Economic geology of the White Cliffs diatomite deposit, Mammoth, Arizona

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ECONOMIC GEOLOGY OF THE
WHITE CLIFFS DIATOMITE DEPOSIT
MAMMOTH, ARIZONA

by

Jonathan Daniel Shenk

A Thesis Submitted to the Faculty of the

DEPARTMENT OF GEOSCIENCES

In Partial Fulfillment of the Requirements
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1 9 9 0

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ABSTRACT

This study defines the distribution, grade, and quality of diatomite at the White Cliffs diatomite deposit, Mammoth, Arizona. The deposit is hosted in a lacustrine facies of the Quiburis Formation, a Miocene to Pliocene basin-fill sediment of the lower San Pedro Valley. The lake bed sediments are divided into three informal members, the Redington, White Cliffs, and Gust James. Diatomite is found only in the White Cliffs member, and three potential ore zones are defined. Grades range from 43 vol% to 81 vol% diatoms, and quality varies from low to high. In Adit Canyon, >40 ft of medium to high quality diatomite averaging 72 vol% diatoms was found. A high potential exists for buried diatomite south of Adit Canyon, and a 200-acre quarry site containing an estimated >9.0 million s.t. of diatomite has been outlined in the Little Gust James Wash area.

1. INTRODUCTION

1.1 Purpose of Study

Even though the White Cliffs diatomite deposit has been worked by several small mining companies since the early 1920s, prior to this study a detailed economic geology investigation had not been carried out. The purpose of this study is to 1) describe the geology of the White Cliffs diatomite deposit and 2) determine the distribution, grade, and quality of the diatomite at White Cliffs. Field work began in the fall of 1986 and consisted of geologic mapping, measuring stratigraphic sections, and sample collecting. Concurrent laboratory work consisted of testing the diatomite for various physical properties and microscopic examination.

1.2 Location

The White Cliffs diatomite deposit is located in secs. 13 and 24, T. 9 S., R. 17 E. and secs. 17, 18, 19, 20, 29, and 30, T. 9 S., R. 18 E., Peppersauce Wash and Clark Ranch 7.5' Quadrangles, Pinal County, Arizona. The deposit is 8 to 10 miles south of Mammoth, a small mining community located 45 miles northeast of Tucson along state highway 77. The study area is reached by crossing the San Pedro River at Mammoth and travelling southeast on a partially paved dirt road (Fig. 1). Access to the deposit is provided by numerous side roads and canyons (Fig. 2).

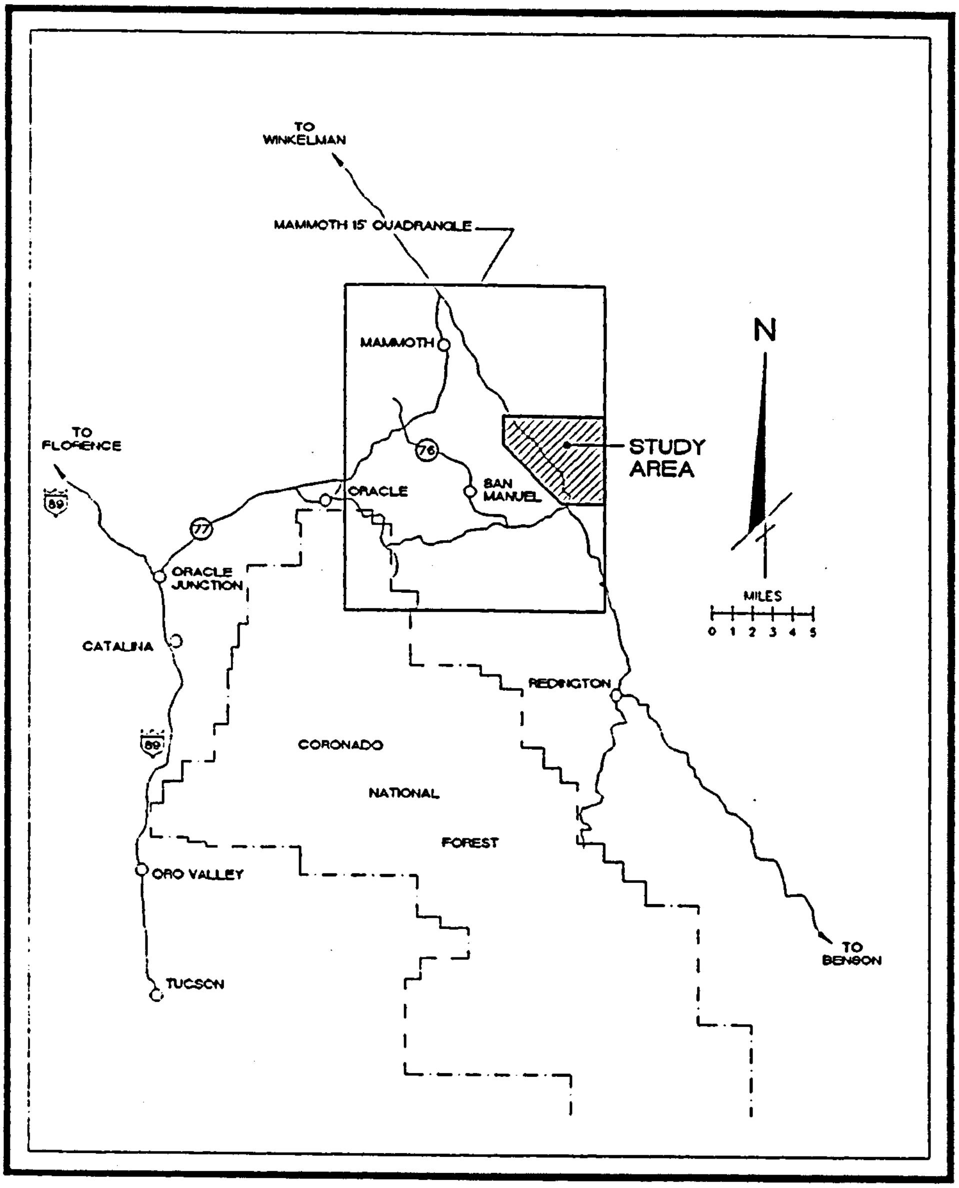

Figure 1 - Location map of study area.

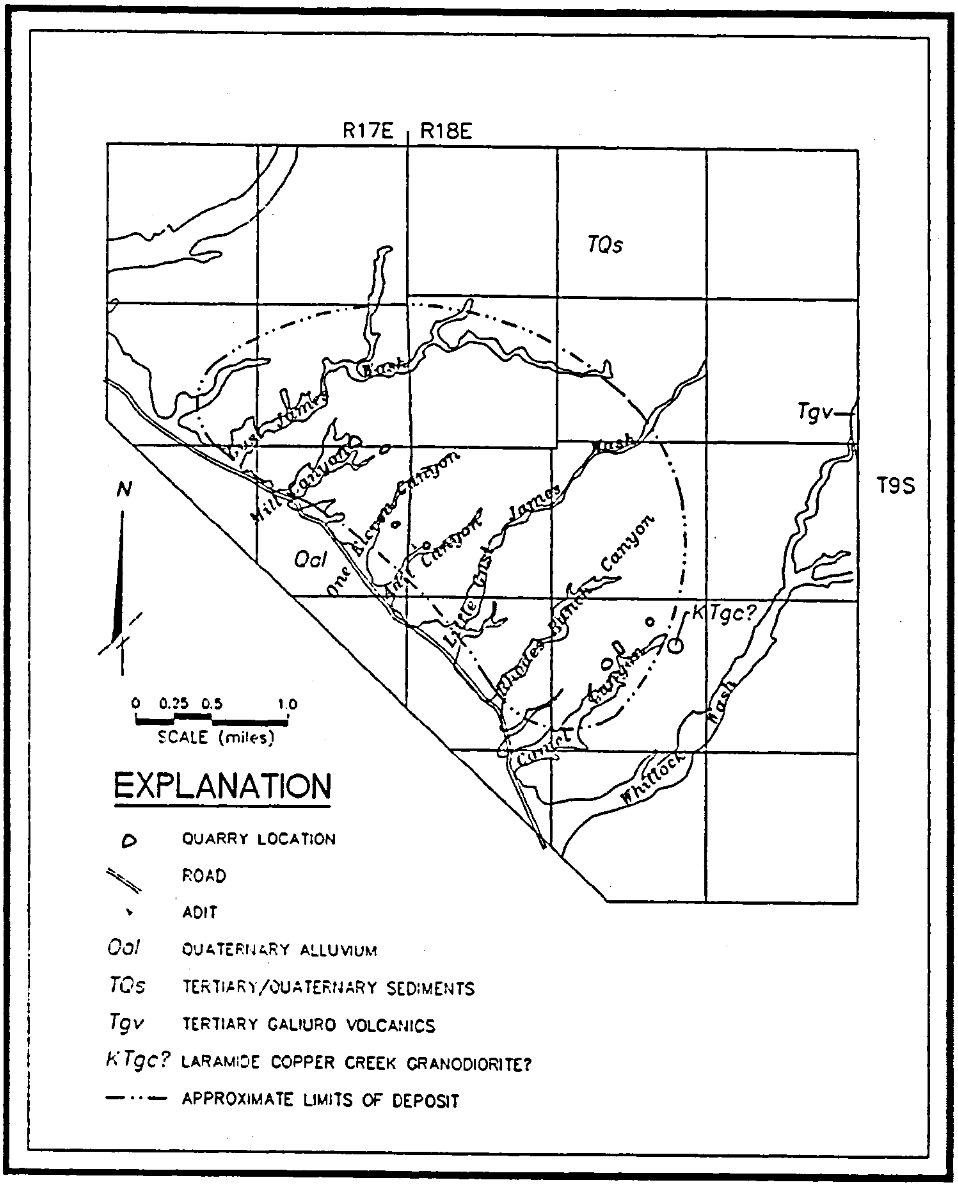

Figure 2 - General map of the study area outlining the approximate limits of the deposit.

The areal extent of diatomaceous sediments at White Cliffs is approximately 6 square miles. The White Cliffs claim group, consisting of 20 unpatented placer mining claims, covers 3,120 acres or approximately 5 square miles (Fig. 3). The surface and mineral rights are managed by the U.S. Bureau of Land Management, and the claims are surrounded by a mix of private, state, and federal land. In the past, additional claims have been staked adjacent to the main claim group.

1.3 Definition of Diatomite

The Glossary of Geology (Bates and Jackson, 1987) defines diatomite as follows:

> "A light-colored soft friable siliceous sedimentary rock, consisting chiefly of opaline frustules of the diatom, a unicellular aquatic plant related to the algae. Some deposits are of lake origin but the largest are marine. Owing to its high surface area, high absorptive capacity, and relative chemical stability, diatomite has a number of uses, esp. as a filter aid and as an extender in paint, rubber, and plastics. The term is generally reserved for deposits of actual or potential commercial value. Syn: diatomaceous earth; kieselguhr. Obsolete syn: infusorial earth; tripoli-powder."

It is important to note the restriction of the term to denote economic or potentially economic deposits. In this report, the term "diatomite" is used for the rock in crude ore form, and the term "diatomaceous earth" (or DE) is used for the processed final product.

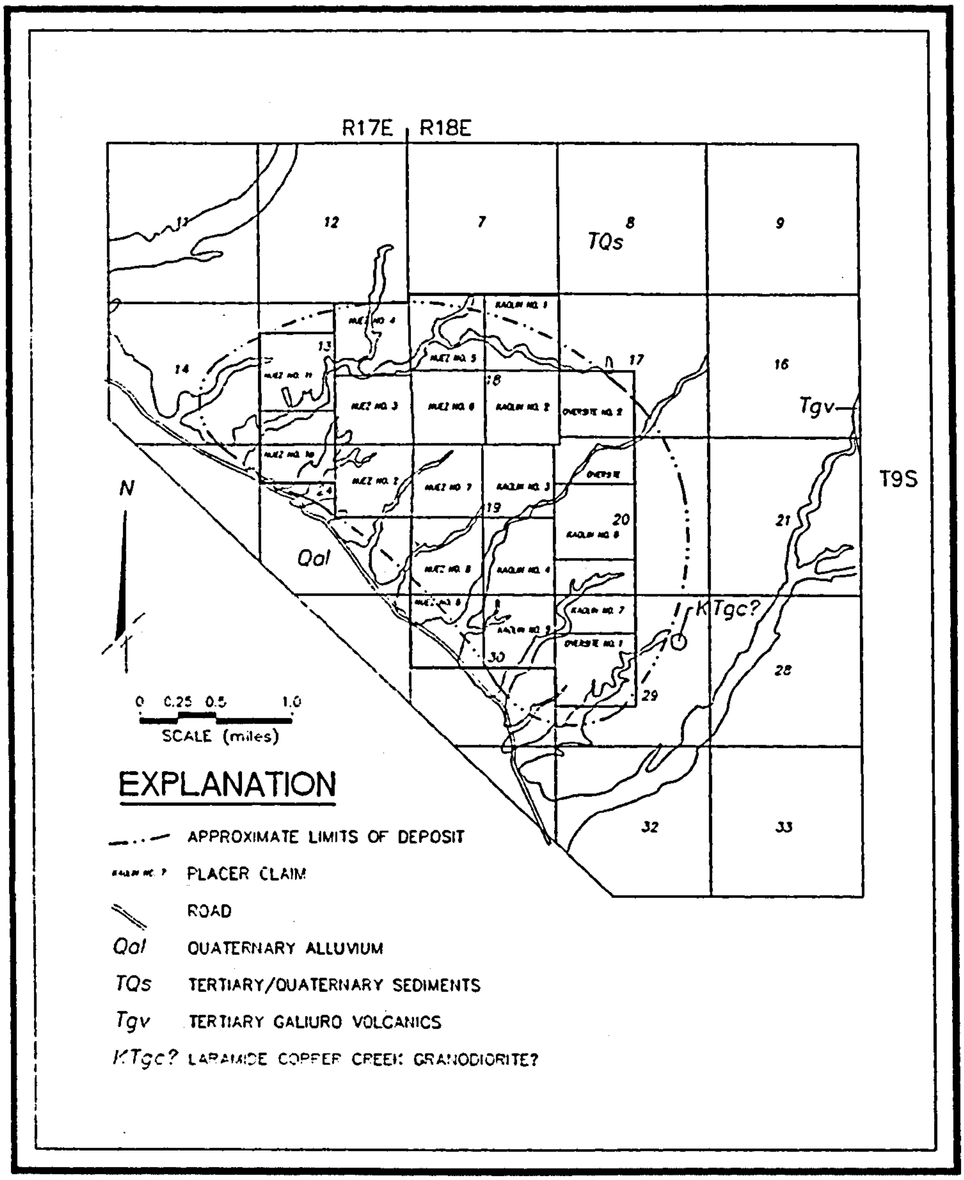

Figure 3 - Map of the White Cliffs claim group.

Several review articles have been written describing diatomite deposits and the diatomaceous earth industry. A few of the more recent include Durham (1973), Kadey (1983), Meisinger (1985), Industrial Minerals (1987), Miles (1987), and Breese (1989). Older publications by Eardley-Wilmot (1928) and Calvert (1930), though somewhat dated, are the only in-depth industry studies available.

1.4 History of Mining and Development

The White Cliffs diatomite deposit has experienced sporadic mining activity over the years, but development efforts never evolved into long-term operations due to several factors, including 1) a lack of geologic control and understanding, 2) inefficient mining and milling techniques, 3) poor product quality, 4) insufficient product research, 5) transportation difficulties, and 6) legal disputes. The following summary of mining activity at White Cliffs was compiled from Arizona Geological Survey file data, Arizona Department of Mines and Mineral Resources file data, Pinal County courthouse documents, U.S. Bureau of Mines Mineral Yearbooks, Calvert (1930), and Paydirt (1940).

1.4.1 The Herreras Years, 1917-1948

The White Cliffs claim group was first staked in 1917 by Andres Herreras, Tucson city building inspector, and his associates. In 1922, G. M. Butler, director of the Arizona

ADIT CANYON
STRATIGRAPHIC CORRELATION DIAGRAM

PLATE VI

JONATHAN DANIEL SHENK
M.S., GEOSCIENCES, 1990

Bureau of Mines, contacted M.R. Campbell, acting director of the U.S. Geological Survey, and R.B. Ladoo of the U.S. Bureau of Mines regarding the potential profitability of the deposit. Both Campbell and Ladoo replied that a deposit 50 miles away from railroad transportation probably could not operate at a profit. Nevertheless, in 1926, the Mammoth Diatomaceous Earth Company started transporting crude ore to Tucson for processing on West Sixth Street. The product was reportedly used, probably as a cement additive, in the construction of Steward Observatory at the University of Arizona and the Congress Hotel in downtown Tucson. It was also used as insulation in the homes of Dr. A.E. Douglass, director of the Steward Observatory, Dean G.M. Butler, director of the Arizona Bureau of Mines, John Murphy, a local real estate promoter, and Harold Bell Wright, author of the famous 1923 western novel "The Mine With the Iron Door". Product testing by Quintas Monier, a Tucson contractor, showed that homes insulated with diatomite were 13 degrees cooler relative to outside temperatures. Other early uses were by the local power and light company in converting engine exhaust into steam and by J.C. Roak to insulate ice refrigerators.

In 1935, the claim group was restaked by Herreras and his family. Efforts by the Arizona Department of Mineral Resources put two promoters, M.G. Staley and F.R. Fisher, in touch with Herreras, and in 1939 the Arizite Products Corporation was formed. Arizite negotiated a lease with

Herreras for four of the claims and began operations in 1940. Arizite reportedly quarried 45 lbs/ft3 crude using chipping hammers, chisels, and spades. Trucks were used to transport the ore to a processing plant 1 mile north of Mammoth. The plant consisted of a hammer mill, a butane furnace, and cyclone air separators. The main product was a -200 mesh, 12-16 lbs/ft3 loose density insulation material. It was shipped in 50-lb bags to Chicago where it was used in steam-pipe packing and refrigerator insulation. Other products included a grease remover sold to laundries in Arizona and various filter aids. Product research focused on concrete admixtures, soil conditioners, asphalt fillers, and construction material. In addition, the tailings were marketed as scouring powder. Arizite operated from 1940 to 1941 when it closed down due to high costs of mining, milling, and freight.

1.4.2 The Secrist Years, 1948-1972

Stanley Secrist bought the property in 1948 and restaked the claims in 1949. In 1952, Secrist added three more claims to the original claim block and leased the property to the Arizona Diatom Corporation. In the following years, Arizona Diatom subleased portions of the property to several different groups. In 1954, Superlite Builders Supply Company sublet one claim and produced 1/8-inch, light-weight aggregate for use in concrete blocks, but discontinued the operation in 1956. In 1959, Arizona Diatom sublet the property to American

Diatoms, Incorporated. The company built a small pilot mill, and by 1963 had tested or developed a paint additive for texturing drywall, several grades of cement additive, several grades of natural insecticide, and a chemical carrier for explosives sold to Apache Powder Company, Benson, Arizona.

American Diatom merged with Arizona Gypsum in 1963, and some personnel from American Diatom formed a separate company known as Associated Enterprises. There was much legal maneuvering in 1963 and 1964, during which lawsuits were filed, satellite claims staked, and the mill disassembled and moved off the property. Arizona Gypsum, apparently no longer under lease to Secrist, continued to produce small quantities of fillers from 1965 to 1970 probably from the small, privately held quarry located near the mouth of One Eleven Canyon. Arizona Gypsum merged with Superior Company in 1971, and Superior continued to produce small quantities of filler for only a short time afterwards.

1.4.3 The University Years, 1972 to present

In 1972, Stanley Secrist passed away, and the property was willed to the University of Arizona. In 1975, the University of Arizona leased the property to Melvin Palmer, who formed Mammoth Mining and Milling, Incorporated. Palmer quarried and stockpiled only small amounts of crude and it is doubtful that he sold significant tonnages.

In 1985, the University entered into a lease agreement with Whitecliff Industries, Incorporated, and Whitecliff is currently operating in the northwest corner of the property. Whitecliff has explored and opened up new quarry sites, erected a processing plant, established an on-site materials testing laboratory, and is maintaining an administrative office in Tucson.

The exploration for new quarry sites is carried out by drilling several 10- to 20-foot-deep, 2-inch-diameter auger holes, followed by trenching to obtain bulk samples. The mining procedure is to 1) remove overburden, 2) rip up the ore, 3) stock pile the crude, 4) allow it to air dry, and 5) feed the crude ore into the processing plant. The plant consists of a hammer mill, a diesel flash furnace, three cyclone air separators, a baghouse, and two storage bins. The lab tests crude ore samples, maintains product quality control, and researches new products and applications.

The final product marketing is run through the Tucson administrative office. Products include filler for roofing asphalt, silica admixture for calcium silicate production, and insulation material in the manufacture of pizza ovens and safes. The products have an average loose-weight, dry bulk density of 8 lbs/ft3 and are packed in 50-lb bags and trucked out-of-state to Illinois (insulation), Texas (roofing asphalt), and New Jersey and Georgia (silica admixture).

1.4.4 Product Research and Development

The results of past product research and development efforts on White Cliffs DE are mixed and difficult to analyze because of a lack of geological information. In general, though, the diatomite samples collected for processing and testing were obtained from the margins of the deposit. As will be seen from the geologic descriptions in this report, the margins of the deposit contain a high percentage of diatomaceous marls. The mixed test results, therefore, probably reflect the quality variability between diatomaceous marl and diatomite. Readers interested in further details concerning past product research should consult Bollaert (1952, 1953, and 1962) and Arizona Geological Survey file data.

Unfortunately, final products could not be analyzed in this study because: 1) a reliable laboratory scale air-classifier for producing DE samples was not available, and 2) the management of Whitecliff Industries had little regard for selective mining techniques and, as a consequence, production could not be correlated back to specific diatomite beds.

2. ECONOMIC GEOLOGY OF THE WHITE CLIFFS DIATOMITE DEPOSIT

Although the White Cliffs diatomite deposit has been recognized since the turn of the century, it has received very little attention from economic geologists. As a consequence, only a few brief published and unpublished economic reports were available on the area. Therefore, this study was undertaken to examine in detail the geology of the White Cliffs deposit and to use this information to determine the economic potential of the White Cliffs claim group.

To accomplish this, a detailed geologic map and two cross-sections of the deposit were completed (Plates I and II), 17 stratigraphic sections were measured (Appendix A), five stratigraphic correlation diagrams were compiled (Plates III to VII), and 34 samples were tested in the laboratory. The geologic mapping and stratigraphic correlations resulted in a reinterpretation of local stratigraphy and the determination of diatomite distribution. The laboratory testing provided a basis for determining diatomite grade and quality.

2.1 Previous Economic Geology Studies

Blake (1902a, 1902b, 1902c, and 1903) was the first to describe the White Cliffs diatomite deposit. He recognized the deposit as having a lacustrine origin and provided photographs and paleontological identifications of the diatoms. He also provided chemical analyses and physical property descriptions of the diatomite and interbedded cherts. Trischka (1929) examined White Cliffs in his study of Arizona diatomite deposits. He recognized two distinct volcanic ash layers at White Cliffs and provided an idealized cross section of the deposit. His report also included a chemical analysis of "Arizona" diatomite. Wilson (1940 and 1944) and Wilson and Roseveare (1949) briefly discussed the White Cliffs deposit and the early diatomite mining operations. Long and Olson (1957) discussed the geology of White Cliffs and included a photograph of the diatoms, a table of basic diatomite physical properties, and a chemical analysis.

The first in-depth economic studies of the White Cliffs deposit were by Bollaert (1952, 1953, and 1962). Bollaert produced a map on which he noted a NW-striking fault and outlined three potential quarry sites around the periphery of the deposit: the North Quarry, the Mill Site Quarry, and the South Quarry (Fig. 4). For each site Bollaert measured stratigraphic sections, estimated crude tonnages, and researched potential final products. Bollaert recognized the need for more extensive testing of the White Cliffs crude, and concluded that future product research should concentrate on miscellaneous fillers and calcined lightweight aggregates.

In 1968, Kaiser Aluminum and Chemical Corporation drilled several holes on the property in a filter aid investigation. Samples were sent to the Colorado School of Mines and tested

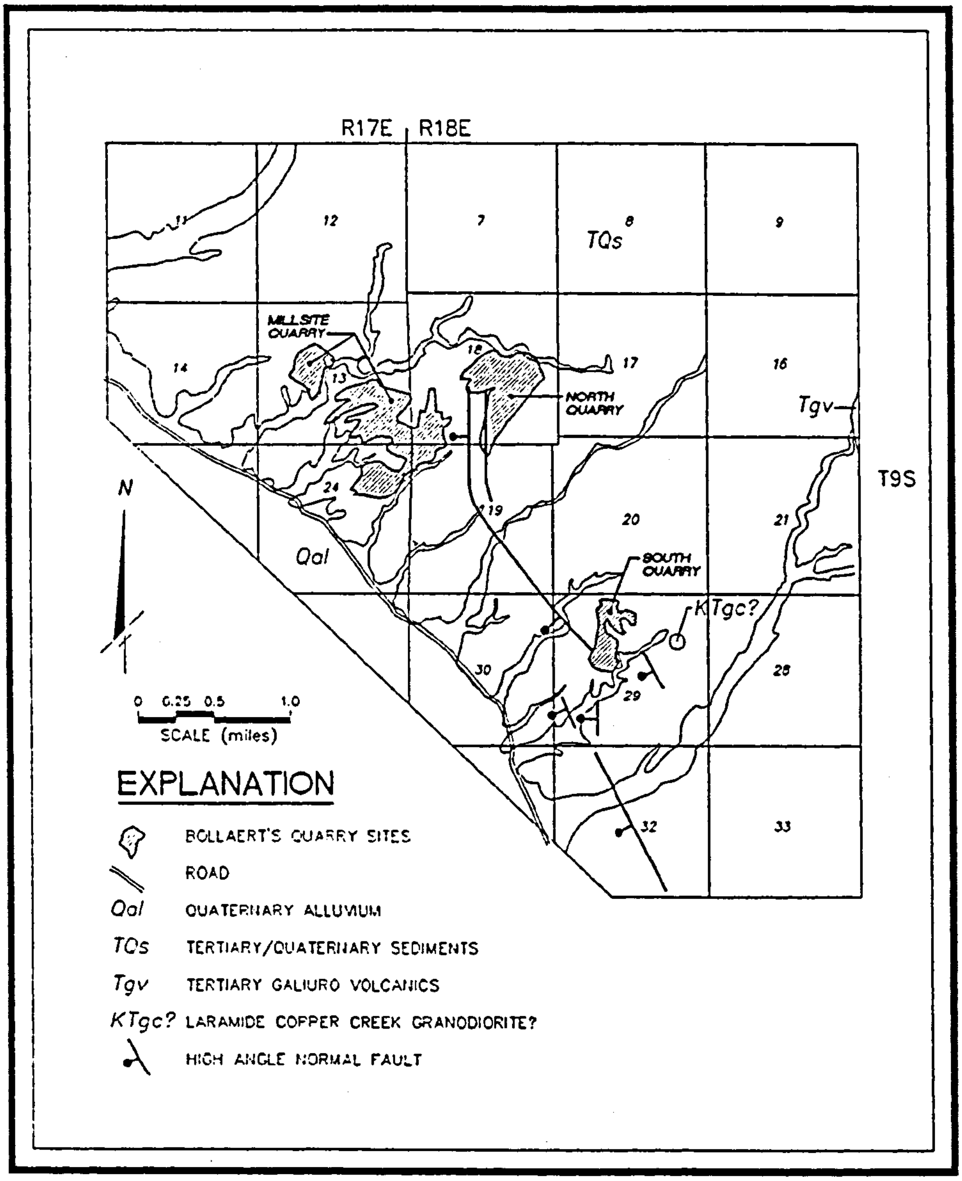

Figure 4 - Location map of Bollaert's potential quarry sites, (after Bollaert 1953 and 1962).

for chemical and physical properties (Arizona Geological Survey file data). The study concluded that an acceptable filter aid product could not be produced from the White Cliffs crude. However, the samples submitted by Kaiser had an average CaO content of 15 percent, indicative of diatomaceous marl, not diatomite. Therefore, the results of the Kaiser filter aid study are inconclusive.

In a summary of Arizona diatomite deposits, Peirce (1969) discussed the stratigraphy and structure of White Cliffs, pointed out that all "white" sediments at White Cliffs were not diatomite, and estimated that a total of 15,000 short tons had been produced from the property. In 1974, Peirce, along with his assistant Vuich, performed assessment work on the deposit for the University of Arizona. Peirce and Vuich divided the sediments into a lower white member, a middle silt member, and an upper white member, used volcanic ash layers as marker beds, and recognized a N- to NW-striking fault and a NW-striking syncline. They produced a simple geologic map and two cross sections and recognized the need for more detailed mapping to fully understand the deposit. A final report was not written, but the field notes, map, and cross sections are available at the Arizona Geological Survey.

In 1986, the present study was undertaken and preliminary results and conclusions were reported in Shenk (1988). The results and conclusions in the present report supersede those in Shenk (1988).

2.2 Regional Geologic Setting

Information on the regional geology of the lower San Pedro Valley was recently summarized by Dickinson (1987 and 1988) and Dickinson and Shafiqullah (1989). The following is summarized from their work unless otherwise noted. Rock units followed by a geologic map symbol are found in the Mammoth 15' Quadrangle (Fig. 5).

2.2.1 Paleozoic and Proterozoic Strata and Basement

The basement rock units in the lower San Pedro Valley range in age from Early to Middle Proterozoic. The Early Proterozoic units consist of the Pinal Schist metasediments and metavolcanics and the Johnny Lyon Granodiorite. Unnamed equigranular granodiorites (Yg) and diorites make up the Early to Middle Proterozoic and are probably local variations of the Middle Proterozoic Oracle/Ruin suite of megacrystic granites (Yo). Overlying the basement are the Middle Proterozoic Apache Group sediments, including associated diabase sills and basaltic lavas (Ya), and Cambrian to Permian clastic and carbonate strata (Ps).

2.2.2 Mesozoic and Laramide Strata

Mesozoic strata consist of the mid-Jurassic Walnut Gap Volcanics and associated volcaniclastics, the nonmarine facies of the Lower Cretaceous Bisbee Group, and the Upper Cretaceous

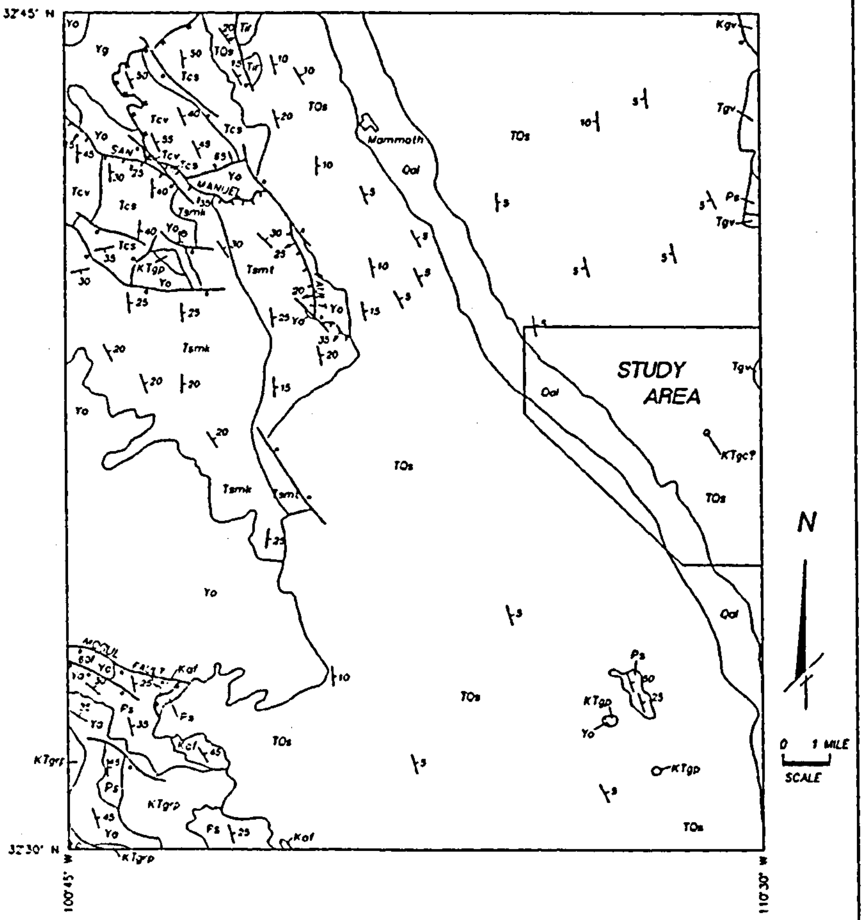

Figure 5 - Geologic map of the Mammoth 15' Quadrangle, (after Dickinson, 1987).

Pinkard Formation, a friable, paralic sandstone. Laramide strata consist of several volcanic units, including the Williamson Canyon, Muleshoe, and Glory Hole (Kgv) Volcanics, with redbeds, conglomerates, and volcaniclastics of the American Flag (Kaf) and Cascabel Formations.

2.2.3 Cretaceous and Tertiary Intrusive Units

A large number of plutons, dikes, and sills were intruded in the region during the Cretaceous and Laramide. These include the Tortilla quartz diorite suite, the Rattler Granodiorite stock, the Leatherwood quartz diorite suite, the Rice Peak granodiorite porphyries (KTgrp), the Copper Creek granodiorite complex, and miscellaneous granitic porphyry dikes and sills. A fault block of quartz monzonite porphyry that outcrops within the study area is tentatively correlated to the Copper Creek granodiorite complex (KTgc?) (Force, pers. comm., 1989). Tertiary intrusive units include the Middle Eocene Wilderness granitic suite and Early Miocene rhyolitic plugs and dikes (Tir).

2.2.4 Mid-Tertiary and Younger Stratified Units

Intense mid-Tertiary extensional deformation began in the mid-Oligocene (30 Ma) and lasted up until the mid-Miocene (16 Ma). Strata deposited during this period include the Oligocene Mineta Formation and Whitetail Conglomerate, the Mid-Tertiary Galiuro Volcanics (Tgv), the Late Oligocene to

Early Miocene Cloudburst Formation (Tcv - lower volcanic member, Tcs - upper sedimentary member), and the Early Miocene San Manuel Formation (Tsmk - Kannally Member, Tsmt - Tucson Wash Member).

After the mid-Miocene, extensional deformation continued but at much reduced rates. High-angle normal faults blocked out prominent mountain ranges, and the intervening basins were filled with sediments. Basin-fill strata (TQs) in the San Pedro Valley consist of two formal units, the Early to Middle Miocene Big Dome Formation and the Late Miocene to Early Pliocene Quiburis Formation (Krieger and others, 1974), along with Pliocene-Pleistocene terrace gravels, alluvial fans, and pediment gravels. Dickinson and Shafiqullah (1989), however, regard the Big Dome Formation as laterally equivalent in both age and lithology to the Quiburis Formation and adopt the name Quiburis in preference to the name Big Dome. The geology of the Quiburis Formation, which hosts the White Cliffs diatomite deposit, is discussed in the next section.

2.3 Geology of the Quiburis Formation

The White Cliffs diatomite deposit is hosted in the Quiburis Formation, a Miocene to Pliocene basin-fill sediment of the lower San Pedro Valley. Numerous maps and reports are available concerning basin-fill sediments in the lower San Pedro Valley (Dickinson, 1987), but only a few deal directly or indirectly with the White Cliffs deposit. These studies can be classified as either general geologic, vertebrate paleontologic, geochronologic, or paleomagnetic studies, and they are summarized below.

2.3.1 General Geologic Studies

Prior to the early 1960's, basin-fill sediments in the San Pedro Valley were referred to as Gila Conglomerate, a name originally applied by Gilbert (1875) to undeformed or mildly deformed sediments in eastern Arizona and western New Mexico. Heindl (1963) raised the Gila to group status, mapped the Cenozoic sediments in the vicinity of Mammoth, and divided the Gila into three formations: the San Manuel, the Quiburis, and the Sacaton. He further separated the Quiburis Formation into a lower fine-grained unit, with laterally equivalent sandstones and pebble conglomerates, and a disconformably overlying upper coarse-grained boulder conglomerate. He did not, however, map the two units separately. Kreiger and others (1974), accepted the names San Manuel Formation and Quiburis Formation but rejected the names Gila Group and Sacaton Formation for this area.

Agenbroad (1967) extended the area of Heindl's mapping south to the town of Redington and encompassed the White Cliffs deposit. He reinterpreted Heindl's fine- and coarse-grained units as lateral facies, mapped them separately, and informally named the fine-grained facies the Redington member and the coarse-grained facies the Tres Alamos member. In the

White Cliffs area, he measured two stratigraphic sections and suggested that the 2- to 3-ft-thick volcanic ash layer outcropping in Gust James Wash could be used as a marker bed.

Ladd (1975), in an attempt to understand the fine- to coarse-grained facies change in detail, studied the sediments in the southern portion of the White Cliffs deposit. He measured seven stratigraphic sections in Camel Canyon and Whitlock Wash, and analyzed the sediments for distribution, thickness, textures, sedimentary structures, and composition. In addition, his study included an in-depth analysis on the origin and diagenesis of the "chert" beds outcropping in Camel Canyon.

Utley (1980), with an approach similar to Ladd's but more regional in scope, attempted to understand the depositional environment of the Quiburis Formation in the vicinity of White Cliffs. He measured 17 stratigraphic sections, (seven are within or border the present study area), and divided the Quiburis into four informal members: the gypsum, limestone, clastic, and alluvial fan members. Utley further divided his limestone member into a lower, middle, and upper lake bed. The combined lower and middle lake beds are equivalent to Peirce and Vuich's lower white member, and the upper lake bed is equivalent to Peirce and Vuich's upper white member. A clastic facies of Utley's limestone member and a tonque of his clastic member are the combined equivalent to Peirce and Vuich's middle silt.

2.3.2 Vertebrate Paleontologic Studies

The vertebrate fossils of the San Pedro Valley have been extensively researched, and Lindsay (1984) has compiled a concise description of the various San Pedro Valley fossil assemblages and provided a selected bibliography. Camel Canyon, at the south end of the study area, is especially rich in fossil fauna, and Lindsay reports the assemblage as late Hemphillian in age (Table 1).

2.3.3 Geochronologic and Paleomagnetic Studies

Using K-Ar, Scarborough (1975) dated four interbedded volcanic ash layers in the Quiburis Formation ranging from 5.21 +/- 0.17 m.y. ago to 6.25 +/- 0.34 m.y. ago. Using presently accepted decay constants, Reynolds and others (1986) recalculated Scarborough's age dates. Lindsay and others (1984) measured a 130 foot stratigraphic section in Camel Canyon, dated one ash bed at the base of the section using fission tracks in zircons (6.6 +/- 0.4 m.y.), and took paleomagnetic readings at thirty sites within the section. On the basis of the paleomagnetic and radiometric data, Lindsay and others placed the Camel Canyon sediments in magnetic chron 5. Table 2 summarizes the radiometric age date data.

Table 1 - List of late Hemphillian vertebrate fossils preserved in Camel Canyon (after Lindsay, 1984).

Artiodactyla	- *Hemiauchenia* sp. (llama)
	- *Megatylopus* sp. (camel)
	- *Texoceros* sp. (pronghorn)
Aves	- indeterminate bird
Carnivora	- *Vulpes stenognathus* (fox)
	- *Canis davisi* (coyote)
	- *Osteoborus* sp. (dog)
	- *Bassariscus* sp. (ringtail)
	- *Agriotherium* cf. *gregorii* (bear)
	- *Machairodus* sp. (stabbing cat)
Perissodactyla	- *Dinohippus* sp. (single-toed horse)
Pisces	- small indeterminate fish
Proboscidea	- *Pliomastodon* sp. (mastodon)

Table 2 - Radiometric age dates on interbedded volcanic ash layers in the Quiburis Formation.

SAMPLE #	DESCRIPTION	AGE DATE (m.y.a.) Scarborough	Reynolds	Lindsay
LDA 1-66	Glass from vitric tuff, Gust James Wash.	5.21 +/- 0.17	5.35	----
61f-68	Med- to fine- grained air-fall ash bed, 2" thick, Camel Canyon.	5.59 +/- 0.15	5.74	----
61-68	Med-grained, lt gray vitric ash bed, 1' thick, Camel Canyon.	5.77 +/- 0.29	5.92	6.6 +/- 0.4
68-68	Med- to fine-grained, lt gray, air-fall ash, 3" thick, Burro Canyon.	6.25 +/- 0.34	6.43	----

Sample numbers and descriptions are from Scarborough (1975). The volcanic ash dated by Lindsay and others (1984) is correlated with unit #14, measured section CC-1L (Ladd, 1975); Ladd correlates his unit #14 with Scarborough's sample 61-68.

2.4 Geology of the White Cliffs Diatomite Deposit

A major portion of this study was the compilation of a geologic map (Plate I). Rocks and sediments found in the study area include granitic bedrock, lake bed sediments, undifferentiated silt and gravel, and alluvium in present day washes, river beds, and floodplains (Fig. 6). Interbedded within the lake bed sediments are volcanic ash layers and thin-bedded conglomerates which provide excellent marker beds. The two most prominent ash layers are labeled the upper ash (UA) and the lower ash (LA) (Fig. 6). Structurally, the lake bed sediments are disrupted by high-angle normal faults and minor folds.

2.4.1 Bedrock

A small, oval-shaped outcrop of Laramide(?) quartz monzonite porphyry, first mapped by Creasey (1967), occurs at the southern end of the field area in Camel Canyon (Fig. 7). Creasey suggested that the quartz monzonite was either Mesozoic or Cenozoic due to its fine-grain size, lack of deformation, and only slight alteration. In this report, the quartz monzonite porphyry is tentatively correlated with the Laramide Copper Creek granodiorite complex (see page 18). Adjacent to the porphyry, thin beds of granitic detritus containing abundant shattered vertebrate fossils interfinger with the surrounding silt.

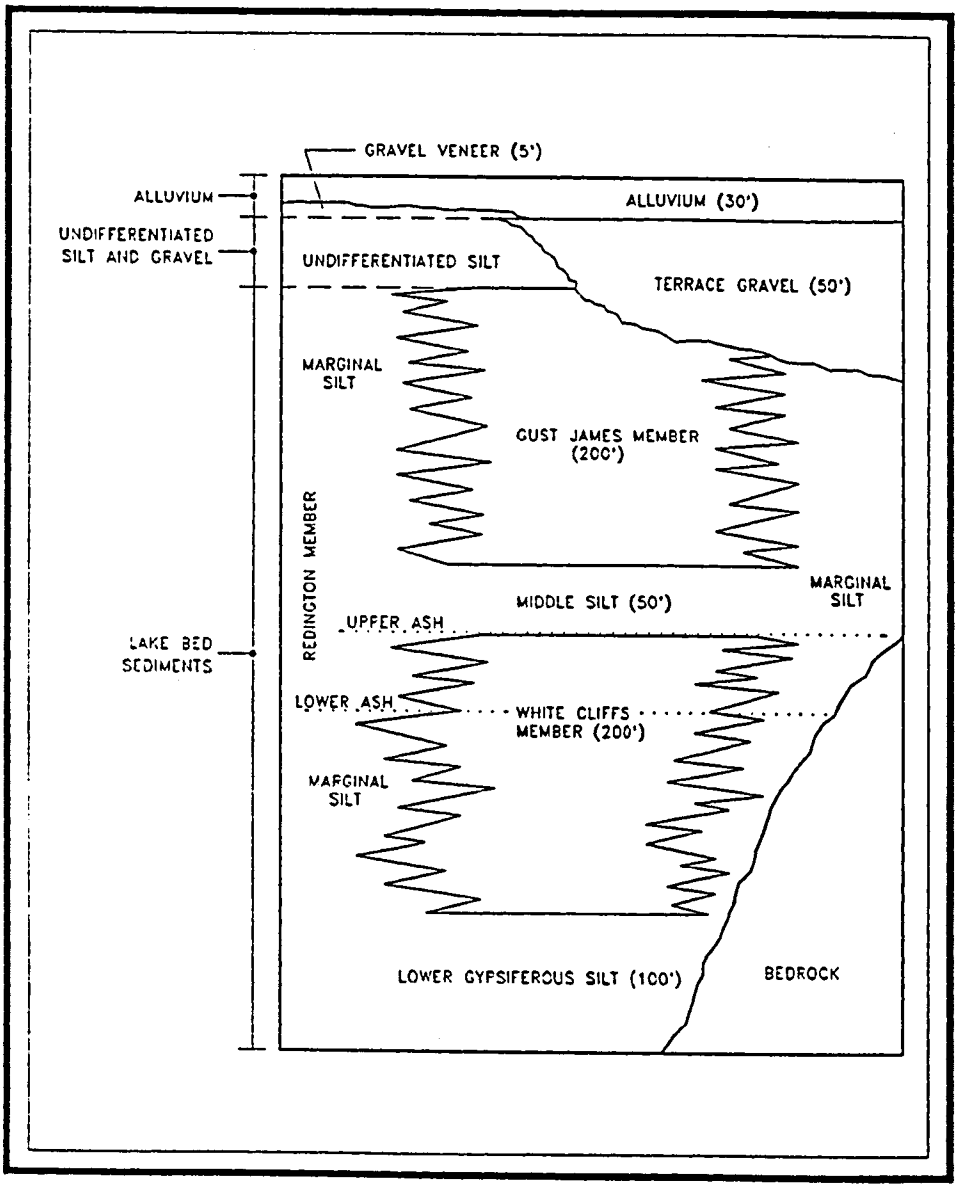

Figure 6 - Generalized stratigraphy of the White Cliffs diatomite deposit showing maximum exposed thickness of sediments.

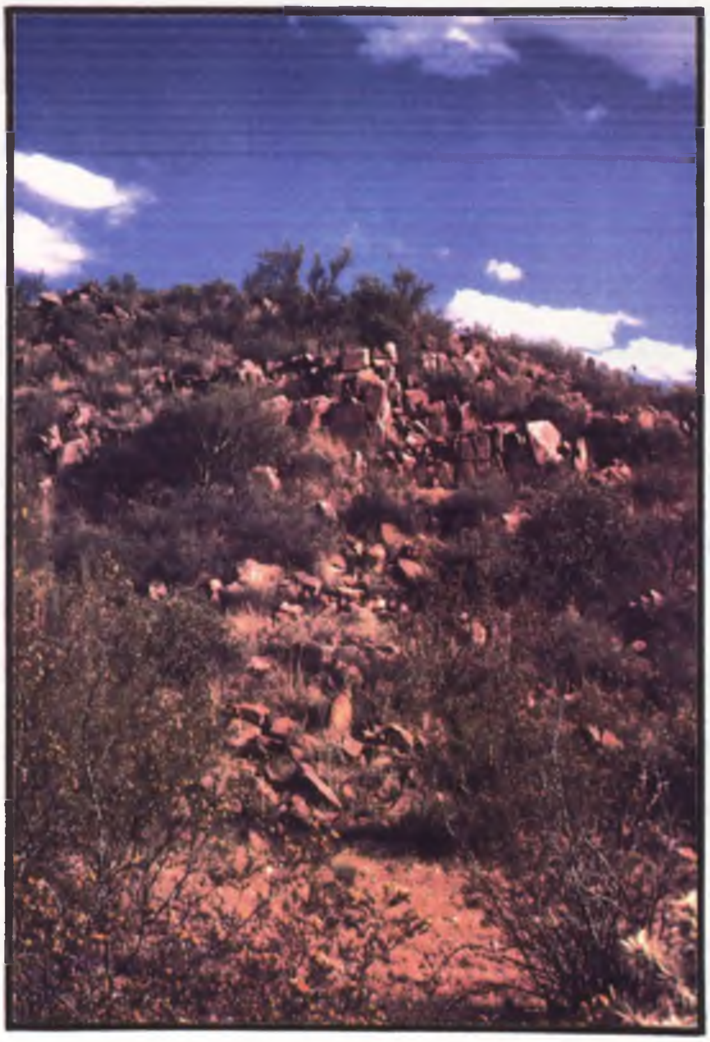

Figure 7 - Outcrop of quartz monzonite in Camel Canyon.

2.4.2 Lake Bed Sediments

The lake bed sediments are composed principally of interbedded silt, marl, and diatomite. The silt is pale orange to brown, unconsolidated to well lithified, and contains variable amounts of carbonate, gypsum, and diatoms. The marl is white to light gray, well lithified, and diatomaceous. Lower quality diatomite is white to light gray, silty, slightly calcareous, and relatively dense. Higher quality diatomite is bright white, low in silt and carbonate content, and low in density. For this report, the lake bed sediments have been divided into three informal members: the Redington member (Rm), the White Cliffs member (WCm), and the Gust James member (GJm) (Fig. 6).

The Redington member is modified from Agenbroad (1967) and is applied here only to the fine-grained clastics of the Quiburis. The Rm can be further broken down into three lithologic units: the lower gypsiferous silt, the middle silt, and the marginal silt (Fig. 6). The lower gypsiferous silt outcrops in Gust James Wash and Mill Canyon, where it forms tall, picturesque cliffs (Fig. 8). The lower contact is unexposed, and the upper contact is gradational with the WCm. The middle silt lies between the WCm and GJm, outcrops extensively throughout the study area, and is equivalent to Peirce and Vuich's middle silt (Arizona Geological Survey file data). The lower contact with the WCm is sharp and in the

Figure 8 - Outcrop of lower gypsiferous silt near the mouth of Gust James Wash.

northern half of the field area it is often marked by the UA. The upper contact with the GJm is gradational. The marginal silt surrounds and interfingers with the diatomaceous, calcareous, and clastic sediments of the GJm and WCm.

The White Cliffs member consists of interbedded marl, silt, diatomite, and chert and is equivalent to Peirce and Vuich's lower white (Arizona Geological Survey file data). In the northwest and west central part of the field area, the WCm consists of marl, silt, and minor diatomite. To the south and east, the WCm consists of diatomite and minor marl, silt, and chert. Further south, in Little Gust James Wash and Rhodes Ranch Canyon, the exposure of the WCm is limited due to cover, and its extent and composition is unknown. In Camel Canyon, however, the WCm is again exposed and consists of silt, diatomite, chert, and minor marl.

The Gust James member consists of diatomaceous marl and silt and is equivalent to Peirce and Vuich's upper white (Arizona Geological Survey file data). No diatomite was found in the GJm. Approximately 200 feet of GJm are preserved near the center of the field area, but away from the center the GJm abruptly thins or is missing due to erosion. The relationship between the WCm, the middle silt, and GJm is well displayed near the mouth of Adit Canyon (Fig. 9).

The diatomaceous sediments exposed in Camel Canyon were thought by Peirce and Vuich (Arizona Geological Survey file data) to be "upper white" (GJm), by Scarborough (1975, pg. 87)

Figure 9 - Relationship between the White Cliffs member (WCm), the Redington member middle silt (Rm), and the Gust James member (GJm) near the mouth of Adit Canyon, looking east. Note the thin-bedded conglomerate (TC) and upper ash (UA) marker beds, and the overlying undifferentiated silt and gravel (TQsg).

to be stratigraphically high in the section, and by Utley (1980, Pl. II) to be "upper lake beds" (GJm). However, detailed mapping has shown the Camel Canyon sediments to be WCm (Pl. I). Previous work places the Camel Canyon sediments, and thus the WCm, in the Upper Miocene (see pgs. 19-24). The younger GJm, therefore, should extend the Quiburis into the Pliocene. Correlation of diatomite horizons between Adit Canyon and Camel Canyon is now possible, and in Little Gust James Wash and Rhodes Ranch Canyon, where exposure of WCm is limited, reasonable assumptions about diatomite distribution, grade, and quality can be made.

2.4.3 Undifferentiated Silt and Gravel

Overlying the lake bed sediments are undifferentiated silt and gravel (TQsg) (Fig. 6). The TQsg is composed of three lithologic units: 1) terrace gravel, 2) thin gravel veneer, and 3) combined lake bed sediments and gravel veneer. In the center of the study area, the TQsg is dominated by terrace gravel and thin gravel veneer, and at the margins of the study area, TQsg is dominated by combined lake bed sediments and gravel veneer (Fig. 10).

2.4.4 Marker Beds

Interbedded within the lake bed sediments are several volcanic ash beds. The ashes are typically light to dark gray, range from less than one inch to 3-ft thick, and vary

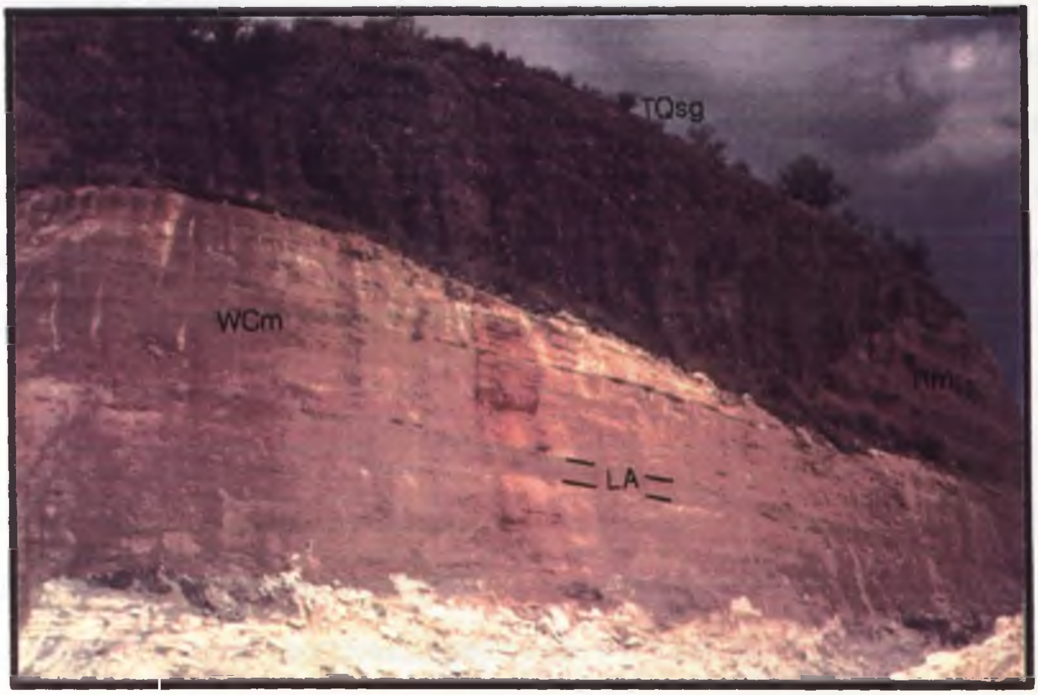

Figure 10 - Outcrop of terrace gravel resting unconformably on stained White Cliff member in One Eleven Canyon quarry. Note lower ash marker bed (LA) in quarry face.

from fresh, unlithified ash through well-lithified, slightly devitrified ash to ash completely altered to montmorillonite. Two prominent ash beds, the upper ash (UA) and the lower ash (LA) marker beds (previously mentioned, pgs. 25 and 30), are discussed below.

The LA is best recognized in the northern portion of the study area where it occurs in the WCm, unaltered and ranging from 2- to 3-feet thick (Fig. 11). In the central portion of the field area, the LA thins, is altered to a pale greenish yellow, and is difficult to verify. In the southern portion of the study area, the LA is tentatively placed in the Rm.

The UA occurs 45 to 55 feet above the LA and is easily traced over virtually the entire field area. It typically is pale orange to light gray with a consistent thickness of about 1 foot. In the northern portion of the field area, the UA is located at the sharp contact between the WCm and the middle silt unit (Fig. 12). In the central and southern portions of the field area, however, the UA is found several feet above this contact in the middle silt (Fig. 9).

Several thin-bedded, locally crossbedded conglomerates occur within the middle silt, and a N40°W paleocurrent direction was obtained from one set of crossbeds in One Eleven Canyon (Fig. 13). In the central and southern portions of the study area, these conglomerates provide excellent local marker beds and are shown on Plate I.

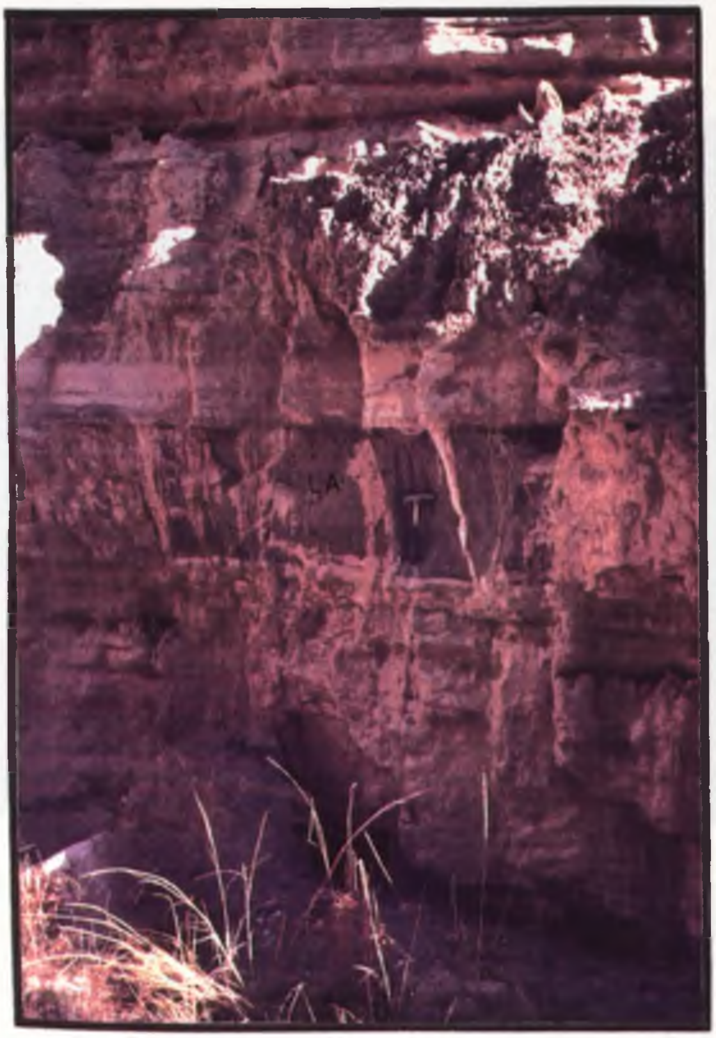

Figure 11 - Lower ash marker bed (LA) in small side canyon northwest of One Eleven Canyon on upthrown side of N-striking normal fault.

Figure 12 - Upper ash marker bed (UA) resting on White Cliff member sediments (WCm) in small side canyon northwest of One Eleven Canyon on downthrown side of N-striking normal fault, near Figure 10. Small bushes approximately 2 to 3 ft tall.

Figure 13 - Thin-bedded conglomerate marker bed in One Eleven Canyon. Crossbeds indicate a N40°W paleocurrent.

2.4.5 Faults

A high-angle, N- to NW-striking normal fault cuts through the center of the field area (Fig. 14). Displacement on the fault, downdropped to the west and southwest, averages about 60 feet. In Camel Canyon, it is difficult to establish the location of this fault but air photos show a NW-striking lineament, interpreted to be the fault, near the mouth of the canyon. In Rhodes Ranch Canyon, the fault is roughly 1000 feet northeast of its position in Camel Canyon, and from here it strikes northwest through Rhodes Ranch Canyon, Little Gust James Wash, and Adit Canyon until it breaks up into two N-striking faults in One Eleven Canyon. North of One Eleven Canyon the fault disappears under cover.

Several minor normal faults also occur throughout the field area. One NW-striking fault in Gust James Wash lies along strike with the major normal fault and is probably an extension of it. Another minor fault in Mill Canyon offsets the LA in one of the quarries (Fig. 15).

2.4.6 Folds

A NW-striking shallowly folded syncline occurs in the northern half of the field area (Fig. 16). In Adit Canyon, the major fault cuts off the northeast limb of the syncline and the beds on the upthrown side of the fault tend to be flat lying. Beds on the downthrown side, however, still dip to the

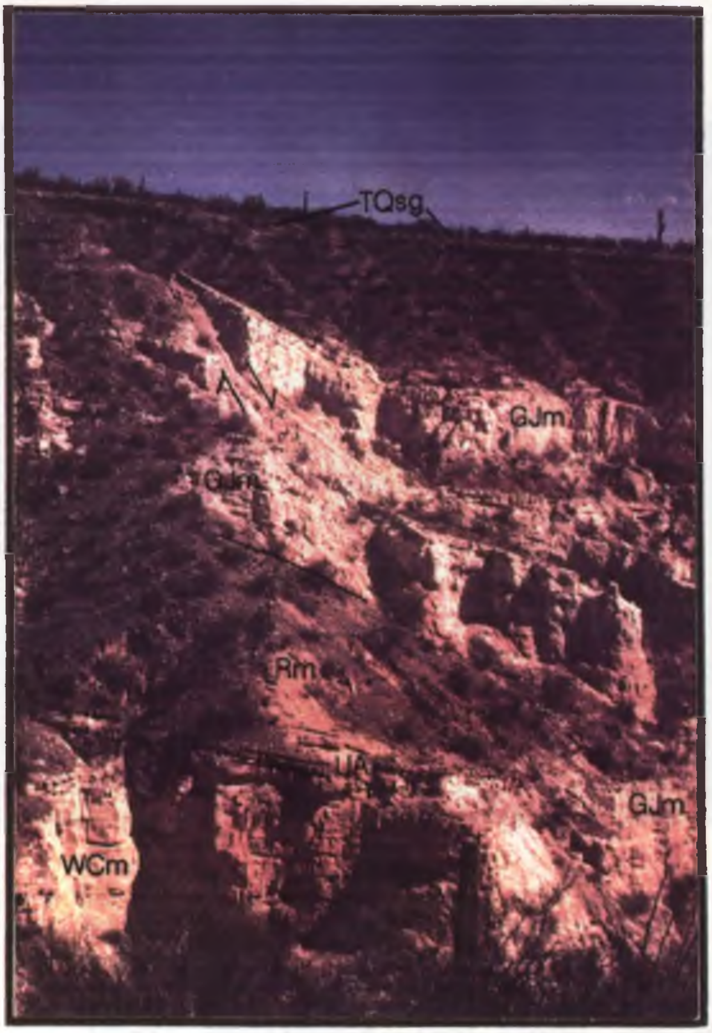

Figure 14 - High-angle normal fault in Adit Canyon looking south, offset approximately 60 ft. Note overlying undifferentiated silt and gravel (TQsg), Gust James member (GJm), Redington member middle silt (Rm), upper ash marker bed (UA), and White Cliffs member (WCm).

Figure 15 - Minor normal fault in small quarry in Mill Canyon, looking south. Note terrace gravels (TQsg) resting unconformably on White Cliffs member (WCm) sediments, and lower ash marker bed (LA).

Figure 16 - Northeast dipping White Cliffs member (WCm) on southwest limb of syncline, looking south into small canyon just south of Mill Canyon.

northeast, except for local southwest dips due to drag folding. A NE-striking moderately folded monocline occurs in Camel Canyon and displaces the WCm sediments approximately 60 to 80 feet.

2.4.7 Northeast-Striking Structure

Indirect evidence points to the existence of a buried NE-striking structure at the southern end of the field area. The southern end is marked by several features, including: 1) the on-line, northeast-strike of two major drainages, Peppersauce Wash to the southwest and Whitlock Wash to the northeast; 2) the southern limit of artesian wells (Agenbroad, 1967); 3) the northernmost outcrop of bedrock fault blocks within the basin-fill (Fig. 5, and Dickinson, 1988); 4) the lack of Lower Miocene San Manuel Formation sediments for several miles to the south (Bykerk-Kaufmann, pers. comm., 1989); 5) the southernmost limit of diatomaceous sediments; 6) the northeast-striking monoclinal folding in Camel Canyon; and 7) the apparent 1000-foot, right-lateral offset of the high-angle normal fault between Camel Canyon and Rhodes Ranch Canyon. If a buried NE-striking structure exists, it is probably a normal fault downdropped on the northwest (Pl. II).

2.5 Stratigraphic Methods

The stratigraphy of the White Cliffs deposit was examined by measuring 17 sections (Appendix A), verifying the measured sections of previous workers (Agenbroad, 1967, Ladd, 1975, and Utley, 1980), and analyzing available drill hole data (Arizona Geological Survey file data) (Appendix B). Five stratigraphic correlation diagrams were compiled using this information (Plates III - VII). In the diagrams, the upper ash marker bed (UA) was used as a horizontal base line, except in Plate III where the lower ash marker bed (LA) was used.

2.5.1 Measured Sections

The procedure followed for measuring a stratigraphic section was first to locate an accessible stratigraphic horizon and then to note its position relative to a volcanic ash marker bed. Once a suitable horizon was located, the weathered surface was cleaned and the section measured using a carpenter's tape and a Jacob's staff. Diatomite samples were collected from selected beds and stored in plastic bags for laboratory analysis.

Several other stratigraphic sections had been measured in the study area by Agenbroad (1967), Ladd (1975), and Utley (1980). An attempt was made to locate and verify their measured sections and to incorporate them into the present study. To differentiate their sections from those measured for this study, the first initial of the previous worker's last name has been added to their section labels. For example, the section HC-1, measured by Agenbroad in One Eleven Canyon, is now section HC-1A.

Of the three previous workers, Ladd's measured sections in Camel Canyon proved to be the most accurate and reliable. As a result, his sections were fully incorporated into this study (Pl. VII). It should be noted that in verifying Ladd's section CC-3L, the section was found to be misplaced on his map. His location description, however, stated that the section was "about 500 feet east of a diatomite quarry", and this allowed the section to be properly located. This corrected location is shown on Plate I.

Due to the scale of Agenbroad's base map, it was difficult to verify the location of his measured sections, but they are accepted as occurring where he located them. When incorporating Agenbroad's sections, some minor changes and reinterpretations needed to be made. In section HC-1A, no gypsum beds were found near the base of the section as described. Agenbroad may have misinterpreted weathered surfaces for gypsiferous stratigraphic horizons; removal of the weathered surface reveals these "gypsum beds" to be marls. In section HC-2A, Agenbroad interpreted the upper 134.2 feet of stratigraphy as Sacaton Formation. This stratigraphy has been reinterpreted to be 106.2 feet of Quiburis Formation and 28.0 feet of undifferentiated silt and gravel (Pl. V).

The sections measured by Utley were difficult to incorporate into the present study. Commonly he did not recognize a volcanic ash marker bed in areas where one occurred. His failure to recognize the importance of these beds is evident from the following quote (Utley, 1980, p. 53):

> "Air-fall ashes within the limestone member are thin- to thick-bedded and appear to be discontinuous. Thin ashes which are associated with a diatomite or limestone sequence are generally difficult to recognize in the field."

In fact, just the opposite is true. The volcanic ash marker beds utilized in this study were found to be continuous over several square miles, and the upper ash marker bed in particular was recognized over virtually the entire field area. In addition, Utley did not recognize several individual diatomite beds in his measured sections, lumping them instead into thick limestone units. This failure to recognize key features of the stratigraphic column, along with his misinterpretation of the diatomaceous sediments in Camel Canyon as "upper lake bed" (GJm) (see pg. 32), severely limits the application of Utley's detailed facies models to the Quiburis Formation in the White Cliffs area. Of the seven sections measured by Utley in the study area, only two have been incorporated in the stratigraphic correlation diagrams (Plate VI). The locations of all seven, however, are shown on Plate I.

2.5.2 Drill Holes

In 1947, an artesian well was drilled at the mouth of Adit Canyon, and, in 1957, three exploratory holes were drilled in Mill Canyon, in Adit Canyon, and on the south rim of Rhodes Ranch Canyon (Arizona Geological Survey file data). The drill logs and survey locations for these holes are given in Appendix B, but unfortunately the stratigraphic descriptions are incomplete precluding their use in the stratigraphic correlation diagrams. The logs do, however, provide general information on the stratigraphy at depth.

In 1968, 11 holes were drilled by Kaiser Aluminum and Chemical Corporation (Arizona Geological Survey file data) and an attempt was made to incorporate these drill logs. Each drill site was located in the field according to the available survey information, and the collar elevation was tied to a volcanic ash marker bed. Of the 11 holes, only one location could not be verified, and six of the ten have been used in the stratigraphic correlations. The Kaiser drill logs describe the sediments simply as waste, marginal diatomite, and diatomite. For purposes of this study, "waste" was interpreted as silt, and "marginal diatomite" was interpreted as marl. The drill logs, site locations, and the projected position of volcanic ash marker beds relative to collar elevations are given in Appendix B.

2.6 Distribution of Diatomite

As previously stated, only the White Cliffs member (WCm) contains diatomite. In the WCm, three potential ore zones (POZs) have been defined relative to the UA and LA marker beds. Measured section AC-2, in the central portion of the deposit, is defined as the type section for the POZs (Pl. VI). It should be stated, however, that the LA is not recognized in AC-2. Instead, a silt bed, located at the same stratigraphic horizon, is interpreted as correlative to the LA and is symbolized by LA(?). From youngest to oldest, POZ1 is defined as the diatomaceous interval 0 to 24 ft below the UA, POZ2 is defined as the diatomaceous interval 0 to 29 ft above the LA(?), and POZ3 is defined as the diatomaceous interval 0 to >20 ft below the LA(?).

It is important to note that 1) the POZs are defined as diatomaceous intervals, and that in addition to diatomite, the POZs contain marl, silt, and chert, 2) the zones are defined relative to marker beds and do not necessarily reflect natural breaks in the stratigraphy, and 3) due to abrupt facies changes, the thickness and purity of the POZs can vary considerably.

2.6.1 Gust James Wash

The northern boundary of diatomaceous sediments occurs just north of Gust James Wash. Here, diatomaceous sediments of the WCm thin and pinch out into gypsiferous silts of the Rm. In the Gust James Wash area (Pl III), the LA is widespread and well preserved, ranging from 1 to >3 ft thick, but exposures of the UA, POZ1, and POZ2 are limited by erosion and cover. In the Kaiser drill holes, however, POZ1 ranges from 3 to 13 ft thick and POZ2 ranges from 1 to 10 ft thick. In contrast, POZ3 is well developed, ranging in thickness from 8 to 15 ft in outcrop and up to 30 ft in drill hole DH-B. It is unclear why POZ3 does not appear in drill hole DH-G.

In outcrop, the diatomite in POZ3 occurs in an interval 12 to 21 feet below the LA in two beds separated by a pale greenish yellow silt bed. The upper diatomite bed ranges from 3.0 to 4.5 ft thick, the silt bed ranges from 1.0 to 2.0 ft thick, and the lower diatomite bed ranges from 2.0 to 3.5 ft thick. In drill hole DH-B, correlative diatomite beds appear to be 10 ft lower in the section. This difference could be due to an abrupt facies change, but it is probably due to stratigraphic displacement caused by faulting and folding in the immediate vicinity of the drill hole.

2.6.2 Mill Canyon

The stratigraphy in Mill Canyon (Pl. IV) is similar to the stratigraphy in Gust James Wash. The LA is again widespread and well exposed, averages 2 ft thick, and is located 50 ft below the UA. The UA, unlike its distribution in Gust James Wash, is also widespread and well exposed, and averages 1 ft thick. POZ1 and POZ2 are better preserved in Mill Canyon, but again are poorly exposed and were not examined in detail. In drill hole DH-A, however, POZ1 is 6 ft thick and POZ2 is 8 ft thick. As in Gust James Wash, POZ3 is well exposed and preserved, ranging from 9 to 25 ft thick in outcrop to >30 ft thick in drill holes.

In the northern half of Mill Canyon, diatomite in POZ3 again occurs in two beds separated by a pale greenish yellow silt bed in an interval 11 to 26 ft below the LA. The upper diatomite bed ranges from 2 to 5 ft thick, the silt bed ranges from 0 to 3 ft thick, and the lower diatomite bed ranges from 3 to 7 ft thick. In the southern half of the canyon, however, this unique interbedded diatomite and silt sequence can not be distinguished from several other diatomite, marl, and silt beds in POZ3. Diatomite beds in the southern half range from 2 to 6 ft thick.

2.6.3 One Eleven Canyon

In One Eleven Canyon (Pl. V), diatomite distribution is best discussed in relation to the high-angle normal fault striking across the canyon. On the downthrown block, the diatomaceous strata are similar to those in the southern half of Mill Canyon. The LA, however, is slightly thinner, averaging 1 ft thick, and the upper portion of the LA is altered to a pale greenish yellow. The UA is 55 ft above the LA at the contact between the WCm and the middle silt, is again widespread and well exposed, and averages 1 ft thick. Although POZ1 and POZ2 are better exposed than further north, they were not examined in detail. POZ3 was examined in the quarry near the mouth of the canyon where it reaches a thickness of >20 ft.

In the quarry, POZ3 consists of 75% interbedded marl and silt and 25% thin-bedded diatomite. Again the diatomite occurs in two beds separated by a pale greenish yellow silt bed in an interval 14 to 20 ft below the LA. It is not clear, however, if these beds correlate directly with the two unique diatomite beds in Gust James Wash and Mill Canyon. The upper diatomite bed is 3 ft thick, the middle silt bed is <1 ft thick, and the lower diatomite bed is 2 ft thick. Drill hole DH-H is located directly above the quarry site, but could not be correlated directly with the exposure in the quarry due to poor stratigraphic control.

On the upthrown block, in contrast to the downthrown block, the LA, the UA, and the three POZs are all well preserved and well exposed. The LA averages 2 ft thick and is located 50 to 55 ft below the UA. The UA is again located at the contact between the WCm and the middle silt and averages 1 ft thick. POZ1 is well developed near the head of One Eleven Canyon, ranges in thickness from 13 to 25 ft, and consists of 85% silty diatomite. POZ2 ranges in thickness from 1 to 10 ft and consists of diatomaceous marl and silt, with up to 60% silty diatomite occurring locally due to abrupt facies changes. POZ3, examined in only one measured section, is >26 ft thick and consists of 75% diatomite and 25% silt. Individual diatomite beds were not differentiated in either POZ1 or POZ3.

2.6.4 Adit Canyon

As in One Eleven Canyon, the distribution of diatomite in Adit Canyon (Pl. VI) is best discussed relative to the high-angle normal fault striking across the canyon. On the downthrown block, the LA(?) is <0.5 ft thick and is difficult to recognize. Due to a facies change, the UA occurs in the middle silt 40 ft above the upper contact of the WCm. Because of this, POZ1 does not occur. POZ2, however, is 11 ft thick, consisting of 8 ft of undifferentiated diatomaceous marl and 3 ft of diatomite. POZ3 is >15 ft thick, consisting of 90% diatomite in beds averaging 3.5 ft thick.

The log of the artesian well drilled in 1947 at the mouth of Adit Canyon records interbedded gypsum and clay beds (Appendix B). Due to the 5 to 10 degree northeast dip of the sediments, it is clear that these gypsum and clay beds are stratigraphically below the exposed outcrops of POZ3. On the basis of this drill log, it has been suggested that these buried gypsum beds may correlate with the economically important gypsum deposits found 15 to 20 miles further north along the San Pedro River, thus making the gypsum deposits older than the diatomite deposit (Peirce, pers. comm., 1987).

While this correlation does not seem unreasonable it is by no means certain, given the potential for abrupt facies changes and bedrock structural disruptions between the two deposits.

The thickest diatomite outcrop found during this study is exposed on the upthrown block in Adit Canyon. The LA is not recognized in this area, but a 2-ft-thick silt bed 60 ft below the UA is interpreted as correlative with the LA. The UA is again located at the contact between the WCm and the middle silt, is widespread and well exposed, and averages 1 foot thick. POZ1 is 24 ft thick, consisting of diatomaceous marl and silt, in beds ranging from 1 to 2 ft thick. POZ2 is 29 ft thick and consists of 60% diatomite, 20% silt, and 20% chert. The individual diatomite beds range in thickness from <1 ft to >7 ft, and the interbedded silt beds are typically <1 ft thick. One prominent chert horizon varies from 0 to 5 ft thick. POZ3 is >20 ft thick and consists of 90% diatomite and 10% silt. The diatomite beds range in thickness from <1 ft to nearly 7 ft. The two thickest and purest diatomite beds in POZ3 are again separated by a pale greenish yellow to very pale orange silt bed and are located in an interval 7 to 20 ft below the 2-ft-thick silt bed. The upper bed is 4.5 ft thick, the silt bed is 1 ft thick, and the lower bed is 6.8 ft thick. It is uncertain, however, if these beds correlate directly with the two diatomite beds in Gust James Wash and Mill Canyon.

2.6.5 Little Gust James Wash

Due to an elevational difference in erosion depth between Little Gust James Wash and more deeply cut canyons to the north (Pl. II), there is very little exposure of the WCm in Little Gust James Wash. Unfortunately, the exposures that do exist could not be studied in detail because of difficult access created by the steep, cliff-forming sediments. In general, however, the UA on the downthrown block is located in the Rm, and on the upthrown block it is located at the top of the WCm. The LA, if it exists, is buried.

The reason for the difference in erosion depth is unclear, but it could be due to the increased development of resistant chert horizons towards the south. On the other hand, Little Gust James Wash may have been downcut to the same elevation as the northern canyons, and because its headwaters are in the Galiuro Mountains, it may have since been partially filled with alluvium. In either case, because of the thickness of diatomite found on the upthrown block in Adit Canyon, the potential for buried diatomite in the Little Gust James Wash area is considered high.

2.6.6 Rhodes Ranch Canyon

As in Little Gust James Wash, there is very little exposure of the WCm in Rhodes Ranch Canyon. On the downthrown block, the UA is located in the Rm, but on the upthrown block it is missing due to erosion. The LA is presumed buried. The 1957 exploratory drill hole, located on the south rim of the canyon and apparently on the upthrown side of the fault, intersected over 100 ft of "D.E. and chert". Due to the presence of chert, this section is interpreted as WCm sediments. Unfortunately, an exact correlation is impossible due to lack of stratigraphic control and incomplete sample descriptions. However, the presence of WCm in the drill hole provides evidence for buried diatomite in Rhodes Ranch Canyon.

2.6.7 Camel Canyon

The southern boundary of diatomaceous sediments at White Cliffs is found in Camel Canyon (Pl VII). Here, the diatomaceous beds of the WCm thin and pinch out into silts of the Rm, and in one location the Rm silts are in depositional contact with bedrock. While several ash beds occur in Camel Canyon, exactly which ash beds correlate with the UA and the LA is difficult to determine. However, one ash bed high in the section has the same appearance as the UA outcrops further north, and it has been tentatively correlated with the UA. This UA? is located 45 ft above another thick ash, which is tentatively correlated with the LA. The 45 feet of sediments between the two ash beds consist entirely of silt, and thus, if the ash bed correlations are correct, neither POZ1 nor POZ2 occurs in Camel Canyon. The LA? is in turn located 42 ft above a 20- to 30-foot-thick interval of diatomite. This diatomite interval is interpreted to be POZ3 with the intervening 42 feet consisting entirely of silt. POZ3 consists of 50% diatomite and 50% silt in beds ranging from 1 to 3.5 ft thick. Note that there is no diatomaceous marl recognized in POZ3, and that below POZ3 there is a thick sequence of interbedded silt, diatomite, and chert. This sequence is probably correlative to the "D.E. and chert" sequence found in the 1957 Rhodes Ranch Canyon exploratory drill hole.

2.7 Diatom Paleontology

A detailed paleontologic examination of the White Cliffs diatom assemblage is beyond the scope of this study. However, a general knowledge of the diatom assemblage is desireable for a better understanding of diatomite quality, and a brief paleontological description is presented below. Diatom studies on other Arizona Miocene-Pliocene rocks and sediments have been carried out in the Muddy Creek Formation of northwestern Arizona (Bradbury and Blair, 1979), in the Verde Formation of central Arizona (Nations and others, 1981), and in the Gila Conglomerate of southeast Arizona and southwest New Mexico (Knechtel, 1938, and Stewart and Cornell, 1990). The early description of the White Cliffs deposit by Blake (1903) included several photographs and two separate paleontological identifications of the diatoms by Dr. D. B. Ward and Dr. A. M. Edwards.

For the present study, diatomite samples collected from the Gust James Wash area (samples GJ-3-1 and GJ-3-2) were sent to Dr. J. Platt Bradbury of the U.S. Geological Survey for diatom identification. Bradbury identified 13 different diatom genera (Table 3) and stated that the assemblage represents a slightly saline to brackish water environment. After receiving the communication from Bradbury, microscopic slides were prepared for examination. A small amount of diatomite was dispersed in distilled water, enough so that the

Table 3 - List of diatoms found in the White Cliffs diatomite deposit.

Actinocyclus ehrenbergii
Amphora spp.
Caloneis silicula
Cyclotella sp. cf. *meneghiniana*
Denticula sp. cf. *D. elegans*
Diploneis sp. cf. *D. bombus*
D. ovalis
Fragilaria sp. cf. *F. brevistriata*
Hyalodiscus sp.
Mastogloia spp.
Melosira juergensi
Melosira moniliformis
Melosira nummuloides
Navicula spp.
Nitzschia spp.
Pinnularia sp. cf. *P. microstauron*
Rhopalodia musculus
R. gibba

All diatoms identified by Bradbury (pers. comm., 1987) in combined samples GJ-3-1 and GJ-3-2, except *Cyclotella*, which was identified by Krebs (pers. comm., 1990) in sample AC-2-24.

water was just slightly turbid, and a few drops were placed on a clean glass slide. The slide was then dried on a hot plate, and a permanent mount was prepared using Hyrax, a high refractive index mounting medium. Using a standard petrographic microscope, the individual diatoms were identified by comparison to similar genera and species illustrated in Lohmam (1938), Patrick and Reimer (1966 and 1975), Czarnecki and Blinn (1977), Germain (1981), Kaczmarska and Rushforth (1983a and 1983b), Bradbury (1984), and Dodd (1987). Figures 17 through 25 illustrate the more common genera identified.

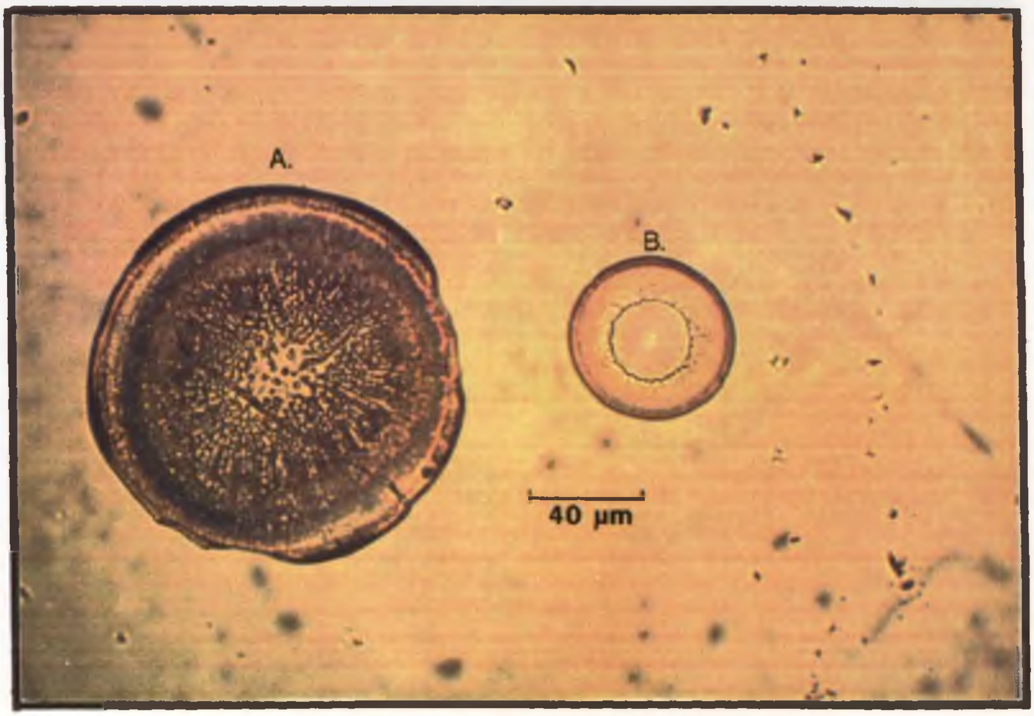

Figure 17 - A. - Actinocyclus ehrenbergii (132 μm) and B. Hyalodiscus (60 μm). Sample of mill tailings, collected 3/2/88, magnification x375.

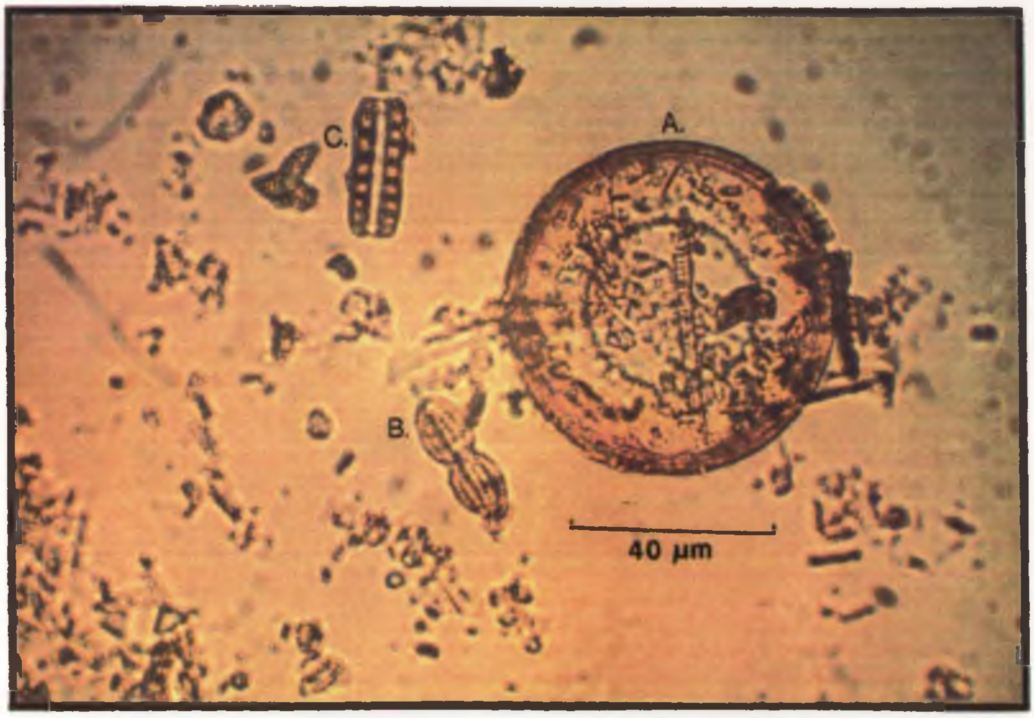

Figure 18 - A. - Hyalodiscus (60 μm), B. - Diploneis bombus (26 μm x 10 μm), and C. - Denticula elegans (28 μm x 11 μm). Sample AC-2-3, magnification x675.

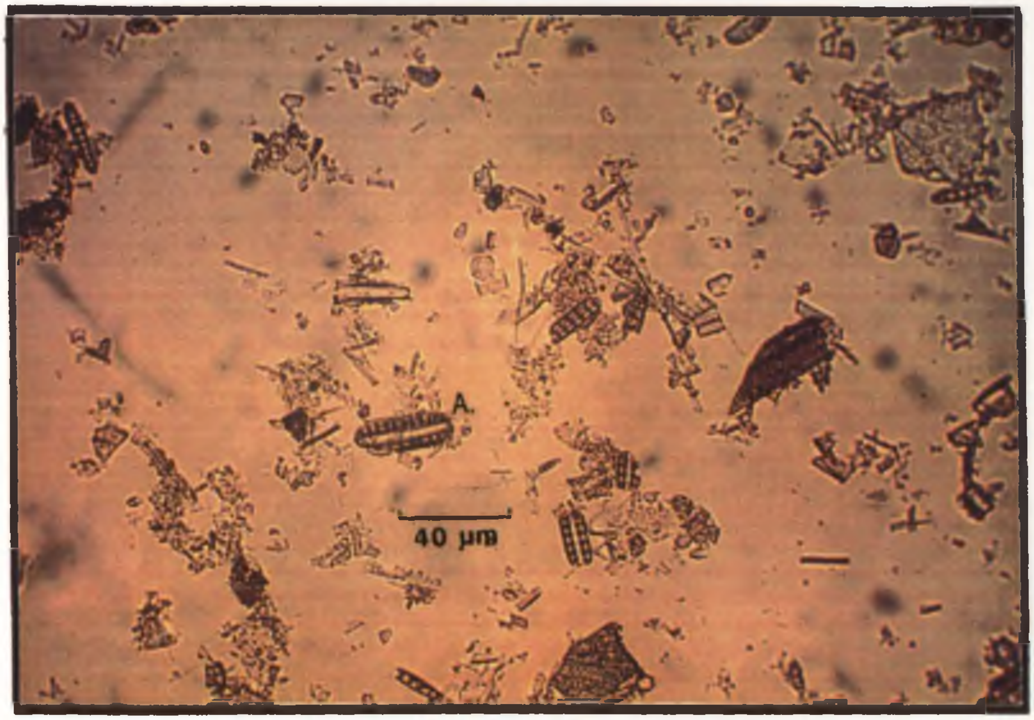

Figure 19 - A. - Denticula elegans (36 µm x 13 µm).
Sample AC-2-3, magnification x375.

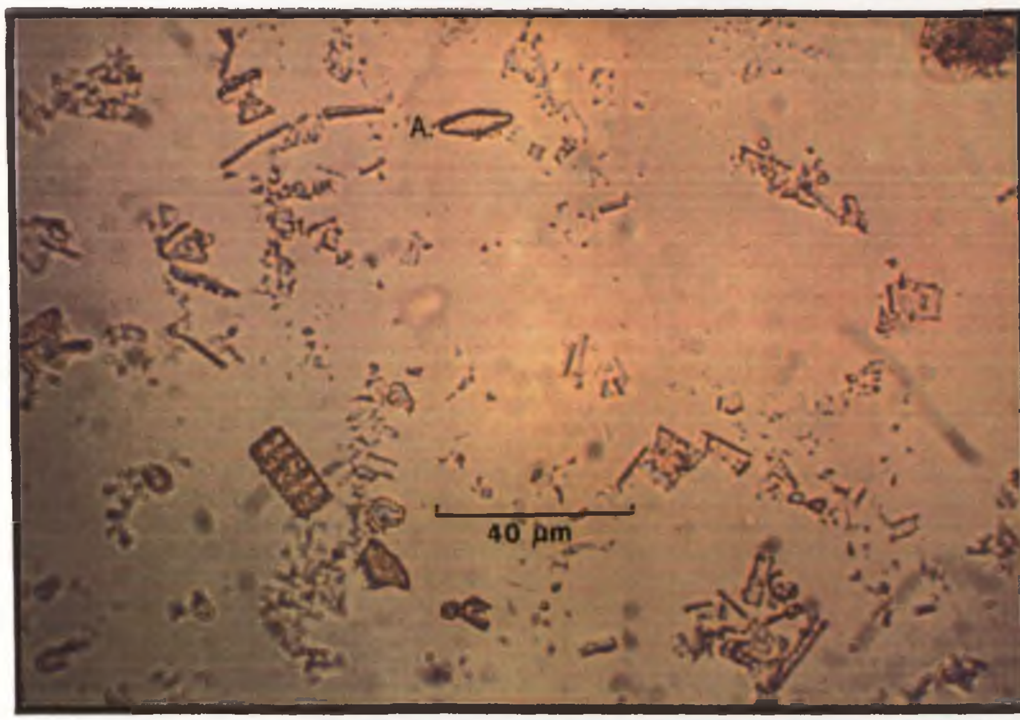

Figure 20 - A. - Fragilaria brevistriata (15 µm x 5 µm). Sample AC-2-34, magnification x675.

Figure 21 - A. - Navicula (40 μm x 12 μm), B. - Denticula elegans (31 μm x 12 μm), and C. - intercalary band (70 μm x 11 μm). Sample AC-2-29, magnification x675.

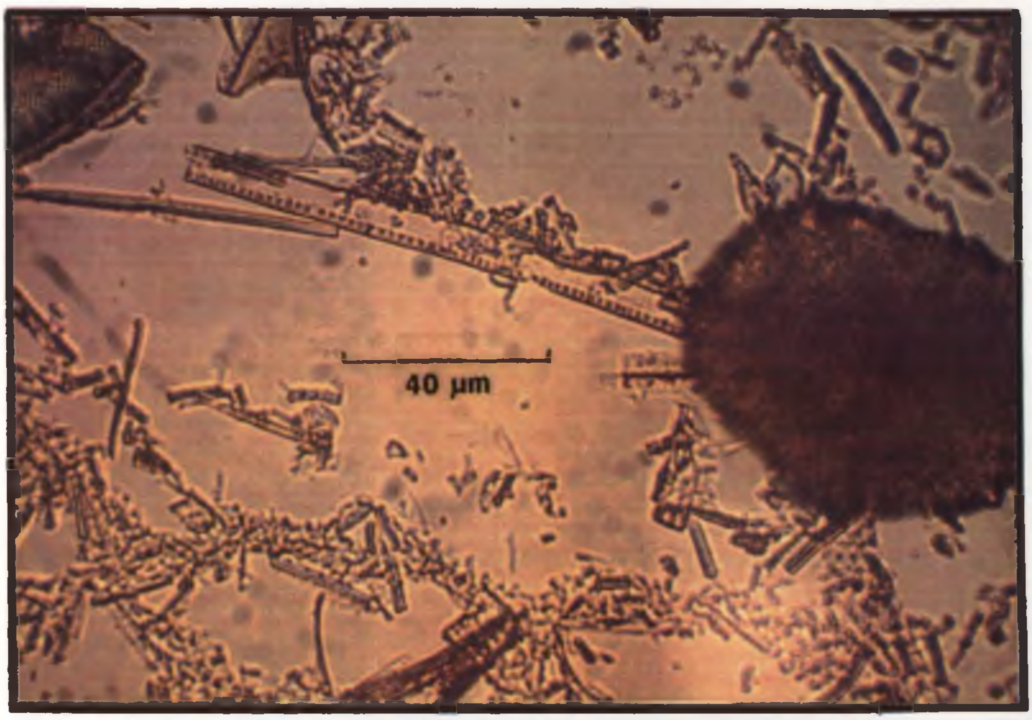

Figure 22 - Nitzschia (100 μm x 8 μm). Sample AC-2-30, magnification x675.

Figure 23 - Mastogloia (55 μm x 15 μm). Sample AC-2-30, magnification x675.

Figure 24 - A. - Diploneis ovalis (44 µm x 36 µm) and B. - Actinocyclus ehrenbergii fragment. Sample AC-2-21, magnification x675.

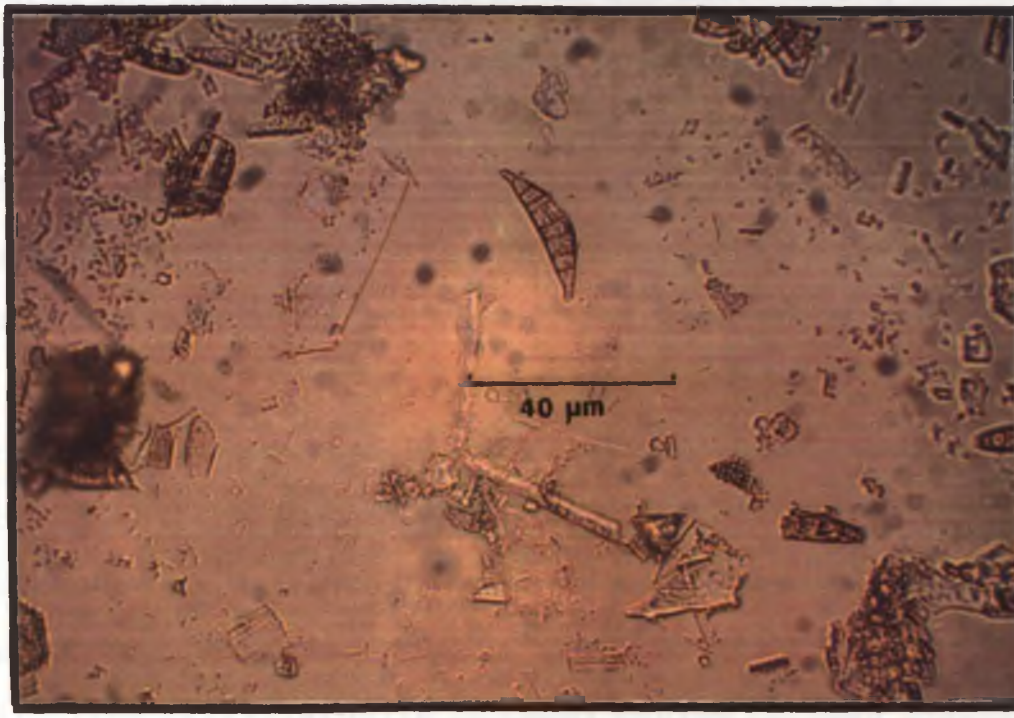

Figure 25 - Rhopalodia musculus (29 µm x 7 µm).
Sample AC-2-1, magnification x675.

2.8 Paleoenvironment

The paleoenvironment of the Quiburis Formation in the White Cliffs area has been described by Utley (1980). Utley invoked a saline lake model to relate facies changes to ephemeral and perennial saline lakes and surrounding mudflats, sandflats, and alluvial fan environments. In general, a saline lake model provides a suitable framework for the White Cliffs deposit. However, because of problems with Utley's measured sections and stratigraphic correlations, details of his paleoenvironmental reconstruction need to be modified.

As described by Utley, the WCm sediments represent a perennial lake environment with facies that changed from central limestone through marginal diatomite to surrounding gypsiferous saline mudflats. However, the WCm sediments actually represent a south to north lateral facies change, ranging from silt-diatomite in Camel Canyon through diatomite-silt-marl in Adit Canyon and One Eleven Canyon to silt-marl-diatomite +/- gypsum in Mill Canyon and Gust James Wash.

This lateral change was probably caused by fluctuations in the water level of a paleolake centered 15 to 20 miles north of White Cliffs. During periods of high precipation and low evaporation rates, the water level rose, the paleolake expanded, and the shoreline migrated southward. Diatomite, silt, and marl were subsequently deposited in slightly brackish water adjacent to the granitic bedrock high. The occurrence of abundant vertebrate fossils in Camel Canyon (Lindsay, 1984) and fossilized plant stem material throughout the deposit (Appendix A) is probably indicative of shallow marshy conditions (Nations and Ranney, 1989). During periods of low precipation and high evaporation rates, the water level fell, the paleolake contracted, and the shoreline migrated northward. Silt, marl, diatomite, and minor gypsum were subsequently deposited in slightly saline water in an environment similar to a salt marsh. During periods of extreme desiccation, brines were concentrated and gypsum and silt were deposited in topograhically low portions of the lower San Pedro Valley under playa-like conditions. The thick, economic gypsum deposits 15 to 20 miles north of White Cliffs were probably formed during these desiccation periods.

2.9 Laboratory Studies

Thirty four samples were tested in the laboratory to determine the grade and quality of the White Cliffs diatomite. In this report, diatomite grade is defined as diatom content on both a vol% and wt% basis, and quality is defined as a function of diatomite friability, diatomite block density, diatom surface area, and percentage of broken diatoms.

2.9.1 Analytical Techniques

Diatom content on a volume percent basis, diatomite friability, and qualitative variations in diatom surface area were determined through milling and centrifuge separation. The analytical technique was as follows: 1) a sample of diatomite was dried overnight at 220° F; 2) the dried sample was disaggregated to a powder in a small electric coffee grinder for 30 seconds; 3) five grams of the powder were placed in a graduated centrifuge tube; 4) the tube was filled with water, shaken vigorously, and spun in a Precision Scientific laboratory centrifuge for 3 minutes at 1,800 rpm. The centrifuge partitioned the diatomite slurry, from top to bottom, into four components: a) clear to turbid water, b) white diatoms, c) grey silt, and d) pieces of unmilled diatomite. The volumes of the diatom, silt, and unmilled components were measured, and the water turbidity was noted as clear, slightly milky, milky, or very milky (Table 4).

Table 4 - Sample lithology, bedding thickness, and laboratory centrifuge data.

	FIELD DATA		CENTRIFUGE DATA			
SAMPLE #	LITHOLOGY	THICK FT	DIATOM VOL%	SILT VOL%	UNMILL VOL%	WATER TURBIDITY
	GUST JAMES WASH, POZ3, DOWNTHROWN BLOCK					
GJ-1-01	MARL	1.75	53%	27%	20%	SL. MILKY
GJ-1-02	DIATOMITE	2.83	74%	20%	5%	MILKY
GJ-1-03	DIATOMITE	1.83	52%	31%	16%	SL. MILKY
GJ-2-01	MARL	0.83	44%	44%	11%	MILKY
GJ-2-02	DIATOMITE	3.17	56%	33%	11%	V. MILKY
GJ-2-03	DIATOMITE	3.00	51%	46%	4%	CLEAR
GJ-3-01	DIATOMITE	4.42	56%	28%	16%	CLEAR
GJ-3-02	SILTY DIAT.	3.33	52%	31%	16%	CLEAR
GJ-4-1	SILTY DIAT.	2.33	54%	21%	25%	CLEAR
GJ-4-02A	SILTY DIAT.	1.71	60%	30%	10%	V. MILKY
GJ-4-02B	SILTY DIAT.	1.71	52%	36%	12%	CLEAR
	MILL CANYON, POZ3, DOWNTHROWN BLOCK					
MC-2-01	DIATOMITE	5.00	64%	17%	20%	MILKY
MC-2-03	DIATOMITE	4.00	51%	44%	5%	CLEAR
Y-1-02A	DIATOMITE	6.50	48%	29%	22%	CLEAR
Y-1-02B	SILTY DIAT.	0.75	42%	14%	44%	SL. MILKY
Y-1-03	DIATOMITE	1.75	56%	17%	27%	V. MILKY
	ADIT CANYON, POZ3, DOWNTHROWN BLOCK					
AC-1-01	DIATOMITE	3.33	74%	23%	3%	CLEAR
AC-1-02	DIATOMITE	3.33	84%	15%	1%	MILKY
AC-1-03	SILTY DIAT.	0.33	35%	47%	18%	SL. MILKY

Table 4 - Sample lithology, bedding thickness, and laboratory centrifuge data (cont.).

FIELD DATA			CENTRIFUGE DATA			
SAMPLE #	LITHOLOGY	THICK FT	DIATOM VOL%	SILT VOL%	UNMILL VOL%	WATER TURBIDITY
	ADIT CANYON, POZ2, UPTHROWN BLOCK					
AC-2-01	SILTY DIAT.	2.58	72%	20%	8%	V. MILKY
AC-2-02	DIATOMITE	1.92	61%	35%	4%	CLEAR
AC-2-03	SILTY DIAT.	3.17	73%	25%	2%	CLEAR
	ADIT CANYON, POZ3, UPTHROWN BLOCK					
AC-2-28	DIATOMITE	2.21	68%	25%	7%	V. MILKY
AC-2-29	DIATOMITE	2.21	70%	27%	3%	V. MILKY
AC-2-30	DIATOMITE	0.67	79%	18%	3%	V. MILKY
AC-2-33	DIATOMITE	2.83	71%	25%	4%	V. MILKY
AC-2-34	DIATOMITE	3.92	67%	29%	3%	MILKY
	CAMEL CANYON, POZ3, UPTHROWN BLOCK					
CC-1-02	DIATOMITE	2.58	70%	28%	2%	SL. MILKY
CC-1-04	DIATOMITE	1.58	67%	29%	3%	MILKY
CC-1-06	DIATOMITE	3.42	64%	34%	2%	MILKY
CC-1-15	DIATOMITE	2.33	51%	46%	4%	MILKY
CC-1-22	SILTY DIAT.	0.50	56%	39%	4%	SL. MILKY
CC-1-24	SILTY DIAT.	1.17	63%	35%	2%	MILKY

Analytical error was calculated to be +/- 2 vol% for the unmilled diatomite vol% and +/- 10 vol% for the diatom vol% and silt vol%. The unmilled diatomite vol% was assumed to be a function of diatomite friability, and the water turbidity, assuming little or no clay component, was assumed to be a function of diatom surface area.

To determine the grade of each sample from the centrifuge results, the volumes of diatoms and silt in the unmilled diatomite component had to be added to the volumes of diatoms and silt in milled component. This was accomplished by assuming that the ratio of diatoms to silt was the same for both the milled and unmilled components, and then normalizing the milled diatom vol% plus silt vol% to 100 vol% (Table 5).

The quality of each sample was determined from the centrifuge data in two steps. Step one, a relative quality level was defined for diatomite friability and diatom surface area. If the unmilled component was ≤ 5 vol%, the diatomite was considered highly friable or high quality; if >5 vol% but <15 vol%, the diatomite was considered moderately friable or medium quality; and if ≥15 vol%, the diatomite was considered slightly friable or low quality. If the water turbidy was very milky, the diatoms were considered to have high surface area or high quality; if slightly milky to milky, the diatoms were considered to have moderate surface area or medium quality; and if clear, the diatoms were considered to have low surface area or low quality. Step two, a rock quality

Table 5 - Normalized grades, rock quality designations, and block density determinations.

SAMPLE #	GRADE DIATOM VOL% (N)	SILT VOL% (N)	QUALITY RQD UNMILL	RQD WATER	RQD AVE	BLK DEN LBS/ FT3
	GUST JAMES WASH, POZ3, DOWNTHROWN BLOCK					
GJ-1-01	66%	34%	1.0	2.0	1.5	70
GJ-1-02	79%	21%	2.0	2.0	2.0	46
GJ-1-03	63%	37%	1.0	2.0	1.5	47
GJ-2-01	50%	50%	2.0	2.0	2.0	--
GJ-2-02	63%	37%	2.0	3.0	2.5	50
GJ-2-03	53%	47%	3.0	1.0	2.0	67
GJ-3-01	67%	33%	1.0	1.0	1.0	47
GJ-3-02	63%	37%	1.0	1.0	1.0	55
GJ-4-1	72%	28%	1.0	1.0	1.0	42
GJ-4-02A	67%	33%	2.0	3.0	2.5	--
GJ-4-02B	59%	41%	2.0	1.0	1.5	--
*AVERAGE	65%	35%			1.7	51
	MILL CANYON, POZ3, DOWNTHROWN BLOCK					
MC-2-01	79%	21%	1.0	2.0	1.5	65
MC-2-03	54%	46%	2.0	1.0	1.5	--
Y-1-02A	62%	38%	1.0	1.0	1.0	51
Y-1-02B	75%	25%	1.0	2.0	1.5	87
Y-1-03	77%	23%	1.0	3.0	2.0	71
*AVERAGE	68%	32%			1.5	62
	ADIT CANYON, POZ3, DOWNTHROWN BLOCK					
AC-1-01	76%	24%	3.0	1.0	2.0	53
AC-1-02	85%	15%	3.0	2.0	2.5	51
AC-1-03	43%	57%	1.0	2.0	1.5	80
*AVERAGE	80%	20%			2.2	52

*Samples GJ-1-01, GJ-2-01, Y-1-02B, and AC-1-03 were not calculated into averages because 1) lithology = marl or 2) bedding thickness <1 ft (see Table 4).

Table 5 - Normalized grades, rock quality designations, and block density determinations (cont.).

SAMPLE #	GRADE DIATOM VOL% (N)	GRADE SILT VOL% (N)	QUALITY RQD UNMILL	QUALITY RQD WATER	QUALITY RQD AVE	BLK DEN LBS/ FT3
		ADIT CANYON, POZ2, UPTHROWN BLOCK				
AC-2-01	78%	22%	2.0	3.0	2.5	57
AC-2-02	64%	36%	3.0	1.0	2.0	55
AC-2-03	74%	26%	3.0	1.0	2.0	53
*AVERAGE	72%	28%			2.2	55
		ADIT CANYON, POZ3, UPTHROWN BLOCK				
AC-2-28	73%	27%	2.0	3.0	2.5	55
AC-2-29	72%	28%	3.0	3.0	3.0	54
AC-2-30	81%	19%	3.0	3.0	3.0	46
AC-2-33	74%	26%	3.0	3.0	3.0	56
AC-2-34	70%	30%	3.0	2.0	2.5	48
*AVERAGE	72%	28%			2.8	53
		CAMEL CANYON, POZ3, UPTHROWN BLOCK				
CC-1-02	71%	29%	3.0	2.0	2.5	--
CC-1-04	70%	30%	3.0	2.0	2.5	48
CC-1-06	65%	35%	3.0	2.0	2.5	45
CC-1-15	53%	47%	3.0	2.0	2.5	67
CC-1-22	59%	41%	3.0	2.0	2.5	--
CC-1-24	64%	36%	3.0	2.0	2.5	64
*AVERAGE	65%	35%			2.5	56

*Samples AC-2-30 and CC-1-22 were not calculated into averages because 1) lithology = marl or 2) bedding thickness <1 ft (see Table 4).

designation (RQD) value was assigned for each quality level: RQD = 1.0 for low quality, RQD = 2.0 for medium quality, and RQD = 3.0 for high quality. The RQD values for diatomite friability and diatom surface area were then averaged together to obtain a RQD average for each sample. Samples with RQD averages ranging from 1.0 to <1.5 were considered low quality, from 1.5 to 2.0 were considered low - medium quality, from >2.0 to 2.5 were considered medium - high quality, and >2.5 were considered high quality (Table 5).

The combined effects of grade and quality were analyzed by determining the diatomite block density (Table 5). Block density is a function of: 1) clastic and chemical sediment mineralogy and content (i.e. grade), and 2) compaction, lithification, and diatom species (i.e. quality) (Kadey, 1983). After a few days in the field, relative variations in block density can be determined by simple hand estimation. In the laboratory, block density is determined absolutely as follows: 1) select at random several (1 to 5) large (20 to 40 cubic centimeters) pieces of diatomite from a single sample and dry them overnight at 220° F, 2) weigh the dried diatomite with a standard laboratory scale, 3) waterproof the diatomite fragments by dipping each piece in melted paraffin, 4) submerge each piece in a graduated beaker half-filled with water and measure the volumetric displacement, 5) sum the volumetric displacements and weights of the fragments to obtain the total volume and total weight of the sample, and

6) divide the total weight by the total volume to calculate block density. Analytical error was determined to be +/- 5 lbs/ft3. Along with diatomite, the densities of silt (102 lbs/ft3), silty sandstone (104 lbs/ft3), and clayey silt (91 lbs/ft3) were also determined. Figure 26 shows 1) a straight line relationship between block density and silt vol% (i.e grade), and 2) a projected density of 37 lbs/ft3 for pure White Cliffs diatomite (i.e. quality).

Diatom content on a weight percent basis was analyzed by wet screening the milled diatomite powder. The analytical technique was as follows: 1) 5 grams of dry diatomite powder were wet screened through a 200-mesh (75 μm) and 325-mesh (45 μm) U.S.A standard testing screen; 2) the +200 mesh and -200 to +325 mesh fractions were dried overnight at 220° F; and 3) the fractions were weighed and converted into percentages (Table 6). Assuming all diatoms are -325 mesh and all contaminants are +325 mesh, then the wt% -325 mesh fraction is equivalent to the wt% diatoms. Strictly speaking, this assumption is false because 1) the large centric diatoms found at White Cliffs (<u>Actinocyclus ehrenbergii</u> and <u>Hyalodiscus</u>, Figs. 17 and 18) are >45 μm, and 2) most silt and all clay size particles are <45 μm. However, for high grade samples with a low percentage of large centric diatoms, the errors should be small and the wet screening test results should come fairly close to the actual wt% diatoms. Because of the above limitations on the wet screening technique, and also because

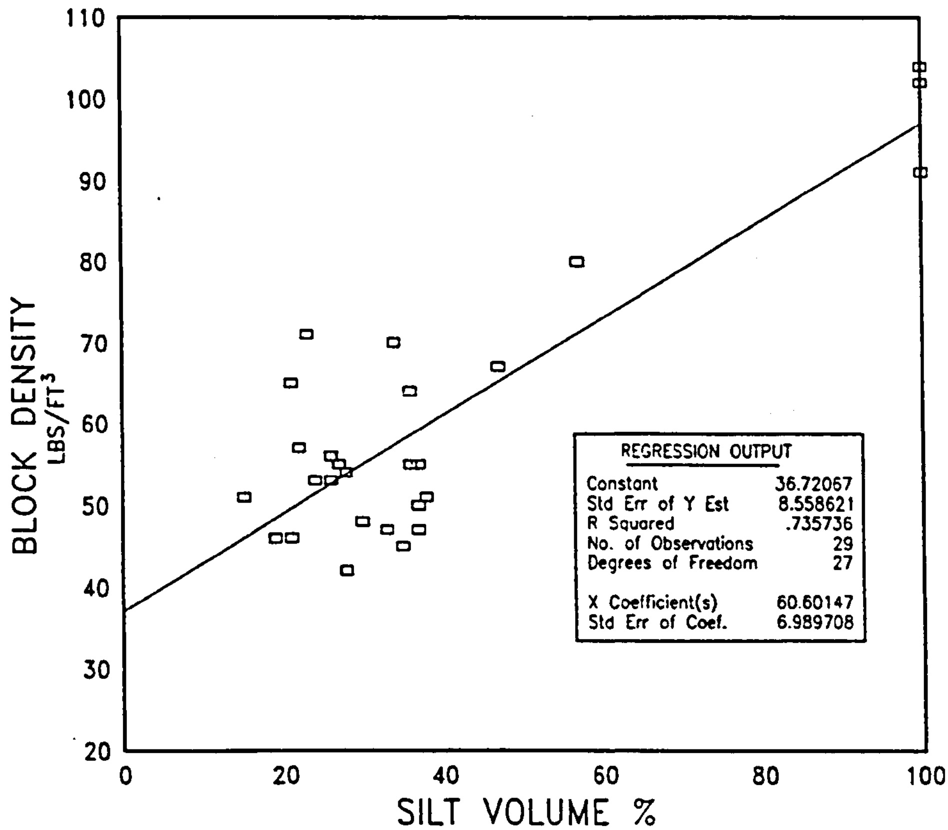

Figure 26 - Graph of block density vs silt vol%. Note straight line relationship and Y-intercept of 37 lbs/ft3.

Table 6 - Weight percent determination of diatom content, Adit Canyon, upthrown block.

SAMPLE #	WEIGHT % +200 (+75 μm)	-200 to +325 (-75 μm to +45 μm)	-325 (-45 μm)
		POZ2	
AC-2-01	22%	12%	65%
AC-2-02	13%	15%	72%
AC-2-03	18%	13%	69%
		POZ3	
AC-2-28	20%	11%	69%
AC-2-29	17%	11%	72%
AC-2-30	11%	10%	80%
AC-2-33	16%	10%	74%
AC-2-34	20%	11%	69%

Contaminants (very fine sand and silt) are assumed +325 mesh and diatoms are assumed -325 mesh.

it is very time consuming, only eight samples were tested. Analytical error was calculated to be +/- 1 wt%, but the error is probably closer to +/- 5 wt% in view of errors in the assumptions. As shown in Figure 27, the obtained wt% results closely match the vol% results. Therefore, vol% diatoms can be assumed to be equivalent to wt% diatoms as a first-order approximation.

Diatom content on a volume percent basis was also determined, along with vol% broken diatoms, by microscopic examination (Table 7). Slides were prepared as follows: 1) a small sample of diatomite, approximately 0.5 cc, was gently disaggregated using a razor blade; 2) a few drops of cinnamic aldehyde, an oil often used in diatom examination, (Bollaert, pers. comm, 1987), were placed on a clean glass slide; 3) a small amount of the powder, approximately 1 cubic mm, was mixed with the oil; and 4) a cover slip was placed over the slide. Using a standard petrographic microscope, the samples were examined at 200x, and the vol% diatoms (broken and whole), micrite, and clastics (silt and clay) were estimated. Problems included: 1) accurate identification of the extremely fine-grained constituents, 2) sample movement in the oil, and 3) obtaining a representative sample. Despite these problems, microscopic examination does provide a rapid, semi-quantitative method for diatomite grade and quality analysis. Error is estimated to range from 5 vol% to 10 vol%.

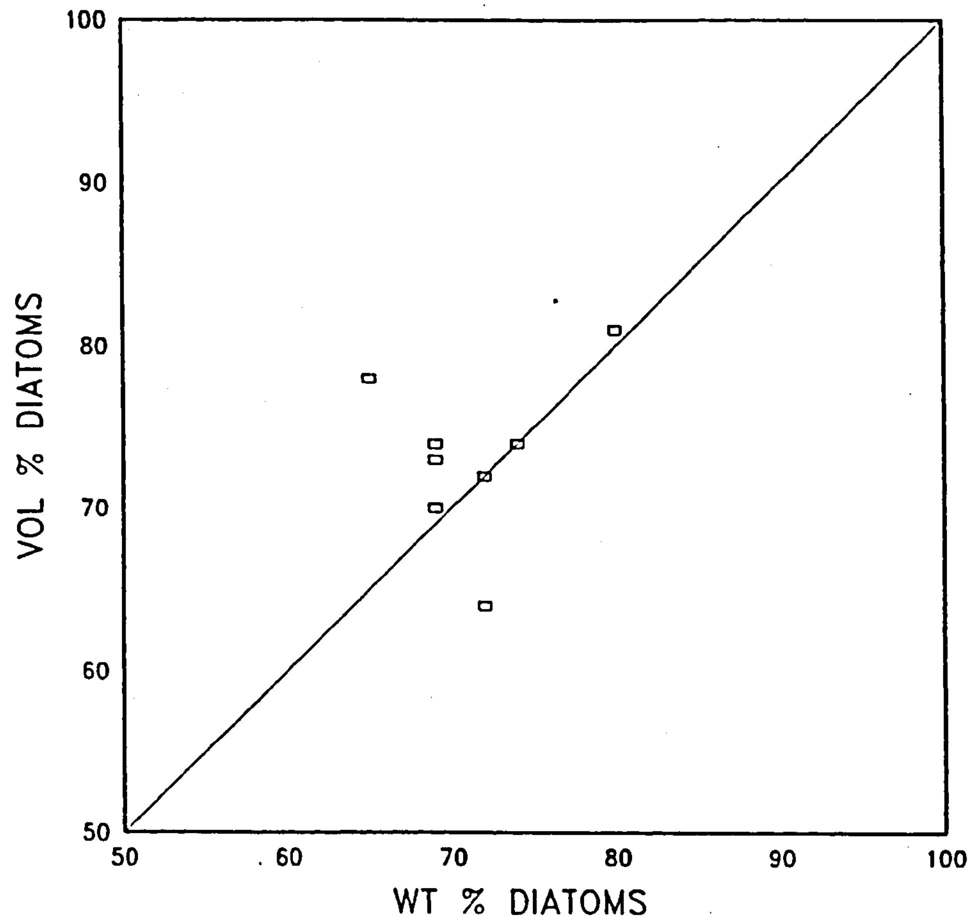

Figure 27 - Graph of wt% diatom vs vol% diatom. Straight line shows one-to-one relationship.

Table 7 - Results of microscopic examination of White Cliffs diatomite.

SAMPLE	DIATOMS VOL%	MICRITE VOL%	CLASTICS VOL%	COMMENTS
		GUST JAMES WASH, POZ3, DOWNTHROWN BLOCK		
GJ-3-01	55	5	40	80% of diatoms broken
		MILL CANYON, POZ3, DOWNTHROWN BLOCK		
MC-4-01	50	5	45	60% to 70% of diatoms broken
MC-4-02	60	5	35	Abundant Rhopalodia, 20% of diatoms broken (dominantly Actinocyclus)
		ADIT CANYON, POZ2, UPTHROWN BLOCK		
AC-2-01	65	5	30	40% of diatoms broken (dominantly Actinocyclus)
AC-2-02	80	0	20	Abundant clay, 20% of diatoms broken (dominantly Actinocyclus, minor Diploneis ovalis)
AC-2-03	55	5	40	Abundant clay, 50% of diatoms broken
		ADIT CANYON, POZ3, UPTHROWN BLOCK		
AC-2-28	75	0	25	15% of diatoms broken (dominantly Actinocyclus)
AC-2-29	90	0	10	<5% of diatoms broken
AC-2-30	90	0	10	Abundant intercalary bands, up to 70%, 5% of diatoms broken (dominantly Actinocyclus)

2.9.2 Grade and Quality of Diatomite

In the Gust James Wash area, 11 POZ3 samples were tested for diatom content, diatom surface area, and diatomite friability, nine POZ3 samples were tested for block density, and one POZ3 sample was microscopically examined for diatom content and percentage of broken diatoms. For diatomite samples from beds >1 ft thick (9 samples), diatom content ranged from 53 vol% to 79 vol%, diatom surface area ranged from low to high, diatomite friability ranged from highly friable to slightly friable, and block density ranged from 42 lbs/ft3 to 67 lbs/ft3. In the sample examined microscopically, 80 vol% of the diatoms were broken. In conclusion, the Gust James Wash area POZ3 diatomite is a low - medium quality ore averaging 65 vol% diatoms.

In Mill Canyon, five POZ3 samples were tested for diatom content, diatom surface area, and diatomite friability, four POZ3 samples were tested for block density, and two POZ3 samples were microscopically examined for diatom content and percentage of broken diatoms. For diatomite samples from beds >1 ft thick (4 samples), diatom content ranged from 50 vol% to 79 vol% diatoms, diatom surface area ranged from low to high, diatomite friability ranged from highly friable to slightly friable, and block density ranged from 51 lbs/ft3 to 71 lbs/ft3. In the samples examined microscopically, 20 vol% to 70 vol% of the diatoms (dominantly <u>Actinocyclus</u>) were broken. In conclusion, the Mill Canyon POZ3 diatomite is a low - medium quality ore averaging 68 vol% diatoms.

In Adit Canyon, on the downthrown block, three POZ3 samples were tested for diatom content, diatom surface area, diatomite friability, and block density. For diatomite samples from beds >1 ft thick (2 samples), diatom content ranged from 76 vol% to 85 vol% diatoms, diatom surface area ranged from low to moderate, diatomite friability was highly friable, and block density ranged from 51 lbs/ft3 to 53 lbs/ft3. In conclusion, the Adit Canyon POZ3 diatomite on the downthrown block is a medium - high quality ore averaging 81 vol% diatoms.

In Adit Canyon, on the upthrown block, three POZ2 samples and five POZ3 samples were tested for diatom content, diatom surface area, diatomite friability and block density. Three POZ2 samples and three POZ3 samples were microscopically examined for diatom content and percentage of broken diatoms. For POZ2 diatomite samples from beds >1 ft thick (3 samples), diatom content ranged from 64 vol% to 80 vol% diatoms and from 65 wt% to 72 wt% diatoms, diatom surface area ranged from low to high, diatomite friability ranged from highly friable to moderately friable, and block density ranged from 53 lbs/ft3 to 57 lbs/ft3. In the samples examined microscopically, 20 vol% to 50 vol% of the diatoms (dominantly Actinocyclus) were broken. In conclusion, the Adit Canyon POZ2 diatomite on the upthrown block is a medium - high quality ore averaging 72 vol% diatoms. For POZ3 diatomite samples from beds >1 ft thick (4 samples), diatom content ranged from 70 vol% to 74 vol% diatoms and from 69 wt% to 72 wt% diatoms, diatom surface area ranged from moderate to high, diatomite friability ranged from highly friable to moderately friable, and block density ranged from 48 lbs/ft3 to 56 lbs/ft3. In the samples examined microscopically, <5 vol% to 15 vol% of the diatoms (dominantly Actinocyclus) were broken. In conclusion, the Adit Canyon POZ3 diatomite on the upthrown block is a high quality ore averaging 72 vol% diatoms.

In Camel Canyon, six POZ3 samples were tested for diatom content, diatom surface area, and diatomite friability, and four POZ3 samples were tested for block density. For diatomite samples from beds >1 ft thick, diatom content ranged from 53 vol% to 71 vol% diatoms, diatom surface area was moderate, diatomite friability was highly friable, and block density ranged from 45 lbs/ft3 to 67 lbs/ft3. In conclusion, the Camel Canyon POZ3 diatomite is a high - medium quality ore averaging 65 vol% diatoms.

2.10 Tonnage Estimates

From the previous discussion, the thickest and highest grade and quality diatomite at White Cliffs is found on the upthrown block in Adit Canyon. Stratigraphic correlations between Adit Canyon and Camel Canyon indicate a high potential for large tonnages of medium to high quality diatomite averaging 70 vol% diatoms to be buried in Little Gust James Wash and Rhodes Ranch Canyon. A 200-acre (8,712,000 sq ft) potential quarry site has been outlined in Little Gust James Wash, E Cen. Sec. 19, T. 9 S., R. 18 E. (Fig. 28 and Pl. II), from which, assuming both POZ2 and POZ3 are minable, >9.0 million s.t. of diatomite yielding an estimated 5.5 to 6 million tons of final product can be obtained (Table 8). If POZ1 is minable as well, the estimated final product tonnage increases to between 7 and 7.5 million tons. If only POZ3 is minable, the total final product tonnage estimate decreases to between 3 and 3.5 million tons (Table 8). At present, current domestic DE production is approximately 687,000 s.t./year, at an average price of $208/ton (Meisinger, 1989). Assuming a 30,000 to 50,000 s.t./year capacity plant (roughly 5% of the market), the estimated tonnages for the proposed quarry site could provide for more than 50 years of production. Given this high potential, further exploration and evaluation of the White Cliffs diatomite deposit is strongly recommended.

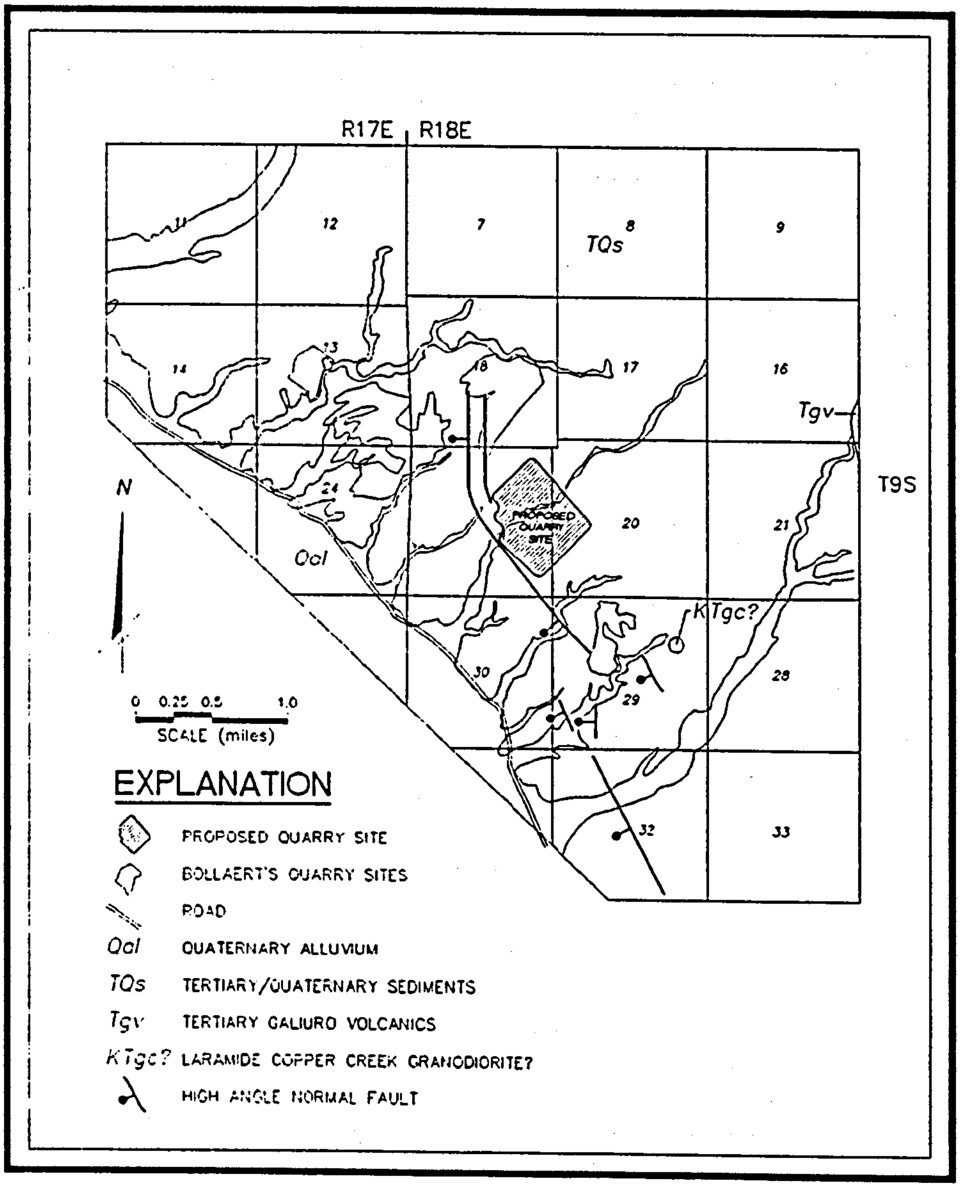

Figure 28 - Outline of potential quarry site in the Little Gust James Wash area.

Table 8 - Tonnage calculations for proposed Little Gust James Wash quarry site.

POZ1 Tonnage Calculations

Quarry size	8,712,000 sq ft
POZ1 thickness	24 ft
POZ1 percentage diatomite	50%
Thickness of diatomite	12 ft
Average block density	55 lbs/ft3
Crude tonnage	2,874,960 s.t.
Average unmilled percentage	10%
Processed diatomite	2,587,464 s.t.
Average grade	65 wt% diatoms
Recoverable DE tonnage	1,681,851 s.t.
Contingency	10%
Total estimated DE tonnage	1,513,666 s.t.

POZ2 Tonnage Calculations

Quarry size	8,712,000 sq ft
POZ2 thickness	29 ft
POZ2 percentage diatomite	60%
Thickness of diatomite	17 ft
Average block density	55 lbs/ft3
Crude tonnage	4,072,860 s.t.
Average unmilled percentage	5 %
Processed diatomite	3,869,217 s.t.
Average grade	73 wt% diatoms
Recoverable DE tonnage	2,824,529 s.t.
Contingency	10%
Total estimated DE tonnage	2,542,076 s.t.

POZ3 Tonnage Calculations

Quarry size	8,712,000 sq ft
POZ3 thickness	25 ft
POZ3 percentage diatomite	90%
Thickness of diatomite	23 ft
Average block density	53 lbs/ft3
Crude tonnage	5,309,964 s.t.
Average unmilled percentage	4%
Processed diatomite	5,097,565 s.t.
Average grade	72 wt% diatoms
Recoverable DE tonnage	3,670,247 s.t.
Contingency	10%
Total estimated DE tonnage	3,303,222 s.t.

3. CONCLUSION

The purpose of this study was to define the distribution, grade, and quality of diatomite at the White Cliffs deposit. Diatomite distribution was studied through geologic mapping and the measurement and correlation of stratigraphic sections. Selected samples were analyzed for grade and quality through laboratory testing and microscopic examination.

The White Cliffs diatomite deposit is hosted in a lacustrine facies of the Quiburis Formation, a Miocene to Pliocene basin-fill sediment of the lower San Pedro Valley. Rocks and sediments found in the study area include granitic bedrock, lake bed sediments, undifferentiated silt and gravel, and alluvium. Interbedded within the lake bed sediments are volcanic ash layers and thin-bedded conglomerates which provided excellent marker beds. The two most prominent ash layers were labeled the upper ash and lower ash. The lake bed sediments were divided into three informal members: the Redington, the White Cliffs, and the Gust James members. The Redington member (Rm), slightly modified from previous definitions, consists of fine-grained, locally gypsiferous clastics, and is divided into three units: the lower gypsiferous silt, the middle silt, and the marginal silt. The newly named White Cliffs member (WCm) consists of interbedded diatomite, diatomaceous marl, silt, and chert. It overlies the Rm lower gypsiferous silt, underlies the Rm middle silt, and interfingers with the Rm marginal silt. The newly named Gust James member (GJm) consists of silt and diatomaceous marl. It overlies the Rm middle silt and interfingers with the Rm marginal silt. Diatomaceous sediments in Camel Canyon at the south end of the study area were thought by previous workers to correlate with the GJm. In this report, however, the Camel Canyon sediments are remapped as WCm. Structural disruptions in the lake bed sediments include major and minor high-angle normal faults and shallowly-folded synclines and monoclines.

In the White Cliffs member, three potential ore zones (POZs) were defined relative to the upper and lower volcanic ash marker beds. Samples collected from the POZs were tested for diatom content, diatomite friability, diatom surface area, and block density, and examined microscopically for diatom content and percentage of broken diatoms. The highest grade and quality diatomite exposed in the study area was discovered in Adit Canyon, on the upthrown block of a major, high-angle normal fault. The correlation of exposed diatomite in Adit Canyon with exposed diatomite in Camel Canyon indicates a high potential for buried diatomite in the Little Gust James Wash and Rhodes Ranch Canyon area. A proposed 200-acre quarry site in the Little Gust James Wash area is estimated to contain >9.0 million s.t. of medium- to high-quality diatomite averaging 70 vol% diatoms. Further exploration and evaluation is strongly recommended.

APPENDIX A

DESCRIPTION OF MEASURED SECTIONS

Color Descriptions

Color descriptions in the measured sections are from the Geological Society of America's Rock-Color Chart (Rock Color Chart Committee, 1948).

Very pale orange (10YR 8/2)

Pale greenish yellow (10Y 8/2)
Dark greenish yellow (10Y 6/6)
Light olive (10Y 5/4)

White (N9)
Bright white (N9)
Very light gray (N8)
Light gray (N7)
Med. gray (N5)

Pinkish gray (5YR 8/1)
Yellowish gray (5Y 8/1)
Light greenish gray (5GY 8/1)
Light olive gray (5Y 6/1)

MEASURED SECTION AC-1
ADIT CANYON

Location: SW1/4, NW1/4, SW1/4, Sec. 19, T. 9 S., R. 18 E.
Clark Ranch 7.5' Quadrangle, Pinal County, AZ.

UNIT #	DESCRIPTION	FEET	METERS
1	Sandstone, gravelly, poorly sorted.	2.00	0.61
2	Silt.	30.00	9.14
3	Ash, (Upper Ash).	1.00	0.30
4	Silt.	40.00	12.19
	------- Potential Ore Zone 2, (Units 5-6) -------		
5	Marl, white, diatomaceous, silty.	7.92	2.41
6	Diatomite, white, silty, lower contact is floor of small, upper adit.	2.75	0.84

7	Silt, Fe-stained.	0.08	0.03
8	Ash, (Lower Ash?).	0.25	0.08
	------ Potential Ore Zone 3, (Units 9-12+) ------		
9	Silty diatomite, white, forms cliff.	7.00	2.13
10	Diatomite, white, (sample AC-1-1).	3.33	1.02
11	Silt, pale greenish yellow, contains plant stems.	1.00	0.30

MEASURED SECTION AC-1
ADIT CANYON (CONT.)

UNIT #	DESCRIPTION	FEET	METERS
12	Diatomite, white, (sample AC-1-2) 3" from top is a 4" layer of silty diatomite, (sample AC-1-3).	3.33	1.02
	TOTAL	98.66	30.07

Units (1 & 2), (7 & 8), and (9 & 10) have been combined on Plate VI.

MEASURED SECTION AC-2
ADIT CANYON

Location: NE1/4, SW1/4, NE1/4, Sec. 19, T. 9 S., R. 18 E.
Clark Ranch 7.5' Quadrangle, Pinal County, AZ

UNIT #	DESCRIPTION	FEET	METERS
1	Marls and silt.	20.00	6.10
2	Silt.	15.00	4.57
3	Ash, (Upper Ash), bench former.	1.00	0.30
	------ Potential Ore Zone 1, (Units 4-14) -------		
4	Marls and silt.	10.00	3.05
5	Marly silt, abundant plant stems and worm burrows, 2" zone of thinly laminated silt near center, base gradational.	0.83	0.25
6	Diatomaceous marl, bright white, massive, structureless, dense, base gradational.	2.00	0.61
7	Diatomaceous silt, bright white to pinkish gray, punky unconsolidated, base gradational.	1.33	0.41
8	Ash, lt. gray, base sharp.	0.25	0.08
9	Cover, silts and marls.	3.42	1.04
10	Marl, bright white, massive, upper contact forms bench, similar to #6, base wavy.	1.00	0.30
11	Calcareous silt, abundant ash, plant stems near top, 3" thick bed of pinkish gray, massive, marl near center.	1.42	0.43

MEASURED SECTION AC-2
ADIT CANYON (CONT.)

UNIT #	DESCRIPTION	FEET	METERS
12	Marl, white to pinkish gray massive, base gradational.	1.25	0.38
13	Calcareous silt, v. pale orange, generally massive, bottom 3" thinly laminated with flat lying plant stems(?), base sharp.	1.67	0.51
14	Marl, pinkish gray, base wavy, undulatory.	0.42	0.13
	--		
15	Diatomaceous silt, v. pale orange to white, slightly calcareous, base undulatory.	2.00	0.61
16	Silt and ash, v. pale orange and lt. gray, ash and silt are interbedded, unconsolidated and unaltered, weathers back.	0.58	0.18
17	Cover, marls and silts, top 3' weathers back, laminated.	5.00	1.52
	------ Potential Ore Zone 2, (Units 18-34) ------		
18	Silty diatomite, bright white, dense, forms bench, base wavy, undulatory.	2.00	0.61
19	Diatomaceous silt, pinkish gray, interbedded, weathers back, contains 4" x 1" chert nodules in lower beds, base sharp to gradational.	1.17	0.36
20	Diatomite, bright white to pinkish gray, unconsolidated, laminated, base gradational.	0.83	0.25

MEASURED SECTION AC-2
ADIT CANYON (CONT.)

UNIT #	DESCRIPTION	FEET	METERS
21	Silt and ash, lt. gray, minor plant stems, base sharp.	0.58	0.18
22	Diatomite, bright white, dense, massive, 1" seam of greenish silt near center, base gradational.	1.67	0.51
23	Silt, dark greenish yellow, abundant plant stems, base weathers back, base sharp.	0.83	0.25
24	Diatomite, white, upper 31" (sample AC-2-1), slightly silty, minor thin silty, pale greenish yellow beds with plant stems, minor chert at 32", middle 23" (sample AC-2-2) appears to be best material, lower 38" (sample AC-2-3) similar to upper 32", base gradational.	7.67	2.34
25	Chert, dark greenish yellow, massive, thickness varies from 0 to 5 feet, top undulatory, sharp base.	5.00	1.52
26	Diatomite, bright white to pale greenish yellow, upper 6" white, lower 5" pale greenish yellow, silty, minor 1/4" chert nodules, base gradational, (sample AC-2-4).	0.92	0.28
27	Silt, pale greenish yellow (10Y 8/2), bottom 1" slightly brown, abundant stems, base gradational, (sample AC-2-5).	0.33	0.10

MEASURED SECTION AC-2
ADIT CANYON (CONT.)

UNIT #	DESCRIPTION	FEET	METERS
28	Diatomite, white to pale greenish yellow, massive, base gradational, (sample AC-2-6).	0.42	0.13
29	Silty diatomite, pale greenish yellow, massive, base gradational, (sample AC-2-7).	2.50	0.76
30	Diatomite, white, massive, base gradational, (sample AC-2-8).	0.50	0.15
31	Diatomaceous silt, pale greenish yellow, minor bioturbation, minor Fe-staining, base gradational, (sample AC-2-9).	0.33	0.10
32	Diatomite, silty, white to pale greenish yellow, massive base gradational, (sample AC-2-10).	0.42	0.13
33	Diatomaceous silt, pale greenish yellow, moderate bioturbation, chert nodules base gradational, (sample AC-2-11).	0.58	0.18
34	Silty diatomite, white to pale greenish yellow, massive, base gradational, (sample AC-2-12).	1.00	0.30
	--		
35	Diatomaceous silt, interbedded silt (pale greenish yellow), and diatomaceous silt (white to pale greenish yellow), base gradational, beds 1/2" - 1" thick, (sample AC-2-13).	0.75	0.23

MEASURED SECTION AC-2
ADIT CANYON (CONT.)

UNIT #	DESCRIPTION	FEET	METERS
36	Silt, pale greenish yellow, minor Fe-staining, plant stems, chert nodules, base gradational, (Lower Ash ?), (sample AC-2-14).	0.58	0.18
37	Silty sand, v. pale orange laminated, abundant bioturbation, base sharp, (Lower Ash ?), (sample AC-2-15).	0.50	0.15
	------ Potential Ore Zone 3, (Units 38-54+) -----		
38	Silty diatomite, white to pale greenish yellow, massive, base gradational, (sample AC-2-16).	0.67	0.20
39	Diatomite, white, massive, base gradational, (sample AC-2-17).	0.92	0.28
40	Silty diatomite, pale greenish, yellow, massive, base gradational, (sample AC-2-18).	0.67	0.20
41	Diatomite, white to pale greenish yellow, massive, base gradational to sharp, (sample AC-2-19).	0.58	0.18
42	Silty diatomite, white to pale greenish yellow, massive, base gradational, (sample AC-2-20).	0.67	0.20
43	Diatomite, white, massive, base gradational, (sample AC-2-21).	0.33	0.10
44	Silty diatomite, pale greenish, yellow, massive, base gradational, (partial sample AC-2-22).	0.33	0.10

MEASURED SECTION AC-2
ADIT CANYON (CONT.)

UNIT #	DESCRIPTION	FEET	METERS
45	Diatomite, base wavy, sharp, (partial sample AC-2-22).	0.25	0.08
46	Diatomaceous silt, pale greenish yellow, minor white pockets, massive, weathers back, minor plant stems, base sharp, (sample AC-2-23).	0.25	0.08
47	Diatomite, white, massive, minor 1" bed of lt. gray silty diatomite, resistant beds, base gradational, (sample AC-2-24).	1.17	0.36
48	Silt, upper 2" pale greenish yellow, abundant plant stems, minor chert nodules 4" x 1" forming at top, abundant plant stems, lower 2" v. pale orange lower 3" finely laminated, base sharp, (sample AC-2-25).	0.33	0.10
49	Diatomite, white to pale greenish yellow, massive, base sharp, (sample AC-2-26).	0.33	0.10
50	Silt, upper 2" pale greenish yellow, middle 3" v. pale orange, lower 1" pale greenish yellow, diatomaceous, moderate plant stems, base sharp, (sample AC-2-27).	0.50	0.15

MEASURED SECTION AC-2
ADIT CANYON (CONT.)

UNIT #	DESCRIPTION	FEET	METERS
51	Diatomite, white to lt. gray, minor seams of silt, thinly laminated lt. gray zone from 11" to 13", massive, base gradational, (sample AC-2-28 - upper 1/2, sample AC-2-29 - lower 1/2, sample AC-2-30 - prime 8" zone 24" to 32" from top).	4.42	1.35
52	Diatomaceous silt, pale greenish yellow, plant stems, abundant chert nodules, base sharp color change, (sample AC-2-31).	0.50	0.15
53	Silt, v. pale orange to pale greenish yellow, thinly laminated, moderate plant stems, bottom 1" v. pale orange, weathers back, base sharp, (sample AC-2-32).	0.58	0.18
54	Diatomite, white to pale greenish yellow, interbedded diatomite and silty diatomite, base gradational (sample AC-2-33 - top 34", sample AC-2-34 - lower 47").	6.75	2.06
	TOTAL	115.00	35.05

Units (4,5 & 6), (7,8 & 9), (15,16 & 17), (20,21 & 22), (26,27,28,29, & 30), (31,32 & 33), (35,36 & 37), (38,39,40,41,42,43,44,45,46 & 47), (48,49 & 50), and (52 & 53) have been combined on Plate VI.

MEASURED SECTION CC-1
CAMEL CANYON

Location: NE1/4, SE1/4, NW1/4, Sec. 29, T. 9 S., R. 18 E., Peppersauce Wash 7.5' Quadrangle, Pinal County, Arizona.

UNIT #	DESCRIPTION	FEET	METERS
	------ Potential Ore Zone 3, (Units 1-15) -------		
1	Ash, v. lt. gray, unaltered, silt sized, sharp base, correlative to Ladd's CC-2/66, (sample CC-1-1).	0.25	0.08
2	Diatomite, white, massive, minor chert nodules (2 mm), bulbous (1 to 2 mm) weathered surface, gradational base, (sample CC-1-2).	2.58	0.79
3	Sandy silt, pale greenish yellow, massive, abundant horizontal and vertical white, silicified(?) plant stems (2 mm diameter), sharp base, (sample CC-1-3).	1.00	0.30
4	Diatomite, white, massive, minor thin (0.5" to 1.0") layers of lt gray, silty diatomite, gradational base, (sample CC-1-4).	1.58	0.48
5	Silt, yellowish gray at base to lt. olive gray at top, fining upward, plant stems (sample CC-1-5).	1.17	0.36
6	Diatomite, white, massive, minor plant stems, sharp base, (sample CC-1-6).	3.42	1.04

MEASURED SECTION CC-1
CAMEL CANYON (cont.)

UNIT #	DESCRIPTION	FEET	METERS
7	Sandy silt, lt. olive gray, minor thin (0.5" to 1.0"), white, diatomaceous interbeds, minor plant stems (2 to 3 mm), gradational base (sample CC-1-7).	2.17	0.66
8	Sandy silt, lt. olive gray, massive, minor vertical plant stems, irregular wavy base, (sample CC-1-8).	1.00	0.30
9	Ash, gray, unaltered, unconsolidated, silt sized, sharp base, overlies discontinuous lenses of pale greenish yellow silt, correlative to Ladd's CC-2/62, (sample CC-1-9).	0.25	0.08
10	Silt, v. pale orange, thinly laminated, minor horizontal plant stems, minor white, diatomaceous interbeds, sharp base, (sample CC-1-10).	1.67	0.51
11	Silty diatomite, lt. olive gray to lt. gray, interbedded, beds 1" to 2" thick, gradational base, (sample CC-1-11).	0.83	0.25
12	Silt, v. pale orange to lt. olive gray, interbedded, beds 1" to 7" thick, weathers back, minor diatomaceous interbeds, sharp base, (sample CC-1-12).	2.00	0.61

MEASURED SECTION CC-1
CAMEL CANYON (cont.)

UNIT #	DESCRIPTION	FEET	METERS
13	Silty diatomite, lt. gray to white, indistinct bedding, 1" thick ash layer 4" from top, correlative to Ladd's CC-2/58 ash layer, gradational base (samples CC-1-13a (ash) & CC-1-13 (diatomite)).	0.75	0.23
14	Diatomaceous silt, lt. gray to v. pale orange, interbedded, beds 1" to 3" thick, easily weathered, sharp base, (sample CC-1-14).	0.58	0.18
15	Diatomite, lt. gray to white, massive, 15" from top is a 2.5" thick, lt. gray, silty diatomite layer, sharp base, (sample CC-1-15).	2.33	0.71

16	Sandy silt, lt. olive gray, thinly (2 mm) laminated, abundant vertical plant stems, sharp base, (sample CC-1-16).	1.00	0.30
17	Silty diatomite, lt. gray, gradational base.	0.08	0.03
18	Sandy silt, lt. greenish gray, massive, abundant plant stems, gradational base, (sample CC-1-17).	0.50	0.15
19	Silt, v. pale orange, massive, abundant vertical plant stems, 5.5" from top is a 2" layer of horizontal plant stems(?), sharp base, (sample CC-1-18).	2.00	0.61

MEASURED SECTION CC-1
CAMEL CANYON (cont.)

UNIT #	DESCRIPTION	FEET	METERS
20	Ash, lt. gray, fresh, unconsolidated, silt sized, sharp base, correlative to Ladd's CC-2/55, (sample CC-1-19).	0.08	0.03
21	Sandy silt, lower 8" is lt. olive gray, gradational into upper 7" v. pale orange, minor vertical stems, sharp base (samples CC-1-20 (upper 7") & CC-1-21 (lower 8")).	1.17	0.36
22	Silty diatomite, lt. gray, massive, gradational base, (sample CC-1-22).	0.50	0.15
23	Sandy silt, v. pale orange, massive, lithified near top, sharp base, (sample CC-1-23).	1.33	0.41
24	Silty diatomite, lt. gray to white, thinly interbedded, beds 0.5" to 1.5" thick, gradational base, (sample CC-1-24).	1.17	0.36
25	Chert, lt. olive, 6" to 7" beds of chert with minor interbedded silt, correlative with Ladd's CC-2/50.	2.58	0.79
	TOTAL	31.99	9.77

This measured section is not shown on Plate VII. It is located approximately 150' west of Ladd's measured section CC-2L, and is correlative to the upper portion of it.

MEASURED SECTION GJ-1
GUST JAMES WASH

Location: NE1/4, NE1/4, SW1/4, Sec. 13, T. 9 S., R. 17 E., Clark Ranch 7.5' Quadrangle, Pinal County, AZ.

UNIT #	DESCRIPTION	FEET	METERS
1	Ash, lt. gray, (Lower Ash)	1.00	0.30
2	Silt, very pale orange, thinly laminated, calcareous, lower contact undulatory.	10.00	3.05
	------- Potential Ore Zone 3, (Units 3-6) -------		
3	Marl, white, massive, diatomaceous, carbonate increasing upward, lower contact sharp, (sample GJ-1-1).	1.75	0.53
4	Diatomite, white, massive, 1" thick beds of gray silt occur between 11" and 22" from top, lower contact gradational, (sample GJ-1-2).	2.83	0.86
5	Silt, pale greenish yellow to white, 1.5" thick beds, diatomaceous, burrowing(?) traces, lower contact sharp.	1.33	0.41
6	Diatomite, white, massive, base gradational, (sample GJ-1-3).	1.83	0.56

7	Silt, pale greenish yellow, 1.5" thick beds, diatomaceous, lower 10' covered.	11.67	0.51
	TOTAL	30.41	9.27

MEASURED SECTION GJ-2
GUST JAMES WASH

Location: NW1/4, NE1/4, SW1/4, Sec. 13, T. 9 S., R. 17 E., Clark Ranch 7.5' Quadrangle, Pinal County, Arizona.

UNIT #	DESCRIPTION	FEET	METERS
1	Ash, lt. gray, (Lower Ash).	1.00	0.30
2	Silt, v. pale orange, thinly laminated, wavy, calcareous, lower contact sharp.	10.00	3.05
	------- Potential Ore Zone 3, (Units 3-6) -------		
3	Marl, white, diatomaceous, lower contact gradational, (sample GJ-2-1).	0.83	0.25
4	Diatomite, white, contains two 1" layers calcareous diatomite, lower contact sharp, (sample GJ-2-2).	3.17	0.97
5	Silt, pale greenish yellow, plant stems, lower contact gradational.	2.00	0.61
6	Diatomite, white, silty, lower contact gradational, (sample GJ-2-3).	3.00	0.91
	--		
7	Silt, pale greenish yellow, abundant plant stems.	1.33	0.41
	TOTAL	21.33	6.50

This measured section is not shown on Plate III. It is located approximately 100' west of measured section GJ-1, and is very similar to it.

MEASURED SECTION GJ-3
GUST JAMES WASH

Location: SW1/4, NW1/4, SE1/4, Sec. 13, T. 9 S., R. 17 E., Clark Ranch 7.5' Quadrangle, Pinal County, AZ.

UNIT #	DESCRIPTION	FEET	METERS
1	Ash, lt. gray, moderately lithified, thinly laminated, lower contact sharp, (Lower Ash).	2.67	0.81
2	Silt, v. pale orange, beds range from 1" to 1.5' thick, diatomaceous, calcareous, ledge former, lower contact sharp.	5.67	1.73
	------- Potential Ore Zone 3, (Units 3-7) -------		
3	Marl, v. lt gray, interbedded, well cemented, beds 3" thick, diatomaceous, silty, lower contact sharp.	5.83	1.78
4	Marl, white, massive, diatomaceous, lower contact gradational.	1.00	0.30
5	Diatomite, white, massive, minor 1" thick beds of silt, lower contact gradational, (sample GJ-3-1).	4.42	1.35
6	Silt, pale greenish yellow, abundant plant stems, lower contact gradational.	0.83	0.25
7	Diatomite, white, massive, slightly silty, lower contact gradational, (sample GJ-3-2).	3.33	1.01

MEASURED SECTION GJ-3
GUST JAMES WASH (cont.)

UNIT #	DESCRIPTION	FEET	METERS
8	Silt, pale greenish yellow, thinly laminated, plant stems, lower contact covered.	3.00	0.91
	TOTAL	26.75	8.14

Units (3 & 4) have been combined on Plate III.

MEASURED SECTION GJ-4
GUST JAMES WASH

Location: SE1/4, SE1/4, SW1/4, Sec. 13, T. 9 S., R. 17 E., Clark Ranch 7.5' Quadrangle, Pinal County, AZ.

UNIT #	DESCRIPTION	FEET	METERS
1	Ash, lt gray, thinly laminated, top half lithified, base sharp, (Lower Ash).	1.42	0.43
2	Silt, v. pale orange to pale grennish yellow to white, thinly laminated, well lithified, diatomaceous, calcareous, base sharp.	5.42	1.65
	------ Potential Ore Zone 3, (Units 3-11) -------		
3	Marl, white to v. pale orange, upper 1' interbedded silt and marl, lower 3' massive, minor chert, base wavy.	4.00	1.22
4	Silt, v. pale orange, slightly wavy laminations, calcareous, weathers back, base gradational.	1.50	0.46
5	Silt, pale greenish gray, massive, calcareous, diatomaceous, forms cliff, base gradational and wavy.	0.83	0.25
6	Diatomite, white, upper 10" massive, middle 11" interbedded, beds 1" thick, bottom 7" massive, silty, (sample GJ-4-1).	2.33	0.71
7	Silt, pale greenish yellow, weathers back, base sharp and wavy.	0.25	0.08
8	Diatomite, white, massive, base gradational.	0.75	0.23

MEASURED SECTION GJ-4
GUST JAMES WASH (cont.)

UNIT #	DESCRIPTION	FEET	METERS
9	Silt, pale greenish yellow, massive, thinly laminated, calcareous, plant stems in lower half, forms cliff, base gradational.	2.25	0.69
10	Diatomite and silt, white to pale greenish yellow, interbedded, beds 1" to 2" thick, base gradational.	0.83	0.25
11	Diatomite, white to pale greenish yellow, massive, silty, minor plant stems, base gradational, (sample GJ-4-2a (top 1/2), sample GJ-4-2b (bottom 1/2)).	3.42	1.04
	--		
12	Silt, thinly laminated, some layers well lithified, calcareous, sandy, plant stems near top, weathers back, base sharp.	3.00	0.91
13	Silt, interbedded, calcareous, sandy, forms cliffs.	5.00	1.52
	TOTAL	31.00	9.44

Units (4 & 5), (6,7 & 8), (9 & 10), and (12 & 13) have been combined on Plate IV.

MEASURED SECTION MC-1
MILL CANYON

Location: NW1/4, SE1/4, SE1/4, Sec. 13, T. 9 S., R. 17 E., Clark Ranch 7.5' Quadrangle, Pinal County, AZ.

UNIT #	DESCRIPTION	FEET	METERS
1	Diatomite, white, massive, base sharp.	0.50	0.15
2	Diatomite, white, unconsolidated, friable, punky, base gradational, (sample MC-1-1).	0.42	0.13
3	Diatomite, white, massive, base gradational, (sample MC-1-2).	0.33	0.10
4	Silt, very pale orange at base to pale greenish yellow at top, massive, minor white, diatomaceous, interbedded layers near top, slightly calcareous, base gradational, (sample MC-1-3).	1.58	0.48
5	Ash, lt gray, unconsolidated, interbedded with well lithified layers, wavy bedding, forms ledge, (Lower Ash), (sample MC-1-4).	2.08	0.64
	------ Potential Ore Zone 3 (Units 6-14+) -------		
6	Marl, white to very pale orange, well indurated, interbedded, beds in lower 3 ft are 2" to 3", middle 3 ft thinly laminated, upper 1 ft massive, white diatomaceous layers interbedded with very pale orange silt, base wavy, (sample MC-1-5).	7.00	2.13

MEASURED SECTION MC-1
MILL CANYON (cont.)

UNIT #	DESCRIPTION	FEET	METERS
7	Silt, very pale orange, poorly consolidated, thinly laminated, calcareous, base sharp, (sample MC-1-6).	1.00	0.30
8	Marl, white to very pale orange, interbedded, contains white, 6" to 7" thick, diatomaceous beds with very pale orange, 2" to 3" thick, silty beds, upper 6" very calcareous, (sample MC-1-7).	2.33	0.71
9	Silt, very pale orange, poorly consolidated, thinly laminated, calcareous, base sharp.	0.42	0.13
10	Diatomite, white, interbedded, beds 1' thick, silty, base wavy.	3.17	0.97
11	Silt, very pale orange, poorly consolidated, thinly laminated, calcareous, base sharp.	0.58	0.18
12	Diatomite, white, massive, calcareous near top, 1' thick pale greenish yellow silt bed near base, base gradational, (sample MC-1-8).	5.25	1.60
13	Silt, pale greenish yellow, unconsolidated, weathers back, vertical plant stems, (sample MC-1-9).	0.67	0.20

MEASURED SECTION MC-1
MILL CANYON (cont.)

UNIT #	DESCRIPTION	FEET	METERS
14	Diatomite, white, massive, 2 ft from top is a pale greenish yellow, 1" to 3" thick, silty layer, base covered in wash, (sample MC-1-10).	5.00	1.52
	TOTAL	30.33	9.24

Units (1,2, & 3) have been combined on Plate IV.

MEASURED SECTION MC-2
MILL CANYON

Location: NW1/4, SW1/4, SE1/4, Sec. 13, T. 9 S., R. 17 E., Clark Ranch 7.5' Quadrangle, Pinal County, AZ.

UNIT #	DESCRIPTION	FEET	METERS
1	Marl, white, weathers blocky, diatomaceous, silty, base gradational.	0.42	0.13
2	Silt, very pale orange, weathers back, base sharp.	0.50	0.15
3	Ash, lt gray, lithified, calcareous, base gradational, (reworked Lower Ash).	0.25	0.08
4	Silt, very pale orange, calcareous, base sharp.	0.50	0.15
5	Ash, lt gray, top and bottom well lithified, middle unconsolidated, bottom portion shows abundant ripples(?) or soft sediment deformation, calcareous, base sharp, (Lower Ash).	0.83	0.25
	------ Potential Ore Zone 3, (Units 6-14+) ------		
6	Marl, very pale orange to white, interbedded, silty, diatomaceous, base gradational.	5.33	1.62
7	Marl, very lt gray, thinly laminated, weathers back, silty, diatomaceous, base sharp.	0.58	0.18
8	Marl, very pale orange to white, interbedded, weathers blocky, lower 2 ft weathers back, silty, diatomaceous, base sharp.	4.00	1.22

MEASURED SECTION MC-2
MILL CANYON (cont.)

UNIT #	DESCRIPTION	FEET	METERS
9	Marl, white, ledge former, diatomaceous, silty, minor olive green chert nodules.	1.00	0.30
10	Silt, pale greenish yellow, thinly laminated, weathers back, diatomaceous, calcareous, base gradational.	0.67	0.20
11	Diatomite, white, massive, forms cliffs, upper 6" calcareous, pale greenish yellow, base gradational, (sample MC-2-1).	5.00	1.52
12	Silt, pale greenish yellow, weathers back, locally forms cliffs, diatomaceous, slightly calcareous, abundant vertical plant stems, base gradational.	1.08	0.33
13	Diatomite, white, forms cliffs, minor thin, 1" to 7" thick, pale greenish yellow silt layers with minor Fe-staining, slightly calcareous, base gradational to sharp, (samples MC-2-2 (Fe-stained silt) & MC-2-3 (diatomite)).	4.00	1.22
14	Silt, pale greenish yellow, thinly laminated, weathers back, abundant vertical plant stems, base sharp.	1.50	0.46
	TOTAL	25.66	7.81

Units (2,3 & 4) and (6,7,8 & 9) have been combined on Plate IV.

MEASURED SECTION MC-3
MILL CANYON

Location: NW1/4, NE1/4, NE1/4, Sec. 24, T. 9 S., R. 17 E., Clark Ranch 7.5' Quadrangle, Pinal County, AZ.

UNIT #	DESCRIPTION	FEET	METERS
1	Ash, ledge former, base sharp, (Lower Ash).	1.00	0.30
	------ Potential Ore Zone 3, (Units 2-8+) -------		
2	Diatomite and silt, interbedded, beds vary from 6" to 12", weathers back.	7.00	2.13
3	Marl, med. gray, diatomaceous, silty.	2.00	0.61
4	Diatomite, white to light gray, slightly calcareous.	2.50	0.76
5	Silt, pale greenish yellow to gray, slightly calcareous.	1.50	0.46
6	Diatomite, white, slightly calcareous.	2.00	0.61
7	Silt, pale greenish yellow to lt. gray, slightly calcareous.	1.00	0.30
8	Diatomite, white.	1.00	0.30
	TOTAL	18.00	5.47

This measured section is not shown on Plate IV. It is located approximately 200' south of DH-A.

MEASURED SECTION MC-4
MILL CANYON

Location: SE1/4, SW1/4, SE1/4, Sec. 13, T. 9 S., R. 17 E.,
Clark Ranch 7.5' Quadrangle, Pinal County, AZ.

UNIT #	DESCRIPTION	FEET	METERS
1	Ash, lt. gray, (Lower Ash).	1.00	0.30
	------ Potential Ore Zone 3, (Units 2-5+) -------		
2	Marl, white, diatomaceous, silty, base gradational.	16.00	4.88
3	Diatomite, white, massive, base gradational, (sample MC-4-1).	2.00	0.61
4	Silt, pale greenish yellow, base gradational, (sample MC-4-3).	1.50	0.46
5	Diatomite, white, massive, base covered (sample MC-4-2).	7.00	2.13
	TOTAL	27.50	8.38

This measured section is located in the large quarry in Mill Canyon. The unit thicknesses are approximate due to difficulty in measuring the steep quarry face.

MEASURED SECTION Y-1
MILL CANYON

Location: SE1/4, NE1/4, NE1/4, Sec. 24, T. 9 S., R. 17 E., Clark Ranch 7.5' Quadrangle, Pinal County, AZ.

UNIT #	DESCRIPTION	FEET	METERS
	-------- Potential Ore Zone 2, (Unit +1) --------		
1	Diatomite, white to very lt gray, dense, interbedded, forms cliffs, base gradational, (sample Y-1-1).	4.33	1.32
	--		
2	Silt, lt gray to pale greenish yellow to white, weathers back, diatomaceous, abundant pale greenish yellow chert nodules, minor plant stems, base gradational, (reworked Lower Ash).	1.00	0.30
3	Ash, lt. gray, unconsolidated, fresh, weathers back, base sharp, (Lower Ash).	0.50	0.15
	------ Potential Ore Zone 3, (Units 4-10+) -------		
4	Silt, very pale greenish yellow to white, thinly bedded, beds 1" to 3" thick, cliff former, weathers back in places, diatomaceous, calcareous, abundant plant stems near base, base gradational.	4.00	1.22
5	Silt, very pale greenish yellow to very lt gray, massive, cliff former, calcareous, minor plant stems near top, base gradational.	2.00	0.61

MEASURED SECTION Y-1
MILL CANYON (cont.)

UNIT #	DESCRIPTION	FEET	METERS
6	Silt, very pale greenish yellow to white, minor diatomaceous interbeds, base weather back, base gradational.	1.17	0.36
7	Diatomite, white to very lt gray, massive, cliff former, minor interbeds of silty diatomite, (samples Y-1-2a (diatomite) and Y-1-2b (silty diatomite).	6.50	1.98
8	Silt, pale greenish yellow, abundant plant stems, abundant chert nodules, base sharp.	1.08	0.33
9	Diatomite, white, dense, massive, base wavy, (sample Y-1-3).	1.75	0.53
10	Silt, pale greenish yellow to white, diatomaceous.	3.00	0.91
	TOTAL	25.33	7.71

Units (2 & 3), and (4,5 & 6) have been combined on Plate VI.

MEASURED SECTION OE-1
ONE ELEVEN CANYON

Location: SW1/4, SW1/4, NW1/4, Sec. 19, T. 9 S., R. 18 E., Clark Ranch 7.5' Quadrangle, Pinal County, AZ.

UNIT #	DESCRIPTION	FEET	METERS
1	Cover, silty, weathered back.	5.00	1.52
2	Marl, pinkish gray to yellowish gray, cliff former, diatomaceous, silty, base gradational, (sample OE-1-1).	1.08	0.33
3	Marl, white, well lithified, massive, diatomaceous, silty, cliff former, base irregular to gradational, (sample OE-1-2).	3.17	0.97
4	Silt, very pale orange, slightly massive near base, calcareous, cliff former, weathers back near top, base gradational, (sample OE-1-3).	1.67	0.51
5	Marl, white, massive, diatomaceous, silty, cliff former, base gradational.	2.17	0.66
6	Silt, very pale orange, massive, thinly laminated near base, calcareous, forms irregular blocks, weathers back near base, base gradational.	3.17	0.97
7	Marl, white to very pale orange, massive, laminated in middle, diatomaceous, silty, cliff former, base gradational to irregular.	2.58	0.79

MEASURED SECTION OE-1
ONE ELEVEN CANYON (cont.)

UNIT #	DESCRIPTION	FEET	METERS
8	Silt, very pale orange, calcareous, diatomaceous, weathers back, bottom forms small ledge, base covered, gradational(?).	4.00	1.22
	TOTAL	22.84	6.97

Units (2 & 3) have been combined on Plate V.

MEASURED SECTION OE-2
ONE ELEVEN CANYON

Location: NE1/4, NE1/4, SE1/4, Sec. 24, T. 9 S., R. 17 E., Clark Ranch 7.5' Quadrangle, Pinal County, AZ.

UNIT #	DESCRIPTION	FEET	METERS
	-------- Potential Ore Zone 2, (Unit +1) --------		
1	Diatomite, white, silty, (sample OE-2-1).	4.17	1.27
	--		
2	Silt, pale greenish yellow, high clay content.	0.58	0.18
3	Ash, gray, (Lower Ash).	0.33	0.10
	------- Potential Ore Zone 3, (Unit 4-7+) -------		
4	Marl, white, diatomaceous, silty.	14.17	4.32
5	Diatomite, white, silty, (sample OE-2-2).	3.17	0.97
6	Silt, pale greenish yellow, high clay content, plant stems.	0.50	0.15
7	Diatomite, white, silty, slightly calcareous, (sample OE-2-3).	2.50	0.76
	TOTAL	25.42	7.75

Units (2 & 3) have been combined on Plate V.

MEASURED SECTION OE-3
ONE ELEVEN CANYON

Location: Center of NW1/4, Sec. 19, T. 9 S., R. 18 E., Clark Ranch 7.5' Quadrangle, Pinal County, AZ.

UNIT #	DESCRIPTION	FEET	METERS
1	Undifferentiated silt and gravel, base sharp, erosional.	40.00	12.19
2	Marl and silt, diatomaceous, cliff former, base undulatory.	10.00	3.05
3	Silt, very pale orange, several 6" thick beds of dense marl near base, at base is 6" crust of nodular, weathered silt, ledge former, erosional (?), base sharp.	34.00	10.36
4	Marl, white, thinly laminated, diatomaceous, silty, weathers back, base covered, sharp(?).	9.00	2.74
5	Marl, white, conglomeratic, sandy with rounded diatomaceous marl clast, 8" from top is an 8" thick diatomaceous bed, lenses in and out, ledge former (samples OE-3-3 (congl. marl), OE-3-4 (8" diat. bed)).	5.00	1.52
6	Marl, white, dense, diatomaceous, silty, minor green chert nodules, cliff former, (sample OE-3-2).	11.00	3.35
7	Silt, abundant plant stems, weathers back, local marker bed.	1.00	0.30
8	Silt, very pale orange, interbedded with diatomaceous silt, weathers back.	25.00	7.62

MEASURED SECTION OE-3
ONE ELEVEN CANYON (cont.)

UNIT #	DESCRIPTION	FEET	METERS
9	Silt, diatomaceous, weathers back, forms stadium like area, upper contact ledge former, base sharp.	40.00	12.19
10	Marls and silt, dense, diatomaceous, cliff former, 2 ft to 3 ft from base is a 1' thick silt bed, weathers back, base undulatory.	16.00	4.88
11	Silt, very pale orange, thinly laminated, weathers back, often covered, base sharp, erosional(?).	6.00	1.83
12	Marl, white, forms small ledge, base undulatory, (sample OE-3-1).	3.00	0.91
13	Silt, very pale orange.	40.00	12.19
14	Ash, bench former, lithified near base, base sharp, (Upper Ash).	1.00	0.30
	-------- Potential Ore Zone 1, (Unit 15+) -------		
15	Diatomite, white, cliff former, base covered.	25.00	7.62
	TOTAL	266.00	81.05

Units (4,5 & 6) and (7,8 & 9) have been combined on Plate V.

MEASURED SECTION OE-4
ONE ELEVEN CANYON

Location: SW1/4, SW1/4, SE1/4, Sec. 18, T. 9 S., R. 18 E., Clark Ranch Quadrangle, Pinal County, AZ.

UNIT #	DESCRIPTION	FEET	METERS
	------- Potential Ore Zone 2, (Units +1-4) ------		
1	Diatomite, white, base gradational.	1.00	0.30
2	Ash, lt. gray, plant stems, base sharp.	0.25	0.08
3	Diatomite, white to pale greenish yellow, top 20" interbedded, 1" to 2" thick layers of diatomite and silty diatomite, bottom 18" massive diatomite, white, gradational into 5" of basal laminated silt, base sharp.	3.58	1.09
4	Diatomite, white to lt greenish gray, interbedded, 1" to 2" thick layers, silty, minor plant stems and Fe-staining, base gradational.	1.50	0.46
	--		
5	Ash, lt greenish gray to med. gray, upper 13" lt greenish gray, moderate plant stems, middle 8" med. gray, crossbedded, basal 1" lt gray, very fine grained, base sharp and undulatory, (Lower Ash).	1.83	0.56
	------ Potential Ore Zone 3, (Units 6-15+) ------		
6	Diatomite, white to lt gray, slightly silty, base gradational.	3.00	0.91

MEASURED SECTION OE-4
ONE ELEVEN CANYON (cont.)

UNIT #	DESCRIPTION	FEET	METERS
7	Silt, pale greenish gray, interbedded, beds 1" to 4" thick, diatomaceous, plant stems, top 1" contains chert, base sharp.	2.08	0.63
8	Diatomite, white to lt gray, silty, minor plant stems, base gradational.	1.33	0.41
9	Silt, pale greenish gray, thinly laminated, diatomaceous, minor plant stems, Fe-staining, base sharp.	1.58	0.48
10	Diatomite, white to pale greenish gray, massive, silty, base gradational.	2.25	0.69
11	Silt, pale greenish gray, diatomaceous, abundant plant stems, base gradational to sharp.	1.83	0.56
12	Chert, dk greenish yellow, weathers back, highly fractured, base gradational.	0.42	0.13
13	Diatomite, white to pale greenish gray, slightly silty, base undulatory.	2.00	0.61
14	Silt, pale greenish gray, contains chert and plant stems, base sharp.	1.50	0.46

MEASURED SECTION OE-4
ONE ELEVEN CANYON (cont.)

UNIT #	DESCRIPTION	FEET	METERS
15	Diatomite, white, interbedded with silt, a prominent silt layer occurs 76" to 88" from top, 1' thick, (samples OE-4-1 (diat. above silt) and OE-4-2 (diat. below silt).	10.00	3.05
	TOTAL	34.15	10.42

Units (1,2,3 & 4) and (12,13,14 & 15) have been combined on Plate V.

MEASURED SECTION OE-5
ONE ELEVEN CANYON

Location: SE1/4, NW1/4, SE1/4, Sec. 18, T. 9 S., R. 18 E., Clark Ranch 7.5' Quadrangle, Pinal County, AZ.

UNIT #	DESCRIPTION	FEET	METERS
1	Silt, very pale orange.	2.00	0.61
2	Marl, white, massive.	1.50	0.46
3	Ash, lt. gray, unconsolidated, (Upper Ash).	0.50	0.15
	------- Potential Ore Zone 1, (Units 4-6) -------		
4	Diatomite, silty, base gradational.	20.00	6.10
5	Ash, lt. gray, base sharp.	0.25	0.08
6	Marl, diatomaceous, silty.	3.00	0.91
	--		
7	Silt, top 5' interbedded with marl.	15.00	4.57
	--------- Potential Ore Zone 2, (Unit 8) --------		
8	Cover, marly, diatomaceous, silty, plant stems.	10.00	3.05
	--		
9	Ash, lt gray to lt greenish gray, sharp base, (Lower Ash).	2.50	0.76
	TOTAL	54.75	16.69

Units (5 & 6) have been combined on Plate V.

APPENDIX B
DESCRIPTION OF DRILL HOLES

KAISER DRILL HOLE - DH-A
MILL CANYON

Location: NW1/4, NE1/4, NE1/4, Sec. 24, T. 9 S., R. 17 E., Clark Ranch 7.5' Quadrangle, Pinal County, AZ.

Survey: 1,170' W of NE corner of Sec. 24, T. 9 S., R. 17 E., and 130' S of the north sideline of Sec. 24. Collar elevation about 2,700'.

UNIT #	DESCRIPTION	FEET	METERS
1	Waste	17.00	5.18
	-------- Potential Ore Zone 1, (Unit 2) ---------		
2	Marginal diatomite	6.00	1.83
	--		
3	Waste	20.00	6.10
	-------- Potential Ore Zone 2, (Unit 4) ---------		
4	Diatomite	8.00	2.44
	--		
5a	Waste	10.00	3.05
	------ Potential Ore Zone 3, (Units 5b-10) ------		
5b	Waste	8.00	2.44
6	Diatomite	2.00	0.61
7	Waste	4.00	1.22
8	Diatomite	4.00	1.22
9	Waste	8.00	2.44
10	Marginal diatomite	6.00	1.83
	--		
11	Waste	14.00	4.27

KAISER DRILL HOLE - DH-A
MILL CANYON (cont.)

UNIT #	DESCRIPTION		FEET	METERS
12	Marginal diatomite		6.00	1.83
		TOTAL	113.00	34.46

The upper ash marker bed is located approximately 9' to 10' below the collar elevation. The lower ash marker bed is located approximately 60' to 61' below the collar elevation.

KAISER DRILL HOLE - DH-B
GUST JAMES WASH

Location: SW1/4, NE1/4, SW1/4, Sec. 18, T. 9 S., R. 18 E., Clark Ranch 7.5' Quadrangle, Pinal County, AZ.

Survey: 2,070' N of SW corner of Sec. 18, T. 9 S., R. 18 E., and 610' E of the west sideline of Sec. 18. Collar elevation about 2,765'.

UNIT #	DESCRIPTION	FEET	METERS
1	Waste	45.50	13.87
	------- Potential Ore Zone 1, (Units 2-4) -------		
2	Diatomite	2.50	0.76
3	Waste	3.00	0.91
4	Diatomite	3.00	0.91
	--		
5	Waste	20.00	6.10
	------- Potential Ore Zone 2, (Units 6-8) -------		
6	Diatomite	2.00	0.61
7	Waste	2.00	0.61
8	Diatomite	3.00	0.91
	--		
9	Waste	17.00	5.18
	------ Potential Ore Zone 3, (Units 10-18) ------		
10	Marginal diatomite	1.00	0.30
11	Waste	5.00	1.52
12	Diatomite	4.00	1.22
13	Waste	2.00	0.61

KAISER DRILL HOLE - DH-B
GUST JAMES WASH (cont.)

UNIT #	DESCRIPTION	FEET	METERS
14	Diatomite	3.00	0.91
15	Waste	5.00	1.52
16	Marginal diatomite	2.00	0.61
17	Waste	4.00	1.22
18	Diatomite	3.00	0.91

19	Waste	10.00	3.05
	TOTAL	137.00	41.73

Upper ash marker bed located approximately 30' to 31' below collar.

KAISER DRILL HOLE - DH-C
ONE ELEVEN CANYON

Location: NE1/4, NW1/4, SE1/4, Sec. 18, T. 9 S., R. 18 E., Clark Ranch 7.5' Quadrangle, Pinal County, AZ.

Survey: 2,320' N of south sideline of Sec. 18, T. 9 S., R. 18 E., and 1,660' W of the east sideline of Sec. 18. Elevation about 2,840'.

UNIT #	DESCRIPTION	FEET	METERS
1	Waste	19.00	5.79
	------- Potential Ore Zone 1, (Units 2-9) -------		
2	Diatomite	1.00	0.30
3	Waste	1.00	0.30
4	Marginal diatomite	2.00	0.61
5	Waste	1.00	0.30
6	Marginal diatomite	2.00	0.61
7	Diatomite	1.00	0.30
8	Waste	3.00	0.91
9	Diatomite	2.00	0.61
	--		
10	Waste	29.00	8.84
	-------- Potential Ore Zone 2, (Unit 11) --------		
11	Marginal diatomite	1.00	0.30
	--		
12	Waste	16.00	4.88
	TOTAL	78.00	23.75

KAISER DRILL HOLE - DH-C
ONE ELEVEN CANYON (cont.)

The upper ash marker bed is missing in the immediate vicinity of DH-C, but nearby it is at the top of POZ1. The lower ash marker bed is 43' below the top of POZ1.

KAISER DRILL HOLE - DH-D
ONE ELEVEN CANYON

Location: SW1/4, SE1/4, SW1/4, Sec. 18, T. 9 S., R. 18 E., Clark Ranch 7.5' Quadrangle, Pinal County, AZ.

Survey: 220' N of south sideline of Sec. 18, T. 9 S., R. 18 E., and 2,080' E of the SW corner of Sec. 18. Elevation about 2,810'.

UNIT #	DESCRIPTION	FEET	METERS
1	Waste	11.00	3.35
2	Diatomite, (sample D-4).	4.00	1.22
3	Waste	1.00	0.30
4	Diatomite	1.00	0.30
5	Waste	2.00	0.61
6	Diatomite, (sample D-8).	5.00	1.52
7	Waste	6.00	1.83
8	Diatomite, (sample D-11).	3.00	0.91
9	Waste	7.00	2.13
10	Diatomite, (sample D-14).	5.00	1.52
11	Waste	1.00	0.30
12	Diatomite	2.00	0.61
13	Waste	2.00	0.61
14	Diatomite	2.00	0.61
15	Waste	15.00	4.57
16	Diatomite, (sample D-23).	2.00	0.61
17	Waste	40.00	12.19

KAISER DRILL HOLE - DH-D
ONE ELEVEN CANYON (cont.)

UNIT #	DESCRIPTION	FEET	METERS
	------ Potential Ore Zone 1, (Units 18-19+) ------		
18	Diatomite	4.00	1.22
19	Waste	12.00	3.66
	TOTAL	125.00	38.07

The upper ash marker bed is assumed to be at the top of unit #18, however it is unconfirmed in the field. All the samples tested by Kaiser were probably from the Gust James member.

KAISER DRILL HOLE - DH-E
ONE ELEVEN CANYON

Location: NW1/4, NW1/4, NW1/4, Sec. 19, T. 9 S., R. 18 E., Clark Ranch 7.5' Quadrangle, Pinal County, AZ.

Survey: 420' E of the NW corner of Sec. 19, T. 9 S., R. 18 E., and 525' S of the N sideline of Sec. 19. Elevation about 2,750'.

UNIT #	DESCRIPTION	FEET	METERS
1	Waste	38.00	11.58
2	Marginal diatomite	2.00	0.61
3	Waste	2.00	0.61
4	Diatomite	2.00	0.61
5	Waste	2.00	0.61
6	Diatomite	2.00	0.61
7	Waste	18.00	5.49
8	Diatomite	9.00	2.74
9	Waste	16.00	4.88
10	Diatomite	2.00	0.61
11	Waste	1.00	0.30
	TOTAL	94.00	28.65

The upper ash marker bed is located approximately 65' below the collar elevation. However, the stratigraphy exposed in canyon wall does not match the stratigraphy in the drill hole. Instead, the lower half of DH-E appears to correlate with the upper half of DH-D. Due to this inconsistency, DH-E was not used for stratigraphic correlations.

KAISER DRILL HOLE - DH-F
MILL CANYON

Location: NW1/4, SE1/4, NE1/4, Sec. 24, T. 9 S., R. 17 E., Clark Ranch 7.5' Quadrangle, Pinal County, AZ.

Survey: 1,680' S of the NE corner of Sec. 24, T. 9 S., R. 17 E., and 1,120' W of the east sideline of Sec. 24. Elevation about 2,685'.

UNIT #	DESCRIPTION	FEET	METERS
1	Waste	2.00	0.61
	------- Potential Ore Zone 2, (Unit +2a) --------		
2a	Diatomite	4.00	1.22
	------ Potential Ore Zone 3, (Units 2b-14) ------		
2b	Diatomite	4.00	1.22
3	Waste	2.00	0.61
4	Marginal diatomite	5.00	1.52
5	Diatomite	7.00	2.13
6	Waste	1.00	0.30
7	Diatomite	2.00	0.61
8	Waste	1.00	0.30
9	Diatomite	2.00	0.61
10	Waste	1.00	0.30
11	Diatomite	3.00	0.91
12	Marginal diatomite	2.00	0.61
13	Waste	1.00	0.30
14	Diatomite	2.00	0.61

KAISER DRILL HOLE - DH-F
MILL CANYON (cont.)

UNIT #	DESCRIPTION		FEET	METERS
15	Waste		11.00	3.35
16	Diatomite		3.00	0.91
17	Marginal diatomite		1.00	0.30
18	Diatomite		5.00	1.52
19	Waste		4.00	1.22
20	Diatomite		2.00	0.61
21	Waste		29.00	8.84
		TOTAL	94.00	28.61

The upper ash marker bed is located approximately 45' above the collar elevation. The lower ash marker bed is missing in the immediate vicinity of DH-F.

KAISER DRILL HOLE - DH-G
GUST JAMES WASH

Location: SE1/4, NW1/4, SE1/4, Sec. 13, T. 9 S., R. 17 E., Clark Ranch 7.5' Quadrangle, Pinal County, AZ.

Survey: 1,670' W of the SE corner of Sec. 13, T. 9 S., R. 17 E., and 1,940' N of the south sideline of Sec. 13. Elevation about 2,680'.

UNIT #	DESCRIPTION	FEET	METERS
1	Waste	25.00	7.62
	-------- Potential Ore Zone 1, (Unit 2) ---------		
2	Diatomite	3.00	0.91
	--		
3	Waste	16.00	4.88
	------- Potential Ore Zone 2, (Units 4-8) -------		
4	Diatomite	2.00	0.61
5	Waste	2.00	0.61
6	Diatomite	2.00	0.61
7	Waste	2.00	0.61
8	Diatomite	2.00	0.61
	--		
9	Waste	50.00	15.24
	TOTAL	104.00	31.70

The upper ash marker bed is located approximately 6' below the collar elevation.

KAISER DRILL HOLE - DH-H
ONE ELEVEN CANYON

Location: NE1/4, NE1/4, SE1/4, Sec. 24, T. 9 S., R. 17 E., Clark Ranch 7.5' Quadrangle, Pinal County, AZ.

Survey: 2,480' N of the SW corner of Sec. 19, T. 9 S., R. 18 E., and 230' E of the west sideline of Sec. 19. Elevation about 2,725'.

UNIT #	DESCRIPTION	FEET	METERS
1	Waste	5.00	1.52
2	Diatomite, (samples H-2, H-6, & H-10)	10.00	3.05
3	Waste	1.00	0.30
4	Marginal diatomite	2.00	0.61
5	Diatomite	2.00	0.61
6	Diatomite	5.00	1.52
7	Waste	2.00	0.61
8	Diatomite	2.00	0.61
9	Waste	2.00	0.61
10	Diatomite	5.00	1.52
11	Waste	55.00	16.76
	TOTAL	91.00	27.72

The upper ash marker bed is approximately 25' below the collar elevation. However, the stratigraphy in the drill hole does not correlate to the outcrop. Therefore, this hole is not used in stratigraphic correlation.

KAISER DRILL HOLE - DH-I
ONE ELEVEN CANYON

Location: NE1/4, SE1/4, NW1/4, Sec. 19, T. 9 S., R. 18 E., Clark Ranch 7.5' Quadrangle, Pinal County, AZ.

Survey: 2,020' E of the NW corner of Sec. 19, T. 9 S., R. 18 E., and 1,660' S of the N sideline of Sec. 19. Elevation about 2,850'.

UNIT #	DESCRIPTION		FEET	METERS
1	Waste		20.00	6.10
2	Diatomite		12.00	3.66
3	Marginal diatomite		4.00	1.22
4	Diatomite		7.00	2.13
5	Marginal diatomite		2.00	0.61
6	Waste		11.00	3.35
		TOTAL	56.00	17.07

This drill hole is not shown on Plate V. It correlates to the top of measured section OE-3.

KAISER DRILL HOLE - DH-J
ADIT CANYON

Location: SW1/4, NE1/4, SW1/4, Sec. 19, T. 9 S., R. 18 E., Clark Ranch 7.5' Quadrangle, Pinal County, AZ.

Survey: 1,770' N of the SW corner of Sec. 19, T. 9 S., R. 18 E., and 1,540' E of the W sideline of Sec. 19. Elevation about 2,750'.

UNIT #	DESCRIPTION	FEET	METERS
1	Waste	9.00	2.74
2	Marginal(?) diatomite	5.00	1.52
3	Waste	2.00	0.61
4	Marginal(?) diatomite	2.00	0.61
5	Waste	13.00	3.96
6	Diatomite	1.00	0.30
7	Waste	5.00	1.52
8	Marginal diatomite	6.00	1.83
9	Waste	20.00	6.10
10	Marginal diatomite	2.00	0.61
11	Waste	22.00	6.71
	TOTAL	87.00	26.51

Unable to confirm drill hole location.

KAISER DRILL HOLE - DH-K
CAMEL CANYON

Location: NW1/4, NE1/4, NW1/4, Sec. 29, T. 9 S., R. 18 E., Clark Ranch 7.5' Quadrangle, Pinal County, AZ.

Survey: 1,600' E of the NW corner of Sec. 29, T. 9 S., R. 18 E., and 770' S of the N sideline of Sec. 29. Elevation about 2,780'.

UNIT #	DESCRIPTION	FEET	METERS
1	Waste	13.00	3.96
2	Diatomite	1.00	0.30
3	Waste	17.00	5.18
4	Marginal diatomite	3.00	0.91
5	Waste	22.00	6.71
6	Marginal diatomite	3.00	0.91
7	Waste	8.00	2.44
	TOTAL	67.00	20.41

Unable to correlate drill hole to marker beds.

1957 EXPLORATORY DRILL HOLE - DH-1
RHODES RANCH CANYON

Location: SE1/4, NW1/4, NW1/4, Sec. 29, T. 9 S., R. 18 E.,
Clark Ranch 7.5' Quadrangle, Pinal County, AZ.

UNIT #	DESCRIPTION	FEET	METERS
1	A trace of diatomaceous earth	75.00	22.86
2	Diatomaceous earth	25.00	7.62
3	Some diatomaceous earth	5.00	1.52
4	Diatomaceous earth	30.00	9.14
5	Diatomaceous earth and chert	5.00	1.52
6	Diatomaceous earth	5.00	1.52
7	Some diatomaceous earth and chert	5.00	1.52
8	No sample	5.00	1.52
9	Diatomaceous earth	40.00	12.19
10	Diatomaceous earth and chert	5.00	1.52
11	Diatomaceous earth	5.00	1.52
12	Diatomaceous earth and some chert	5.00	1.52
13	No sample	5.00	1.52
14	No description, static level of H_2O at 230 feet.	95.00	28.96
15	Diatomaceous earth and some chert	20.00	6.10
16	No sample	30.00	9.14
17	Chert	25.00	7.62

1957 EXPLORATORY DRILL HOLE - DH-1
RHODES RANCH CANYON (cont.)

UNIT #	DESCRIPTION	FEET	METERS
18	No sample	5.00	1.52
19	Chert	30.00	9.14
20	No sample	10.00	3.05
21	Some chert	35.00	10.67
	TOTAL	465.00	141.69

1957 EXPLORATORY DRILL HOLE - DH-2
ADIT CANYON

Location: SW1/4, NW1/4, SW1/4, Sec. 19, T. 9 S., R. 18 E., Clark Ranch 7.5' Quadrangle, Pinal County, AZ.

UNIT #	DESCRIPTION	FEET	METERS
1	No description	25.00	7.62
2	Diatomaceous earth	15.00	4.57
3	Diatomaceous and a little chert	5.00	1.52
4	Diatomaceous earth	35.00	10.67
5	Diatomaceous earth and a little chert, static level of H_2O at 80 feet.	15.00	4.57
6	A little diatomaceous earth	15.00	4.57
7	Diatomaceous earth	65.00	19.81
8	Some diatomaceous earth and a little chert	10.00	3.05
9	No description, hole cased to 225 feet	45.00	13.72
10	Chert	35.00	10.67
11	Chert and diatomaceous earth	20.00	6.10
12	No sample	5.00	1.52
	TOTAL	290.00	88.39

1957 EXPLORATORY DRILL HOLE - DH-3
MILL CANYON

Location: NE1/4, NW1/4, NE1/4, Sec. 24, T. 9 S., R. 17 E., Clark Ranch 7.5' Quadrangle, Pinal County, AZ.

UNIT #	DESCRIPTION	FEET	METERS
1	No description	40.00	12.19
2	Gravel	5.00	1.52
3	Diatomaceous earth and gypsum	5.00	1.52
4	Chert and some diatomaceous earth	5.00	1.52
5	Diatomaceous earth	5.00	1.52
6	No description	40.00	12.19
7	Diatomaceous earth	25.00	7.62
8	Chert	10.00	3.05
9	Some diatomaceous earth and chert	5.00	1.52
10	Chert and diatomaceous earth	5.00	1.52
11	Chert	5.00	1.52
12	Gypsum and diatomaceous earth	40.00	12.19
13	Gypsum	10.00	3.05
14	Gypsum and some diatomaceous earth	5.00	1.52
15	Gypsum	15.00	4.57
16	Some gypsum	5.00	1.52
17	Chert and gypsum	10.00	3.05
18	Gypsum and some chert	5.00	1.52

1957 EXPLORATORY DRILL HOLE - DH-3
MILL CANYON (cont.)

UNIT #	DESCRIPTION	FEET	METERS
19	Gypsum	5.00	1.52
20	No sample	5.00	1.52
21	Chert	5.00	1.52
22	Black mat-hard with chert	5.00	1.52
23	Gypsum and chert	10.00	3.05
24	More gypsum, less chert	5.00	1.52
25	Gypsum	25.00	7.62
	TOTAL	300.00	91.38

1947 ARTESIAN WELL DRILL HOLE - DH-AW
ADIT CANYON

Location: SW1/4, SE1/4, SE1/4, Sec. 24, T. 9 S., R. 18 E., Clark Ranch 7.5' Quadrangle, Pinal County, AZ.

UNIT #	DESCRIPTION	FEET	METERS
1	River gravel	25.00	7.62
2	Coarse river gravel	20.00	6.10
3	River sand, mostly silica	26.00	7.92
4	Sandy gypsum	33.00	10.06
5	Solid gypsum beds	56.00	17.07
6	Gypsum beds and clay seams	160.00	48.77
7	Sandy gypsum, a little water in hole after 325 feet	40.00	12.19
8	Gypsum beds and clay seams	60.00	18.29
9	Gypsum beds	60.00	18.29
10	Sandy clay	60.00	18.29
11	Heavy clay	20.00	6.10
12	Sandy clay	60.00	18.29
13	Sand with clay nodules	40.00	12.19
14	Sand and gravel	20.00	6.10
15	Artesian water bearing sand and fine gravel	120.00	36.58
16	Heavy clay with few boulders	70.00	21.34
	TOTAL	870.00	265.20

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ECONOMIC GEOLOGY OF THE WHITE CLIFFS DIATOMITE DEPOSIT MAMMOTH, ARIZONA

by

Jonathan Daniel Shenk

A Thesis Submitted to the Faculty of the

DEPARTMENT OF GEOSCIENCES

In Partial Fulfillment of the Requirements
For the Degree of

MASTER OF SCIENCE

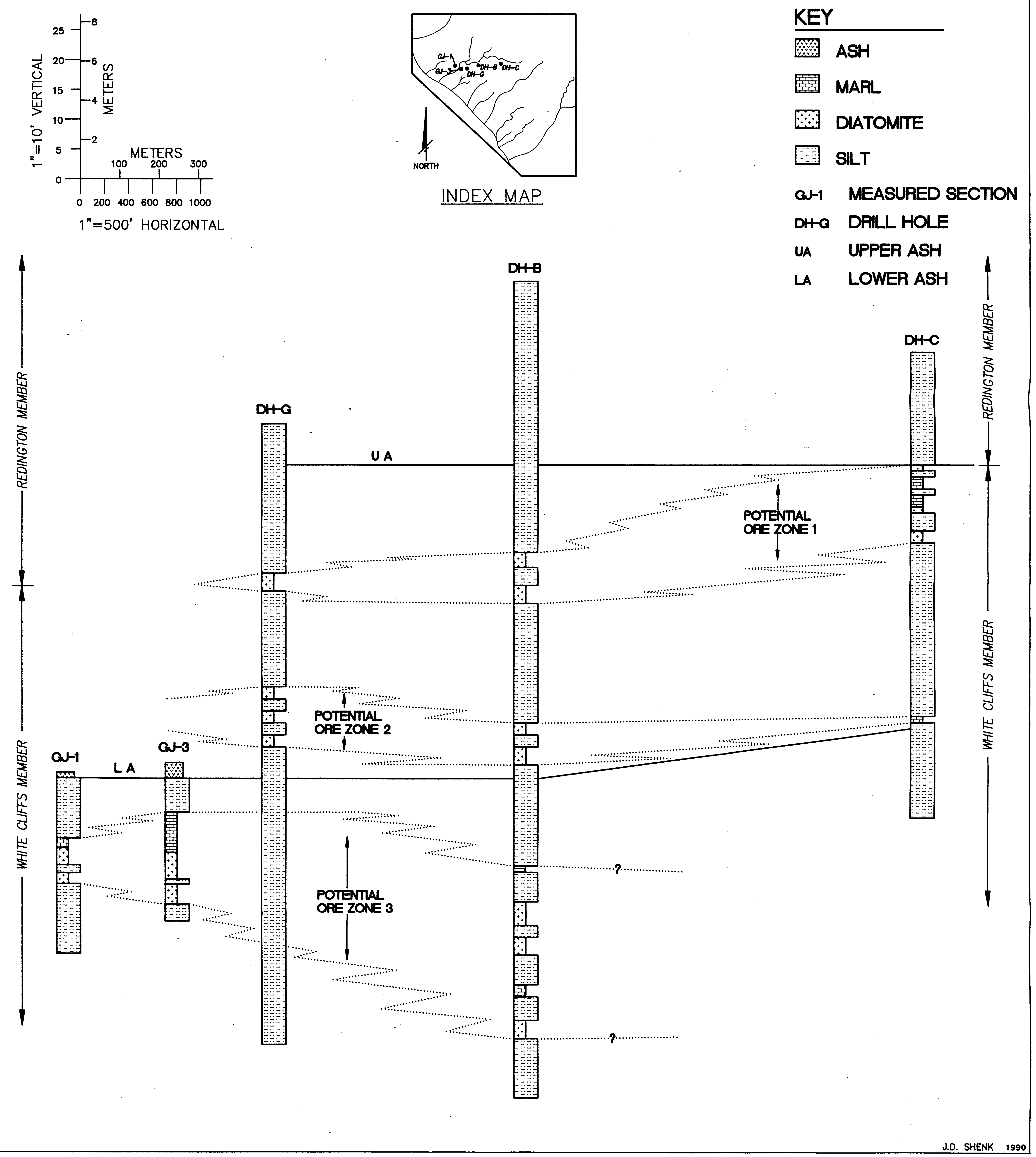
In the Graduate College

THE UNIVERSITY OF ARIZONA

1 9 9 0

GUST JAMES WASH
STRATIGRAPHIC CORRELATION DIAGRAM

PLATE III



JONATHAN DANIEL SHENK
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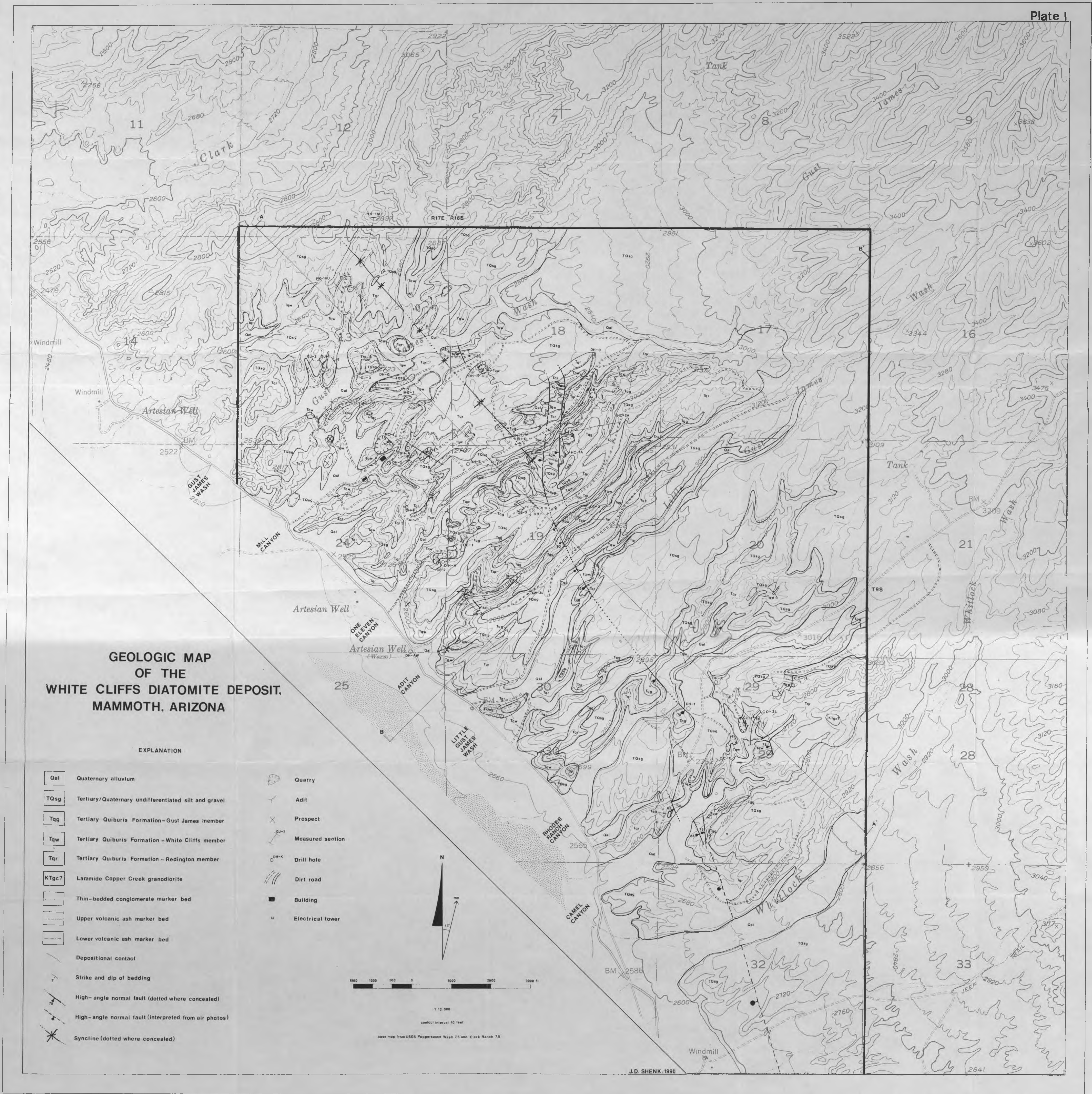
Plate I



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CAMEL CANYON
STRATIGRAPHIC CORRELATION DIAGRAM

PLATE VII

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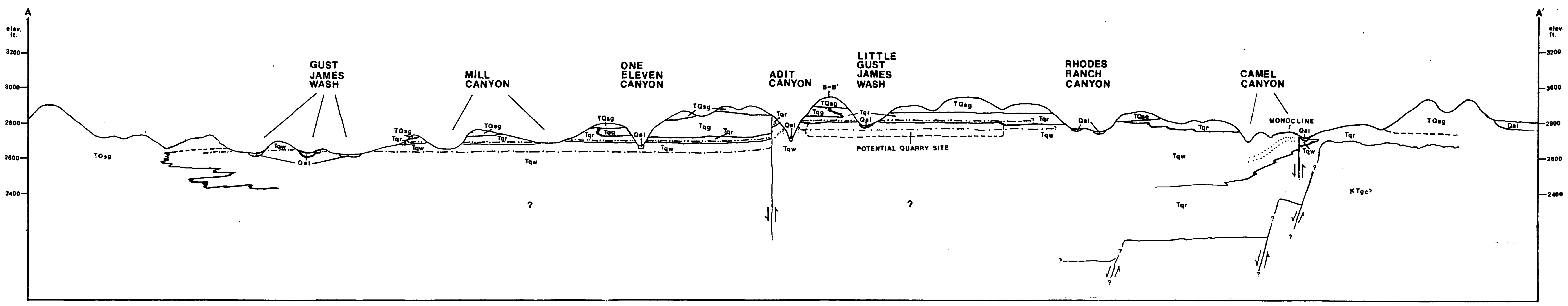
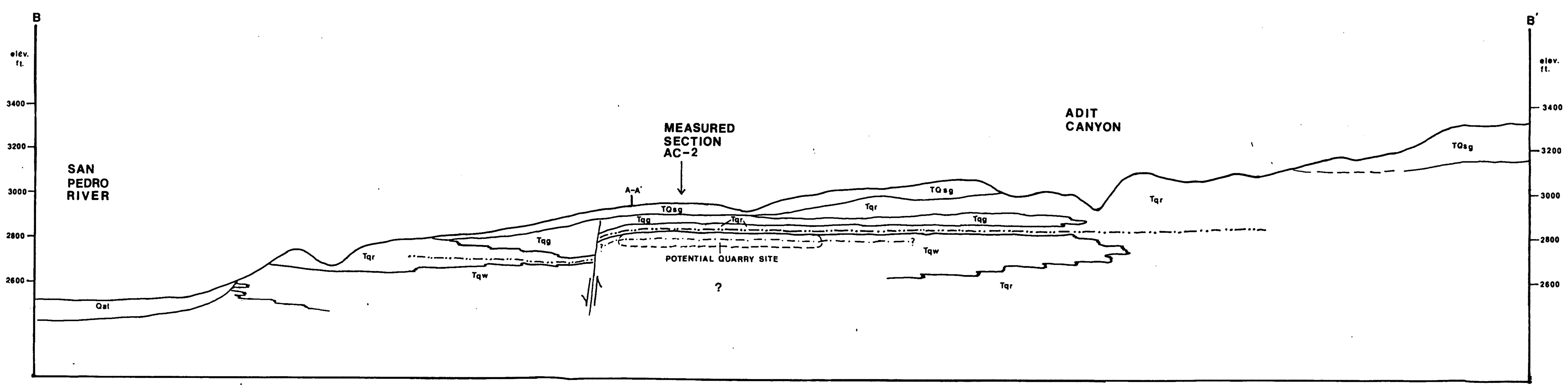
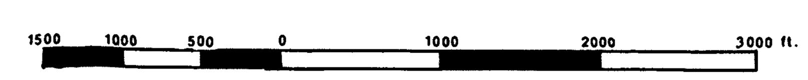
Plate II

GEOLOGIC CROSS SECTIONS OF THE WHITE CLIFFS DIATOMITE DEPOSIT, MAMMOTH, ARIZONA







vertical exaggeration – 2.5x

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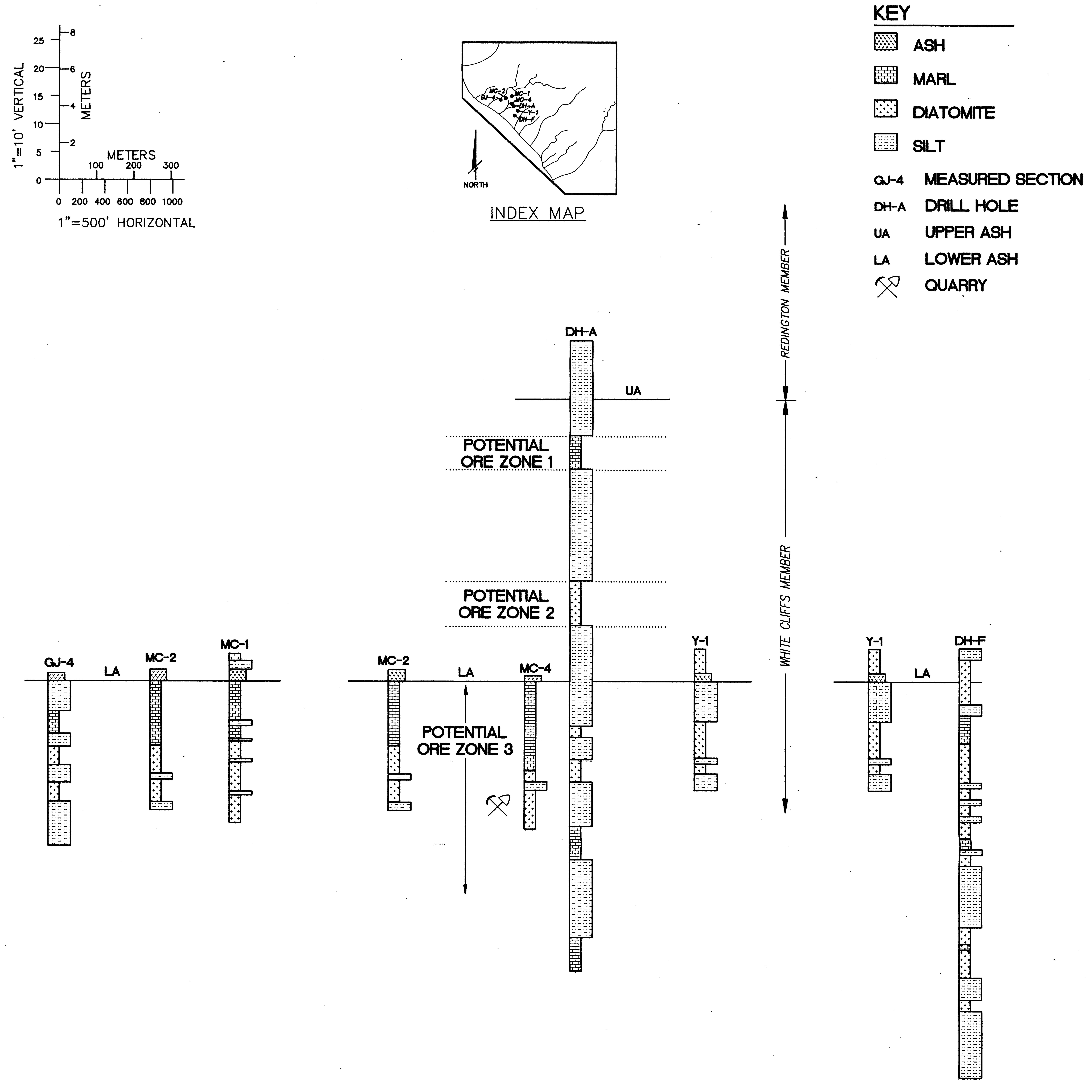
MILL CANYON
STRATIGRAPHIC CORRELATION DIAGRAM

PLATE IV



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1990
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ONE ELEVEN CANYON
STRATIGRAPHIC CORRELATION DIAGRAM

PLATE V

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