

INDUSTRIAL SILICA DEPOSITS OF THE PACIFIC NORTHWEST

By George J. Carter, Hal J. Kelly, and E. W. Parsons

* * * * * information circular 8112



UNITED STATES DEPARTMENT OF THE INTERIOR
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BUREAU OF MINES
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by

George J. Carter,² Hal J. Kelly,³ and E. W. Parsons⁴

SUMMARY

Data obtained from field and laboratory examinations were used by the Bureau of Mines to evaluate 82 silica deposits in the Pacific Northwest. A total of 94 field samples was taken from 64 deposits, and an additional 18 deposits were investigated that did not warrant sampling. Of the 37 deposits found to be of high quality, only 16 were large enough to be classified as

industrial silica resources. Another 27 deposits did not meet quality requirements.

Methods of simple low-cost beneficiation and rapid classification of a large number of samples were investigated in the laboratory. These tests indicated that high-intensity electromagnetic separation was equal or superior to either high-or low-intensity electrostatic separation. In general, the electromagnetic method gave higher recoveries and produced equal or better grade concentrates. A glass button method developed for estimating iron oxide content of silica samples proved to be highly satisfactory as a means of classifying field samples and evaluating beneficiation tests.

INTRODUCTION

Purpose

As a result of expanding demands and depletion of producing deposits, a critical and increasing shortage of industrial silica existed in the Pacific Northwest. Development of the Quartz Mountain and Lane Mountain deposits in Washington and the Bovill silica properties in Idaho, which are in or near production, greatly relieved this shortage. However, many industrial users of silica are still forced to import raw materials to meet the specifi-

¹ Work on manuscript completed June 1961.

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³ Project coordinator, Nonmetallics Laboratory, Bureau of Mines,
Seattle, Wash.

⁴ Mining engineer, Spokane Office of Mineral Resources, Bureau of Mines,
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cations for their particular product. Therefore, to insure fulfilling demands and to provide for future expansion, new sources of industrial silica are needed.

This investigation was undertaken to evaluate and catalog known sources of industrial silica in the Pacific Northwest and to provide reliable information

concerning these deposits.

Scope

The objectives of the field examinations were to evaluate undeveloped silica deposits and to locate and evaluate new silica deposits in the four Pacific Northwest States (Idaho, Montana, Oregon, and Washington). The first phase of sampling was confined, as far as practicable, to areas close to industrial centers. During the second phase, sampling was extended to include deposits throughout most of the four-State area. Finally, more detailed field examinations were made on deposits judged to have the greatest potentialities.

Laboratory experiments were conducted to classify the field samples for chemical or spectrographic analyses and to study simple, low-cost beneficiation methods in order to determine whether marginal deposits could be used. The high-purity samples were analyzed chemically; low-purity samples were analyzed spectrographically. Sample beneficiation was studied using high-intensity electromagnetic and high- and low-intensity electrostatic separation methods. To classify the silica samples and to evaluate the beneficiation tests, a glass-button method of estimating the total iron content was used.

Acknowledgments

The authors are indebted to the Northwestern Glass Co. for furnishing the glass-batch composition used for the glass-button analyses and to the property owners for assisting the field engineers in obtaining field samples and especially to Abner Ingebretson, Spokane, Wash., who furnished material for special tests.

SILICA INDUSTRY REVIEW

Markets

In the years after World War II when normal industrial activities were resumed, the silica market of the Pacific Northwest underwent a period of rapid growth and expansion. The demand for glass sands was greatly increased by the expansion of the container-glass plant in Seattle and the construction of a new plant in Portland. Further, because large blocks of firm, low-cost electric power were available, new industries requiring large quantities of high-purity silica were established in the area. The products of the principal manufacturers in the Northwest now include silicon, silicon carbide, ferro-silicon, sodium silicate, and container glass.

There are three large-volume silica-consuming industries in the Northwest--glass, abrasives, and silicon and ferroalloys. Of the nine plants actively engaged in these industries, three manufacture glass, one produces silicon carbide abrasives, and five produce silicon and ferroalloys. The locations and products of these plants are listed in table 1.

TABLE 1. - Companies consuming large volumes of industrial silica in the Pacific Northwest

Company	Product
Carborundum Co., Vancouver, Wash.....	Silicon carbide.
Electro Metallurgical Co., Portland, Oreg.....	Ferrosilicon.
Keokuk Electro Metals Co. (subsidiary of Vanadium Corp.), Wenatchee, Wash.....	Ferrosilicon and silicon.
National Metallurgical Corp., Springfield, Oreg....	Silicon.
Northwestern Glass Co., Seattle, Wash.....	Container glass.
Ohio Ferroalloys Co., Tacoma, Wash.....	Ferrosilicon and silicon.
Owens-Illinois, Portland, Oreg.....	Container glass.
Pacific Northwest Alloys, Inc., Spokane, Wash.....	Ferrosilicon. ¹
Philadelphia Quartz Co., Tacoma, Wash.....	Sodium silicate.

¹ The principal product of this plant is ferrochrome. Ferro-silicon is produced intermittently.

Other products using silica include foundry and molding sands, fillers and filtration media, refractories, metallurgical fluxes, and construction sand. However, these markets require low volume or lower grade silica than the industrial silica products previously mentioned.

Specifications

In general, consumers want the highest possible purity at the lowest possible price. Because pure material is not available, manufacturers have

been able to use lower grades of silica as long as certain specifications, both physical and chemical, are met.

To the glass industry, iron oxide is the most undesirable impurity. In order to produce clear, colorless, container glass, the Fe_2O_3 content of the sand must be less than 0.06 percent, although 0.25 percent can be tolerated in sand for amber glass. The amounts of oxides such as Al_2O_3 , CaO , MgO , and K_2O in the sand are not critical as they are normal constituents of the glass batch; however, the content of these oxides should be constant. Consumers usually require the raw material to be 98 percent silica sized between 20- and 100-mesh, as coarser particles are difficult to melt and finer particles tend to produce seeds in the glass and create dust control problems.

High-silica content is important to manufacturers of silicon carbide as small amounts of impurities are detrimental to their finished product. For "green grit" silicon carbide, the green-colored high-purity product, 99.5 to 99.7 percent SiO_2 is required, and for the dark-colored silicon carbide,

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"black-grit" 99.3 to 99.5 percent SiO_2 is required. Also there is a very critical tolerance for alumina, which is the coloring impurity in silicon carbide (SiC). Pure SiC is white, and as the amount of aluminum impurity increases, the color progresses from white to straw colored to various shades of green to black. For use in green grit SiC , silica cannot contain more than 0.04 percent Al_2O_3 , as greater amounts result in a black-colored product. For black grit silicon carbide, 0.20 percent Al_2O_3 is the maximum allowable. Other common impurities in quartz, Fe_2O_3 , CaO , and MgO , are each limited to less than 0.10 percent for both products. A particle size range of 1- to 1/4-inch is usually specified, and the manufacturer crushes the quartz to obtain proper grain-size distribution.

General specifications for silica for manufacturing silicon and ferro-silicon are greater than 99 percent SiO_2 , maximum impurity tolerance for making silicon metal is 0.07 percent Fe_2O_3 and 0.25 percent Al_2O_3 and for

making ferrosilicon 0.30 percent Fe_2O_3 and 0.15 percent Al_2O_3 . Only a trace of CaO is allowable. Massive silica is preferred, and the specified particle sizes range from 6 inches to 1/2-inch; the size range of 4 inches to 1 inch is most widely used.

Quartz used for making sodium silicate glass must have a minimum of 98.5 percent SiO_2 and a maximum of 1 percent Al_2O_3 , 0.50 percent CaO , 0.50 percent MgO , and 0.08 percent Fe_2O_3 . Virtually any sand sized from 20- to 100-mesh and meeting clear container-glass specifications will adequately satisfy these specifications.

Supply

From 1951 to 1956, local production supplied one-half to three-fourths of the annual consumption of high-purity silica by Northwest manufacturers; the remainder, mostly glass sand, was shipped in from Nevada, California, and Illinois, and imported from Belgium. When the Owens-Illinois glass plant in Portland was completed in 1956, consumption of silica rose to approximately 200,000 tons per year, 70,000 tons used by glass producers and 130,000 tons by manufacturers of silicon and silicon alloys.⁵ However, in 1957 local production dropped to 80,000 tons because the Dennison silica deposit near Spokane was depleted. The opening of the Quartz Mountain silica deposit in Spokane County, Wash., in 1959, greatly relieved this shortage, and local production resumed at the 1951-1956 quantities.

Until 1960, glass sand was the most notable silica deficiency in the Northwest. Local production was limited to the sand used in making amber glass, which represents only a small part of the total requirement. In 1960 production started at the Bovill, Idaho, silica deposit, the first large-scale local source of container-glass sand. Still lacking is a local source of silica for green-grit silicon carbide, and silica for this product must be imported.

⁵ Mueller, E. E., Industrial Silica in the Pacific Northwest: Pres. at Pacific Northwest Regional Conf., AIME, Seattle, Wash., 1956.

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Outlook

Due to the development of new properties, the outlook for local silica production greatly improved during the late 1950's. The Quartz Mountain deposit, opened in 1959, will supply manufacturers of silicon alloys with high-purity silica for many years at the 1960 rate of consumption. The Bovill deposit is the first large-scale, local supply of container-glass sand. Exploration by the Lane Mountain Silica Co. of a sandstone deposit at the northern end of Lane Mountain indicated that another source of low-iron silica may be available. The company, a cooperative venture of Northwestern Glass Co. of Seattle, Wash., Del Monte Properties Co. of Pebble Beach, Calif., and other owners, began constructing a processing plant designed to crush and wash 400 tons of silica per day with production scheduled to begin in the spring of 1961. Further potential is afforded by sands of the Gem silica deposit near Emmett, Idaho, which, properly beneficiated, will meet glass sand specifications.

FIELD INVESTIGATIONS

Geology of Silica Occurrences

Silica, one of the most abundant materials in the earth's crust, occurs in six distinct mineral and mineraloid forms; however, only quartz occurs in the abundance and purity demanded of industrial silica. This mineral is colorless or white, hard, exhibits no distinct cleavage, has a conchoidal fracture, and is very resistant to weathering and erosion. The common impurities associated with quartz are metallic oxide stains, inclusions, and associated minerals. The staining ranges from slight surface blemishes to complete discoloration. The inclusions are generally feldspar, mica-group minerals, magnetite, and garnet; volcanic glass and a variety of ferromagnesium minerals also may occur. The associated minerals are predominantly feldspar, mica-group minerals, and clay; other accessory minerals occur to a lesser extent.

Silica deposits have three modes of origin: Primary, secondary, and replacement. Although the mechanisms of formation of the deposits of primary origin--quartz-core pegmatites and quartz dikes--are not completely understood, these deposits are usually attributed to the action of hydrothermal solutions. Secondary deposits--sand, sandstone, and quartzite--are formed by erosion and redeposition. Quartz grains are concentrated into sand deposits by the sorting action of wind and water. Consolidation and cementation of the sands produce sandstones, which upon further compaction metamorphose to form quartzites. Sandstone is distinguished from quartzite

metamorphose to form quartzites. Sandstone is distinguished from quartzite by its fracture; sandstone fractures around the grains, whereas quartzite fractures across the grains. Silica deposits have also been formed when the country rock was replaced by siliceous solutions.

Quartz dikes, common in the Northwest and occurring principally in the mountainous regions, are usually small and contain associated minerals that render the quartz unsuitable for high-grade applications. These dikes are usually unsatisfactory sources of silica because available tonnage is small and the deposits are inaccessible.

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Quartz-core pegmatites, locally known as quartz "blowouts," occur in western Montana, northern Idaho, and northeastern and northcentral Washington. They may be distinguished from the more typical pegmatite dikes, which consist of a coarse-grained mixture of crystalline quartz, feldspar, mica, and other accessory minerals. The quartz-core pegmatites are usually lenses of white quartz containing an occasional pod of metallic minerals and having a narrow fringe of feldspar and mica around the edges. The lenses range from the few thousand tons of the Empire Granite property near Dishman, Spokane County, Wash., to the nearly 2 million tons already produced from the Dennison deposit 15 miles north of Spokane. The depth of deposits of this type is usually less than the longest lateral dimension. Evidence obtained from tunnels and drifts also has shown that the quartz-core pegmatites have a definite base; at least, no extensions to great depths are known.

Very few of the sand deposits, which are widespread throughout the Pacific Northwest, meet the requirements of high-grade silica deposits. Potential high-grade deposits are found in northern and central Idaho and in western Oregon. Since accessory minerals constitute a large portion of these deposits, the sands must be beneficiated to obtain a high-grade silica product. Byproducts, such as feldspar, muscovite, and white clay, greatly increase the economic potential because all these products have some commercial value.

In northern Idaho. clay-sand deposits have been formed by the weathering

of granitic source rock; the feldspar has been kaolinized, producing a clay-mica-quartz complex in place. Erosion and redeposition of this complex into adjacent basins has formed deposits, which vary greatly in their mineralogy. Some beds are almost entirely clay, whereas others are largely nonclay minerals. Products from these deposits are quartz sand, muscovite, and white clay.

In east-central Idaho, sand dunes that grade into arkosic sandstone also offer a potential source of high-grade silica. These sands are predominantly quartz and feldspar contaminated by minor amounts of clay. Beneficiation will produce quartz sand and soda-potash feldspar.

The dune sands of the Coos Bay area in southwestern Oregon are composed almost entirely of quartz, feldspar, and rock fragments. Although the quartz does not meet most container-glass-sand specifications, it could be used for amber container glass, and a quartz-feldspar concentrate could be used in a ceramic porcelain.

Sandstone outcrops are found throughout the Northwest; however, high-grade sandstones are found only in northeastern Washington, northern Idaho, and western Montana. In these areas, deposits of siliceous or arkosic sandstone occur, in which the silica is of high quality. These beds are usually light gray or light tan in color and vary considerably in quality.

Quartzite occurs extensively in northern and southeastern Idaho, western Montana, and northeastern Washington. Many of the beds are hundreds of feet thick. The color of the rock is usually light or dark gray; however, pinkish

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varieties are not uncommon. The tonnage of quartzite available is usually very large in any area where it crops out, but the quality can be determined only by extensive sampling.

Silica deposits in southwestern Oregon were formed when the country rock

was replaced by siliceous solutions. In one area, limestone was replaced by clear crystalline quartz; in another, rhyolites and tuffs were replaced by milky white cryptocrystalline quartz. Impurities include remnants of the country rock, inclusions, and staining.

Sampling

Field examinations were performed over a period of 2-1/2 years by mining engineers of the Spokane Office of Mineral Resources. Sampling, begun in July 1957, was confined to areas close to industrial centers. Because high-grade silica deposits are rare in western Washington and northwestern Oregon, most of the sampling was done in northeastern Washington and northern Idaho. In 1958, the area of sampling was expanded; sampling excursions were made into north-central Washington, northern Idaho, western Montana, and eastern and southwestern Oregon. Fieldwork was completed during the summer of 1959 by resampling and more detailed examination of the most promising deposits.

To evaluate the silica resources of the area, samples were taken from all high-grade deposits, the locations of which were obtained by a literature survey. Because additional information was obtained from the Bureau of Mines files and from personal contacts, samples were also taken from new deposits deemed to be of potential commercial value.

In general, the characteristics of the deposit determined the method of sampling. Grab samples, obtained by chipping or breaking off fragments of rock along a traverse across the outcrop, were taken from deposits of consolidated material; trench samples, obtained from a shallow cut or cuts across the face of the outcrop, were taken from unconsolidated deposits.

A total of 96 samples was taken from 64 deposits, 10 in Idaho, 12 in Montana, 5 in Oregon, and 37 in Washington. Eighteen additional deposits were examined, but no samples were taken because of the small size or poor quality of the deposit (appendix C). The areas comprising southern and southeastern Idaho and eastern Montana were not examined because of the great distance from existing markets.

LABORATORY TESTS AND PROCEDURES

Sample Preparation

The field samples of massive quartz, quartzite, and sandstone were prepared for examination in the laboratory by crushing, screening, and magnetic separation. The entire sample was crushed to pass one-fourth inch in a small jaw crusher, and then the amount was reduced to 5 pounds by riffing. This fraction was stage crushed by smooth, double rolls to pass

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Sample Preparation

The field samples of massive quartz, quartzite, and sandstone were prepared for examination in the laboratory by crushing, screening, and magnetic separation. The entire sample was crushed to pass one-fourth inch in a small jaw crusher, and then the amount was reduced to 5 pounds by riffing. This fraction was stage crushed by smooth, double rolls to pass

20-mesh, and the undersize at 100-mesh was removed. The 20- to 100-mesh fraction was then treated by one pass through a magnetic separator to remove tramp iron introduced during crushing. Thus prepared, the laboratory sample was screened at 48-mesh to give two sizes for further examination, 20- to 48-mesh and 48- to 100-mesh. The minus 100- mesh fraction was reserved for later examination if required.

Laboratory treatment of sand samples was as follows: After disaggregation, a laboratory sample of approximately 5 pounds was riffled from the field sample. The laboratory sample was further reduced by riffling to obtain 100 grams to be used in a washing test. This sample was agitated for 10 minutes in a malted-milk-type mixer with a suitable amount of deflocculant to assure disaggregation and dispersion of the clay. The slurry was washed through a 325-mesh screen, and both fractions were collected and dried. The minus 325-mesh clay fraction was stored for pyrometric cone equivalent determination and differential thermal analysis. The remainder of the laboratory sample was washed in a similar manner, but no attempt was made to save the clay fraction. Screen analyses were run on the plus 325-mesh material using the Tyler⁶ $\sqrt{2}$ series of screens from 20- to 200-mesh. The larger laboratory sample was screened into three fractions and handled as described. The minus 20- plus 48- and minus 48- plus 100-mesh fractions were used in the laboratory tests; the minus 100-mesh fraction was labeled and stored.

Beneficiation Tests

Because all classification processes are enhanced by close sizing, beneficiation tests were run on samples of very limited size ranges. The grain size of the material used was limited to that commonly used in glass sand preparation, 20- to 100-mesh, for two reasons. First, the greater the size reduction, the more available the impurities are for removal; second, glass sand is the finest size material that has large-scale industrial use in the area. The 20- to 100-mesh test samples were fractionated at 48-mesh because poor separation was obtained owing to the differences in the trajectories-

ies imparted to the particles by the feed roll.

At first, samples were tested by electromagnetic and both high- and low-intensity electrostatic methods, but when it was noted that the susceptibility to beneficiation could be measured equally well by any of the three methods, this practice was discontinued. Subsequent samples were tested on the electromagnetic separator, and those found to be susceptible to beneficiation were tested further by one or both of the other methods.

High-Intensity Magnetic Separation

A laboratory model high-intensity induced-roll magnetic separator was used in the beneficiation experiments. Five equipment adjustments may be used to obtain optimum conditions for separation. Because of the large number of

⁶ Reference to specific makes or models of equipment is made to facilitate understanding and does not imply endorsement of such brands by the Bureau of Mines.

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samples processed, certain adjustments had to be standardized. The standardized settings are shown in table 2. A uniform feed rate was maintained by locking the feed gate in the open position and using a vibrating feeder to control the rate. This setup was necessary because particle shape varied extremely from sample to sample and highly magnetic material blinded the constricted feed opening. The separator was operated at maximum current intensity, and the splitter adjustment was varied to obtain optimum separation for each sample. Three passes were used to simulate conditions of multirole commercial units.

TABLE 2. - Electromagnetic separator settings

	Roll speed.	Pole gap.	Current intensity.		Feed
--	----------------	--------------	-----------------------	--	------

Run	r.p.m.	inches	amperes	Splitter	rate
1..	60	3/8	Maximum	Adjusted	Constant
2..	50	3/32	..do...	...do...	Do.
3..	30	3/32	..do...	...do...	Do.

Electrostatic Separation

A laboratory model electrostatic separator, powered by an electronic power supply unit, was used in both the low-intensity and high-intensity (high tension) separations. Satisfactory separation was obtained by feeding a stream of particles onto a 6-inch rotating grounded roll, cascading the particles through an electrostatic field, and separating the diverted minerals with an adjustable divider. Separator adjustments facilitating proper operation included feed rate, roll speed, electrode position, and both radial and vertical position of the divider. The power supply unit is equipped to provide electrical potential from 0 to 30 kv., direct current, of either positive or negative polarity.

The preheating effect upon quartz, standardization of polarity, and feed rate were determined through preliminary tests. Negative polarity was found to produce better separation of the silica samples. Although it was possible to standardize the feed rate, it was necessary to use two feed rates because two different particle-size ranges were tested; the rate used for the 48- to 100-mesh fraction was much less than that used for the 20- to 48-mesh fraction. Preheating the quartz did not improve separations because the susceptibility of both pure and impure quartz grains to the electrostatic field was increased equally.

Low-Intensity Separation

Low-intensity separation uses the attractive or "lifting" force of the electrostatic field, generated between the ground roll and the 2-inch revolving roll electrode, to separate the more electrostatically susceptible particles. The divider was adjusted so that the cascading stream of particles fell behind the divider. The voltage was increased until a separation

occurred, that is, the conducting particles were lifted over the divider. The nonconducting part of the sample was re-treated until the desired separation was achieved. Best results were obtained using a slow roll speed, but it was necessary to vary voltage adjustments from sample to sample.

High-Intensity Separation

Separation in the high-intensity electrostatic field was obtained by "pinning" the nonconducting particles to the rotating grounded roll and separating the conducting particles by the placement of an adjustable divider. The high-intensity field is developed by a stationary electrode provided with a line of needle-like discharge points. The divider was adjusted so that the entire stream of particles passed over it through the electrical field in front of the discharge points. Increasing the voltage until the nonconducting part of the feed was deflected behind the divider effected separation. The conducting part was rerun until the desired separation was obtained. In general, a faster roll speed and a lower divider setting were used than in the low-intensity separations.

Evaluation

High-intensity magnetic separation consistently produced results equal to or better than either of the electrostatic methods. When equal beneficiation was obtained by all three methods, the recovery by magnetic separation was generally higher.

Microscopic Examination

A binocular microscope was used to determine the nature of the quartz and the identity of the impurities in the laboratory samples. In general, the crushing of massive quartz produced clear, angular fragments having a fresh appearance, whereas the quartz grains derived from sands and sandstones tended to be clear, subangular to rounded, with a fresh to dull appearance. Cryptocrystalline varieties of quartz were angular and white or cloudy. Impurities were of three types: Quartz stained by iron oxide, inclusions, and associated minerals. Staining was mostly slight; however, the degree of staining ranged from slight surface blemishes to complete grain discoloration. The red or black inclusions were mostly garnet, magnetite, or high-iron glass. A petrographic microscope and oil-immersion powder techniques were used to identify the included minerals. Generally, the associated minerals were clay, mica-group minerals, feldspar, and iron-bearing minerals; however, rock frag-

ments were common in some detrital deposits.

Glass-Button Method

The glass-button test for estimating the iron content uses a visual comparison of the color of a glass button, prepared from a standard composition containing the sample material, with a series of standard glass buttons prepared from reagent-grade chemicals to which known quantities of Fe_2O_3 have been added. Detailed laboratory work has established this test as a

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simple, rapid method of accurately determining the total iron content of silica samples in terms of Fe_2O_3 . This study included evaluation of the effects of the composition of the glass, heating schedule, particle size of the silica, pouring temperature, and mold material. As a means of classifying samples and evaluating beneficiation tests, the glass button method affords an accurate and rapid method of selecting the better samples for further research.

Testing Procedure

Glass buttons were prepared by mixing 10 grams of the silica test sand, ground to pass 200-mesh, with 36 grams of glass batch flux consisting of 20 parts Pb_3O_4 , 10 parts $\text{Na}_2\text{B}_4\text{O}_7$, 5 parts Na_2CO_3 , and 1 part As_2O_3 . The glass mixes were placed in No. 2 high-form porcelain crucibles, heated to $1,075^\circ\text{C}$, held at that temperature for 15 minutes, removed, swirled, and poured into 1-1/8-inch cylindrical cast-iron molds in an annealing well (approx. 200°C) in the top of the furnace. After cooling, the buttons were removed from the annealing well, marked, and evaluated by visual comparison with a series of standard glass buttons. The standards were prepared with reagent grade silicic acid and contained 0.00, 0.02, 0.06, 0.10, 0.15, 0.20, 0.30, 0.50, 1, 2, and 5 percent Fe_2O_3 .

Fine grinding of the silica samples and a low melting temperature were

found necessary when porcelain crucibles were used. Because the crucible material contained approximately 1 percent Fe_2O_3 , steps were taken to reduce the amount of the crucible dissolved by the glass during heating. Grinding reduced the time and temperature required to completely melt the silica sand, and allowed the use of the low melting temperature, which reduced the rate of reaction between the fluxes and the crucible. By using platinum crucibles and maintaining oxidizing conditions, 20- to 100-mesh silica was melted by heating to $1,225^\circ\text{C}$. and holding for 20 minutes.

Evaluation

The glass-button method provides an accurate means of estimating the iron content of silica samples. The accuracy at which analyses were made using porcelain crucibles was ± 0.02 to -0.01 percent of the accepted values from chemical analyses in the range 0.00 to 0.30 percent Fe_2O_3 ; however, above 0.30 percent Fe_2O_3 estimates were consistently high, largely because of crucible contamination. When platinum crucibles were used, an accuracy of ± 0.01 percent was obtained, and crucible contamination was eliminated. Visual comparison proved to be a very satisfactory method of estimating the iron content of the glass buttons. The best applications of the glass-button method were in control when the melting characteristics of the raw material were known and the impurities were relatively constant.

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Special Tests

Thermal Fracturing of Massive Quartz

A rotary kiln test on massive quartz was conducted to determine the effectiveness of thermal shock as a substitute for primary crushing. When heated to 573° C., quartz converts from the alpha to the beta phase, accompanied by a sharp thermal expansion. The large volume change is reversible and nearly instantaneous, and on rapid cooling, severe internal stresses are developed. Fracturing and shattering were produced by the volume changes on heating and cooling through this phase change.

A sample of closely sized quartz was passed through the rotary kiln operating at 1,100° C. and air-quenched or quenched by discharging into cold running water. The 1,100° C. temperature was required to completely heat the quartz pieces above 573° C. in the short kiln-residence time of 15 minutes. Quartz in two size ranges, 1/4- to 1-inch and 1- to 2-inch, was used as kiln feed. When quenched, the coarse sample was severely shattered, and 95 percent passed through a 1-inch screen. Although the fine fraction was highly fractured, the size reduction was not as marked. Water quenching reduced the size of the particles more effectively than air quenching as the thermal gradient was greater. Figure 1 shows the plotted screen analyses before and after thermal fracturing.

Crushing tests on both size fractions after thermal fracturing emphasized the effect of the phase inversions. The thermally fractured quartz was crushed more easily and the size of the crushed material was controlled more closely than similarly crushed unfractured quartz. Equipment wear, as well as time required to process equal volumes of material, was greatly reduced.

Economically the process is not feasible if primary fuel must be used; however, if waste heat is available, the process affords several advantages. Such a system would substantially eliminate the need for primary and secondary crushing and greatly improve the performance of a grinding unit. Also, iron contamination through crusher wear would be reduced.

Froth Flotation

Segrove⁷ recommended three stages of treatment for beneficiation of sands: Water washing to remove ferruginous clay, a surface treatment to remove contamination from silica grains, and froth flotation to remove iron-contaminating granular materials. The sand was treated in a very dilute solution of hydrofluoric acid in the presence of a reducing agent, sodium hyposulfate, to remove surface contamination. Flotation tests revealed that an acid circuit was necessary to remove iron-bearing particles. A pH of 1.5 was found to be optimum as efficiency decreases at higher pH, and recovery is not improved below a pH of 1.5.

⁷ Segrove, H. D., the Production of Sand for Making Colourless Glasses: Jour. Soc. Glass Tech., vol. 40, 1956, p. 363.

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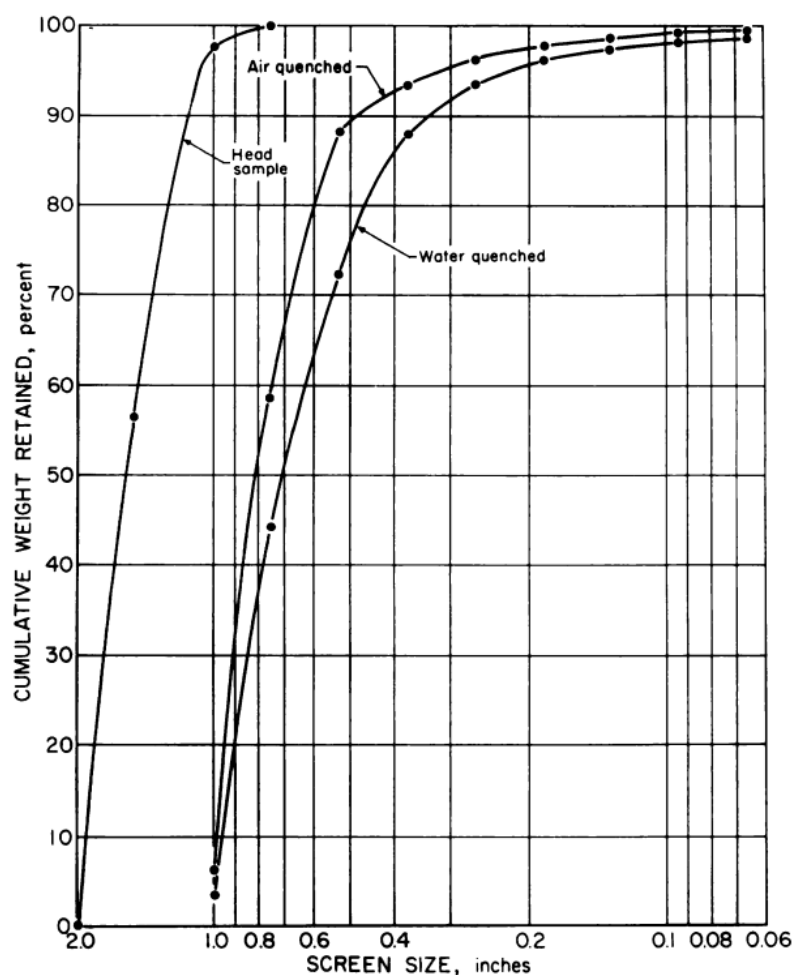


FIGURE 1. - The Effect of Water and Air Quenching

The sands used in the flotation tests were obtained from the Bovill and Cedars-Kelly Creek deposits of Idaho. Both sands were essentially free of iron-bearing minerals but were contaminated by clay and muscovite. Test samples were washed to remove the clay and screened to obtain the 20- to 100-mesh fraction.

The most effective mica concentrates were obtained using an alkaline circuit conditioned with Armac CD and Dowfroth. The pH range of 8 to 11 was investigated, and an intermediate pH of 9.2 to 9.6 was found to produce best results. Below this pH range, the mica concentrate was contaminated by quartz; at higher pH, recovery was poor.

Beneficiation of these sands by flotation was not as effective as

**on the Thermal Fracturing of Massive
Quartz (1- to 2-Inch Fraction).**

electromagnetic or electrostatic separation. The flotation product was contaminated by muscovite which was removed more completely

by the dry separation methods. Also, the dry methods were easier and simpler to operate.

DESCRIPTION OF THE MOST PROMISING DEPOSITS

Evaluation of field and laboratory data made it possible to classify the deposits on the basis of size and quality. Standards were established to facilitate concentrating additional field and laboratory studies on the more promising deposits. Deposits having estimated reserves of less than 250,000, between 250,000 and 1 million tons, and more than 1 million tons were classified as small, medium, and large, respectively. Estimations were based on surface outcrops because no information about the subsurface was available. Only the deposits from which the estimated total iron content

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of the samples was less than 0.15 percent Fe_2O_3 were considered to be high quality. For this study the Fe_2O_3 content was used as an evaluation of purity because iron is undesirable for most products, and rapid estimations could be made in the laboratory by means of the glass-button method. To verify the results of the glass-button tests, chemical or spectrographic analyses were made. Low-iron samples were analyzed chemically, whereas spectrographic analyses were run on the high-iron samples. From these classifications, four categories developed: (1) High-grade deposits, (2) small high-grade deposits, (3) other deposits sampled, and (4) deposits investigated but not sampled. The field and laboratory data and analyses of samples from high-grade deposits and an evaluation of silica resources by States are presented in this section. Test data and analyses used in evaluating these deposits are included as tabulations after each deposit is discussed. This data is also included in

table A-1 to aid the reader in making comparative evaluations of the better deposits. The data and analyses obtained on deposits of classifications 2, 3, and 4 are presented in appendixes A, B, and C, respectively.

Idaho

Only 10 of the 12 Idaho silica deposits investigated were sampled and evaluated. Locations of these deposits are shown in figure 2. The sands and sandstones of the Cedars-Kelly Creek area were the only deposits having the quantity and quality required for industrial silica. Two deposits, the Freeman Lake and Birch Mountain quartz pegmatites, are of high quality but too small for industrial development. The heart of the Freeman Lake deposit has been quarried, and the remaining reserves, although of good quality, would be difficult to mine economically. Of the remaining deposits, six did not satisfy quality specifications, and two did not warrant sampling.

Two additional properties, which warrant special consideration although not sampled in connection with this study, are the Bovill deposit, which was sampled and tested under another project, and the Gem Silica deposit of southeastern Idaho, which has been discussed in a previous Bureau publication.⁸ Because both deposits are of potential economic importance, all available field and laboratory data are reviewed in this report.

Cedars-Kelly Creek Sands and Sandstones (I-6 and I-7)

Location

The Cedars-Kelly Creek sand (I-6) and sandstone (I-7) deposits are in Clearwater County in T. 40 and 41 N., R. 11 E. (fig. 3). Samples were taken from road-cut outcrops along both the old and new roads as indicated in table 3.

⁸ Kelly, H. J., Strandberg, K. G., and Mueller, J. I., Ceramic Industry Development and Raw-Material Resources of Oregon, Washington, Idaho, and Montana: Bureau of Mines Inf. Circ. 7752, 1956, p. 54.

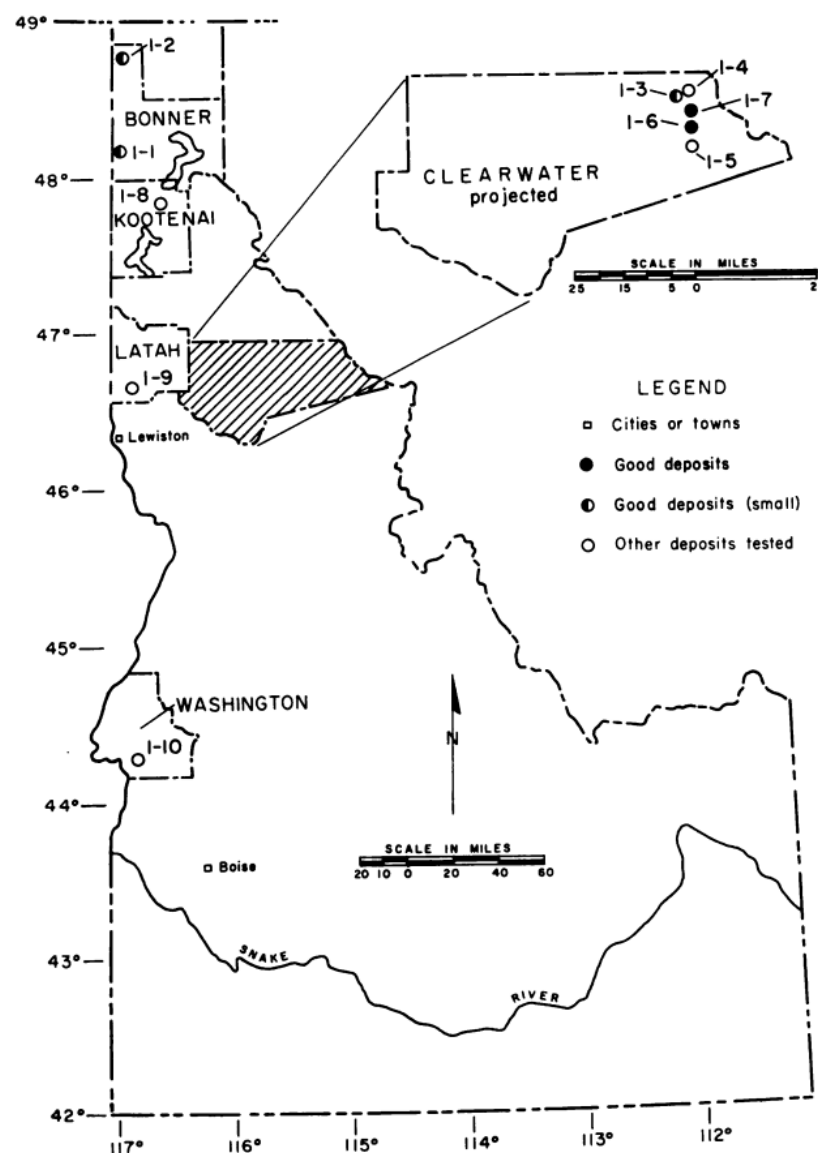


FIGURE 2. - Index Map of Idaho Silica Deposits.

Field Description

Apparently the area between Cedars and Kelly Creek ranger stations has undergone a cycle of low-grade metamorphism. Garnetiferous shales are exposed in road cuts interbedded with sandstones and quartzites. Numerous road cuts expose deposits grading from competent sandstone through weak sandstone to sand, whereas in others interbedding of sand and sandstones was noted. The sandstones range in color from light bluish-gray to light gray or white. The light tan to brown color of the sand deposits is due largely to the color of the associated clay.

All the samples are representative of the deposit or the parts of the deposit from which they were taken. Sample 6-A was taken from the lightest colored zone near the center of the sand outcrop; sample 6-B is representative of the entire outcrop. Over a distance of 0.7 mile this outcrop grades from sand into a weak sandstone sampled as 7-A and further south, into a competent

sandstone sampled as 7-B. After the new road had been constructed, the sand

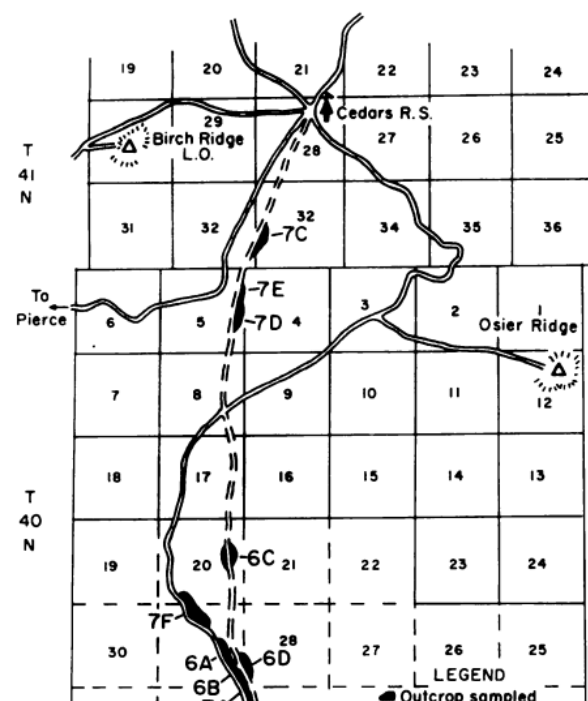
sandstone sampled as 7-B. After the new road had been constructed, the sand was resampled from a newly exposed road cut (6-D). However, due to recent construction activity, this sand outcrop showed wide variation in clay and other contaminants.

The heavy soil and vegetation cover blanketing the area makes estimation of size or extent of these deposits impossible without subsurface exploration.

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Accessibility

The Cedars-Kelly Creek area is in a remote section of Idaho. The nearest rail connections are at Superior, Mont., a distance of approximately 35 miles. The gravel roads, however, are kept in good condition by a lumber company operating in this area.

Laboratory Tests

The quality of the sand was found to be quite uniform; the more notable variations were the clay content and the amount of impurities present. The quartz grains were clear and subangular, and only those of sample 6-C showed more than a trace of staining. The impurities noted were clay, muscovite, partially decomposed feldspar, assorted ferruginous minerals, and rounded frag-

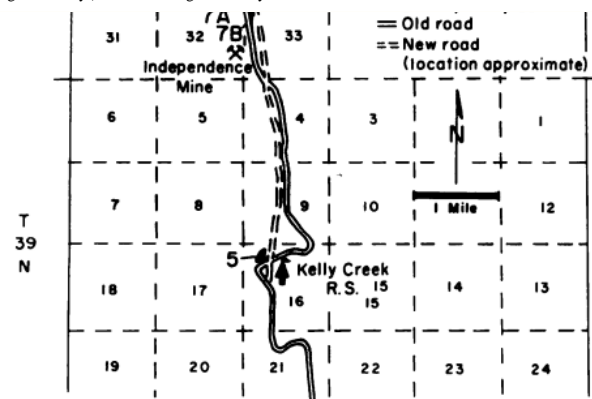


FIGURE 3. - Cedars-Kelly Creek Deposit Area, Clearwater County, Idaho.

minus 200-mesh material varies in total weight-percent from 7 to 21. Because the variation among these samples, especially 6-A and 6-B, was found to be due to the amount of impurities, only the representative sample 6-B was tested further.

Differential thermal analyses and pyrometric cone equivalent (P.C.E.) tests indicated that the clay fraction was good quality kaolinite. The P.C.E. of clay fractions of samples 6-A, 6-B, 6-C, and 6-D were 33 plus, 32-1/2, 29, and 32-1/2, respectively.

terogeneous materials, and sources of impurities of black glass. The plus 48-mesh quartz was largely aggregates, whereas in the finer fractions disaggregation was almost complete. The black glass was noted only in the coarse fractions (plus 48-mesh); the other impurities occurred in all fractions. The clay, muscovite, and ferruginous minerals appeared in increasing amounts in the finer sized material, especially in the minus 100- and minus 200-mesh fractions. Screen analyses, table 4, show a weight-percent variation of almost 20 percent in the plus 100-mesh materials. This variation is due almost entirely to contamination of the sands by clay and muscovite in the fine-size ranges. The

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TABLE 3. - Location and description of Cedars-Kelly Creek
sand and sandstone samples

Sample	Location	Outcrop size	Description
6-A...	4.8 miles north of Kelly Creek Ranger Station on old road.	0.7 miles long, 10 to 35 feet high.	Narrow zone of light-gray sand.
6-B...do.....do.....	Light-tan sand, north end of outcrop.
6-C...	5.1 miles south of Cedars Ranger Station on new road.	12 feet above, 15 feet below road for 250 yards.	Tan to brown sand.
6-D...	7 miles south of Cedars Ranger Station on new road.	Exposure 350 yards by 20 to 25 feet high.	Tan sand, considerable quality variation in outcrop.
7-A...	4.8 miles north of Kelly Creek Ranger Station on old road.	0.7 miles long, 10 to 35 feet high.	Light-gray-white sandstone middle of outcrop.
7-B...do.....do.....	Gray-white sandstone south end of outcrop.
7-C...	1.7 miles south of Cedars Ranger Station on new road.	300 yards long, 40 feet high.	Light-blue to gray sandstone.
7-D...	2.0 miles south of Cedars Ranger Station on new road.	Exposed for 600 yards, 10 to 50 feet high.	Light-gray sandstone at south end of outcrop.
7-E...do.....do.....	Light-gray sandstone interbedded with a competent sandstone at north end of outcrop.
7-F...	6 miles north of Kelly Creek Ranger Station on old road..	500 yards long, 20 to 60 feet high.	Light-tan sandstone.

TABLE 4. - Screen analysis of Cedars-Kelly Creek sands

Screen size, mesh	6-A		6-B		6-D	
	Weight-percent	Cumulative percent	Weight-percent	Cumulative percent	Weight-percent	Cumulative percent
28	11.26	11.26	-	-	6.72	6.72
35	4.49	15.75	7.26	7.26	3.81	10.53
48	15.46	31.21	17.70	24.96	15.67	26.20
65	33.70	64.91	20.37	45.33	31.43	57.63
100	16.91	81.82	17.49	62.82	14.11	71.74
150	8.85	90.67	11.85	74.67	9.07	80.81
200	2.40	93.07	4.17	78.84	4.32	85.13

325	3.42	96.49	10.36	89.20	3.16	88.29
-325	3.51	100.00	10.80	100.00	11.71	100.00

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Only light crushing was necessary to disaggregate even the most competent of the fine-grained sandstones. Microscopic examination showed the quartz grains to be subangular and very clear, with little or no surface staining. Red and black inclusions were the only impurities noted. The red inclusions, identified as garnet, occurred sparsely in all the samples. The black inclusions identified by the color and very low index of refraction as fer-ruginous glass, were prominent only in the samples 7-C, 7-D, 7-E, and 7-F.

Electromagnetic beneficiation of the washed sands was very effective, as almost all the muscovite and iron minerals were removed without difficulty. Sand samples 6-B and 6-D made excellent beneficiated products, whereas sample 6-C did not meet glass-sand specifications because it contained a large amount of stained quartz. Beneficiation by froth flotation of sample 6-B also resulted in acceptable glass sand. Recovery by flotation was 96.4 percent of the head sample, compared with a recovery of 93.2 percent by electromagnetic beneficiation. The quartz concentrates prepared by flotation appeared to contain more muscovite; however, chemical analyses indicated that both products were of equal purity.

Deposit I-6

Component	Sample analysis, percent			
	B ¹	BF ²	C	D
Glass button analysis:				
Head sample, Fe ₂ O ₃	--	--	0.45	0.25
Nonmagnetic product, Fe ₂ O ₃	0.02	0.02	.11	.05
Chemical analysis, head sample:				
Fe ₂ O ₃02	.03	--	.24
SiO ₂	99.25	99.30	--	--

Al ₂ O ₃67	.61	--	--
CaO10	.09	--	--
MgO005	.005	--	--

- ¹ Nonmagnetic product.
² Froth flotation concentrate.

Although sandstone samples 7-C, 7-D, 7-E, and 7-F were improved by electromagnetic separation, the black inclusions were not completely freed by crushing and could not be removed in the size ranges used in the beneficiation tests; hence, the samples could not be classified as high-grade silica. The varying Fe₂O₃ estimates obtained for these samples were almost directly proportional to the occurrence of the black inclusions in the quartz grains. Due to the purity of samples 7-A and 7-B, no beneficiation tests were performed.

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Deposit I-7						
Component	Sample analysis, percent					
	A	B	C	D	E	F
Glass button analysis:						
Head sample, Fe ₂ O ₃	0.03	0.03	0.35	0.85	0.22	0.20
Nonmagnetic product, Fe ₂ O ₃ ...	--	--	.20	.55	.18	.18
Chemical analysis, head sample:						
Fe ₂ O ₃02	.01	--	--	--	--
SiO ₂	94.36	96.30	--	--	--	--
Al ₂ O ₃	3.08	2.25	--	--	--	--
CaO10	.09	--	--	--	--

CaO10	.09	--	--	--	--
MgO036	.009	--	--	--	--

Bovill Clay-Sand

Location

The Bovill clay-sand deposit is in Latah County 36 miles east of Moscow via State Highway 8, which runs through the deposit, in the NE 1/4 T. 40 N. and SE 1/4 T. 41 N., R. 1 W.

Field Description

The clay and sand deposit lies in the low, rolling, timber-covered foothills of northern Idaho and is the decomposition product of local granitic rock. The quality of the clay and sand, as determined from drill hole cores and bulldozer trenches, varies greatly from bed to bed. Colors were observed to range from white to red; however, light gray and tan beds were most common. The areal extent is large, and the bed thickness ranges from a few inches to more than 20 feet. The minerals in the sedimentary beds range from almost 100 percent nonclay, mostly quartz and muscovite, to almost 100 percent clay. Near-surface beds are poorly defined and inconsistent; the lower beds are more homogenous and continuous.

There is evidence that alteration of the feldspar into kaolinite group clay minerals occurred both before and after deposition. The fact that fine-grained clay is bedded with coarse-grained quartz and muscovite indicates that much of the weathering of these beds occurred after deposition. The fine-grained, high-clay beds are clearly the product of predepositional weathering in which the source rock was completely altered before it was transported.

Accessibility

Railroad sidings are available at Bovill, 1 mile east of the deposit. Both the Chicago, Milwaukee, St. Paul Railroad and the Washington, Idaho, and Montana Railroad have sidings here. The latter is a logging railroad, which connects with the Northern Pacific and Great Northern Railways at Potlatch.

Laboratory Tests

Hydraulic classification was used to separate the clay from the nonclay minerals, which were further separated into a muscovite concentrate and a quartz tailing by either electrostatic, electromagnetic, or froth flotation methods. Microscopically the quartz grains were subangular, transparent, and fresh in appearance, with little or no surface iron staining. Impurities in the beneficiated sands consisted of occasional flakes of muscovite and a random grain of an iron-bearing mineral. The coarse-grained (plus 100-mesh) muscovite concentrate was composed of transparent, well-developed crystals; however, the minus 100-mesh fraction was highly altered.

Evaluation of field and laboratory data indicated that large reserves of quartz, clay, and muscovite exist, which could be used industrially: The quartz as container-glass sand, the clay in ceramics or as a filler material, and the muscovite in paint or a coating on asphalt-roofing materials.

Typical chemical analyses, Bovill clay-sand deposit		
Component	Sample analysis, percent	
	A ¹	B ¹
Chemical analysis, head sample:....		
Fe ₂ O ₃	0.036	0.026
SiO ₂	96.28	99.072
Al ₂ O ₃	1.97	.564
CaO08	.025
MgO02	.086

¹ Typical analyses.

Gem Silica

Location

The deposit is in Gem County, about 3 miles south of Emmett bordering State Highway 16.

Field Description

The Gem Silica Co. mined a mixture of clay, silica, and feldspar from a chain of sand hills 3-1/2 miles long. The sands, which are washed to remove the clay are used to supply local markets for silica. The clay is not recovered.

Accessibility

Rail loading facilities are available at Emmett, 3 miles from the deposit.

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Laboratory Tests

Commercial laboratory tests indicated that froth flotation would produce a ceramic-grade feldspar and a quartz sand that would meet glass-sand specifications.

Typical chemical analyses, Gem silica deposit		
Component	Sample analysis, percent	
	A ¹	B ²
Chemical analysis, head sample		
Fe ₂ O ₃	0.095	0.038
SiO ₂	84.78	85.21
Al ₂ O ₃	8.47	8.75
CaO49	.69
MgO06	--

¹ Starrett, C. K., Industrial Silica for Northwest Industries: Raw Materials Survey, Portland, Oregon, Res. Rept. 1, 1958.

² Kelly, H. J., Strandberg, K. G., and Mueller, J. I.,
Ceramic Industry Development and Raw-Material
Resources of Oregon, Washington, Idaho, and Montana:
Bureau of Mines Inf. Circ. 7752. 1956, p. 54.

Evaluation of Idaho Resources

The Bovill silica deposit, from which production was started in the spring of 1960, guarantees an annual supply of quartz sand that will do much to relieve the shortage of glass sand in the area. The value of this deposit is further enhanced by its two byproducts, clay and muscovite. Because the supply from the Bovill deposit will not satisfy the entire demand for silica sand, other possible sources might be the Cedars-Kelly Creek and Gem deposits. However, these deposits may not be developed soon as both are remote with respect to existing glass-sand markets.

Montana

Fifteen deposits were investigated in the survey of Montana silica resources. Of the 12 deposits sampled (fig. 4), 7 proved to be of good quality, although 2 were small and 5 did not meet quality specifications. Three other deposits were not worth sampling.

Daly's Spur (M-1)

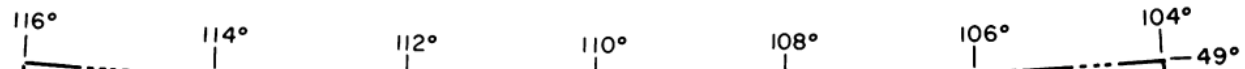
Location

The Daly's Spur deposit is in Beaverhead County, about 13 miles southwest of Dillon on U.S. Highway 91 in the NW1/4 NW1/4 sec. 1, T. 9 S., R. 10 W.

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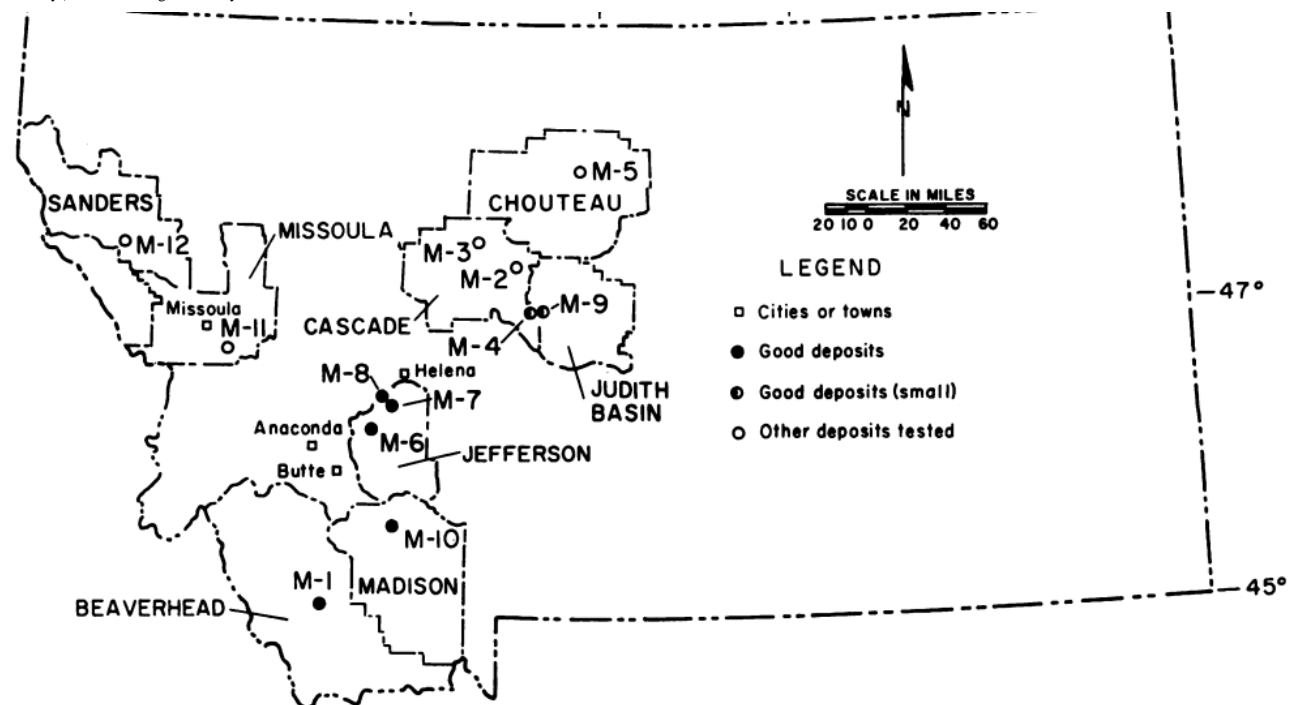


FIGURE 4. - Index Map of Montana Silica Deposits.

Field Description

Outcrops of gray sandstone of the Quadrant formation strike north-south and dip 40° W. to form a cliff at the deposit site. The cliff extends for almost a mile and rises to heights exceeding 150 feet, and the sandstone appears to continue beyond these outcrops. Weathering has greatly weakened the sandstone, and much of the rock crumbles easily.

A quarry excavation extends for approximately 300 feet, abuts against the quarry face, which rises 150 feet above the floor, and is 150 feet wide across the top. The quarry, which is equipped with housed crushing facilities and a spur track to accommodate empty cars for loading is worked through an adit in the quarry floor. Although no activity was observed at the time of inspection, the deposit appears to be worked each year. Past production was estimated to exceed 100,000 tons, which was used as metallurgical flux.

Sample M-1 was taken from broken rock lying on the quarry floor and from ledge outcrops across the quarry face.

Accessibility

Rail transportation is available at the deposit site. A loading spur

rail transportation is available at the deposit site. A loading spur track connects directly with the main line of the Union Pacific Railroad, which parallels the base of the cliff outcrops.

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Laboratory Tests

Light crushing readily produced the desired size reduction of the weakly cemented sandstone. When examined microscopically, the well-rounded quartz grains appeared clear and fresh. An occasional iron-stained grain and a few sparsely scattered iron-bearing minerals constituted the impurities present.

Deposit M-1		
Component	Sample analysis, percent	
	A ¹	B ¹
Glass button analysis:		
Head sample, Fe ₂ O ₃	0.07	--
Nonmagnetic product, Fe ₂ O ₃06	--
Chemical analysis, head sample:		
Fe ₂ O ₃05	0.049
SiO ₂	98.9	97.5
Al ₂ O ₃41	.45
CaO	<.05	<.05
MgO	<.05	<.05

¹ Duplicate chemical analyses.

Basin Blowout (M-6)

Location

The Basin Blowout deposit is in Jefferson County, about 2 miles east of

Basin along U.S. Highway 91 in the SE1/4 sec. 16, T. 6 N., R. 5 W.

Field Description

A lens or plug-shaped outcrop of massive white quartz rising approximately 300 feet above the railroad forms the deposit. The exposure of light-pink feldspar in the back of abandoned quarry workings indicates that the quartz is probably of pegmatitic origin. The quarry floor is 125 feet above the road. Past production, which was used as a metallurgical flux, was estimated to be greater than 200,000 tons.

Broken rock and ledge outcrops were sampled across 400 feet of the quarry opening.

Accessibility

The main line of the Great Northern Railway runs along the base of the deposit, and a loading spur track accommodates empty cars for loading.

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Laboratory Tests

The angular fragments produced by crushing the massive quartz were clear and fresh in appearance. Inclusions of iron minerals with staining halos and surface iron staining were noted on the fragments. Since crushing did not release the inclusions, beneficiation tests were not effective.

Deposit M-6

Sample analysis, percent

Component	A ¹	B ¹
Glass button analysis:		
Head sample, Fe ₂ O ₃	0.04	--
Nonmagnetic product, Fe ₂ O ₃04	--
Chemical analysis, head sample:		
Fe ₂ O ₃029	0.036
SiO ₂	98.9	99.2
Al ₂ O ₃29	.31
CaO	<.05	<.05
MgO	<.05	<.05

¹ Duplicate chemical analyses.

Brown Property (M-7)

Location

The Brown Property is in Jefferson County about 3/4-mile north of Jefferson City and 1/2-mile west of U.S. Highway 91, in sec. 31, T. 8 N., R. 3 W.

Field Description

The deposit is formed by a quartz dike that cuts the quartz monzonite of the Boulder batholith. The quartz is of good quality and massive with some iron staining along joint and fracture surfaces. Outcrops of the ring-shaped dike form a semicircle with the strike varying from north to west and dipping steeply to the east and northeast.

The sample was taken at random for a distance of 700 feet along the strike.

Accessibility

The deposit is accessible by jeep across rolling terrain from the end of a road near the railroad track. The nearest rail siding is at Corbin, approximately 4 miles from the deposit.

Laboratory Tests

The angular, massive quartz fragments were transparent and fresh in appearance and had only minor surface iron staining. The quartz was estimated to contain 0.03 percent Fe₂O₃ and was pure enough that no beneficiation tests were deemed necessary.

Deposit M-7		
Component	Sample analysis, percent	
	A	B ¹
Glass button analysis:		
Head sample, Fe ₂ O ₃	0.03	--
Chemical analysis, head sample:		
Fe ₂ O ₃02	0.07
SiO ₂	99.59	99.63
Al ₂ O ₃36	.14
CaO10	--
MgO007	--

¹ Analysis furnished by owner.

Corral Creek (M-8)

Location

The Corral Creek silica deposit is in Jefferson County, 8-1/2 miles west of Clancy via Lump Gulch and Corral Creek Roads, in the NW1/4 of sec. 8, T. 8 N., R. 4 W.

Field Description

The massive quartz of the Corral Creek deposit outcrops at the crest of a hill north of the road. The lenticular exposure caps the quartz monzonite of the Boulder batholith, which forms the base of the low, rolling hill. The north-south striking quartz body, probably of pegmatitic origin, is white with minor iron staining along joint fractures.

The sample was taken from material chipped from outcrops along a traverse across the center of the deposit.

Accessibility

The deposit is accessible to within 300 yards by dirt and gravel roads. Total distance to Great Northern Railway facilities at Clancy is approximately 8-1/2 miles via county roads.

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Laboratory Tests

Crushing produced clear, angular fragments of fresh quartz with little or no surface iron staining. The estimated iron content, 0.02 percent Fe₂O₃, was so low that no beneficiation tests were performed.

Deposit M-8	
Component	Sample analysis, percent
Glass button analysis:	
Head sample, Fe ₂ O ₃	0.02
Chemical analysis, head sample:	
Fe ₂ O ₃02
SiO ₂	99.46
Al ₂ O ₃45
CaO09
MgO011

Crystal Butte (M-10)

Location

The Crystal Butte silica deposit is in Madison County, 8.9 miles west of Twin Bridges, 1/2 mile north of the road in sec. 4, T. 3 S., R. 4 W.

Field Description

A massive, lenticular quartz body of pegmatitic origin intruded into altered granitic rock to form the Crystal Butte deposit. The long axis of the lens is from northeast to southwest. The quartz is white with a pinkish cast, and some surface iron staining was noted along joint and fracture planes.

The sample was taken at random from the outcrop that forms the top of a rounded hill.

Accessibility

A new, easily constructed road, 1 mile in length, would provide access to the deposit. Quarried rock would have to be trucked 10 miles to the Northern Pacific Railway siding at Twin Bridges.

Laboratory Tests

The clear, angular fragments of quartz had some iron-strained surfaces and contained inclusions of iron minerals enveloped by staining halos. Electromagnetic beneficiation decreased the estimated iron content from 0.04 to 0.02 percent Fe_2O_3 , and recovery was 96.7 percent. Low-intensity electrostatic beneficiation produced a concentrate testing 0.02 percent Fe_2O_3 , with recovery of 95.5 percent of the feed.

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Component	Sample analysis, percent	
	A ¹	B ¹
Glass button analysis:		
Head sample, Fe ₂ O ₃	0.04	--
Nonmagnetic product, Fe ₂ O ₃02	--
Chemical analysis, head sample:		
Fe ₂ O ₃032	0.036
SiO ₂	93.6	98.7
Al ₂ O ₃26	.44
CaO	<.05	<.05
MgO	<.05	<.05

¹ Duplicate chemical analyses.

Evaluation of Montana Resources

All the deposits sampled are at great distances from 1960 markets so immediate use is unlikely. However, the deposits represent large reserves of high-purity silica, and industrial expansion in this area will probably use the reserve. The greatest potential use for material from these deposits seems to be in manufacturing ferrosilicon. The Daly's Spur deposit contains virtually an unlimited reserve, whereas the Basin Blowout deposit is classified as large and the Brown, Corral Creek, and Crystal Butte deposits as medium-sized.

Accessibility to all the deposits is good, especially to the two largest where quarries have been developed and loading facilities installed.

Oregon

During the investigation of the silica resources of Oregon, 13 deposits were examined but only 5 warranted sampling. Location of deposits sampled are shown in figure 5. Four of the deposits proved to be of good quality; however, only two can be considered of value as one is too small and the other, the Eugene Sands, lies within the residential area of Eugene, Oreg. The fifth deposit, the Coos Bay dune sands, although not of high quality, is included in this investigation because beneficiation studies indicate that material from this deposit might be used as a source of a silica-feldspar mixture for manufacturing ceramic ware and amber container glass.

Coos Bay Dune Sands (0-1)

Location

The sands used in this study were taken from dunes adjacent to the

Southern Pacific Railway tracks on the west shore of the North Slough of Coos Bay, in the W1/2 of secs. 15 and 27, T. 24 S., R. 13 W.

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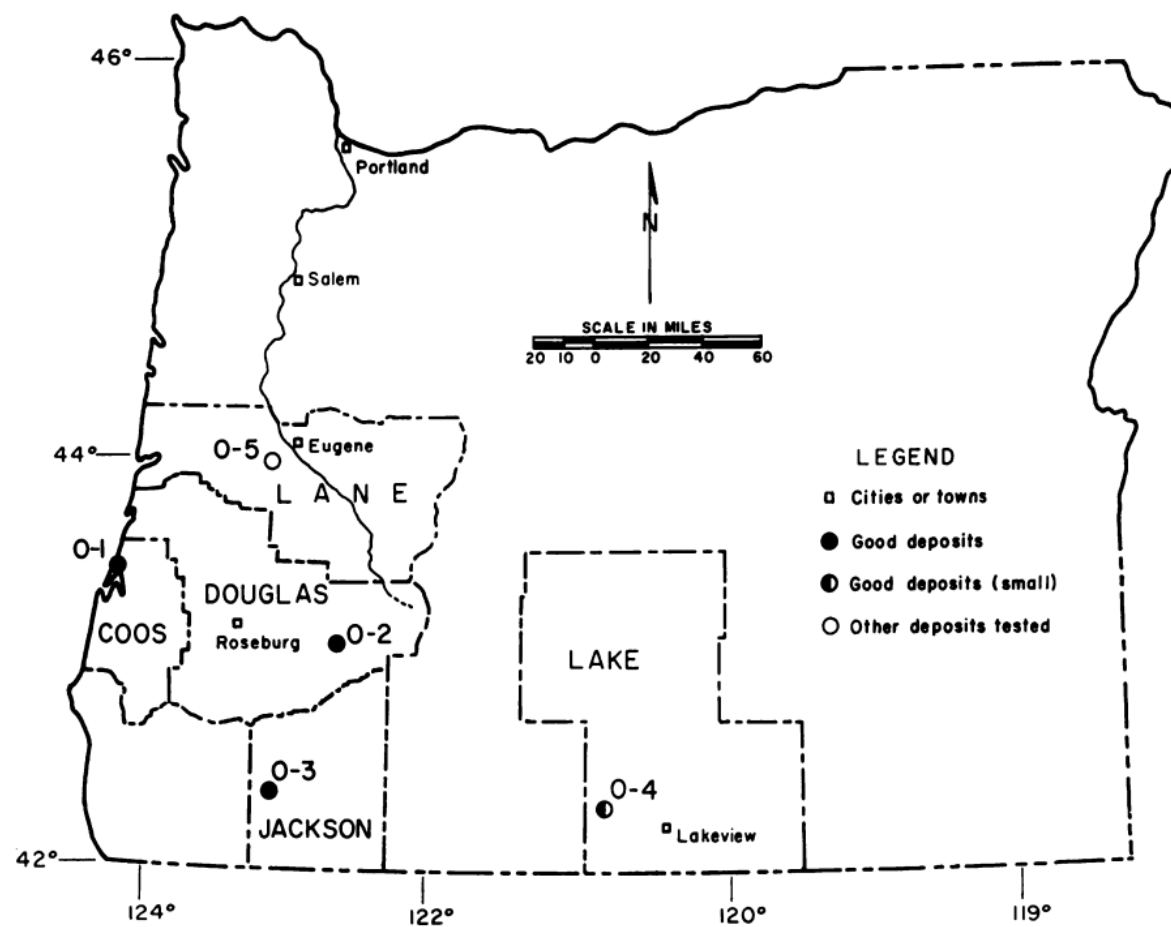


FIGURE 5. -Index Map of Oregon Silica Deposits.

Field Description

Sand dunes parallel the coast of Oregon for many miles north of Coos Bay; at the north end of Coos Bay, the dune belt is 2 miles or more inland. Dune migration is from northwest to southeast as determined by the prevailing winds during the dry season from May to September. The larger dunes are more than 100 feet high and from 1/4- to 1/2-mile long. The sands are light tan and appear to be uniform in grain size.

Sample A was taken from the windward side of a dune east of the road to Sandpoint Lake in the SE1/4 SW1/4 of sec. 15, T. 24 S., R. 13 W. Three samples--B, C, and D--were taken from one large dune adjacent to the rail siding at Rogers. Sample B was taken from the windward side of the dune; samples C and D were taken from the top of the dune; C came from surface material; and D was from material 3 feet below the surface.

Accessibility

Both rail and barge transportation are readily available at the deposit site. Sand could be loaded directly into cars on a rail siding.

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Laboratory Tests

Due to their origin and mode of deposition, the Coos Bay dune sands required no preparation for laboratory testing. Two conclusions can be drawn from the screen analyses (table 5). First, the sands are very closely sized, 85-90 percent of the grains were smaller than 35-mesh but retained on a 65-mesh screen; second, the surface sand (samples A, B, and C) was slightly finer than the subsurface sand (sample D). The sands were composed almost entirely of quartz, feldspar, and rock fragments with only an occasional ferromagnesium mineral. In general, the quartz grains were rounded, transparent or slightly-clouded, and fresh in appearance; however, some grains were observed to be stained or slightly etched, and others were completely discolored by staining.

cloudy or slightly stained, and others were completely discolored by staining. Both the feldspar and rock fragments were well-rounded, and some of the opaque, milky-white feldspar grains showed traces of surface iron staining. The rock fragments were mostly tan to brown and probably of basaltic origin. Twenhofel,⁹ in his examination of sands from this area, reported the composition as 85 to 90 percent quartz and feldspar and 10 to 15 percent rock fragments with traces of magnetite and ilmenite.

Electromagnetic beneficiation proved to be more effective in treating the beach sands than electrostatic methods. Following the standard procedure of making three runs at maximum field intensity, the product tested 0.35 percent Fe_2O_3 , and 71.8 percent of the feed was recovered. The high-intensity electrostatic product tested 0.45 percent Fe_2O_3 with a recovery of 67.4 percent. However, by retreating the tailings and using a six-stage separation instead of three, it was possible to obtain an electromagnetic product testing 0.19 percent Fe_2O_3 and to recover 73.25 percent of the feed. This final product had a P.C.E. of 19 as compared to cone 17 for the head sample. The fused cones were white and had the appearance of a high-grade porcelain body. X-ray diffraction patterns failed to show the presence of any minerals other than quartz and feldspar.

Deposit 0-1			
Component	Sample analysis, percent		
	B ¹	BM ²	C ³
Glass button analysis:			
Head sample, Fe_2O_3	0.90	--	--
Nonmagnetic product35	0.19	--
Chemical analysis, head sample:			
Fe_2O_367	.19	0.78
SiO_2	<10	84.0	82.42
Al_2O_3	<10	8.08	9.17
CaO	1-5	1.10	1.68
MgO	1-5	<.05	.08

¹ Spectrographic analysis rather than chemical analysis.

² Beneficiated using six passes through the high-intensity magnetic separator.

³ Chemical analysis furnished by owner (untreated sand).

⁹ Twenhofel, W.H., Mineralogical and Physical Composition of the Sands of the Oregon Coast from Coos Bay to the Mouth of the Columbia River: Oregon State Dept. of Geol. and Mines. Ind., Bull. 30, 1946, pp. 53-60.

TABLE 5. - Screen analyses of Coos Bay dune sands

Screen size, mesh	Sample A		Sample B		Sample C		Sample D	
	Weight-percent	Cumulative percent	Weight-percent	Cumulative percent	Weight-percent	Cumulative percent	Weight-percent	Cumulative percent
35...	-	-	0.4	0.4	-	-	6.1	6.1
48...	20.0	20.0	14.8	15.2	4.0	4.0	55.4	61.5
65...	72.6	92.6	70.8	86.0	82.0	86.0	33.1	94.6
100...	7.3	99.9	13.8	99.8	13.8	99.8	5.6	100.2
Pan...	.1	100.0	.2	100.0	.2	100.0	-	-

Quartz Mountain (0-2)

Location

The Quartz Mountain silica deposit is in Douglas County and comprises most of sec. 2, T. 28 S., R. 1 E., with extensions into sec. 3 to the west and sec. 35 to the north. Location of the deposit is shown in figure 6.

Field Description

The deposit was formed by the replacement of rhyolite and tuffs with cryptocrystalline quartz. The structure is massive with no indication of attitude; however, joint planes were measured striking N. 60° W. and dipping 59° SW. In general, the rock is hard, dense, and light gray to white. On freshly fractured surfaces, the massive quartz is milky white. In areas where silicification was not complete, the rock is weak and light tan. Joint fracture surfaces were iron stained, especially in and adjacent to areas of incomplete silicification.

Samples were taken along four traverses; sample A came from incompletely silicified tuff; and samples B, C, and D were obtained from more completely silicified material.

Accessibility

The owner has constructed 3 miles of access road necessary to develop the deposit. The nearest rail facilities at Roseburgh a distance of 50 miles via the Little River Road.

Laboratory Tests

Except for sample A, heavy crushing was required to reduce the Quartz Mountain rock to the size ranges required for laboratory tests. The crypto-crystalline quartz fragments were milky white, very angular, and the only impurity noted was stain that seemed to emanate from iron-bearing inclusions. The quartz fragments from sample A were less angular, grayer, highly stained, and contained a small amount of tan, argillaceous material which was probably incompletely silicified country rock.

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Attempts to beneficiate these samples were ineffective.

Deposit 0-2					
Component	Sample analysis, percent				
	A	B	C	D ¹	E ¹
Glass button analysis:					
Head sample, Fe ₂ O ₃	0.50	0.18	0.08	0.09	--
Nonmagnetic product, Fe ₂ O ₃ ...	--	.15	.08	.09	--
Chemical analysis, head sample:					
Fe ₂ O ₃	--	--	.074	.094	0.08
SiO ₂	--	--	98.7	98.4	97.6
Al ₂ O ₃	--	--	.83	.53	.96
CaO	--	---	<.05	<.05	<.05
MgO	--	--	<.05	<.05	<.05

¹ Duplicate chemical analyses.

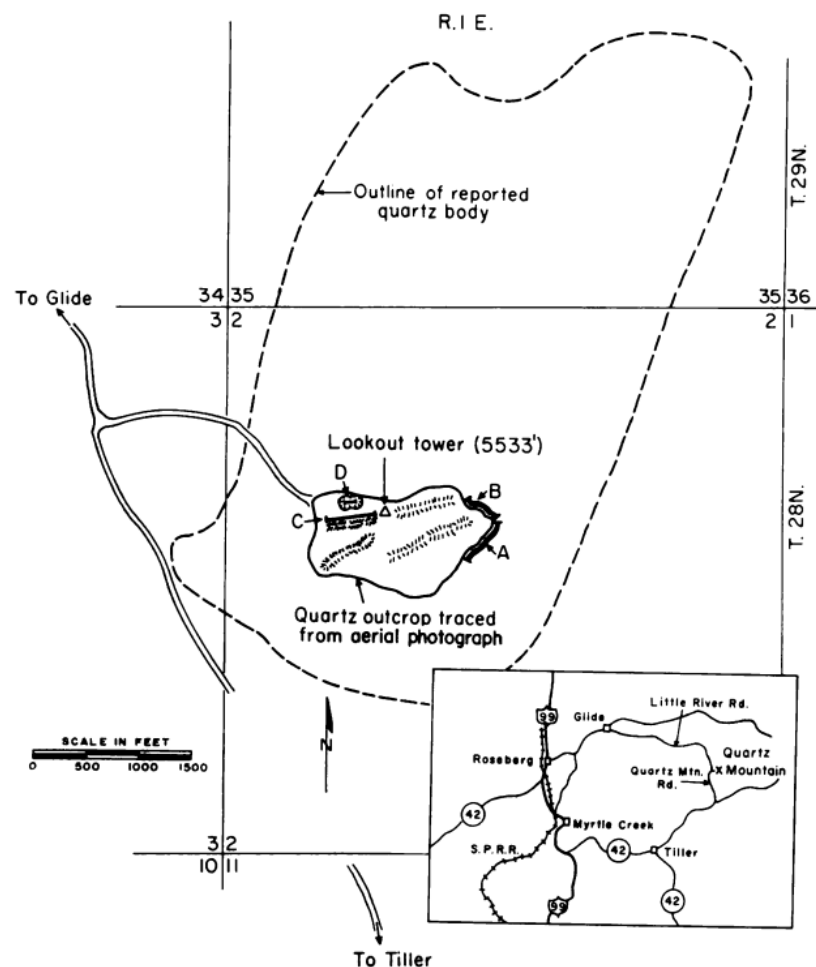


FIGURE 6. - Quartz Mountain Silica Deposit, Douglas County, Oreg.

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Bristol Silica (0-3)

Location

The Bristol silica deposit is in Jackson County about 6-1/2 miles southeast of Rogue River in the SE1/4 sec. 30, T. 36 S., R. 3 W.

Field Description

The deposit is believed to be a replacement of limestone by siliceous solutions. Joints and fractures that traverse the deposit are filled with clay, and at certain horizons the lime content has been reported to exceed 1 percent. The rock is white, hard, and resistant to chipping or fracturing.

Quarrying, which began in 1938, is carried out on six terraced benches, each about 80 feet high. Rock is

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trucked 5 miles to Rogue River for processing. After crushing, sizing, and washing, the quartz is shipped to consumers.

Sample 0-3 was chipped from outcrops and broken rock on benches 4 and 5.

Accessibility

The processing plant at Rogue River is on a rail siding of the Southern Pacific Railway and U.S. Highway 99.

Laboratory Tests

Crushing produced angular, transparent fragments from the quartz sample. Slight surface iron staining was the only impurity noted.

The sample material was only slightly susceptible to beneficiation.

Deposit 0-3		
Component	Sample analysis, percent	
	A ¹	B ¹
Glass button analysis:		
Head sample, Fe ₂ O ₃	0.04	--
Nonmagnetic product, Fe ₂ O ₃03	--
Chemical analysis, head sample:		
Fe ₂ O ₃033	0.029
SiO ₂	98.8	99.0
Al ₂ O ₃25	.19
CaO	<.05	<.05
MgO	<.05	<.05

¹ Duplicate chemical analyses.

Evaluation of Oregon Resources

High-purity silica, contained in both the Bristol and Quartz Mountain deposits is unlikely to satisfy increasing industrial shortages. Activity at the Bristol silica deposit has been in progress for 23 years, and the amount of quartz removed annually has been regulated to conserve resources. Production probably will continue at the established rate; however, highway construction necessitated abandoning the Bristol silica-processing plant, and the date of return to normal production has not been announced. Unless some specific use is developed for the Quartz Mountain silica, the necessity of trucking the quartz 50 miles to a rail siding appears too great an economic disadvantage to permit development at the present time.

Beneficiation tests did not improve the Cape Ray dross enough to

Beneficiation tests did not improve the Coos Bay dune sands enough to warrant consideration as industrial silica reserves. However, the quartz-feldspar concentrate might be used directly as an additive to a ceramic-porcelain body. Other possible uses are for amber container glass and for applications in which low-purity materials are sufficient.

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Washington

Thirty-seven deposits were sampled and tested, and five others were examined during the survey of the silica resources of Washington. Deposit locations are shown in figures 7 and 8. Although 19 deposits were found to be good quality, only the quartzites of Lane Mountain and Lynx Creek and the quartz pegmatites of Blue Grouse Mountain, the Twin Lakes claim, and Quartz Mountain were large enough to be classified as potential industrial deposits. Special consideration was given to the quartzites of the Addy formation in Stevens County because of their marginal purity and almost unlimited reserves.



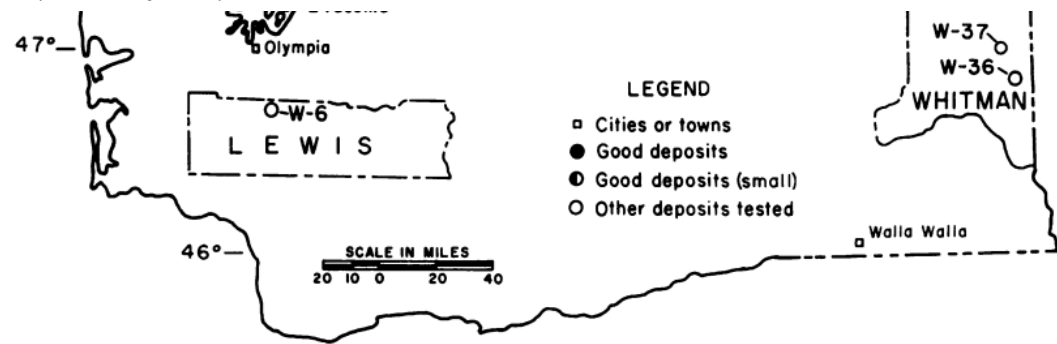


FIGURE 7. - Index Map of Washington Silica Deposits.

Lynx Creek Quartzite (W-5)

Location

The Lynx Creek quartzite, a member of the undifferentiated Covada group, is in Ferry County, about 10 miles northwest of Inchelium, in the S1/2 sec. 14 and N1/2 sec. 23, T. 33 N., R. 35 E.

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Field Description

A massive quartzite outcrop rises more than 100 feet above Lynx Creek to form the deposit. The light-gray quartzite strikes roughly north-south and dips gradually to the

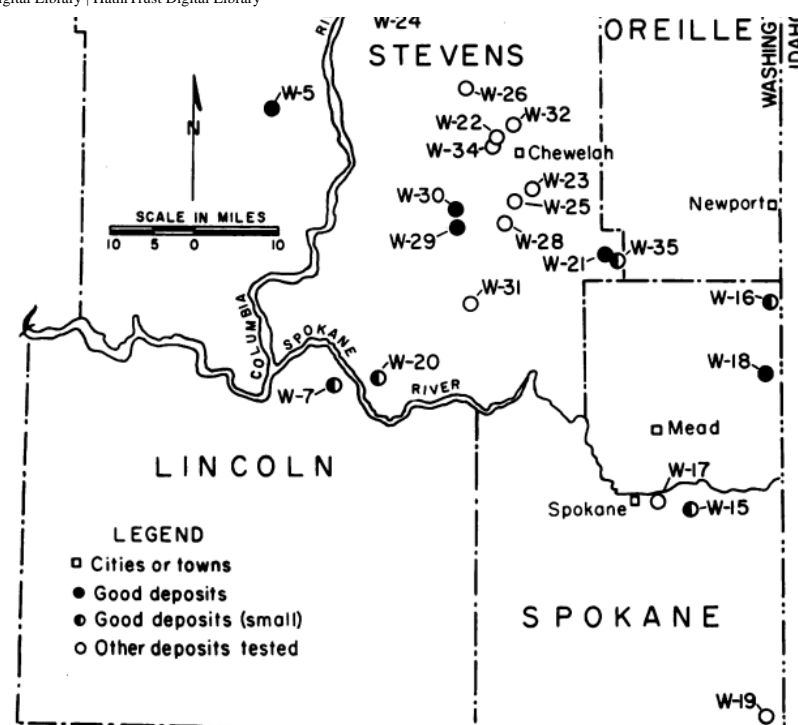


FIGURE 8. - Index Map of Northeastern Washington Silica Deposits.

west. The deposit contains two zones or horizons which appear to have different weathering characteristics. The upper zone of the outcrop is massive and exhibits blocky jointing, whereas close jointing and bedding plane-parting of the lower zone produce small, rhombohedrally shaped pieces. Iron staining occurs along the jointing planes of both zones; however, the staining is darker in the lower zone and mica minerals were noted in the bedding plane partings.

Sample A is representative of the material in the lower zone. Samples B, C, and D were taken 200 yards west of sample A and are representative of the massive zone. Sample B was taken at road level; C, from a ledge 30 feet above B; and D, from another ledge 100 feet above B.

Accessibility

The nearest rail facilities are at Kettle Falls, 34 miles from the deposit.

Laboratory Tests

The angular quartz fragments produced by crushing were milky white, indicating that the quartz was cryptocrystalline. Iron staining observed in samples B, C, and D was slight, whereas the quartz fragments of sample A were heavily stained. Beneficiation tests were not successful.

Deposit W-5				
Component	Sample analysis, percent			
	A	B	C	D
Glass button analysis:				
Head sample, Fe ₂ O ₃	0.35	0.08	0.10	0.12
Nonmagnetic product, Fe ₂ O ₃20	.08	.10	.11
Chemical analysis, head sample:				
Fe ₂ O ₃	--	.08	.09	.12
SiO ₂	--	98.13	98.72	98.49
Al ₂ O ₃	--	1.35	1.00	1.08
CaO	--	.09	.03	.10
MgO	--	.005	.06	.04

Twin Lake Claim (W-12)

Location

The Twin Lakes Claim is in Okanogan County, about 1.5 miles due north of Soap Lake and 3 miles southeast of Malott in the NE1/4 sec. 23, T. 32 N., R. 25 E.

Field Description

Clear, white, massive quartz outcropping through the granitic county rock forms this deposit. Iron-oxide staining is prominent along fracture and joint planes that strike N. 30° E. and dip 70° to the west. The lens-shaped quartz body is honeycombed with abandoned mining prospects. At least seven adits are still detectable; two remain open for more than 30 feet.

A sample was obtained from various points along the outcrops by chipping off fragments of the quartz rock.

Accessibility

By constructing 2 miles of new road, the 15 mile haul to the rail siding at Malott could be reduced to 6 miles. At present, a passable road leads to within 200 yards of the deposit.

Laboratory Tests

The transparent, angular fragments of the crushed massive quartz were fresh in appearance and exhibited only a slight degree of surface iron staining. Magnetic beneficiation reduced the iron content from 0.07 to 0.04 percent Fe_2O_3 , with the removal of only 4 percent of the head sample.

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Deposit W-12		
Component	Sample analysis, percent	
	A	AM ¹
Glass button analysis:		
Head sample, Fe_2O_3	0.07	--
Nonmagnetic product, Fe_2O_304	--
Chemical analysis, head sample:		
Fe_2O_306	0.030
SiO_2	99.70	98.50
Al_2O_331	.37
CaO	<.05	<.05
MgO	<.05	<.05

¹ Chemical analysis of beneficiated sample.

Quartz Mountain (W-18)

Location

The Quartz Mountain silica deposit is in Spokane County, about 18 miles northeast of Spokane and 3 miles southwest of Mount Spokane, in the center of NW1/4 sec. 35, T. 28 N., R. 45 E. (fig. 9).

Field Description

Outcroppings of massive quartz cap the granitic country rock forming the ridge of Quartz Mountain. The actual granite-quartz contact was difficult to determine due to the occurrence of overburden and quartz float in the form of huge boulders. Scattered outcrops to the southwest indicate a possible extension of the quartz body which strikes N 40° E. and dips 60° southeast. The quartz rock was clear to white, and minor iron stains along joint and fracture surfaces was the only impurity noted.

Mine workings include two adits and a vertical shaft, made many years ago in search for gold, and a small quarry, from which road metal was produced. The adits, one on each side of the ridge, were reported to be from 150 to 200 feet long and in granitic rock and quartz talus boulders. On the west side of the ridge, a shaft was driven through 85 feet of massive quartz and 15 feet of gouge material before being abandoned. In 1959, the Hemphill Bros. Quarry Contracting Co. expanded the quarry on the southwest end of the quartz body into a full-scale industrial operation. The quarried rock is crushed and screened at the deposit site, trucked to a rail siding, and washed before shipment.

Sample A was broken from outcrops across the deposit and from ledges and rock fragments in the test quarry; sample B was chipped from the rock stockpiled by the Hemphill Co.

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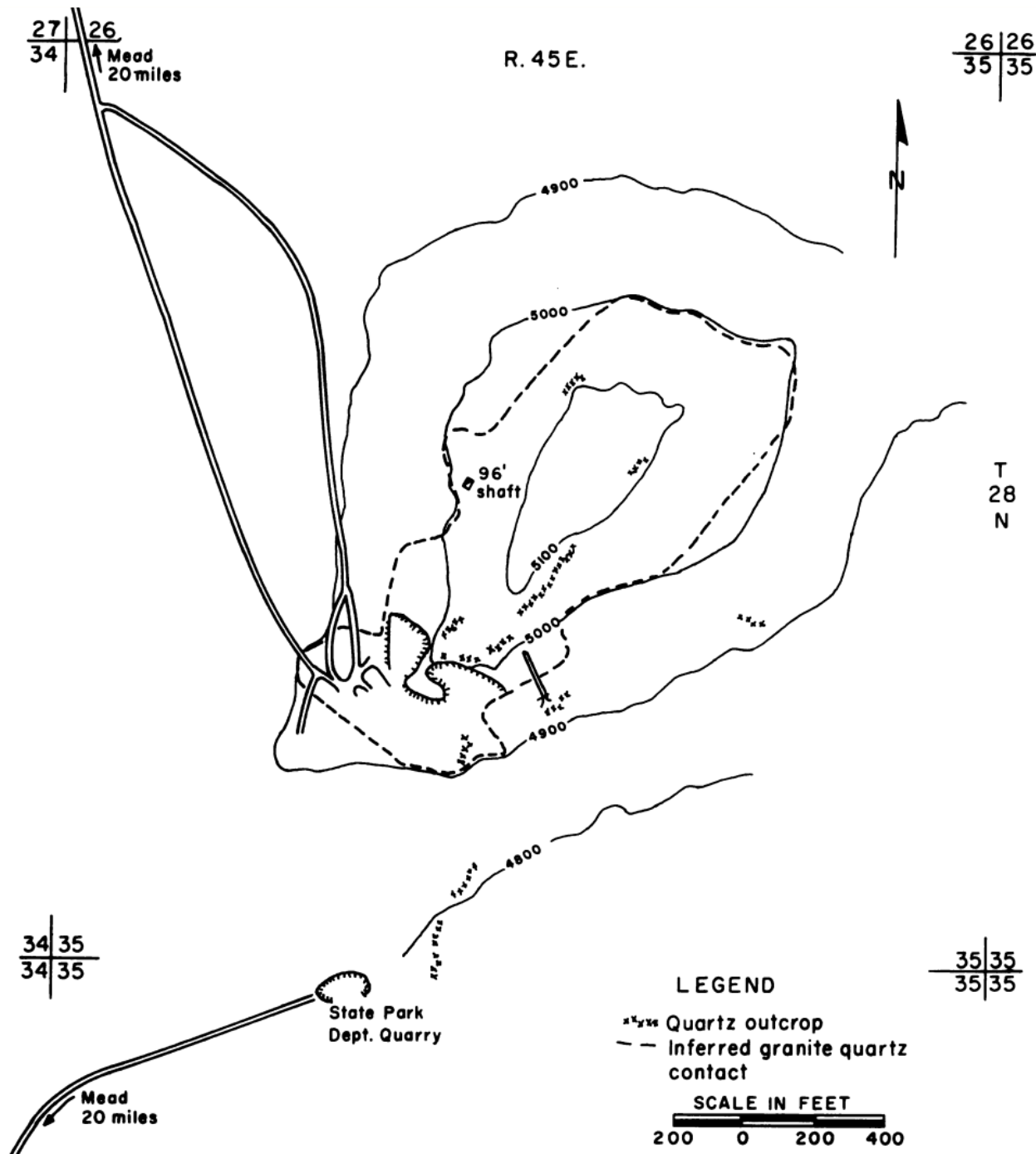


FIGURE 9. - Quartz Mountain Silica Deposit, Spokane County, Wash.

Accessibility

Mead, Wash., 20 miles via county roads from the deposit site, is the nearest rail siding.

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Laboratory Tests

The crushed fragments of both sample A and B were transparent and very angular, and the only impurity detected was slight surface iron staining on a few grains of sample B. Beneficiation of sample A was not attempted, but the purity of sample B was improved from 0.07 to 0.04 percent Fe_2O_3 by magnetic separation.

Deposit W-18				
Component	Sample analysis, percent			
	A	B	C ¹	D ²
Glass button analysis:				
Head sample, Fe_2O_3	0.02	0.07	--	--
Nonmagnetic product, Fe_2O_3 ...	--	.04	--	--
Chemical analysis, head sample:				
Fe_2O_302	--	0.007	0.113
SiO_2	99.61	--	99.75	99.75
Al_2O_336	--	.08	.07
CaO09	--	--	--
MgO009	--	--	--

¹ 7 car composite analysis of silica shipped to silicon manufacturer.

² Average of 10 analyses by 5 industrial laboratories.

Blue Grouse Mountain (W-21)

Location

The Blue Grouse Mountain silica deposit is in Stevens County, about 10 miles north of Deer Park on the east side of the mountain in the SE1/4 sec. 15, T. 30 N., R. 42 E.

Field Description

A cryptocrystalline quartz dike striking N. 72° W. and dipping 65° NE. outcrops in the granite schist slopes of Blue Grouse Mountain to form the deposit. The milky-white quartz rock is brittle and breaks easily when struck with a hammer. Iron staining was heavy along the contact with the granite schist.

Sample A was chipped from outcrops across the quartz deposit. The deposit was resampled later in a similar manner.

Accessibility

Quarried rock would have to be trucked to the railroad siding at Deer Park, a distance of 10 miles via Forest Service and county roads.

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Laboratory Tests

The quartz fragments of both samples were cloudy, angular, and slightly iron-stained. Only randomly occurring iron-bearing minerals were noted in sample A; however, sample B contained a large percentage of black minerals. The black minerals, although only slightly magnetic, were readily removed by magnetic beneficiation. Beneficiation reduced the iron content of sample B from 0.55 to 0.04 percent Fe_2O_3 by the removal of 10 percent of the sample.

Deposit W-21

Component	Sample analysis, percent		
	A	B ¹	BM ²
Glass button analysis:			
Head sample, Fe ₂ O ₃	0.06	0.55	--
Nonmagnetic product, Fe ₂ O ₃06	.04	--
Chemical analysis, head sample:			
Fe ₂ O ₃05	.05	0.049
SiO ₂	99.37	>10	97.8
Al ₂ O ₃52	1 - 5	.50
CaO05	<.01	<.05
MgO029	<.1	<.05

¹ Spectrographic analysis rather than chemical analysis.

² Chemical analysis on beneficiated sample.

Addy Quartzite Formation

Location

The Addy Quartzite formation is exposed extensively throughout Stevens County, particularly in the Chewelah area. Samples were taken from several sites as listed in table 6 and shown in figure 10.

Field Description

Jones¹⁰ mapped all of the quartzites in the Chewelah Quadrangle as one unit, the Addy Quartzite formation. Weaver¹¹, however, divided the quartzite into several units--the Addy, Eagle Mountain, Colville, and undifferentiated quartzite. Since the mapping by Jones was at a larger scale and his contacts were mapped in greater detail, his definition of units and designation of outcrop boundaries has been followed in this report.

The topography formed by quartzite outcroppings is bold and rugged and often characterized by the development of extensive talus slopes. The rock is predominantly a hard, massive, crystalline quartzite, in which the quartz grains are cemented by recrystallization. However, in localized areas recrystallization or cementation is poorly developed, and the resulting rock is a

¹⁰ Jones, R. H. B., Notes on the Geology of the Chewelah Quadrangle of Stevens County, Wash.: Northwest Science, vol. 2, December 1928, p. 111.

¹¹ Weaver, C. E., The Minerals Resources of Stevens County: Washington Geol. Survey Bull. 20, 1920, Olympia, Wash., pp. 56-82.

sandstone. Textural and structural variations range from fine-grained, massive through medium-grained, distinctly bedded to pebbly or conglomeratic quartzites. Impurities strongly influence the prevailing gray-white color of the quartzite. Iron oxide staining produced a pink, grayish-yellow, or brown rock, depending upon the amount present. A dark gray rock resulted from the inclusion of argillaceous material.

Quarries were developed at three of the deposits, the Chewelah, Deitrich, and Lyons Hill; however, production was small, and none remained in operation. The quarried rock was crushed and washed at the deposit site and trucked to rail sidings for shipping.

Because the quartzite outcrops are so vast, more than 250 square miles, reconnaissance sampling was done only in the areas that had good accessibility and large reserves. The grab samples were taken from traverses across the deposit outcrops.

Accessibility

All the deposits investigated are accessible by county or Forest Service roads. The distance from rail transportation ranges from less than 1 mile to approximately 12 miles.

Laboratory Tests

Most of the massive quartzite samples were extremely hard, and crushing produced clear to cloudy, very angular fragments. Clear, subangular to rounded quartz grains resulted from the crushing of the poorly recrystallized material. Since natural contamination was due almost entirely to iron staining, the susceptibility to beneficiation was poor, and only nominal improvement was possible. Results of these tests are shown in table B-2.

The glass button and chemical analyses, table 6, serve to indicate the wide variation in iron content, which apparently is characteristic of these quartzites. As a result of this inconsistency, quarrying operations at the Deitrich and Lyons Hill deposits were discontinued. Only the material from

Dietrich and Lyons Hill deposits were discontinued. Only the material from the Lane Mountain area appears consistent enough to warrant more detailed presentation.

Additional field and laboratory data and spectrographic analyses are tabulated in appendix B.

Lane Mountain (W-29 and W-30)

Location

Two silica deposits are on Lane Mountain in Stevens County. One deposit is a massive quartzite on the southern slopes of the Mountain about 9 miles northwest of Springdale in secs. 34 and 35, T. 31 N., R. 39 E. The other is a friable sandstone exposed on the northern slopes of Lane Mountain about 5 miles west of Waits Lake in secs. 22 and 27, T. 31 N., R. 39 E. Location of both deposits is shown in figure 11.

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	Fe ₂ O ₃ content, percent		
	Glass button analyses	Chemical analyses	
		Bur. Mines	Reported
	0.10	0.11	10.50
	-	-	2 .37
	-	-	1 .89
	.14	.14	2 .14
	.19	.17	1 .38
			1 .52
			2 .23
			3 .30
			3 .60
	.22	.21	1 .47
	.26	.27	-
	.10	.11	-
	.06	.054	-
	.10	.10	2 .36
			2 4 .099
			2 4 .056

TABLE 6 - Location, field description, and analyses of Adc

Name of deposit	Location	Rock type
Chewelah.....	SW1/4 NE1/4 sec. 4, T. 32 N., R. 40 E.	Light-gray quartzite.
Chewelah 2 (Waterman Pit).....	Sec. 28, T. 32 N., R. 40 E.	Mixture of sand and quartzite gravel.
Deitrich (Cottonwood Creek)...	SE1/4 sec. 6, T. 31 N., R. 41 E.	Gray to pink very har quartzite.
Inklers Point.....	Secs. 11 and 14, T. 31 N., R. 40 E.	Bedded pink and gray quartzite.
Iron Mountain.....	Secs. 1 and 2, T. 33 N., R. 39 E	Fine-grained dark-gra quartzite.
Kulzer Siding.....	E1/2 SW1/4 sec. 27 and NE1/4 NW1/4 sec. 34, T. 31 N., R. 40 E.	Gray quartzite.
Lane Mountain (South).....	Secs. 34 and 35, T. 31 N., R. 39 E.	Milky-white to gray quartzite.
Lane Mountain (North).....	Secs. 22 and 27, T. 31 N., R. 39 E.	Light-gray to tan sandstone.
Lyons Hill.....	NW1/4 SW1/4, sec. 13, T. 29 N., R. 39 E.	Poorly cemented tan sandstone.

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- Location, field description, and analyses of Addy quartzite deposits (Con.)

	Location	Rock type	Fe ₂ O ₃ content, percent	
			Glass button analyses	Chemical analyses
			Bur. Mines	Reported
....	Sec. 26, T. 33 N., R. 40 E.	Pink to white quartzite. Light-colored bedded quartzite. Gray quartzite.	.10	.10
....	SW1/4 sec. 26, T. 36 N., R. 40 E.		.12	.096
....	W1/2 sec. 9, T. 32 N., R. 40 E.		.20	.114
				.097
				.20
				1.64
				3.30

cket for Columbia River Hydroelectric Power Using Northwest Minerals: Northwest Silica
. Div. Eng. Off., Portland, Oreg., vols. 1, 2, sec. 2, 1938, p. 22.
Industrial Silica for Northwest Industries: Raw Materials Survey, Portland, Oreg.,
1958, pp. 6-11.
Refractory and Other Uses of Northwest Silica: University of Washington, Thesis, M. S.
, p. 16.

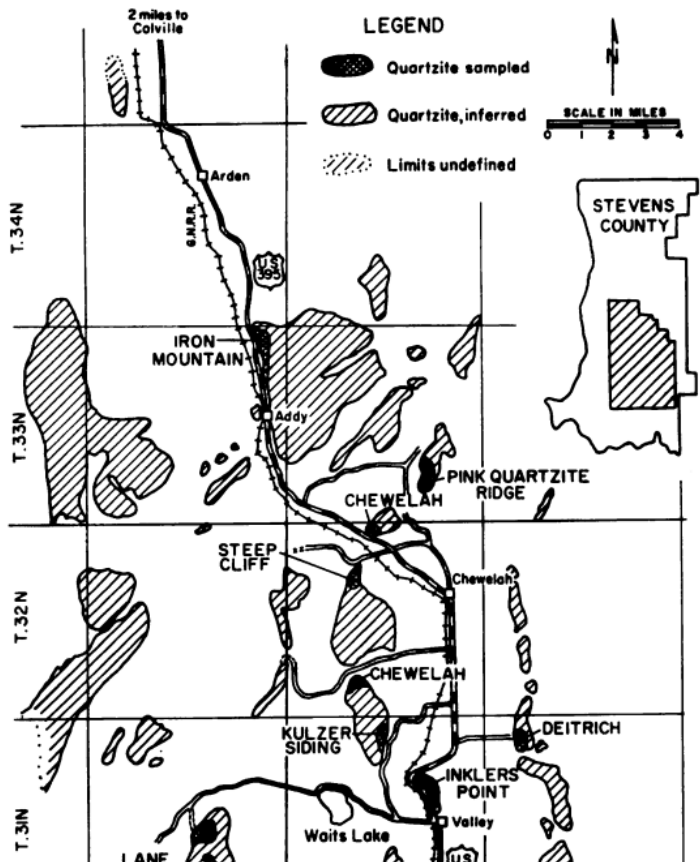
TABLE 6.

Name of deposit
Pink Quartzite
Shallenberger
Steep Cliff
1 Hodge, E. T., Mar
2 Minerals, U. S.
Starrett, C. K.,
Res. Rept. 1:
3 Campbell, R. A.,
Cer. Eng., 1945
4 Washed sample.

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Field Description

Lane Mountain is the site of a local anomaly in the regional metamorphism of Stevens County. In the area represented by samples 29-A, 29-B, and 29-C the rock is a hard, dense, cryptocrystalline quartzite that varies in color from a milky gray-white to a pinkish or yellowish gray and strikes N. 20° W. and dips 20° W. Jointing and fracturing have given the outcrops and talus a blocky appearance. To the north the intensity of the metamorphism diminishes, and the rock becomes softer. A sandy, friable, poorly cemented, gray to yellowish gray sandstone striking N. 40° W. and dipping 45° W. is exposed in the prospect trenches of the Lane Mountain Silica Co., represented by samples 30-A, 30-B,

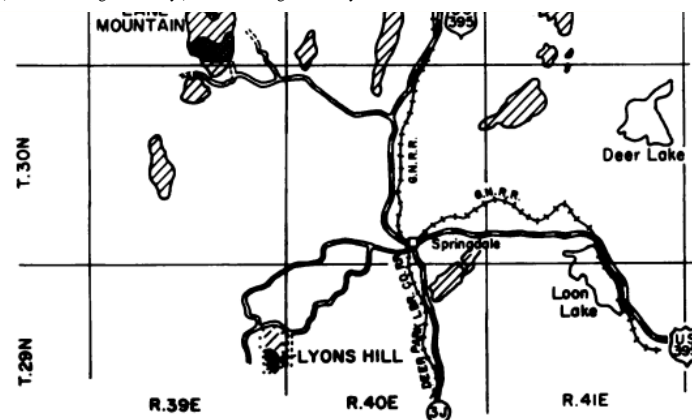


FIGURE 10. - Addy Quartzite Outcrops in the Chewelah Quadrangle of Stevens County, Wash.

dozer trenches and one diamond drill hole. Brush and overburden were stripped off in three places from which samples 30-A, 30-B, and 30-C were taken. A hole was drilled perpendicular to the dip to ascertain the thickness of the bed. To a depth of 40 feet the core was continuous. Below 40 feet the rock became soft and shattered, and core recovery was poor. The hole was finally lost at a depth of 57 feet. Fragments recovered from the bottom of the hole showed less staining than did surface material.

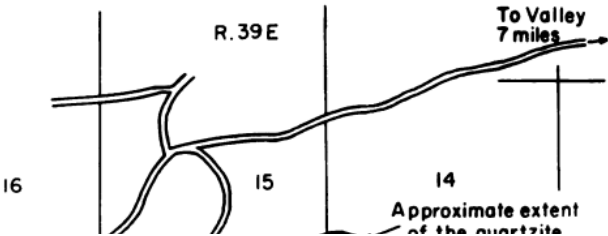
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and 30-C. Farther north, in the area of sample 30-B, layers of the sandstone are more competent and stand out as ribs along the strike. Jointing and fracturing is prominent throughout all the sandstones, and slight iron staining occurs along the planes of parting. Timber and shallow overburden cover most of the mountain, obscuring contacts and deposit borders.

The prospecting on the north slopes by Lane Mountain Silica Co. included several hundred feet of open-cut bull-

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Samples 29-A, 29-B, 29-C were taken by chipping fragments from outcrops and talus across the deposit. Samples 30-A, 30-B, and 30-C were taken from traverses across the

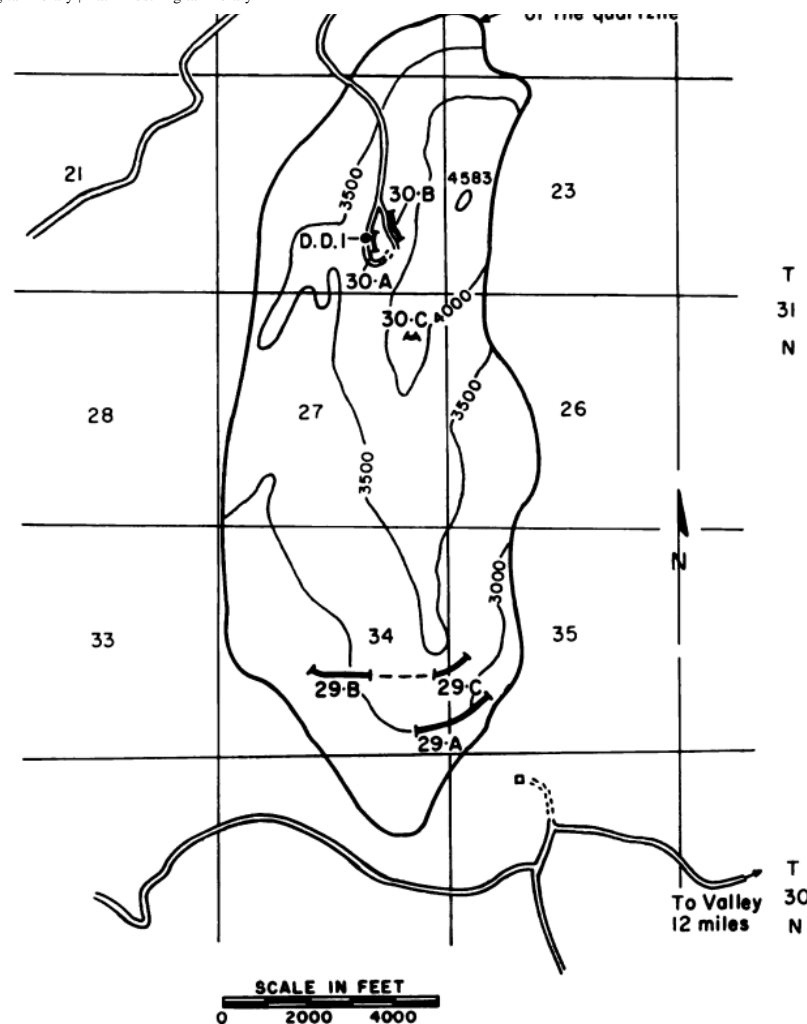


FIGURE 11. - Lane Mountain Silica Deposits, Stevens County, Wash.

of limonite. Neither sample was amenable to pronounced beneficiation although samples from area 29 were improved more than samples from area 30.

On the basis of developmental testing, the Lane Mountain Silica Co. has announced that sandstone will be mined from two quarries and trucked to the plant site where it will be crushed, milled, scrubbed, dried, and stored for shipment to consumers.

trenched areas.

Accessibility

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N
Rail loading facilities are available at Valley, Wash., 12 miles from the south Lane Mountain deposit and 10 miles from the north Lane Mountain site. The Lane Mountain Silica Co. processing plant, now under construction, will be at Valley, Wash.

Laboratory Tests

The quartzite fragments (samples 29-A, 29-B, and 29-C) were clear to cloudy and angular. Surface iron staining accounted for almost all the iron contamination, as only an occasional inclusion was noted. Sample 29-B was notably more iron-stained than either of the others. The quartz grains of samples 30-A, 30-B, and 30-C were subangular to rounded and mostly quite clear. Impurities were largely surface staining and an occasional grain

Deposit W-29

Component	Sample analysis, percent		
	A	B	C
Glass button analysis:			
Head sample, Fe_2O_3	0.10	0.15	0.06
Nonmagnetic product, Fe_2O_308	.12	.04
Chemical analysis, head sample:			
Fe_2O_311	--	.053
SiO_2	98.96	--	--
Al_2O_375	--	--
CaO05	--	--
MgO055	--	--

Deposit W-30

Component	Sample analysis, percent			
	A	B	C	D ¹
Glass button analysis:				
Head sample, Fe_2O_3	0.06	0.05	0.04	--
Nonmagnetic product, Fe_2O_306	.04	.03	--
Chemical analysis, head sample:				
Fe_2O_3	--	.044	--	0.054
SiO_2	--	--	--	97.2
Al_2O_3	--	--	--	.03
CaO	--	--	--	<.05
MgO	--	--	--	<.05

¹ Chemical analyses on composite of samples 30-A, 30-B, and 30-C.

Evaluation of Washington Resources

The Quartz Mountain and Twin Lakes deposits are two of the most promising

sources of massive silica in Washington. The Quartz Mountain deposit is a large, high-grade silica occurrence now being mined as a source of SiO_2 for silicon and ferrosilicon manufacturing. During 1959, 60,000 tons of quartz was quarried, sized, washed, and shipped to consumers. Silica from the Twin Lakes claim, a medium sized deposit, should provide a second source of raw materials for silicon and ferrosilicon producers.

The quality of the Lynx Creek and Blue Grouse Mountain deposits is good although both require special mining or handling to insure uniform quality. The Lynx Creek quartzite would require selective mining, whereas the Blue Grouse Mountain quartz would have to be either selectively mined or crushed and beneficiated, because part of the material is contaminated by iron-bearing minerals. Since Blue Grouse Mountain is only a medium sized deposit, the quartz probably would not warrant any special handling.

Due to the cursory nature of the field examinations and to consumers dissatisfaction with the quality of quartz from these deposits, the Addy Quartzite deposits cannot, at this time, be classified as industrial silica reserves. However, evidence gathered from these investigations indicates

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that there are areas from which high-grade silica may be quarried. Lane Mountain was the most promising area investigated. Material from this area, especially from the Lane Mountain Silica Co. holdings, was of good quality, although product uniformity must be established.

CONCLUSIONS

The critical shortage of industrial silica in the Pacific Northwest in 1957 has been partly relieved. Massive quartz from Quartz Mountain in Spokane County, Wash., has replaced the depleted Dennison deposit as the principal source of silica for silicon and ferrosilicon. At the present rate of output, this deposit should remain a major producer for many years. Development of the Bovill silica deposit offers glass producers their first large, local source of low-iron sand. The reserves are large and laboratory and pilot plant tests indicate that a uniform high-quality glass sand can be produced. The outlook for the Lane Mountain Silica Co., property is promising based on exploratory

field and laboratory data; however, because these sandstones and quartzites are nonhomogeneous, more extensive exploration is needed to establish the merit of this deposit.

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APPENDIX A

TABLE A-1. - Analyses of samples from large, high-grade deposits

Sample	Glass button analysis, percent		Chemical analysis of head sample, percent				
	Head sample, Fe ₂ O ₃	Nonmagnetic product, Fe ₂ O ₃	Fe ₂ O ₃	SiO ₂	Al ₂ O ₃	CaO	MgO
Idaho:							
I-6-B.....	-	0.02	¹ 0.02	99.25	0.67	0.10	0.005
I-6-BF.....	-	.02	¹ .03	99.30	.61	.09	.005
I-6-C.....	0.45	.11	-	-	-	-	-
I-6-D.....	.25	.05	.24	-	-	-	-
I-7-A.....	.03	-	.02	94.36	3.08	.10	.036
I-7-B.....	.03	-	.01	96.30	2.25	.09	.009
I-7-C.....	.35	.20	-	-	-	-	-
I-7-D.....	.85	.55	-	-	-	-	-
I-7-E.....	.22	.18	-	-	-	-	-
I-7-F.....	.20	.18	-	-	-	-	-
Bovill.....	-	-	¹ .036	96.28	1.97	.08	.02
Do.....	-	-	¹ .026	99.072	.564	.025	.086
Gem Silica.....	-	-	.095	84.78	8.47	.49	.06
Do.....	-	-	.038	85.21	8.75	.69	-
Montana:							
M-1.....	.07	.06	.05	98.9	.41	<.05	<.05
	-	-	.049	97.5	.45	<.05	<.05
M-6.....	.04	.04	.029	98.9	.29	<.05	<.05
	-	-	.036	99.2	.31	<.05	<.05
M-7.....	.03	-	.02	99.59	.36	.10	.007
	-	-	.07	99.63	.14	-	-
M-8.....	.02	-	.02	99.46	.45	.09	.011
M-10.....	.04	.02	.032	93.6	.26	<.05	<.05
			.036	98.7	.44	<.05	<.05
Oregon:							
O-1-B.....	.90	.35	² .67	>10	>10	1 5	1 - 5
	-	-	.78	82.42	9.17	1.68	.08
	-	.19	¹ .19	84.0	8.08	1.10	<.05
O-2-A.....	.50	-	-	-	-	-	-
O-2-B.....	.18	.15	-	-	-	-	-
O-2-C.....	.08	.08	.074	98.7	.83	<.05	<.05
O-2-D.....	.09	.09	.094	98.4	.53	<.05	<.05
	-	-	.080	97.6	.96	<.05	<.05
O-3.....	.04	.02	.000	.000	.00	.00	.00

U-5.....	.04	.03	.033	98.8	.25	<.05	<.05
	-	-	.029	99.0	.19	<.05	<.05
Washington:							
W-5-A.....	.35	.20	-	-	-	-	-
W-5-B.....	.08	.08	.08	98.13	1.35	.09	.005
W-5-C.....	.10	.10	.09	98.72	1.00	.03	.06

See footnotes at end of table.

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TABLE A-1. - Analyses of samples from large,
high-grade deposits - Continued

Sample	Glass button analysis, percent		Chemical analysis of head sample, percent				
	Head sample, Fe ₂ O ₃	Nonmagnetic product, Fe ₂ O ₃					
			Fe ₂ O ₃	SiO ₂	Al ₂ O ₃	CaC	MgO
Washington:							
W-5-D.....	0.12	0.11	0.12	98.49	1.08	0.10	0.04
W-12.....	.07	.04	.06	99.7	.31	<.05	<.05
	-	-	¹ .03	98.5	.37	<.05	<.05
W-18-A.....	.02	-	.02	99.61	.36	.09	.009
W-18-B.....	.07	.04	.077	99.75	.08	-	-
	-	-	.113	99.75	.07	-	-
W-21-A.....	.06	.06	.05	99.37	.52	.05	.029
W-21-B.....	.55	.04	² .41	>10	¹ - 5	<.01	<.1
	-	-	¹ .049	97.8	.50	<.05	<.05
W-29-A.....	.10	.08	.11	98.96	.75	.05	.055
W-29-B.....	.15	.12	-	-	-	-	-
W-29-C.....	.06	.04	.053	-	-	-	-
	-	-	.60	-	-	-	-
W-30-A.....	.06	.06	³ .054	97.2	.03	<.05	<.05
W-30-B.....	.05	.04	.044	-	-	-	-

W-30-C.....	.04	.03	.043	-	-	-	-
1	Analysis on beneficiated sample.						
2	Spectrographic analysis.						
3	Analysis on composite of samples 30-A, 30-B, and 30-C.						

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TABLE A-2. - Location and field description of small, high-grade silica deposits

Sample	County	Name of deposit	Location	Type of deposit	Acce
aho: I-1.....	Bonner	Freeman Lake	¹ NEL/4 sec. 12, T. 56 N., R. 6 W.	Quartz pegmatite lens	4 miles
I-2.....do.....	Little Grass Mountain	¹ Secs. 5 and 6, T. 62 N., and secs. 31 and 32, T. 63 N., R. 5 W.	3 quartz pegmatite lenses	42 miles
I-3.....	Clearwater	Birch Mountain	¹ Sec. 25, T. 41 N., R. 10 E.	Quartz pegmatite lens	40 miles
ntana: M-4 ²	Cascade	Hover Creek	³ T. 14 N., R. 8 E.do.....	5 miles
M-9.....	Judith Basin	Belt Creek	³ Sec. 6, T. 14 N., R. 9 E.	2 quartz pegmatite dikes	3-1/2 mi
egon: O-4.....	Lake	Western Mineral Co. dump	⁴ Sec. 32, T. 37 S., R. 17 E.	Opalite replacement	25 miles
shington: W-1.....	Chelan	Burch Mountain	⁴ NEL/4 sec. 32, T. 24 N. and NEL/4 sec. 5, T. 23 N., R. 20 E.	Quartz pegmatite lenses	6 miles
W-2.....do.....	Harris Creek	⁴ NWL/4 sec. 34, T. 27 N., R. 20 E.	Quartz pegmatite lens	18 miles
W-4.....	Ferry	Independent Mountain	⁴ Sec. 22, T. 40 N., R. 35 E.do.....	4 miles
W-7.....	Lincoln	Egypt	⁴ SEL/4 sec. 6, T. 27 N., R. 37 E.	Quartz pegmatite dike	17 miles
W-8.....	Okanogan	Buzzard Silica	⁴ Center sec. 6, T. 33 N., R. 25 E.	Quartz pegmatite lens	10 miles
W-9.....do.....	Loup-Loup	⁴ NEL/4 SW1/4 sec. 6, T. 33 N., R. 25 E.do.....	10 miles
W-10.....do.....	Moly-Quartz Pegmatite	⁴ SW1/4 sec. 11, T. 32 N., R. 25 E.do.....	2 miles
W-11.....do.....	Snow White	⁴ Center sec. 1, T. 35 N N., R. 23 E.do.....	30 miles

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field description of small, high-grade silica deposits - Continued

it	Location	Type of deposit	Accessibility
e	⁴ NE1/4 sec. 31, T. 35 N., R. 13 E.	Quartz dike	16 miles to RR.
	⁴ SW1/4 sec. 20, T. 25 N., R. 44 E.	Quartz pegmatite lens	1 mile to RR.
	⁴ NE1/4 sec. 13, T. 29 N., R. 45 E.	Quartz dike	4 miles to RR.
	⁴ Center S. 1/2 sec. 13, T. 29 N., R. 45 E.	Quartz plug	4 miles to RR.
	⁴ SW1/4 sec. 31, T. 28 N., R. 38 E.	Quartz pegmatite pipe	30 miles to RR.
	⁴ SW1/4 SW1/4 sec. 11, T. 35 N., R. 37 E.	Quartz dike	4 miles to RR.
	⁴ Center NW1/4 sec. 4, T. 35 N., R. 40 E.	Quartz pegmatite lens	9 miles to RR.
	⁴ Sec. 24, T. 30 N., R. 42 E.	2 quartz dikes	12 miles to RR.

n; has been described as large.

TABLE A-2. - Location and

Sample	County	Name of depos
Washington		
W-14.....	Skagit	Mineral City
W-15.....	Spokane	Empire Granit quarry
W-16.....do....	Glander
W-16C.....do....do.....
W-20.....	Stevens	Big Smoke
W-24.....do....	Geisbauer
W-27.....do....	Keeley
W-35.....do....	Steinmetz

¹ Boise meridian.
² The size of deposit M-4 is unknown
³ Principal meridian.
⁴ Willamette meridian.

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TABLE A-3. - Analyses of samples from small,
high-grade silica deposits

Sample	Glass button analysis, percent		Chemical analysis of head sample, percent				
	Head sample, Fe ₂ O ₃	Nonmagnetic product, Fe ₂ O ₃	Fe ₂ O ₃	SiO ₂	Al ₂ O ₃	CaO	MgO
Idaho:							
I-1-A.....	0.02	0.02	0.017	99.3	0.23	<0.05	<0.05
I-1-B.....	.04	.03	.024	98.2	.20	<.05	<.05
I-2-A.....	.10	.09	² . 09	>10	.1 - 1	<.01	<.1
I-2-B.....	.07	.04	-	-	-	-	-
I-3.....	.04	.04	.034	99.2	.23	<.05	<.05

Montana:							
M-4.....	.03	.03	.02	97.9	.22	<.05	<.05
M-9.....	.04	.03	.04	98.3	.18	<.05	<.05
Oregon:							
O-4.....	.08	.07	.079	98.2	.76	<.05	<.05
-	-	-	.061	98.7	.82	<.05	<.05
Washington:							
W-1-A.....	.04	.03	.037	99.7	.27	<.05	<.05
-	-	-	¹ .02	99.0	.21	<.05	<.05
W-1-B.....	.07	.03	.077	99.5	.26	<.05	<.05
-	-	-	¹ .021	98.7	.40	<.05	<.05
W-2.....	.04	.03	.033	98.1	.39	<.05	<.05
-	-	-	¹ .023	98.7	.44	<.05	<.05
W-4.....	.13	.06	² .11	>10	.1 - 1	<.1	<.1
W-7.....	.03	.03	.03	99.94	.04	.03	.005
W-8.....	.02	.02	.021	98.1	.24	<.05	<.05
W-9.....	.03	.02	.029	99.5	.29	<.05	<.05
-	-	-	¹ .021	99.1	.30	<.05	<.05
W-10.....	.07	.06	.054	99.7	.26	<.05	<.05
-	-	-	¹ .040	98.9	.31	<.05	<.05
W-11.....	.03	.03	.023	99.5	.25	<.05	<.05
-	-	-	¹ .026	99.1	.32	<.05	<.05
W-14.....	.03	.03	.04	99.60	.32	.04	.005
W-15.....	.05	.03	.045	99.2	.46	<.05	<.05
-	-	-	¹ .020	98.2	.61	<.05	<.05
W-16-A.....	.20	.06	¹ .06	99.37	.43	.05	.045
W-16-B.....	.21	.08	.18	96.9	.69	<.05	<.05
W-16-C.....	.04	.03	.031	99.7	.24	<.05	<.05
-	-	-	¹ .024	98.7	.26	<.05	<.05
W-20.....	.05	.03	.06	99.6	.33	.02	.007
W-24-A.....	.07	.03	.062	99.4	.38	<.05	<.05
-	-	-	.069	98.8	.34	<.05	<.05
W-24-B.....	.08	.03	.096	97.6	.01	<.05	<.05
W-27.....	.05	.04	.04	99.25	.60	.12	.009
W-35.....	.15	.14	² .16	>10	.1 - 1	<.1	<.1

¹ Analysis on beneficiated sample.
² Spectrographic analysis.

APPENDIX B

E B-1. - Location and field description of lower grade silica deposits

inty	Name of deposit	Location	Type of deposit	Size
water	Cedars Camp	¹ Sec. 21, T. 41 N., R. 11 E.	Quartzite	Unlimited.
o....	Kelly Creek	¹ Sec. 16, T. 39 N., R. 11 E.	Sandstone	Very large.
nai	Two Brothers	¹ El/2 sec. 13, T. 52 N., R. 3 W.	Quartz dike	Very small.
	Joel	¹ NE1/4 sec. 29, T. 39 N., R. 4 W.	Quartz pegmatite dike	Small.
ngton	Weiser	¹ Sec. 23, T. 11 N., R. 4 W.	Sand grading to sandstone	Large.
de	Armington	² SE1/4 sec. 1, T. 18 N., R. 6 E.	Flat bedded sandstone	Small.
o....	Great Falls	² Sec. 33, T. 21 N., R. 4 E.do.....	Do.
au	Virgelle	² Sec. 18, T. 26 N., R. 12 E.do.....	Unlimited.
ula	Lyons Pit	² NE1/4 sec. 17, T. 12 N., R. 17 W.	Pink quartzite	Do.
ers	Plains Road Cut	² Secs. 6 and 7, T. 20 N., R. 26 W.	Gray quartzite	Do.
	Eugene Sand	³ S1/2 NE1/4 sec. 34, T. 17 S., R. 4 W.	Sand	Medium.
	Dreissel	³ Sec. 6, T. 38 N., R. 37 E.	Quartz pegmatite lens	Very small.

TABLE	
Sample	Cou
Idaho: I-4.....	Clear
I-5.....d
I-8.....	Kootenai
I-9.....	Latah
I-10.....	Wahkiakum
Montana: M-2.....	Cascade
M-3.....d
M-5.....	Choteau
M-11.....	Missoula
M-12.....	Sandwich
Oregon: O-5.....	Lane
Washington: W-3.....	Ferry

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. 15 N.,	Sandstone	Small.
36 N.,	Quartzite	Unlimited.
35, T.		
, 43 E.		
NE1/4do.....	Medium.
T. 24		
3 E.		
35, T.do.....	Unlimited.
, 45 E.		
† sec.	Quartzite	Large.
N., R.		
6, T.do.....	Do.
, 41 E.		
nd 14,do.....	Unlimited.
, R. 40		
1 2, T.do.....	Large.
, 39 E.		
sec. 27do.....	Very large.
† NW1/4		
T. 31		
) E.		
† sec.	Sandstone	Large.
3 N., R.		
. 26, T.	Quartzite	Very large.
. 40 E.		
26, T.do.....	Large.
40 E.		
3, T.do.....	Do.
. 40		
20 anddo.....	Unlimited.
5 N., R.		

Size

unlimited

W-6.....	Lewis	Parkins Sandstone	³ Sec. 28, T. 1 W.
W-13.....	Pend Oreille	Eagle Claim	³ Sec. 2, T. and sec. 37 N., R. 1 W. 1/2 NE1/4 sec. 15, N., R. 4; NW1/4 sec. 21 N., R. 1 SW1/4 NE1/4 4, T. 32 40 E.
W-17.....	Spokane	Moran Prairie	³ SE1/4 sec. 31 N., R. 1
W-19.....do.....	Tekoa Mountain	³ Secs. 11 and T. 31 N., E.
W-22.....	Stevens	Chewelah	³ Secs. 1 and 33 N., R. 1 E1/2 SW1/4 and NE1/4 sec. 34, N., R. 4; NW1/4 SW1/4 13, T. 2; 39 E.
W-23.....do.....	Deitrich	³ Center sec. 33 N., R. 1 SW1/4 sec. 36 N., R. 1
W-25.....do.....	Inklers Point	³ W1/2 sec. 32 N., R. 1 E.
W-26.....do.....	Iron Mountain	³ Secs. 16, 17, 21, T. 1; 45 E.
W-28.....do.....	Kulzer Siding	
W-31.....do.....	Lyons Hill	
W-32.....do.....	Pink Quartzite Ridge	
W-33.....do.....	Shellenberger	
W-34.....do.....	Steep Cliff	
W-36.....	Whitman	Kamiak Butte	

See footnotes at end of table.

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APPENDIX B

TABLE B-1. - Location and field description of lower grade silica deposits -Continued

Sample	County	Name of deposit	Location	Type of deposit
Washington (Cont.): W-37.....	Stevens	Steptoe Butte	³ Secs. 19, 20, 29 and 30, T. 18 N., R. 44 E.	Quartzite

Boise meridian.
Principal meridian.
Williamette meridian.

U

TABLE B-2. - Analyses of samples from lower
grade silica deposits

Sample	Glass button analysis, percent		Spectrographic analysis of head sample, percent ¹				
	Head sample, Fe ₂ O ₃	Nonmagnetic product, Fe ₂ O ₃	Fe ₂ O ₃	SiO ₂	Al ₂ O ₃	CaO	MgO
Idaho:							
I-4.....	0.90	-	0.51	>10	5 - 10	<0.1	<0.1
I-5.....	4.50	-	2.10	>10	>10	>10	>10
I-8.....	.22	0.22	.20	>10	5 - 10	<.1	1 - 5
I-9.....	.20	.20	.19	>10	.1 - 1	<.01	<.1
I-10.....	.16	.15	.14	>10	>10	1 - 5	<.1
Montana:							
M-2.....	>5.00	-	2.80	>10	5 - 10	>10	>10
M-3.....	>5.00	-	3.85	>10	>10	1 - 5	1 - 5
M-5.....	1.10	-	.87	>10	>10	1 - 5	1 - 5
M-11.....	.70	-	.60	>10	5 - 10	<.1	.1 - 1
M-12.....	1.00	-	.87	>10	>10	.1 - 1	.1 - 1
Oregon:							
O-5.....	.20	.07	.23	>10	1 - 5	<.1	<.1
Washington:							
W-3.....	.65	-	² 406	65.7	14.5	1.30	.067
	-	-	² .48	72.3	14.5	1.15	.55
W-6.....	.25	-	.27	>10	>10	.1 - 1	.1 - 1
W-13.....	.12	.11	.11	>10	.1 - 1	<.1	<.1
W-17.....	.20	.15	.19	>10	.1 - 1	<.1	<.1
W-19.....	1.00	-	.94	>10	>10	<.01	1 - 5
W-22.....	.10	.08	.11	>10	.1 - 1	<.1	<.1
W-23.....	.14	.08	² .14	99.4	.46	.03	.009
W-25.....	.19	.17	.17	>10	.1 - 1	<.1	<.1

W-26-A.....	.22	.22	³ .21	>10	.1 - 1	<.01	<.1
W-26-B.....	.18	.18	-	-	-	-	-
W-26-C.....	.25	.16	-	-	-	-	-
W-28.....	.26	.24	.27	>10	.1 - 1	<.01	<.1
W-31.....	.10	.09	.10	>10	.1 - 1	<.1	<.1
W-32.....	.10	.09	² .096	99.0	.50	<.05	<.05
	-	-	² .10	98.2	.58	<.05	<.05
W-33.....	.12	.10	² .114	98.6	.72	<.05	<.05
	-	-	² ⁴ .097	98.0	.74	< .05	<.05
W-34.....	.20	-	.20	>10	.1 - 1	< .01	<.1
W-36.....	.65	-	.57	>10	.1 - 1	<.01	<.1
W-37-A.....	.18	.18	.17	>10	1 - 5	<.1	<.1
W-37-B.....	.25	.25	-	-	-	-	-

- ¹ Spectrographic analyses were reported in the following quantitative categories: Over 10 percent, 5 to 10 percent, 1 to 5 percent, 0.1 to 1 percent, etc. Fe₂O₃ was determined quantitatively by fluorescent X-ray spectroscopy.
- ² Chemical analysis.
- ³ Analysis on composite of sample 26-A, 26-B, and 26-C.
- ⁴ Analysis on beneficiated sample.

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of deposit	Reason for not sampling
ymatite lens utcrop	Too small. Do.
tringers likes like	Included rock. Do. Too small.
eous earth	Not applicable for industrial silica.
egmatite	Too small.
as like	Dark sand, con- taminated. Too small.
egmatites .do.....	Do. Do.
eous earth	Not applicable.
tringers	Included rock.
eous earth e	Not exposed. Iron contamina- tion.
ed andesite	Included rock.

APPENDIX C

TABLE C-1. - Deposits examined but not sampled

County	Name of deposit	Location	Type of deposit
Idaho:			
Bonner.....	Found and Glad	¹ Sec. 14, T. 54 N., R. 5 W.	Small pebbles
Kootenai.....	R. M. Property	¹ SE1/4 sec. 13, T. 52 N., R. 3 W.	Quartz ore
Montana:			
Beaverhead..	Armstead	10 miles west of Armstead	Quartz sand
Madison.....	Bonanza Vein	Near Rochester	Quartz diorite
Saunders....	Silver Butte	Unknown	Quartz diorite
Oregon:			
Baker.....	Keating Chalk pit	² SE1/4, sec. 15, T. 8 S., R. 42 E.	Diatomite
Do.....	Nadie Property	² Secs. 29 and 32, T. 11 S., R. 41 E.	Quartz pebbles
Harney.....	Narrows Sand Dunes	² T. 27 S., R. 30 E.	Sand dunes
Jackson.....	Ashland	² NE1/4 sec. 25, T. 39 S., R. 1 W.	Quartz diorite
Josephine...	Ryno Silica	² Sec. 35, T. 34 S., R. 4 W.	Quartz pebbles
Do.....	Snyder-Mackie	² NE1/4 sec. 5, T. 35 S., R. 6 W.
Malheur.....	Westfall Pit	² SE1/4 sec. 34, T. 18 S., R. 41 E.	Diatomite
Wheeler.....	Rock Creek-Antone	² Sec. 12, T. 13 S., R. 24 E.	Quartz sand
Washington:			
Adams.....	Daymon Farm	² Sec. 25, T. 16 N., R. 30 E.	Diatomite
King.....	Franklin strip mine	E. of Black Diamond	Sandstone
Do.....	White River	² NW1/4 sec. 1, T. 19 N., R. 7 E.	Silicification

Oreille mine und Ranch	³ NW1/4 SW1/4 sec. 30, T. 17 N., R. 5 E.	Tailings concentrate Quartz dikes	Calcite contam- ination. Included Rock.
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n.

Pend	Pend
Oreille	
Pierce	Siegm

1 Boise Meridian.
a Willamette meridia

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