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A Marine-Influenced Siliciclastic Unit (Citronelle Formation) in Western Panhandle Florida

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A MARINE-INFLUENCED SILICICLASTIC UNIT (CITRONELLE FORMATION) IN WESTERN PANHANDLE FLORIDA

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ABSTRACT

The Citronelle Formation is the most widely occurring, surficial geologic unit along the northeast Gulf of Mexico. It is a siliciclastic unit consisting primarily of sands and gravels with varying amounts of clay and minor amounts of mica and heavy minerals. Historically, the unit has been thought to be a fluvial deposit of Pliocene age. Evidence presented here suggests, at least in part, a marine origin. In some pits and exposures in southern Walton and Okaloosa Counties in western Florida, sediments that are referred to the Citronelle Formation contain well preserved *Ophiomorpha*, bivalve mollusk casts, shark teeth, terrestrial vertebrate fossils and other trace fossil remains. Various types of bedding, including cross bedding, occur. These apparent nearshore marine depositional facies are the focus of this investigation which will attempt to determine the paleo- environmental depositional regimes, age, and how this facies relates to the Cirtonelle Formation.

Field work was conducted and data were gathered from exposures and outcrops within the study area. Stratigraphic sections were measured and described. Where feasible, sediment samples were collected for sieve analysis. Further sampling of trace fossils (*Ophiomorpha)* and body fossils was conducted for analysis. Cross-bedding orientation was recorded from one locality to determine predominant paleo-current direction. These data, when combined, support the hypothesis that these sediments that have been mapped as Citronelle Formation represent nearshore, marine facies. However, their placement in the Citronelle Formation still remains questionable due to the lithologic similarity of overlying and underlying units.

CHAPTER 1

INTRODUCTION

Statement of Problem

The Citronelle Formation was named by Matson (1916) based upon exposures near Citronelle, Alabama. Matson stated "The name Citronelle Formation is applied to sediments of Pliocene age, chiefly nonmarine, that occur near the seaward margin of the Gulf Coastal Plain, extending from a short distance east of the western boundary of Florida westward to Texas". He concluded that the sediments of the Citronelle Formation, in the type area, were of fluvial origin. This was based upon the nature of the sediments and the absence of fossil remains of either marine or fresh-water organisms. The idea that the Citronelle Formation is a nonmarine, fluvial deposit has been advanced by numerous investigators (Clendenin, 1896; Matson, 1916; Rosen, 1969; Otvos, 2004). Others, however, have proposed that the basal portion of the Citronelle Formation in Alabama represents deposition in a transitional marine environment (Isphording and Lamb, 1971). Coe (1979) proposed that the upper two hundred feet of Citronelle Formation, in Escambia and Santa Rosa Counties, represent transition from estuary to marsh to subaerial environments. During periods of subaerial exposure, numerous streams criss-crossed the area depositing sand and gravel.

The depositional origin of this formation has been a contentious issue since these sediments were first investigated in the late 1800's. An even larger problem has been the placement of the unit in a chronostratigraphic framework. This is due, in part, to the fact that very few fossils have been recovered from the Citronelle Formation. Berry (1916) described a fossil flora that was collected from a black clay unit within the Citronelle Formation in an exposure at Red Bluff on Perdido Bay in Alabama. Based upon his analysis, he concluded that the fossil flora from this locality was from the latter half of the Pliocene epoch. Doering (1958) reassessed Berry's conclusions and proposed that an early Pleistocene age for the Citronelle was just as plausible. He also cast doubt upon whether the fossil leaf-bearing clay unit was even part of the Citronelle Formation.

Other fossils recovered from the Citronelle Formation include pollen, petrified wood and a few fragments of mollusk shells (Marsh, 1966). Estella Leopold concluded, based upon fossil pollen analysis, that the middle and upper portions of the Citronelle Formation are Quaternary in age (Marsh, 1966). Isphording and Lamb (1971) reported on a vertebrate fauna discovered near the base of the Citronelle Formation in Mobile County, Alabama. They proposed a middle Pliocene through Early Pleistocene age for the Citronelle Formation. Manning and MacFadden (1989) describe fossil remains of a Pliocene (late Hemphillian) horse from the Tunica Hills of Louisiana. They concluded, based upon this fossil evidence and the ages of overlying and underlying strata, that the Citronelle Formation in east-central Louisiana is "nearly" Pliocene age. By no means is there a consensus on the primary depositional regime or the age of the Citronelle Formation, and these problems are examined in this study.

Another complicating factor pertaining to Citronelle Formation sediments is their lithologic resemblance to underlying and overlying formations. The Citronelle Formation, in western Florida, is known to overlie Miocene formations of the Alum Bluff Group, Miocene Coarse Clastics, and the Pensacola Clay and is overlain by Pleistocene terrace deposits presumably reworked from the Citronelle Formation (Marsh, 1966). Both overlying and underlying formations are known to contain similar lithologies making formational breaks difficult to discern.

Several hypotheses regarding the nature of the Citronelle Formation in the study area will be tested through the course of the study and they include: 1) the Citronelle Formation includes, in part, sediment that was deposited in near-shore marine environments; 2) the deposition of these sediments took place during the Late Pliocene; 3) the marine-influenced sediments belong to the Citronelle Formation, as currently mapped.

Previous Work

Strata that are now referred to the Citronelle Formation have been investigated and reported on as early as 1854 (Wailes, 1854). Matson (1916) provides a good overview of the early literature. The formation was formally named by Matson (1916) in a United States Geological Survey publication. Since Matson's formal naming of the

Citronelle Formation, numerous investigations have been completed primarily looking at the depositional history and age problems surrounding the unit. The first report on the age of the formation, based upon fossil evidence, was conducted by Berry (1916). He concluded that the Citronelle Formation, based upon his analysis of the fossil plant material, was Pliocene.

Roy (1939) reported that the fossiliferous, clay bearing unit described by Berry (1916) was older than the overlying sediments and could not be used for determining the age of the Cirtronelle Formation. He further suggested dropping the term Citronelle. Carlston (1951) supported Roy's position that these fossil plant-bearing clays were pre-Citronelle and could not be used to date the Citronelle Formation. Doering (1956) provided an overview of opinions regarding the age of the Citronelle and supported the Pleistocene age determination of other, previous authors. He further reported that Deussen (1914) discussed in his report that Pleistocene *Equus* teeth were discovered in a well near Brookshire, Texas, in a unit that underlies the Citronelle Formation.

Cooke (1945) gave a brief overview of the Citronelle Formation's occurrence in Florida. He stated that the Citronelle Formation was supposed to be contemporaneous with other Pliocene formations and was the only littoral or near-shore accumulation of sand and clay in the western part of the state brought down by rivers and distributed by wave action along the Gulf. He also reported that the fossil oyster, *Ostrea westi,* occurs in abundance near Otahite in Okaloosa County presumably in the Citronelle Formation, but could be from older deposits. Based upon Cooke's understanding of the Citronelle Formation, it occurs from western Florida to Gadsden County and then reappears along the central ridge of peninsular Florida from Clay to Highlands County.

Stringfield and LaMoreaux (1957) discussed two additional fossil plant localities that they believed were part of the Citronelle Formation. The fossil flora was examined by a paleobotanist from the U.S. Geological Survey who concluded that these additional faunas were identical to the one Berry (1916) described. With the additional localities showing that the fossiliferous clays were within the Citronelle Formation, they concluded that this cast doubt upon the Pleistocene age determination of previous authors. They further went on to say that they had observed Citronelle Formation underlying the oldest

Pleistocene terrace deposits, further supporting their view that the Citronelle Formation is older than Pleistocene.

Doering (1958) reassessed the Citronelle Formation age issue and concluded that it could be assigned a pre-Nebraskan Pleistocene age, once again questioning the Pliocene age assignment of previous authors. Doering stated that Berry's Pliocene age, based upon the fossil flora, was the only evidence that supported a Pliocene correlation for the Citronelle Formation.

Pirkle, et al. (1963) described sediments in Putnam County, Florida that they referred to the Citronelle Formation. No age assignment was given to these sediments. Their lithologic character and some sedimentary structures were described. A heavy mineral analysis was conducted. Based upon their results, they hypothesized that a large delta deposit was the source for these Citronelle Formation sediments and they were acted upon by subsequent Pleistocene sea-level fluctuation.

Reed (1967) attempted to better define the contact between the Citronelle Formation and the underlying Miocene formations by describing a series of new stratigraphic sections exposed near Matson's type locality at Citronelle, Alabama. There was some confusion regarding a sand unit overlying a clay bed being used to define the base of the Citronelle Formation. Sand beds overlying clay units commonly occur repetitively within the Citronelle Formation, and it can be difficult to tell which one truly represents the basal portion of the unit. Reed mapped a clay bed that was laterally continuous and constructed a composite stratigraphic column showing the repetitive nature of the sand-clay sequences within both the Citronelle Formation and the underlying Miocene Series.

Marsh (1966) investigated the distribution of the Citronelle Formation in Escambia and Santa Rosa Counties, Florida. He identified, for the first time, fossils of a marine origin in the Citronelle Formation. Marine mollusk-shell fragments, foraminifers, fossil wood and carbonized plant remains were identified from well cuttings in some wells in Escambia and Santa Rosa Counties from intervals included in the Citronelle Formation. Marsh also described outcrops that contained numerous fossil burrows constructed by the ghost shrimp, *Callianassa.* As noted previously, samples containing fossil pollen were collected and analyzed by Estella Leopold of the United States

Geological Survey and Marsh reported that the results provided clear fossil evidence for a Quaternary age for the middle and upper parts of the Citronelle Formation in western Florida.

Rosen (1969) utilized heavy mineral analysis to support his hypothesis that the Citronelle Formation represents alluvial deposits formed by coalescing braided streams. The heavy mineral suite found in Citronelle Formation sediments is indicative of the Eastern Gulf Province and contains in decreasing abundance kyanite, staurolite, tourmaline and rutile, along with several other minerals. Rosen believed that the Citronelle Formation was deposited during pre-glacial time.

Isphording and Lamb (1971) discuss the age and origin of Citronelle Formation sediments in Alabama based upon the discovery of vertebrate fossils in a dark, gray, carbonaceous, silty clay found at the base of the Citronelle Formation on Chicksabouge Creek in northern Mobile County, Alabama. Analysis of the vertebrate fossils yielded an age estimate of middle Pliocene (Hemphillian). They go on to state that fossil pollen data collected from nearby western Florida suggest that deposition of Citronelle Formation continued into the pre-glacial Pleistocene. Further analysis of the sediments revealed that they were deposited in a lagoon, estuary or marsh setting that was receiving enough fresh water to keep salinity low. The coarse-grained nature of the sediments lying above the vertebrate layer suggests an increased input of sediment into the basin by fluvial activity. It is likely that the paleoenvironment of the vertebrate fossil layer was not unlike the modern deltaic environment of Mobile Bay.

Coe (1979) investigated the Plio-Pleistocene sediments of Escambia and Santa Rosa Counties, Florida. He concluded that two distinct sediment sequences can be traced laterally: a sand and gravel sequence and a sand-silt-clay sequence. These sequences also are repeated vertically. Correlation of sequences from the highland regions to the lowlands cannot be accomplished due the removal of the upper sequence in the lowland regions. He further concluded, based upon heavy mineral analysis, that the Citronelle sediments originated from high-rank metamorphic rocks of the Appalachians in Alabama. These sediments were deposited in an estuary or a marsh by fluvial activity. Clay analysis supports the hypothesis that deposition of Citronelle sediments occurred in a fresh or low-salinity environment. Alternating coarsening-upward and fining-upward sequences reflect regressive/transgressive sequences during deposition in the Pliocene.

Clark and Schmidt (1982) reported on the shallow stratigraphy of Okaloosa County, Florida. Their brief account outlined the aerial extent, thickness and general lithology of the Citronelle Formation.

Huddleston (1984) investigated the Neogene stratigraphy of the central Florida panhandle. His interpretation was that the fluvial-deltaic/estuarine Citronelle Formation interfingered with shoreline, beach and lagoon sands and muds near the north shore of Choctawhatchee Bay and correlated with downdip, Pliocene marine units. He further postulated that if this was correct then the Citronelle Formation in Walton County was Pliocene in age.

Ervin Otvos has published a number of articles on the Citronelle Formation (Otvos, 1988, Otvos, 1994, Otvos, 1995, Otvos, 1998, Otvos, 2004). In 1998, he provided additional paleontological evidence, based on the occurrence of Japanese umbrella pine pollen (*Sciadopitys*) discovered in a Citronelle backswamp lignite deposit in Mississippi, of a Late Pliocene age. He described a number of localities in western Florida where nearshore, marine sediments containing *Ophiomorpha nodosa* and rare mollusk casts occurred. Based upon the magnitude of the distribution of marine deposits within the Citronelle Formation, the new pollen data, additional sea level data, and epirogenically uplifted sediment surfaces, Otvos (1998) concluded that the original Pliocene age assignment of the Citronelle Formation was vindicated. Otvos (2004) conducted a granulometric analysis of more than 900 sediment samples from Louisiana to west Florida and showed that fine-grained textures in Citronelle Formation sediments are common. Additionally, the fluvial models proposed for explaining depositional environments of parts of the Citronelle Formation should include meandering, transitional meandering-braided and anastomosing stream morphologies. Some fractures and other structures found at Citronelle Formation exposures suggest that tectonism has played a role in shaping the surface topography of the formation.

The distribution of the Citronelle Formation in Florida has been mapped by various authors (Means, et al, 2000; Green, et al, 2001; Scott, et al, 2001). The formation has been mapped from western Escambia County east to central Gadsden County where it grades laterally into the Miccosukee Formation (Cooke and Mossom, 1929). Previous authors (Pirkle, et al, 1963) mapped Citronelle Formation into the peninsular portion of Florida in the past, but the current thinking is that those sediments belong to the Cypresshead Formation, not the Citronelle Formation (Scott, 1988)

Potential Significance

The Citronelle Formation has been studied by numerous authors. However there still remain questions regarding the age of the deposit and the depositional regimes responsible for its emplacement. This work will try to shed additional light on these problems. The Citronelle Formation is a complex deposit of siliciclastics that exhibits rapid, lateral facies changes and resembles both underlying and overlying formations. Data presented in this study may help to show how the Citronelle Formation, in the western panhandle of Florida, was deposited. Newly acquired paleontologic evidence will be presented.

About 93 percent of Floridians get their drinking water from groundwater sources (Berndt, et al., 1998). In western Florida, the primary drinking water aquifer is a surficial aquifer called the Sand and Gravel aquifer. The Citronelle Formation makes up a portion of this aquifer. Additional information on the lithologic and depositional nature of the Citronelle Formation may enhance understanding of aquifer properties and the ability of the Citronelle to continue to produce water for Florida's ever growing population.

CHAPTER 2

STUDY AREA

Western Panhandle of Florida

The study area for this investigation is located in western panhandle Florida and falls primarily within two counties: Walton and Okaloosa. Exposures between Gadsden and Escambia Counties were examined but the primary emphasis was placed on the Citronelle Formation in the two previously mentioned counties. Portions of the field work for this study were conducted 2000 and 2001 as part of a surficial mapping project for the Florida Geological Survey (Means, et al., 2000, Green, et al., 2001). Figure 1 shows the location of the study area and localities where data were obtained.

The location of the study area was chosen because it contains abundant outcrops, sand mines and Citronelle Formation sediments that contain *Ophiomorpha* tubes. Elevations range from ±105 meters to sea level providing sufficient relief to examine up-dip and down-dip facies within the Citronelle Formation.

Eglin Air Force Base (EAFB) lies within the study area. On the base are numerous excavations and borrow-pits utilized for road maintenance. These were very useful for investigating the nature of the Citronelle Formation south of the Yellow River. EAFB is one of the largest land owners in this region covering 464,000 acres between the Yellow River and the coast. One of the sand pits on Eglin was used to construct a stratigraphic column and was sampled for sieve analysis (Figure 11 - sample EAFB). Field work done on EAFB was complicated by the fact that the base has been used for many years as a testing area for numerous weapons. Debris and unexploded ordinance are commonly encountered, not to mention that bombing is still a common activity on EAFB. I was asked several times to evacuate the area due to impending military operations. This was one of many field challenges associated with this project.

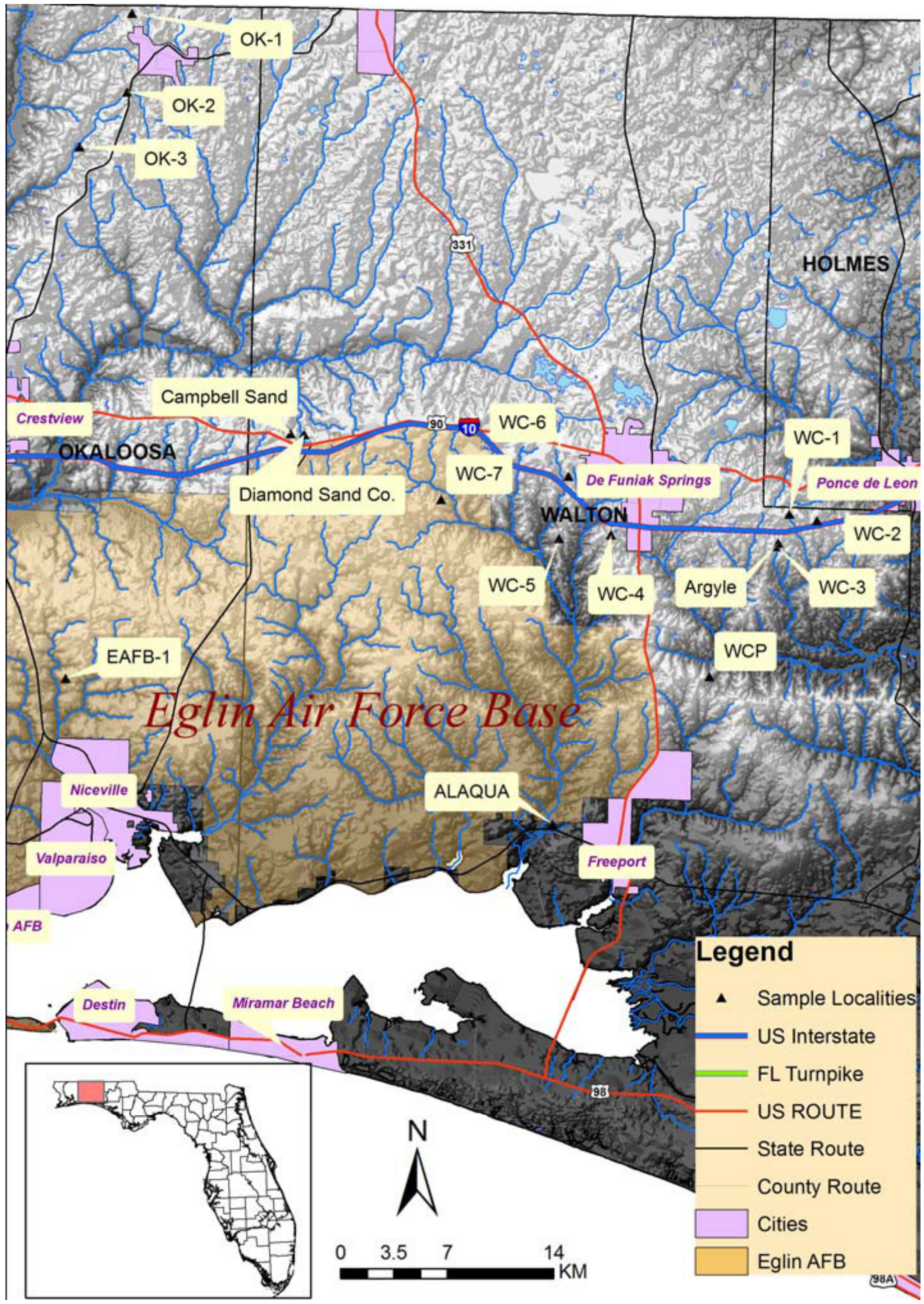


Figure 1 – Study area in western Florida with site localities.

Geological Overview

The deposition of strata in western Florida has been influenced by subsurface structures (Figure 2). The Apalachicola Embayment occurs on the eastern portion of the study area. This negative topographic feature has been associated with faulting during the Triassic and Jurassic Periods. The axis of this feature has shifted though time but was finally filled in with sediment during the Pliocene and Pleistocene (Schmidt, 1984).

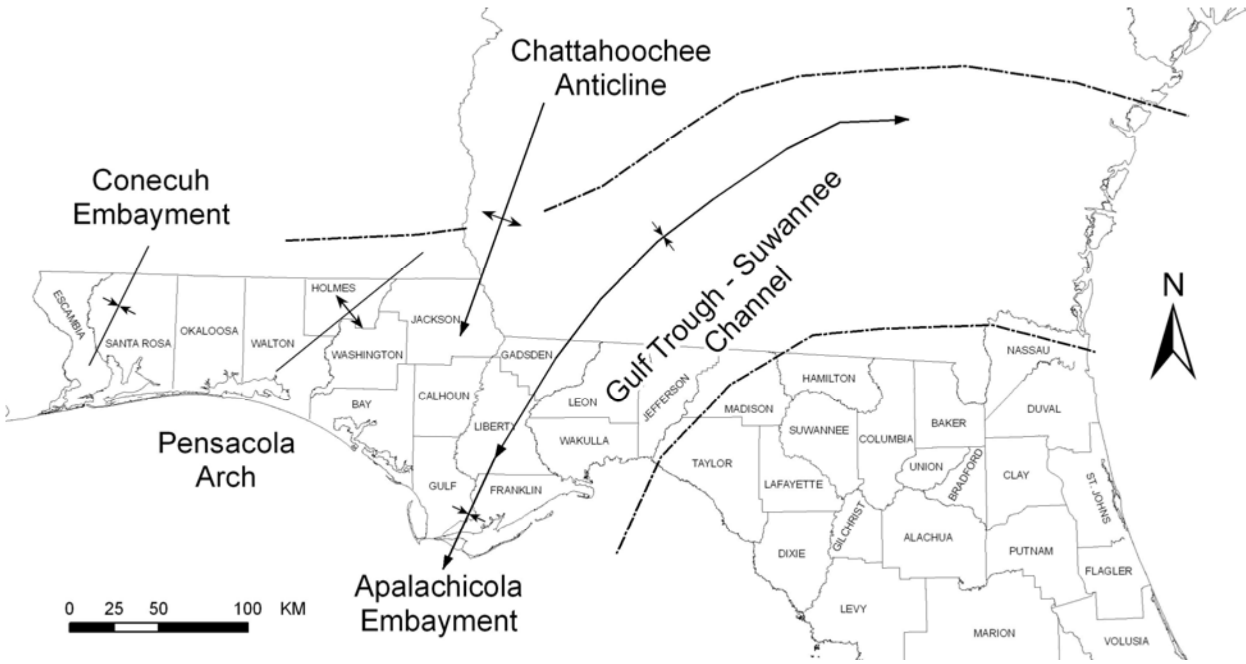


Figure 2 - Geologic structures of northwest Florida (modified from Schmidt, 1984).

The hinge of the Chattahoochee Anticline occurs in Jackson County (Figure 2). Eocene and Oligocene sediments are exposed at the surface here and many younger geologic units pinch out against its flank, especially in Walton County (Clark and Schmidt, 1982). Further to the west the Pensacola Arch and the Conecuh Embayment have influenced the deposition of older strata (Jurassic), but these features are not expressed at the surface. Siliciclastics tend to thicken to the west and southwest into the larger Gulf of Mexico Basin. The deposition of the Citronelle Formation in the study area does not appear to have been influenced by any of these structural features.

The oldest geologic units exposed in the study area are the Alum Bluff Group (Miocene), the undifferentiated coarse clastics (Miocene) and the Bruce Creek Limestone (Miocene) (Figure 3). In southeastern Walton County, carbonates of the Bruce Creek Limestone crop out, but this is the only known surficial exposure of carbonate in the study area. The Alum Bluff Group and undifferentiated coarse clastics are primarily subsurface units, but they are exposed in creeks and river valleys in eastern portions of Walton and throughout Holmes and northern Washington Counties where stream erosion has incised deeply enough to intersect them (Means et al, 2000; Green et al, 2001). The Alum Bluff Group grades laterally into the undifferentiated coarse clastics just west of the Yellow River in Okaloosa County. These formations are primarily composed of greenish, fossiliferous, sandy clays and clayey sands with traces of heavy minerals and mica. The occurrence of fossil mollusks in the Alum Bluff Group and undifferentiated coarse clastics has been used in differentiating them from the overlying Citronelle Formation (Means et al, 2000).

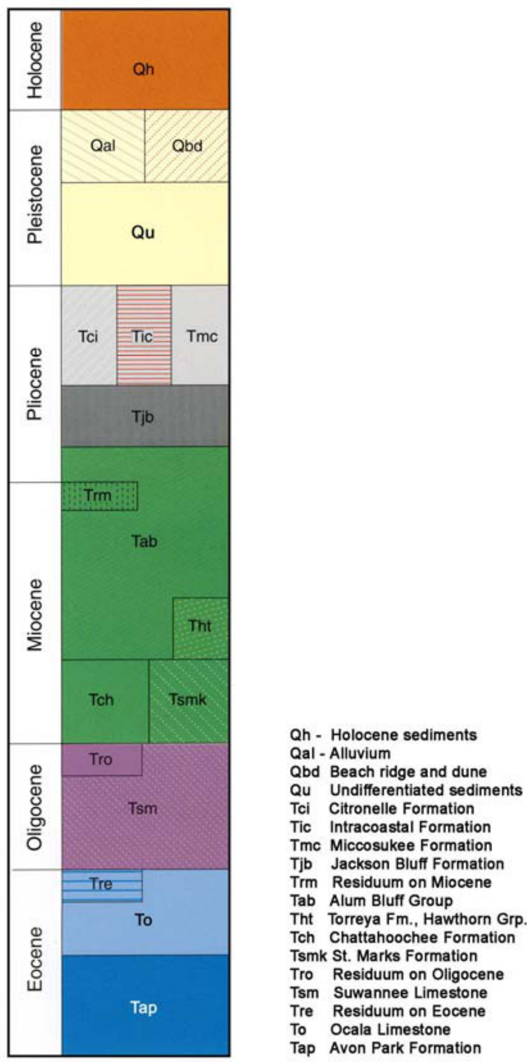


Figure 3 – Stratigraphic column of geologic units in the study area (Scott et al, 2001).

The geologic map of Florida (Scott et al., 2001) shows the distribution of named geologic units that occur within twenty feet of the surface (Figure 4). In the majority of the study area, the Citronelle Formation is the first unit encountered at the surface. Quaternary alluvium has accumulated in some of the major river valleys and Miocene formations are exposed in deeply incised river and stream valleys in the eastern portion of the study area.

The easternmost exposures of Citronelle Formation occur in central Gadsden County (Figure 4) where it grades laterally eastward into the Miccosukee Formation (Rupert, 1990). In Gadsden County, the Citronelle Formation unconformably overlies the Hawthorn Group, Torreya Formation. Citronelle Formation lithologies in Gadsden County include orange to red, clayey, medium to coarse grained quartz sands with occasional clay lenses. Some cross bedding is present. Its thickness ranges from 6 to over 30 meters. The Citronelle Formation occurs at elevations in excess of 90 meters above msl in Gadsden County.

Westward from Gadsden County, the Citronelle Formation occurs at the highest elevations in the state. In northern Walton County is Florida's highest elevation at 105 meters above sea level. The formation occurs from the Alabama State Line south to near Choctawhatchee Bay and west to the Alabama State Line. *Ophiomorpha* bearing sediments referred to the Citronelle Formation are known to crop out along Pensacola Bay in Escambia County at or near sea level.

Geomorphology

The study area falls within the Southern Pine Hills District which is comprised of the Western Highlands and the Gulf Coastal Lowlands physiographic features (Figure 5) (Scott, in prep.; Puri and Vernon, 1964). The Western Highlands contains some of the highest elevations in the state, in excess of 100 meters. Numerous streams and rivers have dissected the landscape creating some of the more dramatic topography in Florida. The Citronelle Formation occurs throughout this geomorphic province.

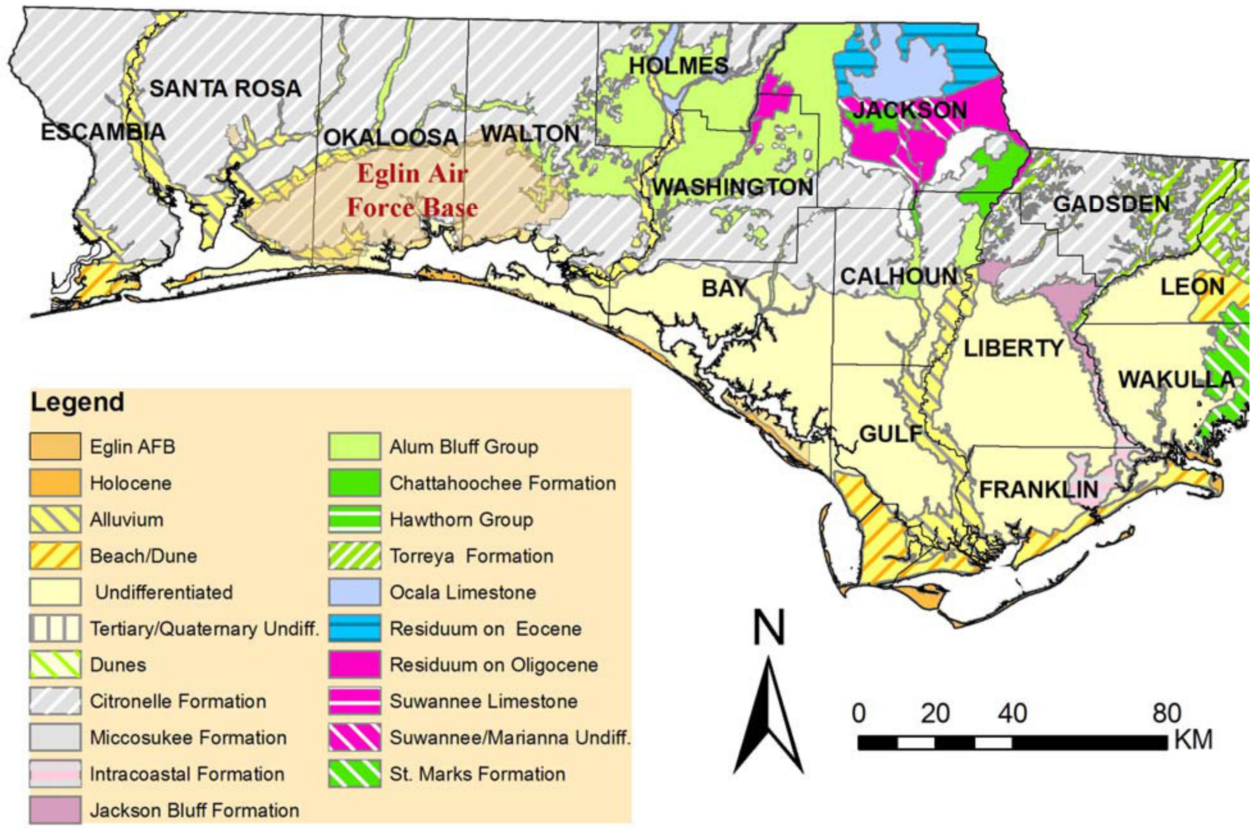


Figure 4 – Geologic map showing the distribution of theCitronelle Formation in Florida (Scott et al, 2001).

The Gulf Coastal Lowlands are characterized by lower elevations and topography and numerous east-west trending features which reflect the marine influence on their formation (Puri and Vernon, 1964). There is an erosional scarp that separates the Gulf Coastal Lowlands from the Western Highlands that may be correlated to the Cody Scarp further east. The toe of this scarp is roughly 7.6 meters in elevation, and the crest is approximately 30.5 meters of elevation (Green et al., 2001).

The near-surface sediments that occur below the transition zone from the Western Highlands to the Gulf Coastal Lowlands are comprised of erosional remnants of the Citronelle Formation and sediments transported by coastal processes. A series of coast-parallel terraces, each separated by an escarpment, exist in the Gulf Coastal Lowlands portion of the study area (Schmidt, 1984). These terraces have been recognized around the state and represent former sea-level high stands. At ±45 meters is the Okeefenokee

Terrace, at ±30 meters is the Wicomico Terrace and at ±10 meters is the Pamlico Terrace. A lower terrace feature, the Silver Bluff Terrace, has been identified in other parts of the state, however it is poorly preserved in southern Walton County (Schmidt, 1984).

A geomorphic feature called the Marianna Lowlands is shown in Figure 5. The Marianna Lowlands occur east of the study area and are not part of this investigation. Karst processes have altered the topography of this geomorphic region, and Miocene units are at or near the surface. Citronelle Formation sediments have been removed from the Marianna Lowlands. For this reason this area is not included in this investigation.

Figure 5 – Physiographic features in the study area (Scott, in prep.; Puri and Vernon, 1964).

CHAPTER 3

METHODS

Field Sampling

Sediment samples were collected for sieve analysis and for lithologic description. Samples for sieve analysis were collected where there were obvious *Ophiomorpha* trace fossils (Table 1). Samples were collected from discrete intervals using a hand trowel (Figure 6). At the three localities where sieve samples were collected, the samples were taken from the base of the section upwards and targeted specific lithologies of interest. Sediment was stored in plastic containers that held approximately 150 grams of material. The goal was to collect no more than 100 grams of sediment based upon recommendations outlined in Balsillie (1995). Several samples exceeded this amount, but none were in excess of 115 grams.

Table 1 – Field localities and sample information.

Locality Name	County	Latitude	Longitude	Datum	Sieve Samples	Notes
Argyle	Walton	30 41 01	86 01 37	WGS-84	no	*Ophiomorpha* and mollusks
EAFB-1	Okaloosa	30 35 44.8	86 30 50.1	NAD-83	yes	*Ophiomorpha*
GAD-1	Gadsden	30 37 28.1	84 50 42.5	WGS-84	no	Cross beds
ALAQUA	Okaloosa	30 30 55	86 10 43	WGS-84	no	*Ophiomorpha*
WCP	Walton	30 36 14.2	86 04 21.3	WGS-84	yes	*Ophiomorpha*
Campbell Sand	Walton	30 44 34.8	86 21 47.1	NAD-83	yes	*Ophiomorpha* and mollusks
Diamond Sand Co.	Walton	30 44 33.13	86 21 13.2	NAD-83	no	*Ophiomorpha and mollusks*
AL-1	Clarke Co., AL	31 44 27.1	88 00 40.1	NAD-83	no	*Ophiomorpha*
WC-1	Walton	30 42 3.0	86 01 11.2	WGS-84	no	sand and gravel
WC-2	Walton	30 41 50.1	86 00 2.0	WGS-84	no	*Ophiomorpha*
WC-3	Walton	30 40 54.5	86 01 41.5	WGS-84	no	*Ophiomorpha*
WC-4	Walton	30 41 12.4	86 08 31.1	WGS-84	no	clayey sand and gravel
WC-5	Walton	30 41 2.7	86 10 38.9	WGS-84	no	clayey sand and gravel
WC-6	Walton	30 43 15.4	86 10 18.2	WGS-84	no	*Ophiomorpha*
WC-7	Walton	30 42 20.6	86 15 31.6	WGS-84	no	*Ophiomorpha* and mollusks
OK-1	Okaloosa	30 59 21.8	86 28 39.2	WGS-84	no	fossil shark teeth and vertebrates
OK-2	Okaloosa	30 56 33.8	86 28 47.8	WGS-84	no	clayey sand and gravel
OK-3	Okaloosa	30 54 36.4	86 30 42.5	WGS-84	no	Clay and clayey sand

Figure 6 – Sieve samples collected at site EAFB.

Bulk samples were taken adjacent to sieve samples for examination under a binocular microscope. Sediment descriptions were performed both prior to and after the sieve analysis in order to examine quartz grains unobscured by clay particles. This sediment was collected using a hand-trenching tool, as well as a hand trowel, and was stored in various-sized plastic ziplock bags.

Outcrop Descriptions

Numerous exposures (Figure 7) were examined both within and outside the study area. Based upon extensive field investigation, as part of a previous mapping project, exposures were selected based upon a number of criteria including access (private property, Eglin Air Force Base), height of the exposure, presence of *Ophiomorpha* or other fossil material, and lithologic character. Seventeen localities were chosen for outcrop description. Some localities were described in more detail than others depending on whether sieve samples were collected or if *Ophiomorpha* occurred there.

Figure 7 – Typical exposure in a sand pit (Campbell Sand).

Lithologic descriptions were performed in the field using a Hastings triplet seven-power hand lens. Descriptions performed in the lab were done using a Leica S4E binocular microscope with an external, LED light source. The general lithologic character was noted and was based upon standard lithologic descriptive techniques employed by the Florida Geological Survey. The detailed lithologic descriptions are in Appendix 1.

Granulometric Analysis

The methodology utilized in the granulometric analysis follows the procedures outlined in Balsillie (1995). Sediment samples, consisting primarily of quartz sand, were examined to determine if there was a significant (greater than a few percent) silt and clay fraction. If the samples appeared to contain less than one percent silt and clay, the samples were dry sieved. If the samples contained in excess of one percent silt and clay, they were wet sieved.

Prior to wet sieving, the sediment samples were emptied into a 500 milliliter glass beaker of known weight. The dry weight of both sample and beaker were recorded. The samples were weighed on a Mettler PG803 balance and results recorded. Distilled water was then added to the samples, and approximately 10 milliliters of a 10 percent calgon solution was added to aid in disaggregation. Samples were allowed to soak for at least one hour.

After soaking in a calgon bath, the sample was poured onto a nylon mesh screen (4 phi) and washed with deionized water until no further discoloration of the exiting water was noticed. The sample that remained on the screen was returned to the beaker and then put into an oven where it was dried at a temperature of 100° Centigrade for at least 12 hours. The sediment was then cooled, reweighed and the results recorded.

Samples that contained no significant silt and clay fractions, along with the wet sieved samples, were then run through a set of metal sieves. The sizes of the sieves ranged from -2.25 phi to 4.0 phi at quarter phi intervals. Sand samples were placed into a sieve stack, and the sieves were secured to a Meinzer II sieve shaker that agitated the sediment for thirty minutes, allowing it to accumulate on each sieve according to size.

Once agitation of the samples was completed, the sediment that accumulated on each sieve was gathered and weighed. The weights were rounded to the nearest thousandth of a gram and entered on a data sheet. The Mettler scale was calibrated regularly to ensure maximum accuracy.

Once all the samples were sieved, the data were entered into the computer program GRANPLOTS (Balsillie et al., 2002). This program statistically computes moment measures and produces probability plots that aid in the interpretation of the depositional environment of the sediment.

X-Ray Diffraction (XRD) Analysis

Four samples were submitted to the Florida State University Center for Materials Research and Technology (MARTECH) for X-Ray analysis. The analysis was performed on a theta-2-theta Bragg-Brentano parafocusing goniometer with a Cu-Kα source and a Ni filter and diffracted beam monochromator. The samples were ground to a powder and dusted onto a greased zero-background holder. Divergence apertures were set to one degree; receiving aperture set to 0.15 degree. The peak positions and d-spacings were identified using the Cu Kα wavelength. The resultant d-spacings were compared to known d-spacings in the International Center for Diffraction Data (ICDD) database to identify the mineral phases. The analysis was conducted by Dr. Eric Lochner from MARTECH.

Paleontological Analysis

Paleontological samples were collected for analysis, when encountered. The paleontological material collected included trace fossils (*Ophiomorpha*), internal and external body casts of bivalve mollusks, external casts of both marine and terrestrial vertebrates and petrified wood. The trace fossils and mollusks were identified by Roger Portell, Director of invertebrate paleontology at the Florida Museum of Natural History in Gainesville, Florida. The terrestrial vertebrate fossils were identified by Dr. Richard Hulbert, collections manager for the vertebrate fossil range at the Florida Museum of Natural History in Gainesville, Florida. Fossil shark teeth were identified by Dr. Gordon Hubble (Gainesville, Florida), an expert on fossil sharks. These specialists not only identified the specimens but also provided information on age ranges and paleoenvironments. The petrified wood was too fragmentary to identify.

Further work with the trace fossils included measuring a one-meter square on the surface of the exposure and determining the density of *Ophiomorpha* tubes. This procedure was conducted at two localities where these trace fossils were exposed in such a way that allowed density counts to be made. Density of trace fossils can be used to interpret depositional environments.

Paleocurrent Analysis

Many localities within the study area contain cross-bedded sediment. At one locality (Campbell Sand), the cross-beds were significant enough to warrant analysis (Figure 8). The orientation and dip direction of cross-beds were measured using a

Brunton compass. Approximately 23 orientations were measured from two lithologic units (E and F) at the Campbell Sand Pit locality in Walton County. These measurements were entered into the computer software Rozeta (Pazera, 2007) to produce a rose diagram showing the distribution of cross bed orientations which reflects the paleocurrent direction.

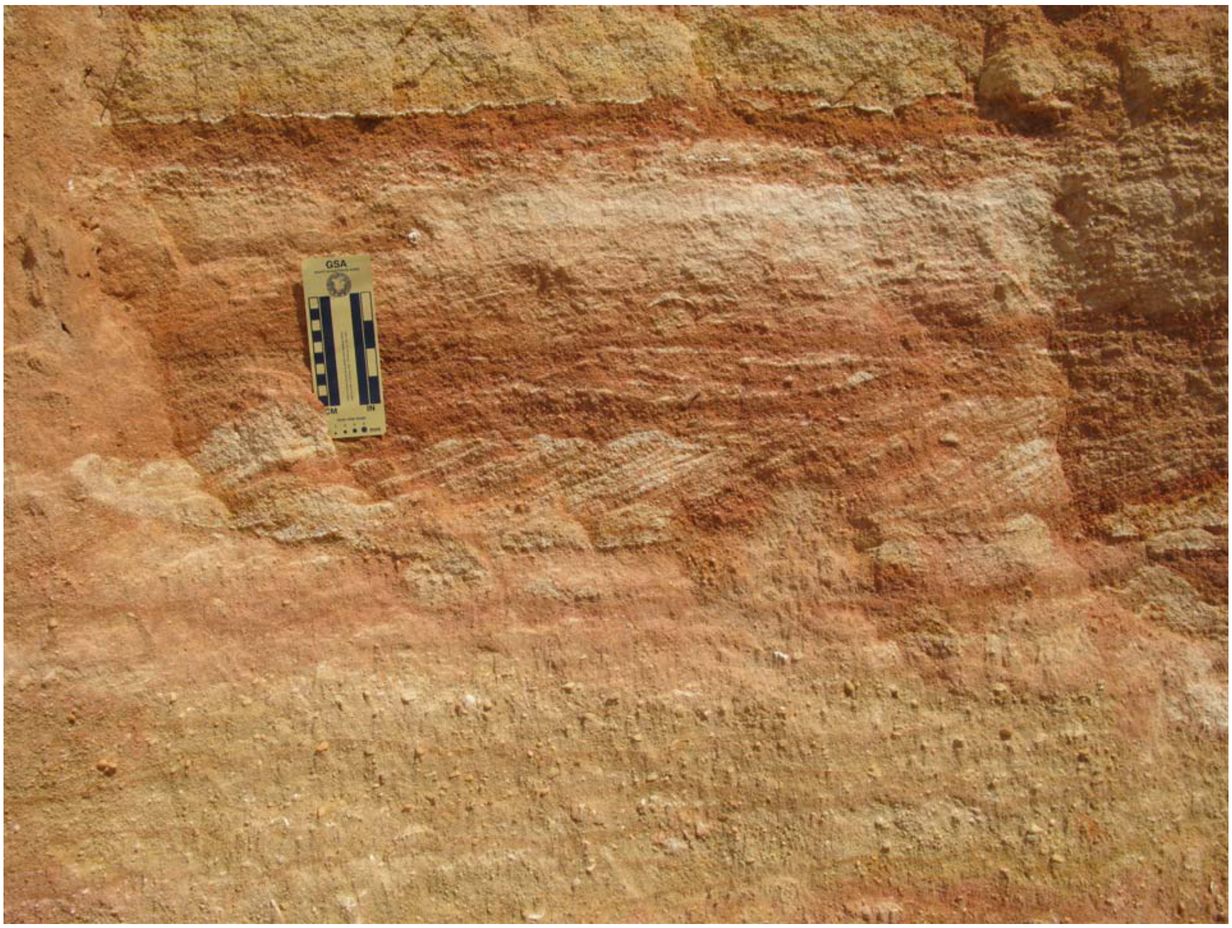


Figure 8 – Cross bedding in sediments at the Campbell Sand Pit locality.

CHAPTER 4

RESULTS

Lithologic Character of the Citronelle Formation in the Study Area

The lithology of the Citronelle Formation in the study area is highly variable both laterally and vertically. Based upon the lithologic descriptions done both in the field and lab (see Appendix A for detailed outcrop description), the general composition of the Citronelle Formation, in Okaloosa and Walton Counties, consists of quartz sand of varying size fractions and varying amounts of clay, heavy minerals and mica. The quartz sand ranges in size from silt to gravel, and sorting varies from poorly sorted to moderately well sorted (standard deviations of grain size ranging from 0.5372 to 1.0534 phi).

The quartz grains consist of clear, quartz with occasional inclusions of rutile and other heavy minerals. Many grains in the medium-to-gravel size range exhibit frosting. The coarse grains and gravel fraction contain a high concentration (over 50%) of quartzite. Most grains are moderately to well rounded. The physical properties of quartz grains (roundness and frosting) did not change significantly from one lithology to the next.

In the sieved samples it was easy to recognize at what size fraction the heavy mineral assemblage occurred. Generally, the heavy minerals appeared in the 2.5 to 3.5 phi range (fine sand size in the Wentworth classification). The heavy mineral assemblage was not analyzed. However it was possible to identify rutile and tourmaline based upon visual identification. Mica was also abundant in the finer fraction and appeared to be muscovite, although no analytical technique was used to make this determination.

At four localities the exposure was carefully described, lithologic breaks were identified, and the section was measured. Stratigraphic columns were constructed for each locality (Figures 9 – 12). See Figure 1 for location map of measured section sites.

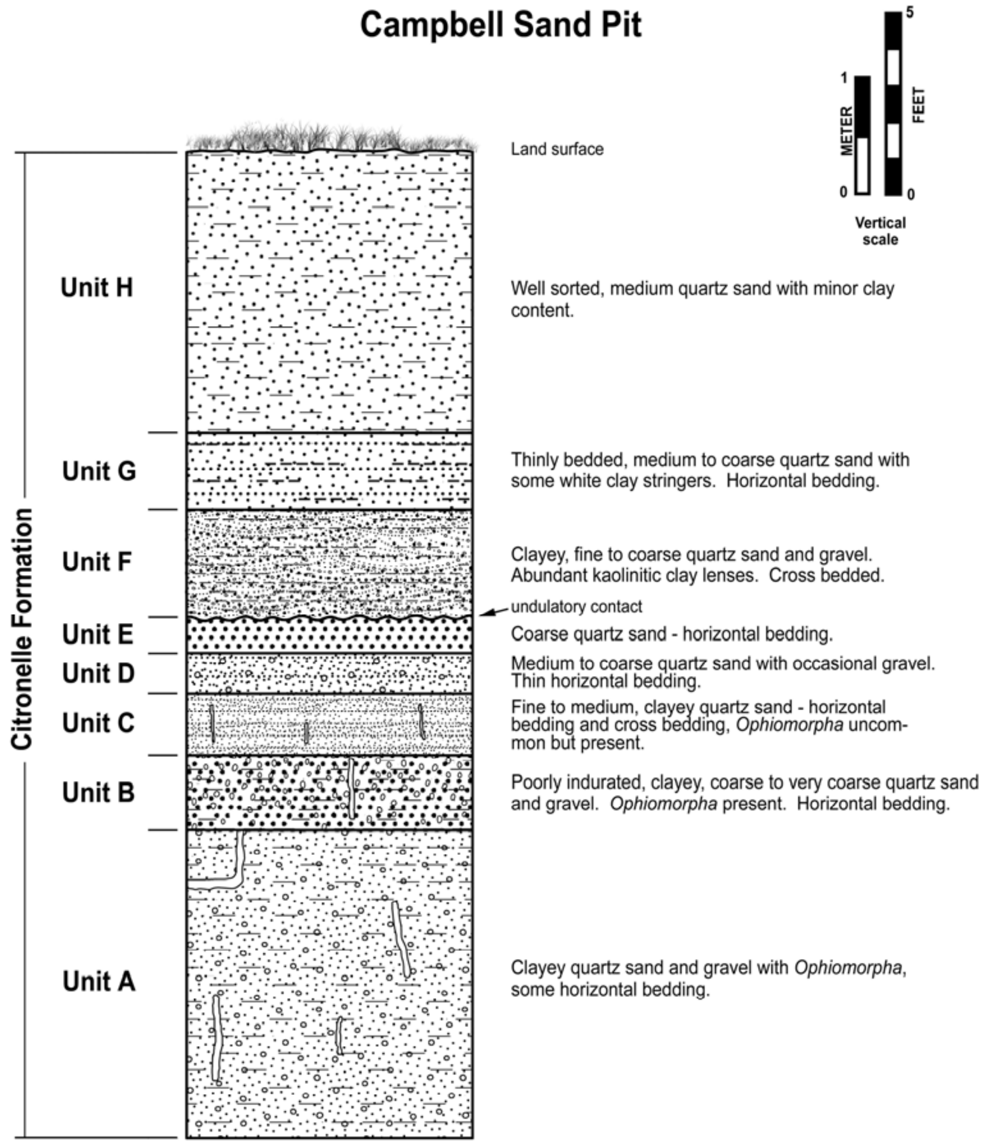


Figure 9 – Stratigraphic column at Campbell Sand Pit locality (CAM). Surface elevation is 70 meters.

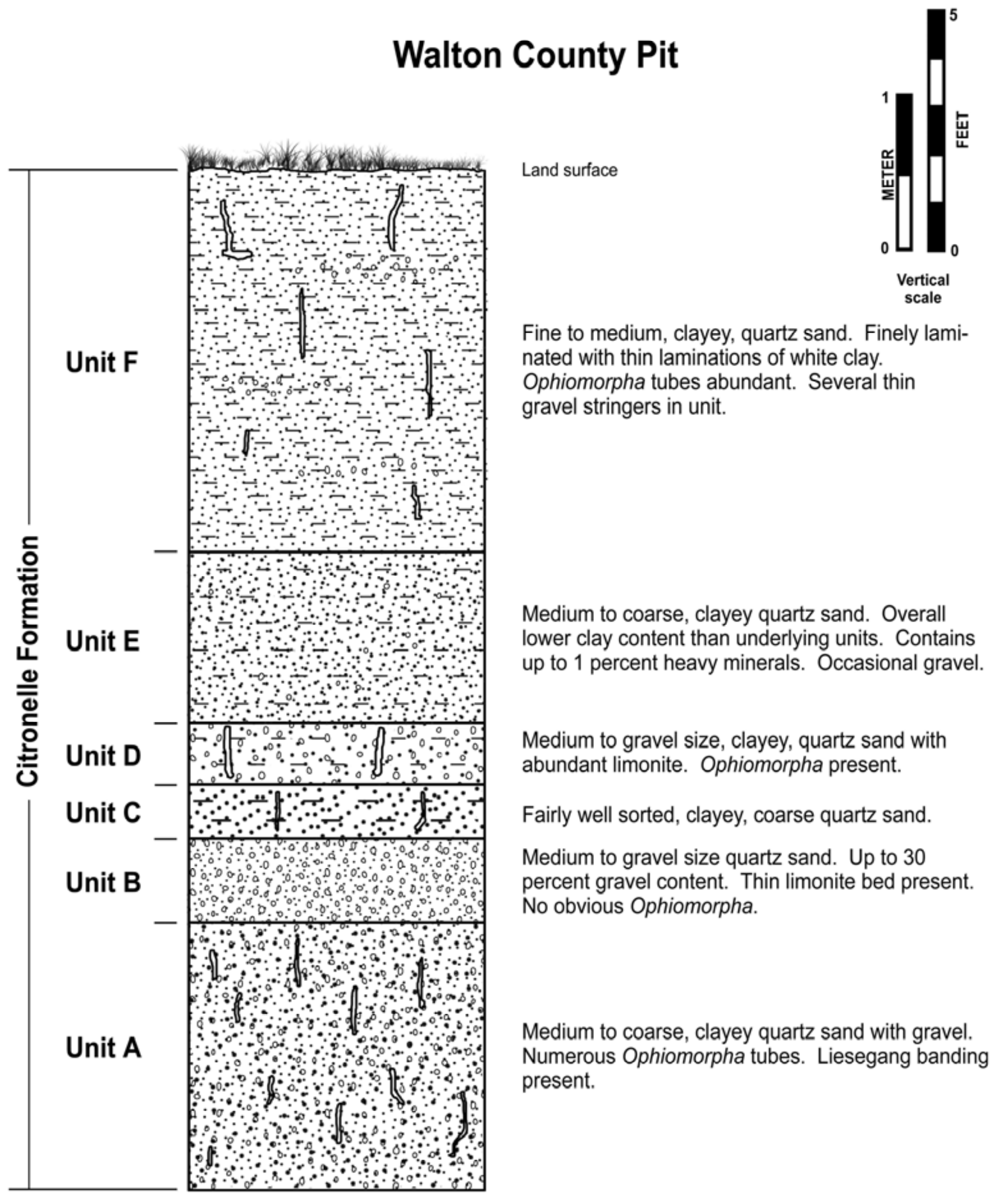


Figure 10 – Stratigraphic column at the Walton County Pit (WCP). Surface elevation is 52 meters.

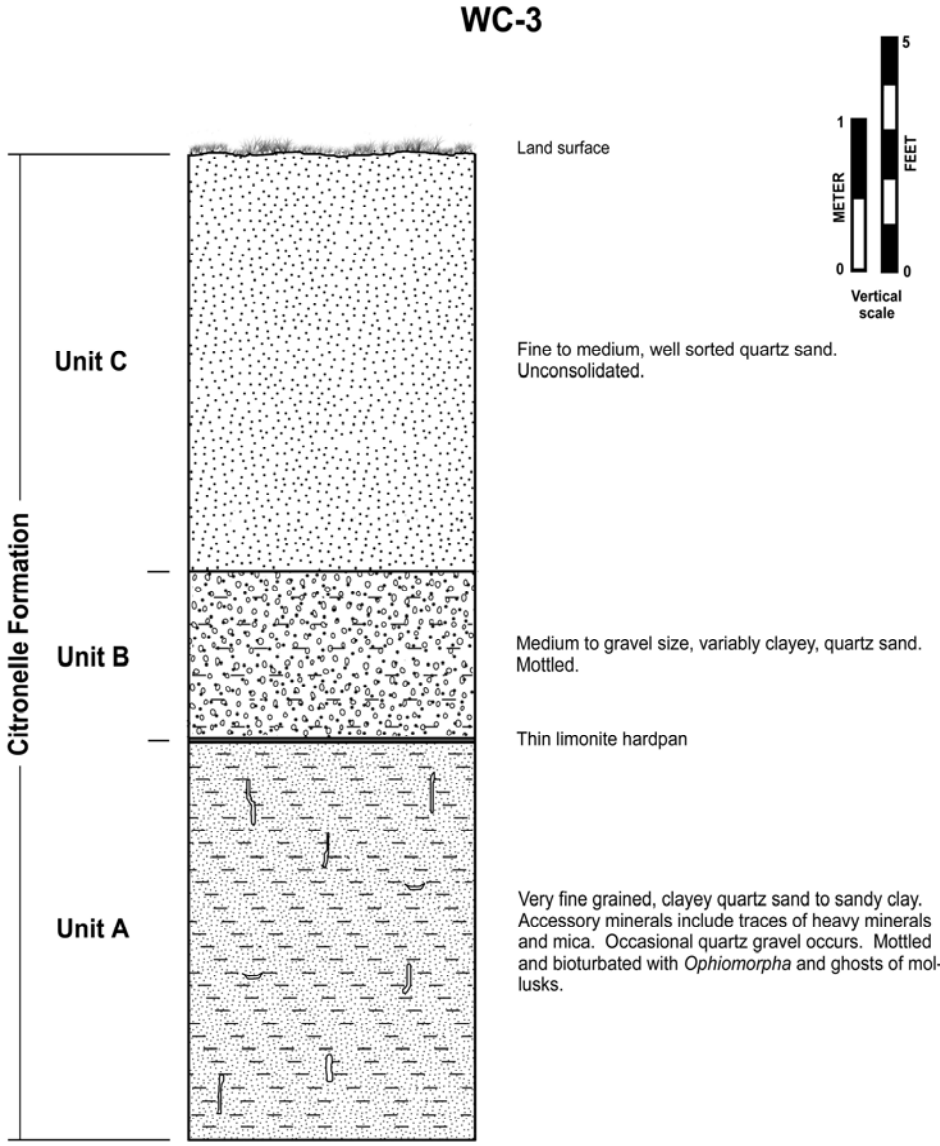


Figure 11 – Stratigraphic column at locality WC-3. Surface elevation is 70 meters.

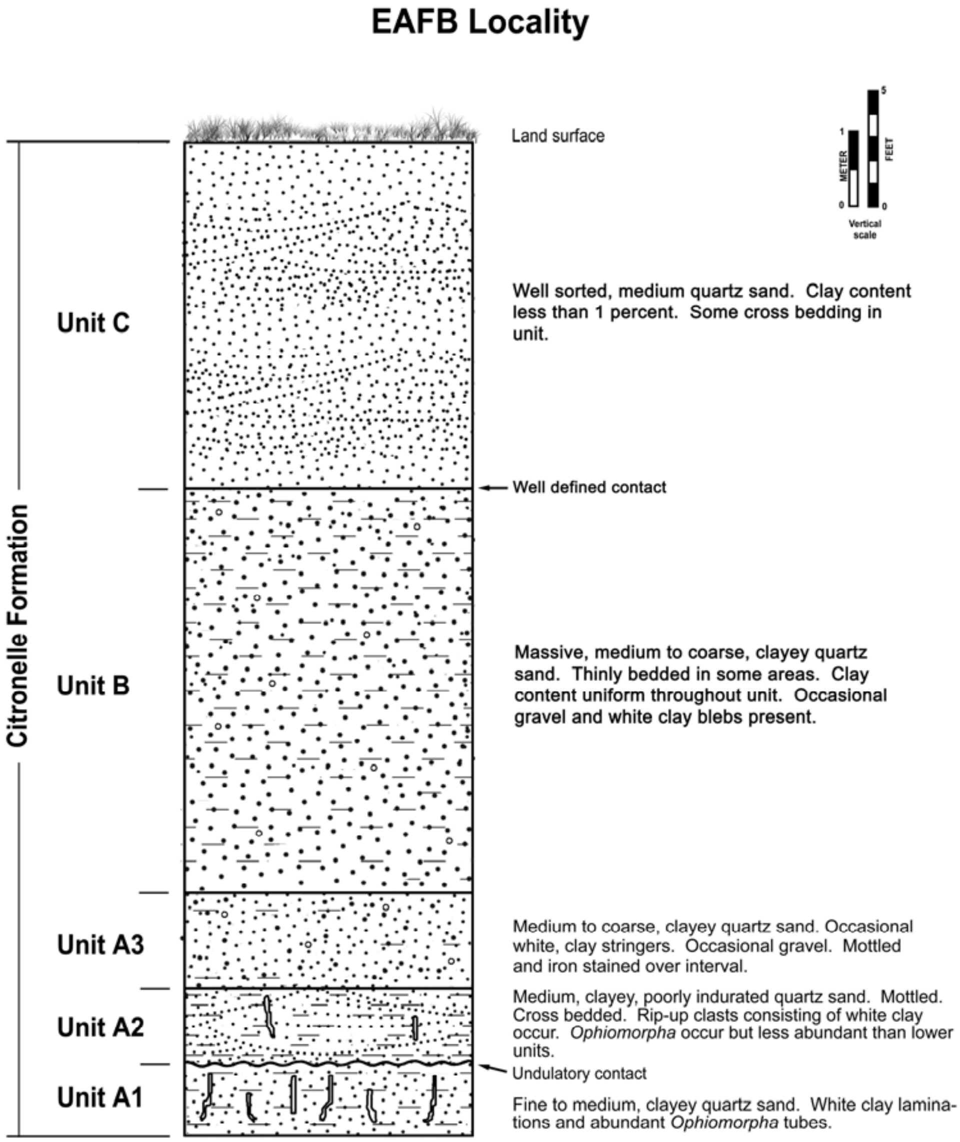


Figure 12 – Stratigraphic column at the Eglin Air Force Base locality (EAFB). Surface elevation is 39 meters.

Granulometry

The results of the granulometric analysis performed on 21 samples from three localities within the field area show that the sediment that comprises the Citronelle Formation, at the sample sites, is moderately well sorted, primarily medium to coarse sand and gravel (mean of mean size values 0.94 phi), and contains an average of 7 percent fine fraction (silt and clay size) (Table 2). No trends were observed in grain size at the sections, meaning that no fining upward or coarsening upward sequences were observed. This could be a function of a lack of sufficient data, however.

Table 2 - Overview of granulometric data.

Sample ID	Mean (phi)	Median (phi)	Std. Deviation	Skewness	Kurtosis	% fines
Camp. A40	1.44	1.4925	0.8020	-0.7135	4.1338	7.69
Camp. A139	1.3500	1.4405	0.8964	-1.0156	4.7636	7.18
Camp.A164	1.2271	1.1364	0.6739	-0.2132	5.6804	2.93
EAFB-A1A	0.9914	0.8166	0.5372	1.3786	9.0473	n/a
EAFB-A1B	0.9764	0.7794	0.5436	1.9023	10.3907	n/a
EAFB-A1C	1.3668	1.0424	0.8441	0.4902	2.7467	13.08
EAFB-A2B	1.3942	1.2634	0.6891	0.2092	3.7533	9.64
EAFB-A3A	0.6665	0.4158	0.8546	0.7645	3.6459	7.57
EAFB-A3B	1.3386	1.1242	1.0038	-0.0092	2.2518	10.44
EAFB-B1	0.5234	0.3533	0.5767	1.3878	7.8669	10.49
EAFB-B2	0.8007	0.6125	0.8052	0.3338	3.4794	3.56
EAFB-C	1.7149	1.5762	0.7481	0.3923	3.803	3.48
WCP-A1(10)	1.1558	1.2006	0.9433	-1.0065	5.3857	6.74
WCP-A2(40)	1.0472	1.0047	0.8106	-0.639	6.4301	5.03
WCP-A3(68)	0.6974	0.5157	0.6385	0.8522	9.7443	4.65
WCP-C1base	0.3013	0.1391	1.0534	0.3085	3.7002	5.32
WCP-C2	0.0618	-0.2249	1.0287	0.7794	4.3962	5.69
WCP-C3top	0.3005	0.0388	0.8918	1.0313	4.6674	5.72
WCP-E1	0.772	0.5884	0.8445	0.4253	4.4771	7.4
WCP-E2	0.8543	0.719	0.8476	0.1132	4.1934	7.31
WCP-E3	0.794	0.6552	0.9015	0.0882	4.2769	6.71

Friedman (1961) showed that modern depositional environments could be differentiated by looking at the grain size distribution of sand samples. For instance, by plotting the third moment measure (skewness) against standard deviation (sorting) of the grain size of modern sediments it is possible to distinguish river sands from beach sands with some limitations. This has been shown to work only on medium to fine and very fine sands – not coarse sediment. Figure 13 shows a plot of skewness versus standard deviation for the 21 samples collected from the study area. Based on Friedman (1961) the plot shows that these samples represent river sand. Although a number of the samples were taken from units that contained marine fossils, a possible explanation for the graph results could be that these sediments could have been deposited in an estuary very near the mouth of the river. Marine processes might not have had the time to sufficiently sort and impart a marine signature on the sediment.

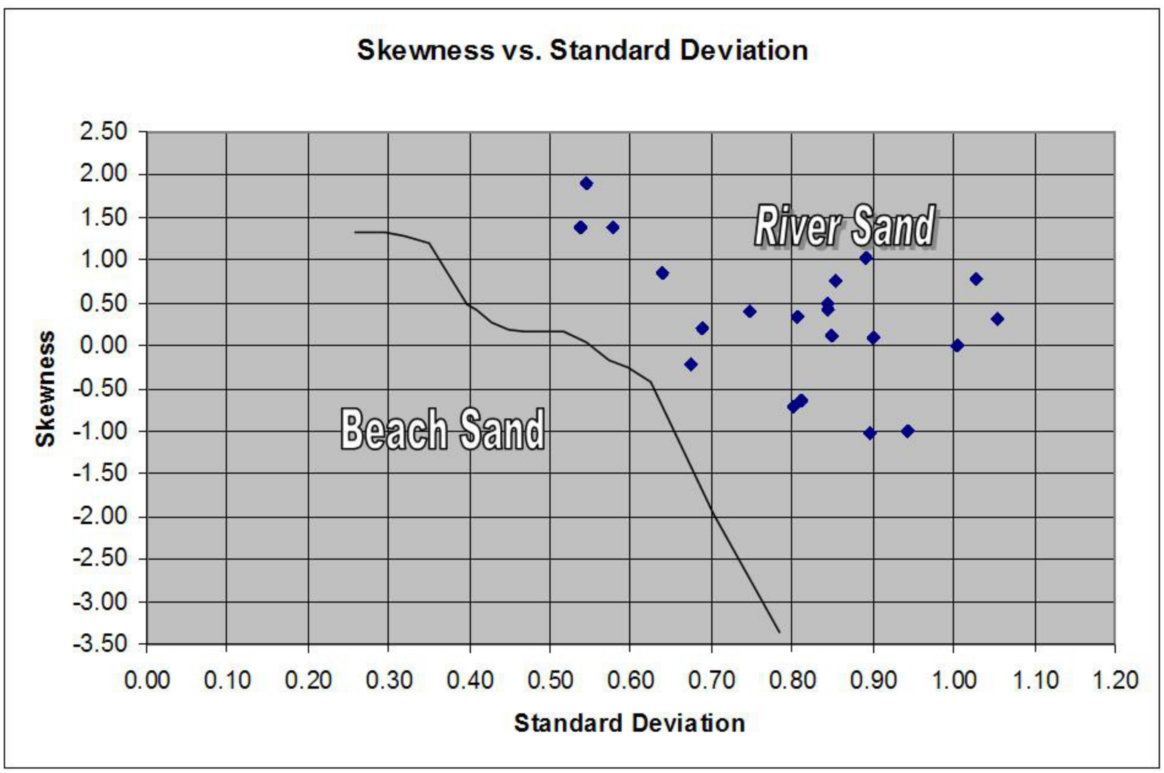


Figure 13 – Plot of skewness versus standard deviation for 21 sediment samples from the study area. After Friedman, 1961.

More details of the granulometric analysis, including distribution plots, probability plots on arithmetic probability paper, additional moment measure calculations, and post sieve microscope description can be found in Appendix B.

Paleontology

The Citronelle Formation is not known to contain an abundance of fossil material (Matson, 1916). Fossils encountered (Table 1) tend to be fossilized (silicified) wood or plant remains. Through the course of this study, fossils were occasionally encountered. The most abundant fossils encountered in Citronelle Formation sediments in the study area are trace fossils known as *Ophiomorpha.* They are thought to be the burrow of a *Callianassid* shrimp. However care must be taken when attributing all tube-like burrow structures to *Callianassid* shrimp (Frey et al., 1978).

Some tubes are in excess of one meter in length. The diameter varies and ranges from less than one centimeter to several centimeters. When it is possible to observe the tubes in three dimensions, due to erosion of exposures, the tubes can be interconnected and wider, bulbous living chambers can be identified. One of the observations made in the field is that the *Ophiomorpha* generally occur in the more clayey units. This, however, could be an artifact of preservation meaning that they did occur in coarser-grained sediments but were not preserved.

At localities WC-2 and Campbell Sand, *Ophiomorpha* tube densities were assessed. At both locations the tubes occurred in densities exceeding 100 per square meter (Figure 14). Density assessment could only be achieved when the horizontal surface of the *Ophiomorpha*- bearing strata was exposed.

The *Ophiomorpha* tubes are comprised of either white, kaolinite (Figure 14) or a limonite-cemented sand (Figure 16). The tubes that have been preserved by limonite still exhibit the mamillary texture on the outer surface, which is characteristic of *Ophiomorpha.* Since there are two different modes of preservation of these tubes, it is reasonable to assume that the original structures were hollow, and the tubes filled with clay after the animal evacuated the structures. Limonite infilling would have occurred post depositionally.

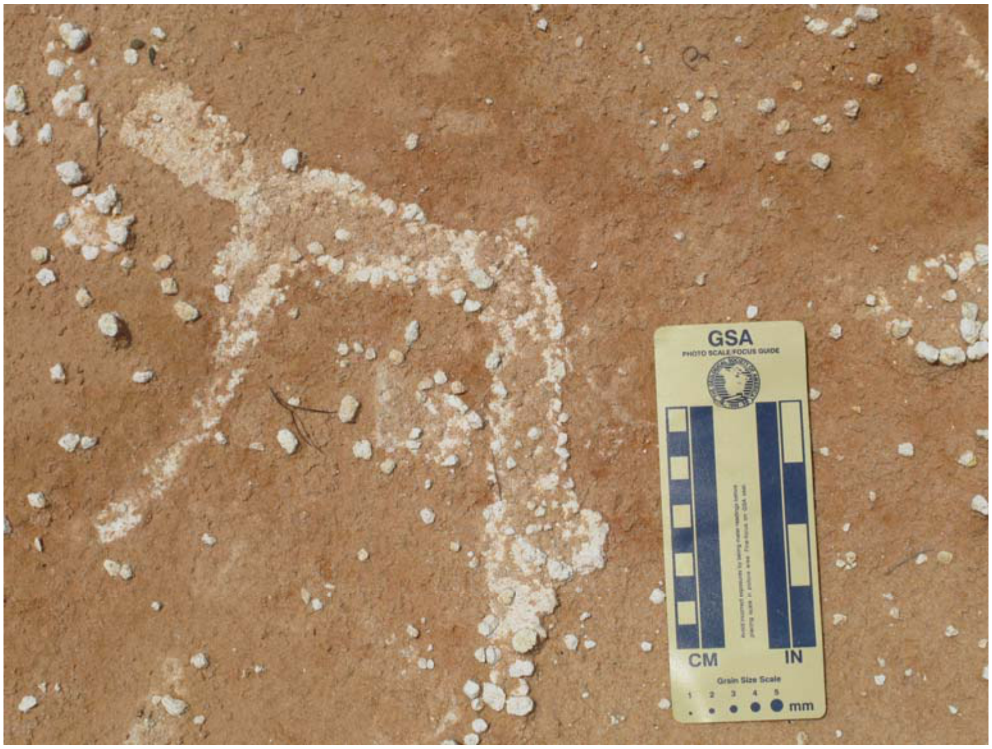


Figure 14 – Kaolinite filled *Ophiomorpha* at EAFB site, horizontal view.

Figure 15 – *Ophiomorpha* density, Campbell Sand Pit locality.

Figure 16 – Sand filled *Ophiomorpha* tube cemented with limonite (WCP).

The second most abundantly encountered fossils in the study area were external and internal casts of bivalve mollusks. The fossils were preserved either as clay infillings or, more interestingly, as thin, limonite crusts (Figures 17 and 18) These fossils were encountered at several localities, but were most abundant at the Campbell Sand Pit. For an overview of fossil localities see Table 1.

Figure 17 – Sandy-clay filled casts of fossil mollusks from Diamond Sand Pit.

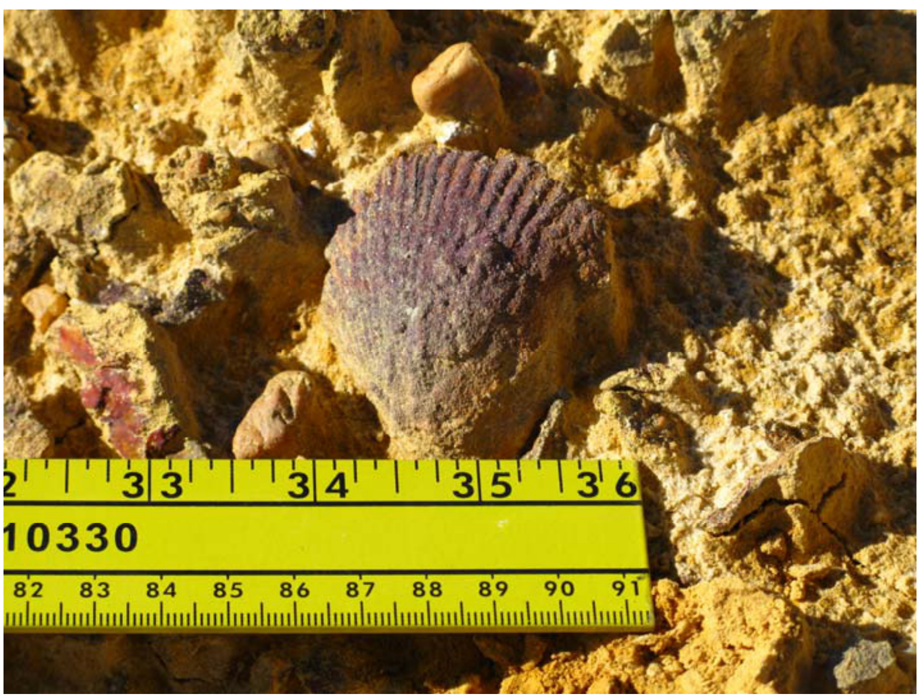


Figure 18 – Limonite crust external cast of fossil mollusk from WC-3.

Table 3 – Fossil mollusks identified from the study area (Diamond Sand Pit).

Taxonomic level	Taxonomic affinity	Number of specimens
Class	Bivalvia	10
Family	Veneridae	9
Family	Cardiidae	2
Genus	*Dosinia*	1
Genus	*Macrocallista*	1

The fossil mollusk material was taken to Roger Portell, Director of invertebrate paleontology at the Florida Museum of Natural History, who identified them. Many specimens could only be identified down to the family taxonomic level, and some were only assigned to class level. The level of preservation of these fossils was insufficient to identify the specimens down to species level. However, the assemblage as a whole is still useful in identifying the environment of deposition. The mollusk fossils were recovered from strata that contained *Ophiomorpha*, however not every stratigraphic unit with *Ophiomorpha* contained mollusks.

It should be noted that the majority of fossil mollusks were collected from the Diamond Sand Pit, which is located just east of the Campbell Sand Pit locality. The fossils were collected by Dr. Jon Bryan prior to the start of this work. The exposure in the Diamond Sand Pit has since been altered, and the measured section was done at the adjacent Campbell Sand Pit locality instead. Fossil mollusks were identified in the Campbell Sand pit as well.

The mollusks identified are all infaunal and are known to occur in mostly nearshore, fairly shallow-water marine environments (R. Portell, personal communication 2009). Some genera from the Veneridae (*Mercenaria*) are found in a range of marine settings from nearshore to estuarine to open water. None of the mollusks were indicative of a particular time interval. This is due to the poor preservation and inability of the fossils to be identified to species level.

Fossil vertebrate material was collected from a sand pit in northern Okaloosa County (OK-1). Included in the assemblage were shark teeth, vertebrae, an astragalas, a calcaneum and various other unidentifiable fragmentary pieces of bone. The fossil preservation was unique for Florida (R. Hulbert, personal communication 2009). Each element appears to have been coated by limonite and the internal, bony portion of the fossils has since been removed (possibly by dissolution).

The fossil vertebrate material was sent to Dr. Richard Hulbert, collections manager of vertebrate paleontology for the Florida Museum of Natural History in Gainesville, Florida. Dr. Hulbert identified a partial left calcaneum and a left astragalas from an unidentified genus of three-toed horse (Equidae). They are from different species, based upon their size difference. Additionally, six casts of vertebrae from marine bony fish and four casts of medium-sized terrestrial mammal vertebrae were identified as to type of element, but they were too poorly preserved to provide a generic or specific identification (Figure 19).

Figure 19 – Vertebrate fossils from (OK-1). A) Marine bony fish vertebrae (UF 242283-242288). B) Left astragalas (Equidae) (UF 242278). C,D,E) Miscellaneous unidentifiable medium-sized land mammal vertebrae (UF 242279 – 242281). F) Left calcaneum (Equidae) (UF 242277).

Based on the occurrence of three-toed horse (Equidae), the minimum age of the fossil-bearing unit at OK-1 is late Pliocene (Blancan) (R. Hulbert, personal communication 2009). However, the unit could just as easily be assigned to the Miocene. No other age diagnostic terrestrial vertebrate fossils were recovered during the course of this study.

Thirteen fossil shark teeth collected from OK-1 were sent to shark expert Dr. Gordon Hubble for identification. (Figure 20). Of the thirteen teeth, eight specimens were identified as *Hemipristis serra* (UF 242426-242433), two were identified as *Negaprion brevirostris* (UF 242434-242435), and the other three teeth could only be identified to the generic level, *Carcharhinus sp.*(UF 242436-242438) The range of occurrence for *Hemipristis serra* is Miocene to Pliocene and *Negaprion brevirostris* ranges from the Miocene to the present. Since the *Carcharhinus* couldn't be identified to the species level, it is not possible to assign it an age.

Figure 20 – Examples of shark teeth from OK-1.

Clay X-Ray Diffraction

Four bulk clay samples were sent to the MARTECH facility at Florida State University for X-ray diffraction analysis. Samples were taken from a thin clay layer, from rip-up clasts and from two *Ophiomorpha* tubes from the Campbell Sand Pit and EAFB localities. All samples analyzed were determined to be primarily kaolinite based on their diffraction peaks compared to a kaolinite and a quartz standard (Appendix C). There appear to be some other phyllosilicate phases, but kaolinite is the primary phase (E. Lochner, personal communication 2009). Two of the Campbell Sand Pit samples contains some quartz.

Paleocurrent Direction

Orientations of cross-beds were measured in two units in the Campbell Sand pit (Units E and F). Many other localities exhibited cross bedding, however this locality allowed for easy measurement as the exposure was thicker and mechanically cut. Thirteen orientations on planar cross beds were measured from unit E and ten from unit F. Paleocurrent direction is perpendicular to the strike of the cross bed. Paleo-current direction was determined and rose-diagrams plotted (Figures 21 & 22).

For unit E, the primary current direction is almost due west. Several measurements show an eastern flow direction, however this is not the dominant paleo-current direction. For unit F, the predominant paleo-current direction is south to southwest with several measurements in a northeast and northwest direction.

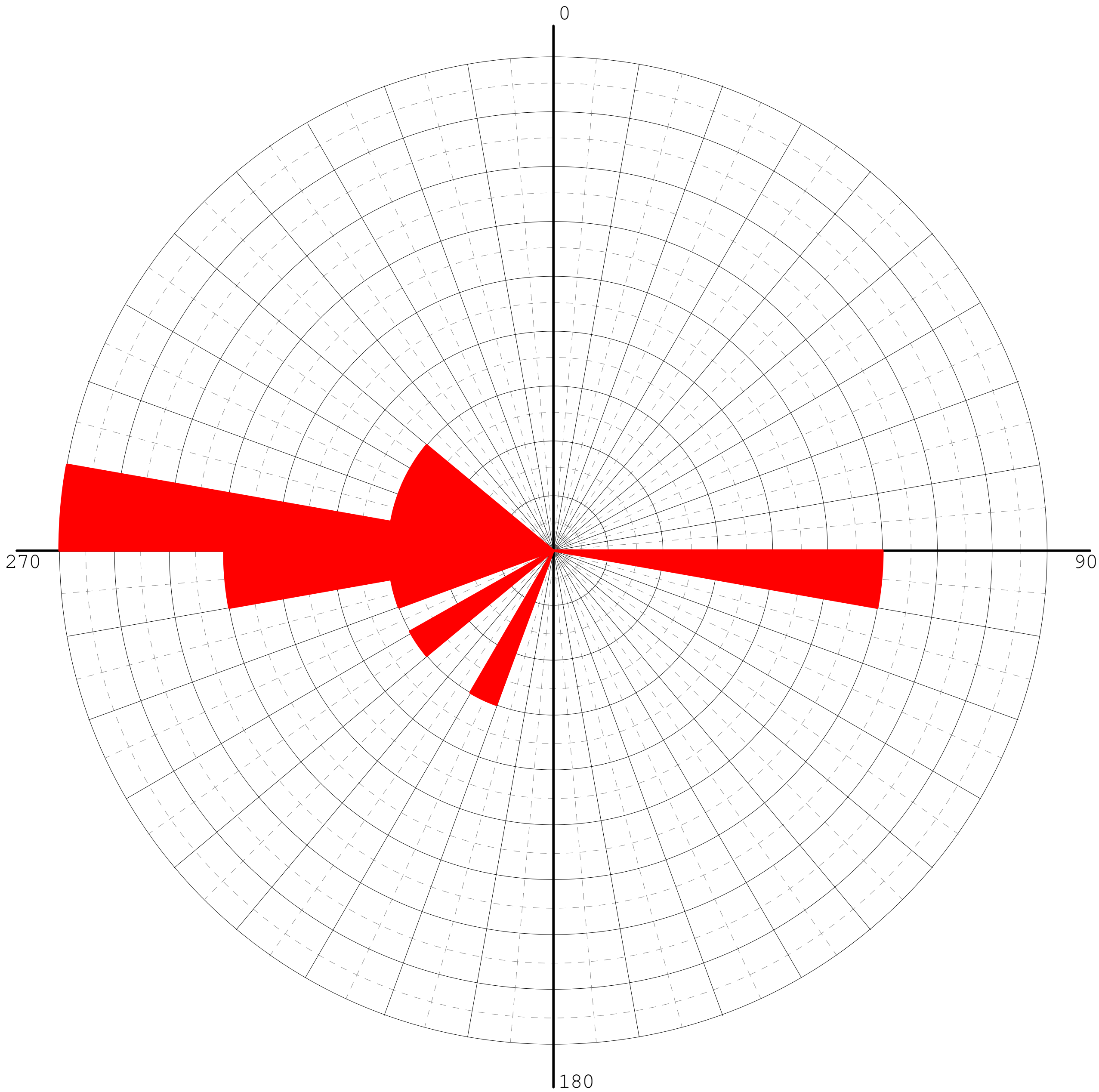


Figure 21 – Rose diagram showing paleocurrent directions in unit E at the Campbell Sand Pit (13 measurements).

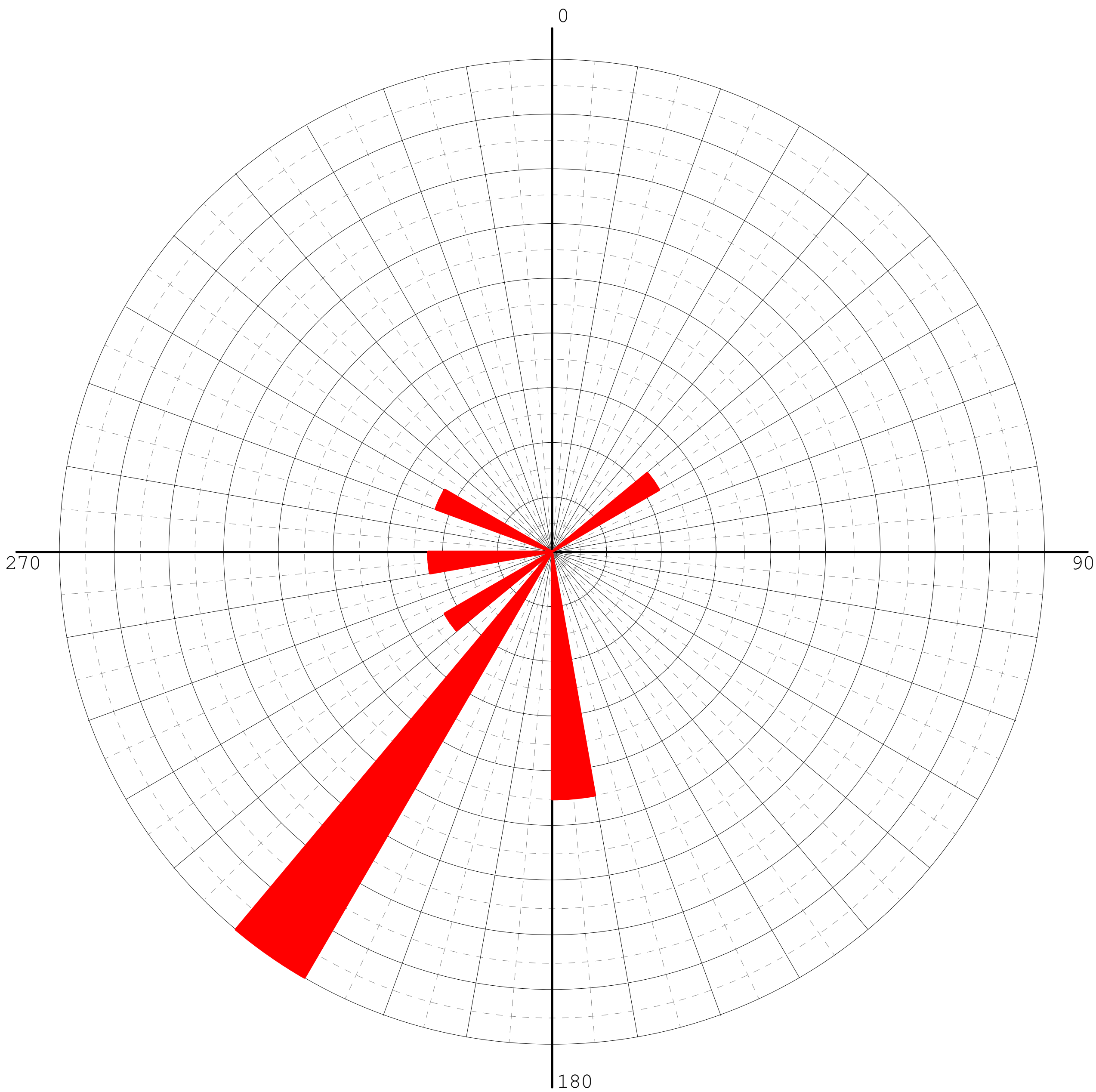


Figure 22 - Rose diagram showing paleocurrent directions in unit F at the Campbell Sand Pit (10 measurements).

CHAPTER 5

DISCUSSION

Lithology

Citronelle Formation lithologies change both vertically and horizonally over short distances in the study area. Clay content and the occurrence of fossils, gravel, heavy minerals and mica are the main lithologic variables. No regional unconformity between the Citronelle Formation and underlying formations was recognized at exposures in the study area, however, some exposures contain a limonitic hardpan between siliciclastic beds with variable clay content. In the eastern portion of the study area the Citronelle Formation was separated from underlying formations based upon elevation (approximately 45.7 meters MSL) and a lithologic transition from reddish, clayey sand and gravel (Citronelle Formation) to greenish, sandy, shelly, micaceous clay (Alum Bluff Group and undifferentiated clastic sediments) (Means et al., 2000; Green et al., 2001).

Marsh (1966) and Coe (1979) both recognized the occurrence of a small percentage of oolitic chert clasts in the Citronelle Formation west of the current study area. Riccio et al. (1972) note that the gravel composition of the Citronelle Formation in Alabama consists of a mixture of quartzite and chert and that the underlying Miocene formations contain gravel comprised primarily of quartzite. Interestingly, no chert clasts were identified in any of the samples examined in the study area. Instead, the gravel consists of quartzite. This suggests that there were different sources supplying sediment during the deposition of the Citronelle Formation in west Florida.

Several schemes have been proposed to overcome the problem of lithologically distinguishing the Citronelle Formation from underlying and overlying formations. Marsh (1966) suggested using the occurrence of fossil shells as an indicator of Miocene formations. He further states, however, that a veneer of marine terrace deposits cap the Citronelle Formation in Escambia and Santa Rosa Counties that is indistinguishable from the underlying Citronelle Formation.

Efforts to define the Citronelle Formation based upon heavy mineral composition have had mixed results (Riccio et al., 1972). In Alabama, Citronelle Formation heavy mineral suites are similar to Miocene formation suites, hence differentiation of the two lithologic units is difficult based on this criterion. Heavy minerals were observed in all of the sieve samples, however their specific mineral composition was not identified.

Riccio et al. (1972) discuss using the physical appearance of clay beds in both Miocene strata and the overlying Citronelle Formation as a lithostratigraphic indicator. Citronelle Formation clays lack the massive bedding present in Miocene formations in southern Alabama. They tend to be white to reddish-orange and consist mineralogically of kaolinite. The Miocene clays are brassy, tan, lavender, green or gray in color and bedding is persistent horizontally. The predominant clay minerals are kaolinite, illite, montmorillonite and chlorite. Four clay samples from the study area were submitted for XRD analysis and were determined to be kaolinite (Appendix C). The samples were taken from a clay bed, rip-up clasts and from *Ophiomorpha* tubes. More sampling and analysis of clay from the study area would need to be done in order to determine if clay mineralogy could be used to differentiate lithostratigraphic units.

Another lithologic component of the Citronelle Formation in southern Alabama that has been used as a distinguishing character is the occurrence of rounded, polished ironstone clasts (Riccio et al., 1972). Common throughout southern Alabama, these clasts have not been identified in abundance in the study area. Limonitic hardpans and occasional limonite clasts have been observed in the northern portion of the study area in particular but none were identified in any of the bulk or sieve samples. This criterion appears to apply in southern Alabama, not further east based on field observations in the study area.

The environment of deposition of the Citronelle Formation has had many interpretations over the years including fluvial, terrace deposits, Pleistocene glacial drift, marine, transitional marine and pre-glacial coalescing braided streams (Isphording and Lamb, 1971). Evidence presented in this study supports a nearshore, marine depositional environment for some sediments previously mapped as Citronelle Formation in the study area (Means et al., 2000, Green et al., 2001). This is not to say that all such sediments are nearshore marine deposits, but at least a portion of them are. The occurrence of *Ophiomorpha*, casts of marine mollusks and shark teeth are the most compelling evidence for a near-shore marine depositional environment for portions of the formation.

Although granulometric results can be inconclusive for certain depositional environments such as beach versus dune (Friedman, 1961), the sorting and skewness of the grain-size distribution can be an important indicator of environment of deposition. Beach sands can be distinguished by their combination of negative skewness and good sorting (low standard deviation) whereas riverine sands are generally positively skewed and less well sorted (Blatt et al., 1980). Based upon their sorting and skewness, sediment samples analyzed in the present study can be considered representative of both fluvial and near-shore marine depositional environments. The sand samples analyzed had a mean grain size of 0.94 phi. This falls near the break between medium and coarse sand on the Wentworth scale. The coarseness of the samples can present a problem when using skewness as an indicator of depositional environment (Friedman, 1961).

The majority of samples analyzed for this project (18 out of 21) were moderately well sorted, falling between 0.5 and 1.0 phi standard deviation. In samples analyzed from unit A at both the Walton County Pit (WCP) and Campbell Sand Pit, standard deviations fall between 0.67 and 0.95 phi and the skewness for five out of the six samples was negative. Unit A at both localities contained *Ophiomorpha*. The WCP locality also contained marine mollusks. Both the sieve analysis and the fossil evidence indicates that these sediments were deposited in a marine environment. The percentages of silt and clay-size particles in the samples from Unit A at both localities ranged from 2.9 to 7.7 percent. This suggests that these sediments were deposited either offshore, away from the winnowing effects of waves of in a lagoonal or estuarine environment. The remaining samples from the four localities sampled did not show as clear a correlation (low standard deviation and negative skewness for sediment that contained *Ophiomorpha*).

Another interesting observation is the occurrence of gravel in fine-grained sediments at most localities. Gravel was occasionally concentrated in bedding planes but more often it was suspended in a finer-grained, clayey matrix. Gravel in excess of 5 centimeters in diameter was collected from fine-grained, clayey sand at the WC-3 locality in unit A. Compositionally, the gravel consists of quartzite like the majority of coarse grains observed in the granulometric analysis. A hypothesis for the origin of the gravel is that tree root balls were eroded from the banks of rivers further north where gravel is common (T. Scott, personal communication 2009). These tree root balls were subsequently washed down-river and ultimately out into the near-shore, marine environment where the gravel clasts were deposited. Another possible mechanism that could have introduced gravel clasts to finer-grained sediments is bioturbation. In many cases the units that contain gravel in a finer-grained matrix exhibit evidence of bioturbation, and are often overlain by coarser-grained sediments.

Granulometric and fossil data presented here show that portions of the Citronelle Formation, as currently mapped in the study area, were deposited in near shore, marine environments which supports the initial hypothesis. Moderately well sorted, fossiliferous sediments are commonly encountered in the study area. Differentiating these marine-influenced Citronelle Formation sediments from underlying fossiliferous formations is further complicated by the fact that both units contain marine fossils.

Elevation and Thickness of the Citronelle Formation

The highest elevations of the Citronelle Formation in western Florida exceed 100 meters (Means et al., 2000; Scott et al., 2001). The formation also crops out near sea level along portions of Pensacola Bay in southern Escambia County. In the study area, the sediments containing *Ophiomorpha* and other marine fossils range in elevation from approximately 29 meters to over 66 meters.

The thickness of the Citronelle Formation in west Florida is variable ranging from zero to over 240 meters thick (Marsh, 1966; Schmidt and Clark , 1982). The formation thickens from east to west with the thickest sequence located in northwestern Escambia County (Marsh, 1966). Its thickness in southern Alabama may exceed 76 meters (Matson, 1916). True determination of the thickness of the Citronelle Formation has been complicated by its lithologic similarity of adjacent lithostratigraphic units. Marsh (1966) included Pleistocene terrace deposits in his Citronelle Formation thickness determination because of their lithologic similarity. Most previous thickness estimates of the Citronelle Formation in western Florida probably include portions of subjacent and suprajacent lithostratigraphic units. The variability in thickness of the Citronelle Formation across the study area is the result of regional dip, incipient topography on underlying lithostratigraphic units (undifferentiated clastics and the Alum Bluff Group) and erosion since the time of deposition (Huddleston, 1984). The thickness of the marine-influenced portion of the Citronelle Formation in the study area could not be determined because the base of the unit was not encountered at any of the field localities. Based upon the exposed portions, minimum thickness of the unit ranged from a few meters to over six meters.

Stratigraphic Relationships

Since the Citronelle Formation is generally devoid of fossils, especially age definitive fossils, stratigraphic relationships are based upon relative stratigraphic position. In the study area the Citronelle Formation rests unconformably on the Miocene Alum Bluff Group in the east and the undifferentiated clastics (thought to be Miocene) west of the Yellow River (Means et al., 2000, Green et al., 2001). Outside the study area at Alum Bluff in western Liberty County, the Citronelle Formation lies unconformably on the lowermost upper Pliocene Jackson Bluff Formation (Huddleston, 1984). Huddleston (1984) identified a phosphoritic sand unit (informal lithostratigraphic unit) in southern Walton County. The upper portion of this unit contained a planktonic foraminiferal assemblage he judged to be equivalent to the Jackson Bluff Formation. On his cross section E-E' he shows this unit downdip, grading upward and interfingering with an undifferentiated Pliocene sand. He showed the undifferentiated Pliocene sand interfingers with the Citronelle Formation and is a lateral equivalent of the phosphoritic sand unit (shown to be earliest Late Pliocene). Based on these correlations, the Citronelle Formation is no older than earliest Late Pliocene.

In the majority of the study area, the Citronelle Formation overlies the Alum Bluff Group and undifferentiated coarse clastics. These units range in age from Middle Miocene (Serravalian) to Late Miocene (Tortonian) (Huddleston, 1984). In central Escambia and Santa Rosa Counties, the Pensacola Clay grades laterally into the "Miocene" coarse clastics. Marsh (1966) assigned the Pensacola Clay to Late Middle to early Late Miocene. This age assignment also applies to the Miocene coarse clastic unit where it interfingers with the Pensacola Clay. This suggests that either the lower Citronelle Formation could be as old as Late Miocene or that erosion or non-deposition occurred between the Late Miocene and Late Pliocene in the study area.

Fossils and Age

The lack of age-diagnostic fossils in the Citronelle Formation has led to much confusion regarding the age and depositional environment of the unit. Berry (1916) was the first investigator to assign an age to the Citronelle Formation based upon fossils. A clay bed containing fossil plants occurs at two Citronelle Formation localities in southern Alabama (Matson, 1916). Based upon eighteen recognized plant species, Berry (1916) placed the formation in the later half of the Pliocene Epoch.

Marsh (1966) reported on fossil pollen in Citronelle sediments in west Florida identified by Estella Leopold of the United States Geological Survey (USGS). She concluded that the middle and upper portions of the Citronelle Formation in western Florida are Quaternary. Marsh also states that fossil shell material was recovered from a number of wells. Material from W-2339 (Florida Geological Survey well number) on Fairpoint Peninsula in Santa Rosa County was examined by Ralph Heath of the USGS. He determined that the species identified represent an assemblage that was Pleistocene to Recent in age. Additional fossil material reported on by Marsh included fossil wood and *Ophiomorpha,* but these were not age diagnostic.

Isphording and Lamb (1971) described a fossil vertebrate assemblage in the Citronelle Formation along Chickasabogue Creek in Mobile County, Alabama. The assemblage includes fish, turtles, crocodilians, perissodactyls, artiodactyls and a river dolphin. Dr. Frank Whitmore of the USGS identified the fossils and concluded that they represented a Hemphilian Land Mammal Age (Late Miocene to Early Pliocene), but he further states that the assemblage is middle Pliocene with closest affinities to the Bone Valley Member of central Florida. The apparent discrepancy comes from the fact that the North American Land Mammal Ages have been further refined since the time of the Isphording and Lamb (1971) publication. Since then, Hulbert and Whitmore (1997) revised the age estimate of Isphording and Lamb (1971) and concluded that the Mauvilla Local Fauna (locality at Chickasabogue Creek) is Late Miocene (7.5 – 6 mya).

Manning and MacFadden (1989) describe a vertebrate fauna from the Tunica Hills in Louisiana. The source of the fossils was reported to be the Citronelle Formation.

They concluded that the fauna represented Late Miocene to Early Pliocene or a late Hemphillian (ca.7 – 4.5 mya) North American Land Mammal Age.

Otvos (1998) reported finding trace amounts of umbrella pine pollen (*Sciadopytis*) at localities in Vancleave, Mississippi and at Mossy Head in Walton County, Florida. Based upon this occurrence, he concluded that the Citronelle Formation at these localities was Pliocene as the umbrella pine went extinct from this continent by the end of the Pliocene (Otvos based this on a personal communication with D. Willard at the USGS).

Unfortunately, fossils recovered during this study do not appear to be restricted to a short time interval. Silicified wood in the northern portion of the study area was noted, however the specimens were very fragmented and not identifiable to the generic level. They are worth noting in the hopes that future investigations may report age diagnostic fossil wood from the Citronelle Formation.

Of the fossil shark teeth recovered at OK-1, specimens of two species and one genus could be identified. The presence of *Hemipristis serra* is most useful in constraining the age of the Citronelle Formation. *Hemipristis serra* has been discovered at numerous sites in Florida where marine fossils occur. It occurs in sediments that range in age from Early Miocene to Late Pliocene and possibly into the Pleistocene. However, at the Upper Pliocene and Pleistocene sites in Florida where *Hemipristis serra* has been recovered, the fossils show evidence of reworking from older units (R. Hulbert, personal communication 2009). Therefore, based upon the occurrence of *Hemipristis serra*, the Citronelle Formation at this locality could be Early Miocene to possibly Late Pliocene in age. This determination is based on the assumption that the shark teeth were deposited at the time of Citronelle Formation deposition and were not reworked form older units to the north. An argument against this is that the teeth are very delicate and cannot survive transport over long distances without being abraded. Of the other fossil shark teeth identified, *Negaprion brevirostris* occurs from the Miocene to present and is not useful in constraining the age of the Citronelle Formation.

Six casts of marine bony fish were recovered from the OK-1 locality. Unfortunately, they were too encrusted with limonite cemented sand to be identified to the generic level. Therefore these specimens were of no use in age determination, however they do provide evidence of a marine origin for the Citronelle Formation at this locality.

Fossils of terrestrial vertebrates were also recovered from OK-1. Of those, the most useful specimens were ankle bones (calcaneum and astragalus) of horses (family *Equidae*). An astragalus from a small, three-toed horse and a calcaneum, that is likely from a different horse taxon, were identified from OK-1. The occurrence of three-toed horse at this locality puts a minimum age on the Citronelle Formation, at this locality, of Late Pliocene, however the specimens could also represent Miocene species (Hulbert, personal communication 2009). None of the remaining vertebrate fossils were identifiable even to the family level so they were not useful in determining age.

The mollusks described in this study were not sufficiently well preserved to identify to species, but rather only to the family level for the most part, thus were not useful in age determination. However, specimens of the family *Veneridae* were generally smaller than Pliocene or Pleistocene specimens, which suggests that they may represent Miocene genera (Portell, personal communication 2009).

The most commonly encountered fossils in the study area are tube-like structures known as *Ophiomorpha,* which are thought to be the burrows of Thalassinidean shrimp, based on modern analogs (Frey et al., 1978). In the study area, the tubes range in size from several millimeters up to five centimeters in diameter and exhibit a knobby, mamillary exterior. Burrow densities range from isolated tubes to over one hundred per square meter. Some of the tubes are interconnected and contain expanded portions that are considered to be living chambers or areas where the inhabitant could turn around. None of the tubes examined contained fossils of the inhabiting organism.

Care must be taken when using *Ophiomorpha* as an environmental indicator (Frey et al., 1978). One must first rule out the possibility that non-marine organisms may have constructed the structures. For instance, crayfish are known to construct knobby-walled burrows. The occurrence of marine mollusks within the *Ophiomorpha* bearing units rules out the possibility of crayfish as they are fresh-water organisms.

Ophiomorpha's known geologic range is from the Permian to the Holocene (Frey et al., 1978), so they are not useful for constraining the age of the Citronelle Formation. They are useful in interpreting the depositional environment. The prevalent view is that

Ophiomorpha are indicators of high-energy beach conditions. However, it has been shown in the Gulf of Mexico region that *Callianassa major* (modern analog) has lower densities near beach areas (Frey et al., 1978). The burrows are known to occur on shoals, tidal flats, tidal stream point bars and lagoon, bay, sound and estuary floors. Generally it can be stated that the occurrence of *Ophiomorpha* provides evidence for deposition in numerous near-shore marine environments but that additional sedimentologic evidence is needed to make a specific environmental interpretation.

The age range for deposition of the Citronelle Formation in the study area based on the fossil evidence is Early Miocene to Late Pliocene. Early Miocene can be ruled out because the Citronelle Formation overlies formations in the upper portion of the Alum Bluff Group (Middle Miocene to Late Pliocene) and coarse clastics that have been shown to be Late Miocene. So a more reasonable age estimate for deposition of the Citronelle Formation would be Middle Miocene to Late Pliocene, based upon the fossil assemblage and stratigraphic position.

Sea Level

The marine-influenced portion of the Citronelle Formation has implications for past sea levels. In the study area, portions of the Citronelle Formation that contain marine fossils occur at elevations ranging from present sea level to over 66 meters above msl. Miller et al. (2005) generated a record of Phanerozoic sea-level change based on $\delta^{18}O$ values, which shows that sea level did not exceed fifty meters above present levels at any time since the Miocene. If this is the case, then some structural or isostatic adjustment must have occurred to allow for the elevations of these marine deposits or the sea-level curve is off by nearly 15 meters.

One potential source of uplift is isostatic adjustment due to dissolution of limestone. Opdyke et al. (1984) estimated that karst regions of northern Florida are losing a minimum of 1.2×10^6 cubic meters of limestone per year through groundwater discharge carrying dissolved calcium carbonate. This equates to losing approximately one meter of surficial limestone every 38,000 years. This amount of loss has led to isostatic uplift of approximately 36 meters since the Pleistocene. They used this estimate to explain the existence of Pleistocene marine sediments situated between 42 and 49 meters above msl along Trail Ridge in northern Florida.

Willett (2006) utilized a more robust data set than Opdyke et al. (1984), and calculated isostatic rebound in the karst regions of the Florida Platform based upon dissolution rates. His calculations were run using differing densities and differing approaches. Estimates for carbonate dissolution were made based upon recent water quality data acquired from large springs (first and second magnitude) in Florida. Utilizing total alkalinity as a proxy for amount of carbonate in solution, he estimated that the karst areas of Florida are losing a minimum of 4.8×10^5 m^3 per year. This equates to losing approximately one meter of limestone every 160,000 years. This amount of carbonate removal suggests that there could have been anywhere from 9 to about 50 meters of uplift of the Florida Platform since the Plio-Pleistocene.

Winker and Howard (1977) looked at three shoreline sequences along the Atlantic Coastal Plain and showed, based upon geomorphic evidence, that all three sequences had been warped. They looked at geomorphic features that stretched from the Cape Fear River in North Carolina to central Florida. They utilized geomorphology instead of elevation to correlate shoreline sequences. They concluded that deformation of these sequences persisted through the Pliocene and Pleistocene.

Cronin (1981) looked at rates and potential causes of vertical crustal movement in the Atlantic Coastal Plain. He used paleontological correlation to constrain the ages of a number of datums along the Atlantic Coastal Plain. Using the current elevations of the datums and their ages, Cronin utilized a number of equations to determine if eustatic sea level could have ever reached these elevations. He concluded that uplift had taken place since the Pliocene at a rate of between 1 and 10 cm/1,000 years. He proposed several mechanisms for this crustal movement including hydro-isostacy, lithospheric flexure or that the uplift rate is overestimated. Lithospheric flexure is the idea that the lithospheric response to sediment loading in a basin causes a peripheral bulge in regions landward of the basin equivalent to roughly 4% to 8% of the total subsidence predicted. This vertical movement occurs within 100 to 400 km from the basin. This may explain why the marine-influenced portion of the Citronelle Formation occurs at anomalously high elevations in western Florida.

Huddleston (1984) stated that his entire study area (of which my study area is a part) was a region of general subsidence from the Early Miocene through Late Pliocene. He noted that siliciclastic sequences thickened in a westward direction toward the depocenter of the Gulf Coast Basin. Based on cores drilled throughout his study area, Huddleston also noted the terrace-like step features at the contact between subsurface units. He postulated that down-to-basin faulting in basement rocks was responsible for the terrace-like features. As sediments were deposited over the faults, gentle flexures developed in the near-surface materials.

Northeast of the study area is the Marianna Lowlands. This geomorphic feature is a karst plain that has experienced dissolution. Siliciclastic sediments were eroded from the Marianna Lowlands exposing the underlying limestone to karstification. It seems reasonable that isostatic adjustment (uplift) due to dissolution has occurred in or near this feature. Subsidence has occurred, due to sediment loading, in the southern portions of the study area (Huddleston, 1984). Cronin (1981) has suggested that lighospheric flexure has caused uplift along the Atlantic Coastal Plain. This concept could explain why the marine-influenced Citronelle Formation exists at elevations exceeding fifty meters. The region could have experienced uplift due to peripheral bulging along a flexure or hinge-line that divides a rising Marianna Lowlands karst region from a subsiding, sediment-loaded southern portion of the study area.

Environments of Deposition

It is clear from the occurrence of marine fossils that a portion of the Citronelle Formation, as currently mapped, was deposited in a near-shore marine environment. Relatively high percentages of silt and clay fractions in the marine deposits suggest that the environment was either offshore away from the winnowing activity of waves or a lagoon or estuary.

It is more difficult to identify the depositional environments of the non-fossiliferous units. The sieve data show the sediments were moderately well sorted, and sedimentary structures including cross-bedding could suggest either a fluvial environment or a marine environment involving current activity (tidal channel). Other sedimentary structures identified outside the study area include cut-and-fill structures and massive cross-bedding with bed thicknesses of several meters. At one locality, OK-1, both marine and terrestrial vertebrates were found. This may represent a near-shore deltaic deposit that received terrestrial fossils from a fluvial source. Both marine and terrestrial vertebrate fossils are commonly found at fossil localities in Florida (Hulbert, personal communication 2009). The paleocurrent data show that the predominant paleocurrent directions were west-southwest. If the cross beds were formed by fluvial processes, and paleo drainage was similar to present drainage patterns, then the paleocurrent directions are consistent with drainage patterns. It is possible that the cross beds could be of marine origin as well, but there was insufficient data to make this determination.

Based on the data presented in this work, a reasonable hypothesis that explains the occurrence of both the marine-influenced and fluvial (?) portions of the Citronelle Formation in the study area is that in the Late Miocene through Late Pliocene, siliciclastics were deposited in numerous coalescing deltas. Sea-level transgressions and regressions occurred throughout the Pliocene with a general trend toward lower sea levels as ice sheets accumulated during the Late Pliocene (Miller et al., 2005). During transgressions sediment accumulated and during regressions it was eroded. Without the aid of age-diagnostic fossils, it is not possible to determine when marine deposition ceased and terrestrial, fluvial deposition began. Throughout the Late Pliocene and Pleistocene calcium carbonate was removed from the Marianna Lowlands to the northeast by dissolution and the marine sediments were uplifted due to isostatic adjustment. Either the uplift rate outpaced the rate of subsidence, or the area where the marine-influenced Citronelle Formation occurs rests near a peripheral bulge due to downwarping in a proximal sedimentary basin (Gulf of Mexico Basin).

CHAPTER 6

CONCLUSIONS

Citronelle Formation in the Study Area

Based on the occurrence of marine fossils, it is concluded that the Citronelle Formation consists of sediments deposited, in part, in a near-shore marine, lagoonal or estuarine environment. This conclusion is consistent with some previous investigations (Marsh, 1966; Isphording and Lamb, 1971; Otvos, 1998). The results from the granulometric analysis were not conclusive regarding the environment of deposition.

The nonfossiliferous sediments encountered contain sedimentary structures such as cross-bedding and cut-and-fill structures that suggest a fluvial origin. Paleo-current analysis shows that the dominant current directions, based on cross-bed orientations in two beds at the Campbell Sand Pit locality were west (Unit E) and southwest (Unit F).

The marine-influenced portion of the Citronelle Formation contains abundant trace-fossils (*Ophiomorpha*) as well as body fossils of marine mollusks. One locality (OK-1) contained both marine and terrestrial vertebrate fossils that were uniquely preserved. Fossil casts of terrestrial vertebrates and shark teeth preserved by limonite-cemented sand has not previously been reported in the scientific literature. This was one of the significant findings of this study. Finding both terrestrial and marine vertebrate fossils at this locality indicates that terrestrial organisms died near a paleo-shore and that their remains were washed into the near-shore marine environment. This is significant as this locality is located in the northernmost portion of the study area. It delineates the northern extent of the marine-influenced sediments in the study area.

Some fossils from the study area were sufficiently well preserved to allow taxonomic affinities to be determined, however none of the fossils described existed over a short enough time span to constrain the age of the Citronelle Formation. They all have fairly long ranges (Miocene to Pliocene). It could not be determined if the Citronelle Formation in the study area was deposited during the Miocene, Pliocene or both. However, the occurrence of *Hemipristis serra* and three-toed horse shows that the

Citronelle Formation, in the study area, is no younger than Late Pliocene, which contradicts some previous investigations (Marsh, 1966).

The lithology of the Citronelle Formation is variable and ranges from a clayey, moderately well sorted quartz sand and gravel to a sandy clay with thin beds of relatively pure kaolinite. The lithologic variability, both laterally and vertically, makes it difficult to distinguish it from other formations in the study area. However, the unit is mappable over the study area. Results from this study do not conclusively show that the marine facies is a part of the Citronelle Formation as currently mapped. Since the underlying Miocene formations are known to contain marine fossils, it is plausible that the marine-influenced sediments are Miocene.

The elevations of the marine-influenced sediments described in this study appear to be higher than any maximum sea-level stand of the Miocene, Pliocene or Pleistocene (Miller et al., 2005), therefore, it is not possible to assign an age to these sediments based strictly upon their current elevations. Isostatic adjustment due to carbonate dissolution has been postulated for the karst regions of Florida, and this might explain the anomalous elevations. Vertical crustal movement due to lithospheric flexure (Cronin, 1981) is another possibility that could explain their present elevations.

APPENDIX A

OUTCROP LITHOLOGIC DESCRIPTIONS

WALTON COUNTY LOCALITIES

Campbell Sand Pit

Pit located: N30°, 44’, 34.8”, W86°, 21’, 47.1” (NAD 83). Campbell Sand, east of Crestview on US 90, Walton County, Florida. Elevation is approximately 230 feet at the top of the section.

They are mining sand and gravel using dredge at this locality. They are mining below the water table as much as 25 feet. Pit has excellent exposures of the *Ophiomorpha* bearing unit. Orangish, clayed cemented sands with iron staining. Cross bedding is prominent in layers above the *Ophiomorpha* zone. Burrows are numerous in the lower part of the pit. Kaolinite lenses are common and are inclined with the cross beds. Kaolinite layers are discontinuous but extensive throughout the upper clayey unit.

Unit A – 274 centimeters thick. Unit consists of a fine to gravel size, primarily medium, clayey quartz sand. Abundant *Ophiomorpha* burrows in life position. Burrows consist of white (kaolinite?) clay with some sand grains. The burrows range in size from a few millimeters to several centimeters in diameter. Most appear to be oriented vertically, however some make a 90 degree bend and are oriented horizontally. The longest measured burrow was 23 centimeters in length. Grain size is bariable with some gravel interspersed randomly. Clay content appears to be variable and the entire unit is pinkish and mottled. Some Liesegang banding is present and consists of pinkish to crimson colored bands of variable width. Grain size does not change across the stained band. At approximately 102 cm the grain size coarsens and then alternates in beds from medium to coarse with a steady coarsening upward sequence. Entire unit is bioturbated but still exhibits some horizontal bedding. At 118 cm is a clay cemented sand cast of what looks to be a mollusk. Another bivalve mold collected at the same level approximately 1 meter to the west. At 246 cm grain size becomes coarse. Coarse bed is approximately 20 cm thick and fines upward. Within this horizon is a lenticular clay bed, concave up, with fine, unconsolidated, white, medium quartz sand underneath. Contains minor amount of mica throughout the entire unit.

Unit B – 67 centimeters thick. The Unit A/Unit B contact shows a marked grain size shift from (Unit A) medium to coarse to very coarse with sporadic gravel-size quartz. Gravel and coarse, quartz sand is very well rounded. Clay content is variable but there is enough to make the unit poorly indurated. *Ophiomorpha* burrows still present but much less abundant than lower unit. Gravel content appears to increase toward tip of the unit. Some sand stringers near clayey zones appears unconsolidated. Iron staining is present. Unit is farily horizontally bedded. At the base of Unit B is a distinct, oxidized iron stain. Photo of unit B had a hammer and ruler in it. Unit appears to be less clayey then the lower unit (Unit A). Unit “B coarsens upward – more gravel in the upper portion of the unit. Units are traceable over at least several hundred yards within the pit. Top of Unit B is undulatory and clay cemented stringers are inclined.

Unit C – 55 centimeters thick. There is a distinct grain size change and an abrupt, horizontal contact. Grain size of quartz sand goes from coarse with some gravel to a fine to medium, quartz sand. From 9 to 13 centimeters from the base of the unit is a layer of more coarse grained material – horizontally bedded. This unit is distinct from the other layers because of the bedding – mostly cross bedding. Cross beds range from 1 millimeter to a half of a centimeter in thickness. The cross beds are iron stained making the bedding obvious. *Ophiomorpha* burrows are uncommon but do occur in this unit. Except for the medium-coarse grained interval, the unit is predominately a fine to medium, quartz sand with one to two percent clay. Clay is coating the quartz grains. Cross bedding is abundant and the beds appear to thicken toward the top of the unit. Color changes and gets more iron stained up section. Possibly a slightly coarser grained interval between 26 and 29 centimeters from the base of the unit. Occasional clay bleb in interval.

Unit D - 36 centimeters thick. Units consists of a medium to coarse quartz sand with occasional gravel clasts floating in a finer grained matrix. Contact between Unit D and Unit C is fairly sharp being primarily a grain size change. Unit appears to fine upward with gravel more abundant at the base. Clay content is between 1 – 3 percent and coats the sand grains. Thin, horizontal bedding is visible as different shades of red and yellow. Some cross bedding may occur within this bed in different parts of the pit, but not where the section was measured.

Unit E – 32 centimeters thick. Contact both above and below this unit is undulatory. As below, the main difference between Unit D and Unit E is a change in grain size. Unit E is overall more coarse than Unit D. Unit exhibits horizontal bedding and color variation. Clay content is enough to make the sand fairly competent. Some intervals up to 0.5 centimeters thick are more resistant to erosion than layers above and below. Some small intervals almost unconsolidated. Unit is laterally variable with respect to overall grain size. Pockets of gravel occur and appear discontinuous. Unit consists of a thinly bedded, fine to gravel size quartz sand. Overall, the grain size is coarse with approximately 10 percent gravel. Grains appear rounded, possibly a slight, overall fining upward sequence. Bedding appears horizontal over interval. All units appear laterally traceable over approximately 300 meters with minor variability in thickness and grain size.

Unit F – 96 centimeters thick. Unit is distinctive because it contains cross beds and large, planar pieces of white (kaolinite?) clay cemented sand in angular, dipping, lenticular beds. Clay appears to adhere to the bedding plane orientation. Some portions of material are blob-like while others are clearly planar. Some chunks are oriented at angles of 60 degrees or more. Some clay chunks appear as chevron shapes. Immediately below the clay are pockets of unconsolidated sand. Grain size ranges from gravel to fine with an overall fairly coarse average grain size. There is horizontal bedding as well. Some beds are more consolidated than others with higher clay content. Areas near the clay are redder than the surrounding unit. The cross bedding and clay beds make this unit unique.

Unit G – From bottom of G to the top of the outcrop is 68 centimeters. Unit consists of numerous 1 to 3 centimeter beds of medium and coarse quartz sand. Beds are defined by a grain size difference and by clay content. Unit is reddish-yellow in color. Beds are horizontal with no obvious cross bedding. Some stringers of white, kaolointic clay but are much less abundant than in previous layer (Unit F). The section has been cut back at the top and possibly another one to two meters of material is missing (based upon looking at the stepped cut and other areas within the pit. Unit is a massive, reddish, clayey medium quartz sand with few clay stringers.

Unit H – Approximately 2 – 3 meters of tan, unconsolidated sand lies over Unit G. The sand is fairly well sorted, rounded, medium quartz sand with minor clay content. No structures are apparent in this unit. Unit G is the top of the Citronelle Formation in this pit.

Diamond Sand Company Pit

Located at 14216 US Highway 90 West at CR 285 intersection, Walton County, Florida. Elevation approximately 220 feet based upon the Mossy Head USGS 1:24,000 scale topo sheet. Walked the west wall. Similar sequence to Campbell Pit. Unit A (from Campbell) occurs at the base but not as well exposed. *Ophiomorpha* burrows were observed. Numerous bedded sequences with oddly oriented clay layers, as in Unit F of Campbell. Evidence of cross bedding and Liesegang banding. Grain sizes range from medium to gravel. Upper unconsolidated sands show evidence of cross bedding in several weathered sections. Looks like a 10 meter maximum exposure from basal water level.

Walton County Pit (WCP)

N30°, 36", 14.2", W86°, 04', 21.3" Washington County, Florida. Heading east on Rock Hill Road from US 331, pits are on the north side of the road down an unmarked dirt road. There are three pits off this road, two privately owned and one is County owned. Section measured near the pit entrance in the southwest corner.

Unit A – 178 centimeters thick. Unit consists primarily of a medium to coarse, clayey quartz sand. Toward top of section are gravel stringers. Clay content gives unit a mottled appearance. Color ranges from a pale orange to pink. Numerous burrow structures throughout the unit. Appears to be Liesegang banding that may follow bedding planes. Gravel stringers are horizontal. No sign of cross bedding or other sedimentary structures. Some limonite development in areas – not planar, just randomly distributed. Banding/staining appears horizontal near top of bed. Gravel is randomly distributed in the upper part of the unit. Burrow structures are in excess of 60 centimeters in length and generally no more than 2.4 centimeters in diameter. Sieve samples were taken at: WCP-A1 (25.4cm), WCP-A2 (101cm) and WCP-A3 (173cm) from the base of the unit.

Unit B – 56 centimeters thick. Unit consists of a medium to coarse quartz sand with 20 – 30 percent gravel. Gravel occurs as horizontal, discontinuous stringers. Gravel clasts consist of appear to be quartzite. There is enough clay content to make the unit competent. There is also a 2 – 3 centimeter band of limonite running through the unit but it is discontinuous. No other apparent bedding. No obvious burrow structures in this unit possibly due to the coarse nature of the clasts. Bulk sample taken at 25 centimeters from base of this unit (WCP-B). Contacts both above and below appear somewhat gradational with no obvious disconformity. Contact based upon grain size difference.

Unit C – 36 centimeters thick. Unit B grades into this unit which consists of a coarse, fairly well sorted, clayey quartz sand. Sand grains are angular to sub rounded. Gravel is sparse. Burrow structures are evident and are primarily oriented vertically. Burrow infill is finer grained than surrounding unit. Clay appears orangish-red and coats the sand grains. Heavy minerals are present throughout but make up less than one percent total. Three samples taken: One at the base of the unit (WCP-C1), one at 18 centimeters (WCP-C2) and one taken at the top of the unit (WCP-C3).

Unit D – 41 centimeters thick. Unit is highly variable in grain size and contains gravel stringers. This coarse unit is traceable over several hundred meters. Unit consists of a medium to gravel size, clayey quartz sand. Contains abundant limonite. This unit contains burrows that have been cemented with limonite. Dark red to maroon staining is abundant. Staining is random in areas and horizontal in others. Obvious burrow structures throughout unit. Gradational contact above and below. Units lateral continuity beyond several hundred meters is unknown. Thickness appears variable based upon limonite content. Trace of heavy minerals present. One bulk sample taken in unit (WCP-D).

Unit E – 114 centimeters thick. At the base of the unit is a medium to coarse, clayey quartz sand with a lower clay content that previous intervals. Contains up to one percent heavy minerals. Occasional gravel clasts. Gravel and clay content increase up section. Reddish, iron staining is prevalent in the upper section. Some thin, up to one centimeter thick, red stained horizontal bands present as well as some more massive, convoluted staining. Burrows are absent from this unit. Three samples taken horizontally at 13 centimeters from base in a less clayey section for sieve analysis (WCP-E1,2,3).

Unit F – at least 254 centimeters thick. Top of the unit is near the road cut and the absolute thickness cannot be determined. Unit consists of a fine to medium, clayey quartz sand. Unit contains much higher clay content, greater than ten percent. Fine laminations (up to one centimeter thick) of white, kaolinitic clay. Iron staining occurs giving the unit a banded appearance. Numerous burrow structures. Burrow size is highly variable with the smaller ones being pencil size in diameter and the larger ones between 5 and 6 centimeters in diameter. Majority of the burrows are oriented vertically in the sediment. Several gravel stringers near 90 centimeters from the base of the unit. Sample taken at 64 centimeters from the base of the unit (WCP-F).

WC-1

N30°, 42', 3.0", W86°01', 11.2" (WGS-84 datum). Walton County, Florida. Clay pit off Macedonia Church Road. Take CR1835 south out of Argyle and turn east on Macedonia Church Road. Clay pit is on the south side of the road approximately one quarter mile from the intersection. This roadside clay pit exposes approximately 15 to 20 feet of clayey sand and gravel. No observable burrows or mollusk casts. Some white clay stringers observed. Elevation ~260 based on USGS 1:24,000 topo sheet (DeFuniak Springs East Quadrangle).

WC-2

N30°, 41', 50.1", W86°, 00', 2.2", (WGS-84 datum). Walton County, Florida. Sand/gravel and clay pit off Macedonia Church Road approximately ¾ mile east of WC-1 locality. Pit located on the north side of the road. Two distinct units exposed. Upper unit is approximately four meters thick and consists of a dark red, clayey quartz sand. Sand ranges from medium to gravel size. Outcrop is old and overgrown thus bedding is not observable if it exists. The upper meter of this unit is less consolidated, but this may be a function of human disturbance. Abundant root traces are noticeable as tubular, lighter colored areas. Gravel content is higher in the lower section of this unit. Much of the gravel is well rounded, sometimes flattened. Consists of quartzite. Limonite chunks consist of limonitic cemented sandstone.

Lower unit is of an undetermined thickness as the pit depth does not penetrate the entire thickness of this unit. Unit consists of clayey, medium to gravel size quartz sand. White clay stringers are present as are abundant *Ophiomorpha* tubes. Clay laminations appear to follow bedding. Unit appears mottled and highly bioturbated. Sediment is poorly sorted. Burrow diameters range from a few millimeters to several centimeters in diameter. Burrow length is indeterminate. Density of burrows appears to be as high as several hundred per square meter. Bulk samples taken from both units. Pit elevation is approximately 250 feet based upon the USGS 1:24,000 scale quadrangle map.

WC-3

N30° 40’ 54.5”, W86°, 01’, 41.5”, (WGS-84 datum). Walton County, Florida. Clay pit southwest of the I-10 overpass on County Road 183 (south of Argyle). Section was measured in the southeast corner of the pit from base to top. 230 feet in elevation at the top of the section according to the USGS 1:24,000 scale DeFuniak Springs East Quadrangle.

Unit A – Approximately 211 centimeters thick. Bottom of pit is filled with sediment so entire thickness of the unit is obscured. Unit consists of a buff, orangish, pinkish, very fine grained, clayey quartz sand to a sandy clay. Accessory minerals include: a trace of heavy minerals, and muscovite. Occasional gravel size, quartzite clast is floating in the finer grained matrix. Fine, millimeter size, clay stringers occur. Unit appears highly bioturbated and mottled. Scattered throughout the entire thickness are ghosts of mollusks. Reddish, iron-staining defines the outline of the mollusks (bivalves). Some mollusks are even replaced by limonite and appear as external casts. Orientation of most mollusks is horizontal – not in life position. Top of the unit is marked by a fairly laterally consistent limonitic hardpan. Some *Ophiomorpha* tubes have been preserved as limonitic casts. The contact between this unit and the overlying unit is undulatory but fairly consistent across the pit. Sample WC-3Aa taken of gravel clasts from around the measured section in a zone that is several meters thick. Quartzite gravel clasts occur randomly throughout the thickness of the exposed unit.

Unit B – Approximately 91 centimeters thick. Thickness is variable across the pit. There is a clear lithologic break defined by a marked increase in grain size and a fairly continuous limonite hardpan between the top of Unit A and the bottom of Unit B. Unit consists of a medium to gravel size quartz sand, variably clayey. Unit appears poorly sorted. Mottled appearance. There are linear, vertical “cracks” visible from the surface of this unit. Color across these features appears to lighten toward the center of the crack. Some of these features appear to be tubular and occur in the upper part of this unit, but don’t appear to be *Ophiomorpha* tubes. They lack the mamillary exterior. Possibly root casts. The basal limonitic hardpan, however, clearly preserves some *Ophiomorpha* tubes. I photographed the fracture features. Some of the fractures intersect at near right angles. Took a bulk sample (WC-3B).

Unit C – approximately 221 centimeters thick. Unit is variable in thickness and consists of a fine to medium, subangular to subrounded, well sorted quartz sand. Occasional pea gravel. Buff to light orange with a trace of clay. Heavy minerals present – less than one percent. Massive unit with no apparent bedding.

WC-4

N30°, 41’, 12.4”, W86°, 08’, 31.1” (WGS-84 datum). Pit located at the intersection of Coy Burgess Loop and Millard Gainey Road, southwest of DeFuniak Springs, south of I-10 near the Southwide Church Walton County, Florida. Elevation at the top of the pit is approximately 220 feet.

Approximately twenty feet of orangish, mottled, clayey quartz sand. Oxidized root casts are abundant in the upper portion of the section. No *Ophiomorpha* observed. Gravel and limonite are abundant accessories. No obvious bedding, but the outfrop is old and weathered making it difficult to see any possible bedding. Looks very similar to other exposures previously called Citronelle Formation.

WC-5

N30°, 41’, 2.7”, W86°, 10’, 38.9”, (WGS-84 datum). Pit surface elevation approximately 200 feet, DeFuniak Springs West, USGS 1:24,000 scale quadrangle map. Clay pit located on the west side of Cosson Road just north of the intersection with Nelson and Senterfiet Roads. Approximately 15 – 20 feet of reddish, oxidized, clayey sand and gravel. Mottled appearance with root casts. Thin beds of gravel and coarse sand with some thinly bedded kaolinite in the exposure. Sediment appears poorly sorted.

WC-6

N30°, 43’,15.4”, W86°, 10’, 18.2”, (WGS-84 datum). Pit surface elevation is 250 feet based upon the DeFuniak Springs West, USGS 1:24,000 scale quadrangle map. Pit located on the east side of Woodyard Road. Abandoned sand and clay pit with approximately 25 feet of exposure. Basal portion consists of a buff to orangish/pink clayey, fine to medium quartz sand with occasional gravel clasts. Below this is an *Ophiomorpha* bearing unit with similar lithology but is reddish in color. The tubes are white with a mamillary exterior. Unit contains a trace of mica and heavy minerals. Thickness undetermined as pit depth is not sufficient. Gravel clasts are well rounded.

The overlying unit consists of a reddish/orange fine to medium, clayey quartz sand with a trace of heavy minerals. Contact with underlying unit is gradational. This unit is approximately 15 – 20 feet thick. No bedding observed but the quarry wall is overgrown and sedimentary structures may be obscured.

The top unit in the section is approximately 5 – 10 feet of clean, buff colored quartz sand. There is a fairly sharp contact between this and the underlying unit. An increase in clay content down section occurs.

WC-7

N30°, 59’, 20.6”, W86°, 15’, 31.6” (WGS-84 datum) Pit on Eglin Air Force Base, Walton County, Florida, and is under restoration. Surface elevation is approximately 210 feet. About 30 feet of exposure which is heavily overgrown. Lower section, approximately 20 feet thick, consists of a pinkish, micaceous clay with *Ophiomorpha* tubes. Casts of mollusks were observed in this pit.

OKALOOSA COUNTY LOCALITIES

EAFB Locality

Location: N30°, 35’, 47.2”, W86°, 30’, 58.9” (NAD 83), Okaloosa County, Florida. Site located off State Road 85 on Eglin Air Force Base.

Unit A1 – approximately 1 meter thick. Consists of fine to medium, sub rounded to sub angular quartz sand. Thin, white clay laminae at the top of unit decreasing down section. Abundant *Ophiomorpha nodosa* consisting of white, kaolinite with some sand – mamillary exterior. Many burrows appear to be oriented horizontally. Sand is unconsolidated at the base of the section. Some mottling occurs in the unit. Sediment samples and *Ophiomorpha* burrow sampled from the base of the section. 3 samples were taken vertically up the section. One bulk sample taken from this unit.

Unit A2 – approximately 1 meter thick. Unit consists of a medium, sub-rounded to sub-angular, clayey, poorly indurated quartz sand. Mottling occurs throughout the unit. Clay content decreases up section. Appears cross-bedded. Contact between this unit the underlying A1 unit is undulatory and may be discontinuous across the pit. The contact between this unit and the overlying unit, A3, is fairly abrupt and is marked by a grain size change from fine-medium to coarse. There are abundant rip-up clasts of white clay ranging in size from gravel to cobble. *Ophiomorpha* burrows are much less abundant in this interval. Three sieve samples, one bulk sample and several rip-up clasts were taken in this unit. Sampled A2c just at the contact between the coarse sand at the base of A3 and top of A2.

Unit A3 – Approximately 1.3 meters thick. Unit consists of a medium to coarse, sub-rounded, clayey quartz sand. Occasional white, clay stringers. Occasional gravel size quartz grains distributed throughout interval. Mottling and oxidized iron staining abundant. The unit appears to be more lithologically uniform than lower units. This unit appears to grade into the overlying Unit B. Two sieve samples and one bulk sample taken from this unit. Sieve sample A3a taken at just above grain size contact between A2c and A3a. Sieve sample A3b taken 27 cm above A3a.

Unit B - 5.5 meters thick. Unit A3 grades into Unit B. Unit B is a massive, reddish, medium to coarse quartz sand. Clay content relatively homogeneous throughout unit. Some thin bedding is noticeable along the quarry wall. Occasional gravel and clay cemented sand blebs in section. The Unit B/Unit C contact is distinctive and continuous across the pit. Occasional limonitic zoned presumably from paleo groundwater levels occur. Two sieve samples taken where the section was measured (B1 and B2). B1 was taken approximately 2 meters above the talus slope at the base of the pit wall and B2 taken approximately 2 meters below the Unit B/Unit C contact.

Unit C – 4.7 meters thick. Unit C rests upon unit B and makes a well defined contact. Unit C consists of a tan, well sorted, medium quartz sand with a clay content less than 1 per cent. In fresh cut section there is some mottling. Some areas where Unit C is exposed there are cross beds preserved. Probably a Pleistocene eolian deposit. One sample taken approximately three meters above the contact between Unit B and Unit C where the section was measured. The contact between Unit B and Unit C is undulatory and differs in elevation by several meters across the extent of the pit.

OK-1

N30°, 59’, 21.8”, W86°, 28’, 39.2” (WGS-84 datum). Pit located in northern Okaloosa County, Florida approximately ¾ mile south of the Alabama state line. Located on the east side of Stokes Road. Surface elevation approximately 200 feet according to the Laurel Hill USGS 1:24,000 USGS topo sheet. Approximately three to five meters of exposure in an abandoned sand pit. Approximately one to two meters of clean, quartz sand overlies a clayey, orangish, quartz sand. At the base of this unit is a limonitic hardpan and underneath is a pinkish, sandy clay/clayey sand containing *Ophiomorpha* burrows and white, clay stringers. A number of unique fossils have been collected from this locality including shark teeth and some terrestrial vertebrate fossils.

OK-2

N30°, 56’, 33.8”, W86°, 28’, 47.8” (WGS-84 datum). Surface elevation approximately 280 feet based upon the Laurel Hill USGS 1:24,000 USGS topo sheet. Roadside sand and clay pit exposing approximately three to five meters of sediment. Orangish, clayey quartz sand with limonite clasts. Upper portion contains numerous root casts. Typical Citronelle Formation exposure.

OK-3

N30°, 54', 36.4", W86°, 30', 42.5" (WGS-84 datum). Surface elevation approximately 230 feet based upon the Oak Grove USGS 1:24,000 topo sheet. Road cut exposure along the north and south side of Plympton Road just east of the bridge over Murder Creek. As much as 20 meters of exposure along a several hundred meter length of Plympton Road. Exposure is comprised of interfingering beds of mottled, reddish-white clay with an orangish, clayey, medium to gravel size quartz sand. No obvious burrow structures, however the upper meter contains root casts or reduction zones due to roots. In examining the exposure I observed that the mottling in the clay beds, when looked at in a horizontal, plan view, are actually polygonal and modern cracks formed along the lighter colored areas that formed the polygonal patterns. This might suggest that these clay units had been dessicated in the past and mud cracks had formed causing the mottled appearance in cross section.

GADSDEN COUNTY LOCALITIES

Gadsden County Pit

N30°, 37', 28.0", W84°, 50', 42.2" (WGS 84 datum). Locality is a roadside clay and sand pit – heading south on CR 269 just north of the I-10 overpass on the NW side of the road. Approximately 50-75 feet of exposure. 20 to 30 feet of clayey, orange, quartz sand and gravel. Unit is bedded – cross bedded in some areas and horizontally bedded in others both laterally and vertically. This unit overlies a clayey, pinkish, mottled, cross-bedded silt to fine quartz sand. Possible *Ophiomorpha* tubes, but poorly preserved. Unit looks very similar to the burrowed unit in Walton and Okaloosa counties – possibly same unit as further west.

WASHINGTON COUNTY LOCALITIES

WA-1(Ebro Locality)

N30°, 26', 41.3", W85°, 52', 47", Washington County, Florida. North side of State Road 20 just west of Ebro. Small, roadside pit now abandoned. Approximately 15 to 20 feet of reddish, clayey sand to sandy clay exposed. Some clay filled fractures and limonite pebbles. No evidence of Ophiomorpha or mollusks. Deposit looks to be Citronelle Formation.

ALABAMA LOCALITIES

Heading west on Alabama SR 84 between Grove Hill and Silas. Numerous road cuts exposing Citronelle Formation. Road cut at N31°, 44’, 18.4”, W87°, 58’, 23.7”. Exposure is approximately 15 feet tall. Consists of orangish-red-pinkish clayey sand with interspersed gravel floating in a finer grained matrix. Some gravel float is angular, limonitic sandstone. Some white, clay-filled structures that are tube-like at the top of the exposure – appear to be root traces and not burrow structures. Some fine cross bedding observed.

Sample AL-1, N31°, 44’, 27.1”, W88°, 00”, 40.1”. At the bottom of a hill approximately one mile east of mile marker 28 on the north side of SR 84 is an abandoned pit. Pit exposes approximately 25 feet of pinkish-orangish-reddish clayey sand. Some lenticular beds of gravel – some layers of gravel as well that contain quartz gravel with angular chunks of bedded hardpan (limonitic sandstone). Along the east wall near the base of the exposure is a clayey sand, mottled, pinkish-white with a limonite hardpan above. The unit is permeated with *Ophiomorpha* burrows. The burrows are preserved as limonitic tubes. Sizes range from the diameter of a pencil to half dollar diameter. No evidence of mollusks. Unit appears to either pinch-out to the west or the west wall is not weathered enough to see them.

APPENDIX B

GRANULOMETRIC PLOTS

Pre-Digestion Grain Size Distribution

Onshore Grab Sample
Sample: Campbell A40
Total Sample Mass: 63.110 grams

Sieve Size (phi)	Sieve Midpt (phi)	Weight (grams)	Freq Weight %	Cumulative Weight %
-2.25	-2.375	0.000	0.000	0.000
-2.00	-2.125	0.000	0.000	0.000
-1.75	-1.875	0.000	0.000	0.000
-1.50	-1.625	0.079	0.125	0.125
-1.25	-1.375	0.097	0.154	0.279
-1.00	-1.125	0.168	0.266	0.545
-0.75	-0.875	0.326	0.517	1.062
-0.50	-0.625	0.826	1.309	2.370
-0.25	-0.375	1.179	1.868	4.239
0.00	-0.125	1.256	1.990	6.229
0.25	0.125	1.325	2.100	8.328
0.50	0.375	2.333	3.697	12.025
0.75	0.625	3.035	4.809	16.834
1.00	0.875	4.131	6.546	23.380
1.25	1.125	4.352	6.896	30.276
1.50	1.375	7.284	11.542	41.817
1.75	1.625	10.983	17.403	59.220
2.00	1.875	11.232	17.797	77.018
2.25	2.125	8.307	13.163	90.181
2.50	2.375	3.114	4.934	95.115
2.75	2.625	1.681	2.664	97.778
3.00	2.875	0.541	0.857	98.636
3.25	3.125	0.303	0.480	99.116
3.50	3.375	0.187	0.296	99.412
3.75	3.625	0.177	0.280	99.693
4.00	3.875	0.118	0.187	99.880

Statistical Results			
Mean:	1.4666	phi	(0.3618 mm)
Standard Dev:	0.8020	phi-units	(0.5736 mm)
Skewness:	-0.7135	dimensionless	
Kurtosis:	4.1338	dimensionless	
5th Moment:	-5.2993	dimensionless	
6th Moment:	30.2184	dimensionless	
RARD *	0.5469	dimensionless	
Median	1.4925	phi	(0.3554 mm)

* RARD = reciprocal absolute relative dispersion (see below)

Statistical Explanation

Calculations based on the Method of Moments

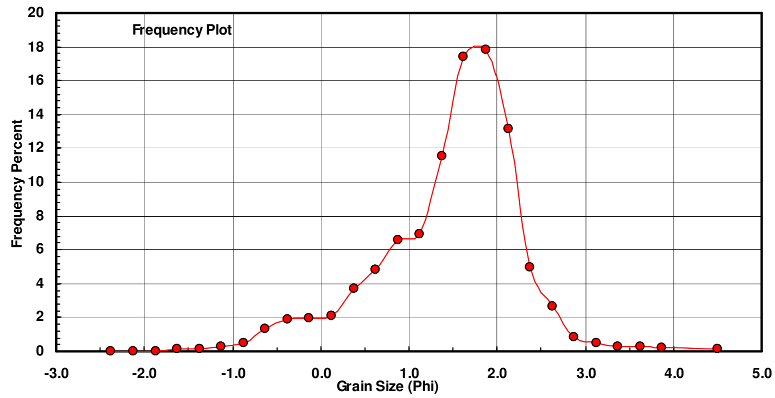
Skewness: 3rd Stand. Moment; Exact Gaussian = 0.0
Kurtosis: 4th Stand. Moment; Exact Gaussian = 3.0

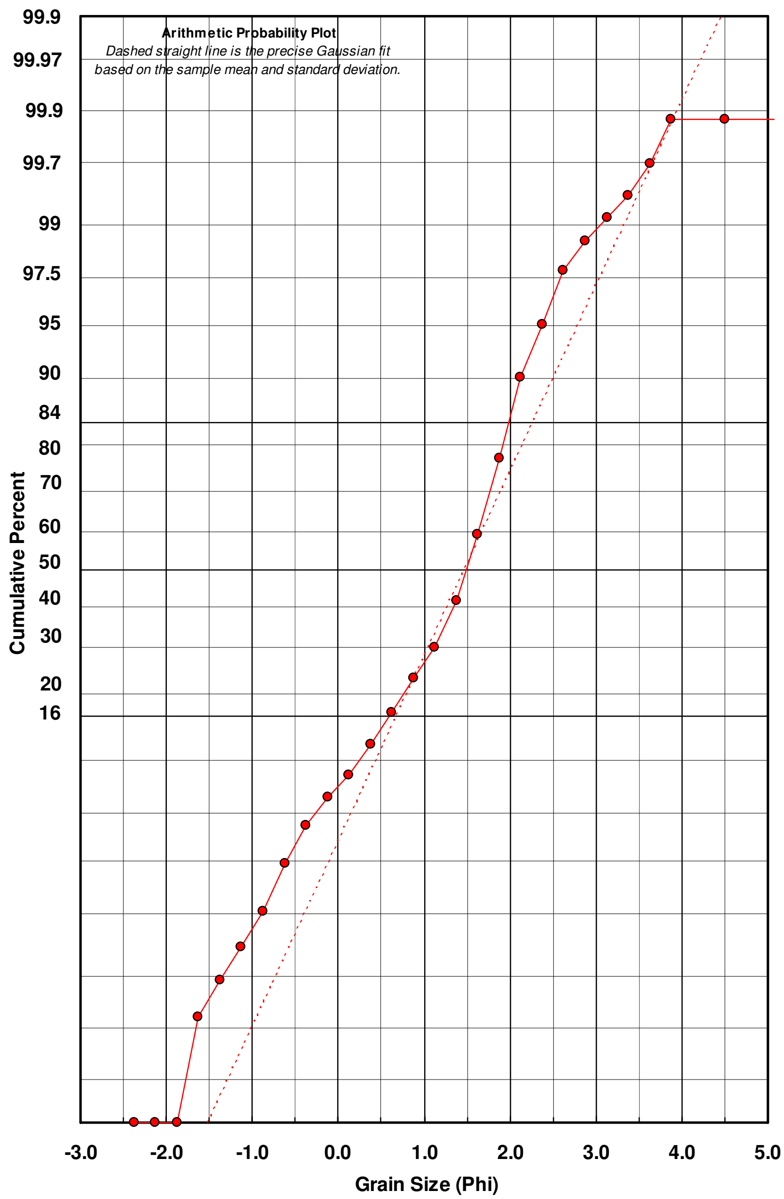
For Further Explanation, See Calculation Sheets

Millimeter data calculated by mm = 2^(-phi)

Reciprocal Absolute Relative Dispersion (RARD) Scale	
< 0.5	Excellent homogeneity (e.g., beaches)
0.5 to 1.0	Good homogeneity
1.0 to 1.33	Fair homogeneity
> 1.33	Poor homogeneity (e.g., glacial)

5.00	4.50	0.076	0.120	100.000





Pre-Digestion Grain Size Distribution

Onshore Grab Sample

Sample: CampbellA139

Total Sample Mass: 62.228 grams

Sieve Size (phi)	Sieve Midpt (phi)	Weight (grams)	Freq Weight %	Cumulative Weight %
-2.25	-2.375	0.220	0.354	0.354
-2.00	-2.125	0.000	0.000	0.354
-1.75	-1.875	0.113	0.182	0.535
-1.50	-1.625	0.214	0.344	0.879
-1.25	-1.375	0.111	0.178	1.057
-1.00	-1.125	0.530	0.852	1.909
-0.75	-0.875	0.629	1.011	2.920
-0.50	-0.625	1.103	1.773	4.692
-0.25	-0.375	1.439	2.312	7.005
0.00	-0.125	1.448	2.327	9.332
0.25	0.125	1.518	2.439	11.771
0.50	0.375	2.215	3.559	15.331
0.75	0.625	2.946	4.734	20.065
1.00	0.875	3.986	6.405	26.470
1.25	1.125	4.237	6.809	33.279
1.50	1.375	7.398	11.889	45.168
1.75	1.625	11.481	18.450	63.618
2.00	1.875	11.110	17.854	81.471
2.25	2.125	6.963	11.189	92.661
2.50	2.375	2.212	3.555	96.216
2.75	2.625	1.134	1.822	98.038
3.00	2.875	0.430	0.691	98.729
3.25	3.125	0.266	0.427	99.156
3.50	3.375	0.181	0.291	99.447
3.75	3.625	0.170	0.273	99.720
4.00	3.875	0.102	0.164	99.884

Statistical Results			
Mean:	1.3503	phi	(0.3922 mm)
Standard Dev:	0.8964	phi-units	(0.5372 mm)
Skewness:	-1.0156	dimensionless	
Kurtosis:	4.7636	dimensionless	
5th Moment:	-9.9710	dimensionless	
6th Moment:	43.7294	dimensionless	
RARD *	0.6638	dimensionless	
Median	1.4405	phi	(0.3684 mm)

* RARD = reciprocal absolute relative dispersion (see below)

Statistical Explanation

Calculations based on the Method of Moments

Skewness: 3rd Stand. Moment; Exact Gaussian = 0.0

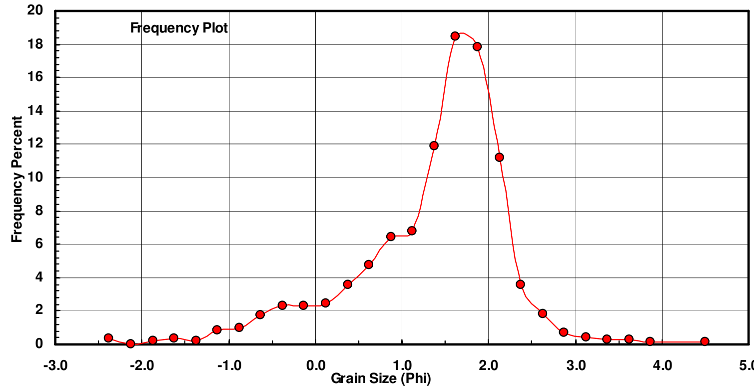
Kurtosis: 4th Stand. Moment; Exact Gaussian = 3.0

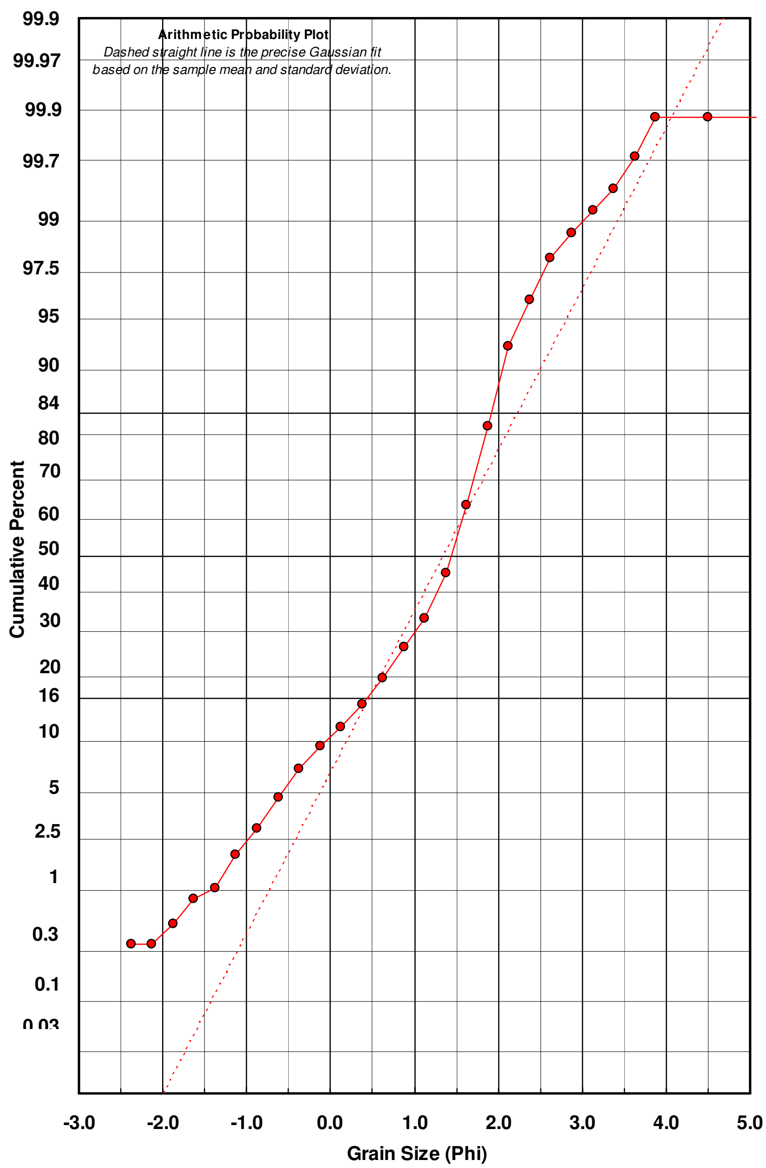
For Further Explanation, See Calculation Sheets

Millimeter data calculated by mm = 2^(-phi)

Reciprocal Absolute Relative Dispersion (RARD) Scale	
< 0.5	Excellent homogeneity (e.g., beaches)
0.5 to 1.0	Good homogeneity
1.0 to 1.33	Fair homogeneity
> 1.33	Poor homogeneity (e.g., glacial)

5.00	4.50	0.072	0.116	100.000





Pre-Digestion Grain Size Distribution

Onshore Grab Sample
Sample: CampbellA164
Total Sample Mass: 86.307 grams

Sieve Size (phi)	Sieve Midpt (phi)	Weight (grams)	Freq Weight %	Cumulative Weight %
-2.25	-2.375	0.000	0.000	0.000
-2.00	-2.125	0.000	0.000	0.000
-1.75	-1.875	0.076	0.088	0.088
-1.50	-1.625	0.042	0.049	0.137
-1.25	-1.375	0.254	0.294	0.431
-1.00	-1.125	0.273	0.316	0.747
-0.75	-0.875	0.253	0.293	1.040
-0.50	-0.625	0.532	0.616	1.657
-0.25	-0.375	0.893	1.035	2.692
0.00	-0.125	1.151	1.334	4.025
0.25	0.125	1.677	1.943	5.968
0.50	0.375	3.658	4.238	10.207
0.75	0.625	6.683	7.743	17.950
1.00	0.875	12.424	14.395	32.345
1.25	1.125	14.413	16.700	49.045
1.50	1.375	18.040	20.902	69.947
1.75	1.625	11.987	13.889	83.836
2.00	1.875	6.154	7.130	90.966
2.25	2.125	3.681	4.265	95.231
2.50	2.375	1.579	1.830	97.060
2.75	2.625	1.125	1.303	98.364
3.00	2.875	0.519	0.601	98.965
3.25	3.125	0.317	0.367	99.333
3.50	3.375	0.202	0.234	99.567
3.75	3.625	0.186	0.216	99.782
4.00	3.875	0.108	0.125	99.907

Statistical Results			
Mean:	1.2271	phi	(0.4272 mm)
Standard Dev:	0.6739	phi-units	(0.6268 mm)
Skewness:	-0.2132	dimensionless	
Kurtosis:	5.6804	dimensionless	
5th Moment:	-2.2758	dimensionless	
6th Moment:	64.5960	dimensionless	
RARD *	0.5491	dimensionless	
Median	1.1364	phi	(0.4549 mm)

* RARD = reciprocal absolute relative dispersion (see below)

Statistical Explanation

Calculations based on the Method of Moments

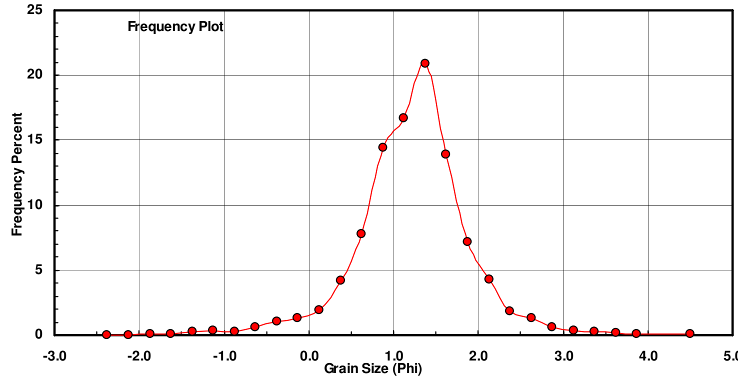
Skewness: 3rd Stand. Moment; Exact Gaussian = 0.0
Kurtosis: 4th Stand. Moment; Exact Gaussian = 3.0

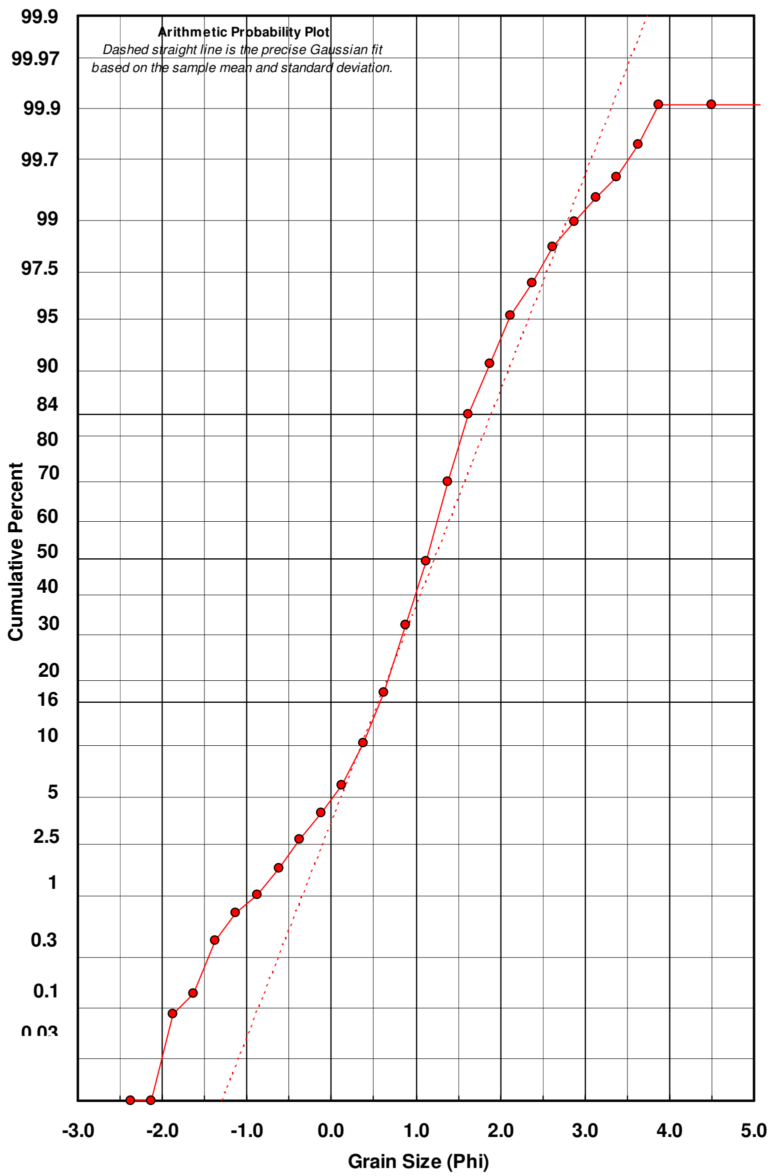
For Further Explanation, See Calculation Sheets

Millimeter data calculated by mm = 2^(-phi)

Reciprocal Absolute Relative Dispersion (RARD) Scale	
< 0.5	Excellent homogeneity (e.g., beaches)
0.5 to 1.0	Good homogeneity
1.0 to 1.33	Fair homogeneity
> 1.33	Poor homogeneity (e.g., glacial)

5.00	4.50	0.080	0.093	100.000





Pre-Digestion Grain Size Distribution

Onshore Grab Sample

Sample: EAFB-A1A

Total Sample Mass: 62.703 grams

Sieve Size (phi)	Sieve Midpt (phi)	Weight (grams)	Freq Weight %	Cumulative Weight %
-2.25	-2.375	0.000	0.000	0.000
-2.00	-2.125	0.000	0.000	0.000
-1.75	-1.875	0.000	0.000	0.000
-1.50	-1.625	0.000	0.000	0.000
-1.25	-1.375	0.000	0.000	0.000
-1.00	-1.125	0.000	0.000	0.000
-0.75	-0.875	0.016	0.026	0.026
-0.50	-0.625	0.090	0.144	0.169
-0.25	-0.375	0.467	0.745	0.914
0.00	-0.125	0.943	1.504	2.418
0.25	0.125	1.472	2.348	4.765
0.50	0.375	4.018	6.408	11.173
0.75	0.625	10.361	16.524	27.697
1.00	0.875	18.250	29.105	56.803
1.25	1.125	13.518	21.559	78.361
1.50	1.375	7.108	11.336	89.697
1.75	1.625	2.760	4.402	94.099
2.00	1.875	1.182	1.885	95.984
2.25	2.125	0.693	1.105	97.089
2.50	2.375	0.485	0.773	97.863
2.75	2.625	0.581	0.927	98.790
3.00	2.875	0.234	0.373	99.163
3.25	3.125	0.167	0.266	99.429
3.50	3.375	0.105	0.167	99.597
3.75	3.625	0.099	0.158	99.754
4.00	3.875	0.064	0.102	99.856
5.00	4.50	0.090	0.144	100.000

Statistical Results			
Mean:	0.9914	phi	(0.503 mm)
Standard Dev:	0.5372	phi-units	(0.6891 mm)
Skewness:	1.3786	dimensionless	
Kurtosis:	9.0473	dimensionless	
5th Moment:	35.9569	dimensionless	
6th Moment:	207.5134	dimensionless	
RARD *	0.5419	dimensionless	
Median	0.8166	phi	(0.5678 mm)

* RARD = reciprocal absolute relative dispersion (see below)

Statistical Explanation

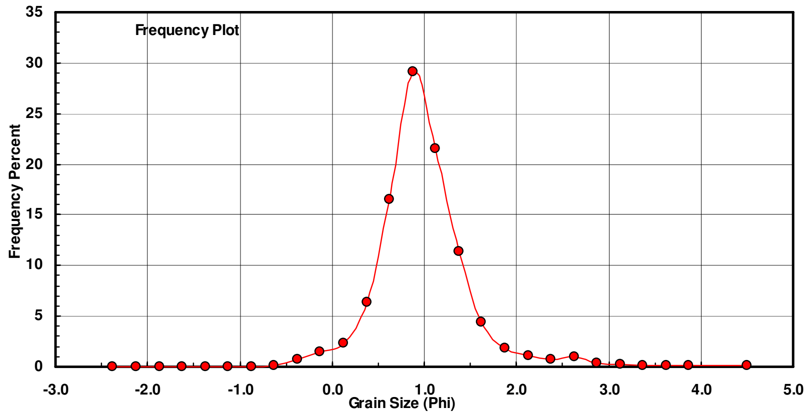
Calculations based on the Method of Moments

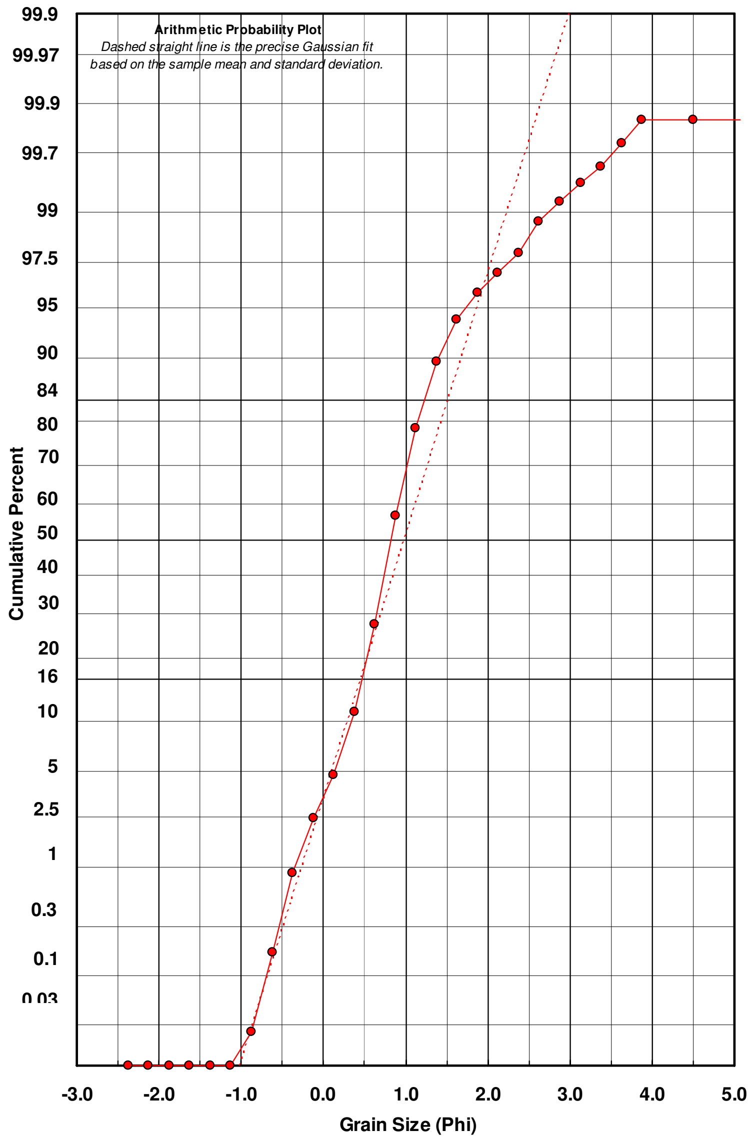
Skewness: 3rd Stand. Moment; Exact Gaussian = 0.0
Kurtosis: 4th Stand. Moment; Exact Gaussian = 3.0

For Further Explanation, See Calculation Sheets

Millimeter data calculated by mm = 2^(-phi)

Reciprocal Absolute Relative Dispersion (RARD) Scale	
< 0.5	Excellent homogeneity (e.g., beaches)
0.5 to 1.0	Good homogeneity
1.0 to 1.33	Fair homogeneity
> 1.33	Poor homogeneity (e.g., glacial)


Frequency Plot
Frequency Percent
35
30
25
20
15
10
5
0
-3.0
-2.0
-1.0
0.0
1.0
2.0
3.0
4.0
5.0
Grain Size (Phi)


Arithmetic Probability Plot
Dashed straight line is the precise Gaussian fit
based on the sample mean and standard deviation.
Cumulative Percent
99.9
99.97
99.9
99.7
99
97.5
95
90
84
80
70
60
50
40
30
20
16
10
5
2.5
1
0.3
0.1
0.03
-3.0
-2.0
-1.0
0.0
1.0
2.0
3.0
4.0
5.0
Grain Size (Phi)

EAFB A1A

Pre-Digestion Grain Size Distribution

Onshore Grab Sample
Sample: EAFB-A1B
Total Sample Mass: 70.587 grams

Sieve Size (phi)	Sieve Midpt (phi)	Weight (grams)	Freq Weight %	Cumulative Weight %
-2.25	-2.375	0.000	0.000	0.000
-2.00	-2.125	0.000	0.000	0.000
-1.75	-1.875	0.000	0.000	0.000
-1.50	-1.625	0.000	0.000	0.000
-1.25	-1.375	0.000	0.000	0.000
-1.00	-1.125	0.000	0.000	0.000
-0.75	-0.875	0.029	0.041	0.041
-0.50	-0.625	0.058	0.082	0.123
-0.25	-0.375	0.169	0.239	0.363
0.00	-0.125	0.603	0.854	1.217
0.25	0.125	1.480	2.097	3.314
0.50	0.375	5.721	8.105	11.419
0.75	0.625	14.164	20.066	31.485
1.00	0.875	21.161	29.979	61.463
1.25	1.125	13.975	19.798	81.261
1.50	1.375	6.313	8.944	90.205
1.75	1.625	2.530	3.584	93.789
2.00	1.875	1.153	1.633	95.423
2.25	2.125	0.896	1.269	96.692
2.50	2.375	0.610	0.864	97.556
2.75	2.625	0.551	0.781	98.337
3.00	2.875	0.333	0.472	98.809
3.25	3.125	0.291	0.412	99.221
3.50	3.375	0.175	0.248	99.469
3.75	3.625	0.152	0.215	99.684
4.00	3.875	0.099	0.140	99.824

Statistical Results			
Mean:	0.9764	phi	(0.5082 mm)
Standard Dev:	0.5436	phi-units	(0.686 mm)
Skewness:	1.9023	dimensionless	
Kurtosis:	10.3907	dimensionless	
5th Moment:	45.8478	dimensionless	
6th Moment:	250.3612	dimensionless	
RARD *	0.5568	dimensionless	
Median	0.7794	phi	(0.5826 mm)

* RARD = reciprocal absolute relative dispersion (see below)

Statistical Explanation

Calculations based on the Method of Moments

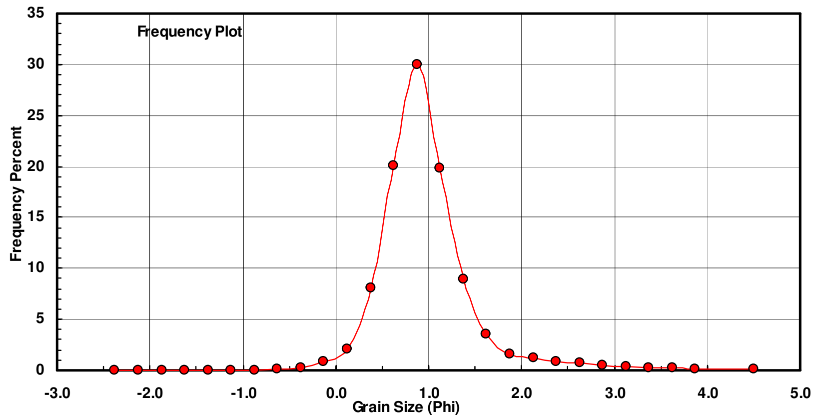
Skewness: 3rd Stand. Moment; Exact Gaussian = 0.0
Kurtosis: 4th Stand. Moment; Exact Gaussian = 3.0

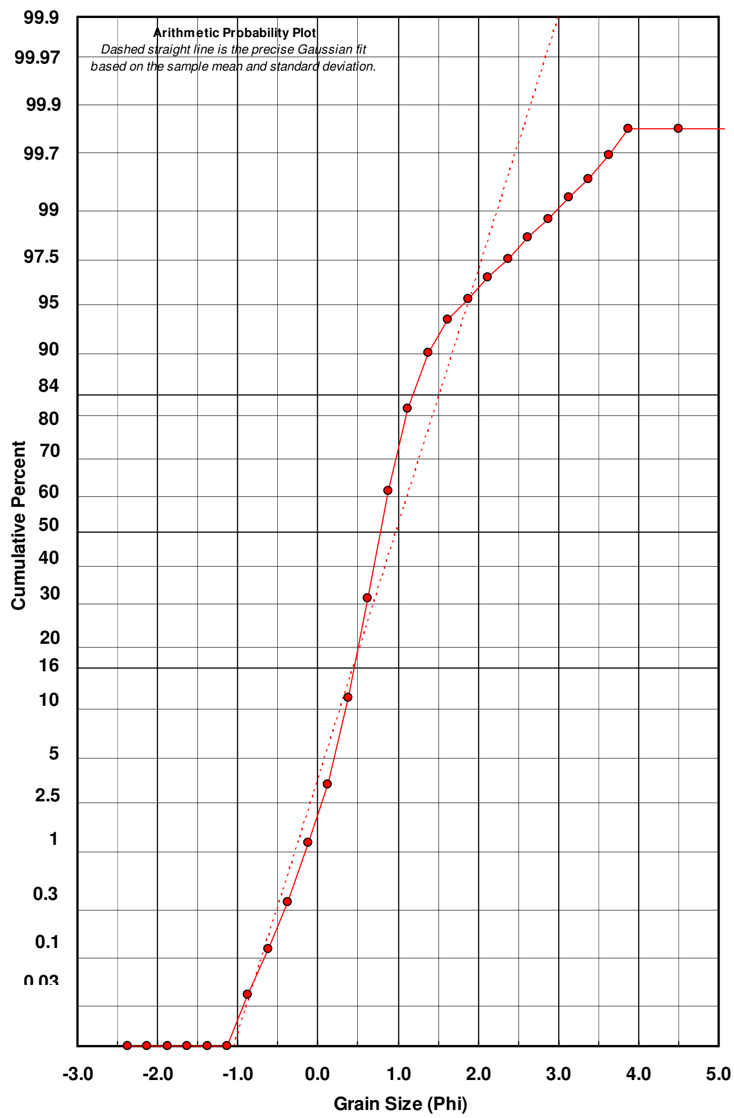
For Further Explanation, See Calculation Sheets

Millimeter data calculated by mm = 2^(-phi)

Reciprocal Absolute Relative Dispersion (RARD) Scale	
< 0.5	Excellent homogeneity (e.g., beaches)
0.5 to 1.0	Good homogeneity
1.0 to 1.33	Fair homogeneity
> 1.33	Poor homogeneity (e.g., glacial)

5.00	4.50	0.124	0.176	100.000





Pre-Digestion Grain Size Distribution

Onshore Grab Sample
Sample: EAFB-A1C
Total Sample Mass: 56.570 grams

Sieve Size (phi)	Sieve Midpt (phi)	Weight (grams)	Freq Weight %	Cumulative Weight %
-2.25	-2.375	0.000	0.000	0.000
-2.00	-2.125	0.000	0.000	0.000
-1.75	-1.875	0.000	0.000	0.000
-1.50	-1.625	0.000	0.000	0.000
-1.25	-1.375	0.000	0.000	0.000
-1.00	-1.125	0.000	0.000	0.000
-0.75	-0.875	0.055	0.097	0.097
-0.50	-0.625	0.101	0.179	0.276
-0.25	-0.375	0.456	0.806	1.082
0.00	-0.125	0.849	1.501	2.583
0.25	0.125	1.388	2.454	5.036
0.50	0.375	3.527	6.235	11.271
0.75	0.625	7.331	12.959	24.230
1.00	0.875	9.898	17.497	41.727
1.25	1.125	6.991	12.358	54.085
1.50	1.375	4.485	7.928	62.013
1.75	1.625	3.477	6.146	68.160
2.00	1.875	3.364	5.947	74.106
2.25	2.125	4.360	7.707	81.814
2.50	2.375	3.657	6.465	88.278
2.75	2.625	3.507	6.199	94.478
3.00	2.875	1.599	2.827	97.304
3.25	3.125	0.696	1.230	98.535
3.50	3.375	0.320	0.566	99.100
3.75	3.625	0.256	0.453	99.553
4.00	3.875	0.156	0.276	99.829

Statistical Results			
Mean:	1.3668	phi	(0.3878 mm)
Standard Dev:	0.8441	phi-units	(0.5571 mm)
Skewness:	0.4902	dimensionless	
Kurtosis:	2.7467	dimensionless	
5th Moment:	3.4124	dimensionless	
6th Moment:	14.3699	dimensionless	
RARD *	0.6176	dimensionless	
Median	1.0424	phi	(0.4855 mm)

* RARD = reciprocal absolute relative dispersion (see below)

Statistical Explanation

Calculations based on the Method of Moments

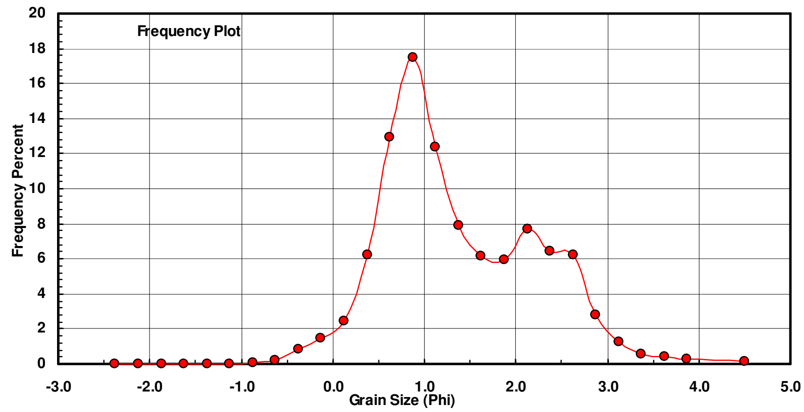
Skewness: 3rd Stand. Moment; Exact Gaussian = 0.0
Kurtosis: 4th Stand. Moment; Exact Gaussian = 3.0

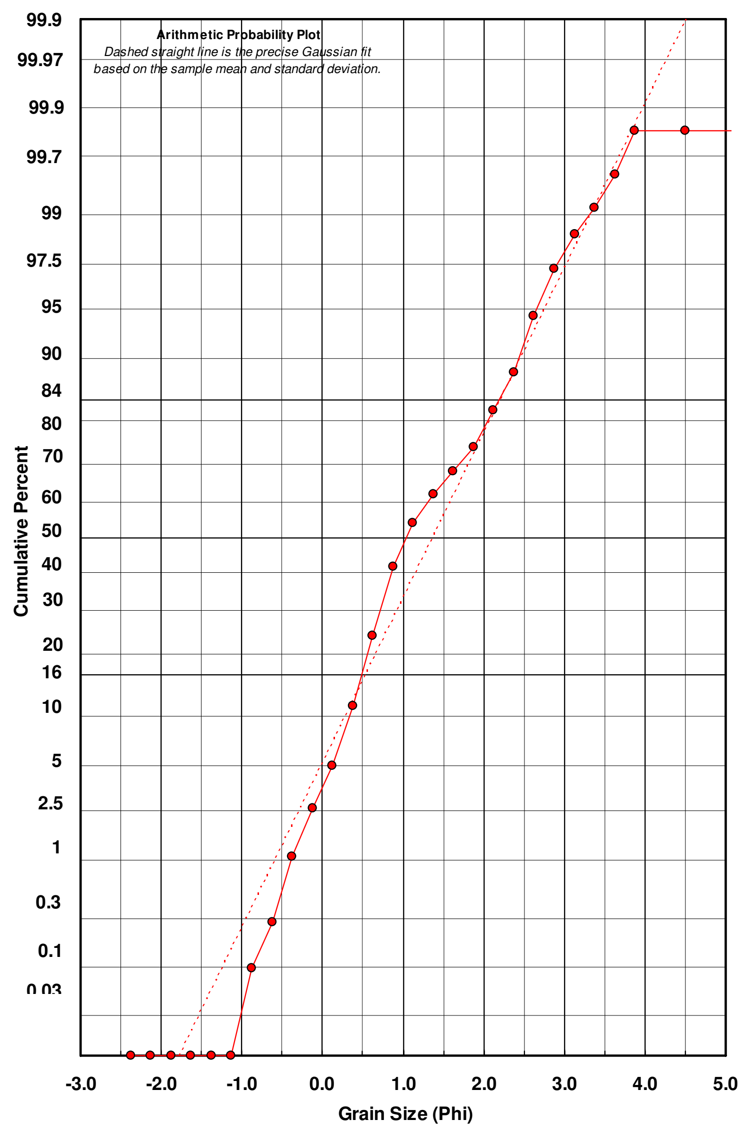
For Further Explanation, See Calculation Sheets

Millimeter data calculated by mm = 2^(-phi)

Reciprocal Absolute Relative Dispersion (RARD) Scale	
< 0.5	Excellent homogeneity (e.g., beaches)
0.5 to 1.0	Good homogeneity
1.0 to 1.33	Fair homogeneity
> 1.33	Poor homogeneity (e.g., glacial)

5.00	4.50	0.097	0.171	100.000





Pre-Digestion Grain Size Distribution

Onshore Grab Sample
Sample: EAFB-A2B
Total Sample Mass: 102.174 grams

Sieve Size (phi)	Sieve Midpt (phi)	Weight (grams)	Freq Weight %	Cumulative Weight %
-2.25	-2.375	0.000	0.000	0.000
-2.00	-2.125	0.000	0.000	0.000
-1.75	-1.875	0.000	0.000	0.000
-1.50	-1.625	0.027	0.026	0.026
-1.25	-1.375	0.054	0.053	0.079
-1.00	-1.125	0.000	0.000	0.079
-0.75	-0.875	0.089	0.087	0.166
-0.50	-0.625	0.104	0.102	0.268
-0.25	-0.375	0.448	0.438	0.707
0.00	-0.125	0.930	0.910	1.617
0.25	0.125	1.929	1.888	3.505
0.50	0.375	4.932	4.827	8.332
0.75	0.625	8.958	8.767	17.099
1.00	0.875	12.659	12.390	29.489
1.25	1.125	12.795	12.523	42.012
1.50	1.375	14.746	14.432	56.444
1.75	1.625	14.444	14.137	70.581
2.00	1.875	11.539	11.293	81.874
2.25	2.125	8.973	8.782	90.656
2.50	2.375	4.396	4.302	94.959
2.75	2.625	2.809	2.749	97.708
3.00	2.875	1.018	0.996	98.704
3.25	3.125	0.502	0.491	99.195
3.50	3.375	0.278	0.272	99.468
3.75	3.625	0.239	0.234	99.701
4.00	3.875	0.170	0.166	99.868

Statistical Results			
Mean:	1.3942	phi	(0.3805 mm)
Standard Dev:	0.6891	phi-units	(0.6202 mm)
Skewness:	0.2092	dimensionless	
Kurtosis:	3.7533	dimensionless	
5th Moment:	3.2720	dimensionless	
6th Moment:	32.4288	dimensionless	
RARD *	0.4943	dimensionless	
Median	1.2634	phi	(0.4166 mm)

* RARD = reciprocal absolute relative dispersion (see below)

Statistical Explanation

Calculations based on the Method of Moments

Skewness: 3rd Stand. Moment; Exact Gaussian = 0.0

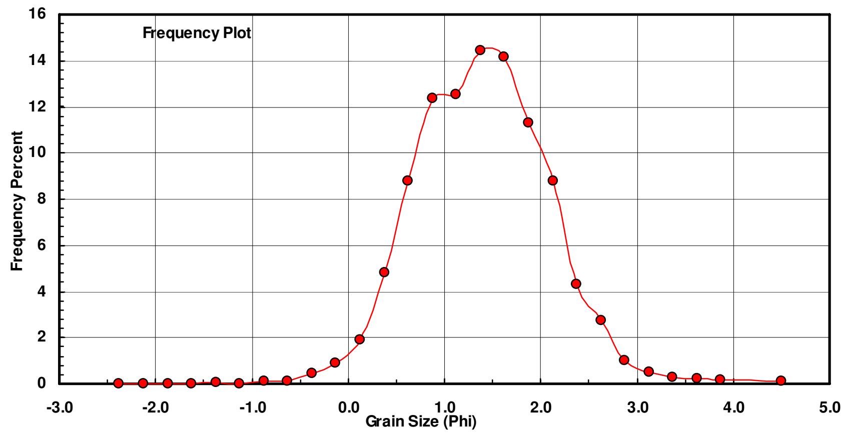
Kurtosis: 4th Stand. Moment; Exact Gaussian = 3.0

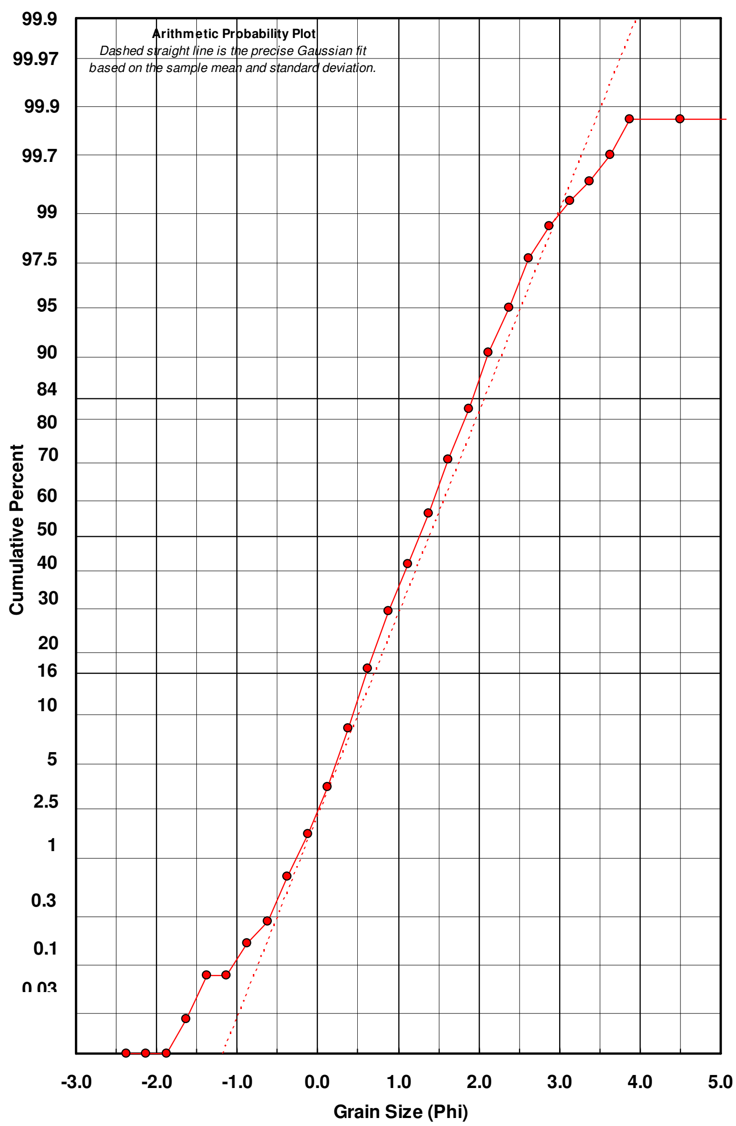
For Further Explanation, See Calculation Sheets

Millimeter data calculated by mm = 2^(-phi)

Reciprocal Absolute Relative Dispersion (RARD) Scale	
< 0.5	Excellent homogeneity (e.g., beaches)
0.5 to 1.0	Good homogeneity
1.0 to 1.33	Fair homogeneity
> 1.33	Poor homogeneity (e.g., glacial)

5.00	4.50	0.135	0.132	100.000





Pre-Digestion Grain Size Distribution

Onshore Grab Sample

Sample: EAFB-A3A

Total Sample Mass: 83.089 grams

Sieve Size (phi)	Sieve Midpt (phi)	Weight (grams)	Freq Weight %	Cumulative Weight %
-2.25	-2.375	0.000	0.000	0.000
-2.00	-2.125	0.000	0.000	0.000
-1.75	-1.875	0.000	0.000	0.000
-1.50	-1.625	0.018	0.022	0.022
-1.25	-1.375	0.075	0.090	0.112
-1.00	-1.125	0.298	0.359	0.471
-0.75	-0.875	0.863	1.039	1.509
-0.50	-0.625	2.764	3.327	4.836
-0.25	-0.375	5.938	7.147	11.982
0.00	-0.125	8.333	10.029	22.011
0.25	0.125	8.931	10.749	32.760
0.50	0.375	12.474	15.013	47.773
0.75	0.625	11.351	13.661	61.434
1.00	0.875	8.649	10.409	71.843
1.25	1.125	5.416	6.518	78.362
1.50	1.375	4.467	5.376	83.738
1.75	1.625	3.497	4.209	87.947
2.00	1.875	2.831	3.407	91.354
2.25	2.125	2.763	3.325	94.679
2.50	2.375	1.703	2.050	96.729
2.75	2.625	1.359	1.636	98.364
3.00	2.875	0.531	0.639	99.003
3.25	3.125	0.290	0.349	99.353
3.50	3.375	0.179	0.215	99.568
3.75	3.625	0.175	0.211	99.779
4.00	3.875	0.112	0.135	99.913

Statistical Results			
Mean:	0.6665	phi	(0.63 mm)
Standard Dev:	0.8546	phi-units	(0.553 mm)
Skewness:	0.7645	dimensionless	
Kurtosis:	3.6459	dimensionless	
5th Moment:	7.3128	dimensionless	
6th Moment:	27.3480	dimensionless	
RARD *	1.2822	dimensionless	
Median	0.4158	phi	(0.7496 mm)

* RARD = reciprocal absolute relative dispersion (see below)

Statistical Explanation

Calculations based on the Method of Moments

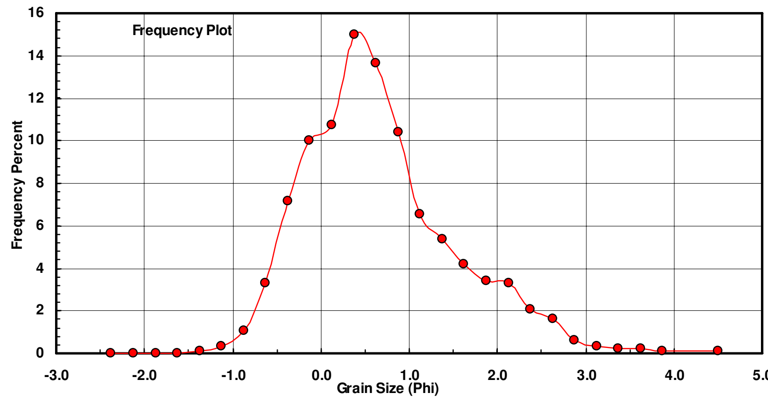
Skewness: 3rd Stand. Moment; Exact Gaussian = 0.0
Kurtosis: 4th Stand. Moment; Exact Gaussian = 3.0

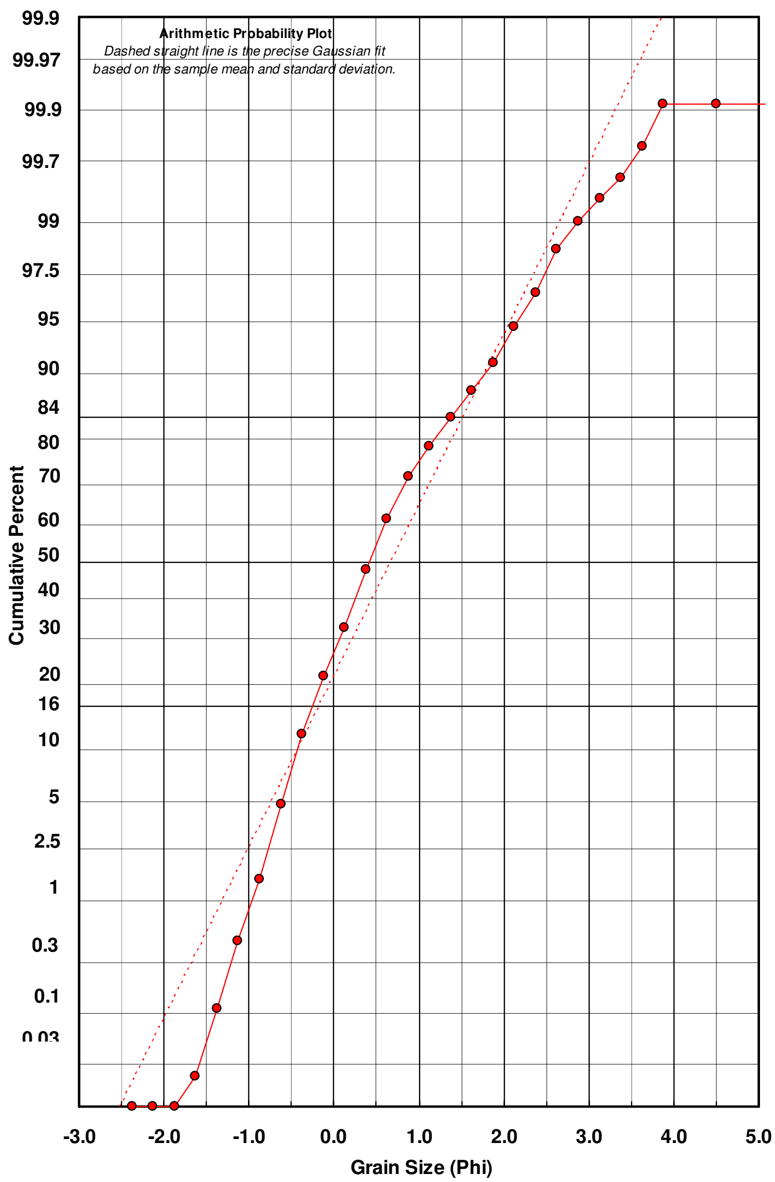
For Further Explanation, See Calculation Sheets

Millimeter data calculated by mm = 2^(-phi)

Reciprocal Absolute Relative Dispersion (RARD) Scale	
< 0.5	Excellent homogeneity (e.g., beaches)
0.5 to 1.0	Good homogeneity
1.0 to 1.33	Fair homogeneity
> 1.33	Poor homogeneity (e.g., glacial)

5.00	4.50	0.072	0.087	100.000





Pre-Digestion Grain Size Distribution

Onshore Grab Sample
Sample: EAFB-A3B
Total Sample Mass: 82.618 grams

Sieve Size (phi)	Sieve Midpt (phi)	Weight (grams)	Freq Weight %	Cumulative Weight %
-2.25	-2.375	0.000	0.000	0.000
-2.00	-2.125	0.000	0.000	0.000
-1.75	-1.875	0.128	0.155	0.155
-1.50	-1.625	0.087	0.105	0.260
-1.25	-1.375	0.082	0.099	0.359
-1.00	-1.125	0.064	0.077	0.437
-0.75	-0.875	0.289	0.350	0.787
-0.50	-0.625	0.736	0.891	1.678
-0.25	-0.375	1.965	2.378	4.056
0.00	-0.125	3.242	3.924	7.980
0.25	0.125	4.522	5.473	13.453
0.50	0.375	7.942	9.613	23.066
0.75	0.625	9.432	11.416	34.483
1.00	0.875	7.861	9.515	43.998
1.25	1.125	4.975	6.022	50.019
1.50	1.375	3.989	4.828	54.848
1.75	1.625	3.955	4.787	59.635
2.00	1.875	5.356	6.483	66.118
2.25	2.125	9.029	10.929	77.046
2.50	2.375	7.700	9.320	86.366
2.75	2.625	6.956	8.419	94.786
3.00	2.875	2.488	3.011	97.797
3.25	3.125	0.827	1.001	98.798
3.50	3.375	0.356	0.431	99.229
3.75	3.625	0.304	0.368	99.597

Statistical Results			
Mean:	1.3386	phi	(0.3954 mm)
Standard Dev:	1.0038	phi-units	(0.4987 mm)
Skewness:	-0.0092	dimensionless	
Kurtosis:	2.2518	dimensionless	
5th Moment:	-0.2627	dimensionless	
6th Moment:	9.4160	dimensionless	
RARD *	0.7499	dimensionless	
Median	1.1242	phi	(0.4588 mm)

* RARD = reciprocal absolute relative dispersion (see below)

Statistical Explanation

Calculations based on the Method of Moments

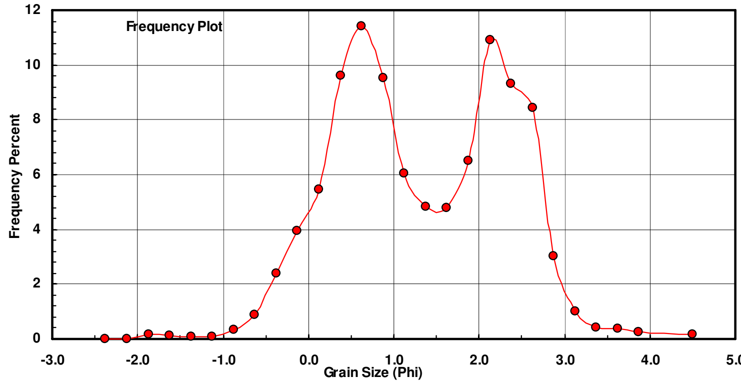
Skewness: 3rd Stand. Moment; Exact Gaussian = 0.0
Kurtosis: 4th Stand. Moment; Exact Gaussian = 3.0

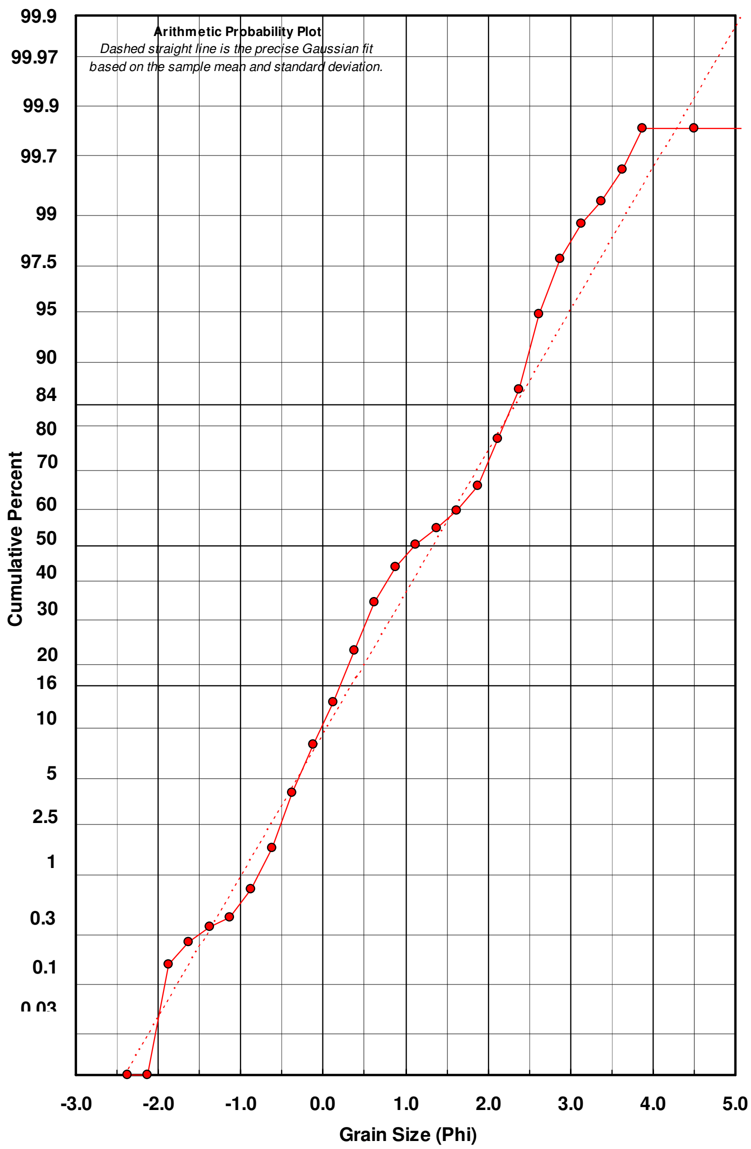
For Further Explanation, See Calculation Sheets

Millimeter data calculated by mm = 2^(-phi)

Reciprocal Absolute Relative Dispersion (RARD) Scale	
< 0.5	Excellent homogeneity (e.g., beaches)
0.5 to 1.0	Good homogeneity
1.0 to 1.33	Fair homogeneity
> 1.33	Poor homogeneity (e.g., glacial)

4.00	3.875	0.198	0.240	99.837
5.00	4.50	0.135	0.163	100.000





Pre-Digestion Grain Size Distribution

Onshore Grab Sample
Sample: EAFB-B1
Total Sample Mass: 62.088 grams

Sieve Size (phi)	Sieve Midpt (phi)	Weight (grams)	Freq Weight %	Cumulative Weight %
-2.25	-2.375	0.000	0.000	0.000
-2.00	-2.125	0.000	0.000	0.000
-1.75	-1.875	0.000	0.000	0.000
-1.50	-1.625	0.000	0.000	0.000
-1.25	-1.375	0.000	0.000	0.000
-1.00	-1.125	0.019	0.031	0.031
-0.75	-0.875	0.087	0.140	0.171
-0.50	-0.625	0.572	0.921	1.092
-0.25	-0.375	2.955	4.759	5.851
0.00	-0.125	5.789	9.324	15.175
0.25	0.125	8.507	13.702	28.877
0.50	0.375	14.363	23.133	52.010
0.75	0.625	13.469	21.693	73.703
1.00	0.875	8.080	13.014	86.717
1.25	1.125	3.432	5.528	92.245
1.50	1.375	1.800	2.899	95.144
1.75	1.625	1.012	1.630	96.774
2.00	1.875	0.593	0.955	97.729
2.25	2.125	0.433	0.697	98.426
2.50	2.375	0.238	0.383	98.810
2.75	2.625	0.248	0.399	99.209
3.00	2.875	0.157	0.253	99.462
3.25	3.125	0.115	0.185	99.647
3.50	3.375	0.076	0.122	99.770
3.75	3.625	0.076	0.122	99.892
4.00	3.875	0.047	0.076	99.968

Statistical Results			
Mean:	0.5234	phi	(0.6957 mm)
Standard Dev:	0.5767	phi-units	(0.6705 mm)
Skewness:	1.3878	dimensionless	
Kurtosis:	7.8669	dimensionless	
5th Moment:	31.2804	dimensionless	
6th Moment:	162.5063	dimensionless	
RARD *	1.1020	dimensionless	
Median	0.3533	phi	(0.7828 mm)

* RARD = reciprocal absolute relative dispersion (see below)

Statistical Explanation

Calculations based on the Method of Moments

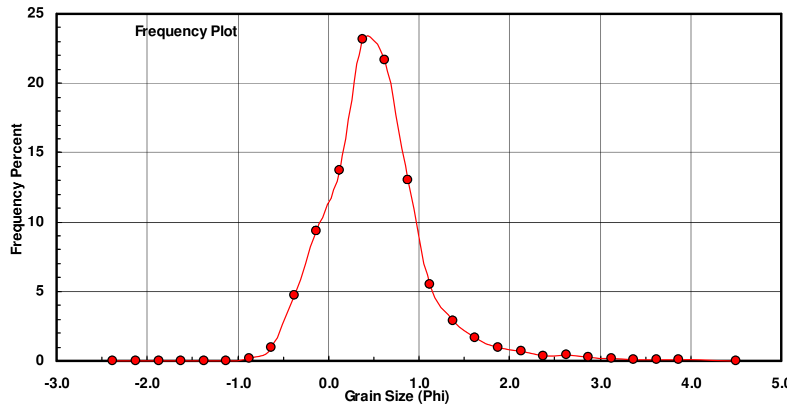
Skewness: 3rd Stand. Moment; Exact Gaussian = 0.0
Kurtosis: 4th Stand. Moment; Exact Gaussian = 3.0

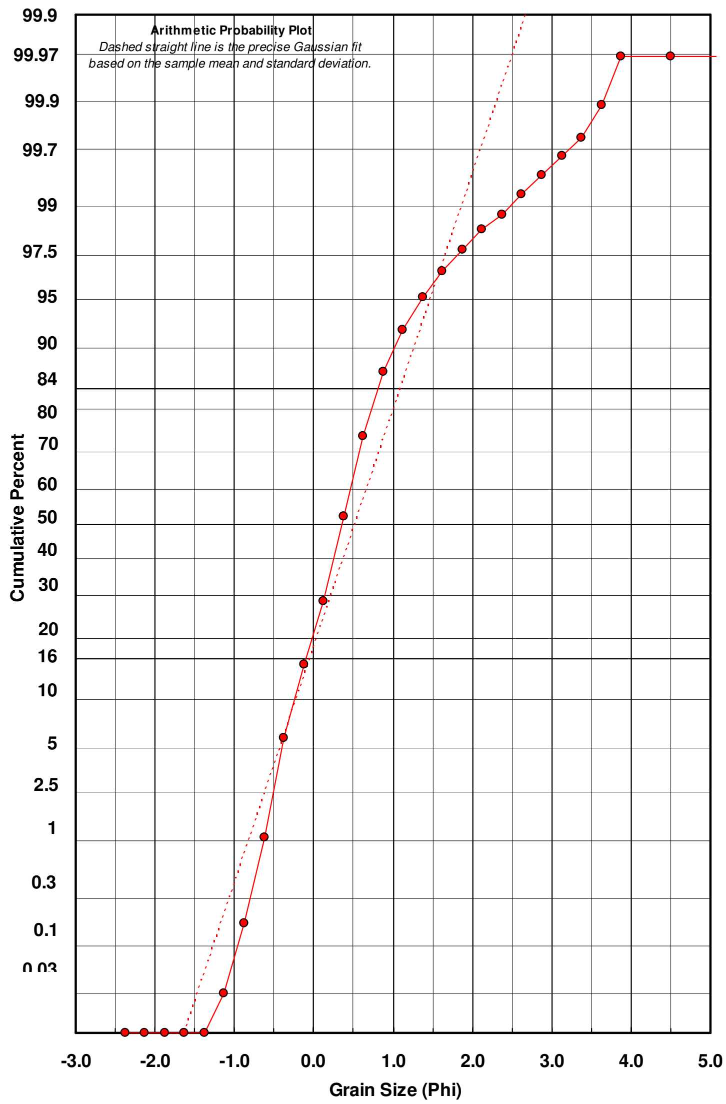
For Further Explanation, See Calculation Sheets

Millimeter data calculated by mm = 2^(-phi)

Reciprocal Absolute Relative Dispersion (RARD) Scale	
< 0.5	Excellent homogeneity (e.g., beaches)
0.5 to 1.0	Good homogeneity
1.0 to 1.33	Fair homogeneity
> 1.33	Poor homogeneity (e.g., glacial)

5.00	4.50	0.020	0.032	100.000





Pre-Digestion Grain Size Distribution

Onshore Grab Sample

Sample: EAFB-B2

Total Sample Mass: 84.401 grams

Sieve Size (phi)	Sieve Midpt (phi)	Weight (grams)	Freq Weight %	Cumulative Weight %
-2.25	-2.375	0.000	0.000	0.000
-2.00	-2.125	0.100	0.118	0.118
-1.75	-1.875	0.000	0.000	0.118
-1.50	-1.625	0.000	0.000	0.118
-1.25	-1.375	0.167	0.198	0.316
-1.00	-1.125	0.270	0.320	0.636
-0.75	-0.875	0.523	0.620	1.256
-0.50	-0.625	1.859	2.203	3.458
-0.25	-0.375	4.505	5.338	8.796
0.00	-0.125	6.044	7.161	15.957
0.25	0.125	6.516	7.720	23.677
0.50	0.375	10.755	12.743	36.420
0.75	0.625	12.067	14.297	50.717
1.00	0.875	10.532	12.479	63.196
1.25	1.125	7.740	9.171	72.366
1.50	1.375	6.944	8.227	80.594
1.75	1.625	6.063	7.184	87.777
2.00	1.875	4.396	5.208	92.986
2.25	2.125	2.954	3.500	96.486
2.50	2.375	1.180	1.398	97.884
2.75	2.625	0.761	0.902	98.786
3.00	2.875	0.349	0.414	99.199
3.25	3.125	0.236	0.280	99.479
3.50	3.375	0.152	0.180	99.659
3.75	3.625	0.148	0.175	99.834
4.00	3.875	0.095	0.113	99.947
5.00	4.50	0.045	0.053	100.000

Statistical Results			
Mean:	0.8007	phi	(0.5741 mm)
Standard Dev:	0.8052	phi-units	(0.5723 mm)
Skewness:	0.3338	dimensionless	
Kurtosis:	3.4794	dimensionless	
5th Moment:	3.8415	dimensionless	
6th Moment:	25.8966	dimensionless	
RARD *	1.0055	dimensionless	
Median	0.6125	phi	(0.6541 mm)

* RARD = reciprocal absolute relative dispersion (see below)

Statistical Explanation

Calculations based on the Method of Moments

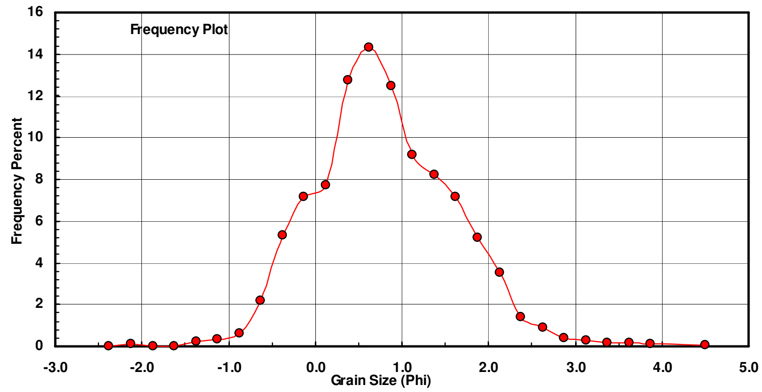
Skewness: 3rd Stand. Moment; Exact Gaussian = 0.0

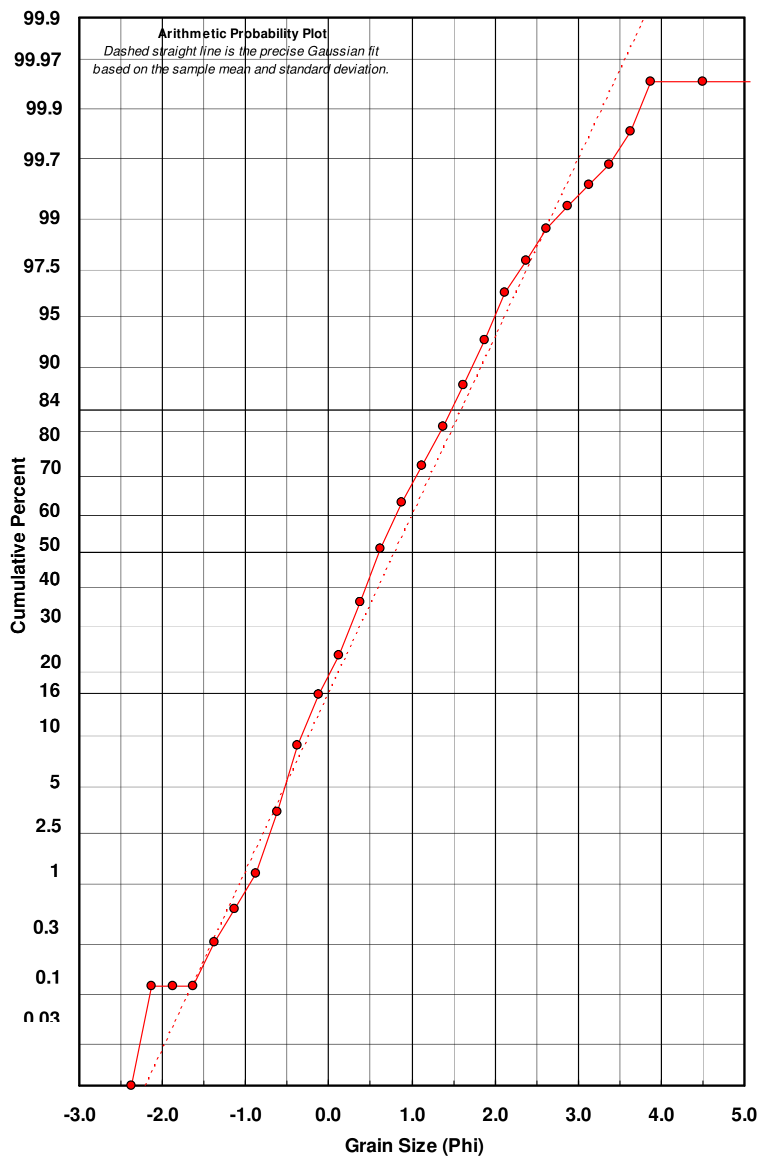
Kurtosis: 4th Stand. Moment; Exact Gaussian = 3.0

For Further Explanation, See Calculation Sheets

Millimeter data calculated by mm = 2^(-phi)

Reciprocal Absolute Relative Dispersion (RARD) Scale	
< 0.5	Excellent homogeneity (e.g., beaches)
0.5 to 1.0	Good homogeneity
1.0 to 1.33	Fair homogeneity
> 1.33	Poor homogeneity (e.g., glacial)


Frequency Plot
Frequency Percent
Grain Size (Phi)


Arithmetic Probability Plot
Dashed straight line is the precise Gaussian fit based on the sample mean and standard deviation.
Cumulative Percent
Grain Size (Phi)

EAFB B2

Pre-Digestion Grain Size Distribution

Onshore Grab Sample

Sample: EAFB-C

Total Sample Mass: 90.665 grams

Sieve Size (phi)	Sieve Midpt (phi)	Weight (grams)	Freq Weight %	Cumulative Weight %
-2.25	-2.375	0.000	0.000	0.000
-2.00	-2.125	0.000	0.000	0.000
-1.75	-1.875	0.000	0.000	0.000
-1.50	-1.625	0.000	0.000	0.000
-1.25	-1.375	0.030	0.033	0.033
-1.00	-1.125	0.000	0.000	0.033
-0.75	-0.875	0.006	0.007	0.040
-0.50	-0.625	0.000	0.000	0.040
-0.25	-0.375	0.115	0.127	0.167
0.00	-0.125	0.403	0.444	0.611
0.25	0.125	0.821	0.906	1.517
0.50	0.375	2.318	2.557	4.073
0.75	0.625	4.548	5.016	9.090
1.00	0.875	6.899	7.609	16.699
1.25	1.125	8.184	9.027	25.725
1.50	1.375	10.987	12.118	37.844
1.75	1.625	13.693	15.103	52.947
2.00	1.875	13.181	14.538	67.485
2.25	2.125	11.711	12.917	80.401
2.50	2.375	6.301	6.950	87.351
2.75	2.625	4.761	5.251	92.602
3.00	2.875	2.295	2.531	95.134
3.25	3.125	1.463	1.614	96.747
3.50	3.375	0.945	1.042	97.790
3.75	3.625	0.942	1.039	98.829
4.00	3.875	0.653	0.720	99.549

Statistical Results			
Mean:	1.7149	phi	(0.3046 mm)
Standard Dev:	0.7481	phi-units	(0.5954 mm)
Skewness:	0.3923	dimensionless	
Kurtosis:	3.8030	dimensionless	
5th Moment:	4.8015	dimensionless	
6th Moment:	27.5688	dimensionless	
RARD *	0.4362	dimensionless	
Median	1.5762	phi	(0.3354 mm)

* RARD = reciprocal absolute relative dispersion (see below)

Statistical Explanation

Calculations based on the Method of Moments

Skewness: 3rd Stand. Moment; Exact Gaussian = 0.0

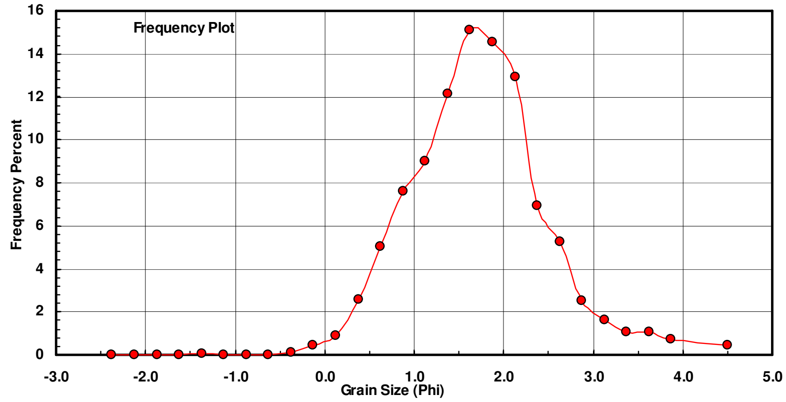
Kurtosis: 4th Stand. Moment; Exact Gaussian = 3.0

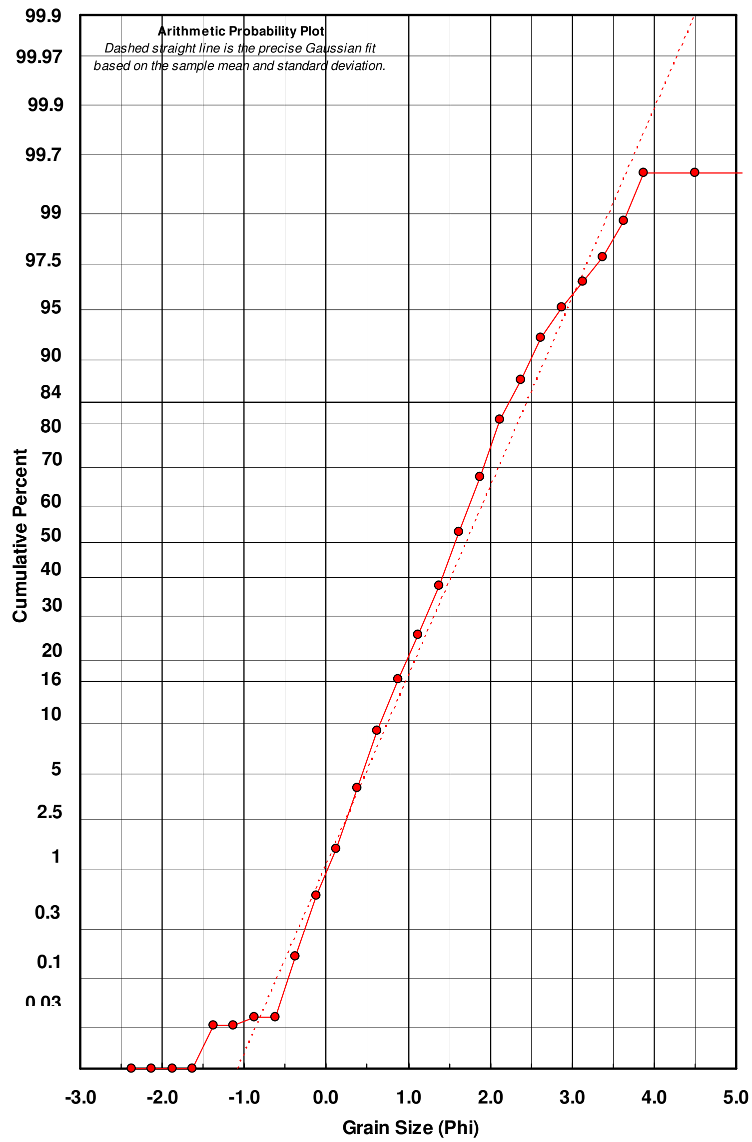
For Further Explanation, See Calculation Sheets

Millimeter data calculated by mm = 2^(-phi)

Reciprocal Absolute Relative Dispersion (RARD) Scale	
< 0.5	Excellent homogeneity (e.g., beaches)
0.5 to 1.0	Good homogeneity
1.0 to 1.33	Fair homogeneity
> 1.33	Poor homogeneity (e.g., glacial)

5.00	4.50	0.409	0.451	100.000





EAFB C

Pre-Digestion Grain Size Distribution

Onshore Grab Sample

Sample: WCP-A1(10")

Total Sample Mass: 107.311 grams

Sieve Size (phi)	Sieve Midpt (phi)	Weight (grams)	Freq Weight %	Cumulative Weight %
-2.25	-2.375	0.762	0.710	0.710
-2.00	-2.125	0.433	0.404	1.114
-1.75	-1.875	0.498	0.464	1.578
-1.50	-1.625	0.843	0.786	2.363
-1.25	-1.375	0.732	0.682	3.045
-1.00	-1.125	0.849	0.791	3.837
-0.75	-0.875	0.860	0.801	4.638
-0.50	-0.625	1.422	1.325	5.963
-0.25	-0.375	1.973	1.839	7.802
0.00	-0.125	2.325	2.167	9.968
0.25	0.125	2.906	2.708	12.676
0.50	0.375	5.355	4.990	17.666
0.75	0.625	7.706	7.181	24.847
1.00	0.875	10.086	9.399	34.246
1.25	1.125	11.800	10.996	45.242
1.50	1.375	16.879	15.729	60.971
1.75	1.625	17.648	16.446	77.417
2.00	1.875	11.868	11.059	88.476
2.25	2.125	6.384	5.949	94.426
2.50	2.375	2.228	2.076	96.502
2.75	2.625	1.490	1.388	97.890
3.00	2.875	0.757	0.705	98.596
3.25	3.125	0.490	0.457	99.052
3.50	3.375	0.336	0.313	99.365
3.75	3.625	0.331	0.308	99.674
4.00	3.875	0.177	0.165	99.839
5.00	4.50	0.173	0.161	100.000

Statistical Results			
Mean:	1.1558	phi	(0.4488 mm)
Standard Dev:	0.9433	phi-units	(0.52 mm)
Skewness:	-1.0065	dimensionless	
Kurtosis:	5.3857	dimensionless	
5th Moment:	-10.9124	dimensionless	
6th Moment:	50.1580	dimensionless	
RARD *	0.8161	dimensionless	
Median	1.2006	phi	(0.4351 mm)

* RARD = reciprocal absolute relative dispersion (see below)

Statistical Explanation

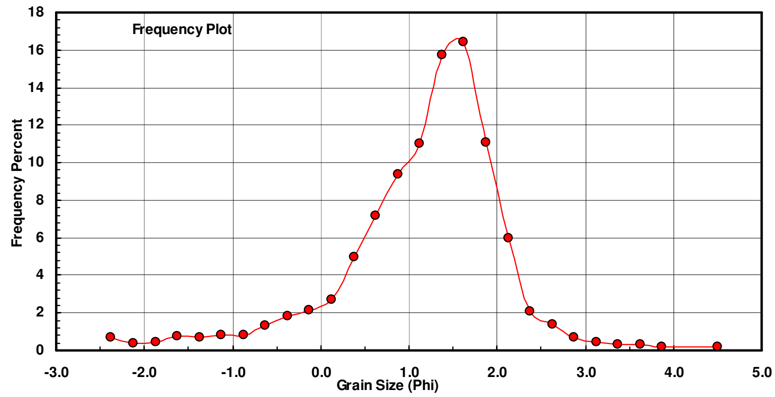
Calculations based on the Method of Moments

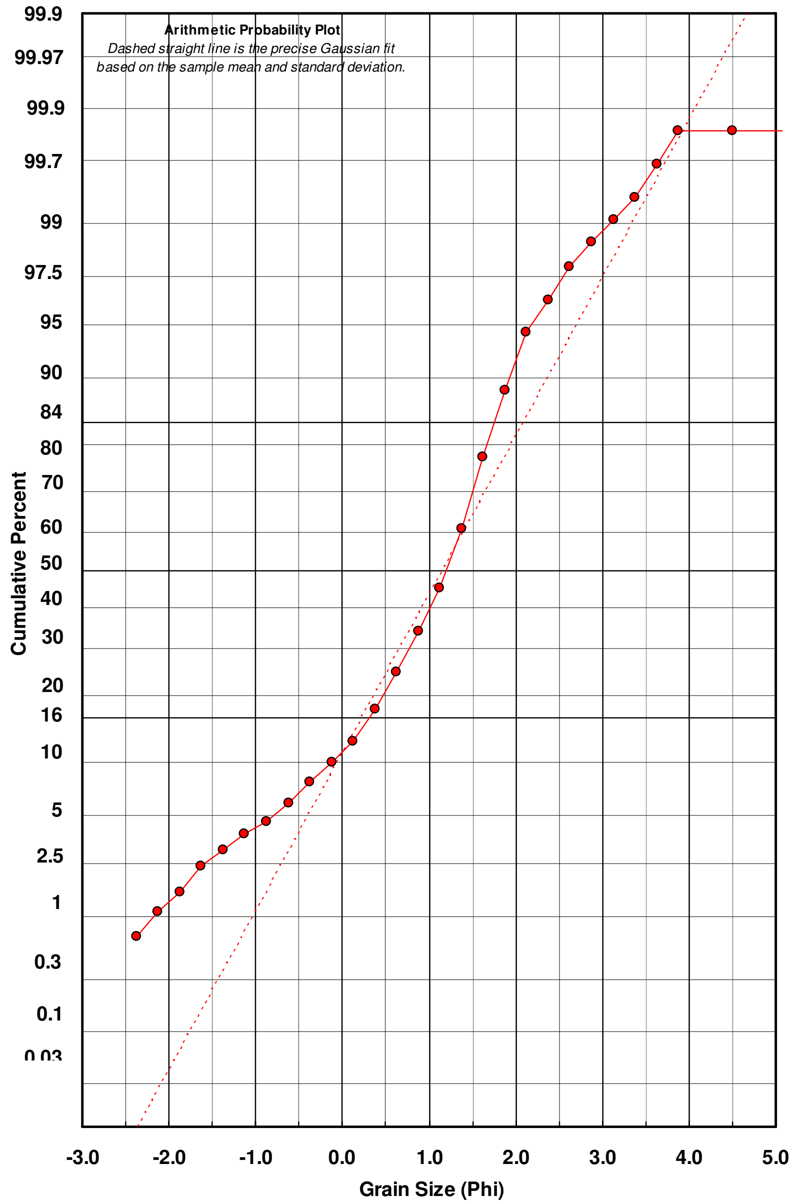
Skewness: 3rd Stand. Moment; Exact Gaussian = 0.0
Kurtosis: 4th Stand. Moment; Exact Gaussian = 3.0

For Further Explanation, See Calculation Sheets

Millimeter data calculated by mm = 2^(-phi)

Reciprocal Absolute Relative Dispersion (RARD) Scale	
< 0.5	Excellent homogeneity (e.g., beaches)
0.5 to 1.0	Good homogeneity
1.0 to 1.33	Fair homogeneity
> 1.33	Poor homogeneity (e.g., glacial)


Frequency Plot
Frequency Percent
Grain Size (Phi)
18
16
14
12
10
8
6
4
2
0
-3.0
-2.0
-1.0
0.0
1.0
2.0
3.0
4.0
5.0


Arithmetic Probability Plot
Dashed straight line is the precise Gaussian fit
based on the sample mean and standard deviation.
Cumulative Percent
Grain Size (Phi)
99.9
99.97
99.9
99.7
99
97.5
95
90
84
80
70
60
50
40
30
20
16
10
5
2.5
1
0.3
0.1
0.03
-3.0
-2.0
-1.0
0.0
1.0
2.0
3.0
4.0
5.0

WCP A1

Pre-Digestion Grain Size Distribution

Onshore Grab Sample
Sample: WCP-A2(40")
Total Sample Mass: 83.529 grams

Sieve Size (phi)	Sieve Midpt (phi)	Weight (grams)	Freq Weight %	Cumulative Weight %
-2.25	-2.375	0.405	0.485	0.485
-2.00	-2.125	0.307	0.368	0.852
-1.75	-1.875	0.102	0.122	0.975
-1.50	-1.625	0.336	0.402	1.377
-1.25	-1.375	0.295	0.353	1.730
-1.00	-1.125	0.338	0.405	2.135
-0.75	-0.875	0.607	0.727	2.861
-0.50	-0.625	0.934	1.118	3.979
-0.25	-0.375	1.327	1.589	5.568
0.00	-0.125	1.854	2.220	7.788
0.25	0.125	2.611	3.126	10.914
0.50	0.375	6.014	7.200	18.113
0.75	0.625	9.231	11.051	29.165
1.00	0.875	11.264	13.485	42.650
1.25	1.125	11.830	14.163	56.813
1.50	1.375	15.206	18.204	75.017
1.75	1.625	11.226	13.440	88.457
2.00	1.875	4.730	5.663	94.119
2.25	2.125	1.936	2.318	96.437
2.50	2.375	0.743	0.890	97.327
2.75	2.625	0.685	0.820	98.147
3.00	2.875	0.410	0.491	98.638
3.25	3.125	0.330	0.395	99.033
3.50	3.375	0.227	0.272	99.304
3.75	3.625	0.236	0.283	99.587
4.00	3.875	0.223	0.267	99.854
5.00	4.50	0.122	0.146	100.000

Statistical Results			
Mean:	1.0472	phi	(0.4839 mm)
Standard Dev:	0.8106	phi-units	(0.5702 mm)
Skewness:	-0.6390	dimensionless	
Kurtosis:	6.4301	dimensionless	
5th Moment:	-9.0378	dimensionless	
6th Moment:	76.9534	dimensionless	
RARD *	0.7740	dimensionless	
Median	1.0047	phi	(0.4984 mm)

* RARD = reciprocal absolute relative dispersion (see below)

Statistical Explanation

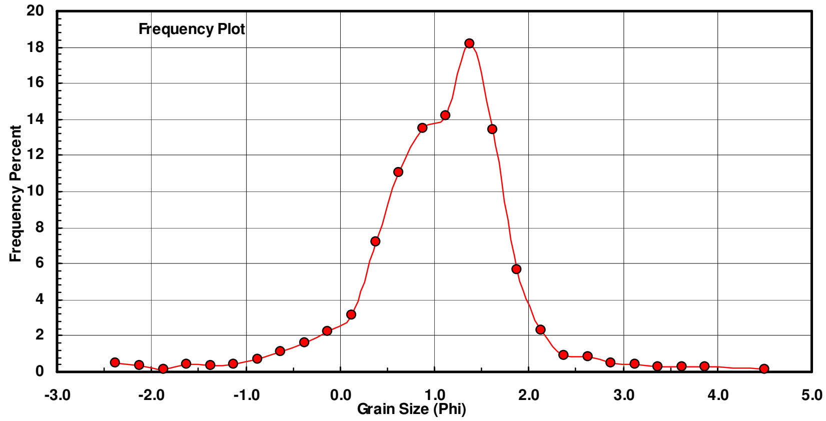
Calculations based on the Method of Moments

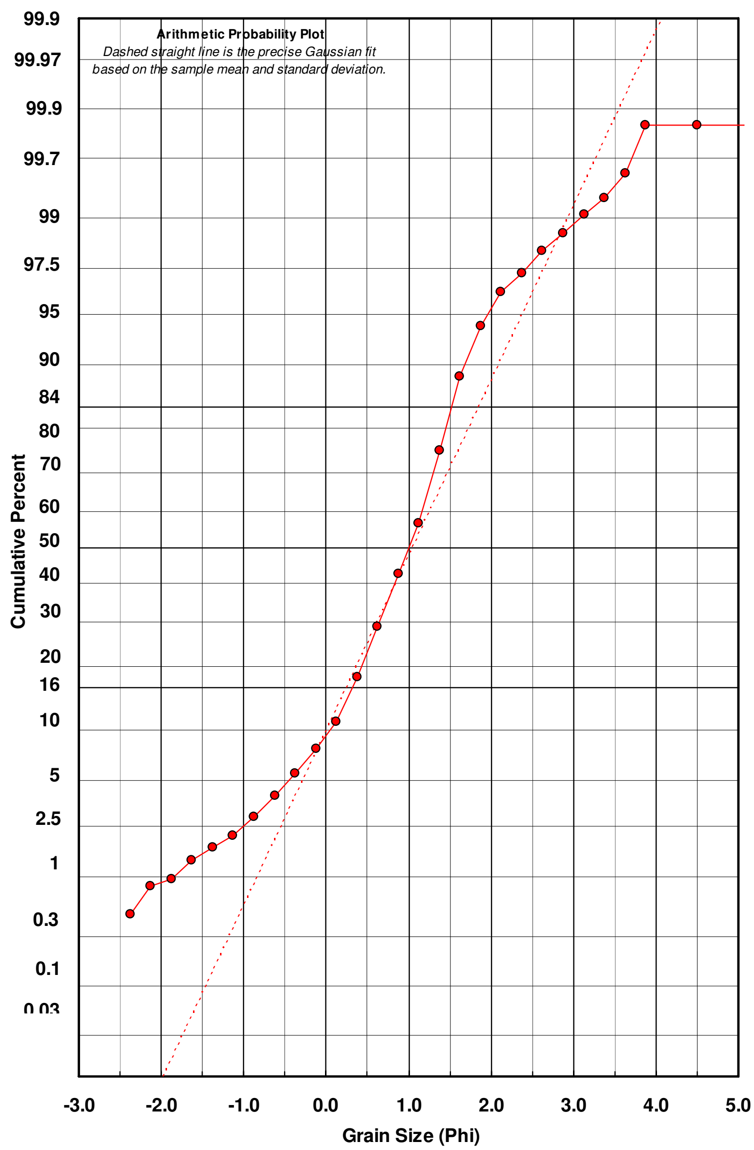
Skewness: 3rd Stand. Moment; Exact Gaussian = 0.0
Kurtosis: 4th Stand. Moment; Exact Gaussian = 3.0

For Further Explanation, See Calculation Sheets

Millimeter data calculated by mm = 2^(-phi)

Reciprocal Absolute Relative Dispersion (RARD) Scale	
< 0.5	Excellent homogeneity (e.g., beaches)
0.5 to 1.0	Good homogeneity
1.0 to 1.33	Fair homogeneity
> 1.33	Poor homogeneity (e.g., glacial)


Frequency Plot
Frequency Percent
Grain Size (Phi)


Arithmetic Probability Plot
Dashed straight line is the precise Gaussian fit
based on the sample mean and standard deviation.
Cumulative Percent
Grain Size (Phi)

WCP A2

Pre-Digestion Grain Size Distribution

Onshore Grab Sample
Sample: WCP-A3(68")
Total Sample Mass: 114.664 grams

Sieve Size (phi)	Sieve Midpt (phi)	Weight (grams)	Freq Weight %	Cumulative Weight %
-2.25	-2.375	0.355	0.310	0.310
-2.00	-2.125	0.000	0.000	0.310
-1.75	-1.875	0.159	0.139	0.448
-1.50	-1.625	0.191	0.167	0.615
-1.25	-1.375	0.142	0.124	0.739
-1.00	-1.125	0.180	0.157	0.896
-0.75	-0.875	0.316	0.276	1.171
-0.50	-0.625	0.732	0.638	1.810
-0.25	-0.375	1.703	1.485	3.295
0.00	-0.125	3.948	3.443	6.738
0.25	0.125	8.197	7.149	13.887
0.50	0.375	22.861	19.937	33.824
0.75	0.625	32.967	28.751	62.575
1.00	0.875	21.155	18.450	81.025
1.25	1.125	8.310	7.247	88.272
1.50	1.375	4.845	4.225	92.497
1.75	1.625	2.858	2.492	94.990
2.00	1.875	1.668	1.455	96.444
2.25	2.125	1.147	1.000	97.445
2.50	2.375	0.615	0.536	97.981
2.75	2.625	0.676	0.590	98.571
3.00	2.875	0.445	0.388	98.959
3.25	3.125	0.369	0.322	99.281
3.50	3.375	0.273	0.238	99.519
3.75	3.625	0.268	0.234	99.752
4.00	3.875	0.145	0.126	99.879
5.00	4.50	0.139	0.121	100.000

Statistical Results			
Mean:	0.6974	phi	(0.6167 mm)
Standard Dev:	0.6385	phi-units	(0.6424 mm)
Skewness:	0.8522	dimensionless	
Kurtosis:	9.7443	dimensionless	
5th Moment:	16.3787	dimensionless	
6th Moment:	185.8915	dimensionless	
RARD *	0.9156	dimensionless	
Median	0.5157	phi	(0.6995 mm)

* RARD = reciprocal absolute relative dispersion (see below)

Statistical Explanation

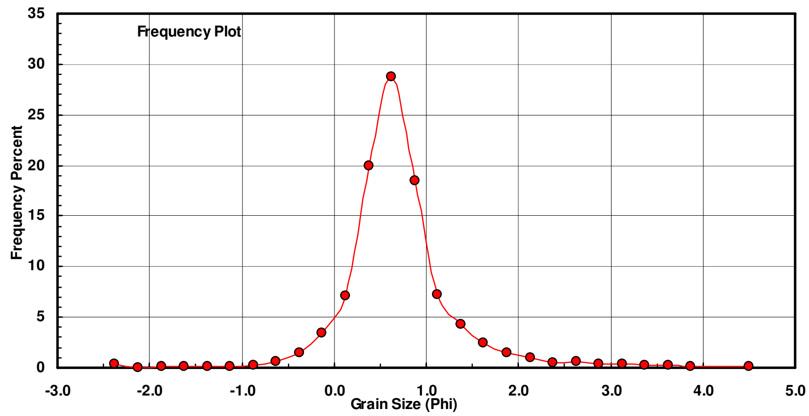
Calculations based on the Method of Moments

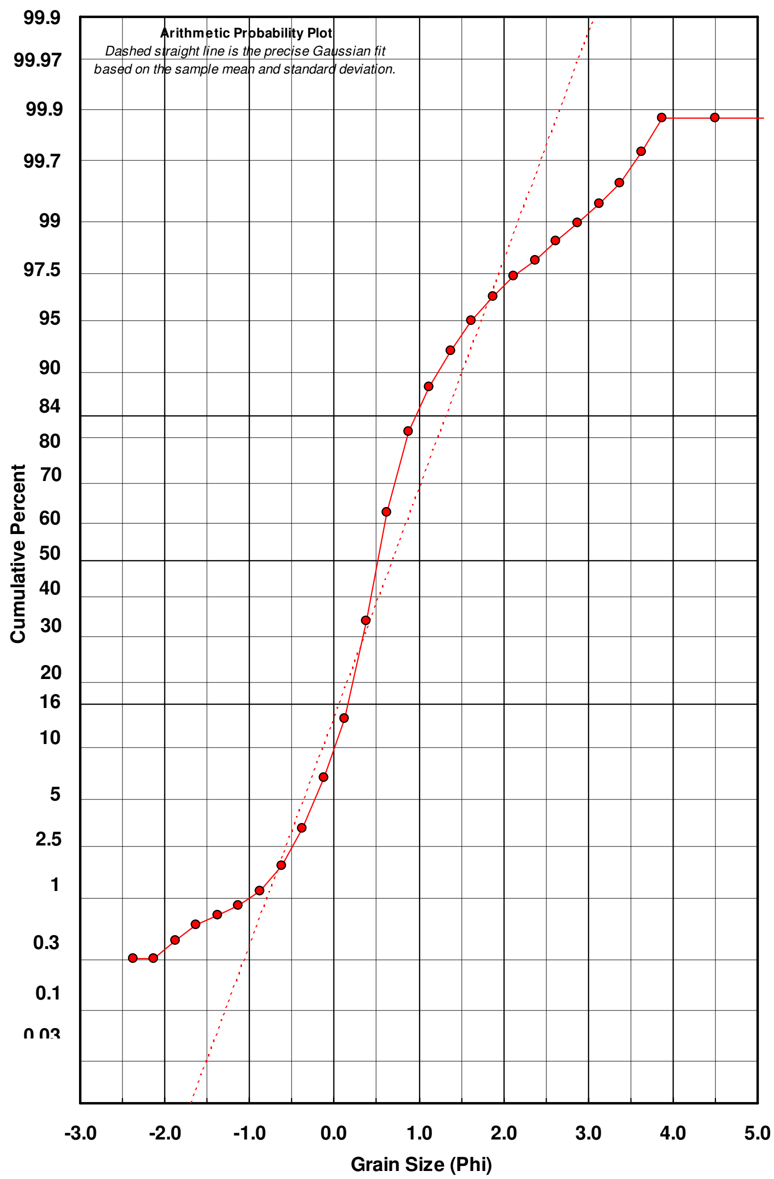
Skewness: 3rd Stand. Moment; Exact Gaussian = 0.0
Kurtosis: 4th Stand. Moment; Exact Gaussian = 3.0

For Further Explanation, See Calculation Sheets

Millimeter data calculated by mm = 2^(-phi)

Reciprocal Absolute Relative Dispersion (RARD) Scale	
< 0.5	Excellent homogeneity (e.g., beaches)
0.5 to 1.0	Good homogeneity
1.0 to 1.33	Fair homogeneity
> 1.33	Poor homogeneity (e.g., glacial)


Frequency Plot
Frequency Percent
Grain Size (Phi)


Arithmetic Probability Plot
Dashed straight line is the precise Gaussian fit based on the sample mean and standard deviation.
Cumulative Percent
Grain Size (Phi)

WCP A3

Pre-Digestion Grain Size Distribution

Onshore Grab Sample

Sample: WCP-C1-(base)

Total Sample Mass: 68.905 grams

Sieve Size (phi)	Sieve Midpt (phi)	Weight (grams)	Freq Weight %	Cumulative Weight %
-2.25	-2.375	0.936	1.358	1.358
-2.00	-2.125	0.142	0.206	1.564
-1.75	-1.875	0.480	0.697	2.261
-1.50	-1.625	0.869	1.261	3.522
-1.25	-1.375	1.607	2.332	5.854
-1.00	-1.125	1.716	2.490	8.345
-0.75	-0.875	2.986	4.334	12.678
-0.50	-0.625	5.711	8.288	20.967
-0.25	-0.375	7.547	10.953	31.919
0.00	-0.125	6.762	9.814	41.733
0.25	0.125	5.341	7.751	49.484
0.50	0.375	6.295	9.136	58.620
0.75	0.625	6.056	8.789	67.409
1.00	0.875	5.805	8.425	75.833
1.25	1.125	4.398	6.383	82.216
1.50	1.375	4.577	6.642	88.859
1.75	1.625	3.112	4.516	93.375
2.00	1.875	1.489	2.161	95.536
2.25	2.125	0.822	1.193	96.729
2.50	2.375	0.422	0.612	97.341
2.75	2.625	0.479	0.695	98.036
3.00	2.875	0.332	0.482	98.518
3.25	3.125	0.284	0.412	98.930
3.50	3.375	0.208	0.302	99.232
3.75	3.625	0.219	0.318	99.550
4.00	3.875	0.206	0.299	99.849
5.00	4.50	0.104	0.151	100.000

Statistical Results			
Mean:	0.3013	phi	(0.8115 mm)
Standard Dev:	1.0534	phi-units	(0.4818 mm)
Skewness:	0.3085	dimensionless	
Kurtosis:	3.7002	dimensionless	
5th Moment:	4.0976	dimensionless	
6th Moment:	26.1685	dimensionless	
RARD *	3.4966	dimensionless	
Median	0.1391	phi	(0.9081 mm)

* RARD = reciprocal absolute relative dispersion (see below)

Statistical Explanation

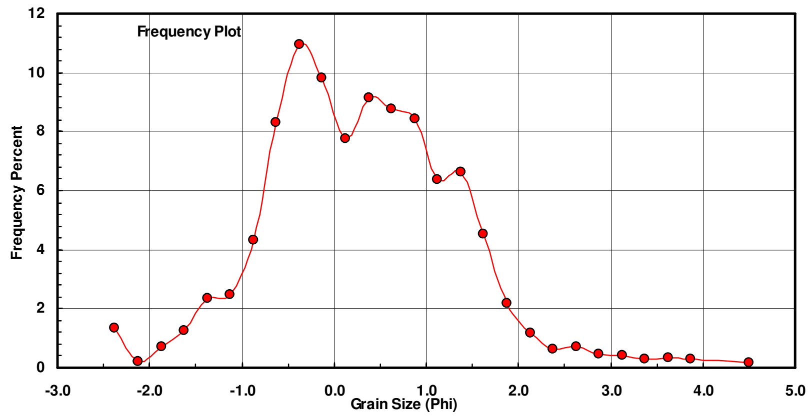
Calculations based on the Method of Moments

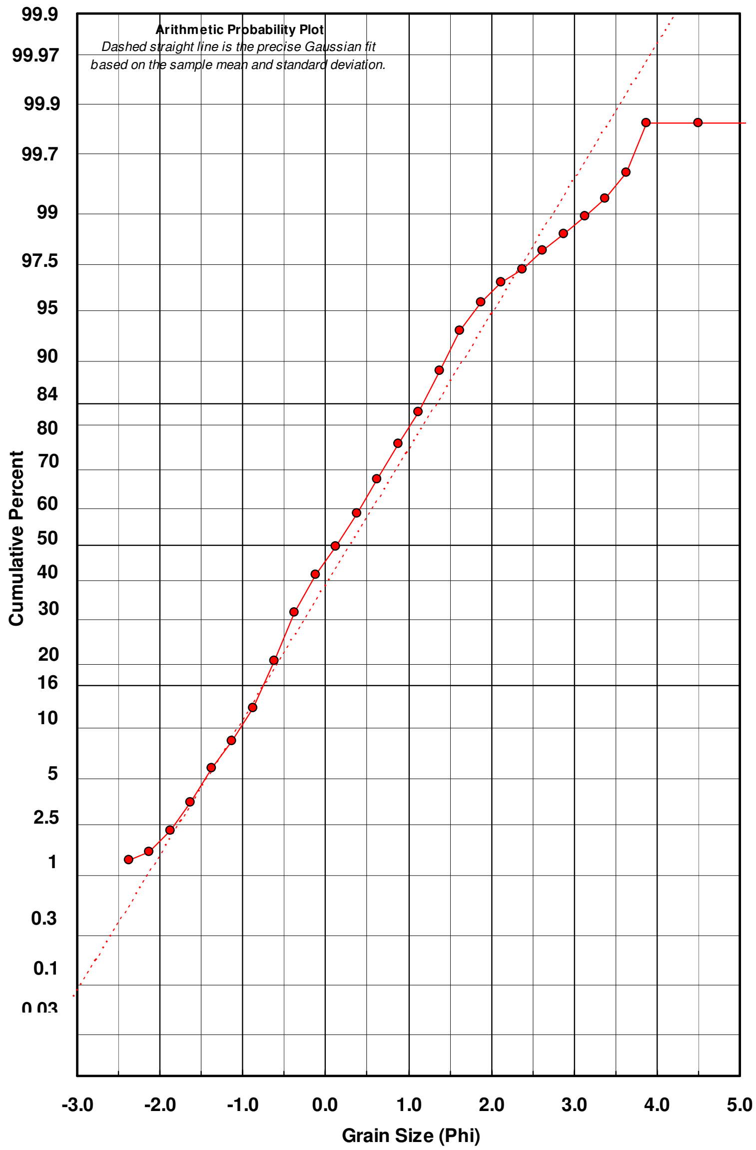
Skewness: 3rd Stand. Moment; Exact Gaussian = 0.0
Kurtosis: 4th Stand. Moment; Exact Gaussian = 3.0

For Further Explanation, See Calculation Sheets

Millimeter data calculated by mm = 2^(-phi)

Reciprocal Absolute Relative Dispersion (RARD) Scale	
< 0.5	Excellent homogeneity (e.g., beaches)
0.5 to 1.0	Good homogeneity
1.0 to 1.33	Fair homogeneity
> 1.33	Poor homogeneity (e.g., glacial)


Frequency Plot
Frequency Percent
Grain Size (Phi)
12
10
8
6
4
2
0
-3.0
-2.0
-1.0
0.0
1.0
2.0
3.0
4.0
5.0


Arithmetic Probability Plot
Dashed straight line is the precise Gaussian fit
based on the sample mean and standard deviation.
Cumulative Percent
Grain Size (Phi)
99.9
99.97
99.9
99.7
99
97.5
95
90
84
80
70
60
50
40
30
20
16
10
5
2.5
1
0.3
0.1
0.03
-3.0
-2.0
-1.0
0.0
1.0
2.0
3.0
4.0
5.0

WCP C1

Pre-Digestion Grain Size Distribution

Onshore Grab Sample

Sample: WCP-C2

Total Sample Mass: 86.468 grams

Sieve Size (phi)	Sieve Midpt (phi)	Weight (grams)	Freq Weight %	Cumulative Weight %
-2.25	-2.375	0.788	0.911	0.911
-2.00	-2.125	0.761	0.880	1.791
-1.75	-1.875	0.909	1.051	2.843
-1.50	-1.625	0.980	1.133	3.976
-1.25	-1.375	1.610	1.862	5.838
-1.00	-1.125	3.572	4.131	9.969
-0.75	-0.875	6.017	6.959	16.928
-0.50	-0.625	9.843	11.383	28.311
-0.25	-0.375	12.453	14.402	42.713
0.00	-0.125	10.497	12.140	54.853
0.25	0.125	8.232	9.520	64.373
0.50	0.375	8.048	9.307	73.680
0.75	0.625	5.339	6.175	79.855
1.00	0.875	3.836	4.436	84.291
1.25	1.125	2.538	2.935	87.226
1.50	1.375	2.762	3.194	90.421
1.75	1.625	2.532	2.928	93.349
2.00	1.875	1.757	2.032	95.381
2.25	2.125	1.179	1.364	96.744
2.50	2.375	0.596	0.689	97.434
2.75	2.625	0.636	0.736	98.169
3.00	2.875	0.411	0.475	98.645
3.25	3.125	0.335	0.387	99.032
3.50	3.375	0.254	0.294	99.326
3.75	3.625	0.263	0.304	99.630
4.00	3.875	0.184	0.213	99.843
5.00	4.50	0.136	0.157	100.000

Statistical Results			
Mean:	0.0618	phi	(0.9581 mm)
Standard Dev:	1.0287	phi-units	(0.4901 mm)
Skewness:	0.7794	dimensionless	
Kurtosis:	4.3962	dimensionless	
5th Moment:	8.7085	dimensionless	
6th Moment:	37.4058	dimensionless	
RARD *	16.6569	dimensionless	
Median	-0.2249	phi	(1.1687 mm)

* RARD = reciprocal absolute relative dispersion (see below)

Statistical Explanation

Calculations based on the Method of Moments

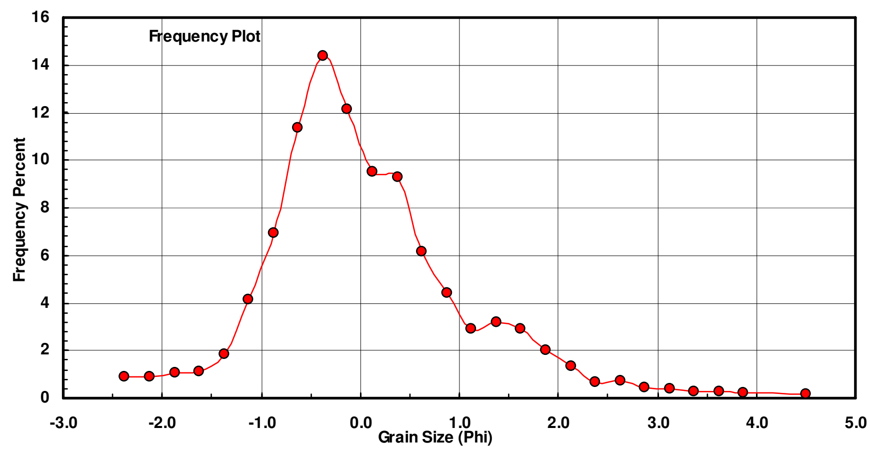
Skewness: 3rd Stand. Moment; Exact Gaussian = 0.0

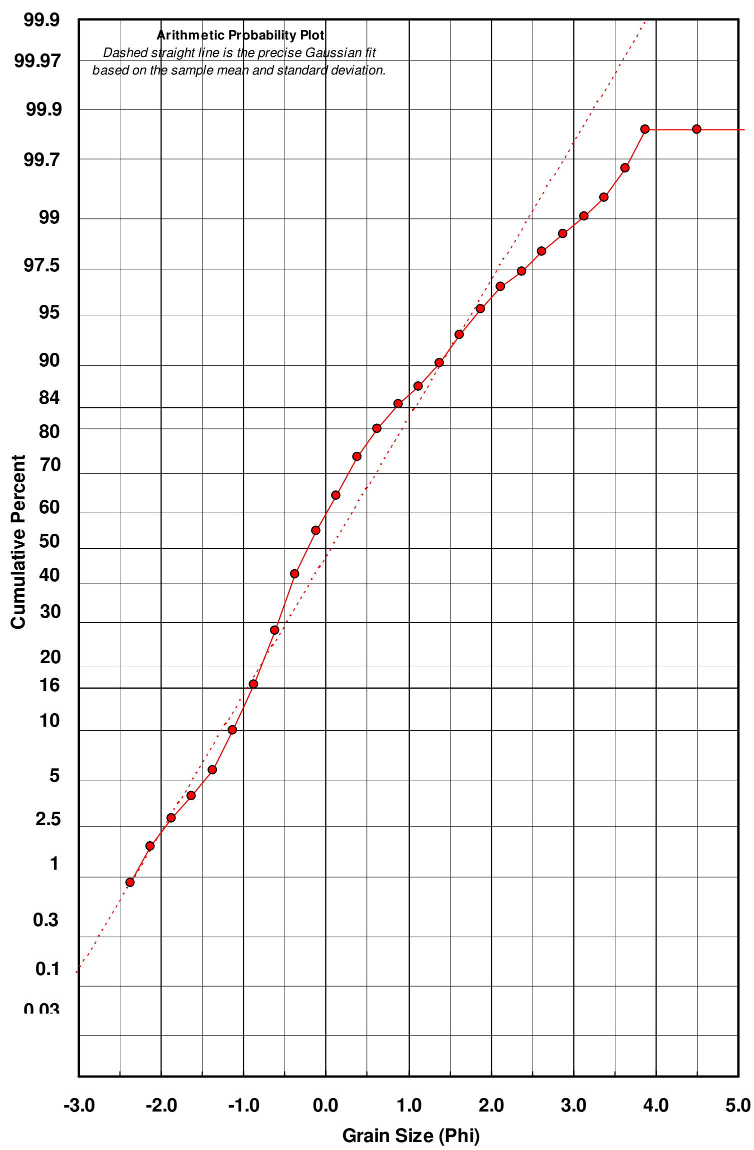
Kurtosis: 4th Stand. Moment; Exact Gaussian = 3.0

For Further Explanation, See Calculation Sheets

Millimeter data calculated by mm = 2^(-phi)

Reciprocal Absolute Relative Dispersion (RARD) Scale	
< 0.5	Excellent homogeneity (e.g., beaches)
0.5 to 1.0	Good homogeneity
1.0 to 1.33	Fair homogeneity
> 1.33	Poor homogeneity (e.g., glacial)


Frequency Plot
Frequency Percent
Grain Size (Phi)
16
14
12
10
8
6
4
2
0
-3.0
-2.0
-1.0
0.0
1.0
2.0
3.0
4.0
5.0


Arithmetic Probability Plot
Dashed straight line is the precise Gaussian fit based on the sample mean and standard deviation.
Cumulative Percent
Grain Size (Phi)
99.9
99.97
99.9
99.7
99
97.5
95
90
84
80
70
60
50
40
30
20
16
10
5
2.5
1
0.3
0.1
0.03
-3.0
-2.0
-1.0
0.0
1.0
2.0
3.0
4.0
5.0

WCP C2

Pre-Digestion Grain Size Distribution

Onshore Grab Sample

Sample: WCP-C3(top)

Total Sample Mass: 72.353 grams

Sieve Size (phi)	Sieve Midpt (phi)	Weight (grams)	Freq Weight %	Cumulative Weight %
-2.25	-2.375	0.000	0.000	0.000
-2.00	-2.125	0.000	0.000	0.000
-1.75	-1.875	0.063	0.087	0.087
-1.50	-1.625	0.363	0.502	0.589
-1.25	-1.375	0.332	0.459	1.048
-1.00	-1.125	1.090	1.507	2.554
-0.75	-0.875	2.807	3.880	6.434
-0.50	-0.625	6.420	8.873	15.307
-0.25	-0.375	9.994	13.813	29.120
0.00	-0.125	9.879	13.654	42.774
0.25	0.125	7.981	11.031	53.804
0.50	0.375	8.944	12.362	66.166
0.75	0.625	6.739	9.314	75.480
1.00	0.875	4.833	6.680	82.160
1.25	1.125	2.975	4.112	86.271
1.50	1.375	2.884	3.986	90.257
1.75	1.625	2.240	3.096	93.353
2.00	1.875	1.403	1.939	95.293
2.25	2.125	1.023	1.414	96.706
2.50	2.375	0.544	0.752	97.458
2.75	2.625	0.574	0.793	98.252
3.00	2.875	0.352	0.487	98.738
3.25	3.125	0.279	0.386	99.124
3.50	3.375	0.201	0.278	99.402
3.75	3.625	0.200	0.276	99.678
4.00	3.875	0.155	0.214	99.892
5.00	4.50	0.078	0.108	100.000

Statistical Results			
Mean:	0.3005	phi	(0.8119 mm)
Standard Dev:	0.8918	phi-units	(0.5389 mm)
Skewness:	1.0313	dimensionless	
Kurtosis:	4.6674	dimensionless	
5th Moment:	12.2183	dimensionless	
6th Moment:	47.3469	dimensionless	
RARD *	2.9674	dimensionless	
Median	0.0388	phi	(0.9735 mm)

* RARD = reciprocal absolute relative dispersion (see below)

Statistical Explanation

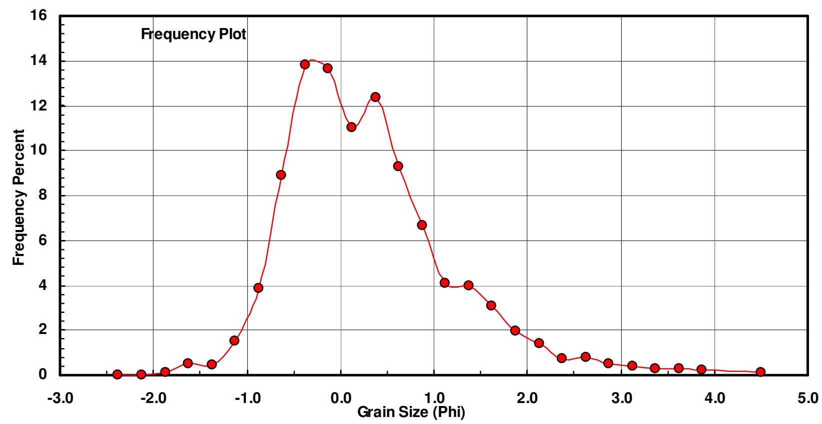
Calculations based on the Method of Moments

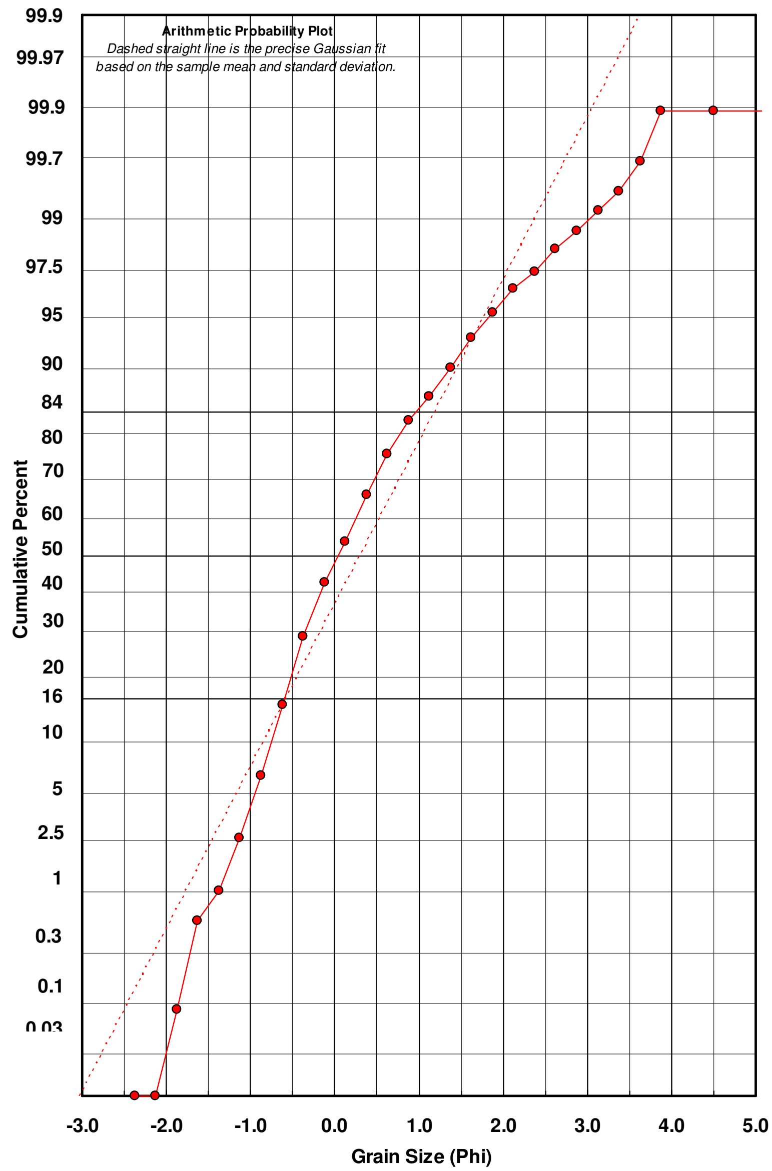
Skewness: 3rd Stand. Moment; Exact Gaussian = 0.0
Kurtosis: 4th Stand. Moment; Exact Gaussian = 3.0

For Further Explanation, See Calculation Sheets

Millimeter data calculated by mm = 2^(-phi)

Reciprocal Absolute Relative Dispersion (RARD) Scale	
< 0.5	Excellent homogeneity (e.g., beaches)
0.5 to 1.0	Good homogeneity
1.0 to 1.33	Fair homogeneity
> 1.33	Poor homogeneity (e.g., glacial)


Frequency Plot
Frequency Percent
Grain Size (Phi)


Arithmetic Probability Plot
Dashed straight line is the precise Gaussian fit based on the sample mean and standard deviation.
Cumulative Percent
Grain Size (Phi)

WCP C3(TOP)

Pre-Digestion Grain Size Distribution

Onshore Grab Sample
Sample: WCP-E1
Total Sample Mass: 75.551 grams

Sieve Size (phi)	Sieve Midpt (phi)	Weight (grams)	Freq Weight %	Cumulative Weight %
-2.25	-2.375	0.000	0.000	0.000
-2.00	-2.125	0.122	0.161	0.161
-1.75	-1.875	0.124	0.164	0.326
-1.50	-1.625	0.346	0.458	0.784
-1.25	-1.375	0.222	0.294	1.077
-1.00	-1.125	0.349	0.462	1.539
-0.75	-0.875	0.648	0.858	2.397
-0.50	-0.625	1.589	2.103	4.500
-0.25	-0.375	3.314	4.386	8.887
0.00	-0.125	4.822	6.382	15.269
0.25	0.125	6.048	8.005	23.274
0.50	0.375	10.433	13.809	37.084
0.75	0.625	11.431	15.130	52.214
1.00	0.875	10.601	14.032	66.245
1.25	1.125	6.946	9.194	75.439
1.50	1.375	6.270	8.299	83.738
1.75	1.625	4.262	5.641	89.379
2.00	1.875	2.546	3.370	92.749
2.25	2.125	1.890	2.502	95.251
2.50	2.375	1.081	1.431	96.682
2.75	2.625	0.964	1.276	97.958
3.00	2.875	0.481	0.637	98.594
3.25	3.125	0.334	0.442	99.036
3.50	3.375	0.219	0.290	99.326
3.75	3.625	0.224	0.296	99.623
4.00	3.875	0.179	0.237	99.860
5.00	4.50	0.106	0.140	100.000

Statistical Results			
Mean:	0.7720	phi	(0.5856 mm)
Standard Dev:	0.8445	phi-units	(0.5569 mm)
Skewness:	0.4253	dimensionless	
Kurtosis:	4.4771	dimensionless	
5th Moment:	5.4437	dimensionless	
6th Moment:	39.2283	dimensionless	
RARD *	1.0938	dimensionless	
Median	0.5884	phi	(0.6651 mm)

* RARD = reciprocal absolute relative dispersion (see below)

Statistical Explanation

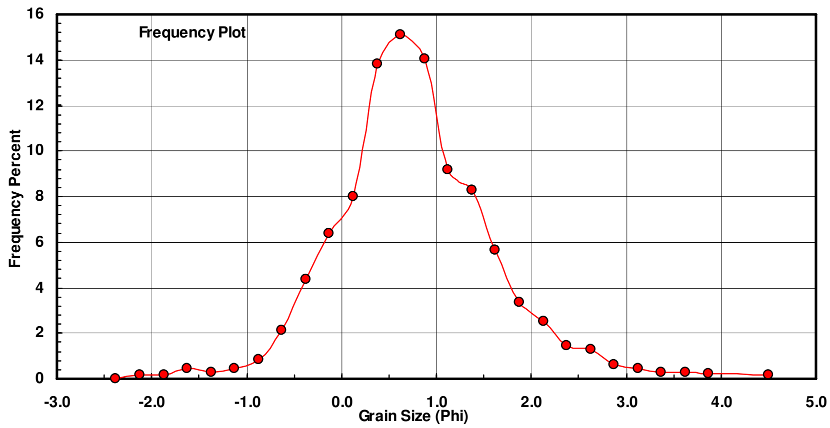
Calculations based on the Method of Moments

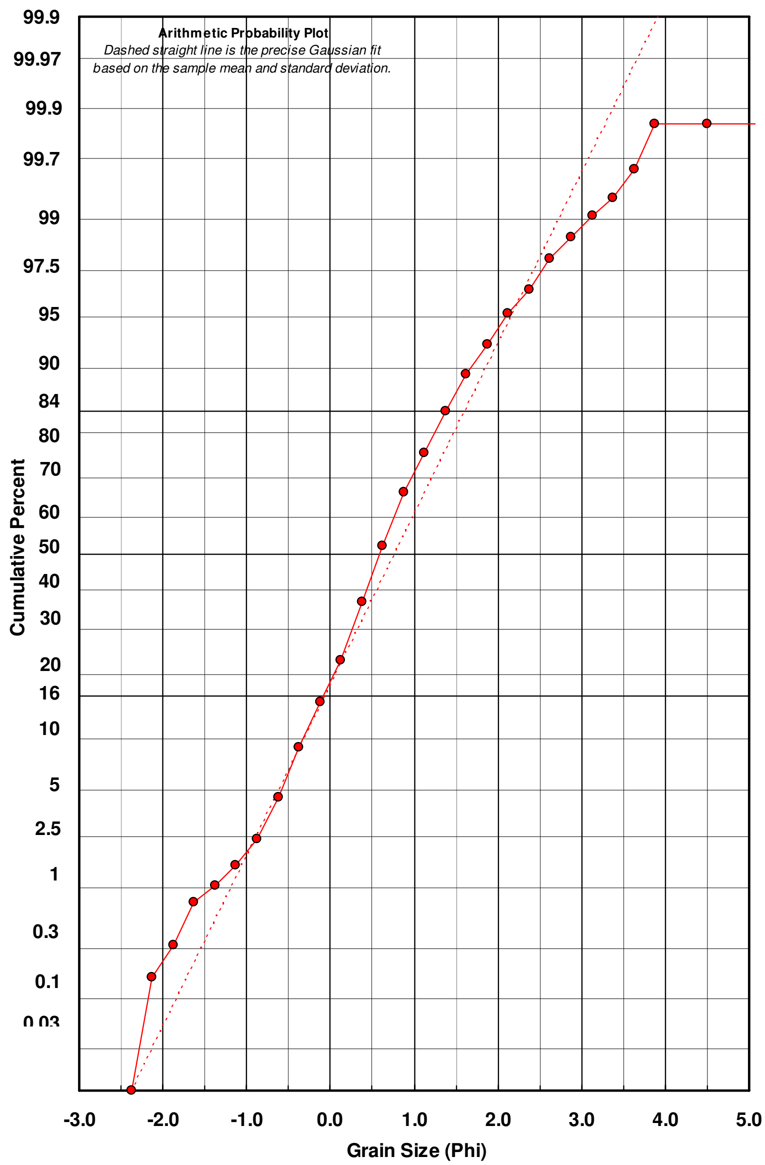
Skewness: 3rd Stand. Moment; Exact Gaussian = 0.0
Kurtosis: 4th Stand. Moment; Exact Gaussian = 3.0

For Further Explanation, See Calculation Sheets

Millimeter data calculated by mm = 2^(-phi)

Reciprocal Absolute Relative Dispersion (RARD) Scale	
< 0.5	Excellent homogeneity (e.g., beaches)
0.5 to 1.0	Good homogeneity
1.0 to 1.33	Fair homogeneity
> 1.33	Poor homogeneity (e.g., glacial)


Frequency Plot
Frequency Percent
Grain Size (Phi)


Arithmetic Probability Plot
Dashed straight line is the precise Gaussian fit based on the sample mean and standard deviation.
Cumulative Percent
Grain Size (Phi)

WCP E1

Pre-Digestion Grain Size Distribution

Onshore Grab Sample

Sample: WCP-E2

Total Sample Mass: 79.405 grams

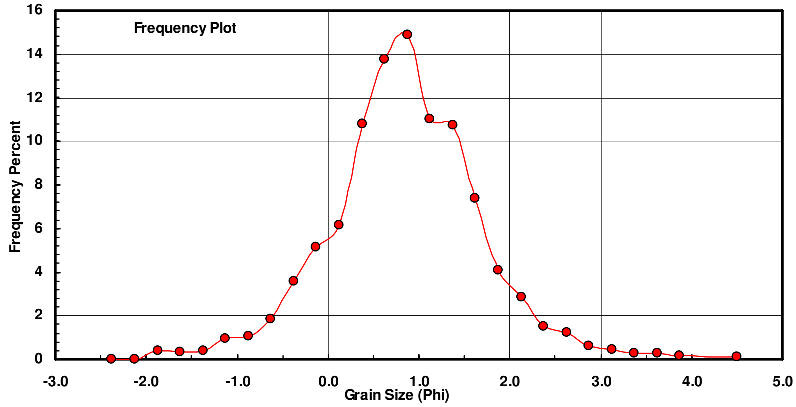
Sieve Size (phi)	Sieve Midpt (phi)	Weight (grams)	Freq Weight %	Cumulative Weight %
-2.25	-2.375	0.000	0.000	0.000
-2.00	-2.125	0.000	0.000	0.000
-1.75	-1.875	0.316	0.398	0.398
-1.50	-1.625	0.273	0.344	0.742
-1.25	-1.375	0.316	0.398	1.140
-1.00	-1.125	0.759	0.956	2.096
-0.75	-0.875	0.841	1.059	3.155
-0.50	-0.625	1.465	1.845	5.000
-0.25	-0.375	2.822	3.554	8.554
0.00	-0.125	4.094	5.156	13.709
0.25	0.125	4.887	6.155	19.864
0.50	0.375	8.565	10.786	30.650
0.75	0.625	10.920	13.752	44.403
1.00	0.875	11.821	14.887	59.290
1.25	1.125	8.737	11.003	70.293
1.50	1.375	8.512	10.720	81.013
1.75	1.625	5.885	7.411	88.424
2.00	1.875	3.256	4.100	92.524
2.25	2.125	2.255	2.840	95.364
2.50	2.375	1.200	1.511	96.876
2.75	2.625	0.985	1.240	98.116
3.00	2.875	0.475	0.598	98.714
3.25	3.125	0.337	0.424	99.139
3.50	3.375	0.230	0.290	99.428
3.75	3.625	0.225	0.283	99.712
4.00	3.875	0.132	0.166	99.878
5.00	4.50	0.097	0.122	100.000

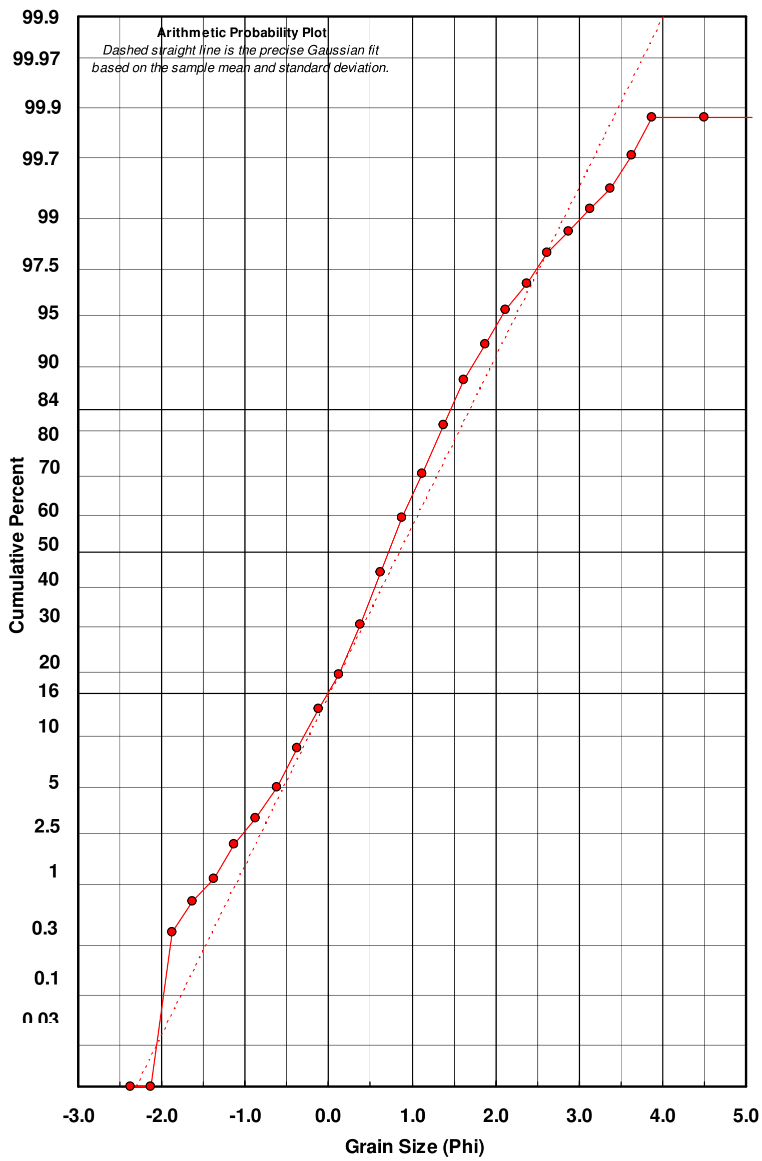
Statistical Results			
Mean:	0.8543	phi	(0.5531 mm)
Standard Dev:	0.8476	phi-units	(0.5557 mm)
Skewness:	0.1132	dimensionless	
Kurtosis:	4.1934	dimensionless	
5th Moment:	2.3902	dimensionless	
6th Moment:	32.9296	dimensionless	
RARD *	0.9923	dimensionless	
Median	0.7190	phi	(0.6075 mm)

* RARD = reciprocal absolute relative dispersion (see below)

Statistical Explanation
Calculations based on the Method of Moments
Skewness: 3rd Stand. Moment; Exact Gaussian = 0.0
Kurtosis: 4th Stand. Moment; Exact Gaussian = 3.0
For Further Explanation, See Calculation Sheets
Millimeter data calculated by mm = 2^(-phi)

Reciprocal Absolute Relative Dispersion (RARD) Scale	
< 0.5	Excellent homogeneity (e.g., beaches)
0.5 to 1.0	Good homogeneity
1.0 to 1.33	Fair homogeneity
> 1.33	Poor homogeneity (e.g., glacial)


Frequency Plot
Frequency Percent
Grain Size (Phi)
16
14
12
10
8
6
4
2
0
-3.0
-2.0
-1.0
0.0
1.0
2.0
3.0
4.0
5.0


Arithmetic Probability Plot
Dashed straight line is the precise Gaussian fit
based on the sample mean and standard deviation.
Cumulative Percent
Grain Size (Phi)
99.9
99.97
99.9
99.7
99
97.5
95
90
84
80
70
60
50
40
30
20
16
10
5
2.5
1
0.3
0.1
0.03
-3.0
-2.0
-1.0
0.0
1.0
2.0
3.0
4.0
5.0

WCP E2

Pre-Digestion Grain Size Distribution

Onshore Grab Sample

Sample: WCP-E3

Total Sample Mass: 74.222 grams

Sieve Size (phi)	Sieve Midpt (phi)	Weight (grams)	Freq Weight %	Cumulative Weight %
-2.25	-2.375	0.282	0.380	0.380
-2.00	-2.125	0.108	0.146	0.525
-1.75	-1.875	0.000	0.000	0.525
-1.50	-1.625	0.491	0.662	1.187
-1.25	-1.375	0.328	0.442	1.629
-1.00	-1.125	0.673	0.907	2.536
-0.75	-0.875	1.007	1.357	3.892
-0.50	-0.625	1.909	2.572	6.464
-0.25	-0.375	2.998	4.039	10.504
0.00	-0.125	4.293	5.784	16.288
0.25	0.125	5.167	6.962	23.249
0.50	0.375	8.751	11.790	35.039
0.75	0.625	9.865	13.291	48.331
1.00	0.875	10.248	13.807	62.138
1.25	1.125	7.320	9.862	72.000
1.50	1.375	7.031	9.473	81.473
1.75	1.625	5.049	6.803	88.276
2.00	1.875	2.951	3.976	92.252
2.25	2.125	2.087	2.812	95.063
2.50	2.375	1.144	1.541	96.605
2.75	2.625	0.980	1.320	97.925
3.00	2.875	0.473	0.637	98.562
3.25	3.125	0.329	0.443	99.006
3.50	3.375	0.223	0.300	99.306
3.75	3.625	0.225	0.303	99.609
4.00	3.875	0.181	0.244	99.853
5.00	4.50	0.109	0.147	100.000

Statistical Results			
Mean:	0.7940	phi	(0.5767 mm)
Standard Dev:	0.9015	phi-units	(0.5353 mm)
Skewness:	0.0882	dimensionless	
Kurtosis:	4.2769	dimensionless	
5th Moment:	1.3740	dimensionless	
6th Moment:	34.3422	dimensionless	
RARD *	1.1354	dimensionless	
Median	0.6552	phi	(0.635 mm)

* RARD = reciprocal absolute relative dispersion (see below)

Statistical Explanation

Calculations based on the Method of Moments

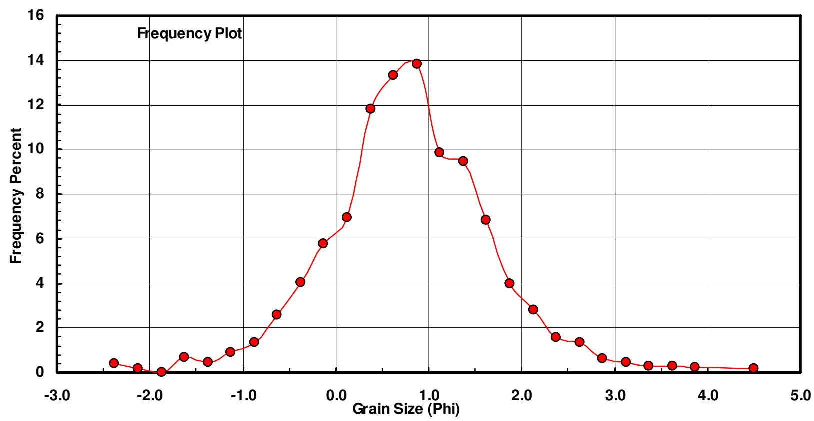
Skewness: 3rd Stand. Moment; Exact Gaussian = 0.0

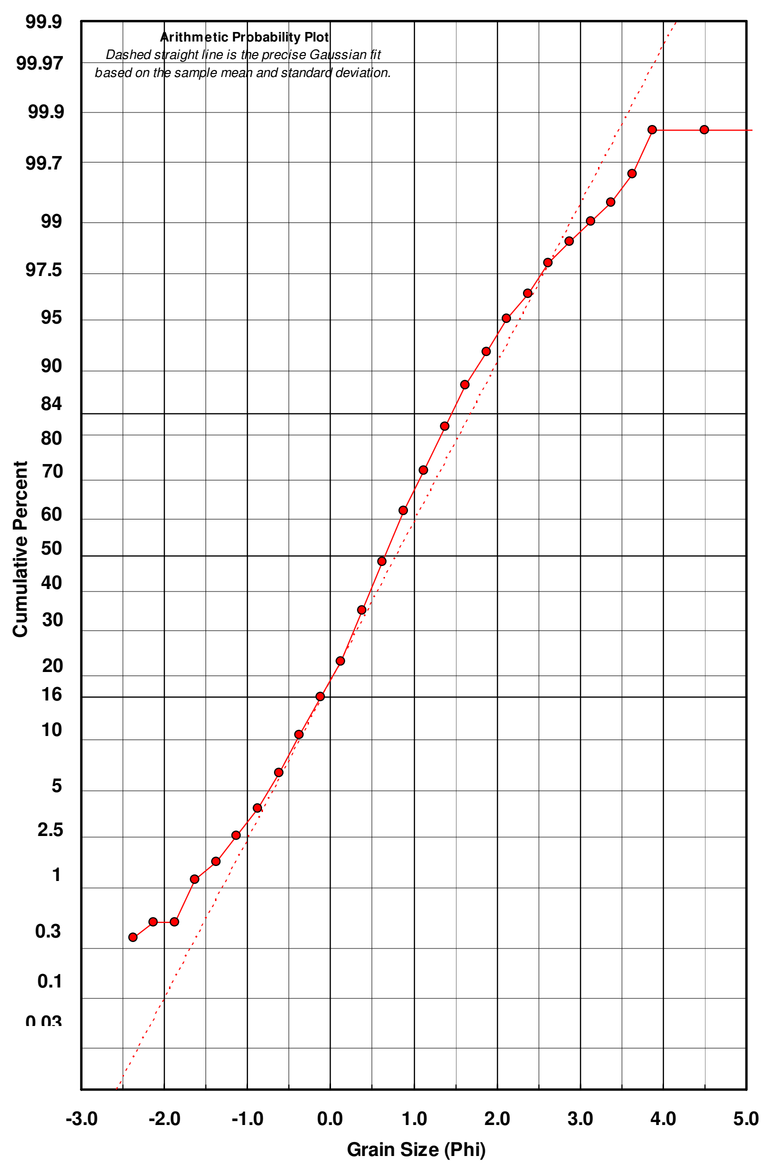
Kurtosis: 4th Stand. Moment; Exact Gaussian = 3.0

For Further Explanation, See Calculation Sheets

Millimeter data calculated by mm = 2^(-phi)

Reciprocal Absolute Relative Dispersion (RARD) Scale	
< 0.5	Excellent homogeneity (e.g., beaches)
0.5 to 1.0	Good homogeneity
1.0 to 1.33	Fair homogeneity
> 1.33	Poor homogeneity (e.g., glacial)

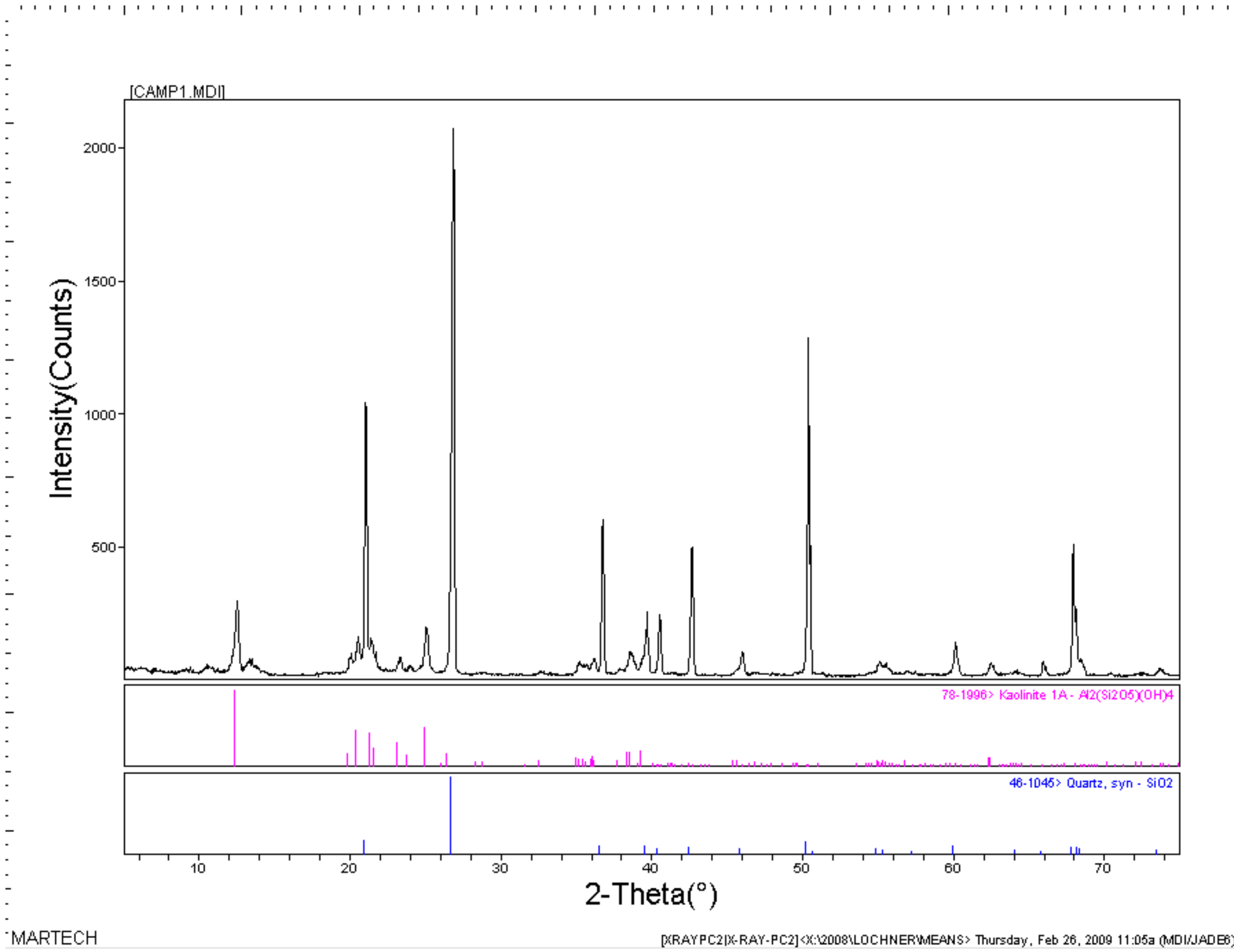

Frequency Plot
Frequency Percent
Grain Size (Phi)


Arithmetic Probability Plot
Dashed straight line is the precise Gaussian fit
based on the sample mean and standard deviation.
Cumulative Percent
Grain Size (Phi)

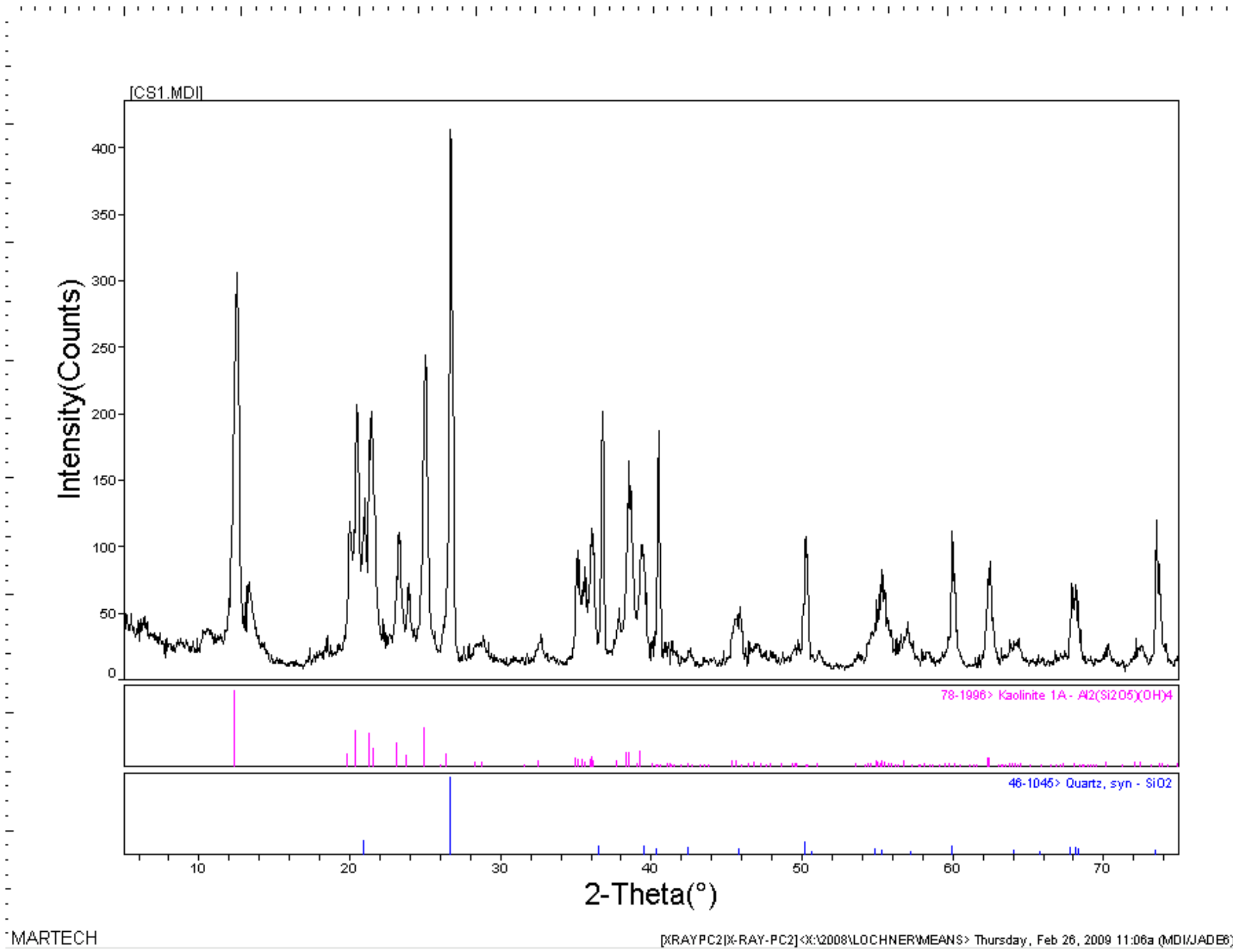
WCP E3

APPENDIX C

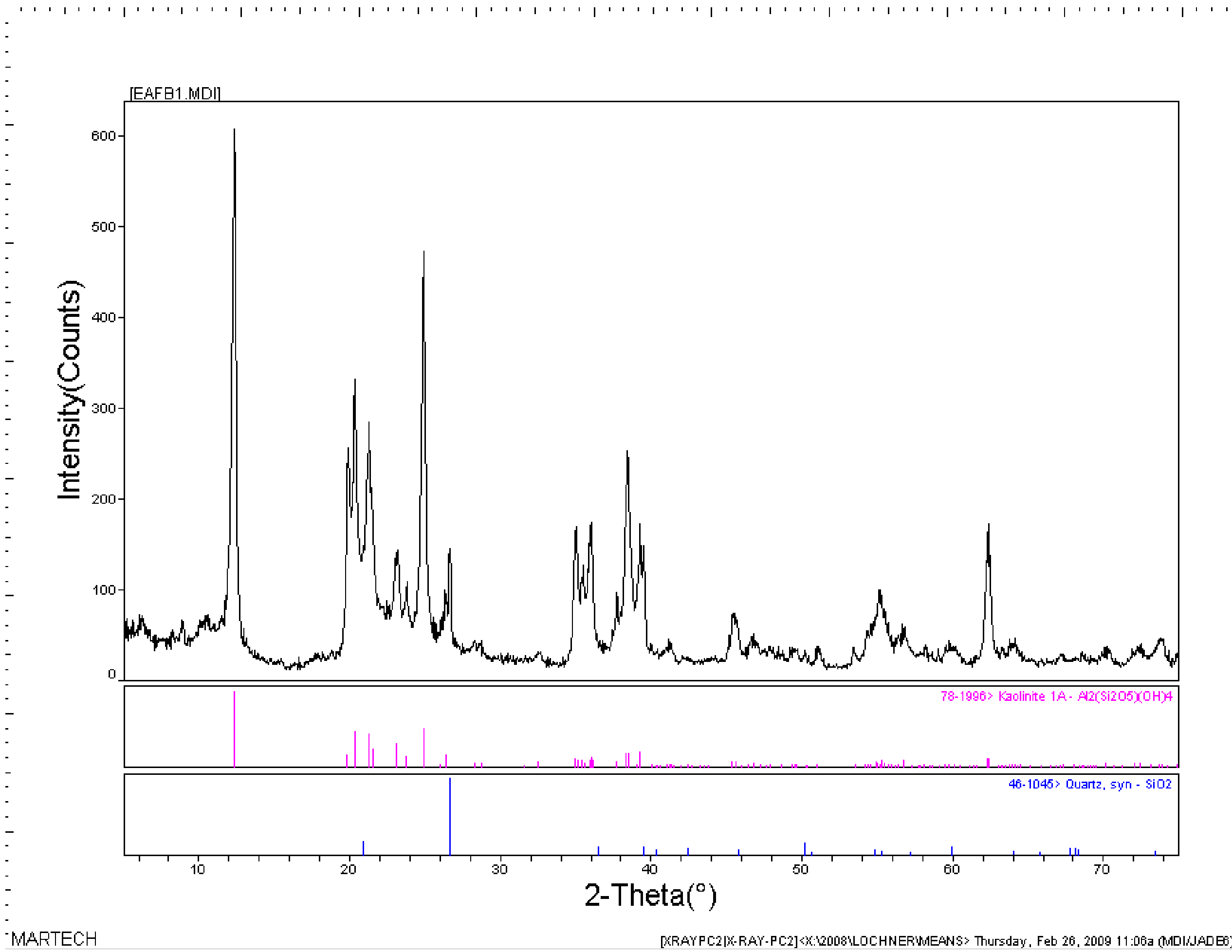
X-RAY DIFFRACTOGRAMS



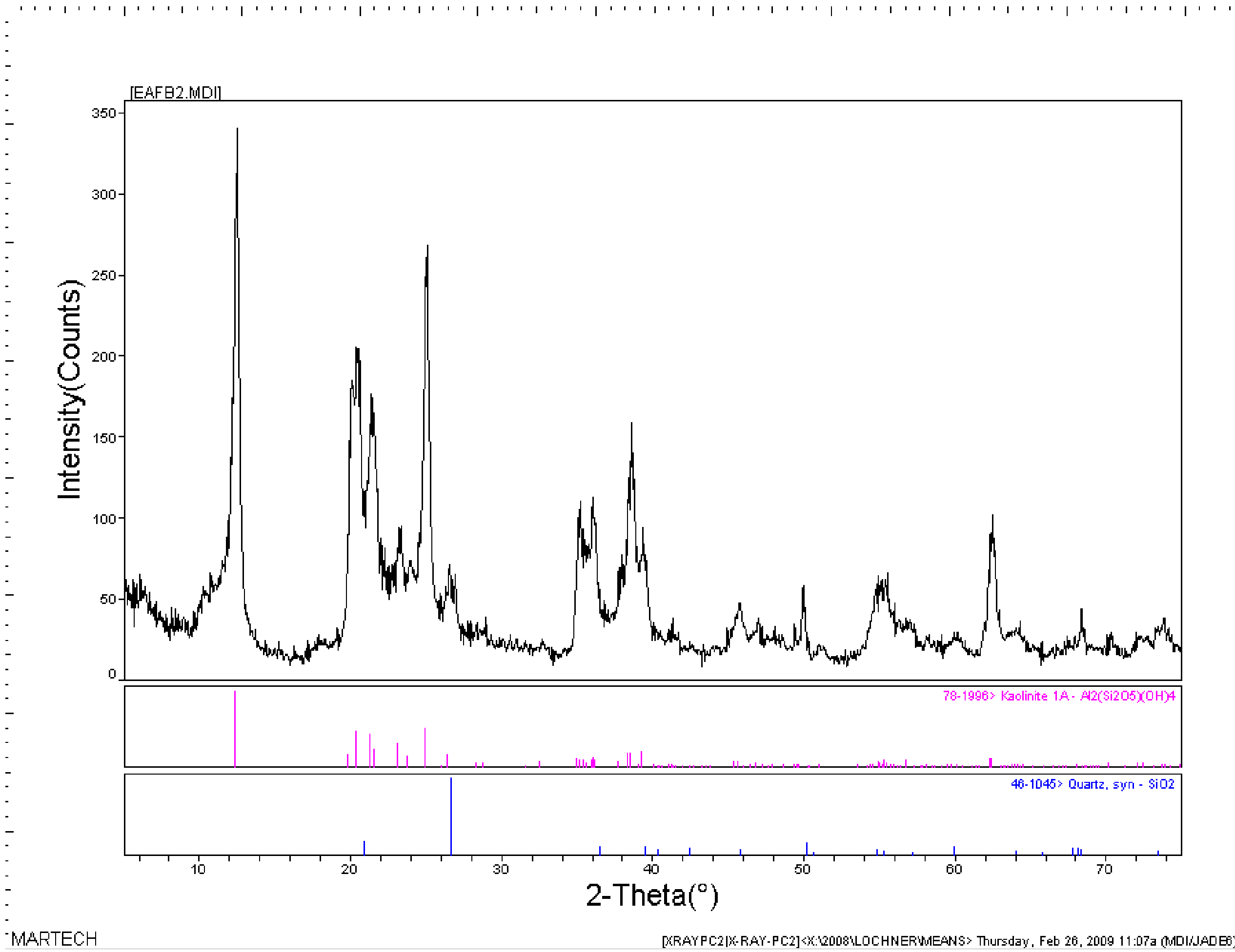
Campbell Sand Pit – Sample 1 (clay stringer). Top graph represents the sample peaks, second bar graph represents a kaolinite standard, and the third bar graph represents a quartz standard.



Campbell Sand Pit – Sample 2 (*Ophiomorpha* tube). Top graph represents the sample peaks, second bar graph represents a kaolinite standard, and the third bar graph represents a quartz standard.



EAFB – Sample 1 (rip-up clasts). Top graph represents the sample peaks, second bar graph represents a kaolinite standard, and the third bar graph represents a quartz standard.



EAFB – Sample 2 (*Ophiomorpha* tube). Top graph represents the sample peaks, second bar graph represents a kaolinite standard, and the third bar graph represents a quartz standard.

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BIOGRAPHICAL SKETCH

GUY HARLAN MEANS, P.G.
Curriculum Vitae, 2009
March 27, 2009

Date of Birth: January 13, 1968
Country of Citizenship: USA
Birthplace: Tallahassee, Florida

EDUCATION:

Master of Science – Geology
Florida State University, Tallahassee, FL 32304
Awarded May 1, 2009

Bachelor of Science – Geology
Florida State University, Tallahassee, FL 32304
Awarded August 1996

Associate of Arts
Tallahassee Community College, Tallahassee, FL
Awarded July 1991

PROFESSIONAL WORK EXPERIENCE:

Professional Geologist I
Florida Geological Survey (FGS)
Dates: February 1, 2005 – present
Job duties as listed below – job title change upon receipt of Professional Geologist license.

Job duties include managing geologic projects, maintaining geologic databases, public education and outreach, and scientific research and publication of results. Other duties include: Northwest Florida Water Management District (NWFWMD) geologist, providing geological information to the public about the NWFWMD, performing geologic descriptions of cores and cuttings, entering geologic data into database format, interpreting geologic data, gathering water quality/quantity data and analyzing these data, sedimentology lab work including granulometric analyses, permeability testing of core samples using falling head permeameters, other lab work as needed, and giving geologic lectures to the public and private sectors. Currently involved with the Florida Springs Initiative as an advisor to the Florida Springs Task Force. I oversee all aspects of springs research and water quality monitoring at FGS.

Geologist II
Florida Geological Survey (FGS)
903 W. Tennessee Street, Tallahassee, FL 32304
Dates: July 24, 2000 – February 1, 2005
Supervisor: Thomas M. Scott, Ph.D, P.G., Assistant State Geologist
(850) 488-9380

Research Associate
Florida Geological Survey (FGS)
903 West Tennessee Street, Tallahassee, FL 32304
Dates: July 14, 1995 – July 2000
Supervisor: Ken Campbell, P.G.

Job duties included: 1) worked with the Ambient Groundwater Monitoring Project as a drill rig hand and field geologist. Learned to operate and run a Mobil Drill rig converted to do wire line coring. 2) worked on numerous projects requiring field work – gained knowledge of state-wide geology in the process. 3) collected, identified and curated numerous invertebrate and vertebrate fossils from localities around the state 4) described and entered lithologic data on cores and cuttings from all parts of the state 5) performed hydraulic conductivity testing on core samples using falling head permeameters 6) collected and analyzed geologic data and published technical reports and papers on the results 7) worked on the STATEMAP program and produced a number of surficial geologic and bedrock maps for selected parts of the state.

Field Biologist
Coastal Plains Institute and Land Conservancy
Tallahassee, FL
Part time during summers prior to 1996

Job duties included checking and maintaining drift fences in the Munson Sand Hills area south of Tallahassee. Herpetological surveying of the Torreya State Park and other areas. Am familiar with the vertebrate faunas of Florida – particularly the panhandle region.

FIELD EXPERIENCE:

Rivers of the Panhandle and North-central Florida – 1980 to present. Explored and conducted archaeological and paleontological surveys of over 40 karst river systems. Logged over 1,000 hours underwater with SCUBA. Collected and curated thousands of historic and prehistoric artifacts and fossils from these rivers and made significant archaeological and paleontological discoveries including the discovery of an intact Paleoindian site (8Je-1004). Work closely with the Florida Museum of Natural History (Gainesville) and the Department of State, Division of Historical Resources in locating and donating fossils and archaeological sites of state significance. Contact for the Division of Historical Resources is James Dunbar (850) 245-6307, and Roger Portell with the Florida Museum of Natural History at (352) 392-1721.

Natural and Manmade Geologic Exposures of Florida – Have visited, described and collected fossils from natural and manmade (mines and borrow pits) geological exposures from across the state (Dry Tortugas to Jacksonville and across to Pensacola). I am very familiar with the lithostratigraphy and hydrostratigraphy of Florida and have led numerous Florida geologic field trips for students and professionals.

Big Bend Region, Texas – 1980 to present. Visited the Big Bend National Park and Big Bend Ranch State Park on six trips exploring the geological, archaeological and biological aspects of this vast area. Examined Tertiary volcanics of the Chisos Mountains. Hiked and explored the "Solitario" in the Big Bend Ranch State Park, which is a large, intrusive dome structure created by the emplacement of a laccolith. Examined Mesozoic strata that contain prolific fossil deposits which include the largest pterosaur ever discovered *Quetzalcoatlus.* Examined numerous archaeological sites that exist in both parks that are associated with springs and the Rio Grande River. Hiked extensively in both parks.

Mexico City and Vicinity – December 1 – 7th, 2007. Visited UNAM (National University of Mexico) and looked at the national invertebrate type collection and met with Mexican geologists and paleontologists including the Director of the museum. Investigated prehistoric ruins of Teotihuacan and Temple Mayor. Visited the National Museum of Anthropology and photographed artifacts with Crotalid motifs and other animal motifs. Discussed the possibility of returning in the future with a group of students to do paleontological field work in conjunction with a NSF grant.

Grand Bahama Island and Grand Turk Island – July 2006, Investigated coral reef habitats and island geology. Pleistocene and modern carbonates.

Australia – August 1 – 21st, 2005. Traversed the northern portion of Australia from Cairns to the Kimberly region and south to Ayers Rock looking at the geology and natural history of these regions. Visited numerous National Parks in karst terrains, igneous and metamorphic provinces and sedimentary basins. Visited 1.6 billion year old stramatolite reefs near Kingfisher Camp, caverns in Silurian marble in Chillagoe National

Park, Devonian arkosic deposits of the Bungle Bungle Range, Precambrian metamorphic terrains of the Kimberly region, gold, tin, silver and other ore producing regions in the Kimberly, diamond mine in Kimberly, 300,000 year old Wolf Creek meteorite impact site, 4,000 year old Henbury meteorite impact site, and climbed Ayers Rock and visited the Olgas Range.

Jamaica – July, 2004 and March, 2003. Visited the Seven Rivers paleontological site and conducted field work which included excavation of invertebrate and vertebrate fossils for the National Geographic Society, the Florida Museum of Natural History and the Howard University Department of Paleobiology. Excavated the remains of primitive sea cows, *Pezosiren portelli* (Domning, 2001) and associated vertebrates and invertebrates. Also visited quarries and collected Miocene and Pliocene invertebrate fossils. Contact Daryl Domning, Howard University or Roger Portell, Florida Museum of Natural History.

Maui – Summer 2000. Explored the island of Maui looking at the geology. Investigated most of the island including the Haleakla Crater and associated volcanic terrain.

Florida Bay – February and July 2000 and 2001. Conducted seagrass inventories and faunal survey's of marine organisms looking for changes in the Bay due to diverted fresh water input. Worked with the United States Geological Survey (see publications) in setting up monitoring sites. Researched the sedimentology of Bay sediments and how they have changed over time.

North Florida – May 1999. Research diver on the Aucilla River Prehistory Project. Project principal investigators: S. David Webb, University of Florida, and James Dunbar, Florida Bureau of Underwater Archaeology. Duties included diving in the dark water (tannic stained) Aucilla River at Sloth Hole and conducting underwater excavation of the site. During the field season, we also investigated a site my brother and I co-discovered on a tributary to the Aucilla – the Wacissa River. The site was named in our honor: the Ryan-Harley Site (8Je-1004) see publication list attached.

Ecuadorian Amazon – July-August 1989. Investigated the Ecuadorian lowland jungle along the Rio Napo learning about tropical ecology. Constructed a balsa raft and floated down a portion of the river. Also explored by dugout canoe.

Galapagos Islands (Ecuador) – July 1989. Investigated the shield volcanos of the Galapagos Islands looking at the geology and ecology of this unique place. Climbed the volcano Sierra Negra and observed the active volcano Volcan Chico on the island of Isabella.

Peru – July 1988. Explored the Peruvian Andes and visited Machu Picchu and other highland archaeological sites. Investigated the Andean Paramo habitat (8,000 – 13,000 feet) along the Urubamba River. Explored the Peruvian lowland jungle visiting the famed culpa, the site where thousands of parrots come to eat mineral laden river deposits.

Costa Rica – July 1987. Explored most of the country looking at the geology and ecology. Climbed and witnessed the eruption of an active volcano, Volcan Arenal, and visited Santa Rosa National Park. Visited La Selva Biological Station and observed the Bushmaster (*Lachesis muta*) in the wild.

Mexico – July 1985. Investigated the desert region of northern Mexico looking at the ecology. Traveled throughout the southeastern portion of Mexico to the Yucatan Peninsula and observed the karst geology and Aztec and Mayan ruins.

DOCUMENTARY FILMING

National Geographic Society – Assisted in the making of several National Geographic Explorer segments including: King Rattler. Assisted in the making and appeared in a part for National Geographic Television entitled: Snake Wranglers.

British Broadcasting Corporation – Appeared in a segment on the Miami Circle archaeological site. Assisted in the making of a segment on the Pleistocene animals of North America.

Karst Production, Inc. – Aided in the editing and production of documentary film entitled: Waters Journey – Hidden Rivers of Florida.

TEACHING EXPERIENCE

University of Florida – Guest lecture in Ecology of Florida's Springs class, August 28, 2008, Lecture entitled: Distribution and Classification of Florida's Springs. Professor Bob Knight.

Florida State University – Guest lecture in Geoarchaeology Graduate Course, January 10, 2007, The Geoarchaeology of the Ryan/Harley Site (8Je-1004) in the Wacissa River, North Florida. Professor Steve Kish.

Florida State University – Graduate Student Teaching Assistant, Summer 2000. Taught a field course for undergraduates.

Florida State University – January 2001. Guest lecture and field trip to Lake Jackson, Florida for a Graduate Anthropology course. Professor Michael Faught.

INVITED LECTURES AND PRESENTATIONS

Hernando Audubon Society, 50^{th} Anniversary Meeting, February 26, 2009, Brooksville, Florida, **Keynote Speaker,** The Geology of Florida's Springs.

Tallahassee Chapter of Rotary Club, February 11, 2009, Tallahassee, Florida, Alpine Glaciers.

Tallahassee Community College, Wakulla County Extension Green Guide Course – February 10, 2009, Crawfordville, Florida, A Geological Overview of Florida with Emphasis on Wakulla County.

Rainbow River Conservation, Incorporated, Annual Meeting, Keynote Speaker, December 6, 2008, Dunnellon, Florida, Marion County's Precious Spring Resources.

Tallahassee Community College, Wakulla County Extension Green Guide Course – November 18, 2008, Crawfordville, Florida, A Geological Overview of Florida with Emphasis on Wakulla County.

Florida Rural Water Association Annual Technical Conference – August 12, 2008, Daytona Beach, Florida, **Keynote Speaker**, Using Florida's Springs to Gauge Groundwater Quality and Quantity.

Florida Department of Health Annual OSTDS Conference – July 23, 2008, Tallahassee Florida, An Overview of Florida Geology with an Emphasis on Springs.

Apalachee Canoe and Kayak Club – July 16, 2008, Tallahassee, Florida, The Karst Geology of Florida.

American Ground Water Trust, Institute for Teachers – May 16, 2008, Thonotosassa, Florida, The Geology of Florida's Springs.

The Florida Trail Association, Tallahassee Chapter – April 8, 2008, Tallahassee, Florida, The Geology of Florida's Springs.

Hernando County Water Awareness Series: Understanding Sinkholes and Why They Occur - April 4, 2008, Brooksville, Florida, Florida's Karst Geology.

Tallahassee Community College, Wakulla County Extension Green Guide Course – April 2, 2008, Crawfordville, Florida, A Geological Overview of Florida with Emphasis on Wakulla County.

The Nature Conservancy Guest Lecturer Series – March 19, 2008, Blowing Rocks Preserve, Florida, Florida's Karst Geology.

Gulf of Mexico Alliance – September 25, 2007, St. Petersburg, Florida, An Overview of the Geology of Florida.

Marion County Springs Festival – September 21, 2007, Rainbow Springs, Florida, The Geology of Florida's Springs.

Everglades Geological Society – September 18, 2007, Ft. Meyers, Florida, Springs and Swallets of Florida.

American Ground Water Trust Teacher Workshop – June 1, 2007, Crystal Springs, Florida, Overview of the Hydrogeology of Florida with an Emphasis on Springs.

Hernando County Storm Water Workshop – May 10, 2007, Brooksville, Florida, What Lies Beneath – The Geology of Florida's Springs.

Florida Trail Association – May 8, 2007, Tallahassee, Florida, Across the Top End of Australia.

Antarctic Geological Drilling (ANDRILL) Workshop – May 4, 2007, Tallahassee, Florida – Florida State University Antarctic Research Facility, The Geology of the Wakulla Springshed.

Bay County Planning Commission – April 19, 2007, Panama City, Florida, A Hydrogeologic Overview of Bay County, Florida.

Florida Department of Environmental Protection – March 14, 2007, Tallahassee, Florida, The Geology of Florida's Springs.

Tallahassee Civitans – February 15, 2007, Tallahassee, Florida, The Geology and Paleontology between the Aucilla and Apalachicola Rivers.

Wakulla Springs Working Group – February 7th, 2007, Tallahassee, Florida, An Overview of the Spring Creek Spring Group.

Florida Trail Association – January 9, 2007, Tallahassee, Florida, The Geology and Paleontology Between the Aucilla and Apalachicola Rivers.

Florida Paleontological Society – December 9, 2006, Melbourne, Florida, Calcite Collecting in Florida.

Florida Association of Environmental Professionals, Tallahassee Chapter – November 17, 2006, Tallahassee, Florida, Geological Overview of Leon County and Vicinity.

Karst Waters Institute – October 23, 2006, Florida State University, Tallahassee, Florida. Karst Features in the Wakulla Spring Springshed.

Big Cypress National Preserve – October 4, 2006, Ochopee, Florida, The Geology of Florida's Springs.

Silver River Museum and Environmental Education Center – August 31, 2006, Ocala, Florida, The Floridan aquifer system: Florida's Fragile Underground Reservoir.

Sierra Club of Gainesville – February 2, 2006, Gainesville – University of Florida Campus, The Geology of Florida's Springs.

Wakulla Springs Working Group – February 2, 2006, Douglas Building, Tallahassee, FGS Swallet Project – Swallets in the Wakulla Springshed.

City of Ocala, City Council – October 11, 2005, Ocala, Florida, Geology and Hydrogeology of Marion County with an Emphasis on Springs.

Marion County Springs Festival – September 24, 2005, Rainbow Springs State Park, Marion County's Springs.

Geological Society of America, Southeast Section Meeting – March 18, 2005, Biloxi, Mississippi, Florida Springs Protection Areas.

Florida Department of Health – February 9, 2005, Tallahassee, A Geological Overview of Florida.

Branford Rotary Club – February 8, 2005, Branford, Geology and Water Resources of Suwannee County and Vicinity.

FAMU/FSU School of Engineering – Water Resource Lecture Series – February 4, 2005, Tallahassee, Springs Related Issues.

Marion County Springs Festival – September 25, 2004, Ocala, Florida, Marion County's Precious Springs.

Annual Meeting of the Florida Groundwater Association – May 15, 2004, Orlando, Florida, Florida's Springs – Windows into Our Aquifers.

Hernando County – December 12, 2003, Brooksville, Florida, Springs Initiative Funded Projects at the Florida Geological Survey.

Florida Paleontological Society – December 6, 2003, Bristol, Florida, The Human History of the Upper Apalachicola River Valley.

Florida Department of Health Regional Meeting – November 18, 2003, Tallahassee, Florida, Hydrogeology of Florida's Karst Regions.

The Ocala Leadership Council – October 16, 2003, Ocala, Florida, Springs of Marion County.

The Tallahassee Museum of History and Natural Science – September 28, 2003, Tallahassee, Florida, Florida During the Pleistocene.

The Marion County Springs Festival – September 27, 2003, Rainbow Springs State Park, Two Lectures: 1) Where Does Out Spring Water Come From? 2) The Florida Springs Initiative.

The Florida Department of Environmental Protection, Quarterly Monitoring Meeting – September 17, 2003, St. Augustine, Florida, FGS Springs Initiative Update.

The Florida Section of the American Institute of Professional Geologists, Annual Meeting – August 28, 2003, Lakeland, Florida, The FGS Role in the Florida Springs Initiative.

The Florida Local Environmental Resource Agencies (FLERA) Conference - July 9 – 11, 2003, Florida Springs Initiative. Speaker/Panelist.

Florida Cave Management Workshop – April 16 – 17, 2003, The Florida Springs Initiative and Cave Management – Politics, Funding and Public Policy. Panelist

The Florida Springs Conference – February 5 – 7, 2003, Gainesville, Florida, Status of the Florida Geological Survey Bulletin 31 Update. Speaker, exhibitor and organizer.

Florida Groundwater Society - August 2002, The Florida Springs Initiative.

Florida State University, Department of Geological Sciences – Spring 2002, The Geoarchaeology of the Ryan-Harley Site (8Je-1004).

The Florida Phosphate Council – October 18, 2001, A Geological Assessment of the Miami Circle Site.

Everglades Geological Society – September 2001, The STATEMAP Program at the Florida Geological Survey.

Florida Geological Survey – January 9, 2001, Brown Bag Lecture: The Geology of Maui.

Florida Geological Survey – March 1999. Brown Bag Lecture: The Miami Circle Site

FIELD TRIPS

Central Florida Phosphate District Fieldtrip, Southeastern Section of the Geological Society of America, March 11, 2009, Co-leader with T. Scott.

Tallahassee Community College, Wakulla County Extension Green Guide Course – Field trip to the Leon Sinks Geological Area, January 31, 2009.

Tallahassee Community College, Wakulla County Extension Green Guide Course – Field trip to the Leon Sinks Geological Area, November 23, 2008.

The Florida Trail Association, Tallahassee Chapter – April 12, 2008, Hike to Sheppard Spring in the St. Marks National Wildlife Refuge.

University of South Florida Paleoecology Class – January 19, 2008, Co-led field trip to Alum Bluff to investigate fossiliferous strata exposed and teach students about Florida paleoecology.

Association of American State Geologists Annual Meeting – June 8 through June 13th, 2007, Co-led field trips to the Everglades, Windley Key Fossil Reef Geological State Park, and John Pennekamp Coral Reef State Park.

Antarctic Geological Drilling Workshop – May 5, 2007, Led field trip to Wakulla Spring.

The National Groundwater Association – February 26, 2007, Co-led field trip investigating the karst features in the upper Peace River basin.

The Florida Trail Association – January 27, 2007, Led field trip to Alum Bluff via the Apalachicola Bluffs and Ravines trail, Jefferson County, Florida. Discussed the stratigraphy and paleontology of the strata exposed at Alum Bluff.

Florida Paleontological Society – December 8, 2006, Led trip to Dickerson Quarries in St. Lucie and Okeechobee Counties looking at Pleistocene sediments and fossils.

National Groundwater Association Annual Meeting – October 1, 2006, Co-led a field trip looking at the geology of the Everglades National Park.

University of South Florida, Geology Club – April 21, 2006. Led trip to Vulcan Quarry in Brooksville. Investigated the Suwannee Limestone exposed in the quarry.

University of South Florida, Paleontology Class – April 15, 2006, Led trip to Alum Bluff and Rock Bluff on the Apalachicola River. Investigated molluscan faunas of lithologic units exposed. Professor Peter Harries, USF.

University of South Florida Geology Alumni – February 12, 2005, Led trip to Vulcan Quarry in Brooksville and investigated Suwannee/Ocala Limestone contact.

The Florida Paleontological Society – December 6, 2003, Led field trip to Alum Bluff on the Apalachicola River.

Southeastern Geological Society (SEGS) – August, 2003, Co-led SEGS field trip to Marianna Caverns State Park and on to Jackson Blue Spring.

Southeastern Geological Society (SEGS) – November, 2002, Led field trip to the upper Apalachicola River looking at the geology of the region.

ABSTRACTS AND PUBLICATIONS

Herrera, J.C., Portell, R.W. & **Means, G.H**.. 2008. First late Pleistocene regular sea urchin reported from Florida with notes on morphological variation among geographically separate modern populations. *North American Echinoderm Conference Abstr. with Prog*., 5:28.

Herrera, J.C., Portell, R.W., and **Means, G.H.**, 2006, Echinoids of a middle to late Pleistocene deposit from the central Atlantic coast of Florida, abstract, 2006 Abstracts with Programs, Southeastern Section of the Geological Society of America, Volume 38, Number 3.

Balsillie, J.H., **Means, G.H,** Dunbar, J.D., and Means, R.C., 2006, Geoarchaeological Consideration of the Ryan-Harley Site (8Je-1004) in the Wacissa River Northern Florida, Cenozoic Vertebrates of the America's: Papers to Honor S. David Webb, Florida Museum of Natural History Bulletin, Volume 45, Number 4, pp 541 - 562.

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BOOKS

Bryan, J., Scott, T., and **Means, G.H.,** 2008, Roadside Geology of Florida, Mountain Press Publishing Company, Missoula, Montana, 376 pages.

INFORMAL PUBLICATIONS & GUIDEBOOKS

Scott, T.M., and **Means, G.H.,** 2005, Geological discussion of the Rucks' pit northeastern Okechobee County, Florida, in: Rucks' Pit Okechobee County, Florida, USA, Southeastern Geological Society Field Trip Guidebook 45, p. 6-10.

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PROFESSIONAL LICENSES/CERTIFICATIONS

Florida Licensed Professional Geologist (P.G. #2359), October 2004

NAUI and NASDS Open Water Dive Certification (since 1982)

Certified Research Diver – Florida State University Academic Dive Program and Florida Department of Environmental Protection

Certified Nitrox Diver – SSI September 2007

DAN Certified Oxygen Provider, October 2007

American Safety and Health Institute, First Aid and CPR

TRAINING

Ground Penetrating Radar – two day class offered by MALA geoscience. Operation of 50, 100 and 250 MHz antenna GPR and post processing of the data. October 14 & 15, 2008 in Tallahassee, FL.

Glacier Mountaineering School – Completed August 23, 2008. Six day course in Cascade Range of Washington. Ascended Mt. Daniel and trained on the Mt. Daniel Alpine Glacier. Aspects of glacier mountaineering including: self arrest, crampon use, knot tying, belaying, rappelling, glacier traversing, crevasse rescue, mountain survival skills.

Introduction to ArcGIS I – Completed November 16, 2007.

Making Sense of Environmental Data with HydroGeo Analyst – Completed June 19, 2007.

FOREIGN LANGUAGE

Spanish (working knowledge)

HONORS AND AWARDS

2007 Florida Geological Survey Team Extra Effort Award, AASG Annual Meeting Organizational Team

2005 Florida Geological Survey Team Extra Effort Award, Springs Initiative Team

2005 Florida Geological Survey Extra Effort Award

2003 Florida Geological Survey Team Extra Effort Award, Manatee Spring Team

2003 Florida Geological Survey Extra Effort Award

2000 Davis Productivity Award, Florida Department of Environmental Protection

2000 Florida Geological Survey Team Extra Effort Award

1999 Florida Department of Environmental Protection Team Performance Award

1998 Florida Geological Survey Extra Effort Award

1996 Florida Geological Survey Team Extra Effort Award

PROFESSIONAL SOCIETY MEMBERSHIPS

Society for American Archaeology

Florida Anthropological Society

Florida Paleontological Society, Vice President 2006-2007, 2007-2008, 2008-2009

Southeastern Geological Society, Vice President 2002, President 2003, Treasurer, 2009

Geological Society of America

Florida Association of Professional Geologists

American Institute of Professional Geologists