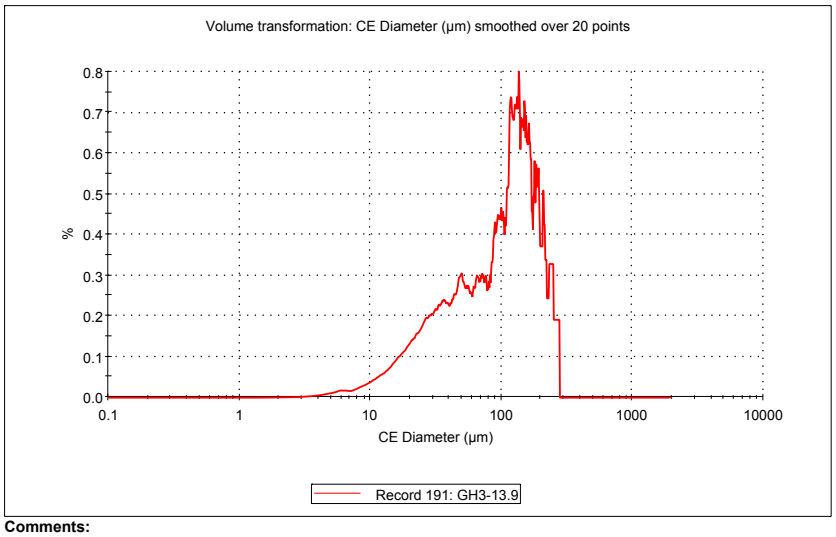
CE Diameter D[v, 0.1]: 23.92

CE Diameter D[v, 0.5]: 102

CE Diameter D[v, 0.9]: 199.1

CE Diameter STDV (µm): 8.35

CE Diameter RSD (%): 140.96



Comments:

Morphologi
Malvern Instruments Worldwide
www.malvern.com

CE Diameter Report - Volume Distribution

Malvern

Measurement Details

Sample Name: GH3-14.3

SOP Name: Xiao Qi-Japan 2015-new.vsop

User Name: itscdl

Date: Tuesday, May 17, 2016 6:55:52 PM

Edited: True

Edited On: Thursday, May 19, 2016 7:45:29 PM

Analysis

SOP Analysis: 3.0

SOP Segmentation: None

SOP Optic(s) used: 5x, 20x

SOP Fill Holes: True

SOP Trash Size: 10

Result

CE Diameter Minimum (µm): 0.54

CE Diameter Maximum (µm): 231.27

CE Diameter D[4,3] (µm): 85.71

CE Diameter D[3,2](µm): 64.07

Particles Counted: 7012

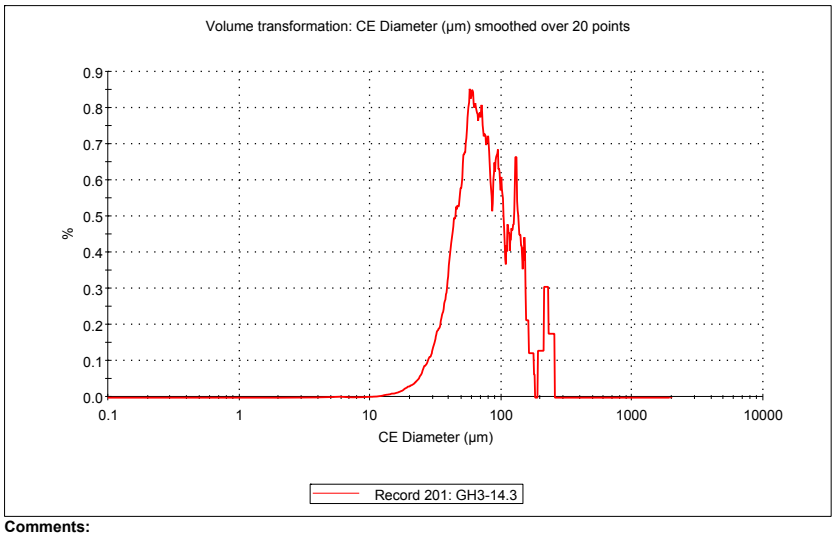
CE Diameter D[v, 0.1]: 39.57

CE Diameter D[v, 0.5]: 71.82

CE Diameter D[v, 0.9]: 139.2

CE Diameter STDV (µm): 15.68

CE Diameter RSD (%): 204.22



Comments:

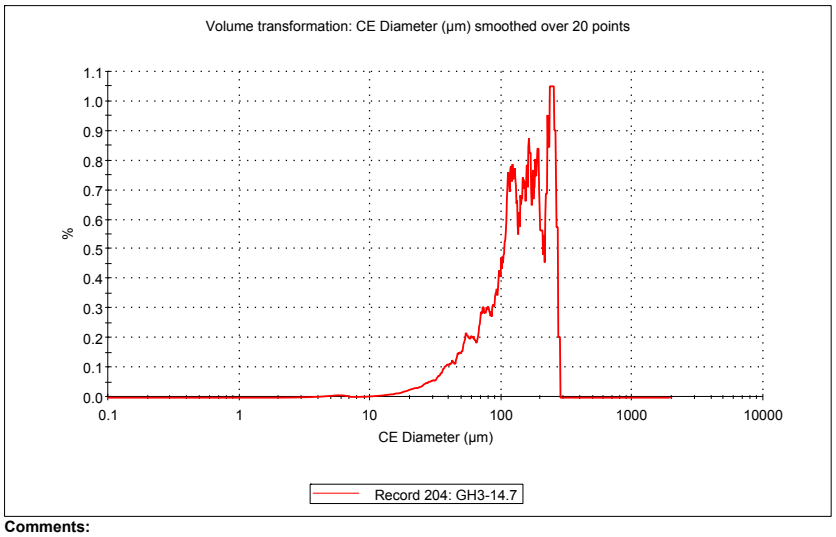
CE Diameter Report - Volume Distribution

Malvern

Measurement Details	
Sample Name: GH3-14.7	
SOP Name: Xiao Qi-Japan 2015-new.vsop	**Edited:** True
User Name: itscdl	**Edited On:** Thursday, May 19, 2016 7:58:09 PM
Date: Tuesday, May 17, 2016 9:18:42 PM	

Analysis	
SOP Analysis: 3.0	**SOP Fill Holes:** True
SOP Segmentation: None	**SOP Trash Size:** 10
SOP Optic(s) used: 5x, 20x	

Result	
CE Diameter Minimum (µm): 0.54	**CE Diameter D[v, 0.1]:** 54.95
CE Diameter Maximum (µm): 255.28	**CE Diameter D[v, 0.5]:** 142.9
CE Diameter D[4,3] (µm): 145.8	**CE Diameter D[v, 0.9]:** 242.9
CE Diameter D[3,2](µm): 94.41	**CE Diameter STDV (µm):** 8.69
Particles Counted: 14245	**CE Diameter RSD (%):** 243.53



Comments:

Morphologi
Malvern Instruments Worldwide
www.malvern.com

CE Diameter Report - Volume Distribution

Malvern

Measurement Details

Sample Name: GH3-15.1-15.2

SOP Name: Xiao Qi-Japan 2015-new.vsop

User Name: itscdl

Date: Tuesday, May 17, 2016 9:09:53 AM

Edited: True

Edited On: Thursday, May 19, 2016 7:20:14 PM

Analysis

SOP Analysis: 3.0

SOP Segmentation: None

SOP Optic(s) used: 5x, 20x

SOP Fill Holes: True

SOP Trash Size: 10

Result

CE Diameter Minimum (µm): 0.54

CE Diameter Maximum (µm): 254.05

CE Diameter D[4,3] (µm): 152

CE Diameter D[3,2](µm): 125.5

Particles Counted: 5338

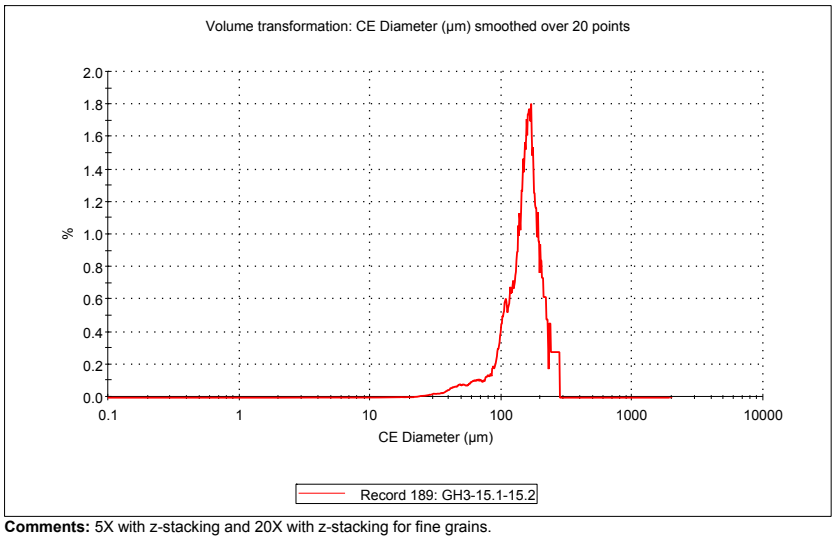
CE Diameter D[v, 0.1]: 92.15

CE Diameter D[v, 0.5]: 153.8

CE Diameter D[v, 0.9]: 206.1

CE Diameter STDV (µm): 10.29

CE Diameter RSD (%): 387.72



Comments: 5X with z-stacking and 20X with z-stacking for fine grains.

CE Diameter Report - Volume Distribution

Malvern

Measurement Details

Sample Name: GH3-15.5

SOP Name: Xiao Qi-Japan 2015-new.vsop

User Name: itscdl

Date: Tuesday, May 17, 2016 9:56:17 AM

Edited: True

Edited On: Thursday, May 19, 2016 7:22:06 PM

Analysis

SOP Analysis: 3.0

SOP Segmentation: None

SOP Optic(s) used: 5x, 20x

SOP Fill Holes: True

SOP Trash Size: 10

Result

CE Diameter Minimum (µm): 0.54

CE Diameter Maximum (µm): 274.61

CE Diameter D[4,3] (µm): 141.4

CE Diameter D[3,2](µm): 113.5

Particles Counted: 19697

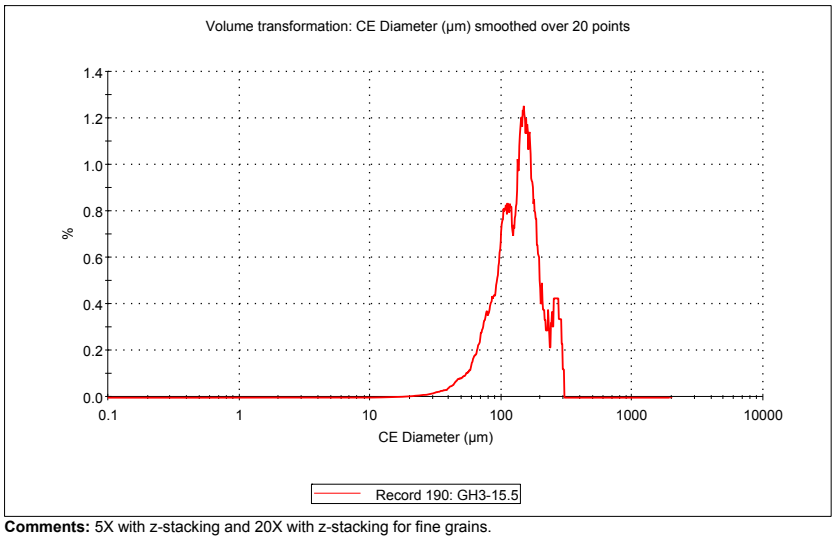
CE Diameter D[v, 0.1]: 74.5

CE Diameter D[v, 0.5]: 137.6

CE Diameter D[v, 0.9]: 218.5

CE Diameter STDV (µm): 9.56

CE Diameter RSD (%): 382.01



Comments: 5X with z-stacking and 20X with z-stacking for fine grains.

CE Diameter Report - Volume Distribution

Malvern

Measurement Details

Sample Name: GH3-15.9

SOP Name: Xiao Qi-Japan 2015-new.vsop

User Name: itscdl

Date: Monday, May 16, 2016 8:36:49 PM

Edited: True

Edited On: Thursday, May 19, 2016 6:07:52 PM

Analysis

SOP Analysis: 3.0

SOP Segmentation: None

SOP Optic(s) used: 5x, 20x

SOP Fill Holes: True

SOP Trash Size: 10

Result

CE Diameter Minimum (µm): 0.54

CE Diameter Maximum (µm): 289.89

CE Diameter D[4,3] (µm): 145.3

CE Diameter D[3,2](µm): 96.33

Particles Counted: 13956

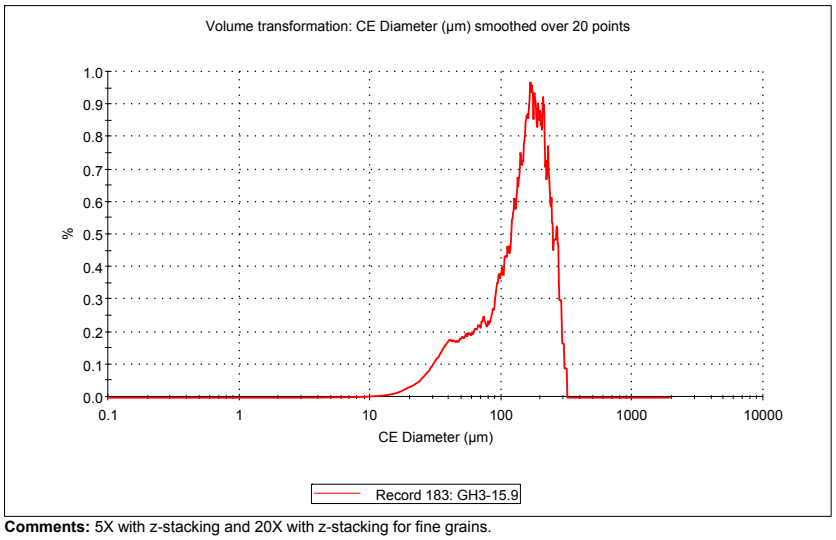
CE Diameter D[v, 0.1]: 45.84

CE Diameter D[v, 0.5]: 146.6

CE Diameter D[v, 0.9]: 237.7

CE Diameter STDV (µm): 20.18

CE Diameter RSD (%): 162.21



Comments: 5X with z-stacking and 20X with z-stacking for fine grains.

CE Diameter Report - Volume Distribution

Malvern

Measurement Details

Sample Name: GH3-16.1

SOP Name: Xiao Qi-Japan 2015-new.vsop

User Name: itscdl

Date: Tuesday, May 17, 2016 5:37:03 PM

Edited: True

Edited On: Thursday, May 19, 2016 7:37:43 PM

Analysis

SOP Analysis: 3.0

SOP Segmentation: None

SOP Optic(s) used: 5x, 20x

SOP Fill Holes: True

SOP Trash Size: 10

Result

CE Diameter Minimum (µm): 0.54

CE Diameter Maximum (µm): 269.29

CE Diameter D[4,3] (µm): 130.5

CE Diameter D[3,2](µm): 89.34

Particles Counted: 9387

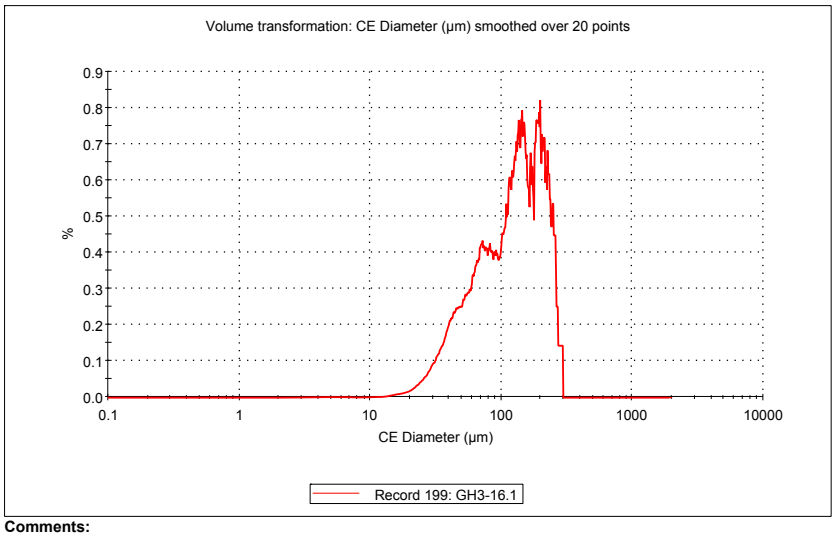
CE Diameter D[v, 0.1]: 46.14

CE Diameter D[v, 0.5]: 124.8

CE Diameter D[v, 0.9]: 224.4

CE Diameter STDV (µm): 15.45

CE Diameter RSD (%): 218.88



Comments:

Morphologi
Malvern Instruments Worldwide
www.malvern.com

CE Diameter Report - Volume Distribution

Malvern

Measurement Details

Sample Name: GH3-16.5

SOP Name: Xiao Qi-Japan 2015-new.vsop

User Name: itscdl

Date: Tuesday, May 17, 2016 4:06:58 PM

Edited: True

Edited On: Thursday, May 19, 2016 7:34:45 PM

Analysis

SOP Analysis: 3.0

SOP Segmentation: None

SOP Optic(s) used: 5x, 20x

SOP Fill Holes: True

SOP Trash Size: 10

Result

CE Diameter Minimum (µm): 0.54

CE Diameter Maximum (µm): 354.96

CE Diameter D[4,3] (µm): 171.2

CE Diameter D[3,2](µm): 125.5

Particles Counted: 4628

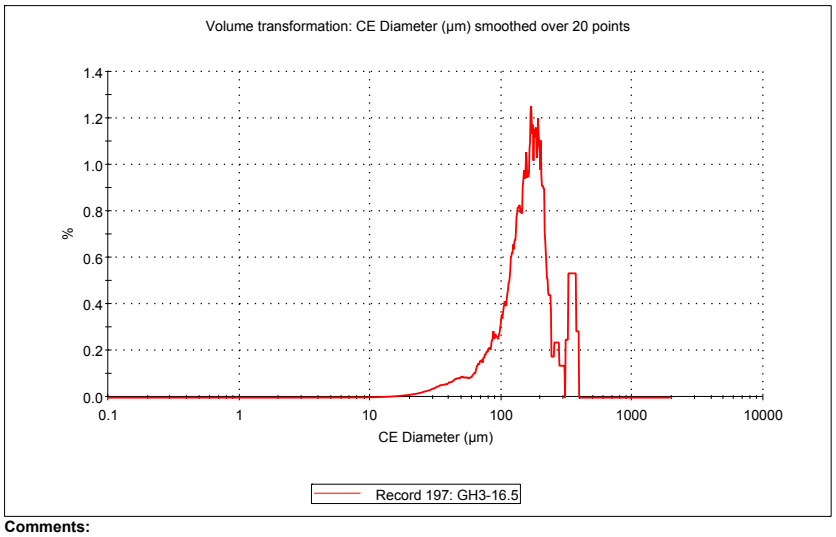
CE Diameter D[v, 0.1]: 78.48

CE Diameter D[v, 0.5]: 160

CE Diameter D[v, 0.9]: 333.2

CE Diameter STDV (µm): 22.47

CE Diameter RSD (%): 216.67



Comments:

Morphologi
Malvern Instruments Worldwide
www.malvern.com

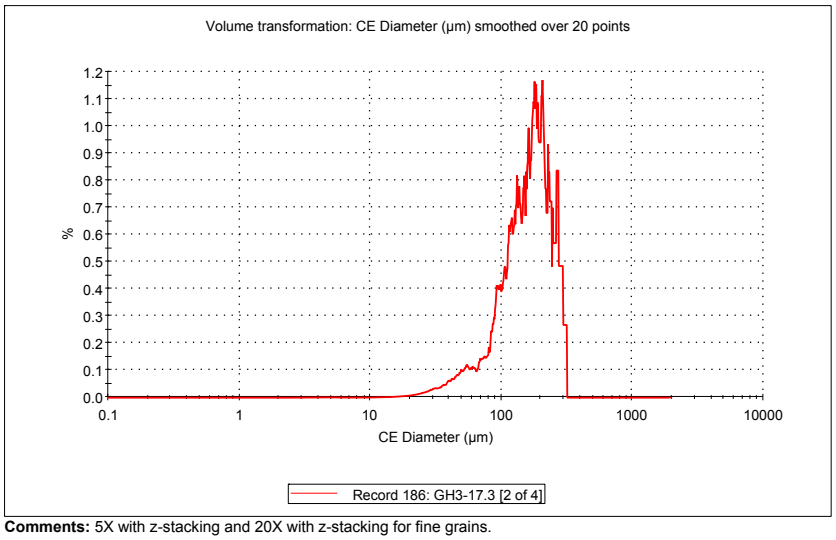
CE Diameter Report - Volume Distribution

Malvern

Measurement Details	
Sample Name: GH3-17.3 [2 of 4]	
SOP Name: Xiao Qi-Japan 2015-new.vsop	**Edited:** True
User Name: itscdl	**Edited On:** Thursday, May 19, 2016 7:13:32 PM
Date: Monday, May 16, 2016 11:59:14 PM	

Analysis	
SOP Analysis: 3.0	**SOP Fill Holes:** True
SOP Segmentation: None	**SOP Trash Size:** 10
SOP Optic(s) used: 5x, 20x	

Result	
CE Diameter Minimum (µm): 0.54	**CE Diameter D[v, 0.1]:** 80.69
CE Diameter Maximum (µm): 287.35	**CE Diameter D[v, 0.5]:** 166.9
CE Diameter D[4,3] (µm): 165.4	**CE Diameter D[v, 0.9]:** 247.2
CE Diameter D[3,2](µm): 127.2	**CE Diameter STDV (µm):** 16.60
Particles Counted: 3347	**CE Diameter RSD (%):** 301.23



Comments: 5X with z-stacking and 20X with z-stacking for fine grains.

CE Diameter Report - Volume Distribution

Malvern

Measurement Details

Sample Name: GH3-18.1 [3 of 4]

SOP Name: Xiao Qi-Japan 2015-new.vsop

User Name: itscdl

Date: Tuesday, May 17, 2016 12:40:41 AM

Edited: True

Edited On: Thursday, May 19, 2016 7:16:18 PM

Analysis

SOP Analysis: 3.0

SOP Segmentation: None

SOP Optic(s) used: 5x, 20x

SOP Fill Holes: True

SOP Trash Size: 10

Result

CE Diameter Minimum (µm): 0.54

CE Diameter Maximum (µm): 276.82

CE Diameter D[4,3] (µm): 157.1

CE Diameter D[3,2](µm): 136.2

Particles Counted: 10034

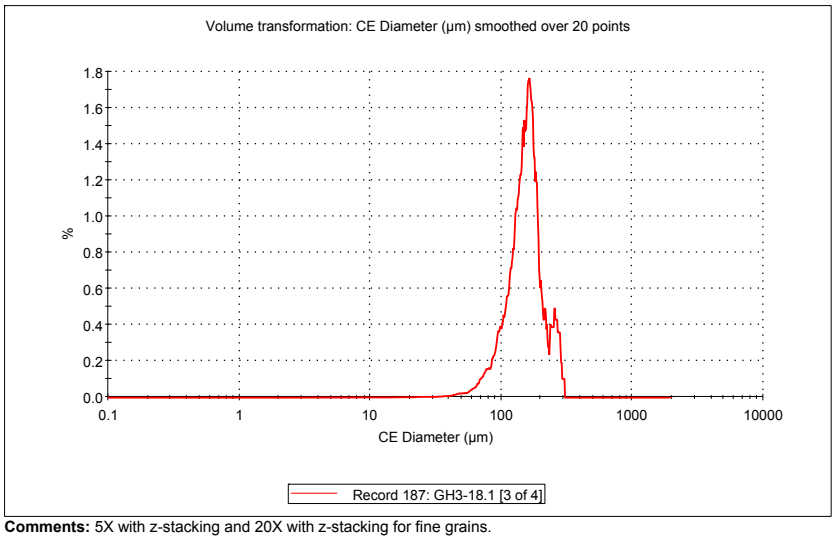
CE Diameter D[v, 0.1]: 98.88

CE Diameter D[v, 0.5]: 154.2

CE Diameter D[v, 0.9]: 216.9

CE Diameter STDV (µm): 13.32

CE Diameter RSD (%): 386.79



Comments: 5X with z-stacking and 20X with z-stacking for fine grains.

CE Diameter Report - Volume Distribution

Malvern

Measurement Details

Sample Name: GH3-18.5

SOP Name: Xiao Qi-Japan 2015-new.vsop

User Name: itscdl

Date: Tuesday, May 17, 2016 1:22:06 AM

Edited: True

Edited On: Thursday, May 19, 2016 7:19:20 PM

Analysis

SOP Analysis: 3.0

SOP Segmentation: None

SOP Optic(s) used: 5x, 20x

SOP Fill Holes: True

SOP Trash Size: 10

Result

CE Diameter Minimum (µm): 0.54

CE Diameter Maximum (µm): 269.73

CE Diameter D[4,3] (µm): 145.4

CE Diameter D[3,2](µm): 94.38

Particles Counted: 144563

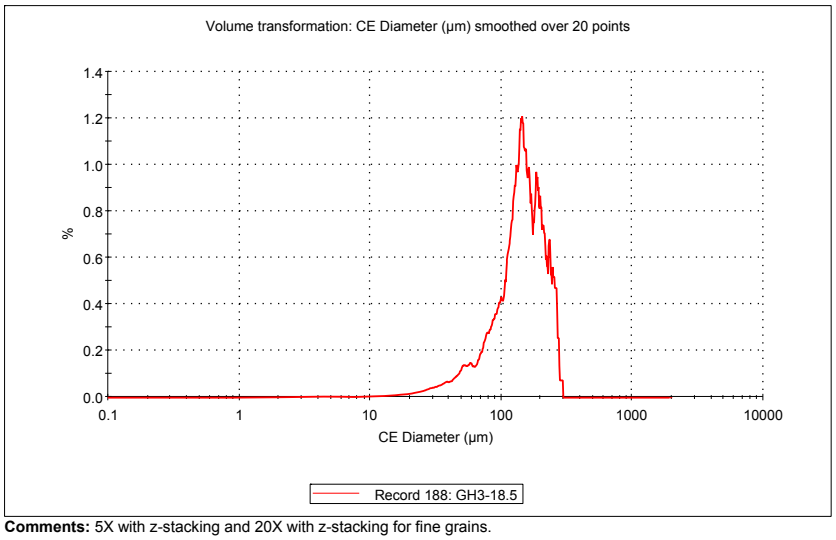
CE Diameter D[v, 0.1]: 66.07

CE Diameter D[v, 0.5]: 142.1

CE Diameter D[v, 0.9]: 223.7

CE Diameter STDV (µm): 4.36

CE Diameter RSD (%): 242.11



Comments: 5X with z-stacking and 20X with z-stacking for fine grains.

CE Diameter Report - Volume Distribution

Malvern

Measurement Details

Sample Name: GH3-18.9

SOP Name: Xiao Qi-Japan 2015-new.vsop

User Name: itscdl

Date: Tuesday, May 17, 2016 8:39:33 PM

Edited: True

Edited On: Thursday, May 19, 2016 7:55:29 PM

Analysis

SOP Analysis: 3.0

SOP Segmentation: None

SOP Optic(s) used: 5x, 20x

SOP Fill Holes: True

SOP Trash Size: 10

Result

CE Diameter Minimum (µm): 0.54

CE Diameter Maximum (µm): 240.05

CE Diameter D[4,3] (µm): 141.5

CE Diameter D[3,2](µm): 82.61

Particles Counted: 152932

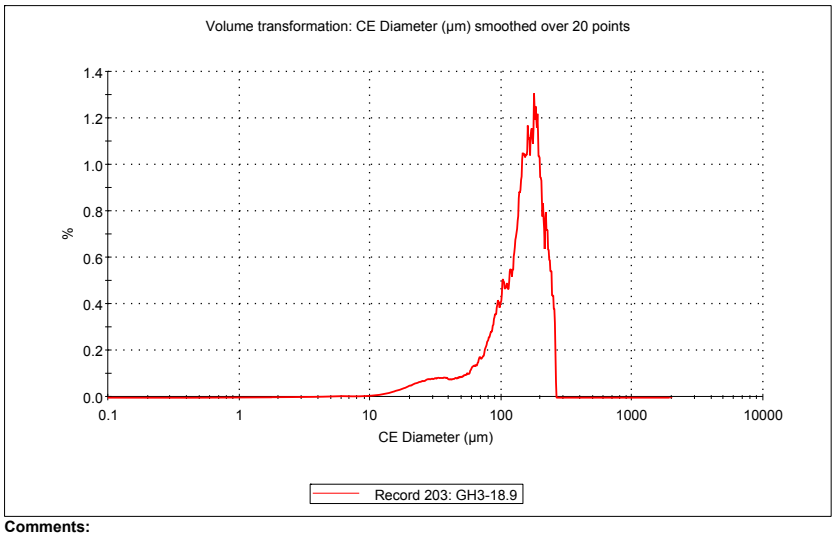
CE Diameter D[v, 0.1]: 51.92

CE Diameter D[v, 0.5]: 147.3

CE Diameter D[v, 0.9]: 217.9

CE Diameter STDV (µm): 4.20

CE Diameter RSD (%): 223.14



Comments:

CE Diameter Report - Volume Distribution

Malvern

Measurement Details

Sample Name: GH3-19.1

SOP Name: Xiao Qi-Japan 2015-new.vsop

User Name: itscdl

Date: Wednesday, April 06, 2016 9:57:11 AM

Edited: True

Edited On: Thursday, May 19, 2016 6:05:22 PM

Analysis

SOP Analysis: 3.0

SOP Segmentation: None

SOP Optic(s) used: 5x, 20x

SOP Fill Holes: True

SOP Trash Size: 10

Result

CE Diameter Minimum (µm): 0.54

CE Diameter Maximum (µm): 170.84

CE Diameter D[4,3] (µm): 77.45

CE Diameter D[3,2](µm): 52.85

Particles Counted: 36375

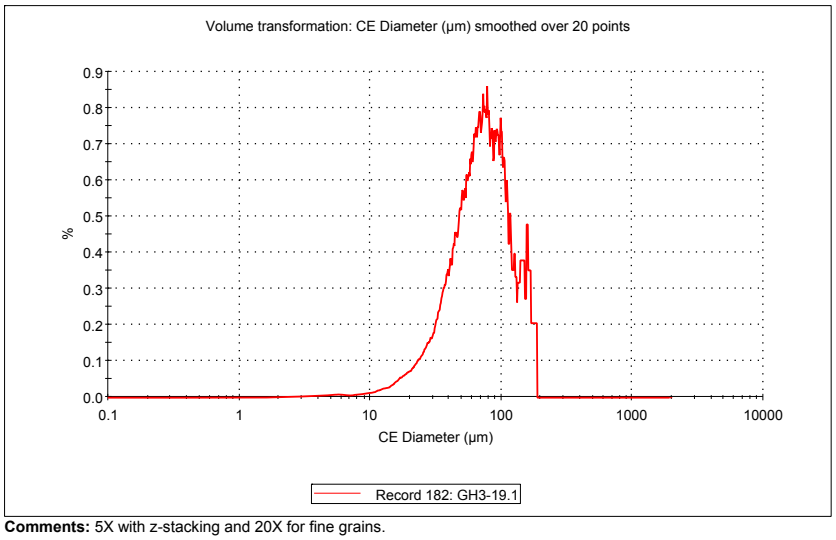
CE Diameter D[v, 0.1]: 32.78

CE Diameter D[v, 0.5]: 70.86

CE Diameter D[v, 0.9]: 136

CE Diameter STDV (µm): 7.33

CE Diameter RSD (%): 205.66



Comments: 5X with z-stacking and 20X for fine grains.

CE Diameter Report - Volume Distribution

Malvern

Measurement Details

Sample Name: GH3-19.3

SOP Name: Xiao Qi-Japan 2015-new.vsop

User Name: itscdl

Date: Monday, April 04, 2016 9:07:23 PM

Edited: True

Edited On: Thursday, May 19, 2016 6:00:09 PM

Analysis

SOP Analysis: 3.0

SOP Segmentation: None

SOP Optic(s) used: 5x, 20x

SOP Fill Holes: True

SOP Trash Size: 10

Result

CE Diameter Minimum (µm): 0.54

CE Diameter Maximum (µm): 306.37

CE Diameter D[4,3] (µm): 141.6

CE Diameter D[3,2](µm): 79.83

Particles Counted: 32482

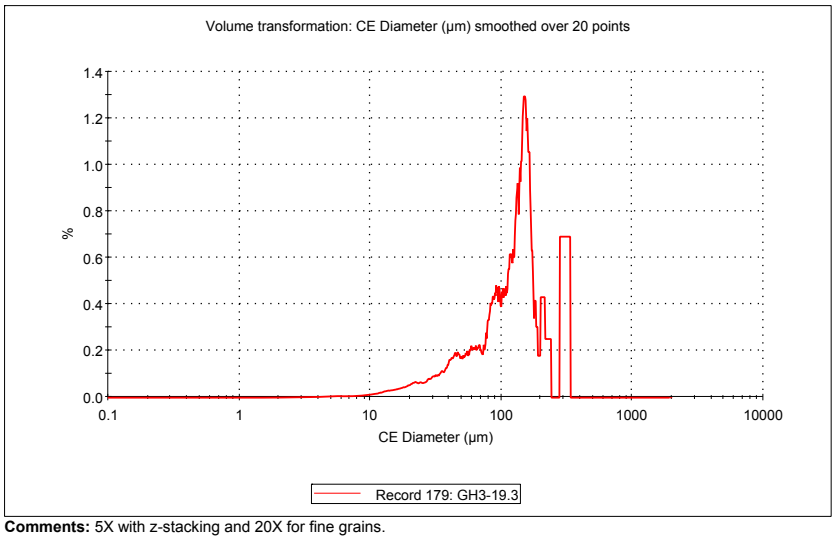
CE Diameter D[v, 0.1]: 42.88

CE Diameter D[v, 0.5]: 136.8

CE Diameter D[v, 0.9]: 302.4

CE Diameter STDV (µm): 8.26

CE Diameter RSD (%): 204.25



Comments: 5X with z-stacking and 20X for fine grains.

CE Diameter Report - Volume Distribution

Malvern

Measurement Details

Sample Name: GH3-19.5

SOP Name: Xiao Qi-Japan 2015-new.vsop

User Name: itscdl

Date: Tuesday, April 05, 2016 9:52:12 AM

Edited: True

Edited On: Thursday, May 19, 2016 6:01:57 PM

Analysis

SOP Analysis: 3.0

SOP Segmentation: None

SOP Optic(s) used: 5x, 20x

SOP Fill Holes: True

SOP Trash Size: 10

Result

CE Diameter Minimum (µm): 0.54

CE Diameter Maximum (µm): 211.96

CE Diameter D[4,3] (µm): 94.98

CE Diameter D[3,2](µm): 57.29

Particles Counted: 29846

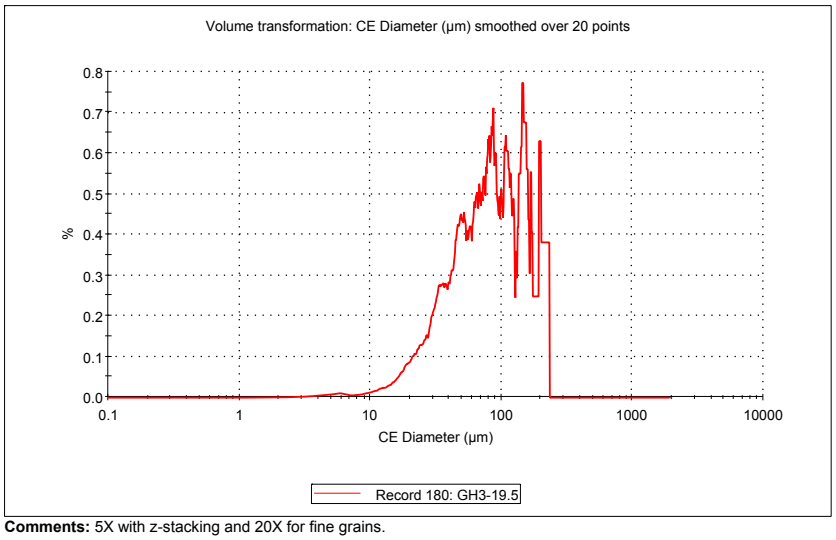
CE Diameter D[v, 0.1]: 31.13

CE Diameter D[v, 0.5]: 82.84

CE Diameter D[v, 0.9]: 181

CE Diameter STDV (µm): 7.85

CE Diameter RSD (%): 200.30



Comments: 5X with z-stacking and 20X for fine grains.

CE Diameter Report - Volume Distribution

Malvern

Measurement Details

Sample Name: GH3-19.7

SOP Name: Xiao Qi-Japan 2015-new.vsop

User Name: itscdl

Date: Tuesday, May 17, 2016 11:43:57 AM

Edited: True

Edited On: Thursday, May 19, 2016 7:25:38 PM

Analysis

SOP Analysis: 3.0

SOP Segmentation: None

SOP Optic(s) used: 5x, 20x

SOP Fill Holes: True

SOP Trash Size: 10

Result

CE Diameter Minimum (µm): 0.54

CE Diameter Maximum (µm): 273.68

CE Diameter D[4,3] (µm): 153.6

CE Diameter D[3,2](µm): 87

Particles Counted: 54721

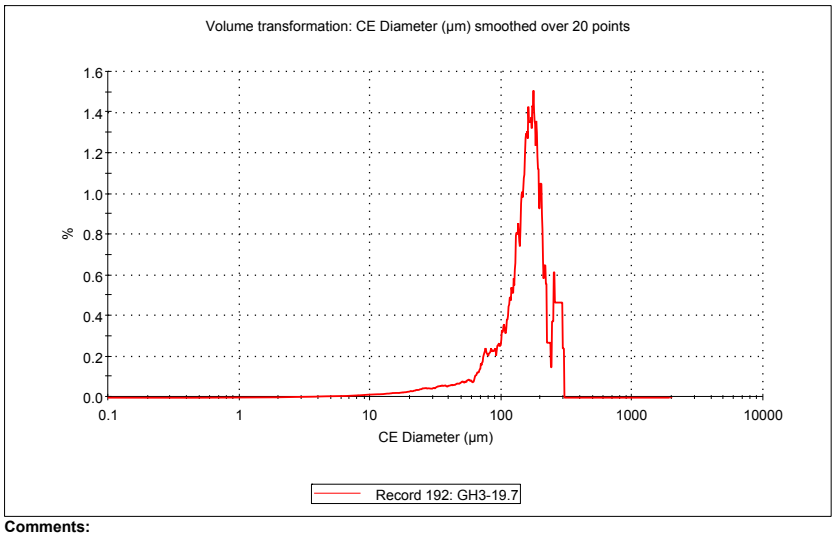
CE Diameter D[v, 0.1]: 67.69

CE Diameter D[v, 0.5]: 156.7

CE Diameter D[v, 0.9]: 230

CE Diameter STDV (µm): 4.32

CE Diameter RSD (%): 199.98



Comments:

Morphologi
Malvern Instruments Worldwide
www.malvern.com

Morphologi Ver. 8.20
Serial Number : MAL1115686

File name: GH3-final data with additional samples.vmes
Record Number: 192
20 May 2016 4:08:40 PM

CE Diameter Report - Volume Distribution

Malvern

Measurement Details

Sample Name: 15-AKI-GH3-19.8-19.9

SOP Name: Xiao Qi-Japan 2015.vsop

User Name: itscdl

Date: Tuesday, January 19, 2016 5:08:09 PM

Edited: True

Edited On: Thursday, May 19, 2016 4:40:41 PM

Analysis

SOP Analysis: 1.0

SOP Segmentation: None

SOP Optic(s) used: 10x, 20x

SOP Fill Holes: True

SOP Trash Size: 50

Result

CE Diameter Minimum (µm): 1.13

CE Diameter Maximum (µm): 254.09

CE Diameter D[4,3] (µm): 155

CE Diameter D[3,2](µm): 85.98

Particles Counted: 66230

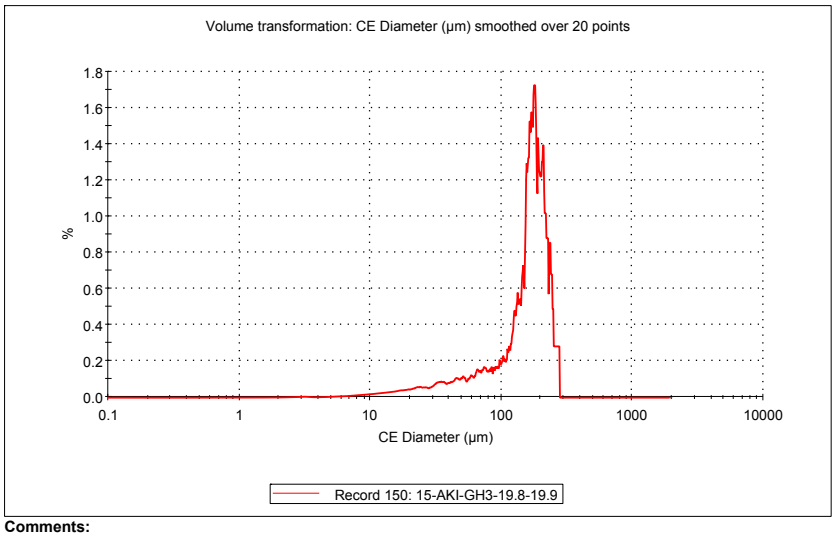
CE Diameter D[v, 0.1]: 49.05

CE Diameter D[v, 0.5]: 166.5

CE Diameter D[v, 0.9]: 221.5

CE Diameter STDV (µm): 6.38

CE Diameter RSD (%): 178.39



Comments:

CE Diameter Report - Volume Distribution

Malvern

Measurement Details

Sample Name: 15-AKI-GH3-20.1

SOP Name: Xiao Qi-Japan 2015.vsop

User Name: itscdl

Date: Wednesday, January 20, 2016 10:04:43 AM

Edited: True

Edited On: Thursday, May 19, 2016 4:47:27 PM

Analysis

SOP Analysis: 1.0

SOP Segmentation: None

SOP Optic(s) used: 10x, 20x

SOP Fill Holes: True

SOP Trash Size: 50

Result

CE Diameter Minimum (µm): 1.13

CE Diameter Maximum (µm): 172.44

CE Diameter D[4,3] (µm): 92.48

CE Diameter D[3,2](µm): 53.66

Particles Counted: 57046

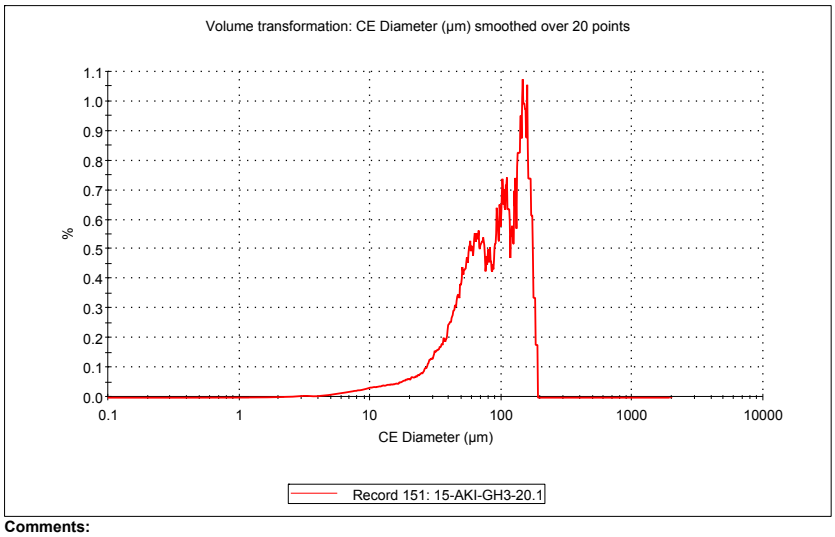
CE Diameter D[v, 0.1]: 32.63

CE Diameter D[v, 0.5]: 88.89

CE Diameter D[v, 0.9]: 156.4

CE Diameter STDV (µm): 6.06

CE Diameter RSD (%): 169.08



Comments:

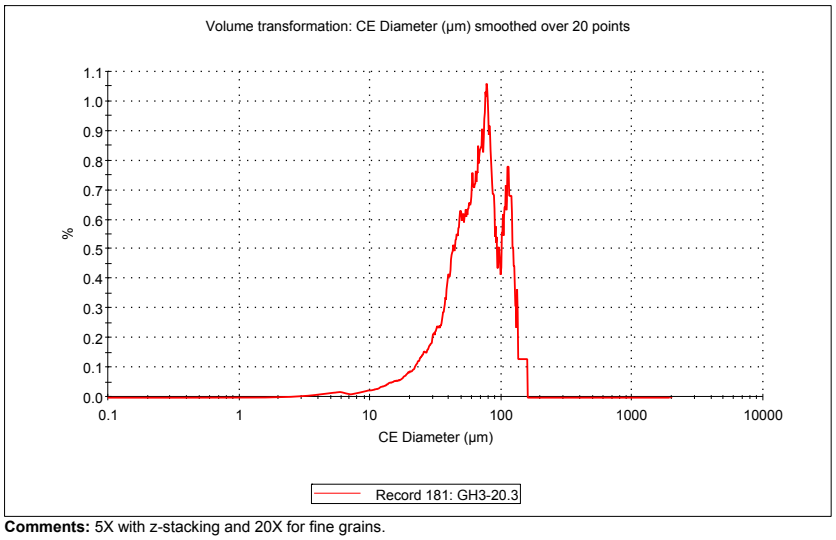
CE Diameter Report - Volume Distribution

Malvern

Measurement Details	
Sample Name: GH3-20.3	
SOP Name: Xiao Qi-Japan 2015-new.vsop	**Edited:** True
User Name: itscdl	**Edited On:** Thursday, May 19, 2016 6:04:25 PM
Date: Tuesday, April 05, 2016 12:40:46 PM	

Analysis	
SOP Analysis: 3.0	**SOP Fill Holes:** True
SOP Segmentation: None	**SOP Trash Size:** 10
SOP Optic(s) used: 5x, 20x	

Result	
CE Diameter Minimum (µm): 0.54	**CE Diameter D[v, 0.1]:** 28.61
CE Diameter Maximum (µm): 143.86	**CE Diameter D[v, 0.5]:** 65.21
CE Diameter D[4,3] (µm): 68.55	**CE Diameter D[v, 0.9]:** 114
CE Diameter D[3,2](µm): 45.5	**CE Diameter STDV (µm):** 6.44
Particles Counted: 48499	**CE Diameter RSD (%):** 177.47



Comments: 5X with z-stacking and 20X for fine grains.

CE Diameter Report - Volume Distribution

Malvern

Measurement Details

Sample Name: GH3-20.5

SOP Name: Xiao Qi-Japan 2015-new.vsop

User Name: itscdl

Date: Monday, April 04, 2016 6:25:04 PM

Edited: True

Edited On: Thursday, May 19, 2016 5:58:18 PM

Analysis

SOP Analysis: 3.0

SOP Segmentation: None

SOP Optic(s) used: 5x, 20x

SOP Fill Holes: True

SOP Trash Size: 10

Result

CE Diameter Minimum (µm): 0.54

CE Diameter Maximum (µm): 185.79

CE Diameter D[4,3] (µm): 85.85

CE Diameter D[3,2](µm): 44.76

Particles Counted: 45267

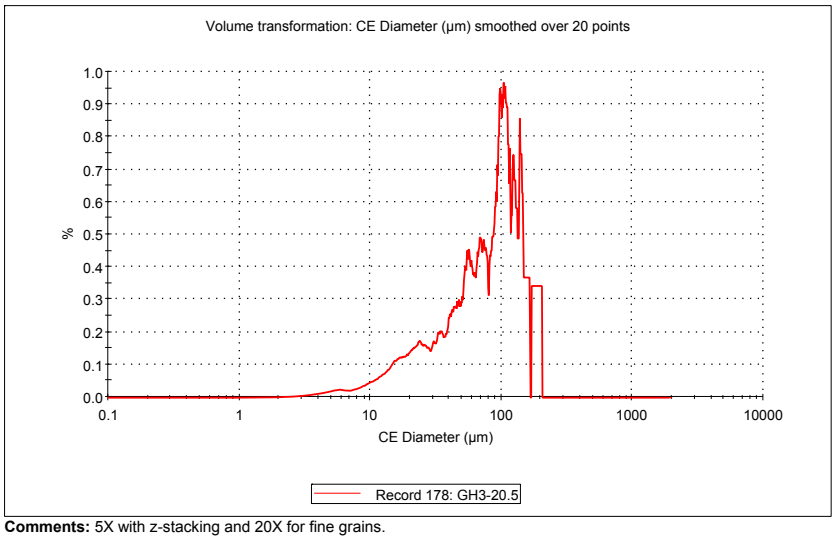
CE Diameter D[v, 0.1]: 21.29

CE Diameter D[v, 0.5]: 87.66

CE Diameter D[v, 0.9]: 149.4

CE Diameter STDV (µm): 5.88

CE Diameter RSD (%): 156.24



Comments: 5X with z-stacking and 20X for fine grains.

CE Diameter Report - Volume Distribution

Malvern

Measurement Details

Sample Name: GH3-20.9

SOP Name: Xiao Qi-Japan 2015-new.vsop

User Name: itscdl

Date: Thursday, March 31, 2016 3:31:45 PM

Edited: True

Edited On: Thursday, May 19, 2016 5:50:02 PM

Analysis

SOP Analysis: 3.0

SOP Segmentation: None

SOP Optic(s) used: 5x, 20x

SOP Fill Holes: True

SOP Trash Size: 10

Result

CE Diameter Minimum (µm): 0.54

CE Diameter Maximum (µm): 227.15

CE Diameter D[4,3] (µm): 145.5

CE Diameter D[3,2](µm): 98.17

Particles Counted: 21742

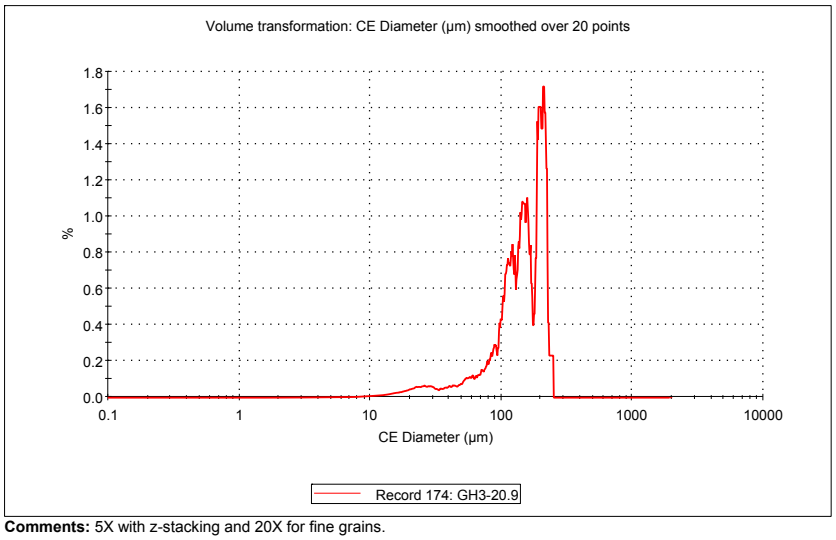
CE Diameter D[v, 0.1]: 64.59

CE Diameter D[v, 0.5]: 147.8

CE Diameter D[v, 0.9]: 204.4

CE Diameter STDV (µm): 10.23

CE Diameter RSD (%): 229.02



Comments: 5X with z-stacking and 20X for fine grains.

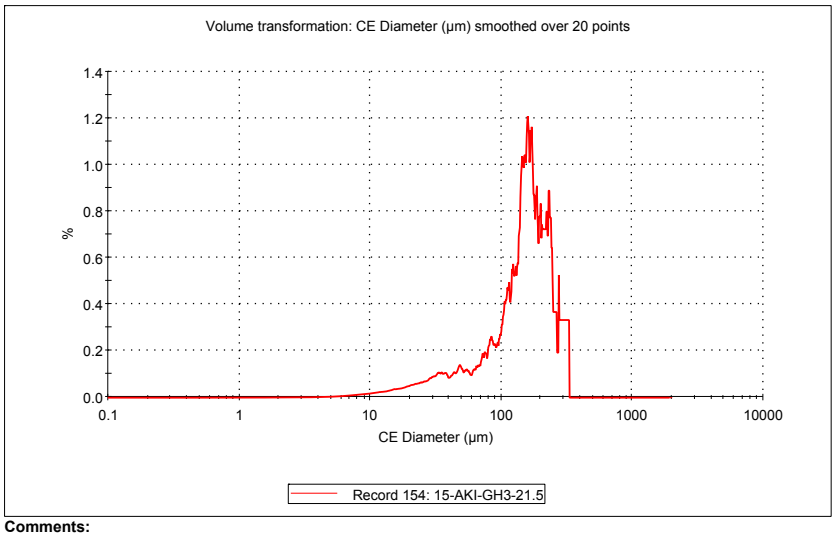
CE Diameter Report - Volume Distribution

Malvern

Measurement Details	
Sample Name: 15-AKI-GH3-21.5	
SOP Name: Xiao Qi-Japan 2015.vsop	**Edited:** True
User Name: itscdl	**Edited On:** Thursday, May 19, 2016 5:01:08 PM
Date: Wednesday, January 20, 2016 12:07:49 PM	

Analysis	
SOP Analysis: 1.0	**SOP Fill Holes:** True
SOP Segmentation: None	**SOP Trash Size:** 50
SOP Optic(s) used: 10x, 20x	

Result	
CE Diameter Minimum (µm): 1.13	**CE Diameter D[v, 0.1]:** 45.36
CE Diameter Maximum (µm): 300.51	**CE Diameter D[v, 0.5]:** 153.1
CE Diameter D[4,3] (µm): 153	**CE Diameter D[v, 0.9]:** 240.2
CE Diameter D[3,2](µm): 85.57	**CE Diameter STDV (µm):** 7.90
Particles Counted: 62595	**CE Diameter RSD (%):** 188.39



Comments:

CE Diameter Report - Volume Distribution

Malvern

Measurement Details

Sample Name: GH3-22.1

SOP Name: Xiao Qi-Japan 2015-new.vsop

User Name: itscdl

Date: Thursday, March 31, 2016 5:54:29 PM

Edited: True

Edited On: Thursday, May 19, 2016 5:52:49 PM

Analysis

SOP Analysis: 3.0

SOP Segmentation: None

SOP Optic(s) used: 5x, 20x

SOP Fill Holes: True

SOP Trash Size: 10

Result

CE Diameter Minimum (µm): 0.54

CE Diameter Maximum (µm): 163.33

CE Diameter D[4,3] (µm): 79.3

CE Diameter D[3,2](µm): 40.76

Particles Counted: 28853

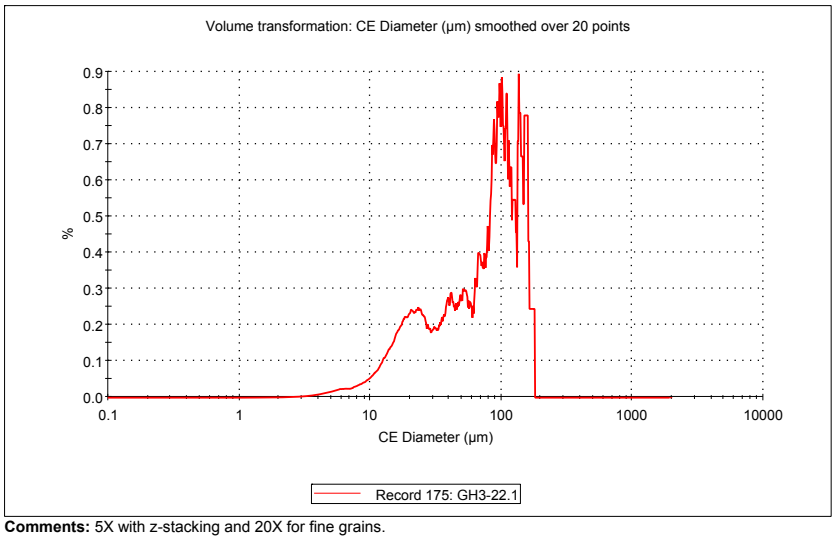
CE Diameter D[v, 0.1]: 17.84

CE Diameter D[v, 0.5]: 81.42

CE Diameter D[v, 0.9]: 144.6

CE Diameter STDV (µm): 7.16

CE Diameter RSD (%): 134.69



Comments: 5X with z-stacking and 20X for fine grains.

CE Diameter Report - Volume Distribution

Malvern

Measurement Details

Sample Name: GH3-22.3

SOP Name: Xiao Qi-Japan 2015-new.vsop

User Name: itscdl

Date: Friday, April 01, 2016 1:06:02 PM

Edited: True

Edited On: Thursday, May 19, 2016 5:54:28 PM

Analysis

SOP Analysis: 3.0

SOP Segmentation: None

SOP Optic(s) used: 5x, 20x

SOP Fill Holes: True

SOP Trash Size: 10

Result

CE Diameter Minimum (µm): 0.54

CE Diameter Maximum (µm): 223.99

CE Diameter D[4,3] (µm): 142.2

CE Diameter D[3,2](µm): 88.35

Particles Counted: 15777

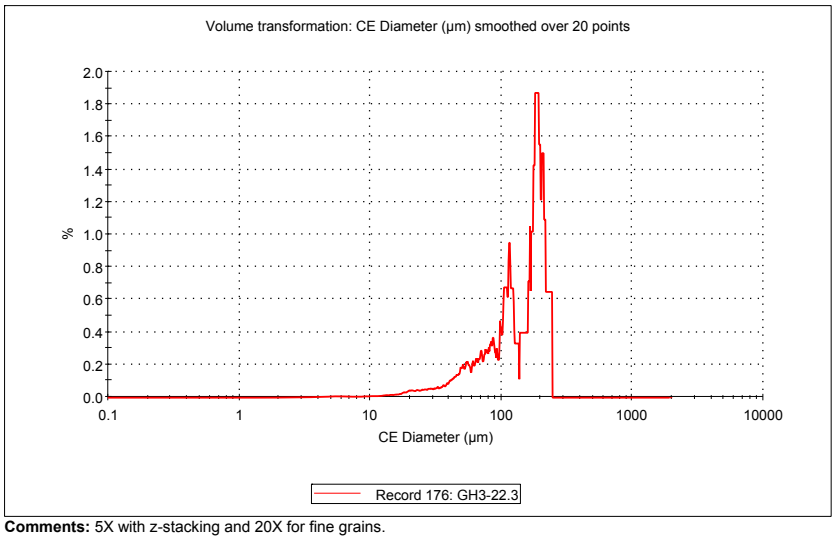
CE Diameter D[v, 0.1]: 52.74

CE Diameter D[v, 0.5]: 150.4

CE Diameter D[v, 0.9]: 220.1

CE Diameter STDV (µm): 7.35

CE Diameter RSD (%): 217.85



Comments: 5X with z-stacking and 20X for fine grains.

CE Diameter Report - Volume Distribution

Malvern

Measurement Details

Sample Name: GH3-22.5

SOP Name: Xiao Qi-Japan 2015-new.vsop

User Name: itscdl

Date: Monday, April 04, 2016 1:46:40 PM

Edited: True

Edited On: Thursday, May 19, 2016 5:56:02 PM

Analysis

SOP Analysis: 3.0

SOP Segmentation: None

SOP Optic(s) used: 5x, 20x

SOP Fill Holes: True

SOP Trash Size: 10

Result

CE Diameter Minimum (µm): 0.54

CE Diameter Maximum (µm): 219.00

CE Diameter D[4,3] (µm): 131.8

CE Diameter D[3,2](µm): 58.21

Particles Counted: 141337

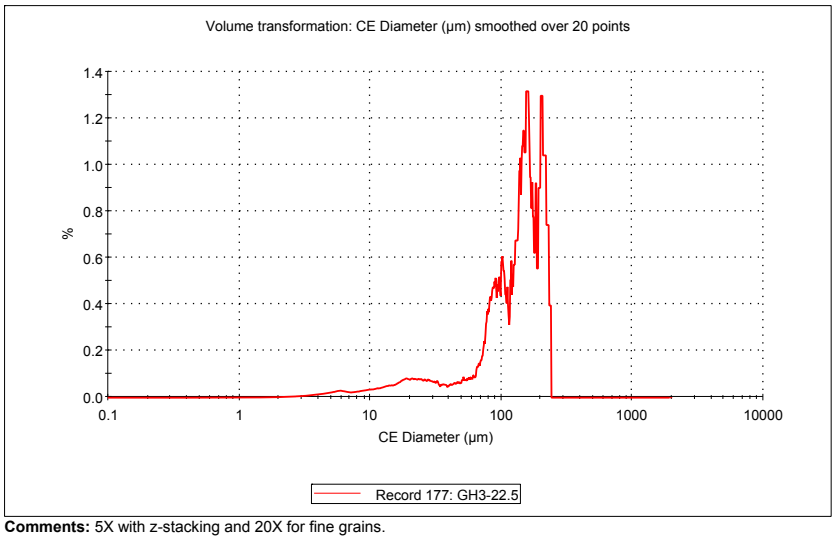
CE Diameter D[v, 0.1]: 30.23

CE Diameter D[v, 0.5]: 139

CE Diameter D[v, 0.9]: 208.3

CE Diameter STDV (µm): 3.56

CE Diameter RSD (%): 170.41



Comments: 5X with z-stacking and 20X for fine grains.

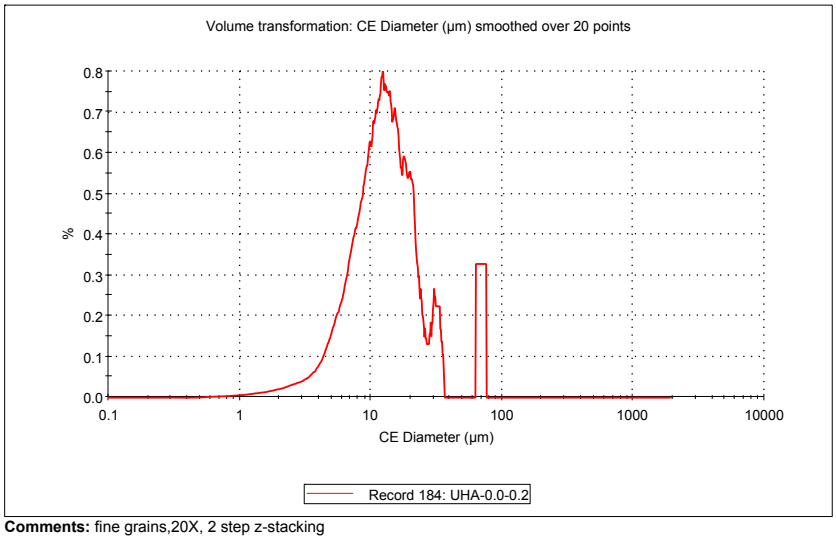
CE Diameter Report - Volume Distribution

Malvern

Measurement Details	
Sample Name: UHA-0.0-0.2	
SOP Name: Xiao Qi-Japan 2015-fine grain-new.vsop	**Edited:** True
User Name: itscdl	**Edited On:** Thursday, May 19, 2016 9:02:31 PM
Date: Thursday, April 28, 2016 12:20:23 PM	

Analysis	
SOP Analysis: 3.0	**SOP Fill Holes:** True
SOP Segmentation: None	**SOP Trash Size:** 10
SOP Optic(s) used: 20x	

Result	
CE Diameter Minimum (µm): 0.54	**CE Diameter D[v, 0.1]:** 5.956
CE Diameter Maximum (µm): 69.58	**CE Diameter D[v, 0.5]:** 12.77
CE Diameter D[4,3] (µm): 17.04	**CE Diameter D[v, 0.9]:** 30.45
CE Diameter D[3,2](µm): 10.18	**CE Diameter STDV (µm):** 2.44
Particles Counted: 55370	**CE Diameter RSD (%):** 127.42



Comments: fine grains,20X, 2 step z-stacking

Morphologi
Malvern Instruments Worldwide
www.malvern.com

Morphologi Ver. 8.20
Serial Number : MAL1115686

File name: UHA-final data-addition-May 17.vmes
Record Number: 184
20 May 2016 3:16:53 PM

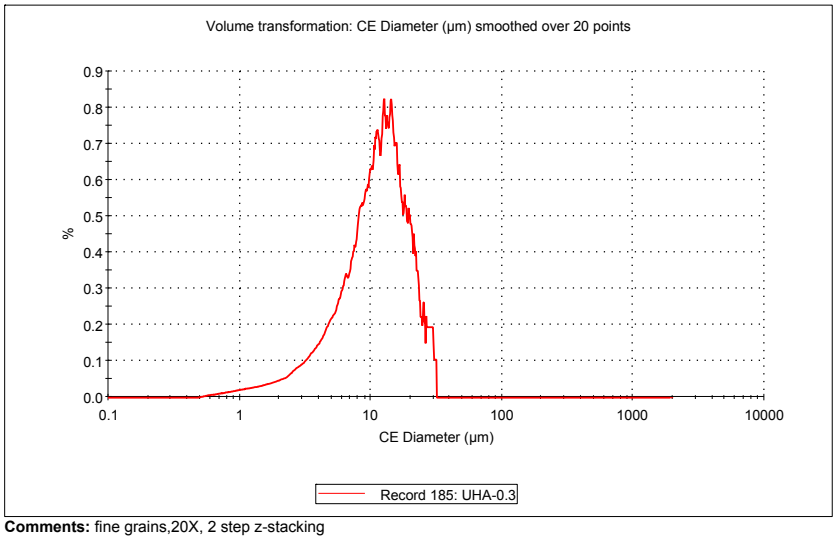
CE Diameter Report - Volume Distribution

Malvern

Measurement Details	
Sample Name: UHA-0.3	
SOP Name: Xiao Qi-Japan 2015-fine grain-new.vsop	**Edited:** True
User Name: itscdl	**Edited On:** Thursday, May 19, 2016 9:02:58 PM
Date: Thursday, April 28, 2016 12:54:00 PM	

Analysis	
SOP Analysis: 3.0	**SOP Fill Holes:** True
SOP Segmentation: None	**SOP Trash Size:** 10
SOP Optic(s) used: 20x	

Result	
CE Diameter Minimum (µm): 0.54	**CE Diameter D[v, 0.1]:** 4.195
CE Diameter Maximum (µm): 29.00	**CE Diameter D[v, 0.5]:** 11.39
CE Diameter D[4,3] (µm): 12.12	**CE Diameter D[v, 0.9]:** 20.78
CE Diameter D[3,2](µm): 7.581	**CE Diameter STDV (µm):** 1.56
Particles Counted: 75002	**CE Diameter RSD (%):** 115.47



Comments: fine grains,20X, 2 step z-stacking

Morphologi
Malvern Instruments Worldwide
www.malvern.com

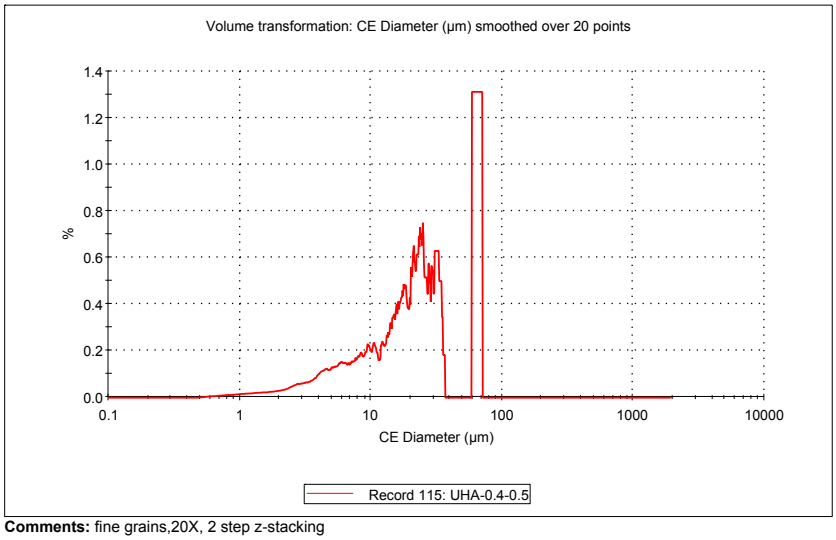
CE Diameter Report - Volume Distribution

Malvern

Measurement Details	
Sample Name: UHA-0.4-0.5	
SOP Name: Xiao Qi-Japan 2015-fine grain-new.vsop	**Edited:** True
User Name: itscdl	**Edited On:** Thursday, May 19, 2016 8:19:35 PM
Date: Thursday, April 28, 2016 9:09:42 PM	

Analysis	
SOP Analysis: 3.0	**SOP Fill Holes:** True
SOP Segmentation: None	**SOP Trash Size:** 10
SOP Optic(s) used: 20x	

Result	
CE Diameter Minimum (µm): 0.54	**CE Diameter D[v, 0.1]:** 5.489
CE Diameter Maximum (µm): 64.93	**CE Diameter D[v, 0.5]:** 22.75
CE Diameter D[4,3] (µm): 29.6	**CE Diameter D[v, 0.9]:** 64.1
CE Diameter D[3,2](µm): 11.89	**CE Diameter STDV (µm):** 1.51
Particles Counted: 24067	**CE Diameter RSD (%):** 121.04



Comments: fine grains,20X, 2 step z-stacking

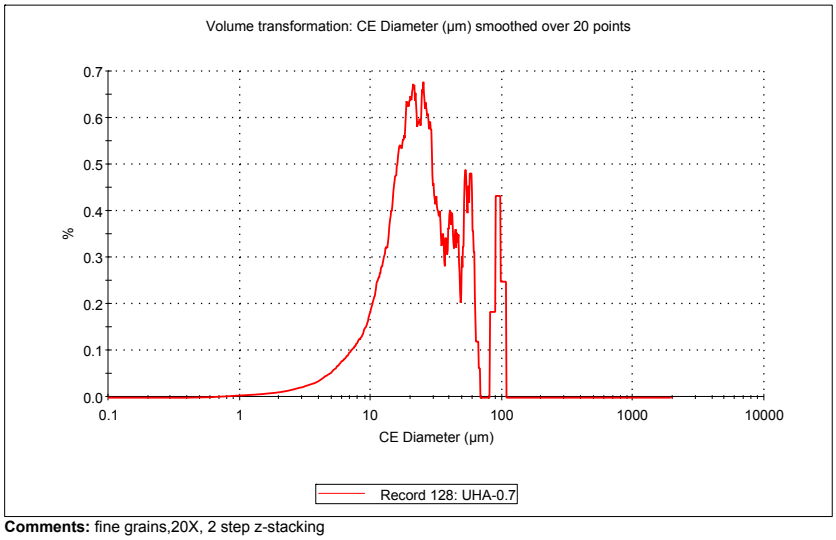
CE Diameter Report - Volume Distribution

Malvern

Measurement Details	
Sample Name: UHA-0.7	
SOP Name: Xiao Qi-Japan 2015-fine grain-new.vsop	**Edited:** True
User Name: itscdl	**Edited On:** Thursday, May 19, 2016 8:26:27 PM
Date: Wednesday, April 06, 2016 1:49:02 PM	

Analysis	
SOP Analysis: 3.0	**SOP Fill Holes:** True
SOP Segmentation: None	**SOP Trash Size:** 10
SOP Optic(s) used: 20x	

Result	
CE Diameter Minimum (µm): 0.54	**CE Diameter D[v, 0.1]:** 9.674
CE Diameter Maximum (µm): 98.22	**CE Diameter D[v, 0.5]:** 23.79
CE Diameter D[4,3] (µm): 31.57	**CE Diameter D[v, 0.9]:** 59.72
CE Diameter D[3,2](µm): 16.9	**CE Diameter STDV (µm):** 2.54
Particles Counted: 129762	**CE Diameter RSD (%):** 153.89



Comments: fine grains,20X, 2 step z-stacking

Morphologi
Malvern Instruments Worldwide
www.malvern.com

CE Diameter Report - Volume Distribution

Malvern

Measurement Details

Sample Name: UHA-0.9

SOP Name: Xiao Qi-Japan 2015-fine grain-new.vsop

User Name: itscdl

Date: Thursday, April 28, 2016 8:30:07 PM

Edited: True

Edited On: Thursday, May 19, 2016 8:17:59 PM

Analysis

SOP Analysis: 3.0

SOP Segmentation: None

SOP Optic(s) used: 20x

SOP Fill Holes: True

SOP Trash Size: 10

Result

CE Diameter Minimum (µm): 0.54

CE Diameter Maximum (µm): 38.36

CE Diameter D[4,3] (µm): 11.88

CE Diameter D[3,2](µm): 7.389

Particles Counted: 104594

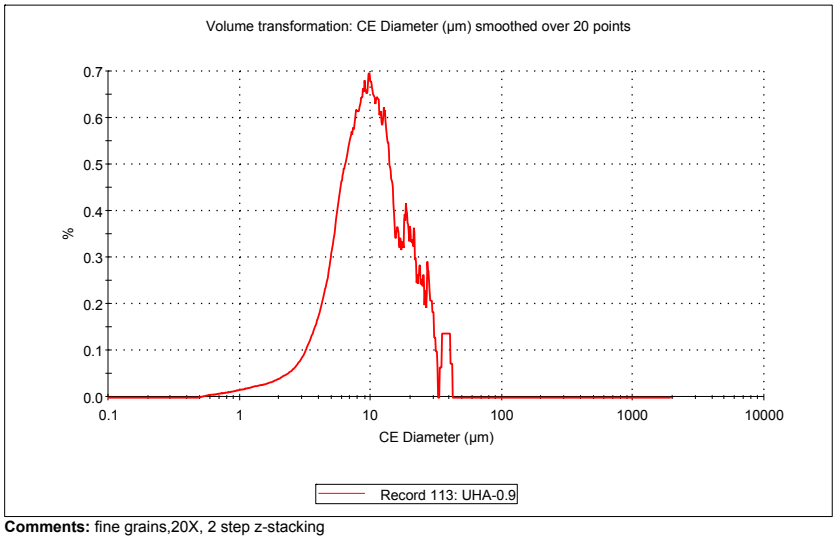
CE Diameter D[v, 0.1]: 4.3

CE Diameter D[v, 0.5]: 9.719

CE Diameter D[v, 0.9]: 22.8

CE Diameter STDV (µm): 1.73

CE Diameter RSD (%): 115.06



Comments: fine grains,20X, 2 step z-stacking

Morphologi
Malvern Instruments Worldwide
www.malvern.com

Morphologi Ver. 8.20
Serial Number : MAL1115686

File name: UHA-final data-addition-May 17.vmes
Record Number: 113
20 May 2016 3:18:38 PM

CE Diameter Report - Volume Distribution

Malvern

Measurement Details

Sample Name: UHA-1.0-1.1

SOP Name: Xiao Qi-Japan 2015-fine grain-new.vsop

User Name: itscdl

Date: Friday, April 29, 2016 9:30:08 AM

Edited: True

Edited On: Thursday, May 19, 2016 9:08:40 PM

Analysis

SOP Analysis: 3.0

SOP Segmentation: None

SOP Optic(s) used: 20x

SOP Fill Holes: True

SOP Trash Size: 10

Result

CE Diameter Minimum (µm): 0.54

CE Diameter Maximum (µm): 61.32

CE Diameter D[4,3] (µm): 15.36

CE Diameter D[3,2](µm): 9.622

Particles Counted: 56126

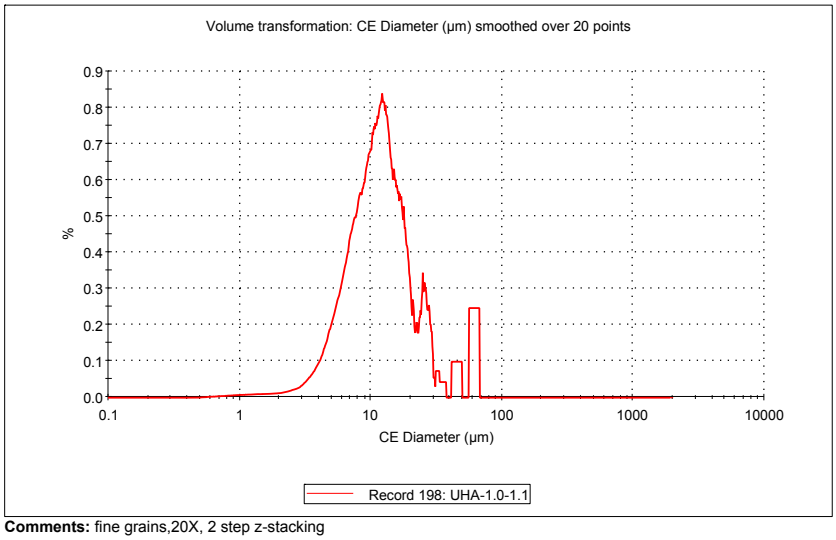
CE Diameter D[v, 0.1]: 5.709

CE Diameter D[v, 0.5]: 11.75

CE Diameter D[v, 0.9]: 26.7

CE Diameter STDV (µm): 2.40

CE Diameter RSD (%): 130.49



Comments: fine grains,20X, 2 step z-stacking

Morphologi
Malvern Instruments Worldwide
www.malvern.com

Morphologi Ver. 8.20
Serial Number : MAL1115686

File name: UHA-final data-addition-May 17.vmes
Record Number: 198
20 May 2016 3:19:09 PM

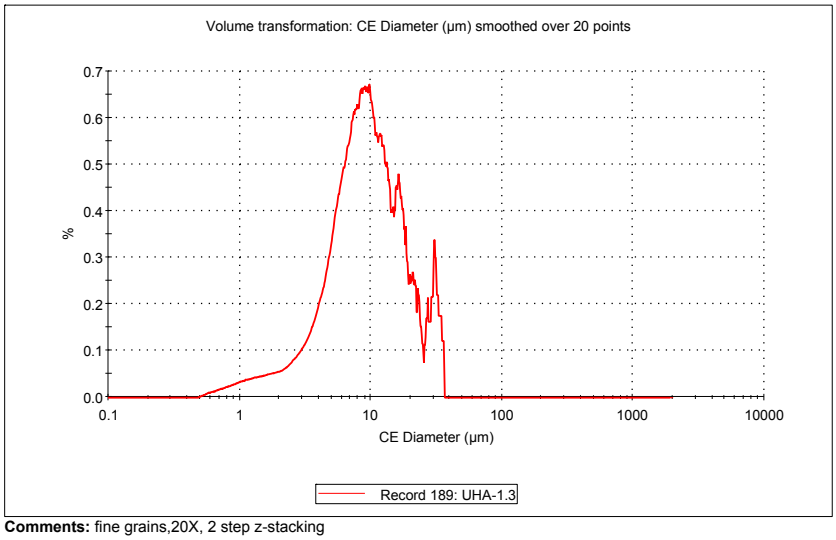
CE Diameter Report - Volume Distribution

Malvern

Measurement Details	
Sample Name: UHA-1.3	
SOP Name: Xiao Qi-Japan 2015-fine grain-new.vsop	**Edited:** True
User Name: itscdl	**Edited On:** Thursday, May 19, 2016 9:04:31 PM
Date: Thursday, April 28, 2016 3:45:52 PM	

Analysis	
SOP Analysis: 3.0	**SOP Fill Holes:** True
SOP Segmentation: None	**SOP Trash Size:** 10
SOP Optic(s) used: 20x	

Result	
CE Diameter Minimum (µm): 0.54	**CE Diameter D[v, 0.1]:** 3.646
CE Diameter Maximum (µm): 33.21	**CE Diameter D[v, 0.5]:** 9.118
CE Diameter D[4,3] (µm): 11.11	**CE Diameter D[v, 0.9]:** 21.32
CE Diameter D[3,2](µm): 6.396	**CE Diameter STDV (µm):** 1.35
Particles Counted: 144298	**CE Diameter RSD (%):** 107.35



Comments: fine grains,20X, 2 step z-stacking

Morphologi
Malvern Instruments Worldwide
www.malvern.com

Morphologi Ver. 8.20
Serial Number : MAL1115686

File name: UHA-final data-addition-May 17.vmes
Record Number: 189
20 May 2016 3:19:28 PM

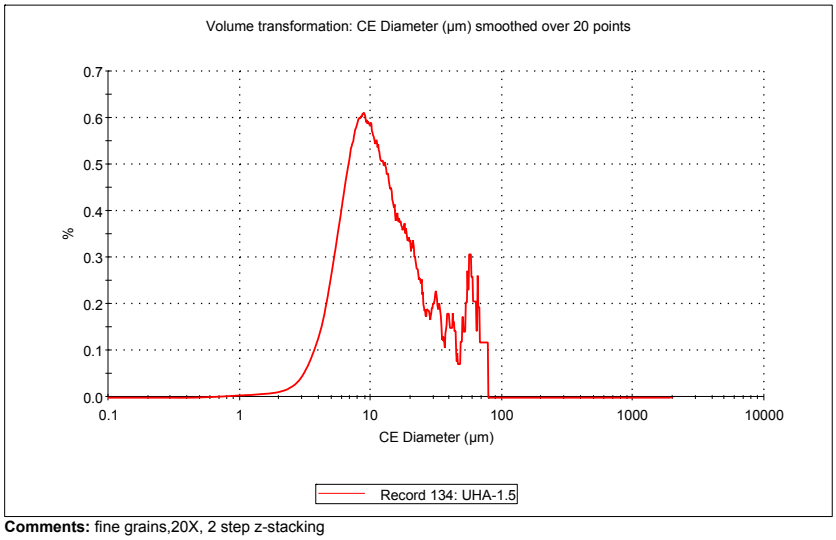
CE Diameter Report - Volume Distribution

Malvern

Measurement Details	
Sample Name: UHA-1.5	
SOP Name: Xiao Qi-Japan 2015-fine grain-new.vsop	**Edited:** True
User Name: itscdl	**Edited On:** Thursday, May 19, 2016 8:35:20 PM
Date: Wednesday, April 06, 2016 8:59:34 PM	

Analysis	
SOP Analysis: 3.0	**SOP Fill Holes:** True
SOP Segmentation: None	**SOP Trash Size:** 10
SOP Optic(s) used: 20x	

Result	
CE Diameter Minimum (µm): 0.54	**CE Diameter D[v, 0.1]:** 5.287
CE Diameter Maximum (µm): 71.70	**CE Diameter D[v, 0.5]:** 11.3
CE Diameter D[4,3] (µm): 17.72	**CE Diameter D[v, 0.9]:** 41.11
CE Diameter D[3,2](µm): 9.642	**CE Diameter STDV (µm):** 2.63
Particles Counted: 137897	**CE Diameter RSD (%):** 113.12



Comments: fine grains,20X, 2 step z-stacking

Morphologi
Malvern Instruments Worldwide
www.malvern.com

Morphologi Ver. 8.20
Serial Number : MAL1115686

File name: UHA-final data-addition-May 17.vmes
Record Number: 134
20 May 2016 3:19:52 PM

CE Diameter Report - Volume Distribution

Malvern

Measurement Details

Sample Name: UHA-1.6-1.7

SOP Name: Xiao Qi-Japan 2015-fine grain-new.vsop

User Name: itscdl

Date: Thursday, April 28, 2016 5:53:31 PM

Edited: True

Edited On: Thursday, May 19, 2016 9:04:52 PM

Analysis

SOP Analysis: 3.0

SOP Segmentation: None

SOP Optic(s) used: 20x

SOP Fill Holes: True

SOP Trash Size: 10

Result

CE Diameter Minimum (µm): 0.54

CE Diameter Maximum (µm): 41.99

CE Diameter D[4,3] (µm): 16.97

CE Diameter D[3,2](µm): 11.56

Particles Counted: 32785

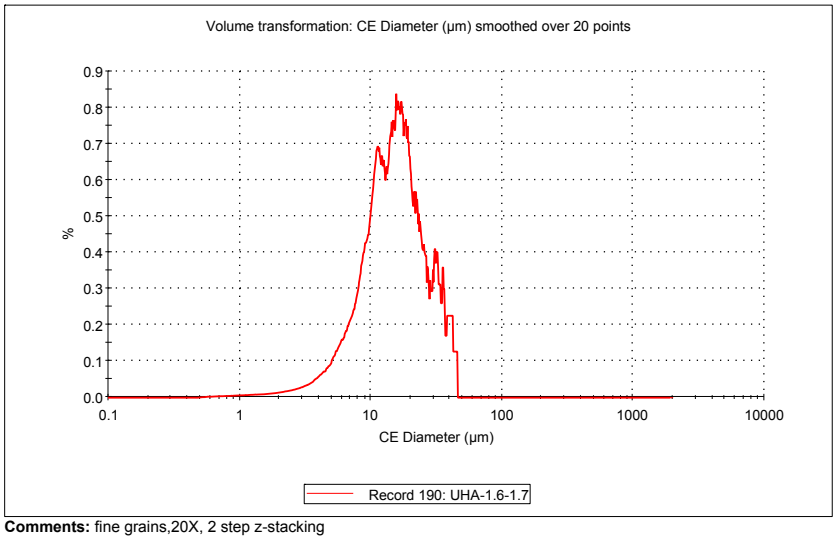
CE Diameter D[v, 0.1]: 7.037

CE Diameter D[v, 0.5]: 15.09

CE Diameter D[v, 0.9]: 30.69

CE Diameter STDV (µm): 2.35

CE Diameter RSD (%): 147.29



Comments: fine grains,20X, 2 step z-stacking

Morphologi
Malvern Instruments Worldwide
www.malvern.com

Morphologi Ver. 8.20
Serial Number : MAL1115686

File name: UHA-final data-addition-May 17.vmes
Record Number: 190
20 May 2016 3:20:05 PM

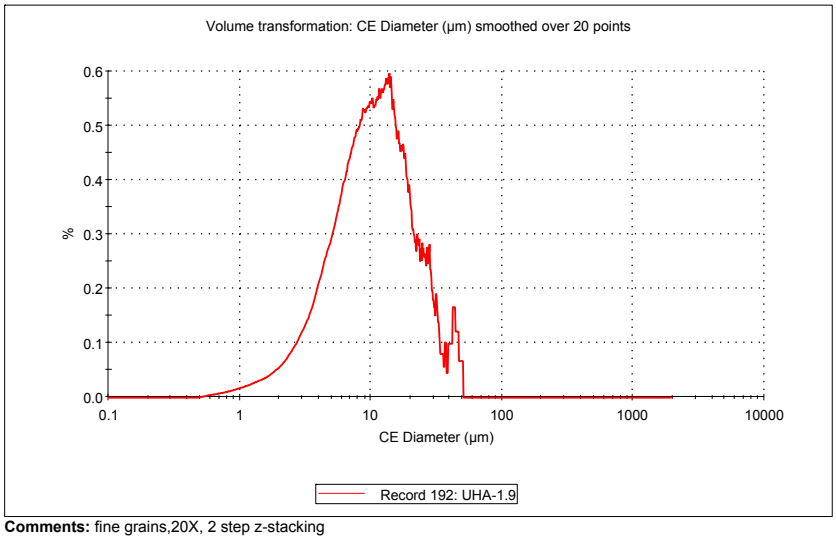
CE Diameter Report - Volume Distribution

Malvern

Measurement Details	
Sample Name: UHA-1.9	
SOP Name: Xiao Qi-Japan 2015-fine grain-new.vsop	**Edited:** True
User Name: itscdl	**Edited On:** Thursday, May 19, 2016 9:05:51 PM
Date: Thursday, April 28, 2016 7:53:03 PM	

Analysis	
SOP Analysis: 3.0	**SOP Fill Holes:** True
SOP Segmentation: None	**SOP Trash Size:** 10
SOP Optic(s) used: 20x	

Result	
CE Diameter Minimum (µm): 0.54	**CE Diameter D[v, 0.1]:** 3.808
CE Diameter Maximum (µm): 46.02	**CE Diameter D[v, 0.5]:** 10.46
CE Diameter D[4,3] (µm): 12.84	**CE Diameter D[v, 0.9]:** 25.38
CE Diameter D[3,2](µm): 7.302	**CE Diameter STDV (µm):** 1.67
Particles Counted: 198676	**CE Diameter RSD (%):** 106.85



Comments: fine grains,20X, 2 step z-stacking

Morphologi
Malvern Instruments Worldwide
www.malvern.com

Morphologi Ver. 8.20
Serial Number : MAL1115686

File name: UHA-final data-addition-May 17.vmes
Record Number: 192
20 May 2016 3:20:28 PM

CE Diameter Report - Volume Distribution

Malvern

Measurement Details

Sample Name: UHA-2.1

SOP Name: Xiao Qi-Japan 2015-fine grain-new.vsop

User Name: itscdl

Date: Thursday, April 28, 2016 9:55:17 PM

Edited: True

Edited On: Thursday, May 19, 2016 9:06:43 PM

Analysis

SOP Analysis: 3.0

SOP Segmentation: None

SOP Optic(s) used: 20x

SOP Fill Holes: True

SOP Trash Size: 10

Result

CE Diameter Minimum (µm): 0.54

CE Diameter Maximum (µm): 52.38

CE Diameter D[4,3] (µm): 15.4

CE Diameter D[3,2](µm): 10.18

Particles Counted: 112403

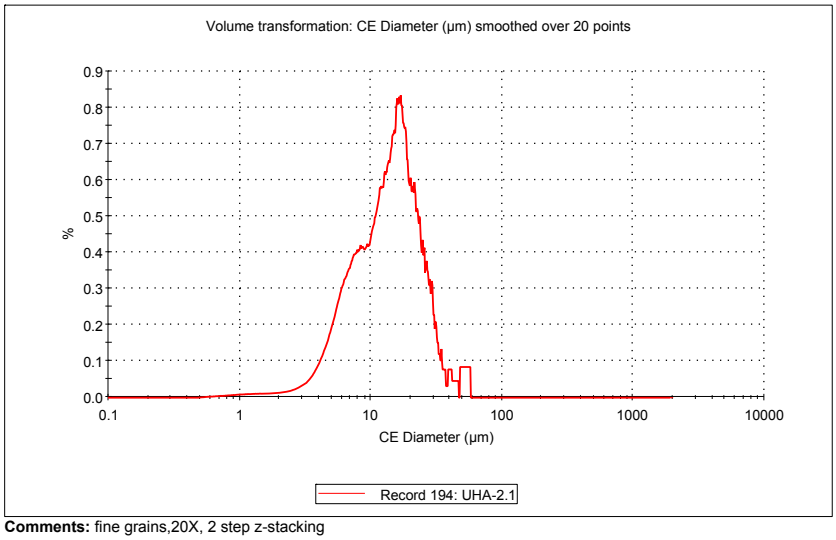
CE Diameter D[v, 0.1]: 5.766

CE Diameter D[v, 0.5]: 13.89

CE Diameter D[v, 0.9]: 26.46

CE Diameter STDV (µm): 2.25

CE Diameter RSD (%): 135.55



Comments: fine grains,20X, 2 step z-stacking

Morphologi
Malvern Instruments Worldwide
www.malvern.com

Morphologi Ver. 8.20
Serial Number : MAL1115686

File name: UHA-final data-addition-May 17.vmes
Record Number: 194
20 May 2016 3:28:11 PM

CE Diameter Report - Volume Distribution

Malvern

Measurement Details

Sample Name: UHA-2.3-2.4

SOP Name: Xiao Qi-Japan 2015-fine grain-new.vsop

User Name: itscdl

Date: Thursday, April 28, 2016 10:44:04 PM

Edited: True

Edited On: Thursday, May 19, 2016 9:07:01 PM

Analysis

SOP Analysis: 3.0

SOP Segmentation: None

SOP Optic(s) used: 20x

SOP Fill Holes: True

SOP Trash Size: 10

Result

CE Diameter Minimum (µm): 0.54

CE Diameter Maximum (µm): 48.30

CE Diameter D[4,3] (µm): 14.55

CE Diameter D[3,2](µm): 7.456

Particles Counted: 206750

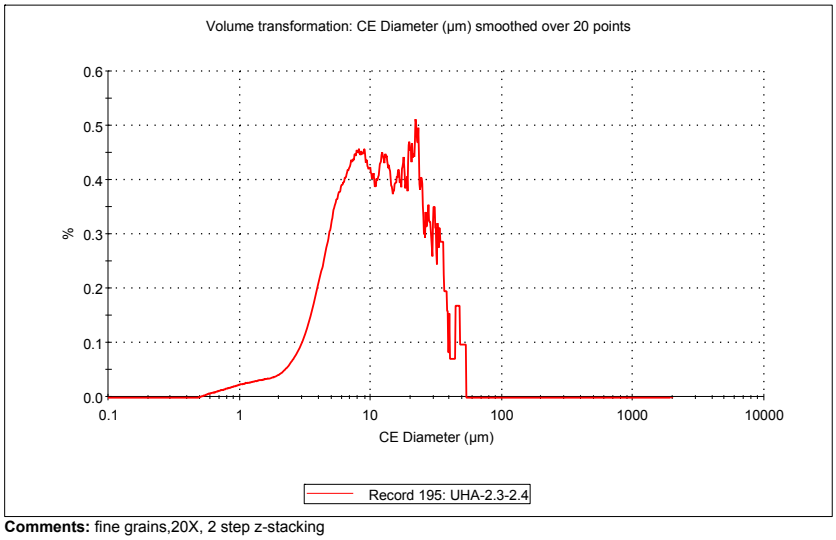
CE Diameter D[v, 0.1]: 3.951

CE Diameter D[v, 0.5]: 11.26

CE Diameter D[v, 0.9]: 29.73

CE Diameter STDV (µm): 1.48

CE Diameter RSD (%): 111.12



Comments: fine grains,20X, 2 step z-stacking

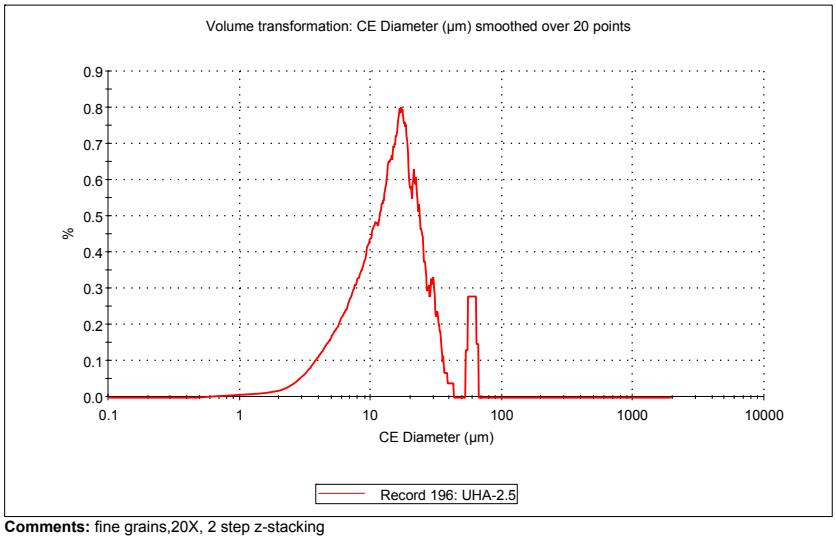
CE Diameter Report - Volume Distribution

Malvern

Measurement Details	
Sample Name: UHA-2.5	
SOP Name: Xiao Qi-Japan 2015-fine grain-new.vsop	**Edited:** True
User Name: itscdl	**Edited On:** Thursday, May 19, 2016 9:07:25 PM
Date: Friday, April 29, 2016 7:50:56 AM	

Analysis	
SOP Analysis: 3.0	**SOP Fill Holes:** True
SOP Segmentation: None	**SOP Trash Size:** 10
SOP Optic(s) used: 20x	

Result	
CE Diameter Minimum (µm): 0.54	**CE Diameter D[v, 0.1]:** 5.513
CE Diameter Maximum (µm): 60.40	**CE Diameter D[v, 0.5]:** 14.7
CE Diameter D[4,3] (µm): 17.37	**CE Diameter D[v, 0.9]:** 29.61
CE Diameter D[3,2](µm): 10.34	**CE Diameter STDV (µm):** 2.17
Particles Counted: 101578	**CE Diameter RSD (%):** 130.25



Comments: fine grains,20X, 2 step z-stacking

Morphologi
Malvern Instruments Worldwide
www.malvern.com

Morphologi Ver. 8.20
Serial Number : MAL1115686

File name: UHA-final data-addition-May 17.vmes
Record Number: 196
20 May 2016 3:28:34 PM

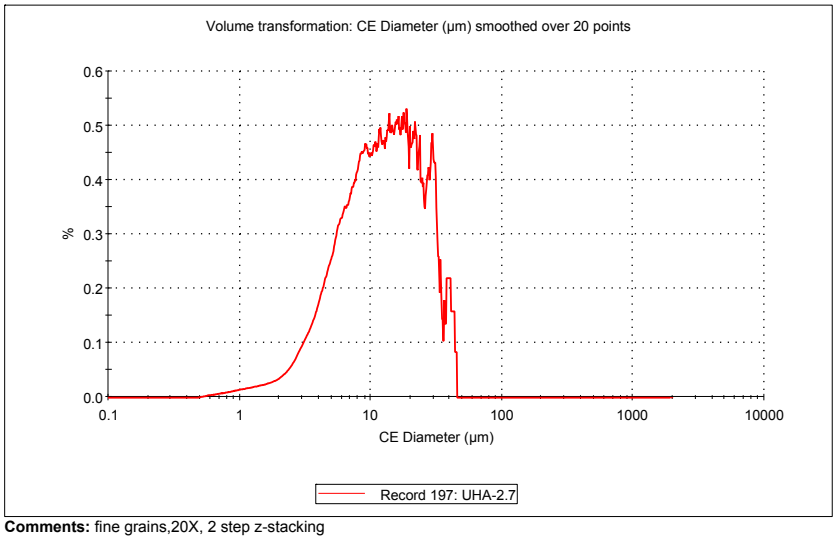
CE Diameter Report - Volume Distribution

Malvern

Measurement Details	
Sample Name: UHA-2.7	
SOP Name: Xiao Qi-Japan 2015-fine grain-new.vsop	**Edited:** True
User Name: itscdl	**Edited On:** Thursday, May 19, 2016 9:07:51 PM
Date: Friday, April 29, 2016 8:24:09 AM	

Analysis	
SOP Analysis: 3.0	**SOP Fill Holes:** True
SOP Segmentation: None	**SOP Trash Size:** 10
SOP Optic(s) used: 20x	

Result	
CE Diameter Minimum (µm): 0.54	**CE Diameter D[v, 0.1]:** 4.359
CE Diameter Maximum (µm): 41.38	**CE Diameter D[v, 0.5]:** 12.46
CE Diameter D[4,3] (µm): 14.86	**CE Diameter D[v, 0.9]:** 28.98
CE Diameter D[3,2](µm): 8.39	**CE Diameter STDV (µm):** 1.77
Particles Counted: 97593	**CE Diameter RSD (%):** 116.14



Comments: fine grains,20X, 2 step z-stacking

Morphologi
Malvern Instruments Worldwide
www.malvern.com

Morphologi Ver. 8.20
Serial Number : MAL1115686

File name: UHA-final data-addition-May 17.vmes
Record Number: 197
20 May 2016 3:28:48 PM

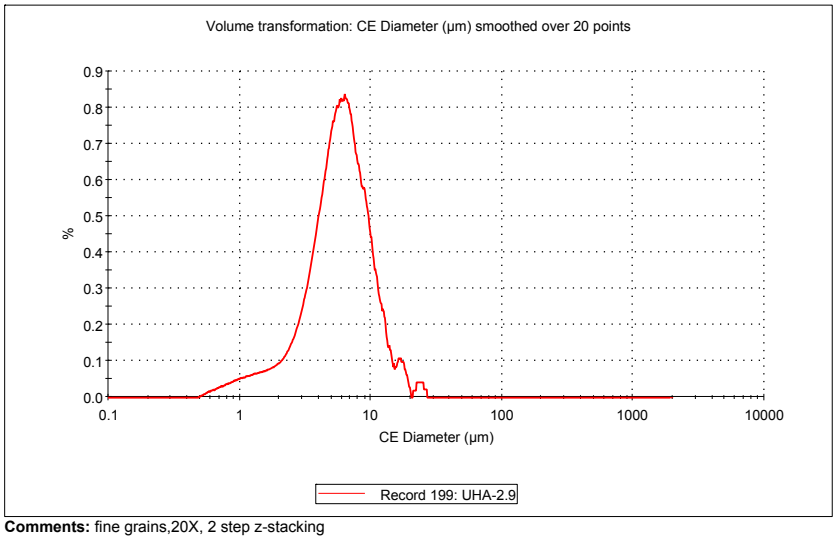
CE Diameter Report - Volume Distribution

Malvern

Measurement Details	
Sample Name: UHA-2.9	
SOP Name: Xiao Qi-Japan 2015-fine grain-new.vsop	**Edited:** True
User Name: itscdl	**Edited On:** Thursday, May 19, 2016 9:09:03 PM
Date: Friday, April 29, 2016 8:57:07 AM	

Analysis	
SOP Analysis: 3.0	**SOP Fill Holes:** True
SOP Segmentation: None	**SOP Trash Size:** 10
SOP Optic(s) used: 20x	

Result	
CE Diameter Minimum (µm): 0.54	**CE Diameter D[v, 0.1]:** 2.569
CE Diameter Maximum (µm): 24.49	**CE Diameter D[v, 0.5]:** 5.839
CE Diameter D[4,3] (µm): 6.497	**CE Diameter D[v, 0.9]:** 10.72
CE Diameter D[3,2](µm): 4.396	**CE Diameter STDV (µm):** 1.19
Particles Counted: 254605	**CE Diameter RSD (%):** 93.25



Comments: fine grains,20X, 2 step z-stacking

CE Diameter Report - Volume Distribution

Malvern

Measurement Details

Sample Name: UHA-3.5

SOP Name: Xiao Qi-Japan 2015-fine grain-new.vsop

User Name: itscdl

Date: Friday, April 29, 2016 10:02:20 AM

Edited: True

Edited On: Thursday, May 19, 2016 9:15:03 PM

Analysis

SOP Analysis: 3.0

SOP Segmentation: None

SOP Optic(s) used: 20x

SOP Fill Holes: True

SOP Trash Size: 10

Result

CE Diameter Minimum (µm): 0.54

CE Diameter Maximum (µm): 36.28

CE Diameter D[4,3] (µm): 10.43

CE Diameter D[3,2](µm): 5.886

Particles Counted: 201728

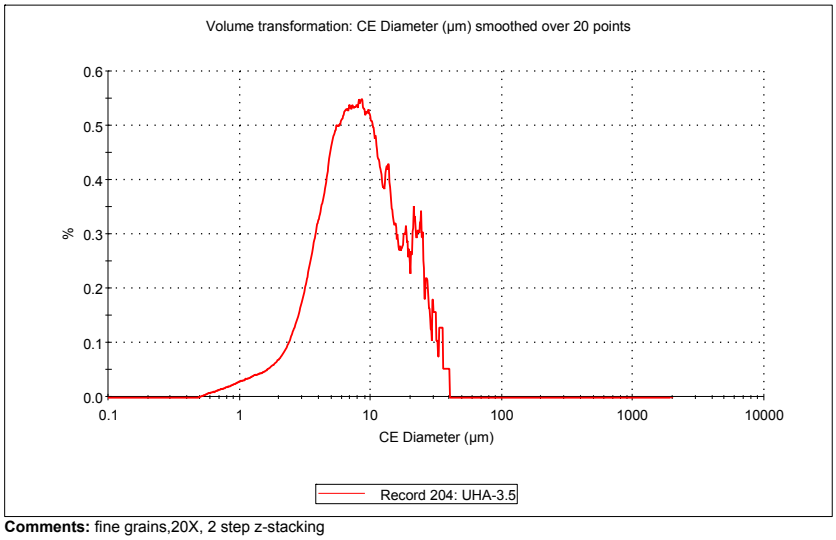
CE Diameter D[v, 0.1]: 3.171

CE Diameter D[v, 0.5]: 8.056

CE Diameter D[v, 0.9]: 22.33

CE Diameter STDV (µm): 1.41

CE Diameter RSD (%): 100.09



Comments: fine grains,20X, 2 step z-stacking

CE Diameter Report - Volume Distribution

Malvern

Measurement Details

Sample Name: UHA-3.7

SOP Name: Xiao Qi-Japan 2015-fine grain-new.vsop

User Name: itscdl

Date: Friday, April 29, 2016 10:34:56 AM

Edited: True

Edited On: Thursday, May 19, 2016 9:09:42 PM

Analysis

SOP Analysis: 3.0

SOP Segmentation: None

SOP Optic(s) used: 20x

SOP Fill Holes: True

SOP Trash Size: 10

Result

CE Diameter Minimum (µm): 0.54

CE Diameter Maximum (µm): 38.60

CE Diameter D[4,3] (µm): 15

CE Diameter D[3,2](µm): 9.475

Particles Counted: 40112

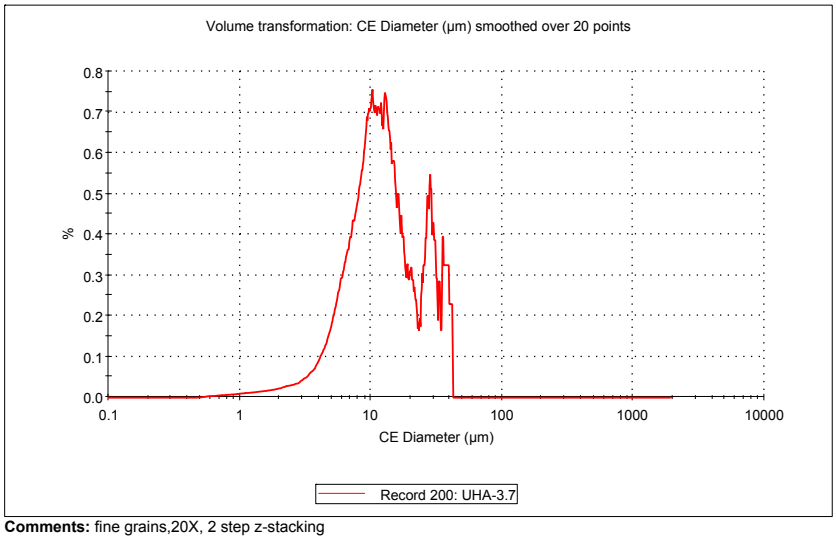
CE Diameter D[v, 0.1]: 5.634

CE Diameter D[v, 0.5]: 12.01

CE Diameter D[v, 0.9]: 29.36

CE Diameter STDV (µm): 2.08

CE Diameter RSD (%): 130.49



Comments: fine grains,20X, 2 step z-stacking

Morphologi
Malvern Instruments Worldwide
www.malvern.com

CE Diameter Report - Volume Distribution

Malvern

Measurement Details

Sample Name: UHA-3.9

SOP Name: Xiao Qi-Japan 2015-fine grain-new.vsop

User Name: itscdl

Date: Friday, April 29, 2016 11:11:55 AM

Edited: True

Edited On: Thursday, May 19, 2016 9:10:20 PM

Analysis

SOP Analysis: 3.0

SOP Segmentation: None

SOP Optic(s) used: 20x

SOP Fill Holes: True

SOP Trash Size: 10

Result

CE Diameter Minimum (µm): 0.54

CE Diameter Maximum (µm): 50.55

CE Diameter D[4,3] (µm): 17.89

CE Diameter D[3,2](µm): 10.27

Particles Counted: 100786

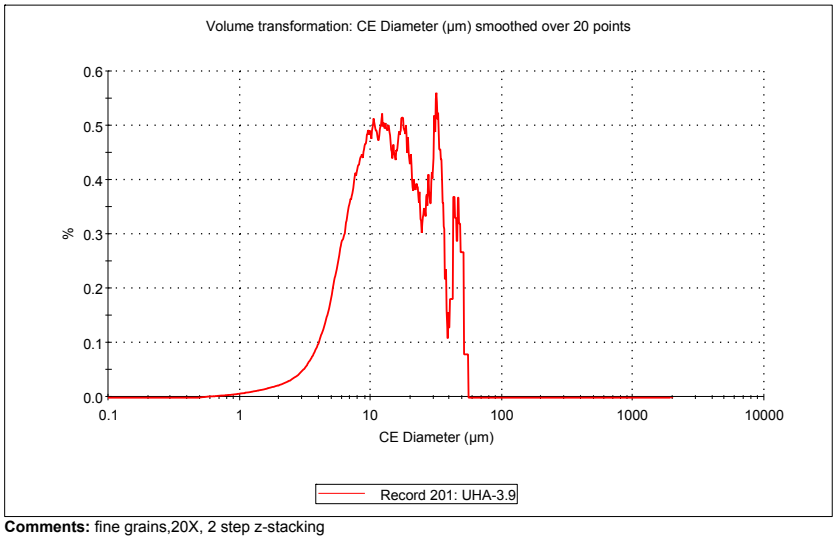
CE Diameter D[v, 0.1]: 5.53

CE Diameter D[v, 0.5]: 14.01

CE Diameter D[v, 0.9]: 34.17

CE Diameter STDV (µm): 2.24

CE Diameter RSD (%): 124.03



Comments: fine grains,20X, 2 step z-stacking

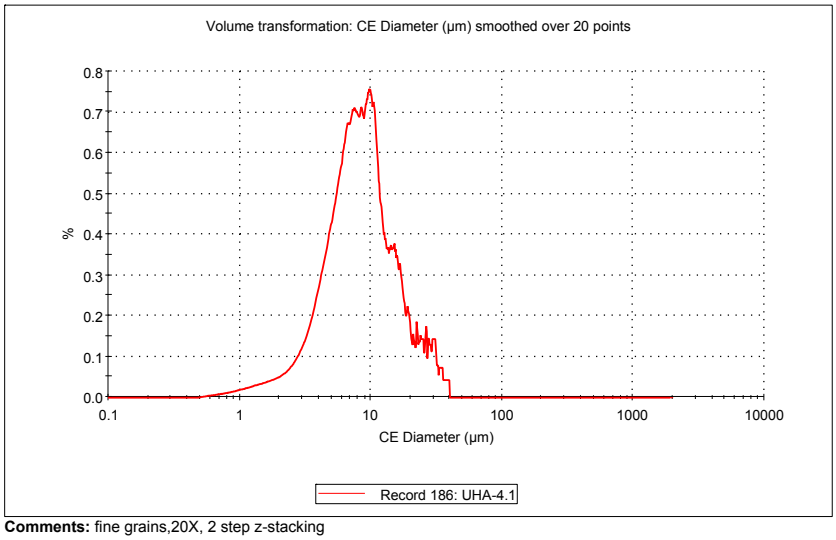
CE Diameter Report - Volume Distribution

Malvern

Measurement Details	
Sample Name: UHA-4.1	
SOP Name: Xiao Qi-Japan 2015-fine grain-new.vsop	**Edited:** True
User Name: itscdl	**Edited On:** Thursday, May 19, 2016 9:03:26 PM
Date: Thursday, April 28, 2016 1:26:10 PM	

Analysis	
SOP Analysis: 3.0	**SOP Fill Holes:** True
SOP Segmentation: None	**SOP Trash Size:** 10
SOP Optic(s) used: 20x	

Result	
CE Diameter Minimum (µm): 0.54	**CE Diameter D[v, 0.1]:** 3.757
CE Diameter Maximum (µm): 36.26	**CE Diameter D[v, 0.5]:** 8.189
CE Diameter D[4,3] (µm): 9.88	**CE Diameter D[v, 0.9]:** 17.94
CE Diameter D[3,2](µm): 6.421	**CE Diameter STDV (µm):** 1.71
Particles Counted: 163449	**CE Diameter RSD (%):** 104.83



Comments: fine grains,20X, 2 step z-stacking

Morphologi
Malvern Instruments Worldwide
www.malvern.com

Morphologi Ver. 8.20
Serial Number : MAL1115686

File name: UHA-final data-addition-May 17.vmes
Record Number: 186
20 May 2016 3:29:41 PM

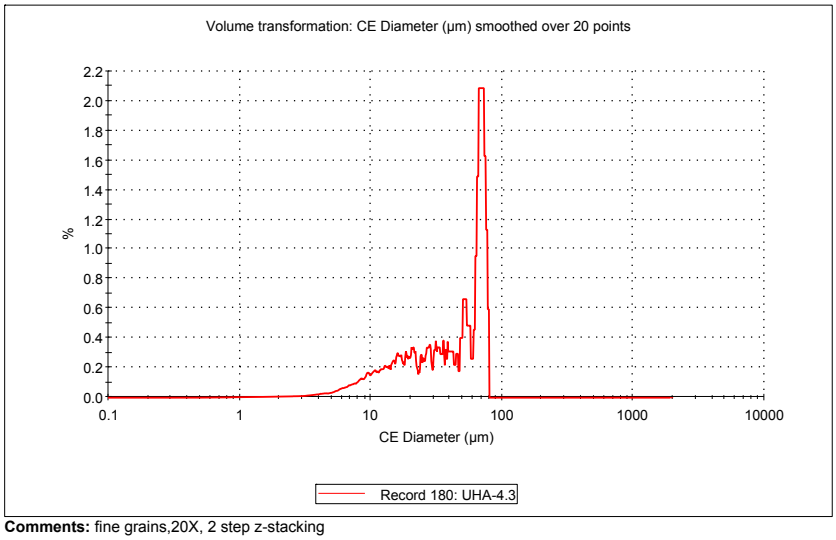
CE Diameter Report - Volume Distribution

Malvern

Measurement Details	
Sample Name: UHA-4.3	
SOP Name: Xiao Qi-Japan 2015-fine grain-new.vsop	**Edited:** True
User Name: itscdl	**Edited On:** Thursday, May 19, 2016 9:00:53 PM
Date: Thursday, April 28, 2016 12:18:09 AM	

Analysis	
SOP Analysis: 3.0	**SOP Fill Holes:** True
SOP Segmentation: None	**SOP Trash Size:** 10
SOP Optic(s) used: 20x	

Result	
CE Diameter Minimum (µm): 0.54	**CE Diameter D[v, 0.1]:** 11.04
CE Diameter Maximum (µm): 72.97	**CE Diameter D[v, 0.5]:** 48.6
CE Diameter D[4,3] (µm): 44.67	**CE Diameter D[v, 0.9]:** 71.84
CE Diameter D[3,2](µm): 22.95	**CE Diameter STDV (µm):** 2.57
Particles Counted: 16715	**CE Diameter RSD (%):** 166.87



Comments: fine grains,20X, 2 step z-stacking

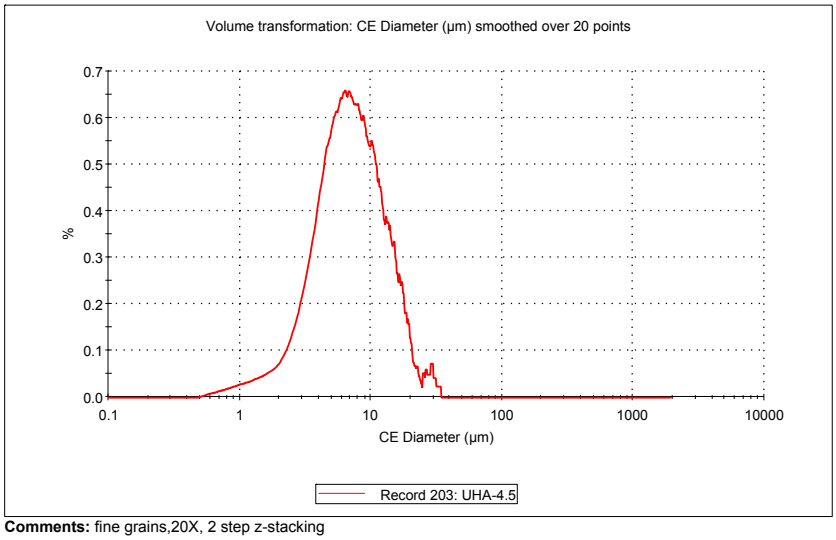
CE Diameter Report - Volume Distribution

Malvern

Measurement Details	
Sample Name: UHA-4.5	
SOP Name: Xiao Qi-Japan 2015-fine grain-new.vsop	**Edited:** True
User Name: itscdl	**Edited On:** Thursday, May 19, 2016 9:11:27 PM
Date: Thursday, April 28, 2016 2:07:03 PM	

Analysis	
SOP Analysis: 3.0	**SOP Fill Holes:** True
SOP Segmentation: None	**SOP Trash Size:** 10
SOP Optic(s) used: 20x	

Result	
CE Diameter Minimum (µm): 0.54	**CE Diameter D[v, 0.1]:** 3.063
CE Diameter Maximum (µm): 31.46	**CE Diameter D[v, 0.5]:** 6.818
CE Diameter D[4,3] (µm): 8.122	**CE Diameter D[v, 0.9]:** 14.62
CE Diameter D[3,2](µm): 5.327	**CE Diameter STDV (µm):** 1.46
Particles Counted: 294288	**CE Diameter RSD (%):** 97.23



Comments: fine grains,20X, 2 step z-stacking

Morphologi
Malvern Instruments Worldwide
www.malvern.com

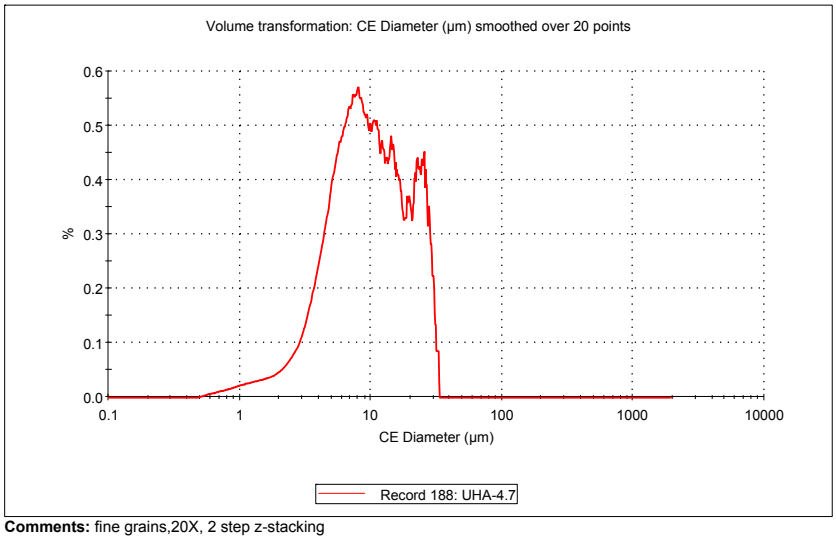
CE Diameter Report - Volume Distribution

Malvern

Measurement Details	
Sample Name: UHA-4.7	
SOP Name: Xiao Qi-Japan 2015-fine grain-new.vsop	**Edited:** True
User Name: itscdl	**Edited On:** Thursday, May 19, 2016 9:04:07 PM
Date: Thursday, April 28, 2016 2:39:44 PM	

Analysis	
SOP Analysis: 3.0	**SOP Fill Holes:** True
SOP Segmentation: None	**SOP Trash Size:** 10
SOP Optic(s) used: 20x	

Result	
CE Diameter Minimum (µm): 0.54	**CE Diameter D[v, 0.1]:** 3.813
CE Diameter Maximum (µm): 30.47	**CE Diameter D[v, 0.5]:** 9.317
CE Diameter D[4,3] (µm): 11.57	**CE Diameter D[v, 0.9]:** 23.41
CE Diameter D[3,2](µm): 6.848	**CE Diameter STDV (µm):** 1.57
Particles Counted: 164158	**CE Diameter RSD (%):** 109.17



Comments: fine grains,20X, 2 step z-stacking

Morphologi
Malvern Instruments Worldwide
www.malvern.com

Morphologi Ver. 8.20
Serial Number : MAL1115686

File name: UHA-final data-addition-May 17.vmes
Record Number: 188
20 May 2016 3:30:24 PM

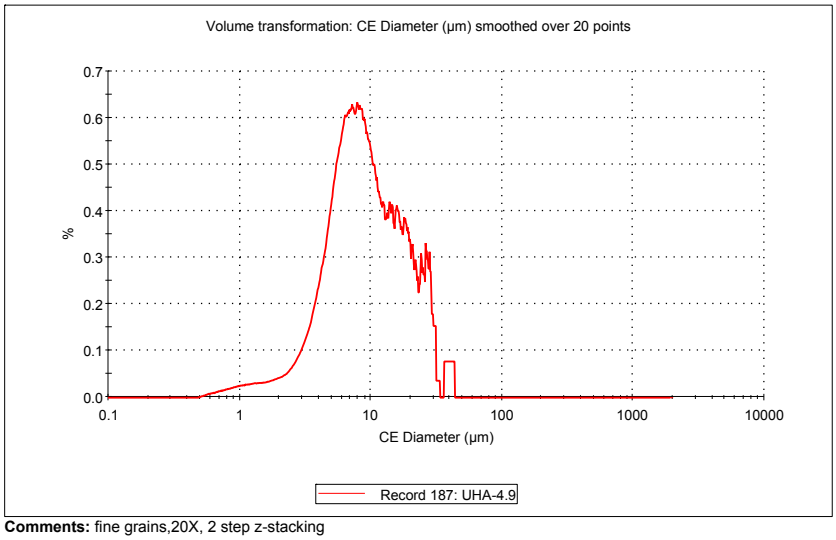
CE Diameter Report - Volume Distribution

Malvern

Measurement Details	
Sample Name: UHA-4.9	
SOP Name: Xiao Qi-Japan 2015-fine grain-new.vsop	**Edited:** True
User Name: itscdl	**Edited On:** Thursday, May 19, 2016 9:03:47 PM
Date: Thursday, April 28, 2016 3:12:27 PM	

Analysis	
SOP Analysis: 3.0	**SOP Fill Holes:** True
SOP Segmentation: None	**SOP Trash Size:** 10
SOP Optic(s) used: 20x	

Result	
CE Diameter Minimum (µm): 0.54	**CE Diameter D[v, 0.1]:** 3.892
CE Diameter Maximum (µm): 39.65	**CE Diameter D[v, 0.5]:** 8.656
CE Diameter D[4,3] (µm): 11.21	**CE Diameter D[v, 0.9]:** 22.29
CE Diameter D[3,2](µm): 6.636	**CE Diameter STDV (µm):** 1.51
Particles Counted: 153599	**CE Diameter RSD (%):** 110.94



Comments: fine grains,20X, 2 step z-stacking

Morphologi
Malvern Instruments Worldwide
www.malvern.com

Morphologi Ver. 8.20
Serial Number : MAL1115686

File name: UHA-final data-addition-May 17.vmes
Record Number: 187
20 May 2016 3:30:34 PM

CE Diameter Report - Volume Distribution

Malvern

Measurement Details

Sample Name: UHA-5.1

SOP Name: Xiao Qi-Japan 2015-fine grain-new.vsop

User Name: itscdl

Date: Thursday, April 28, 2016 1:45:25 AM

Edited: True

Edited On: Thursday, May 19, 2016 9:11:01 PM

Analysis

SOP Analysis: 3.0

SOP Segmentation: None

SOP Optic(s) used: 20x

SOP Fill Holes: True

SOP Trash Size: 10

Result

CE Diameter Minimum (µm): 0.54

CE Diameter Maximum (µm): 44.09

CE Diameter D[4,3] (µm): 10.36

CE Diameter D[3,2](µm): 6.286

Particles Counted: 105302

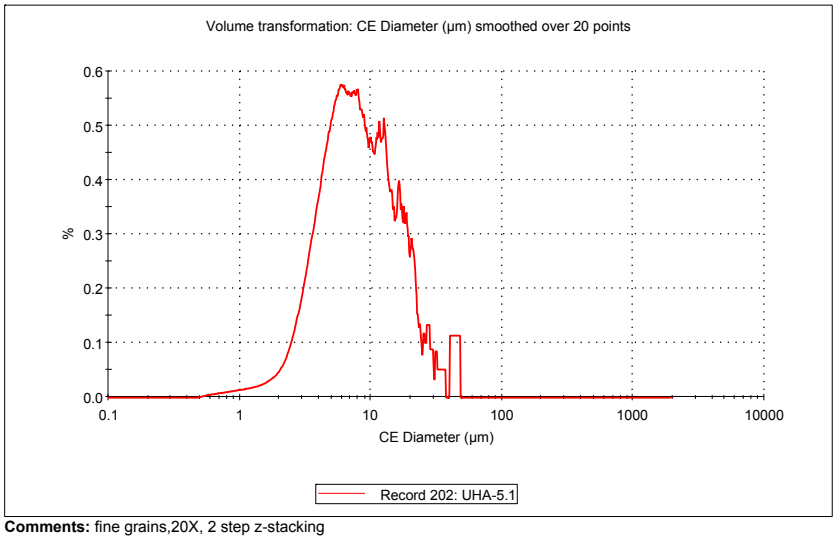
CE Diameter D[v, 0.1]: 3.47

CE Diameter D[v, 0.5]: 7.829

CE Diameter D[v, 0.9]: 19.83

CE Diameter STDV (µm): 1.74

CE Diameter RSD (%): 101.10



Comments: fine grains,20X, 2 step z-stacking

Morphologi
Malvern Instruments Worldwide
www.malvern.com

Morphologi Ver. 8.20
Serial Number : MAL1115686

File name: UHA-final data-addition-May 17.vmes
Record Number: 202
20 May 2016 3:30:47 PM

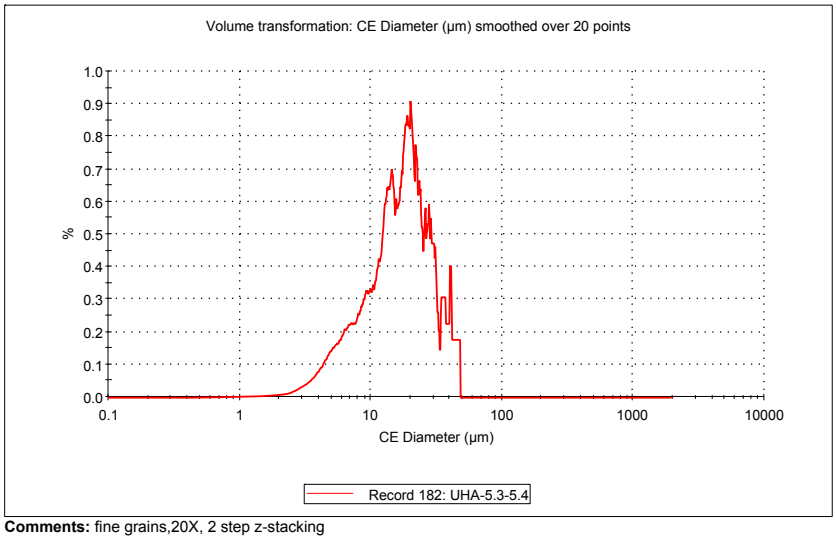
CE Diameter Report - Volume Distribution

Malvern

Measurement Details	
Sample Name: UHA-5.3-5.4	
SOP Name: Xiao Qi-Japan 2015-fine grain-new.vsop	**Edited:** True
User Name: itscdl	**Edited On:** Thursday, May 19, 2016 9:01:31 PM
Date: Thursday, April 28, 2016 11:07:18 AM	

Analysis	
SOP Analysis: 3.0	**SOP Fill Holes:** True
SOP Segmentation: None	**SOP Trash Size:** 10
SOP Optic(s) used: 20x	

Result	
CE Diameter Minimum (µm): 0.54	**CE Diameter D[v, 0.1]:** 6.548
CE Diameter Maximum (µm): 43.83	**CE Diameter D[v, 0.5]:** 17.16
CE Diameter D[4,3] (µm): 18.39	**CE Diameter D[v, 0.9]:** 31.03
CE Diameter D[3,2](µm): 12.52	**CE Diameter STDV (µm):** 3.15
Particles Counted: 12553	**CE Diameter RSD (%):** 128.28



Comments: fine grains,20X, 2 step z-stacking

Morphologi
Malvern Instruments Worldwide
www.malvern.com

Morphologi Ver. 8.20
Serial Number : MAL1115686

File name: UHA-final data-addition-May 17.vmes
Record Number: 182
20 May 2016 3:31:08 PM

CE Diameter Report - Volume Distribution

Malvern

Measurement Details

Sample Name: UHA-5.5

SOP Name: Xiao Qi-Japan 2015-fine grain-new.vsop

User Name: itscdl

Date: Thursday, April 28, 2016 11:41:00 AM

Edited: True

Edited On: Thursday, May 19, 2016 9:01:47 PM

Analysis

SOP Analysis: 3.0

SOP Segmentation: None

SOP Optic(s) used: 20x

SOP Fill Holes: True

SOP Trash Size: 10

Result

CE Diameter Minimum (µm): 0.54

CE Diameter Maximum (µm): 58.34

CE Diameter D[4,3] (µm): 16.92

CE Diameter D[3,2](µm): 9.267

Particles Counted: 20009

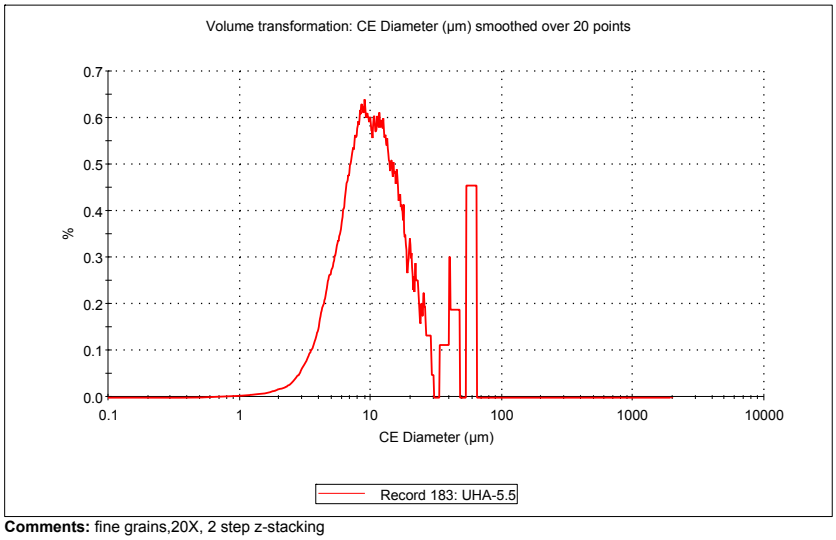
CE Diameter D[v, 0.1]: 5.017

CE Diameter D[v, 0.5]: 11.1

CE Diameter D[v, 0.9]: 43.14

CE Diameter STDV (µm): 2.58

CE Diameter RSD (%): 107.96



Comments: fine grains,20X, 2 step z-stacking

Morphologi
Malvern Instruments Worldwide
www.malvern.com

Morphologi Ver. 8.20
Serial Number : MAL1115686

File name: UHA-final data-addition-May 17.vmes
Record Number: 183
20 May 2016 3:31:21 PM

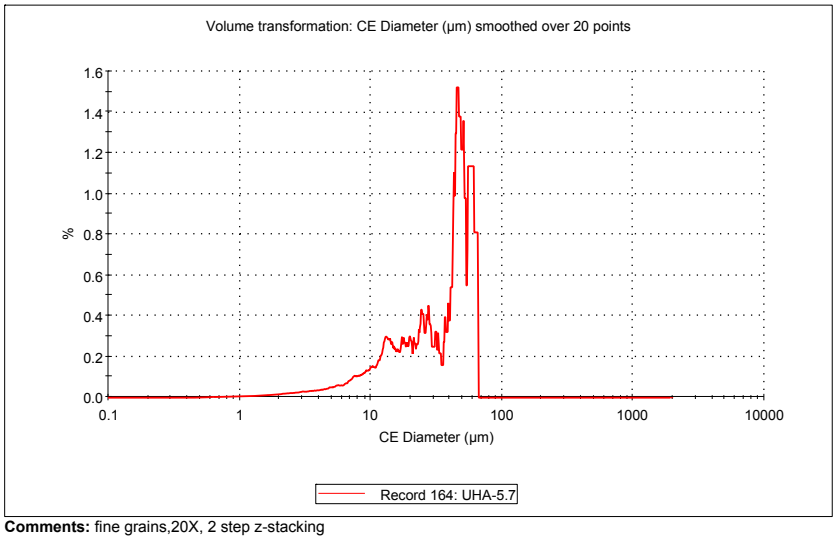
CE Diameter Report - Volume Distribution

Malvern

Measurement Details	
Sample Name: UHA-5.7	
SOP Name: Xiao Qi-Japan 2015-fine grain-new.vsop	**Edited:** True
User Name: itscdl	**Edited On:** Thursday, May 19, 2016 8:54:00 PM
Date: Wednesday, April 27, 2016 10:53:13 AM	

Analysis	
SOP Analysis: 3.0	**SOP Fill Holes:** True
SOP Segmentation: None	**SOP Trash Size:** 10
SOP Optic(s) used: 20x	

Result	
CE Diameter Minimum (µm): 0.54	**CE Diameter D[v, 0.1]:** 9.884
CE Diameter Maximum (µm): 60.26	**CE Diameter D[v, 0.5]:** 42.1
CE Diameter D[4,3] (µm): 36.16	**CE Diameter D[v, 0.9]:** 59.28
CE Diameter D[3,2](µm): 18.29	**CE Diameter STDV (µm):** 1.89
Particles Counted: 29748	**CE Diameter RSD (%):** 147.15



Comments: fine grains,20X, 2 step z-stacking

Morphologi
Malvern Instruments Worldwide
www.malvern.com

CE Diameter Report - Volume Distribution

Malvern

Measurement Details

Sample Name: UHA-5.9

SOP Name: Xiao Qi-Japan 2015-fine grain-new.vsop

User Name: itscdl

Date: Wednesday, April 20, 2016 2:22:13 PM

Edited: True

Edited On: Thursday, May 19, 2016 8:50:46 PM

Analysis

SOP Analysis: 3.0

SOP Segmentation: None

SOP Optic(s) used: 20x

SOP Fill Holes: True

SOP Trash Size: 10

Result

CE Diameter Minimum (µm): 0.54

CE Diameter Maximum (µm): 49.54

CE Diameter D[4,3] (µm): 25.74

CE Diameter D[3,2](µm): 17.05

Particles Counted: 17203

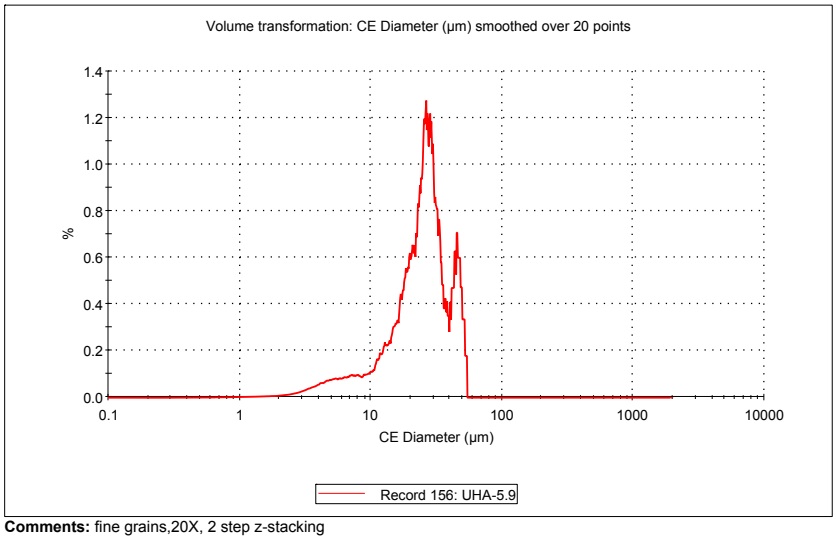
CE Diameter D[v, 0.1]: 9.825

CE Diameter D[v, 0.5]: 25.48

CE Diameter D[v, 0.9]: 43.55

CE Diameter STDV (µm): 2.92

CE Diameter RSD (%): 153.63



Comments: fine grains,20X, 2 step z-stacking

Morphologi
Malvern Instruments Worldwide
www.malvern.com

CE Diameter Report - Volume Distribution

Malvern

Measurement Details

Sample Name: UHA-6.1

SOP Name: Xiao Qi-Japan 2015-fine grain-new.vsop

User Name: itscdl

Date: Wednesday, April 27, 2016 10:17:05 AM

Edited: True

Edited On: Thursday, May 19, 2016 8:53:27 PM

Analysis

SOP Analysis: 3.0

SOP Segmentation: None

SOP Optic(s) used: 20x

SOP Fill Holes: True

SOP Trash Size: 10

Result

CE Diameter Minimum (µm): 0.54

CE Diameter Maximum (µm): 31.59

CE Diameter D[4,3] (µm): 13.47

CE Diameter D[3,2](µm): 8.464

Particles Counted: 12092

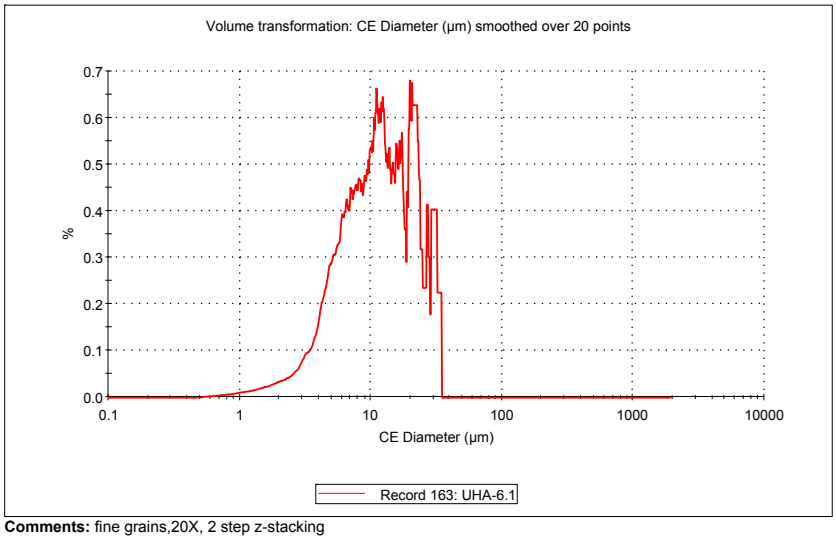
CE Diameter D[v, 0.1]: 4.61

CE Diameter D[v, 0.5]: 11.57

CE Diameter D[v, 0.9]: 24.87

CE Diameter STDV (µm): 2.03

CE Diameter RSD (%): 115.06



Comments: fine grains,20X, 2 step z-stacking

Morphologi
Malvern Instruments Worldwide
www.malvern.com

CE Diameter Report - Volume Distribution

Malvern

Measurement Details

Sample Name: UHA-6.3

SOP Name: Xiao Qi-Japan 2015-fine grain-new.vsop

User Name: itscdl

Date: Wednesday, April 27, 2016 12:23:01 PM

Edited: True

Edited On: Thursday, May 19, 2016 8:55:12 PM

Analysis

SOP Analysis: 3.0

SOP Segmentation: None

SOP Optic(s) used: 20x

SOP Fill Holes: True

SOP Trash Size: 10

Result

CE Diameter Minimum (µm): 0.54

CE Diameter Maximum (µm): 114.58

CE Diameter D[4,3] (µm): 43.42

CE Diameter D[3,2](µm): 20.2

Particles Counted: 45636

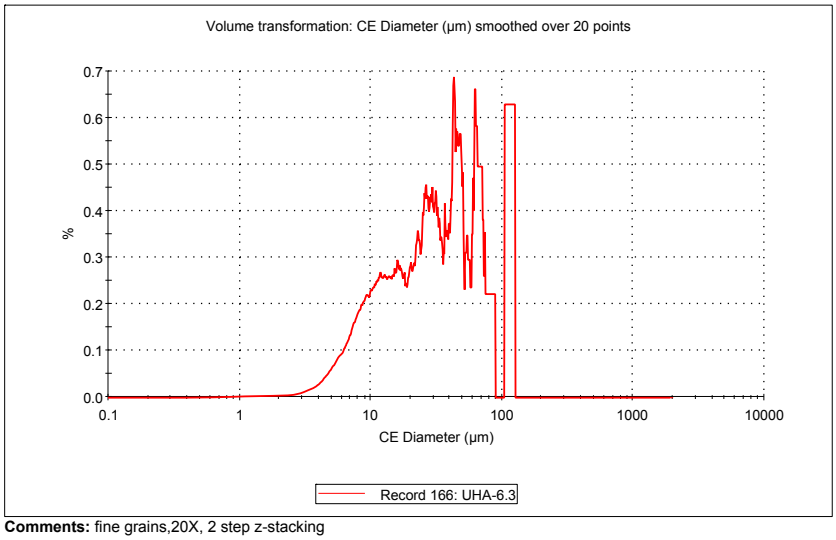
CE Diameter D[v, 0.1]: 9.068

CE Diameter D[v, 0.5]: 33.52

CE Diameter D[v, 0.9]: 113.4

CE Diameter STDV (µm): 3.12

CE Diameter RSD (%): 157.81



Comments: fine grains,20X, 2 step z-stacking

Morphologi
Malvern Instruments Worldwide
www.malvern.com

CE Diameter Report - Volume Distribution

Malvern

Measurement Details

Sample Name: UHA-6.5

SOP Name: Xiao Qi-Japan 2015-fine grain-new.vsop

User Name: itscdl

Date: Wednesday, April 27, 2016 1:06:24 PM

Edited: True

Edited On: Thursday, May 19, 2016 8:55:39 PM

Analysis

SOP Analysis: 3.0

SOP Segmentation: None

SOP Optic(s) used: 20x

SOP Fill Holes: True

SOP Trash Size: 10

Result

CE Diameter Minimum (µm): 0.54

CE Diameter Maximum (µm): 56.74

CE Diameter D[4,3] (µm): 23.42

CE Diameter D[3,2](µm): 7.226

Particles Counted: 51190

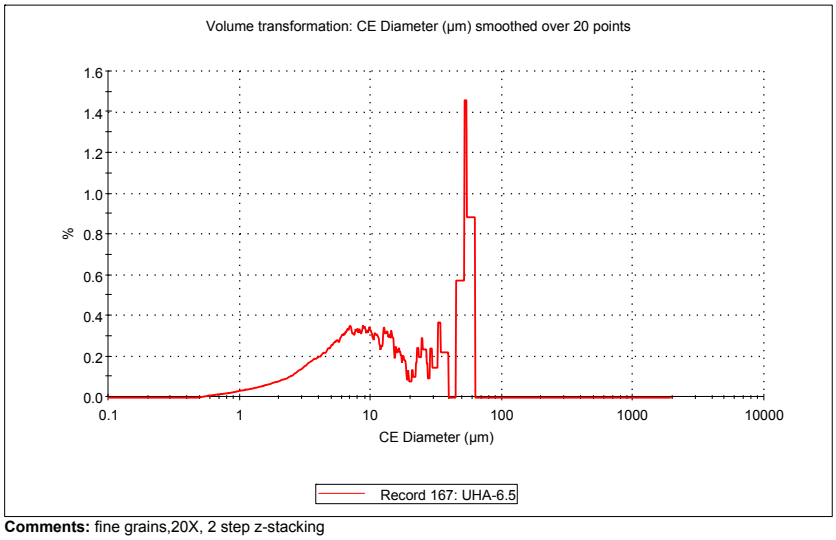
CE Diameter D[v, 0.1]: 3.114

CE Diameter D[v, 0.5]: 13.47

CE Diameter D[v, 0.9]: 56.25

CE Diameter STDV (µm): 1.19

CE Diameter RSD (%): 95.78



Comments: fine grains,20X, 2 step z-stacking

Morphologi
Malvern Instruments Worldwide
www.malvern.com

Morphologi Ver. 8.20
Serial Number : MAL1115686

File name: UHA-final data-addition-May 17.vmes
Record Number: 167
20 May 2016 3:32:26 PM

CE Diameter Report - Volume Distribution

Malvern

Measurement Details

Sample Name: UHA-6.8-6.9

SOP Name: Xiao Qi-Japan 2015-fine grain-new.vsop

User Name: itscdl

Date: Wednesday, April 27, 2016 2:28:36 PM

Edited: True

Edited On: Thursday, May 19, 2016 8:56:17 PM

Analysis

SOP Analysis: 3.0

SOP Segmentation: None

SOP Optic(s) used: 20x

SOP Fill Holes: True

SOP Trash Size: 10

Result

CE Diameter Minimum (µm): 0.54

CE Diameter Maximum (µm): 24.75

CE Diameter D[4,3] (µm): 11.05

CE Diameter D[3,2](µm): 6.506

Particles Counted: 13841

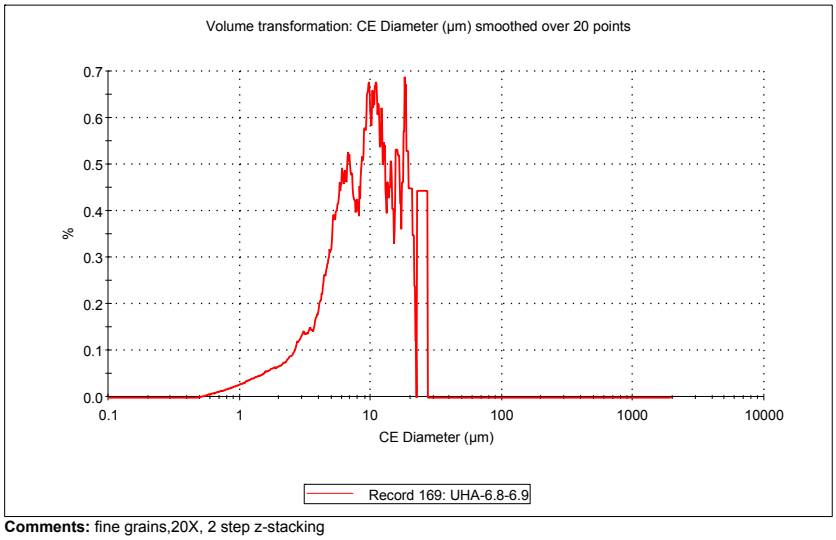
CE Diameter D[v, 0.1]: 3.43

CE Diameter D[v, 0.5]: 9.681

CE Diameter D[v, 0.9]: 20.06

CE Diameter STDV (µm): 1.44

CE Diameter RSD (%): 103.61



Comments: fine grains,20X, 2 step z-stacking

Morphologi
Malvern Instruments Worldwide
www.malvern.com

Morphologi Ver. 8.20
Serial Number : MAL1115686

File name: UHA-final data-addition-May 17.vmes
Record Number: 169
20 May 2016 3:32:41 PM

CE Diameter Report - Volume Distribution

Malvern

Measurement Details

Sample Name: UHA-8.3

SOP Name: Xiao Qi-Japan 2015-fine grain-new.vsop

User Name: itscdl

Date: Wednesday, April 27, 2016 7:50:13 PM

Edited: True

Edited On: Thursday, May 19, 2016 8:59:23 PM

Analysis

SOP Analysis: 3.0

SOP Segmentation: None

SOP Optic(s) used: 20x

SOP Fill Holes: True

SOP Trash Size: 10

Result

CE Diameter Minimum (µm): 0.54

CE Diameter Maximum (µm): 30.42

CE Diameter D[4,3] (µm): 18.33

CE Diameter D[3,2](µm): 13.09

Particles Counted: 1077

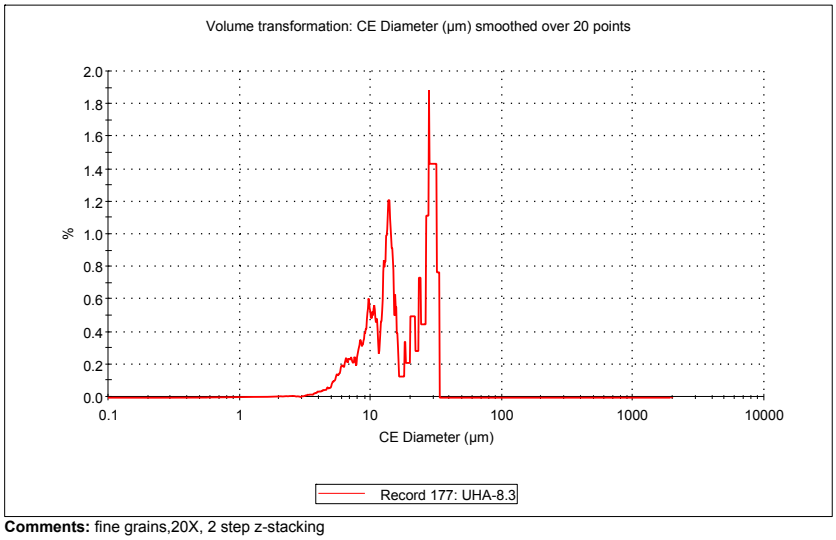
CE Diameter D[v, 0.1]: 7.471

CE Diameter D[v, 0.5]: 14.66

CE Diameter D[v, 0.9]: 30.11

CE Diameter STDV (µm): 3.07

CE Diameter RSD (%): 148.87



Comments: fine grains,20X, 2 step z-stacking

Morphologi
Malvern Instruments Worldwide
www.malvern.com

CE Diameter Report - Volume Distribution

Malvern

Measurement Details

Sample Name: UHA-8.6

SOP Name: Xiao Qi-Japan 2015-fine grain-new.vsop

User Name: itscdl

Date: Wednesday, April 20, 2016 9:14:51 PM

Edited: True

Edited On: Thursday, May 19, 2016 8:52:27 PM

Analysis

SOP Analysis: 3.0

SOP Segmentation: None

SOP Optic(s) used: 20x

SOP Fill Holes: True

SOP Trash Size: 10

Result

CE Diameter Minimum (µm): 0.54

CE Diameter Maximum (µm): 68.85

CE Diameter D[4,3] (µm): 32.28

CE Diameter D[3,2](µm): 14.82

Particles Counted: 15922

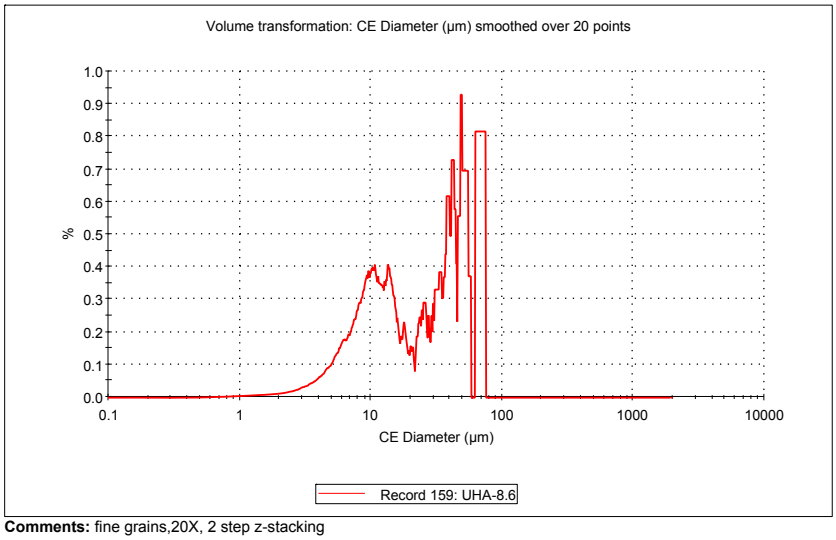
CE Diameter D[v, 0.1]: 7.054

CE Diameter D[v, 0.5]: 29.98

CE Diameter D[v, 0.9]: 67.86

CE Diameter STDV (µm): 2.41

CE Diameter RSD (%): 136.58



Comments: fine grains,20X, 2 step z-stacking

CE Diameter Report - Volume Distribution

Malvern

Measurement Details

Sample Name: UHA-9.1

SOP Name: Xiao Qi-Japan 2015-fine grain-new.vsop

User Name: itscdl

Date: Wednesday, April 27, 2016 3:04:44 PM

Edited: True

Edited On: Thursday, May 19, 2016 8:56:50 PM

Analysis

SOP Analysis: 3.0

SOP Segmentation: None

SOP Optic(s) used: 20x

SOP Fill Holes: True

SOP Trash Size: 10

Result

CE Diameter Minimum (µm): 0.54

CE Diameter Maximum (µm): 43.95

CE Diameter D[4,3] (µm): 21.07

CE Diameter D[3,2](µm): 14.42

Particles Counted: 9597

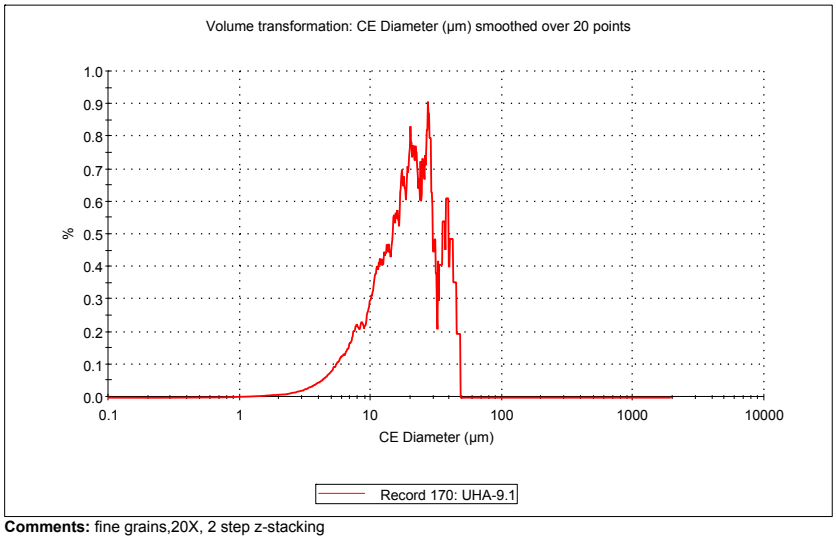
CE Diameter D[v, 0.1]: 7.898

CE Diameter D[v, 0.5]: 19.56

CE Diameter D[v, 0.9]: 36.1

CE Diameter STDV (µm): 3.30

CE Diameter RSD (%): 139.05



Comments: fine grains,20X, 2 step z-stacking

Morphologi
Malvern Instruments Worldwide
www.malvern.com

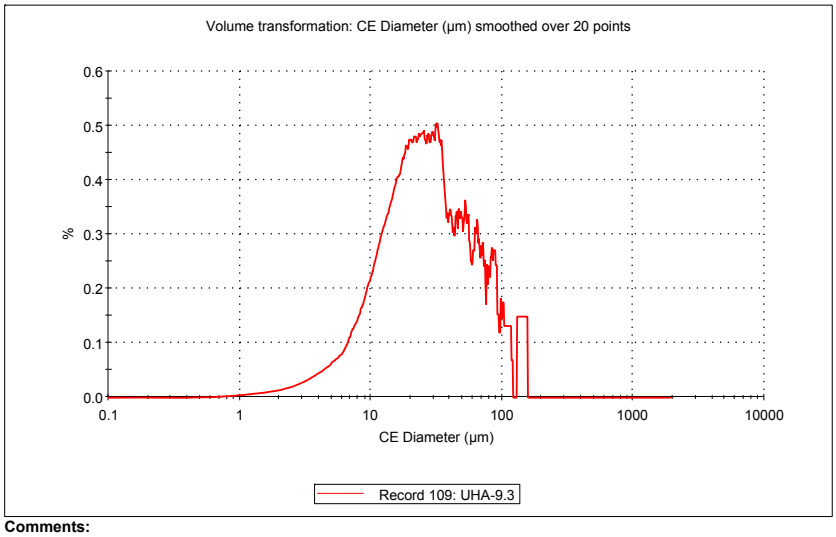
CE Diameter Report - Volume Distribution

Malvern

Measurement Details	
Sample Name: UHA-9.3	
SOP Name: Xiao Qi-Japan 2015-new.vsop	**Edited:** True
User Name: itscdl	**Edited On:** Thursday, May 19, 2016 8:14:14 PM
Date: Wednesday, May 18, 2016 12:23:21 AM	

Analysis	
SOP Analysis: 3.0	**SOP Fill Holes:** True
SOP Segmentation: None	**SOP Trash Size:** 10
SOP Optic(s) used: 5x, 20x	

Result	
CE Diameter Minimum (µm): 0.54	**CE Diameter D[v, 0.1]:** 8.848
CE Diameter Maximum (µm): 142.43	**CE Diameter D[v, 0.5]:** 25.87
CE Diameter D[4,3] (µm): 36.29	**CE Diameter D[v, 0.9]:** 80.74
CE Diameter D[3,2](µm): 16.83	**CE Diameter STDV (µm):** 2.55
Particles Counted: 202868	**CE Diameter RSD (%):** 142.08



Comments:

Morphologi
Malvern Instruments Worldwide
www.malvern.com

Morphologi Ver. 8.20
Serial Number : MAL1115686

File name: UHA-final data-addition-May 17.vmes
Record Number: 109
20 May 2016 3:33:30 PM

CE Diameter Report - Volume Distribution

Malvern

Measurement Details

Sample Name: UHA-9.7

SOP Name: Xiao Qi-Japan 2015-fine grain-new.vsop

User Name: itscdl

Date: Wednesday, April 27, 2016 1:38:41 PM

Edited: True

Edited On: Thursday, May 19, 2016 8:55:57 PM

Analysis

SOP Analysis: 3.0

SOP Segmentation: None

SOP Optic(s) used: 20x

SOP Fill Holes: True

SOP Trash Size: 10

Result

CE Diameter Minimum (µm): 0.54

CE Diameter Maximum (µm): 28.22

CE Diameter D[4,3] (µm): 14.69

CE Diameter D[3,2](µm): 9.672

Particles Counted: 5308

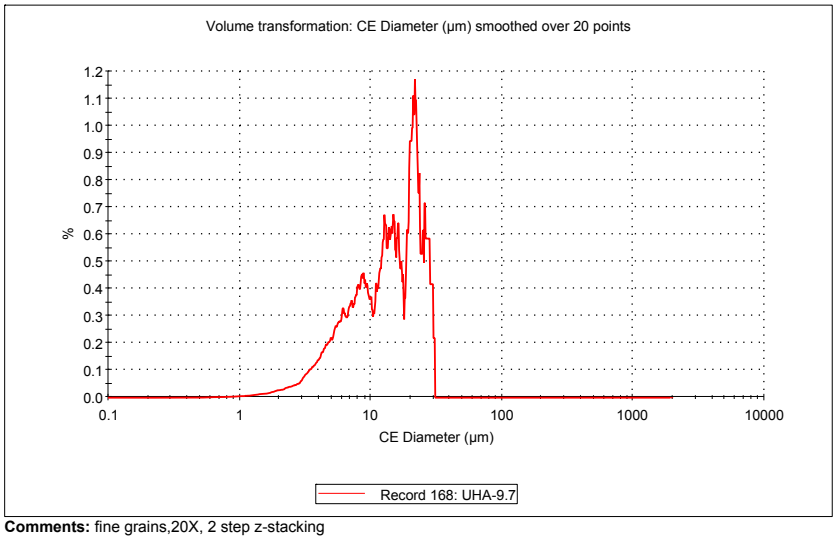
CE Diameter D[v, 0.1]: 4.986

CE Diameter D[v, 0.5]: 13.8

CE Diameter D[v, 0.9]: 25.46

CE Diameter STDV (µm): 2.43

CE Diameter RSD (%): 113.21



Comments: fine grains,20X, 2 step z-stacking

Morphologi
Malvern Instruments Worldwide
www.malvern.com

Morphologi Ver. 8.20
Serial Number : MAL1115686

File name: UHA-final data-addition-May 17.vmes
Record Number: 168
20 May 2016 3:33:40 PM

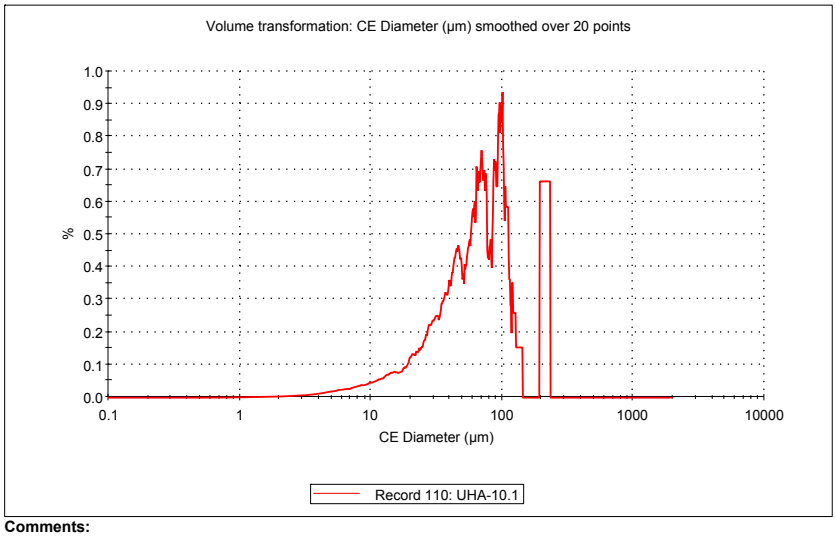
CE Diameter Report - Volume Distribution

Malvern

Measurement Details	
Sample Name: UHA-10.1	
SOP Name: Xiao Qi-Japan 2015-new.vsop	**Edited:** True
User Name: itscdl	**Edited On:** Thursday, May 19, 2016 8:15:13 PM
Date: Wednesday, May 18, 2016 9:35:47 AM	

Analysis	
SOP Analysis: 3.0	**SOP Fill Holes:** True
SOP Segmentation: None	**SOP Trash Size:** 10
SOP Optic(s) used: 5x, 20x	

Result	
CE Diameter Minimum (µm): 0.54	**CE Diameter D[v, 0.1]:** 22.52
CE Diameter Maximum (µm): 212.85	**CE Diameter D[v, 0.5]:** 69.11
CE Diameter D[4,3] (µm): 82.51	**CE Diameter D[v, 0.9]:** 209.5
CE Diameter D[3,2](µm): 40.12	**CE Diameter STDV (µm):** 3.45
Particles Counted: 40067	**CE Diameter RSD (%):** 187.41



Comments:

CE Diameter Report - Volume Distribution

Malvern

Measurement Details

Sample Name: UHA-10.5

SOP Name: Xiao Qi-Japan 2015-fine grain-new.vsop

User Name: itscdl

Date: Wednesday, April 20, 2016 9:03:49 AM

Edited: True

Edited On: Thursday, May 19, 2016 8:47:42 PM

Analysis

SOP Analysis: 3.0

SOP Segmentation: None

SOP Optic(s) used: 20x

SOP Fill Holes: True

SOP Trash Size: 10

Result

CE Diameter Minimum (µm): 0.54

CE Diameter Maximum (µm): 79.17

CE Diameter D[4,3] (µm): 47.11

CE Diameter D[3,2](µm): 23.94

Particles Counted: 27264

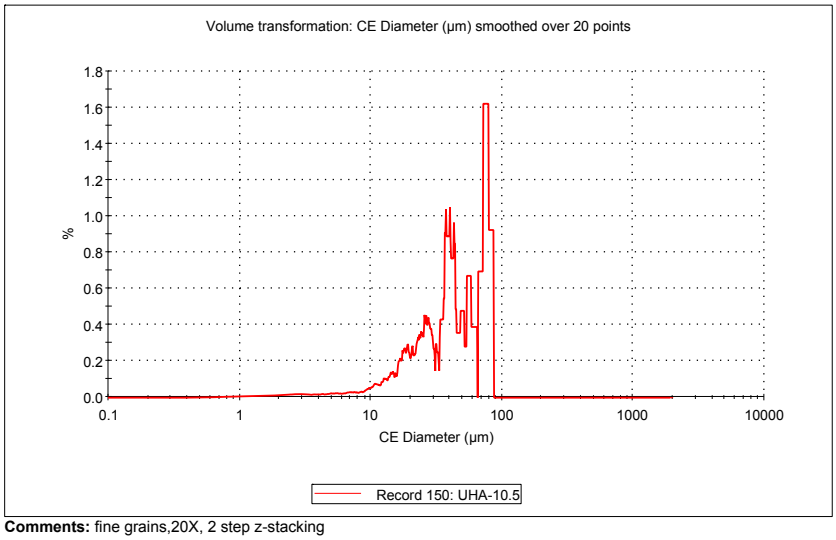
CE Diameter D[v, 0.1]: 16.67

CE Diameter D[v, 0.5]: 43.35

CE Diameter D[v, 0.9]: 78.01

CE Diameter STDV (µm): 1.73

CE Diameter RSD (%): 149.95



Comments: fine grains,20X, 2 step z-stacking

Morphologi
Malvern Instruments Worldwide
www.malvern.com

CE Diameter Report - Volume Distribution

Malvern

Measurement Details

Sample Name: UHA-10.6-10.7

SOP Name: Xiao Qi-Japan 2015-fine grain-new.vsop

User Name: itscdl

Date: Wednesday, April 27, 2016 4:54:44 PM

Edited: True

Edited On: Thursday, May 19, 2016 8:58:09 PM

Analysis

SOP Analysis: 3.0

SOP Segmentation: None

SOP Optic(s) used: 20x

SOP Fill Holes: True

SOP Trash Size: 10

Result

CE Diameter Minimum (µm): 0.54

CE Diameter Maximum (µm): 48.83

CE Diameter D[4,3] (µm): 21.11

CE Diameter D[3,2](µm): 9.114

Particles Counted: 29961

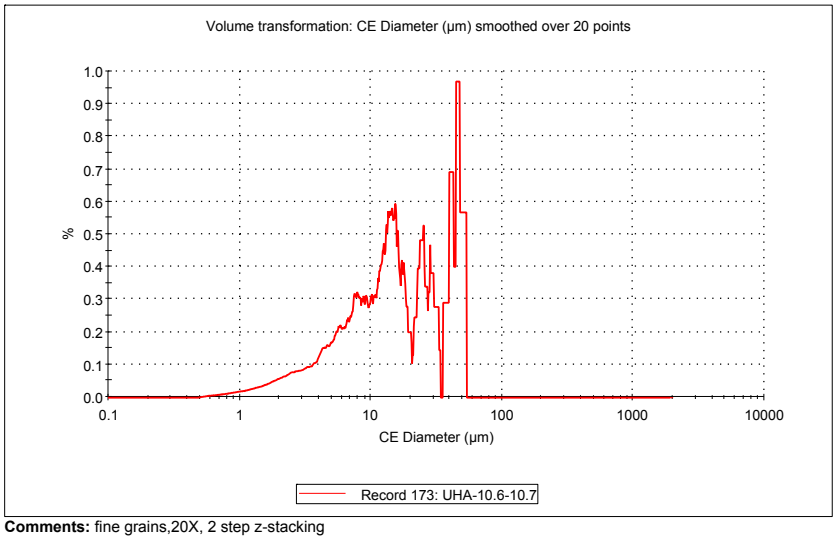
CE Diameter D[v, 0.1]: 4.321

CE Diameter D[v, 0.5]: 15.47

CE Diameter D[v, 0.9]: 48.32

CE Diameter STDV (µm): 1.47

CE Diameter RSD (%): 109.97



Comments: fine grains,20X, 2 step z-stacking

Morphologi
Malvern Instruments Worldwide
www.malvern.com

Morphologi Ver. 8.20
Serial Number : MAL1115686

File name: UHA-final data-addition-May 17.vmes
Record Number: 173
20 May 2016 3:21:55 PM

CE Diameter Report - Volume Distribution

Malvern

Measurement Details

Sample Name: UHA-10.9

SOP Name: Xiao Qi-Japan 2015-new.vsop

User Name: itscdl

Date: Tuesday, May 17, 2016 10:56:37 PM

Edited: True

Edited On: Thursday, May 19, 2016 8:10:38 PM

Analysis

SOP Analysis: 3.0

SOP Segmentation: None

SOP Optic(s) used: 5x, 20x

SOP Fill Holes: True

SOP Trash Size: 10

Result

CE Diameter Minimum (µm): 0.54

CE Diameter Maximum (µm): 104.14

CE Diameter D[4,3] (µm): 33.2

CE Diameter D[3,2](µm): 11.25

Particles Counted: 202698

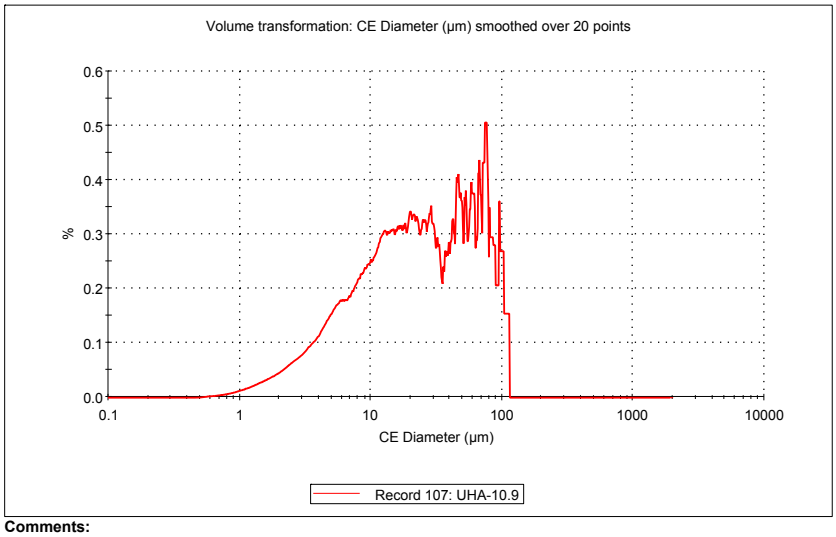
CE Diameter D[v, 0.1]: 4.807

CE Diameter D[v, 0.5]: 22.85

CE Diameter D[v, 0.9]: 77.13

CE Diameter STDV (µm): 1.67

CE Diameter RSD (%): 107.24



Comments:

Morphologi
Malvern Instruments Worldwide
www.malvern.com

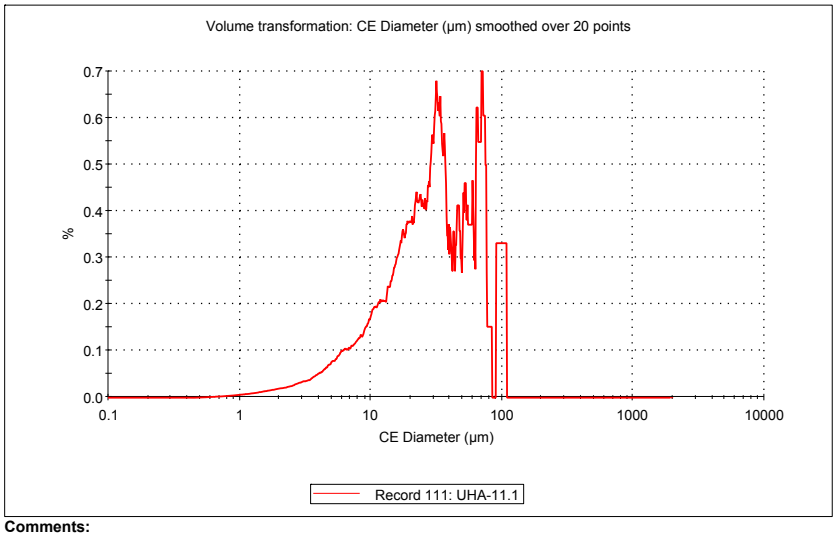
CE Diameter Report - Volume Distribution

Malvern

Measurement Details	
Sample Name: UHA-11.1	
SOP Name: Xiao Qi-Japan 2015-new.vsop	**Edited:** True
User Name: itscdl	**Edited On:** Thursday, May 19, 2016 8:15:43 PM
Date: Wednesday, May 18, 2016 10:18:22 AM	

Analysis	
SOP Analysis: 3.0	**SOP Fill Holes:** True
SOP Segmentation: None	**SOP Trash Size:** 10
SOP Optic(s) used: 5x, 20x	

Result	
CE Diameter Minimum (µm): 0.54	**CE Diameter D[v, 0.1]:** 8.355
CE Diameter Maximum (µm): 98.87	**CE Diameter D[v, 0.5]:** 30.66
CE Diameter D[4,3] (µm): 36.97	**CE Diameter D[v, 0.9]:** 69.41
CE Diameter D[3,2](µm): 16.74	**CE Diameter STDV (µm):** 2.13
Particles Counted: 41055	**CE Diameter RSD (%):** 135.69



Comments:

Morphologi
Malvern Instruments Worldwide
www.malvern.com

Morphologi Ver. 8.20
Serial Number : MAL1115686

File name: UHA-final data-addition-May 17.vmes
Record Number: 111
20 May 2016 3:22:34 PM

CE Diameter Report - Volume Distribution

Malvern

Measurement Details

Sample Name: UHA-11.3

SOP Name: Xiao Qi-Japan 2015-fine grain-new.vsop

User Name: itscdl

Date: Wednesday, April 27, 2016 7:13:34 PM

Edited: True

Edited On: Thursday, May 19, 2016 8:59:14 PM

Analysis

SOP Analysis: 3.0

SOP Segmentation: None

SOP Optic(s) used: 20x

SOP Fill Holes: True

SOP Trash Size: 10

Result

CE Diameter Minimum (µm): 0.54

CE Diameter Maximum (µm): 42.56

CE Diameter D[4,3] (µm): 25.76

CE Diameter D[3,2](µm): 12.55

Particles Counted: 21908

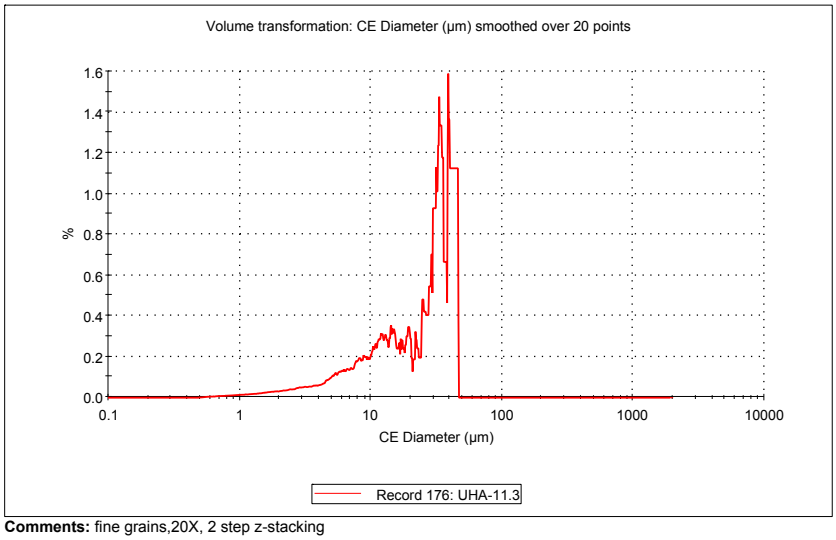
CE Diameter D[v, 0.1]: 6.356

CE Diameter D[v, 0.5]: 28.77

CE Diameter D[v, 0.9]: 41.95

CE Diameter STDV (µm): 1.54

CE Diameter RSD (%): 124.68



Comments: fine grains,20X, 2 step z-stacking

Morphologi
Malvern Instruments Worldwide
www.malvern.com

Morphologi Ver. 8.20
Serial Number : MAL1115686

File name: UHA-final data-addition-May 17.vmes
Record Number: 176
20 May 2016 3:22:44 PM

CE Diameter Report - Volume Distribution

Malvern

Measurement Details

Sample Name: UHA-11.5

SOP Name: Xiao Qi-Japan 2015-new.vsop

User Name: itscdl

Date: Wednesday, May 18, 2016 11:01:30 AM

Edited: True

Edited On: Thursday, May 19, 2016 8:16:41 PM

Analysis

SOP Analysis: 3.0

SOP Segmentation: None

SOP Optic(s) used: 5x, 20x

SOP Fill Holes: True

SOP Trash Size: 10

Result

CE Diameter Minimum (µm): 0.54

CE Diameter Maximum (µm): 110.42

CE Diameter D[4,3] (µm): 44.94

CE Diameter D[3,2](µm): 20.05

Particles Counted: 41855

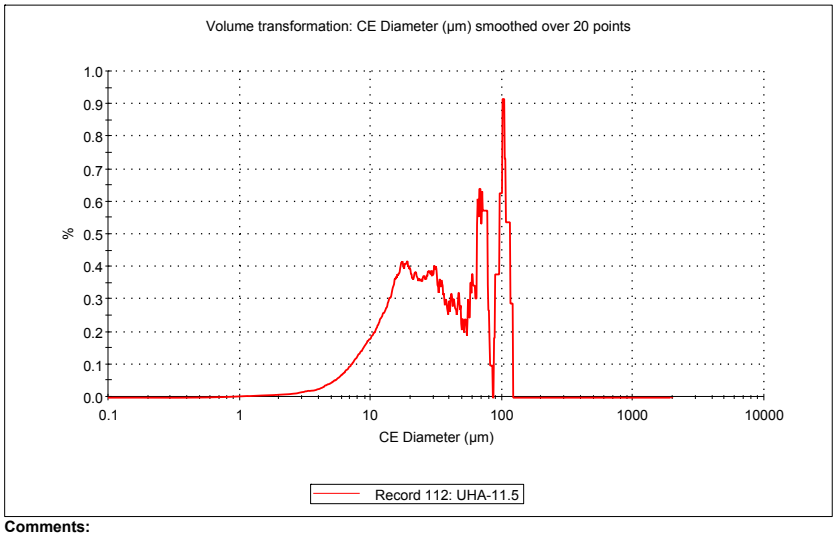
CE Diameter D[v, 0.1]: 10.03

CE Diameter D[v, 0.5]: 32.56

CE Diameter D[v, 0.9]: 103.6

CE Diameter STDV (µm): 2.59

CE Diameter RSD (%): 155.97



Comments:

CE Diameter Report - Volume Distribution

Malvern

Measurement Details

Sample Name: UHA-11.7

SOP Name: Xiao Qi-Japan 2015-fine grain-new.vsop

User Name: itscdl

Date: Wednesday, April 20, 2016 4:29:30 PM

Edited: True

Edited On: Thursday, May 19, 2016 8:51:31 PM

Analysis

SOP Analysis: 3.0

SOP Segmentation: None

SOP Optic(s) used: 20x

SOP Fill Holes: True

SOP Trash Size: 10

Result

CE Diameter Minimum (µm): 0.54

CE Diameter Maximum (µm): 69.60

CE Diameter D[4,3] (µm): 44.46

CE Diameter D[3,2](µm): 26.9

Particles Counted: 13300

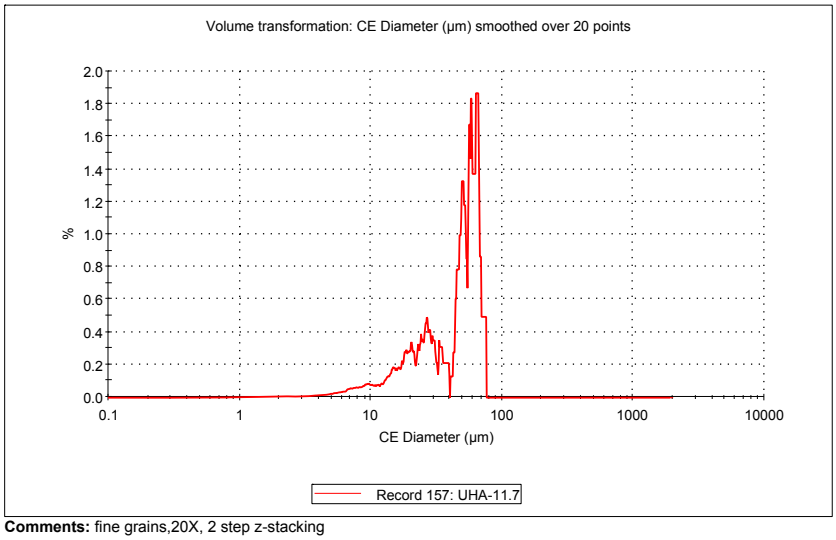
CE Diameter D[v, 0.1]: 15.58

CE Diameter D[v, 0.5]: 48.99

CE Diameter D[v, 0.9]: 63.04

CE Diameter STDV (µm): 2.76

CE Diameter RSD (%): 178.44



Comments: fine grains,20X, 2 step z-stacking

Morphologi
Malvern Instruments Worldwide
www.malvern.com

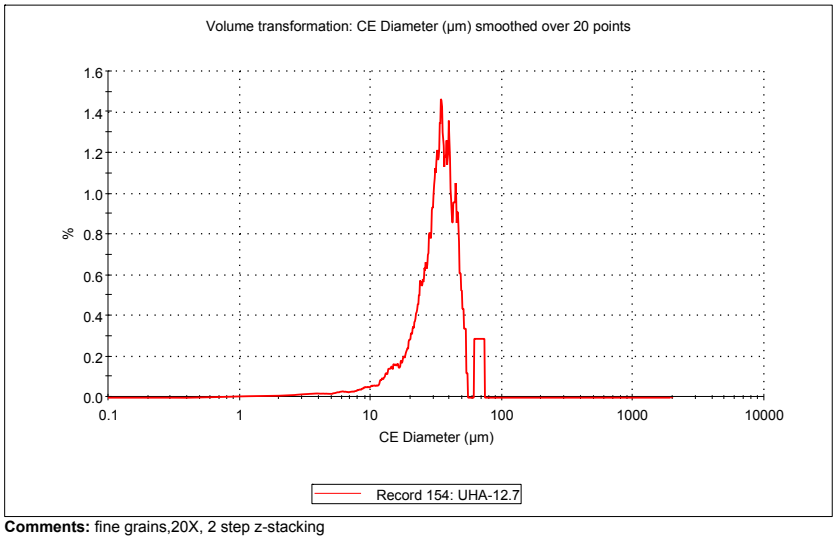
CE Diameter Report - Volume Distribution

Malvern

Measurement Details	
Sample Name: UHA-12.7	
SOP Name: Xiao Qi-Japan 2015-fine grain-new.vsop	**Edited:** True
User Name: itscdl	**Edited On:** Thursday, May 19, 2016 8:49:12 PM
Date: Wednesday, April 20, 2016 12:39:13 PM	

Analysis	
SOP Analysis: 3.0	**SOP Fill Holes:** True
SOP Segmentation: None	**SOP Trash Size:** 10
SOP Optic(s) used: 20x	

Result	
CE Diameter Minimum (µm): 0.54	**CE Diameter D[v, 0.1]:** 16.19
CE Diameter Maximum (µm): 67.09	**CE Diameter D[v, 0.5]:** 33.19
CE Diameter D[4,3] (µm): 33.51	**CE Diameter D[v, 0.9]:** 48.03
CE Diameter D[3,2](µm): 21.72	**CE Diameter STDV (µm):** 1.98
Particles Counted: 47736	**CE Diameter RSD (%):** 168.61



Comments: fine grains,20X, 2 step z-stacking

Morphologi
Malvern Instruments Worldwide
www.malvern.com

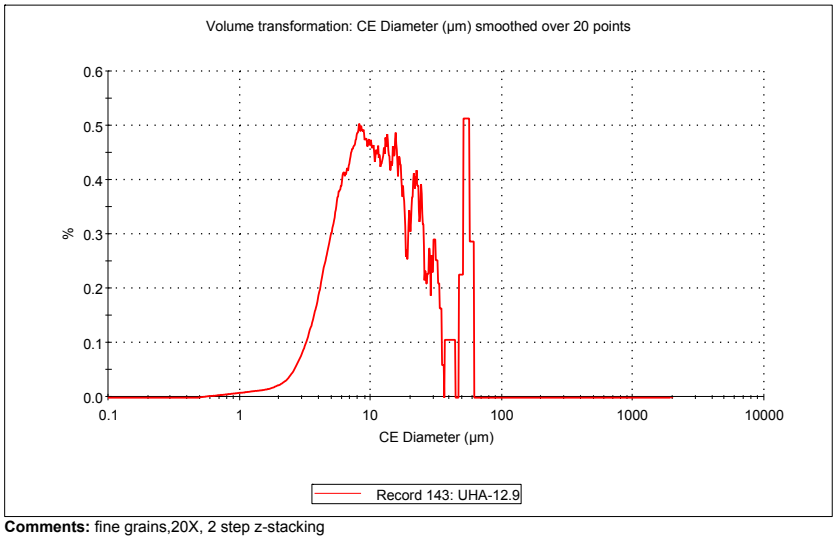
CE Diameter Report - Volume Distribution

Malvern

Measurement Details	
Sample Name: UHA-12.9	
SOP Name: Xiao Qi-Japan 2015-fine grain-new.vsop	**Edited:** True
User Name: itscdl	**Edited On:** Thursday, May 19, 2016 8:42:57 PM
Date: Monday, April 18, 2016 12:00:59 PM	

Analysis	
SOP Analysis: 3.0	**SOP Fill Holes:** True
SOP Segmentation: None	**SOP Trash Size:** 10
SOP Optic(s) used: 20x	

Result	
CE Diameter Minimum (µm): 0.54	**CE Diameter D[v, 0.1]:** 4.571
CE Diameter Maximum (µm): 55.81	**CE Diameter D[v, 0.5]:** 11.78
CE Diameter D[4,3] (µm): 17.15	**CE Diameter D[v, 0.9]:** 39.96
CE Diameter D[3,2](µm): 8.833	**CE Diameter STDV (µm):** 2.08
Particles Counted: 47783	**CE Diameter RSD (%):** 115.34



Comments: fine grains,20X, 2 step z-stacking

Morphologi
Malvern Instruments Worldwide
www.malvern.com

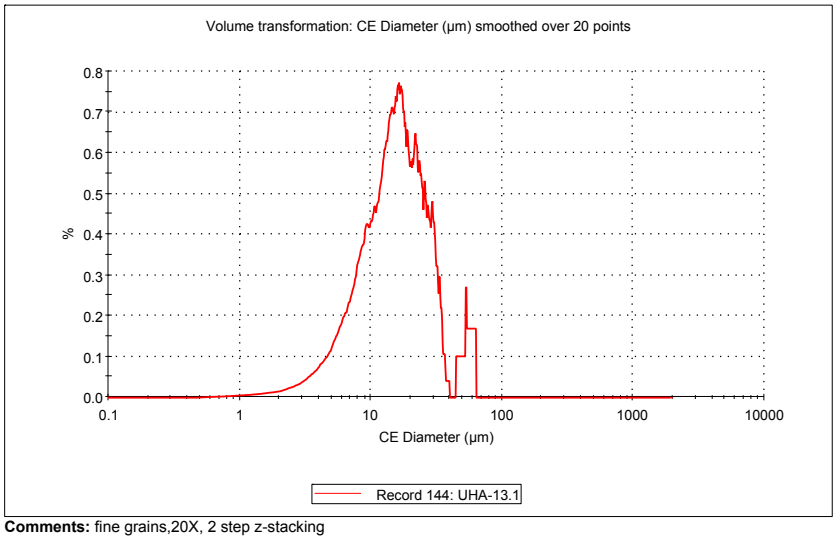
CE Diameter Report - Volume Distribution

Malvern

Measurement Details	
Sample Name: UHA-13.1	
SOP Name: Xiao Qi-Japan 2015-fine grain-new.vsop	**Edited:** True
User Name: itscdl	**Edited On:** Thursday, May 19, 2016 8:43:27 PM
Date: Tuesday, April 19, 2016 10:27:01 AM	

Analysis	
SOP Analysis: 3.0	**SOP Fill Holes:** True
SOP Segmentation: None	**SOP Trash Size:** 10
SOP Optic(s) used: 20x	

Result	
CE Diameter Minimum (µm): 0.54	**CE Diameter D[v, 0.1]:** 6.505
CE Diameter Maximum (µm): 58.21	**CE Diameter D[v, 0.5]:** 15.49
CE Diameter D[4,3] (µm): 18.02	**CE Diameter D[v, 0.9]:** 30.56
CE Diameter D[3,2](µm): 11.52	**CE Diameter STDV (µm):** 2.54
Particles Counted: 53377	**CE Diameter RSD (%):** 134.74



Comments: fine grains,20X, 2 step z-stacking

Morphologi
Malvern Instruments Worldwide
www.malvern.com

Morphologi Ver. 8.20
Serial Number : MAL1115686

File name: UHA-final data-addition-May 17.vmes
Record Number: 144
20 May 2016 3:24:15 PM

CE Diameter Report - Volume Distribution

Malvern

Measurement Details

Sample Name: UHA-13.3

SOP Name: Xiao Qi-Japan 2015-fine grain-new.vsop

User Name: itscdl

Date: Tuesday, April 19, 2016 4:45:43 PM

Edited: True

Edited On: Thursday, May 19, 2016 8:47:28 PM

Analysis

SOP Analysis: 3.0

SOP Segmentation: None

SOP Optic(s) used: 20x

SOP Fill Holes: True

SOP Trash Size: 10

Result

CE Diameter Minimum (µm): 0.54

CE Diameter Maximum (µm): 142.32

CE Diameter D[4,3] (µm): 89.28

CE Diameter D[3,2](µm): 56

Particles Counted: 27139

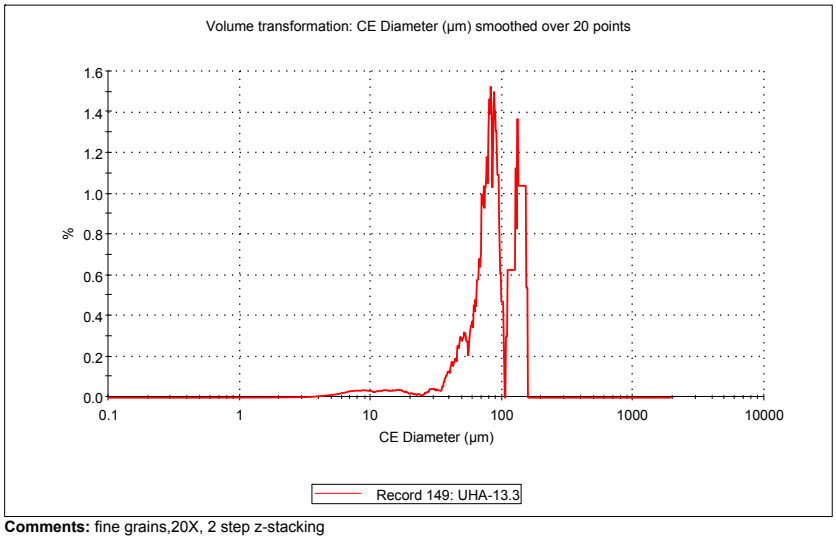
CE Diameter D[v, 0.1]: 46.47

CE Diameter D[v, 0.5]: 85.36

CE Diameter D[v, 0.9]: 140.8

CE Diameter STDV (µm): 3.92

CE Diameter RSD (%): 220.70



Comments: fine grains,20X, 2 step z-stacking

CE Diameter Report - Volume Distribution

Malvern

Measurement Details

Sample Name: UHA-13.5

SOP Name: Xiao Qi-Japan 2015-fine grain-new.vsop

User Name: itscdl

Date: Tuesday, April 19, 2016 11:12:02 AM

Edited: True

Edited On: Thursday, May 19, 2016 8:43:59 PM

Analysis

SOP Analysis: 3.0

SOP Segmentation: None

SOP Optic(s) used: 20x

SOP Fill Holes: True

SOP Trash Size: 10

Result

CE Diameter Minimum (µm): 0.54

CE Diameter Maximum (µm): 72.67

CE Diameter D[4,3] (µm): 34.32

CE Diameter D[3,2](µm): 26.78

Particles Counted: 10570

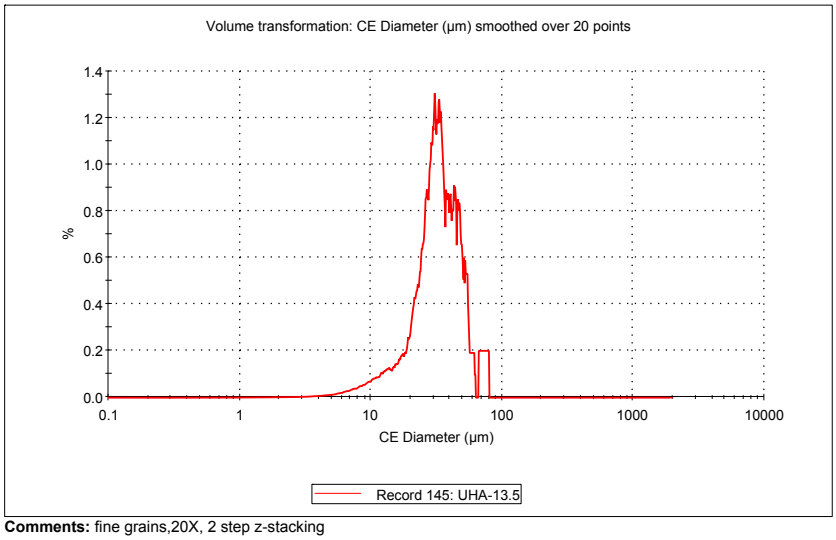
CE Diameter D[v, 0.1]: 17.73

CE Diameter D[v, 0.5]: 32.31

CE Diameter D[v, 0.9]: 50.3

CE Diameter STDV (µm): 5.31

CE Diameter RSD (%): 195.54



Comments: fine grains,20X, 2 step z-stacking

Morphologi
Malvern Instruments Worldwide
www.malvern.com

CE Diameter Report - Volume Distribution

Malvern

Measurement Details

Sample Name: UHA-13.7

SOP Name: Xiao Qi-Japan 2015-fine grain-new.vsop

User Name: itscdl

Date: Tuesday, April 19, 2016 11:45:47 AM

Edited: True

Edited On: Thursday, May 19, 2016 8:44:23 PM

Analysis

SOP Analysis: 3.0

SOP Segmentation: None

SOP Optic(s) used: 20x

SOP Fill Holes: True

SOP Trash Size: 10

Result

CE Diameter Minimum (µm): 0.54

CE Diameter Maximum (µm): 51.14

CE Diameter D[4,3] (µm): 26.89

CE Diameter D[3,2](µm): 19.35

Particles Counted: 73439

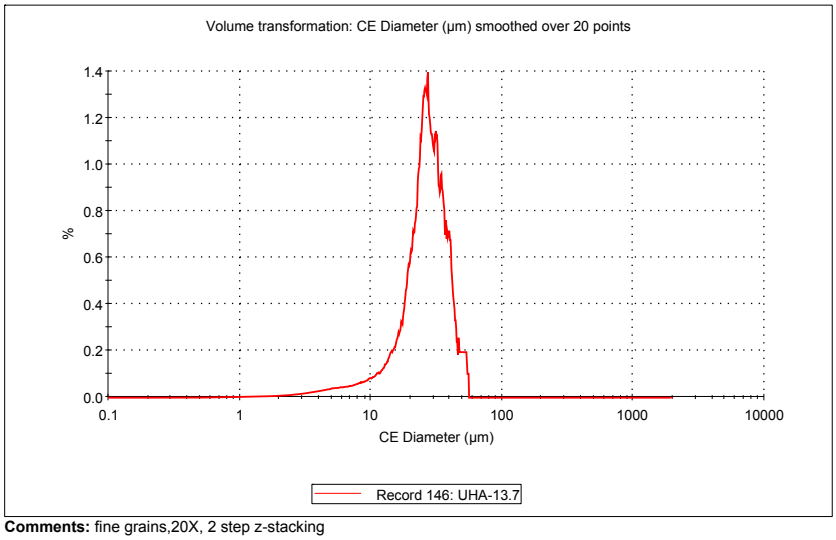
CE Diameter D[v, 0.1]: 13.87

CE Diameter D[v, 0.5]: 26.42

CE Diameter D[v, 0.9]: 40.01

CE Diameter STDV (µm): 2.70

CE Diameter RSD (%): 177.77



Comments: fine grains,20X, 2 step z-stacking

Morphologi
Malvern Instruments Worldwide
www.malvern.com

Morphologi Ver. 8.20
Serial Number : MAL1115686

File name: UHA-final data-addition-May 17.vmes
Record Number: 146
20 May 2016 3:25:00 PM

CE Diameter Report - Volume Distribution

Malvern

Measurement Details

Sample Name: UHA-13.9

SOP Name: Xiao Qi-Japan 2015-fine grain-new.vsop

User Name: itscdl

Date: Wednesday, April 27, 2016 11:24:49 PM

Edited: True

Edited On: Thursday, May 19, 2016 9:00:27 PM

Analysis

SOP Analysis: 3.0

SOP Segmentation: None

SOP Optic(s) used: 20x

SOP Fill Holes: True

SOP Trash Size: 10

Result

CE Diameter Minimum (µm): 0.54

CE Diameter Maximum (µm): 95.91

CE Diameter D[4,3] (µm): 23.31

CE Diameter D[3,2](µm): 9.639

Particles Counted: 236423

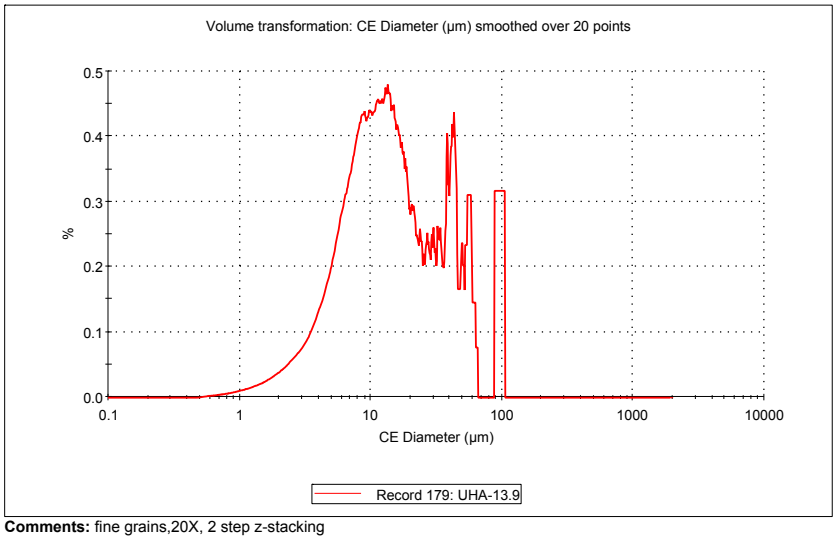
CE Diameter D[v, 0.1]: 4.804

CE Diameter D[v, 0.5]: 13.89

CE Diameter D[v, 0.9]: 53.25

CE Diameter STDV (µm): 1.90

CE Diameter RSD (%): 113.22



Comments: fine grains,20X, 2 step z-stacking

Morphologi
Malvern Instruments Worldwide
www.malvern.com

Morphologi Ver. 8.20
Serial Number : MAL1115686

File name: UHA-final data-addition-May 17.vmes
Record Number: 179
20 May 2016 3:25:13 PM

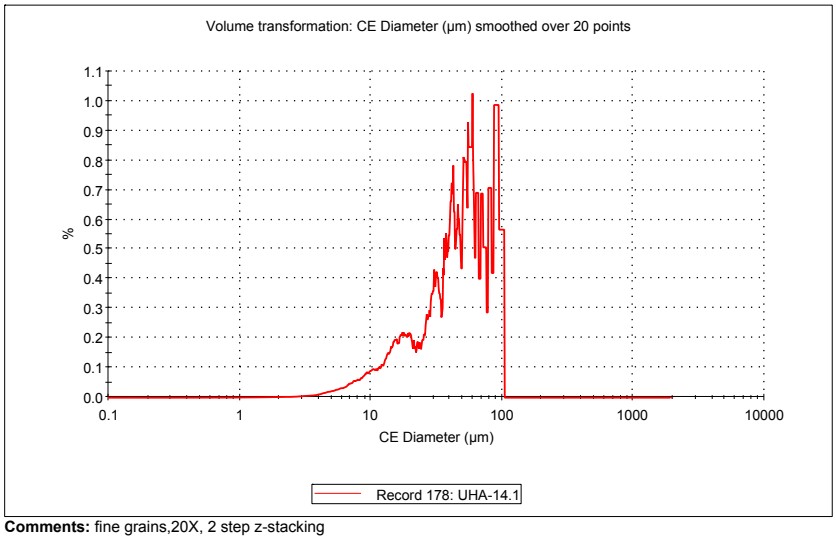
CE Diameter Report - Volume Distribution

Malvern

Measurement Details	
Sample Name: UHA-14.1	
SOP Name: Xiao Qi-Japan 2015-fine grain-new.vsop	**Edited:** True
User Name: itscdl	**Edited On:** Thursday, May 19, 2016 8:59:49 PM
Date: Wednesday, April 27, 2016 10:51:38 PM	

Analysis	
SOP Analysis: 3.0	**SOP Fill Holes:** True
SOP Segmentation: None	**SOP Trash Size:** 10
SOP Optic(s) used: 20x	

Result	
CE Diameter Minimum (µm): 0.54	**CE Diameter D[v, 0.1]:** 15.55
CE Diameter Maximum (µm): 95.19	**CE Diameter D[v, 0.5]:** 49.06
CE Diameter D[4,3] (µm): 51.24	**CE Diameter D[v, 0.9]:** 93.82
CE Diameter D[3,2](µm): 31.16	**CE Diameter STDV (µm):** 4.36
Particles Counted: 10611	**CE Diameter RSD (%):** 190.33



Comments: fine grains,20X, 2 step z-stacking

Morphologi
Malvern Instruments Worldwide
www.malvern.com

CE Diameter Report - Volume Distribution

Malvern

Measurement Details

Sample Name: UHA-14.3

SOP Name: Xiao Qi-Japan 2015-fine grain-new.vsop

User Name: itscdl

Date: Wednesday, April 27, 2016 11:46:26 AM

Edited: True

Edited On: Thursday, May 19, 2016 8:54:29 PM

Analysis

SOP Analysis: 3.0

SOP Segmentation: None

SOP Optic(s) used: 20x

SOP Fill Holes: True

SOP Trash Size: 10

Result

CE Diameter Minimum (µm): 0.54

CE Diameter Maximum (µm): 39.94

CE Diameter D[4,3] (µm): 12.46

CE Diameter D[3,2](µm): 8.516

Particles Counted: 73508

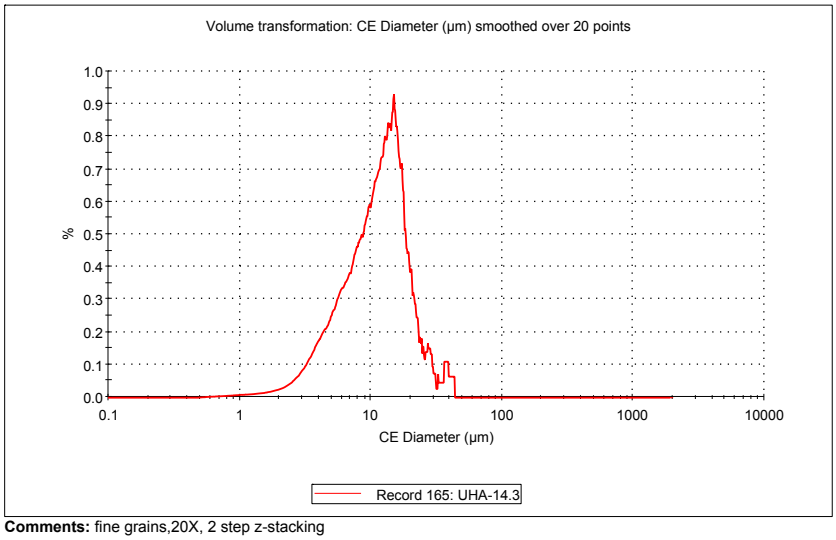
CE Diameter D[v, 0.1]: 4.67

CE Diameter D[v, 0.5]: 11.6

CE Diameter D[v, 0.9]: 20.15

CE Diameter STDV (µm): 2.20

CE Diameter RSD (%): 117.50



Comments: fine grains,20X, 2 step z-stacking

Morphologi
Malvern Instruments Worldwide
www.malvern.com

Morphologi Ver. 8.20
Serial Number : MAL1115686

File name: UHA-final data-addition-May 17.vmes
Record Number: 165
20 May 2016 3:25:47 PM

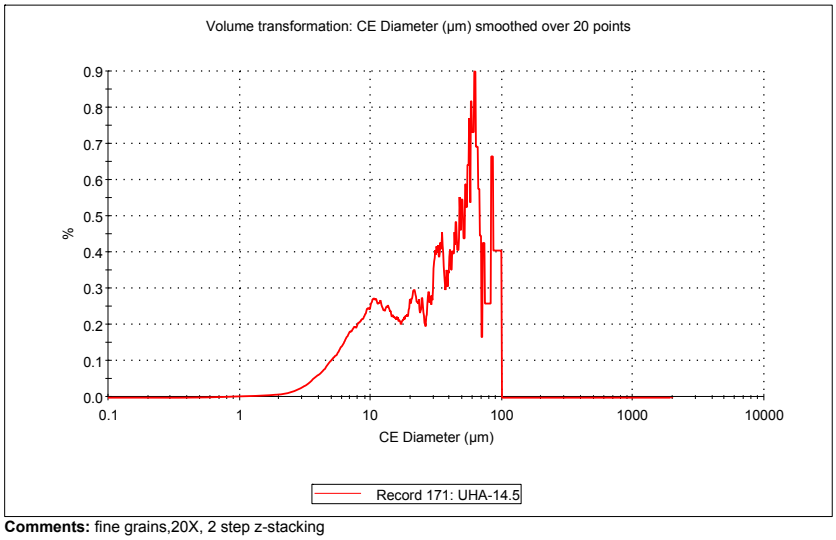
CE Diameter Report - Volume Distribution

Malvern

Measurement Details	
Sample Name: UHA-14.5	
SOP Name: Xiao Qi-Japan 2015-fine grain-new.vsop	**Edited:** True
User Name: itscdl	**Edited On:** Thursday, May 19, 2016 8:57:36 PM
Date: Wednesday, April 27, 2016 3:38:48 PM	

Analysis	
SOP Analysis: 3.0	**SOP Fill Holes:** True
SOP Segmentation: None	**SOP Trash Size:** 10
SOP Optic(s) used: 20x	

Result	
CE Diameter Minimum (µm): 0.54	**CE Diameter D[v, 0.1]:** 7.337
CE Diameter Maximum (µm): 90.28	**CE Diameter D[v, 0.5]:** 34.26
CE Diameter D[4,3] (µm): 38.53	**CE Diameter D[v, 0.9]:** 77.32
CE Diameter D[3,2](µm): 17	**CE Diameter STDV (µm):** 2.55
Particles Counted: 57099	**CE Diameter RSD (%):** 140.13



Comments: fine grains,20X, 2 step z-stacking

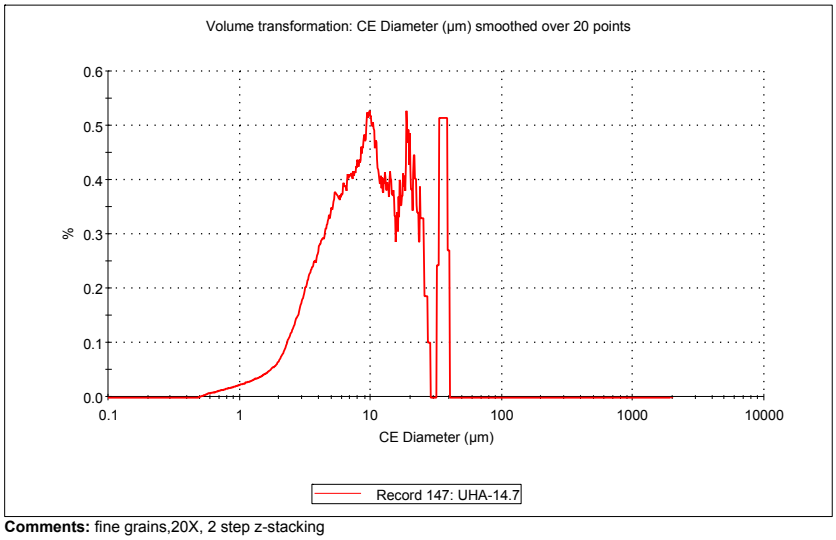
CE Diameter Report - Volume Distribution

Malvern

Measurement Details	
Sample Name: UHA-14.7	
SOP Name: Xiao Qi-Japan 2015-fine grain-new.vsop	**Edited:** True
User Name: itscdl	**Edited On:** Thursday, May 19, 2016 8:44:41 PM
Date: Tuesday, April 19, 2016 2:54:54 PM	

Analysis	
SOP Analysis: 3.0	**SOP Fill Holes:** True
SOP Segmentation: None	**SOP Trash Size:** 10
SOP Optic(s) used: 20x	

Result	
CE Diameter Minimum (µm): 0.54	**CE Diameter D[v, 0.1]:** 3.227
CE Diameter Maximum (µm): 36.24	**CE Diameter D[v, 0.5]:** 9.705
CE Diameter D[4,3] (µm): 12.9	**CE Diameter D[v, 0.9]:** 25.84
CE Diameter D[3,2](µm): 6.552	**CE Diameter STDV (µm):** 1.44
Particles Counted: 34891	**CE Diameter RSD (%):** 102.19



Comments: fine grains,20X, 2 step z-stacking

Morphologi
Malvern Instruments Worldwide
www.malvern.com

Morphologi Ver. 8.20
Serial Number : MAL1115686

File name: UHA-final data-addition-May 17.vmes
Record Number: 147
20 May 2016 3:26:16 PM

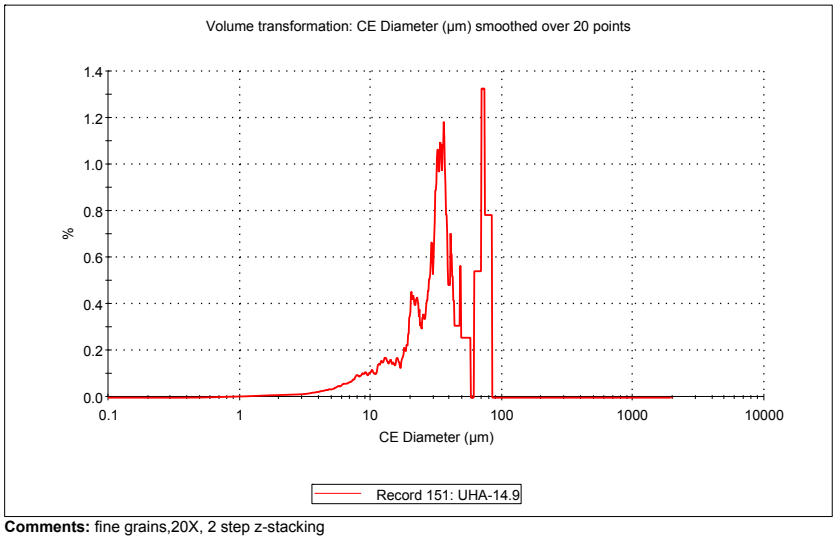
CE Diameter Report - Volume Distribution

Malvern

Measurement Details	
Sample Name: UHA-14.9	
SOP Name: Xiao Qi-Japan 2015-fine grain-new.vsop	**Edited:** True
User Name: itscdl	**Edited On:** Thursday, May 19, 2016 8:48:07 PM
Date: Wednesday, April 20, 2016 9:51:14 AM	

Analysis	
SOP Analysis: 3.0	**SOP Fill Holes:** True
SOP Segmentation: None	**SOP Trash Size:** 10
SOP Optic(s) used: 20x	

Result	
CE Diameter Minimum (µm): 0.54	**CE Diameter D[v, 0.1]:** 12.1
CE Diameter Maximum (µm): 76.38	**CE Diameter D[v, 0.5]:** 34.34
CE Diameter D[4,3] (µm): 39.72	**CE Diameter D[v, 0.9]:** 75.65
CE Diameter D[3,2](µm): 21.17	**CE Diameter STDV (µm):** 2.08
Particles Counted: 23674	**CE Diameter RSD (%):** 160.70



Comments: fine grains,20X, 2 step z-stacking

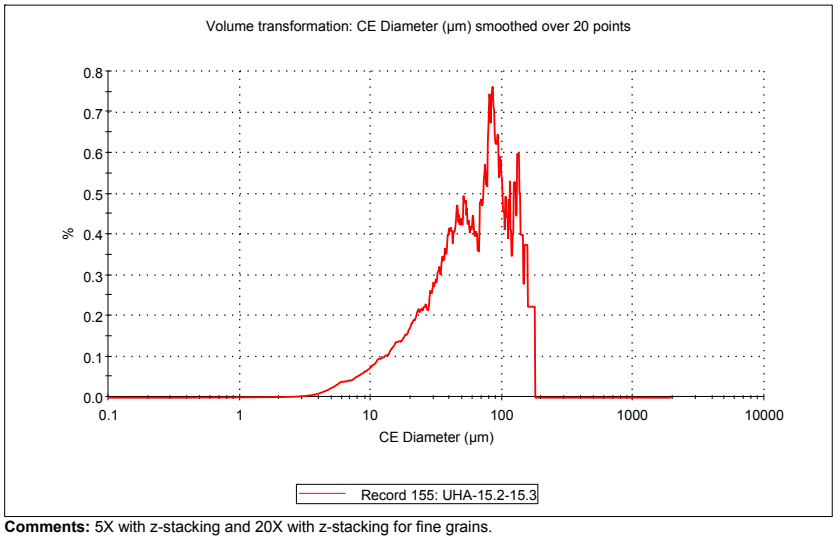
CE Diameter Report - Volume Distribution

Malvern

Measurement Details	
Sample Name: UHA-15.2-15.3	
SOP Name: Xiao Qi-Japan 2015-new.vsop	**Edited:** True
User Name: itscdl	**Edited On:** Thursday, May 19, 2016 8:50:20 PM
Date: Wednesday, April 20, 2016 1:43:32 PM	

Analysis	
SOP Analysis: 3.0	**SOP Fill Holes:** True
SOP Segmentation: None	**SOP Trash Size:** 10
SOP Optic(s) used: 5x, 20x	

Result	
CE Diameter Minimum (µm): 0.54	**CE Diameter D[v, 0.1]:** 17.22
CE Diameter Maximum (µm): 162.58	**CE Diameter D[v, 0.5]:** 62.28
CE Diameter D[4,3] (µm): 68.78	**CE Diameter D[v, 0.9]:** 131
CE Diameter D[3,2](µm): 35.73	**CE Diameter STDV (µm):** 4.17
Particles Counted: 128835	**CE Diameter RSD (%):** 193.35



Comments: 5X with z-stacking and 20X with z-stacking for fine grains.

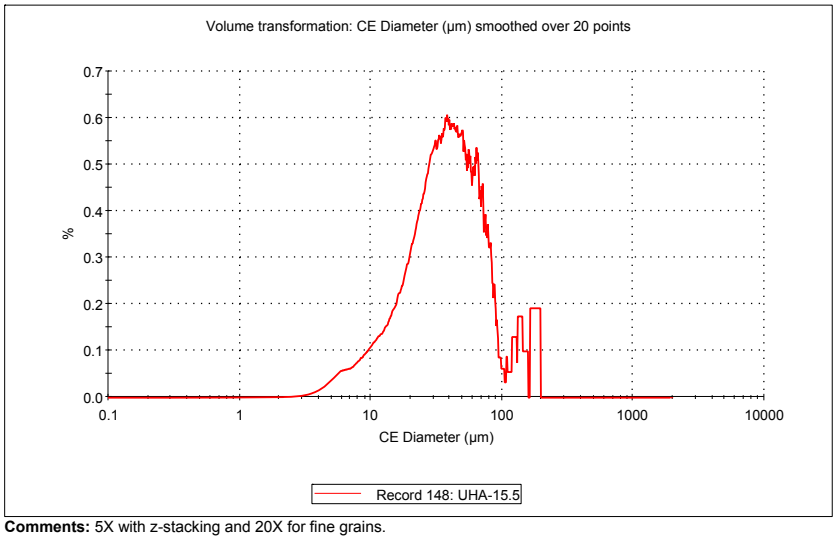
CE Diameter Report - Volume Distribution

Malvern

Measurement Details	
Sample Name: UHA-15.5	
SOP Name: Xiao Qi-Japan 2015-new.vsop	**Edited:** True
User Name: itscdl	**Edited On:** Thursday, May 19, 2016 8:46:32 PM
Date: Tuesday, April 19, 2016 4:11:41 PM	

Analysis	
SOP Analysis: 3.0	**SOP Fill Holes:** True
SOP Segmentation: None	**SOP Trash Size:** 10
SOP Optic(s) used: 5x, 20x	

Result	
CE Diameter Minimum (µm): 0.54	**CE Diameter D[v, 0.1]:** 13.61
CE Diameter Maximum (µm): 179.09	**CE Diameter D[v, 0.5]:** 38.06
CE Diameter D[4,3] (µm): 48.5	**CE Diameter D[v, 0.9]:** 84.52
CE Diameter D[3,2](µm): 26.78	**CE Diameter STDV (µm):** 5.20
Particles Counted: 154768	**CE Diameter RSD (%):** 156.74



Comments: 5X with z-stacking and 20X for fine grains.

CE Diameter Report - Volume Distribution

Malvern

Measurement Details

Sample Name: UHA-15.7

SOP Name: Xiao Qi-Japan 2015-fine grain-new.vsop

User Name: itscdl

Date: Wednesday, April 20, 2016 11:20:39 AM

Edited: True

Edited On: Thursday, May 19, 2016 8:48:28 PM

Analysis

SOP Analysis: 3.0

SOP Segmentation: None

SOP Optic(s) used: 20x

SOP Fill Holes: True

SOP Trash Size: 10

Result

CE Diameter Minimum (µm): 0.54

CE Diameter Maximum (µm): 64.18

CE Diameter D[4,3] (µm): 39.67

CE Diameter D[3,2](µm): 24.43

Particles Counted: 12030

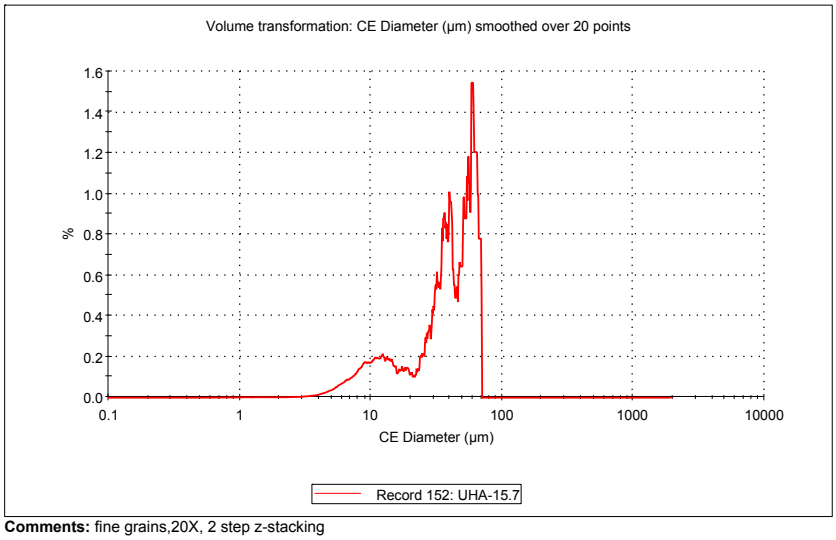
CE Diameter D[v, 0.1]: 10.89

CE Diameter D[v, 0.5]: 39.23

CE Diameter D[v, 0.9]: 63.09

CE Diameter STDV (µm): 3.69

CE Diameter RSD (%): 177.38



Comments: fine grains,20X, 2 step z-stacking

CE Diameter Report - Volume Distribution

Malvern

Measurement Details

Sample Name: UHA-15.9

SOP Name: Xiao Qi-Japan 2015-new.vsop

User Name: itscdl

Date: Tuesday, May 17, 2016 11:39:43 PM

Edited: True

Edited On: Thursday, May 19, 2016 8:12:03 PM

Analysis

SOP Analysis: 3.0

SOP Segmentation: None

SOP Optic(s) used: 5x, 20x

SOP Fill Holes: True

SOP Trash Size: 10

Result

CE Diameter Minimum (µm): 0.54

CE Diameter Maximum (µm): 137.04

CE Diameter D[4,3] (µm): 72.23

CE Diameter D[3,2](µm): 27.95

Particles Counted: 106848

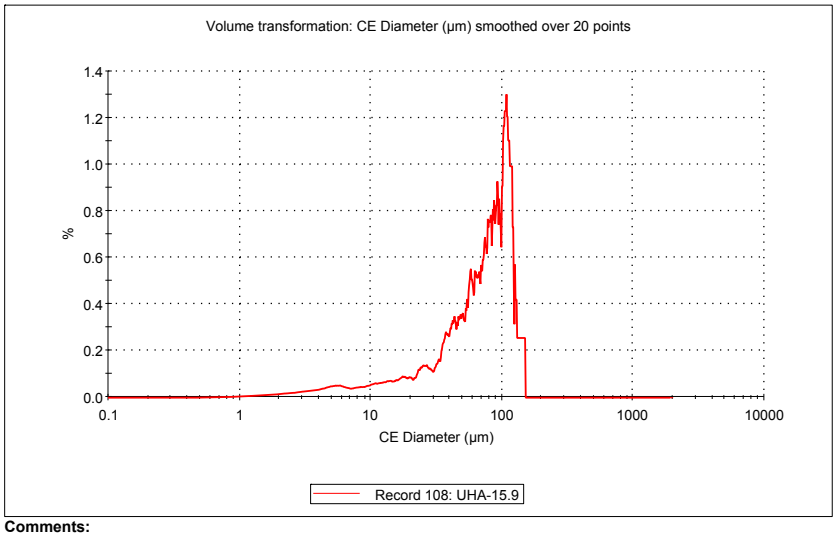
CE Diameter D[v, 0.1]: 16.47

CE Diameter D[v, 0.5]: 74.9

CE Diameter D[v, 0.9]: 113.5

CE Diameter STDV (µm): 1.84

CE Diameter RSD (%): 130.83



Comments:

Morphologi
Malvern Instruments Worldwide
www.malvern.com

CE Diameter Report - Volume Distribution

Malvern

Measurement Details

Sample Name: UHA-16.1

SOP Name: Xiao Qi-Japan 2015-fine grain-new.vsop

User Name: itscdl

Date: Wednesday, April 27, 2016 6:38:43 PM

Edited: True

Edited On: Thursday, May 19, 2016 8:58:54 PM

Analysis

SOP Analysis: 3.0

SOP Segmentation: None

SOP Optic(s) used: 20x

SOP Fill Holes: True

SOP Trash Size: 10

Result

CE Diameter Minimum (µm): 0.54

CE Diameter Maximum (µm): 24.71

CE Diameter D[4,3] (µm): 9.336

CE Diameter D[3,2](µm): 4.276

Particles Counted: 18191

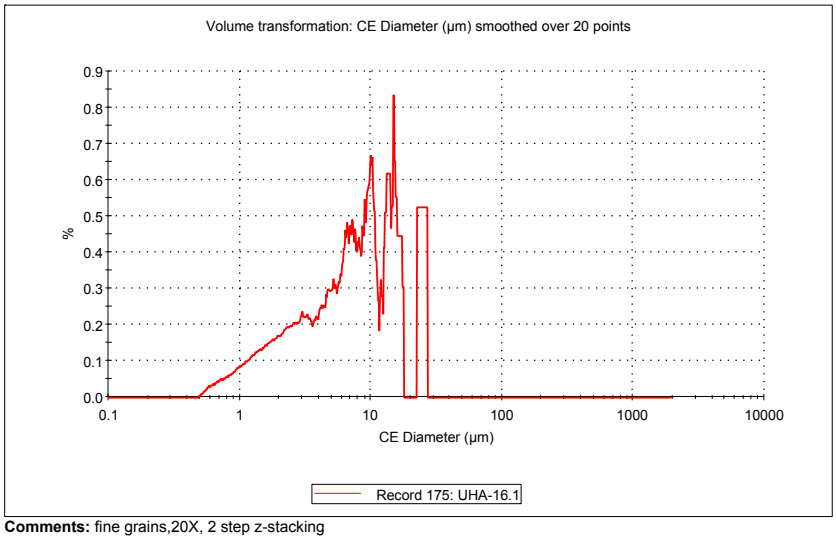
CE Diameter D[v, 0.1]: 1.743

CE Diameter D[v, 0.5]: 7.812

CE Diameter D[v, 0.9]: 16.24

CE Diameter STDV (µm): 0.88

CE Diameter RSD (%): 81.45



Comments: fine grains,20X, 2 step z-stacking

Morphologi
Malvern Instruments Worldwide
www.malvern.com

Morphologi Ver. 8.20
Serial Number : MAL1115686

File name: UHA-final data-addition-May 17.vmes
Record Number: 175
20 May 2016 3:27:43 PM