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TABLE OF CONTENTS

The Research Foundation's geologist spent two days in the Associated Enterprises' Las Vegas office studying the information contained in their files. He then spent approximately two and one-half days on the property making an inspection for purposes of estimating tonnages of material, amount of overburden, sampling, and interpreting the general geology of the area. He was accompanied on the property by Mr. C. Neil Vogel, a representative of Associated Enterprises, who acted as guide. He also spent some time with Dr. George Roseveare, of the University of Arizona in Tucson, who is currently conducting a research program on Arizona diatomaceous earth. Consultation was also made with Dr. George G. Olson who had previously compiled reports on diatomaceous earth for the Arizona Development Board of Phoenix.

CONCLUSIONS AND RECOMMENDATIONS

Consistent with the purpose and scope of the project, the Research Foundation makes the following conclusions and recommendations:

1. There is at least one million tons of diatomaceous earth that can be mined with little or no stripping. At least another one million tons can be mined with stripping up to 30 feet depth.

2. Diatomaceous earth can be mined from the first category of material at a rate of approximately 28,000 tons per year at a cost of $0.89 per short ton. This cost includes ownership and operating costs but excludes property acquisition costs. If Associated Enterprises leases rather than buys the property and pays a royalty of 50 cents per ton, the total cost of feed to the mill will be $1.39 at the 28,000 ton per year rate of production. The breakdown of costs can be found in the Mining Equipment and Methods section of this report.

3. The estimated cost of milling 28,000 tons per year is $20.02 per short ton if the Alpine-Lukens flow sheet furnished by Associated Enterprises is followed. A breakdown of these costs is given in the Estimate of Processing Costs section of this report.

4. The marketability of the products made by the Alpine-Lukens flow sheet included in this report is unknown at the time of this report.

5. Before making heavy expenditures for construction and operation, Associated Enterprises should undertake a program to produce sample quantities of the various products for evaluation by potential customers. These products should be made from representative material obtained from the deposit.

LOCATION AND EXTENT OF PROPERTY

The property is located on the east side of the San Pedro River in the Old Hat mining district, Pinal County, Arizona, and consists of: all of Sec. 13, T.9S., R.17E. except that the $N\frac{1}{2}$ of the $NW\frac{1}{4}$ of that Sec. is excluded; the $NE\frac{1}{4}$ and the $N\frac{1}{2}$ of the $NW\frac{1}{4}$ of Sec. 24, T.9S., R.17E; all of Sec. 18, T.9S., R.18E; all of Sec. 19, T.9S., R.18E; the $N\frac{1}{2}$ of Sec. 30, T.9S., R.18E; the $SW\frac{1}{4}$ of Sec. 17, T.9S., R.18E; the $W\frac{1}{2}$ of Sec. 20, T.9S., R.18E; the $NW\frac{1}{4}$ of Sec. 29, T.9S., R.18E; the $N\frac{1}{2}$ of the $SW\frac{1}{4}$ of Sec. 29, T.9S., R.18E. All of these locations are to the Gila and Salt River Base Line and Meridian.

The area embraced by the above description totals 3,120 acres. An additional 40 acres located in the $NE\frac{1}{4}$ of the $SE\frac{1}{4}$ of Sec. 24., T.9S., R.17E. may at Associated Enterprises option also be included with the above described property because of its close property control relationship.

Accessability and Utilities

The property is situated eight miles southeast of Mammoth, Arizona, and may be reached by a combination of one mile of asphalt paved road and 7.1 miles of graded county road. Access to the property may also be gained by a graded county road leading east out of San Manuel, Arizona, for a distance of 5.5 miles. This latter route necessitates fording the San Petro River which, during flood time, would be

impassible. However, it is anticipated that this road could serve the property for at least 9 months out of the year.

Railroad service connecting with the Southern Pacific Railroad is available at the San Manuel Smelter a distance of approximately 5 miles from the property and if need be an eight mile spur could be constructed to the property from Mammoth, Arizona. This would necessitate bridging the San Pedro River.

Electric power is available from the Arizona Public Service Company's lines which cross the property carrying 12,000 volts. Costs of electric power for the area would approximate $600.00 per month for the first 500 kilowatts with additional power being $1.02 per kilowatt. The energy charge would be approximately 1.18 cents per kilowatt hour for the first 400 kilowatt hours per kilowatt per month. Additional energy would cost 0.93 cents per kilowatt hour.

Gas is available from the El Paso Natural Gas Company's line located directly across the San Pedro River at a distance of approximately 5 miles from the property. This line carries gas at a pressure of 25 pounds per square inch. The cost for gas would be approximately 43.7 cents per thousand cubic feet for the first 2,500 therms (one therm = 100,000 Btu) and 41.7 cents per mcf over 2,500 therms per month.

A currently operating water well in the SE$\frac{1}{4}$ of Sec. 24, T.9S., R.18E (within $\frac{1}{4}$ mile of the property) delivers artesian water to the surface at a rate of 390 gallons per minute from an acquifer 680 feet below the surface with the well being collared at an

elevation of 2550 feet above sea level. Geological indications are favorable for developing a similar well on the property in the $SW\frac{1}{4}$ of the $NW\frac{1}{4}$ of Sec. 30, T.9S., R.18E. An exploration drill hole located in the $W\frac{1}{2}$ of the $SW\frac{1}{4}$ of Sec. 19, T.9S., R.18E., bottomed at a depth of 290 feet and cased to a depth of 225 feet has a static water level at 80 feet below the surface. This hole was collared at an elevation of 2,600 feet above sea level. Although no flow rate is known for this well, this information does indicate that modest amounts of water are available on the property at relatively shallow depths.

GEOLOGY

Bedrock in the area consists chiefly of lacustrine deposits of diatomaceous earth, mudstone, volcanic ash and chert of Pliocene or Pleistocene Age. The total stratigraphic thickness of these deposits, as indicated from drill hole data and surface outcrops, approximates 1,200 feet. The apparent strike of the beds is N30°W and they dip gently (up to 6°30') to the northeast. The mudstone deposits are found predominantly at the middle of the stratigraphic section and generally occur as thick lenses. The chert is found as lenses within the diatomaceous earth but generally near its contact with overlying and underlying beds of mudstone or volcanic ash. These lenses of chert range in diameter from a few inches to 50 feet or more but generally are from 20 to 30 feet in diameter and 1 to 2 feet in thickness. The volcanic ash has been deposited in relatively thin continuous beds which range in thickness from a few inches to a few feet. The diatomaceous earth is found in fairly continuous beds which range in thickness from a few inches up to 100 feet. In some areas the diatomaceous beds consist of alternate layers of pure white pulverulent material which is soft to the touch and layers of a more arenaceous material which is more abrasive. These layers may vary in thickness from a few inches to approximately 50 feet. The more arenaceous material is generally found in the lower portions of the diatomaceous earth beds. The area is in most places covered

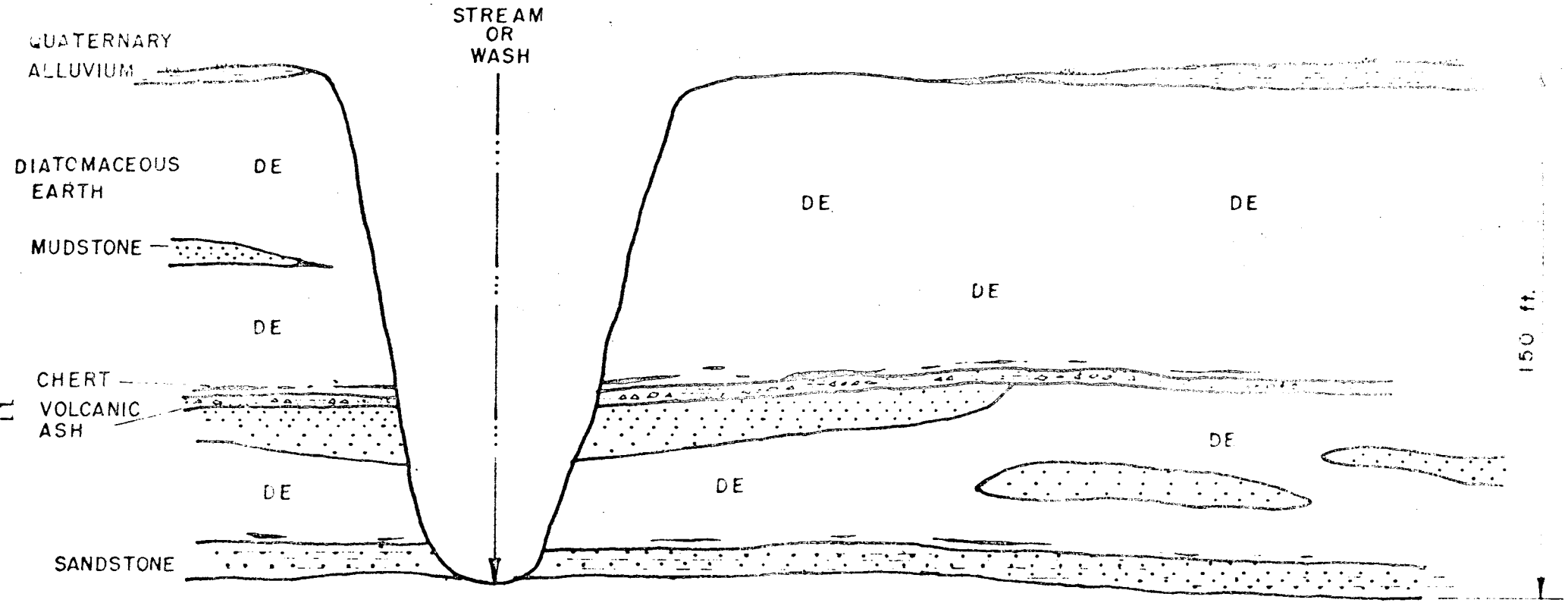
with a blanket of detrital material which generally does not exceed 30 feet in thickness.

The diatomaceous earth deposits are terminated near the southwest border of the property by a fault scarp which trends northwesterly. Several artesian wells some of which produce hot water exist along this fault. The channel of the San Pedro River is controlled by the scarp. Apparently the block of ground to the north of the fault was upthrown gradually and tilted to the northeast thereby permitting existing stream flowing in a southwesterly direction to erode at a pace at least equal to the uplift. This interpretation is further borne out by the existence of hanging valleys which trend in a southwesterly direction.

For a typical cross section of the deposits, see Figure 1.

Exposure and Areal Distribution

The best exposures of rock are in the canyon walls of the southwest trending streams. In these canyons the beds of diatomaceous earth and volcanic ash and the lenses of chert and mudstone may easily be seen. At the surface the bedrock is for the most part concealed by detrital material. The exposures as seen on the canyon walls indicate that the combining factors of differential erosion, regional dip of the strata and the lenticularity of the mudstone deposits has resulted in a sporadic distribution of a large number of diatomaceous earth beds which would, in part, be exposed at the surface if it were not for



TYPICAL CROSS SECTION OF DIATOMACEOUS EARTH DEPOSITS AT MAMMOTH ARIZONA

FIGURE 1

the existence of a thin mantle of detrital material.

With the removal of from 0 to 30 feet of unconsolidated detrital overburden, a total volume of diatomaceous earth equivalent to a block having an areal extent of at least one square mile and a minimum thickness of 50 feet could be exposed. This quantity should be considered as a modest appraisal and was arrived at in the following manner:

> The total area covered by the claims which contain diatomaceous earth exceeds 3 square miles. Some of the diatomaceous earth which formerly existed in this area has been lost by erosion and some of the existing diatomaceous earth should be excluded from consideration because of an excessive amount of overburden. However, visual inspection of the entire area indicates that at least one third of the 3 square miles has not been adversely affected by erosion or the accumulation of overburden in excess of 30 feet. In regard to thickness, it is felt that 50 feet is a conservative figure to use. Exposures created by erosion indicate that the thickness of the diatomaceous earth beds are less than 50 feet in some places. This, however, would be more than offset by the many places where thicknesses approaching 100 feet exist.

ORE RESERVE TONNAGE COMPUTATIONS

In order to arrive at a realistic figure for the minimum tonnage of diatomaceous earth contained on the property, it was necessary to determine the density of a representative sample of the material. This was done in the following manner: A solid piece of diatomaceous earth taken from the $NE\frac{1}{4}$ of the $NE\frac{1}{4}$ of Sec. 24, T.9S., R.17E. which by visual inspection appeared to be representative of a bed of diatomaceous earth at least 50 feet thick was reduced in size by grinding to form a rectangular block which measured 3.341 cm x 3.562 cm x 3.250 cm, thereby giving a volume of 38.68 cm^3. This block was then dried to a constant weight of 28.92 g. Now,

$$\frac{28.92 \text{ g}}{38.68 \text{ cm}^3} = 0.747 \text{ g cm}^3 = \text{density}$$

To obtain density in lbs ft^3

$$0.747 \times 62.43 = 46.63 \text{ lbs ft}^3$$

Although this density figure is somewhat less and more conservative than that reported by Blake (1903), whose determinations indicate that the material should average 54.35 lbs per cu ft, it is felt that it is compatible with Blakes inasmuch as it is made on a dry sample basis; his sample may have contained moisture.

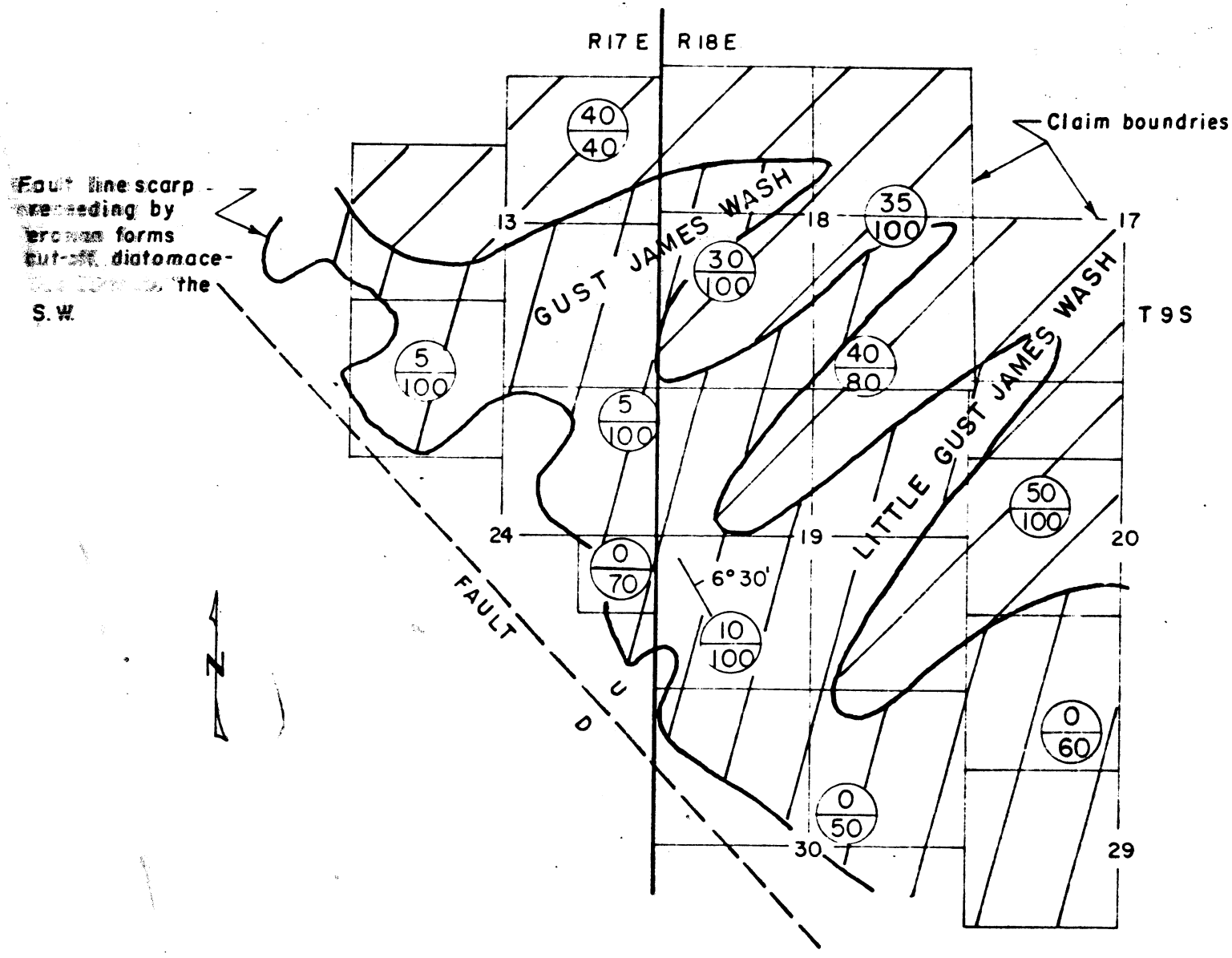
Therefore, if we take the minimum attainable quantity of one square mile of diatomaceous earth beds having a thickness of 50 feet we have a total of 32,000,000 tons. This figure should not be construed to be an estimate of the total tonnage of

diatomaceous earth on the property but rather it should be considered as an estimate of readily mined material which could be made available by the removal of a maximum of 30 feet of loose unconsolidated overburden. At least 1,000,000 tons of diatomaceous earth is estimated to be readily mined without the removal of any overburden. Actually the total tonnage for the deposit would be far in excess of this figure.

For a map depicting the relationship of overburden to diatomaceous earth, see Figure 2.

FIGURE 2

GENERALIZED SURFICIAL GEOLOGY OF ASSOCIATED ENTERPRISES DIATOMACEOUS EARTH PROPERTY IN PINAL COUNTY, ARIZONA



OVERBURDEN PREDOMINANTLY OVER 30 ft. THICK

OVERBURDEN PREDOMINANTLY LESS THAN 30 ft. THICK

0/60 FIGURES INDICATING APPROXIMATE RELATIONSHIP OF OVERBURDEN TO DIATOMACEOUS EARTH - IN FEET OF THICKNESS

Information obtained in the field on Sep. 13, 14, & 15 1963 by C.S.M.R.F. Footages are approximate

QUALITY OF THE RAW MATERIAL AND THE ANTICIPATED PRODUCT

A review of the information contained in the files of Associated Enterprises Corporation indicates that they have seriously attempted to arrive at a fair appraisal of the quality of the diatomaceous earth contained on this property. The complete files of Associated Enterprises were made available to the Research Foundation. Copies of those items which are considered to be most pertinent are included in the appendix of this report for reference.

The quality of any mineral commodity is determined by the specific end use requirements. If diatomaceous earth material is to be considered for use as a filter aid or as a filler in a fine, white bond paper the specifications for that material would be considerably more exacting than they would be if the material were being considered for use as a building construction material constituent or as a filler in kraft paper. Those characteristics required for a high quality filter aid material may be of little importance or they may actually be detrimental if the material is considered for another use such as a pozzolan for portland cement concrete structures.

It is noted from a comparison of the required specifications of pozzolan for the Glen Canyon Dam (DS-5012 page 14) issued by the Bureau of Reclamation and the results of testing of diatomaceous earth from this deposit as reported in Walter H. Prices letter to John S. McNabb referenced D-294 that the

portland cement concrete made with diatomaceous earth from the White Cliffs deposit failed to meet the requirements of compressive strength.

As it is not known exactly what products Associated Enterprises anticipates marketing and since it was not within the scope of this project to determine what the potential of the market is, it is not possible, nor would it be fair to judge the deposit by such qualifying terms as high, medium, or low grade.

Mr. W. B. Pratt of Associated Enterprises has indicated that, at the present time, they are not interested in producing material which would meet the specifications of a filter aid or other end products which must meet rigid specifications. He is interested rather in creating a number of products which could be utilized by certain elements of the construction, agricultural and manufacturing industries which would not require critical quality control measures or highly specialized milling procedures. Mr. Pratt anticipates the production of these materials in the order of 28,000 tons per year.

After production of these relatively crude products is well underway, Associated Enterprises anticipates that they will be able to modify their mining and milling operations to produce specialty products such as various grades of filter aid material.

Due to lack of information it has not been possible to determine if diatomaceous earth products of filter aid quality can or cannot be refined from the raw material of this deposit.

Characteristics of the Raw Material

Five grab samples of diatomaceous earth were collected from various locations on the property. In the selection of these samples care was taken to get material which, by visual inspection, was fairly representative of a large portion of the deposit. However, it must be emphasized that for a complete appraisal of the deposit a systematic channel sampling and drilling program would be required. Laboratory examination of these samples indicates that they are composed of diatomaceous earth having the following characteristics:

Physical Properties of Crude Material

Color - Off white on fresh surface, off white to yellowish gray on weathered surface.

Fracture - conchoidal or irregular

Apparent density (dried to constant weight at 110°C) 46.67 lbs per ft^3

Absorption (water) 84.4% of its own dry weight.

Texture - fine grained, chalklike, generally soft and friable but contains some hard abrasive grains palpable to the touch.

Solubility - insoluble in acids (except hydrofluoric)

Appearance of Diatoms Under Microscope

Shape - pods, needles, spheres, in descending order of percentage.

Size - pods average 15 x 4 x 4 microns; spheres average 110 microns; needles average 150 x 4 x 4 microns.

Percentage of Total Volume - from 20 to 30 percent by volume of the material appeared to be composed of diatoms. This percentage is made up primarily of the pod shaped diatom. Only a minor fraction is made up of spherical shaped diatoms.

Analysis

Moisture in material, dried at 110°C, 14.1% by weight

Chemical analysis of dry material is as follows:

	Percent
Silica (SiO_2)	89.50
Alumina (Al_2O_3)	2.99
Ferric Oxide (Fe_2O_3)	0.64
Calcium Oxide (CaO)	1.22
Magnesium Oxide (MgO)	0.51
Sodium Oxide (Na_2O)	0.48
Potassium Oxide (K_2O)	0.44
Undetermined	4.22
	100.00

The particular sample on which the above chemical determinations were made was taken from an adit located in the SW¼ of the NW¼ of the SW¼ of Sec. 19, T.9S., R.18E. In cutting the sample a 2½ inch auger hole was first drilled horizontally into the breast of the adit at a distance of 45 feet from the portal. This location was approximately 70 feet from the surface of the ground above. The sample was then augered from the hole and immediately placed in a polyethylene sack which was tied at the

top. The sack and its contents was then placed in a new one gallon paint pail and the friction type lid was fitted tightly into place. These precautions were taken primarily to secure a sample from which moisture content determination could be made which would be applicable to the bulk of the mine run material away from exposed surfaces. It should be noted that this sample contained relatively more moisture than previously reported for samples taken from this deposit. It is thought that those previous samples were probably collected from exposed surfaces and consequently were partially air dried. The moisture content, as determined from this analysis indicates that the bank run material should be kiln dried before it is fed to the mill. This probably will not present any serious problems as it is noted from the chemical analyses that the alumina content is relatively low indicating that intolerable bonding would probably not be encountered during the drying process.

OWNERSHIP AND ROYALTIES

It is understood that Associated Enterprises currently leases the property with an option to purchase it for $450,000. Their current leasing agreement, according to Mr. W. B. Pratt, requires that they pay either 50 cents per ton of mined material or $843.00 per month whichever is greater.

Ownership and lease agreements should be verified inasmuch as this has not been done by the Research Foundation.

MINING EQUIPMENT AND METHODS

The following mining equipment and methods are suggested for the proposed operation to produce 28,000 tons of mill feed per year.

Basic Equipment

One crawler type tractor of the Caterpillar D-4 class equipped with a 1 3/4 cu yd front end loader bucket having a width of 80 inches equipped with a ripper employing 3 curved shank teeth.

One gasoline powered dump truck having a payload capacity of 18,000 pounds equipped with a 10 cu yd body.

Procedure

It is anticipated that two men each working a 40 hour week will be able to operate the tractor loader and the dump truck. This method is considered possible for this deposit because of the existence of large reserves of raw material attainable with the removal of little or no overburden. One man will drive the truck from the mill to the quarry area which would be a distance of approximately 1/2 mile. The other man will then load the truck, by using the tractor loader, with at least 4 ton of broken diatomaceous earth which would be approximately 9.5 cu yd. While the truck driver is making the trip to the mill the tractor operator would be employed in stripping, if necessary and ripping additional diatomaceous earth. By making 23 trips

with the truck per day the required 92 tons of bank run material which would be required to make 79.3 short tons of dry mill feed could be transported to the mill. If necessary, the yardage capacity of the truck may be increased by extension of sideboards. This may be required if it is found that 23 trips per day cannot be made.

MINING COSTS

Total Investment:

One D-4 Caterpillar crawler type tractor with 1 3/4 cu yd, 80-inch bucket and 3 tooth (curved shank) ripper	$25,000.00
One dump truck with payload capacity of 18,000 pounds with 10 cu yd body	7,500.00
Total investment	$32,500.00

Average Useful Life:

Five years.

Depreciation, Annual:

Straight-line method.

$$\frac{\$32,500.00 \text{ total investment}}{5 \text{ years average useful life}} = \$6,500,00 \text{ annual deprec.}$$

Interest, Taxes, and Insurance:

Computed at 10% of average investment

$$\frac{\frac{1}{2} \times 5 + 1}{5} \times 100 = 60\% \text{ of total investment}$$

60% x $32,500.00 = $19,500 = average investment

10% x $19,500.00 = $1,950.00 = interest, taxes, and insurance annual

Repairs, Maintenance, Supplies:

Includes ripper teeth, truck tires, cat tracks

$32,500.00 total investment x 10% = $3,250.00 repairs, maintenance and supplies annual

Tractor Fuel and Lube:

$1.00 per hour for 1,000 hours = $1,000 annual

Truck Fuel, Oil, Grease

50 cents per hour for 1000 hours = $500.00 annual

Labor (Direct Cost)

Two men operating excavator and truck

4,000 hours at $2.50 per hour = $10,000

(Indirect Cost) - including pensions, paid vacations, insurance, disability pay, social security and unemployment taxes. Estimated at 15% of direct labor cost = 1,550

Total Labor Costs $11,500

Tabulation of Cost of Ownership and Operation

Depreciation	$6,500
Interest, taxes, insurance	1,950
Repairs, maintenance, supplies	3,250
Tractor fuel and lube	1,000
Truck fuel, oil, grease	500
Labor	11,500
	$24,700

Total Cost per ton for Mining

$24,700.00 cost of ownership and operation
27,778 short tons of mill feed
= $0.889 per ton

Plus royalty payment of 50 cents per ton

Figure based on verbal communication with Mr. W. B. Pratt of Associated Enterprises = $ 0.50

$1.389 cost of raw material

ESTIMATE OF PROCESSING COSTS

A Preliminary Estimate of the Cost of Drying, Milling Air Classifying, and Bagging Pinal County, Arizona Diatomaceous Material

The following preliminary cost estimate is based on drying the subject material, and then treating it in accordance with a flow sheet prepared by Alpine-Lukens Corporation for a European client in 1958 (Figure 3). The feed tonnage is based on 72 metric tons per day, or 25,200 metric tons per year for 350 operating days. The capital cost has been based principally on equipment cost figures estimated by Alpine-Lukens. These costs were furnished in 1958 on an f.o.b. factory basis in Germany. The Colorado School of Mines Research Foundation has done no actual tests or process development work on this material, so no inference is made as to the quantity, quality, or marketability of the individual products.

Capital Cost

	Estimated Delivered Cost
Truck hopper for mine-run ore	$ 1,600
18" x 10' apron feeder with 2 Hp motor	4,100
10" x 16" jaw crusher with 20 Hp motor	4,300
14" x 50' belt conveyor with 3 Hp motor	2,000
5' diameter x 40' rotary dryer with 15 Hp drive motor, and 10 Hp fan motor	36,000
24" x 14" crushing rolls with 20 Hp motor	8,000
50' bucket elevator, with 6" buckets and 2 Hp motor	1,600

Alpine-Lukens Equipment, 1958	$39,000	
20% price increase for inflation	7,800	
Estimated cost in 1963	$46,800	
Crating at 15%	7,020	
Tariff at 13.75%	6,435	
Insurance at $0.50/$100	234	
Freight, est. 50 tons at $60	3,000	
Total est. Alpine-Luken Equipment, rounded-off		$ 63,500
3- bagging and weighing machine units including sewing machines and conveyors		15,000
Total estimated equipment cost		$136,100
Times factor for dry processing plants[1/]		x 3.36
Estimated fixed capital investment rounded-off to nearest $1,000		$457,000

1/ Factor relating total capital investment to delivered equipment cost, based on actual construction experience for plants ranging in cost from $500,000 to $5,000,000. In addition to equipment, the items included in the factor average equal equipment installation, piping installation, electrical installations, buildings, yard improvements, service facilities, land for plant site, engineering and construction constractor's fee, and contingency. Taken from "Plant Design and Economics for Chemical Engineers" by Max S. Peters, McGraw-Hill.

Direct Operating Costs

Raw Materials

The cost of mining the raw material is developed in a separate estimate. The present estimate includes only the subject processing steps.

Labor-Operating

Based on the plan of four men covering one job. Each man works an average of 42 hours per week with 43 hours' pay. An average rate of $2.50 per hour is assumed. The cost per man-year would be:

$$\$2.50 \times 43 \times 52.14 = \$5,605$$

Job Title	No. of Men per shift	No. of Men Total	Cost per year
Crusher and dryer operator	1	4	$ 22,420
Mill and classifier operator	1	4	22,420
Bagger	3	12	67,260
Loader	3	12	67,260
Shift foreman	1	4	22,420
Total Operating Labor	9	36	$201,780

Supervision

Plant superintendent — $10,000 per year

Maintenance

Based on the services of two maintenance mechanics working 40 hours per week, plus 3% of the capital cost annually for maintenance materials.

$$\text{Maintenance labor } \frac{\$2.75 \times 40 \times 365 \times 2}{7} = \$11,472$$

Maintenance materials 0.03 x $457,000 = 13,710

Total maintenance = $25,182 per year

Plant Supplies

For such items as gaskets, packings, lubricants, lubricating equipment, charts and other recording instrument supplies, sanitary supplies, and all other supplies distinguished from maintenance materials by their characteristic of being required on a routine basis while a plant is operating. Expense incurred for such items may normally be estimated as an amount equivalent to about 15% of annual maintenance costs.

$25,182 x 0.15 = $3,777 per year

Utilities

Electric Power

Installed horsepower in the plant is estimated at about 160. To allow for electrical losses, and miscellaneous uses such as lighting, a ratio of one kw per Hp is used here. A cost of $0.01 per kwhw is assumed.

160 x 24 x 350 x $0.01 = $13,440 per year

Gas for Drying

Assuming 14% moisture in feed, drying to 1% at 50% thermal efficiency would require 897,272 Btu per wet metric ton. Gas from Arizona Public Service Company, for under 2,500,000 cu ft per month, would be $0.437 per 1,000 cu ft. A heating value of 1,000 Btu per cu ft is assumed. Also, a five-mile gas line

would have to be laid into the property for which a cost of $30,000 and a twenty-year write off is assumed.

Gas:

$$\frac{25,200 \times 897,272 \times \$0.437}{0.86 \times 1,000,000} = \$11,490 \text{ per year}$$

Pipeline:

$30,000 ÷ 20 = $ 1,500 per year

Total gas cost $12,990 per year

Total utilities = $26,430 per year

Summary of Direct Operating Costs

	Cost per Year	Cost per Short Ton of Feed
Labor-operating	$201,780	$7.264
Supervision	10,000	0.360
Maintenance	25,182	0.906
Plant supplies	3,777	0.136
Utilities	26,430	0.952
Total Direct Costs	$267,169	$9.618

Indirect Operating Costs

Payroll Overhead

To cover company expense incurred through pensions, paid vacations, group insurance, disability pay, social security, and unemployment taxes. Estimated at 15% of total payroll.

	Cost per Year
Labor-operating	$201,780
Supervision	10,000
Maintenance labor	11,472
Laboratory labor	6,000
Overhead labor	12,600
Total payroll	$241,852

$241,852 x 0.15 = $36,278 per year

Laboratory

	Cost per Year
One chemist	$6,000
Laboratory supplies	500
Total laboratory	$6,500

Plant Overhead

	Cost per Year
Accountant	$ 7,200
Shipping clerk	5,400
Total plant overhead labor	12,600
Office supplies	500
Total plant overhead	$13,100

Packaging

According to the flowsheet, all products, totaling the head tonnage, would be bagged. It is realized that the bulk densities of the three products indicated would be different, but for simplicity in this very preliminary estimate, a bulk

density of 20 pounds per cu ft has been assumed as an average, and bag cost estimated on this basis. The 20-pound figure is shown on the Sponsor's advertising brochures for ground mine-run material. Paper bags, polyethylene-treated for water-proofing, large enough to hold 50 pounds of such material can be purchased in carload lots from Bemis Bros. Bag Company for approximately $180.00 per 1,000, including printing to the customer's order.

$$\frac{25{,}200 \times 2{,}204.6 \times \$0.18}{50} = \$200{,}001 \text{ per year}$$

Shipping

Processing costs in this estimate are based on the products f.o.b. plant.

Summary of Indirect Operating Costs

	Cost per	
	Year	Short Ton of Feed
Payroll overhead	$ 36,278	$ 1.306
Laboratory	6,500	0.234
Plant overhead	13,100	0.472
Packaging	200,001	7.200
Total Indirect Costs	$255,879	$ 9.212

Fixed Operating Costs

Depreciation

Based on assumption that plant and equipment, with proper maintenance, would last for 20 years.

$$\frac{\$457,000}{20} = \$22,850 \text{ per year}$$

Property Taxes

Estimated as one percent of capital cost annually.

$\$457,000 \times 0.01 = \$4,570$ per year

Plant Insurance

Estimated as 1.25 percent of capital cost annually

$\$457,000 \times 0.0125 = \$5,713$ per year

Summary of Fixed Operating Costs

	Cost per	
	Year	Short Ton of Feed
Depreciation	$22,850	$0.823
Property taxes	4,570	0.164
Plant insurance	5,713	0.206
Total Fixed Costs	$33,133	$1.193

Summary of Direct, Indirect, and Fixed Operating Costs

Items not included in the following cost summary are ore mining and delivery to plant, administration, sales, research, financing, or shipping costs of products to customers.

	Cost per	
	Year	Short Ton of Feed
Direct Operating Costs	$267,169	$ 9.618
Indirect Operating Costs	255,879	9.212
Fixed Operating Costs	33,133	1.193
Total Costs	$556,181	$20.023

Total cost of mining and milling, including royalty payments $21.41

Comments on Flowsheet Submitted by Associated Enterprises For Processing Diatomaceous Earth

It is noted that the flowsheet form Alpine-Lukens Corporation was prepared in connection with a proposal for a European customer in 1958. Therefore, there is no reason to believe that the products or tonnages indicated are supposed to be associated with any potential market outlets developed by the Sponsor.

Assuming that the model of Perplex mill shown in the drawing would disintegrate 3 Metric tph of the Sponsor's material, and that the classifier products would split approximately in the ratio experienced in the text made at the University of Arizona by Dr. Geo. H. Roseveare, the annual output of "products" from the plant would be about as follows:

	metric tons	short tons
Milled Mine Run Material	8,400	9,259
"Coarse" Product	5,600	6,173
Diatomite Product	11,200	12,346
Total = Feed (mill)	25,200	27,778

The above figures are based on working 24 hours per day and 350 days per year.

In the letter from Alpine-Lukens on their grinding tests, it is stated "The grinding behavior of the material having a moisture content of 5.5% can be expected to improve with a lower water content? Conversely, it would be indicated that the underground material, at about 14% moisture, would probably cause trouble in the mill as well as in the air classifier. General experience in dry climate diatomaceous earth deposits

APPENDIX

The following is a list of the information submitted by Mr. W. B. Pratt of Associated Enterprises which is considered pertinent to this project.

1. Letter from W.H. Gellrich of Alpine American Corporation to W. B. Pratt dated July 16, 1963.
2. Letter from W. H. Gellrich of Alpine-Lukens Corporation to John McNabb dated November 7, 1958 with "Quotations on Plant for Processing Diatomaceous Earth" and schematic interpretation of flowsheet by the Research Foundation of a mill designed by Alpine dated 5-8-58 and numbered 104-024B.
3. Unsigned report of grinding test referenced "Test No. 14121 and 14121A respectively" to Twin Star Industries dated August 18, 1958.
4. Letter from John E. Funnell of Southwest Research Institute for W. B. Pratt dated June 18, 1956.
5. Letter from W. H. Price of the U.S. Bureau of Reclamation to John S. McNabb dated January 24, 1958.
6. Pozzolan Specifications Par. C-1 through Par. C-4 (pages 13, 14, 15, and 16) taken from the Bureau of Reclamation's Invitation for bid No. DS-5012 pertaining to Pozzolan for Glen Canyon Dam and Powerplant.
7. Letter from Arthur C. Dreshfield of Chicago Testing Laboratory to John L. McNabb dated January 22, 1958.

8. Technical Report No. 6661 from Chicago Testing Laboratory to John S. McNabb dated January 22, 1958.

9. Field Engineers Report submitted by Miles M. Carpenter to Department of Mineral Resources, State of Arizona on March 10, 1941.

10. Analysis report submitted by H. M. Bulbrook of Industrial Laboratories of Fort Worth Texas to Twin Star Industries on September 10, 1958.

11. Technical report from Engineer Ernst Rott of Vienna Austria to Technical Engineer, Dr. Emil Hornstein dated November 5, 1952.

12. Unsigned logs of three exploration drill holes.

13. Unsigned report of analytical data designated as (Test No. 13-F)

14. Letter from J. L. Sheehan of Combustion Engineering, Inc. to John S. McNabb dated December 27, 1957 with accompanying laboratory report No. 4625.

15. Analytical report No. 6775 signed by John T. Long, Jr. of ARC Laboratories submitted to Associated Minerals dated April 26, 1961.

ALPINE AMERICAN Corp.
69 NICHOLAS ROAD SAXONVILLE, MASSACHUSETTS
FRAMINGHAM [redacted] CABLE ADDRESS — ALPINE
877 • 1310

PROCESSING MACHINERY FOR AMERICAN INDUSTRY

www 617

July 16, 1963

Associated Management Engineers Inc.
Room 201
1111 South Las Vegas Blvd.
Las Vegas, Nevada

Attention: Mr. W. B. Pratt

Dear Mr. Pratt:

It was certainly a pleasure to hear from you again. We still have all our old records concerning the test work performed for you and we would like to confirm that the prices given to you on November 7, 1958, should be multiplied with a factor of approximately 1.2, reflecting an approximate 20% price increase during the last few years.

Unfortunately we are not able to locate the drawing #104.024 B which was taken as a basis for my quotation, however, we have requested an additional copy from the Alpine, AG. We would appreciate to obtain your thoughts about the complete set up and if you are interested at the present time on a very similar installation or if you have some major changes in mind necessitating possibly different sized equipment. If your files on our discussion prior to November, 1958, should not be complete, we will be pleased to send you any information necessary for your further investigations.

For the time being we would like to include a leaflet on the Air Jet Sieve 200 , an analytical screening device which is excellently suited for the screening of diatomaceous earth, a leaflet on the Mikroplex classifier of the type MP and a leaflet on the Perplex Universal mill with English translation.

We are looking forward with great interest to your comments so that we can submit to you necessary data and quotations.

Thank you for your continued interest.

Very truly yours,
ALPINE AMERICAN CORP.

Wolfgang Gellrich

W. H. Gellrich Dr.-Ing.
Vice President

WHG:CG

Encs. AJS 200 Leaflet
MP Leaflet
Perplex Universal Mill Leaflet with translation

NOV 10 1958

ALPINE-LUKENS CORPORATION

227 CALIFORNIA ST., NEWTON 58, MASSACHUSETTS

TELEPHONE: BI 4-3968 • CABLE ADDRESS: ALPINE

November 7, 1958

Mr. John McNabb
Twin Star Industries, Inc.
1111 South Congress Avenue
Austin 4, Texas

Dear Mr. McNabb:

I hope you had sufficient opportunity to check into the possibility and costs of such accessory equipment as silos, bins, conveyors, and precrusher for the diatomaceous earth so that the information submitted today will give you a complete and clear picture of the proposed operation in Austin.

You will find attached a drawing of a grinding and classification plant which was outlayed by the Alpine people for a European customer for the beneficiation of diatomaceous earth. Let me first explain the general operation as shown in drawing #104.024B.

The raw material is fed on to a conveyor belt where tramp iron is removed. Material drops on to a precrusher which grinds down the material to 3/4" to 17/16". This preground material is then conveyed by a bucket elevator into a silo and fed through a rotary plate feeder into the Perplex B 630 U grinding mill. There is another magnet in front of the grinder so as to prevent the destruction of the grinder by tramp iron.

The ground material is collected in a larger silo directly underneath the mill and can be conveyed through a reversible conveying screw either to feed a 800 MP Mikroplex classifier or to a bagging off system. This conveying screw is driven by a variable speed drive motor and can be used as feeding system for the 800 MP.

By this means you can take out the ground material as it is and sell it for your cement or other application and you may also classify this material in the 800 MP so as to produce a fine special purpose fraction.

The coarse material from the classifier can be bagged off immediately at the classifier itself. The fine material is conveyed up into a high efficiency cyclone to be collected in a

silo underneath. There is no additional fan necessary as the Mikroplex classifier represents a huge fan which is able to convey material and air up to a height of approximately 30 feet. The surplus air from the cyclone is returned to the classifier so as to minimize the loss of superfine material. Below the last silo for the fine fraction, you will find another conveying screw which is feeding the same or another bagging off system.

The other equipment shown on this drawing is of little interest for your operation. It refers to a burned diatomaceous earth which is also processed through the Mikroplex.

You will find attached a quotation on the equipment as outlined. This quotation is kept in detail so as to allow you to substitute parts which you might acquire in your area. The position numbers coincide with the position marked in red in the above mentioned drawing.

The total price for the complete installation as outlined would be between $37,000.00 and $39,000.00 depending on the length of connecting pipelines, etc. This complete price is somewhat higher than that estimated in our discussion in San Francisco. However, we did not include prices on silos, etc. which do add up to about $7,000.00 to $8,000.00 making up for this difference.

All prices mentioned in the quotation are prices at the factory in Germany. There would be 13-3/4% duty on the total amount in addition to charges for export crating and transportation

I hope that these information are sufficiently clear and would appreciate to hear from you on any subject which you want further explanation on.

We will be glad to do anything within reason to help you continue and complete your planned setup for the diatomaceous earth.

Please give my regards to your President, Mr. W. B. Pratt.

Very truly yours,

ALPINE-LUKENS CORPORATION

W. H. Gellrich

W. H. Gellrich, Dr.-Ing.
Technical Director

WHG:fc

Enc. Quotation 800 MP
Drawing #104.024B

ALPINE-LUKENS CORPORATION

Newton 95, Mass.

Quotation on Plant for Processing Diatomaceous Earth

Position No.		
0	DOSING BELT to be provided by your company	
1	PRECRUSHER to be provided by your company	
2	BUCKET ELEVATOR to be provided by your company	
3	GRAVITY PIPELINE diameter 120 x 350 mm per meter	$50.00
4	SILO diameter upper part 2500 mm lower part 450 mm, 4200 mm high with clean out covers having a capacity of 250 to 280 cu. ft.	1,910.00
5	ROTARY FEEDING PLATE 45/100 with variable speed geared motor	1,495.00
6	GRAVITY PIPELINE from feeder to magnet box	94.00
6-a	MAGNET BOX with 2 permanent magnets	530.00
6-b	INTERMEDIATE PIECE magnet box to grinding mill	110.00
8	ALPINE PERPLEX UNIVERSAL MILL Model B 630 U	2,160.00
	ROTARY CURRENT SQUIRREL CAGE MOTOR 38 HP with 1500 RPM	780.00
9	SILO top part 2500 mm x 3300 mm total capacity approx. 770 cu. ft.	2,185.00
9-a	LOWER PART OF SILO without conveying screw	892.00
9-b	CONVEYING SCREW complete with variable speed drive geared motor with 2 discharge outlets	3,910.00
9-c	BUTTERFLY VALVE on socket of the ventilating dome 160 mm diameter	73.00
9-d	PIPELINE 160 mm diameter from ventilating dome to filter, complete with flanges, seals gaskets, etc. per meter $37.00	37.00

Position No.			
10	INTERMEDIATE PIECE between conveying screw outlet and 800 MP classifier		$63.00
11	MIKROPLEX SPIRAL AIR CLASSIFIER 800 MP Vulkollan protected		$14,705.00
	ROTARY CURRENT SQUIRREL CAGE MOTOR 38 HP, 1500 RPM		780.00
12	RUBBER VIBRATION DAMPING SUPPORT for 800 MP classifier		72.00
13	GRAVITY PIPELINE for coarse product		105.00
13-a	TWO WAY CONNECTION PIECE for coarse product		188.00
13-b	BAGGING OFF SEALS	$170.00 ea.	355.00
14	PIPELINE for fine product 350 mm diam. leading from 800 MP to cyclone	per 2 meters	68.00
14-a	TWO BENDS with flanges and clean out covers	$193.00 ea.	386.00
14-b	TWO CONNECTION PIECES between classifier or cyclone and pipeline	$58.00 ea.	116.00
15	ONE HIGH EFFICIENCY CYCLONE 900 mm diam. height 2440 mm		480.00
16	SILO top part 2500 mm diam. 3300 mm height with supporting grate and clean-out cover		1,890.00
16-a	LOWER PART OF SILO without discharge screw		915.00
16-b	CONVEYING SCREW 315 mm diam. with variable speed geared motor		2,660.00
17	TRANSITION PIECE from cyclone to pipeline for recycling air to classifier		89.00
17-a 17-c	BEND 315 mm diam. 90° with flanges	$130.00 ea.	260.00
17-b	PIPELINE diam. 315 mm from cyclone back to classifier	each 2 meters	68.00

Alpine - Lukens

AUG 18 1958

Test No. 14121
and 14121A respectively
run in Germany

For: Twin Star Industries, Inc.
Austin 4, Texas

Material Processed: Your two different kinds of diatomaceous earth marked I and II.

Test Requirement: Grinding and classification of the diatomaceous earth to produce a finished fine produce below 325 mesh. The coarse fraction should contain most of the impurities.

A. Grinding Tests

For all grinding tests, the Perplex-Universal Mill B 315U was taken. The mill was operated with beaters rotating with a speed of 3500 rpm. The material was ground with screen inserts having slotted openings 0.75mm large. The material was passed through at a rate of 1600-1700 lbs./h with a power consumption of approximately 2 kw. The grinding behaviour of the material having a moisture content of 5.5% can be expected to improve with a lower water content.

The fineness of the ground material - Test No. 14121/1 and 2 and Test No. 14121/A 1 and 2 is very near the same and can be represented by the attached particle size curve as attained by screen tests on the Alpine air jet sieve.

315 — 16 — 1700 lbs/h

630 5300 - 5600 lbs/h

1000 9600 - 10000 lbs/h

Test No. 14121
and 14121A respectively

For: Twin Star Industries, Inc.
Austin 4, Texas

Material Processed: Your two different kinds of diatomaceous earth marked I and II.

Test Requirement: Grinding and classification of the diatomaceous earth to produce a finished fine produce below 325 mesh. The coarse fraction should contain most of the impurities.

B. Classification Tests
Material 14121

For these classification tests the Mikroplex Spiral Air Classifier MP 400 was used which has approximately the same performance quality as the MP 800 model. The MP 800 has approximately 2-1/2 times as high a throughput as the MP 400.

Test No. 14121/	Setting of Guiding Vanes	Speed	Power Consumption	Throughput Fine Fraction
3	20°	2000	6 kw	1056 lbs/h
4	20°	2000	6.5 kw	1120 lbs/h
5	30°	2000	6.5 kw	1320 lbs/h
6	20°	1700	4-5 kw	1050 lbs/h
7	25°	1700	4-5 kw	1320 lbs/h
8	30°	1700	4-5 kw	1320 lbs/h
9	30°	1700	4-5 kw	1400 lbs/h
10*	30°	1700	4-5 kw	1500 lbs/h
11*	30°	1700	4-5 kw	1800 lbs/h

* Blind 40mm for coarser classification

14121/A					
	3	20°	2000	6 kw	1100 lbs/h
	4	20°	2000	6 kw	1200 lbs/h
	5	30°	1700	4-5 kw	1300 lbs/h
	6	30°	1700	4-5 kw	1500 lbs/h
	7*	30°	1700	4-5 kw	1500 lbs/h
	8*	30°	1700	4-5 kw	1950 lbs/h

SOUTHWEST RESEARCH INSTITUTE
6500 CULEBRA ROAD
SAN ANTONIO 6, TEXAS

June 18, 1956

Mr. W. B. Pratt, President
Twin Star Industries, Inc.
906 Capital National Bank Building
Austin, Texas

Dear Mr. Pratt:

Our examination of the samples of diatomaceous earth from Arizona has been completed, and a better picture of the physical and other properties of the material is available. To summarize, the diatomite is of fresh water origin and was deposited on an intermittent basis. The presence of volcanic glass fragments throughout the samples suggests that it may have been deposited at a time concurrent with volcanic activity in the region. This is of historical interest only, except that if such was the case, volcanic glass may be expected throughout the entire deposit. On the other hand, the volcanic glass may extend only to shallow depths and would be the result of surface contamination. Other impurities in the samples consist of quartz, mica, gypsum, clay minerals (unidentified), soluble salts, tourmaline and occasional grains of garnet and zircon. In general, particles of these minerals are much smaller than the volcanic glass fragments. Soluble salts are difficult to identify microscopically unless of definite crystal shapes and unless they remain unaffected by the oils used in petrographic studies. The results of calcining tests indicated the presence of soluble salts in that an appreciable amount of fluxing material was apparent in some of the heated samples. Of particular interest were two pieces of the material which had been heated to 2200°F. in an electric furnace. One was very discolored in localized zones, apparently from iron minerals, and contained a good deal of glassy material due to the presence of one or more fluxing substances. The other piece was uniformly slightly discolored, tending toward a cream-gray. Both were too hard to be scratched with other than metal points. Calcining did not appear to strengthen the diatoms. Data from tests and studies are indicated below.

Physical Properties (crude form)

A. Color - Generally white or near white to light gray with organic and iron oxide staining on surface and along parting planes.
B. Solubility - insoluble in acids (except hydrofluoric), except for some impurities.
C. Texture - Generally very fine-grained with some grit; friable and soft.
D. Apparent density (crude dry lump) - 51 to 57 pounds per cubic foot.
E. Absorption (water) - twice the weight of the dry material (made on lump material).
F. Fracture - parallel with bedding, otherwise either conchoidal or irregular.

Microscopic Appearance

A. Particle size of diatoms - less than 2 microns to approximately 275 microns for individual diatoms; majority less than 10 microns. Largest diatoms are needles or pointed rods.
B. Particle shape - needles, pods, discs; proportions of each varied from one sample to the other.
C. Index of refraction of diatoms - 1.46 - 1.47
D. Impurities - quartz, gypsum, volcanic glass, biotite mica, and occasional grains of tourmaline, garnet, and zircon; average impurity content is slightly above 10 percent. Particle size ranges from less than 4 microns to more than 100 microns.

Photomicrographs made from representative portions of a number of samples of the material are enclosed.

Chemical Analysis

	No. 1	No. 2
Moisture in material, dried at 105°C.	4.20	4.30
Additional Ignition Loss at 1000°C.	5.24	4.62
Silica (SiO_2)	76.92	79.04
Ferric oxide (Fe_2O_3)	1.52	1.51
Alumina (Al_2O_3)	5.12	5.27
Titanium oxide (TiO_2)	0.13	0.13
Phosphorous pentoxide (P_2O_5)	0.13	0.11
Calcium oxide (CaO)	3.06	1.61
Magnesium oxide (MgO)	1.48	1.09
Sodium oxide (Na_2O)	1.11	1.21
Potassium oxide (K_2O)	1.02	1.01
Undetermined	0.10	0.08

The above data indicates a diatomite of fair quality based on impurities, fines, broken diatoms and uniformity. On the basis of a classification made by some producers of diatomaceous earth, most of the diatoms examined would fall into the range of very small to moderately small. The classification referred to is shown below.

Very small -	Less than 10 microns
Moderately small -	Less than 20 microns
Medium-sized -	From 30-50 microns
Large -	100 microns

Nearly all of the material is very fine-grained. The nature of particles in individual samples is indicated in the following notes made from microscopic studies.

Microscopic Studies

One of the whitest portions (composing a small spotty portion of the whole) of the large lump of material submitted are composed primarily of fragile, thin, transparent discs of rather uniform diameter, a large portion being around 140-150 microns. These discs shatter very easily and it is difficult to prevent their breaking while preparing slides for microscopic study. There is some fine-

grained foreign material, estimated to be on the order of 3 to 5 percent. This portion of the lump also contains some needles and pod-shaped diatoms, but those present are generally less than 20 microns in length. Several were found to range up to about 280 microns in length. Portions of the lump near the surface are stained, probably by soluble and leachable salts. Amber and gray-green colored volcanic ash particles are embedded throughout the mass. Many of those particles are visible to the naked eye. This was the purest diatomite examined among the samples submitted.

In another sample taken from a white section of the large lump, the fines content is very high and is composed principally of pods and needles less than 10 microns long, with an occasional pod up to 45 microns. Discs are few in number and most are shattered. Contamination is less than 5% and is coarser grained than diatoms, consisting mostly of quartz and gypsum fragments.

A sample taken from a grayish area of the large lump contains a high proportion of diatoms. Fines content is high, consisting mostly of pods and needles, less than 5 microns long. Some unbroken discs are present as well as numerous others which have been shattered. Contaminants are present mostly in very fine grains and agglomerates with a few up to 60 microns in diameter. They compose less than 10% of the total particles and consist mainly of clay minerals and mica. In general the diatom content is slightly higher than that for samples in jars.

Sample #1. Primarily clay minerals plus quartz, mica, gypsum and other mineral grains; diatoms are very few in number and consist of both the disc and pod-shapes. Material is very fine-grained, as a whole, with quartz and volcanic ash particles being largest. Size of diatoms ranges from less than 10 microns to about 135 microns.

Sample #1A. Material is soft and chalky, generally very fine-grained; volcanic ash particles visible to naked eye in every piece broken open. Length of pods and needles - 10 to 120 microns long, mostly 10 to 50 microns, diameter of discs - 10 to 120 microns dia; many broken. Contaminants consist of grains of volcanic ash, quartz, tourmaline, clay minerals zircon, biotite mica, gypsum, garnet, soluble salts and compose about 8 to 10% of sample. Many of finest particles appear to be disc fragments.

Sample #2. (assumed since one jar was not numbered) Material is white, chalky and soft to semi-hard; very fine-grained. Contains disc, needle and pod-shaped diatoms plus considerable contaminants consisting of grains of quartz, gypsum, biotite mica, volcanic ash, occasional zircon and garnet. Contaminants compose less than 10% of particles. Diatoms are small (from less than 10 to 50 microns) and most discs have been broken.

Sample #3. Fine-grained, white, chalky, soft to semi-hard. Contains very few discs; pods and needles vary from less than 10 microns in length to a few around 150 to 180 microns - disc fragments are plentiful (contaminants, principally clay minerals, compose less than 10% of particles).

Sample #4. Fine-grained, white, generally soft and chalky, somewhat less con-

taminated. Discs, pods and needles with higher disc content than in previous samples; diatoms about of same size order as in other samples with average less than 20 microns. Discs up to 150 microns in diameter, but average is smaller than this. Contaminants compose less than 5% of grains.

Sample #5. Larger pieces generally white; and chalky powdered portion light cream-gray. (colored discs - blue and orange) Sample contains clay minerals along with mica, tourmaline, volcanic glass and gypsum; contaminants compose less than 8% of particles. High proportion of shattered discs. Sample in general is very fine-grained. Pods and needles are generally small - from less than 10 microns to 40 or 50 microns in length.

Sample #6. Material is white, soft, and chalky. Particles are mostly pods and needles; discs are few and generally shattered, averaging about 20 microns. Pods range up to 90 microns long, but the majority are in the range of 10 to 30 microns. Contaminants are fine-grained and individual grains measure from less than 4 to about 40 microns with majority around 5 microns. Contaminants are primarily clay minerals and compose between 15 and 20% of particles.

Air Tabled - 100 feed

Sample #5. Fines extremely high. Few discs are present; diatoms are mostly needles and pods less than 10 microns long. Contamination is high and fine-grained.

Sample #6. About the same as Sample #5.

Sample #7. Contains a higher percentage of diatoms than some of the raw samples. Composed of a mixture of discs, needles and pods. Contaminants are generally of small grain size and average less than 4 microns. Many discs are shattered, but an appreciable portion are whole or nearly so. Sample is very fine-grained.

Heads. Very fine-grained and with few discs; some pods are present. Many particles, less than 4 microns, are too small to identify. A large number of the total particles are disc fragments.

Air Tabled - 20 + 40

Sample #5. Material as received was granular. Most particles are less than 4 microns. Discs are few in number with many shattered; needles are up to 50 microns long; pods are generally small and average less than 20 microns. Contaminants are very fine-grained and appear to be clay minerals for the main part.

Several factors which should be evaluated are the similarity or dissimilarity of the diatomite in the various strata of the deposit, purity of the diatomite within the deposit and away from contaminated and exposed surfaces, and moisture content and bulk density of material within the deposit. This information would be useful whether the material is sold in crude form or is sold as a refined product and could be derived from samples taken from a freshly exposed face of the deposit.

Please contact me if you have any questions regarding the above.

Yours very truly,

John E. Funnell

John E. Funnell, Supervisor
Mineral Technology Department

JEF:ih
cc: Mr. Warren Beaman

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
COMMISSIONER'S OFFICE
BUILDING 53, DENVER FEDERAL CENTER
DENVER 2, COLORADO

JAN 27 1958

IN REPLY
REFER TO: D-294

Mr. John S. McNabb
Vice President, Mining
Twin Stars Industries, Incorporated
1111 So. Congress Street
Austin, Texas

JAN 24 1958

Dear Mr. McNabb:

Information on pozzolan requested in your telephone conversation with Mr. R. J. Elfert on January 3, 1958, follows:

Sample No. M-3027C, diatomaceous earth from White Cliff deposit, San Manuel, Arizona	
Fineness passing No. 325 sieve	* 88.6
Specific gravity	2.38
Water requirement, percent of control	*114
Change of drying shrinkage, percentile	* 0.03
Compressive strength:	
2-inch cubes of pozzolan-portland cement	
at 28 days' age, percent control	* 73
at 90 days' age, percent control	74.6
2- by 4-inch cylinders of pozzolan--lime mortar at 7 days' age, psi	*942
Reduction of reactive expansion percent of control at 14 days' age	* 87
Silicon dioxide (SiO_2) plus Aluminum oxide (Al_2O_3) plus Ferric oxide (Fe_2O_3) percent	* 89.7
Magnesium oxide (MgO) percent	* 1.73
Sulfur trioxide (SO_3)	* 0.25
Ignition loss, percent	* 1.23
Moisture, percent	* 0.08

*These tests are required by our general pozzolan specifications.

Tests were performed in accordance with our "Specifications for Pozzolan" and "Methods of Test for Pozzolans," dated December 15, 1956, which are general in nature and which have now been changed to meet the requirements for Glen Canyon Dam as contained in our Invitation No. DS-5012, Pozzolan for Glen Canyon Dam and Powerplant, copy of which has been mailed your company.

Sincerely yours

Walter H. Price, Chief
Division of Engineering
Laboratories

A. E. Burnett

ACTING

DEPARTMENT OF MINERAL RESOURCES
STATE OF ARIZONA
Field Engineers Report
****

Mine AIRIZITE (Diatomaceous Earthe Deposit)

District Old Hat, Pinal Countv, Arizona Date March 10, 1941

Subject Arizite Products Corporation Propertv Eng. Miles M.Carpenter. E.M.

This is a special report made under instructions of the Director for the information and use of the Arizona Corporation Commission. One dav was spent on the examination, March 6. In addition to inspecting the grounds in the vicinitv of the present workings, a traverse was made of the large canyon to the east for a distance of about a mile and a quarter, then crossing to the next canyon north and following it westward to the highway, then south to the mine road and east to the working. Not nearly all of the property controlled by this company was covered, but with previous knowldge of this deposit the conclusions herein expressed are believed to be well founded.

LOCATION: The property is located on the east side of the San Pedro River, about ten miles south from the town of Mammoth. With reference to the public land survey it lies in Township 9 S, Ranges 17 and 18 East. The common corner NE of Sec. 25, R. 17 E and NW of Sec. 30. R. 18 E provides a starting point for tracing the boundaries. From this point the ground controlled by this companv extends two miles north, one mile south, one mile west, and one and one-half miles east, less the South half of Sec. 30.

AREA AND TITLES: According to the company map this comprises an area of about 3760 acres. It is held by placer location of public domain and patented land. Four 160 acre claims are owned by the Arizite Productions Corporation, the balance by Andres M Herreras of Tucson, from whom the corporation has a long term lease and operating contract. titles or contract were not checked.

TOPOGRAPHY: Topographically, this diatomaceous earth deposit is part of the foothill slope rising from the east bank of the San Pedro River and continuing to the Sombrero Butte area of the Galiura mountains. It is cut by west running canyons having moderately steep banks and narrow widths

GEOLOGY: No thorough and detailed geologic study of this deposit has been reported, so far as known, but a preliminary examination by Carl Trischka, Chief Geologist of the Phelps Dodge Corporation was reported in the technical press and is summarized in a recent circular on DIATOMACEOUS EARTH, compiled by Eldred Wilson, geologist of the Arizona Bureau of Mines. Reference is made to these sources for technical descriptions of the material and the concurrence. My own brief study checks the conclusion that this deposit was accumulated in a lake or playa over a long period of time during which quantities of volcanic ash settled in layers over the accumulating deposit and small amounts of medium acidic lava found its way into the deposit and became volcanic glass, sometimes in sheets and sometimes in modules resembling chort. Also, sedimentation occurred showing in some places as beds of clay but more generally as sand or silk like material intimately associated with diatomite, forming the material referred to as "second class" bv the operators.

In most of the deposit examined the structure is stratified, more or less regularly horizontal, but some exposure suggest erosion of the beds as originally laid down by cross canyons and later filling with different material. Beds of the purer diatomite appear to have a thickness of four

to ten feet for the most part, but were noted only a few inches thick and again 20 feet or more. It is difficult to judge the character of material in the weathered faces.

TONNAGE: Trischka states: "The thickness of the deposit ranges from 40 to 70 ft.". and speaking of the entire deposit says: It covers 10 to 20 square miles." The area of the holdings under consideration is some six square miles and it is presumed that practically all the ground taken up showed evidence of being underlaid with diatomaceous. It is impossible to estimate the depth, for the depth below the present day surface is not known. Figured from existing exposures, depths vary from 20ft, to 150 ft. or more. A mile or so east from the loading bin, the depth exposed in the canyon channel and on the adjacent benches is believed to approach 200 ft. (See Photos Nos 6 & 7) It is quite possible that a detailed measurement of the exposures would show an average thickness of close to 100 ft. The management estimates an average of 2 yds to the ton. (54 cu.ft.) This appears to be in line, and assuming an average depth of 54 ft.gives one ton of material for each square foot of surface. This area of 3760 acres would contain 163,785,600 tons. This figure is not presented as an estimate but rather as a conservative suggestion of its immensity. Drilling to determine the depth and prove the horizontal continuity might increase this figure several times. (40 acres 3,312,000 tons plus our drill holes)

VALUE: The value of this deposit depends on so many factors of development processing, marketing and handling that a concrete valuation from this point does not appear justified. It is manifest that the deposit is the foundation of whatever enterprise may be builded upon it and as such has an essentialvalue. A fair and reasonable method of arriving at a value is to start with the selling price of the products and work backwards. From the selling pricededuct the costs of processing, transporting and selling the finished products; developing, mining and hauling the crude material; royalties and all other overhead expense. The balance remaining would be available for amortization of investment, profits and property value. The amortization is fixed,the profits can be regulated and from the remainder considered as incomefrom the property the valuation can be fixed.

A development arises in this connection that has no precedent in the experience of the reporting engineer. At the present rate of production, assumed to be 10,000 tons per year on a plant capacity of 30 tons per day, and reducing the tonnage to 100,000,000, it would require 100 years to work that tonnage and no formula has been found to compute the present value of production 100 years hence.
If it is essential to assign a value to the property, it appears reasonable to allow about 25 times the annual profits and surplus.

PRESENT OPERATIONS: Present operations are on a restricted scale due, presumably, to lack of market. Neither the mill nor the mine was working at the time of inspection.

Mining is currently being done thru a tunnel drive 30 ft. or so into the face shown in Photos No.2 & 3. A flat stope is started, and the two grades of material, first and second, are mined seperately. Photo No.4 shows the center section of this stope. A track leads to the 30 ton loading bin in front of the tunnel.

The working is equipped with gasoline engine driven air compressor and hipping hammers.

Crude material is drawn from the bin thru double chutes into dump trucks hauled about 12 miles and dumped into the receiving bin at the mill. When water is not running in the San Pedro River crossing is made south of Mammoth and then the distance is about 11 miles. Management states that the hauling cost is slightly under $ 1.00 per ton.

MILLING: Crude material is taken from the 30 ton receiving bin and put thru the primary crusher, a No.2 Little Giant hammermill type, then lifted by vertical bin. Fed thru Willran pulverizer and drawn into super-separator with heat conduit mesh material is drawn into bag house and the coarser pro duct goes to a 10 ft. mechanical separator where the diatomite goes to a St. Regis packer and the ash to waste.

Mill operator states that the first grade material loses 5 % upward in ash, and in the second grade that the ash loss might reach 15 %.

POWER: originates at the Coolidge Dam plant and is brought in at 2300 volts and transformed to 440 volts. All units of the plant are motor driven, using about 140 motor horse power in eight motors ranging in size from ½ HP to 50 HP.

FUEL: for drying is Butane gas stored in a large tank in the yard.

MILL BUILDING: is of structural steel frame covered with galvanized iron Floors are of cement, well finished. Width of building is 50ft. and length 60 ft., the west half has walls about 45 ft. high, and the east half about 25 ft. Photos 8 & 9 show two views of the mill.

PRACTICAL CONSIDERATIONS: This propery is not only of immense size but can be mined economically by modern rock moving equipment. It is not sufficiently uniform to mined as a whole for treatment in the present plan, but it occurs so that the waste can be removed and the desired material recovered progressively. There are scores of beds that appear suitable for opening, some in which the first grade of diatomite is abundant and others where volcanic ash and impure diatomite predominate.

Material could be handled in sizable blocks by first removing the overburden which is light in some places and considerable in others; then the successivelayers. Work could be arranged so the different types of material would be exposed at the same time. Drag line, bulldozer or shovel and trucks could doubtless be adapted to this job, and a little experimenting would show what combination was most satisfactory. Costs would depend largely upon the scale of operation, but even on the present small capacity of 30 tons per day it is believed that, with suitable equipment, a cost of $ 1.00 per ton of clean material is feasible.

As above indicated, there is no question of quantity or availability in this deposit. It is ample for any size plant now on the horizon. The problem is one of processing and marketing the material and on thisphase of the undertaking your reporting engineer does not feel qualified by knowledge or experience to advise.

S/ Miles M. Carpenter, E. M.

Field Engineer, Southern District.

Alpine-Lukens

HARRY M. BULBROOK, M. A. IN SC. SEP 11 1958 FORM A-2

INDUSTRIAL LABORATORIES

CONSULTING INDUSTRIAL AND ANALYTICAL CHEMISTS
REFEREE CHEMISTS: AMERICAN OIL CHEMISTS SOCIETY
P. O. BOX 185 ∞∞ EDISON 6-2102 [illegible]
FORT WORTH 1, TEXAS

ANALYTICAL REPORT 9-10-58

Sample of ~~DIATOMACEOUS EARTH~~

Received from ~~TWIN STAR INDUSTRIES, INC.~~

~~AUSTIN, TEXAS~~

Marked ~~DIATOMACEOUS EARTH~~ Date Received ~~8-23-58~~

Conc. Made in Germany

MOISTURE	4.93%
SILICON DIOXIDE	75.46%
WET SCREEN (-325)	99.51%
pH	8.98
BULK DENSITY	14.63 LBS/CU. FT.
OIL ABSORPTION (ASTM D 281-31)	124.6 LBS/100 LBS

Laboratory No. H 2358-1

Respectfully submitted,

INDUSTRIAL LABORATORIES,

By H M Bulbrook

No. 1.	No.	No. 3
0'- 75' A trace of D. E.	25'- 30' D. E.	40'- 45' Gravel
75'-100' D. E.	30'- 35' D. E.	
100'-105' Some D. E.	35'- 40' D. E.	45'- 50' D. E. & Gypsum
105'-110' D. E.	40'- 45' D. E. & a little Chert	50'- 55' Chert and some D. E.
110'-115' D. E.	45' - 50' D. E.	55'- 60' D. E.
115'-120' D. E.	50'- 55' D. E.	100'-105' D. E.
120'-125' D. E.	55'- 60' D. E.	105'-110' D. E.
125'-130' D. E.	60'- 65' D. E.	110'-115' D. E.
130'-135' D. E.	65'- 70' D. E.	115'-120' D. E.
135'-140' D. E. & Chert	70'- 75' D. E.	120'-125' D. E.
140'-145' D. E.	75'- 80' D. E.	125'-130' Chert
145'-150' Some D. E. & Chert	80'- 85' D. E. & a little Chert	130'-135' Chert
150'-155' No sample	85'- 90' D. E. & a little Chert	135'-140' Some D. E. and Chert
155'-190' D. E.	90'- 95' D. E. & a little Chert	140'-145' Chert and D. E.
190'-195' D. E.	95'-100' A little D. E.	145'-150' Chert
195'-200' D. E. and Chert	100'-105' A little D. E.	150'-165' Gypsum and D. E.
200'-205' D. E.	105'-110' A little D. E.	165'-190' Gypsum and D. E.
205'-210' D. E. & Some Chert	145'-150' D. E.	190'-195' Gypsum
210'-215' No sample	150'-160' D. E.	195'-200' Gypsum
310'-320' D. E. & Some chert	160'-165' D. E.	200'-205' Gypsum and some D. E.
* Static Level of H_2O @ 230'		
320'-330' D. E. and Some Chert	165'-170' D. E.	205'-210' Gypsum
330'-355' No sample	170'-175' D. E.	210'-215' Gypsum
355'-360' No sample	175'-180' Some D.E. & little Chert	215'-220' Gypsum
360'-365' Chert	180'-185' " "	220'-225' Some Gypsum
365'-370' Chert	250'-255' Chert	225'-230' Chert & Gypsum
375-380' Chert	255'-265' Chert	230'-235' Chert & Gypsum
380'-385' Chert	265'-280' Chert and D. E.	235'-240' Gypsum & some Chert
385'-390' No sample	280'-285' Chert and D. E.	240'-245' Gypsum
390'-395' Chert	285'-290' No sample	245'-250' No sample
395'-400' Chert	* Static Level of H_2O	250'-255' Chert
400'-405' Chert	@ 80' Hole cased	255'-260' Black Mat-Hard with Chert
405'-410' Chert	to 225' with $5\frac{1}{2}$"	260'-265' Gypsum & Chert
410'-420' Chert	Pipe.	265'-270' Gypsum & Chert
420'-425' No sample		270'-275' More Gyp-Less Chert
425'-430' No sample		275'-300' Gypsum
430'-465' Some Chert		

COMBUSTION ENGINEERING, INC.

RAYMOND DIVISION

PULVERIZING, AIR SEPARATING AND FLASH DRYING SYSTEMS

1315 NORTH BRANCH STREET
CHICAGO 22, ILLINOIS

December 27, 1957

DEC 30 1957

Twin Star Industries, Inc.
906 Capital National Bank Building
Austin, Texas

Attention: Mr. John S. McNabb
Vice President

Subject: Pulverizing Diotamaceous Earth

Gentlemen:

First of all, let me say that it was a pleasure to have you, Mr. Pratt and Mr. Nolan here in our laboratory to witness the recent test work accomplished.

Enclosed please find three copies of our report #4625, detailing this test work. As you will remember, Bill was going to try another separation or two after you left Wednesday morning to see whether he could obtain a little lower recovery of fines simply to give you a range of product. He did do a little better on the final run, and we also included a sample of this that we sent over to the Chicago Testing Laboratories. We would, of course, be very interested in the results from this further testing by the Chicago Laboratories.

At the beginning of this test work, there was some doubt in our minds as to whether this material could be handled satisfactorily and economically on the Imp Mill, and it was for this reason that we first started with the Roller Mill. However, after concluding the test work and simply basing our conclusions on the samples that we had here in our laboratory, we would say that this would make a good application for the Imp Mill. Maintenance would have to be considered, and it would be most likely that you would want to set up a hard surfacing program for your hammers. However, it would not be such that hammers would only last a matter of days in our best judgment. I am sure you realize, however, that it is extremely difficult to try to pinpoint the life to be expected because of the wide variations you could experience in the deposit as well as the possibility of different fineness of grind at this stage of the game.

Once again, let me say that it was a pleasure to meet you and your associates and to accomplish this test work for you. We are very much interested in your problem and will expect to hear from you. Contact Mr. Hebner any time there are any questions.

Sincerely,

COMBUSTION ENGINEERING, INC.
Raymond Division

J. L. Sheehan

JLSheehan/sh
Encl.

Run #	4	5	6		
			Feed	Fines	Tails
Machine	#10 Imp - - - - - -		30" Mechanical Air Separator		
Material	As received - - - -		Prod. Run #5		
Hammers	3-3-0	3^b-3^b-0 - -	none		
Amps	50	50	- -		
Inlet °F	250	280			
Cyclone °F	170	155-70			
Final H_2O	1.6	2.0			
Whizzers			24-24		
RPM			1230		
Time-mins	3	6	5		
Weight-lbs	65	218	90	70	20
Rate-lbs/hr	1300	2800	1080		
Recovery %	- -	- -	- -	78	22
Thru 70					
100		99.4			97.9
140					94.0
200	- -	95.8		99.5	82.0
325	94.6	87.0		98.2	59.0
B.D.#/cu.ft.		16.4		19.0	

Run #	7			8		
	Feed	Fines	Tails	Feed	Fines	Tails
Machine	30" Separator			30" Separator		
Material	Prod. Run #5			Prod. #5		
Whizzers	24-24			24-24		
RPM	1230			820		
Time-mins	6			3		
Weight-lbs	62	47	15	39	18	21
Rate-lbs/hr	620			780		
Recovery %		76	24		46	54
Thru 325		- -	- -	- -	98.8	- -
B.D. #/cu.ft.	- - - - - - - - - - - - - - - - - -				19.3	

Run #	9			10		
	Feed	Fines	Tails	Feed	Fines	Tails
Machine	30" Sep.			30" Sep.		
Material	#5 Prod.			#5 Prod.		
Whizzers	24-24			24-24		
RPM	1020			1320		
Time-mins	6			6		
Weight-lbs	81	66	15	81	65	16
Rate-lbs/hr	810			810		
Recovery %		81	19		80	20
Thru 325		97.7			99.2	

Run #	11			12
	Feed	Fines	Tails	
Machine	30" Sep.			#10 Imp Mill
Material	Prod. #5			As recd
Whizzers	24-12			- -
Hammers	- -			3 bar-s knife-O
Amps	- -			50
Inlet °F				300
Cyc. °F	- -			170
Time-mins	6			6
Weight-lbs	84	69	15	330
Rate-lbs/hr	840			3300
Recovery %		82	18	
Thru 70			99.5	99.1
100			99.0	98.3
140			97.0	97
200			90.0	95
325		99.75	57.0	85.3

Run #	13			14		
	Feed	Fines	Tails	Feed	Fines	Tails
Machine	30" Separator for all remaining runs - - - - - - -					
Material	Prod. #12 for all remaining runs - - - - - - -					
Whizzers	24-12			24-24		
RPM	1320			1320		
Time-mins	6			6		
Weight-lbs	88	67	21	74	57	17
Rate-lbs/hr	880			740		
Recovery %		76	24		77	23
Thru 325		98.1				

Run #	15			16		
	Feed	Fines	Tails	Feed	Fines	Tails
Whizzers	24-24			24-24		
Fan	4-1" and 4-2" long			4-1" and 4-2" long		
RPM	1320			1020		
Time-mins	4			4		
Weight-lbs	62	52	10	60	32	18
Rate-lbs/hr	930			900		
Recovery %		84	16		64	36
Thru 70			98			
100			95			
140			90			
200			80			
325		97.0	52.5		97.3	

William W. Hainey

eb

PRODUCT DEVELOPMENT APPLIED RESEARCH

ARC LABORATORIES

Division of Arizona Research Consultants, Inc.
917 W. HATCHER RD. PHOENIX, ARIZONA WINDSOR 3-3573

FOR: Associated Minerals
30 Pima Plaza
Scottsdale, Arizona

DATE April 26, 1961

LAB No. 6775

RESULTS

Diatomaceous earth 14121A/3

Silica	74.30 %
Alumina	4.22
Iron (Fe_2O_3)	1.24
Calcium oxide	6.55
Magnesium oxide	1.62
Sodium oxide	0.43
Potassium oxide	0.41
Loss on Ignition	11.03
Moisture as recieved	4.30
pH of 50% slurry	9.6
Specific gravity	2.18
Oil absorbtion	
Gardner-Colemna modified	116 lbs/ 100 lbs. D.E.
Pounds/cu.ft.	19.1
Bulking factor	0.38 gals./lb.
Color	Off-white

Respectfully submitted,
ARC LABORATORIES

John T. Long, Jr.

SELECTED BIBLIOGRAPHY

Blake, W.P., 1903, Diatom-earth in Arizona: Trans. Am. Instit. Mining Engineers, v. 33, p. 38-45, New York.

Bowles, Oliver and Justice, C.W., 1933, Growth and development of the nonmetallic mineral industries: U.S. Bur. Mines Infor. Circ. 6687.

Creasey, S.C., Jackson, E. D., and Gulbrandsen, R.A., 1961, Reconnaissance geologic map of parts of the San Pedro and Aravaipa Valleys, south-central Arizona: U.S. Geol. Sur. Mineral Inv. Field Studies Map MF-238.

Cummins, Arthur, B., 1960, Diatomite chapter in Industrial minerals and rocks, 3rd ed: Am. Inst. Mining Met. and Petr. Engineers, New York.

Davis, C. W., 1925, Diatomaceous earth: U.S. Bur. Mines Report Inv. 2718.

Hatmaker, Paul, 1931, Diatomite: U.S. Bur. Mines Infor. Circ. 6391.

Long, John T. Jr. and Olson, George, G., , Diatomaceous earth in Arizona: prepared by Arizona Research Consultants for the Arizona Development Board, Phoenix, Arizona.

Oakeshott, Gordon B., 1957, Diatomite chapter in Mineral Commodities of California: Calif. Depart. Natural Resources Div. Mines Bull. 176, p. 183-193.

Otis, L. M., 1960, Diatomite chapter in Mineral facts and problems: U.S. Bur. Mines Bull. 585.

Phalen, W.C., 1920, Diatomaceous (infusorial) earth: U.S. Bur. Mines Report Inv. 2097.

Santmyers, R.M., 1931, Quartz and silica: U.S. Bur. Mines Infor. Circ. 6474.

Trischka, Carl, 1929, Diatomite in Arizona: Engineering and Mining Journal, v. 127, no. 1, p. 13-14.

Wilson, E.D. and Roseveare, C.H., 1949, Arizona Bureau of Mines mineral technology series no. 42, Bull. 155, p. 17-18.