# LATE HOLOCENE STRATIGRAPHIC HISTORY OF THE GULF OF AQABA COASTAL PLAIN, JORDAN

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Master of Science

By

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ABSTRACT

Construction of the lower tidal lagoon at the Ayla Oasis Development in Aqaba, Jordan provided a unique opportunity to study the 3-D architecture of coastal plain sediment of the northern Gulf of Aqaba. Previous studies of sediment cores had identified a mid-Holocene transgression and a late Holocene regression. In this study, one cross-section of buried structures adjacent to the archaeological site of Tel el-Kheleifeh ($8^{th}$-$4^{th}$ C. BCE) and two stratigraphic columns of 7 m-high outcrops that extended to a depth of 3.2 m below sea level were described and sampled for grain-size, SEM, and radiocarbon age analyses. The base of the section contains subtidal and beach sand and cobble gravel containing abundant shells and coral fragments. Three vertically stacked beachrock layers that developed in the intertidal zone indicate a rising sea level. The uppermost beachrock is found at an elevation of 1.3 m above present sea level and is constrained to be younger than 3.5 ka based on radiocarbon dating of shells. Raised reef, wave-cut notches, and other sea level indicators across the Gulf of Aqaba and northern Red Sea attest to a mid-Holocene highstand. A down-cutting event that eroded the beach sediment and is marked by an irregular unconformity and channels cut to depths below modern sea level. The channels are filled with a blue-gray gravel and sand with abundant rip-up clasts, terrestrial organic material, cross-bedding and convolute bedding which denote high flow velocities and rapid sedimentation. Radiocarbon dating of sediment above the channel constraint its age to before 3.1 ka. As rapid sea level change is not supported by

regional evidence, the erosion and deposition of blue-gray channels are interpreted to represent inundation and drawdown of the sea by a tsunami. Similar erosion and deposition in low-lying areas has been documented in tsunamis in Sumatra, Chili, and the Kuril Islands.

APPROVAL PAGE

The faculty listed below, appointed by the Dean of the College of Arts and Sciences, have examined a thesis titled "Late Holocene Stratigraphic History of the Gulf of Aqaba Coastal Plain, Jordan" presented by Janet Smith, candidate for the Master of Science degree, and certify that in their opinion it is worthy of acceptance.

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# CHAPTER 1

## INTRODUCTION

Aqaba, Jordan, located on the north shore of the Gulf of Aqaba, is the only port for the nation and is a vibrant tourist destination and essential for commerce and trade in the region. The location of the city at the head of the gulf has been at the nexus of trade between Africa, Asia, and the Mediterranean via land and sea routes for millennia. The long cultural history is preserved in the records at archaeological tells (artificial mounds) and the extant Aqaba Castle located at various sites across Aqaba (Figures 1 and 2).

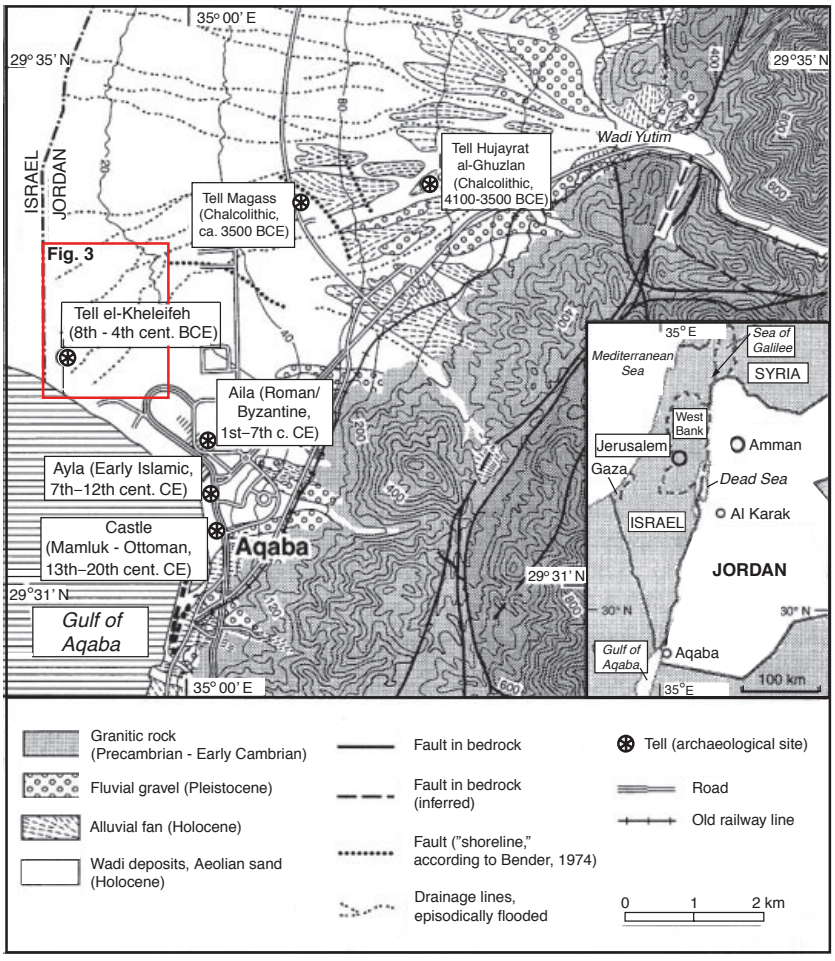



Figure 1: Map of Aqaba, Jordan showing the location of archaeological sites. Red rectangle outlines the area of the Ayla Oasis development shown in Figure 3. Modified after Brückner (1999) and Alison and Niemi (2010).

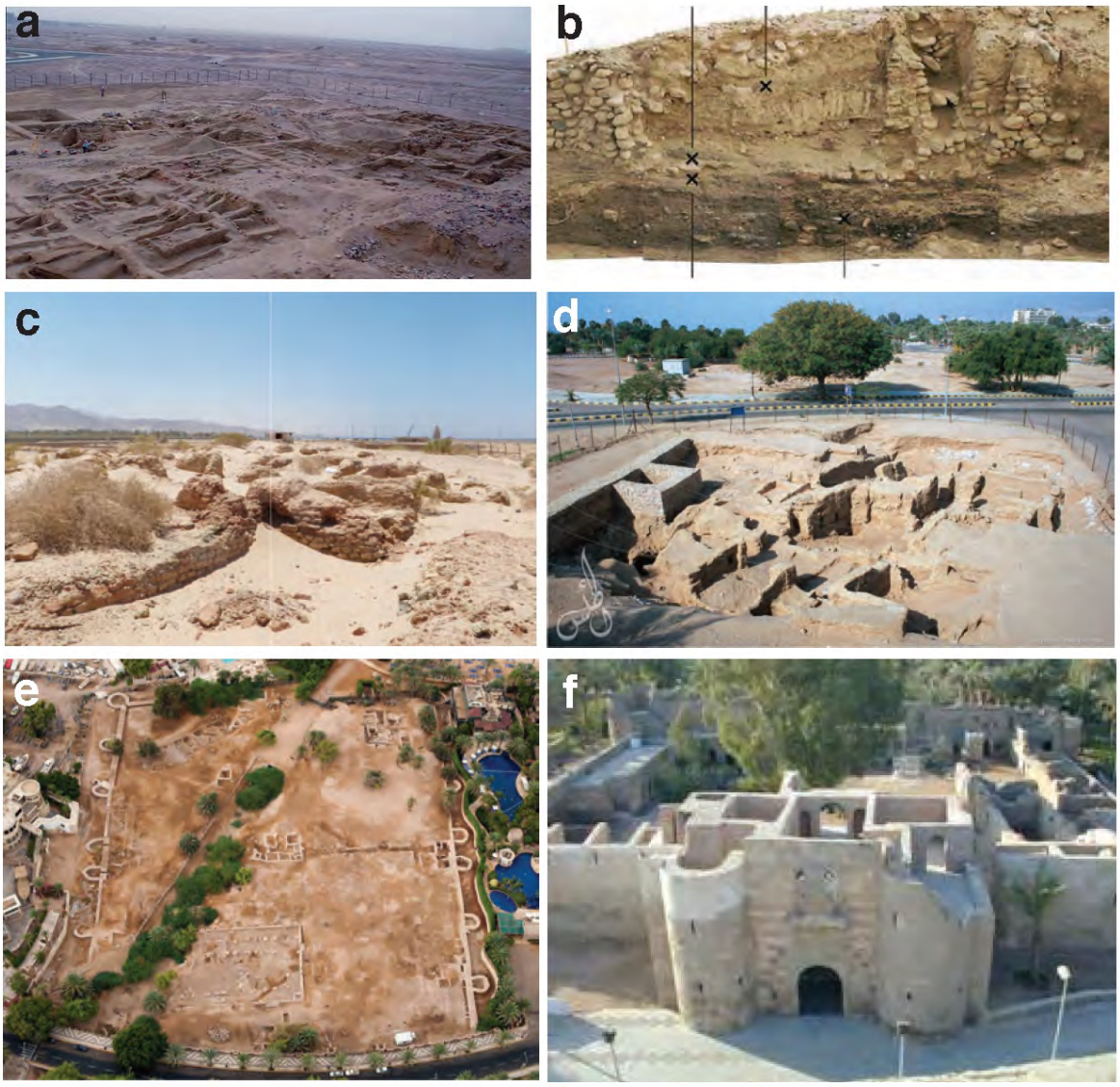



Figure 2: Photographs of the archaeological sites in Aqaba. a) Aerial photograph of the Chalcolithic site of Tell Hujayrat al-Ghuzlan (Klimscha, 2013). b) The road was cut through Tell Magass exposing a 6-m-high cross section of the Chalcolithic mound (Notroff et al., 2014). c) A photograph of Tell el-Kheleifeh viewed toward the southeast shows sand dunes infilling the site excavated in 1938-1940 by Nelson Glueck (Pratico, 1993). d) Nabataean/Roman to Byzantine Aila (1st – 7th Century CE) excavated by S. Thomas Parker (North Carolina State University) from 1994-2002 exposed a 3rd century mudbrick church (Parker, 1997). Photograph from Atlas Tours. e) Aerial view of the fortified Islamic city of Ayla showing the outline of the city wall with towers (Kennedy, 2014) was excavated by Donald Whitcomb (Oriental Institute, Chicago) from 1986-1999 and Kristoffer Damsgaard (University of Copenhagen) from 2009-2010. f) Oblique aerial photograph of the Mamluk to Ottoman Aqaba castle excavated by Johnny De Meulemeester and Reem Al Shqour (University of Ghent) (Al Shqour, 2019).

The earliest occupation of Aqaba is seen at the Chalcolithic-aged (5th to 4th millennium BCE) Tell Magass and Tell Hujayrat al-Ghuzlan located 4.2 km and 5.3 km from the shoreline, respectively, at an elevation >100 m on an alluvial fan (Khalil and Schmidt, 2009; Klimscha, 2013; Notroff et al., 2014). The late Iron Age (8th and 4th centuries BCE) site of Tell el-Kheleifeh is located 500 m north of the shoreline in the middle of the valley (Pratico, 1993). The Nabatean port city of Aila, established in the 1st century CE and extending to the Byzantine period (4th century CE), is located approximately 200 m from the modern shore of the Gulf and about 2 km southeast of Tell el-Kheleifeh. Farther southeast is the walled Islamic city of Ayla (7th - 12th century CE) (Whitcomb, 1994) and Castle or Khan (13th – 20th century CE; Al Shqour, 2019). This scattered pattern of archeological site distribution is unusual as most settlements in antiquity in the Near East have built large tells at one site over many centuries.

The archaeological site of Tell el-Kheleifeh is of particular interest as it is adjacent to the stratigraphic data examined in this paper. Tell el-Kheleifeh was first surveyed by German architect and historian Fritz Frank in 1934 (Pratico, 1993). Frank speculated the tell was the ancient port city of King Solomon known in the Bible as Ezion-Geber. Nelson Glueck, an American archaeologist excavated the site in three seasons between 1938-1940. Glueck identified five periods of occupation between the 10th and 5th centuries BCE. He also agreed with Frank the tell was the port city of Ezion-Geber (Pratico, 1993). Additional analyses of Glueck's excavation archival materials and pottery sherds determined the site to be too young to have been occupied by King Solomon (Pratico, 1993) as Solomon lived around 950 BCE and the pottery dates were between the 8th and 4th centuries BCE. Tel el-Kheleifeh is located along the international border between Israel and Jordan at the western edge on the Ayla Oasis Development about 500 m from the modern shoreline.

The modern city of Aqaba has experienced extensive growth from the 1990s to today. Population in the mid-1990s was around 60,000. According to the Oxford Business Group's 2018 report, as of 2018, the population had reached nearly 180,000. The city has a land area of approximately 375 $km^2$ (Ghazal, 2016) with 24 km of coastline. Expansion towards the south includes the building of a new port. In 2001, the Aqaba Special Economic Zone Authority (ASEZA) took over administration of the city. ASEZA decreased local taxes and made the city a duty-free zone as a way to attract tourists. The vision of ASEZA is to grow Aqaba into a major tourist destination as well as increase industry and trade, and heighten environmental awareness by establishing offshore nature preserves. Aqaba has no cap on foreign investment. As of 2017, the city had over $20 billion invested with $10 billion invested in tourism and the port. ASEZA projects the population to reach 200,000 by the end of 2020.

As part of the urban revitalization, the Ayla Oasis Development is a residential and tourist area located along the westernmost edge of the city of Aqaba (Figure 3). The Ayla Oasis Development covers an area of 4.3 $km^2$ with a narrow sea frontage along the Gulf of Aqaba located west of the Jordanian Royal Palace (Manasrah, 2015). Construction began in 2008 and infrastructure was completed in 2014. Hotels and the golf course opened in 2018. The Ayla Oasis Development added 17 km of "coastline" to the city with the creation of three lagoons (Al-Rshaidat et al., 2020). The lower lagoon is connected directly to the gulf by a 235-m-wide opening and is tidally dominated at present sea level. Water depth in the lower tidal lagoon is about 10 m deep. Water is pumped up to the middle and upper lagoons which have surface elevations of 3 m above mean sea level (asl) and 6 masl, respectively. The water depth in the middle and upper lagoons is approximately 2 m. The lagoons were flooded in May 2012 (Al-Rshaidat et al., 2020).

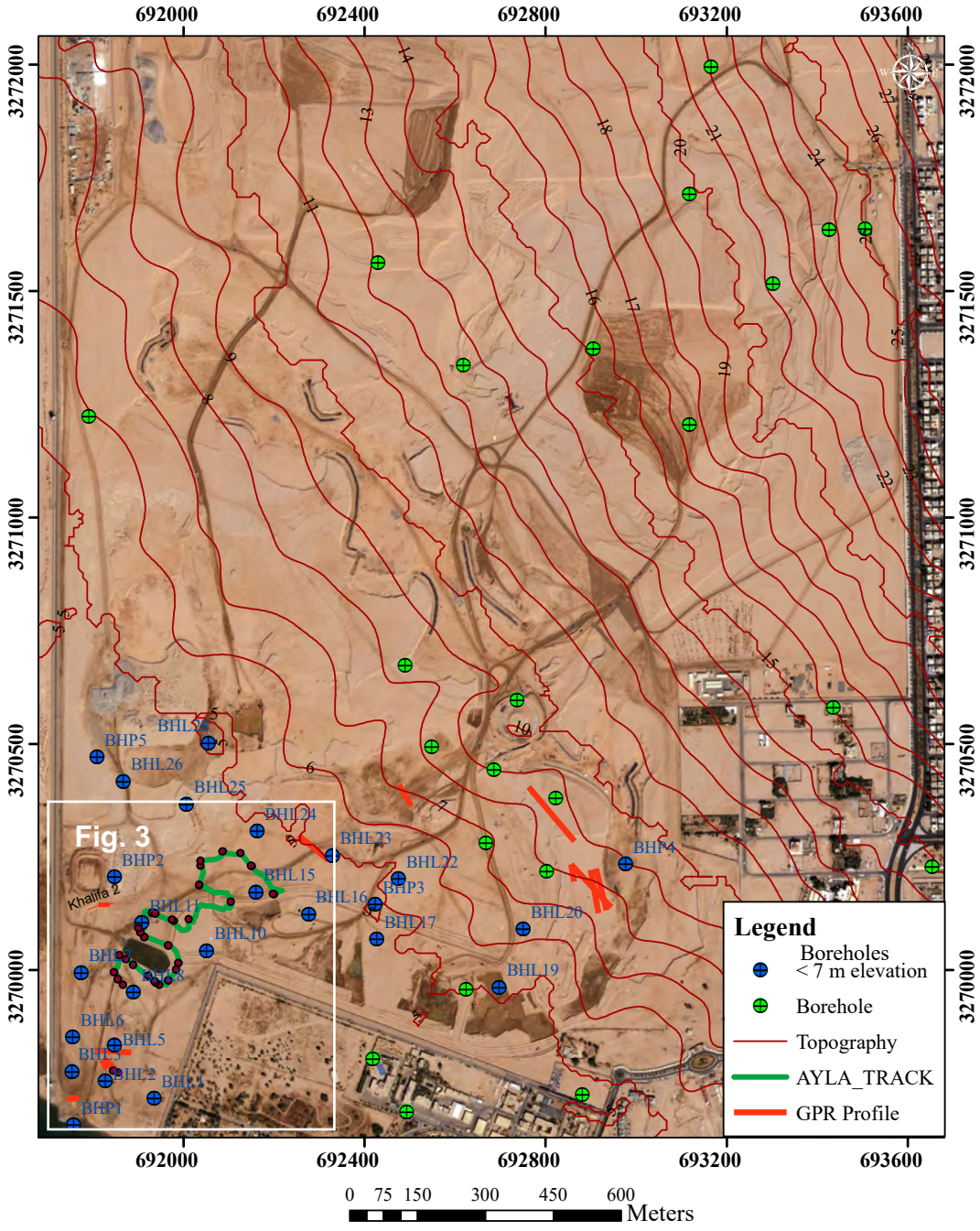



Figure 3: Google Earth map of the Ayla Oasis development site from 2010 showing the early stages of construction. Topographic contours and borehole locations are from consulting reports by the Arab Center for Engineering Studies in Amman, Jordan. Green line with red dot waypoints is a GPS track of the wall surveyed in February 2010.

The construction of the lower tidal lagoon at the Ayla Oasis development involved excavation below sea level and below the water table. A series of dewatering wells were installed across the site in order to create dry excavation conditions and provided a unique opportunity to study the 3-D architecture of the stratigraphy exposed along the lagoon construction site. This study examines the stratigraphic sections and field relationships of sediment collected at the Ayla Oasis construction site during February 2010 when the floor of the lagoon was at about -3 m below sea level (bsl). Furthermore, during July-August 2010, the lagoon construction exposed buried structures adjacent to the Late Iron Age ($8^{th}$ and $4^{th}$ centuries BCE; Pratico, 1993) archaeological site of Tel el-Kheleifeh. These outcrops were documented and provide insight into paleoenvironmental conditions at this important site.

Two previous studies have presented paleoenvironmental data for the Aqaba coastal plain of the Gulf of Aqaba based on borehole data (Brückner, 1999; Alison and Niemi, 2010). Brückner (1999) collected five sediment cores from about 350 m to 700 m inland from the coastline corresponding to surface elevation between 3 and 5 m asl. These cores were extracted along a transect from the coast to Tel el-Kheleifeh and beyond. From these data, Brückner (1999) interpreted a marine transgression followed by a regression. At around 6.2 ka, the shoreline was 600 m inland from its current position and by 3.7 ka the shoreline had moved to 270 m inland based on Brückner (1999). Alison and Niemi (2010) interpret marine deposits at 5 mbsl changing to brackish water to freshwater conditions at 2-3 mbsl around 6 ka based on freshwater ostracod identification from cores in Aqaba, followed by a regression. Neither study discusses the possibility of a higher-than-present sea level.

The excavation of the Ayla Oasis's lower tidal lagoon construction site exposed sediment to -3 m bsl at the time of the field study in 2010. The outcrops showed several blueish-

colored, mostly gravel- and sand-filled channels cutting through intertidal marine deposits. The channels have never been exposed or previously described, and their interpretation is the subject of this thesis. Furthermore, the stratigraphic section of TK-4 is close to Tell el-Kheleifeh was mapped and shows clear stratigraphic relationships between the blue-gray channel and later stratigraphy.

In this study, two stratigraphic columns and a stratigraphic section were described and sampled in the field in 2010 and over 2000 m of subsurface outcrop exposed in the construction site walls were examined and photographed. Grain-size, XRD, and SEM analyses provide additional insight to the changes in the coastal environment of the Aqaba region. The previously documented transgressive sequence appears to extend to higher-than-present sea levels and the regressive sequence is punctuated by a down-cutting erosional event that extends below modern sea level.

CHAPTER 2

REGIONAL ENVIRONMENTAL SETTING

Aqaba, Jordan lies on the northern shore of the Gulf of Aqaba at the southern end of the Wadi ‘Arabah valley (Figure 4).

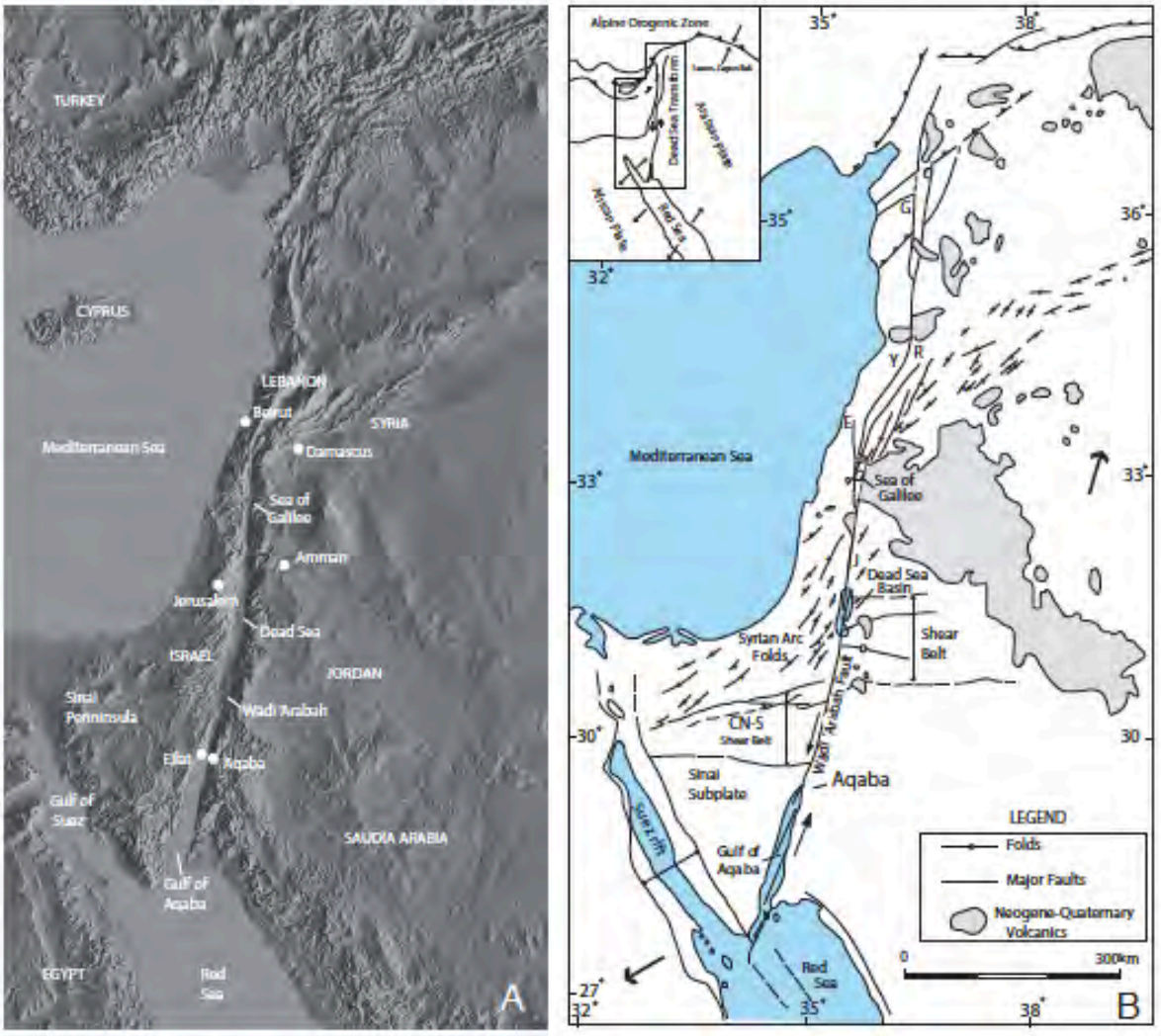



Figure 4: Dead Sea Transform (After Niemi, 2014)

The Gulf of Aqaba is roughly 180 km long and is the northeastern branch of the Red Sea. The Straits of Tiran mark the boundary between the gulf and the Red Sea to the south and restricts circulation between the two water bodies. The low influx of freshwater into the gulf results in

high temperatures, increased salinity, and increased evaporation rates (e.g. Morcos, 1970). The tidal range at the north end of the gulf near the city of Aqaba is less than a meter. In the Gulf of Aqaba, coral reefs only grow along the west and eastern shores (e.g. Al-Rifaiy and Cherif, 1988; Bouchon et al., 1981; Friedman, 1965; Shaked et al., 2004). The water depth of the gulf exceeds 1500 m. The Aqaba fault system underneath the gulf forms a steep escarpment and narrow shelf adjacent to the eastern shore of the gulf (Tibor et al., 2010; Hartman et al., 2014).

Wadi ‘Arabah and the region, including Aqaba, is a hyperarid environment and receives less than 50 mm of rainfall annually (Aqaba Meteorological Station, 1955-1985). Rainfall in Aqaba occurs primarily during the months between November and March and is sporadic. Two separate weather systems supply the region with precipitation. One is the mid-latitude cyclone known as the Cyprus Low which brings moisture from the Mediterranean Sea. The other weather system is the Red Sea trough which is an extension of the tropical monsoon season which occurs to the south (Black et al., 2011). These two systems also bring precipitation north of Aqaba to the Jordanian Plateau and farther north.

Wadi ‘Arabah valley is a NE-trending, linear valley formed along the Dead Sea Transform fault (DST). The valley extends from the Gulf of Aqaba to the Dead Sea. The wadi (ephemeral stream) drains southwestward into the gulf from a divide 80 km north of Aqaba. The valley floor is comprised of mudflats and alluvial fan deposits which are Pleistocene to Holocene in age (Figure 5). Drainage into Wadi ‘Arabah comes from the mountains that flank the valley. The mountains to the east have a higher elevation up to 1200 m compared to the mountain range to the west that have elevations of approximately 600 m. The largest drainage system in the southern ‘Arabah valley is the Wadi Yutim which has a drainage basin originating at the eastern plateau.

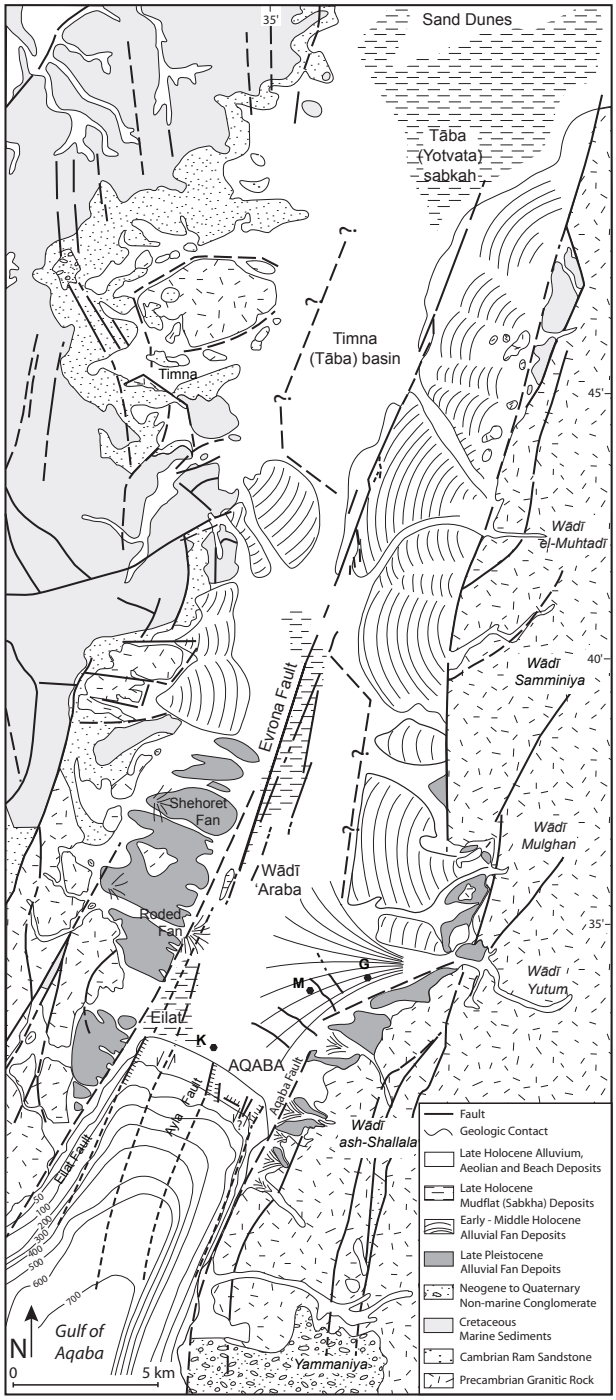



Figure 5: Geologic map of the Aqaba-Eilat region (After Niemi, 2014).

The catchment of the basin is approximately 4500 $km^2$. The city of Aqaba is largely built on the alluvial fans of Wadi Yutim. The basin is prone to flash flood events due to higher annual precipitation on the Jordan plateau to the east.

The Gulf of Aqaba and Wadi ‘Arabah formed along the Dead Sea Transform Fault (DST) that extends from the gulf and eastern Turkey (Figures 1 and 4). The DST is a sinistral transform plate boundary system which separates the Sinai subplate from the Arabian plate (Freund et al., 1970). A component of divergence has down-dropped a rift valley along normal faults that parallel the DST and uplift of the flanking mountains (Garfunkel, 1981). A series of pullapart basins along the Gulf of Aqaba, Dead Sea, and the Sea of Galilee were created between *en echelon*, left-stepping strike-slip faults (Figure 4) (e.g. Ben-Avraham et al., 1979; Ben-Avraham, 1985).

A cumulative, left-lateral offset of 105 km along the DST juxtaposes various bedrock (e.g. Freund et al., 1970). The mountains to the east are much older than those to the west of the valley (Figure 5). Eastern mountains are Precambrian to Cambrian in age. Western mountains are of Cretaceous age. East of Aqaba and extending 50 km northeast the mountains are comprised of Precambrian igneous rocks of the Aqaba Granite Complex (Rashdan, 1988). The rocks are a composition of granite, monzogranite, granodiorite, and quartz diorite (Ibrahim and McCourt, 1995; Jarrar et al., 2003). Felsite dikes crosscut the granite. An unconformity caps this sequence. Over the crystalline bedrock is a series of Cambrian arkosic sandstones and conglomerates. These rocks transition to Cambrian quartzose sandstones to Silurian Nubian Sandstone. The Nubian Sandstone outcrops 50 km NE of Aqaba. To the west the elevations are lower than the mountains to the east. The rocks west of Aqaba are composed of

Cretaceous sandstones, limestones, and dolomites. The limestone is fossiliferous and interbedded with chert, shale, and phosphate.

The Evrona fault is the active strike-slip fault mapped along the western side of the northern Gulf of Aqaba that extends onshore into Eilat (Kanari et al., 2020). A slip rate for the Evrona fault of 2.3-3.4 mm/yr was calculated from seismic reflection data of an offset coral reef front on the shelf (Makowsky et al. 2008, Hartman et al., 2014). In Eilat, near the Shehoret fan, and Taba Sabkha (Figure 5), paleoseismic data show that the Evrona fault ruptured in the historic earthquake of 1068 CE (Amit et al., 2002; Klinger et al., 2015; Kanari et al., 2020; Zilberman et al., 2005). Guidioboni and Comastri (2005) and Ambraseys (2009) describe the historical earthquake of 1068 CE as being devastating. One contemporary account states that "its inhabitants all perished except for 12 persons who had gone fishing at sea" (Guidoboni and Comastri, 2005, p. 53). Another historical reference refers to the destruction of the city by a "withdrawal and return to the sea" as described by Ibn al-Jauzi, an author from the 12$^{th}$ century (Ambraseys, 2009, p. 274). Whitcomb (1994) excavated portions of the fortified wall city of Islamic Ayla and found evidence for earthquakes in the 8$^{th}$ and 11$^{th}$ centuries CE.

Along the eastern side of the Gulf of Aqaba, Tibor at al. (2010) and Hartman et al. (2014) map the steep drop forming the narrow shelf to the deeper basin as the Aqaba fault (Figure 5). Slip rate estimates of the presumed normal fault is 0.4 ± 0.1 mm/yr. The offshore Aqaba fault comes onshore beneath the city of Aqaba, although its exact position is largely unknown. Motion from the Aqaba fault appears to fan out into a horsetail splay of a series of northwest-striking cross faults (Niemi and Smith, 1999; Slater and Niemi, 2003; Mansoor et al., 2004). The cross faults have ruptured in earthquakes which displaced archaeological structures between the 2$^{nd}$ and 7$^{th}$ centuries CE (Thomas et al., 2007).

The Nuweiba earthquake was the largest seismic event along the DST in the 20th century and occurred in 1995 (Shamir et al., 2003). The earthquake ruptured a fault under the Gulf of Aqaba and structural damage occurred in Aqaba and neighboring city, Eilat in Israel. The epicenter was near the Egyptian city of Nuweiba, and was felt as far as Lebanon and Syria. Evidence for liquefaction, differential settling, and apparently a small tsunami in Aqaba and Eilat were documented (Wust, 1997).

# CHAPTER 3

# METHODS

## *Field Work*

Along the Ayla Oasis lagoon construction site in February and August of 2010 over 2 km of sediment to a depth of >3 mbsl were surveyed. One cross-section (TK 4) of exposed and buried walls and two stratigraphic columns (AO-2 and AO-3) were drawn, described, and sampled. A buried structure at AO-1 was determined to be modern and not discussed in this thesis. Figure 6 shows the location of the sections. A log of the samples is given in Appendix A. Figure 7 shows the outcrop of AO-2.

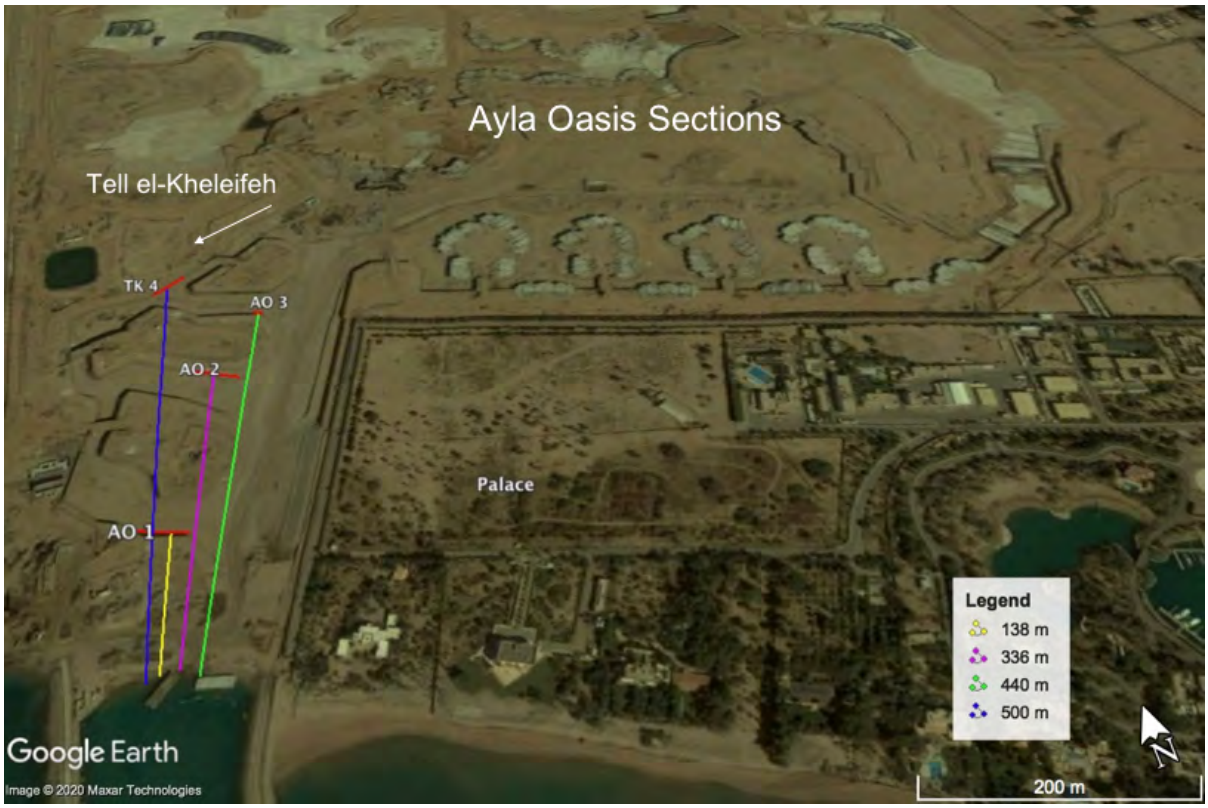



Figure 6: Location of stratigraphic sections described in this study plotted on a 2011 Google Earth image. The distance from the shoreline to each site is given in the legend.

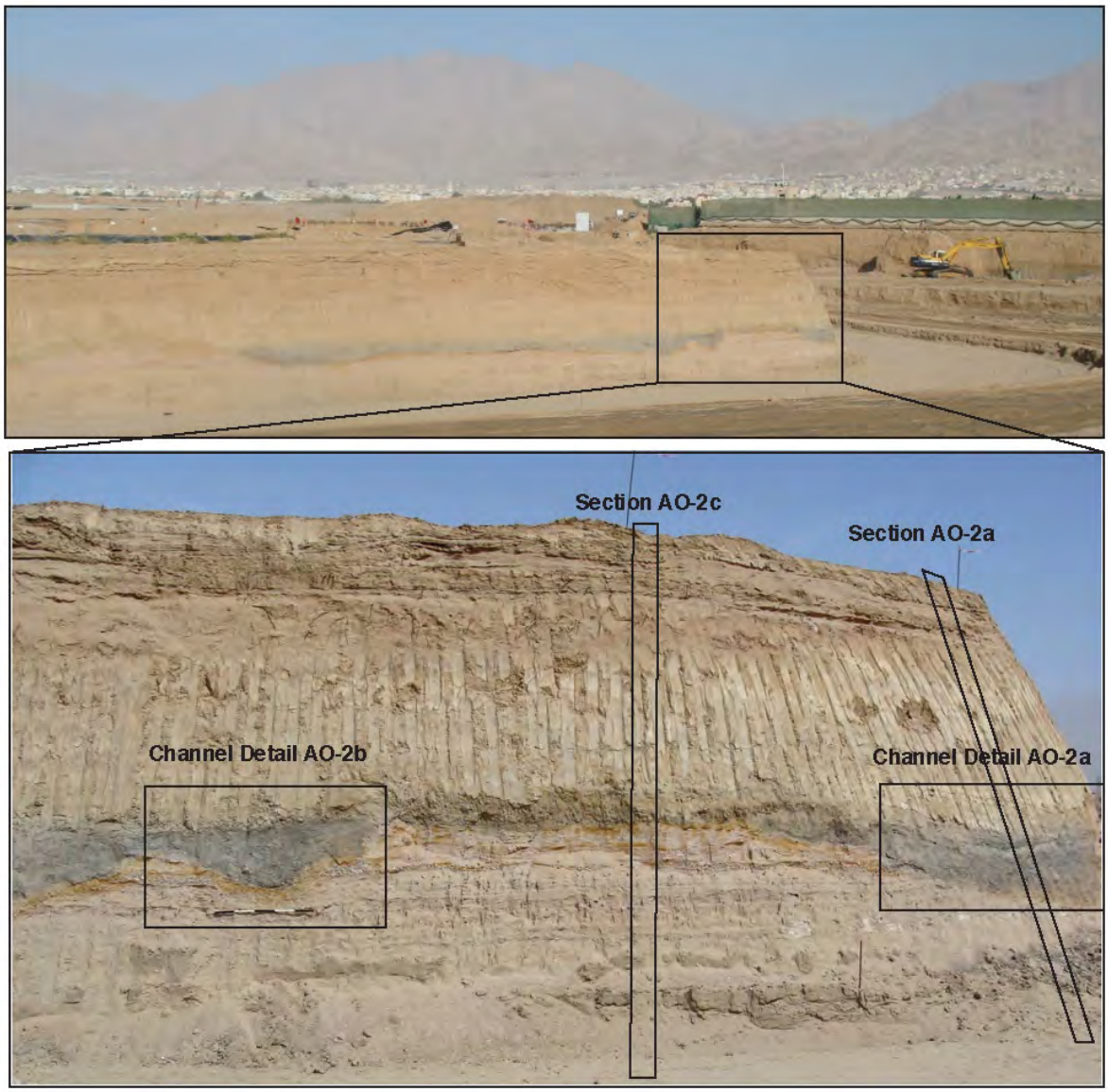



Figure 7: Photographs of the AO-2 section location 338 m from the shoreline. See Figure 6 for map location.

In the field, a surveyor from the Ayla Oasis Development company reported that the depth of the lagoon (i.e. the base of AO-2 and AO-3 sections) was being excavated to 3.2 mbsl. This datum indicates that the surface elevation at the AO-2 and AO-3 site is at 3.8 m or around 4 masl. This is a reasonable estimation given the topographic map and drill core elevations and proximity to the Jordanian Royal Palace Property boundary (Figure 3).

*XRD, SEM, EDS*

Samples from several units (Appendix A) were analyzed by powder X-ray diffraction (XRD). The samples were finely ground and homogenized. The untreated mounts were analyzed on a Rigaku Miniflex automated diffractometer. The samples were scanned from 5-40° 2$\boldsymbol{\theta}$, 0.05 step width, 3/s step using CoKa radiation with 1.7902 Å Fe filter. Patterns were processed using MDI Jade software.

Scanning electron microscope (SEM) analysis was conducted for sample TK-4-13. The bulk sample was mounted, carbon coated and analyzed with a Tescan VEGA 3 LMU scanning electron microscope with a Bruker Quantax EDS system. EDS (Energy Dispersive spectroscopy) was used to identify key minerals in the sample. SEM images were taken for sample AO-2 unit 6. (See Appendix E)

*Grain-Size Analysis*

Four sections AO-1, AO-2, AO-3, and TK-4 at the Ayla Oasis development were analyzed. There were 42 total sediment samples collected across the four exposures. The bulk sediment samples were weighed and then rinsed with a sodium hexametaphosphate solution to disaggregate compaction. Organic material was skimmed from the top of the submerged sample and collected for analysis. The samples were oven-dried for 24 hours, and weighed again to determine moisture loss.

The samples range in size from clay to coarse sand. A total of 8 pans (7 sieves plus the pan) at one phi intervals (Appendix B) were used to determine the percentage of each grain-size fraction ranging from granules to <53 microns. The sediment was sieved by shaker for 10 minutes. Each grain-size fraction was weighed and recorded in a table (See Appendix B).

Statistical analysis parameters for the grain sizes was determined by the Gradistat program, version 8 (Blott and Pye, 2001). The Microsoft Excel worksheet and graphic program for the Gradistat program was developed by Blott (2010). Weights for each grain-size fraction was entered into the worksheet. Grain-size mathematical calculations are described using the Method of Moments in Microsoft Visual Basic programming language (Appendix C).

*Radiocarbon Dating*

Three wood and one charcoal samples were sent to the Center for Accelerator Mass Spectrometry (CAMS) at the Lawrence Livermore National Laboratory for radiocarbon age analyses. These samples were collected from within the blue-gray channel fill and from the sand unit that caps it. As the production of radiocarbon in the atmosphere has fluctuated over time, radiocarbon ages need to be calibrated to adjust them to calendar ages (BCE/CE) or to years before present (cal BP) with present given as 1950 CE. We utilized the CALIB 7.10 radiocarbon calibration program to calibrate the terrestrial carbon sample ages utilizing the Intcal13 radiocarbon curve. Results are reported in Table 1.

Table 1: Radiocarbon Results from the Ayla Oasis Exposures

| CAMS No. | Sample No. | Material | Depth | Elevation | $d^{13}C$ | fraction Modern | $D^{14}C$ |
|---|---|---|---|---|---|---|---|
| **163766** | AO-2-15 | wood | 4.6 m | -0.8 m | -25 | 0.6831 ± 0.0025 | -316.9 ± 2.5 |
| **163767** | AO-2-18 | charcoal | 4.2 m | -0.2-0.6 m | -25 | 0.6941 ± 0.0026 | -305.9 ± 2.6 |
| **163768** | AO-3-1 | wood | 3.6 m | 0.3-0.5 m | -25 | 0.6472 ± 0.0023 | -352.8 ± 2.3 |
| **163769** | AO-7b-1 | wood | ~ 4.5 m | NA | -25 | 0.4924 ± 0.0018 | -507.6 ± 1.8 |

| CAMS No. | Sample No. | $^{14}C$ age | Calibrated age (2σ) | Median Probability | Calendar age (2 σ) |
|---|---|---|---|---|---|
| **163766** | AO-2-15 | 3060 ± 30 | 3181-3359 cal BP | 3278 cal BP | 1410-1232 BCE |
| **163767** | AO-2-18 | 2935 ± 30 | 2979-3173 cal BP | 3092 cal BP | 1224-1030 BCE |
| **163768** | AO-3-1 | 3495 ± 30 | 3609-3826 cal BP | 3688 cal BP | 1877-1660 BCE |
| **163769** | AO-7b-1 | 5690 ± 30 | 6406-6549 cal BP | 6468 cal BP | 4600-4457 BCE |

1) δ13C values are the assumed values according to Stuiver and Polach (1977) when given without decimal places. Values measured for the material itself are given with a single decimal place.
2) The quoted age is in radiocarbon years using the Libby half-life of 5568 years and following the conventions of Stuiver and Polach (1977).
3) Radiocarbon concentration is given as fraction Modern, D14C, and conventional radiocarbon age.
4) Sample preparation backgrounds have been subtracted, based on measurements of samples of $^{14}C$-free coal. Backgrounds were scaled relative to sample size.
5) The CALIB 7.10 program with the IntCal13 radiocarbon curve was used to calibrate radiocarbon ages.

C-14 ages of shells presented in Brückner (1999) were also calibrated. Because of the storage of old carbon in the ocean, radiocarbon dating of shells or other marine material will yield an age several hundred years older than the actual age. Therefore, a marine reservoir correction must be made. The average global ocean correction is given as 400 yr (Stuiver and Braziunas, 1993). However, basins restricted from the global ocean and changes to seawater circulation cause the region marine reservoir to vary from the global value. Delta R (ΔR) is given as the difference of the region reservoir to the average global ocean reservoir correction. In the marine reservoir correction database for the program CALIB (Stuiver and Reimer, 1993), the regional ΔR for the Gulf of Aqaba in Aqaba is 224 ± 35 yr or 121 ± 30 yr based on analyses of modern *Porites* coral presented in Felis et al. (2004). The weighted mean value for

these data yields a ΔR of 165 ± 72 yr. Brückner (1999) used the global marine reservoir correction of 402 yrs. for adjustment of radiocarbon analyses of shells sampled from boreholes near Tel el-Kheleifeh. Given that the Gulf of Aqaba reservoir correction data were not available to Brückner (1999), we have re-calibrated his Beta Analytic C-14 ages using the CALIB 7.10 program with the Marine-13 radiocarbon curve and a ΔR of 165 ± 72 yr (Table 2).

Table 2: Recalibration of the radiocarbon data from the Brückner (1999) study near Tel el-Kheleifeh

| **Beta No.** | **Sample No.** | **Material** | **Depth** | **Elev.** | **$^{12}C$ /$^{13}C$ ratio** | **$^{14}C$** | **Calibrated age (2 σ)** | **Median Probability** | **Calendar age (2 σ)** |
|---|---|---|---|---|---|---|---|---|---|
| **121046** | AQ 5/11F | *Codakia* shell | 5.1 m | -1.4 | 3.1 | 3740 ± 50 | 3249-3687 cal BP | 3472 cal BP | 1738-1300 BCE |
| **121047** | AQ 6/15F | shell | 7.7 m | -2.6 | 3.4 | 6200 ± 50 | 6268-6665 cal BP | 6459 cal BP | 4717-4319 BCE |

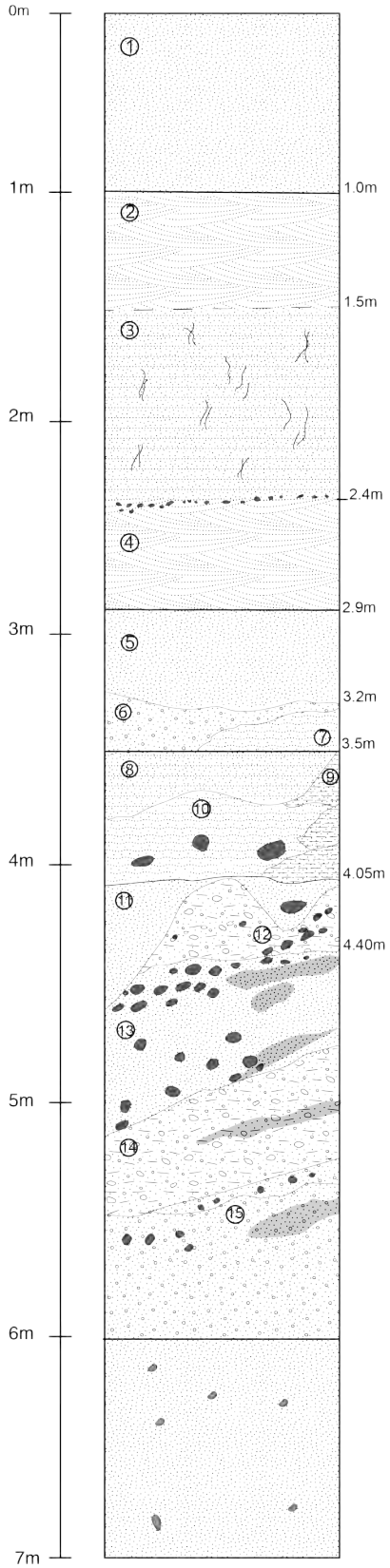
1) The CALIB 7.10 program with the Marine13 radiocarbon curve and a ΔR of 165 ± 72 yrs. was used to calibrate radiocarbon ages.

# CHAPTER 4

# RESULTS

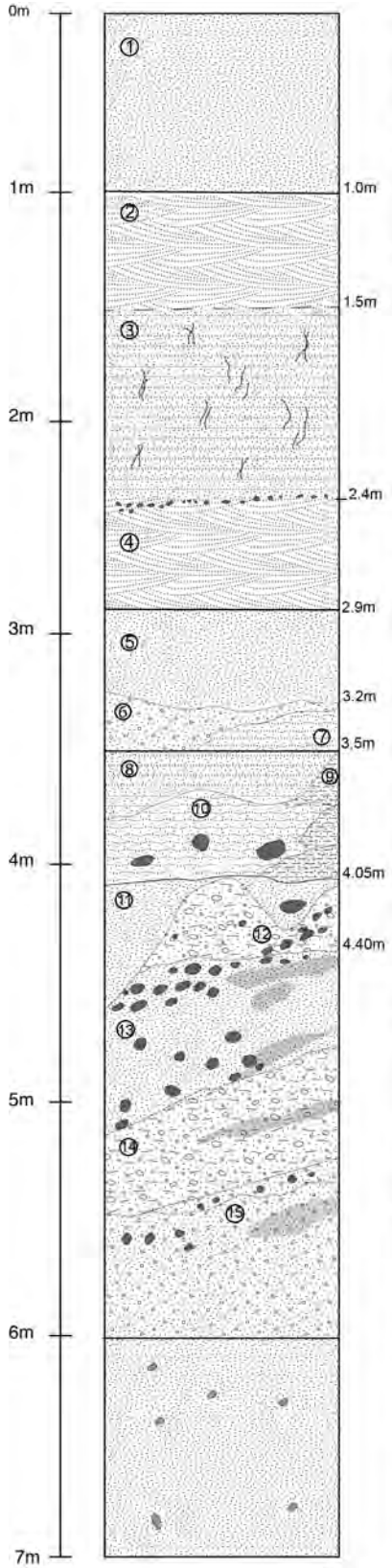
## *Stratigraphic Sections*

Two stratigraphic columns (AO-2 and AO-3), located 336 and 440 m from the shoreline, respectively, were measured and described (Figures 8 and 9). Section AO-2 is 7 m in height, and has 14 units. Unit 14 marks the base of the section which contains pinkish sand with pebbles, shells, and sand dollars. Unit 13 is beachrock approximately 22 cm thick, but is broken into a disjointed layer. Unit 12 contains parallel inclined interbeds of sand and pebbles. Marine gastropods, clam shells, and coral fragments were found in Unit 12. Unit 11 is the base of the channel and contains blue-gray sand with rip-up clasts. Unit 10 is iron stained at the top with slightly cemented gray sand and denotes fill in the channel sequence. Unit 9 overlies a channel sequence and is interbedded sandy and silty clay. Units 6, 7, and 8 are all distinct units of sand, silt, and clay with some units indurated and some units containing calcium carbonate nodules. Unit 5 contains sand with calcium carbonate nodules and appears to mark the base of the pedogenic unit. Unit 4 has cobbles at the top with loose and broken roots in fine sand. Unit 2 is layers of light brown silty clay and Unit 3 is cross-stratified and bioturbated medium to fine sandy soil. The top of the section, Unit 1, is brown sand and in places is construction fill from the excavation of lagoons.




| Unit | Description | Sample | Facies |
|---|---|---|---|
| 1 | Fill | | Alluvium and Aeolian |
| 2 | Cross-bedding, fine to medium sand, aeolian, no root casts | | |
| 3 | Well-sorted medium sand, calcitedroot casts, magnetite, clam shell, pebbles, laminated bedding | | Distal Alluvial Fan and Mudflat |
| 4 | Granules,3.5 cm thick pebbles, shells, coarse sand, cross-laminated SE | | Foreshore Beach Face |
| 5 | Brown sand, blue at base appears white when dried, XRD | AO 3-11, very well sorted fine sand | |
| 6 | Irregular contact, pink coarse sand, pebbles, shells, | AO 3-5, mod well sorted medium sand | |
| 7 | Erosional contact, yellow sand, blue-gray ripple beds, caps channel, XRD | AO 3-4, mod well sorted fine sand AO 3-7, well sorted fine sand | Channel |
| 8 | Clay with interbeds fine blue-gray sand | AO 3-3, poorly sorted coarse sand AO 3-10, mod sorted med sand | |
| 9 | Laminated sand with few shells | | Foreshore Beach Face |
| 10 | Sand, rip up clasts in upper unit, XRD | AO 3-8, well sorted med sand AO 3-9, mod sort coarse sand | |
| 11 | Sand fill | AO 3-13, well sorted fine sand | |
| 12 | Sand with low angle cross-stratification, shells and gravel on bedding planes | AO 3-12, mod sorted coarse sand | |
| 13 | Beachrock imbricated SE | AO 3-14, hand sample beachrock AO 3-15 thin section | Intertidal |
| 14 | Beachrock, gravel and sand | | |
| 15 | Beachrock, cobbles | | |
| 16 | Sand, oysters, sand dollars | | Subtidal |

Figure 8: Stratigraphic section AO-2




| Unit | Description | Sample | Facies |
|---|---|---|---|
| 1 | Fill | | Alluvium and Aeolian |
| 2 | Cross-bedding, fine to medium sand, aeolian, no root casts | | |
| 3 | Well-sorted medium sand, calcitedroot casts, magnetite, clam shell, pebbles, laminated bedding | | Distal Alluvial Fan and Mudflat |
| 4 | Granules,3.5 cm thick pebbles, shells, coarse sand, cross-laminated SE | | Foreshore Beach Face |
| 5 | Brown sand, blue at base appears white when dried, XRD | AO 3-11, very well sorted fine sand | |
| 6 | Irregular contact, pink coarse sand, pebbles, shells, | AO 3-5, mod well sorted medium sand | |
| 7 | Erosional contact, yellow sand, blue-gray ripple beds, caps channel, XRD | AO 3-4, mod well sorted fine sand AO 3-7, well sorted fine sand | Channel |
| 8 | Clay with interbeds fine blue-gray sand | AO 3-3, poorly sorted coarse sand AO 3-10, mod sorted med sand | |
| 9 | Laminated sand with few shells | | Foreshore Beach Face |
| 10 | Sand, rip up clasts in upper unit, XRD | AO 3-8, well sorted med sand AO 3-9, mod sort coarse sand | |
| 11 | Sand fill | AO 3-13, well sorted fine sand | |
| 12 | Sand with low angle cross-stratification, shells and gravel on bedding planes | AO 3-12, mod sorted coarse sand | |
| 13 | Beachrock imbricated SE | AO 3-14, hand sample beachrock AO 3-15 thin section | Intertidal |
| 14 | Beachrock, gravel and sand | | |
| 15 | Beachrock, cobbles | | |
| 16 | Sand, oysters, sand dollars | | Subtidal |

Figure 9: Stratigraphic section AO-3

Section AO-3 contains 16 units, and is also 7 m in height. The base of the section is unit 16 which is bioturbated sand with sand dollars and oysters. Unit 15 is beachrock encrusted with worm snails and oysters. Unit 14 is beachrock with gravel, sand, shells, and coral fragments. Unit 13 contains beachrock pieces imbricated to the southeast and 3 layers of beachrock. Unit 12 is sand with low-angle cross-stratification containing shells and gravel. Unit 11 is a well-sorted sand fill with convoluted bedding marking the base of the channel, and channel margin trends N10°E. Unit 10 is sand with rip up clasts in the upper channel fill unit. Unit 9 is in the channel and is laminated sand with shells. Unit 8 is blue-gray sand interbedded with clay and is above the channel sequence. Unit 7 is yellow sand at the top overlying blue-gray ripple beds below. Unit 6 denotes an irregular contact and contains pink coarse sand, pebbles and shells. Unit 5 is brown, well-sorted fine sand. Unit 4 is cross-laminated coarse sand trending to the southeast, and contains pebbles. Unit 3 is laminated sand beds with calcite root casts and pebbles. Unit 2 is fine aeolian sand which is cross bedded. The top of section AO-3 is Unit 1 is construction fill from the excavation of the Ayla Oasis Development.

A section referred to as AO-1 is a buried structure and was also sampled and photographed in the field. Grain-size analysis was run on the samples. The top of the structure infilling contained modern debris and was determined to be a modern well. Grain size data is provided in the appendix, but further discussion of the structure is not included in this thesis.

*Facies Model*

The stratigraphy from the AO-2 and AO-3 stratigraphic section and observations from other outcrops in the tidal lagoon construction site was used to divide the sedimentary units

into six different facies: 1) subtidal, 2) beachrock, 3) foreshore, 4) channel, 5) distal alluvial fan/mudflat, and 6) aeolian and alluvium

The oldest exposed horizon is defined as subtidal facies. The layer is partially exposed, and it begins at a depth of 6 m from the surface. This layer is characterized by bioturbated grayish pink sand with pebbles. The well-sorted, fine-grained sand is mesokurtic with symmetrical skew with unimodal distribution. Fauna includes sand dollars and oysters.

Overlying the subtidal zone is a cemented intertidal unit characterized by beachrock (Figure 11). This zone is indicative of the upper shoreface where seawater mixes with freshwater in the swash zone. Beachrock forms in seawater high in calcium carbonate where it mixes with the freshwater lens from groundwater flowing seaward. The water becomes supersaturated with carbonate as carbon dioxide is released resulting in precipitation of carbonate which forms the cement. This layer in the AO-2 section measured 22 cm in thickness and was broken into a disjointed unit. In the AO-3 section, three distinct levels of beachrock were documented. The vertical stacking of the beachrock indicates rising sea level. Encrusting oyster shells (*Spondylus spinosus*) were noted on some cobbles. Encrustation of the worm snails, *Vermetidae* were found on the surface of a beachrock fragment. Thin section analysis shows the beachrock consists of moderately sorted, sub-angular clasts composed of quartz and plagioclase grains, granitic lithic clasts, and some bioclasts. At least one bioclast can be identified as foraminifera (*Rotaliina*). Primary fabric-selective porosity leads to the formation of acicular aragonite crystals forming isopachous growth on the grains in the beachrock. The crystals are arranged perpendicular to the grain surfaces. A micritic envelope encompassing the grains is indicative of microbial activity prior to cementation. The shape and orientation of

the aragonite cement is also indicative of the upper shoreface (Scholl and Ulmer-Scholle, 2003).

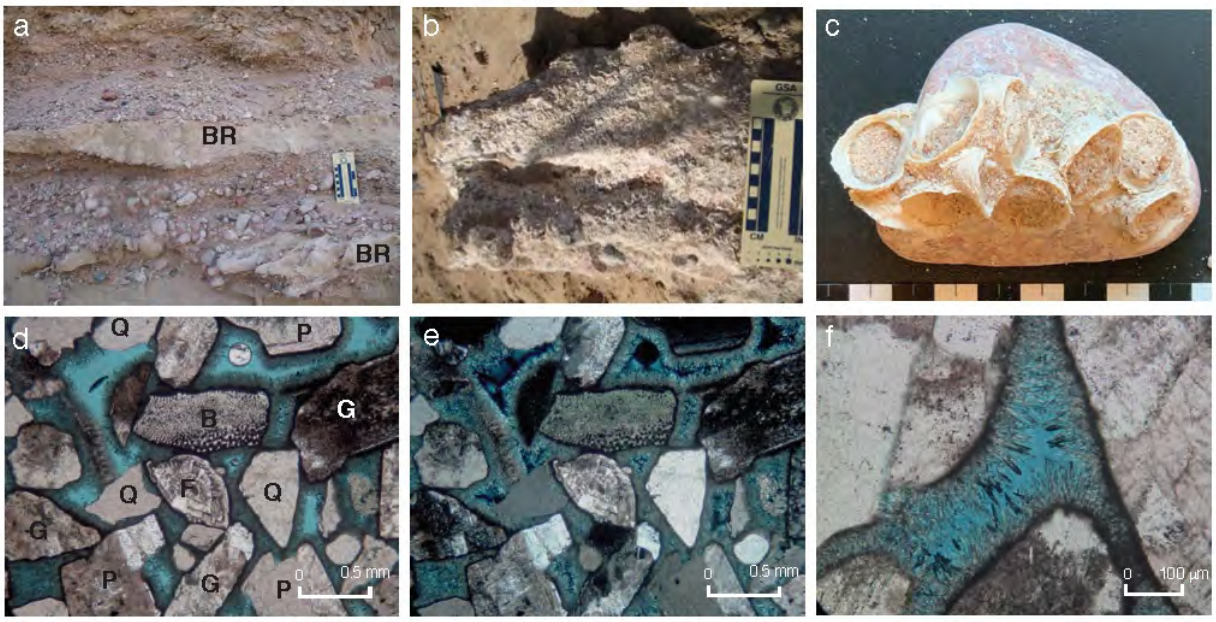



Figure 11: Beachrock exposed in the Ayla Oasis outcrop, hand specimens, and thin sections. a) Photograph of outcrop near section AO-3 showing two levels of beachrock (BR) formation. Scale is 10 cm. b) The surface of a dislodged block of beachrock showing the encrustation of Vermetidae worm snails on the surface. Scale is 10 cm. c) Granite clast from below the cobble unit under the upper beach rock in section AO-3 showing encrustation of the *Spondylus spinosus* oysters. Scale in centimeters. d) Photomicrograph of the beachrock showing the angular coarse sand in plane light. Sand is composed of quartz (Q), plagioclase feldspar (P), and granitic rock fragments and is classified as a feldspathic lithic arenite. Two bioclasts can be identified as a Rotaliina foraminifera (F) and a coral? bioclast (B). e) Photomicrograph of the beachrock shown in (d) in polarized light. f) Detailed photomicrograph of the grain boundary of the beachrock showing acicular aragonite cement typical of the marine intertidal zone (Scholl and Ulmer-Scholle, 2003). Note the micritic coating of the clasts.

Overlying the beachrock facies in the intertidal zone is the beachface measuring just over a meter in thickness and designated the foreshore facies. The foreshore facies is within the swash zone and is characterized by high energy wave activity. The swash zone sometimes cements and sometimes does not. The beachface may also move to higher elevations during a storm. This unit consists of moderately well-sorted medium to coarse grained pinkish brown to pale brown sand with platykurtic coarse skewness which dips gently seaward between 2 and 5 degrees. Wave activity in the swash zone reworks the sediment resulting in the well-sorted nature of the grains. An 85-cm-thick bed of sand, pebbles, and cobbles has gently southwest inclined, parallel bedding, and is capped by cross-bedded sand. A variety of marine shells were found in the foreshore facies corresponding to the intertidal zone from section AO-2 (Figure 12).


Figure 12: Coral and shell fragments found in the intertidal zone section of AO-2. a) *Porites cylindrica* (Dana, 1846), b) *Dosinia anus* (Philippi, 1848), c) *Venus foveolata* (Sowerby, 1853), d) *Lambis Lambis* (Linnaeus, 1758), e) *Cerithium Thericium Lutosum* (Adams, 1845), f) *Cantharus fumosus* (Dillwyn, 1817), g) *Polinices tumidus* (Swanson, 1840), h) *Trochus maculatus* (Linnaeus, 1758) Scale bar = 1cm. Shell identification is based on similarities to mollusk fossils from the Farasan Island in the southern Red Sea, Saudi Arabia (Bantan and Abu-Zied, 2014).

The shells found in the foreshore facies are all marine animals found in shallow water depths of 5 m. *Porites cylindrica* (Dana, 1846), commonly referred to as a "stony coral", is species common in mid-latitude waters. Its habitat includes lagoons and back-reef margins. *Dosinia anus* (Philippi, 1848) and *Venus foveolata* (Sowerby, 1853) are marine clams found in shallow waters with sandy substrate. *Lambis Lambis* (Linnaeus, 1758), is a marine animal, commonly known as a spider conch, found in the warmer waters of the Indo-Pacific. Its habitat includes reef flats with shallow water depths of 5 m. *Cerithium Thericium Lutosum* (Adams, 1845), is a common marine snail with a habitat of very shallow water. *Cantharus fumosus* (Dillwyn, 1817), *Polinices tumidus* (Swanson, 1840),and *Trochus maculatus* (Linnaeus, 1758) are shallow water marine snails commonly found in the Red Sea as throughout the Indo-Pacific. The bivalve shells were found disarticulated, with some abrasion visible. Disarticulation can indicate depositional energy of sediment (El-Sorogy, 2015). Since the shells were disarticulated and given the lack of abrasion on the shells they were likely carried by high energy and subsequently buried by rapid sediment deposition. The beachrock and uncemented beach facies denote the intertidal zone climbing higher in elevation with rising sea level thus moving the beachface farther inland in a transgression. The top of the foreshore facies sediment is capped by an erosional unconformity with irregular relief.

Sporadically across the outcrop are channels filled with a distinct blue-gray sediment (Figures 7 and 10) that was labelled the "blue channels" in the field and are designated as the channel facies.

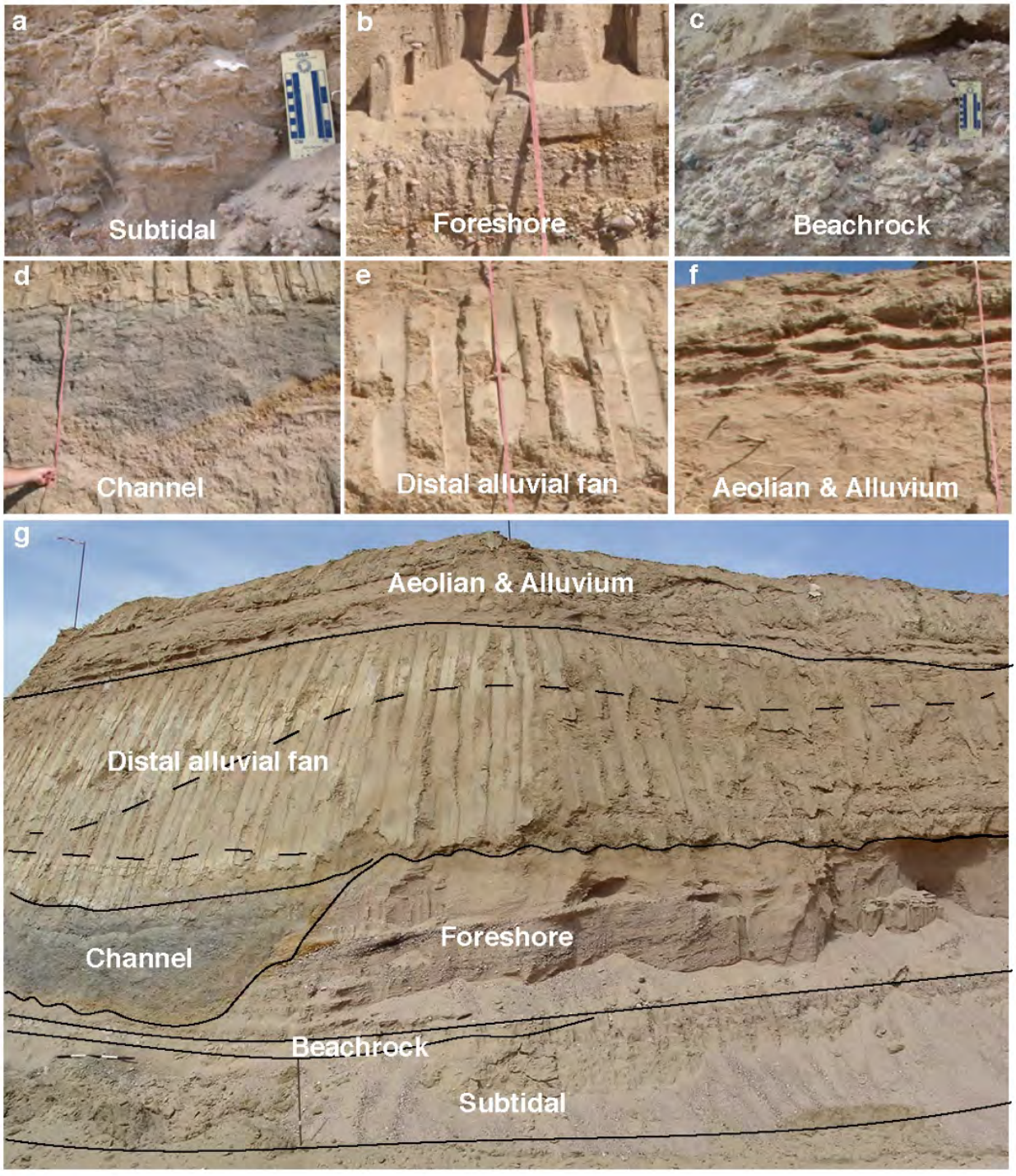



Figure 10: Facies model

The base of the channels cut below present sea level. The erosion at the base of the channel connects with the irregular unconformity at the top of the foreshore facies and they appear to be genetically linked. The channel-fill thickness varies but in places is >1.5 m. Sediment within the channels ranges in color from dark gray at the bottom to grayish brown. The basal layer of the channels has abundant organic-rich material such as roots and wood fragments. Grain size of the sediment is sometimes well-sorted, coarse-to-medium sands. In other places, the channel is filled with sandy gravel that is either structureless or has cross-bedding (Figure 13).

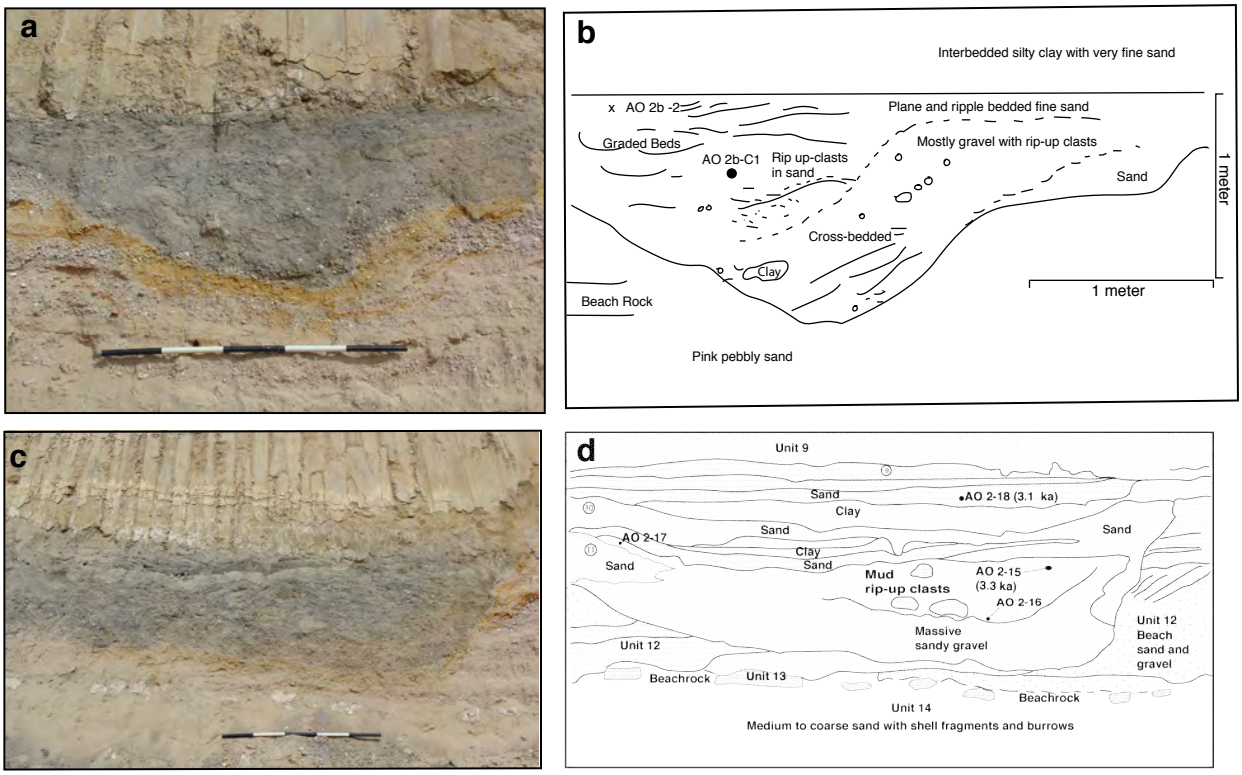



Figure 13: Details of the channel exposed at the AO-2 outcrop.

Rip-up clasts in the channel fill are abundant and composed of mud or fine sand (materials that are uncommon in the foreshore facies). Convoluted beds of sand sometimes make up the basal layer of the channel (Figure 14). The middle layer sometimes contains *Cerithium* gastropods, but woody fragments are abundant. Capping the channel sequences are ripple beds, graded beds, and some plane-bedded sand with organic material in the ripple lag denoting a lowering of flow velocity. Soft-sediment deformation seen as convolute bedding and fluid-escape structures (Figure 14) suggests rapid deposition of water-laden sediment.

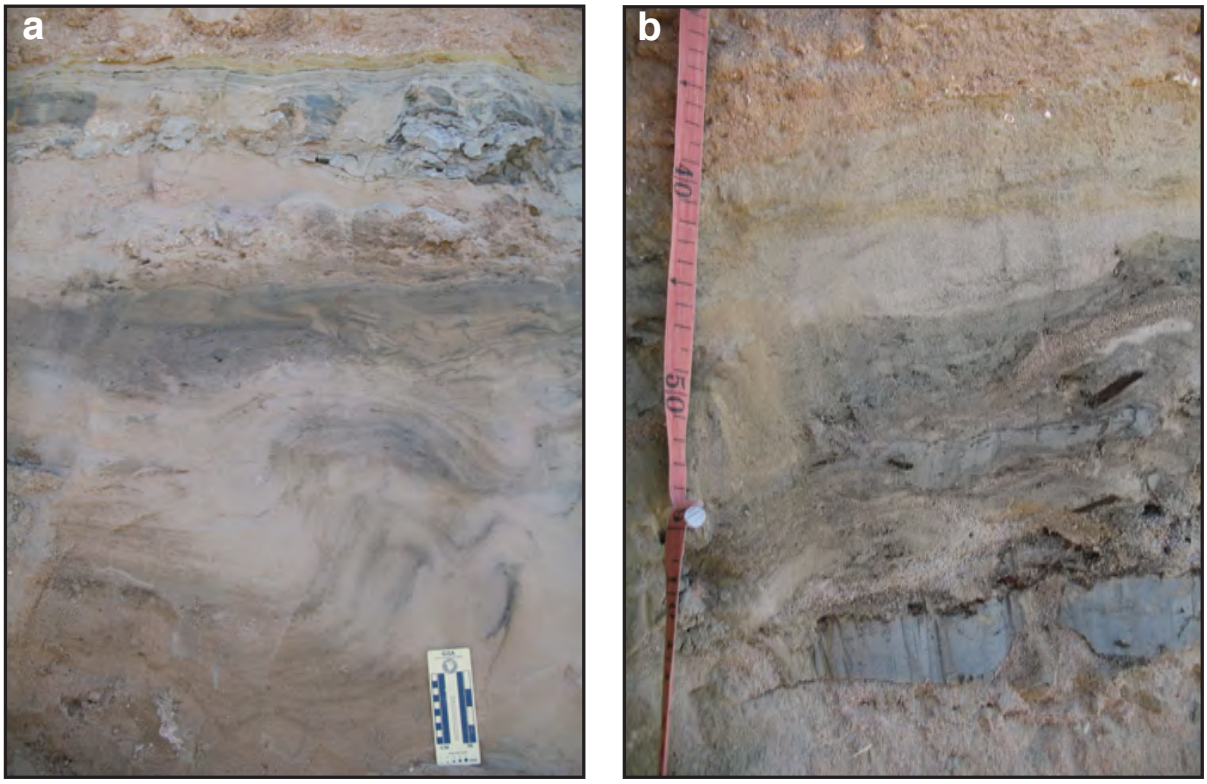



Figure 14: Convolute beds and terrestrial organic matter at the AO-3 outcrop

A distinct change in sedimentation is marked by distal alluvial fan and mudflat facies that overlies either the channel facies or the foreshore facies. The top of the channels are filled with yellow to yellowish brown layers of very well-sorted fine sand with alternating mud layers. The sediment of the distal alluvial fan and mud flat facies range in thickness between 2 to 3 m. The layers consist of interbedded sandy silt with clay directly above the channels to indurated sandy silt in the upper layers of the unit. Carbonate nodules and broken roots are also found in the layers. The sediment is moderately well-sorted fine sand. The top of the fan layer is marked with fine sand, cobbles, and loose roots.

The upper approximately 1 m of section contains ripple bedded and cross-bedded fine to medium sand that is interbedded with mud. The mud sometimes fills ripple swales and has mudcracks. This layer in other places is missing and artificial fill takes its place. The uppermost part of the section was designated as the aeolian and alluvium facies.

*Buried Archaeological Structures*

According to Pratico (1993), the elevation of the top of Tell el-Kheleifeh was measured as 6.83 masl and the 1938-1940 excavations by Nelson Glueck extended to a maximum depth of 4.37 masl. Therefore, the elevation of the land surface at the time of the founding of the settlement was approximately 2.5 masl. The distance from the shoreline to the southern edge of the tell is today about 500 m. Today, the distance from the shoreline to land at approximately 2.5 mbsl is approximately 200 m inland. These calculations suggest that Tel el-Kheleifeh was closer to the shoreline when it was occupied, perhaps a distance of 200 m.

Buried anthropogenic structures were found at the lagoon construction in August 2010 just south of the Tell el-Kheleifeh archaeological site (Figure 15). The map location of Tell el-

Kheleifeh is shown on figures 3 and 6. There are four structures exposed across the outcrop labelled TK-1, TK-2, TK-3, and TK-4.

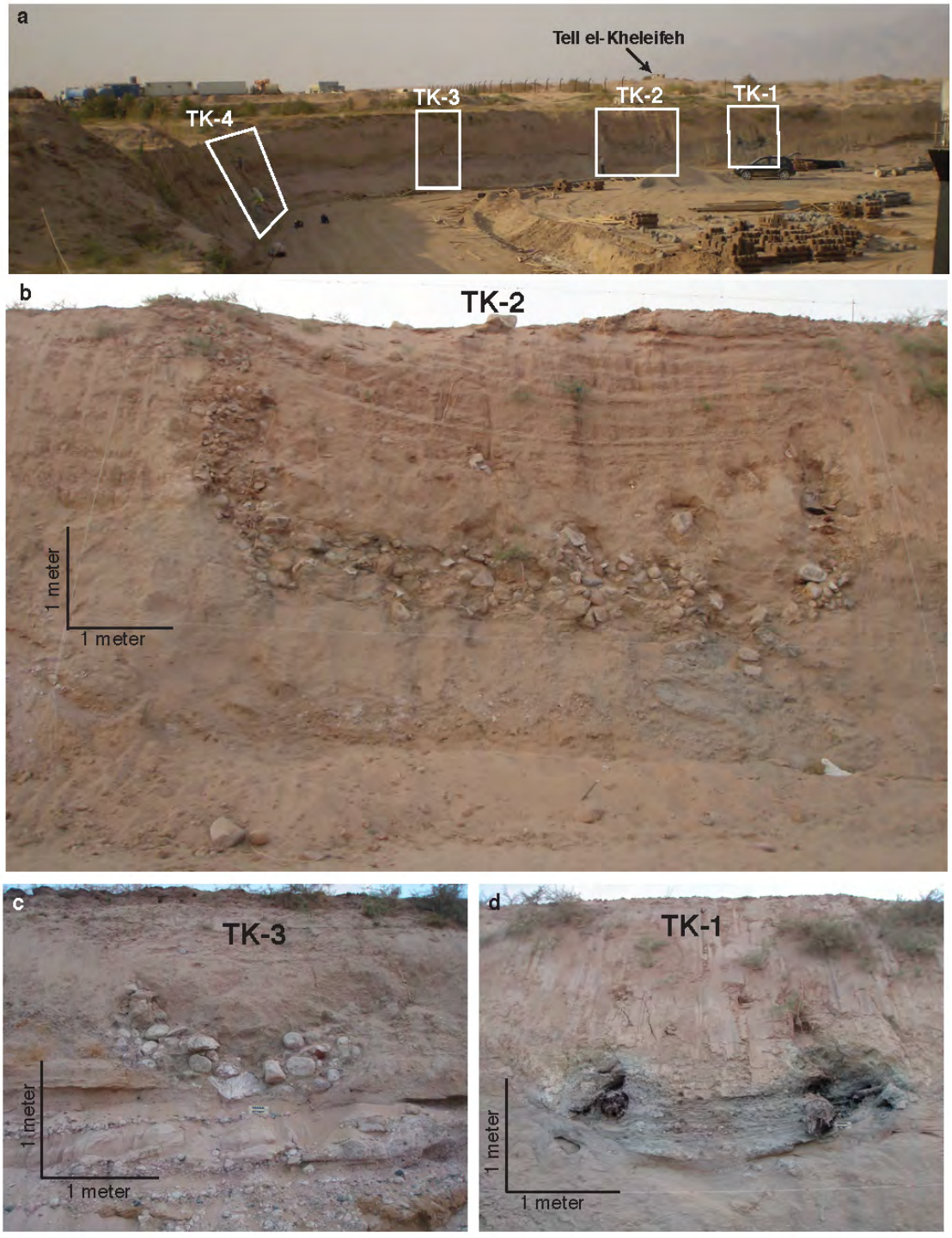



Figure 15: Photographs of buried walls near Tell el-Kheleifeh exposed in the Ayla Oasis lagoon construction in August 2010.

These structures appear to be walls, some with floors or rubble. The purpose of the structures is unknown. The top of the TK-1 structure is approximately 2 m below the surface and is just over 3 m wide. There are no walls at TK-1. There are two trees which appear to be palm trees lying down horizontally. There is a blue-gray sediment in between the trees that is composed of sandy gravel with abundant rip-up clasts interbedded with sand. There is no base to this feature. The feature is channel shaped and cuts into the pink foreshore beach facies. This outcrop may be equivalent to the channel facies exposed at sections AO-2 and AO-3.

The structure at TK-2 is 7 m wide. The top of the wall on the right is buried approximately 1.5 m below the surface. The wall on the left appears to extend to the ground surface, has a foundation trench that appears higher in elevation, and is likely younger than the wall on the right. The wall on the right is associated with a boulder and cobble rubble horizon that extends 7 m horizontally and is at least 1 m thick. Additional walls may be in this section as seen from boulders that are higher in the fill. The fill of TK-2 is pale brown sand with exposed cobbles which is structureless. Above the boulders the infill dips away from the wall on the left and bows into the center of the structure. Under the structure is beachrock overlying sand and pebbles of the foreshore facies.

TK-3 is a smaller structure measuring 2 m across with what appears to be two walls and a floor. The top of each wall structure is approximately a meter below the surface, and floor at its center is at a depth of 2 m. The structure is overlying beachrock and foreshore facies sediment.

The structure and units for TK-4 are outlined in Figure 16 with a corresponding image from the field. The outcrop measures 5.5 m in height. The top of each wall of the TK-4 structure

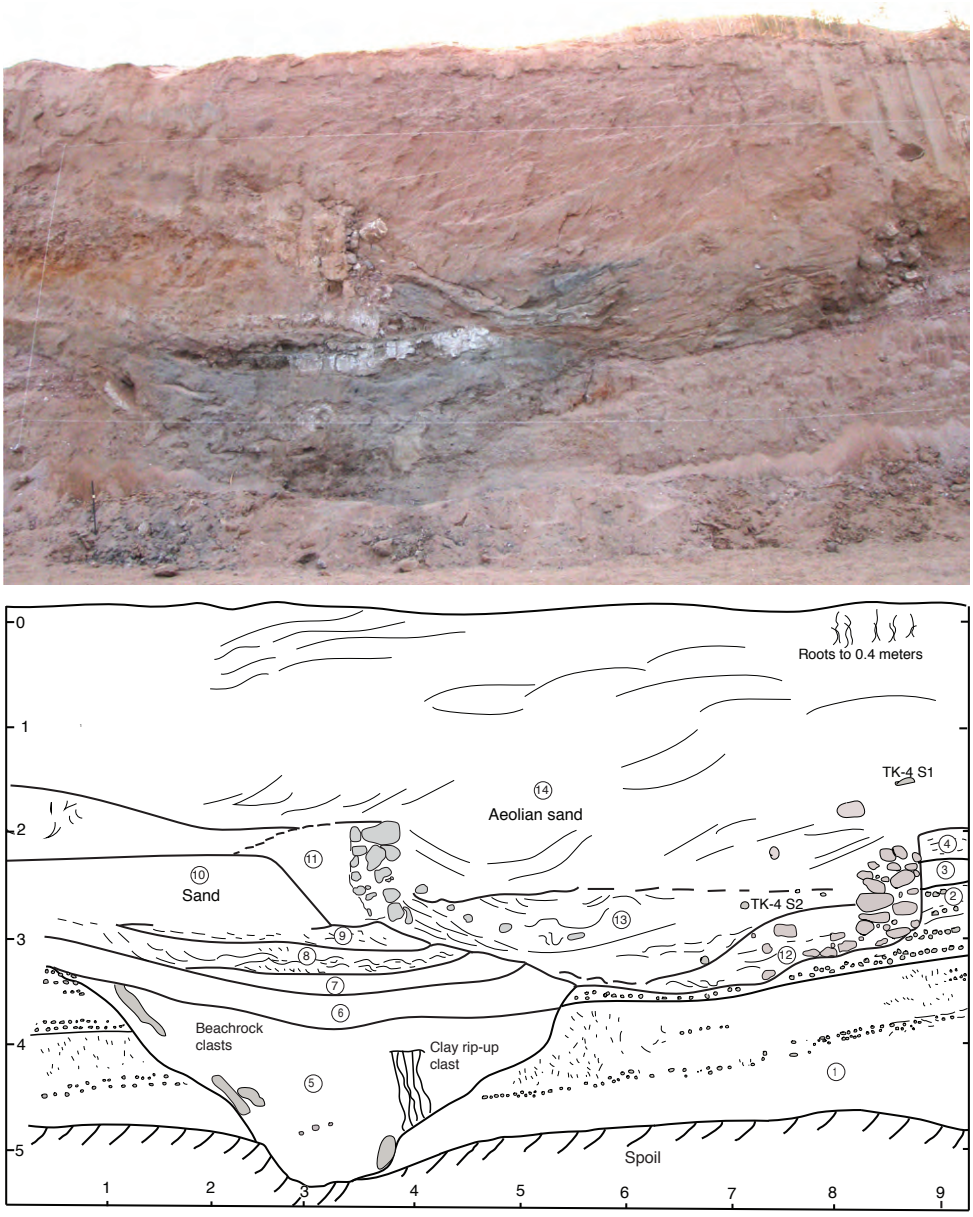



Figure 16: Section drawing of the TK-4 buried structure

is approximately 2 m below the surface and buried by aeolian sands of Unit 14. The walls are about 1 m in height and about 4 m apart. Boulders and cobbles in the wall are composed of granite, coral fragments, and beachrock blocks. The fill in between the walls is about 1.5 m at the center. The lower units in the fill (Units 12 and 13) show evidence of water flow including

cross stratification, ripple beds, and convolute bedding. The structure has no apparent floor and is sitting on top of the subtidal and foreshore facies (Unit 1) which is pink sand interbedded with pebbles, beachrock facies (Unit 3) and the channel facies (Units 5-8).

Beneath the TK-4 structure an erosional channel of blue-gray sediment cuts into the foreshore beach facies. The depth of the base of the channel is approximately 2.5 m which is evidence for erosion below current sea level. The eastern wall was built up against beachrock as indicated in Unit 2 (Figure 16). Given a ground surface elevation of 4 masl, the elevation of the beachrock in Unit 2 is 1.3 masl. The foundation trench (Unit 11) of the western wall was cut into the alluvial fan sediment of Unit 10. The top of Unit 10 is likely the land surface at the time of the walled structure at 2.4 masl as noted by the oxidation of this horizon and root casts.

*Age Control and Elevation*

The results for the radiocarbon analysis from the blue-gray channel and sediment overlying it are given in (Table 1). The sample labeled AO-2-18 was charcoal collected from a depth of 4.2 m from the surface which corresponds to an elevation of -0.2 to -0.6 mbsl, and is above the channel sequence. The calibrated age range for this sample is 2979-3173 cal BP with a median age of 3092 cal BP. This date of 3.1 ka likely caps the event that created the channels. The other sample from AO-2-15 was a wood fragment taken from a depth of 4.6 m which corresponds to an elevation of -0.8 mbsl. The sample was collected from the channel sequence at the AO-2 location. The age range for the sample is 3181-3359 with a median age of 3278 cal BP (i.e. 3.3 ka). The AO-3 sample was also a wood fragment collected at a depth of 3.6 m which corresponds to an elevation around sea level, and is within the channel sequence. The age range is 3609-3826 cal BP with a median age of 3688 cal BP (i.e. 3.7 ka).

The AO-7b sample from within the channel has a mean age of 6.5 ka and is older than the 3.3 ka age from the same channel fill and may be inherited age. These data indicate that the channel likely formed after 3.3 ka and before 3.1 ka.

Surface level for the Ayla Oasis Development prior to excavation for the artificial lagoons was 4 masl at the TK-4, AO-2, and AO-3 sites. The base of the excavation was -3.2 mbsl. The exposures measured 7 m. The channel sequence downcuts through the foreshore sediment to various depths up to 2.5 m. This places the base of the channel and the depth of erosion below modern sea level.

A survey of the outcrop at the Ayla Oasis tidal lagoon site (waypoint track in Figure 3) showed that the foreshore facies extended 700 m inland from the shoreline. The highest elevation of the beachrock was measured in the TK-4 section where it was mapped at 2.7 m below the ground surface. Given that the elevation of the TK-4 site is 4 masl, the beachrock marks a highstand of sea level at +1.3 m. The beachrock was not directly dated but must be older than the channel that cross cuts it which is dated to 3.3 ka. Furthermore, Bruckner (1999) radiocarbon dated a *Codakia* (clam) shell (sample AQ-5) that was collected from a depth of 5.1 m in a borehole located at approximately 340 m from the shoreline was which corresponds to 1.4 mbsl. The recalibrated ages using the Gulf of Aqaba ΔR correction (Table 2) yield a mean probability of 3472 cal BP (i.e. 3.5 ka). The TK-4 beachrock which lies at a higher elevation denoting the sea had transgressed farther inland, must be younger than 3.5 ka.

Brückner (1999) also radiocarbon dated a shell (sample AQ-6) from the marine deposits collected from a depth of 7.7 m in a borehole located approximately 600 m from the shoreline. This corresponds to an elevation of 2.6 mbsl. The shell was dated to the age range 6268-6665 cal BP with a median age of 6459 cal BP (6.5 ka). As the shell was collected from

the subtidal facies which has an assemblage of shells indicating a water depth of 5 m, these data suggest that sea level at 6.5 ka may have already been higher-than-present. We recalibrated his ages using the ΔR correction (Table 2).

# CHAPTER 5

# DISCUSSION

## *Tell el-Kheleifeh*

The age-old question of the location of the Biblical port city of Ezion-Geber remains a mystery despite the assumptions of Frank and Glueck. Pratico (1993) all but confirmed that the ruins of Tell el-Kheleifeh are not Ezion-Geber by re-calibrating the ages of pottery samples collected during Glueck's excavation of the Tell. Bruckner (1999) questioned more the location of tell along the coastline of Aqaba. He speculated ports associated with the ancient settlement are more likely along the eastern coast of Aqaba. Bruckner (1999) surmised that if the Tell was actually the port of Ezion-Geber, given its location of 550 m from the modern coastline, then the shore must have been closer to the Tell in order for the settlement to have been a port. As well, Bruckner (1999) reasoned climate must have been warmer and wetter in order for trees to grow that were suitable to build ships belonging to the port. This is interesting to note with respect to the two overturned trees found in the outcrop at TK-1, although the buried trees appear to have been palm trees.

Bruckner (1999) collected samples from six boreholes that extend from 3 masl to 5 masl elevation along a 700 m transect from the coastline to 100 m north of the archaeological site of Tell el-Kheleifeh. Depths of the cores ranged from 6 m to 9.75 m. From the core data, Bruckner (1999) interpreted a marine transgression at 6 ka with regressive sequences and change to alluvial conditions after 3.5 ka.

*Sea Level Highstand*

Outcrops at the sites AO-2, AO-3, and TK-4 sites in the wall of the lower tidal lagoon construction site at the Ayla Oasis development provided a 3-D exposure of the strata architecture that had never been seen. We define a sequence that includes a lower subtidal facies overlain by beachrock and foreshore facies that were deposited in the intertidal zone. Overlying these beach sediments is an enigmatic unconformity that shows an erosional down-cutting event that extended below present sea level followed by a rapid infilling of the erosional channels. Overlying the erosional event, there is little evidence of continued beachface deposition. Stratigraphically above the channels are layers that include mudflat deposits, distal alluvial fan deposits, and sand dunes.

Our study of the Ayla Oasis tidal lagoon outcrops shows that *in situ* beachrock at the TK-4 site located 500 m inland from the modern shoreline lies at an elevation of 1.3 masl. Mauz et al., (2015) investigated beachrock outcrops along the coast of the Mediterranean Sea and argued that beachrock formation is a reliable indicator for relative sea level change because of the limited geographic locations of coral reefs and of the non-linear growth rate of coral colonies (Montaggioni, 2005). The rapid lithification of beachrock which occurs in decades preserves evidence of the intertidal zone (Hopley, 1986).

Al-Ramadan (2014) studied beachrock from the Gulf of Aqaba and discerned its formation begins with organic processes. He notes that micrite envelopes are around the siliciclastic grains in the Gulf of Aqaba beachrock. The micrite envelopes are microcrystals of high-magnesium calcite (HMC), and Al-Ramadan (2014) suggests the envelopes are the result of boring activity by algae whose decay created anaerobic conditions which led to the carbonate precipitation. The beachrock samples in Al-Ramadan's study also contain acicular

aragonite cement growing perpendicular to the micritic envelopes which he notes are formed through evaporation of seawater during low tides (e.g., Stoddart and Cann, 1965; Hanor, 1978). The beachrock sample from Ayla Oasis has micritic envelopes around the grains with acicular aragonite cement growing perpendicular to the envelopes. Al-Ramadan (2014) draws a conclusion that beachrock cementation is organic by linking algal activity and micritic coatings on the grains. While beachrock formation is fairly rapid, the presence of algae points to the water level at a consistent elevation for a period of time to allow the algae to grow. Given the beachrock at our location has the same features as the beachrock in the Al-Ramadan (2013) study it is likely conditions which lead to algal growth were favorable in the intertidal zone at Ayla Oasis.

At the Ayla Oasis, vertical succession of at least three beachrock layers indicates an aggrading beachface likely due to rising sea level. The highest position of beachrock at the Ayla Oasis outcrops reflects the maximum transgression and is found at 1.3 masl. Bruckner (1999) did not report beachrock in his borehole sediment, and he attributed marine sediments he found above modern sea level to be storm deposits only. In the coring study of Allison and Niemi (2010), a 6 ka marine transgression is overlain with regressive sequences (lagoons, backshore lake, alluvium, and dunes) capped by anthropogenic deposits. The data were not interpreted as evidence for higher-than-present sea level even though marine foraminifera was found in a layer above sea level. This points more to the limitations of methodology as elevation is difficult to record in a coring campaign and the point source data of cores cannot match the newly excavated continuous outcrop of the subsurface.

There is a growing body of evidence that the Gulf of Aqaba and the northern Red Sea had higher-than-present sea level based on elevated coral reefs, elevated wave-cut notches, and

beachrock (Figure 17). Hein et al. (2011) discussed coastal morphology along the Red Sea at the site of Mersa at the Wadi Gawasis in Egypt, and the relationship of those changes with sea level fluctuation, changing climate, and sediment deposition. Their research leads them to conclude a 0.5 to 2 masl at 5 ka was linked to melt after the last glacial maximum and isostatic rebound. Hein et al. (2011) tracked changes in sea level with data from features along the Red Sea Coast. The beachrock from the TK-4 site is included on the curve (Figure 17).

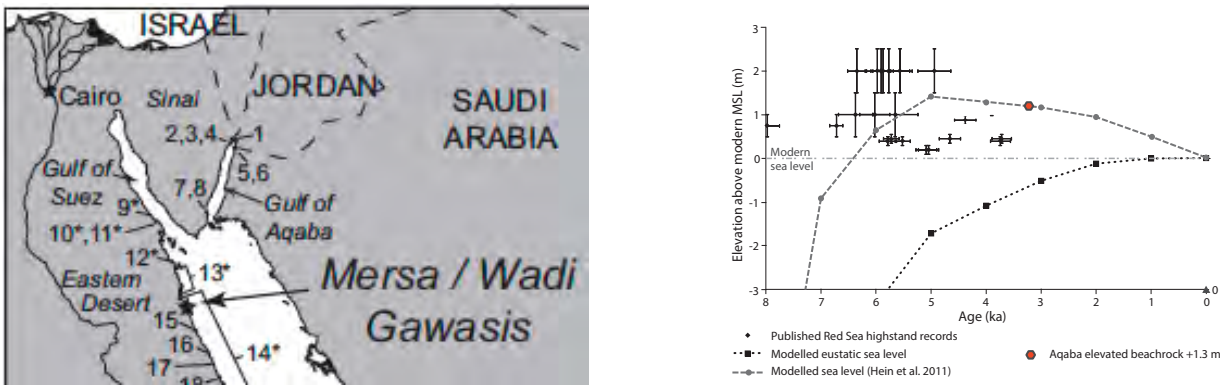



Figure 17: Holocene sea level curve for the Gulf of Aqaba and Northern Red Sea (Hein et al. 2011). See Table 3 for locations of sites.

Other research conducted in the area which points to higher-than-present sea level looked at elevated and buried coral reefs in the Gulf of Aqaba. Al-Rifaiy and Cherif (1988) studied a sequence of fossilized reefs south of Aqaba along the border between Jordan and Saudi Arabia. Their investigation led them to interpret seven terraces of fossil reef units, all above modern sea level, with the most recent unit at the shore and is partially submerged. The terraces vary in height between 1 and 10 m and rise inland by approximately 30 m. Al-Rifaiy and Cherif (1988) determined the terraces were built over three cycles with a 4$^{th}$ cycle of current modern reef growth. The modern reef overlies the submerged terrace. One terrace they studied is located 1-2 masl, and interpreted to be mid-Holocene. They did not use radiocarbon

dating on the organics found in their research, but correlated it to an elevated reef in Eilat (Friedmann, 1965). The elevation however corresponds to beachrock found 1.3 masl at TK-4. They concluded the cycles were determined by changes in eustatic sea level by glacial and interglacial periods in the late Pleistocene. However, they also surmised coastal erosion and tectonic activity to be a factor in reef burial and regrowth.

Shaked et al. (2004) discussed buried coral reefs as proxies for climate and sea level change. They studied a late Holocene reef under the Interuniversity Marine Lab in Eilat, Israel on the Gulf of Aqaba. The buried reef was found under siliciclastic sediments. Pristine preservation of the reef suggested rapid deposition of sediment. Shaked et al (2004) excavated further under the buried reef to discover two distinct periods of growth and destruction of the reef. Their study of the buried reefs suggested a history of a reef developing ca 5 ka at approximately 1 masl. The most recent age from radiometric dating of corals from the buried reef revealed a date of 2.3 ka. Shaked et al. (2004) concluded an earthquake occurred 2300 years ago and buried the reef. These and other studies along the Gulf of Aqaba and the northern Red Sea (Table 3) supports higher-than-present sea level in the mid-Holocene.

Table 3: Holocene higher-than-present sea level indicators along the Gulf of Aqaba and northern Red Sea (Data from Hein et al., 2011)

| Site ID | Site Name | North Lat. | East Long. | Sea Level Marker | Elevation Above Modern MSL | Reported Radiocarbon Age (BP) | Calibrated (1 sigma) Radiocarbon Age OR U/Th Age (BP) | Citation |
|---|---|---|---|---|---|---|---|---|
| 1 | Eilat, Israel, Gulf of Aqaba | 29° 32' | 34° 57' | Coral terrace | -1 m to 1 m | 4770 ± 140 | 4827 ± 211 | Friedman, 1965 |
| 2 | Eilat, Israel, Gulf of Aqaba | 29° 31' | 34° 56' | Emergent reef terrace | 2 m | 4450 - 5750 | 4423 - 6017 | Moustafa et al., 2000 |
| 3 | Eilat, Israel, Gulf of Aqaba | 29° 31' | 34° 56' | Coral terrace | 1 m | N/A | 5380 ± 50 | Shaked et al., 2004 |
| 4 | Eilat, Israel, Gulf of Aqaba | 29° 31' | 34° 56' | Coral terrace | 1 m | N/A | 4960 ± 50 | Shaked et al., 2004 |
| 5 | Jordanian Coast of Gulf of Aqaba | 29° 27' | 34° 58' | Reef Terrace | 0.45 - 0.55 m | 5570 - 6210 | 5774 - 6480 | Dullo and Montaggioni, 1998 |
| 6 | Jordanian Coast of Gulf of Aqaba | 29° 27' | 34° 58' | Reef Terrace | 1 - 2 m | Interpreted as mid-Holocene | N/A | Al-Kifaiy and Cherif, 1988; Bouchon et al., 1981 |
| 7 | Umm-Sid Reef: Esh-Shaura El-Manqata, Egypt | 28° 13' | 34° 26' | Reef Terrace | 0.5 m | Range of dates: 2500 - 6800 (mean 4885) | N/A | Gvirtzman et al., 1992; Gvirtzman, 1994 |
| 8 | Umm-Sid Reef: Maria Schroeder Wreck, Egypt | 28° 11' | 34° 27' | Reef Terrace | 0.5 m | Range of dates: 5300 - 6500 (mean 5800) | N/A | Gvirtzman et al., 1992; Gvirtzman, 1994 |
| 9 | Ras Shukeir, Egypt | 28° 08' | 33° 14' | Coral terrace | 1 m | 5420 ± 350 | 5655 ± 410 | Plaziat et al., 1998 |
| 10 | Ras Dib, Egypt | 28° 01' | 33° 24' | Coral terrace | 2 m | 5740 ± 360 | 5978 ± 395 | Plaziat et al., 1998 |
| 11 | Ras Dib, Egypt | 28° 01' | 33° 24' | Coral terrace | 2 m | 5550 ± 380 | 5773 ± 428 | Plaziat et al., 1998 |
| 12 | Gebel Abu Shaar, Egypt | 27° 18' | 33° 45' | Shell middens | 2 m | 5365 - 6075 | 5572 - 6352 | Plaziat et al., 1998 |
| 13 | Hurghada, Safaga, Giftun Islands, Egypt | 26° 45' to 27° 13' | 33° 58' to 33° 51' | Reef terrace | 0.2 - 0.45 m | 3930 - 5580 | 3721 - 5792 | Dullo and Montaggioni, 1998 |
| 14 | Safaga to Ras Banas, Egypt | 23° 56' to 26° 43' | 35° 29' to 33° 56' | Erosional terrace | 1 m | 5390 - 6410 | 5615 - 6713 | Plaziat et al., 1998 |
| | | | | | | N/A | | |

*Blue-Gray Channels*

The unique aspect of the transgressive and regressive sequence of the Ayla Oasis exposure is the presence of an erosional down-cutting event and subsequent rapid channel infilling that marks the boundary between subtidal and beach sediment and the overlying alluvium and aeolian sediment. The channel erosion cuts to depths that are below modern sea level. In only a few locations, beach sediment is seen above the channel deposits. The data suggest that either sea level rapidly fell below present and rose back up around 3.2 ka, or another mechanism needs to be explored to explain the features. One mechanism that can cause extensive erosion and rapid deposition within channels is a tsunami.

Given the location of the channels found at Ayla Oasis, the distance to the shore could have been closer given the channel sequences cut into the foreshore beach face. This supports evidence sea level was higher-than-present. Sediments found within the erosional channels are congruent with fast-moving water. The color of the sediment in the channels is gray to grayish-blue or dark brown. Sedimentary structures found within the channels include rip-up clasts, cross beds, pebbles, cobbles, and convoluted beds (soft sediment deposition – rapid dewatering – static liquefaction). Massive beds of pebbly sand, rip-up clasts, and soft-sediment deformation structures point towards a possible flood event or tsunami.

Dawson and Stewart (2007) discuss characteristics of tsunami deposit beds in a tectonically active margin. Those features include an erosional base and rip-up clasts. Umitsu et al. (2006) discuss the modern tsunami at Sumatra and the features created by the flow. They note the color of the deposits ranges from white to green to dark gray based on the thickness of the tsunami deposits. They also describe erosional swales created near the beach ridges filled with chaotic tsunami deposits.

Simms et al. (2017) discuss an erosional feature identified in a GPR survey and coring campaign conducted along the Cascadia subduction zone in Northern California. The erosional features are described as cutting to a depth of 1.5 m. Simms et al. (2017) also note an abundance of organic material within the erosional feature and that the erosion extended approximately 110 m inland.

All of the channel-fill sediment at the Ayla Oasis exposures show an abundance of terrestrial vegetation. The blue-gray channels at Ayla Oasis share similar features with modern tsunami deposits along active tectonic margins such as the Chilean coast, Indonesia, and ancient buried features in the Cascadia Subduction Zone. The bedforms and organic material,

color, and sediment size of the channels at Ayla Oasis suggest evidence of tsunami which likely occurred between 3.3 ka and 3.1 ka. The sediment above the blue channels include mudflats and distal alluvial fans, and sand dunes indicating a regression of the shoreline.

# CHAPTER 6

# CONCLUSION

Investigating the sediment and interpreting the facies at AO-2, AO-3, and TK-4 outcrops at Ayla Oasis points to two conclusions. First, beachrock exposed at the TK-4 site is 1.3 m higher than present sea level. Radiocarbon dates from shells below the beachrock and the channel sequence that incised through the beachrock and constrain the age of the beachrock to be younger than 3.5 and older than 3.3 ka. This is significant due to the location of the exposure and its proximity to the archaeological site of Tell el-Kheleifeh, and could possibly lead to a reinterpretation of the purpose of the Tell and its importance in history. Second, the erosional event which led to the formation of the channels marks a boundary between the foreshore facies and distal alluvial deposits. The sedimentary structures and within the channels such as convoluted beds, cross-beds, rip-up clasts, and abundant organic material suggest an event with flow velocity strong enough to downcut 1-2 m through beach deposits followed by rapid infilling. As sea level is not likely to regionally change rapidly, the erosional event is more likely evidence for a local tsunami. Age of sediment in the channel and overlying the channel constrain the event to be between 3.3 ka and 3.1 ka. Since the Gulf of Aqaba and the city of Aqaba lie on an active tectonic plate boundary, the impact of a tsunami stemming from an earthquake could have a significant effect on the inhabitants of the region. Given Aqaba's projected growth over the next decade, the need for increased awareness of tsunami potential in the Gulf of Aqaba is evident.

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# APPENDIX A

## Sample Metadata

**AO - 1**
**Location: 29 32'35" N, 34 58'47" E**

| Sample # | Unit | Munsell Color | Grain Size | Parameters | Field Notes & Lab Analysis |
|---|---|---|---|---|---|
| AO-1 6 | 10 | | C-14 Sample | | Charcoal, Sample not processed |
| AO-1 8 | 10 | 10 YR 4/4 Dark yellowish brown | Moderately well sorted fine sand | Unimodal, Fine Skew, Platykurtic | Above channel, clay layer |
| AO-1 3 | 4 | 5 YR 6/3 Light reddish brown | Moderately well sorted medium sand | Trimodal, Coarse Skew, Platykurtic | Outside wall B, parallel to channel black sediment "very fine sand", shells |
| AO-1 5 | 18 | 7.5 YR 7/4 Pink | Well sorted fine sand | Unimodal, Fine Skew, Very Leptokurtic | Outside wall A, shells in sand layer |
| AO-1 4 | 31 | 10 YR 4/4 Dark yellowish brown | Poorly sorted medium sand | Bimodal, Very Fine Skew, Very Platykurtic | Top of channel, clay |
| AO-1 13 | 22 | 10 YR 5/4 Yellowish brown | Moderately well sorted fine sand | Bimodal, Coarse Skew, Very Leptokurtic | In Channel |
| AO-1 2 | 20 | 10 YR 5/2 Grayish brown | Very wel sorted fine sand | Unimodal, Symmetrical, Platykurtic | In channel, gastropod shells |
| AO-1 1 | 19 | | C-14 Sample | | Charcoal, Sample not processed |
| AO-1 11 | 19 | 7.5 YR 4/1 Dark gray | Well sorted fine sand | Unimodal, Symmetrical, Leptokurtic | In channel top unit 19, carbon layer, gastropod shell, woody fragments, XRD |
| AO-1 12 | 19 | 7.5 YR 4/1 Dark gray | Moderately well sorted fine sand | Unimodal, Coarse skew, Leptokurtic | In channel roots from unit 19, XRD |
| AO-1 9 | 1 | 10 YR 6/3 Pale brown | Well sorted fine sand | Unimodal, Coarse Skew, Mesokurtic | Below channel, pink sand |
| AO-1 10 | 26 | 10 YR 6/3 Pale brown | Well sorted medium sand | Unimodal, Coarse Skew, Mesokurtic | Below channel |
| AO-1 7 | 27 | 5 YR 6/2 Pinkish gray | Well sorted fine sand | Unimodal, Symmetrical, Mesokurtic | Base of unit, blue sand with shells |

**AO - 2**

**Location: 29 32' 40" N, 34 58' 51" E**

| Sample # | Unit | Depth (m) | Munsell Color | Grain Size | Parameters | Field Notes & Lab Analysis |
|---|---|---|---|---|---|---|
| AO-2 4 | 4 | 1.3 | 10 YR 5/6 Yellowish brown | Moderately well sorted fine sand | Unimodal, Coarse Skew, Mesokurtic | Highly weathered granitic cobbles, top of unit possible soil horizon, modern roots, top of unit reddish in color, fine sand, no evident bedding |
| AO-2 5 | 5 | 2.18 | 7.5 YR 6/4 Light brown | Well sorted fine sand | Unimodal, Fine Skew, Platykurtic | Fine sand indurate with calcite, base of pedogenic unit (4&5) possible BK horizon |
| AO-2 6 | 6 | 2.67 | 10 YR 7/3 Very pale brown | Very well sorted very fine sand | Unimodal, Symmetrical, Leptokurtic | Sandy-silty-clay, carbonate nodules & root casts |
| AO-2 7 | 7 | 2.85 | 10 YR 6/4 Light yellowish brown | Moderately well sorted fine sand | Bimodal, Fine Skew, Leptokurtic | Sandy silt, indurated |
| AO-2 8 | 8 | 3.25 | 10 YR 6/4 Light yellowish brown | Moderately well sorted fine sand | Bimodal, Fine Skew, Leptokurtic | XRD, Fine sand, carbonate nodules |
| AO-2 9 | 9 | 3.6 | 10 YR 6/4 Light yellowish brown | Moderately well sorted fine sand | Bimodal, Coarse Skew Mesokurtic | Interbedded sand/silt/clay |
| AO-2 10 | 10 | 4.05 | 7.5 YR 7/2 Pinkish Gray | Moderately well sorted fine sand | Unimodal, Symmetrical, Leptokurtic | Top of channel, gray coarse sand slightly cemented, top of unit iron oxide stain |
| AO-2 18 | 10 | 4.2 | | C-14 Sample | | Charcoal |
| AO-2 15 | 11 | 4.6 | | C-14 Sample | | Wood fragment |
| AO-2 12a | 12 | 5.2 | 7.5 YR 5/4 Brown | Moderately sorted coarse sand | Bimodal, Very Fine Skew, Mesokurtic | Below channel, Rip up clasts, coarse sand, bluish gray |
| AO-2 12b | 12 | 5.4 | 7.5 YR 5/4 Brown | Moderately sorted medium sand | Bimodal, Coarse Skew Platykurtic | 85cm thick parallel inclined bedding, interbedded sand & pebbles, slightly indurated vertical root casts, iron staining at top of unit with sand waves & cross-bedding, clams, gastropod shells. |
| No Sample | | | | Beachrock | | Beachrock 22cm thick broken in disjointed layer (unit sampled at section AO 3) |

**AO - 3**

**Location: 29 32'43" N, 34 58' 53" E**

| Sample # | Unit | Depth (m) | Munsell Color | Grain Size | Parameters | Field Notes & Lab Analysis |
|---|---|---|---|---|---|---|
| AO-3 16 | 11 | 3.2 | | C-14 Sample | | Sample not run |
| AO-3 11 | 5 | 3.2 | Very pale brown | Well sorted very fine sand | Unimodal, Coarse Skew, Mesokurtic | Brown, irregular structure, blue at base rises north, XRD |
| AO-3 5 | 6 | 3.35 | Reddish brown | Moderately well sorted medium sand | Unimodal, Fine Skew, Leptokurtic | Irregular contact, pink coarse sand, loose pebbles, shells (concave up clams, disarticulated below shells) |
| AO-3 4 | 7 | 3.4 | Yellow | Moderately well sorted fine sand | Bimodal, Symmetrical, Very Leptokurtic | Erosional contact yellow sand |
| AO-3 7 | 7 | 3.5 | Grayish brown | Well sorted fine sand | Bimodal, Fine Skew, Very Leptokurtic | In channel, blue-gray ripple bedded sand, caps channel sequence, XRD |
| AO-3 3 | 8 | 3.55 | Gray | Poorly sorted coarse sand | Bimodal, Very Fine Skew, Very Platykurtic | In channel, XRD |
| AO-3 1 | 8 | 3.6 | | C-14 Sample | | Wood fragment |
| AO-3 10 | 8 | 3.64 | Grayish brown | Moderately well sorted fine sand | Bimodal, Fine Skew, Leptokurtic | In channel, fine blue sand interbedded with clay, XRD |
| AO-3 8 | 10 | 3.95 | Light brown | Well sorted medium sand | Unimodal, Symmetrical, Mesokurtic | XRD, Sand with rip up clasts upper part of unit |
| AO-3 9 | 10 | 3.9 | Light yellowish brown | Moderately sorted coarse sand | Bimodal, Very Fine Skew, Platykurtic | Rip up clasts upper unit |
| AO-3 13 | 11 | 4.3 | Yellowish brown | Well sorted fine sand | Unimodal, Symmetrical, Leptokurtic | Sand |
| AO-3 12 | 12 | 4.5 | Pale brown | Moderately sorted coarse sand | Bimodal, Fine Skew, Very Platykurtic | Rip up clasts at channel base |
| AO 3-14 | 14 | 4.5 | | Beachrock with oysters (photo) | | |
| AO-3 15 | 15 | 7.45 | | Beachrock thin section | | |

**TK - 4**

**Location: 29 32'46" N, 34 58'50" E**

Ground Elevation 4masl

Base of Channel 1.5m below present sea level

| Sample # | Unit | Depth (m) | Munsell Color | Grain Size | Parameters | Field Notes & Lab Analysis |
|---|---|---|---|---|---|---|
| TK-4 S1 | 14 | 1.7m | | | | Pottery Sherd - Sample not run |
| TK-4 14 | 14 | 2.0 | 7.5 YR 6/4 Light brown | Moderately well sorted fine sand | Unimodal, Symmetrical, Very Leptokurtic | Top of Unit |
| TK-4 11 | 11 | 2.3 | 7.5 YR 6/3 Light brown | Poorly sorted coarse sand | Polymodal, Very Fine Skew, Platykurtic | Above layer 9, next to layer 10, touches wall A |
| TK-4 3 | 3 | 2.5 | 7.5 YR 6/3 Light brown | Moderately sorted fine sand | Trimodal, Coarse Skew, Leptokurtic | Above layer 2, outside wall B |
| TK-4 S2 | 13 | 2.7m | | | | Pottery Sherd - Sample not run |
| TK-4 2 | 2 | 2.7 | 7.5 YR 7/4 Pink | Moderately sorted fine sand | Bimodal, Coarse Skew, Mesokurtic | Above beachrock, outside wall B, sand with shells and pebbles |
| TK-4 10 | 10 | 2.8 | 7.5 YR 6/3 Light brown | Well sorted fine sand | Unimodal, Coarse Skew, Leptokurtic | Above layer 9, outside wall A |
| TK-4 13 | 13 | 3.0 | 10 YR 5/1 Gray | Well sorted fine sand | Unimodal, Symmetrical, Leptokurtic | Channel inside wall above pink sand, XRD, SEM/EDS, blue-gray sediment with concretions and pyrite framboids |
| TK-4 9 | 9 | 3.2 | 7.5 YR 7/3 Pink | Moderately sorted coarse sand | Bimodal, Very Fine Skew, Platykurtic | Above channel outside wall A |
| TK-4 12 | 12 | 3.3 | 7.5 YR 7/4 Pink | Moderately well sorted fine sand | Bimodal, Symmetrical, Very Leptokurtic | Base of channel inside wall |
| TK-4 8 | 8 | 3.5 | 7.5 YR 7/4 Pink | Moderately well sorted fine sand | Unimodal, Coarse Skew, Leptokurtic | Above channel outside wall A |
| TK-4 6 | 6 | 3.8 | | | | Radiocarbon sample |
| TK-4 5a | 5 | 4.5 | 10 YR 7/3 Very pale brown | Poorly sorted very fine sand | Trimodal, Very Coarse Skew, Very Platykurtic | Above beachrock |
| TK-4 1 | 1 | 4.5 | 7.5 YR 8/4 Pink | Moderately sorted fine sand | Bimodal, Very Coarse Skew, Mesokurtic | Base of Unit, Pink sand capped by beachrock |

# APPENDIX B

Grain Size Logs

Sample Number: AO-1 9, Unit1
Raw Mass (g): 173.10
Dried Mass (g): 173
Field Notes and Descriptors: Pink Sand

| Sieve Number | Diameter (mm) | Mass of Empty Sieve (g) | Mass of Sieve + Soil Retained (g) | Soil Retained (g) | Percent Retained | Grain Size |
|---|---|---|---|---|---|---|
| 10 | 2 | 479 | 480 | 1 | 0.58% | Lg Grains |
| 18 | 1 | 361 | 365 | 4 | 2.31% | VC Sand |
| 30 | 0.60 | 307 | 315 | 8 | 4.62% | Coarse Sand |
| 60 | 0.25 | 283 | 336 | 53 | 30.64% | Med Sand |
| 100 | 0.15 | 265 | 353 | 88 | 50.87% | Fine Sand |
| 230 | 0.075 | 345 | 358 | 13 | 7.51% | VF Sand |
| 270 | 0.053 | 344 | 345 | 1 | 0.58% | Silt |
| Pan | 0.038 | 360 | 360 | 0 | 0.00% | Clay |

Sample Number: AO-1 3, Layer 4
Raw Mass (g): 65.65
Dried Mass (g): 65
Field Notes and Descriptors: Shells, Black VF Sand XRD

| Sieve Number | Diameter (mm) | Mass of Empty Sieve (g) | Mass of Sieve + Soil Retained (g) | Soil Retained (g) | Percent Retained | Grain Size |
|---|---|---|---|---|---|---|
| 10 | 2 | 479 | 485 | 6 | 9.23% | Lg Grains |
| 18 | 1 | 361 | 367 | 6 | 9.23% | VC Sand |
| 30 | 0.60 | 307 | 324 | 17 | 26.15% | Coarse Sand |
| 60 | 0.25 | 283 | 293 | 10 | 15.38% | Med Sand |
| 100 | 0.15 | 265 | 289 | 24 | 39.92% | Fine Sand |
| 230 | 0.075 | 345 | 346 | 1 | 1.54% | VF Sand |
| 270 | 0.053 | 344 | 344 | 0 | 0.00% | Silt |
| Pan | 0.038 | 360 | 361 | 1 | 1.54% | Clay |

Sample Number: AO-1 8, Unit 10
Raw Mass (g): 387
Dried Mass (g): 387
Field Description and Notes: Blue Clay

| Sieve Number | Diameter (mm) | Mass of Empty Sieve (g) | Mass of Sieve + Soil Retained (g) | Soil Retained (g) | Percent Retained | Grain Size |
|---|---|---|---|---|---|---|
| 10 | 2 | 479 | 0 | 0 | 0.00% | Lg Grains |
| 18 | 1 | 361 | 0 | 0 | 0.00% | VC Sand |
| 30 | 0.60 | 307 | 0 | 0 | 0.00% | Coarse Sand |
| 60 | 0.25 | 283 | 0 | 0 | 0.00% | Med Sand |
| 100 | 0.15 | 265 | 361 | 96 | 24.81% | Fine Sand |
| 230 | 0.075 | 345 | 500 | 156 | 40.31% | VF Sand |
| 270 | 0.053 | 344 | 409 | 165 | 16.80% | Silt |
| Pan | 0.038 | 360 | 430 | 70 | 18.09% | Clay |

Sample Number: AO-1 5-1, Unit18
Raw Mass (g): 28.61
Dried Mass (g): 28
Field Description and Notes: Shells

| Sieve Number | Diameter (mm) | Mass of Empty Sieve (g) | Mass of Sieve + Soil Retained (g) | Soil Retained (g) | Percent Retained | Grain Size |
|---|---|---|---|---|---|---|
| 10 | 2 | 479 | 480 | 1 | 3.57% | Lg Grains |
| 18 | 1 | 361 | 361 | 0 | 0.00% | VC Sand |
| 30 | 0.60 | 307 | 307 | 0 | 0.00% | Coarse Sand |
| 60 | 0.25 | 283 | 285 | 2 | 7.14% | Med Sand |
| 100 | 0.15 | 265 | 283 | 18 | 64.30% | Fine Sand |
| 230 | 0.075 | 345 | 350 | 5 | 17.85% | VF Sand |
| 270 | 0.053 | 344 | 346 | 2 | 7.14% | Silt |
| Pan | 0.038 | 360 | 360 | 0 | 0.00% | Clay |

Sample Number: AO-1 11, Carbon top of unit 19
Raw Mass (g): 95.16
Dried Mass (g): 95
Field Descriptors and Notes: XRD, Aquatic gastropod shell, wood (or plant) fragments

| Sieve Number | Diameter (mm) | Mass of Empty Sieve (g) | Mass of Sieve + Soil Retained (g) | Soil Retained (g) | Percent Retained | Grain Size |
|---|---|---|---|---|---|---|
| 10 | 2 | 479 | 479 | 0 | 0.00% | Lg Grains |
| 18 | 1 | 361 | 362 | 1 | 1.05% | VC Sand |
| 30 | 0.60 | 307 | 311 | 4 | 4.21% | Coarse Sand |
| 60 | 0.25 | 283 | 297 | 14 | 14.73% | Med Sand |
| 100 | 0.15 | 265 | 316 | 51 | 53.68% | Fine Sand |
| 230 | 0.075 | 345 | 367 | 22 | 23.16% | VF Sand |
| 270 | 0.053 | 344 | 346 | 2 | 2.11% | Silt |
| Pan | 0.038 | 360 | 361 | 1 | 1.05% | Clay |

Sample Number: AO-1 12, roots from Unit 19
Raw Mass (g): 58
Dried Mass (g): 58
Field Descriptors and Notes: XRD, Bark/Wood, Granules

| Sieve Number | Diameter (mm) | Mass of Empty Sieve (g) | Mass of Sieve + Soil Retained (g) | Soil Retained (g) | Percent Retained | Grain Size |
|---|---|---|---|---|---|---|
| 10 | 2 | 479 | 480 | 1 | 1.72% | Lg Grains |
| 18 | 1 | 361 | 363 | 2 | 3.45% | VC Sand |
| 30 | 0.60 | 307 | 308 | 1 | 1.72% | Coarse Sand |
| 60 | 0.25 | 283 | 293 | 10 | 17.24% | Med Sand |
| 100 | 0.15 | 265 | 298 | 24 | 41.38% | Fine Sand |
| 230 | 0.075 | 345 | 363 | 18 | 31.03% | VF Sand |
| 270 | 0.053 | 344 | 345 | 1 | 1.72% | Silt |
| Pan | 0.038 | 360 | 361 | 1 | 1.72% | Clay |

Sample Number: AO-1 2, Unit20
Raw Mass (g): 5.57
Dried Mass (g): 5.55
Descriptors: Gastropod Shells

| Sieve Number | Diameter (mm) | Mass of Empty Sieve (g) | Mass of Sieve + Soil Retained (g) | Soil Retained (g) | Percent Retained | Grain Size |
|---|---|---|---|---|---|---|
| 10 | 2 | 479 | 479 | 0 | 0.00% | Lg Grains |
| 18 | 1 | 361 | 361 | 0 | 0.00% | VC Sand |
| 30 | 0.60 | 307 | 307 | 0 | 0.00% | Coarse Sand |
| 60 | 0.25 | 283 | 283 | 0 | 0.00% | Med Sand |
| 100 | 0.15 | 265 | 265 | 0 | 0.00% | Fine Sand |
| 230 | 0.075 | 345 | 350 | 5.55 | 100.00% | VF Sand |
| 270 | 0.053 | 344 | 340 | 0 | 0.00% | Silt |
| Pan | 0.038 | 360 | 360 | 0 | 0.00% | Clay |

Sample Number: AO-1 13, Unit 22
Raw Mass (g): 245
Dried Mass (g): 245
Descriptors:

| Sieve Number | Diameter (mm) | Mass of Empty Sieve (g) | Mass of Sieve + Soil Retained (g) | Soil Retained (g) | Percent Retained | Grain Size |
|---|---|---|---|---|---|---|
| 10 | 2 | 479 | 500 | 21 | 8.57% | Lg Grains |
| 18 | 1 | 361 | 364 | 3 | 1.22% | VC Sand |
| 30 | 0.60 | 307 | 310 | 3 | 1.22% | Coarse Sand |
| 60 | 0.25 | 283 | 342 | 59 | 24.08% | Med Sand |
| 100 | 0.15 | 265 | 378 | 113 | 46.12% | Fine Sand |
| 230 | 0.075 | 345 | 388 | 43 | 17.55% | VF Sand |
| 270 | 0.053 | 344 | 346 | 2 | 0.82% | Silt |
| Pan | 0.038 | 360 | 361 | 1 | 0.41% | Clay |

Sample Number: AO 1-10, Unit 26
Raw Mass (g): 198.27
Dried Mass (g): 198
Descriptors: Pink Sand

| Sieve Number | Diameter (mm) | Mass of Empty Sieve (g) | Mass of Sieve + Soil Retained (g) | Soil Retained (g) | Percent Retained | Grain Size |
|---|---|---|---|---|---|---|
| 10 | 2 | 479 | 481 | 2 | 1.01% | Lg Grains |
| 18 | 1 | 361 | 368 | 7 | 3.54% | VC Sand |
| 30 | 0.60 | 307 | 318 | 11 | 5.56% | Coarse Sand |
| 60 | 0.25 | 283 | 370 | 87 | 43.94% | Med Sand |
| 100 | 0.15 | 265 | 347 | 82 | 41.41% | Fine Sand |
| 230 | 0.075 | 345 | 354 | 9 | 4.54% | VF Sand |
| 270 | 0.053 | 344 | 344 | 0 | 0.00% | Silt |
| Pan | 0.038 | 360 | 360 | 0 | 0.00% | Clay |

Sample Number: AO-1 7, Unit21
Raw Mass (g): 127.23
Dried Mass (g): 126
Descriptors: Blue Sand, Large Shell

| Sieve Number | Diameter (mm) | Mass of Empty Sieve (g) | Mass of Sieve + Soil Retained (g) | Soil Retained (g) | Percent Retained | Grain Size |
|---|---|---|---|---|---|---|
| 10 | 2 | 479 | 480 | 1 | 0.79% | Lg Grains |
| 18 | 1 | 361 | 362 | 1 | 0.79% | VC Sand |
| 30 | 0.60 | 307 | 310 | 3 | 2.38% | Coarse Sand |
| 60 | 0.25 | 283 | 318 | 35 | 27.78% | Med Sand |
| 100 | 0.15 | 265 | 331 | 66 | 52.38% | Fine Sand |
| 230 | 0.075 | 345 | 363 | 18 | 14.29% | VF Sand |
| 270 | 0.053 | 344 | 345 | 1 | 0.79% | Silt |
| Pan | 0.038 | 360 | 361 | 1 | 0.79% | Clay |

Sample Number: AO-1 4, Unit31
Raw Mass (g): 45
Dried Mass (g): 45
Descriptors: Clay Sample

| Sieve Number | Diameter (mm) | Mass of Empty Sieve (g) | Mass of Sieve + Soil Retained (g) | Soil Retained (g) | Percent Retained | Grain Size |
|---|---|---|---|---|---|---|
| 10 | 2 | 479 | 0 | 0 | 0.00% | Lg Grains |
| 18 | 1 | 361 | 0 | 0 | 0.00% | VC Sand |
| 30 | 0.60 | 307 | 320 | 12 | 26.67% | Coarse Sand |
| 60 | 0.25 | 283 | 303 | 18 | 40.00% | Med Sand |
| 100 | 0.15 | 265 | 0 | 0 | 0.00% | Fine Sand |
| 230 | 0.075 | 345 | 0 | 0 | 0.00% | VF Sand |
| 270 | 0.053 | 344 | 0 | 0 | 0.00% | Silt |
| Pan | 0.038 | 360 | 375 | 15 | 33.33% | Clay |

Sample Number: AO Sect 2, Unit 4
Raw Mass (g): 98
Dried Mass (g): 97
Descriptors:

| Sieve Number | Diameter (mm) | Mass of Empty Sieve (g) | Mass of Sieve + Soil Retained (g) | Soil Retained (g) | Percent Retained | Grain Size |
|---|---|---|---|---|---|---|
| 10 | 2 | 479 | 481 | 2 | 2.06% | Lg Grains |
| 18 | 1 | 361 | 365 | 4 | 4.12% | VC Sand |
| 30 | 0.60 | 307 | 318 | 11 | 11.34% | Coarse Sand |
| 60 | 0.25 | 283 | 304 | 21 | 21.65% | Med Sand |
| 100 | 0.15 | 265 | 286 | 21 | 21.65% | Fine Sand |
| 230 | 0.075 | 345 | 377 | 32 | 32.99% | VF Sand |
| 270 | 0.053 | 344 | 346 | 2 | 2.06% | Silt |
| Pan | 0.038 | 360 | 364 | 4 | 4.12% | Clay |

Sample Number: AO 2, Unit 5
Raw Mass (g): 27
Dried Mass (g): 27
Descriptors:

| Sieve Number | Diameter (mm) | Mass of Empty Sieve (g) | Mass of Sieve + Soil Retained (g) | Soil Retained (g) | Percent Retained | Grain Size |
|---|---|---|---|---|---|---|
| 10 | 2 | 479 | 479 | 0 | 0.00% | Lg Grains |
| 18 | 1 | 361 | 361 | 0 | 0.00% | VC Sand |
| 30 | 0.60 | 307 | 307 | 0 | 0.00% | Coarse Sand |
| 60 | 0.25 | 283 | 284 | 1 | 3.70% | Med Sand |
| 100 | 0.15 | 265 | 280 | 15 | 55.55% | Fine Sand |
| 230 | 0.075 | 345 | 354 | 9 | 33.33% | VF Sand |
| 270 | 0.053 | 344 | 346 | 2 | 7.40% | Silt |
| Pan | 0.038 | 360 | 360 | 0 | 0.00% | Clay |

Sample Number: AO Sect 2, Unit 6
Raw Mass (g): 425
Dried Mass (g): 385
Descriptors:

| Sieve Number | Diameter (mm) | Mass of Empty Sieve (g) | Mass of Sieve + Soil Retained (g) | Soil Retained (g) | Percent Retained | Grain Size |
|---|---|---|---|---|---|---|
| 10 | 2 | 479 | 479 | 0 | 0.00% | Lg Grains |
| 18 | 1 | 361 | 361 | 0 | 0.00% | VC Sand |
| 30 | 0.60 | 307 | 307 | 0 | 0.00% | Coarse Sand |
| 60 | 0.25 | 283 | 283 | 0 | 0.00% | Med Sand |
| 100 | 0.15 | 265 | 317 | 52 | 13.51% | Fine Sand |
| 230 | 0.075 | 345 | 610 | 266 | 69.10% | VF Sand |
| 270 | 0.053 | 344 | 395 | 51 | 13.25% | Silt |
| Pan | 0.038 | 360 | 376 | 16 | 4.15% | Clay |

Sample Number: AO Sect 2, Unit 7
Raw Mass (g): 124
Dried Mass (g): 124
Descriptors: Limestone (Rounded), Wood or Grass

| Sieve Number | Diameter (mm) | Mass of Empty Sieve (g) | Mass of Sieve + Soil Retained (g) | Soil Retained (g) | Percent Retained | Grain Size |
|---|---|---|---|---|---|---|
| 10 | 2 | 479 | 479 | 0 | 0.00% | Lg Grains |
| 18 | 1 | 361 | 361 | 0 | 0.00% | VC Sand |
| 30 | 0.60 | 307 | 313 | 6 | 4.84% | Coarse Sand |
| 60 | 0.25 | 283 | 298 | 15 | 12.10% | Med Sand |
| 100 | 0.15 | 265 | 314 | 49 | 39.52% | Fine Sand |
| 230 | 0.075 | 345 | 347 | 37 | 29.84% | VF Sand |
| 270 | 0.053 | 344 | 347 | 3 | 2.42% | Silt |
| Pan | 0.038 | 360 | 374 | 14 | 11.29% | Clay |

Sample Number: AO 2-8, Unit 8
Raw Mass (g): 96
Dried Mass (g): 96
Descriptors: XRD Black Sand

| Sieve Number | Diameter (mm) | Mass of Empty Sieve (g) | Mass of Sieve + Soil Retained (g) | Soil Retained (g) | Percent Retained | Grain Size |
|---|---|---|---|---|---|---|
| 10 | 2 | 479 | 479 | 0 | 0.00% | Lg Grains |
| 18 | 1 | 361 | 362 | 1 | 1.04% | VC Sand |
| 30 | 0.60 | 307 | 310 | 3 | 3.13% | Coarse Sand |
| 60 | 0.25 | 283 | 287 | 4 | 4.17% | Med Sand |
| 100 | 0.15 | 265 | 303 | 38 | 39.58% | Fine Sand |
| 230 | 0.075 | 345 | 383 | 38 | 39.58% | VF Sand |
| 270 | 0.053 | 344 | 346 | 2 | 2.08% | Silt |
| Pan | 0.038 | 360 | 370 | 10 | 10.42% | Clay |

Sample Number: AO Sect 2, Unit 9 (3.7m)
Raw Mass (g): 66
Dried Mass (g): 66
Descriptors: XRD

| Sieve Number | Diameter (mm) | Mass of Empty Sieve (g) | Mass of Sieve + Soil Retained (g) | Soil Retained (g) | Percent Retained | Grain Size |
|---|---|---|---|---|---|---|
| 10 | 2 | 479 | 480 | 1 | 1.52% | Lg Grains |
| 18 | 1 | 361 | 365 | 4 | 6.06% | VC Sand |
| 30 | 0.60 | 307 | 313 | 6 | 9.09% | Coarse Sand |
| 60 | 0.25 | 283 | 292 | 9 | 13.64% | Med Sand |
| 100 | 0.15 | 265 | 277 | 12 | 18.18% | Fine Sand |
| 230 | 0.075 | 345 | 365 | 20 | 30.30% | VF Sand |
| 270 | 0.053 | 344 | 348 | 4 | 6.06% | Silt |
| Pan | 0.038 | 360 | 370 | 10 | 15.15% | Clay |

Sample Number: AO Sect 2, Unit 10
Raw Mass (g): 78.70
Dried Mass (g): 78
Descriptors: Wood Fragment

| Sieve Number | Diameter (mm) | Mass of Empty Sieve (g) | Mass of Sieve + Soil Retained (g) | Soil Retained (g) | Percent Retained | Grain Size |
|---|---|---|---|---|---|---|
| 10 | 2 | 479 | 480 | 1 | 1.28% | Lg Grains |
| 18 | 1 | 361 | 364 | 3 | 3.85% | VC Sand |
| 30 | 0.60 | 307 | 313 | 6 | 7.69% | Coarse Sand |
| 60 | 0.25 | 283 | 306 | 23 | 29.49% | Med Sand |
| 100 | 0.15 | 265 | 294 | 29 | 37.18% | Fine Sand |
| 230 | 0.075 | 345 | 356 | 11 | 14.10% | VF Sand |
| 270 | 0.053 | 344 | 345 | 1 | 1.28% | Silt |
| Pan | 0.038 | 360 | 364 | 4 | 5.13% | Clay |

Sample Number: AO 2-12a
Raw Mass (g): 154
Dried Mass (g): 154
Descriptors: Unit 12, Black Stain

| Sieve Number | Diameter (mm) | Mass of Empty Sieve (g) | Mass of Sieve + Soil Retained (g) | Soil Retained (g) | Percent Retained | Grain Size |
|---|---|---|---|---|---|---|
| 10 | 2 | 479 | 573 | 94 | 61.03% | Lg Grains |
| 18 | 1 | 361 | 379 | 18 | 11.69% | VC Sand |
| 30 | 0.60 | 307 | 319 | 12 | 7.79% | Coarse Sand |
| 60 | 0.25 | 283 | 290 | 7 | 4.54% | Med Sand |
| 100 | 0.15 | 265 | 284 | 19 | 12.34% | Fine Sand |
| 230 | 0.075 | 345 | 348 | 3 | 1.95% | VF Sand |
| 270 | 0.053 | 344 | 344 | 0 | 0.00% | Silt |
| Pan | 0.038 | 360 | 361 | 1 | 0.650% | Clay |

Sample Number: AO 2-12b
Raw Mass (g): 133
Descriptors: Large shells, coral, granite pebbles

| Sieve Number | Diameter (mm) | Mass of Empty Sieve (g) | Mass of Sieve + Soil Retained (g) | Soil Retained (g) | Percent Retained | Grain Size |
|---|---|---|---|---|---|---|
| 10 | 2 | 479 | 537 | 58 | 43.61% | Lg Grains |
| 18 | 1 | 361 | 362 | 1 | 0.75% | VC Sand |
| 30 | 0.60 | 307 | 369 | 61 | 45.86% | Coarse Sand |
| 60 | 0.25 | 283 | 295 | 10 | 7.52% | Med Sand |
| 100 | 0.15 | 265 | 266 | 1 | 0.75% | Fine Sand |
| 230 | 0.075 | 345 | 346 | 1 | 0.75% | VF Sand |
| 270 | 0.053 | 344 | 345 | 1 | 0.75% | Silt |
| Pan | 0.038 | 360 | 0 | 0 | 0.000% | Clay |

Sample Number: AO 3-11
Raw Mass (g): 259
Dried Mass (g): 256
Descriptors: Brown Clay, XRD

| Sieve Number | Diameter (mm) | Mass of Empty Sieve (g) | Mass of Sieve + Soil Retained (g) | Soil Retained (g) | Percent Retained | Grain Size |
|---|---|---|---|---|---|---|
| 10 | 2 | 479 | 479 | 0 | 0.00% | Lg Grains |
| 18 | 1 | 361 | 361 | 0 | 0.00% | VC Sand |
| 30 | 0.60 | 307 | 307 | 0 | 0.00% | Coarse Sand |
| 60 | 0.25 | 283 | 288 | 5 | 1.95% | Med Sand |
| 100 | 0.15 | 265 | 302 | 37 | 14.45% | Fine Sand |
| 230 | 0.075 | 345 | 408 | 63 | 24.61% | VF Sand |
| 270 | 0.053 | 344 | 469 | 125 | 48.83% | Silt |
| Pan | 0.038 | 360 | 386 | 26 | 10.15% | Clay |
| | | | | | | |

Sample Number: AO 3-5
Raw Mass (g): 196
Dried Mass (g): 195
Descriptors:

| Sieve Number | Diameter (mm) | Mass of Empty Sieve (g) | Mass of Sieve + Soil Retained (g) | Soil Retained (g) | Percent Retained | Grain Size |
|---|---|---|---|---|---|---|
| 10 | 2 | 479 | 491 | 12 | 6.15% | Lg Grains |
| 18 | 1 | 361 | 418 | 57 | 29.23% | VC Sand |
| 30 | 0.60 | 307 | 395 | 88 | 45.13% | Coarse Sand |
| 60 | 0.25 | 283 | 301 | 18 | 9.23% | Med Sand |
| 100 | 0.15 | 265 | 280 | 15 | 7.69% | Fine Sand |
| 230 | 0.075 | 345 | 350 | 5 | 2.56% | VF Sand |
| 270 | 0.053 | 344 | 344 | 0 | 0.00% | Silt |
| Pan | 0.038 | 360 | 360 | 0 | 0.00% | Clay |

Sample Number: AO 3-4
Raw Mass (g): 348
Dried Mass (g): 213
Descriptors:

| Sieve Number | Diameter (mm) | Mass of Empty Sieve (g) | Mass of Sieve + Soil Retained (g) | Soil Retained (g) | Percent Retained | Grain Size |
|---|---|---|---|---|---|---|
| 10 | 2 | 479 | 483 | 4 | 1.88% | Lg Grains |
| 18 | 1 | 361 | 363 | 2 | 0.94% | VC Sand |
| 30 | 0.60 | 307 | 309 | 2 | 0.94% | Coarse Sand |
| 60 | 0.25 | 283 | 290 | 7 | 3.29% | Med Sand |
| 100 | 0.15 | 265 | 312 | 47 | 22.06% | Fine Sand |
| 230 | 0.075 | 345 | 466 | 121 | 56.81% | VF Sand |
| 270 | 0.053 | 344 | 354 | 10 | 4.69% | Silt |
| Pan | 0.038 | 360 | 380 | 20 | 9.39% | Clay |

Sample Number: AO 3-7, Sect 7
Raw Mass (g): 461
Dried Mass (g): 458
Descriptors: XRD, Snail Shells & Fragments, Wood Fragments

| Sieve Number | Diameter (mm) | Mass of Empty Sieve (g) | Mass of Sieve + Soil Retained (g) | Soil Retained (g) | Percent Retained | Grain Size |
|---|---|---|---|---|---|---|
| 10 | 2 | 479 | 480 | 1 | 0.22% | Lg Grains |
| 18 | 1 | 361 | 363 | 2 | 0.44% | VC Sand |
| 30 | 0.60 | 307 | 311 | 4 | 0.87% | Coarse Sand |
| 60 | 0.25 | 283 | 294 | 11 | 2.40% | Med Sand |
| 100 | 0.15 | 265 | 298 | 33 | 7.21% | Fine Sand |
| 230 | 0.075 | 345 | 677 | 332 | 72.49% | VF Sand |
| 270 | 0.053 | 344 | 354 | 10 | 2.18% | Silt |
| Pan | 0.038 | 360 | 425 | 65 | 14.19% | Clay |

Sample Number: AO 3-10, unit 8
Raw Mass (g): 80
Dried Mass (g): 80
Descriptors: Blue Sand

| Sieve Number | Diameter (mm) | Mass of Empty Sieve (g) | Mass of Sieve + Soil Retained (g) | Soil Retained (g) | Percent Retained | Grain Size |
|---|---|---|---|---|---|---|
| 10 | 2 | 479 | 479 | 0 | 0.00% | Lg Grains |
| 18 | 1 | 361 | 362 | <1 | 0.00% | VC Sand |
| 30 | 0.60 | 307 | 308 | <1 | 0.00% | Coarse Sand |
| 60 | 0.25 | 283 | 283 | <1 | 0.00% | Med Sand |
| 100 | 0.15 | 265 | 291 | 26 | 32.09% | Fine Sand |
| 230 | 0.075 | 345 | 383 | 38 | 46.91% | VF Sand |
| 270 | 0.053 | 344 | 349 | 5 | 6.17% | Silt |
| Pan | 0.038 | 360 | 372 | 12 | 14.81% | Clay |

Sample Number: AO 3-3, Unit 8
Raw Mass (g): 637
Dried Mass (g): 636
Descriptors: XRD

| Sieve Number | Diameter (mm) | Mass of Empty Sieve (g) | Mass of Sieve + Soil Retained (g) | Soil Retained (g) | Percent Retained | Grain Size |
|---|---|---|---|---|---|---|
| 10 | 2 | 479 | 650 | 171 | 26.89% | Lg Grains |
| 18 | 1 | 361 | 485 | 124 | 19.50% | VC Sand |
| 30 | 0.60 | 307 | 371 | 64 | 10.06% | Coarse Sand |
| 60 | 0.25 | 283 | 320 | 37 | 5.82% | Med Sand |
| 100 | 0.15 | 265 | 332 | 67 | 10.53% | Fine Sand |
| 230 | 0.075 | 345 | 432 | 87 | 13.68% | VF Sand |
| 270 | 0.053 | 344 | 397 | 53 | 8.33% | Silt |
| Pan | 0.038 | 360 | 393 | 33 | 5.19% | Clay |

Sample Number: AO 3-12, Base Channel
Raw Mass (g): 154
Dried Mass (g): 153
Descriptors: Granite Pebbles

| Sieve Number | Diameter (mm) | Mass of Empty Sieve (g) | Mass of Sieve + Soil Retained (g) | Soil Retained (g) | Percent Retained | Grain Size |
|---|---|---|---|---|---|---|
| 10 | 2 | 479 | 522 | 43 | 28.10% | Lg Grains |
| 18 | 1 | 361 | 384 | 23 | 15.03% | VC Sand |
| 30 | 0.60 | 307 | 322 | 15 | 4.66% | Coarse Sand |
| 60 | 0.25 | 283 | 296 | 13 | 8.49% | Med Sand |
| 100 | 0.15 | 265 | 307 | 42 | 27.45% | Fine Sand |
| 230 | 0.075 | 345 | 357 | 12 | 3.36% | VF Sand |
| 270 | 0.053 | 344 | 349 | 5 | 1.43% | Silt |
| Pan | 0.038 | 360 | 360 | 0 | 0.00% | Clay |

Sample Number: AO 3-8, Unit 10
Raw Mass (g): 330
Dried Mass (g): 330
Descriptors: Clam Shell Fragment

| Sieve Number | Diameter (mm) | Mass of Empty Sieve (g) | Mass of Sieve + Soil Retained (g) | Soil Retained (g) | Percent Retained | Grain Size |
|---|---|---|---|---|---|---|
| 10 | 2 | 479 | 483 | 4 | 1.21% | Lg Grains |
| 18 | 1 | 361 | 372 | 11 | 3.33% | VC Sand |
| 30 | 0.60 | 307 | 326 | 19 | 5.76% | Coarse Sand |
| 60 | 0.25 | 283 | 461 | 178 | 53.94% | Med Sand |
| 100 | 0.15 | 265 | 373 | 108 | 32.73% | Fine Sand |
| 230 | 0.075 | 345 | 354 | 9 | 2.73% | VF Sand |
| 270 | 0.053 | 344 | 345 | 0 | 0.30% | Silt |
| Pan | 0.038 | 360 | 361 | <1 | 0.00% | Clay |

Sample Number: AO 3-9, Unit 10
Raw Mass (g): 283
Dried Mass (g): 283
Descriptors:

| Sieve Number | Diameter (mm) | Mass of Empty Sieve (g) | Mass of Sieve + Soil Retained (g) | Soil Retained (g) | Percent Retained | Grain Size |
|---|---|---|---|---|---|---|
| 10 | 2 | 479 | 594 | 115 | 40.63% | Lg Grains |
| 18 | 1 | 361 | 424 | 63 | 22.26% | VC Sand |
| 30 | 0.60 | 307 | 337 | 30 | 10.60% | Coarse Sand |
| 60 | 0.25 | 283 | 302 | 19 | 6.70% | Med Sand |
| 100 | 0.15 | 265 | 295 | 30 | 10.60% | Fine Sand |
| 230 | 0.075 | 345 | 360 | 15 | 5.30% | VF Sand |
| 270 | 0.053 | 344 | 352 | 8 | 2.82% | Silt |
| Pan | 0.038 | 360 | 363 | 3 | 1.06% | Clay |

Sample Number: AO 3-13, Unit 11
Raw Mass (g): 270
Dried Mass (g): 270
Descriptors:

| Sieve Number | Diameter (mm) | Mass of Empty Sieve (g) | Mass of Sieve + Soil Retained (g) | Soil Retained (g) | Percent Retained | Grain Size |
|---|---|---|---|---|---|---|
| 10 | 2 | 479 | 479 | 0 | 0.00% | Lg Grains |
| 18 | 1 | 361 | 362 | 1 | 0.37% | VC Sand |
| 30 | 0.60 | 307 | 310 | 3 | 1.10% | Coarse Sand |
| 60 | 0.25 | 283 | 350 | 67 | 24.80% | Med Sand |
| 100 | 0.15 | 265 | 416 | 151 | 55.93% | Fine Sand |
| 230 | 0.075 | 345 | 385 | 40 | 14.90% | VF Sand |
| 270 | 0.053 | 344 | 346 | 2 | 0.74% | Silt |
| Pan | 0.038 | 360 | 366 | 6 | 2.22% | Clay |

Sample Number: TK 4-1
Raw Mass (g): 20
Dried Mass (g): 20
Descriptors: shells & coral mass 167g (removed prior to sorting)

| Sieve Number | Diameter (mm) | Mass of Empty Sieve (g) | Mass of Sieve + Soil Retained (g) | Soil Retained (g) | Percent Retained % | Grain Size |
|---|---|---|---|---|---|---|
| 20 | 0.85 | 57 | 58.67 | 1.67 | 8.35 | Lg Grains |
| 30 | 0.60 | 56.75 | 59.47 | 2.72 | 13.60 | VC Sand |
| 40 | 0.42 | 55.5 | 56.47 | 0.97 | 4.85 | Coarse Sand |
| 60 | 0.25 | 53.2 | 57.93 | 2.73 | 13.65 | Med Sand |
| 100 | 0.15 | 53 | 63.87 | 10.87 | 54.35 | Fine Sand |
| 230 | 0.063 | 51.7 | 52.63 | 0.93 | 4.65 | VF Sand |
| Pan | 0.038 | 65.76 | 65.87 | 0.11 | 0.55 | Clay |

Sample Number: TK 4-2
Raw Mass (g): 4.84
Dried Mass (g): 4.84
Descriptors: shells & coral mass 55g (removed prior to sorting)

| Sieve Number | Diameter (mm) | Mass of Empty Sieve (g) | Mass of Sieve + Soil Retained (g) | Soil Retained (g) | Percent Retained | Grain Size |
|---|---|---|---|---|---|---|
| 20 | 0.85 | 57 | 57.4 | 0.27 | 5.58% | Lg Grains |
| 30 | 0.60 | 56.75 | 57.59 | 0.84 | 17.35% | VC Sand |
| 40 | 0.42 | 55.5 | 55.82 | 0.32 | 6.61% | Coarse Sand |
| 60 | 0.25 | 53.2 | 55.76 | 0.56 | 11.57% | Med Sand |
| 100 | 0.15 | 53 | 55.14 | 2.01 | 41.53% | Fine Sand |
| 230 | 0.063 | 51.7 | 52.24 | 0.54 | 11.16% | VF Sand |
| Pan | 0.038 | 65.5 | 65.8 | 0.3 | 6.20% | Clay |

Sample Number: TK 4-3
Raw Mass (g): 108
Dried Mass (g): 108
Descriptors:

| Sieve Number | Diameter (mm) | Mass of Empty Sieve (g) | Mass of Sieve + Soil Retained (g) | Soil Retained (g) | Percent Retained | Grain Size |
|---|---|---|---|---|---|---|
| 20 | 0.85 | 338 | 348 | 10 | 9.26% | Lg Grains |
| 30 | 0.60 | 307 | 317 | 10 | 9.26% | VC Sand |
| 40 | 0.42 | 299 | 316 | 17 | 15.74% | Coarse Sand |
| 60 | 0.25 | 283 | 292 | 9 | 8.33% | Med Sand |
| 100 | 0.15 | 265 | 308 | 43 | 39.81% | Fine Sand |
| 230 | 0.063 | 248 | 261 | 13 | 12.04% | VF Sand |
| Pan | 0.038 | 361 | 367 | 6 | 5.56% | Clay |

Sample Number: TK 4-4
Raw Mass (g): 176
Dried Mass (g): 176
Descriptors:

| Sieve Number | Diameter (mm) | Mass of Empty Sieve (g) | Mass of Sieve + Soil Retained (g) | Soil Retained (g) | Percent Retained | Grain Size |
|---|---|---|---|---|---|---|
| 20 | 0.85 | 338 | 387 | 49 | 27.84% | Lg Grains |
| 30 | 0.60 | 307 | 324 | 17 | 9.66% | VC Sand |
| 40 | 0.42 | 299 | 314 | 15 | 8.52% | Coarse Sand |
| 60 | 0.25 | 283 | 295 | 12 | 6.82% | Med Sand |
| 100 | 0.15 | 265 | 305 | 40 | 22.73% | Fine Sand |
| 230 | 0.063 | 248 | 277 | 29 | 16.48% | VF Sand |
| Pan | 0.038 | 361 | 375 | 14 | 7.95% | Clay |

Sample Number: TK 4-5A
Raw Mass (g): 20
Dried Mass (g): 20
Descriptors:

| Sieve Number | Diameter (mm) | Mass of Empty Sieve (g) | Mass of Sieve + Soil Retained (g) | Soil Retained (g) | Percent Retained | Grain Size |
|---|---|---|---|---|---|---|
| 20 | 0.85 | 338 | 342 | 4 | 20.00% | Lg Grains |
| 30 | 0.60 | 307 | 308 | 1 | 5.00% | VC Sand |
| 40 | 0.42 | 299 | 300 | 1 | 5.00% | Coarse Sand |
| 60 | 0.25 | 283 | 284 | 1 | 5.00% | Med Sand |
| 100 | 0.15 | 265 | 267 | 2 | 10.00% | Fine Sand |
| 230 | 0.063 | 248 | 251 | 3 | 15.00% | VF Sand |
| Pan | 0.038 | 361 | 369 | 8 | 40.00% | Clay |

Sample Number: TK 4-8
Raw Mass (g): 67
Dried Mass (g): 67
Descriptors:

| Sieve Number | Diameter (mm) | Mass of Empty Sieve (g) | Mass of Sieve + Soil Retained (g) | Soil Retained (g) | Percent Retained | Grain Size |
|---|---|---|---|---|---|---|
| 20 | 0.85 | 338 | 339 | 1.8 | 2.69% | Lg Grains |
| 30 | 0.60 | 307 | 309 | 2.2 | 3.28% | VC Sand |
| 40 | 0.42 | 299 | 304 | 5 | 7.46% | Coarse Sand |
| 60 | 0.25 | 283 | 301 | 18 | 26.86% | Med Sand |
| 100 | 0.15 | 265 | 300 | 35 | 52.24% | Fine Sand |
| 230 | 0.063 | 248 | 251 | 3 | 4.48% | VF Sand |
| Pan | 0.038 | 361 | 363 | 2 | 2.99% | Clay |

Sample Number: TK 4-9
Raw Mass (g): 74
Dried Mass (g): 74
Descriptors:

| Sieve Number | Diameter (mm) | Mass of Empty Sieve (g) | Mass of Sieve + Soil Retained (g) | Soil Retained (g) | Percent Retained | Grain Size |
|---|---|---|---|---|---|---|
| 20 | 0.85 | 338 | 380 | 42 | 56.76% | Lg Grains |
| 30 | 0.60 | 307 | 314 | 7 | 9.46% | VC Sand |
| 40 | 0.42 | 299 | 304 | 5 | 6.76% | Coarse Sand |
| 60 | 0.25 | 283 | 285 | 2 | 2.70% | Med Sand |
| 100 | 0.15 | 265 | 273 | 8 | 13.51% | Fine Sand |
| 230 | 0.063 | 248 | 255 | 7 | 9.46% | VF Sand |
| Pan | 0.038 | 361 | 361 | 0.99 | 1.35% | Clay |

Sample Number: TK 4-10
Raw Mass (g): 50
Dried Mass (g): 50
Descriptors:

| Sieve Number | Diameter (mm) | Mass of Empty Sieve (g) | Mass of Sieve + Soil Retained (g) | Soil Retained (g) | Percent Retained | Grain Size |
|---|---|---|---|---|---|---|
| 20 | 0.85 | 338 | 339 | 1 | 2.00% | Lg Grains |
| 30 | 0.60 | 307 | 308 | 1 | 2.00% | VC Sand |
| 40 | 0.42 | 299 | 304 | 5 | 10.00% | Coarse Sand |
| 60 | 0.25 | 283 | 297 | 14 | 28.00% | Med Sand |
| 100 | 0.15 | 265 | 290 | 25 | 50.00% | Fine Sand |
| 230 | 0.063 | 248 | 251 | 3 | 6.00% | VF Sand |
| Pan | 0.038 | 361 | 362 | 1 | 2.00% | Clay |

Sample Number: TK 4-11
Raw Mass (g): 82
Dried Mass (g): 82
Descriptors:

| Sieve Number | Diameter (mm) | Mass of Empty Sieve (g) | Mass of Sieve + Soil Retained (g) | Soil Retained (g) | Percent Retained | Grain Size |
|---|---|---|---|---|---|---|
| 20 | 0.85 | 338 | 377 | 39 | 47.56% | Lg Grains |
| 30 | 0.60 | 307 | 314 | 7 | 8.54% | VC Sand |
| 40 | 0.42 | 299 | 306 | 7 | 8.54% | Coarse Sand |
| 60 | 0.25 | 283 | 287 | 4 | 4.88% | Med Sand |
| 100 | 0.15 | 265 | 277 | 12 | 14.63% | Fine Sand |
| 230 | 0.063 | 248 | 254 | 6 | 7.32% | VF Sand |
| Pan | 0.038 | 361 | 368 | 7 | 8.54% | Clay |

Sample Number: TK 4-12
Raw Mass (g): 105
Dried Mass (g): 105
Descriptors:

| Sieve Number | Diameter (mm) | Mass of Empty Sieve (g) | Mass of Sieve + Soil Retained (g) | Soil Retained (g) | Percent Retained | Grain Size |
|---|---|---|---|---|---|---|
| 20 | 0.85 | 338 | 340 | 2 | 1.90% | Lg Grains |
| 30 | 0.60 | 307 | 309 | 2 | 1.90% | VC Sand |
| 40 | 0.42 | 299 | 302 | 3 | 2.86% | Coarse Sand |
| 60 | 0.25 | 283 | 285 | 2 | 1.90% | Med Sand |
| 100 | 0.15 | 265 | 303 | 38 | 36.19% | Fine Sand |
| 230 | 0.063 | 248 | 293 | 45 | 42.86% | VF Sand |
| Pan | 0.038 | 361 | 374 | 13 | 12.38% | Clay |

Sample Number: TK 4-13
Raw Mass (g): 190
Dried Mass (g): 190
Descriptors: XRD, quartz concretions & calcite and aragonite with framboids (pyrite spheres), SEM Report

| Sieve Number | Diameter (mm) | Mass of Empty Sieve (g) | Mass of Sieve + Soil Retained (g) | Soil Retained (g) | Percent Retained | Grain Size |
|---|---|---|---|---|---|---|
| 20 | 0.85 | 338 | 340 | 2 | 1.05% | Lg Grains |
| 30 | 0.60 | 307 | 308 | 1 | 0.53% | VC Sand |
| 40 | 0.42 | 299 | 302 | 3 | 1.58% | Coarse Sand |
| 60 | 0.25 | 283 | 290 | 7 | 3.68% | Med Sand |
| 100 | 0.15 | 265 | 334 | 69 | 36.32% | Fine Sand |
| 230 | 0.063 | 248 | 315 | 97 | 51.05% | VF Sand |
| Pan | 0.038 | 361 | 372 | 11 | 5.79% | Clay |

Sample Number: TK 4-14
Raw Mass (g): 39
Dried Mass (g): 39
Descriptors:

| Sieve Number | Diameter (mm) | Mass of Empty Sieve (g) | Mass of Sieve + Soil Retained (g) | Soil Retained (g) | Percent Retained | Grain Size |
|---|---|---|---|---|---|---|
| 20 | 0.85 | 338 | 339 | 1 | 2.56% | Lg Grains |
| 30 | 0.60 | 307 | 308 | 1 | 2.56% | VC Sand |
| 40 | 0.42 | 299 | 301 | 2 | 5.13% | Coarse Sand |
| 60 | 0.25 | 283 | 287 | 4 | 10.26% | Med Sand |
| 100 | 0.15 | 265 | 281 | 16 | 41.03% | Fine Sand |
| 230 | 0.063 | 248 | 261 | 13 | 33.33% | VF Sand |
| Pan | 0.038 | 361 | 363 | 2 | 5.13% | Clay |

# APPENDIX C

## Grain Size Analysis Calculations and Statistics

## Method of Moments Statistical Calculation Equations

*Statistical formulae used in the calculation of grain size parameters, and suggested descriptive terminology. f* is the frequency in percent; *m* is the mid-point of each class interval in metric ($m_m$) or phi ($m_f$) units; $P_x$ and $\phi_x$ are grain diameters, in metric or phi units respectively, at the cumulative percentile value of *x*.

(a) Arithmetic Method of Moments

| Mean | Standard Deviation | Skewness | Kurtosis |
|---|---|---|---|
| $\bar{x}_a = \frac{\sum f m_m}{100}$ | $\sigma_a = \sqrt{\frac{\sum f (m_m - \bar{x}_a)^2}{100}}$ | $Sk_a = \frac{\sum f (m_m - \bar{x}_a)^3}{100\sigma_a^3}$ | $K_a = \frac{\sum f (m_m - \bar{x}_a)^4}{100\sigma_a^4}$ |

(b) Geometric Method of Moments

| Mean | Standard Deviation | Skewness | Kurtosis |
|---|---|---|---|
| $x_g = \exp \frac{\sum f \ln m_m}{100}$ | $\sigma_g = \exp \sqrt{\frac{\sum f (\ln m_m - \ln \bar{x}_g)^2}{100}}$ | $Sk_g = \frac{\sum f (\ln m_m - \ln \bar{x}_g)^3}{100 \ln \sigma_g^3}$ | $K_g = \frac{\sum f (\ln m_m - \ln \bar{x}_g)^4}{100 \ln \sigma_g^4}$ |

| Sorting ($\sigma_g$) | | Skewness ($Sk_g$) | | Kurtosis ($K_g$) | |
|---|---|---|---|---|---|
| Very well sorted | < 1.27 | Very fine skewed | $< -1.30$ | Very platykurtic | < 1.70 |
| Well sorted | 1.27 – 1.41 | Fine skewed | $-1.30 - -0.43$ | Platykurtic | 1.70 – 2.55 |
| Moderately well sorted | 1.41 – 1.62 | Symmetrical | $-0.43 - +0.43$ | Mesokurtic | 2.55 – 3.70 |
| Moderately sorted | 1.62 – 2.00 | Coarse skewed | $+0.43 - +1.30$ | Leptokurtic | 3.70 – 7.40 |
| Poorly sorted | 2.00 – 4.00 | Very coarse skewed | $> +1.30$ | Very leptokurtic | > 7.40 |
| Very poorly sorted | 4.00 – 16.00 | | | | |
| Extremely poorly sorted | > 16.00 | | | | |

(c) Logarithmic Method of Moments

| Mean | Standard Deviation | Skewness | Kurtosis |
|---|---|---|---|
| $\bar{x}_f = \frac{\sum f m_f}{100}$ | $\sigma_f = \sqrt{\frac{\sum f (m_f - \bar{x}_f)^2}{100}}$ | $Sk_f = \frac{\sum f (m_f - \bar{x}_f)^3}{100\sigma_f^3}$ | $K_f = \frac{\sum f (m_f - \bar{x}_f)^4}{100\sigma_f^4}$ |

| Sorting ($\sigma_f$) | | Skewness ($Sk_f$) | | Kurtosis ($K_f$) | |
|---|---|---|---|---|---|
| Very well sorted | < 0.35 | Very fine skewed | $> +1.30$ | Very platykurtic | < 1.70 |
| Well sorted | 0.35 – 0.50 | Fine skewed | $+0.43 - +1.30$ | Platykurtic | 1.70 – 2.55 |
| Moderately well sorted | 0.50 – 0.70 | Symmetrical | $-0.43 - +0.43$ | Mesokurtic | 2.55 – 3.70 |
| Moderately sorted | 0.70 – 1.00 | Coarse skewed | $-0.43 - -1.30$ | Leptokurtic | 3.70 – 7.40 |
| Poorly sorted | 1.00 – 2.00 | Very coarse skewed | $< -1.30$ | Very leptokurtic | > 7.40 |
| Very poorly sorted | 2.00 – 4.00 | | | | |
| Extremely poorly sorted | > 4.00 | | | | |

## SAMPLE STATISTICS

SAMPLE IDENTITY: **AO-1 9, Unit 1**

ANALYST & DATE: JES,

SAMPLE TYPE: Unimodal, Well Sorted

TEXTURAL GROUP: Sand

SEDIMENT NAME: Well Sorted Fine Sand

GPS: 29 32'35" N, 34 58'47" E

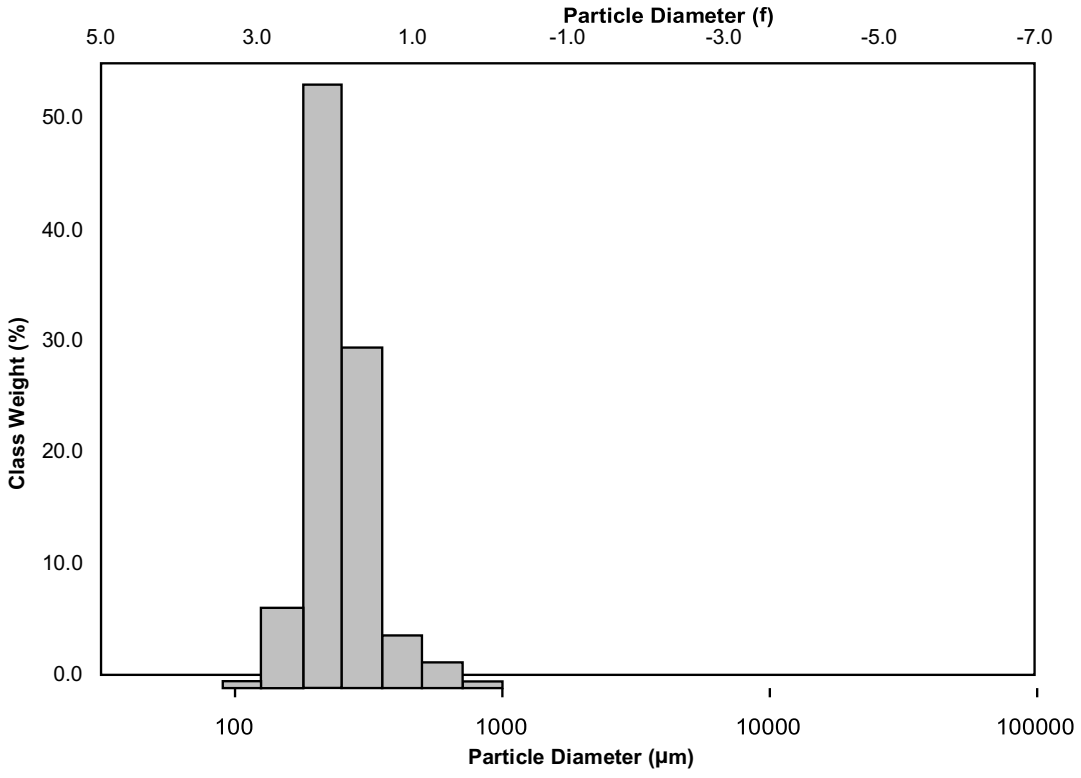
| | ∝m | ϕ |
|---|---|---|
| MODE 1: | 215.0 | 2.237 |
| MODE 2: | | |
| MODE 3: | | |
| $D_{10}$: | 181.9 | 1.530 |
| MEDIAN or $D_{50}$: | 233.8 | 2.097 |
| $D_{90}$: | 346.2 | 2.459 |
| ($D_{90}$ / $D_{10}$): | 1.903 | 1.607 |
| ($D_{90}$ - $D_{10}$): | 164.3 | 0.928 |
| ($D_{75}$ / $D_{25}$): | 1.466 | 1.312 |
| ($D_{75}$ - $D_{25}$): | 93.18 | 0.552 |

GRAIN SIZE DISTRIBUTION

| | | | |
|---|---|---|---|
| GRAVEL: | 0.0% | COARSE SAND: | 3.0% |
| SAND: | 100.0% | MEDIUM SAND: | 36.3% |
| MUD: | 0.0% | FINE SAND: | 60.1% |
| | | V FINE SAND: | 0.6% |
| V COARSE GRAVEL: | 0.0% | V COARSE SILT: | 0.0% |
| COARSE GRAVEL: | 0.0% | COARSE SILT: | 0.0% |
| MEDIUM GRAVEL: | 0.0% | MEDIUM SILT: | 0.0% |
| FINE GRAVEL: | 0.0% | FINE SILT: | 0.0% |
| V FINE GRAVEL: | 0.0% | V FINE SILT: | 0.0% |
| V COARSE SAND: | 0.0% | CLAY: | 0.0% |

| | METHOD OF MOMENTS | | | FOLK & WARD METHOD | | |
|---|---|---|---|---|---|---|
| | Arithmetic | Geometric | Logarithmic | Geometric | Logarithmic | Description |
| | ∝m | ∝m | □ | ∝m | □ | |
| MEAN ( $\bar{x}$ ): | 260.3 | 244.4 | 2.033 | 242.7 | 2.043 | Fine Sand |
| SORTING (□): | 94.57 | 1.344 | 0.427 | 1.338 | 0.420 | Well Sorted |
| SKEWNESS ( $Sk$): | 2.729 | 0.938 | -0.938 | 0.200 | -0.200 | Coarse Skewed |
| KURTOSIS ($K$ ): | 14.21 | 5.366 | 5.366 | 1.106 | 1.106 | Mesokurtic |

## GRAIN SIZE DISTRIBUTION



## SAMPLE STATISTICS

SAMPLE IDENTITY: **AO-1 3, Unit 4** ANALYST & DATE: JES,

SAMPLE TYPE: Trimodal, Moderately Well Sorted TEXTURAL GROUP: Sand

SEDIMENT NAME: Moderately Well Sorted Medium Sand GPS: 29 32'35" N, 34 58'47" E

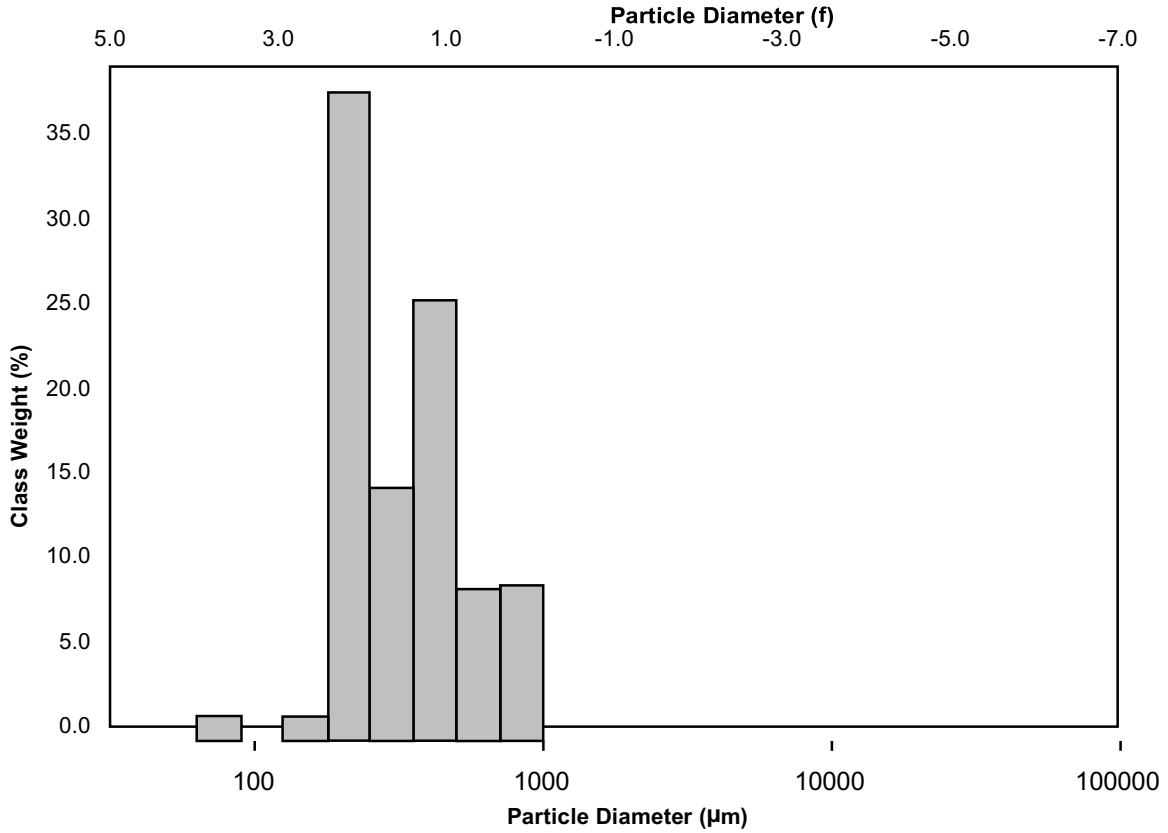
| | ∝m | ϕ |
|---|---|---|
| MODE 1: | 215.0 | 2.237 |
| MODE 2: | 427.5 | 1.247 |
| MODE 3: | 855.0 | 0.247 |
| $D_{10}$: | 191.4 | 0.536 |
| MEDIAN or $D_{50}$: | 314.0 | 1.671 |
| $D_{90}$: | 689.6 | 2.385 |
| ($D_{90}$ / $D_{10}$): | 3.602 | 4.448 |
| ($D_{90}$ - $D_{10}$): | 498.1 | 1.849 |
| ($D_{75}$ / $D_{25}$): | 2.098 | 1.952 |
| ($D_{75}$ - $D_{25}$): | 240.2 | 1.069 |

GRAIN SIZE DISTRIBUTION

| | | | |
|---|---|---|---|
| GRAVEL: | 0.0% | COARSE SAND: | 18.5% |
| SAND: | 100.0% | MEDIUM SAND: | 41.5% |
| MUD: | 0.0% | FINE SAND: | 38.5% |
| | | V FINE SAND: | 1.5% |
| V COARSE GRAVEL: | 0.0% | V COARSE SILT: | 0.0% |
| COARSE GRAVEL: | 0.0% | COARSE SILT: | 0.0% |
| MEDIUM GRAVEL: | 0.0% | MEDIUM SILT: | 0.0% |
| FINE GRAVEL: | 0.0% | FINE SILT: | 0.0% |
| V FINE GRAVEL: | 0.0% | V FINE SILT: | 0.0% |
| V COARSE SAND: | 0.0% | CLAY: | 0.0% |

| | METHOD OF MOMENTS | | | FOLK & WARD METHOD | | |
|---|---|---|---|---|---|---|
| | Arithmetic ∝m | Geometric ∝m | Logarithmic □ | Geometric ∝m | Logarithmic □ | Description |
| MEAN ( $\bar{x}$ ): | 376.0 | 327.1 | 1.612 | 326.5 | 1.615 | Medium Sand |
| SORTING (□): | 198.2 | 1.642 | 0.715 | 1.615 | 0.691 | Moderately Well Sorted |
| SKEWNESS ( $Sk$): | 1.169 | 0.133 | -0.133 | 0.202 | -0.202 | Coarse Skewed |
| KURTOSIS ($K$ ): | 3.586 | 2.937 | 2.937 | 0.836 | 0.836 | Platykurtic |

## GRAIN SIZE DISTRIBUTION



## SAMPLE STATISTICS

SAMPLE IDENTITY: **AO-1 8, Unit 10** ANALYST & DATE: JES,

SAMPLE TYPE: Unimodal, Moderately Well Sorted TEXTURAL GROUP: Sand

SEDIMENT NAME: Moderately Well Sorted Fine Sand GPS: 29 32'35" N, 34 58'47" E

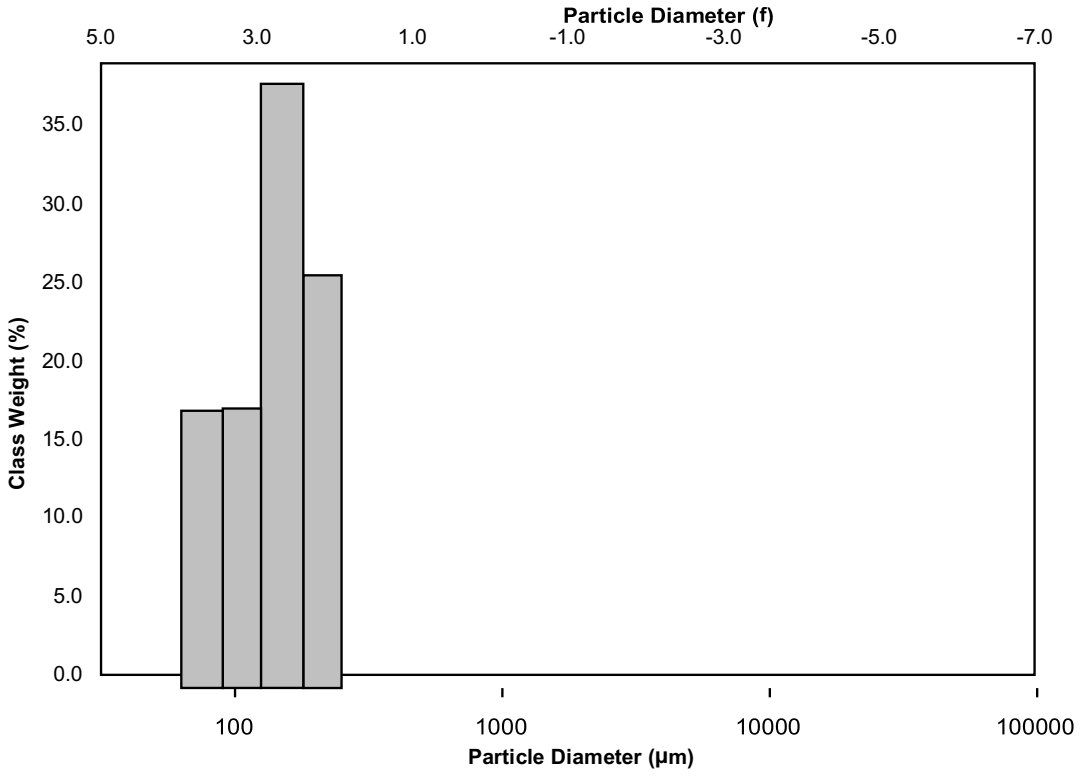
| | ∝m | ϕ |
|---|---|---|
| MODE 1: | 152.5 | 2.737 |
| MODE 2: | | |
| MODE 3: | | |
| $D_{10}$: | 76.73 | 2.191 |
| MEDIAN or $D_{50}$: | 143.3 | 2.803 |
| $D_{90}$: | 219.0 | 3.704 |
| ($D_{90}$ / $D_{10}$): | 2.854 | 1.691 |
| ($D_{90}$ - $D_{10}$): | 142.3 | 1.513 |
| ($D_{75}$ / $D_{25}$): | 1.744 | 1.324 |
| ($D_{75}$ - $D_{25}$): | 76.66 | 0.802 |

GRAIN SIZE DISTRIBUTION

| | | | |
|---|---|---|---|
| GRAVEL: | 0.0% | COARSE SAND: | 0.0% |
| SAND: | 100.0% | MEDIUM SAND: | 0.0% |
| MUD: | 0.0% | FINE SAND: | 65.1% |
| | | V FINE SAND: | 34.9% |
| V COARSE GRAVEL: | 0.0% | V COARSE SILT: | 0.0% |
| COARSE GRAVEL: | 0.0% | COARSE SILT: | 0.0% |
| MEDIUM GRAVEL: | 0.0% | MEDIUM SILT: | 0.0% |
| FINE GRAVEL: | 0.0% | FINE SILT: | 0.0% |
| V FINE GRAVEL: | 0.0% | V FINE SILT: | 0.0% |
| V COARSE SAND: | 0.0% | CLAY: | 0.0% |

| | METHOD OF MOMENTS | | | FOLK & WARD METHOD | | |
|---|---|---|---|---|---|---|
| | Arithmetic | Geometric | Logarithmic | Geometric | Logarithmic | Description |
| | ∝m | ∝m | □ | ∝m | □ | |
| MEAN ( $\bar{x}$ ): | 146.7 | 136.1 | 2.877 | 135.8 | 2.881 | Fine Sand |
| SORTING (□): | 48.17 | 1.427 | 0.513 | 1.487 | 0.572 | Moderately Well Sorted |
| SKEWNESS ( $Sk$): | 0.058 | -0.404 | 0.404 | -0.191 | 0.191 | Fine Skewed |
| KURTOSIS ($K$ ): | 1.892 | 2.034 | 2.034 | 0.894 | 0.894 | Platykurtic |

## GRAIN SIZE DISTRIBUTION



## SAMPLE STATISTICS

SAMPLE IDENTITY: **AO-1 5-1, Unit 18**

ANALYST & DATE: JES,

SAMPLE TYPE: Unimodal, Well Sorted

TEXTURAL GROUP: Sand

SEDIMENT NAME: Well Sorted Fine Sand

GPS: 29 32'35" N, 34 58'47" E

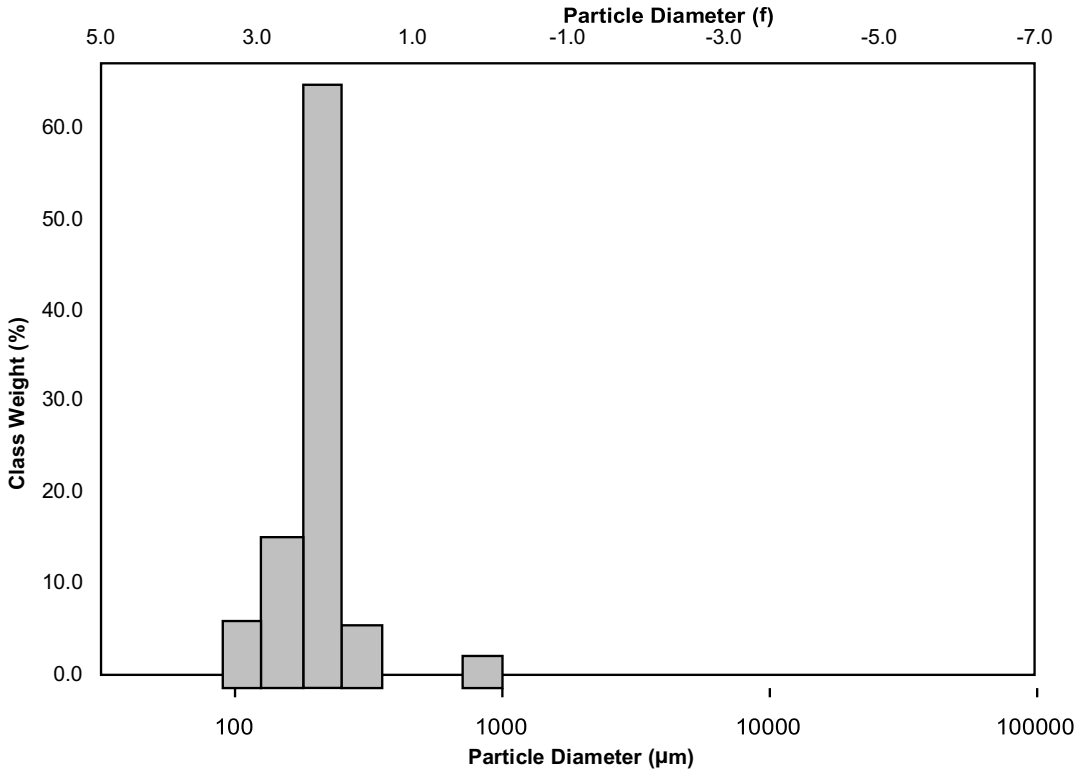
| | ∝m | ϕ |
|---|---|---|
| MODE 1: | 215.0 | 2.237 |
| MODE 2: | | |
| MODE 3: | | |
| $D_{10}$: | 132.5 | 1.950 |
| MEDIAN or $D_{50}$: | 204.5 | 2.290 |
| $D_{90}$: | 258.9 | 2.916 |
| ($D_{90}$ / $D_{10}$): | 1.953 | 1.495 |
| ($D_{90}$ - $D_{10}$): | 126.4 | 0.966 |
| ($D_{75}$ / $D_{25}$): | 1.291 | 1.175 |
| ($D_{75}$ - $D_{25}$): | 52.39 | 0.369 |

GRAIN SIZE DISTRIBUTION

| | | | |
|---|---|---|---|
| GRAVEL: | 0.0% | COARSE SAND: | 3.6% |
| SAND: | 100.0% | MEDIUM SAND: | 7.1% |
| MUD: | 0.0% | FINE SAND: | 82.2% |
| | | V FINE SAND: | 7.1% |
| V COARSE GRAVEL: | 0.0% | V COARSE SILT: | 0.0% |
| COARSE GRAVEL: | 0.0% | COARSE SILT: | 0.0% |
| MEDIUM GRAVEL: | 0.0% | MEDIUM SILT: | 0.0% |
| FINE GRAVEL: | 0.0% | FINE SILT: | 0.0% |
| V FINE GRAVEL: | 0.0% | V FINE SILT: | 0.0% |
| V COARSE SAND: | 0.0% | CLAY: | 0.0% |

| | METHOD OF MOMENTS | | | FOLK & WARD METHOD | | |
|---|---|---|---|---|---|---|
| | Arithmetic | Geometric | Logarithmic | Geometric | Logarithmic | Description |
| | ∝m | ∝m | □ | ∝m | □ | |
| MEAN ( $\bar{x}$ ): | 225.3 | 204.2 | 2.292 | 195.4 | 2.356 | Fine Sand |
| SORTING (□): | 128.8 | 1.435 | 0.521 | 1.328 | 0.409 | Well Sorted |
| SKEWNESS ( $Sk$): | 4.102 | 1.701 | -1.701 | -0.193 | 0.193 | Fine Skewed |
| KURTOSIS ($K$ ): | 20.49 | 9.414 | 9.414 | 1.720 | 1.720 | Very Leptokurtic |

## GRAIN SIZE DISTRIBUTION



## SAMPLE STATISTICS

SAMPLE IDENTITY: **AO-1 11, Unit 19**

ANALYST & DATE: JES,

SAMPLE TYPE: Unimodal, Well Sorted

TEXTURAL GROUP: Sand

SEDIMENT NAME: Well Sorted Fine Sand

GPS: 29 32'35" N, 34 58'47" E

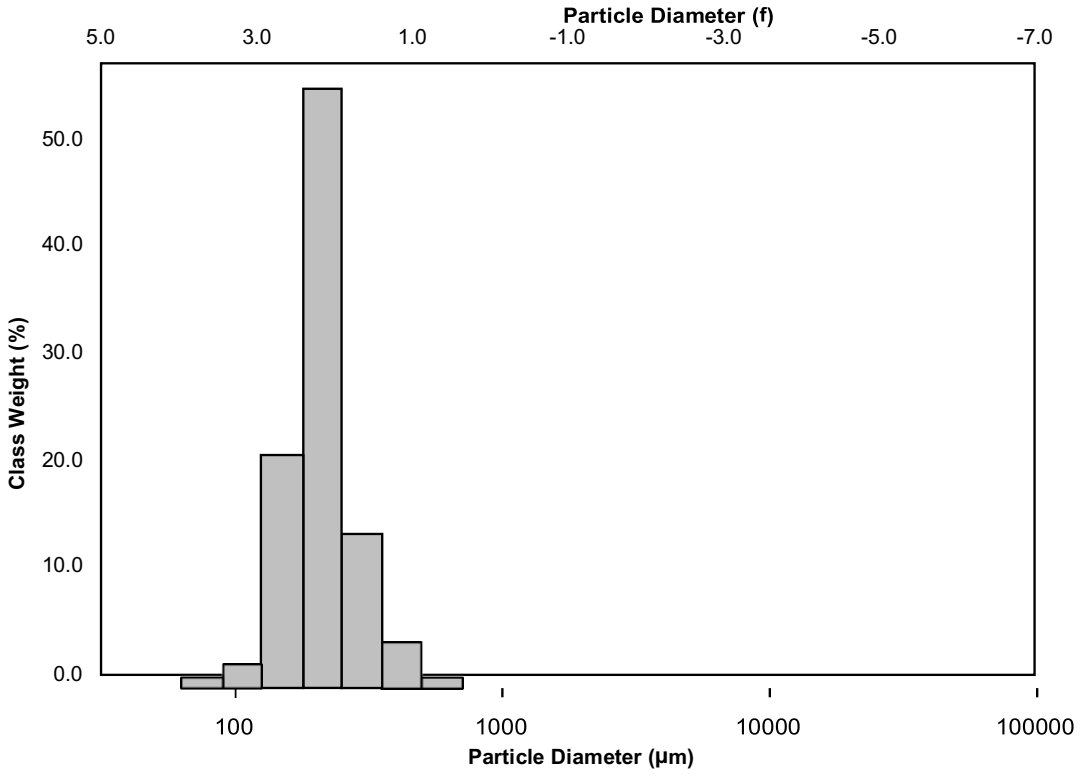
| | ∝m | ϕ |
|---|---|---|
| MODE 1: | 215.0 | 2.237 |
| MODE 2: | | |
| MODE 3: | | |
| $D_{10}$: | 139.2 | 1.657 |
| MEDIAN or $D_{50}$: | 208.1 | 2.265 |
| $D_{90}$: | 317.1 | 2.845 |
| ($D_{90}$ / $D_{10}$): | 2.278 | 1.717 |
| ($D_{90}$ - $D_{10}$): | 177.9 | 1.188 |
| ($D_{75}$ / $D_{25}$): | 1.375 | 1.225 |
| ($D_{75}$ - $D_{25}$): | 66.16 | 0.460 |

GRAIN SIZE DISTRIBUTION

| | | | |
|---|---|---|---|
| GRAVEL: | 0.0% | COARSE SAND: | 1.1% |
| SAND: | 100.0% | MEDIUM SAND: | 18.9% |
| MUD: | 0.0% | FINE SAND: | 76.8% |
| | | V FINE SAND: | 3.2% |
| V COARSE GRAVEL: | 0.0% | V COARSE SILT: | 0.0% |
| COARSE GRAVEL: | 0.0% | COARSE SILT: | 0.0% |
| MEDIUM GRAVEL: | 0.0% | MEDIUM SILT: | 0.0% |
| FINE GRAVEL: | 0.0% | FINE SILT: | 0.0% |
| V FINE GRAVEL: | 0.0% | V FINE SILT: | 0.0% |
| V COARSE SAND: | 0.0% | CLAY: | 0.0% |

| | METHOD OF MOMENTS | | | FOLK & WARD METHOD | | |
|---|---|---|---|---|---|---|
| | Arithmetic | Geometric | Logarithmic | Geometric | Logarithmic | Description |
| | ∝m | ∝m | □ | ∝m | □ | |
| MEAN ( $\bar{x}$ ): | 222.7 | 208.8 | 2.260 | 206.1 | 2.279 | Fine Sand |
| SORTING (□): | 76.92 | 1.365 | 0.449 | 1.355 | 0.438 | Well Sorted |
| SKEWNESS ( $Sk$): | 1.928 | 0.241 | -0.241 | 0.012 | -0.012 | Symmetrical |
| KURTOSIS ($K$ ): | 9.095 | 4.663 | 4.663 | 1.332 | 1.332 | Leptokurtic |

## GRAIN SIZE DISTRIBUTION



## SAMPLE STATISTICS

SAMPLE IDENTITY: **AO-1 12, Unit 19** ANALYST & DATE: JES,

SAMPLE TYPE: Unimodal, Moderately Well Sorted TEXTURAL GROUP: Sand

SEDIMENT NAME: Moderately Well Sorted Fine Sand GPS: 29 32'35" N, 34 58'47" E

| | ∝m | ϕ |
|---|---|---|
| MODE 1: | 215.0 | 2.237 |
| MODE 2: | | |
| MODE 3: | | |
| $D_{10}$: | 135.0 | 1.585 |
| MEDIAN or $D_{50}$: | 203.6 | 2.296 |
| $D_{90}$: | 333.3 | 2.889 |
| ($D_{90}$ / $D_{10}$): | 2.468 | 1.822 |
| ($D_{90}$ - $D_{10}$): | 198.2 | 1.304 |
| ($D_{75}$ / $D_{25}$): | 1.542 | 1.311 |
| ($D_{75}$ - $D_{25}$): | 87.26 | 0.625 |

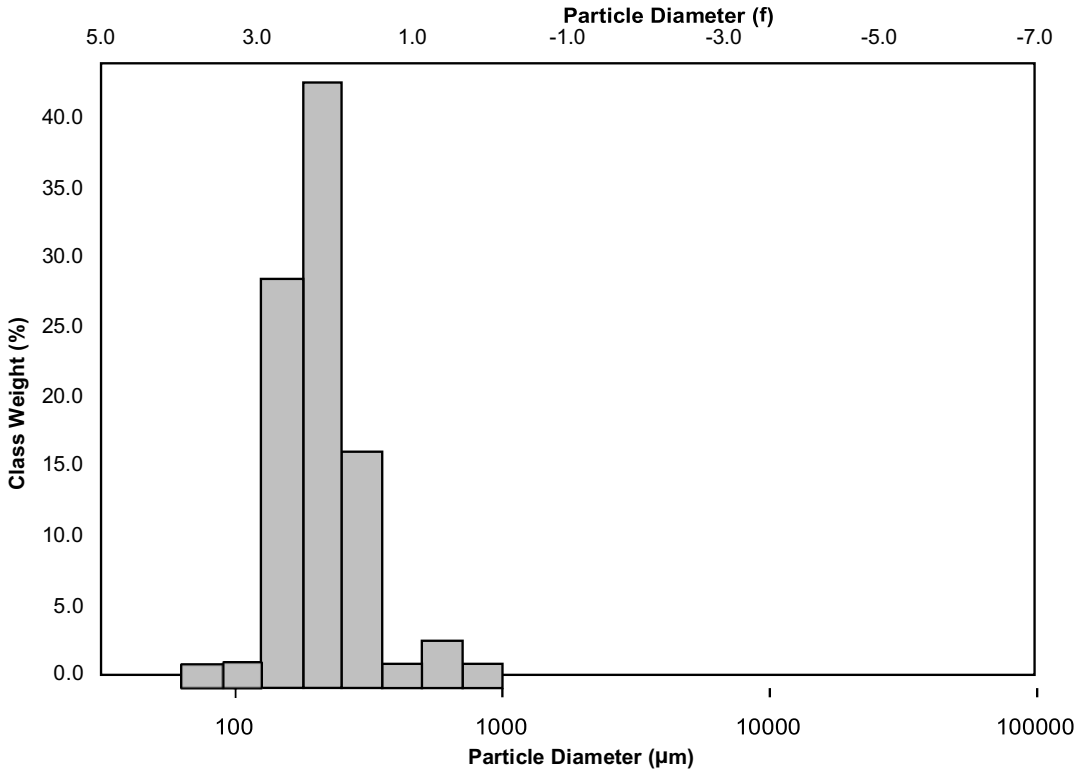
GRAIN SIZE DISTRIBUTION

| | |
|---|---|
| GRAVEL: 0.0% | COARSE SAND: 5.2% |
| SAND: 100.0% | MEDIUM SAND: 19.0% |
| MUD: 0.0% | FINE SAND: 72.4% |
| | V FINE SAND: 3.4% |
| V COARSE GRAVEL: 0.0% | V COARSE SILT: 0.0% |
| COARSE GRAVEL: 0.0% | COARSE SILT: 0.0% |
| MEDIUM GRAVEL: 0.0% | MEDIUM SILT: 0.0% |
| FINE GRAVEL: 0.0% | FINE SILT: 0.0% |
| V FINE GRAVEL: 0.0% | V FINE SILT: 0.0% |
| V COARSE SAND: 0.0% | CLAY: 0.0% |

METHOD OF MOMENTS FOLK & WARD METHOD

| | Arithmetic | Geometric | Logarithmic | Geometric | Logarithmic | Description |
|---|---|---|---|---|---|---|
| | ∝m | ∝m | □ | ∝m | □ | |
| MEAN ( $\bar{x}$ ): | 234.6 | 210.5 | 2.248 | 205.7 | 2.282 | Fine Sand |
| SORTING (□): | 125.5 | 1.495 | 0.580 | 1.474 | 0.559 | Moderately Well Sorted |
| SKEWNESS ( $Sk$): | 2.915 | 0.946 | -0.946 | 0.182 | -0.182 | Coarse Skewed |
| KURTOSIS ($K$ ): | 13.12 | 5.281 | 5.281 | 1.311 | 1.311 | Leptokurtic |

## GRAIN SIZE DISTRIBUTION



## SAMPLE STATISTICS

SAMPLE IDENTITY: **AO-1 2, Unit 20**

ANALYST & DATE: JES,

SAMPLE TYPE: Unimodal, Very Well Sorted

TEXTURAL GROUP:

SEDIMENT NAME:

GPS: 29 32'35" N, 34 58'47" E

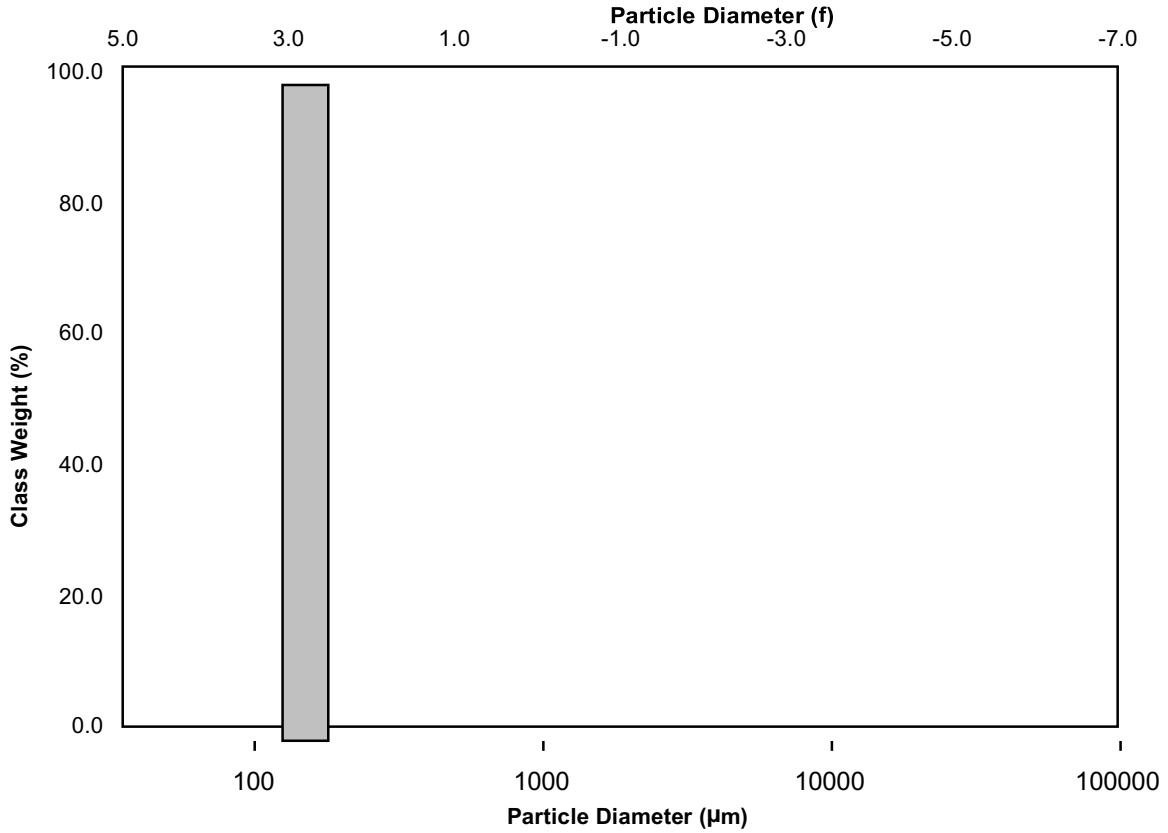
| | ∝m | ϕ |
|---|---|---|
| MODE 1: | 152.5 | 2.737 |
| MODE 2: | | |
| MODE 3: | | |
| $D_{10}$: | 129.6 | 2.527 |
| MEDIAN or $D_{50}$: | 150.0 | 2.737 |
| $D_{90}$: | 173.6 | 2.947 |
| ($D_{90}$ / $D_{10}$): | 1.339 | 1.167 |
| ($D_{90}$ - $D_{10}$): | 43.91 | 0.421 |
| ($D_{75}$ / $D_{25}$): | 1.200 | 1.101 |
| ($D_{75}$ - $D_{25}$): | 27.39 | 0.263 |

GRAIN SIZE DISTRIBUTION

| | |
|---|---|
| GRAVEL: | COARSE SAND: |
| SAND: | MEDIUM SAND: |
| MUD: | FINE SAND: |
| | V FINE SAND: |
| V COARSE GRAVEL: | V COARSE SILT: |
| COARSE GRAVEL: | COARSE SILT: |
| MEDIUM GRAVEL: | MEDIUM SILT: |
| FINE GRAVEL: | FINE SILT: |
| V FINE GRAVEL: | V FINE SILT: |
| V COARSE SAND: | CLAY: |

| | METHOD OF MOMENTS | | | FOLK & WARD METHOD | | |
|---|---|---|---|---|---|---|
| | Arithmetic | Geometric | Logarithmic | Geometric | Logarithmic | Description |
| | ∝m | ∝m | □ | ∝m | □ | |
| MEAN ( $\bar{x}$ ): | 152.5 | 150.0 | 2.737 | 150.0 | 2.737 | Fine Sand |
| SORTING (□): | 0.000 | 1.000 | 0.000 | 1.118 | 0.161 | Very Well Sorted |
| SKEWNESS ( $Sk$): | #DIV/0! | -0.781 | #DIV/0! | 0.000 | 0.000 | Symmetrical |
| KURTOSIS ($K$ ): | #DIV/0! | 0.720 | #DIV/0! | 0.738 | 0.738 | Platykurtic |

## GRAIN SIZE DISTRIBUTION



## SAMPLE STATISTICS

SAMPLE IDENTITY: **AO-1 13, Unit 22** ANALYST & DATE: JES,

SAMPLE TYPE: Bimodal, Moderately Well Sorted TEXTURAL GROUP: Sand

SEDIMENT NAME: Moderately Well Sorted Fine Sand GPS: 29 32'35" N, 34 58'47" E

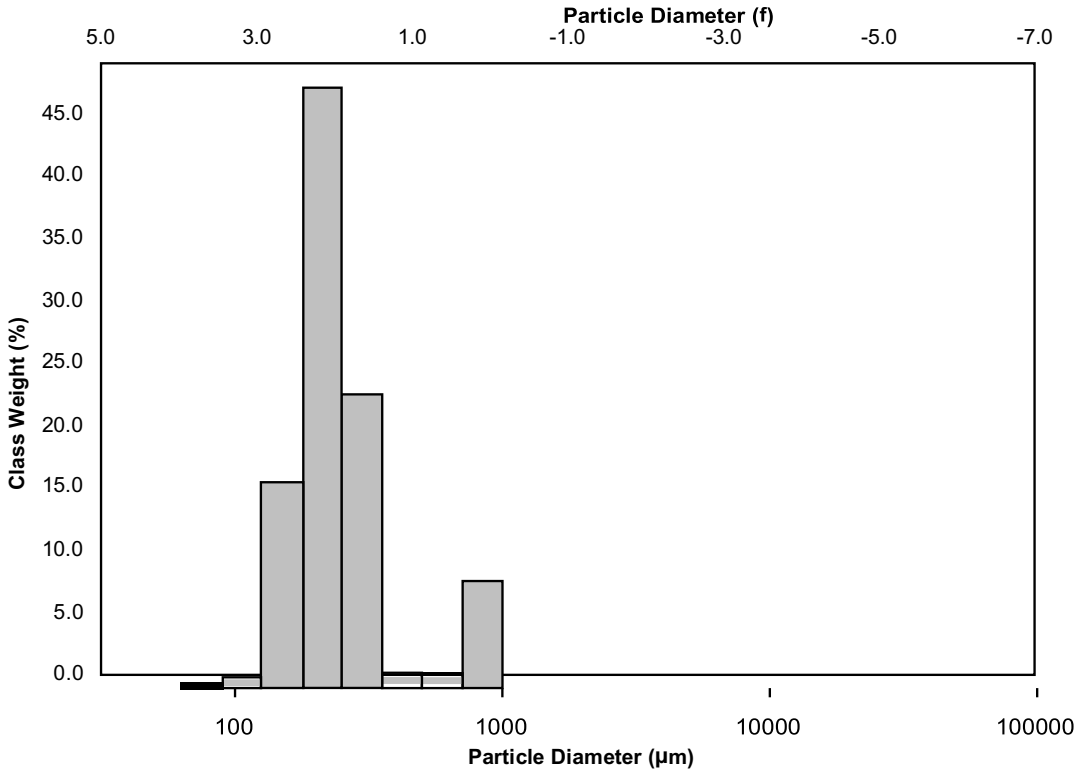
| | ∝m | ϕ |
|---|---|---|
| MODE 1: | 215.0 | 2.237 |
| MODE 2: | 855.0 | 0.247 |
| MODE 3: | | |
| $D_{10}$: | 150.0 | 1.085 |
| MEDIAN or $D_{50}$: | 224.8 | 2.153 |
| $D_{90}$: | 471.5 | 2.737 |
| ($D_{90}$ / $D_{10}$): | 3.144 | 2.524 |
| ($D_{90}$ - $D_{10}$): | 321.5 | 1.652 |
| ($D_{75}$ / $D_{25}$): | 1.539 | 1.348 |
| ($D_{75}$ - $D_{25}$): | 101.4 | 0.622 |

GRAIN SIZE DISTRIBUTION

| | | | |
|---|---|---|---|
| GRAVEL: | 0.0% | COARSE SAND: | 9.8% |
| SAND: | 100.0% | MEDIUM SAND: | 25.3% |
| MUD: | 0.0% | FINE SAND: | 63.7% |
| | | V FINE SAND: | 1.2% |
| V COARSE GRAVEL: | 0.0% | V COARSE SILT: | 0.0% |
| COARSE GRAVEL: | 0.0% | COARSE SILT: | 0.0% |
| MEDIUM GRAVEL: | 0.0% | MEDIUM SILT: | 0.0% |
| FINE GRAVEL: | 0.0% | FINE SILT: | 0.0% |
| V FINE GRAVEL: | 0.0% | V FINE SILT: | 0.0% |
| V COARSE SAND: | 0.0% | CLAY: | 0.0% |

| | METHOD OF MOMENTS | | | FOLK & WARD METHOD | | |
|---|---|---|---|---|---|---|
| | Arithmetic ∝m | Geometric ∝m | Logarithmic □ | Geometric ∝m | Logarithmic □ | Description |
| MEAN ( $\bar{x}$): | 285.9 | 246.5 | 2.020 | 232.8 | 2.103 | Fine Sand |
| SORTING (□): | 187.6 | 1.592 | 0.671 | 1.551 | 0.633 | Moderately Well Sorted |
| SKEWNESS ( $Sk$): | 2.358 | 1.353 | -1.353 | 0.296 | -0.296 | Coarse Skewed |
| KURTOSIS ($K$ ): | 7.434 | 4.856 | 4.856 | 1.712 | 1.712 | Very Leptokurtic |

## GRAIN SIZE DISTRIBUTION



## SAMPLE STATISTICS

SAMPLE IDENTITY: **AO-1 10, Unit 26**

ANALYST & DATE: JES,

SAMPLE TYPE: Unimodal, Well Sorted

TEXTURAL GROUP: Sand

SEDIMENT NAME: Well Sorted Medium Sand

GPS: 29 32'35" N, 34 58'47" E

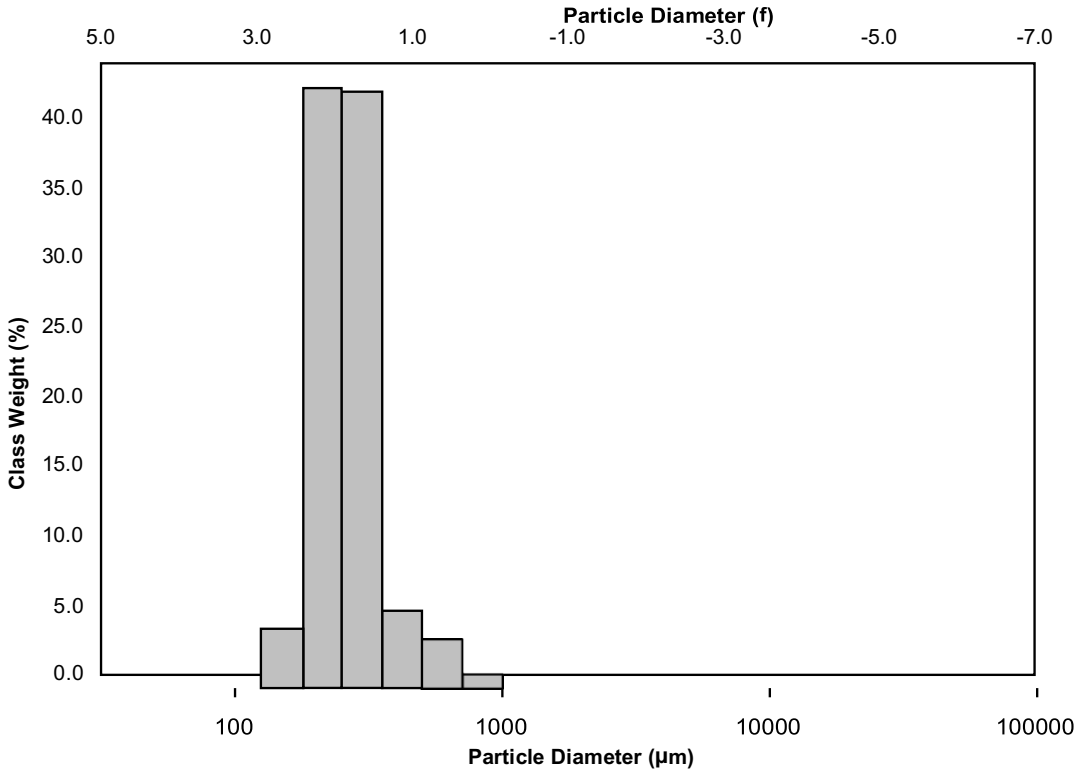
| | ∝m | ϕ |
|---|---|---|
| MODE 1: | 215.0 | 2.237 |
| MODE 2: | | |
| MODE 3: | | |
| $D_{10}$: | 188.0 | 1.484 |
| MEDIAN or $D_{50}$: | 258.2 | 1.953 |
| $D_{90}$: | 357.4 | 2.411 |
| ($D_{90}$ / $D_{10}$): | 1.901 | 1.625 |
| ($D_{90}$ - $D_{10}$): | 169.4 | 0.927 |
| ($D_{75}$ / $D_{25}$): | 1.489 | 1.345 |
| ($D_{75}$ - $D_{25}$): | 103.5 | 0.574 |

GRAIN SIZE DISTRIBUTION

| | | | |
|---|---|---|---|
| GRAVEL: | 0.0% | COARSE SAND: | 4.6% |
| SAND: | 100.0% | MEDIUM SAND: | 49.5% |
| MUD: | 0.0% | FINE SAND: | 46.0% |
| | | V FINE SAND: | 0.0% |
| V COARSE GRAVEL: | 0.0% | V COARSE SILT: | 0.0% |
| COARSE GRAVEL: | 0.0% | COARSE SILT: | 0.0% |
| MEDIUM GRAVEL: | 0.0% | MEDIUM SILT: | 0.0% |
| FINE GRAVEL: | 0.0% | FINE SILT: | 0.0% |
| V FINE GRAVEL: | 0.0% | V FINE SILT: | 0.0% |
| V COARSE SAND: | 0.0% | CLAY: | 0.0% |

| | METHOD OF MOMENTS | | | FOLK & WARD METHOD | | |
|---|---|---|---|---|---|---|
| | Arithmetic | Geometric | Logarithmic | Geometric | Logarithmic | Description |
| | ∝m | ∝m | □ | ∝m | □ | |
| MEAN ( $\bar{x}$ ): | 282.7 | 264.9 | 1.917 | 258.3 | 1.953 | Medium Sand |
| SORTING (□): | 104.8 | 1.350 | 0.433 | 1.330 | 0.412 | Well Sorted |
| SKEWNESS ( $Sk$): | 2.623 | 1.034 | -1.034 | 0.141 | -0.141 | Coarse Skewed |
| KURTOSIS ($K$ ): | 12.51 | 5.170 | 5.170 | 1.020 | 1.020 | Mesokurtic |

## GRAIN SIZE DISTRIBUTION



## SAMPLE STATISTICS

SAMPLE IDENTITY: **AO-1 7, Unit 27**

ANALYST & DATE: JES,

SAMPLE TYPE: Unimodal, Well Sorted

TEXTURAL GROUP: Sand

SEDIMENT NAME: Well Sorted Fine Sand

GPS: 29 32'35" N, 34 58'47" E

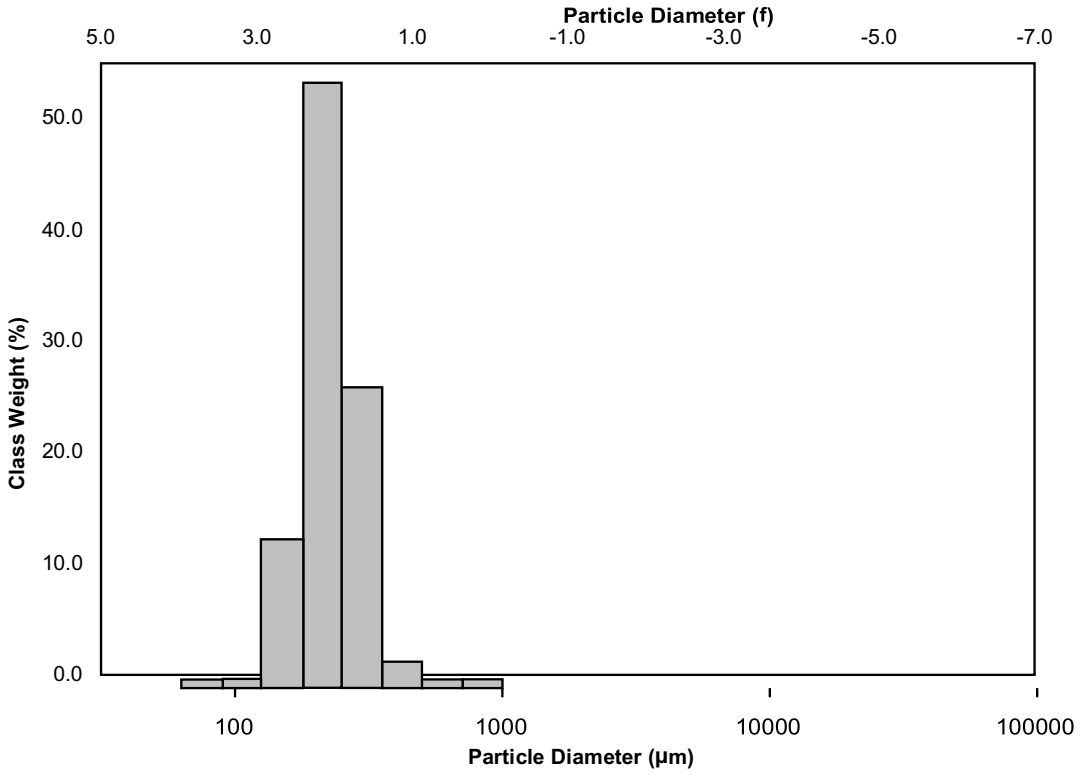
| | ∝m | ϕ |
|---|---|---|
| MODE 1: | 215.0 | 2.237 |
| MODE 2: | | |
| MODE 3: | | |
| $D_{10}$: | 155.0 | 1.604 |
| MEDIAN or $D_{50}$: | 223.0 | 2.165 |
| $D_{90}$: | 328.9 | 2.690 |
| ($D_{90}$ / $D_{10}$): | 2.123 | 1.677 |
| ($D_{90}$ - $D_{10}$): | 174.0 | 1.086 |
| ($D_{75}$ / $D_{25}$): | 1.428 | 1.274 |
| ($D_{75}$ - $D_{25}$): | 81.60 | 0.514 |

GRAIN SIZE DISTRIBUTION

| | | | |
|---|---|---|---|
| GRAVEL: | 0.0% | COARSE SAND: | 1.6% |
| SAND: | 100.0% | MEDIUM SAND: | 30.2% |
| MUD: | 0.0% | FINE SAND: | 66.7% |
| | | V FINE SAND: | 1.6% |
| V COARSE GRAVEL: | 0.0% | V COARSE SILT: | 0.0% |
| COARSE GRAVEL: | 0.0% | COARSE SILT: | 0.0% |
| MEDIUM GRAVEL: | 0.0% | MEDIUM SILT: | 0.0% |
| FINE GRAVEL: | 0.0% | FINE SILT: | 0.0% |
| V FINE GRAVEL: | 0.0% | V FINE SILT: | 0.0% |
| V COARSE SAND: | 0.0% | CLAY: | 0.0% |

| | METHOD OF MOMENTS | | | FOLK & WARD METHOD | | |
|---|---|---|---|---|---|---|
| | Arithmetic | Geometric | Logarithmic | Geometric | Logarithmic | Description |
| | ∝m | ∝m | □ | ∝m | □ | |
| MEAN ( $\bar{x}$ ): | 241.6 | 226.7 | 2.141 | 230.5 | 2.117 | Fine Sand |
| SORTING (□): | 87.93 | 1.354 | 0.437 | 1.316 | 0.396 | Well Sorted |
| SKEWNESS ( $Sk$): | 3.313 | 0.434 | -0.434 | 0.074 | -0.074 | Symmetrical |
| KURTOSIS ($K$ ): | 21.85 | 6.405 | 6.405 | 1.085 | 1.085 | Mesokurtic |

## GRAIN SIZE DISTRIBUTION



## SAMPLE STATISTICS

SAMPLE IDENTITY: **AO-1 4, Unit 31**

ANALYST & DATE: JES,

SAMPLE TYPE: Bimodal, Poorly Sorted

TEXTURAL GROUP: Sand

SEDIMENT NAME: Poorly Sorted Medium Sand

GPS: 29 32'35" N, 34 58'47" E

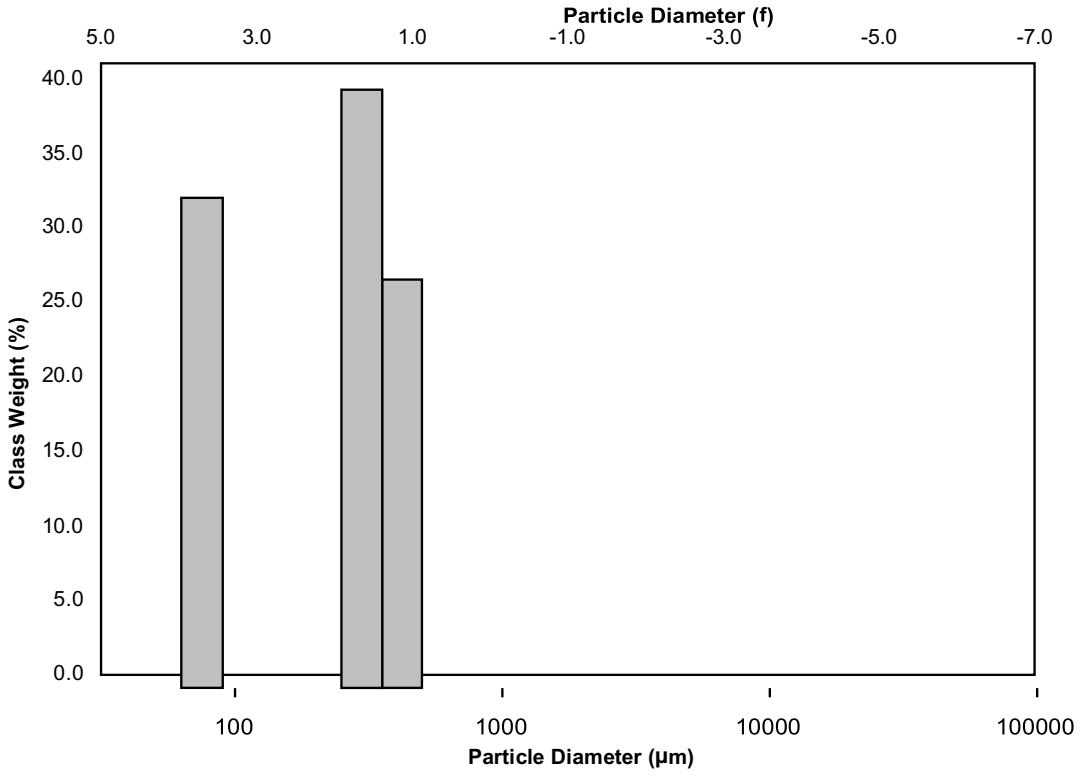
| | ∝m | ϕ |
|---|---|---|
| MODE 1: | 302.5 | 1.747 |
| MODE 2: | 76.50 | 3.731 |
| MODE 3: | | |
| $D_{10}$: | 70.12 | 1.185 |
| MEDIAN or $D_{50}$: | 289.3 | 1.789 |
| $D_{90}$: | 439.7 | 3.834 |
| ($D_{90}$ / $D_{10}$): | 6.272 | 3.235 |
| ($D_{90}$ - $D_{10}$): | 369.6 | 2.649 |
| ($D_{75}$ / $D_{25}$): | 4.406 | 2.462 |
| ($D_{75}$ - $D_{25}$): | 280.4 | 2.139 |

GRAIN SIZE DISTRIBUTION

| | | | |
|---|---|---|---|
| GRAVEL: | 0.0% | COARSE SAND: | 0.0% |
| SAND: | 100.0% | MEDIUM SAND: | 66.7% |
| MUD: | 0.0% | FINE SAND: | 0.0% |
| | | V FINE SAND: | 33.3% |
| V COARSE GRAVEL: | 0.0% | V COARSE SILT: | 0.0% |
| COARSE GRAVEL: | 0.0% | COARSE SILT: | 0.0% |
| MEDIUM GRAVEL: | 0.0% | MEDIUM SILT: | 0.0% |
| FINE GRAVEL: | 0.0% | FINE SILT: | 0.0% |
| V FINE GRAVEL: | 0.0% | V FINE SILT: | 0.0% |
| V COARSE SAND: | 0.0% | CLAY: | 0.0% |

| | METHOD OF MOMENTS | | | FOLK & WARD METHOD | | |
|---|---|---|---|---|---|---|
| | Arithmetic ∝m | Geometric ∝m | Logarithmic □ | Geometric ∝m | Logarithmic □ | Description |
| MEAN ( $\bar{x}$): | 260.5 | 206.6 | 2.275 | 206.5 | 2.276 | Fine Sand |
| SORTING (□): | 139.4 | 2.069 | 1.049 | 2.054 | 1.038 | Poorly Sorted |
| SKEWNESS ( $Sk$): | -0.297 | -0.590 | 0.590 | -0.551 | 0.551 | Very Fine Skewed |
| KURTOSIS ($K$ ): | 1.565 | 1.510 | 1.510 | 0.540 | 0.540 | Very Platykurtic |

## GRAIN SIZE DISTRIBUTION



## SAMPLE STATISTICS

SAMPLE IDENTITY: **AO 2 - Unit 4**

ANALYST & DATE: JES

SAMPLE TYPE: Unimodal, Moderately Sorted

TEXTURAL GROUP: Sand

SEDIMENT NAME: Moderately Sorted Fine Sand

GPS: 29.3240N, 34.5851E

Depth: 1.30m

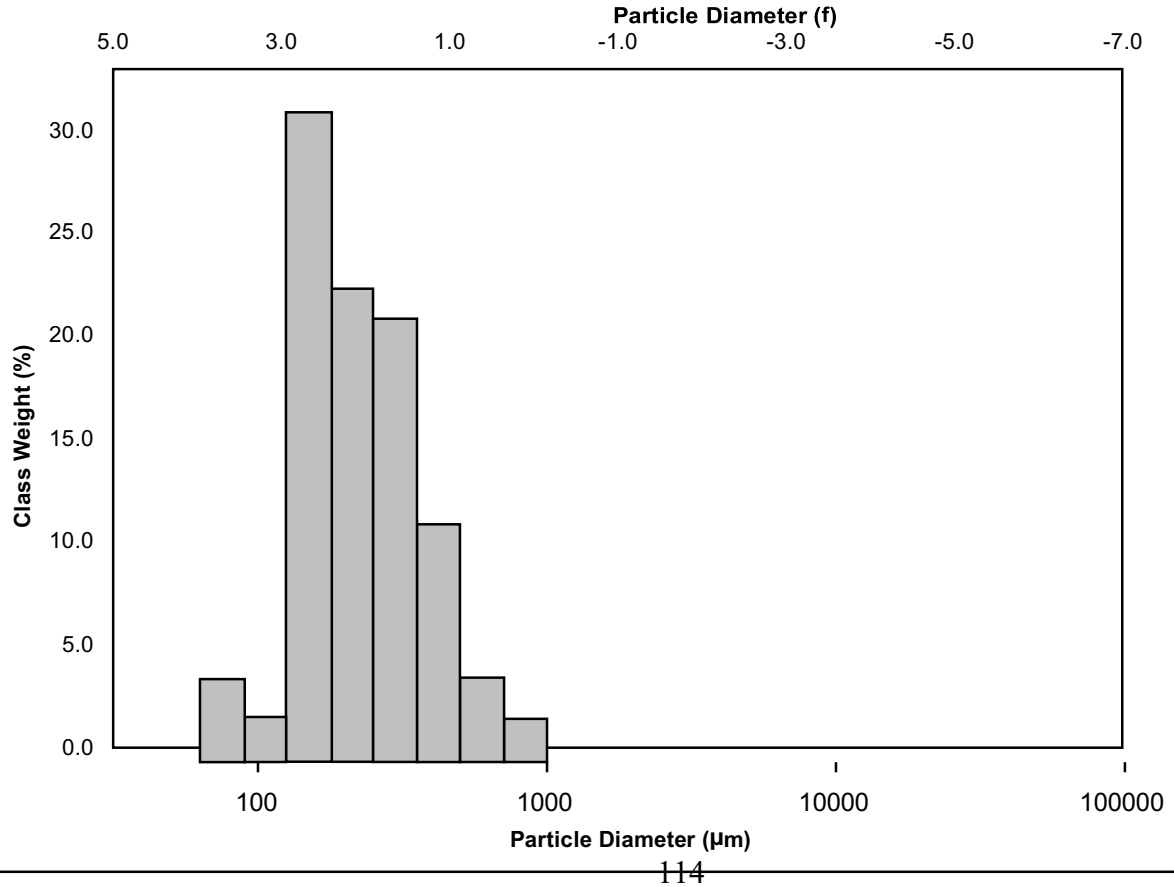
| | ∝m | ϕ |
|---|---|---|
| MODE 1: | 152.5 | 2.737 |
| MODE 2: | | |
| MODE 3: | | |
| $D_{10}$: | 130.4 | 1.166 |
| MEDIAN or $D_{50}$: | 212.1 | 2.237 |
| $D_{90}$: | 445.5 | 2.939 |
| ($D_{90}$ / $D_{10}$): | 3.417 | 2.520 |
| ($D_{90}$ - $D_{10}$): | 315.1 | 1.773 |
| ($D_{75}$ / $D_{25}$): | 2.044 | 1.618 |
| ($D_{75}$ - $D_{25}$): | 160.6 | 1.031 |

GRAIN SIZE DISTRIBUTION

| | | | |
|---|---|---|---|
| GRAVEL: | 0.0% | COARSE SAND: | 6.2% |
| SAND: | 100.0% | MEDIUM SAND: | 33.0% |
| MUD: | 0.0% | FINE SAND: | 54.6% |
| | | V FINE SAND: | 6.2% |
| V COARSE GRAVEL: | 0.0% | V COARSE SILT: | 0.0% |
| COARSE GRAVEL: | 0.0% | COARSE SILT: | 0.0% |
| MEDIUM GRAVEL: | 0.0% | MEDIUM SILT: | 0.0% |
| FINE GRAVEL: | 0.0% | FINE SILT: | 0.0% |
| V FINE GRAVEL: | 0.0% | V FINE SILT: | 0.0% |
| V COARSE SAND: | 0.0% | CLAY: | 0.0% |

| | METHOD OF MOMENTS | | | FOLK & WARD METHOD | | |
|---|---|---|---|---|---|---|
| | Arithmetic | Geometric | Logarithmic | Geometric | Logarithmic | Description |
| | ∝m | ∝m | □ | ∝m | □ | |
| MEAN ( $\bar{x}$ ): | 258.8 | 223.2 | 2.163 | 222.3 | 2.169 | Fine Sand |
| SORTING (□): | 147.9 | 1.653 | 0.725 | 1.647 | 0.720 | Moderately Sorted |
| SKEWNESS ( $Sk$): | 1.824 | 0.310 | -0.310 | 0.143 | -0.143 | Coarse Skewed |
| KURTOSIS ($K$ ): | 7.072 | 3.046 | 3.046 | 0.961 | 0.961 | Mesokurtic |

## GRAIN SIZE DISTRIBUTION



## SAMPLE STATISTICS

SAMPLE IDENTITY: **AO 2 - 5**

ANALYST & DATE: JES,

SAMPLE TYPE: Unimodal, Well Sorted

TEXTURAL GROUP: Sand

SEDIMENT NAME: Well Sorted Fine Sand

GPS: 29 32' 40" N, 34 58' 51" E
Depth: 2.18m

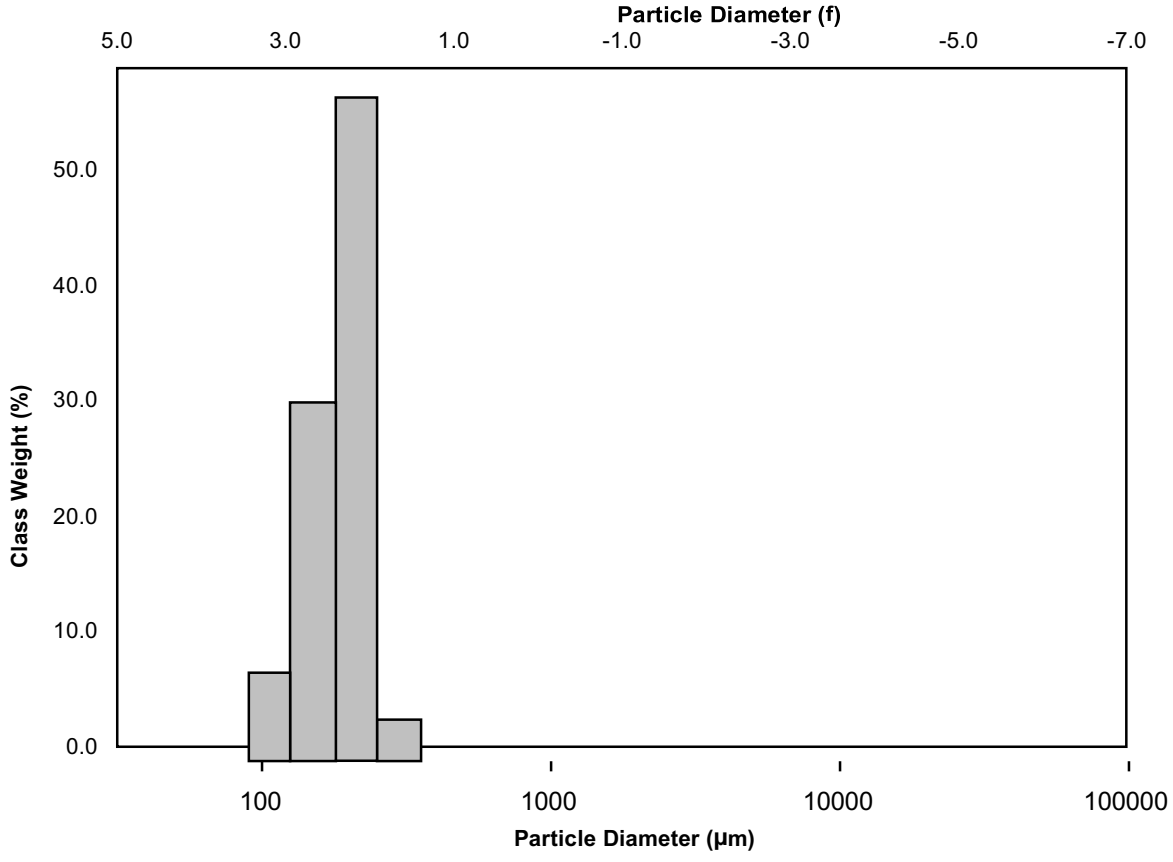
| | ∝m | ϕ |
|---|---|---|
| MODE 1: | 215.0 | 2.237 |
| MODE 2: | | |
| MODE 3: | | |
| $D_{10}$: | 128.6 | 2.054 |
| MEDIAN or $D_{50}$: | 190.1 | 2.395 |
| $D_{90}$: | 240.9 | 2.959 |
| ($D_{90}$ / $D_{10}$): | 1.873 | 1.441 |
| ($D_{90}$ - $D_{10}$): | 112.3 | 0.905 |
| ($D_{75}$ / $D_{25}$): | 1.455 | 1.248 |
| ($D_{75}$ - $D_{25}$): | 68.88 | 0.541 |

GRAIN SIZE DISTRIBUTION

| | | | |
|---|---|---|---|
| GRAVEL: | 0.0% | COARSE SAND: | 0.0% |
| SAND: | 100.0% | MEDIUM SAND: | 3.7% |
| MUD: | 0.0% | FINE SAND: | 88.9% |
| | | V FINE SAND: | 7.4% |
| V COARSE GRAVEL: | 0.0% | V COARSE SILT: | 0.0% |
| COARSE GRAVEL: | 0.0% | COARSE SILT: | 0.0% |
| MEDIUM GRAVEL: | 0.0% | MEDIUM SILT: | 0.0% |
| FINE GRAVEL: | 0.0% | FINE SILT: | 0.0% |
| V FINE GRAVEL: | 0.0% | V FINE SILT: | 0.0% |
| V COARSE SAND: | 0.0% | CLAY: | 0.0% |

| | METHOD OF MOMENTS | | | FOLK & WARD METHOD | | |
|---|---|---|---|---|---|---|
| | Arithmetic ∝m | Geometric ∝m | Logarithmic □ | Geometric ∝m | Logarithmic □ | Description |
| MEAN ( $\bar{x}$ ): | 189.4 | 181.8 | 2.460 | 182.4 | 2.455 | Fine Sand |
| SORTING (□): | 42.28 | 1.267 | 0.342 | 1.286 | 0.363 | Well Sorted |
| SKEWNESS ( $Sk$): | 0.069 | -0.562 | 0.562 | -0.282 | 0.282 | Fine Skewed |
| KURTOSIS ($K$): | 3.204 | 2.931 | 2.931 | 0.866 | 0.866 | Platykurtic |

## GRAIN SIZE DISTRIBUTION



## SAMPLE STATISTICS

SAMPLE IDENTITY: **AO 2 - Unit 6**

ANALYST & DATE: JES,

SAMPLE TYPE: Unimodal, Very Well Sorted

TEXTURAL GROUP: Sand

SEDIMENT NAME: Very Well Sorted Fine Sand

GPS: 29.3240N, 34.5851E

Depth: 2.67m

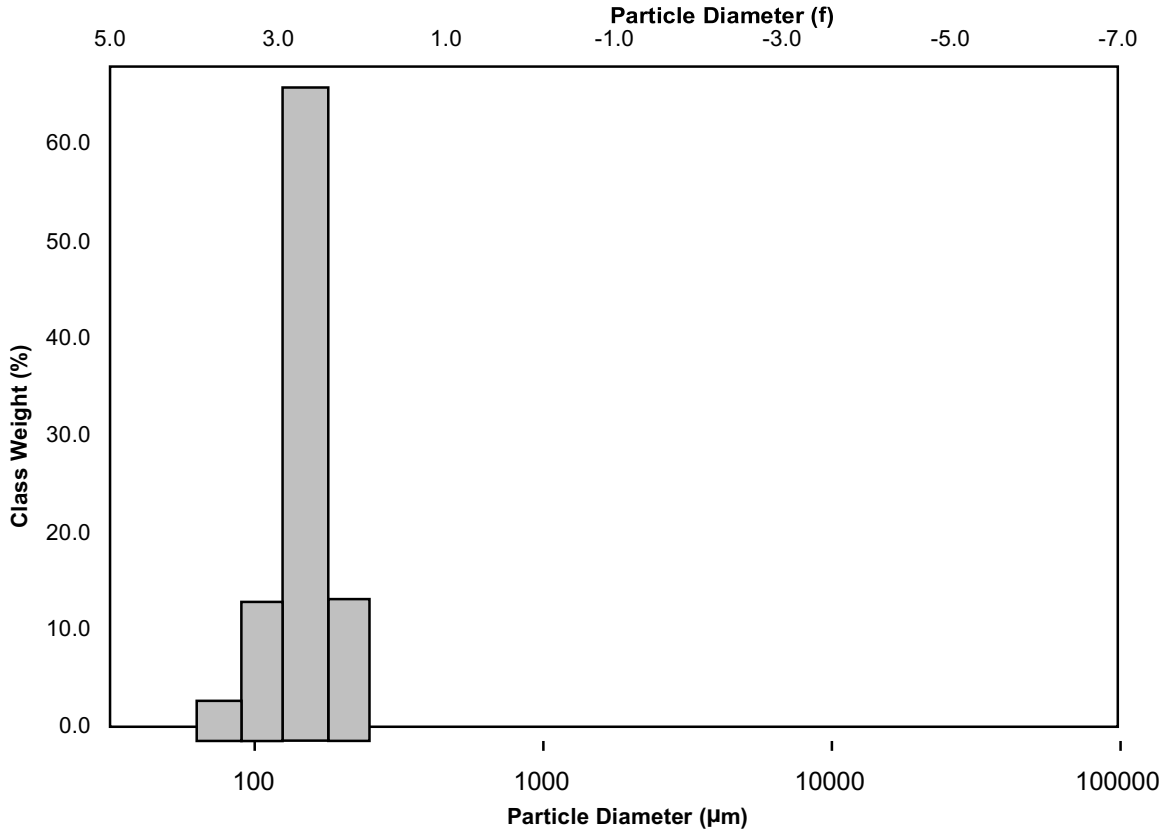
| | ∝m | ϕ |
|---|---|---|
| MODE 1: | 152.5 | 2.737 |
| MODE 2: | | |
| MODE 3: | | |
| $D_{10}$: | 104.1 | 2.351 |
| MEDIAN or $D_{50}$: | 148.5 | 2.752 |
| $D_{90}$: | 196.0 | 3.265 |
| ($D_{90}$ / $D_{10}$): | 1.884 | 1.389 |
| ($D_{90}$ - $D_{10}$): | 91.98 | 0.914 |
| ($D_{75}$ / $D_{25}$): | 1.302 | 1.149 |
| ($D_{75}$ - $D_{25}$): | 39.29 | 0.381 |

GRAIN SIZE DISTRIBUTION

| | | | |
|---|---|---|---|
| GRAVEL: | 0.0% | COARSE SAND: | 0.0% |
| SAND: | 100.0% | MEDIUM SAND: | 0.0% |
| MUD: | 0.0% | FINE SAND: | 82.6% |
| | | V FINE SAND: | 17.4% |
| V COARSE GRAVEL: | 0.0% | V COARSE SILT: | 0.0% |
| COARSE GRAVEL: | 0.0% | COARSE SILT: | 0.0% |
| MEDIUM GRAVEL: | 0.0% | MEDIUM SILT: | 0.0% |
| FINE GRAVEL: | 0.0% | FINE SILT: | 0.0% |
| V FINE GRAVEL: | 0.0% | V FINE SILT: | 0.0% |
| V COARSE SAND: | 0.0% | CLAY: | 0.0% |

| | METHOD OF MOMENTS | | | FOLK & WARD METHOD | | |
|---|---|---|---|---|---|---|
| | Arithmetic | Geometric | Logarithmic | Geometric | Logarithmic | Description |
| | ∝m | ∝m | □ | ∝m | □ | |
| MEAN ( $\bar{x}$ ): | 151.8 | 145.9 | 2.777 | 147.1 | 2.765 | Fine Sand |
| SORTING (□): | 32.17 | 1.254 | 0.326 | 1.258 | 0.331 | Very Well Sorted |
| SKEWNESS ( $Sk$): | 0.144 | -0.798 | 0.798 | -0.081 | 0.081 | Symmetrical |
| KURTOSIS ($K$ ): | 3.732 | 4.586 | 4.586 | 1.365 | 1.365 | Leptokurtic |

## GRAIN SIZE DISTRIBUTION



## SAMPLE STATISTICS

SAMPLE IDENTITY: **AO 2 - 7**

ANALYST & DATE: JES,

SAMPLE TYPE: Bimodal, Moderately Well Sorted

TEXTURAL GROUP: Sand

SEDIMENT NAME: Moderately Well Sorted Fine Sand

GPS: 29 32' 40" N, 34 58' 51" E
Depth: 2.85m

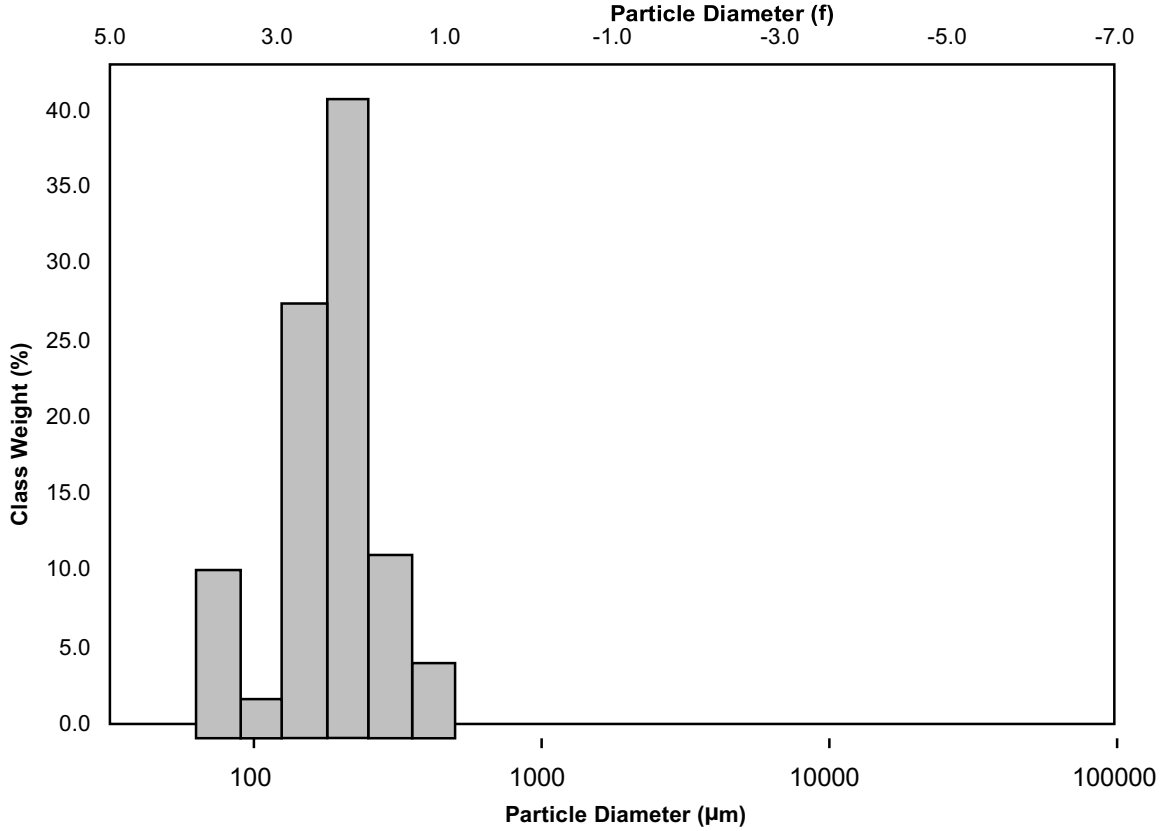
| | ∝m | ϕ |
|---|---|---|
| MODE 1: | 215.0 | 2.237 |
| MODE 2: | 76.50 | 3.731 |
| MODE 3: | | |
| $D_{10}$: | 86.41 | 1.710 |
| MEDIAN or $D_{50}$: | 189.9 | 2.397 |
| $D_{90}$: | 305.7 | 3.533 |
| ($D_{90}$ / $D_{10}$): | 3.538 | 2.066 |
| ($D_{90}$ - $D_{10}$): | 219.3 | 1.823 |
| ($D_{75}$ / $D_{25}$): | 1.629 | 1.336 |
| ($D_{75}$ - $D_{25}$): | 90.30 | 0.704 |

GRAIN SIZE DISTRIBUTION

| | | | |
|---|---|---|---|
| GRAVEL: | 0.0% | COARSE SAND: | 0.0% |
| SAND: | 100.0% | MEDIUM SAND: | 16.9% |
| MUD: | 0.0% | FINE SAND: | 69.4% |
| | | V FINE SAND: | 13.7% |
| V COARSE GRAVEL: | 0.0% | V COARSE SILT: | 0.0% |
| COARSE GRAVEL: | 0.0% | COARSE SILT: | 0.0% |
| MEDIUM GRAVEL: | 0.0% | MEDIUM SILT: | 0.0% |
| FINE GRAVEL: | 0.0% | FINE SILT: | 0.0% |
| V FINE GRAVEL: | 0.0% | V FINE SILT: | 0.0% |
| V COARSE SAND: | 0.0% | CLAY: | 0.0% |

| | METHOD OF MOMENTS | | | FOLK & WARD METHOD | | |
|---|---|---|---|---|---|---|
| | Arithmetic ∝m | Geometric ∝m | Logarithmic □ | Geometric ∝m | Logarithmic □ | Description |
| MEAN ( $\bar{x}$ ): | 199.0 | 180.3 | 2.472 | 184.4 | 2.439 | Fine Sand |
| SORTING (□): | 80.41 | 1.526 | 0.610 | 1.507 | 0.592 | Moderately Well Sorted |
| SKEWNESS ( $Sk$): | 0.880 | -0.448 | 0.448 | -0.167 | 0.167 | Fine Skewed |
| KURTOSIS ($K$ ): | 4.171 | 3.157 | 3.157 | 1.315 | 1.315 | Leptokurtic |

## GRAIN SIZE DISTRIBUTION



## SAMPLE STATISTICS

SAMPLE IDENTITY: **AO 2 - Unit 8**

ANALYST & DATE: JES,

SAMPLE TYPE: Bimodal, Moderately Well Sorted

TEXTURAL GROUP: Sand

SEDIMENT NAME: Moderately Well Sorted Fine Sand

GPS: 29.3240N, 34.5851E

Depth: 3.25m

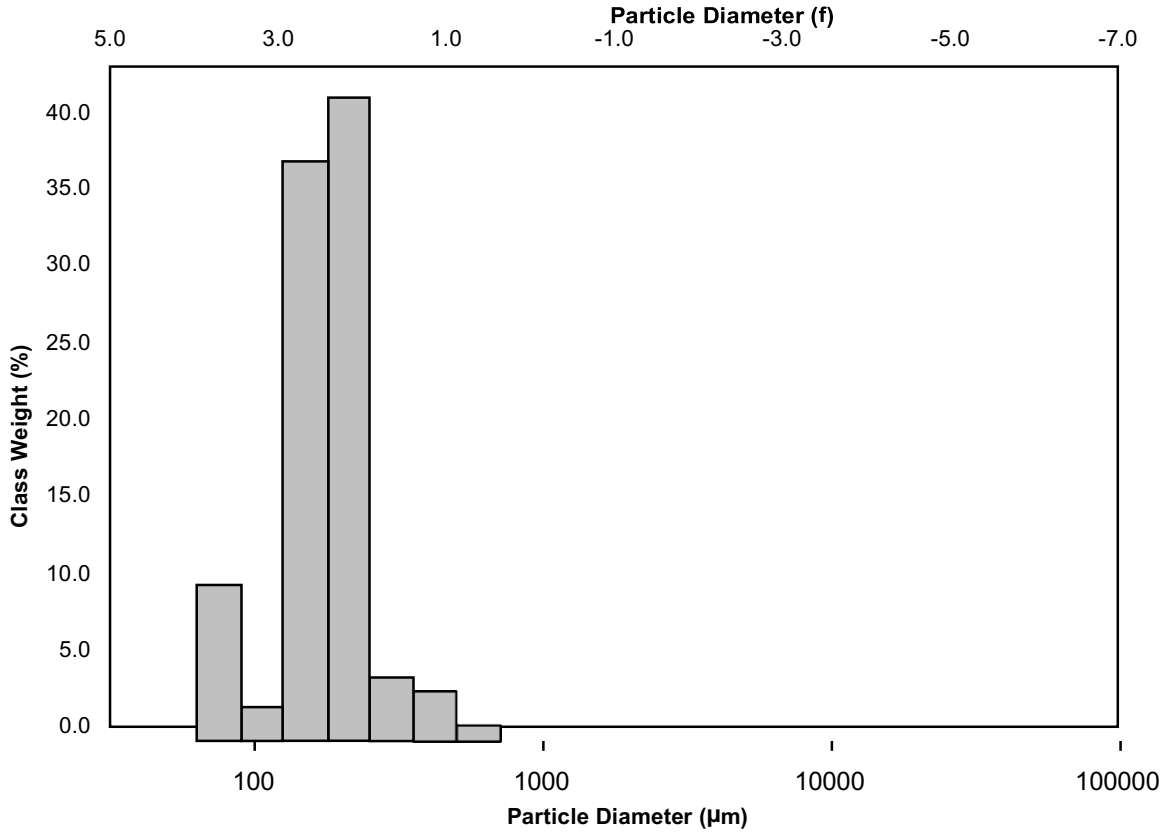
| | ∝m | ϕ |
|---|---|---|
| MODE 1: | 215.0 | 2.237 |
| MODE 2: | 76.50 | 3.731 |
| MODE 3: | | |
| $D_{10}$: | 88.72 | 2.020 |
| MEDIAN or $D_{50}$: | 176.6 | 2.502 |
| $D_{90}$: | 246.6 | 3.495 |
| ($D_{90}$ / $D_{10}$): | 2.779 | 1.730 |
| ($D_{90}$ - $D_{10}$): | 157.9 | 1.475 |
| ($D_{75}$ / $D_{25}$): | 1.552 | 1.288 |
| ($D_{75}$ - $D_{25}$): | 77.46 | 0.634 |

GRAIN SIZE DISTRIBUTION

| | | | |
|---|---|---|---|
| GRAVEL: | 0.0% | COARSE SAND: | 1.0% |
| SAND: | 100.0% | MEDIUM SAND: | 7.3% |
| MUD: | 0.0% | FINE SAND: | 79.2% |
| | | V FINE SAND: | 12.5% |
| V COARSE GRAVEL: | 0.0% | V COARSE SILT: | 0.0% |
| COARSE GRAVEL: | 0.0% | COARSE SILT: | 0.0% |
| MEDIUM GRAVEL: | 0.0% | MEDIUM SILT: | 0.0% |
| FINE GRAVEL: | 0.0% | FINE SILT: | 0.0% |
| V FINE GRAVEL: | 0.0% | V FINE SILT: | 0.0% |
| V COARSE SAND: | 0.0% | CLAY: | 0.0% |

| | METHOD OF MOMENTS | | | FOLK & WARD METHOD | | |
|---|---|---|---|---|---|---|
| | Arithmetic ∝m | Geometric ∝m | Logarithmic □ | Geometric ∝m | Logarithmic □ | Description |
| MEAN ( $\bar{x}$ ): | 188.0 | 171.4 | 2.544 | 174.9 | 2.516 | Fine Sand |
| SORTING (□): | 79.80 | 1.482 | 0.567 | 1.455 | 0.541 | Moderately Well Sorted |
| SKEWNESS ( $Sk$): | 2.130 | -0.123 | 0.123 | -0.102 | 0.102 | Fine Skewed |
| KURTOSIS ($K$ ): | 10.92 | 4.154 | 4.154 | 1.387 | 1.387 | Leptokurtic |

## GRAIN SIZE DISTRIBUTION



## SAMPLE STATISTICS

SAMPLE IDENTITY: **AO 2 - Unit 9**

ANALYST & DATE: JES,

SAMPLE TYPE: Bimodal, Moderately Sorted

TEXTURAL GROUP: Sand

SEDIMENT NAME: Moderately Sorted Fine Sand

GPS: 29.3240N, 34.5851E

Depth: 3.7m

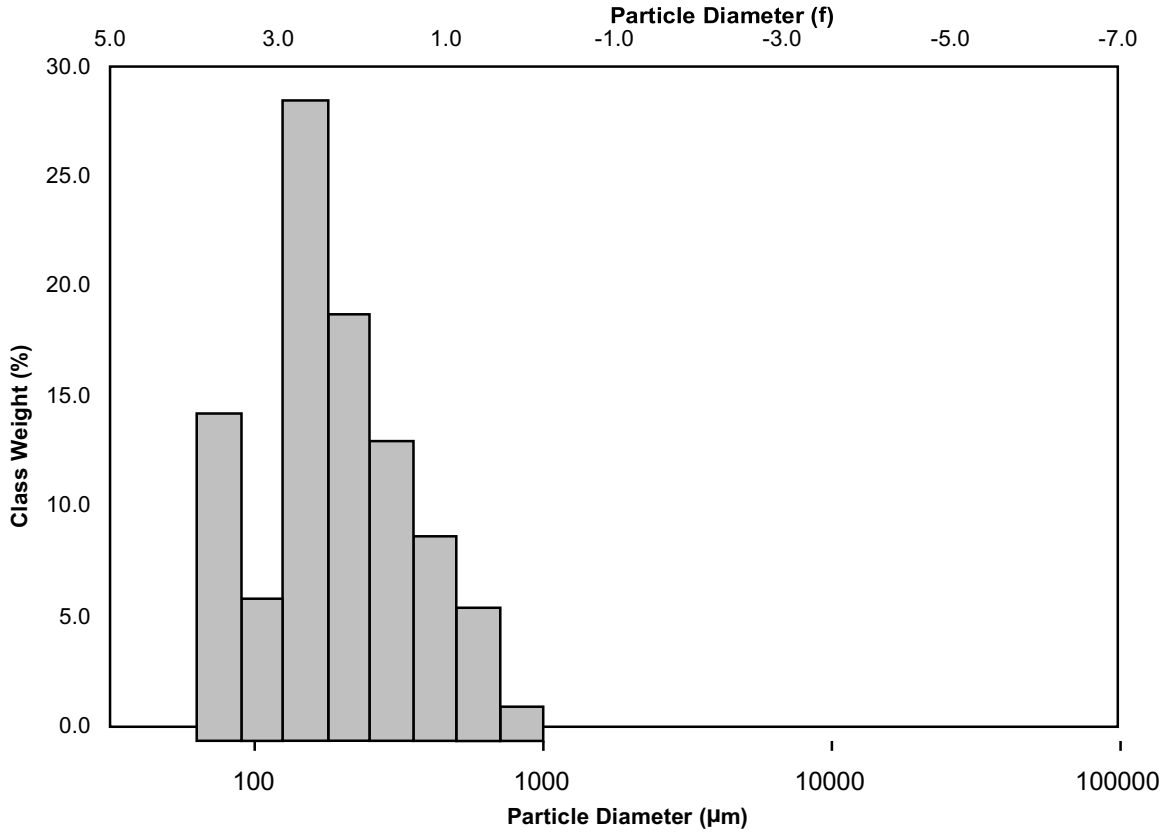
| | ∝m | ϕ |
|---|---|---|
| MODE 1: | 152.5 | 2.737 |
| MODE 2: | 76.50 | 3.731 |
| MODE 3: | | |
| $D_{10}$: | 79.72 | 1.132 |
| MEDIAN or $D_{50}$: | 176.8 | 2.500 |
| $D_{90}$: | 456.4 | 3.649 |
| ($D_{90}$ / $D_{10}$): | 5.725 | 3.225 |
| ($D_{90}$ - $D_{10}$): | 376.7 | 2.517 |
| ($D_{75}$ / $D_{25}$): | 2.190 | 1.627 |
| ($D_{75}$ - $D_{25}$): | 155.7 | 1.131 |

GRAIN SIZE DISTRIBUTION

| | | | |
|---|---|---|---|
| GRAVEL: | 0.0% | COARSE SAND: | 7.6% |
| SAND: | 100.0% | MEDIUM SAND: | 22.7% |
| MUD: | 0.0% | FINE SAND: | 48.5% |
| | | V FINE SAND: | 21.2% |
| V COARSE GRAVEL: | 0.0% | V COARSE SILT: | 0.0% |
| COARSE GRAVEL: | 0.0% | COARSE SILT: | 0.0% |
| MEDIUM GRAVEL: | 0.0% | MEDIUM SILT: | 0.0% |
| FINE GRAVEL: | 0.0% | FINE SILT: | 0.0% |
| V FINE GRAVEL: | 0.0% | V FINE SILT: | 0.0% |
| V COARSE SAND: | 0.0% | CLAY: | 0.0% |

| | METHOD OF MOMENTS | | | FOLK & WARD METHOD | | |
|---|---|---|---|---|---|---|
| | Arithmetic ∝m | Geometric ∝m | Logarithmic □ | Geometric ∝m | Logarithmic □ | Description |
| MEAN ( $\bar{x}$ ): | 233.2 | 189.7 | 2.398 | 182.4 | 2.455 | Fine Sand |
| SORTING (□): | 158.3 | 1.834 | 0.875 | 1.928 | 0.947 | Moderately Sorted |
| SKEWNESS ( $Sk$): | 1.669 | 0.291 | -0.291 | 0.100 | -0.100 | Coarse Skewed |
| KURTOSIS ($K$ ): | 5.868 | 2.515 | 2.515 | 1.099 | 1.099 | Mesokurtic |

## GRAIN SIZE DISTRIBUTION



## SAMPLE STATISTICS

SAMPLE IDENTITY: **AO 2 - Unit 10**

ANALYST & DATE: JES,

SAMPLE TYPE: Unimodal, Moderately Well Sorted

TEXTURAL GROUP: Sand

SEDIMENT NAME: Moderately Well Sorted Fine Sand

GPS: 29.3240N, 34.5851E

Depth: 4.05m

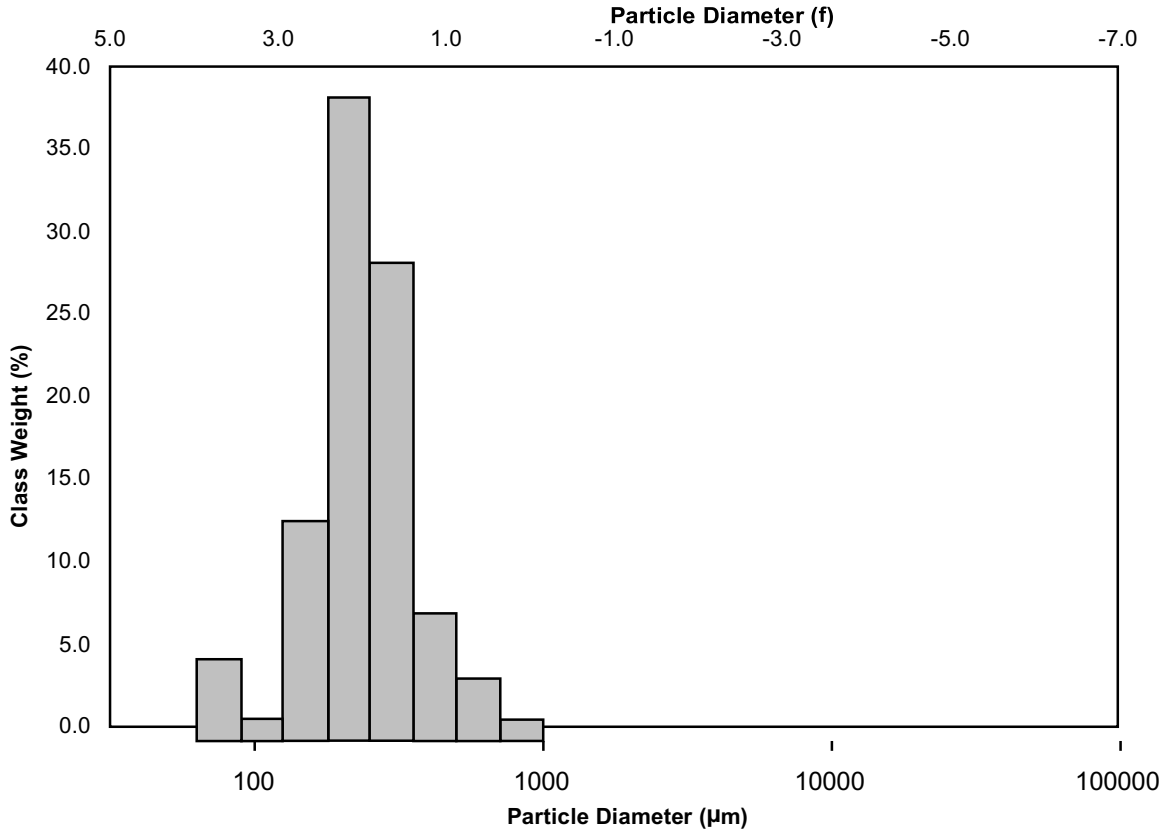
| | ∝m | ϕ |
|---|---|---|
| MODE 1: | 215.0 | 2.237 |
| MODE 2: | | |
| MODE 3: | | |
| $D_{10}$: | 137.2 | 1.313 |
| MEDIAN or $D_{50}$: | 233.6 | 2.098 |
| $D_{90}$: | 402.5 | 2.866 |
| ($D_{90}$ / $D_{10}$): | 2.935 | 2.183 |
| ($D_{90}$ - $D_{10}$): | 265.3 | 1.553 |
| ($D_{75}$ / $D_{25}$): | 1.640 | 1.419 |
| ($D_{75}$ - $D_{25}$): | 119.9 | 0.714 |

GRAIN SIZE DISTRIBUTION

| | | | |
|---|---|---|---|
| GRAVEL: | 0.0% | COARSE SAND: | 5.1% |
| SAND: | 100.0% | MEDIUM SAND: | 37.2% |
| MUD: | 0.0% | FINE SAND: | 51.3% |
| | | V FINE SAND: | 6.4% |
| V COARSE GRAVEL: | 0.0% | V COARSE SILT: | 0.0% |
| COARSE GRAVEL: | 0.0% | COARSE SILT: | 0.0% |
| MEDIUM GRAVEL: | 0.0% | MEDIUM SILT: | 0.0% |
| FINE GRAVEL: | 0.0% | FINE SILT: | 0.0% |
| V FINE GRAVEL: | 0.0% | V FINE SILT: | 0.0% |
| V COARSE SAND: | 0.0% | CLAY: | 0.0% |

| | METHOD OF MOMENTS | | | FOLK & WARD METHOD | | |
|---|---|---|---|---|---|---|
| | Arithmetic | Geometric | Logarithmic | Geometric | Logarithmic | Description |
| | ∝m | ∝m | □ | ∝m | □ | |
| MEAN ( $\bar{x}$ ): | 263.1 | 234.3 | 2.093 | 233.9 | 2.096 | Fine Sand |
| SORTING (□): | 127.3 | 1.571 | 0.651 | 1.572 | 0.653 | Moderately Well Sorted |
| SKEWNESS ( $Sk$): | 1.911 | -0.180 | 0.180 | -0.052 | 0.052 | Symmetrical |
| KURTOSIS ($K$ ): | 8.562 | 4.079 | 4.079 | 1.438 | 1.438 | Leptokurtic |

## GRAIN SIZE DISTRIBUTION



## SAMPLE STATISTICS

SAMPLE IDENTITY: **AO 2 - Unit 12a Blk Stain**

ANALYST & DATE: JES,

SAMPLE TYPE: Bimodal, Moderately Sorted

TEXTURAL GROUP: Sand

SEDIMENT NAME: Moderately Sorted Coarse Sand

GPS: 29.3240N, 34.5851E

Depth: 4.70m

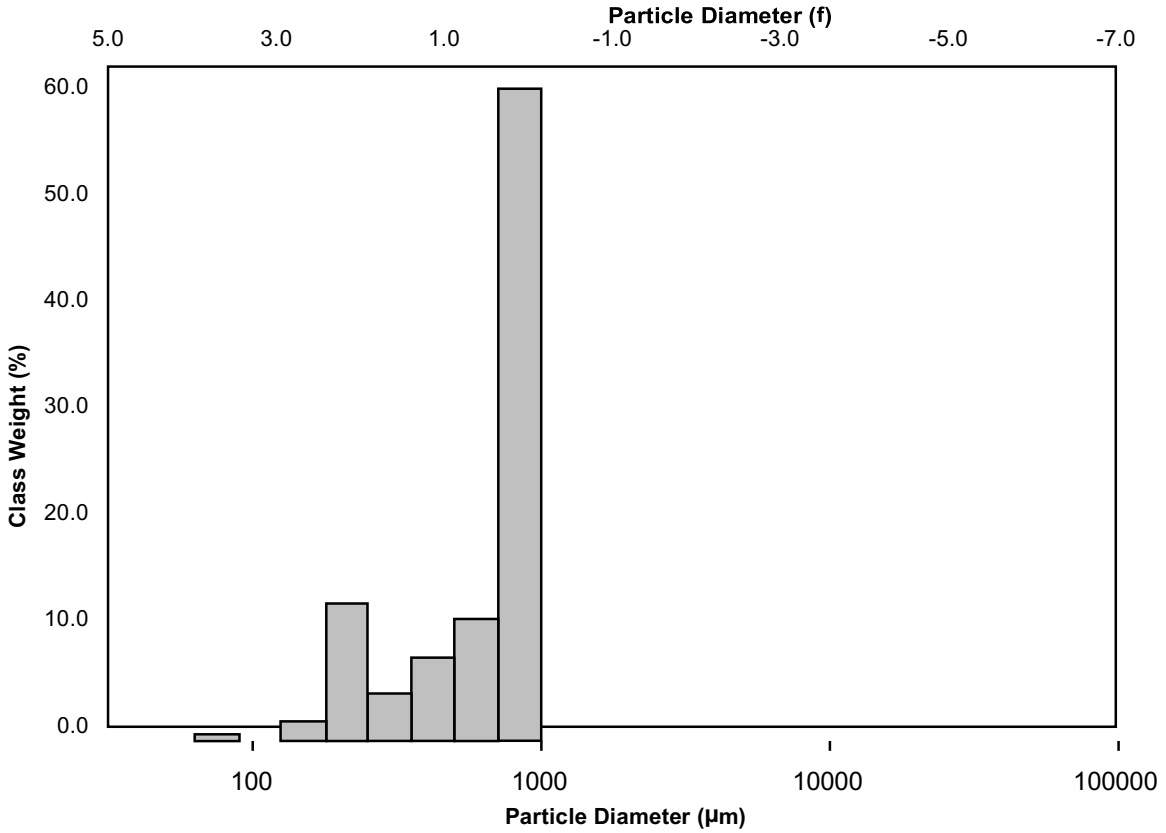
| | ∝m | ϕ |
|---|---|---|
| MODE 1: | 855.0 | 0.247 |
| MODE 2: | 215.0 | 2.237 |
| MODE 3: | | |
| $D_{10}$: | 219.2 | 0.081 |
| MEDIAN or $D_{50}$: | 755.4 | 0.405 |
| $D_{90}$: | 945.4 | 2.190 |
| ($D_{90}$ / $D_{10}$): | 4.313 | 27.05 |
| ($D_{90}$ - $D_{10}$): | 726.2 | 2.109 |
| ($D_{75}$ / $D_{25}$): | 1.921 | 5.653 |
| ($D_{75}$ - $D_{25}$): | 416.7 | 0.942 |

GRAIN SIZE DISTRIBUTION

| | | | |
|---|---|---|---|
| GRAVEL: | 0.0% | COARSE SAND: | 72.7% |
| SAND: | 100.0% | MEDIUM SAND: | 12.3% |
| MUD: | 0.0% | FINE SAND: | 14.3% |
| | | V FINE SAND: | 0.7% |
| V COARSE GRAVEL: | 0.0% | V COARSE SILT: | 0.0% |
| COARSE GRAVEL: | 0.0% | COARSE SILT: | 0.0% |
| MEDIUM GRAVEL: | 0.0% | MEDIUM SILT: | 0.0% |
| FINE GRAVEL: | 0.0% | FINE SILT: | 0.0% |
| V FINE GRAVEL: | 0.0% | V FINE SILT: | 0.0% |
| V COARSE SAND: | 0.0% | CLAY: | 0.0% |

| | METHOD OF MOMENTS | | | FOLK & WARD METHOD | | |
|---|---|---|---|---|---|---|
| | Arithmetic ∝m | Geometric ∝m | Logarithmic □ | Geometric ∝m | Logarithmic □ | Description |
| MEAN ( $\bar{x}$ ): | 669.6 | 587.1 | 0.768 | 572.2 | 0.805 | Coarse Sand |
| SORTING (□): | 255.3 | 1.731 | 0.791 | 1.733 | 0.793 | Moderately Sorted |
| SKEWNESS ( $Sk$): | -0.911 | -1.360 | 1.360 | -0.687 | 0.687 | Very Fine Skewed |
| KURTOSIS ($K$ ): | 2.187 | 3.722 | 3.722 | 1.019 | 1.019 | Mesokurtic |

## GRAIN SIZE DISTRIBUTION



## SAMPLE STATISTICS

SAMPLE IDENTITY: **AO 2 - Unit 12b**

ANALYST & DATE: JES,

SAMPLE TYPE: Bimodal, Moderately Well Sorted

TEXTURAL GROUP: Sand

SEDIMENT NAME: Moderately Well Sorted Medium Sand

GPS: 29.3240N, 34.5851E

Depth: 5.4m

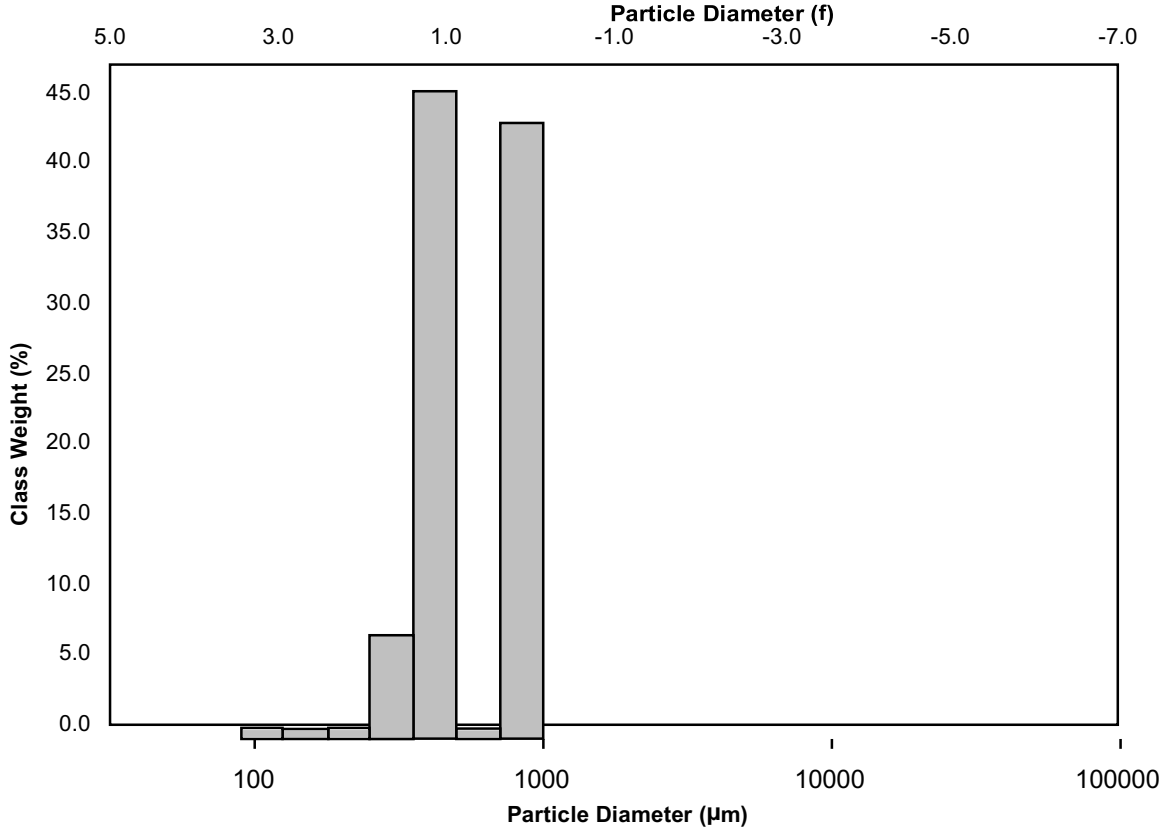
| | ∝m | ϕ |
|---|---|---|
| MODE 1: | 427.5 | 1.247 |
| MODE 2: | 855.0 | 0.247 |
| MODE 3: | | |
| $D_{10}$: | 355.6 | 0.113 |
| MEDIAN or $D_{50}$: | 479.4 | 1.061 |
| $D_{90}$: | 924.5 | 1.492 |
| ($D_{90}$ / $D_{10}$): | 2.600 | 13.17 |
| ($D_{90}$ - $D_{10}$): | 568.9 | 1.378 |
| ($D_{75}$ / $D_{25}$): | 2.066 | 4.696 |
| ($D_{75}$ - $D_{25}$): | 424.0 | 1.047 |

GRAIN SIZE DISTRIBUTION

| | | | |
|---|---|---|---|
| GRAVEL: | 0.0% | COARSE SAND: | 44.4% |
| SAND: | 100.0% | MEDIUM SAND: | 53.4% |
| MUD: | 0.0% | FINE SAND: | 1.5% |
| | | V FINE SAND: | 0.8% |
| V COARSE GRAVEL: | 0.0% | V COARSE SILT: | 0.0% |
| COARSE GRAVEL: | 0.0% | COARSE SILT: | 0.0% |
| MEDIUM GRAVEL: | 0.0% | MEDIUM SILT: | 0.0% |
| FINE GRAVEL: | 0.0% | FINE SILT: | 0.0% |
| V FINE GRAVEL: | 0.0% | V FINE SILT: | 0.0% |
| V COARSE SAND: | 0.0% | CLAY: | 0.0% |

| | METHOD OF MOMENTS | | | FOLK & WARD METHOD | | |
|---|---|---|---|---|---|---|
| | Arithmetic | Geometric | Logarithmic | Geometric | Logarithmic | Description |
| | ∝m | ∝m | □ | ∝m | □ | |
| MEAN ( $\bar{x}$): | 599.8 | 544.0 | 0.878 | 539.7 | 0.890 | Coarse Sand |
| SORTING (□): | 230.4 | 1.528 | 0.612 | 1.493 | 0.578 | Moderately Well Sorted |
| SKEWNESS ( $Sk$): | 0.076 | -0.558 | 0.558 | 0.277 | -0.277 | Coarse Skewed |
| KURTOSIS ($K$): | 1.329 | 3.335 | 3.335 | 0.688 | 0.688 | Platykurtic |

## GRAIN SIZE DISTRIBUTION



## SAMPLE STATISTICS

SAMPLE IDENTITY: **AO 3-11, Unit 5**

ANALYST & DATE: JES,

SAMPLE TYPE: Unimodal, Well Sorted

TEXTURAL GROUP: Sand

SEDIMENT NAME: Well Sorted Very Fine Sand

GPS: 29 32'43" N, 34 58'53" E

Depth: 3.2 m

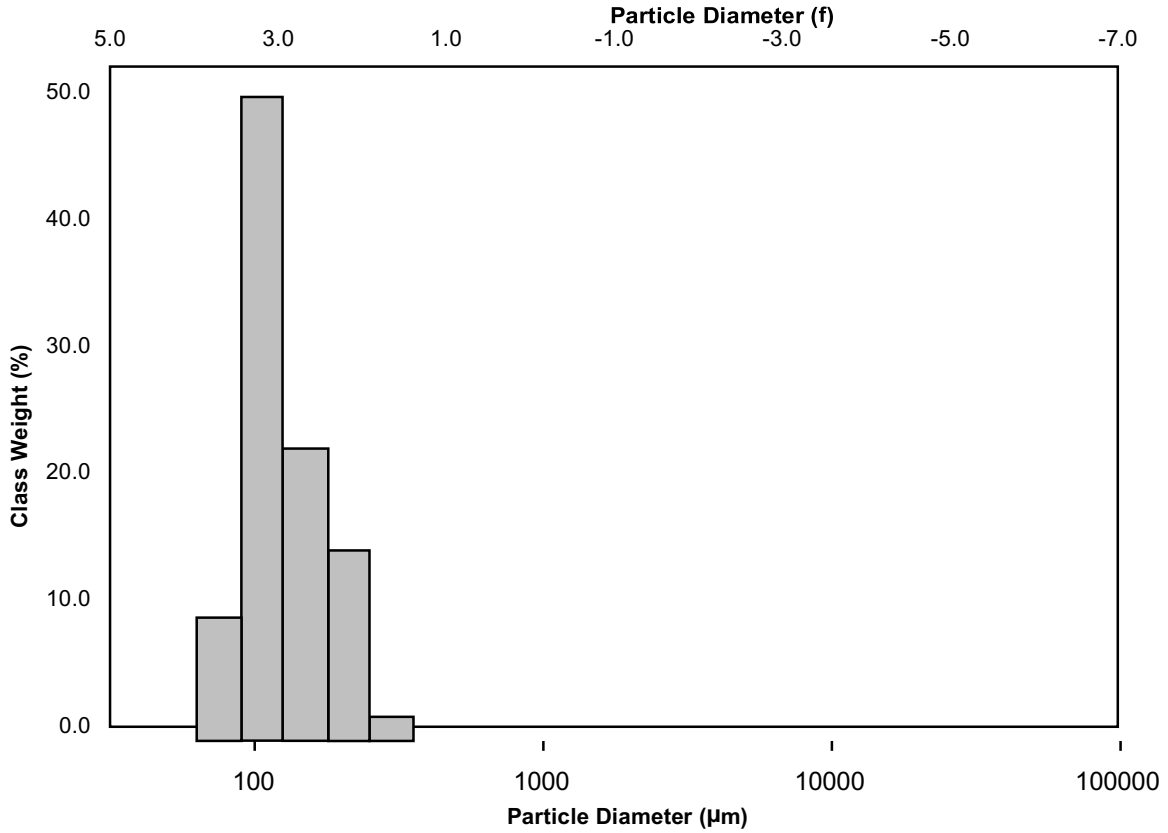
| | ∝m | ϕ |
|---|---|---|
| MODE 1: | 107.5 | 3.237 |
| MODE 2: | | |
| MODE 3: | | |
| $D_{10}$: | 89.52 | 2.264 |
| MEDIAN or $D_{50}$: | 117.7 | 3.087 |
| $D_{90}$: | 208.2 | 3.482 |
| ($D_{90}$ / $D_{10}$): | 2.326 | 1.538 |
| ($D_{90}$ - $D_{10}$): | 118.7 | 1.218 |
| ($D_{75}$ / $D_{25}$): | 1.593 | 1.253 |
| ($D_{75}$ - $D_{25}$): | 59.02 | 0.672 |

GRAIN SIZE DISTRIBUTION

| | | | |
|---|---|---|---|
| GRAVEL: | 0.0% | COARSE SAND: | 0.0% |
| SAND: | 100.0% | MEDIUM SAND: | 2.0% |
| MUD: | 0.0% | FINE SAND: | 39.1% |
| | | V FINE SAND: | 59.0% |
| V COARSE GRAVEL: | 0.0% | V COARSE SILT: | 0.0% |
| COARSE GRAVEL: | 0.0% | COARSE SILT: | 0.0% |
| MEDIUM GRAVEL: | 0.0% | MEDIUM SILT: | 0.0% |
| FINE GRAVEL: | 0.0% | FINE SILT: | 0.0% |
| V FINE GRAVEL: | 0.0% | V FINE SILT: | 0.0% |
| V COARSE SAND: | 0.0% | CLAY: | 0.0% |

| | METHOD OF MOMENTS | | | FOLK & WARD METHOD | | |
|---|---|---|---|---|---|---|
| | Arithmetic | Geometric | Logarithmic | Geometric | Logarithmic | Description |
| | ∝m | ∝m | □ | ∝m | □ | |
| MEAN ( $\bar{x}$ ): | 134.8 | 125.8 | 2.991 | 126.0 | 2.988 | Fine Sand |
| SORTING (□): | 47.58 | 1.377 | 0.462 | 1.401 | 0.487 | Well Sorted |
| SKEWNESS ( $Sk$): | 1.282 | 0.556 | -0.556 | 0.259 | -0.259 | Coarse Skewed |
| KURTOSIS ($K$ ): | 4.465 | 2.780 | 2.780 | 0.997 | 0.997 | Mesokurtic |

## GRAIN SIZE DISTRIBUTION



## SAMPLE STATISTICS

SAMPLE IDENTITY: **AO 3-5, Unit 6**

ANALYST & DATE: JES,

SAMPLE TYPE: Unimodal, Moderately Well Sorted

TEXTURAL GROUP: Sand

SEDIMENT NAME: Moderately Well Sorted Medium Sand

GPS: 29 32'43" N, 34 58'53" E

Depth: 3.4 m

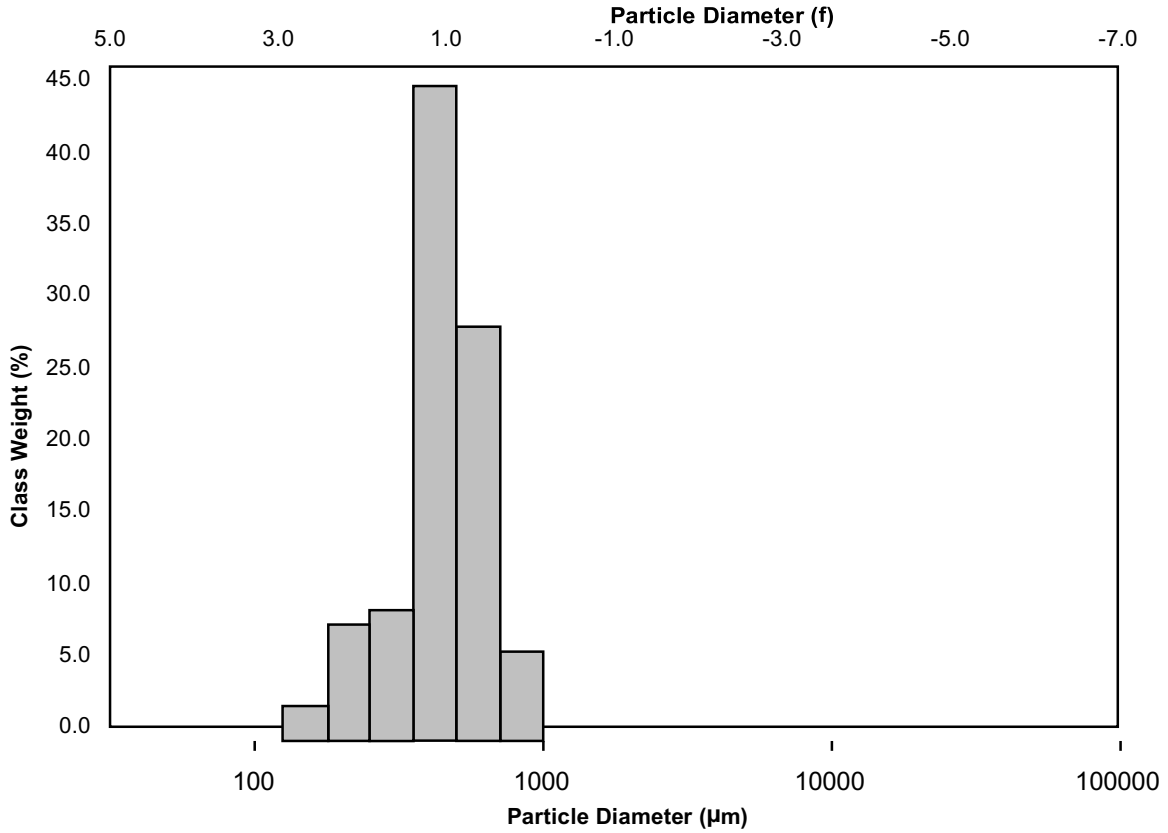
| | ∝m | ϕ |
|---|---|---|
| MODE 1: | 427.5 | 1.247 |
| MODE 2: | | |
| MODE 3: | | |
| $D_{10}$: | 247.3 | 0.561 |
| MEDIAN or $D_{50}$: | 447.5 | 1.160 |
| $D_{90}$: | 678.0 | 2.015 |
| ($D_{90}$ / $D_{10}$): | 2.741 | 3.594 |
| ($D_{90}$ - $D_{10}$): | 430.6 | 1.455 |
| ($D_{75}$ / $D_{25}$): | 1.530 | 1.748 |
| ($D_{75}$ - $D_{25}$): | 196.1 | 0.613 |

GRAIN SIZE DISTRIBUTION

| | | | |
|---|---|---|---|
| GRAVEL: | 0.0% | COARSE SAND: | 35.4% |
| SAND: | 100.0% | MEDIUM SAND: | 54.4% |
| MUD: | 0.0% | FINE SAND: | 10.3% |
| | | V FINE SAND: | 0.0% |
| V COARSE GRAVEL: | 0.0% | V COARSE SILT: | 0.0% |
| COARSE GRAVEL: | 0.0% | COARSE SILT: | 0.0% |
| MEDIUM GRAVEL: | 0.0% | MEDIUM SILT: | 0.0% |
| FINE GRAVEL: | 0.0% | FINE SILT: | 0.0% |
| V FINE GRAVEL: | 0.0% | V FINE SILT: | 0.0% |
| V COARSE SAND: | 0.0% | CLAY: | 0.0% |

| | METHOD OF MOMENTS | | | FOLK & WARD METHOD | | |
|---|---|---|---|---|---|---|
| | Arithmetic | Geometric | Logarithmic | Geometric | Logarithmic | Description |
| | ∝m | ∝m | □ | ∝m | □ | |
| MEAN ( $\bar{x}$ ): | 470.8 | 435.3 | 1.200 | 444.5 | 1.170 | Medium Sand |
| SORTING (□): | 159.5 | 1.450 | 0.536 | 1.460 | 0.546 | Moderately Well Sorted |
| SKEWNESS ( $Sk$): | 0.397 | -0.737 | 0.737 | -0.120 | 0.120 | Fine Skewed |
| KURTOSIS ($K$ ): | 3.252 | 3.665 | 3.665 | 1.284 | 1.284 | Leptokurtic |

## GRAIN SIZE DISTRIBUTION



## SAMPLE STATISTICS

SAMPLE IDENTITY: **AO 3-4, Unit 7**

ANALYST & DATE: JES,

SAMPLE TYPE: Bimodal, Moderately Well Sorted

TEXTURAL GROUP: Sand

SEDIMENT NAME: Moderately Well Sorted Fine Sand

GPS: 29 32'43" N, 34 58'53" E

Depth: 3.42 m

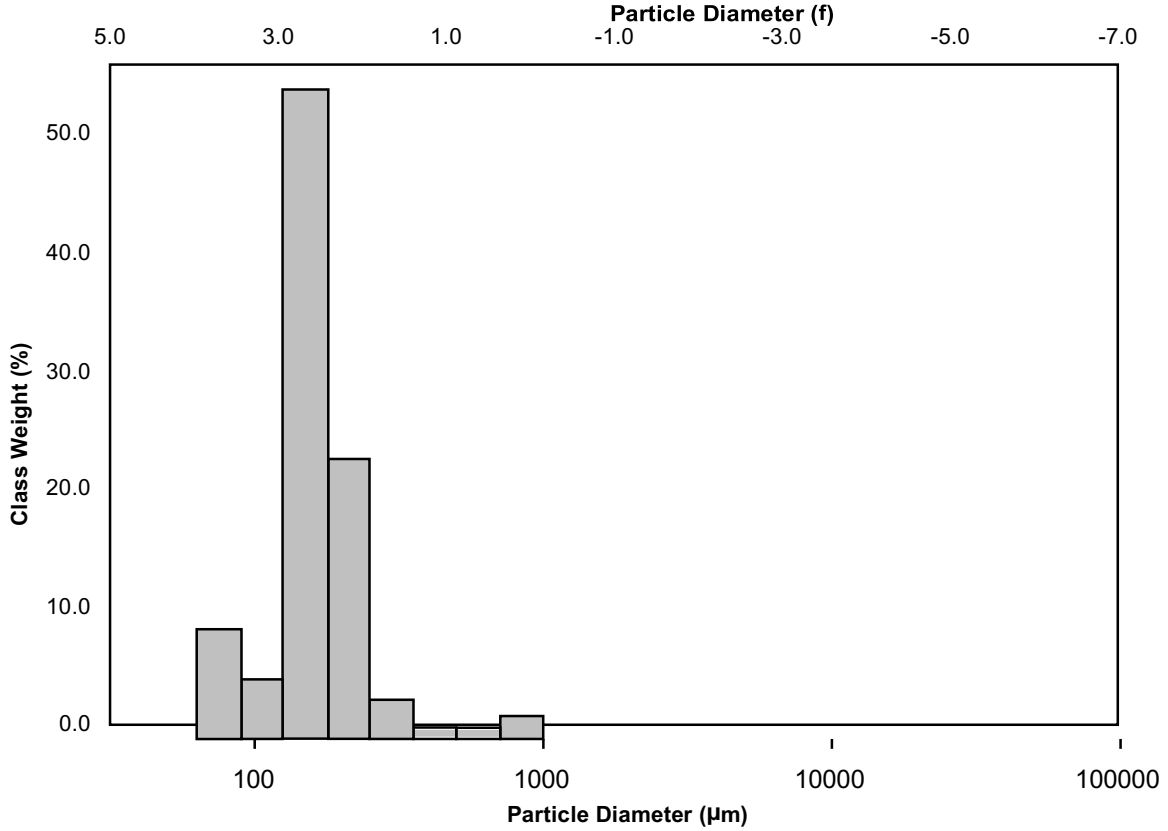
| | ∝m | ϕ |
|---|---|---|
| MODE 1: | 152.5 | 2.737 |
| MODE 2: | 76.50 | 3.731 |
| MODE 3: | | |
| $D_{10}$: | 93.93 | 2.063 |
| MEDIAN or $D_{50}$: | 157.4 | 2.667 |
| $D_{90}$: | 239.3 | 3.412 |
| ($D_{90}$ / $D_{10}$): | 2.547 | 1.654 |
| ($D_{90}$ - $D_{10}$): | 145.3 | 1.349 |
| ($D_{75}$ / $D_{25}$): | 1.427 | 1.215 |
| ($D_{75}$ - $D_{25}$): | 57.28 | 0.513 |

GRAIN SIZE DISTRIBUTION

| | | | |
|---|---|---|---|
| GRAVEL: | 0.0% | COARSE SAND: | 2.8% |
| SAND: | 100.0% | MEDIUM SAND: | 4.2% |
| MUD: | 0.0% | FINE SAND: | 78.9% |
| | | V FINE SAND: | 14.1% |
| V COARSE GRAVEL: | 0.0% | V COARSE SILT: | 0.0% |
| COARSE GRAVEL: | 0.0% | COARSE SILT: | 0.0% |
| MEDIUM GRAVEL: | 0.0% | MEDIUM SILT: | 0.0% |
| FINE GRAVEL: | 0.0% | FINE SILT: | 0.0% |
| V FINE GRAVEL: | 0.0% | V FINE SILT: | 0.0% |
| V COARSE SAND: | 0.0% | CLAY: | 0.0% |

| | METHOD OF MOMENTS | | | FOLK & WARD METHOD | | |
|---|---|---|---|---|---|---|
| | Arithmetic ∝m | Geometric ∝m | Logarithmic □ | Geometric ∝m | Logarithmic □ | Description |
| MEAN ( $\bar{x}$ ): | 182.0 | 161.4 | 2.631 | 163.4 | 2.614 | Fine Sand |
| SORTING (□): | 115.2 | 1.512 | 0.596 | 1.419 | 0.505 | Moderately Well Sorted |
| SKEWNESS ( $Sk$): | 4.248 | 1.146 | -1.146 | 0.086 | -0.086 | Symmetrical |
| KURTOSIS ($K$ ): | 23.88 | 7.361 | 7.361 | 1.621 | 1.621 | Very Leptokurtic |

## GRAIN SIZE DISTRIBUTION



## SAMPLE STATISTICS

SAMPLE IDENTITY: **AO 3-7, Unit 7**

ANALYST & DATE: JES,

SAMPLE TYPE: Bimodal, Well Sorted

TEXTURAL GROUP: Sand

SEDIMENT NAME: Well Sorted Fine Sand

GPS: 29 32'43" N, 34 58'53" E

Depth: 3.5 m

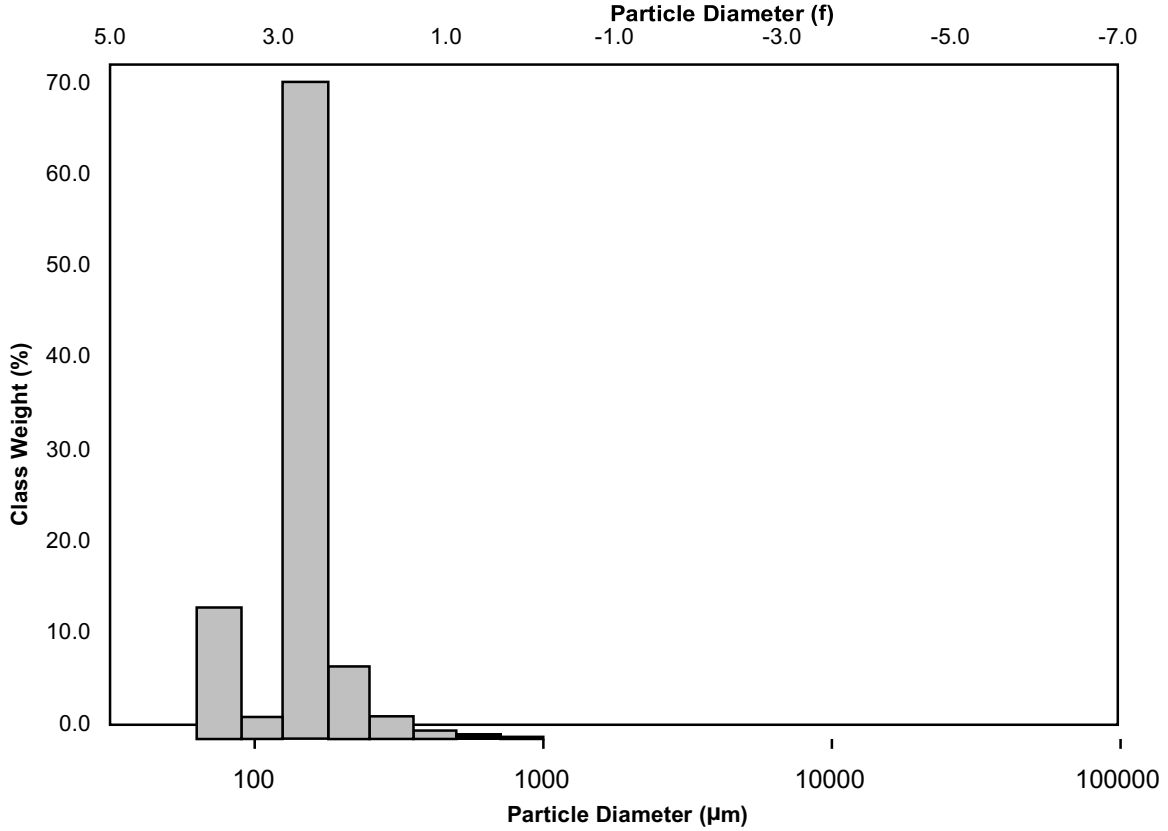
| | ∝m | ϕ |
|---|---|---|
| MODE 1: | 152.5 | 2.737 |
| MODE 2: | 76.50 | 3.731 |
| MODE 3: | | |
| $D_{10}$: | 81.00 | 2.399 |
| MEDIAN or $D_{50}$: | 148.0 | 2.756 |
| $D_{90}$: | 189.6 | 3.626 |
| ($D_{90}$ / $D_{10}$): | 2.341 | 1.511 |
| ($D_{90}$ - $D_{10}$): | 108.6 | 1.227 |
| ($D_{75}$ / $D_{25}$): | 1.286 | 1.141 |
| ($D_{75}$ - $D_{25}$): | 37.33 | 0.363 |

GRAIN SIZE DISTRIBUTION

| | | | |
|---|---|---|---|
| GRAVEL: | 0.0% | COARSE SAND: | 0.7% |
| SAND: | 100.0% | MEDIUM SAND: | 3.3% |
| MUD: | 0.0% | FINE SAND: | 79.7% |
| | | V FINE SAND: | 16.4% |
| V COARSE GRAVEL: | 0.0% | V COARSE SILT: | 0.0% |
| COARSE GRAVEL: | 0.0% | COARSE SILT: | 0.0% |
| MEDIUM GRAVEL: | 0.0% | MEDIUM SILT: | 0.0% |
| FINE GRAVEL: | 0.0% | FINE SILT: | 0.0% |
| V FINE GRAVEL: | 0.0% | V FINE SILT: | 0.0% |
| V COARSE SAND: | 0.0% | CLAY: | 0.0% |

| | METHOD OF MOMENTS | | | FOLK & WARD METHOD | | |
|---|---|---|---|---|---|---|
| | Arithmetic ∝m | Geometric ∝m | Logarithmic □ | Geometric ∝m | Logarithmic □ | Description |
| MEAN ($\bar{x}$): | 154.8 | 143.4 | 2.802 | 145.4 | 2.782 | Fine Sand |
| SORTING (□): | 65.76 | 1.398 | 0.483 | 1.325 | 0.406 | Well Sorted |
| SKEWNESS ($Sk$): | 4.768 | 0.295 | -0.295 | -0.173 | 0.173 | Fine Skewed |
| KURTOSIS ($K$): | 41.47 | 6.731 | 6.731 | 1.962 | 1.962 | Very Leptokurtic |

## GRAIN SIZE DISTRIBUTION



## SAMPLE STATISTICS

SAMPLE IDENTITY: **AO 3-10, Unit 8**

ANALYST & DATE: JES,

SAMPLE TYPE: Bimodal, Moderately Well Sorted

TEXTURAL GROUP: Sand

SEDIMENT NAME: Moderately Well Sorted Fine Sand

GPS: 29 32'43" N, 34 58'53" E

Depth: 3.6m

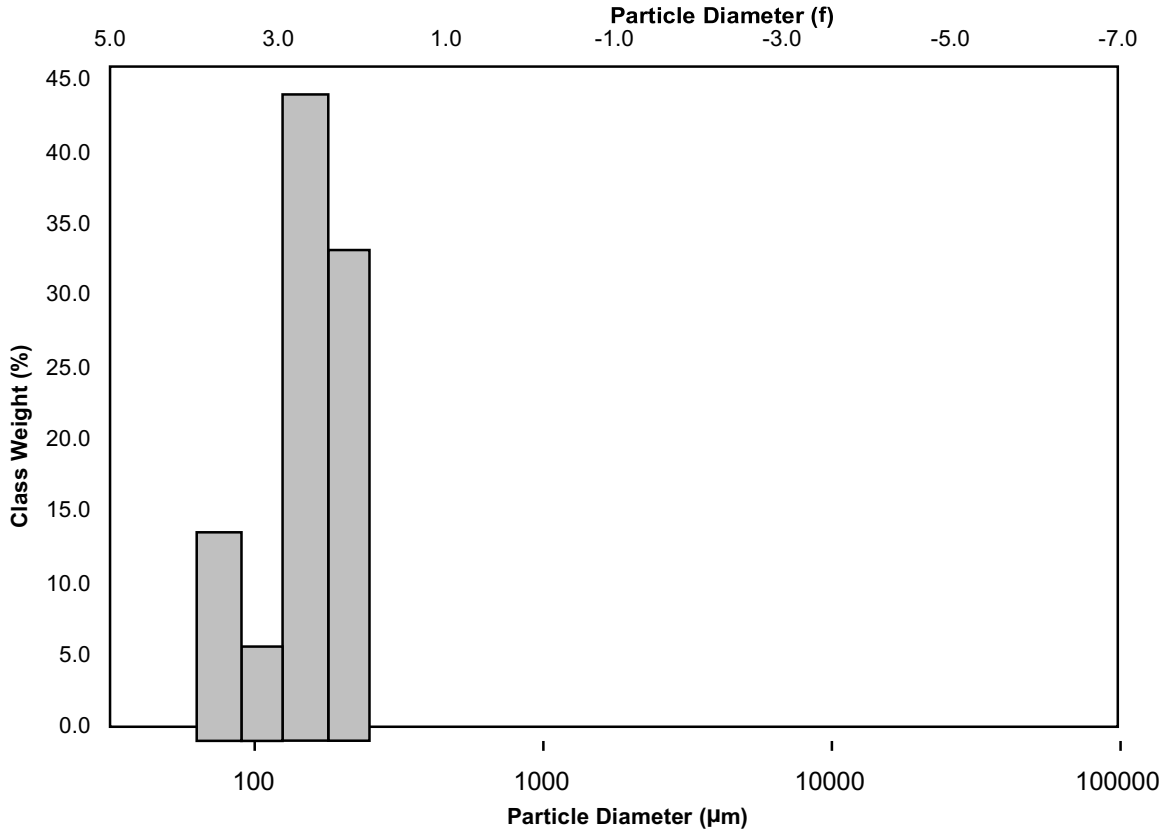
| | ∝m | ϕ |
|---|---|---|
| MODE 1: | 152.5 | 2.737 |
| MODE 2: | 76.50 | 3.731 |
| MODE 3: | | |
| $D_{10}$: | 80.15 | 2.148 |
| MEDIAN or $D_{50}$: | 156.6 | 2.675 |
| $D_{90}$: | 225.7 | 3.641 |
| ($D_{90}$ / $D_{10}$): | 2.816 | 1.695 |
| ($D_{90}$ - $D_{10}$): | 145.5 | 1.493 |
| ($D_{75}$ / $D_{25}$): | 1.501 | 1.247 |
| ($D_{75}$ - $D_{25}$): | 64.60 | 0.586 |

GRAIN SIZE DISTRIBUTION

| | | | |
|---|---|---|---|
| GRAVEL: | 0.0% | COARSE SAND: | 0.0% |
| SAND: | 100.0% | MEDIUM SAND: | 0.0% |
| MUD: | 0.0% | FINE SAND: | 79.0% |
| | | V FINE SAND: | 21.0% |
| V COARSE GRAVEL: | 0.0% | V COARSE SILT: | 0.0% |
| COARSE GRAVEL: | 0.0% | COARSE SILT: | 0.0% |
| MEDIUM GRAVEL: | 0.0% | MEDIUM SILT: | 0.0% |
| FINE GRAVEL: | 0.0% | FINE SILT: | 0.0% |
| V FINE GRAVEL: | 0.0% | V FINE SILT: | 0.0% |
| V COARSE SAND: | 0.0% | CLAY: | 0.0% |

| | METHOD OF MOMENTS | | | FOLK & WARD METHOD | | |
|---|---|---|---|---|---|---|
| | Arithmetic ∝m | Geometric ∝m | Logarithmic □ | Geometric ∝m | Logarithmic □ | Description |
| MEAN ( $\bar{x}$ ): | 158.5 | 148.2 | 2.755 | 147.2 | 2.765 | Fine Sand |
| SORTING (□): | 46.88 | 1.406 | 0.492 | 1.465 | 0.550 | Moderately Well Sorted |
| SKEWNESS ( $Sk$): | -0.313 | -0.844 | 0.844 | -0.272 | 0.272 | Fine Skewed |
| KURTOSIS ($K$ ): | 2.150 | 2.756 | 2.756 | 1.218 | 1.218 | Leptokurtic |

## GRAIN SIZE DISTRIBUTION



## SAMPLE STATISTICS

SAMPLE IDENTITY: **AO 3-3, Unit 8**

ANALYST & DATE: JES,

SAMPLE TYPE: Bimodal, Poorly Sorted

TEXTURAL GROUP: Sand

SEDIMENT NAME: Poorly Sorted Coarse Sand

GPS: 29 32'43" N, 34 58'53" E

Depth: 3.70m

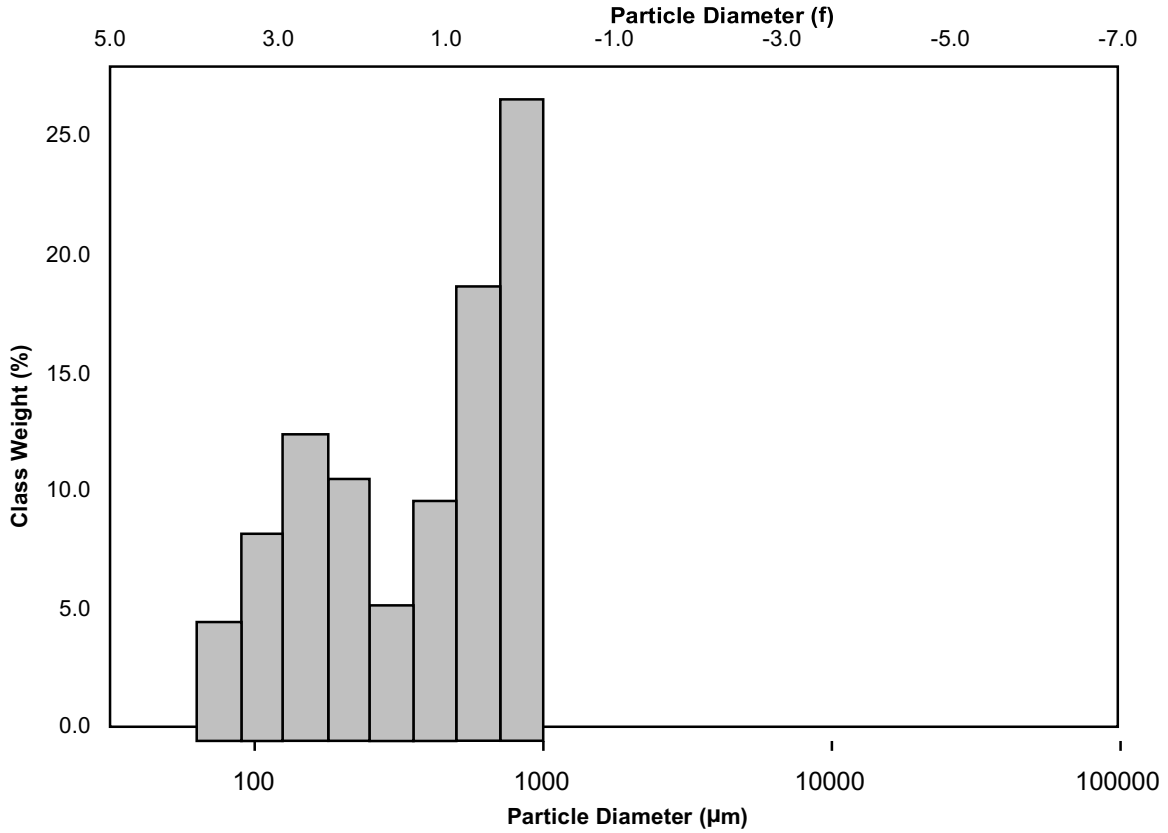
| | ∝m | ϕ |
|---|---|---|
| MODE 1: | 855.0 | 0.247 |
| MODE 2: | 152.5 | 2.737 |
| MODE 3: | | |
| $D_{10}$: | 108.8 | 0.184 |
| MEDIAN or $D_{50}$: | 442.2 | 1.177 |
| $D_{90}$: | 880.4 | 3.200 |
| ($D_{90}$ / $D_{10}$): | 8.092 | 17.42 |
| ($D_{90}$ - $D_{10}$): | 771.6 | 3.017 |
| ($D_{75}$ / $D_{25}$): | 4.285 | 5.570 |
| ($D_{75}$ - $D_{25}$): | 557.6 | 2.099 |

GRAIN SIZE DISTRIBUTION

| | | | |
|---|---|---|---|
| GRAVEL: | 0.0% | COARSE SAND: | 46.4% |
| SAND: | 100.0% | MEDIUM SAND: | 15.9% |
| MUD: | 0.0% | FINE SAND: | 24.2% |
| | | V FINE SAND: | 13.5% |
| V COARSE GRAVEL: | 0.0% | V COARSE SILT: | 0.0% |
| COARSE GRAVEL: | 0.0% | COARSE SILT: | 0.0% |
| MEDIUM GRAVEL: | 0.0% | MEDIUM SILT: | 0.0% |
| FINE GRAVEL: | 0.0% | FINE SILT: | 0.0% |
| V FINE GRAVEL: | 0.0% | V FINE SILT: | 0.0% |
| V COARSE SAND: | 0.0% | CLAY: | 0.0% |

| | METHOD OF MOMENTS | | | FOLK & WARD METHOD | | |
|---|---|---|---|---|---|---|
| | Arithmetic | Geometric | Logarithmic | Geometric | Logarithmic | Description |
| | ∝m | ∝m | □ | ∝m | □ | |
| MEAN ( $\bar{x}$ ): | 464.9 | 350.5 | 1.512 | 363.8 | 1.459 | Medium Sand |
| SORTING (□): | 291.2 | 2.217 | 1.148 | 2.247 | 1.168 | Poorly Sorted |
| SKEWNESS ( $Sk$): | 0.145 | -0.430 | 0.430 | -0.342 | 0.342 | Very Fine Skewed |
| KURTOSIS ($K$ ): | 1.473 | 1.776 | 1.776 | 0.664 | 0.664 | Very Platykurtic |

## GRAIN SIZE DISTRIBUTION



## SAMPLE STATISTICS

SAMPLE IDENTITY: **AO 3-12, Unit 9**

ANALYST & DATE: JES,

SAMPLE TYPE: Bimodal, Moderately Sorted

TEXTURAL GROUP: Sand

SEDIMENT NAME: Moderately Sorted Coarse Sand

GPS: 29 32'43" N, 34 58'53" E

Depth: 4.0 m

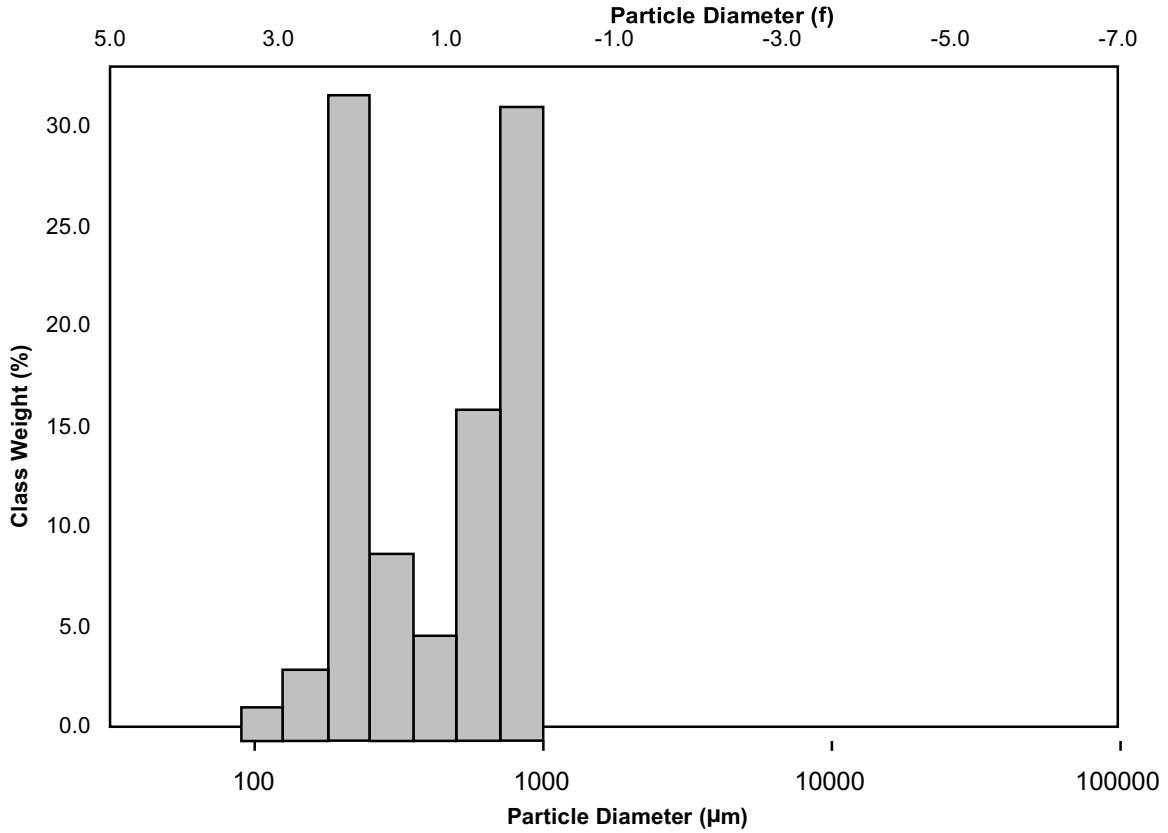
| | ∝m | ϕ |
|---|---|---|
| MODE 1: | 215.0 | 2.237 |
| MODE 2: | 855.0 | 0.247 |
| MODE 3: | | |
| $D_{10}$: | 189.0 | 0.156 |
| MEDIAN or $D_{50}$: | 460.2 | 1.120 |
| $D_{90}$: | 897.7 | 2.404 |
| ($D_{90}$ / $D_{10}$): | 4.751 | 15.44 |
| ($D_{90}$ - $D_{10}$): | 708.8 | 2.248 |
| ($D_{75}$ / $D_{25}$): | 3.447 | 5.588 |
| ($D_{75}$ - $D_{25}$): | 542.1 | 1.785 |

GRAIN SIZE DISTRIBUTION

| | | | |
|---|---|---|---|
| GRAVEL: | 0.0% | COARSE SAND: | 48.7% |
| SAND: | 100.0% | MEDIUM SAND: | 14.9% |
| MUD: | 0.0% | FINE SAND: | 34.8% |
| | | V FINE SAND: | 1.6% |
| V COARSE GRAVEL: | 0.0% | V COARSE SILT: | 0.0% |
| COARSE GRAVEL: | 0.0% | COARSE SILT: | 0.0% |
| MEDIUM GRAVEL: | 0.0% | MEDIUM SILT: | 0.0% |
| FINE GRAVEL: | 0.0% | FINE SILT: | 0.0% |
| V FINE GRAVEL: | 0.0% | V FINE SILT: | 0.0% |
| V COARSE SAND: | 0.0% | CLAY: | 0.0% |

| | METHOD OF MOMENTS | | | FOLK & WARD METHOD | | |
|---|---|---|---|---|---|---|
| | Arithmetic | Geometric | Logarithmic | Geometric | Logarithmic | Description |
| | ∝m | ∝m | □ | ∝m | □ | |
| MEAN ($\bar{x}$): | 499.9 | 409.4 | 1.288 | 427.2 | 1.227 | Medium Sand |
| SORTING (□): | 279.6 | 1.883 | 0.913 | 1.850 | 0.887 | Moderately Sorted |
| SKEWNESS ($Sk$): | 0.180 | -0.162 | 0.162 | -0.153 | 0.153 | Fine Skewed |
| KURTOSIS ($K$): | 1.342 | 1.499 | 1.499 | 0.563 | 0.563 | Very Platykurtic |

## GRAIN SIZE DISTRIBUTION



## SAMPLE STATISTICS

SAMPLE IDENTITY: **AO 3-8, Unit 10**

ANALYST & DATE: JES,

SAMPLE TYPE: Unimodal, Well Sorted

TEXTURAL GROUP: Sand

SEDIMENT NAME: Well Sorted Medium Sand

GPS: 29 32'43" N, 34 58'53" E

Depth: 3.9 m

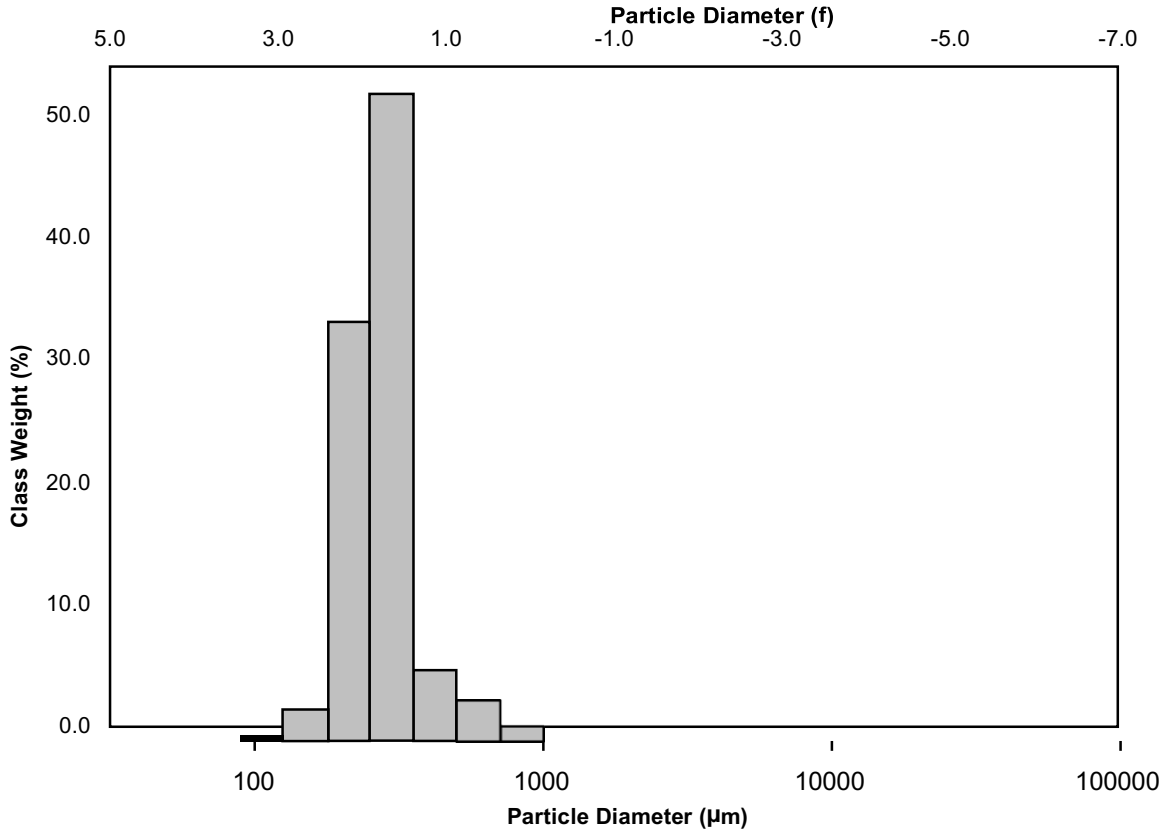
| | ∝m | ϕ |
|---|---|---|
| MODE 1: | 302.5 | 1.747 |
| MODE 2: | | |
| MODE 3: | | |
| $D_{10}$: | 193.0 | 1.468 |
| MEDIAN or $D_{50}$: | 274.2 | 1.866 |
| $D_{90}$: | 361.4 | 2.373 |
| ($D_{90}$ / $D_{10}$): | 1.872 | 1.616 |
| ($D_{90}$ - $D_{10}$): | 168.3 | 0.905 |
| ($D_{75}$ / $D_{25}$): | 1.438 | 1.321 |
| ($D_{75}$ - $D_{25}$): | 98.24 | 0.524 |

GRAIN SIZE DISTRIBUTION

| | | | |
|---|---|---|---|
| GRAVEL: | 0.0% | COARSE SAND: | 4.5% |
| SAND: | 100.0% | MEDIUM SAND: | 59.7% |
| MUD: | 0.0% | FINE SAND: | 35.5% |
| | | V FINE SAND: | 0.3% |
| V COARSE GRAVEL: | 0.0% | V COARSE SILT: | 0.0% |
| COARSE GRAVEL: | 0.0% | COARSE SILT: | 0.0% |
| MEDIUM GRAVEL: | 0.0% | MEDIUM SILT: | 0.0% |
| FINE GRAVEL: | 0.0% | FINE SILT: | 0.0% |
| V FINE GRAVEL: | 0.0% | V FINE SILT: | 0.0% |
| V COARSE SAND: | 0.0% | CLAY: | 0.0% |

| | METHOD OF MOMENTS | | | FOLK & WARD METHOD | | |
|---|---|---|---|---|---|---|
| | Arithmetic | Geometric | Logarithmic | Geometric | Logarithmic | Description |
| | ∝m | ∝m | □ | ∝m | □ | |
| MEAN ( $\bar{x}$ ): | 293.1 | 275.7 | 1.859 | 267.9 | 1.900 | Medium Sand |
| SORTING (□): | 103.9 | 1.336 | 0.418 | 1.317 | 0.398 | Well Sorted |
| SKEWNESS ( $Sk$): | 2.718 | 0.909 | -0.909 | 0.020 | -0.020 | Symmetrical |
| KURTOSIS ($K$ ): | 13.46 | 5.731 | 5.731 | 1.100 | 1.100 | Mesokurtic |

## GRAIN SIZE DISTRIBUTION



## SAMPLE STATISTICS

SAMPLE IDENTITY: **AO 3-9, Unit 10**

ANALYST & DATE: JES,

SAMPLE TYPE: Bimodal, Moderately Sorted

TEXTURAL GROUP: Sand

SEDIMENT NAME: Moderately Sorted Coarse Sand

GPS: 29 32'43" N, 34 58'53" E

Depth: 3.8m

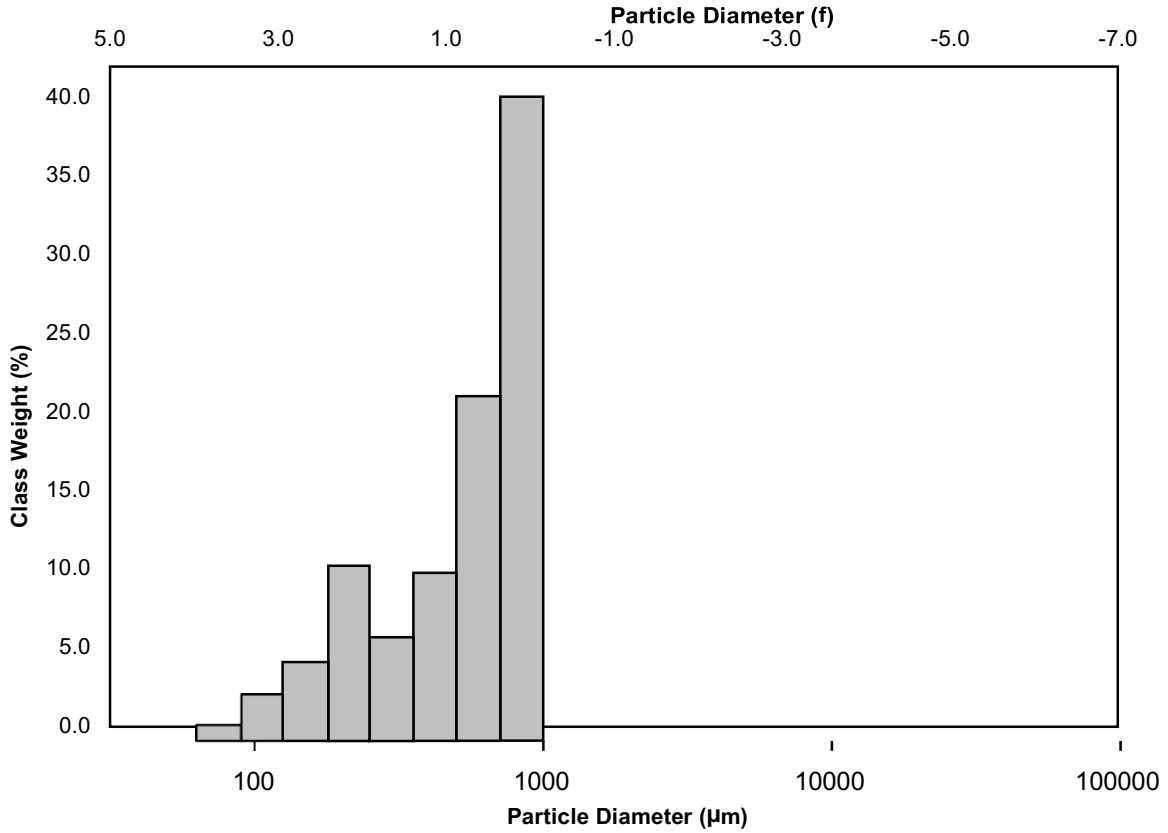
| | ∝m | ϕ |
|---|---|---|
| MODE 1: | 855.0 | 0.247 |
| MODE 2: | 215.0 | 2.237 |
| MODE 3: | | |
| $D_{10}$: | 184.6 | 0.122 |
| MEDIAN or $D_{50}$: | 612.7 | 0.707 |
| $D_{90}$: | 919.2 | 2.437 |
| ($D_{90}$ / $D_{10}$): | 4.979 | 20.05 |
| ($D_{90}$ - $D_{10}$): | 734.6 | 2.316 |
| ($D_{75}$ / $D_{25}$): | 2.467 | 5.285 |
| ($D_{75}$ - $D_{25}$): | 481.6 | 1.302 |

GRAIN SIZE DISTRIBUTION

| | | | |
|---|---|---|---|
| GRAVEL: | 0.0% | COARSE SAND: | 62.9% |
| SAND: | 100.0% | MEDIUM SAND: | 17.3% |
| MUD: | 0.0% | FINE SAND: | 15.9% |
| | | V FINE SAND: | 3.9% |
| V COARSE GRAVEL: | 0.0% | V COARSE SILT: | 0.0% |
| COARSE GRAVEL: | 0.0% | COARSE SILT: | 0.0% |
| MEDIUM GRAVEL: | 0.0% | MEDIUM SILT: | 0.0% |
| FINE GRAVEL: | 0.0% | FINE SILT: | 0.0% |
| V FINE GRAVEL: | 0.0% | V FINE SILT: | 0.0% |
| V COARSE SAND: | 0.0% | CLAY: | 0.0% |

| | METHOD OF MOMENTS | | | FOLK & WARD METHOD | | |
|---|---|---|---|---|---|---|
| | Arithmetic ∝m | Geometric ∝m | Logarithmic □ | Geometric ∝m | Logarithmic □ | Description |
| MEAN ( $\bar{x}$ ): | 582.5 | 490.0 | 1.029 | 491.9 | 1.023 | Medium Sand |
| SORTING (□): | 267.0 | 1.880 | 0.911 | 1.895 | 0.922 | Moderately Sorted |
| SKEWNESS ( $Sk$): | -0.395 | -1.044 | 1.044 | -0.512 | 0.512 | Very Fine Skewed |
| KURTOSIS ($K$ ): | 1.690 | 3.023 | 3.023 | 0.890 | 0.890 | Platykurtic |

## GRAIN SIZE DISTRIBUTION



## SAMPLE STATISTICS

SAMPLE IDENTITY: **AO 3-13, Unit 11**

ANALYST & DATE: JES,

SAMPLE TYPE: Unimodal, Well Sorted

TEXTURAL GROUP: Sand

SEDIMENT NAME: Well Sorted Fine Sand

GPS: 29 32'43" N, 34 58'53" E

Depth: 4.30 m

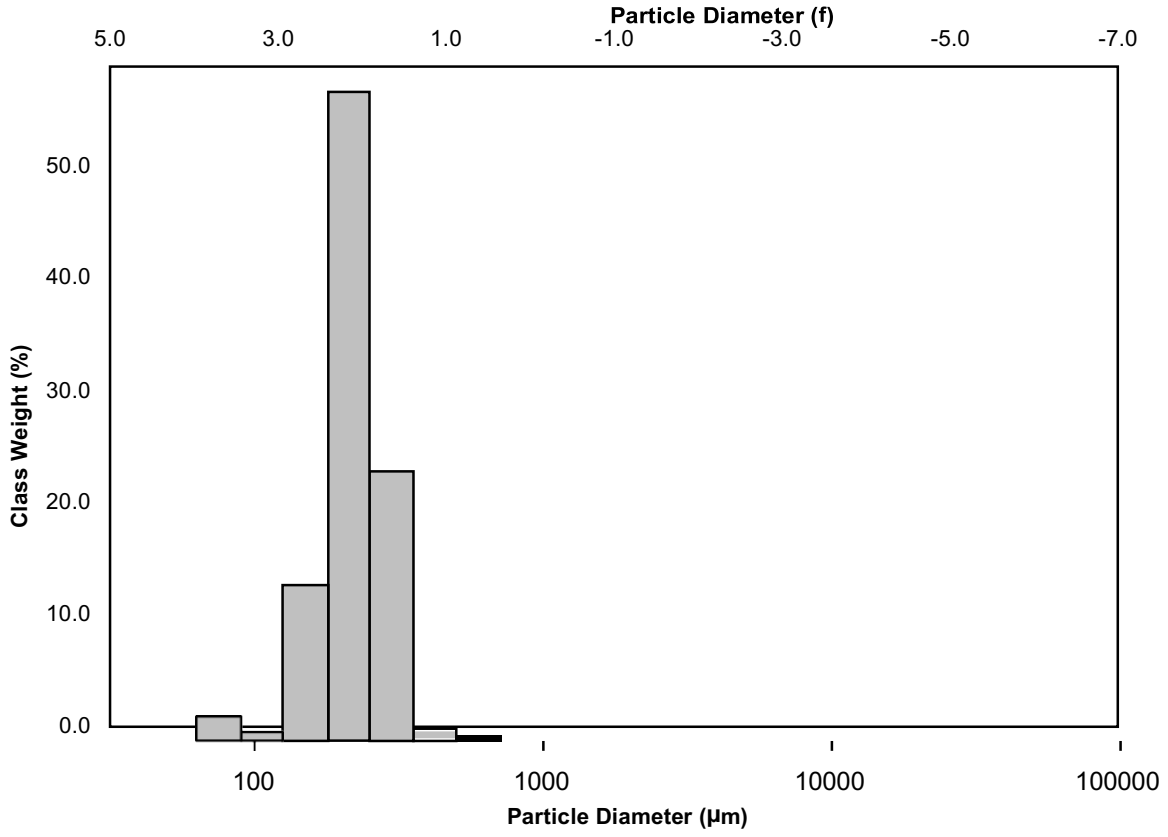
| | ∝m | ϕ |
|---|---|---|
| MODE 1: | 215.0 | 2.237 |
| MODE 2: | | |
| MODE 3: | | |
| $D_{10}$: | 148.5 | 1.668 |
| MEDIAN or $D_{50}$: | 217.4 | 2.201 |
| $D_{90}$: | 314.6 | 2.751 |
| ($D_{90}$ / $D_{10}$): | 2.118 | 1.649 |
| ($D_{90}$ - $D_{10}$): | 166.1 | 1.083 |
| ($D_{75}$ / $D_{25}$): | 1.356 | 1.222 |
| ($D_{75}$ - $D_{25}$): | 66.75 | 0.439 |

GRAIN SIZE DISTRIBUTION

| | | | |
|---|---|---|---|
| GRAVEL: | 0.0% | COARSE SAND: | 0.4% |
| SAND: | 100.0% | MEDIUM SAND: | 25.9% |
| MUD: | 0.0% | FINE SAND: | 70.8% |
| | | V FINE SAND: | 3.0% |
| V COARSE GRAVEL: | 0.0% | V COARSE SILT: | 0.0% |
| COARSE GRAVEL: | 0.0% | COARSE SILT: | 0.0% |
| MEDIUM GRAVEL: | 0.0% | MEDIUM SILT: | 0.0% |
| FINE GRAVEL: | 0.0% | FINE SILT: | 0.0% |
| V FINE GRAVEL: | 0.0% | V FINE SILT: | 0.0% |
| V COARSE SAND: | 0.0% | CLAY: | 0.0% |

| | METHOD OF MOMENTS | | | FOLK & WARD METHOD | | |
|---|---|---|---|---|---|---|
| | Arithmetic | Geometric | Logarithmic | Geometric | Logarithmic | Description |
| | ∝m | ∝m | □ | ∝m | □ | |
| MEAN ( $\bar{x}$ ): | 227.3 | 215.5 | 2.214 | 221.1 | 2.177 | Fine Sand |
| SORTING (□): | 62.44 | 1.333 | 0.415 | 1.314 | 0.393 | Well Sorted |
| SKEWNESS ( $Sk$): | 0.989 | -0.837 | 0.837 | 0.015 | -0.015 | Symmetrical |
| KURTOSIS ($K$ ): | 7.800 | 5.917 | 5.917 | 1.272 | 1.272 | Leptokurtic |

## GRAIN SIZE DISTRIBUTION



## SAMPLE STATISTICS

SAMPLE IDENTITY: **TK 4-1** ANALYST & DATE: JES,

SAMPLE TYPE: Bimodal, Moderately Sorted TEXTURAL GROUP: Sand

SEDIMENT NAME: Moderately Sorted Fine Sand

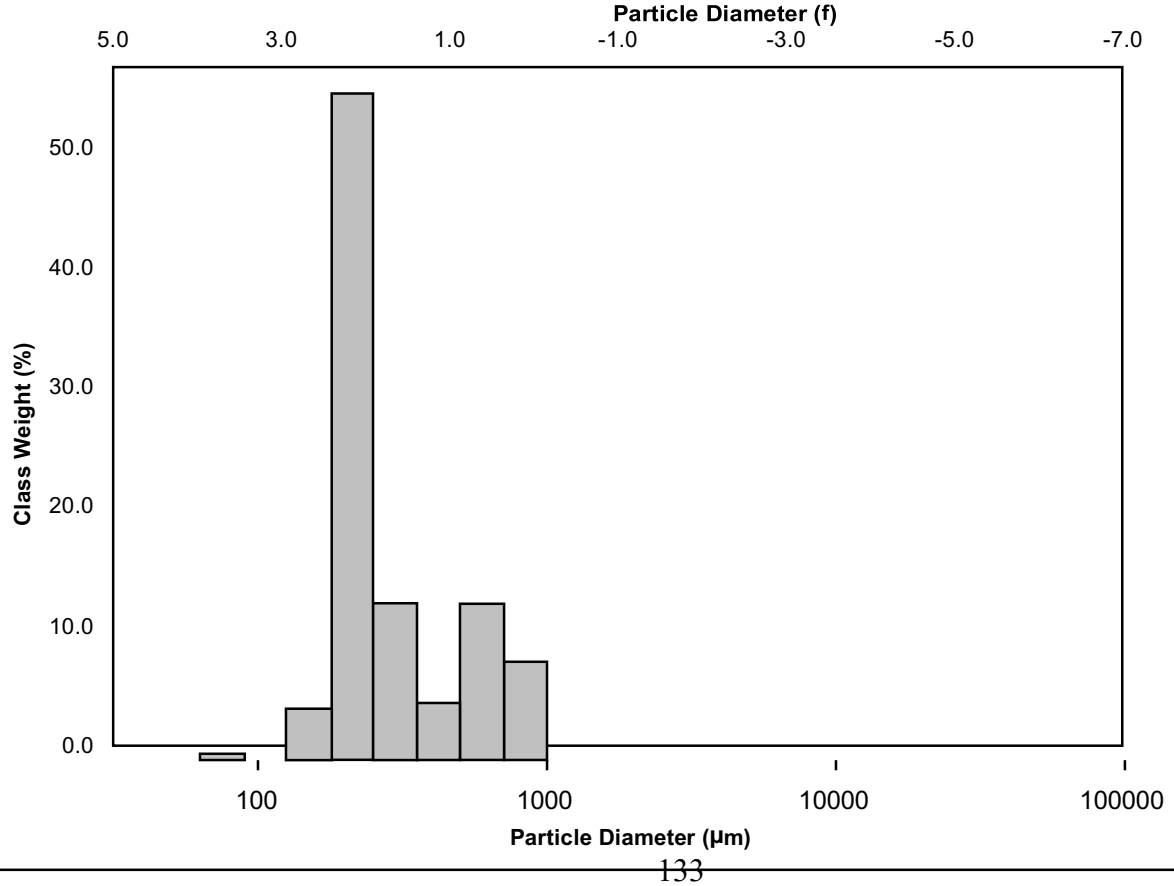
| | ∝m | ϕ |
|---|---|---|
| MODE 1: | 215.0 | 2.237 |
| MODE 2: | 605.0 | 0.747 |
| MODE 3: | | |
| $D_{10}$: | 185.3 | 0.555 |
| MEDIAN or $D_{50}$: | 236.0 | 2.083 |
| $D_{90}$: | 680.4 | 2.432 |
| ($D_{90}$ / $D_{10}$): | 3.672 | 4.378 |
| ($D_{90}$ - $D_{10}$): | 495.1 | 1.877 |
| ($D_{75}$ / $D_{25}$): | 1.987 | 1.756 |
| ($D_{75}$ - $D_{25}$): | 200.2 | 0.991 |

GRAIN SIZE DISTRIBUTION

| | | | |
|---|---|---|---|
| GRAVEL: | 0.0% | COARSE SAND: | 22.0% |
| SAND: | 100.0% | MEDIUM SAND: | 18.5% |
| MUD: | 0.0% | FINE SAND: | 59.0% |
| | | V FINE SAND: | 0.5% |
| V COARSE GRAVEL: | 0.0% | V COARSE SILT: | 0.0% |
| COARSE GRAVEL: | 0.0% | COARSE SILT: | 0.0% |
| MEDIUM GRAVEL: | 0.0% | MEDIUM SILT: | 0.0% |
| FINE GRAVEL: | 0.0% | FINE SILT: | 0.0% |
| V FINE GRAVEL: | 0.0% | V FINE SILT: | 0.0% |
| V COARSE SAND: | 0.0% | CLAY: | 0.0% |

| | METHOD OF MOMENTS | | | FOLK & WARD METHOD | | |
|---|---|---|---|---|---|---|
| | Arithmetic ∝m | Geometric ∝m | Logarithmic □ | Geometric ∝m | Logarithmic □ | Description |
| MEAN ($\bar{x}$): | 340.1 | 290.2 | 1.785 | 297.9 | 1.747 | Medium Sand |
| SORTING (□): | 206.8 | 1.658 | 0.730 | 1.663 | 0.734 | Moderately Sorted |
| SKEWNESS ($Sk$): | 1.412 | 0.855 | -0.855 | 0.627 | -0.627 | Very Coarse Skewed |
| KURTOSIS ($K$): | 3.696 | 2.713 | 2.713 | 0.911 | 0.911 | Mesokurtic |

## GRAIN SIZE DISTRIBUTION



## SAMPLE STATISTICS

SAMPLE IDENTITY: **TK 4-2** ANALYST & DATE: JES,

SAMPLE TYPE: Bimodal, Moderately Sorted TEXTURAL GROUP: Sand

SEDIMENT NAME: Moderately Sorted Fine Sand

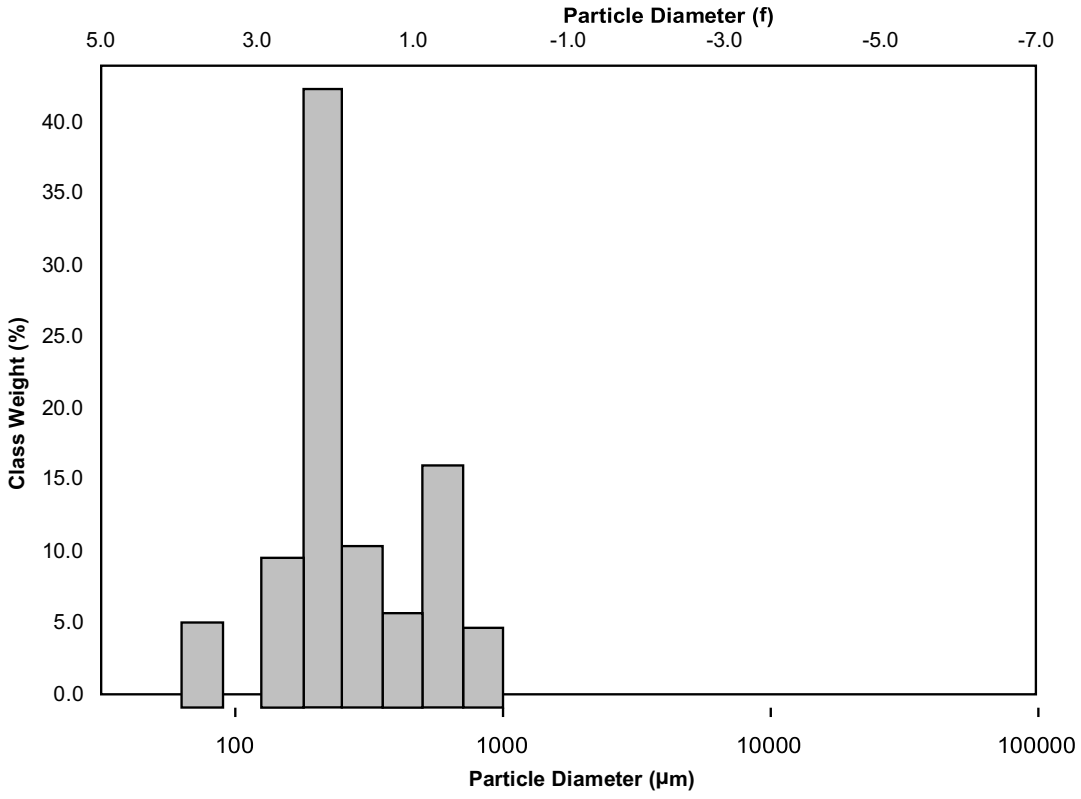
| | ∝m | ϕ |
|---|---|---|
| MODE 1: | 215.0 | 2.237 |
| MODE 2: | 605.0 | 0.747 |
| MODE 3: | | |
| $D_{10}$: | 141.5 | 0.623 |
| MEDIAN or $D_{50}$: | 233.0 | 2.101 |
| $D_{90}$: | 649.3 | 2.821 |
| ($D_{90}$ / $D_{10}$): | 4.588 | 4.528 |
| ($D_{90}$ - $D_{10}$): | 507.8 | 2.198 |
| ($D_{75}$ / $D_{25}$): | 2.349 | 2.067 |
| ($D_{75}$ - $D_{25}$): | 257.9 | 1.232 |

GRAIN SIZE DISTRIBUTION

| | | | |
|---|---|---|---|
| GRAVEL: | 0.0% | COARSE SAND: | 22.9% |
| SAND: | 100.0% | MEDIUM SAND: | 18.2% |
| MUD: | 0.0% | FINE SAND: | 52.7% |
| | | V FINE SAND: | 6.2% |
| V COARSE GRAVEL: | 0.0% | V COARSE SILT: | 0.0% |
| COARSE GRAVEL: | 0.0% | COARSE SILT: | 0.0% |
| MEDIUM GRAVEL: | 0.0% | MEDIUM SILT: | 0.0% |
| FINE GRAVEL: | 0.0% | FINE SILT: | 0.0% |
| V FINE GRAVEL: | 0.0% | V FINE SILT: | 0.0% |
| V COARSE SAND: | 0.0% | CLAY: | 0.0% |

| | METHOD OF MOMENTS | | | FOLK & WARD METHOD | | |
|---|---|---|---|---|---|---|
| | Arithmetic ∝m | Geometric ∝m | Logarithmic □ | Geometric ∝m | Logarithmic □ | Description |
| MEAN ( $\bar{x}$): | 327.0 | 269.1 | 1.894 | 284.7 | 1.812 | Medium Sand |
| SORTING (□): | 205.4 | 1.821 | 0.864 | 1.878 | 0.909 | Moderately Sorted |
| SKEWNESS ( $Sk$): | 1.137 | 0.094 | -0.094 | 0.279 | -0.279 | Coarse Skewed |
| KURTOSIS ($K$ ): | 3.253 | 2.670 | 2.670 | 1.041 | 1.041 | Mesokurtic |

## GRAIN SIZE DISTRIBUTION



## SAMPLE STATISTICS

SAMPLE IDENTITY: **TK 4-3** ANALYST & DATE: JES,

SAMPLE TYPE: Trimodal, Moderately Sorted TEXTURAL GROUP: Sand

SEDIMENT NAME: Moderately Sorted Fine Sand

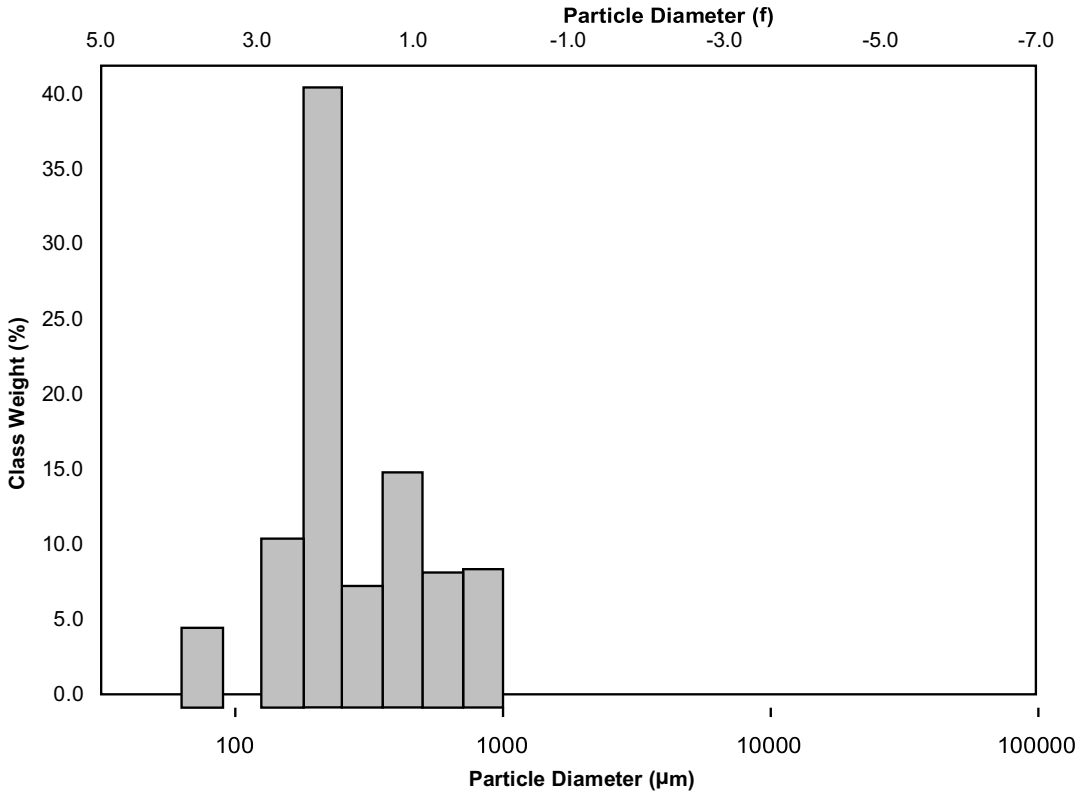
| | ∝m | ϕ |
|---|---|---|
| MODE 1: | 215.0 | 2.237 |
| MODE 2: | 427.5 | 1.247 |
| MODE 3: | 855.0 | 0.247 |
| $D_{10}$: | 143.0 | 0.535 |
| MEDIAN or $D_{50}$: | 235.2 | 2.088 |
| $D_{90}$: | 690.4 | 2.806 |
| ($D_{90}$ / $D_{10}$): | 4.828 | 5.249 |
| ($D_{90}$ - $D_{10}$): | 547.4 | 2.271 |
| ($D_{75}$ / $D_{25}$): | 2.270 | 1.983 |
| ($D_{75}$ - $D_{25}$): | 242.9 | 1.182 |

GRAIN SIZE DISTRIBUTION

| | | | |
|---|---|---|---|
| GRAVEL: | 0.0% | COARSE SAND: | 18.5% |
| SAND: | 100.0% | MEDIUM SAND: | 24.1% |
| MUD: | 0.0% | FINE SAND: | 51.9% |
| | | V FINE SAND: | 5.6% |
| V COARSE GRAVEL: | 0.0% | V COARSE SILT: | 0.0% |
| COARSE GRAVEL: | 0.0% | COARSE SILT: | 0.0% |
| MEDIUM GRAVEL: | 0.0% | MEDIUM SILT: | 0.0% |
| FINE GRAVEL: | 0.0% | FINE SILT: | 0.0% |
| V FINE GRAVEL: | 0.0% | V FINE SILT: | 0.0% |
| V COARSE SAND: | 0.0% | CLAY: | 0.0% |

| | METHOD OF MOMENTS | | | FOLK & WARD METHOD | | |
|---|---|---|---|---|---|---|
| | Arithmetic ∝m | Geometric ∝m | Logarithmic □ | Geometric ∝m | Logarithmic □ | Description |
| MEAN ( $\bar{x}$): | 335.9 | 275.2 | 1.861 | 281.0 | 1.831 | Medium Sand |
| SORTING (□): | 216.1 | 1.830 | 0.872 | 1.884 | 0.914 | Moderately Sorted |
| SKEWNESS ( $Sk$): | 1.235 | 0.134 | -0.134 | 0.288 | -0.288 | Coarse Skewed |
| KURTOSIS ($K$ ): | 3.531 | 2.690 | 2.690 | 1.130 | 1.130 | Leptokurtic |

## GRAIN SIZE DISTRIBUTION



## SAMPLE STATISTICS

SAMPLE IDENTITY: **TK 4-4**

ANALYST & DATE: JES,

SAMPLE TYPE: Trimodal, Poorly Sorted

TEXTURAL GROUP: Sand

SEDIMENT NAME: Poorly Sorted Fine Sand

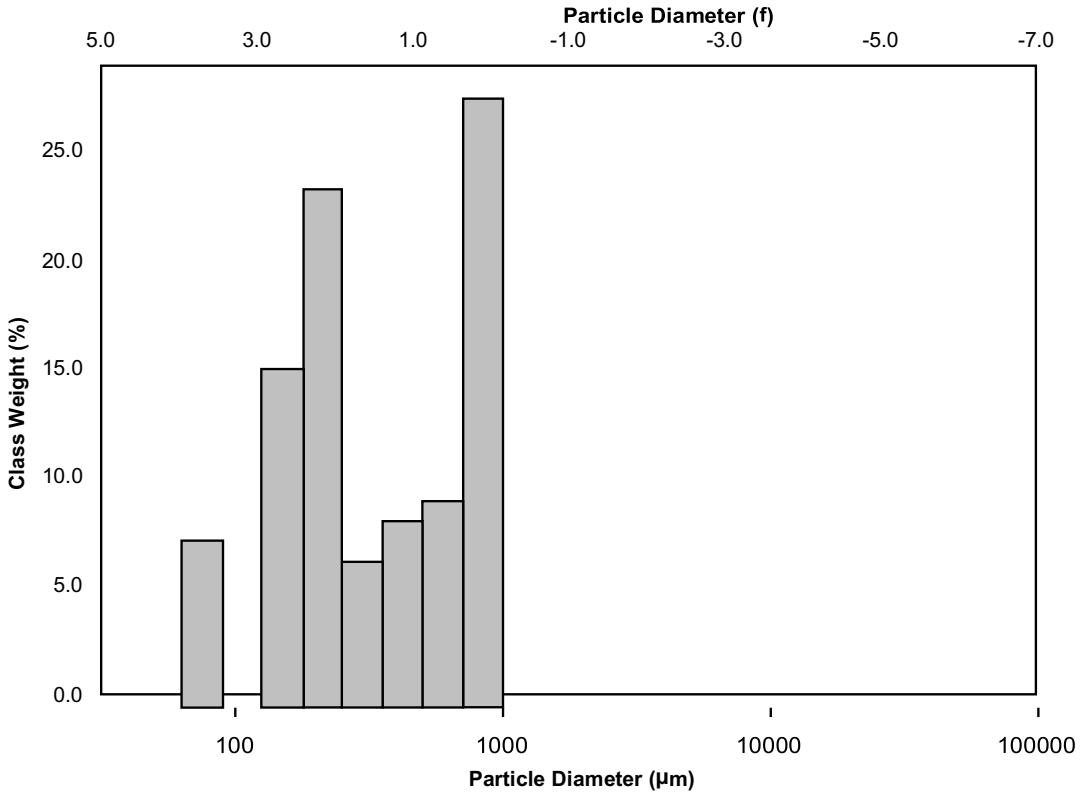
| | ∝m | ϕ |
|---|---|---|
| MODE 1: | 855.0 | 0.247 |
| MODE 2: | 215.0 | 2.237 |
| MODE 3: | 76.50 | 3.731 |
| $D_{10}$: | 130.8 | 0.177 |
| MEDIAN or $D_{50}$: | 289.3 | 1.789 |
| $D_{90}$: | 884.2 | 2.935 |
| ($D_{90}$ / $D_{10}$): | 6.760 | 16.53 |
| ($D_{90}$ - $D_{10}$): | 753.4 | 2.757 |
| ($D_{75}$ / $D_{25}$): | 4.051 | 5.549 |
| ($D_{75}$ - $D_{25}$): | 553.8 | 2.018 |

GRAIN SIZE DISTRIBUTION

| | | | |
|---|---|---|---|
| GRAVEL: | 0.0% | COARSE SAND: | 37.5% |
| SAND: | 100.0% | MEDIUM SAND: | 15.3% |
| MUD: | 0.0% | FINE SAND: | 39.2% |
| | | V FINE SAND: | 8.0% |
| V COARSE GRAVEL: | 0.0% | V COARSE SILT: | 0.0% |
| COARSE GRAVEL: | 0.0% | COARSE SILT: | 0.0% |
| MEDIUM GRAVEL: | 0.0% | MEDIUM SILT: | 0.0% |
| FINE GRAVEL: | 0.0% | FINE SILT: | 0.0% |
| V FINE GRAVEL: | 0.0% | V FINE SILT: | 0.0% |
| V COARSE SAND: | 0.0% | CLAY: | 0.0% |

| | METHOD OF MOMENTS | | | FOLK & WARD METHOD | | |
|---|---|---|---|---|---|---|
| | Arithmetic ∝m | Geometric ∝m | Logarithmic □ | Geometric ∝m | Logarithmic □ | Description |
| MEAN ( $\bar{x}$): | 433.6 | 324.8 | 1.622 | 328.6 | 1.605 | Medium Sand |
| SORTING (□): | 295.8 | 2.176 | 1.122 | 2.229 | 1.157 | Poorly Sorted |
| SKEWNESS ( $Sk$): | 0.445 | -0.165 | 0.165 | 0.088 | -0.088 | Symmetrical |
| KURTOSIS ($K$ ): | 1.532 | 1.842 | 1.842 | 0.726 | 0.726 | Platykurtic |

## GRAIN SIZE DISTRIBUTION



## SAMPLE STATISTICS

SAMPLE IDENTITY: **TK 4-5a** ANALYST & DATE: JES,

SAMPLE TYPE: Trimodal, Poorly Sorted TEXTURAL GROUP: Sand

SEDIMENT NAME: Poorly Sorted Very Fine Sand

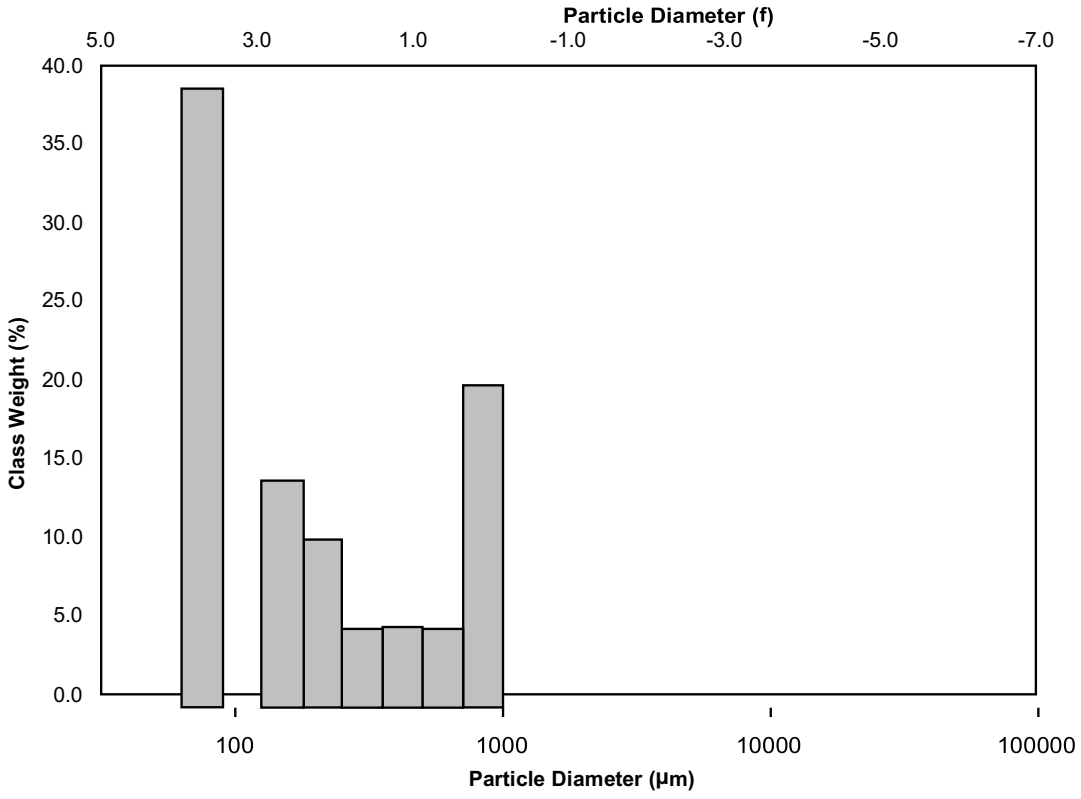
| | ∝m | ϕ |
|---|---|---|
| MODE 1: | 76.50 | 3.731 |
| MODE 2: | 855.0 | 0.247 |
| MODE 3: | 152.5 | 2.737 |
| $D_{10}$: | 68.88 | 0.247 |
| MEDIAN or $D_{50}$: | 159.4 | 2.649 |
| $D_{90}$: | 842.6 | 3.860 |
| ($D_{90}$ / $D_{10}$): | 12.23 | 15.62 |
| ($D_{90}$ - $D_{10}$): | 773.7 | 3.613 |
| ($D_{75}$ / $D_{25}$): | 6.351 | 3.667 |
| ($D_{75}$ - $D_{25}$): | 421.3 | 2.667 |

GRAIN SIZE DISTRIBUTION

| | | | |
|---|---|---|---|
| GRAVEL: | 0.0% | COARSE SAND: | 25.0% |
| SAND: | 100.0% | MEDIUM SAND: | 10.0% |
| MUD: | 0.0% | FINE SAND: | 25.0% |
| | | V FINE SAND: | 40.0% |
| V COARSE GRAVEL: | 0.0% | V COARSE SILT: | 0.0% |
| COARSE GRAVEL: | 0.0% | COARSE SILT: | 0.0% |
| MEDIUM GRAVEL: | 0.0% | MEDIUM SILT: | 0.0% |
| FINE GRAVEL: | 0.0% | FINE SILT: | 0.0% |
| V FINE GRAVEL: | 0.0% | V FINE SILT: | 0.0% |
| V COARSE SAND: | 0.0% | CLAY: | 0.0% |

| | METHOD OF MOMENTS | | | FOLK & WARD METHOD | | |
|---|---|---|---|---|---|---|
| | Arithmetic ∝m | Geometric ∝m | Logarithmic □ | Geometric ∝m | Logarithmic □ | Description |
| MEAN ( $\bar{x}$): | 312.7 | 194.4 | 2.363 | 206.5 | 2.276 | Fine Sand |
| SORTING (□): | 301.5 | 2.586 | 1.371 | 2.681 | 1.423 | Poorly Sorted |
| SKEWNESS ( $Sk$): | 0.994 | 0.449 | -0.449 | 0.330 | -0.330 | Very Coarse Skewed |
| KURTOSIS ($K$ ): | 2.303 | 1.655 | 1.655 | 0.584 | 0.584 | Very Platykurtic |

## GRAIN SIZE DISTRIBUTION



## SAMPLE STATISTICS

SAMPLE IDENTITY: **TK 4-8** ANALYST & DATE: JES,

SAMPLE TYPE: Unimodal, Moderately Well Sorted TEXTURAL GROUP: Sand

SEDIMENT NAME: Moderately Well Sorted Fine Sand

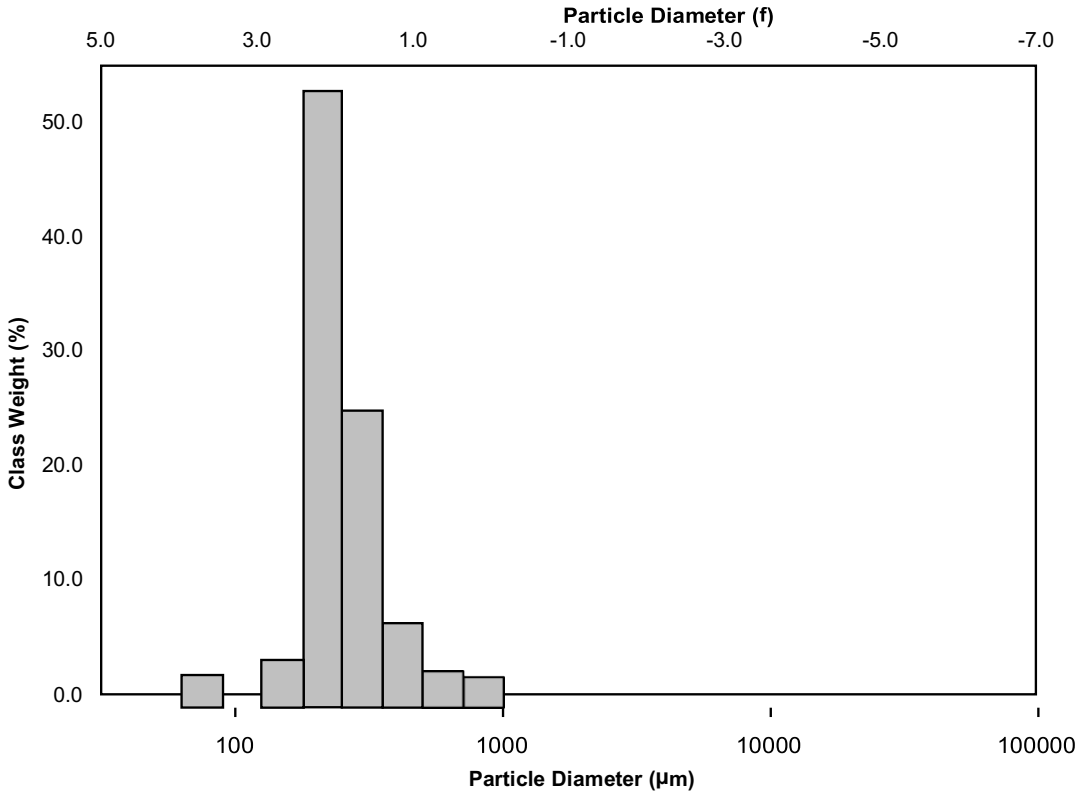
| | ∝m | ϕ |
|---|---|---|
| MODE 1: | 215.0 | 2.237 |
| MODE 2: | | |
| MODE 3: | | |
| $D_{10}$: | 182.9 | 1.267 |
| MEDIAN or $D_{50}$: | 235.2 | 2.088 |
| $D_{90}$: | 415.5 | 2.451 |
| ($D_{90}$ / $D_{10}$): | 2.272 | 1.935 |
| ($D_{90}$ - $D_{10}$): | 232.7 | 1.184 |
| ($D_{75}$ / $D_{25}$): | 1.519 | 1.352 |
| ($D_{75}$ - $D_{25}$): | 104.3 | 0.603 |

GRAIN SIZE DISTRIBUTION

| | | | |
|---|---|---|---|
| GRAVEL: | 0.0% | COARSE SAND: | 6.0% |
| SAND: | 100.0% | MEDIUM SAND: | 34.3% |
| MUD: | 0.0% | FINE SAND: | 56.7% |
| | | V FINE SAND: | 3.0% |
| V COARSE GRAVEL: | 0.0% | V COARSE SILT: | 0.0% |
| COARSE GRAVEL: | 0.0% | COARSE SILT: | 0.0% |
| MEDIUM GRAVEL: | 0.0% | MEDIUM SILT: | 0.0% |
| FINE GRAVEL: | 0.0% | FINE SILT: | 0.0% |
| V FINE GRAVEL: | 0.0% | V FINE SILT: | 0.0% |
| V COARSE SAND: | 0.0% | CLAY: | 0.0% |

| | METHOD OF MOMENTS | | | FOLK & WARD METHOD | | |
|---|---|---|---|---|---|---|
| | Arithmetic ∝m | Geometric ∝m | Logarithmic □ | Geometric ∝m | Logarithmic □ | Description |
| MEAN ( $\bar{x}$): | 277.4 | 250.7 | 1.996 | 248.4 | 2.009 | Fine Sand |
| SORTING (□): | 135.2 | 1.495 | 0.580 | 1.418 | 0.503 | Moderately Well Sorted |
| SKEWNESS ( $Sk$): | 2.482 | 0.316 | -0.316 | 0.286 | -0.286 | Coarse Skewed |
| KURTOSIS ($K$ ): | 10.40 | 5.660 | 5.660 | 1.301 | 1.301 | Leptokurtic |

## GRAIN SIZE DISTRIBUTION



## SAMPLE STATISTICS

SAMPLE IDENTITY: **TK 4-9** ANALYST & DATE: JES,

SAMPLE TYPE: Bimodal, Moderately Sorted TEXTURAL GROUP: Sand

SEDIMENT NAME: Moderately Sorted Coarse Sand

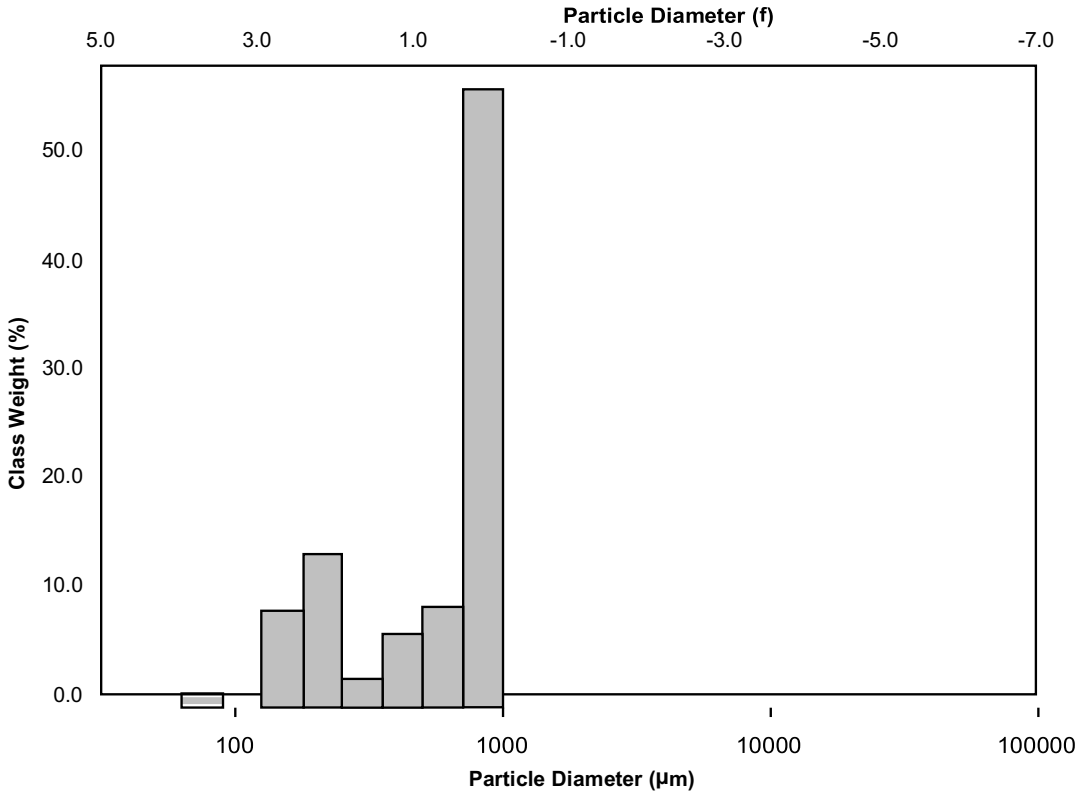
| | ∝m | ϕ |
|---|---|---|
| MODE 1: | 855.0 | 0.247 |
| MODE 2: | 215.0 | 2.237 |
| MODE 3: | | |
| $D_{10}$: | 174.5 | 0.087 |
| MEDIAN or $D_{50}$: | 739.6 | 0.435 |
| $D_{90}$: | 941.4 | 2.519 |
| ($D_{90}$ / $D_{10}$): | 5.396 | 28.94 |
| ($D_{90}$ - $D_{10}$): | 767.0 | 2.432 |
| ($D_{75}$ / $D_{25}$): | 3.149 | 8.604 |
| ($D_{75}$ - $D_{25}$): | 586.9 | 1.655 |

GRAIN SIZE DISTRIBUTION

| | | | |
|---|---|---|---|
| GRAVEL: | 0.0% | COARSE SAND: | 66.2% |
| SAND: | 100.0% | MEDIUM SAND: | 9.5% |
| MUD: | 0.0% | FINE SAND: | 23.0% |
| | | V FINE SAND: | 1.3% |
| V COARSE GRAVEL: | 0.0% | V COARSE SILT: | 0.0% |
| COARSE GRAVEL: | 0.0% | COARSE SILT: | 0.0% |
| MEDIUM GRAVEL: | 0.0% | MEDIUM SILT: | 0.0% |
| FINE GRAVEL: | 0.0% | FINE SILT: | 0.0% |
| V FINE GRAVEL: | 0.0% | V FINE SILT: | 0.0% |
| V COARSE SAND: | 0.0% | CLAY: | 0.0% |

| | METHOD OF MOMENTS | | | FOLK & WARD METHOD | | |
|---|---|---|---|---|---|---|
| | Arithmetic ∝m | Geometric ∝m | Logarithmic □ | Geometric ∝m | Logarithmic □ | Description |
| MEAN ( $\bar{x}$): | 624.1 | 516.2 | 0.954 | 515.7 | 0.955 | Coarse Sand |
| SORTING (□): | 288.8 | 1.957 | 0.968 | 1.939 | 0.955 | Moderately Sorted |
| SKEWNESS ( $Sk$): | -0.657 | -1.018 | 1.018 | -0.720 | 0.720 | Very Fine Skewed |
| KURTOSIS ($K$ ): | 1.679 | 2.591 | 2.591 | 0.682 | 0.682 | Platykurtic |

## GRAIN SIZE DISTRIBUTION



## SAMPLE STATISTICS

SAMPLE IDENTITY: **TK 4-10**

ANALYST & DATE: JES,

SAMPLE TYPE: Unimodal, Well Sorted

TEXTURAL GROUP: Sand

SEDIMENT NAME: Well Sorted Fine Sand

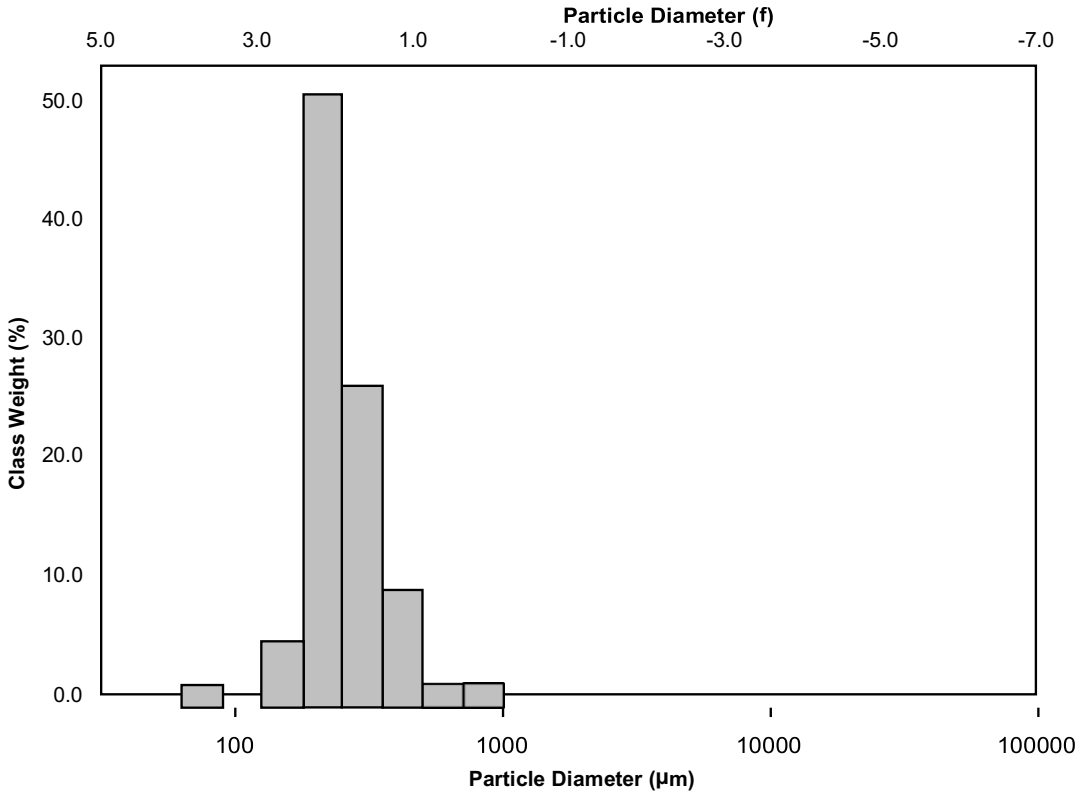
| | ∝m | ϕ |
|---|---|---|
| MODE 1: | 215.0 | 2.237 |
| MODE 2: | | |
| MODE 3: | | |
| $D_{10}$: | 182.4 | 1.296 |
| MEDIAN or $D_{50}$: | 237.2 | 2.076 |
| $D_{90}$: | 407.1 | 2.455 |
| ($D_{90}$ / $D_{10}$): | 2.232 | 1.894 |
| ($D_{90}$ - $D_{10}$): | 224.7 | 1.159 |
| ($D_{75}$ / $D_{25}$): | 1.537 | 1.366 |
| ($D_{75}$ - $D_{25}$): | 108.0 | 0.620 |

GRAIN SIZE DISTRIBUTION

| | | | |
|---|---|---|---|
| GRAVEL: | 0.0% | COARSE SAND: | 4.0% |
| SAND: | 100.0% | MEDIUM SAND: | 38.0% |
| MUD: | 0.0% | FINE SAND: | 56.0% |
| | | V FINE SAND: | 2.0% |
| V COARSE GRAVEL: | 0.0% | V COARSE SILT: | 0.0% |
| COARSE GRAVEL: | 0.0% | COARSE SILT: | 0.0% |
| MEDIUM GRAVEL: | 0.0% | MEDIUM SILT: | 0.0% |
| FINE GRAVEL: | 0.0% | FINE SILT: | 0.0% |
| V FINE GRAVEL: | 0.0% | V FINE SILT: | 0.0% |
| V COARSE SAND: | 0.0% | CLAY: | 0.0% |

| | METHOD OF MOMENTS | | | FOLK & WARD METHOD | | |
|---|---|---|---|---|---|---|
| | Arithmetic ∝m | Geometric ∝m | Logarithmic □ | Geometric ∝m | Logarithmic □ | Description |
| MEAN ( $\bar{x}$): | 274.8 | 251.5 | 1.991 | 249.8 | 2.001 | Fine Sand |
| SORTING (□): | 122.2 | 1.451 | 0.537 | 1.388 | 0.473 | Well Sorted |
| SKEWNESS ( $Sk$): | 2.529 | 0.337 | -0.337 | 0.237 | -0.237 | Coarse Skewed |
| KURTOSIS ($K$ ): | 11.70 | 5.647 | 5.647 | 1.116 | 1.116 | Leptokurtic |

## GRAIN SIZE DISTRIBUTION



## SAMPLE STATISTICS

SAMPLE IDENTITY: **TK 4-11** ANALYST & DATE: JES,

SAMPLE TYPE: Polymodal, Poorly Sorted TEXTURAL GROUP: Sand

SEDIMENT NAME: Poorly Sorted Coarse Sand

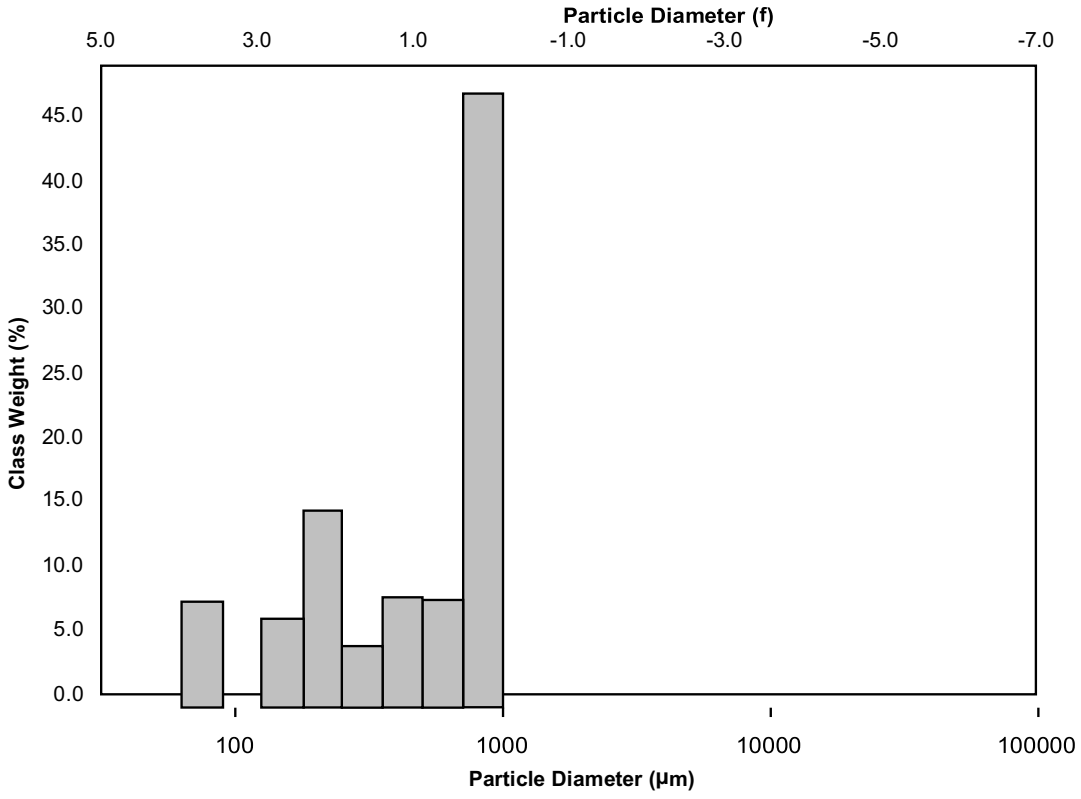
| | ∝m | ϕ |
|---|---|---|
| MODE 1: | 855.0 | 0.247 |
| MODE 2: | 215.0 | 2.237 |
| MODE 3: | 427.5 | 1.247 |
| $D_{10}$: | 134.4 | 0.104 |
| MEDIAN or $D_{50}$: | 642.2 | 0.639 |
| $D_{90}$: | 930.5 | 2.895 |
| ($D_{90}$ / $D_{10}$): | 6.922 | 27.86 |
| ($D_{90}$ - $D_{10}$): | 796.1 | 2.791 |
| ($D_{75}$ / $D_{25}$): | 3.779 | 8.384 |
| ($D_{75}$ - $D_{25}$): | 614.2 | 1.918 |

GRAIN SIZE DISTRIBUTION

| | | | |
|---|---|---|---|
| GRAVEL: | 0.0% | COARSE SAND: | 56.1% |
| SAND: | 100.0% | MEDIUM SAND: | 13.4% |
| MUD: | 0.0% | FINE SAND: | 21.9% |
| | | V FINE SAND: | 8.5% |
| V COARSE GRAVEL: | 0.0% | V COARSE SILT: | 0.0% |
| COARSE GRAVEL: | 0.0% | COARSE SILT: | 0.0% |
| MEDIUM GRAVEL: | 0.0% | MEDIUM SILT: | 0.0% |
| FINE GRAVEL: | 0.0% | FINE SILT: | 0.0% |
| V FINE GRAVEL: | 0.0% | V FINE SILT: | 0.0% |
| V COARSE SAND: | 0.0% | CLAY: | 0.0% |

| | METHOD OF MOMENTS | | | FOLK & WARD METHOD | | |
|---|---|---|---|---|---|---|
| | Arithmetic ∝m | Geometric ∝m | Logarithmic □ | Geometric ∝m | Logarithmic □ | Description |
| MEAN ( $\bar{x}$): | 558.7 | 429.5 | 1.219 | 469.3 | 1.092 | Medium Sand |
| SORTING (□): | 309.5 | 2.232 | 1.158 | 2.183 | 1.127 | Poorly Sorted |
| SKEWNESS ( $Sk$): | -0.305 | -0.853 | 0.853 | -0.633 | 0.633 | Very Fine Skewed |
| KURTOSIS ($K$ ): | 1.367 | 2.434 | 2.434 | 0.777 | 0.777 | Platykurtic |

## GRAIN SIZE DISTRIBUTION



## SAMPLE STATISTICS

SAMPLE IDENTITY: **TK 4-12** ANALYST & DATE: JES,

SAMPLE TYPE: Bimodal, Moderately Well Sorted TEXTURAL GROUP: Sand

SEDIMENT NAME: Moderately Well Sorted Fine Sand

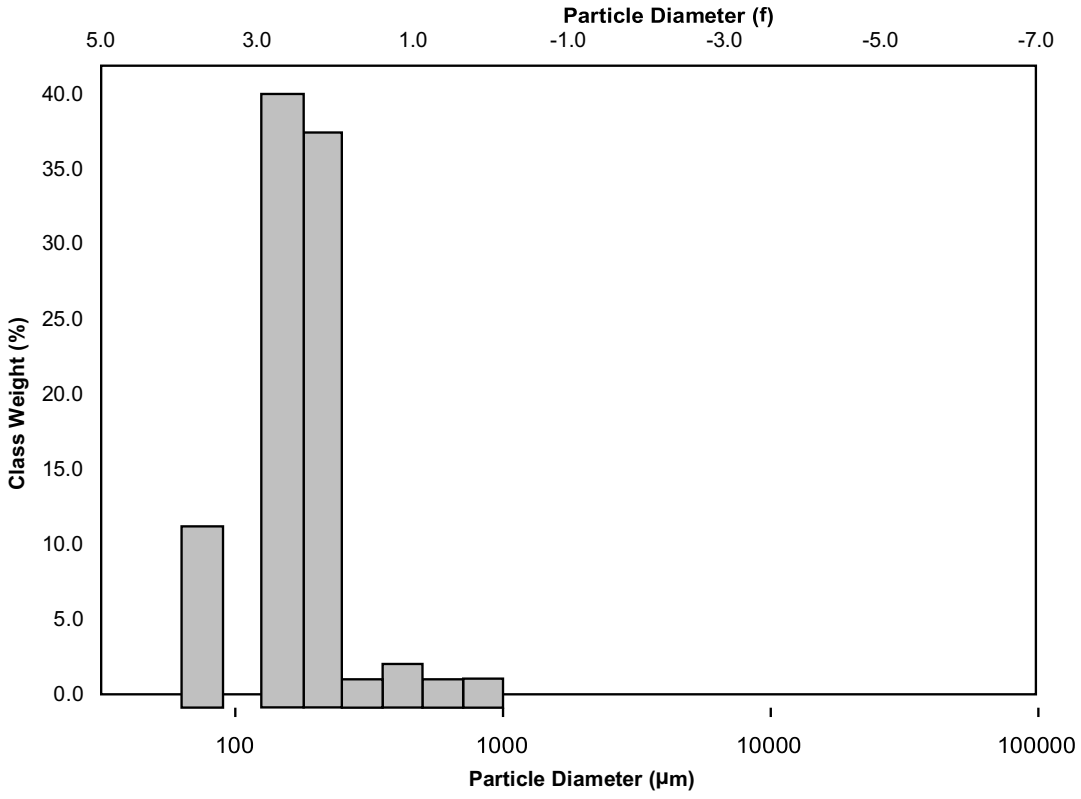
| | ∝m | ϕ |
|---|---|---|
| MODE 1: | 152.5 | 2.737 |
| MODE 2: | 76.50 | 3.731 |
| MODE 3: | | |
| $D_{10}$: | 84.03 | 2.019 |
| MEDIAN or $D_{50}$: | 172.1 | 2.538 |
| $D_{90}$: | 246.8 | 3.573 |
| ($D_{90}$ / $D_{10}$): | 2.936 | 1.770 |
| ($D_{90}$ - $D_{10}$): | 162.7 | 1.554 |
| ($D_{75}$ / $D_{25}$): | 1.547 | 1.284 |
| ($D_{75}$ - $D_{25}$): | 76.18 | 0.630 |

GRAIN SIZE DISTRIBUTION

| | | | |
|---|---|---|---|
| GRAVEL: | 0.0% | COARSE SAND: | 3.8% |
| SAND: | 100.0% | MEDIUM SAND: | 4.8% |
| MUD: | 0.0% | FINE SAND: | 79.1% |
| | | V FINE SAND: | 12.4% |
| V COARSE GRAVEL: | 0.0% | V COARSE SILT: | 0.0% |
| COARSE GRAVEL: | 0.0% | COARSE SILT: | 0.0% |
| MEDIUM GRAVEL: | 0.0% | MEDIUM SILT: | 0.0% |
| FINE GRAVEL: | 0.0% | FINE SILT: | 0.0% |
| V FINE GRAVEL: | 0.0% | V FINE SILT: | 0.0% |
| V COARSE SAND: | 0.0% | CLAY: | 0.0% |

| | METHOD OF MOMENTS | | | FOLK & WARD METHOD | | |
|---|---|---|---|---|---|---|
| | Arithmetic ∝m | Geometric ∝m | Logarithmic □ | Geometric ∝m | Logarithmic □ | Description |
| MEAN ( $\bar{x}$): | 198.4 | 172.8 | 2.533 | 173.1 | 2.530 | Fine Sand |
| SORTING (□): | 126.0 | 1.589 | 0.668 | 1.520 | 0.604 | Moderately Well Sorted |
| SKEWNESS ( $Sk$): | 3.376 | 0.662 | -0.662 | 0.031 | -0.031 | Symmetrical |
| KURTOSIS ($K$ ): | 16.50 | 5.303 | 5.303 | 1.674 | 1.674 | Very Leptokurtic |

## GRAIN SIZE DISTRIBUTION



## SAMPLE STATISTICS

SAMPLE IDENTITY: **TK 4-13**

ANALYST & DATE: JES,

SAMPLE TYPE: Unimodal, Well Sorted

TEXTURAL GROUP: Sand

SEDIMENT NAME: Well Sorted Fine Sand

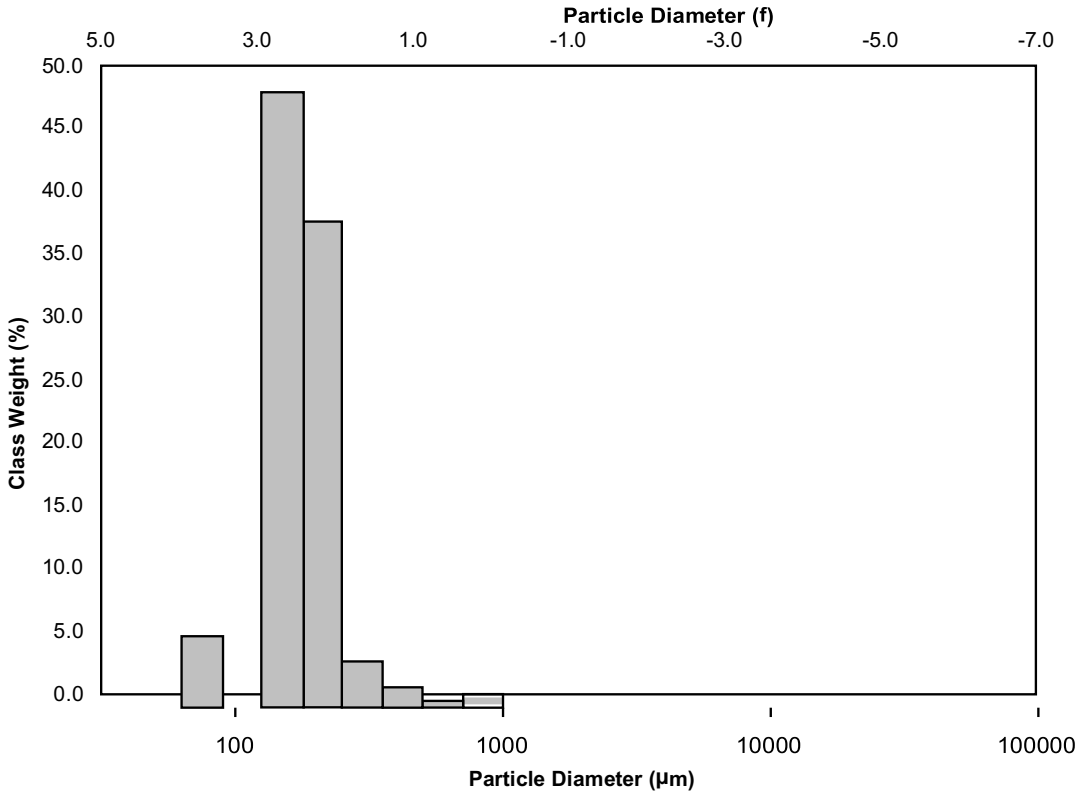
| | ∝m | ϕ |
|---|---|---|
| MODE 1: | 152.5 | 2.737 |
| MODE 2: | | |
| MODE 3: | | |
| $D_{10}$: | 128.8 | 2.041 |
| MEDIAN or $D_{50}$: | 171.4 | 2.544 |
| $D_{90}$: | 243.0 | 2.957 |
| ($D_{90}$ / $D_{10}$): | 1.886 | 1.448 |
| ($D_{90}$ - $D_{10}$): | 114.1 | 0.915 |
| ($D_{75}$ / $D_{25}$): | 1.479 | 1.253 |
| ($D_{75}$ - $D_{25}$): | 68.75 | 0.565 |

GRAIN SIZE DISTRIBUTION

| | | | |
|---|---|---|---|
| GRAVEL: | 0.0% | COARSE SAND: | 1.6% |
| SAND: | 100.0% | MEDIUM SAND: | 5.3% |
| MUD: | 0.0% | FINE SAND: | 87.4% |
| | | V FINE SAND: | 5.8% |
| V COARSE GRAVEL: | 0.0% | V COARSE SILT: | 0.0% |
| COARSE GRAVEL: | 0.0% | COARSE SILT: | 0.0% |
| MEDIUM GRAVEL: | 0.0% | MEDIUM SILT: | 0.0% |
| FINE GRAVEL: | 0.0% | FINE SILT: | 0.0% |
| V FINE GRAVEL: | 0.0% | V FINE SILT: | 0.0% |
| V COARSE SAND: | 0.0% | CLAY: | 0.0% |

| | METHOD OF MOMENTS | | | FOLK & WARD METHOD | | |
|---|---|---|---|---|---|---|
| | Arithmetic ∝m | Geometric ∝m | Logarithmic □ | Geometric ∝m | Logarithmic □ | Description |
| MEAN ( $\bar{x}$): | 190.4 | 174.8 | 2.516 | 174.4 | 2.520 | Fine Sand |
| SORTING (□): | 92.76 | 1.421 | 0.507 | 1.381 | 0.466 | Well Sorted |
| SKEWNESS ( $Sk$): | 4.528 | 0.767 | -0.767 | -0.008 | 0.008 | Symmetrical |
| KURTOSIS ($K$ ): | 30.68 | 7.807 | 7.807 | 1.303 | 1.303 | Leptokurtic |

## GRAIN SIZE DISTRIBUTION



## SAMPLE STATISTICS

SAMPLE IDENTITY: **TK 4-14** ANALYST & DATE: JES,

SAMPLE TYPE: Unimodal, Moderately Well Sorted TEXTURAL GROUP: Sand

SEDIMENT NAME: Moderately Well Sorted Fine Sand

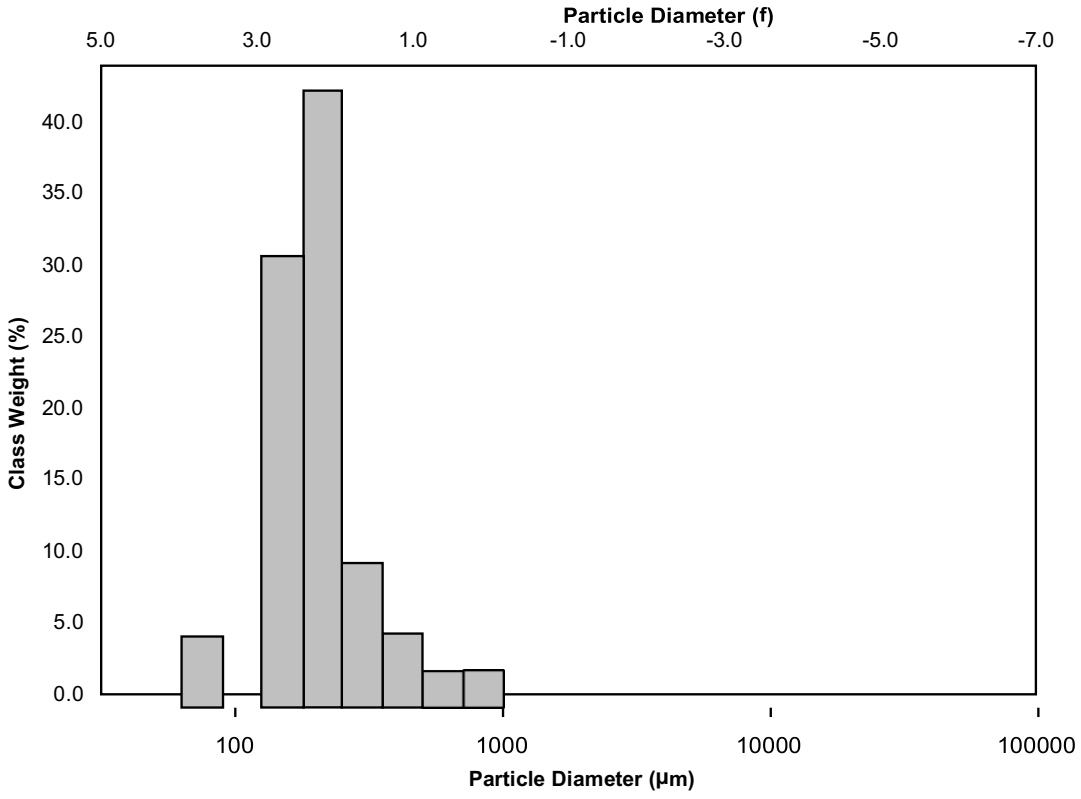
| | ∝m | ϕ |
|---|---|---|
| MODE 1: | 215.0 | 2.237 |
| MODE 2: | | |
| MODE 3: | | |
| $D_{10}$: | 131.8 | 1.470 |
| MEDIAN or $D_{50}$: | 197.4 | 2.341 |
| $D_{90}$: | 361.0 | 2.923 |
| ($D_{90}$ / $D_{10}$): | 2.738 | 1.988 |
| ($D_{90}$ - $D_{10}$): | 229.1 | 1.453 |
| ($D_{75}$ / $D_{25}$): | 1.552 | 1.309 |
| ($D_{75}$ - $D_{25}$): | 85.82 | 0.635 |

GRAIN SIZE DISTRIBUTION

| | | | |
|---|---|---|---|
| GRAVEL: | 0.0% | COARSE SAND: | 5.1% |
| SAND: | 100.0% | MEDIUM SAND: | 15.4% |
| MUD: | 0.0% | FINE SAND: | 74.4% |
| | | V FINE SAND: | 5.1% |
| V COARSE GRAVEL: | 0.0% | V COARSE SILT: | 0.0% |
| COARSE GRAVEL: | 0.0% | COARSE SILT: | 0.0% |
| MEDIUM GRAVEL: | 0.0% | MEDIUM SILT: | 0.0% |
| FINE GRAVEL: | 0.0% | FINE SILT: | 0.0% |
| V FINE GRAVEL: | 0.0% | V FINE SILT: | 0.0% |
| V COARSE SAND: | 0.0% | CLAY: | 0.0% |

| | METHOD OF MOMENTS | | | FOLK & WARD METHOD | | |
|---|---|---|---|---|---|---|
| | Arithmetic ∝m | Geometric ∝m | Logarithmic □ | Geometric ∝m | Logarithmic □ | Description |
| MEAN ( $\bar{x}$): | 233.3 | 204.5 | 2.290 | 200.9 | 2.316 | Fine Sand |
| SORTING (□): | 139.4 | 1.574 | 0.654 | 1.562 | 0.643 | Moderately Well Sorted |
| SKEWNESS ( $Sk$): | 2.768 | 0.728 | -0.728 | 0.079 | -0.079 | Symmetrical |
| KURTOSIS ($K$ ): | 11.74 | 4.885 | 4.885 | 1.622 | 1.622 | Very Leptokurtic |

## GRAIN SIZE DISTRIBUTION



# APPENDIX D

## Radiocarbon Calibration Data

## Appendix D Radiocarbon Data
### D.1 Ayla Oasis Samples

CALIB REV7.1.0 RADIOCARBON CALIBRATION PROGRAM*
Copyright 1986-2018 M Stuiver and PJ Reimer
*To be used in conjunction with:
Stuiver, M., and Reimer, P.J., 1993, Radiocarbon, 35, 215-230.

**AO-2-15**

Lab Code CAMS 163766
Sample Description : wood
Radiocarbon Age BP 3060 +/- 30
Calibration data set: intcal13.14c # Reimer et al. 2013

| % area enclosed | cal AD age ranges | relative area under probability distribution |
|---|---|---|
| 68.3 (1 sigma) | cal BC 1389- 1337 | 0.548 |
| | 1321- 1277 | 0.452 |
| 95.4 (2 sigma) | cal BC 1410- 1257 | 0.958 |
| | 1249- 1232 | 0.042 |

Median Probability: -1329

**AO-2-15**
Lab Code CAMS 163766
Sample Description : wood
Radiocarbon Age BP 3060 +/- 30
Calibration data set: intcal13.14c # Reimer et al. 2013

| % area enclosed | cal BP age ranges | relative area under probability distribution |
|---|---|---|
| 68.3 (1 sigma) | cal BP 3226 - 3270 | 0.452 |
| | 3286 - 3338 | 0.548 |
| 95.4 (2 sigma) | cal BP 3181 - 3198 | 0.042 |
| | 3206 - 3359 | 0.958 |

Median Probability: 3278

**AO-2-18**
Lab Code CAMS 163767
Sample Description charcoal
Radiocarbon Age BP 2935 +/- 30
Calibration data set: intcal13.14c # Reimer et al. 2013

| % area enclosed | cal AD age ranges | relative area under probability distribution |
|---|---|---|
| 68.3 (1 sigma) | cal BC 1209- 1109 | 0.938 |
| | 1098- 1089 | 0.062 |
| 95.4 (2 sigma) | cal BC 1224- 1030 | 1.000 |

Median Probability: -1143

**AO-2-18**
Lab Code CAMS 163767
Sample Description charcoal
Radiocarbon Age BP 2935 +/- 30
Calibration data set: intcal13.14c # Reimer et al. 2013

| % area enclosed | cal BP age ranges | relative area under probability distribution |
|---|---|---|
| 68.3 (1 sigma) | cal BP 3038 - 3047 | 0.062 |
| | 3058 - 3158 | 0.938 |
| 95.4 (2 sigma) | cal BP 2979 - 3173 | 1.000 |

Median Probability:  3092

**AO-3-1**

Lab Code CAMS 162768
Sample Description wood
Radiocarbon Age BP 3435 +/- 30
Calibration data set: intcal13.14c # Reimer et al. 2013

| % area enclosed | cal AD age ranges | relative area under probability distribution |
|---|---|---|
| 68.3 (1 sigma) | cal BC 1859- 1854 | 0.028 |
| | 1771- 1689 | 0.972 |
| 95.4 (2 sigma) | cal BC 1877- 1839 | 0.132 |
| | 1827- 1794 | 0.069 |
| | 1784- 1660 | 0.798 |

Median Probability: -1739

**AO-3-1**

Lab Code CAMS 162768
Sample Description wood
Radiocarbon Age BP 3435 +/- 30
Calibration data set: intcal13.14c # Reimer et al. 2013

| % area enclosed | cal BP age ranges | relative area under probability distribution |
|---|---|---|
| 68.3 (1 sigma) | cal BP 3638 - 3720 | 0.972 |
| | 3803 - 3808 | 0.028 |
| 95.4 (2 sigma) | cal BP 3609 - 3733 | 0.798 |
| | 3743 - 3776 | 0.069 |
| | 3788 - 3826 | 0.132 |

Median Probability: 3688

**AO-7b-1**

Lab Code CAMS 163769
Sample Description wood
Radiocarbon Age BP 5690 +/- 30
Calibration data set: intcal13.14c # Reimer et al. 2013

| % area enclosed | cal AD age ranges | relative area under probability distribution |
|---|---|---|
| 68.3 (1 sigma) | cal BC 4548- 4486 | 0.953 |
| | 4471- 4466 | 0.047 |
| 95.4 (2 sigma) | cal BC 4600- 4457 | 1.000 |

Median Probability: -4519

**AO-7b-1**

Lab Code CAMS 163769
Sample Description wood
Radiocarbon Age BP 5690 +/- 30
Calibration data set: intcal13.14c # Reimer et al. 2013

| % area enclosed | cal BP age ranges | relative area under probability distribution |
|---|---|---|
| 68.3 (1 sigma) | cal BP 6415 - 6420 | 0.047 |
| | 6435 - 6497 | 0.953 |
| 95.4 (2 sigma) | cal BP 6406 - 6549 | 1.000 |

Median Probability: 6468

References for calibration datasets:

## D.2 Brückner (1999) Radiocarbon Data

RADIOCARBON CALIBRATION PROGRAM*
CALIB REV7.1.0
Copyright 1986-2018 M Stuiver and PJ Reimer
*To be used in conjunction with:
Stuiver, M., and Reimer, P.J., 1993, Radiocarbon, 35, 215-230.

**AQ 5/11F**

Lab Code Beta 121046
Sample Description *Codakia punctata* (LINNE 1767)
Radiocarbon Age BP 3740 +/- 50
Delta R = 165.0 +/- 72.0
Calibration data set: marine13.14c # Reimer et al. 2013

| % area enclosed | cal AD age ranges | relative area under probability distribution |
|---|---|---|
| 68.3 (1 sigma) | cal BC 1620- 1416 | 1.000 |
| 95.4 (2 sigma) | cal BC 1738- 1300 | 1.000 |

Median Probability: -1523

**AQ 5/11F**

Lab Code Beta 121046
Sample Description *Codakia punctata* (LINNE 1767)
Radiocarbon Age BP 3740 +/- 50
Delta R = 165.0 +/- 72.0
Calibration data set: marine13.14c # Reimer et al. 2013

| % area enclosed | cal BP age ranges | relative area under probability distribution |
|---|---|---|
| 68.3 (1 sigma) | cal BP 3365 - 3569 | 1.000 |
| 95.4 (2 sigma) | cal BP 3249 - 3687 | 1.000 |

Median Probability: 3472

**AQ 6/15F**

Lab Code Beta 121047
Sample Description clam shell fragment
Radiocarbon Age BP 6200 +/- 60
Delta R = 165.0 +/- 72.0
Calibration data set: marine13.14c # Reimer et al. 2013

| % area enclosed | cal AD age ranges | relative area under probability distribution |
|---|---|---|
| 68.3 (1 sigma) | cal BC 4612- 4395 | 1.000 |
| 95.4 (2 sigma) | cal BC 4716- 4319 | 1.000 |

Median Probability: -4510

**AQ 6/15F**

Lab Code Beta 121047
Sample Description clam shell fragment
Radiocarbon Age BP 6200 +/- 60
Delta R = 165.0 +/- 72.0
Calibration data set: marine13.14c # Reimer et al. 2013

| % area enclosed | cal BP age ranges | relative area under probability distribution |
|---|---|---|
| 68.3 (1 sigma) | cal BP 6344 - 6561 | 1.000 |
| 95.4 (2 sigma) | cal BP 6268 - 6665 | 1.000 |

Median Probability: 6459

**D.3 Friedman (1965)Radiocarbon Data**

RADIOCARBON CALIBRATION PROGRAM*
CALIB REV7.1.0

*To be used in conjunction with:
Stuiver, M., and Reimer, P.J., 1993, Radiocarbon, 35, 215-230.

Friedman C
Lab Code
Friedman Coral Ages (1965)
Radiocarbon Age BP  4770 +/-  140
  Delta R =  165.0 +/-  72.0
Calibration data set: marine13.14c  # Reimer et al. 2013

| % area enclosed | cal BP age ranges | relative area under probability distribution |
|---|---|---|
| 68.3 (1 sigma) | cal BP 4585 - 5029 | 1.000 |
| 95.4 (2 sigma) | cal BP 4421 - 5261 | 1.000 |

Median Probability:  4824

References for calibration datasets:
Reimer PJ, Bard E, Bayliss A, Beck JW, Blackwell PG, Bronk Ramsey C, Buck CE Cheng H, Edwards RL, Friedrich M, Grootes PM, Guilderson TP, Haflidason H, Hajdas I, Hatté C, Heaton TJ, Hogg AG, Hughen KA, Kaiser KF, Kromer B, Manning SW, Niu M, Reimer RW, Richards DA, Scott EM, Southon JR, Turney CSM, van der Plicht J.
IntCal13 and MARINE13 radiocarbon age calibration curves 0-50000 years calBP
Radiocarbon 55(4). DOI: 10.2458/azu_js_rc.55.16947

Comments:
* This standard deviation (error) includes a lab error multiplier.
** 2 sigma = 2 x square root of (sample std. dev.^2 + Delta R uncertainty ^2)
where ^2 = quantity squared.
[ ] = calibrated range impinges on end of calibration data set
0* = cannot calibrate due to nuclear testing C-14.
1955* or 1960* denote influence of nuclear testing C-14

NOTE:  Cal ages and ranges are rounded to the nearest year which may be too precise in many instances.  Users are advised to round results to the nearest 10 yr for samples with standard deviation in the radiocarbon age greater than 50 yr.

## D.4 Moustafa (2000) Radiocarbon Calibration

RADIOCARBON CALIBRATION PROGRAM*
CALIB REV7.1.0

*To be used in conjunction with:
Stuiver, M., and Reimer, P.J., 1993, Radiocarbon, 35, 215-230.

H2 Lab KI
Lab Code

Moustafa Corals (2000)
Radiocarbon Age BP 4600 +/- 50
Delta R = 165.0 +/- 72.0

| Calibration data set: marine13.14c | | # Reimer et al. 2013 |
|---|---|---|
| % area enclosed | cal BP age ranges | relative area under probability distribution |
| 68.3 (1 sigma) | cal BP 4503 - 4730 | 0.923 |
| | 4747 - 4770 | 0.077 |
| 95.4 (2 sigma) | cal BP 4395 - 4823 | 1.000 |

Median Probability: 4611

F3 Lab KI
Lab Code
Moustafa Corals (2000)
Radiocarbon Age BP 4890 +/- 40
Delta R = 165.0 +/- 72.0

| Calibration data set: marine13.14c | | # Reimer et al. 2013 |
|---|---|---|
| % area enclosed | cal BP age ranges | relative area under probability distribution |
| 68.3 (1 sigma) | cal BP 4836 - 5072 | 1.000 |
| 95.4 (2 sigma) | cal BP 4807 - 5243 | 1.000 |

Median Probability: 4982

H5 GrA 78
Lab Code
Moustafa Corals (2000)
Radiocarbon Age BP 4600 +/- 60
Delta R = 165.0 +/- 72.0

| Calibration data set: marine13.14c | | # Reimer et al. 2013 |
|---|---|---|
| % area enclosed | cal BP age ranges | relative area under probability distribution |
| 68.3 (1 sigma) | cal BP 4503 - 4735 | 0.917 |
| | 4745 - 4771 | 0.083 |
| 95.4 (2 sigma) | cal BP 4375 - 4834 | 1.000 |

Median Probability: 4610

F6 GrA 78
Lab Code
Moustafa Corals (2000)
Radiocarbon Age BP 4960 +/- 60
Delta R = 165.0 +/- 72.0

| Calibration data set: marine13.14c | | # Reimer et al. 2013 |
|---|---|---|
| % area enclosed | cal BP age ranges | relative area under probability distribution |
| 68.3 (1 sigma) | cal BP 4953 - 5228 | 1.000 |
| 95.4 (2 sigma) | cal BP 4835 - 5296 | 1.000 |

Median Probability:  5076

F7 GrA 78
Lab Code
Moustafa Corals (2000)
Radiocarbon Age BP  5140 +/-  60
  Delta R =  165.0 +/-  72.0
Calibration data set: marine13.14c  # Reimer et al. 2013
  % area enclosed  cal BP age ranges  relative area under probability distribution
  68.3 (1 sigma)  cal BP 5208 - 5459  1.000
  95.4 (2 sigma)  cal BP 5041 - 5550  1.000
  Median Probability:  5317

F8 GrA 78
Lab Code
Moustafa Corals (2000)
Radiocarbon Age BP  5750 +/-  60
  Delta R =  165.0 +/-  72.0
Calibration data set: marine13.14c  # Reimer et al. 2013
  % area enclosed  cal BP age ranges  relative area under probability distribution
  68.3 (1 sigma)  cal BP 5883 - 6107  1.000
  95.4 (2 sigma)  cal BP 5747 - 6197  1.000
  Median Probability:  5986

F9 GrA 78
Lab Code
Moustafa Corals (2000)
Radiocarbon Age BP  5100 +/-  60
  Delta R =  165.0 +/-  72.0
Calibration data set: marine13.14c  # Reimer et al. 2013
  % area enclosed  cal BP age ranges  relative area under probability distribution
  68.3 (1 sigma)  cal BP 5131 - 5417  1.000
  95.4 (2 sigma)  cal BP 4963 - 5490  1.000
  Median Probability:  5257

F11 GrA 7
Lab Code
Moustafa Corals (2000)
Radiocarbon Age BP  5370 +/-  60
  Delta R =  165.0 +/-  72.0
Calibration data set: marine13.14c  # Reimer et al. 2013
  % area enclosed  cal BP age ranges  relative area under probability distribution
  68.3 (1 sigma)  cal BP 5456 - 5658  1.000
  95.4 (2 sigma)  cal BP 5314 - 5763  1.000
  Median Probability:  5564

F23 GrA 7
Lab Code
Moustafa Corals (2000)
Radiocarbon Age BP  4920 +/-  90
  Delta R =  165.0 +/-  72.0
Calibration data set: marine13.14c  # Reimer et al. 2013
  % area enclosed  cal BP age ranges  relative area under probability distribution

```
  68.3 (1 sigma)     cal BP 4861 - 5137                    0.892
                            5152 - 5191                    0.108
  95.4 (2 sigma)     cal BP 4717 - 4755                    0.011
                            4765 - 5317                    0.989
  Median Probability:  5028

F24 GrA 7
Lab Code
Moustafa Corals (2000)
Radiocarbon Age BP   4450 +/-   90
  Delta R =  165.0 +/-    72.0
Calibration data set: marine13.14c              # Reimer et al. 2013
  % area enclosed       cal BP age ranges           relative area under
                                                  probability distribution
  68.3 (1 sigma)     cal BP 4229 - 4560                    1.000
  95.4 (2 sigma)     cal BP 4085 - 4730                    0.989
                            4747 - 4770                    0.011
  Median Probability:  4402

 References for calibration datasets:
Reimer PJ, Bard E, Bayliss A, Beck JW, Blackwell PG, Bronk Ramsey C, Buck CE
Cheng H, Edwards RL, Friedrich M, Grootes PM, Guilderson TP, Haflidason H,
Hajdas I, Hatté C, Heaton TJ, Hogg AG, Hughen KA, Kaiser KF, Kromer B,
Manning SW, Niu M, Reimer RW, Richards DA, Scott EM, Southon JR, Turney CSM,
van der Plicht J.
IntCal13 and MARINE13 radiocarbon age calibration curves 0-50000 years calBP
Radiocarbon 55(4). DOI: 10.2458/azu_js_rc.55.16947

Comments:
* This standard deviation (error) includes a lab error multiplier.
** 2 sigma = 2 x square root of (sample std. dev.^2 + Delta R uncertainty
^2)
where ^2 = quantity squared.
[ ] = calibrated range impinges on end of calibration data set
0* = cannot calibrate due to nuclear testing C-14.
1955* or 1960* denote influence of nuclear testing C-14

NOTE:  Cal ages and ranges are rounded to the nearest year which
       may be too precise in many instances.  Users are advised to
       round results to the nearest 10 yr for samples with standard
       deviation in the radiocarbon age greater than 50 yr.
```

The median probability is calculated as a weighted mean given the following equation:

$$\text{weighted mean of } \Delta R = \mu = \frac{\Sigma_i \frac{\Delta R_i}{\sigma_i^2}}{\Sigma_i \frac{1}{\sigma_i^2}}$$

where $\sigma_i$ = uncertainty in $\Delta R_i$

$$\text{variance of } \Delta R = \frac{\frac{1}{n-1} \cdot \Sigma_i \left( \frac{\Delta R_i - \mu}{\sigma_i} \right)^2}{\frac{1}{n} \cdot \Sigma_i \frac{1}{\sigma_i^2}}$$

$$\text{Standard Deviation of } \Delta R = \sqrt{\text{variance}}$$

References for calibration datasets:
Reimer PJ, Bard E, Bayliss A, Beck JW, Blackwell PG, Bronk Ramsey C, Buck CE Cheng H, Edwards RL, Friedrich M, Grootes PM, Guilderson TP, Haflidason H, Hajdas I, Hatté C, Heaton TJ, Hogg AG, Hughen KA, Kaiser KF, Kromer B, Manning SW, Niu M, Reimer RW, Richards DA, Scott EM, Southon JR, Turney CSM, van der Plicht J.
IntCal13 and MARINE13 radiocarbon age calibration curves 0-50000 years calBP Radiocarbon 55(4). DOI: 10.2458/azu_js_rc.55.16947

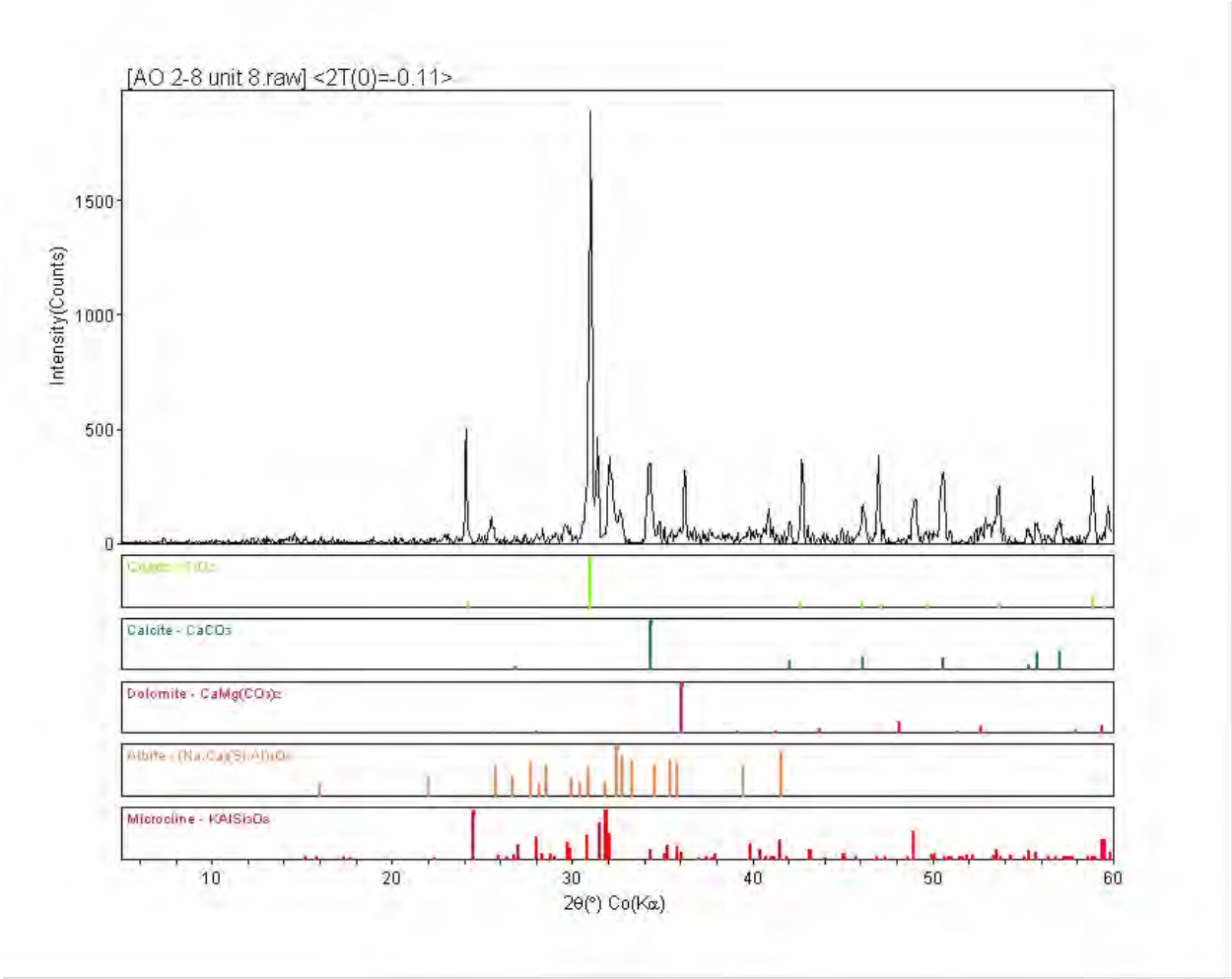
Comments:
* This standard deviation (error) includes a lab error multiplier.
** 2 sigma = 2 x square root of (sample std. dev.^2 + Delta R uncertainty
^2)
where ^2 = quantity squared.
[ ] = calibrated range impinges on end of calibration data set 0* = cannot calibrate due to nuclear testing C-14.
1955* or 1960* denote influence of nuclear testing C-14

NOTE: Cal ages and ranges are rounded to the nearest year which may be too precise in many instances. Users are advised to round results to the nearest 10 yr for samples with standard deviation in the radiocarbon age greater than 50 yr.

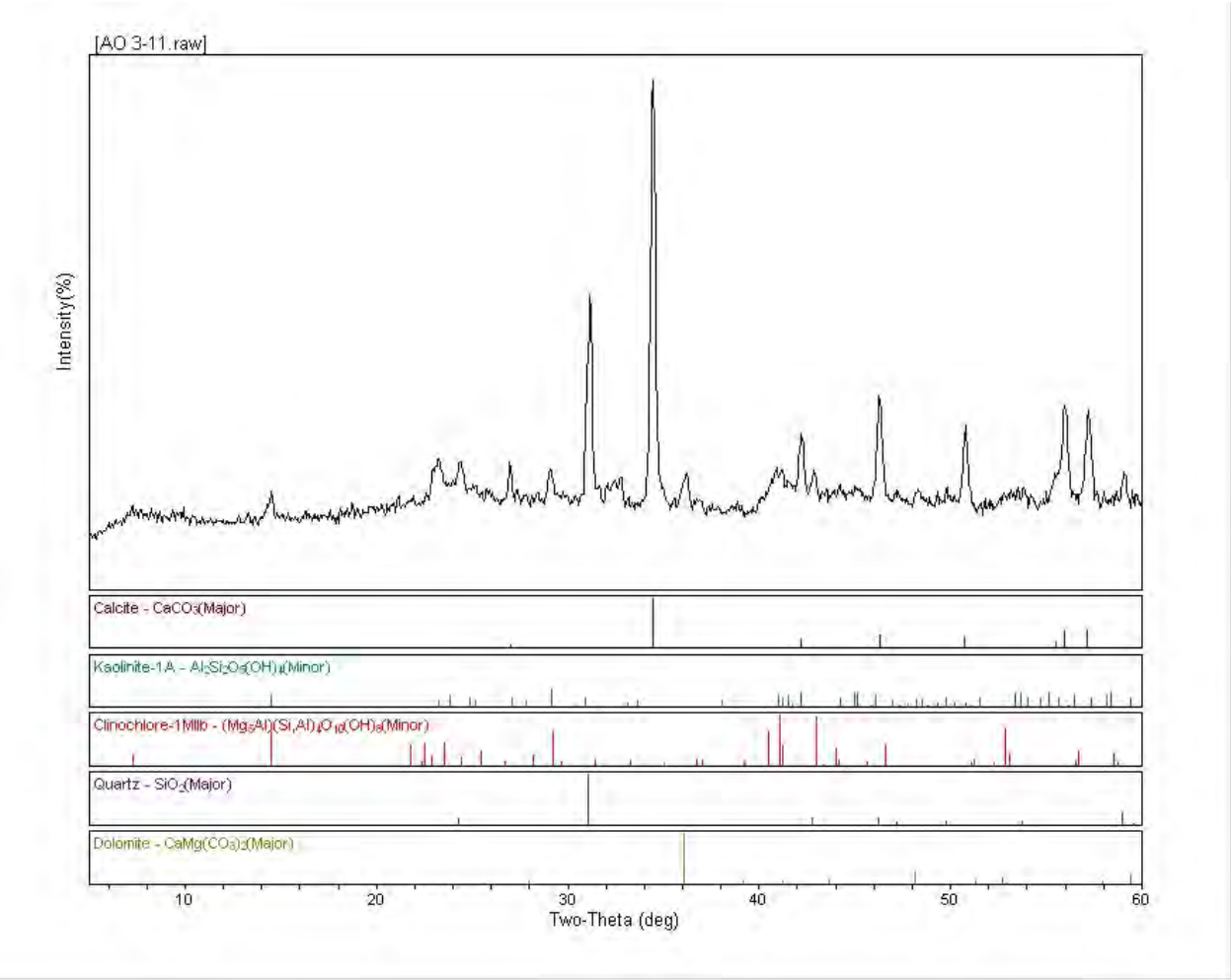
# APPENDIX E

## XRD, SEM, and EDS Data

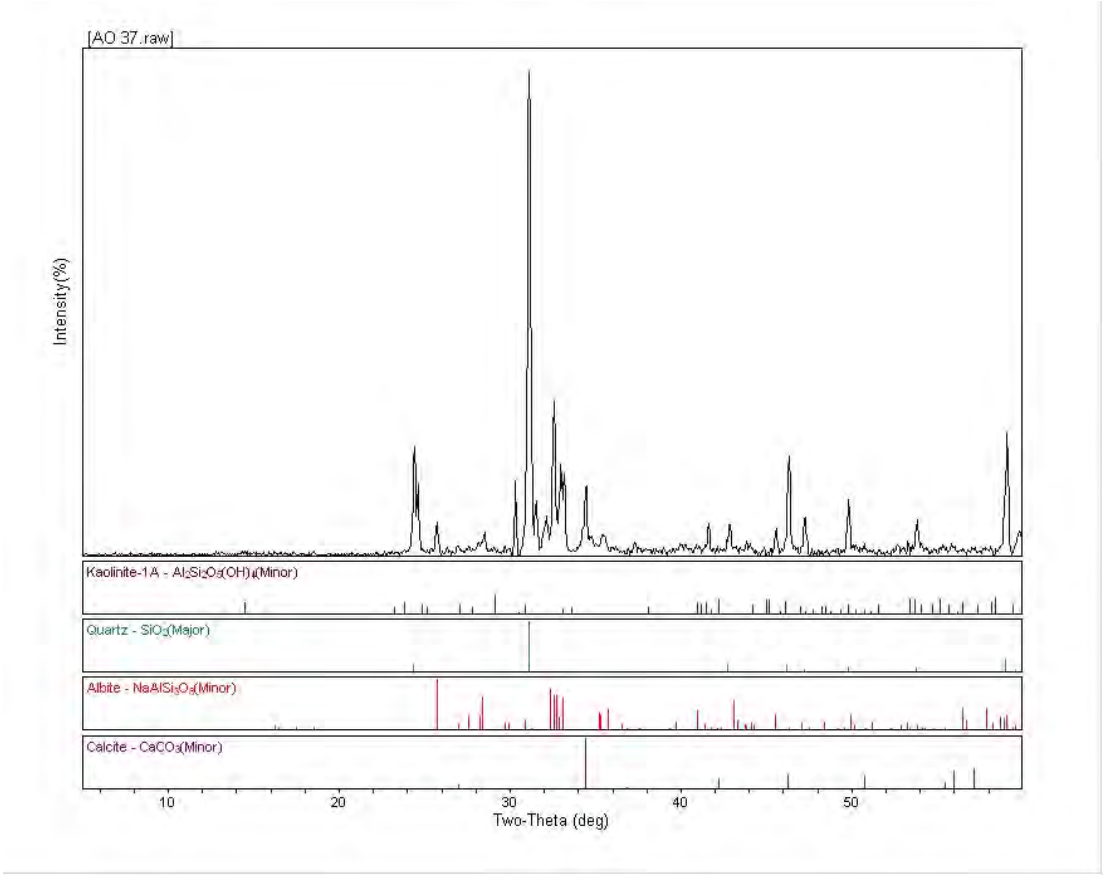
XRD AO-2 8, Unit 8



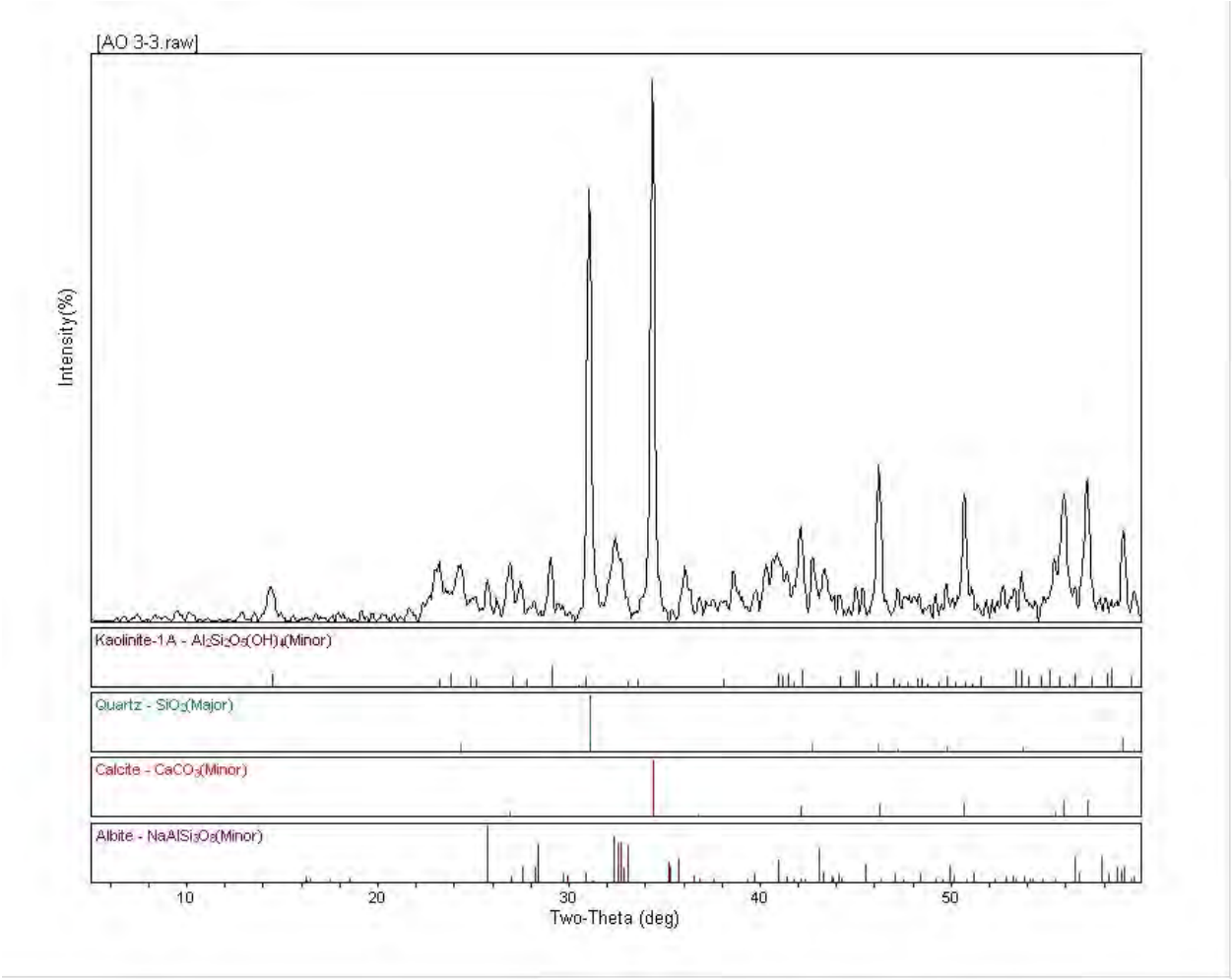
XRD AO-3 11, Unit 5



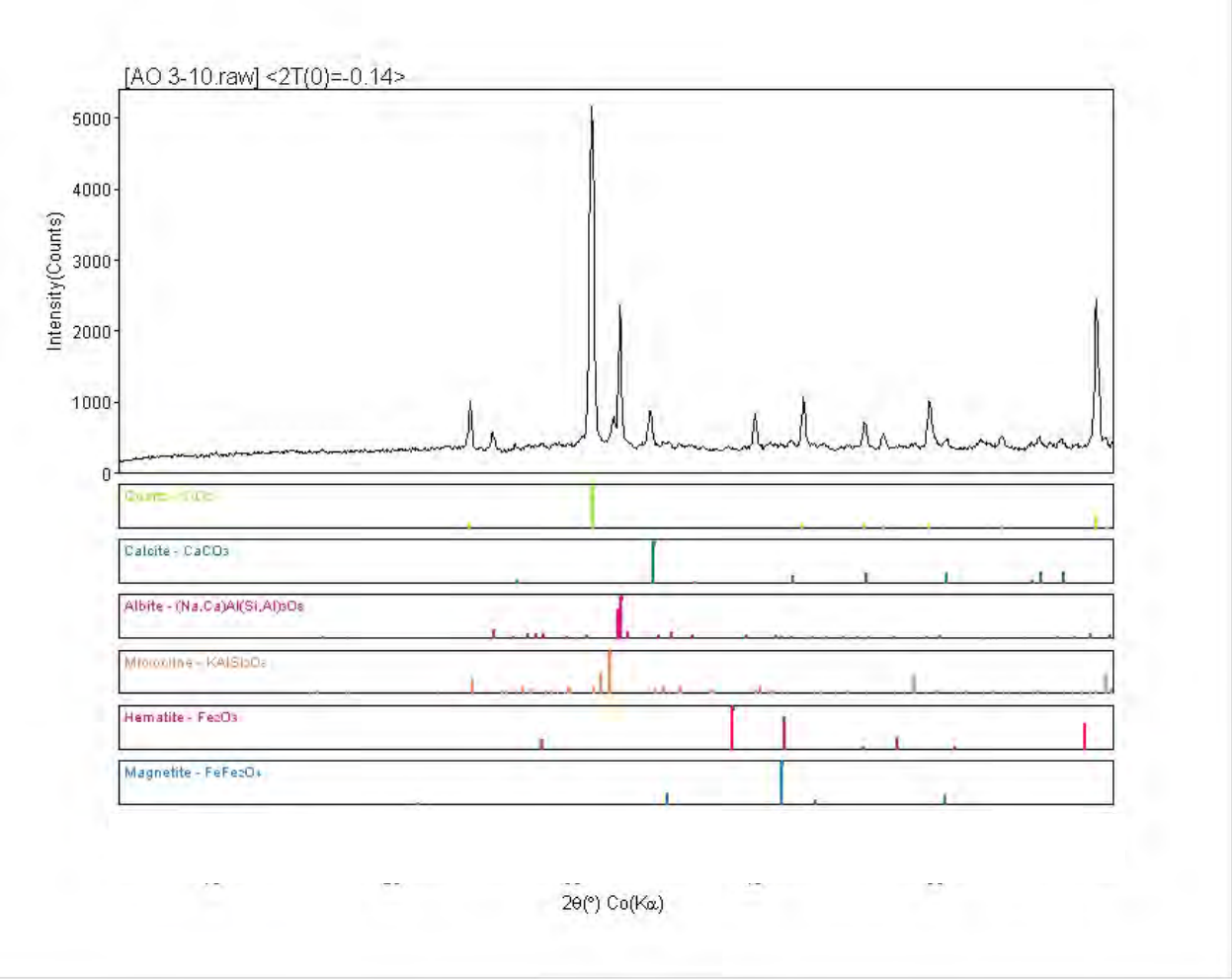
XRD AO-3 7, Unit 7



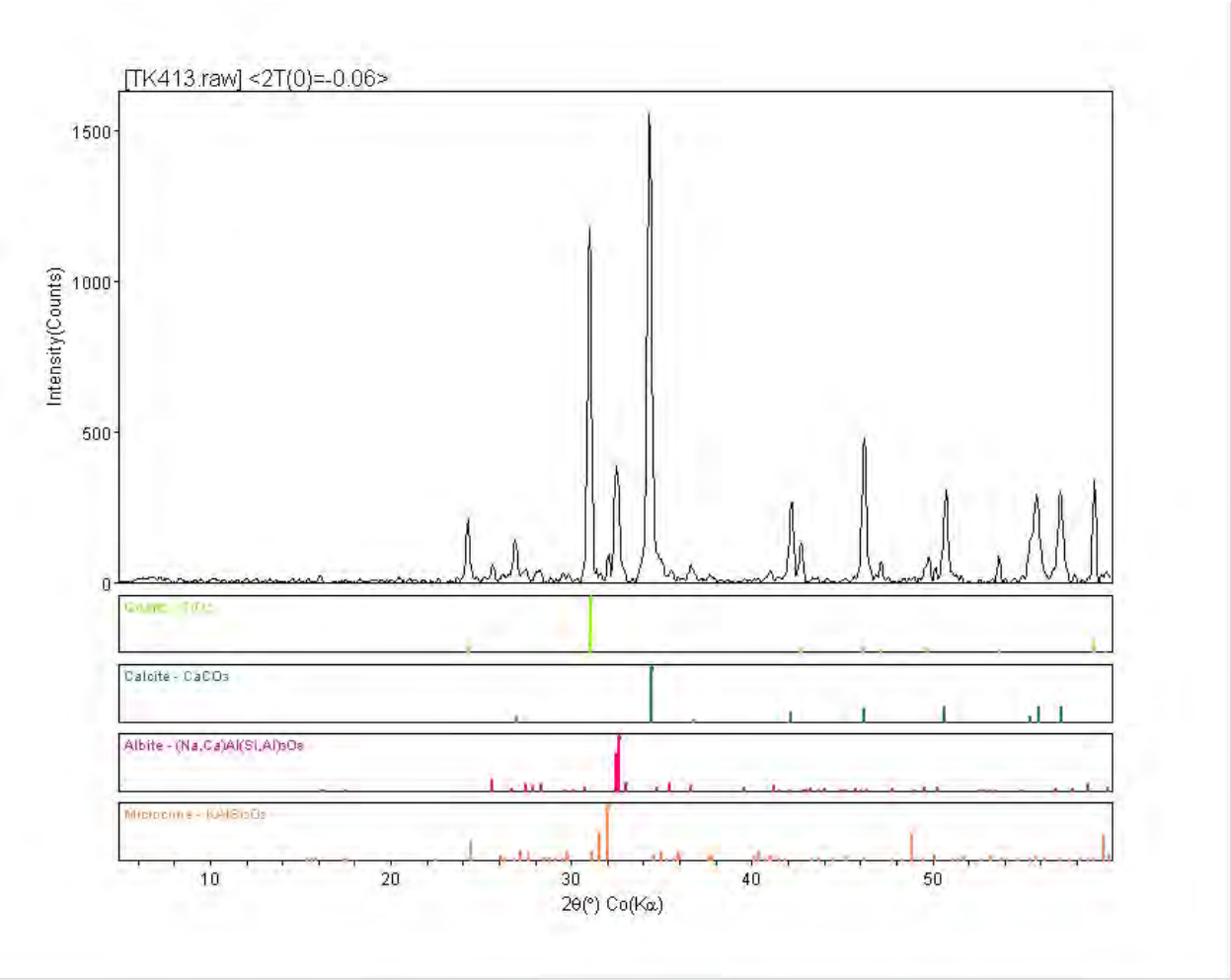
XRD AO-3 3, Unit 8



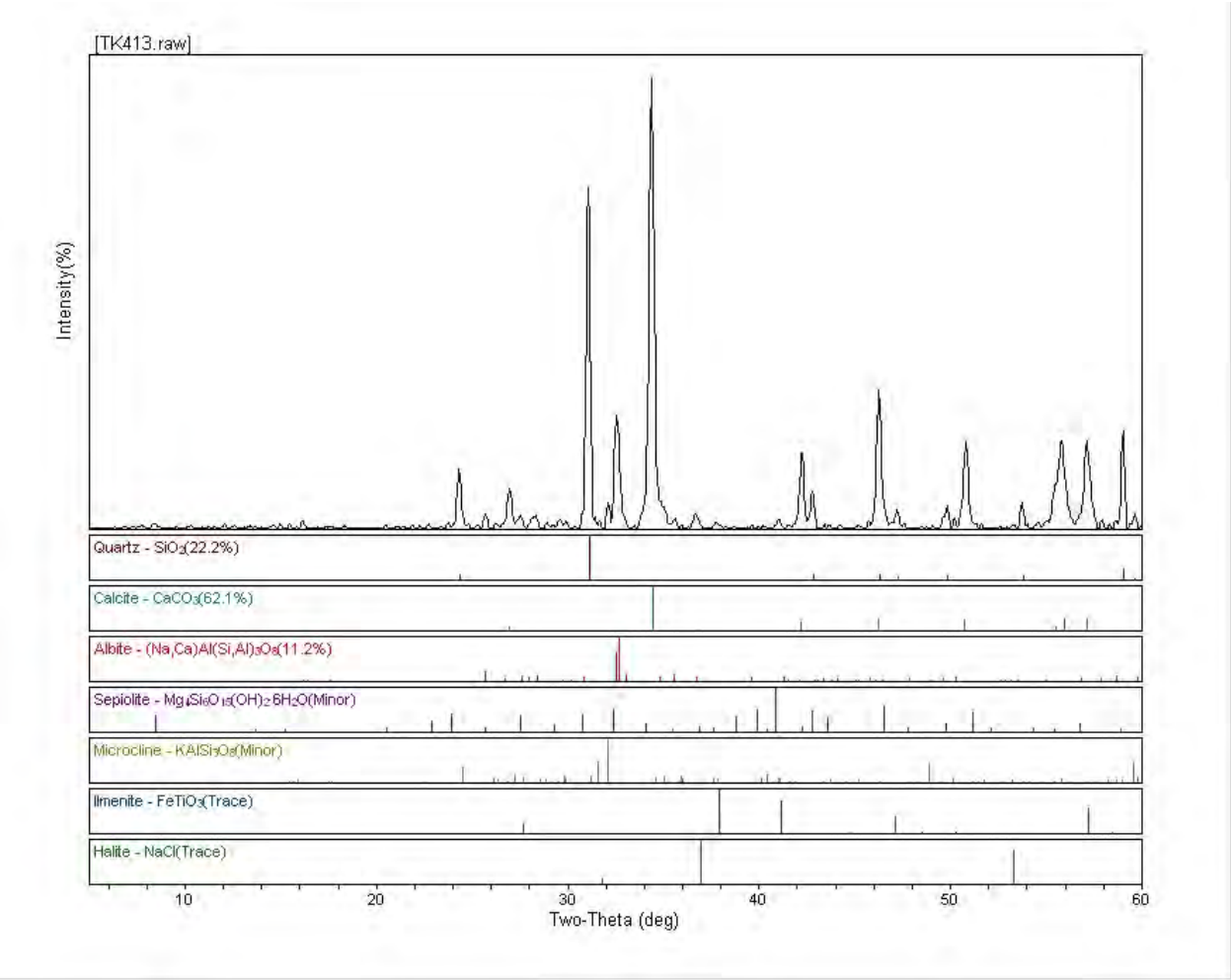
XRD AO-3 10, Unit 8



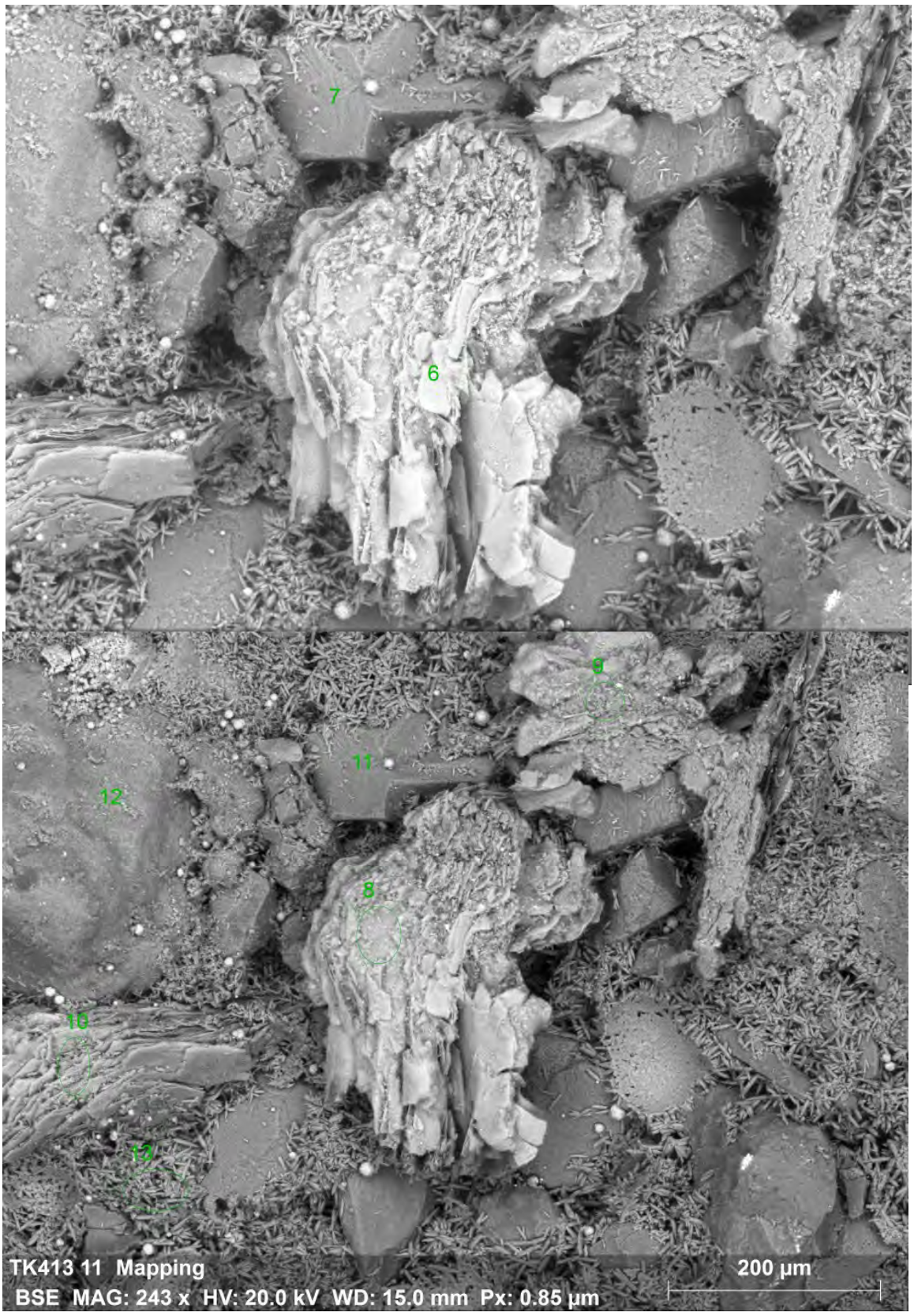
XRD TK-4, Unit 13 Bulk Sample

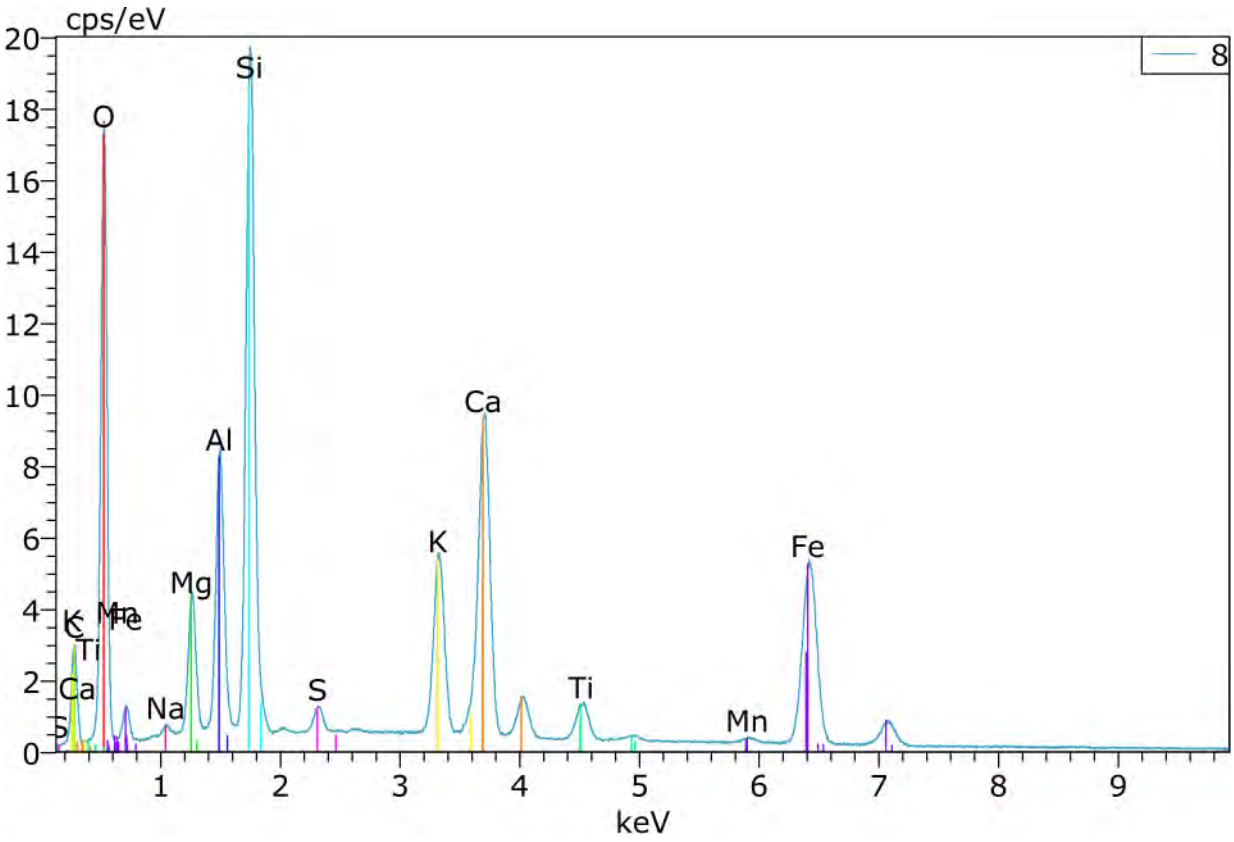


XRD TK-4, Unit 13 Concretion Sample



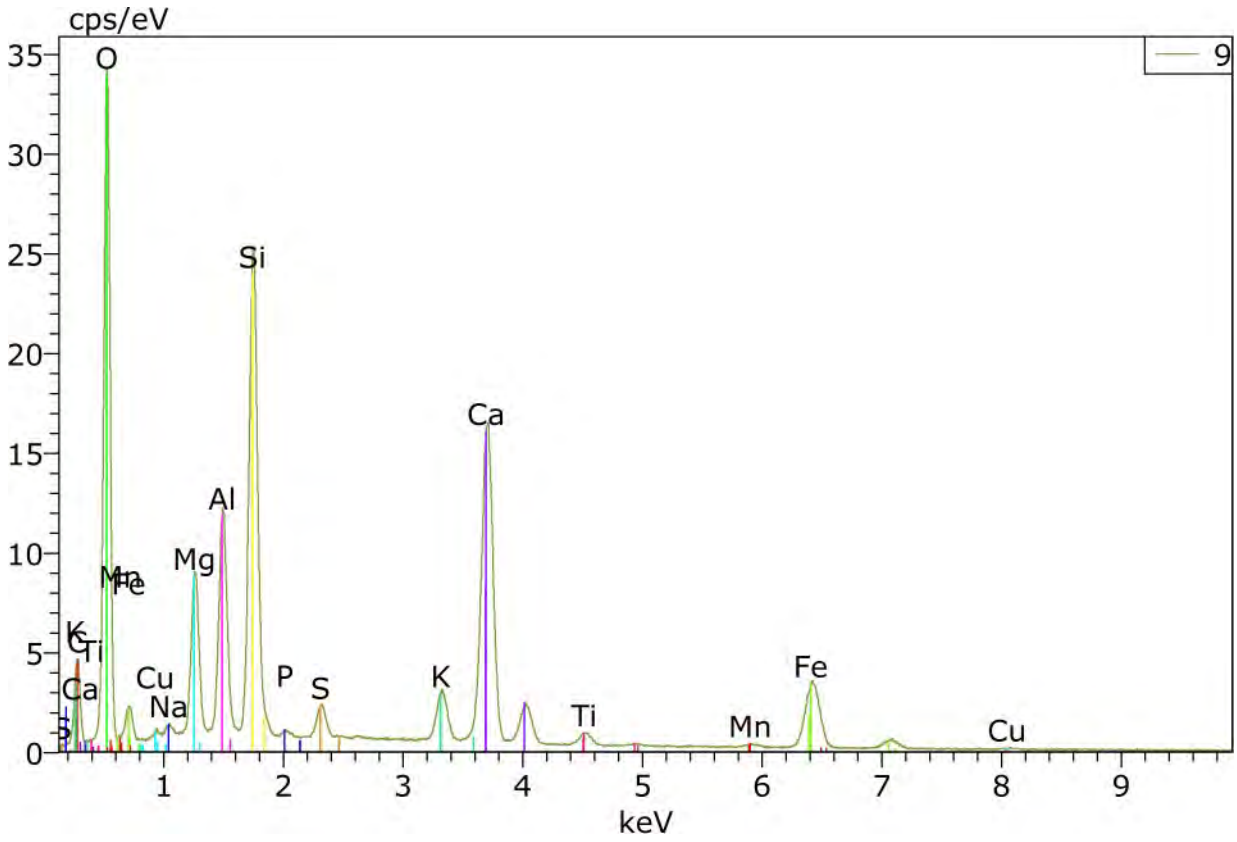
TK 4-13 SEM


7
6
9
11
12
8
10
13
TK413 11 Mapping
BSE MAG: 243 x HV: 20.0 kV WD: 15.0 mm Px: 0.85 µm
200 µm



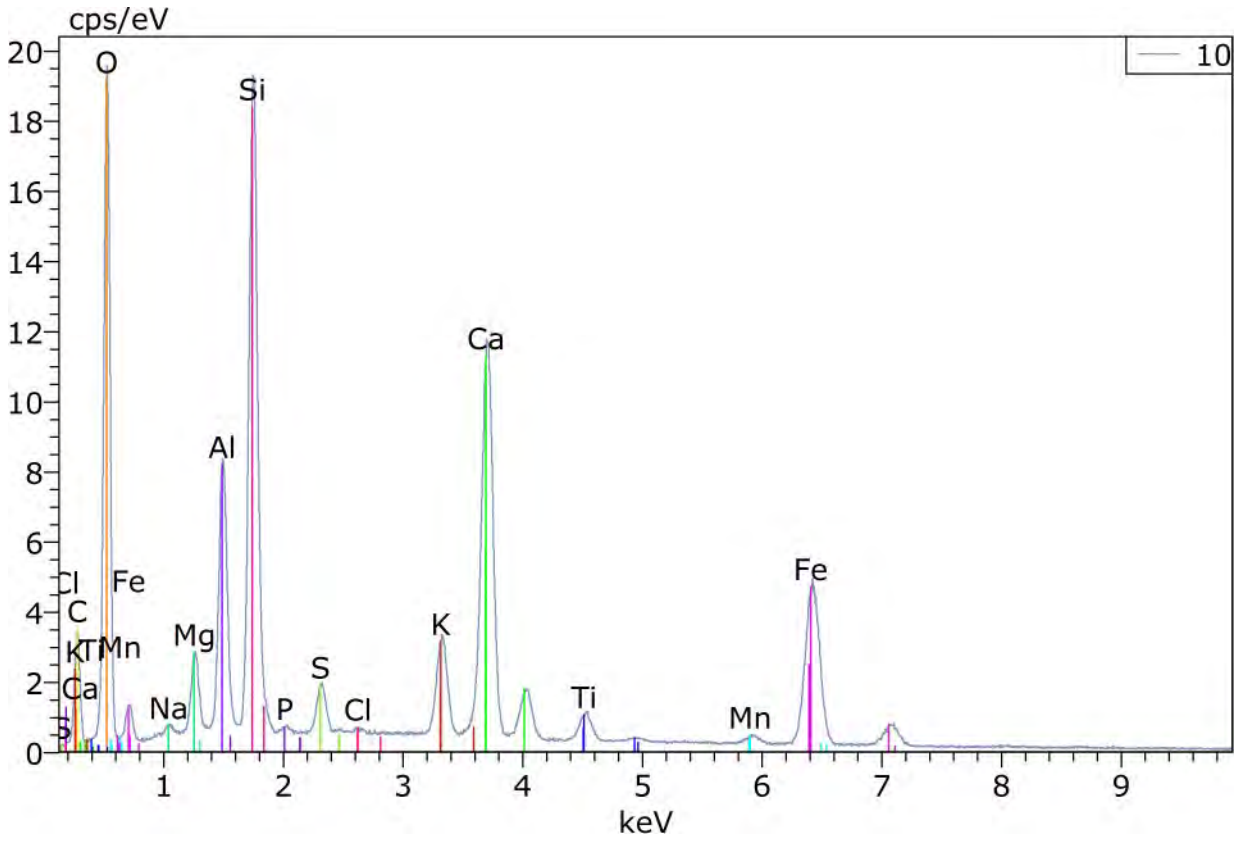

Spectrum: 8

| El | AN | Series | unn. C [wt.%] | norm. C [wt.%] | Atom. C [at.%] | Error (1 Sigma) [wt.%] |
|---|---|---|---|---|---|---|
| C | 6 | K-series | 11.15 | 11.02 | 18.84 | 1.39 |
| O | 8 | K-series | 42.58 | 42.09 | 54.03 | 4.64 |
| Na | 11 | K-series | 0.44 | 0.44 | 0.39 | 0.06 |
| Mg | 12 | K-series | 3.17 | 3.13 | 2.65 | 0.20 |
| Al | 13 | K-series | 5.44 | 5.37 | 4.09 | 0.29 |
| Si | 14 | K-series | 11.00 | 10.87 | 7.95 | 0.49 |
| S | 16 | K-series | 0.49 | 0.49 | 0.31 | 0.04 |
| K | 19 | K-series | 3.85 | 3.81 | 2.00 | 0.14 |
| Ca | 20 | K-series | 8.86 | 8.76 | 4.49 | 0.28 |
| Ti | 22 | K-series | 1.45 | 1.43 | 0.61 | 0.07 |
| Mn | 25 | K-series | 0.52 | 0.52 | 0.19 | 0.04 |
| Fe | 26 | K-series | 12.22 | 12.08 | 4.44 | 0.35 |
| | | Total: | 101.17 | 100.00 | 100.00 | |



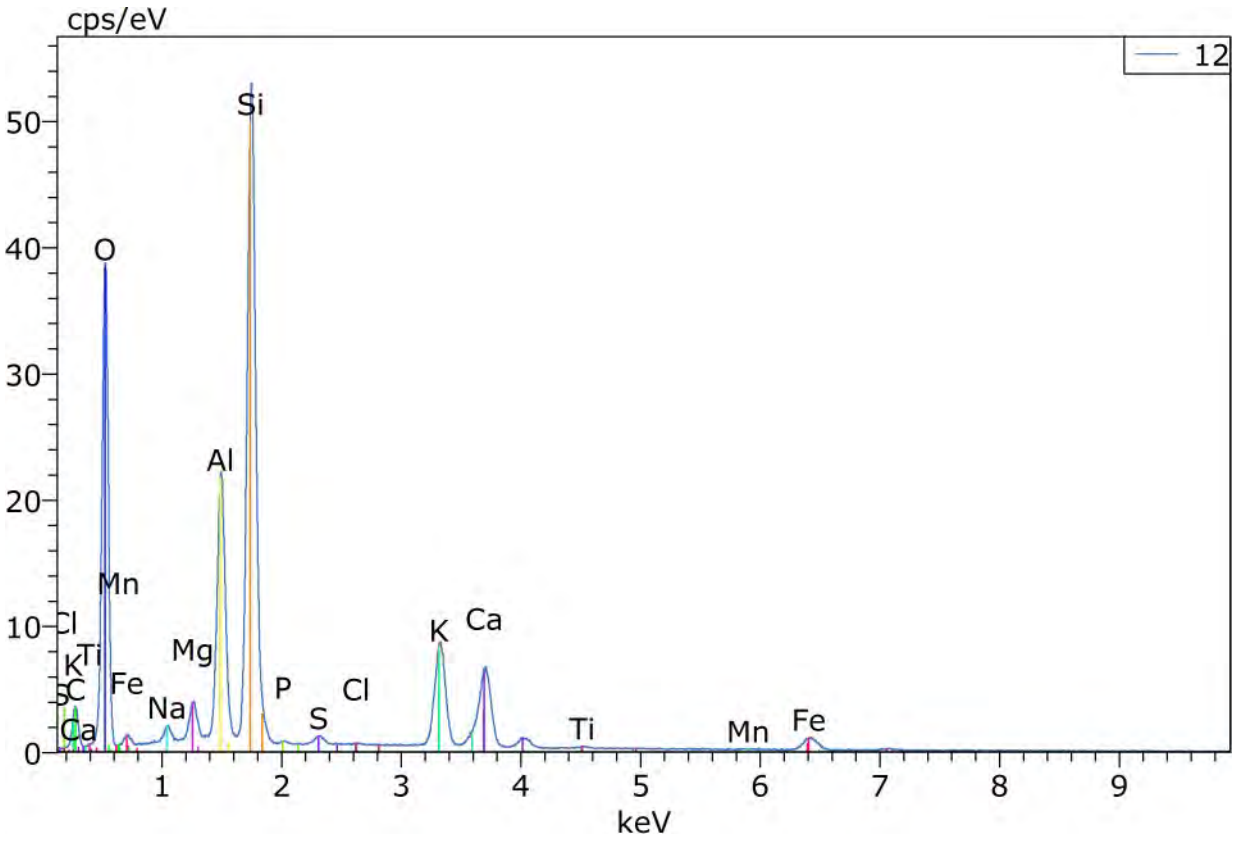

Spectrum: 9

| El | AN | Series | unn. C [wt.%] | norm. C [wt.%] | Atom. C [at.%] | Error (1 Sigma) [wt.%] |
|---|---|---|---|---|---|---|
| C | 6 | K-series | 11.65 | 10.99 | 17.56 | 1.47 |
| O | 8 | K-series | 55.00 | 51.90 | 62.22 | 5.97 |
| Na | 11 | K-series | 0.34 | 0.32 | 0.27 | 0.05 |
| Mg | 12 | K-series | 3.14 | 2.96 | 2.34 | 0.20 |
| Al | 13 | K-series | 3.92 | 3.69 | 2.63 | 0.21 |
| Si | 14 | K-series | 7.79 | 7.35 | 5.02 | 0.36 |
| P | 15 | K-series | 0.11 | 0.10 | 0.06 | 0.03 |
| S | 16 | K-series | 0.75 | 0.71 | 0.42 | 0.05 |
| K | 19 | K-series | 1.52 | 1.43 | 0.70 | 0.07 |
| Ca | 20 | K-series | 13.24 | 12.49 | 5.98 | 0.41 |
| Ti | 22 | K-series | 0.76 | 0.72 | 0.29 | 0.05 |
| Mn | 25 | K-series | 0.40 | 0.38 | 0.13 | 0.04 |
| Fe | 26 | K-series | 7.18 | 6.77 | 2.33 | 0.22 |
| Cu | 29 | K-series | 0.19 | 0.18 | 0.05 | 0.03 |
| | | Total: | 105.99 | 100.00 | 100.00 | |



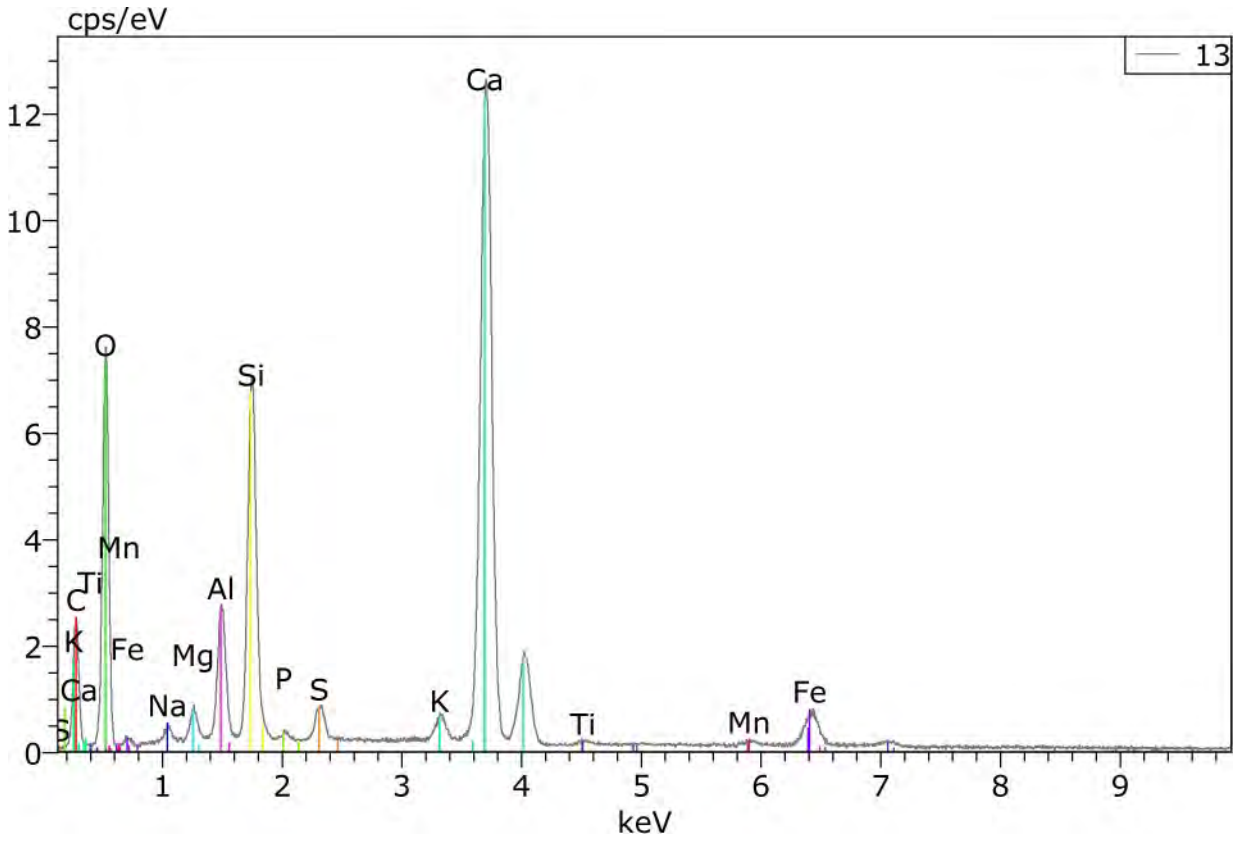

Spectrum: 10

| El | AN | Series | unn. C [wt.%] | norm. C [wt.%] | Atom. C [at.%] | Error (1 Sigma) [wt.%] |
|---|---|---|---|---|---|---|
| C | 6 | K-series | 12.45 | 11.81 | 19.68 | 1.59 |
| O | 8 | K-series | 47.27 | 44.84 | 56.10 | 5.22 |
| Na | 11 | K-series | 0.51 | 0.48 | 0.42 | 0.06 |
| Mg | 12 | K-series | 1.88 | 1.79 | 1.47 | 0.13 |
| Al | 13 | K-series | 5.29 | 5.02 | 3.72 | 0.28 |
| Si | 14 | K-series | 10.44 | 9.90 | 7.06 | 0.47 |
| P | 15 | K-series | 0.12 | 0.11 | 0.07 | 0.03 |
| S | 16 | K-series | 0.95 | 0.90 | 0.56 | 0.06 |
| Cl | 17 | K-series | 0.08 | 0.08 | 0.04 | 0.03 |
| K | 19 | K-series | 2.15 | 2.04 | 1.04 | 0.09 |
| Ca | 20 | K-series | 11.20 | 10.63 | 5.31 | 0.35 |
| Ti | 22 | K-series | 1.08 | 1.02 | 0.43 | 0.06 |
| Mn | 25 | K-series | 0.67 | 0.64 | 0.23 | 0.05 |
| Fe | 26 | K-series | 11.34 | 10.75 | 3.86 | 0.33 |
| | | Total: | 105.41 | 100.00 | 100.00 | |



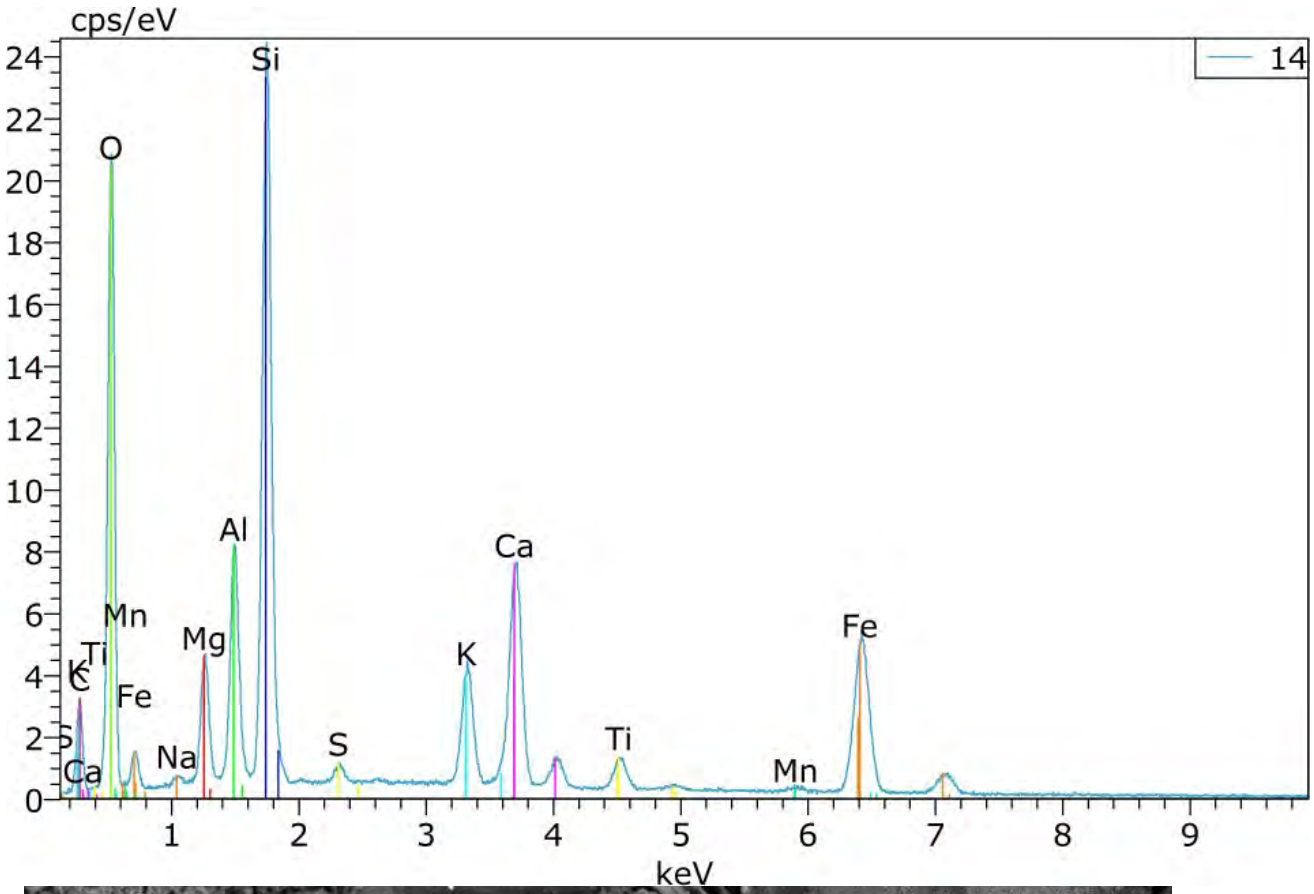

Spectrum: 12

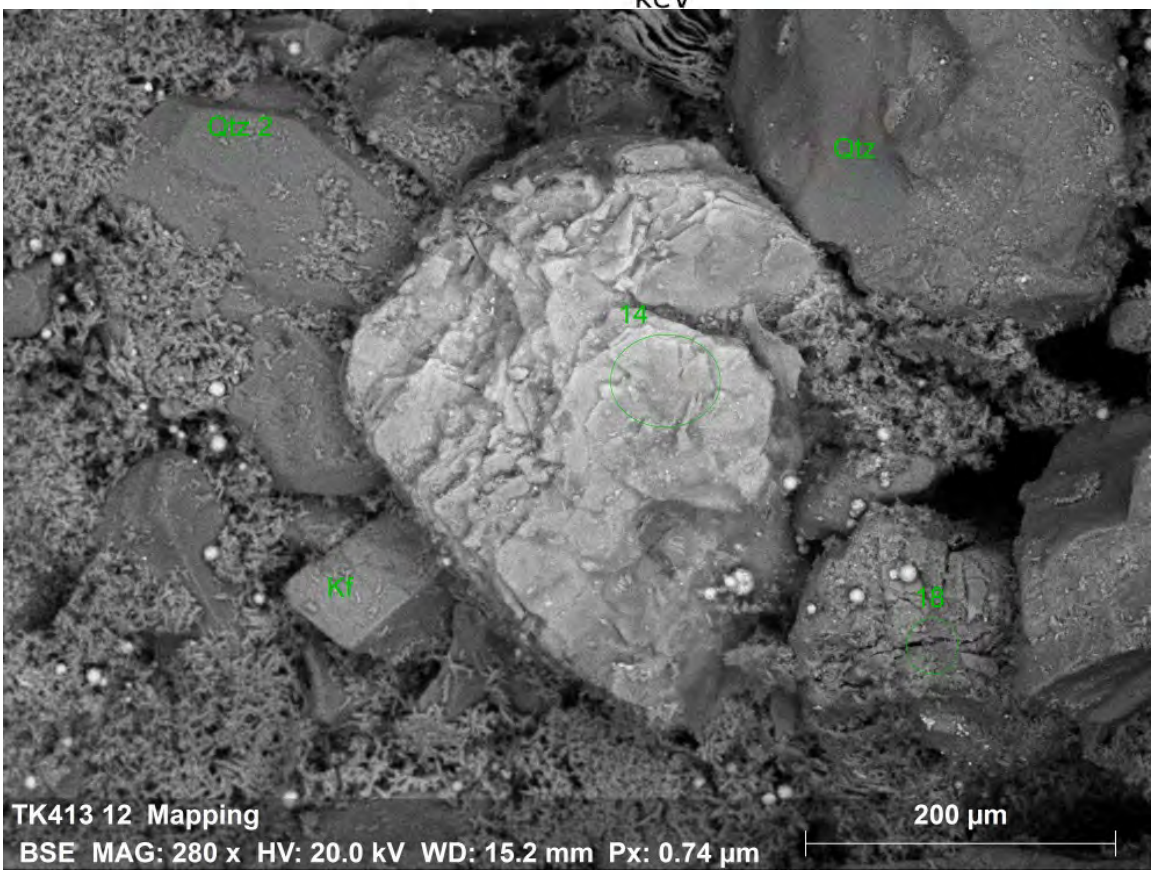
| El | AN | Series | unn. C [wt.%] | norm. C [wt.%] | Atom. C [at.%] | Error (1 Sigma) [wt.%] |
|---|---|---|---|---|---|---|
| C | 6 | K-series | 11.98 | 9.83 | 15.34 | 1.63 |
| O | 8 | K-series | 63.48 | 52.07 | 61.03 | 6.95 |
| Na | 11 | K-series | 1.22 | 1.00 | 0.81 | 0.11 |
| Mg | 12 | K-series | 1.76 | 1.45 | 1.12 | 0.12 |
| Al | 13 | K-series | 9.56 | 7.84 | 5.45 | 0.48 |
| Si | 14 | K-series | 20.45 | 16.77 | 11.20 | 0.90 |
| P | 15 | K-series | 0.13 | 0.11 | 0.07 | 0.03 |
| S | 16 | K-series | 0.34 | 0.28 | 0.16 | 0.04 |
| Cl | 17 | K-series | 0.05 | 0.04 | 0.02 | 0.03 |
| K | 19 | K-series | 5.48 | 4.49 | 2.16 | 0.19 |
| Ca | 20 | K-series | 5.37 | 4.41 | 2.06 | 0.18 |
| Ti | 22 | K-series | 0.12 | 0.10 | 0.04 | 0.03 |
| Mn | 25 | K-series | 0.03 | 0.03 | 0.01 | 0.03 |
| Fe | 26 | K-series | 1.95 | 1.60 | 0.54 | 0.08 |
| | | Total: | 121.92 | 100.00 | 100.00 | |

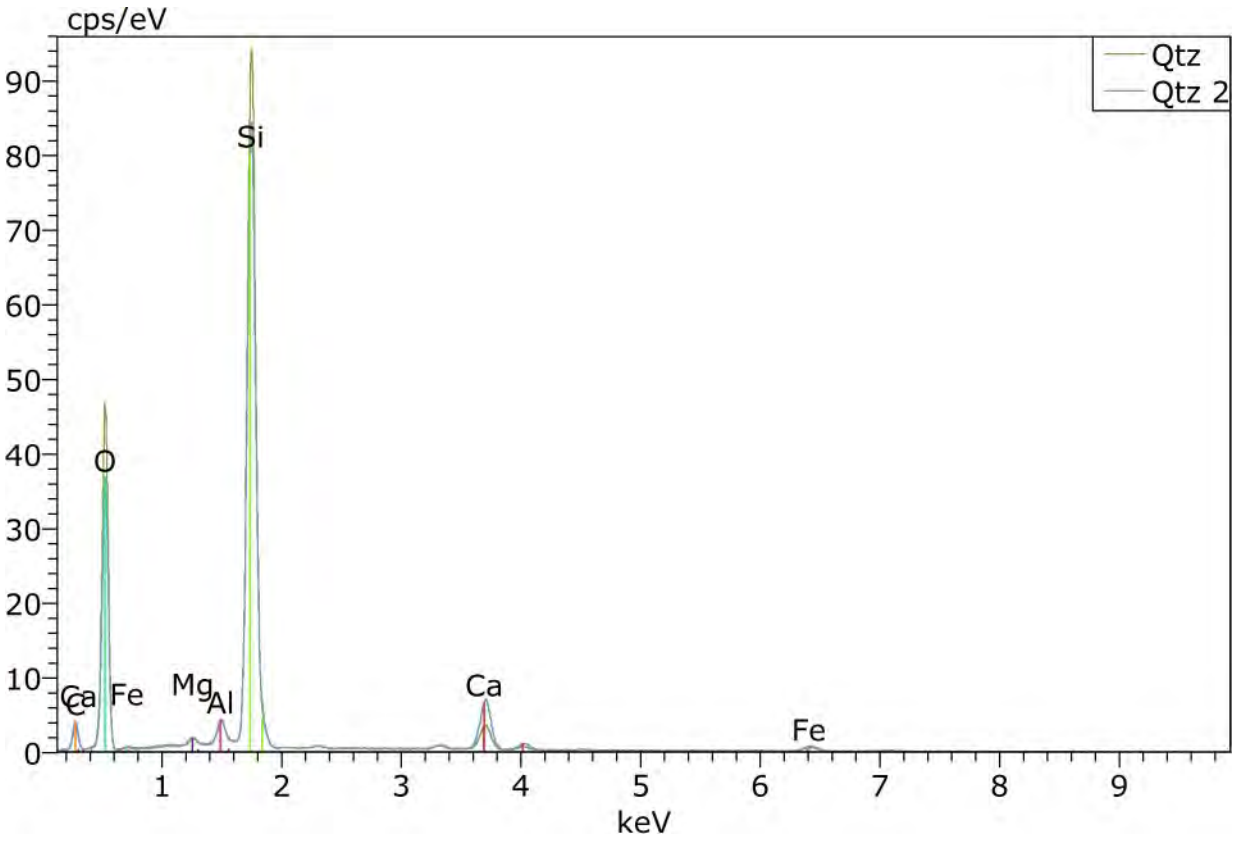


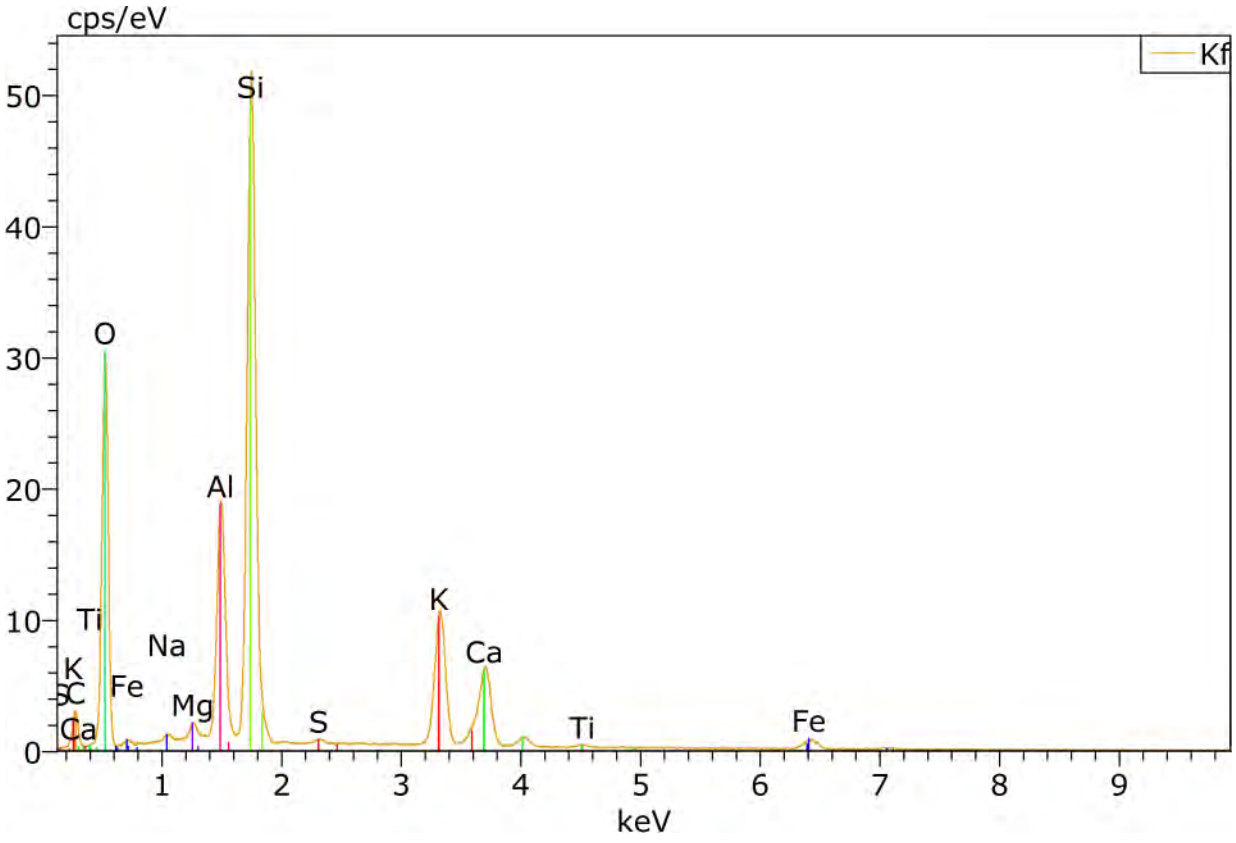

Spectrum: 13

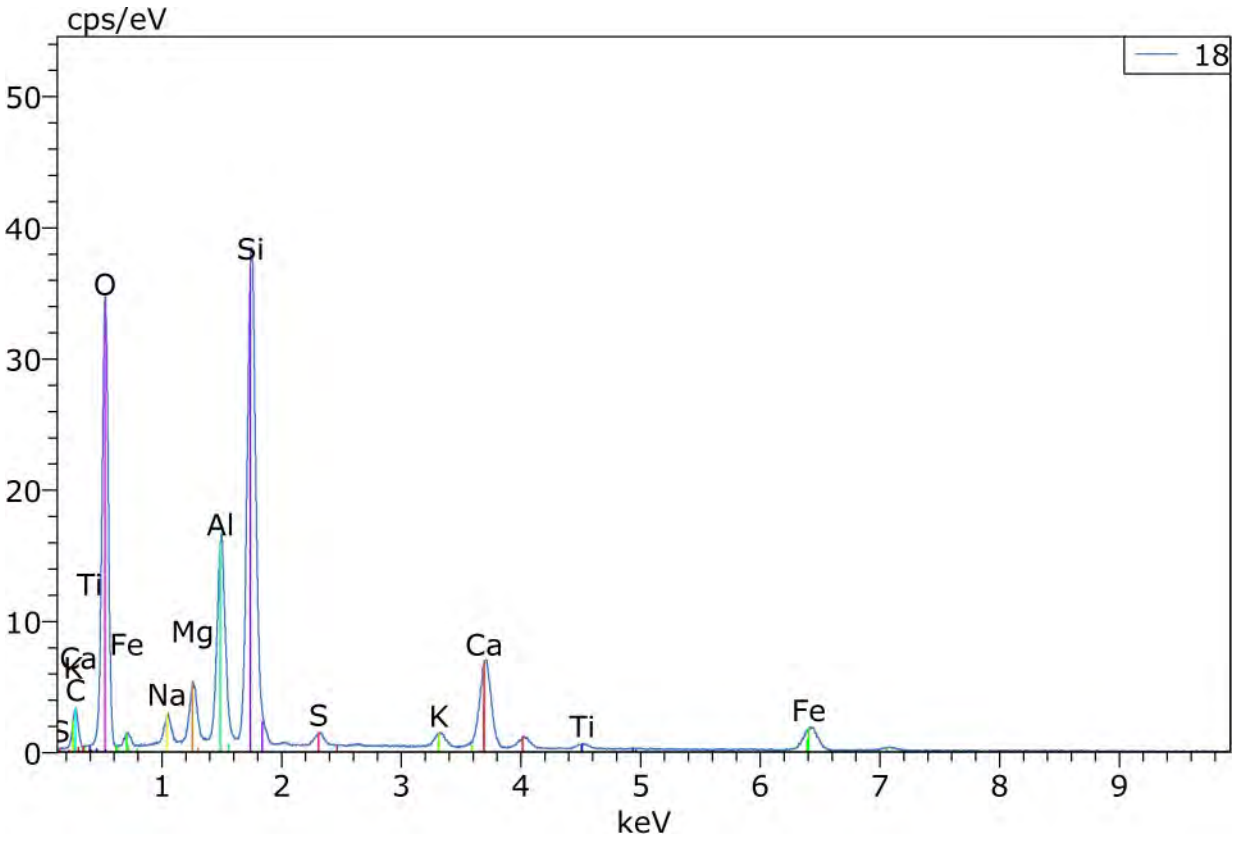
| El | AN | Series | unn. C [wt.%] | norm. C [wt.%] | Atom. C [at.%] | Error (1 Sigma) [wt.%] |
|---|---|---|---|---|---|---|
| C | 6 | K-series | 16.94 | 14.31 | 22.85 | 2.39 |
| O | 8 | K-series | 54.98 | 46.46 | 55.69 | 6.67 |
| Na | 11 | K-series | 0.91 | 0.77 | 0.64 | 0.09 |
| Mg | 12 | K-series | 1.12 | 0.95 | 0.75 | 0.09 |
| Al | 13 | K-series | 4.03 | 3.40 | 2.42 | 0.22 |
| Si | 14 | K-series | 8.78 | 7.42 | 5.07 | 0.40 |
| P | 15 | K-series | 0.21 | 0.18 | 0.11 | 0.04 |
| S | 16 | K-series | 1.04 | 0.88 | 0.52 | 0.07 |
| K | 19 | K-series | 0.64 | 0.54 | 0.27 | 0.05 |
| Ca | 20 | K-series | 26.85 | 22.69 | 10.86 | 0.81 |
| Ti | 22 | K-series | 0.17 | 0.14 | 0.06 | 0.03 |
| Mn | 25 | K-series | 0.32 | 0.27 | 0.09 | 0.04 |
| Fe | 26 | K-series | 2.36 | 2.00 | 0.69 | 0.09 |
| | | Total: | 118.35 | 100.00 | 100.00 | |

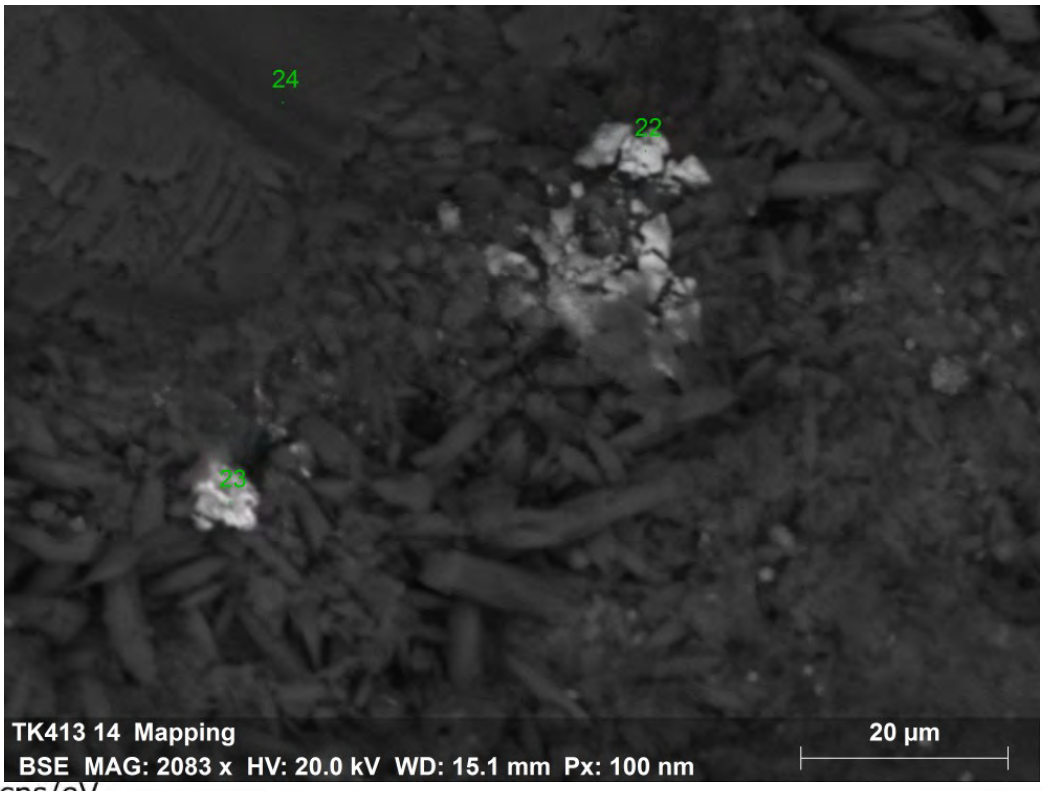

cps/eV
14
Si
O
Mn
Ti
K
C
Fe
Mg
Al
Na
S
Ca
K
Ca
Ti
Mn
Fe
keV

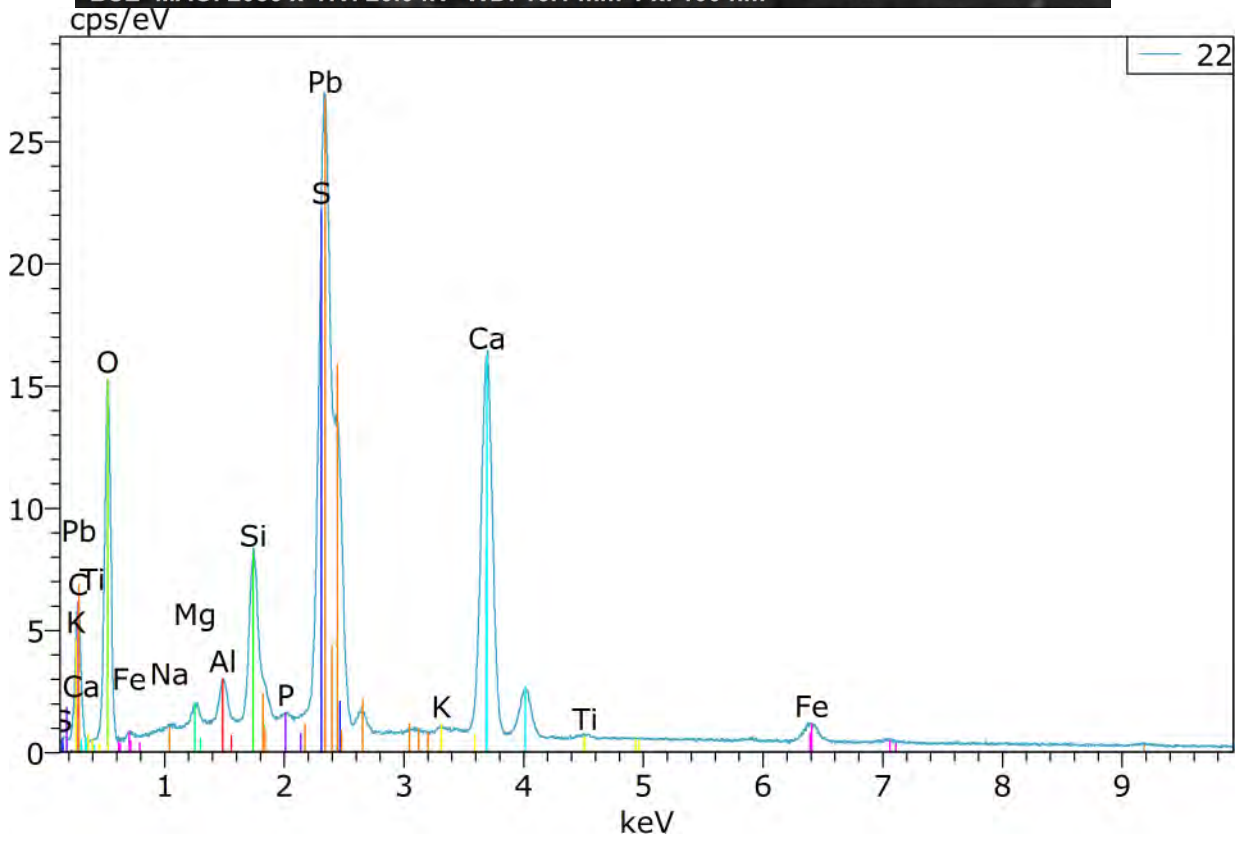

Qtz 2
Qtz
14
Kf
18
TK413 12 Mapping
BSE MAG: 280 x HV: 20.0 kV WD: 15.2 mm Px: 0.74 µm
200 µm


cps/eV
Qtz
Qtz 2
Si
O
C
Ca
Fe
Mg
Al
Ca
Fe
keV


cps/eV
Kf
Si
O
Al
Ti
K
Na
Ca
K
C
Ca
Fe
Mg
S
Ti
Fe
keV

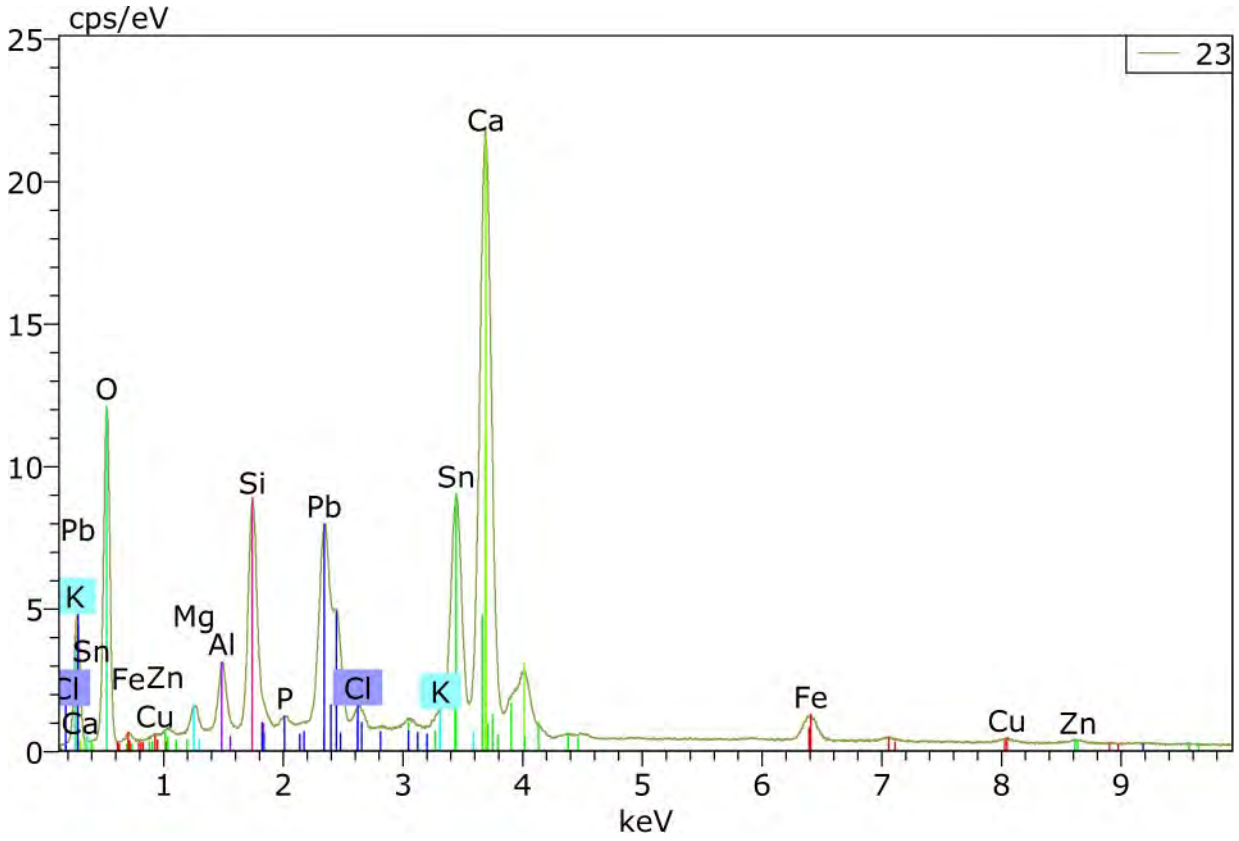

cps/eV
18
50
40
30
20
10
0
O
Si
Al
Ti
Mg
Fe
Ca
K
C
Na
S
K
Ca
Ti
Fe
1
2
3
4
5
6
7
8
9
keV


24
22
23
TK413 14 Mapping
BSE MAG: 2083 x HV: 20.0 kV WD: 15.1 mm Px: 100 nm
20 µm


cps/eV
22
Pb
S
Ca
O
Si
Pb
Ti
C
K
Mg
Ca
Fe
Na
Al
P
K
Ti
Fe
keV
0
5
10
15
20
25
1
2
3
4
5
6
7
8
9

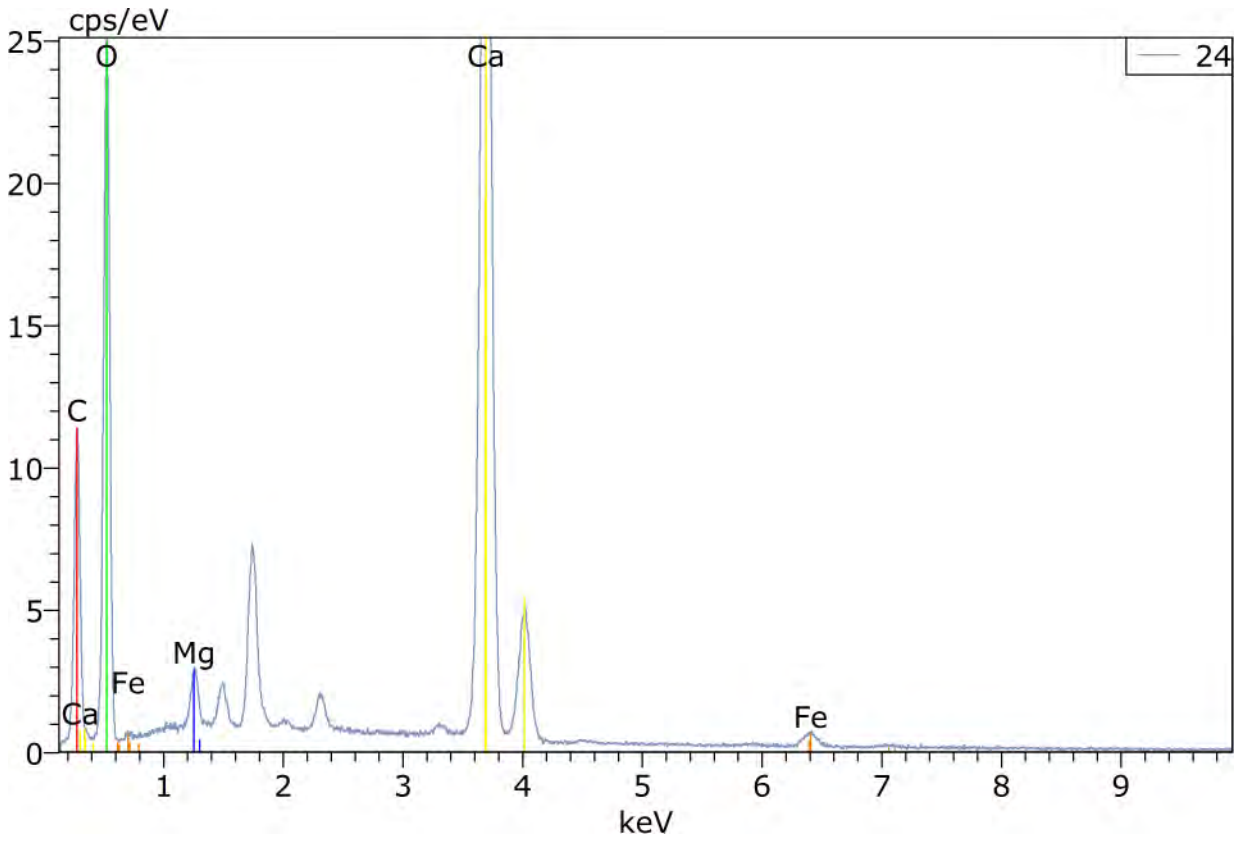
Spectrum: 22

| El | AN | Series | unn. C [wt.%] | norm. C [wt.%] | Atom. C [at.%] | Error (1 Sigma) [wt.%] |
|---|---|---|---|---|---|---|
| C | 6 | K-series | 9.66 | 10.79 | 23.73 | 1.23 |
| O | 8 | K-series | 28.35 | 31.64 | 52.26 | 3.25 |
| Na | 11 | K-series | 0.05 | 0.05 | 0.06 | 0.03 |
| Mg | 12 | K-series | 0.31 | 0.34 | 0.37 | 0.04 |
| Al | 13 | K-series | 0.59 | 0.66 | 0.64 | 0.05 |
| Si | 14 | K-series | 2.24 | 2.50 | 2.35 | 0.12 |
| P | 15 | K-series | 0.05 | 0.06 | 0.05 | 0.03 |
| S | 16 | K-series | 4.07 | 4.54 | 3.74 | 0.17 |
| K | 19 | K-series | 0.26 | 0.29 | 0.19 | 0.03 |
| Ca | 20 | K-series | 16.21 | 18.10 | 11.93 | 0.50 |
| Ti | 22 | K-series | 0.16 | 0.18 | 0.10 | 0.03 |
| Fe | 26 | K-series | 1.62 | 1.80 | 0.85 | 0.07 |
| Pb | 82 | L-series | 26.03 | 29.06 | 3.71 | 0.82 |
| | | Total: | 89.59 | 100.00 | 100.00 | |



Spectrum: 23

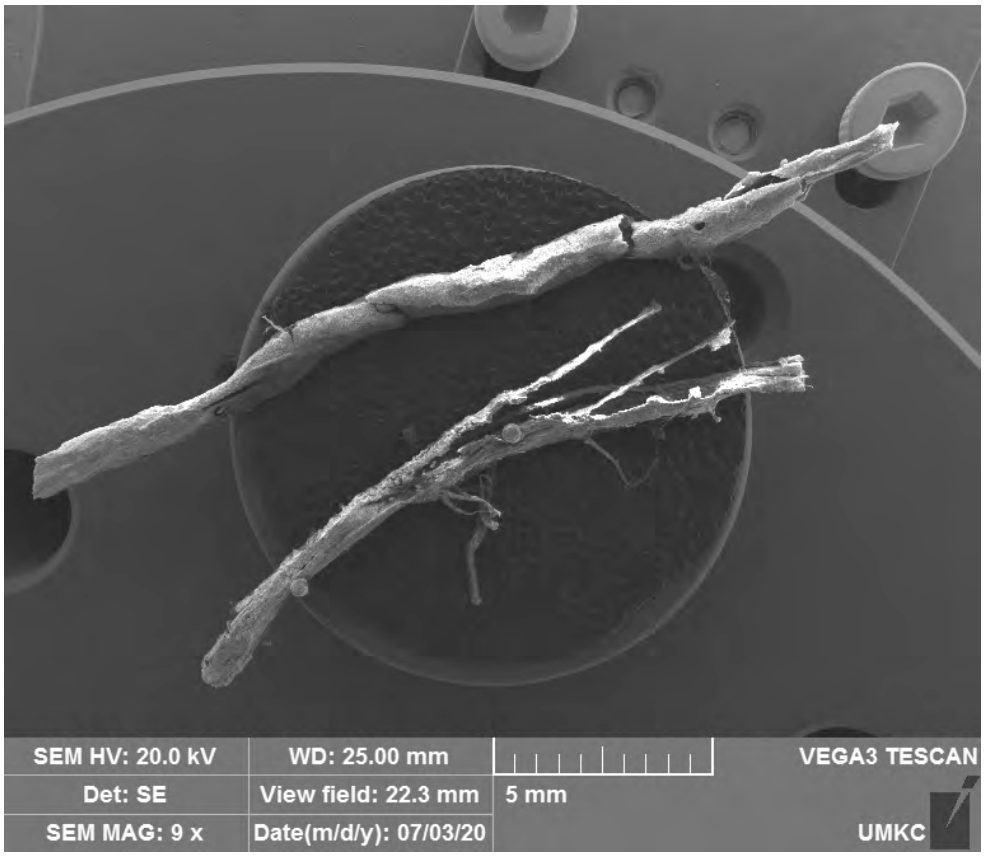
| El | AN | Series | unn. C [wt.%] | norm. C [wt.%] | Atom. C [at.%] | Error (1 Sigma) [wt.%] |
|---|---|---|---|---|---|---|
| C | 6 | K-series | 10.19 | 9.78 | 21.41 | 1.23 |
| O | 8 | K-series | 33.42 | 32.08 | 52.71 | 3.71 |
| Mg | 12 | K-series | 0.75 | 0.72 | 0.78 | 0.07 |
| Al | 13 | K-series | 1.54 | 1.48 | 1.44 | 0.10 |
| Si | 14 | K-series | 4.72 | 4.53 | 4.24 | 0.23 |
| P | 15 | K-series | 0.21 | 0.20 | 0.17 | 0.03 |
| Cl | 17 | K-series | 0.34 | 0.33 | 0.24 | 0.04 |
| K | 19 | K-series | 0.54 | 0.52 | 0.35 | 0.04 |
| Ca | 20 | K-series | 19.05 | 18.29 | 12.00 | 0.58 |
| Fe | 26 | K-series | 2.03 | 1.95 | 0.92 | 0.08 |
| Cu | 29 | K-series | 0.44 | 0.42 | 0.17 | 0.04 |
| Zn | 30 | K-series | 0.33 | 0.32 | 0.13 | 0.04 |
| Sn | 50 | L-series | 18.92 | 18.16 | 4.02 | 0.58 |
| Pb | 82 | L-series | 11.71 | 11.24 | 1.43 | 0.38 |
| | | Total: | 104.18 | 100.00 | 100.00 | |



Spectrum: 24

| El | AN | Series | unn. C [wt.%] | norm. C [wt.%] | Atom. C [at.%] | Error (1 Sigma) [wt.%] |
|---|---|---|---|---|---|---|
| C | 6 | K-series | 18.54 | 15.23 | 22.92 | 2.35 |
| O | 8 | K-series | 69.54 | 57.14 | 64.53 | 8.06 |
| Mg | 12 | K-series | 0.88 | 0.72 | 0.54 | 0.08 |
| Ca | 20 | K-series | 31.66 | 26.02 | 11.73 | 0.95 |
| Fe | 26 | K-series | 1.08 | 0.89 | 0.29 | 0.06 |
| | | Total: | 121.70 | 100.00 | 100.00 | |

Rootlets AO-2, Unit 6



# VITA

After a career in finance which took her from Little Rock, Arkansas to Dallas, Texas, New York City, Washington DC, and finally to Kansas City Janet Smith changed her career path. After leaving the brokerage industry, Janet spent a few years in radio as a producer and on-air talent at a local radio station. Then after her second child was born, she became a stay-at-home mom for several years before deciding to go back to school to earn her second bachelor's degree.

She began her degree pursuit at the University of Missouri – Kansas City in the summer of 2012 and graduated in the summer of 2015 with a B.S. in Geology. As an undergraduate at UMKC, she was active in Geology Club. She received scholarships and an undergraduate research grant. She traveled Jordan and the Bahamas to assist in fieldwork for graduate research for UMKC students. Janet analyzed clay minerals and geochronology from the cosmogenic nuclide Berylium-10 of a sediment core taken from the Al-Jafr basin in Jordan. She presented posters at the American Association of Geographers' (AAG) annual meeting and at the Geological Society of America's (GSA) annual meeting. Janet also gave a talk at the AAG annual meeting on her research the following year.

She began her master's studies in the fall of 2015. Janet taught Environmental Science lab for four semesters. She is a student member of the Geological Society of America and Sigma Xi. Janet is married to Douglas Smith, a public defender for the state of Missouri and they have three children.