ARIZONA DEPARTMENT OF MINES AND MINERAL RESOURCES AZMILS DATA

PRIMARY NAME: METEOR CRATER

ALTERNATE NAMES:
SATURN PLACER PAT. MS 1806
JUPITER PLACER PAT. MS 1806
VENUS PLACER PAT. MS 1806
MARS PLACER PAT. MS 1806

COCONINO COUNTY MILS NUMBER: 254

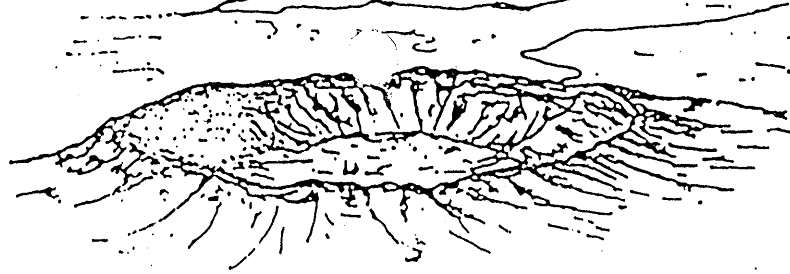
LOCATION: TOWNSHIP 19 N RANGE 12.5E SECTION 13 QUARTER C
LATITUDE: N 35DEG 01MIN 39SEC LONGITUDE: W 111DEG 01MIN 18SEC
TOPO MAP NAME: METEOR CRATER - 7.5 MIN

CURRENT STATUS: PAST PRODUCER

COMMODITY:
SILICON

BIBLIOGRAPHY:
BLM MINING DISTRICT SHEETS 147 & 148
ADMMR METEOR CRATER FILE
MAINWORING, T.A., MKT. FOR METEOR CRATER SILICA SAND IN AZ. & SO. CALIF., STANFORD RESEARCH INST. 1954,
ADMMR U FILE
COMMODITY: SILICA SAND, STISHOVITE, COESITE

Canyon Diablo Meteorites



"Except for life itself, meteorites are the most interesting things on earth"

Canyon Diablo meteorites are the world's most famous and most attractive meteorites. They are remnants of a giant cosmic bolide, presumably an Apollo asteroid, which struck northern Arizona 50,000 years ago creating a mile-wide and 600-feet-deep explosion impact/crater now known as Meteor Crater or, in scientific circles, Barringer Crater. The kinetic energy of intense shock of impact at about 20 km/sec volatilized or otherwise destroyed nearly all of the meteorite. This "cosmic cannonball", 30 meters across and weighing about 200,000 tons, was travelling with a velocity of 20 km/sec and packed a 15-magaton wallop. Less than 30 tons survived volatilization to be collected and displayed in the world's great museums. Meteor craters can be described, at least poetically, as the result of an irresistible force meeting an immovable object. Less than a dozen are known on earth with associated meteorites. More than 100 ancient impact scars or structures are known. Geologists term them "astroblemes". Meteor Crater, Arizona, was the first meteorite crater to be identified and is the example par excellence.

Canyon Diablo meteorites were first brought to scientific attention by A. E. Foote in 1891, who did not associate them with the nearby crater which he supposed to be volcanic. He also discovered minute diamonds in some of them which we now know were converted from the minerals graphtite and cohenite by the shock. It remained for D. Moreau Barringer in 1908 to demonstrate that a cosmic bolide created Meteor Crater. His twenty year attempt to mine the supposedly buried body is a heroic but frustrating epic in the annals of mining.

These nickel-iron meteorites are classified as medium octahedrites based upon their type of crystallinity. In composition they are 92% iron, 7% nickel and 1% "other" - consisting especially of cobalt and interesting amounts of the plantinum-group metals. Nickel-irons are rare among observed falls but are common among finds apparently because they are distinctive and resist weathering.

The Canyon Diablo meteorites have had many remarkable scientific uses; for example, in helping to establish cosmic abundances of the elements and as a standard for sulphur isotope ratios. In the mid-1950's, a Canyon Diablo meteorite also was used to first establish the age of the solar system as 4.5 billion years and by inference the age of the Earth, a dating which has been sustained.

Owning one of the rare Canyon Diablo meteorites, a messenger from outer space perturbed from the asteroidal belt, is a privilege demanding reponsible curatorship.

If Arizona ever decides to designate an official state rock, this meteorite should be the obvious rock of choice.

Robert S. Dietz

ENGIN. & MINING
[illegible] - 11-48 - Vol. 149 - No. 11

NAME OF MINE: METEOR SILICA, INC.		COUNTY: Coconino	
OWNER:		DISTRICT:	
		METALS: Silica Sand	
	OPERATOR AND ADDRESS		MINE STATUS
Date:		Date:	
10/46	W.A. Moeur, President, Phoenix Natl. Bank Bldg., Phx.	10/46	Shipping

SKETCH - METEOR CRATER

PAY DIRT - Jan. 19, 1962

Feb. 16, 1929

Meteor Crater Exploration & Mining Co., sinking a shaft in Arizona to locate remains of a meteor supposed to have buried itself in the desert, was recently employing 25 men.

(This was taken from Skillings Mining Review February 22, 1969 (40 Years Ago) page 24

ARIZONA DEPARTMENT OF MINES AND MINERAL RESOURCES

INFORMATION FROM MINE CARDS IN MUSEUM

ARIZONA

COCONINO CO.

BARRINGER(METEOR)CRATER

MILS # 254

Meteor CRATER (File)

4-AKA's

MM-1288 Meteorite(Ni-Fe)
4477 Meteorite(Fe-Ni)
4478 Meteorite(Fe-Ni)
4479 Meteorite(Fe-Ni)
5597 Meteorite(Fe-Ni)
5598 Iron oxide (meteoritic)
5599 Iron oxide (meteoritic)

Date Printed: 07/09/1999

ARIZONA DEPARTMENT OF MINES AND MINERAL RESOURCES

INFORMATION SUMMARY

Information from: **Ken Phillips**

Company:

Address:
City, State ZIP:
Phone:

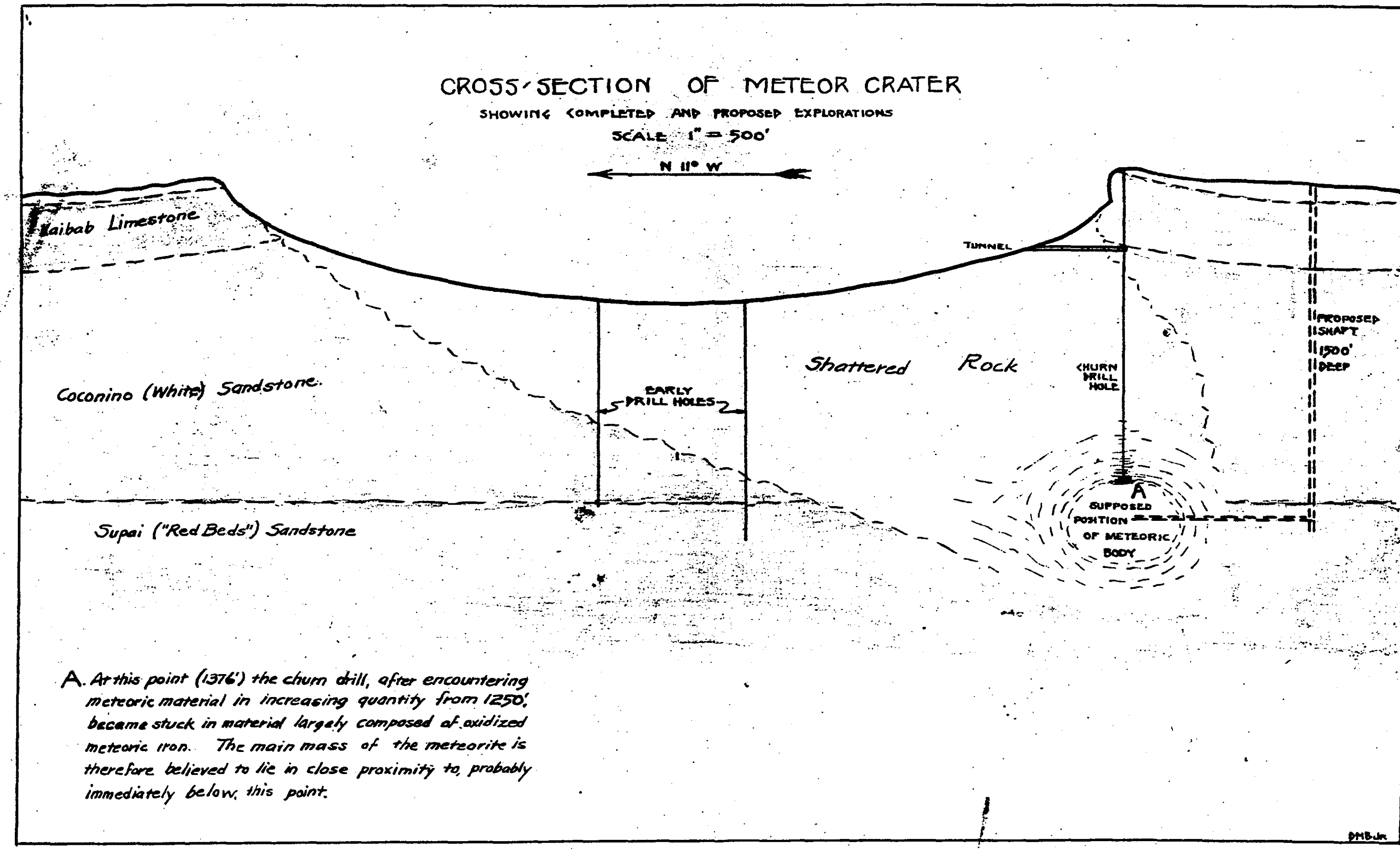
MINE: **Meteor Crater**

ADMMR Mine File: Meteor Crater
County: **Coconino**
AzMILS Number: **254**

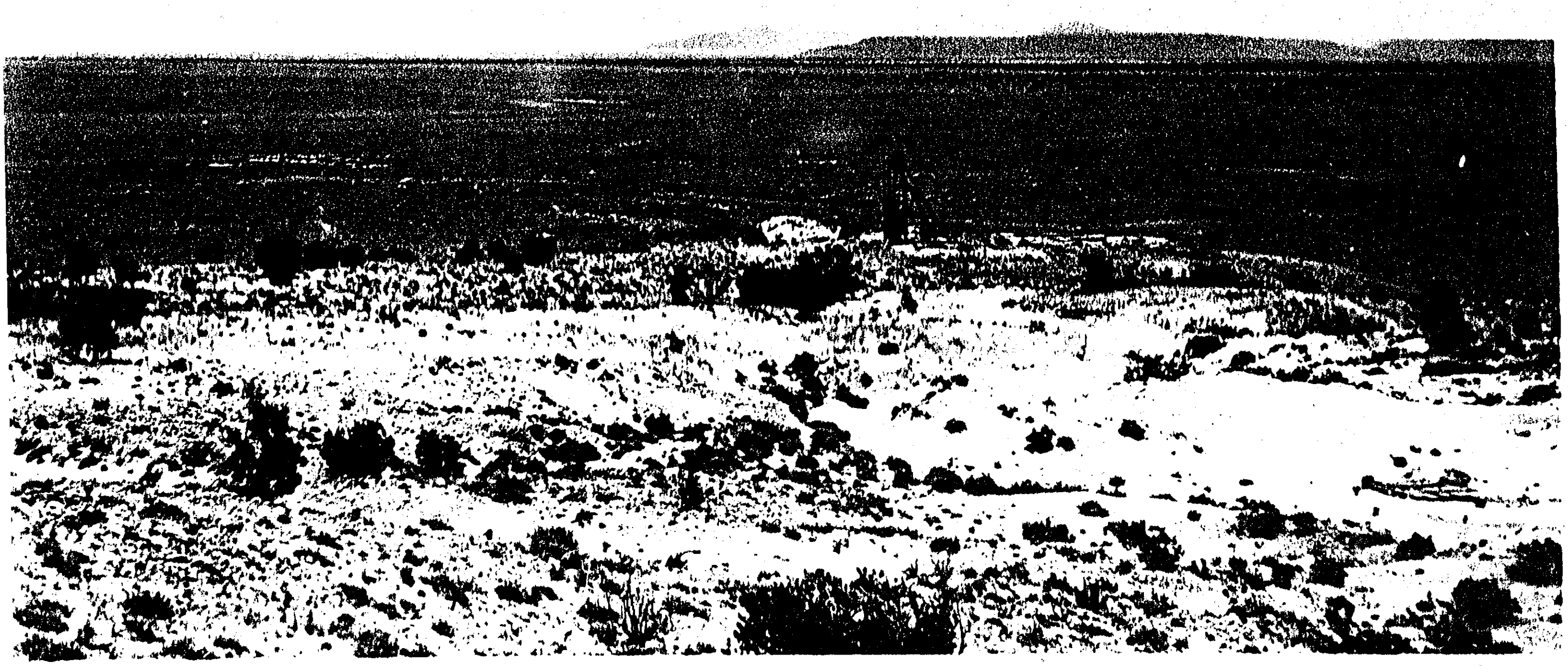
<u>SUMMARY</u>

Meteor Crater is a privately owned group of patented mining claims which covers one of the best preserved meteor impact sites on earth. The impact site was historically developed for a sourse of ferro alloy metals and high purity silica sand. Its current status as a scientific and tourist site now far outweighs its mineral resource development potential.

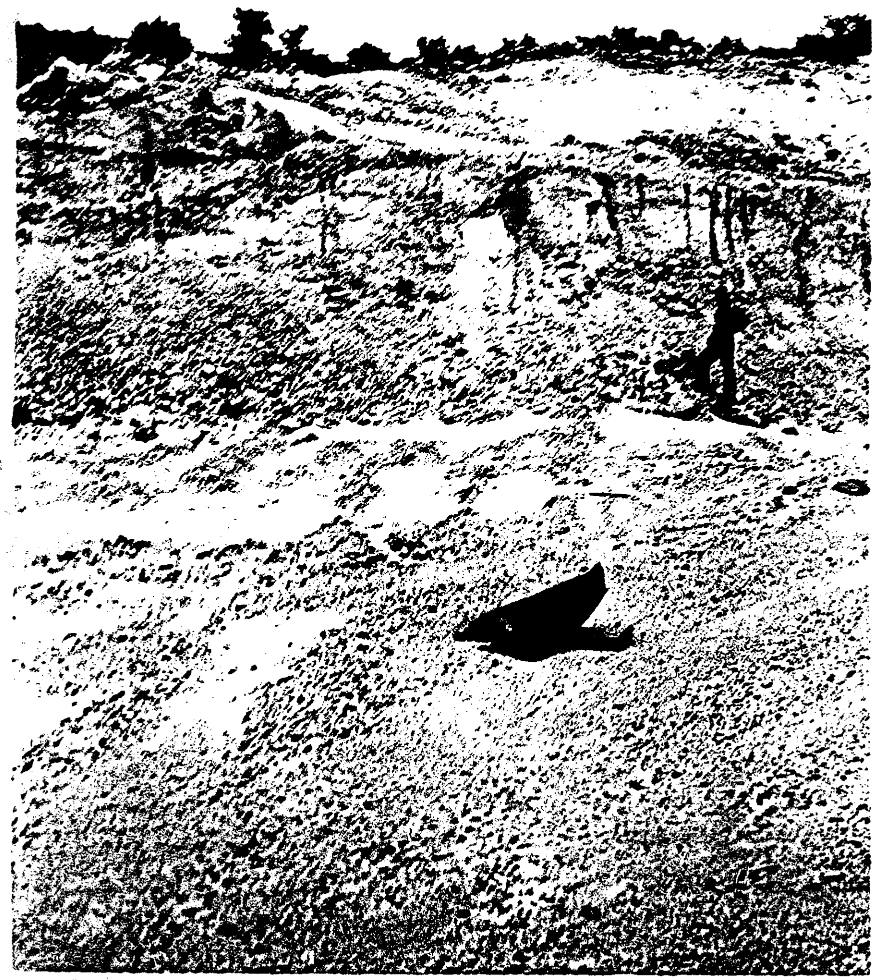
Ken A. Phillips, Chief Engineer   Date: July 7, 1999


CROSS-SECTION OF METEOR CRATER
SHOWING COMPLETED AND PROPOSED EXPLORATIONS
SCALE 1" = 500'
N 11° W
Kaibab Limestone
Coconino (White) Sandstone
Supai ("Red Beds") Sandstone
TUNNEL
EARLY DRILL HOLES
Shattered Rock
CHURN DRILL HOLE
PROPOSED SHAFT 1500' DEEP
A
SUPPOSED POSITION OF METEORIC BODY
A. At this point (1376') the churn drill, after encountering meteoric material in increasing quantity from 1250', became stuck in material largely composed of oxidized meteoric iron. The main mass of the meteorite is therefore believed to lie in close proximity to, probably immediately below, this point.
DMB.Jr.

A-123-1 C-1950



A-123-2 C-1950



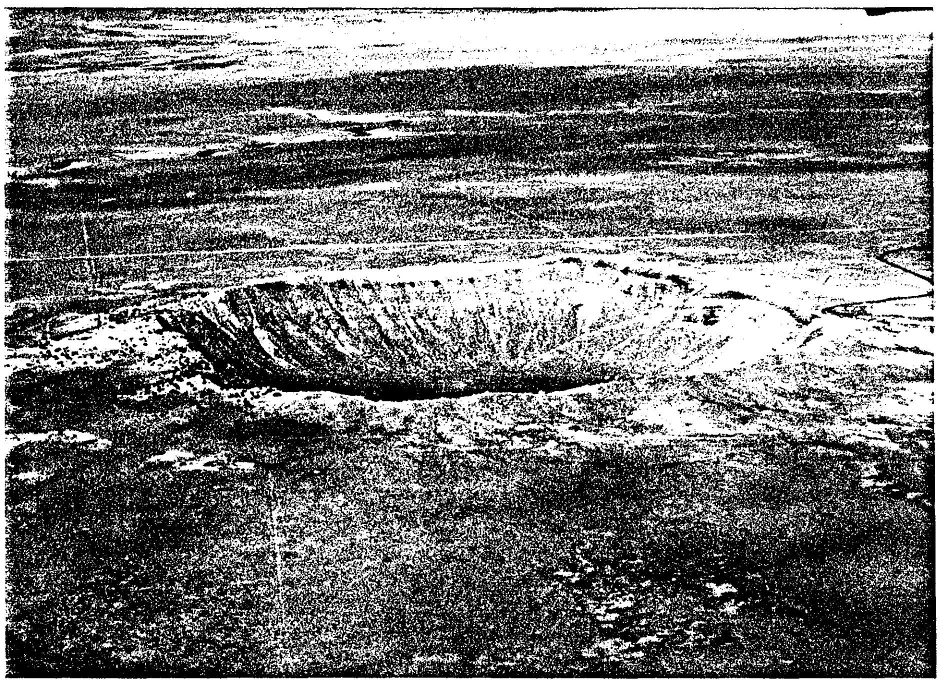
A-123-3

A-123-4

C-1950

METEOR CRATER

10/92
photo by Leroy Kissinger
negative in photo file



Meteor Crater

November 22, 1919

Dr. L. D. Ricketts,
Warren, Arizona.

My Dear Dr. Ricketts:

It has been difficult to reach and express a well-reasoned opinion upon the proposed drilling venture at Coon Butte crater because the phenomenon is entirely unique. Many leading scientists have applied time and effort to solving the question of the origin of the crater, only to disagree. After spending two days there, as directed, and upon reviewing the published papers on the subject, it is my judgment that it would not be a reasonable venture to search for a deposit of nickel ore either within or without the crater in the hope that such a deposit, suitable for mining, does in reality exist there. I shall not attempt to re-describe the occurrence. The crater has been well described in Mr. Barringer's paper and in the publications which he cites, but there are several outstanding facts respecting Coon Butte that require emphasis because of their relative importance:

First, in traveling across the flat-lying limestones of the Canyon Diablo country, the butte is visible for twenty miles or more. The upturned limestones, comprising the rim of the butte, stand 160 to 200 feet above the surrounding country. It is primarily a structural hill with a hole in the center; not a hole in flat-lying rocks with rock debris piled around.

Second. It is found in a region of volcanic activity. San Francisco Peak, a volcanic mountain, looms up 45 miles northwest of the crater. (See the figures accompanying this paper for graphic summaries of the geology.)

Third. An anticlinal structure is plainly visible about 1½ miles northwest of the crater. The fold shows in the brown sandstone of "Moencopie formation" overlying the Kaibab limestone. It is low but distinct, with its axis bearing in the same direction as the main NW-SE fault of the crater described in Mr. Barringer's paper. This anticlinal structure does not receive mention in any of the descriptions of the crater that I have seen. It is important since there seems to be a definite relation between the anticline and the crater, as to position and as to trend of structural lines. My observations confirm Mr. Barringer's statements concerning the ejected limestone and sandstone boulders, his descriptions of deformation, metamorphosed white sandstone and other facts mentioned by him. There is a little native iron now visible around the crater, but I did find fragments near the northeast rim. Fragments of metamorphosed red sandstone were also found in the vicinity of these few pieces of nickel-iron.

Standing alone, the facts as seen in the field would lead to the logical inference that the crater was of geologic origin, related in some way to the volcanic forces which have recently been active in the San Francisco volcanic field. This explanation is disturbed by the scattering boulders and fragments of native nickel-iron, totalling six tons or more in weight, which have been found surrounding the crater with concentric distribution. Since native nickel-iron is generally assumed to be of meteoric origin, it has been concluded regardless of the obvious geologic relations that the crater was formed by the fall of a large meteor. If, in reality, this iron is not meteoric but terrestrial, and if a rational theory of its origin in connection with the formation of the crater can be maintained, we will arrive at an explanation which accounts for all of the facts. A study of the technical literature on this iron shows that there is no unanimity of belief in its meteoric origin. Moissan, after making chemical analyses of many fragments of Canyon Diablo iron, questions whether it is of meteoric origin. Dr. Carl Hintze in his "Handbuch der Mineralogie" also suggests that this iron is terrestrial. Cohen, one of the foremost authorities on meteorites, as quoted by Farrington in Vol. XIII "Memoirs of the National Academy of Science" remarks that, "It is not certain whether the Canyon Diablo iron is meteoric or, like the Greenland nickel-iron, of terrestrial origin, in common with the latter it has a very low percentage of nickel, at least in portions of it a comparatively high percentage of carbon." In the same work, Huntington, another authority on meteorites, discusses the possibility of the terrestrial origin of this iron. These men are all chemists and students of meteorites rather than structural geologists. The Canyon Diablo iron carries minute diamonds and carbons, and for that reason has been an interesting subject of study to chemical investigators.

Prof. A. E. Nordenskiold and K.J.V. Steenstrup, between the years 1870 and 1884, discovered large boulders of native nickel-iron, weighing as much as twenty tons, occurring in connection with basalt flows on Mt. Ovifak, near the Island of Disco, off the west coast of Greenland. Lenticular and disc-like pieces of the metal were also found embedded in the rock. These fragments had the pitted appearance characteristic of meteorites and were long thought to be of meteoric origin, for the iron gave the Widmannstatten figures. Steenstrup found a thickness of fifty feet of basalt filled from top to bottom with iron grains as a constituent part of the rock. These grains showed Widmannstatten figures. This iron carries amorphous carbon and corundum, according to Moissan. Various suggestions have been made as to origin. Possibly it may have been present in the original magma or reduced by carbon on its path to the surface. It has been suggested that the iron and nickel may have been brought up in gaseous form as carbonyls, $NI (CO)_4$, $FE (CO)_5$, and $FE_2(CO)_7$. This suggestion has been made by C. Winkler. In this connection, it is of interest that the Mond process for the obtaining of metallic nickel depends upon the conversion of nickel in a matte to a gas, nickel carbonyl, which is later decomposed, thus depositing metallic nickel.

The great abundance of iron found in connection with the Coon Butte crater, as compared with the relatively small amount of meteoric iron found in the six hundred meteoric falls catalogued by Farrington, is a fact that requires some explanation. It is necessary to build up an hypothesis, which will account for the nickel staining of the metamorphosed sandstone in Barringer's drill holes, and the numerous small fragments of nickel-iron found in the crushed sandstones, and which will also account for the chlorine in the so-called "shale balls". Such an hypothesis is here attempted. Gaseous emanations are a common volcanic phenomenon. It is not unreasonable to suppose that nickel carbonyl, possibly iron carbonyl, carbon dioxide and chlorine, with other volcanic gases, arose from a deep-seated magma to the top of the observed anticlinal structure. Possibly these gases abstracted additional iron from the red sandstones of the Supai formation on their way to the surface and upon reaching the point of greatest weakness, where fracturing had occurred, deposited their metallic contents in the form of native nickel-iron. A later accumulation of volcanic forces, in the form of compressed volcanic vapors and gases possibly, caused an explosion in this place of weakness, forming the crater and casting out the previous accumulation of nickel-iron. Explosions in volcanic areas without accompanying extrusions of lavas to surface are well known. At several epochs in its history, the top of Mt. Vesuvius has been torn away by convulsions which have not produced lava. On July 15, 1888, the summit and sides of the Japenese mountain Kobanbai were blown off by a steam explosion. No liquid rock was ejected. The ancient lavas of this mountain have been cold for ages and the relation of the rocks to the catastrophe was wholly passive. At Lake Lonar, in India, there is a nearly circular hollow, 300 to 400 feet deep, a mile in diameter. The origin of this hollow has been ascribed to a volcanic explosion. Thus it is not unreasonable that Coon Butte crater may have had a similar origin.

The foregoing statement may account for the facts as seen. Attacking the subject from a different angle, there are many reasons which lead to the belief that the hole was not caused by a fall of meteorites. C. K. Gilbert, in 1896, as shown in an article published in "Science", Vol. 3, made a ten-foot contour map and model of Coon Butte and the surrounding area. He calculated the amount of material which had been cast out of the hole, and found that it was about 82,000,000 cubic yards; and calculated the cubic contents of the hole, which he found to be about 82,000,000 cubic yards. He shows that there could have been no introduction of 10 or 20 million tons of foreign material. The results of a magnetic survey made under Gilbert's direction showed that the earth's magnetic field was undisturbed in the vicinity of the crater. Any large mass of nickel-iron existing in the vicinity would be expected to affect the dip needle. This has later been checked by Dr. Magie as shown in Mr. Barringer's papers. On the basis of the lack of magnetic attractions, it is maintained that the meteorite or meteorites came in as a mass of fragments. Such a mass would not cause attractions. Mr. Barringer, not finding a mass of small meteorites in the center of the crater, after putting down numerous drill holes and shafts, concludes that this mass lies under the south wall of the hole. Examination of this wall leads me to believe that the formations are too regular and undisturbed there to permit of the introduction of 20 million tons of loose material in the manner which he postulates. I can see no reason for assuming that this material is out under any particular wall of the crater since the crater is so nearly symmetrical. Not finding the meteoric material in the center of the crater, it is assumed to be elsewhere. It is inconceivable that a mass of fragmental material could have been shot beneath the walls of this crater without some considerable quantity of the fragments dragging behind with the crushed sandstone, a much greater quantity than the drill holes show. It is true that Mr. Barringer finds fragments of nickel-bearing material in the course of his drilling, but that is much more reasonably accounted for on the basis of a terrestrial origin for the nickel-iron.

Dr. Magie's experiments with the pistol shots do not seem to be on a sufficiently large scale to be strictly comparable with the crater. A study of shell holes on the European battle lines might supply a proper analogy. In order to be exactly fair, it would be well to carry out experiments with craters formed by ordinary dynamite explosions, such as are used in blasting ore. Also a study of mine craters on the western front might be pertinent. The type of holes formed by such internal explosions is strictly analogous to the Coon Butte crater.

It may be that exploration for additional quantities of nickel-iron carrying platinum is considered advisable regardless of ideas as to its origin; if so, diamond drilling on the rim of the crater or at the bottom of the crater would be practicable and relatively inexpensive. Water can be obtained in one of the shafts. In my judgment, the work, which has already been done, is a true indication of the conditions which further explotatory work may be expected to reveal..

Yours very truly,

HUGH M. ROBERTS

(Copied by)
(S.M.Y.)
(Aug. 27, 1929)

GEORGE M. COLVOCORESSES
MINING AND METALLURGICAL ENGINEER
HUMBOLDT, ARIZONA

REPORT ON METEOR CRATER

AS A MINING PROSPECT

LOCATION.

Meteor Crater is in Coconino County, north central Arizona; a fair road connects with the main line of the Santa Fe Railroad at Sunshine Station six miles north of the Crater. The new State Highway between Winslow and Flagstaff crosses this road. The distance to Winslow is 24 miles and to Flagstaff 43 miles.

Construction of a branch railroad from Sunshine to the Crater would be a comparatively simple matter as the ground is nearly level until it rises on the sides of the Crater, and the estimated cost of such a line, including loading and terminal facilities, is approximately $150,000.00. With a branch line built to Sunshine, the distances by rail from the Crater will be as follows:

To Winslow	26 miles
To Flagstaff	45 "
To Smelters at	
Clarkdale	161 "
Clemenceau	163 "
Humboldt	170 "

To any of those smelters a freight rate of $2.00 or less per ton on ore from the Crater should be obtainable.

The property covered by the lease to the Meteor Crater Exploration & Mining Company consists of 2369 acres of patented land to which the Standard Iron Company holds clear title. This includes all of the ground in which it is reasonably possible that any of the meteoric material may be found and also affords a location for surface plant and townsite.

Good water is found in Canyon Diablo three miles distant and rights are included in the lease. The Standard Iron Company has built two dams across this Canyon, also a pumping station at the lower dam connected by pipe line to the Crater. An ample supply of water for present needs is thus assured and if desired later additional or higher dams could be constructed and the supply substantially increased.

TOPOGRAPHY.

The Crater rises to a height of 150 feet from a nearly level plain, 5700 feet above sea level. This plateau is cut by deep canyons formed by recent erosion, among which may be mentioned Canyon Diablo, two and one-half miles from the Crater, and Padre Canyon farther to the West.

The rock formations come to or very near the surface with little or no covering of soil, the vegetation is very sparse, consisting of native grasses and shrubs, practically no trees except a few small cedars.

CLIMATE.

The region is one of warm summers in spite of its elevation and fairly cold winters, the temperature varying from 100° above to 10° below zero. The mean annual rainfall is only eight inches and most of the precipitation as rain or snow occurs during December and January; in July and August there are heavy thunder storms covering small areas.

Very heavy winds prevail at certain seasons of the year and wind erosion is much more pronounced than that by rain or frost.

GEOLOGY.

The country consists of nearly horizontal layers of sedimentary rock. The surface near the Crater is brown Moencopie sandstone of Permian Age with a thickness of only thirty feet; below this is found the Kaibab limestone of Pennsylvania Age, some two hundred and fifty feet thick, and next 800 to 1000 feet of gray and white Coconino sandstone formed during the lower Pennsylvanian, and still lower the Supai formation of Red Beds sandstone, also classed as lower Pennsylvanian. The so-called Pennsylvanian strata in this district were formed during the Carboniferous Era.

Underlying these is the Red-wall limestone so prominent in the Grand Canyon.

The rocks around the rim of the Crater have all been shattered, displaced and uplifted by the impact of the meteoric mass, and now dip gently outward from the rim. Fragments of all the formations lying above the red sandstone are found cast up about the rim. The fact that none of the red-rock is found among these fragments clearly indicates that the meteoric mass (which was probably a compact cluster of iron meteorites or the head of a comet) did not penetrate to a depth greater than that at which this formation lies, and the fact that the formation is undisturbed below the center of the Crater precludes the possibility that the Crater was formed by any explosion of steam or gas with a deep seated origin, which would have cast up the Redbed rock and the Red-wall limestone as well as other rocks of an even lower strata.

The geology of the country surrounding Meteor Crater, unlike the geology of ore deposits in place, has no direct bearing upon the ore body itself since these rocks are in no way connected with the meteoric mass (which was of celestial and not terrestrial origin), but they merely served as a bed into which the cluster of meteorites plunged and in which it is now believed to be imprisoned. The geology is only important as indicating the depth at which the main mass of the meteorites may be expected to lie, and also the nature of the ground in which the exploration and development must be carried on.

HISTORY.

According to the late G.K.Gilbert of the United States Geological Survey the discovery of iron near the Crater was first reported by Mexican sheepherders in 1886. In 1891 samples of the iron were sent to Dr. A. E. Foote of Philadelphia who was so much interested that he visited the Crater the same year, determined the iron to be of meteoric origin, and wrote the first of a long series of scientific papers which have been published concerning the Crater, its probable origin and possible value.

Dr. Gilbert and assistants visited and examined the Crater a few months later and favored the theory that it was formed by a steam explosion rather than by the impact of a meteorite, but made no attempt to explain the presence of the meteoric material except on the very improbable theory of an accidental coincidence.

In 1902 D. M. Barringer, a Consulting Engineer and Geologist of Philadelphia, became convinced that the Crater was not only caused by the fall of a huge cluster of meteorites, but also that the meteoric mass, or a great part of it, was still buried in the vicinity. Accordingly he obtained patent to the land on behalf of the Standard Iron Company and proceeded to make careful scientific studies as well as certain explorations, described further in this report.

While many scientists have recorded the results of their studies of the Crater, Mr. Barringer's work stands out as the most thorough and complete, and he has been ably seconded by Dean W. F. Magie of the Princeton Physics Department, Professor Elihu Thompson of Boston, the late Dr. Branner of University of California, Professor Russell of Princeton and B. C. Tilghman of Philadelphia, - all of whom have substantially agreed with Barringer's conclusions. Others, including Dr. Fairchild of Rochester, Dr. Farrington of Chicago, the late Dr. Hovey of New York, Dr. Merrill of the Smithsonian, agree in the main with his opinions, while a few including the late Dr. Gilbert did not agree, but the results of Mr. Barringer's exploration work and subsequent exploration were not known to Dr. Gilbert.

If Barringer's conclusions were not accepted, then, as N.H. Darton of the United States Geological Survey says, the Crater is indeed "an enigma" and one which Science cannot afford to leave unsolved, for no other known cause could have accounted for the phenomena which have been and may be observed by any trained investigator; and in the face of these existing facts all other hypotheses as to the origin of the Crater or subsequent fate of the cluster of meteorites appear to be so far fetched as to be wholly incredible or at variance with the known laws of physics and chemistry.

OREBODY.

The orebody sought is the main mass of the meteorite, (or rather the main cluster of iron meteorites which by its impact made the Crater). The "outcrop" is represented by the thousands of members of the cluster (in reality an insignificant percentage of the whole) which were stripped off during its passage through the atmosphere, and fell around the Crater. There is no evidence that they are fragments caused by an explosion, or that they were broken off a larger body, for the majority of the pieces found had originally a smooth, rounded outline, like river gravel. This was no doubt due to the slight grinding or milling action in the mass as it moved through space - a very gentle abrasion, but continued through unimaginable lengths of time.

These outcrop fragments vary in weight from a few ounces to nearly a ton. The great majority of them have been oxidized since their fall, but hundreds of metallic, unoxidizable nuclei have been discovered; they are the well-known "Canyon Diablo" meteorites. The analyses of the two kinds of iron are about as follows:

	A. Metallic Iron	B. Oxidized Iron or "Iron Shale"
Iron......................	93 %	62 %
Nickel....................	6.4 %	3.9 %
Also small amounts of Co., P., C., S., Cu. (and Cl. in "B").		
Platinum..................	.35 oz. per ton	.20 oz. per ton.
Iridium...................	.16 " " "	.10 " " "
Also traces of Palladium, Ruthenium and Rhodium.		

At the present market prices, the average gross value of all analyses of the meteoric iron in nickel, platinum and iridium is $101.45 per ton, and for the oxidized "shale", $74.70.

There seems to be no reason to doubt that the specimens found around the Crater are typical samples of the main mass of the cluster, or that the average analyses of the whole will closely approximate the analyses of the samples so far taken. More than forty samples have been analysed, and in them the percentages of the metals vary within reasonable limits, the values ranging from $60.00 minimum to $170.00 maximum, with the average as given above. It appears very conservative, therefore, to estimate $50.00 per ton as representing the average recoverable value of the mass.

The size of the meteoric ore body cannot be determined with any degree of accuracy. It may be approximately estimated by assuming a speed for the falling meteor, and calculating the force required to accomplish the work of making the Crater. If we assume (as seems probable) a speed of three to five miles per second, then the weight of the projectile would approximate 10,000,000 tons. This would represent a spheroidal cluster of iron nodules about 400 feet in diameter. Since the Crater has about ten times this diameter at the rim, this estimate checks with the formula of artillery engineers relating to non-explosive projectiles, and it has been calculated that between 350 and 400 million tons of rock have been shattered, dislodged, and thrown out of the crater, though some of the fragments naturally fell back into the excavation.

PREVIOUS WORK.

The exploration work at Meteor Crater aside from scientific studies has consisted of the following:

A. 27 drill holes put down by the Standard Iron Company at various points on the bottom of the Crater bowl.

B. A shaft 220 feet deep sunk by Standard Iron Company near the center of the bowl.

C. A churn drill hole 1376 feet deep sunk by the United States Mining, Smelting and Refining Company from the South rim.

The results of A. and B. were negative, for while small fragments of meteoric material were found in many of the drill holes, no solid body was encountered and this fact served to strengthen the opinion formed from other evidence that the meteorite fell at an angle and lodged under the south rim, and on this theory the last churn drill hole (C.) was sunk to a point 1600 feet south of the nearest of the old holes.

The result of C. is the most important of all available evidence for undoubtedly a mass of meteoric material checked and finally stopped the drill altogether, and since many fragments of oxidized meteoric material containing nickel and platinum were brought up by the drill it seems reasonably sure that this drill penetrated the upper edge or shell of the main meteoric cluster and is bottomed close to where the greatest mass should lie. The log of this hole records that for the last 100 feet of drilling hard obstacles were frequently encountered and the sludge contained substantial quantities of magnetic iron oxide and nickel (minerals which are not found anywhere in the surrounding country rock) and its progress was finally checked by impenetrable material, which both Mr. Barringer and Mr. Plumb (the Engineer in charge of the drilling) identified as being largely meteoric (oxidized meteoric iron.)

Samples of the drill sludge (largely clay introduced for the purpose of grouting the hole) from a depth of approximately 1340 feet has been analyzed at the laboratory of the Southwest Metals Company at Humboldt, Arizona, with following results:

Sample No. 1. Drillings from which 30/40% of earthy material has been removed, contained:

Fe. 5.9%; Silica 56.6%; Nickel 0.8%.

Sample No. 2. Magnetic iron oxide, partially concentrated from the above sample, contained:

Fe. 10.8%; Silica 47.4%; Nickel 0.35%.

The samples were not sufficiently large to permit a quantitative analysis for platinum, but a qualitative analysis showed the presence of platinum minerals.

The United States Company took great care to use a drill bit containing no nickel, also the clay carried no nickel content, and accordingly, it is quite certain that neither the nickel nor platinum metals could possibly have come from either of these sources.

The relative proportion of the nickel and iron is of special importance. In the oxidized meteoric material as picked up in large quantities on or near the surface of the Crater, the average content of iron is 62% and of nickel 5.9%, the nickel therefore representing overly 1/11th of the iron content. In the sample of sludge from the drilling at a depth of 1340 feet, the meteoric material was also oxidized and relative content of nickel to iron is as 1 to 20, - the difference may probably be accounted for by the additional percentage of iron, which was worn off the drill bit, but the fact remains that the positive determination of nickel and platinum metals in the drillings is the most definite proof that has yet been found of the existence and the location of meteoric material at a substantial depth below the rim of the crater and since no small body of this nature could possibly have forced its way thru one-half mile of solid rocks we must logically conclude that the main ore body lies close to the bottom of the drill hole.

This work also established the fact that further drilling would be useless since the nature of the ground is such as to make drilling with a churn or diamond drill extremely expensive and difficult and if even a small mass of unoxidized meteoric iron should be reached neither could penetrate it to any appreciable extent or yield a satisfactory core or sludge.

PROPOSED EXPLORATION AND DEVELOPMENT.

We shall aim to build upon the work already done and start from the point where previous explorers have left off. Recognizing the futility of further drilling, and the difficulty of sinking any shaft directly above the meteoric mass, it is intended to locate a shaft some 800 feet south of the last drill hole where unbroken sedimentary formation should be encountered. To make doubly sure on this point before actually starting to sink, we plan to put down one or more diamond drill holes from the collar of the proposed shaft in order to pilot the formation and definitely determine the character of the rocks which we will encounter.

Sinking a serviceable working shaft to a depth of 1300 feet in the limestone and sandstone presents no engineering difficulty and the entire cost, including the necessary equipment and surface plant, should not exceed $150,000.00. A responsible contractor has already agreed to undertake this work at approximately this figure.

Subsequent drifting from the bottom of the shaft some 800 feet to a point directly below the bottom of the churn drill hole will involve an expenditure of not over $50,000.00, unless extremely heavy or broken ground is encountered, and we hope to obviate this possibility by drifting along or in the Redbed Sandstone, which should lie nearly in line with the bottom of the meteoric material and should be found practically undisturbed by the impact.

Assuming the meteoric mass to be reached by the cross cut, further development will naturally consist in penetrating this ore body, drifting below and around it and tapping it at intervals in order to determine its size and shape and to obtain average samples at various points. The nature and extent of this work will be largely governed by such conditions as may be found to actually exist and the same will be true concerning the subsequent method of mining. The total cost of all preliminary exploration and development should not exceed $250,000.00, but to provide for unforeseen contingencies and play absolutely safe double this amount will be available if necessary under the financial plan of the Meteor Crater Exploration & Mining Company, and the expenditure of this sum should definitely determine whether or not and to what extent the venture will prove financially profitable.

Further funds which may thereafter be spent in order to properly equip the property for mining a large daily tonnage, to provide a permanent camp and build a railroad spur from the main line of the Santa Fe will all be in the nature of an investment, the value of which can be calculated in advance with reasonable accuracy. Additional outlay for these purposes may amount to $500,000.00, but such an investment will not be in any sense speculative and need not be considered at the present time.

MINING THE ORE BODY.

The methods and cost of mining cannot be accurately forecast from present knowledge, but certain observations may be made:- The great quantity of small nodules constituting the outcrop and the evidence furnished by the churn drill, together with the statement of astronomers that the falling mass was almost certainly a cluster of small units render it probable that the ore body will resemble a bed of metallic and oxidized iron gravel, and will not be found to consist of one or a small number of huge iron fragments which could not be mined except at heavy and perhaps prohibitive expense. The small pieces of ore can be mined cheaply and efficiently and if by unlikely chance these should be found intimately mixed with rock or sand a simple gravity concentration will by reason of their relative weight effect a very clean concentration.

Also since a large proportion of the surface ore and all the meteoric fragments brought up by the drill are found to be oxidized and in the form of comparatively soft iron shale, it is logical to expect that the bulk of the main ore body will be found in similar condition which would make drilling and blasting even the largest fragments comparatively easy.

All available evidence therefore indicates that we shall find the ore in the form of a spheroid about 400 feet in diameter, probably somewhat flattened out and elongated laterally, and consisting of a compact cluster of many thousand small pieces, most of which will be oxidized and comparable to ordinary hematite.

We must expect heavy ground by reason of the shattering of the overlying rocks but mining an ore body of this character will be no more expensive or difficult than mining the copper ores of the Jerome or Bisbee districts.

No permanent water level is found in the Crater region down to a depth of 2000 feet, but the basin of the Crater and the crushed material below it would serve to accumulate a large quantity of water which might amount to several billion gallons if all the crushed area were thoroughly saturated, and/the water imprisoned in impervious surrounding strata.

Such a condition does not exist for we know that a shallow lake formely occupied the bed of the crater whereas this is now dry and no water stands in the bottom of the old shaft 200 feet below the center of the bowl.

The churn drill from the south rim repeatedly lost the water from the hole even at its greatest depth and clay had to be constantly pumped in for grouting. Apparently the water circulates freely at this depth which is probably in line with the upper portion of the ore body and the entire catchment area formed by the Crater must drain thru fissures in the rock to a lower level. Undoubtedly some water will be entrapped in pockets in the sand and broken rocks, but this will seep in to the workings very gradually and there is no reason to anticipate wet mining conditions nor an unduly heavy cost for pumping.

METALLURGY AND MARKETS.

The metallurgical treatment of the meteoric material will not be complicated and in general should follow the practice established in treating the Sudbury nickel-copper-iron ores. Sulphur in some form will be added and it will probably be advisable to mix the nickel-iron from the meteorite with copper sulphide ores, which occur abundantly within 200 miles and near to the smelters previously mentioned. The first step in smelting will then be to produce a nickel-copper matte which will be converted to a high grade then roasted and reduced and the nickel and copper subsequently separated and refined by the Orford, Mond or Hybinette process, any one of which will permit the recovery of a large percentage of the nickel and copper, and of the platinum metals.

It is probable that the iron in the meteoric material cannot be recovered with profit as it will be necessary to slag this off in order to recover the nickel, copper and precious metals, but since the smelters at both Humboldt and Clemenceau are short of iron for flux and willing to pay for it, there is every probability that excellent terms can be made for the treatment of the meteoric ore at one or both of these smelters, and that some payment can thus be obtained for the iron.

At a later date it may become advisable to erect a smelter at or near the Crater, but inasmuch as existing smelters are anxious to purchase additional custom material and could equip themselves at small expense to utilize the meteoric iron to excellent advantage in combination with their charge of copper ore, there will be no need for the Meteor Crater Exploration & Mining Company to consider any such expenditure until after its justification can be definitely determined.

Difficulty might be foreseen in arranging for the treatment of the nickel-copper matte and refining and marketing the nickel and nickel and platinum metals contained. Arizona smelters are not equipped for these operations and would not be well placed to undertake them, but for many reasons a production of nickel and platinum of domestic origin is most desirable to the trade as well as to the United States Government, and there is strong reason to believe that one or another of the companies refining and selling nickel and precious metals would be prepared to purchase the matte on advantageous terms and carry on all the subsequent operations without involving competition in the nickel and platinum markets.

As to the market for nickel, platinum and iridium, it is well known that these are among the few metals in which the United States is entirely deficient. Practically all the nickel used in the United States (which consumes the bulk of the nickel produced in the world) and also in Europe, now comes from Canada or New Caledonia, and the opening up of a commercially valuable body of nickel ore in the United States would have a very substantial military as well as commercial value.

The world's production of nickel in 1924 was close to 40,000 short tons, as compared to 8,000 tons in 1900 and 28,000 tons in 1910, before the war temporarily stimulated the price and demand.

The United States consumption of nickel is almost 20,000 tons per annum and appears to increase normally each year at the rate of approximately 10%.

An output of 500 tons per day of Meteor Crater ore of expected average grade would yield 9000 tons of nickel per annum. If this quantity of metal were produced from any foreign source it would certainly fail to find a market without keen competition and reduction in selling price, but produced from domestic ores and representing the only substantial domestic production it is quite certain to be readily absorbed by the United States market through reduction in imports and probably without any lowering of the selling price, which is quoted at 35¢ per pound, although a substantially lower figure is obtained on large contracts and is taken into consideration in estimating the recoverable value in Meteor Crater ore.

Platinum, alloyed with iridium, has also become a metal vitally important for commercial and military purposes with the development of the radio and the aeroplane, and a serious shortage of platinum exists and will probably continue to exist as long as the Soviet government controls the supply previously obtained from Russia. Iridium is principally used as an alloy of platinum and is almost always found in conjunction with platinum but in very small quantities, and here also there is a shortage.

The world's annual production of platinum metals is about 150,000 troy ounces, the annual demand is over double this amount, but a great portion of the consumption is recovered from secondary sources. The yearly output of the Crater producing 500 tons of ore per day would be some 54,000 ounces of platinum and iridium, or say 30% of the United States consumption. The markets for platinum and iridium are very sensitive and so large an increase in normal production would unquestionably result in reducing the present market prices, which condition is also given due weight in figuring the recoverable value of Meteor Crater ore at only $30.00 per ton as compared to $65.00 per ton at present market prices.

WORKING COSTS AND PROFITS.

From data available, the average of the main meteoric mass can be estimated from the surface and drill samples as stated above, to have a probable recoverable value in nickel, platinum and iridium(excluding altogether the iron) of $30.00 per ton. It is impossible to know that the main mass has a similar composition to the specimens found or to estimate what percentage of this mass may be reduced in value through oxidation or enriched through reconcentration, but all available evidence would indicate that the estimate of $30.00 is conservative as to any expected tonnage and also that the mass may be reasonably expected to weigh in the neighborhood of 10,000,000 tons.

The cost of operating at Meteor Crater will involve several variable factors, but after a branch line is constructed to the railroad and the property fully equipped for economic operation, the following estimate is submitted as making due allowance for all probable contingencies:

	PER NET DRY TON OF METEORIC MATERIAL.	
	(a) If mass is found in soft and oxidized condition	(b) If mass is found to be hard metallic iron nodules.
Mining and Hoisting, including current development	$ 5.00	$ 10.00
Freight to Smelter at Humboldt, Clarkdale or Clemenceau (allowing for moisture)	2.25	2.10
Smelter toll to smelt to matte (allowing credit for iron flux)	4.50	3.90
Converting to high grade matte	1.00	1.00
Separating and refining nickel, including roasting and reduction of matte	3.00	3.00
Separating and refining Platinum and iridium	3.00	3.00
General Expense, overhead, taxes and marketing metals	2.00	2.00
	$ 20.75	$ 25.00

The average content of the material (as indicated by surface samples) and estimated recoveries in commercial form are as follows:

AVERAGE CONTENT

Iron	80 to 90%	recover		No value except for flux.	
Nickel	5.84%	recover	90% @ $	.30 Per lb.	$ 31.50
Platinum	0.278 oz.	"	0.2 oz. @ $106.00	Per oz.	21.20
Iridium	0.122 oz.	"	0.1 oz. @ $120.00	Per oz.	12.00
Recoverable value on basis of present prices					$ 64.70

(Note:) In estimating the recoverable value at only $50.00 per ton in the body of this report, allowance is made for probable reduction in value through drop in the present market prices of the metals contained.

It will be noted that while the working costs are expected to be somewhat higher if much of the mass is found to be still metallic, the values will also in that case be correspondingly greater. That most of it will be in this condition is an unlikely contingency, for the following reasons:

(a) A large majority of the material found around the Crater, on account of its chlorine content, was readily oxidizable, and is now in the form of "iron shale".

(b) There is perfectly free circulation of oxygen-bearing water through the ore-body, as proved by the last drill hole.

(c) The meteoric material brought up from this hole was all oxidized.

If a large percentage of the mass is still in the form of metal, much of it is expected to be in small enough pieces to handle without difficulty. Larger pieces can be drilled and blasted with high explosive, or cut with an oxy-hydrogen torch, altho such operation would be very expensive and inconvenient.

GENERAL SUMMARY.

Considering Meteor Crater as a mining prospect the surface indications, results of drilling and all other available evidence and the application in so far as possible of the principles of astronomy, geology, physics, chemistry and mathematics point to the probable existence at a depth of less than 1500 feet of a very large and valuable orebody.

The outcrop consists of the many thousand fragments of meteoric material found on the surface or mixed with the debris from the great hole. The location of the orebody is definitely indicated by the last churn drill hole, the size must be approximated from the work performed in digging itself into the earth and displacing so huge a quantity of solid rocks.

The character and value of the ore body are assumed from analysis of the outcrop samples which should in this case be representative of the main mass and checked by all the data and samples obtained from the last drill hole.

The facts set forth as such in this report can be verified by personal examination of the premises or by inspection of well - authenticated records. The deductions made from these facts and the assumptions are matters of opinion and the reasoning which leads to the conclusion that this orebody exists as described and at an approximately known point, cannot be proved or disproved until the proposed exploration has reached a definite state of progress involving the expenditure of not less than $250,000.00 and perhaps a maximum of double that amount.

The justification of this exploration cannot be found in any known principles of ore deposition, since this ore deposit is of celestial origin and so far as we now know it is absolutely unique and has no counterpart on the surface of our globe.

The total aggregate cost of exploration, development, equipment and providing railway facilities should not exceed $1,000,000.00 and the last half to three quarters of this expenditure need only be made when and if positive evidence is available regarding the size, value and suitability for profitable mining of the meteoric mass.

The terms of the 99 year operating lease will provide for the repayment of all the initial expenditure for development and equipment from 75% of the net profits of operating when and if the same are earned, after which, assuming that this repayment is made, the owners of the property and the Exploration Company will divide the remaining profits on a 35-65 basis, 35% to the owners and 65% to the Exploration Company.

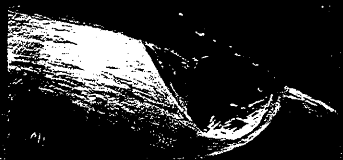
The gamble in this investment is represented by the purchase of the Preferred Stock (with its practical bonus of Common) to the total amount of from $250,000.00 to a maximum of $500,000.00. This purchase will be purely speculative and returns may be nil, or as indicated above the Preferred Stock may be redeemed with interest and the owners of same by virtue of their holdings in the Common Stock, may further divide profits amounting to over $130,000,000.00 or more than $10,000.00 per share of Preferred Stock, including of course, the value of the shares of Common Stock which will be a bonus to the second subscription to be made only after the size and the commercial value of the mass is proved.

This speculation differs from most ventures in mining prospects because win or lose financially it will have a real scientific value, and the results will surely be extremely valuable from a scientific standpoint and contribute materially to our knowledge of astronomy and geology. Wholly aside from this all the available evidence presented by the physical facts and logical deductions therefrom in my opinion amply justify the development of this prospect and the financial risk involved, which should be taken only by those who are able and willing to speculate and who are glad to avail themselves of the opportunity to follow up this fascinating exploration with its attendant scientific value and probability of so large a financial reward.

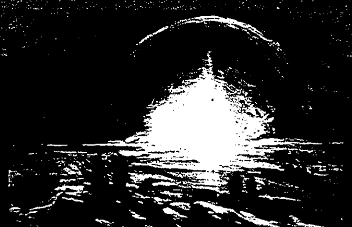
(Signed) G.M.Colvocoresses,

Humboldt, Arizona.
December 27, 1926.

Attached map showing outline of Crater, probable location of ore body and proposed exploration work.



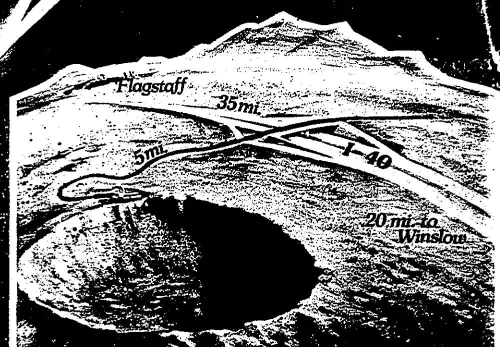
Imagine a giant meteoric mass weighing millions of tons, plummeting toward Earth at a speed of nearly 45,000 mph.



. . . Impacting from a near-vertical descent with an explosive force equal to 15 million tons of TNT, displacing over 300 million tons of rock and destroying all plant and animal life within 100 miles.

And even today, 30,000 years after its devastating [illegible]t, Meteor Crater remains a gaping chasm 570 feet in [illegible] (sufficient to engulf a 60-story skyscraper) and over 3 miles in circumference. The floor is large enough to accommodate 20 football fields side by side.

METEOR CRATER. Truly this planet's most penetrating Natural Attraction.



Meteor Crater exit is just 40 miles east of Flagstaff and 20 miles west of Winslow on I-40, only hours to 8 National Parks and 19 National Monuments.
Open year 'round:
May 15 thru Sept. 15—6AM to 6PM
Sept. 16 thru Nov. 14—7AM to 5PM
Nov. 15 thru Mar. 15—7:30AM to 4:30PM
Mar. 16 thru May 14—7AM to 5PM
Admission charged

For additional information:

1988 - NJN

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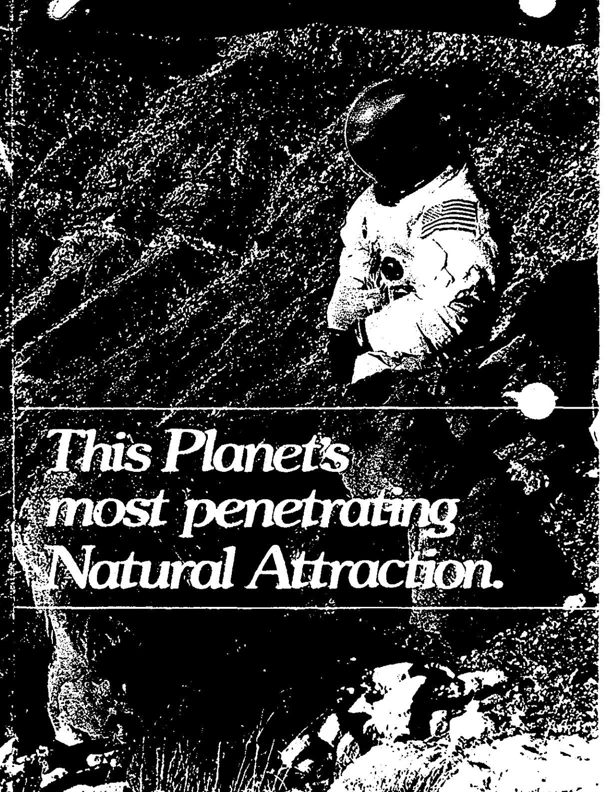
Meteor Crater Enterprises 121 E. Birch, Flags[illegible] AZ 86001
Telephone (602) 774-835[illegible]

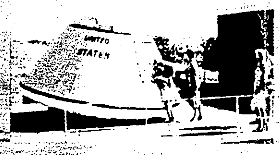


This Planet's most penetrating Natural Attraction.

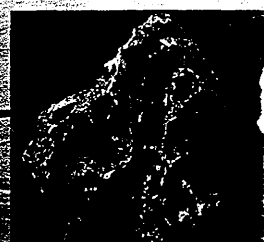
Walk in the footsteps of the U.S. Astronauts.

Meteor Crater is the best-preserved impact site on earth, with topographical terrain that closely resembles the surface of the moon and other planets. So closely, in fact, that NASA designated Meteor Crater as the training site for *all* U.S. Astronauts, for learning crater mechanics, thus enabling them to recognize impact cratering on the moon's surface.

The Astronaut Hall of Fame is a fascinating exhibit depicting man's exploration of space and honoring the brave Americans who have journeyed there.

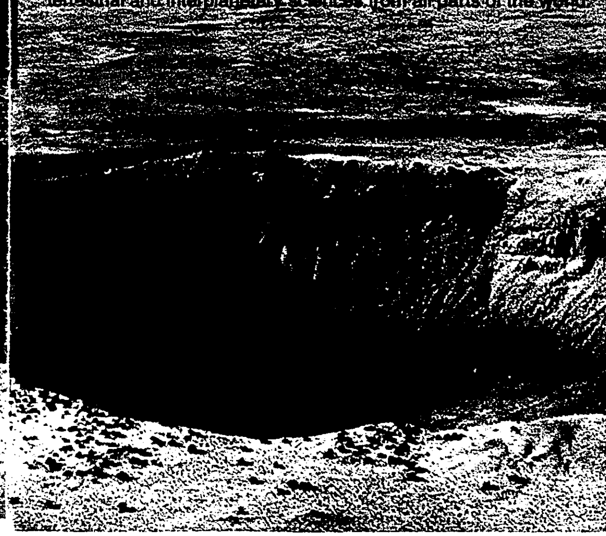


Walk where the Astronauts trained. See an actual NASA [illegible]



Experience the magni[illegible] best-preserved crater.

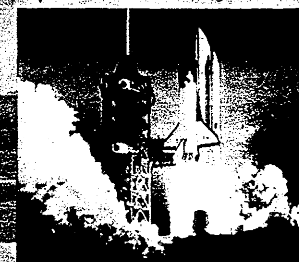
The breathtaking view from the [illegible] the depths of Meteor Crater is like taking a step into [illegible] feet deep and nearly a mile across, this giant crater [illegible] 30,000 years ago by a nickel-iron meteor more dense than any material found on earth, traveling through space at nearly 45,000 mph. Designated a Natural Landmark, Meteor Crater is understandably one of the most popular [illegible] attractions in northern Arizona, and is visited annually by tourists and those interested in terrestrial and interplanetary sciences from all parts of the world.

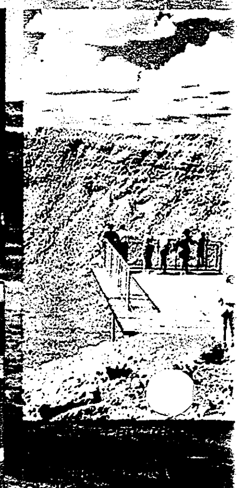


See one of the finest astrogeological exhibit[illegible] in the world.

Meteor Crater's Museum of Astrogeology provides visitors an easy-to-understand history and background of its origin and importance in the study of Earth and Space sciences. Films and exhibits vividly portray how the meteor impacted [illegible] devastation that resulted. Awesome meteorite fragmen[illegible] including the largest ever found in the area, are on display for visitors to see and touch.

Fine gift and lapidary shops, plus a delightful coffee shop, insure that your visit to Meteor Crater will be a most memorable experience.





[illegible] provides an excellent area for relaxing or picnicing.

METEOR CRATER SILICA SAND

Stanford Research Institute

April 1954

I - Geology file

STANFORD RESEARCH INSTITUTE

STANFORD, CALIFORNIA

Ariz Development Board
1500 W Jefferson

April 1954

THE MARKET FOR METEOR CRATER SILICA SAND IN ARIZONA AND SOUTHERN CALIFORNIA

by

Thomas A. Mainwaring

SRI Project 998

Prepared for

Barringer Crater Company
Philadelphia, Pennsylvania

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Weldon B. Gibson

Weldon B. Gibson, Director
Economics Research Division

FOREWORD

This study of the market for Meteor Crater silica sand was conducted by Thomas A. Mainwaring, project leader, and William E. Spaulding. Dr. William D. Smiley assisted on certain phases of the work.

The Institute wishes to acknowledge the assistance and cooperation received from many users and distributors of silica sand, as well as individuals associated with other organizations located in Arizona and California.

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Section I

INTRODUCTION

Meteor Crater Silica Sand Deposit

The Barringer Crater Company is the owner of a considerable acreage of land in Northern Arizona on which the Meteor Crater is located. A large deposit of silica sand is adjacent to the south rim of the Crater on land owned by the Company. This deposit has been worked on a relatively small scale from time to time in the past. At present, however, the sand deposit is not being operated.

The Crater sand deposit is located south of U. S. Highway 66 at a point approximately 43 miles east of Flagstaff and 15 miles west of Winslow. The most recent operator of the Crater deposit loaded the sand into trucks at the deposit. The trucks traveled north a distance of 1.8 miles of dirt road and 4.8 miles of paved road to the intersection with Highway 66, then proceeded north over 1.1 miles of dirt road to a rail siding on the Santa Fe tracks known as Sunshine Station. The total distance from the sand deposit to the rail siding is 7.7 miles. Sand processing and loading equipment is located at Sunshine Station. The equipment includes pulverizing, screening, and conveyer equipment.

Objectives of the Study

The general objective of this study is to analyze the market for Crater sand in a manner which will assist in ultimately determining the economic feasibility of operating the deposit and marketing the sand in Arizona and Southern California. The specific objectives of the research work are:

1. To determine the size of the market for silica sand by geographical area; by type of sand, i.e., physical and chemical specifications; and by value of sand.

2. To ascertain present sources of supply and marketing channels used in serving the market.

3. To estimate the portion of the market which might be obtained by Crater sand.

4. To determine the maximum production costs allowable at the Crater sand deposit.

The objectives outlined above cover only an investigation of the market. The Institute recognizes the need for additional research work. The availability of the Institute's facilities for such work has already been discussed with the Barringer Crater Company. The additional research would consist of a technical and economic study of the sand deposit and the operations which would be required to produce marketable sand. The research work might include exploration, drilling, and sampling of the deposit for the purpose of determining the character and extent of the sand; determination of the most economical methods of processing the sand to meet market requirements; preparation of preliminary flow sheets, capital cost estimates for facilities and processing equipment, and preliminary estimates of processing and other operating costs.

Method and Sources

The first phase of the research work consisted of a short period devoted to indoctrination of the project team with the subject and to a literature search for information which could be utilized during the study. During this period the sand deposit was visited and information regarding former operations of the deposit was obtained from a number of sources in Phoenix.

The great bulk of research time and effort was utilized on work in the field for the purpose of gathering original information required for the study. In most cases information was obtained during personal contacts with organizations located in the market areas, although in a few instances contact was made by telephone. Because of the time and distance involved, a limited number of contacts were made by mail with organizations in Arizona located at a considerable distance outside the Phoenix area. Interviews were conducted by Institute members primarily with users and distributors of sand and with industrial associations. Including preliminary work in Northern California, information was obtained by Institute members from about 70 organizations located in California and 20 organizations in Arizona.

Information obtained during interviews with users of silica sand was recorded on pretested questionnaire forms. However, the discussions with users were not limited to specific questions, and the market investigators obtained much additional information which was utilized in the study and appears in this report.

All major glass manufacturers in the Southern California area were personally contacted. Estimates of sand consumption received from sources believed to be reliable were used in the case of a few small glass manufacturers. Estimates of total sand utilization by other industries in the area were either obtained from industry sources considered to be reliable or were made by projection of data obtained by the Institute during interviews conducted among a sample of members of the industries. These estimates were later reviewed for accuracy by leading sand distributors. With the assistance of these distributors, a few revisions were made to the preliminary estimates.

With one exception, data regarding the Arizona market were obtained directly from users and distributors of sand. Information was not received from the largest foundry in Arizona. The reluctance of this company to divulge information regarding its sand use is understandable in light of its dominant position in the industry in the area. The method utilized in arriving at estimates of the amount of sand consumed by this foundry is described later in the report.

Assumptions and Definitions

The market for sand covered in this study includes only that portion of the market consisting of sand whose value delivered in the market is equal to or exceeds the cost of transporting Crater sand to the market. In defining the market for sand it was assumed that Crater sand cannot compete with sands having a value delivered in a market lower than the present cost for transporting Crater sand to the market. This assumes that the amount of any reduction in freight rates for Crater sand, which might be possible through negotiations with carriers, will not be greater than the cost of mining, processing, and loading the sand into freight cars at Sunshine Station.

Excluded also from the study are those sands with which Crater sand cannot compete for a certain use. For example, certain feldspar sands, although containing a substantial portion of silica, are purchased for their high alumina content. The portion of feldspar sands purchased for such uses therefore is not included in the study. The alumina content of Crater sand is known to be relatively low.

Prices used as producers' prices f.o.b. deposit represent producers' net sales prices, i.e., the value of the sand to the producer after payment of commissions to sales agents and distributors. In most cases agents and distributors assisted in developing the net prices; but in a few cases estimates were used. In the case of direct sales by producers, however, no adjustment was made for the cost of sales.

The net-back value of a particular sand f.o.b. Sunshine Station is equal to the present value of the sand delivered in the market less the cost of transporting the sand to the market from Sunshine Station.

Section II

SUMMARY AND CONCLUSIONS

Size of the Market

The market in Southern California for sand and silica flour whose values in the market are equal to, or exceed the cost of, transporting Meteor Crater sand to the market is estimated at 156,500 tons of sand and 23,500 tons of silica flour annually. Sand consumed in the market which is obtained from captive deposits or those operated by a company closely associated with a consumer is not included in these figures.

The market for high cost sand and silica flour in Arizona, on the other hand, is small. It is estimated that 2,400 tons of sand and 600 tons of silica flour comprise the market annually in Arizona.

Market Requirements

The acceptability of sand in the market, aside from considerations of cost, is determined chiefly by its chemical and physical qualities. Market requirements, both chemical and physical, are exacting; chemical and physical qualities required in sand vary considerably by type of use. Certain industrial uses for sand, however, account for important segments of the Southern California market. Glass manufacture, foundry work, ceramics manufacture, and cleanser manufacture are among the important uses for sand and silica flour.

Cost of Supplying the Market

Two factors chiefly influence the cost of supplying sand to the market. One of these is mining and adequately processing the sand to meet market requirements, both chemical and physical. The other factor is transporting sand to the market. Because sand is a relatively low value commodity, distance between the source of supply and the market is of great importance.

Deposits of sand naturally suitable for many of the uses requiring high cost sand are not advantageously located for economically serving the Southern California and Arizona markets. As a result, sand from Nevada and eastern states are used in each of these markets.

In recent years California users and suppliers have been successful in lowering the cost of sand for certain uses through adequately processing local California sand. Processing California sand, although it involved changing the chemical composition, has been more economical than transporting sand from out-of-state sources.

Market Outlook

The success of some sand users and suppliers in economically processing California sand for certain uses has stimulated interest on the part of other users and suppliers in finding closer sources of supply for the Southern California market. At present, another supplier is planning to install processing equipment for California sand at an early date. Some of the experienced Southern California sand users and suppliers are of the opinion that more California sand can be processed economically for certain uses than is now being done. If this proves to be the case, the market value of sand for one or more important segments of the market will be reduced.

The Outlook for Meteor Crater Sand

As indicated in the Introduction, conclusions regarding the economic feasibility of supplying the Southern California and Arizona markets with Meteor Crater sand are beyond the scope of the market study. Additional research work, described in the Introduction, is required to determine if sand suitable for the market could be produced profitably at Meteor Crater within maximum price limits shown in this report.

The following conclusions can be drawn from this research work.

1. The Meteor Crater deposit is advantageously located for serving the Arizona market, but this market is small. Future industrial development of Arizona, however, may provide an attractive market for Crater sand.

The deposit is not advantageously located for serving the bulk of the market. Of the 158,900 tons of sand comprising the Southern California and Arizona markets, only 14,400 tons are supplied from sources located at greater distances from the markets than Meteor Crater. A substantial portion of the 24,100 tons of silica flour, however, is supplied from deposits located further from the markets than Meteor Crater. A flour from a closer source of supply in California is now attempting to penetrate the market at a lower price. Silica flour processed from California sand, however, has been unsatisfactory for use in household cleanser manufacture because its color is too dark. Silica flour used by Southern California cleanser manufacturers is produced in Illinois and Oklahoma. A large cleanser manufacturer in Southern California is of the opinion that silica flour suitable for use in household cleanser can be produced from Crater sand. The consumption of silica flour by cleanser manufacturers is 13,000 tons a year, representing about one-half of the total silica flour market in the area.

Only 14,400 tons of sand have higher freight rates to the markets than the freight rates from Sunshine Station. In order to compete for the remainder of the market, therefore, Meteor Crater sand would have to be sold at lower prices f.o.b. deposit than sands presently used. Somewhat less than 24,100 tons of silica flour have higher freight rates to the markets than freight rates from Sunshine Station.

2. Meteor Crater sand probably must compete for markets with other sands on a price basis. The qualities of Crater sand which have been ascertained to date are not those for which an extraordinary demand exists in the market areas covered by the study. Moreover, with the exception of the cost of sand, buyers in these markets are satisfied with the sands they now use.

3. Based on the various uses investigated, it appears that processing of Meteor Crater sand to alter grain size distribution is required to prepare it for the market. Some partially processed Meteor Crater sand has been marketed in the past. This met the chemical requirements for glass manufacturing, but did not meet the physical.

4. An attractive market for Crater sand in the future might result from greater use of the shell molding process in foundries. Grains of sand used in shell molding generally are finer than those used in sand molding. Foundries using the shell molding process may be more selective in respect to grain size ranges and may use more ranges. The available analysis of Crater sand shows that the sand has a wide grain size range and a relatively large portion of fine grains.

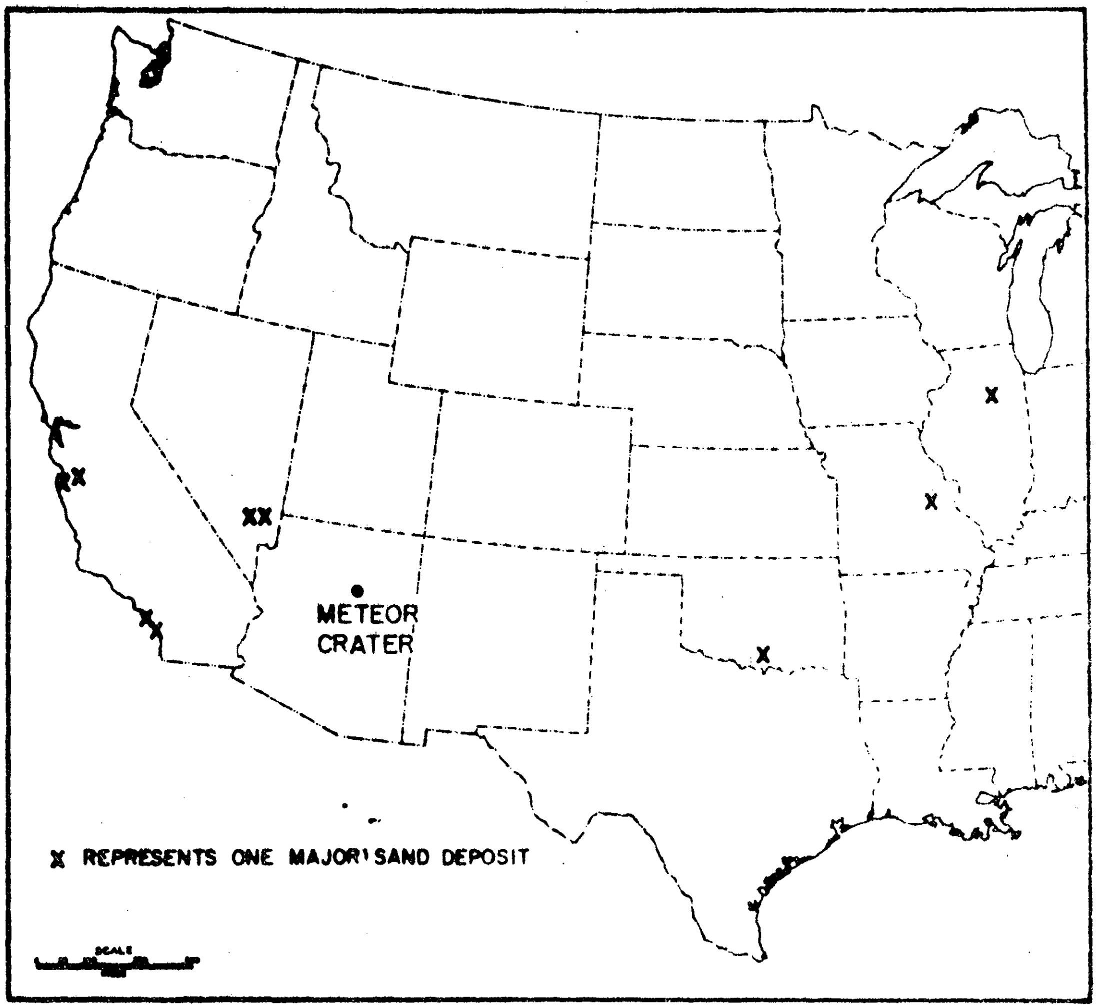

EXHIBIT I

LOCATION OF MAJOR SAND DEPOSITS SUPPLYING THE ARIZONA AND SOUTHERN CALIFORNIA MARKETS

A-998-1

Section III

THE SOUTHERN CALIFORNIA GLASS SAND MARKET

Utilization of Silica Sand

Silica sand is an important raw material used in the manufacture of glass. Approximately 70 percent of the content of finished glass produced in Southern California consists of silica. The silica content of the basic sand used by Southern California glass manufacturers included in this study is approximately 99 percent.

At present two basic sands are used by Southern California glass manufacturers. One of these is a high silica sand produced by two organizations in the Overton district of Nevada. The other sand is produced at a deposit in Corona, California, which is operated by the Owens-Illinois Glass Company. Considerably smaller amounts of sand from Del Monte and Oceanside, California, are added to the Nevada sand for the purpose of raising the alumina content of the glass because these California sands are relatively high in alumina. It is more economical to use these sands for their alumina content than to use feldspar from Arizona.

Marketing Channels

The Southern California glass sand market considered in this study is supplied directly by silica sand producers. Sand is delivered to glass manufacturers in bulk shipments of carlot quantities. The exception to this rule is that one or two small specialty glass manufacturers are supplied by truckload deliveries from distributors' stocks. The amount of sand supplied in this manner, however, is insignificant.

Buyers' Attitudes and Habits

Buyers of Nevada silica sand, which, as explained later, is the only glass sand that might be displaced by Crater sand, are satisfied with the quality of the material and the service provided them by Nevada producers. It was reported that there probably are not any long-term contracts between Nevada producers and glass manufacturers. Buyers are greatly interested in obtaining glass sand at lower cost. However, it is indicated that in order to induce them to change suppliers, a substantial price advantage must be offered by a new supplier. Some of the glass manufacturers are anticipating substantially lower glass sand prices in the future. The opinion of some buyers is that Crater sand cannot be marketed economically in Southern California as glass sand because of the high transportation costs involved in getting it to the market. The present freight rate for sand from Sunshine Station to Los Angeles is $5.21 per ton in closed cars, including the federal transportation tax. The Crater deposit has been investigated by at least one glass manufacturer interested in operating its own deposit but has been rejected because of the relatively high estimated total cost of operation and transportation.

Experience with Crater Sand

During the most recent operation of the Crater sand deposit, the sand was sold to Ball Brothers of California, a manufacturer of glass containers located in Los Angeles. Ball Brothers assisted in this study by providing an account of its experience with Crater sand.

According to an executive of the company, the Crater sand received by Ball Brothers was well suited chemically for all types of glass manufactured in the Southern California area. However, the sand was unsatisfactory physically for use in making glass because of its high content of fines. About 17 percent of the Crater sand received by Ball Brothers passed a 200-mesh screen and 5 to 7 percent passed a 325-mesh screen. Fines passed out the plant's stack in an amount which exceeded the limit of dust output permitted by the smog control authorities. Ball Brothers was required to reduce its output of dust and did so by changing its source of supply of sand.

Ball Brothers provided the following physical and chemical analyses of Crater sand which the company received. The screen analyses represents an average for a substantial number of cars.

Physical Analysis		Chemical Analysis	
+40 mesh	= 2.6%		
+80 mesh	= 47.9%	SiO_2	= 98.7 %
+100 mesh	= 13.7%	Al_2O_3	= 1.3 %
+150 mesh	= 12.5%	Fe_2O_3	= 0.05%
+200 mesh	= 6.2%	CaO	= 0.04%
-200 mesh	= 17.0%		
	99.9		

Market Data

As explained previously, Del Monte and Oceanside sands are purchased by Southern California glass manufacturers expressly for their alumina content. Crater sand cannot compete with these sands for this use. Del Monte and Oceanside sands, therefore, are excluded from the market data.

Certain glass manufacturers in Southern California are supplied by a deposit operated at a manufacturer or a deposit operated by a company linked through common ownership. Investigation shows that the glass sand consumption of these companies cannot be considered part of the market for a potential supplier of Crater sand. The consumption of these companies, therefore, is excluded from the market data. The remaining glass sand used in Southern California is produced in Nevada.

Market data shown in Exhibit 2 represent the consumption of five glass manufacturing companies and one manufacturer of sodium silicate, or water-glass, whose sand consumption is included in the table in order to prevent detailed information regarding this company from being revealed. The five glass manufacturing companies include one manufacturer of figured and wired flat glass, and four manufacturers of glass containers. The estimated annual consumption of a new glass container plant now under construction is included in the market data. Since this company has not yet begun manufacturing operations, its sand requirements are considered to be potential business for a supplier of Crater sand. The estimate of this company's requirements is split between the two Nevada suppliers appearing in Exhibit 2 because at the time this company was contacted its sand supplier had not been selected. There are no manufacturers of clear flat glass located west of Arkansas; all clear flat glass used in the western states is shipped into the area from eastern states or foreign countries. If in the future, western consumption of clear flat glass should be supplied by Southern California producers, the market for silica sand would, of course, be considerably increased.

Plans of the Crystal Silica Company may have considerable effect on the future glass sand market in Southern California. This company is the owner of a sand deposit located at Oceanside, California, which is reported to be of considerable size. For a period of years, the company has been a supplier of sand used chiefly for building purposes. As noted earlier, Crystal Silica sand now is used to a limited extent in glass manufacture. The company plans to become a major supplier of sand for clear glass manufacture.

According to an official of the Crystal Silica Company, who was interviewed during this study, Oceanside sand is similar in characteristics to Corona sand. The company believes that with adequate processing its sand can be used.in the manufacture of clear glass, as Corona sand is. The Crystal Silica Company executive stated that the company already has committed itself to build the new processing plant. With a freight rate of $1.48 per ton from Oceanside to Los Angeles, it is estimated that this company may be able to deliver glass sand in Los Angeles for about $6.00 per ton. This assumes that the sand will be acceptable to glass manufacturers and that production will be at a sufficiently high level. There is considerable interest among Southern California glass manufacturers in the Crystal Silica plan and some people believe that the plan may be workable. These people are of the opinion that satisfactory clear glass might be produced from processed Oceanside sand although the chemical composition of the glass would be different from that now produced using Nevada and Del Monte sands.

The present price of Nevada glass sand, as shown in Exhibit 2, is $3.80 f.o.b. deposit. This price reflects a recent decrease of $0.50 per ton. The reason for the price cut was not definitely learned. Some members of the glass and sand industries think that

Exhibit 2

GLASS SAND MARKET DATA
SOUTHERN CALIFORNIA

Representative Sands Used: Screen Analysis	Representative Sands Used: Chemical Analysis	Representative Producer	Shipping Point and f.o.b. Value per Ton	Estimated Annual Consumption (tons)	Value per Ton in Carlots in Los Angeles[1]	Net-back Value per Ton f.o.b. Sunshine Station in Carlots
+ 40 mesh = 2.0% + 80 = 38.0 +100 = 21.0 +150 = 30.0 +200 = 7.0 -200 = 1.5	SiO_2 = 99.4% Al_2O_3 = 0.45 Fe_2O_3 = 0.04 CaO = 0.03	Nevada Silica Sand Co., Inc.	Glass Sand, Nevada $3.80	56,000	$ 7.12[2]	$ 1.91[2]
+ 20 mesh = 0.0% + 40 = 6.0 + 60 = 22.2 +100 = 41.2 +150 = 25.5 +200 = 4.3 -200 = 0.9	SiO_2 = 99.3% Al_2O_3 = 0.5 Fe_2O_3 = 0.05 TiO_2 = trace CaO = trace MgO = trace Na_2O = trace K_2O = trace	The Nunn Co.	Mead Lake, Nevada $3.80	25,000	$ 7.12[2]	$ 1.91[2]
			Total	81,000		

1/ Includes price f.o.b. shipping point, freight rate in carlots, and 3% federal transportation tax.
2/ Based on closed car shipments of bulk sand.

the objective of the price reduction may have been to discourage the Crystal Silica Company in its plan to market sand for clear glass manufacture.

Summary

The glass sand market open to Crater sand in Southern California represents the largest and most concentrated single market in the area included in the study. Six companies annually consume a total of 81,000 tons of silica sand having a net-back f.o.b. value at Sunshine Station of $1.91 per ton. Should the plans of the Crystal Silica Company to supply the glass sand market from its Oceanside deposit materialize, the net-back f.o.b. value of Crater sand at Sunshine Station would decrease to about $0.80 or less a ton.

Crater sand has been proved to be chemically suitable for glass manufacture. Physical processing is required, however, to eliminate a high content of fines which prevent its use in the Los Angeles area due to the smog situation. All glass manufacturing plants in the area covered by this study are located in, or close to, Los Angeles.

If Crater sand were processed sufficiently to meet glass sand market requirements, the offer of a considerable price reduction to buyers probably would be required in order to capture a substantial portion of the market. Buyers would be reluctant to change suppliers unless a substantial price advantage is offered.

Section IV

THE SOUTHERN CALIFORNIA FOUNDRY SAND MARKET

Utilization of Silica Sand

Silica sand is utilized in the production of castings in steel, malleable iron, gray iron, and nonferrous foundries. The major uses for the sand are in molds and in cores. Relatively small amounts of sand are used for furnace bottoms, openers, and tappers in steel foundries.

High silica sand is especially desired for the casting of steel. Iron and nonferrous foundries use high silica sand, but in these foundries sands with lower silica content also are used. Grain size and uniform distribution of grain size of sand are important in foundry work chiefly because they affect the permeability of the mold. Fines in the sand are undesirable because they tend to lower the permeability of the mold. Gas which cannot escape may cause holes in the castings. Sand grains which are round in shape are considered to be superior to those which are angular because angular-shaped grains can pack more closely, resulting in decreased permeability of the molding sand. Sand whose grains contain fractures are not desired for foundry use because heat from the metal may split the grains at the fractures resulting in undesirable fines. Finer grain sizes, however, may be used in the shell molding process, a process which may increase in importance in the future. It is indicated that the shell molding process may result in foundries becoming more selective in regard to sand size ranges and in more size ranges being used in the future.

As more sand reclaiming equipment is installed in foundries, the consumption of silica sand will decrease. However, if use of the shell molding process should become widespread, an increase in foundry sand consumption may be expected. To date no economical method for removing the resin binder from sand used in shell molding has been developed. Sand used in shell molding, therefore, cannot be reused, as is often the case with sand used in sand molding.

Marketing Channels

In the Southern California area the market is supplied chiefly by producers' sales agents and jobbers of foundry materials. Most foundry sand is delivered to foundries in bulk shipments, although some sand is delivered to foundries in sacks.

Buyers' Attitudes and Habits

Most of the buyers visited during the field work are satisfied with the foundry sand they now are using. A few buyers mentioned that they are interested in obtaining lower cost sand. Uniformity of sand is highly desirable. Under these conditions there probably is considerable reluctance to change from use of a sand which experience has shown to be workable unless considerable superiority in a new sand can be demonstrated or a considerable savings in cost can be realized by the buyer.

Experience with Crater Sand

Meteor Crater sand has been offered to foundry supply distributors and to foundries in the past. According to two distributors, Crater sand was not suited for foundry use because of its high content of fines; two foundries which used sand from the Crater experienced difficulties with the sand because of the high fines content. One of the difficulties was that three times the amount of linseed oil added to a given amount of Ottawa sand used for cores in steel casting was required for the same amount of Crater sand. Thus, because of the cost of linseed oil, it is expensive to use Crater sand in cores for steel casting.

One of the distributors believes that the shape of Crater sand grains is not well-suited for foundry use. According to the same distributor, the fusion point of Crater sand is too low for foundry use. Another source reported that Crater sand broke down under the heat required for steel casting but withstood the heat required for iron and nonferrous casting. Examination of Crater sand shows the presence of fractures in the grains.

Market Data

The foundry sand market in Southern California considered in this study includes only foundry sand which has a value of $5.21 or more per ton delivered in carlots in the market. The present freight rate from Sunshine Station to Los Angeles is $5.21 per ton in closed cars, including the federal transportation tax. Naturally bonded sand, i.e., sand with considerable clay content, is excluded from the market figures because such sand is purchased expressly for its bonded qualities.

Market data for Southern California, as summarized in Exhibit 3, were arrived at with the assistance of leading foundry sand distributors in Los Angeles after preliminary estimates had been made by the Institute based on information obtained during personal interviews conducted among a sample of the foundries. In the Southern California area there are about 14 steel foundries, 57 malleable and gray iron foundries, and a considerably greater number of nonferrous foundries.

It can be expected that if the Crystal Silica Company should be successful in producing and marketing sand for use in clear glass manufacture, it will attempt to produce and market sand for use in foundries in Southern California. It is not possible within the scope of this study to ascertain the type of foundry sand which might

Exhibit 3

FOUNDRY SAND MARKET DATA
SOUTHERN CALIFORNIA

Consumption in Steel Foundries

Representative Sands Used: Screen Analysis	Representative Sands Used: Chemical Analysis	Representative Producer	Shipping Point and f.o.b. Value per Ton	Estimated Annual Consumption (tons)	Value per Ton in Carlots in Los Angeles[1]	Net-back Value per Ton f.o.b. Sunshine Station in Carlots
+ 30 mesh = 0.0% + 40 = 2.5 + 50 = 28.8 + 70 = 38.1 +100 = 21.7 +140 = 7.0 Pan = 1.9	SiO_2 = 99.7%	Standard Silica Corporation	Ottawa, Ill. $2.56		$ 14.17[2]	$ 8.96[2]
+ 30 mesh = 0.0% + 40 = 3.2 + 50 = 42.0 + 70 = 39.8 +100 = 12.5 +140 = 2.2 Pan = 0.3	SiO_2 = 99.7%	Standard Silica Corporation	Ottawa, Ill. $2.56		$ 14.17[2]	$ 8.96[2]
+ 30 mesh = 0.9% + 40 = 18.8 + 50 = 44.1 + 70 = 27.2 +100 = 7.6 +140 = 1.3 Pan = 0.1	SiO_2 = 99.7%	Standard Silica Corporation	Ottawa, Ill. $2.56		$ 14.17[2]	$ 8.96[2]
			Total Illinois sands	12,000		
+ 40 mesh = 2.6% + 50 = 10.0 + 70 = 26.2 +100 = 33.8 +140 = 23.6 +200 = 3.4 +270 = 0.2 Pan = 0.2	SiO_2 = 99.4% Al_2O_3 = 0.45 Fe_2O_3 = 0.04 CaO = 0.03	Nevada Silica Sand Co., Inc.	Glass Sand, Nevada $4.30		$ 7.62[2]	$ 2.41[2]
			Total Nevada sands	3,000		
			Grand Total	15,000		

1/ Includes price f.o.b. shipping point, freight rate in carlots, and 3% federal transportation tax.
2/ Based on closed car shipments of bulk sand.

Exhibit 3 (Continued)

FOUNDRY SAND MARKET DATA
SOUTHERN CALIFORNIA

Consumption in Malleable and Gray Iron Foundries

Representative Sands Used: Screen Analysis	Representative Sands Used: Chemical Analysis	Representative Producer	Shipping Point and f.o.b. Value per Ton	Estimated Annual Consumption (tons)	Value per Ton in Carlots in Los Angeles[1]	Net-back Value per Ton f.o.b. Sunshine Station in Carlots
+ 40 mesh = 2.6% + 50 = 10.0 + 70 = 26.2 +100 = 33.8 +140 = 23.6 +200 = 3.4 +270 = 0.2 Pan = 0.2	SiO_2 = 99.4% Al_2O_3 = 0.45 Fe_2O_3 = 0.04 CaO = 0.03	Nevada Silica Sand Co., Inc.	Glass Sand, Nevada $4.30		$ 7.62[2]	$ 2.41[2]
+ 50 mesh = 1.0% + 70 = 6.0 +100 = 19.6 +140 = 38.6 +200 = 28.4 +270 = 5.0 Pan = 1.4	SiO_2 = 99.4% Al_2O_3 = 0.45 Fe_2O_3 = 0.04 CaO = 0.03	Nevada Silica Sand Co., Inc.	Glass Sand, Nevada $4.30		$ 7.62[2]	$ 2.41[2]
			Total Nevada sands	4,250		
+ 20 mesh = 0.1% + 30 = 1.6 + 40 = 29.6 + 50 = 40.3 + 70 = 25.7 +100 = 2.6	SiO_2 = 81.2% Al_2O_3, Fe_2O_3 = 11.5 CaO = 1.7 K_2O = 2.2 Na_2O = 3.1	Del Monte Properties	Pacific Grove, California $3.60		$ 7.63[2]	$ 2.42[2]
+ 40 mesh = 1.3% + 50 = 9.8 + 70 = 67.2 +100 = 17.2 +140 = 2.2 +200 = 1.1 +270 = 0.6 Pan = 0.6	SiO_2 = 81.2% Al_2O_3, Fe_2O_3 = 11.5 CaO = 1.7 K_2O = 2.2 Na_2O = 3.1	Del Monte Properties	Pacific Grove, California $3.60		$ 7.63[2]	$ 2.42[2]
			Total California sands	7,750		
			Grand Total	12,000		

1/ Includes prices f.o.b. shipping point, freight rate in carlots, and 3% federal transportation tax.
2/ Based on closed car shipments of bulk sand.

Exhibit 3 (Continued)

FOUNDRY SAND MARKET DATA
SOUTHERN CALIFORNIA

Consumption in Nonferrous Foundries

Representative Sands Used: Screen Analysis	Representative Sands Used: Chemical Analysis	Representative Producer	Shipping Point and f.o.b. Value per Ton	Estimated Annual Consumption (tons)	Value per Ton in Carlots in Los Angeles[1/]	Net-back Value per Ton f.o.b. Sunshine Station in Carlots
+ 40 mesh = 2.6% + 50 = 10.0 + 70 = 26.2 +100 = 33.8 +140 = 23.6 +200 = 3.4 +270 = 0.2 Pan = 0.2	SiO_2 = 99.4% Al_2O_3 = 0.45 Fe_2O_3 = 0.04 CaO = 0.03	Nevada Silica Sand Co., Inc.	Glass Sand, Nevada $4.30		$ 7.62[2/]	$ 2.41[2/]
+ 50 mesh = 1.0% + 70 = 6.0 +100 = 19.6 +140 = 38.6 +200 = 28.4 +270 = 5.0 Pan = 1.4	SiO_2 = 99.4% Al_2O_3 = 0.45 Fe_2O_3 = 0.04 CaO = 0.03	Nevada Silica Sand Co., Inc.	Glass Sand, Nevada $4.30		$ 7.62[2/]	$ 2.41[2/]
			Total Nevada sands	2,000		
+ 20 mesh = 0.1% + 30 = 1.6 + 40 = 29.6 + 50 = 40.3 + 70 = 25.7 +100 = 2.6	SiO_2 = 81.2% Al_2O_3, Fe_2O_3 = 11.5 CaO = 1.7 K_2O = 2.2 Na_2O = 3.1	Del Monte Properties	Pacific Grove, California $3.60		$ 7.63[2/]	$ 2.42[2/]
+ 40 mesh = 1.3% + 50 = 9.8 + 70 = 67.2 +100 = 17.2 +140 = 2.2 +200 = 1.1 +270 = 0.6 Pan = 0.6	SiO_2 = 81.2% Al_2O_3, Fe_2O_3 = 11.5 CaO = 1.7 K_2O = 2.2 Na_2O = 3.1	Del Monte Properties	Pacific Grove, California $3.60		$ 7.63[2/]	$ 2.42[2/]
			Total California sands	4,000		
			Grand Total	6,000		

1/ Includes price f.o.b. shipping point, freight rate in carlots, and 3% federal transportation tax.
2/ Based on closed car shipments of bulk sand.

be produced by the Crystal Silica Company or the price at which it might be marketed in the Southern California area. The possibility of more severe competition for the foundry sand market arising from this source in the future, however, should not be overlooked in this study.

SUMMARY

The foundry market for high cost sand in the Southern California area is estimated at 33,000 tons. All of this tonnage has a net-back f.o.b. value at Sunshine Station exceeding $2.40 per ton.

Variances of physical and chemical characteristics of Crater sand from those of various sands now used by foundries indicate that considerable processing of Crater sand may be required before it can compete in the market for premium-priced foundry sands. This conclusion is borne out by reports of the experiences of foundries which have used Crater sand for casting operations.

Assuming that Crater sand met specifications of foundry sands now used, a price incentive to foundries might be required in order to capture a substantial portion of the foundry market. It is indicated that foundrymen are reluctant to change from foundry sands which have proved to be workable unless a strong incentive is offered to them.

The Crystal Silica Company should be regarded as a potential supplier of foundry sand in the Southern California area. Because of the proximity of its Oceanside, California, deposit to the market, considerably lower freight costs than those of its competitors might give this company a competitive price advantage in the market.

Growth of the use of the shell molding process might provide a more attractive foundry market for Crater sand in the future. Grains of sands used in shell molding generally are finer than those used in sand molding. It is expected that foundries using the shell molding process will be more selective with respect to grain size ranges and that more grain size ranges will be used. Physical analysis of Crater sand shows that the sand has a wide size range and, therefore, that it might be adapted for use in the shell molding process.

Section V

THE SOUTHERN CALIFORNIA CERAMICS SAND MARKET

Utilization of Silica Sand

Silica flour, i.e., fine silica sand, has a variety of uses in the ceramics industry. A major use of silica flour by Southern California ceramics manufacturers is as an additive to the body material of certain products, including sanitary ware, dinnerware, wall tile, and white goods specialties. Another major use of the flour is in the manufacture of glazes and frit (which is used as the basis for certain glazes). A relatively small amount of silica sand is used in the manufacture of frit and as setting sand in kilns; however, the amount of sand used for these purposes is not large and is omitted.

Marketing Channels

Southern California ceramics manufacturers are supplied by sand producers direct and also by sand producers' sales agents and jobbers of ceramics materials. Most users buy silica flour in 50-pound or 100-pound sacks, but there are some carload deliveries of bulk flour.

Buyers' Attitudes and Habits

Ceramics manufacturers visited during the field work are satisfied with the quality of the silica flour they now use and the service they receive from their suppliers. The importance of uniformity of silica flour was mentioned by some of the buyers. Most of the buyers indicated that the only reason that they might change their sources of supply would be to take advantage of lower cost. Many of the buyers are interested in obtaining the material at lower prices than they now must pay.

Experience with Crater Sand

None of the ceramics manufacturers visited mentioned previous experience with Crater sand.

Market Data

As shown in Exhibit 4, silica used by the Southern California ceramics industry is in the form of silica flour. This segment of the silica market is included in the study as a possible market for the relatively high fines content of Crater sand. The necessity of removal of at least a portion of the fines from Crater sand in order to produce a sand suitable for glass manufacture and foundry use is mentioned in preceding sections of the report. If the fines were separated from Crater sand, a market for the fines would be desirable. Silica flour might also be produced by grinding Crater sand.

Exhibit 4

CERAMICS SAND MARKET DATA
SOUTHERN CALIFORNIA

Representative Sands Used: Screen Analysis	Representative Sands Used: Chemical Analysis	Representative Producer	Shipping Point and f.o.b. Value per Ton	Estimated Annual Consumption (tons)	Value per Ton in Carlots in Los Angeles[1]	Net-back Value per Ton f.o.b. Sunshine Station in Carlots
-200 mesh = 99% -325 = 91-93	SiO_2 = 99+% CaO+MgO = 0.2 Al_2O_3 = 0.2 Alkalies = 0.2 Fe_2O_3 = 0.05 MnO = 0.05 TiO_2 = 0.2 Co+Cr = 0.01 Metallic = 0.01	Pennsylvania Glass Sand Corp. of Okla.	Mill Creek, Oklahoma $8.15[2]		$ 19.52[3]	$ 14.31[3]
		International Minerals ~~and Metals Corp.~~ he means Chemical (?)	Kingman, ~~Arizona~~ $15.00[2]		$ 20.21[3]	$ 15.00[3]
		Del Monte Properties	Pacific Grove, California $12.85[2]		$ 16.88[3]	$ 11.67[3]
-140 mesh = 100% -200 = 98 -325 = 85	SiO_2 = 99.61% Fe_2O_3 = 0.02 Al_2O_3 = 0.10 TiO_2 = 0.01	Pioneer Silica Products Co.	Pacific, Missouri $10.35[4]		$ 21.72[3]	$ 16.51[3]
-100 mesh = 98% -200 = 90	SiO_2 = 99+% Fe_2O_3 = 0.05 Cu = 0.05max. CaO = 0.10max.	Pennsylvania Glass Sand Corp. of Okla.	Mill Creek, Oklahoma $10.50[4]		$ 21.87[3]	$ 16.66[3]
			Total silica flour	10,500		

1/ Includes price f.o.b. shipping point, freight rate in carlots, and 3% federal transportation tax.
2/ Value of flour in bulk.
3/ Based on closed car shipments.
4/ Value of flour in sacks of 50 or 100 pounds.

There are about 5 manufacturers of sanitary ware, 12 manufacturers of glazed wall tile, 12 major dinnerware manufacturers, and 100 artware manufacturers, excluding very small shops, in the Southern California area.

Summary

The ceramics market for silica flour in Southern California is estimated at 10,500 tons a year. All of this flour has a value exceeding $11.50 per ton when netted back to Sunshine Station.

Physical processing of Crater sand would be required to produce a silica flour which would meet market requirements. It is indicated that chemical processing of Crater sand also would be required to produce a product with a silica content meeting market requirements.

Ceramics manufacturers would be reluctant to change from the silica flour they now use unless they could obtain a savings in cost. It is indicated, however, that if a product meeting manufacturers' requirements were offered at a lower cost, a substantial portion of this market might be captured by Crater silica flour.

Section VI

MISCELLANEOUS SAND USES IN SOUTHERN CALIFORNIA

Utilization of Silica Sand

There are a number of major miscellaneous uses for silica sand and flour in the market. These major uses are: grit-type cleansers, water filtering, material for sandblasting and stucco. Sands used for other building purposes, for paving, and for railroad engines to increase wheel traction are so low in market value that Crater sand cannot compete with them economically in the Southern California market. Silica sand is a major raw material used in the manufacture of glass and porcelain electrical insulators. There is, however, only one electrical insulator manufacturer located in the Southern California and Arizona area. Silica sand requirements for electrical insulator manufacture in the area are not significant in this study.

Cleansers

Silica flour is a component of materials used in the manufacture of grit-type cleansers. In addition to high silica content and fineness of grain size, the color of the flour is important to manufacturers of household cleansers. Silica flour used in these cleansers must not only be white, but must retain its whiteness when it is wet.

Water Filtering

Silica sand is used for filtering ground water. Sizeable amounts of sand are used by municipalities and other suppliers of water when new filter units are initially filled. After the sand is in place, however, the consumption rate is low. The engineer of one city water department estimates that the loss of sand in filters is about one percent a year.

Blasting Uses

Steel shot and other synthetic blasting materials have replaced premium-priced sand as a blasting material to a considerable extent. One reason given for the limited use of silica sand for blasting purposes is that stringent state regulations require the use of expensive equipment to reduce the health hazard created by silica dust. In cases where sand is used and conditions are such that the sand can be reused, a high quality sand generally is utilized. In many instances, for example, in sandblasting buildings where the sand cannot be reused, an inexpensive sand is utilized.

Stucco Plaster

High quality sand is used as a component of stucco finishing plaster. Sand used for this purpose apparently need not be extremely high in silica content. The sand is included in the study, however, because of its market value.

Marketing Channels

The larger cleanser manufacturers are supplied direct by sand producers in carload quantities. Sand used for filtering purposes is sold direct by producers to contractors who serve water companies and municipal water departments. Large users of sand for blasting purposes are served direct by sand producers, and the smaller users are served by dealers. Stucco plaster sand is sold direct by producers to dealers who supply plastering contractors.

Buyers' Attitudes and Habits

Cleanser manufacturers are able to obtain from eastern sources silica flour which meets their requirements. They prefer to use local western sand because transportation costs from western sources of supply would be much less than transportation costs they now must pay. The major manufacturers do not, however, use western sand because the western sands which have been offered to them are not sufficiently white. The whiteness specification for sand used by one large manufacturer is: whiteness, as determined in the Photovolt No. 610 Reflectometer, using red, green, and blue filters singly, should give an average percent reflectance of not less than 85 percent. This is read on a flat surface of the powdered sample through a suitable glass plate.

The actual purchases of sand for filter units of municipalities are made by companies which contract to construct the filter units. The extent to which contractors control the selection of the sand varies considerably. In the case of one water district contacted during the study, the contractor was permitted to use sand which met certain specifications, but the source of the sand was not specified. A city in Arizona, however, specified the producer of the sand which is to be used in its filters.

Experience with Crater Sand

A Los Angeles organization engaged in the distribution of chemicals and other industrial raw materials has attempted recently to interest Southern California cleanser manufacturers in silica flour produced from Crater sand. Samples of silica flour ground from Crater sand were submitted to the two largest producers of household cleansers in the area.

One of the two cleanser manufacturers who received samples of the Crater flour reported that it was too dark for use in its cleanser. It appears, however, that this sample was obtained by grinding Crater sand in a rubber-lined mill which imparted a dark color to the flour. The other cleanser manufacturer who received a sample of the Crater flour reported the color to be acceptable and indicated that, if Crater silica flour were available, he would purchase it for use in cleanser manufacture. This sample was obtained by grinding Crater sand in a stone-lined mill.

Crater sand allegedly has been used previously in the manufacture of cleansers. The names of manufacturers who used Crater sand, however, were not ascertained during the study.

Former use of Crater sand for any of the other miscellaneous uses covered in this section was not reported by any of the sources of information contacted during the study.

<u>Market Data</u>

Market data covering miscellaneous uses for silica sand in Southern California are summarized in Exhibit 5. There are three major manufacturers of grit-type cleansers with plants located in the area and a few smaller manufacturers. There are, of course, numerous users of sand for filter, sandblasting, and stucco plaster purposes. The amount of sand used for filter purposes during a year varies greatly depending upon the construction of new filter units. The figure shown in Exhibit 5 is an estimate of average annual consumption over a period of years.

<u>Summary</u>

Miscellaneous uses for silica in Southern California represent an annual market for 13,000 tons of silica flour and 42,500 tons of silica sand.

Physical characteristics of the sand and the silica flour consumed in this segment of the market differ considerably from indicated physical characteristics of Crater sand. Physical processing of Crater sand is indicated if the sand were to be prepared to meet market requirements for silica flour or sand.

The sand sold to this portion of the market is supplied by California producers whose transportation costs to the market are considerably lower than transportation costs from Sunshine Station. During periods of competitive market activity on the part of producers, California producers would have a competitive advantage due to lower transportation costs.

Assuming that Crater sand were processed sufficiently to meet the sand market requirements, it would appear difficult for the sand to capture a substantial portion of this market unless it were offered at lower cost to users than the sand they now purchase. Present suppliers of this market are well established in the market. They are,

Exhibit 5

MISCELLANEOUS SAND USES DATA
SOUTHERN CALIFORNIA

Representative Sands Used: Screen Analysis	Representative Sands Used: Chemical Analysis	Representative Producer	Shipping Point and f.o.b. Value per Ton	Estimated Annual Consumption (tons)	Value per Ton in Carlots in Los Angeles[1]	Net-back Value per Ton f.o.b. Sunshine Station in Carlots
- 40 mesh = 100% -200 = 95 -325 = 80	SiO_2 = 99.5% min. Moisture = 0.1% max.	Pennsylvania Glass Sand Corp. of Okla.	Mill Creek, Oklahoma $8.00[2]		$ 19.37[3]	$ 14.16[3]
+100 mesh = 0.7% +140 = 4.0 +325 = 14.0-35.0	SiO_2 = over 99%	Standard Silica Corporation	Ottawa, Illinois $7.50 (approx.)[2]		$ 19.11 (approx.)[3]	$ 13.90 (approx.)[3]
		Total silica flour for cleanser use		13,000		
+ 12 mesh = 29.5% + 16 = 94.0 + 20 = 96.0 + 30 = 99.0 - 30 = 1.0	SiO_2 = 91.1% Al_2O_3 = 4.9 Fe_2O_3 = 0.07 CaO = 0.06 MgO = 0.05 Na_2O+K_2O = 3.42	Crystal Silica Company	Oceanside, California $5.50[2]		$ 6.98[3]	$ 1.77[3]
+ 16 mesh = 49.0% + 20 = 78.0 + 30 = 96.5 + 40 = 99.5 - 40 = 0.5	SiO_2 = 91.1% Al_2O_3 = 4.9 Fe_2O_3 = 0.07 CaO = 0.06 MgO = 0.05 Na_2O+K_2O = 3.42	Crystal Silica Company	Oceanside, California $5.50[2]		$ 6.98[3]	$ 1.77[3]
		Monterey Sand Company	Monterey, California			
		Total silica sand for filter use		2,500		

1/ Includes price f.o.b. shipping point, freight rate in carlots, and 3% federal transportation tax.
2/ Value of sand or flour in bulk.
3/ Based on closed car shipments.

Exhibit 5 (Continued)

MISCELLANEOUS SAND USES DATA
SOUTHERN CALIFORNIA

Representative Sands Used: Screen Analysis	Representative Sands Used: Chemical Analysis	Representative Producer	Shipping Point and f.o.b. Value per Ton	Estimated Annual Consumption (tons)	Value per Ton in Carlots in Los Angeles[1]	Net-back Value per Ton f.o.b. Sunshine Station in Carlots
+ 12 mesh = 29.5% + 16 = 94.0 + 20 = 96.0 + 30 = 99.0 - 30 = 1.0	SiO_2 = 91.1% Al_2O_3 = 4.9 Fe_2O_3 = 0.07 CaO = 0.06 MgO = 0.05 Na_2O+K_2O = 3.42	Crystal Silica Company	Oceanside, California			
+ 16 mesh = 49.0% + 20 = 78.0 + 30 = 96.5 + 40 = 99.5 - 40 = 0.5	SiO_2 = 91.1% Al_2O_3 = 4.9 Fe_2O_3 = 0.07 CaO = 0.06 MgO = 0.05 Na_2O+K_2O = 3.42	Crystal Silica Company	Oceanside, California			
+ 20 mesh = 3.0% + 30 = 58.5 + 40 = 94.5 - 40 = 5.5	SiO_2 = 91.1% Al_2O_3 = 4.9 Fe_2O_3 = 0.07 CaO = 0.06 MgO = 0.05 Na_2O+K_2O = 3.42	Crystal Silica Company	Oceanside, California			
+ 40 mesh = 21.0% + 50 = 68.0 + 60 = 80.0 + 80 = 95.0 - 80 = 5.0	SiO_2 = 91.1 Al_2O_3 = 4.9 Fe_2O_3 = 0.07 CaO = 0.06 MgO = 0.05 Na_2O+K_2O = 3.42	Crystal Silica Company	Oceanside, California $9.10 (average)[2]		$ 10.58[3]	$ 5.37[3]
		Monterey Sand Company	Monterey, California			
		Total silica sand for blasting use		15,000		

1/ Includes price f.o.b. shipping point, freight rate in carlots, and 3% federal transportation tax.
2/ Value of sand in sacks.
3/ Based on closed car shipments.

Exhibit 5 (Continued)

MISCELLANEOUS SAND USES DATA
SOUTHERN CALIFORNIA

Representative Sands Used: Screen Analysis	Representative Sands Used: Chemical Analysis	Representative Producer	Shipping Point and f.o.b. Value per Ton	Estimated Annual Consumption (tons)	Value per Ton in Carlots in Los Angeles 1/	Net-back Value per Ton f.o.b. Sunshine Station in Carlots
+ 1[illegible] mesh = 49.0%	SiO_2 = 91.1%					
+ 20 = 78.0	Al_2O_3 = 4.9	Crystal	Oceanside,			
+ 30 = 96.5	Fe_2O_3 = 0.07	Silica	California			
+ 40 = 99.5	CaO = 0.06	Company				
- 40 = 0.5	MgO = 0.05					
	Na_2O+K_2O = 3.42					
+ 20 mesh = 3.0%	SiO_2 = 91.1%					
+ 30 = 58.5	Al_2O_3 = 4.9	Crystal	Oceanside,			
+ 40 = 94.5	Fe_2O_3 = 0.07	Silica	California			
- 40 = 5.5	CaO = 0.06	Company				
	MgO = 0.05					
	Na_2O+K_2O = 3.42					
+ 40 mesh = 21.0%	SiO_2 = 91.1%					
+ 50 = 68.0	Al_2O_3 = 4.9	Crystal	Oceanside,			
+ 60 = 80.0	Fe_2O_3 = 0.07	Silica	California			
+ 80 = 95.0	CaO = 0.06	Company				
- 80 = 5.0	MgO = 0.05					
	Na_2O+K_2O = 3.42					
+ 50 mesh = 4.0%						
+ 60 = 29.0	SiO_2 = 84.0%	Crystal	Oceanside,			
+ 80 = 70.0	Al_2O_3 = 8.0	Silica	California			
- 80 = 30.0		Company				
			$9.10 (average)2/		$ 10.583/	$ 5.373/
		Monterey Sand Company	Monterey, California			
		Del Monte Properties	Pacific Grove, California			
		Total silica sand for stucco plaster		25,000		
		Grant Total all miscellaneous uses - flour		13,0004/		
		- sand		42,500		

1/ Includes price f.o.b. shipping point, freight rate in carlots, and 3% federal transportation tax.
2/ Value of sand in sacks.
3/ Based on closed car shipments.
4/ Between 1,000 and 2,000 additional tons of silica flour are used annually as paint extenders. This consumption is spread among a large number of paint companies. This relatively small segment of the total market was not investigated in detail during the field work.

moreover, better located geographically than a producer of Crater sand would be for providing the best service to customers.

The Crater sand deposit is located closer to the Southern California market and has lower freight rates to the market than the deposits of any of the suppliers of silica flour who now serve Southern California cleanser manufacturers. As a result, the netback value of Crater silica flour per ton f.o.b. Sunshine Station is about $14.00, whereas the f.o.b. values at the deposits of silica flours presently supplying the cleanser manufacturers is only about $7.50 to $8.00 per ton. Southern California cleanser manufacturers consume 13,000 tons of silica flour a year. A California sand supplier whose deposit is located closer to the market than Sunshine Station is reported to have attempted to process his sand sufficiently to obtain a degree of whiteness acceptable to cleanser manufacturers. Cleanser manufacturers, however, have not found this California silica flour to be satisfactory. Color requirements for silica flour used by cleanser manufacturers account for considerable difficulty in competing for this portion of the market. However, it has been indicated by one cleanser manufacturer that the color of Crater flour is satisfactory for this use.

Section VII

THE ARIZONA MARKET

Utilization of Silica Sand

The Arizona market for silica sand should be considered in conjunction with the Southern California market. While it provides an attractive supplemental market, it is probably not sufficiently large to be considered a single market for Crater sand at this time.

Silica flour is utilized by some Arizona copper smelters for maintenance work in reverberatory furnaces. A silica slurry is applied to the furnace roof and walls which prolongs the life of the furnace. Crater sand was used for this purpose at Clarkdale, Arizona, because the sand was chemically suitable for the purpose and was located near the smelter. Crater sand used at Clarkdale was screened and the oversize was ground. The smelter at Clarkdale was closed during 1950. Investigation showed that some of the smelters in Arizona who use the process mine their own silica sand. Some smelters, however, purchase their silica flour. Only the amount which is purchased from suppliers is included as part of the Arizona silica sand market.

The market for sand in Arizona includes sand used in foundries for casting steel, iron, and nonferrous metals. Foundry sand use is described in more detail in a previous section of the report.

Consumption of sand for blasting, filtering, and as a material in stucco plaster is included in the market for sand in Arizona. Sand of relatively high value is used by a few organizations who are able to reuse the sand in their blasting equipment. Only four or five cities in Arizona are reported to use sand filters in their water systems. Annual loss of filter sand in place is reported to be about one per cent which is an insignificant amount. Arizona requirements for sand to fill new municipal filters fluctuate too severly to be included in the total market estimate for the state, but these requirements are not large. Sand used in filters of private water systems is included in the market estimate, although the amount is small. The amount of sand used in stucco finishing plaster is also small, reflecting the common use in Arizona of other types of building materials.

Consumption of sand by railroad companies for increasing engine wheel traction is excluded from the market for silica sand because of its low market value. Some sand, however, might be sold to the Santa Fe at a price f.o.b. Sunshine Station indicated to be $1.50-$1.75 per yard. Certain sand used for blasting which is not expected to be a permanent use is also excluded from the market.

The amount of silica flour consumed by ceramics manufacturers, including the amount which will be used by a new manufacturer, is only one ton per year—an insignificant amount. Silica flour is used by these manufacturers only as an additive to the glaze or frit which they purchase. No silica sand is used by Arizona ceramics manufacturers.

At present there are no manufacturers of glass or fiberglass located in Arizona. However, should a glass manufacturing plant be established in the state, a new market for Crater sand would open up. As shown previously in the report, the experience of one glass manufacturer indicates that Crater sand is well suited chemically for glass manufacturing use. The physical fineness, which caused discontinuance of Crater sand use for glass manufacture in Los Angeles, might not be detrimental in a smog-free area of Arizona.

There are no manufacturers of asbestos products, wall tile, electrical insulators, frit, sanitary ware, or grit-type cleansers with manufacturing plants located in Arizona. Either silica sand or silica flour can be utilized in the manufacture of each of these products. Each of these uses contributes to the total market for silica in Southern California.

Marketing Channels

Part of the foundry sand market in Arizona included in this study is supplied direct by sand producers and a portion of the market is probably supplied by producers' sales agents. An insignificant portion of this market is served by a Los Angeles jobber of foundry supplies with sand which is produced in California, New York, Illinois, and Nevada. This sand is backhauled from Los Angeles in less-than-carload lots.

Sand used for blasting, filtering in private water systems, and as a material in stucco plaster is distributed by an Arizona jobber who buys direct from a sand producer. One manufacturer of stucco finishing plaster buys sand direct from a sand producer.

Buyers' Attitudes and Habits

Arizona users of silica sand who were interviewed during the study are satisfied with the quality of the sand they now use. Interest was expressed, however, in sand at lower cost. As in California, there probably is reluctance to change from the use of sand which has proved to be workable unless a considerable savings in cost is offered to the buyer.

Experience with Crater Sand

Only one user of silica sand in Arizona reported experience with Crater sand. According to this source, the Crater sand was too fine in size for steel foundry work. It was also reported that Crater sand broke down under the heat required for casting steel, but that it withstood the heat required for iron and nonferrous casting.

Market Data

Market data for Arizona are summarized in Exhibit 6. The great bulk of the estimated market in Arizona consists of the requirements of six organizations, one of which is a jobber supplying sand to other organizations.

As explained in the Introduction, information regarding its sand consumption could not be obtained from the largest foundry in Arizona. Estimates of the amount of sand used by this company were possible through the use of certain published data and information obtained during field work in Arizona and California. Future consumption of the foundry at its new plant, however, may exceed the estimate used in this study. Types of sand selected as representative of those used in the foundry are based largely on practices of California foundries, adjustments being made for geographical location. In other instances where new plants or new equipment are being installed, manufacturers' estimates of their future sand requirements, rather than their past consumption, were used in the study.

Summary

The market for silica sand in Arizona is small, amounting to only 3,000 tons a year. This is equivalent to about 60 carloads of sand a year, or an average of about one carload a week. The Arizona market alone, therefore, undoubtedly is not large enough to support mining operations at the Crater sand deposit.

Assuming that Crater sand was processed sufficiently to meet general market requirements and could be sold in California, the Arizona market would provide an attractive addition to the California market. The value of Crater sand f.o.b. Sunshine Station netted back from the Arizona market averages approximately $11 per ton. The net-back value of silica flour is about $16.50 per ton.

Lower transportation costs from the deposit to the Arizona market than those of other suppliers would provide a competitive sales advantage for Crater sand. If Crater sand meeting market requirements, therefore, could be offered at prices lower than users now pay, a substantial portion of the Arizona silica sand market could probably be captured by Crater sand.

Exhibit 6

ARIZONA MARKET DATA

Representative Sands Used: Screen Analysis	Representative Sands Used: Chemical Analysis	Representative Producer	Shipping Point and f.o.b. Value per Ton	Estimated Annual Consumption (tons)	Value per Ton in Carlots in Phoenix[1]	Net-back Value per Ton f.o.b. Sunshine Station in Carlots
+ 40 mesh = 0.8%	SiO_2 = 97.02%					
+ 50 = 7.6	Al_2O_3 = 1.41					
+ 70 = 20.2	Fe_2O_3 = 0.19					
+100 = 30.6	TiO_2 = 0.05	West Coast Silica	Mead Lake, Nevada			
+140 = 30.8	CaO = 0.09					
+200 = 8.4	MgO = 0.12					
+270 = 1.0	Na_2O = 0.04					
Pan = 0.6	K_2O = 0.66					
+ 30 mesh = 0.4%						
+ 40 = 7.0						
+ 50 = 17.0	SiO_2 = 97.64%					
+ 70 = 27.4	Al_2O_3)	West Coast Silica	Mead Lake, Nevada			
+100 = 20.2	Fe_2O_3) = 1.10					
+140 = 19.0	CaO = 0.50					
+200 = 7.2						
+270 = 1.5						
Pan = 0.5						
			Mead Lake, Nev. approx. $1.65 (average)	100	$ 9.94[2]	$ 6.44[2]
+ 40 mesh = 2.6%						
+ 50 = 10.0						
+ 70 = 26.2	SiO_2 = 99.4%					
+100 = 33.8	Al_2O_3 = 0.45	Nevada Silica Sand Co., Inc.	Glass Sand, Nevada			
+140 = 23.6	Fe_2O_3 = 0.04					
+200 = 3.4	CaO = 0.03					
+270 = 0.2						
Pan = 0.2						
+ 50 mesh = 1.0%						
+ 70 = 6.0	SiO_2 = 99.4%					
+100 = 19.6	Al_2O_3 = 0.45	Nevada Silica Sand Co., Inc.	Glass Sand, Nevada			
+140 = 38.6	Fe_2O_3 = 0.04					
+200 = 28.4	CaO = 0.03					
+270 = 5.0						
Pan = 1.4						
			Glass Sand, Nevada $4.30	100	$ 12.59[2]	$ 9.09[2]
			Total Nevada sands	200		

1/ Includes price f.o.b. shipping point, freight rate in carlots, and 3% federal transportation tax.
2/ Based on closed car shipments of bulk sand.

Exhibit 6 (Continued)

ARIZONA MARKET DATA

Representative Sands Used: Screen Analysis	Representative Sands Used: Chemical Analysis	Representative Producer	Shipping Point and f.o.b. Value per Ton	Estimated Annual Consumption (tons)	Value per Ton in Carlots in Phoenix 1/	Net-back Value per Ton f.o.b. Sunshine Station in Carlots
+ 30 mesh = 0.0% + 40 = 2.5 + 50 = 28.8 + 70 = 38.1 +100 = 21.7 +140 = 7.0 Pan = 1.9	SiO_2 = 99.7%	Standard Silica Corporation	Ottawa, Illinois $2.56		$ 14.17 2/	$ 10.67 2/
+ 30 mesh = 0.0% + 40 = 3.2 + 50 = 42.0 + 70 = 39.8 +100 = 12.5 +140 = 2.2 Pan = 0.3	SiO_2 = 99.7%	Standard Silica Corporation	Ottawa, Illinois $2.56		$ 14.17 2/	$ 10.67 2/
+ 30 mesh = 0.9% + 40 = 18.8 + 50 = 44.1 + 70 = 27.2 +100 = 7.6 +140 = 1.3 Pan = 0.1	SiO_2 = 99.7%	Standard Silica Corporation	Ottawa, Illinois $2.56		$ 14.17 2/	$ 10.67 2/
			Total Illinois sands	1,000		
+ 40 mesh = 0.1% + 50 = 1.6 + 70 = 10.6 +100 = 40.0 +150 = 32.3 +200 = 12.7 -200 = 2.7	SiO_2 = 95+% Water Content = 0.5% max.	Pennsylvania Glass Sand Corp. of Okla.	Mill Creek, Oklahoma $5.50 3/	400	$ 16.87 4/	$ 13.37 4/
+ 35 mesh = 0.1% + 48 = 0.6 + 65 = 2.0 +100 = 7.7 +150 = 8.5 +200 = 10.8 -200 = 70.3	SiO_2 = 96.0% Fe_2O_3 = 1.5 Al_2O_3 = 1.6 CaO = 0.6	Paul Lime Company	Paul Spur, Arizona	600		approx. $ 16.90 3,4/

1/ Includes price f.o.b. shipping point, freight rate in carlots, and 3% federal transportation tax.
2/ Based on closed car shipments of bulk sand.
3/ Value of sand in sacks.
4/ Based on closed car shipments.

Exhibit 6 (Continued)

ARIZONA MARKET DATA

Representative Sands Used: Screen Analysis	Representative Sands Used: Chemical Analysis	Representative Producer	Shipping Point and f.o.b. Value per Ton	Estimated Annual Consumption (tons)	Value per Ton in Carlots in Phoenix 1/	Net-back Value per Ton f.o.b. Sunshine Station in Carlots
+ 12 mesh = 89.5%	SiO_2 = 91.1%					
+ 16 = 94.0	Al_2O_3 = 4.9	Crystal				
+ 20 = 96.0	Fe_2O_3 = 0.07	Silica				
+ 30 = 99.0	CaO = 0.06	Company				
- 30 = 1.0	MgO = 0.05					
	Na_2O+K_2O = 3.42					
+ 16 mesh = 49.0%	SiO_2 = 91.1%					
+ 20 = 78.0	Al_2O_3 = 4.9	Crystal				
+ 30 = 96.5	Fe_2O_3 = 0.07	Silica				
+ 40 = 99.5	CaO = 0.06	Company				
- 40 = 0.5	Na_2O+K_2O = 3.42					
+ 20 mesh = 3.0%	SiO_2 = 91.1%					
+ 30 = 58.5	Al_2O_3 = 4.9	Crystal				
+ 40 = 94.5	Fe_2O_3 = 0.07	Silica				
- 40 = 5.5	CaO = 0.06	Company				
	MgO = 0.05					
	Na_2O+K_2O = 3.42					
+ 40 mesh = 21.0%	SiO_2 = 91.1%					
+ 50 = 68.0	Al_2O_3 = 4.9	Crystal				
+ 60 = 60.0	Fe_2O_3 = 0.07	Silica				
+ 80 = 95.0	CaO = 0.06	Company				
- 80 = 5.0	MgO = 0.05					
	Na_2O+K_2O = 3.42					
+ 50 mesh = 4.0%						
+ 60 = 29.0	SiO_2 = 84%	Crystal				
+ 80 = 70.0	Al_2O_3 = 8	Silica				
- 80 = 30.0		Company				
			Oceanside, California $9.10 (average)2/	800	$ 15.263/	$ 11.763/
			Grand Total - flour	600		
			sand	2,400		

1/ Includes price f.o.b. shipping point, freight rate in carlots, and 3% federal transportation tax.
2/ Value of sand in sacks.
3/ Based on closed car shipments.