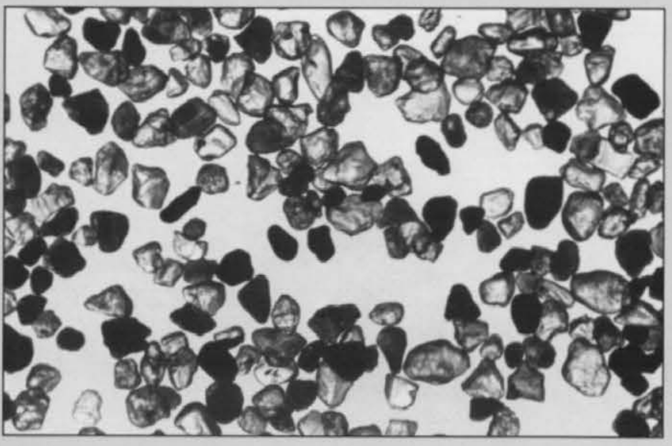
SPECIAL PAPER 22



SILICA
IN OREGON

1990

1859

STATE OF OREGON
DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES
DONALD A. HULL, STATE GEOLOGIST

STATE OF OREGON
DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES
910 State Office Building 1400 SW Fifth Avenue
Portland, Oregon 97201

SPECIAL PAPER 22

SILICA IN OREGON

By Ronald P. Geitgey
Appendix by Gary L. Baxter
Oregon Department of Geology and Mineral Industries

1990

Conducted and published in conformance with ORS 516.030

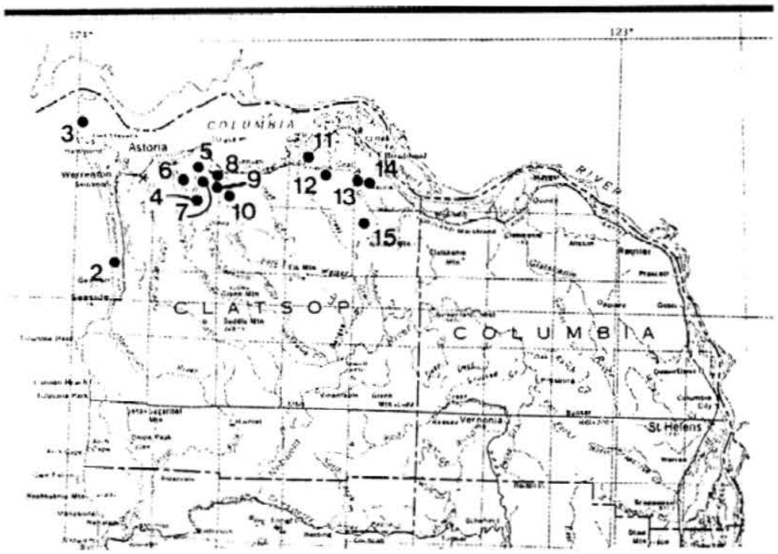
1859

Oregon Department of Geology and Mineral Industries Special Papers, ISSN 0278-3703

ERRATA SHEET, SPECIAL PAPER 22, SILICA IN OREGON
OREGON DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES

During preparation of this publication, some items were omitted.

Please add (1) missing lines showing locations of samples 4, 7, and 9 on the map on Plate 1 and (2) the missing quarter section information for samples 2 through 15 on the sample locations table on Plate 2.



Sample no.		Sec.	T.	R.
1	W½W½	34	24 S.	13 W.
2	SW¼NE¼	33	7 N.	10 W.
3	NE¼NE¼	36	9 N.	11 W.
4	SE¼NE¼	34	8 N.	9 W.
5	SW¼SE¼	15	8 N.	9 W.
6	SE¼NW¼	21	8 N.	9 W.
7	SW¼SE¼	22	8 N.	9 W.
8	SW¼NW¼	24	8 N.	9 W.
9	SE¼SE¼	24	8 N.	9 W.
10	SE¼SW¼	29	8 N.	8 W.
11	SE¼NE¼	8	8 N.	7 W.
12	NE¼SW¼	15	8 N.	7 W.
13	NW¼NW¼	19	8 N.	6 W.
14	NW¼NW¼	19	8 N.	6 W.
15	SE¼SE¼	6	7 N.	6 W.
16	NE¼NE¼	10	1 N.	9 E.
17	SW¼SW¼	20	4 N.	25 E.
18	NW¼NE¼	10	4 N.	25 E.
19	SE¼NW¼	29	3 N.	26 E.
20	NE¼SW¼	19	4 S.	29 E.
21	SW¼SE¼	33	4 S.	29 E.
22	NW¼NW¼	4	5 S.	29 E.
23	SW¼NW¼	15	4 N.	40 E.
24	NW¼NW¼	6	5 N.	42 E.
25	NW¼SE¼	28	6 N.	43 E.
26	NW¼NE¼	22	6 N.	43 E.
27	NE¼SE¼	12	5 N.	43 E.
28	NW¼NE¼	27	20 S.	42 E.
29	NW¼NE¼	27	20 S.	42 E.
30	SW¼SE¼	13	20 S.	44 E.
31	SW¼SW¼	25	20 S.	44 E.
32	NE¼SW¼	29	21 S.	45 E.
33	SE¼SE¼	20	22 S.	44 E.
34	SW¼NE¼	1	23 S.	43 E.
35	SE¼SE¼	19	24 S.	43 E.
36	NE¼NW¼	22	41 S.	35 E.
37	SW¼SW¼	27	29 S.	23 E.
38	SW¼NW¼	6	26 S.	20 E.
39	SE¼SE¼	33	29 S.	17 E.
40	SW¼NW¼	34	30 S.	2 E.
41	SE¼NE¼	33	30 S.	2 E.
42	SE¼NW¼	2	28 S.	1 E.
43	SW¼NW¼	2	28 S.	1 E.
44	SW¼SE¼	30	36 S.	3 W.
45	SW¼SE¼	30	36 S.	3 W.

CONTENTS

ILLUSTRATIONS

Page

FIGURES

TABLES

PLATES (folded separately)

COVER PHOTOGRAPHS (top to bottom)

1. Quartz Mountain silica deposit, Douglas County.
2. Bristol Silica and Limestone Company pit and primary crusher, Jackson County.
3. Dune sand from CooSand Corporation mine in Coos County.
4. Colored glass containers produced by Owens-Illinois, Inc., Portland, from dune sand mined by CooSand Corporation, Coos County.

SILICA IN OREGON

SUMMARY

Silica is produced by three companies in Oregon for various end uses including colored container glass, nickel smelting, ferrosilicon production, filter bed media, and decorative rock for exposed-aggregate panels, roofing, and landscaping. This report reviews these operations and surveys other silica occurrences to identify additional sources of silica and industrial sand. Basic chemical, mineralogical, and screen-size data are presented for 45 samples from a variety of geological environments throughout the state. Quartzo-feldspathic sandstones of potential commercial interest are identified in Clatsop, Morrow, and Malheur Counties. In northwestern Clatsop County near Astoria, the Youngs Bay sandstone member of the Astoria Formation contains approximately 85 percent SiO_2 and 0.25 percent Fe_2O_3. A sample from the Herren formation in the Arbuckle Mountain area of southeastern Morrow County contains approximately 97 percent SiO_2 and 0.05 percent Fe_2O_3. Samples from the Owyhee Reservoir area of northern Malheur County contain approximately 80 percent SiO_2 and 0.25 percent Fe_2O_3.

ACKNOWLEDGMENTS

I wish to thank the following reviewers for their respective criticisms and perspectives of the manuscript: Ray Harris, Geological Survey of Wyoming; Dennis Olmstead, Oregon Department of Geology and Mineral Industries; Hank Reed, Billings, Montana; and Palmer Sweet, Virginia Division of Mineral Resources. I derived considerable benefit from discussions of various aspects of silica occurrence and production with the following individuals: Mike Cummings, Portland State University; Mark Ferns, Jerry Gray, and Len Ramp, Oregon Department of Geology and Mineral Industries; Mike Pungercar, Dow Corning Corporation; Butch Rannells, Quartz Mountain; Al Starkey, Bristol Silica and Limestone Company; and Ron Gibson. I am grateful also to Denny Jones and Ron Reinhart for guidance to and information on the Basin Creek and Green Point Creek occurrences, respectively. Laboratory analyses were performed by Gary Baxter and Chuck Radasch; the report was prepared for publication by Beverly Vogt and Klaus Neuendorf; and the plates were prepared by Mark Neuhaus, all of the Oregon Department of Geology and Mineral Industries.

INTRODUCTION

PURPOSE OF STUDY

The purpose of this report is to survey potential sources of silica and industrial sand in Oregon and to present basic chemical, mineralogical, and screen-size data for each occurrence. Testing the suitability of a sample for all possible industrial end uses is not feasible, and the data presented are meant only to provide a preliminary evaluation. This work must be considered a reconnaissance study to identify areas and geologic environments that merit more detailed investigation. Determination of the resource value of these occurrences will require much more extensive analysis including geologic mapping, detailed sampling, beneficiation testing, and marketing studies.

SILICA, SILICON, SILICONES, SILICATES

Silica is a term applied to all forms of SiO_2. It occurs naturally as crystalline quartz and in very fine-grained or cryptocrystalline varieties of chalcedony, including agate, jasper, flint, and chert. Under various conditions, SiO_2 may also crystallize as tridymite or cristobalite and can occur in a hydrous form as opal. Silica can also occur naturally or be manufactured as an amorphous compound.

Silicon is elemental Si, a silvery-grayish metal that can be smelted from silica but does not occur naturally in uncombined form.

Silicones are a large group of manufactured chemical polymers whose structures are silicon and oxygen chains to which various organic groups (carbon and hydrogen) are attached, forming compounds ranging from oily liquids to rubbery solids with lubricating, insulating, and moisture-resistant properties.

Silicates are a large group of both natural minerals and manufactured compounds that contain silicon, oxygen, and numerous other elements. The naturally occurring forms include the major rock-forming minerals such as quartz, feldspars, ferromagnesian minerals, micas, and clay minerals. Silicates of many elements can be manufactured, the most common ones being sodium silicates or "water glass." Various sodium silicates are essential components in domestic and industrial detergents as well as in binders and adhesives (Coope, 1989).

USES OF SILICA

Silica in its various forms has chemical and physical characteristics that make it valuable in many industrial applications. The major uses of silica include glass and ceramic manufacturing, construction aggregates, foundry sands for metal casting, air-abrasive sands, hydraulic fracturing sands for oil and gas production, production of silicon metal and compounds, base metal smelting, and functional fillers in numerous products such as rubber, plastics, and paints. Silica for these various end uses may be produced from unconsolidated sands, from sandstones, quartzites, quartz veins, quartz replacement bodies, or residual quartz boulders. Mining methods include surface mining, underground mining, and dredging, and some silica is produced as a by-product or co-product of other mining or manufacturing activities. Each end use has its own physical and chemical specifications that are often reflected in the market value of the siliceous raw material.

A commercial distinction is made between sand used for aggregate or construction purposes and industrial sand used for the manufacturing of various products. The two uses are not mutually exclusive, but construction sand is largely a particle-size designation and need not necessarily contain quartz, while industrial sand is valuable for its high silica content. Sand for construction uses is currently worth a few dollars per ton, while high-purity silica for the production of silicon metal has various stringent compositional requirements and may be valued at over $100 per ton. Particle size, shape, and distribution and the cost of processing to meet specifications also determine the value and suitability of a silica source for a particular end use.

SPECIFICATIONS AND REQUIREMENTS FOR INDUSTRIAL SILICA

Industrial silica sources are valued for their purity, consistency, and ease of processing. Beyond this very general statement, specifications are as varied as the end uses themselves. The requirements for glass sand and metallurgical silica ore illustrate the range of some of the specifications.

Silica sands for glass manufacture must have a uniform particle size, an absence of refractory minerals, and a low iron content. Massive quartz deposits can be crushed to the desirable size range, but crushing is expensive, and special equipment and precautions must be used to prevent the introduction of iron or other deleterious components. Uniform particle size, preferably in the range of 20 mesh to 150 mesh (approximately 0.8 mm to 0.1 mm) promotes complete and uniform melting with other batch components. Finer grains could be blown out in the furnace flue gases, and coarser grains may only partially melt, forming a defect in the glass product. Similarly, refractory minerals such as rutile, zircon, or tourmaline would remain unmelted. Iron is a strong coloring agent in glass, so sand for clear flat glass or clear container glass must have maximum iron contents from 0.10 percent to less than 0.01 percent. Colored container glass and fiberglass mixes can tolerate 0.10 percent to 0.25 percent Fe_2O_3 in the glass sand (Bentzen, 1980). Most commercial glass mixes contain various amounts of alumina (Al_2O_3), alkalis (Na_2O, K_2O), and alkaline earths (CaO, MgO), so although high-purity silica sand may be desirable, it is not absolutely essential. Feldspathic sands may be usable if their alumina, alkali, and alkaline-earth proportions are appropriate to the glass formulation and their composition is consistent.

The metallurgical uses of silica include the production of ferrosilicon, silicon metal, and silicon carbide. Ferrosilicon, an alloy of iron and silicon in various proportions, is used as a smelting and alloying agent in the production of various steels, nickel metal, and magnesium metal. Silicon metal is used to alloy aluminum and other metals, to produce organosilicon compounds such as silicones, and, in its ultrapure forms, to make semiconductor devices.

Silica sources for metallurgical uses are typically massive varieties of quartz crushed to particle sizes of 1 in. or larger. These larger lumps, rather than sand grains, are necessary to maintain porosity for gas evolution, to promote uniform melting, and to prevent the loss of silica from the furnace during the smelting process. The silica must be mechanically stable during heating; that is, it must not decrepitate or break down into finer particles due to thermal expansion or moisture loss.

Purity requirements vary widely. Because specifications for semiconductor silicon metal require impurity levels in parts-per-billion ranges, its production is more economic if high-purity feed stock can be used; quartz for ferrosilicon production, however, may contain up to 2 percent of various metal and alkali oxides (Murphy and Brown, 1985). The chemical specifications of Dow Corning Corporation (Springfield, Oregon) for quartz to produce silicon metal used to manufacture silicones are listed in Table 1. Dow Corning is also testing a new method of smelting silicon metal in a plasma furnace using high-purity silica sand as feed stock rather than lump quartz (Industrial Minerals, 1990).

Table 1. *Dow Corning Corporation chemical specifications for quartz for silicon metal production (Pungercar, Dow Corning Corporation, Springfield, Oregon, personal communication, 1989).*

SiO_2	99.4	percent minimum
Fe_2O_3	0.15	percent maximum
Al_2O_3	0.15	percent maximum
CaO	0.05	percent maximum
TiO_2	0.05	percent maximum

BENEFICIATION TECHNIQUES

In recent years, industry specifications have become increasingly stringent. To remain competitive, nearly every industrial silica producer has to use some form of beneficiation to meet and maintain product requirements. Many of the techniques are derived from those used in metal ore dressing.

Some combination of crushing, milling, washing, and screening is used as necessary to produce an optimum grain size for a particular end use. For many industrial applications, the most detrimental contaminant is iron, which may be present as oxide grains, oxide coatings, sulfides, ferromagnesian minerals, and iron-rich clays. Associated with these iron-bearing minerals are many other contaminating elements such as aluminum, titanium, calcium, magnesium, chromium, cobalt, and manganese. Iron-bearing minerals typically have higher specific gravities than quartz, so spiral separators or other methods of hydroclassification may be used to lower the iron content. Some iron-bearing mineral grains can be removed by high-intensity magnetic separation using either permanent magnets or electromagnets. Coatings and clays can be removed by attrition scrubbing, a method in which a mixture of about 75 percent ore and 25 percent water is vigorously agitated to abrade the grain surfaces. Acids, bases, or other chemicals may be added to dissolve the coatings and help remove the resultant fine material or slimes. Froth flotation techniques have also been developed to separate the various minerals present such as quartz from feldspar (Bentzen, 1980; Brown and Redeker, 1980). All such techniques are useful only if the impurities occur as discreet grains or if they can be liberated from the quartz by milling. Impurity minerals that occur as inclusions encapsulated in the quartz grains may be impossible, or at least uneconomic, to separate.

PREVIOUS INVESTIGATIONS IN OREGON

Previous investigations of industrial silica sources in Oregon have largely been parts of regional surveys of the Pacific Northwest (Hodge, 1938; Ladoo, 1946; Carter and others, 1962; Burlington Northern, 1972). Extensive testing of a foundry sand from the Eugene area was summarized by Lowry (1947), but the deposit was never placed in large-scale production. It now lies within the city of Eugene, and part of the deposit has been removed for fill in road construction. The mineralogy and physical characteristics of coastal dunes were described by Twenhofel (1946), and beneficiation testing was conducted by the U.S. Bureau of Mines (Carter and others, 1964). Test results of some fluvial and glacial sands were reported by Gray (1984). This latter study suggested that a more extensive investigation of sand deposits from marine and fluvial environments was warranted.

SAMPLING AND ANALYTICAL PROCEDURES

Samples were collected in a variety of ways depending on the occurrence. Samples from all operating properties were taken from stockpiles and processing plants and as such do not necessarily represent the deposit as a whole or define its variability. All other samples were taken from surface or outcrop exposures. Specific sample sites were chosen from what were judged in the field to be representative exposures. About 5 pounds were collected from shallow pits on limited exposures, vertical channels on thicker exposures, and rock chips from about a 10- by 10-ft area in well-cemented sandstones and quartz replacement bodies. No subsurface samples were taken, and no attempt was made to collect a suite of samples that would accurately represent an occurrence over its entire thickness or areal extent. Geologic mapping of sufficient detail to permit estimation of deposit volumes has not been completed in many areas of Oregon, particularly in the central and eastern counties.

A total of 45 samples was collected in 11 counties from several geologic environments including coastal dunes, interior dunes, marine sediments, fluvial sediments, volcaniclastic sediments, and quartz replacement bodies. All of the sedimentary units consist of quartzofeldspathic arkosic sands, although in some the feldspars are altered or weathered to clays, and in others the feldspars are silicified. Few of the occurrences sampled would be marketable without some form of beneficiation. Depending on the characteristics of the deposit and the end-use specifications, beneficiation may be as simple as crushing, washing, screening, or magnetic separation or as complex and costly as froth flotation. The sample locations and characteristics are summarized in Plates 1 and 2.

Details of sample preparation, analytical procedures, and quality control are described in the Appendix. Samples were prepared by drying, crushing, and grinding where required. Sand samples were dry-screened with Tyler Standard Series screens, and their particle-size distributions are tabulated in Plate 2. Selected sand samples were subjected to attrition-scrubbing and wet screening. A portion of the minus-20-/plus-200-mesh fraction was taken for chemical analysis of both the as-received and the scrubbed material. The chemical data in Plate 2 were obtained by X-ray fluorescence (XRF) analysis. Precision of the XRF laboratory was checked by blind samples and accuracy by direct current plasma (DCP) emission spectrometric analysis and wet-chemical analysis of selected samples by another laboratory. Trace-element chemistry of the six rock samples was determined by DCP and is summarized in the section entitled "Quartz replacement bodies" (p. 11). Wet-chemical analysis of these high-silica rock samples indicates that the XRF values for SiO_2 are systematically 1 percent to 2 percent low.

CURRENT OREGON PRODUCTION

At present, there are three producers of industrial silica in Oregon: CooSand Corporation in Coos County, Quartz Mountain in Douglas County, and Bristol Silica and Limestone Company in Jackson County.

COOSAND CORPORATION

CooSand Corporation mines quartzofeldspathic beach dunes on the north side of Coos Bay near North Bend (Plate 1). The dune sand is mined, loaded directly into rail cars by a front-end loader, and shipped to a processing plant in Clackamas, near Portland, where it is dried and then beneficiated by magnetic separation (Figure 1). Most of the production is sold to Owens-Illinois, Inc., in Portland to manufacture green and brown glass containers. Lesser amounts are sold for locomotive traction sand and air abrasives. CooSand has been in production since 1964 and

Figure 1. CooSand Corporation in North Bend, Coos County. Quartzofeldspathic dune sand is mined by front end loader and shipped by rail to Portland for production of colored glass containers.

in recent years has shipped about 25,000 tons per year to its Clackamas plant.

Sample 1 is unprocessed sand from the CooSand property. Virtually all of the sand is between 35 and 100 mesh (Tyler Standard Series), well within the optimum size range for many industrial applications. Chemical analysis of the sample (Plate 2) compares favorably with previously published analyses (Carter, and others, 1964; Grant, 1987). Beneficiation testing by the U.S. Bureau of Mines (Carter and others, 1964) and CooSand (reported in Grant, 1987) indicates that flint glass quality silica could be produced from this deposit by magnetic separation, scrubbing, acid leaching, and froth flotation. Beneficiation costs, including probable recovery rates of around 50 percent, would be significant, but the higher quality product would command a higher price in a larger market, and the feldspar could have value as a co-product for ceramics or filler applications. The CooSand property has the advantages of excellent grain size distribution, ease of mining, and convenience of location with respect to rail and water transportation.

QUARTZ MOUNTAIN

Quartz Mountain is located about 35 mi southeast of Roseburg in Douglas County (Plate 1). Since mining began there in 1971, virtually all production has been shipped by truck to Riddle, Oregon, initially for use by the M.A. Hanna Company for smelting nickel from the Nickel Mountain deposit. Hanna ceased operation in 1985, but Glenbrook Nickel has reopened the property and is using Quartz Mountain silica for the production of ferrosilicon and nickel metal. Crushing and screening to minus 6 in./plus $^{3}/_{4}$ in. improve the product's performance in smelting by eliminating fine particles and reducing the alumina content, presumably by removing clay minerals from fracture surfaces. Current production is about 25,000 tons annually. Reserves may be in excess of 100 million tons, and the owners of Quartz Mountain are seeking additional markets

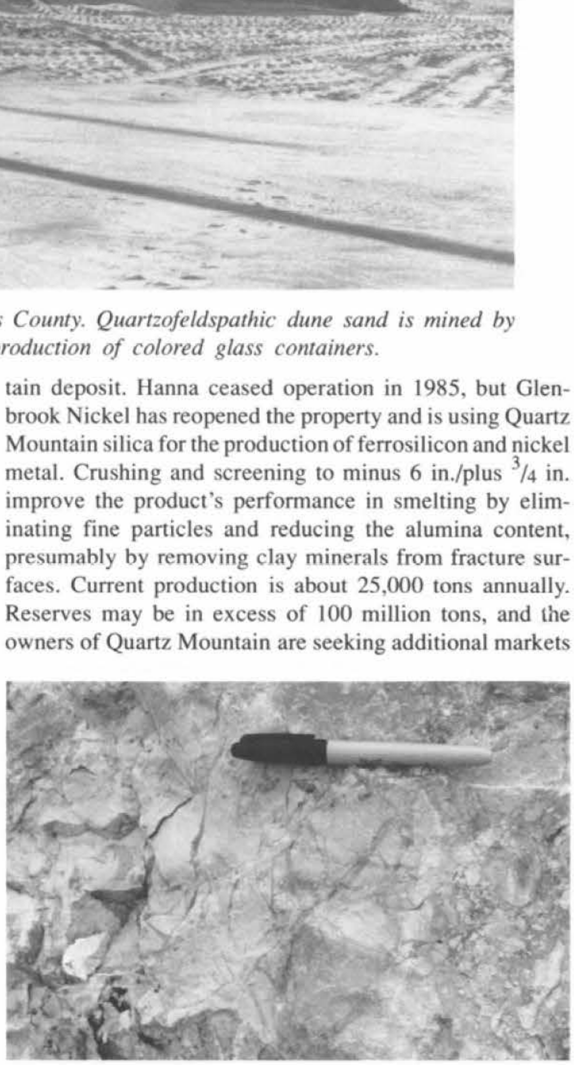


Figure 2. Relict volcanic texture in quartz replacement body of the Quartz Mountain deposit, Douglas County.

Figure 3. Quartz Mountain, Douglas County. Quartz replacement body is mined, crushed, and screened on site and shipped by truck to Riddle, Oregon, for use in nickel smelting and ferrosilicon production.

(G. Rannells, Quartz Mountain, personal communication, 1990).

The geology of the Quartz Mountain silica deposit was described by Ramp (1960). Relict textures indicate the deposit is the result of silicification of a volcanic tuff (Figure 2). Samples 42 and 43 (Plates 1 and 2) were taken from a stockpile and from a working face in the Quartz Mountain pit (Figure 3), respectively.

BRISTOL SILICA AND LIMESTONE COMPANY

The Bristol Silica and Limestone Company deposit is located in Jackson County about 12 mi northwest of Medford near the towns of Rogue River and Gold Hill (sample locations 44 and 45, Plates 1 and 2). The initial claims were staked in 1937, and production has continued since that time. The silica body appears to be a replacement of a carbonate lens within the Applegate Group (Oregon Department of Geology and Mineral Industries, 1943, page 55; Brooks, 1989, page 47).

The deposit is mined by open-pit methods, and primary crushing is done at the pit (Figure 4). The material is transported by truck to a plant located on a rail line about 5 mi away where it is further crushed, screened, and bagged (Figure 5). Bristol produces crushed quartz in several size ranges for decorative stone, exposed aggregate panels, roofing, poultry grit, nursery bedding, and filter bed media. Past production has been sold for metallurgical uses and for the manufacture of silicon metal and silicon carbide. A small amount of limestone and dolomite also has been produced for agricultural and horticultural markets (A. Starkey, General Manager, Bristol Silica and Limestone Company, personal communication, 1989). Samples 44 and 45 were taken from a pit stockpile and from a crushing plant, respectively.

Figure 4. Main pit of the Bristol Silica and Limestone Company, Jackson County; quartz replacement body in carbonate host rock.

Figure 5. A portion of the Bristol Silica and Limestone Company processing plant where crushed quartz from the pit is further crushed, screened, and bagged.

SILICA OCCURRENCES IN OREGON

COASTAL DUNES (samples 1-3)

The Oregon coast consists of sand beaches and dune fields punctuated by rocky headlands. The sands contain varying proportions of quartz, feldspar, rock fragments, and heavy minerals including ferromagnesian minerals, magnetite, ilmenite, chromite, and others. Sand composition is a function of the composition of coastal rocks, the geology of the contributing drainage basins, and wind and wave action. Concentrations of heavy minerals, known also as "black sands" or "mineral sands," occur primarily south of Coos Bay in Coos and Curry Counties and immediately south of rocky headlands on the central and northern coast. While too low in silica and too high in metallics to be considered as potential sources for industrial silica, the mineral sands are potential sources of titanium, chromium, zirconium, and precious metals. Previous workers have described various characteristics of the coastal sands. Kulm and others (1986), Peterson and others (1986), and Kulm and Peterson (1990) summarized the occurrences and the literature of the mineral sands; Twenhofel (1946) described the mineralogical and physical composition of sands north of Coos Bay; Cooper (1958) discussed the geomorphology, vegetation, and origin of the dunes; and Carter and others (1964) conducted beneficiation studies of the Oregon coastal dunes sands.

From Coos Bay northward, particularly in areas of active dunes, the sands frequently have SiO_2 contents above 75 percent and Fe_2O_3 contents below 1 percent. In Clatsop County, silica content drops,and iron content rises, presumably as a result of the influx of sediment from the Columbia River drainage basin. From Coos Bay to Florence, there is an extensive dune field that has chemical and physical characteristics necessary for industrial silica. However, except for an imbedded claim block near Reedsport (Grant, 1987) and an operating property at North Bend, both owned by CooSand, most of the area is part of the Oregon Dunes National Recreation Area and is currently unavailable for development.

The coastal dunes exhibit an extremely narrow particle size distribution, between 35 and 100 mesh as reported by Twenhofel (1946, p. 56) and as illustrated by samples 1, 2, and 3 of this report. Grains are typically subrounded to subangular, and many exhibit iron oxide coatings (Figure 6). Attrition scrubbing produced no effect on appearance or total iron content of sample 1. However, acid leaching was found by Carter and others (1964) to be effective in reducing total iron content.

ASTORIA AREA (samples 4-14)

Northwest Oregon is underlain by a thick section of Tertiary sediments that have been studied extensively for their hydrocarbon potential. The results of several years of investigations are summarized by Niem and Niem (1985). Much of the area is underlain by the lower to middle Miocene Astoria Formation, which includes arkosic sandstones. Two sandstone units (units Tay_1 and Tay_2 of Niem and Niem, 1985) of the Youngs Bay member were selected for sampling, based on (1) their thickness and areal extent as reported by several workers (Carter, 1976; Nelson, 1978; Coryell, 1978; Cooper, 1980) and (2) the proximity of the units to rail and water transportation.

Both sandstone units are lenticular and have been in-

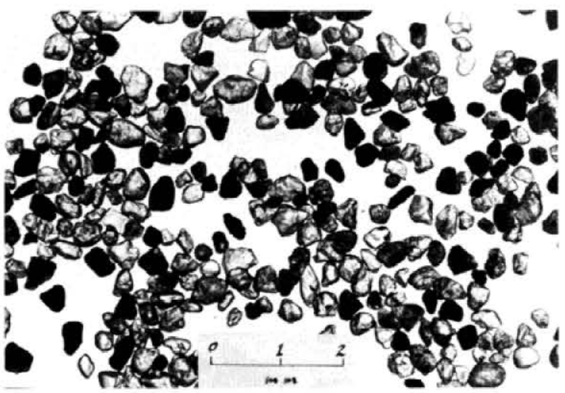


Figure 6. Sample 1 in transmitted light. Scrubbed dune sand from the CooSand Corporation operation, Coos County, -35/+65-mesh fraction representing 83 percent of the sample. Transparent grains are quartz and feldspar; opaque grains are polycrystalline quartz (chert).

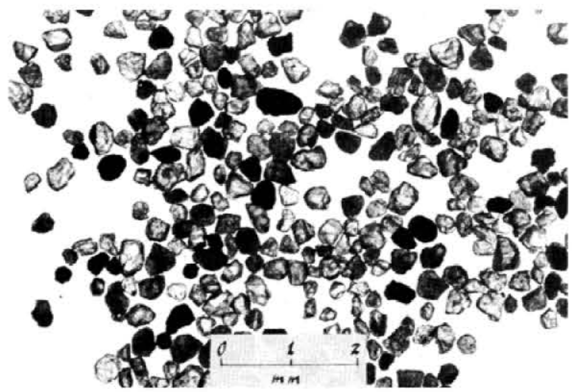


Figure 7. Sample 9 in transmitted light. Scrubbed sand from the Youngs Bay member of the Astoria Formation, Clatsop County, -35/+65-mesh fraction representing 30 percent of the sample. Transparent grains are quartz and feldspar; opaque grains are polycrystalline quartz (chert).

terpreted as submarine canyon deposits. Unit Tay_1 is up to 200 ft thick, and unit Tay_2 is up to about 1,000 ft thick. Samples 4 and 5 are from unit Tay_1, and samples 6 through 10 are from unit Tay_2. Youngs Bay member sandstones are feldspathic with subangular to subrounded grains (Figure 7) and a fairly broad particle size distribution, although well over 90 percent of the grains are plus 200 mesh in most samples. The plus-20-mesh fraction is largely clumps of non-disaggregated grains, and few individual grains are larger than 20 mesh. Muscovite and ferromagnesian minerals are present in amounts of less than 1 percent, and lithic fragments are present only in trace amounts.

Iron staining is present both on outcrop and on grain surfaces of some of the samples, but the iron content was lowered from about 1 percent to about 0.25 percent, and the grain surfaces were thoroughly cleaned by attrition scrubbing. Both units appear to have a light-colored clay matrix, but XRD analysis of the minus-200-mesh fraction of both dry-screened and attrition-scrubbed, wet-screened samples indicated primarily quartz and feldspar with only traces of clay minerals.

The middle Miocene Gnat Creek formation (informal) (Niem and Niem, 1985) is a fluvial shallow marine unit that crops out between 10 and 20 mi east of Astoria. Referred to previously as the Clifton formation (Murphy 1981), the Gnat Creek has a basal arkosic facies up to 300 ft thick with an areal extent of about 10 mi^2. Samples 11 through 14 were collected from the basal arkosic facies. The grain size distribution is somewhat narrower than in the Youngs Bay member of the Astoria Formation, and the lithic-fragment, mica, and ferromagnesian-mineral contents are higher, estimated at 2 percent to 4 percent for each. Most of the quartz and feldspar grains are angular to subangular with some rounded to well-rounded polycrystalline quartz grains (chert). Iron staining and clay coatings are common on grain surfaces, but they are readily removed by attrition scrubbing. Scrubbed samples show a marked decrease in iron, although the iron content is still higher than in the Astoria Formation samples. The basal arkosic facies of the Gnat Creek formation has been mined in the past as a source of silica for the production of portland cement.

VANTAGE SANDSTONE (samples 15-16)

The Columbia River Basalt Group has numerous sedimentary interbeds between basalt flows. Most interbeds represent fluvial or lacustrine environments in which claystones, siltstones, sandstones, tuffaceous sediments, and coal are developed on flow tops. A widespread fluvial unit, the Vantage Member of the Ellensburg Formation (as redefined by Swanson and others 1979), rests on top of the Grande Ronde Basalt and at the base of the Wanapum Basalt of the Columbia River Basalt Group. Two samples were taken from the Vantage Member in areas where it is primarily an arkosic sandstone. Sample 15 is from a 20-ft-thick outcrop in Clatsop County, and sample 16 is from a 25-ft-thick road cut in Hood River County. Both samples exhibit angular to subangular quartz and feldspar grains with up to 5 percent micaceous minerals including muscovite, biotite, and chlorite. Rock fragments and ferromagnesian minerals comprise about 2 percent of the samples (Figure 8). Sample 15 retained some iron staining on grain surfaces after scrubbing, but sample 16 was thoroughly cleaned. Scrubbing reduced the grain size of the micas and concentrated them in the finer fractions. The exposed areal extent of the Vantage Member is rarely large since it lies between basalt flows, but in some areas enough of the Wanapum Basalt has been removed by erosion to permit at least limited access to the sandstone.

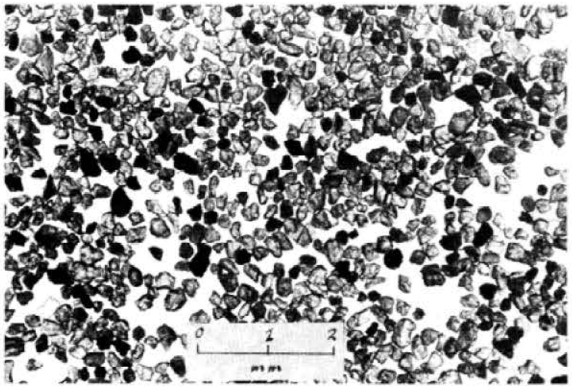


Figure 8. Sample 16 in transmitted light. Scrubbed sand from the Vantage sandstone, Hood River County; -48/+100-mesh grains are quartz and feldspar with traces of muscovite; opaque grains are polycrystalline quartz (chert) and ferromagnesian minerals.

BOARDMAN AREA (samples 17-19)

A suite of samples from glacially derived deposits in the Boardman area, Morrow County, was analyzed by Gray (1984) to evaluate the deposits' potential as silica sources. For comparison, screen-analysis data from that work are plotted in this study, and splits from three samples were analyzed by XRD and XRF. Sample 17 (Gray's sample site no. 5) is from an active dune field, sample 18 (Gray's sample site no. 4) is a glacial fluvial sand from an active aggregate operation, and sample 19 (Gray's sample site no. 6) is a glacial lake sediment. All are arkosic, but each also contains a rich suite of various ferromagnesian minerals, lithic fragments, and magnetite, and consequently all are unsatisfactory sources for silica or for silica-feldspar products. After screening, scrubbing, magnetic separation, and heavy liquid separation, only 10 percent to 30 percent of the sample remained, and the Fe_2O_3 content was only reduced to about 0.75 percent (Gray, 1984).

ARBUCKLE MOUNTAIN AREA (samples 20-22)

Uplift along the crest of the Blue Mountain anticline has exposed about 2,000 ft of coal-bearing continental arkosic sediments first recognized as a distinct unit by Pigg (1961) and mapped as a fluvial sandstone (unit Tsf) by Walker (1973). The sediments were informally named the Herren formation by Shorey (1976) and further subdivided into three members by Ferns and Brooks (1986). The outcrop areal extent of the Herren formation exceeds 30 mi^2. Three samples were collected from outcrops of white- to buff-colored arkosic sandstone composed of angular quartz and feldspar grains with traces of muscovite and less than 1 percent dark grains including ferromagnesian minerals and lithic fragments (Figure 9). Samples were well cemented and only partially disaggregated by the preparation methods used. The 30 percent to 40 percent plus-20-mesh fractions (Plate 2) are quartz-cemented grain aggregates rather than large single grains. XRD analysis indicated traces of kaolin in the plus-200-mesh fraction and minor or major amounts of kaolin in the minus-200-mesh fraction in all three samples. Attrition scrubbing of sample 22 raised its SiO_2 content from 88 percent to about 97 percent. This was probably the result of removal of kaolin, since a mineral balance calculation indicates that the remaining Al_2O_3 and K_2O can be accounted for by potassium feldspar.

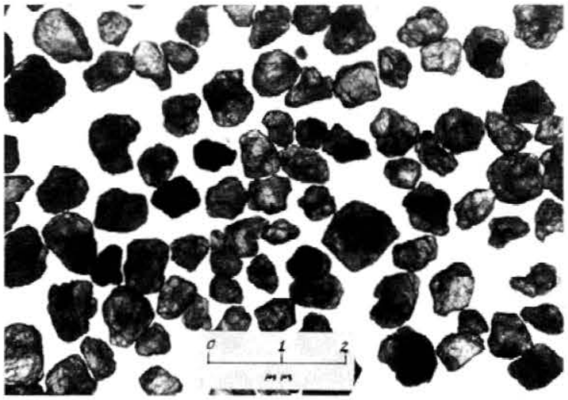


Figure 9. Sample 22 in transmitted light. Scrubbed sand from the Herren formation, Morrow County, -20/+35-mesh fraction representing 26 percent of the sample. Most grains are quartz, and the remainder are potassium feldspar.

TROY AREA (samples 23-27)

Basalts of the Columbia River Basalt Group are exposed in the Grande Ronde River drainage area in northern Umatilla and Union Counties and in the vicinity of Troy in Wallowa County. Sedimentary interbeds between flows include mudstones, siltstones, sandstones, volcaniclastic rocks, and coal. The area has been mapped by Walker (1979), Ross (1978), and Swanson and others (1981), and the Grande Ronde lignite coal field has been summarized by Ferns (1985). The interbeds are often covered intervals, poorly exposed, and subject to landsliding, and, as a result, thicknesses are difficult to measure accurately. Samples 24 and 26 are from the Grouse Creek interbed of Ross (1978), and sample 23 is from unit Tu, Umatilla Member, of Swanson and others (1981) and may be equivalent to the Grouse Creek interbed. Samples 25 and 27 are from the Squaw Canyon interbed of Ross (1978).

The Grouse Creek arkoses contain angular to subangular grains of quartz and feldspar with 1 percent to 2 percent muscovite and only traces of ferromagnesian minerals or lithic fragments. Iron staining is common but readily removed by scrubbing. The outcrops sampled were over 20 ft thick, and Ross recorded some intervals with thicknesses in excess of 300 ft.

Samples 25 and 27 are from Squaw Canyon outcrops with about 5 ft of exposed thickness. They contain angular to subangular quartz and feldspar grains, well-rounded grains or pellets of chalcedony, up to 30 percent clear glass shards, and up to 5 percent muscovite and lithic fragments. Iron oxide is present both as a stain and as cement.

OWYHEE AREA (samples 28-35)

The Owyhee Upland region of eastern Oregon is a geologically complex area of volcanics, volcanically derived sediments, and fluvial sediments apparently transported from the Blue Mountains highland to the north and from the Idaho Batholith to the east. The eruptive rocks overlap both geographically and temporally, and their emplacement intermittently interrupted the drainages, causing ponding and abrupt changes in flow regimes. The fluvial sediments include arkosic sandstones. Some are micaceous and many contain only small amounts of ferromagnesian minerals or lithic fragments. Some of the sandstone units are several hundred feet thick, and some are laterally continuous with surface exposures of several square miles.

The area was mapped by Corcoran and others (1962) and by Kittleman and others (1967), but current mapping by several workers is leading to revisions in correlation, stratigraphy, and nomenclature. Recently published maps include those by Ramp and Ferns (1989) and Ferns (1989a,b). Samples were collected from five separate arkosic sandstone units, and their test data are summarized in Plate 2.

Numerous epithermal centers have been identified in the Owyhee area, and many are active precious-metal exploration targets in which sandstone units host the mineralization. Some of the prominent topographic highs are silicified sandstones associated with these epithermal systems.

Many of the sediments in the region are either altered volcanic ash or contain a high proportion of volcanic ash. Alteration includes the development of clays, zeolites, potassium feldspar, cristobalite, and quartz. The zeolite clinoptilolite and bentonite clay are produced commercially from the Sucker Creek Formation. Sample 35, which was collected as a grab sample from a road cut, was originally assumed to be a zeolite. XRD analysis indicated that the sample was cristobalite with only traces of quartz and feldspar, so it was included in this study as a possible silica source. The bed may have been diatomite, although no diatoms were detected microscopically, or it may be an ash from which the alkalis were leached after emplacement.

No discreet iron-bearing minerals are apparent, suggesting that beneficiation to reduce the iron may be impractical.

Cristobalite is manufactured for a foundry medium for high-precision metal castings. Being a form of SiO_2 that is stable at high temperatures, it exhibits greater dimensional stability than quartz in contact with molten metal so that castings with cristobalite molds require less machining. Apparently no attempt is presently made to utilize naturally occurring cristobalite for this purpose.

INTERIOR SAND DUNES (samples 36-39)

Dune fields are developed in several areas of southeastern Oregon, often in playa lake basins. Although isolated from any major market areas, the fields have considerable areal extent and offer relatively simple mining conditions. Four dune fields were sampled: Pueblo Valley, Harney County, sample 36; Alkali Lake, Lake County, sample 37; Fossil Lake, Lake County, sample 38; and Summer Lake, Lake County, sample 39.

The interior dunes are developed primarily from weathered volcanic rocks and have not been reworked by wind or wave action as extensively as the coastal dunes. They are not nearly as well sorted, and chemically and mineralogically they have no value as a source for silica (see Plate 2). All four samples are mixtures of feldspar grains, lithic fragments, pumice fragments, glass shards, and ferromagnesian minerals. Quartz is only a minor constituent.

QUARTZ REPLACEMENT BODIES (samples 40-45)

Silicification in several areas of southwestern Oregon has produced quartz veins and larger replacement bodies of massive quartz (Ramp and Mason, 1969). Although some of the veins are high-purity silica, they contain only limited tonnages, and at present none are in production. Three quartz replacement bodies were sampled: the Quartz Mountain and Bristol Silica deposits, which were described earlier, and Quartz Mountain, an active prospect near Abbott Butte on the Douglas/Jackson County line. This latter Quartz Mountain is about 2 mi from Abbott Butte and will be referred to as Quartz Mountain/Abbott to distinguish it from Quartz Mountain in Douglas County (there are three additional topographic features in Oregon named Quartz Mountain in Lake, Deschutes, and Malheur Counties).

Quartz Mountain and Quartz Mountain/Abbott are silicified volcanic rock, and the Bristol deposit is a silicified carbonate. Each exhibits some chemical variations within the quartz body, but none has been completely characterized or delineated by drilling. The analyses presented in this study are of only two samples from each occurrence and may not necessarily represent the range of compositions of the deposit. Trace-element analyses for the six samples are presented in Table 2. The Quartz Mountain/Abbott deposit is on the southern flank of the mountain; the crest itself is volcanic rock. Claims were staked on the deposit in 1985 and are being actively maintained while the owners evaluate the quartz resources and work to obtain approval of their proposed operating plan (R. Gibson, owner, Quartz Mountain/Abbott claims, personal communication, 1990).

Table 2. *Trace-element analyses of quartz replacement bodies.*

Sample no.	Ag (ppm)	Au (ppb)	Ca (ppm)	Cd (ppm)	Cr (ppm)	Cu (ppm)	Co (ppm)	Fe (ppm)	Mg (ppm)	Mn (ppm)	Mo (ppm)	Na (ppm)	Ni (ppm)	P (ppm)	Pb (ppm)	Ti (ppm)	Zn (ppm)
40	1.0	< 1	600	< 1	8	2.5	140	1300	300	44	5	400	2	40	2	2800	5.0
41	1.0	4	900	< 1	12	2.5	130	1800	100	130	3	400	2	30	< 2	2700	0.5
42	0.5	< 1	800	< 1	18	3.0	2	2400	< 100	180	3	400	2	20	2	1200	4.5
43	0.5	< 1	700	< 1	14	4.0	1	1900	< 100	160	3	300	1	20	< 2	1500	5.0
44	< 0.5	< 1	6800	< 1	10	3.0	1	1500	300	74	< 1	200	1	3400	< 2	20	1.0
45	< 0.5	3	8200	< 1	8	2.0	130	1300	1500	18	< 1	300	2	3900	< 2	50	9.5

Direct current plasma emission spectrometric analyses, XRAL, Don Mills, Ontario, Canada.

Samples 40-41, Quartz Mountain/Abbott Butte, Jackson County.

Samples 42-43, Quartz Mountain, Douglas County.

Samples 44-45, Bristol Silica and Limestone Company, Jackson County.

DISCUSSION

The data collected in this study indicate there is considerable potential for increased production of quartz and of silica sands in Oregon. Deposits currently in production meet specifications for certain markets, and production may be able to expand by utilizing additional beneficiation techniques, by more aggressive marketing, or both.

The quartz replacement bodies, Quartz Mountain and Bristol Silica, supply high-quality products for specific markets, and Quartz Mountain/Abbott has a potential to meet similar specifications. Bristol Silica has the advantages of multiple markets and of a mill located on a rail line 5 mi from the mine, although no product is currently shipped by rail. Quartz Mountain currently has only one market, Glenbrook Nickel, and a 45-mi truck haul from high altitude, but its quartz provides superior performance for ferrosilicon and nickel production, and the deposit has indicated reserves in excess of 100 million tons. Quartz Mountain/Abbott remains to be evaluated.

At least some parts of each quartz replacement deposit are not suitable for higher value end uses such as silicon metal production. Zones of the Bristol deposit contain apatite, resulting in excessive levels of calcium and phosphorus, and Quartz Mountain and Quartz Mountain/Abbott have titanium levels that are too high for silicon production. Their chemical variability has not been determined by sufficiently detailed drilling to establish accurate ore-grade control, but any one of the deposits may have zones within it that are of higher purity.

The coastal dunes are attractive for development because of their physical and chemical characteristics, their ease of mining, and their proximity to transportation. Beneficiation to reduce the iron content and perhaps the feldspar content would increase the value and expand the market for coastal sands. Although the physical properties of the coastal dunes consistently fall within the range for industrial applications, their mineralogical and chemical compositions are subject to local variations that can preclude their use for some markets or at least require extensive beneficiation. These chemical variations, coupled with the withdrawal from mineral entry of large tracts of dune areas, sharply reduce the number of occurrences potentially suitable for development.

Of the areas sampled in this study, neither the Boardman area, Morrow County, nor the interior dunes of Harney and Lake Counties have sands that are pure enough to justify development for quartz or quartz-feldspar products. However, the sands are suitable for some construction purposes.

Interbeds in the Columbia River Basalt Group such as the Vantage sandstone and the Grouse Creek interbed may be exploitable in certain circumstances. The Vantage crops out in parts of several counties. Detailed mapping to identify zones of appropriate chemical and physical characteristics could guide exploration, but development would depend on locating an occurrence of sufficient volume and minimal basalt overburden. Should the lignite coal of the Troy area be mined, the arkosic sand interbeds would have to be removed and could be a valuable co-product. In the absence of coal mining, however, basalt overburden and the isolated location will preclude large-scale commercial production of these sands.

Arkosic sandstones in the three remaining areas, Astoria, Arbuckle Mountain, and Owyhee, have high potential and deserve more detailed sampling and beneficiation studies.

The sandstones of the Astoria area, particularly the Youngs Bay member of the Astoria Formation, are geologically well delineated. Mapping is sufficiently detailed to set limits on an exploration area, indicated reserves are large, the sands are friable and show marked improvement with only rudimentary beneficiation, and outcrops are on or near both water and rail transportation.

The Herren formation exposed near Arbuckle Mountain in Morrow County exhibited the highest SiO_2 content of all the sandstones sampled, both before and after scrubbing. The area is an active prospect for epithermal gold, and silicification may account for both the 96.7 percent SiO_2 content and the induration of the sandstone. Although somewhat removed from major market areas and dependent solely on truck transportation, the large inferred reserves and the chemical composition indicate the area is an appropriate target for further exploration.

The Owyhee region is the largest and least well mapped of the three areas. It has multiple, thick arkosic sandstone units of wide areal extent whose potential cannot be evaluated with only a limited number of samples. The grain size distribution and chemistry of the samples collected suggest that with beneficiation some of the sandstones could meet specifications for certain industrial applications. Much of the area is relatively isolated at present, but the development of precious-metal mines may improve access, and the Basin Creek area samples were taken from outcrops only 5 mi from rail transportation. The resource potential of the arkosic sands can be better evaluated as the current mapping program progresses.

REFERENCES CITED

Beaulieu, J.D., and Hughes, P.W., 1975, Environmental geology of western Coos and Douglas Counties, Oregon: Oregon Department of Geology and Mineral Industries Bulletin 87, 148 p., map scale 1:62,500.

———1977, Land use geology of central Jackson County, Oregon: Oregon Department of Geology and Mineral Industries Bulletin 94, 87 p., map scale 1:62,500.

Bentzen, E.H., III, 1980, Production and processing problems of western glass sands, *in* Schochow, S.D., ed., Proceedings of the 15th Forum on the Geology of Industrial Minerals, June 1979, Golden, Colo.: Colorado Geological Survey Resources Series 8, p. 63-74.

Brooks, H.C., 1989, Limestone deposits in Oregon: Oregon Department of Geology and Mineral Industries Special Paper 19, 72 p.

Brown, C.J., and Redeker, I.M., 1980, Processing glass-grade sand from dune sands: Congress papers, 4th Industrial Minerals Congress, Atlanta, Georgia, p. 59 [abs. in Industrial Minerals, May 1980, p. 27].

Burlington Northern, 1972, Silica rock deposits in the Pacific Northwest: Burlington Northern, Industrial and Real Estate Development Department, Raw Materials Research Report 3, 50 p.

Carter, G.J., Harris, H.M., and Strandberg, K.G., 1964, Beneficiation studies of the Oregon coastal dune sands for use as glass sand: U.S. Bureau of Mines Report of Investigations 6484, 21 p.

Carter, G.J., Kelly, H.J., and Parsons, E.W., 1962, Industrial silica deposits of the Pacific Northwest: U.S. Bureau of Mines Information Circular 8112, 57 p.

Carter, J.W., 1976, The environmental and engineering geology of the Astoria Peninsula area, Clatsop County, Oregon: Corvallis, Oreg., Oregon State University master's thesis, 138 p.

Coope, B.M., 1989, Synthetic silicas and silicon chemicals: Industrial Minerals, no. 258 (March 1989), p. 43-55.

Cooper, D.M., 1980, Sedimentation, stratigraphy, and facies variation of the lower to middle Miocene Astoria Formation in Oregon: Corvallis, Oreg., Oregon State University doctoral dissertation, 524 p.

Cooper, W.S., 1958, Coastal sand dunes of Oregon and Washington: Geological Society of America Memoir 72, 169 p.

Corcoran, R.E., Doak, R.A., Porter, P.W., Pritchett, F.I., and Privrasky, N.C., 1962, Geology of the Mitchell Butte Quadrangle, Oregon: Oregon Department of Geology and Mineral Industries Geological Map Series GMS-2, scale 1:125,000.

Coryell, G.F., 1978, Stratigraphy, sedimentation, and petrology of the Tertiary rocks in the Bear Creek—Wickiup Mountain—Big Creek area, Clatsop County, Oregon: Corvallis, Oreg., Oregon State University master's thesis, 178 p.

Ferns, M.L., 1985, Preliminary report on northeastern Oregon lignite and coal resources, Union, Wallowa, and Wheeler Counties: Oregon Department of Geology and Mineral Industries Open File Report O-85-2, 20 p.

———1989a, Geology and mineral resources map of the Grassy Mountain Quadrangle, Malheur County, Oregon: Oregon Department of Geology and Mineral Industries Geological Map Series GMS-57, scale 1:24,000.

———1989b, Geology and mineral resources map of the Owyhee Dam Quadrangle, Malheur County, Oregon: Oregon Department of Geology and Mineral Industries Geological Map Series GMS-55, scale 1:24,000.

Ferns, M.L., and Brooks, H.C., 1986, Geology and coal resources of the Arbuckle Mountain coal field, Morrow County, Oregon: Oregon Department of Geology and Mineral Industries Open File Report O-86-5, 25 p., map scales 1:24,000 and 1:100,000.

Grant, A.R., 1987, Report of mineral examination, Fox No. 2, 3, 6, 7, 8, 9, and 10 placer claims, Douglas County, Oregon: Unpublished report, U.S. Forest Service, Region 6, Portland, Oregon.

Gray, J.J., 1984, Bench testing of silica sand from deposits in Clatsop and Morrow Counties, Oregon: Oregon Department of Geology and Mineral Industries Open File Report O-84-5, 12 p.

Hodge, E.T., 1938, Northwest silica minerals, *in* Market for Columbia River hydroelectric power using northwest minerals: Portland, Oreg., War Department, U.S. Army Corps of Engineers, Office of Division of Engineering, North Pacific Division, v. 1, pt. 1, 175 p.

Industrial Minerals, 1990, Progress on Dow Corning silicon project (World of Minerals—Canada): Industrial Minerals, no. 269 (February 1990), p. 9.

Kittleman, L.R., Green, A.R., Haddock, G.H., Hagood, A.R., Johnson, A.M., McMurray, J.M., Russell, R.G., and Weeden, D.A., 1967, Geologic map of the Owyhee region, Malheur County, Oregon: Eugene, Oreg., University of Oregon Museum of Natural History Bulletin 8, scale 1:125,000.

Kulm, L.D., and Peterson, C.D., 1990, Preliminary evaluation of heavy-mineral content of continental shelf placer deposits off Cape Blanco, Rogue River, and Umpqua River, *in* Joint State-Federal Oregon Placer Minerals Task Force, Preliminary feasibility study: Oregon placer minerals: Oregon Department of Geology and Mineral Industries Open-File Report O-89-12, p. A1-A28.

Kulm, L.D., Peterson, C.D., and Stribling, M.C., 1986, Inventory of heavy minerals and metals, southern Washington, Oregon, and northern California continental shelf and coastal region: Oregon Department of Geology and Mineral Industries Open File Report O-86-10, 111 p.

Ladoo, R.B., 1946, Industrial silica for Pacific Northwest industries: Raw Materials Survey Research Report 1, 40 p.

Lowry, W.D., 1947, Foundry sand produced near Eugene, Oregon: Transactions of the American Institute of Mining and Metallurgical Engineers, v. 173, p. 532-541.

Murphy, G.F., and Brown, R.E., 1985, Silicon, *in* Mineral Facts and Problems: U.S. Bureau of Mines Bulletin 675, p. 713-728.

Murphy, T.M., 1981, The geology of the Nicolai Mountain-Gnat Creek area, Clatsop County, northwest Oregon: Corvallis, Oreg., Oregon State University master's thesis, 355 p.

Nelson, M.P., 1978, Tertiary stratigraphy and sedimentation in the Lewis and Clark River-Youngs River area, Clatsop County, northwestern Oregon: Corvallis, Oreg., Oregon State University master's thesis, 242 p.

Niem, A.R., and Niem, W.A., 1985, Oil and gas investigation of the Astoria Basin, Clatsop and northernmost Tillamook Counties, northwest Oregon; Oregon Department of Geology and Mineral Industries Oil and Gas Investigation OGI-14, 8 p., map scale 1:100,000.

Oregon Department of Geology and Mineral Industries, 1943, Oregon metal mines handbook—Jackson County: Oregon Department of Geology and Mineral Industries Bulletin 14-C, v. II, sec. 2, 208 p.

Peterson, C.D., Komar, P.D., and Scheidegger, K.F., 1986, Distribution, geometry, and origin of heavy-mineral placer deposits on Oregon beaches: Journal of Sedimentary Petrology, v. 56, no. 1, p. 67-77.

Pigg, J.H., 1961, The lower Tertiary sedimentary rocks in the Pilot Rock and Heppner areas, Oregon: Eugene, Oreg., University of Oregon master's thesis, 67 p.

Ramp, L., 1960, The Quartz Mountain silica deposit: Oregon Department of Geology and Mineral Industries, Ore Bin, v. 22, no. 11, p. 109-114, map scale 1:21,120.

Ramp, L., and Ferns, M.L., 1989, Geology and mineral resources map of the Double Mountain Quadrangle, Malheur County, Oregon: Oregon Department of Geology and Mineral Industries Geological Map Series GMS-58, scale 1:24,000.

Ramp, L., and Mason, R.S., 1969, Silica, *in* Weissenborn, A.E., ed., Mineral and water resources of Oregon: Oregon Department of Geology and Mineral Industries Bulletin 64, p. 237-241.

Ross, M.E., 1978, Stratigraphy, structure, and petrology of Columbia River basalt in a portion of the Grande Ronde River-Blue Mountains area of Oregon and Washington: Richland, Wash., Rockwell Hanford Operations Report RHO-SA-58, 460 p., map scale 1:48,000.

Shorey, E.F., 1976, Geology of part of southern Morrow County, northeast Oregon: Corvallis, Oreg., Oregon State University master's thesis, 131 p.

Swanson, D.A., Anderson, J.L., Camp. V.E., Hooper, P.R., Taubeneck, W.H., and Wright, T.L., 1981, Reconnaissance geologic map of the Columbia River Basalt Group, northern Oregon and western Idaho: U.S. Geological Survey Open-File Report 81-797, 33 p., scale 1:250,000.

Swanson, D.A., Wright, T.L., Hooper, P.R., and Bentley, R.D., 1979, Revisions in stratigraphic nomenclature of the Columbia River Basalt Group: U.S. Geological Survey Bulletin 1457-G, 59 p.

Timm, S., 1979, The structure and stratigraphy of the Columbia River basalt in the Hood River Valley, Oregon: Portland, Oreg., Portland State University master's thesis, 60 p., map scale 1:31,680.

Twenhofel, W.H., 1946, Mineralogical and physical composition of the sands of the Oregon coast from Coos Bay to the mouth of the Columbia River: Oregon Department of Geology and Mineral Industries Bulletin 30, 46 p.

Walker, G.W., 1973, Reconnaissance geologic map of the Pendleton Quadrangle, Oregon and Washington: U.S. Geological Survey Miscellaneous Geologic Investigations Map I-727, scale 1:250,000.

———1979, Reconnaissance geologic map of the Oregon part of the Grangeville Quadrangle, Baker, Union, Umatilla, and Wallowa Counties, Oregon: U.S. Geological Survey Miscellaneous Investigations Series Map I-1116, scale 1:250,000.

APPENDIX
LABORATORY PROCEDURES

by Gary L. Baxter, Chemist, Oregon Department of Geology and Mineral Industries

SAMPLES SUBMITTED AND TESTS PERFORMED

Thirty-eight sand (21 free-flowing, seven "lightly" cemented, and 10 "heavily" cemented) and seven silicified rock samples were submitted to the Department laboratory. The tests performed included (for the sands) sieve analysis, attrition scrubbing followed by sieve analysis, mineralogy by X-ray diffraction, and (for all samples) chemical analysis. All work, except chemical analysis, was performed in the Department laboratory. The test methods employed are generalized below; details are available on request.

SAMPLE PREPARATION

CRUSHING, DISAGGREGATION, AND SPLITTING

Free-flowing sands: Each sample was split in a Jones-type splitter as required to obtain the subsamples for the various tests.

Lightly cemented sands: Each sample was screened through a 10-mesh screen. The oversized material was lightly disaggregated with a porcelain mortar and pestle; the disaggregated material was rescreened; and the undersized fraction from the disaggregation step was combined with the first minus-10-mesh material. The minus-10-mesh portion was then split as required for testing.

Heavily cemented sands: Each sample was crushed to minus ¼-in. mesh in a chipmunk jaw crusher equipped with Mn-steel jaws. A split of the crushed material was then disaggregated in a porcelain mortar and pestle.

Rocks: Each sample was crushed (double pass) to minus ¼-in. mesh as above; a split of the size required for testing was then obtained.

MILLING (pulverizing)

Samples for chemical analysis were milled in corundum medium in an Angstrom disc mill or, in a few cases, in tungsten carbide medium in a similar type mill. Samples for XRD analysis were milled in chrome-steel medium in an Angstrom disc mill. The milling process employed generally produces an analytical sample that is largely minus 200 mesh.

SIEVE ANALYSIS

Nominal 100-gram samples were dried overnight at 105 °C, cooled in a desiccator, and weighed to ± 0.01 gram. Each sample was then dry sieved using 20-, 28-, 35-, 48-, 65-, 100-, 150-, and 200-mesh sieves (8-in., Tyler Standard Series) on a Gilson SS-12R sieve shaker for 15 minutes. Sieved fractions were weighed to ± 0.01 gram. A trial test indicated that a period of 15 minutes was sufficient shaking time. The sieves were of all-stainless steel construction and were cleaned between samples with compressed air and, where required for coarser screens, a wire brush.

ATTRITION SCRUBBING AND SIEVE ANALYSIS

A Hamilton Beach household blender with a plastic-coated cutter was employed to attrition-scrub the sand samples. The four-bladed cutter was coated by dipping in Tool-Dip (a plastic used to coat tools) after filing off the sharp edges. The coating was necessary to prevent wear by the abrasive slurry. This modified blender as not intended to duplicate attrition scrubbing in a manner that could be scaled up to an industrial operation. Rather, it was used only to assess the effectiveness of such an approach to upgrade the sands. From 25 percent to 50 percent of many samples passed a 200-mesh screen after scrubbing, suggesting that the action may have been more vigorous than any that would be used commercially.

A 250± 0.1 gram subsample of a sand (disaggregated as indicated above) was added to 250± 1 ml of water and stirred at 11,500 RPM for 20 minutes. After scrubbing, the slurry was wet-screened through a 200-mesh screen. The plus-200-mesh material on the screen was dried at 60 °C at least one hour; this fraction was then transferred to a beaker and dried at 105 °C for 16 hours, cooled, and weighed. The dried material was then dry-screened and weighed to determine the plus-20-, minus-20/plus-150-, and minus-150-mesh fractions. A comparison of the chemistry of the beneficiated and as-received samples is presented in Table 3.

Table 3. *Comparison of the chemistry of selected sands, raw and beneficiated in two different ways.*

Sample no.	Note	SiO_2	Al_2O_3	CaO	MgO	Na_2O	K_2O	Fe_2O_3	MnO	TiO_2	P_2O_5	SO_3	LOI	Total
11	1	75.8	11.1	0.71	1.05	1.83	2.69	1.90	0.03	0.44	0.04	—	3.62	99.4
11A	2	84.3	8.04	0.78	0.29	1.74	2.78	0.53	0.02	0.23	0.02	—	0.85	99.8
(1)	3	94.03	5.15	0.74	0.29	0.37	0.40	0.44	—	—	—	0.24	—	101.66
14	1	75.9	11.4	0.67	0.48	1.41	2.66	1.78	0.02	0.42	0.03	—	4.54	99.5
14A	2	87.2	6.77	0.44	0.17	1.32	2.81	0.31	0.01	0.16	0.02	—	0.77	100.2
(2)	3	94.86	4.51	0.77	0.29	0.04	0.37	0.45	—	—	—	0.24	—	101.53
15	1	76.5	11.4	0.23	0.39	0.92	2.74	2.03	0.03	0.29	0.03	—	4.39	99.1
15A	2	89.3	5.46	0.15	0.11	0.78	2.96	0.21	< 0.01	0.11	0.02	—	0.62	99.9
(3)	3	96.71	3.17	0.73	0.27	—	0.28	0.44	—	—	—	0.26	—	101.86

The sample numbers in parentheses are Gray's (1984) sample site numbers for the corresponding sample locations in this report. The suffix "A" indicates an attrition-scrubbed sample. A dash indicates that the concentration of a given constituent was not determined.

Note 1. This sample was not beneficiated. The chemical data are that of the -20/+200-mesh fraction of the raw sample.

Note 2. This sample was beneficiated by attrition-scrubbing only; the method used for attrition-scrubbing is described elsewhere in this study. The chemical data are those of the -20/+200 mesh fraction after scrubbing.

Note 3. This sample was beneficiated by wet scrubbing, three stages of high-intensity magnetic separation, and three stages of heavy-liquid separation (as described in Gray, 1984). Because the -28/+150-mesh fraction of the raw sand was carried through these beneficiation steps, these chemical data are not directly comparable with the corresponding data for the samples mentioned in Notes 1 and 2 above.

MINERALOGY BY X-RAY DIFFRACTION (XRD)

XRD patterns were obtained for minus-20/plus-200- and minus-200-mesh fractions of sand subsamples dry-sieved separately. XRD patterns of other size fractions of a limited number of samples (both dry-screened and wet-screened) were also obtained; the results for these are not included in the data table. The samples were scanned from 4° to 55° 2θ at a rate of 2° 2θ per minute. The relative amounts reported were estimated from the heights of the major peaks of the minerals present.

CHEMICAL ANALYSIS

X-ray Assay Laboratories (XRAL, Don Mills, Ontario, Canada) provided X-ray fluorescence (XRF) analyses for major and minor oxides on all sand (minus-20/plus-200-mesh fraction) and rock samples and on selected attrition-scrubbed (minus-20/plus-200 mesh) samples. XRAL also provided direct current plasma (DCP) emission spectrometric analyses for 16 trace elements in the seven rock samples.

QUALITY CONTROL

Sieve Analysis

Two replicates of three free-flowing sands were sieved as described above. The precision was fair to good (in comparing "percent between sieves"), as might be expected from such heterogeneous samples.

Chemical Analysis

For a measurement of the precision of the XRF data, separate splits of five samples were submitted to XRAL as blind samples (see Table 4). For comparison with the XRF data, Bondar-Clegg and Co., Ltd. (N. Vancouver, B.C., Canada) provided DCP analysis for the major and minor oxides and wet-chemical analysis for SiO_2 in five samples (see Table 5). Additional data that compare the XRF data from XRAL with a second (unnamed) laboratory include the analyses of six "raw" sand samples. The data from the second laboratory were previously reported in Gray (1984) and must be viewed with certain qualifications (different sample fractions) (see Table 6).

The precision of the XRF data was adequate for the purpose of this report. However, the (supposedly more accurate) wet-chemical analyses for SiO_2 indicated that the XRF SiO_2 analyses were systematically 1 percent to 2 percent low. This fact should be kept in mind when the data for "high-purity silica" are reviewed. No standard reference materials were available for submission to the outside laboratories for check analyses in order to measure the accuracy of the data.

Table 4. *Comparison of XRAL's XRF data for original and blind samples.*

Sample no.	SiO_2	Al_2O_3	CaO	MgO	Na_2O	K_2O	Fe_2O_3	MnO	TiO_2	P_2O_5	LOI	Sum
9	76.7	12.2	0.46	0.30	1.43	3.41	0.77	0.01	0.44	0.05	3.16	98.9
Blind	76.2	12.1	0.45	0.30	1.36	3.36	0.80	0.01	0.44	0.05	3.00	98.1
4A	85.9	7.24	0.45	0.18	1.36	2.94	0.23	< 0.01	0.16	0.02	0.70	99.2
Blind	87.0	7.25	0.43	0.17	1.26	2.96	0.33	< 0.01	0.15	0.02	0.54	100.1
32A	81.6	9.63	0.81	0.13	2.64	3.22	0.22	0.02	0.08	0.03	1.62	100.0
Blind	81.2	9.74	0.82	0.13	2.70	3.23	0.23	0.02	0.08	0.03	1.47	99.6
1A	82.5	9.45	1.19	0.22	2.62	2.26	0.69	0.01	0.13	0.04	0.62	99.7
Blind	82.4	9.51	1.22	0.23	2.74	2.29	0.68	0.01	0.13	0.04	0.70	100.0
1	74.2	13.5	0.96	0.33	3.90	3.65	0.89	0.02	0.23	0.06	1.47	99.2
Blind	74.3	13.4	0.95	0.32	3.83	3.68	0.95	0.02	0.22	0.06	1.77	99.5

"A" suffix on sample number indicates attrition-scrubbed.

Table 5. *Comparison of data derived by three different analytical methods.*

Sample no.	Method	SiO_2	Al_2O_3	CaO	MgO	Na_2O	K_2O	Fe_2O_3	MnO	TiO_2	P_2O_5	LOI	Sum
36	XRF	65.0	15.5	2.93	0.91	4.07	3.57	3.23	0.08	0.66	0.09	3.08	99.1
	DCP	65.10	14.70	2.96	0.81	3.70	3.32	3.32	0.08	0.58	0.11	2.89	97.57
	Wet chem	65.95	—	—	—	—	—	—	—	—	—	—	—
44	XRF	97.9	0.17	1.07	0.04	< 0.01	0.01	0.09	0.02	0.03	0.72	0.16	100.2
	DCP	96.40	0.10	1.03	0.03	0.02	0.05	0.09	0.02	0.01	0.37	0.26	98.38
	Wet chem	99.90	—	—	—	—	—	—	—	—	—	—	—
28A	XRF	77.2	12.7	0.81	0.12	4.00	3.79	0.20	0.01	0.09	0.04	0.31	99.3
	DCP	77.70	11.80	0.84	0.09	3.66	3.63	0.28	0.02	0.09	0.09	0.59	98.79
	Wet chem	78.70	—	—	—	—	—	—	—	—	—	—	—
34A	XRF	80.5	10.4	0.34	0.10	2.97	4.06	0.27	0.01	0.08	0.03	0.54	99.3
	DCP	80.20	9.87	0.41	0.05	2.72	4.00	0.31	0.01	0.06	0.18	0.71	98.52
	Wet chem	82.40	—	—	—	—	—	—	—	—	—	—	—
38A	XRF	57.20	18.3	6.91	2.76	4.25	1.25	5.59	0.11	0.81	0.15	2.39	99.7
	DCP	56.60	17.90	6.90	2.84	4.34	1.25	5.77	0.12	0.82	0.28	1.88	98.70
	Wet chem	58.50	—	—	—	—	—	—	—	—	—	—	—

"A" suffix on sample number indicates attrition-scrubbed.

Table 6. *Comparison of XRF data from two different laboratories.*

Sample no.	SiO_2	Al_2O_3	CaO	MgO	Na_2O	K_2O	Fe_2O_3	MnO	TiO_2	P_2O_5	SO_3	LOI	Total
17	69.8	12.4	3.17	1.61	2.96	2.32	5.13	0.09	0.98	0.17	—	1.39	100.2
(5)	70.15	12.97	3.07	1.16	1.50	1.98	5.58	—	0.14	—	0.9	—	97.45
19	65.8	13.0	3.64	1.90	2.77	2.13	5.85	0.10	1.08	0.20	—	3.00	99.6
(6)	67.07	13.89	3.53	1.74	1.67	1.86	6.65	—	0.22	—	0.02	—	96.65
18	70.3	11.7	3.34	1.46	3.04	2.36	4.42	0.08	0.76	0.15	—	1.77	99.6
(4)	70.06	12.76	3.39	1.36	1.90	1.97	5.85	—	0.13	—	0.0	—	97.42
15	76.5	11.4	0.23	0.39	0.92	2.74	2.03	0.03	0.29	0.03	—	4.39	99.1
(3)	78.46	14.82	1.20	0.60	0.43	2.34	3.32	—	—	—	0.24	—	101.41
14	75.9	11.4	0.67	0.48	1.41	2.66	1.78	0.02	0.42	0.03	—	4.54	99.5
(2)	80.63	13.38	1.27	0.60	1.10	2.31	2.28	—	—	—	0.20	—	101.77
11	75.8	11.1	1.05	0.71	1.83	2.69	1.90	0.03	0.44	0.04	—	3.62	99.4
(1)	80.12	10.67	1.57	0.67	1.12	2.11	3.14	—	—	—	0.19	—	99.59

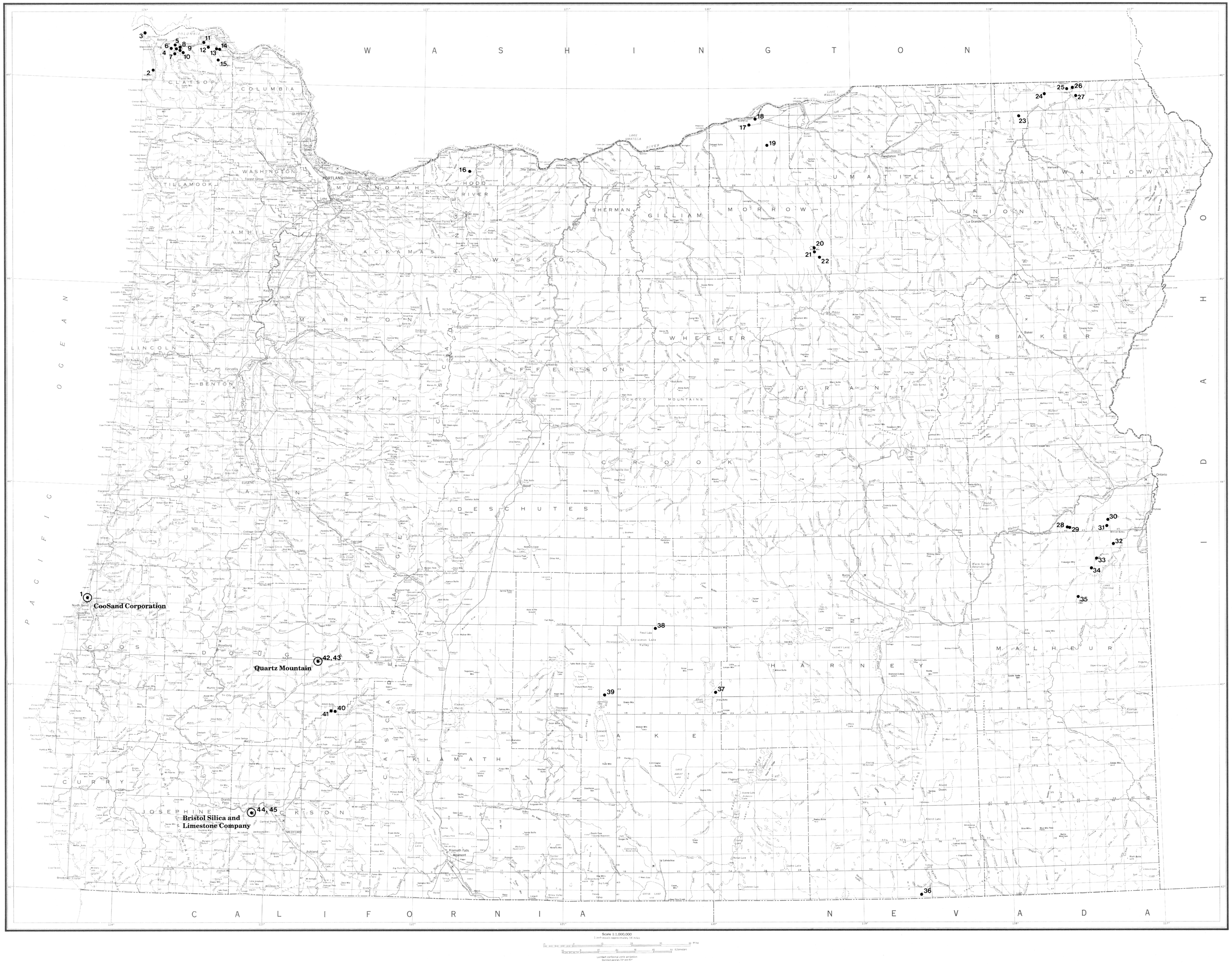
The sample numbers in parentheses are Gray's (1984) sample site numbers for the corresponding sample locations in this report. A dash indicates that the concentration of a given constituent was not determined.

These data may not be directly comparable. In this report the -20/+200 mesh fraction of the raw sample was the analytical sample.
For Gray (1984), the raw sample was the analytical sample.

STATE OF OREGON
DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES
DONALD A. HULL, STATE GEOLOGIST

INDEX MAP OF SILICA SAMPLE LOCALITIES

Special Paper 22
Silica in Oregon
By Ronald P. Geitgey
Plate 1



Sample no.	Area
1	North Bend
2	Del Rey Beach
3	Clatsop Spit
4	Wallooskee River
5	Pipeline Road
6	Youngs River
7	Pipeline Road
8	John Day River
9	John Day River
10	Pipeline Road
11	Knappa
12	Knappa Junction
13	Gnat Creek
14	Gnat Creek
15	Nicolai Mtn.
16	Green Point Creek
17	Boardman
18	Boardman
19	Finley Buttes
20	Arbuckle Mtn.
21	Arbuckle Mtn.
22	Arbuckle Mtn.
23	Lookout Mtn.
24	Long Meadows G.S.
25	Troy
26	Troy
27	Troy
28	Basin Creek
29	Basin Creek
30	Cow Hollow
31	Cow Hollow
32	Sand Hollow
33	Grassy Mtn.
34	Twin Springs Creek
35	Eddy Spring
36	Denio
37	Alkali Lake
38	Fossil Lake
39	Summer Lake
40	Quartz Mtn./Abbott
41	Quartz Mtn./Abbott
42	Quartz Mtn.
43	Quartz Mtn.
44	Bristol Silica
45	Bristol Silica

●45	**Sample locality and number**
⊙45	**Silica producer**

STATE OF OREGON
DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES
DONALD A. HULL, STATE GEOLOGIST

Special Paper 22
Silica in Oregon
By Ronald P. Geitgey
Plate 2

LOCATIONS, DESCRIPTIONS, AND ANALYTICAL DATA FOR SILICA SAMPLES; SCREEN ANALYSES, HISTOGRAMS, AND CUMULATIVE FREQUENCY CURVES FOR SAND AND SANDSTONE SAMPLES

Sample locations

Sample no.		Sec.	T.	R.	County	Area	Quadrangle	Lithology	Induration	Geologic map unit	References
1	W½W½	34	24 S.	13 W.	Coos	North Bend	North Bend 7½'	Dune sand	None	Unstabilized dunes	Beaulieu and Hughes (1975)
2	SW¼	33	7 N.	10 W.	Clatsop	Del Rey Beach	Gearhart 7½'	Beach sand	None	Quaternary beach sand	Niem and Niem (1985)
3	NE¼	36	9 N.	11 W.	Clatsop	Clatsop Spit	Warrenton 7½'	Beach sand	None	Quaternary beach sand	Niem and Niem (1985)
4	SE¼	34	8 N.	9 W.	Clatsop	Wallooskee River	Astoria 7½'	Marine sandstone	Friable	Astoria Fm., Youngs Bay mbr	Niem and Niem (1985)
5	SW¼	15	8 N.	9 W.	Clatsop	Pipeline Road	Astoria 7½'	Marine sandstone	Friable	Astoria Fm., Youngs Bay mbr	Niem and Niem (1985)
6	SE¼	21	8 N.	9 W.	Clatsop	Youngs River	Astoria 7½'	Marine sandstone	Friable	Astoria Fm., Youngs Bay mbr	Niem and Niem (1985)
7	SW¼	22	8 N.	9 W.	Clatsop	Pipeline Road	Astoria 7½'	Marine sandstone	Friable	Astoria Fm., Youngs Bay mbr	Niem and Niem (1985)
8	SW¼	24	8 N.	9 W.	Clatsop	John Day River	Cathlamet Bay 7½'	Marine sandstone	Friable	Astoria Fm., Youngs Bay mbr	Niem and Niem (1985)
9	SE¼	24	8 N.	9 W.	Clatsop	John Day River	Cathlamet Bay 7½'	Marine sandstone	Friable	Astoria Fm., Youngs Bay mbr	Niem and Niem (1985)
10	SE¼	29	8 N.	8 W.	Clatsop	Pipeline Road	Cathlamet Bay 7½'	Marine sandstone	Friable	Astoria Fm., Youngs Bay mbr	Niem and Niem (1985)
11	SE¼	8	8 N.	7 W.	Clatsop	Knappa	Knappa 7½'	Sandstone	Friable	Gnat Creek fm.	Niem and Niem (1985)
12	NE¼	15	8 N.	7 W.	Clatsop	Knappa Junction	Knappa 7½'	Sandstone	Friable	Gnat Creek fm.	Niem and Niem (1985)
13	NW¼	19	8 N.	6 W.	Clatsop	Gnat Creek	Cathlamet 7½'	Sandstone	Friable	Gnat Creek fm.	Niem and Niem (1985)
14	NW¼	19	8 N.	6 W.	Clatsop	Gnat Creek	Cathlamet 7½'	Sandstone	Friable	Gnat Creek fm.	Niem and Niem (1985)
15	SE¼	6	7 N.	6 W.	Clatsop	Nicolai Mtn.	Nicolai Mtn. 7½'	Sandstone	Friable	Vantage sandstone	Niem and Niem (1985)
16	NE¼NE¼	10	1 N.	9 E.	Hood River	Green Point Creek	Dee 7½'	Sandstone	Friable	Vantage sandstone	Timm (1979)
17	SW¼SW¼	20	4 N.	25 E.	Morrow	Boardman	Boardman 7½'	Dune sand	None	Fluvioglacial deposits	Walker (1973)
18	NW¼NE¼	10	4 N.	25 E.	Morrow	Boardman	Boardman 7½'	Sand	None	Fluvioglacial deposits	Walker (1973)
19	SE¼NW¼	29	3 N.	26 E.	Morrow	Finley Buttes	Strawberry Canyon NE 7½'	Sand	Friable	Glacial lake sediments	Walker (1973)
20	NE¼SW¼	19	4 S.	29 E.	Morrow	Arbuckle Mtn.	Arbuckle Mtn. 7½'	Sandstone	Cemented	Herren fm.	Ferns and Brooks (1986)
21	SW¼SE¼	33	4 S.	29 E.	Morrow	Arbuckle Mtn.	Matlock Prairie 7½'	Sandstone	Cemented	Herren fm.	Ferns and Brooks (1986)
22	NW¼NW¼	4	5 S.	29 E.	Morrow	Arbuckle Mtn.	Matlock Prairie 7½'	Sandstone	Cemented	Herren fm.	Ferns and Brooks (1986)
23	SW¼NW¼	15	4 N.	40 E.	Union	Lookout Mtn.	Fry Meadow 7½'	Sandstone	Friable	Interbed, Saddle Mountain Basalt	Swanson and others (1981)
24	NW¼NW¼	6	5 N.	42 E.	Wallowa	Long Meadows G.S.	Eden 7½'	Sandstone	Friable	Grouse Creek interbed	Ross (1978)
25	NW¼SE¼	28	6 N.	43 E.	Wallowa	Troy	Troy 7½'	Sandstone	Friable	Squaw Canyon interbed	Ross (1978)
26	NW¼NE¼	22	6 N.	43 E.	Wallowa	Troy	Troy 7½'	Sandstone	Friable	Grouse Creek interbed	Ross (1978)
27	NE¼SE¼	12	5 N.	43 E.	Wallowa	Troy	Troy 7½'	Sandstone	Friable	Grouse Creek interbed	Ross (1978)
28	NW¼NE¼	27	20 S.	42 E.	Malheur	Basin Creek	Harper 15'	Sandstone	Friable	Grassy Mountain Fm.	Kittleman and others (1967)
29	NW¼NE¼	27	20 S.	42 E.	Malheur	Basin Creek	Harper 15'	Sandstone	Friable	Grassy Mountain Fm.	Kittleman and others (1967)
30	SW¼SE¼	13	20 S.	44 E.	Malheur	Cow Hollow	Double Mtn. 7½'	Sandstone	Friable	Tuffaceous sandstone (Tig)	Ramp and Ferns (1989)
31	SW¼SW¼	25	20 S.	44 E.	Malheur	Cow Hollow	Double Mtn. 7½'	Sandstone	Friable	Tuffaceous sandstone (Tig)	Ramp and Ferns (1989)
32	NE¼SW¼	29	21 S.	45 E.	Malheur	Sand Hollow	Owyhee Dam 7½'	Sandstone	Cemented	Arkosic sandstone (Tas)	Ferns (1989b)
33	SE¼SE¼	20	22 S.	44 E.	Malheur	Grassy Mtn.	Grassy Mtn. 7½'	Sandstone	Friable	Arkosic sandstone (Tgs)	Ferns (1989a)
34	SW¼NE¼	1	23 S.	43 E.	Malheur	Twin Springs Creek	Twin Springs 7½'	Sandstone	Cemented	Arkosic sandstone	Cummings (1989)
35	SE¼SE¼	19	24 S.	43 E.	Malheur	Eddy Spring	Quartz Mtn. Basin 7½'	Altered ash bed	Massive	Deer Butte Fm.	Kittleman and others (1967)
36	NE¼NW¼	22	41 S.	35 E.	Harney	Denio	Colony Ranch 7½'	Dune sand	None	——	——
37	SW¼SW¼	27	29 S.	23 E.	Lake	Alkali Lake	Venator Canyon 7½'	Dune sand	None	——	——
38	SW¼NW¼	6	26 S.	20 E.	Lake	Fossil Lake	Fossil Lake 7½'	Dune sand	None	——	——
39	SE¼SE¼	33	29 S.	17 E.	Lake	Summer Lake	Sheeplick Draw 7½'	Dune sand	None	——	——
40	SW¼NW¼	34	30 S.	2 E.	Jackson	Quartz Mtn./Abbott	Abbott Butte 15'	Quartz replacement	Massive	——	——
41	SE¼NE¼	33	30 S.	2 E.	Jackson	Quartz Mtn./Abbott	Abbott Butte 15'	Quartz replacement	Massive	——	——
42	SE¼NW¼	2	28 S.	1 E.	Douglas	Quartz Mtn.	Quartz Mtn. 15'	Quartz replacement	Massive	Silica rock (Ttsi)	Ramp (1960)
43	SW¼NW¼	2	28 S.	1 E.	Douglas	Quartz Mtn.	Quartz Mtn. 15'	Quartz replacement	Massive	Silica rock (Ttsi)	Ramp (1960)
44	SW¼SE¼	30	36 S.	3 W.	Jackson	Bristol Silica	Gold Hill 7½'	Quartz replacement	Massive	Applegate Group	Beaulieu and Hughes (1977)
45	SW¼SE¼	30	36 S.	3 W.	Jackson	Bristol Silica	Gold Hill 7½'	Quartz replacement	Massive	Applegate Group	Beaulieu and Hughes (1977)

Chemical analyses of as-received samples (weight percent). X-ray fluorescence analyses by XRAL.

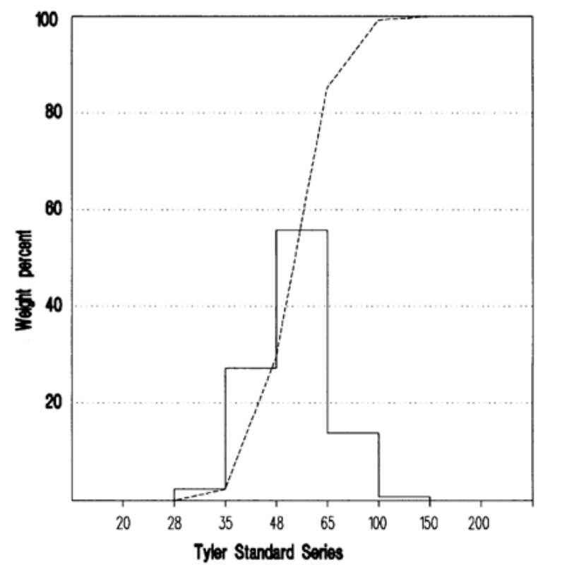
Sample no.	SiO_2	Al_2O_3	CaO	MgO	Na_2O	K_2O	Fe_2O_3	MnO	TiO_2	P_2O_5	LOI	Total
1	82.5	9.45	1.19	0.22	2.62	2.26	0.69	0.01	0.13	0.04	0.62	99.7
2	71.1	13.8	3.09	1.16	3.66	2.10	2.99	0.05	0.51	0.11	1.08	99.7
3	49.1	8.19	6.40	6.66	1.47	0.70	21.8	0.34	4.98	0.35	0.07	99.9
4	77.8	11.2	0.56	0.45	1.46	2.95	1.15	0.01	0.47	0.02	3.31	99.4
5	75.5	12.3	0.59	0.55	1.45	2.76	0.86	< 0.01	0.36	0.03	4.39	98.8
6	75.1	10.9	1.36	0.55	1.89	2.68	3.13	0.05	0.40	0.12	3.00	99.2
7	77.4	11.8	0.48	0.47	1.34	2.75	1.00	0.01	0.38	0.04	3.85	99.5
8	75.1	12.1	1.45	0.57	1.89	2.19	1.69	0.03	0.63	0.09	3.85	99.6
9	76.7	12.2	0.46	0.30	1.43	3.41	0.77	0.01	0.44	0.05	3.16	98.9
10	72.7	13.6	0.73	0.58	1.83	3.30	2.05	0.04	0.48	0.05	4.08	99.4
11	75.8	11.1	0.71	1.05	1.83	2.69	1.90	0.03	0.44	0.04	3.62	99.4
12	71.9	12.5	1.80	0.97	2.14	2.49	2.82	0.04	0.48	0.05	3.54	98.7
13	75.7	11.4	0.13	0.37	0.48	2.28	2.08	0.02	0.42	0.03	5.62	98.5
14	75.9	11.4	0.67	0.48	1.41	2.66	1.78	0.02	0.42	0.03	4.54	99.5
15	76.5	11.4	0.23	0.39	0.92	2.74	2.03	0.03	0.29	0.03	4.39	99.1
16	74.6	11.8	0.94	0.80	1.78	3.12	2.10	0.03	0.59	0.04	3.00	98.8
17	69.8	12.4	3.17	1.61	2.96	2.32	5.13	0.09	0.98	0.17	1.39	100.2
18	70.3	11.7	3.34	1.46	3.04	2.36	4.42	0.08	0.76	0.15	1.77	99.6
19	65.8	13.0	3.64	1.90	2.77	2.13	5.85	0.10	1.08	0.20	3.00	99.6
20	77.8	9.99	1.62	0.64	2.51	1.81	1.59	0.04	0.24	0.05	3.00	99.3
21	87.9	7.38	< 0.01	0.07	< 0.01	1.41	0.19	0.01	0.21	0.03	2.16	99.4
22	88.0	7.61	< 0.01	0.10	0.07	1.59	0.17	0.02	0.21	0.04	2.16	100.0
23	65.6	15.9	1.76	0.52	2.37	1.08	4.14	0.03	0.75	0.04	7.47	99.7
24	78.5	10.1	0.59	0.23	2.30	3.09	1.70	0.04	0.18	0.04	2.00	98.8
25	62.8	16.5	1.54	0.84	2.30	3.07	4.14	0.05	0.69	0.09	7.54	99.6
26	77.3	11.1	0.73	0.34	2.29	2.93	1.65	0.03	0.25	0.04	2.85	99.5
27	64.9	14.4	1.25	0.63	2.52	3.22	4.67	0.09	0.48	0.07	6.47	98.7
28	74.2	13.5	0.96	0.33	3.90	3.65	0.89	0.02	0.23	0.06	1.47	99.2
29	85.5	6.82	0.35	0.19	1.22	2.65	0.96	0.01	0.21	0.04	1.93	99.9
30	59.5	13.9	3.72	1.41	3.63	2.40	3.75	0.06	0.62	0.13	10.0	99.1
31	62.5	12.6	5.49	1.12	2.73	3.62	3.04	0.08	0.48	0.20	7.54	99.4
32	76.1	10.7	1.46	0.33	2.48	3.24	0.78	0.02	0.15	0.08	2.93	98.3
33	75.1	11.2	1.38	0.53	2.91	3.07	1.52	0.04	0.25	0.08	2.62	98.7
34	77.1	11.1	0.37	0.15	2.89	4.31	1.01	0.01	0.15	0.08	1.62	98.8
35	87.4	3.96	0.35	0.45	0.55	0.84	0.88	< 0.01	0.21	0.04	4.62	99.3
36	65.0	15.5	2.93	0.91	4.07	3.57	3.23	0.08	0.66	0.09	3.08	99.1
37	54.1	14.5	9.76	3.28	3.61	2.07	4.00	0.08	0.69	0.12	7.23	99.4
38	56.2	17.3	6.23	2.79	3.72	1.37	5.95	0.11	0.81	0.18	4.54	99.2
39	57.2	15.9	6.53	1.89	4.03	2.39	4.50	0.10	0.68	0.19	6.16	99.6
40	98.6	0.33	< 0.01	0.04	< 0.01	0.05	0.10	0.02	0.56	0.02	0.47	100.2
41	97.7	0.45	< 0.01	0.03	< 0.01	0.06	0.17	0.03	0.50	0.02	0.77	99.7
42	97.8	0.54	< 0.01	0.02	< 0.01	0.05	0.21	0.03	0.25	0.01	0.62	99.5
43	97.0	0.60	< 0.01	0.03	< 0.01	0.04	0.19	0.03	0.29	0.01	0.62	98.8
44	97.9	0.17	1.07	0.04	< 0.01	0.01	0.09	0.02	0.03	0.72	0.16	100.2
45	97.0	0.12	1.24	0.15	< 0.01	0.02	0.08	< 0.01	0.03	0.79	0.16	99.6

Chemical analyses of attrition-scrubbed samples (weight percent). X-ray fluorescence analyses by XRAL.

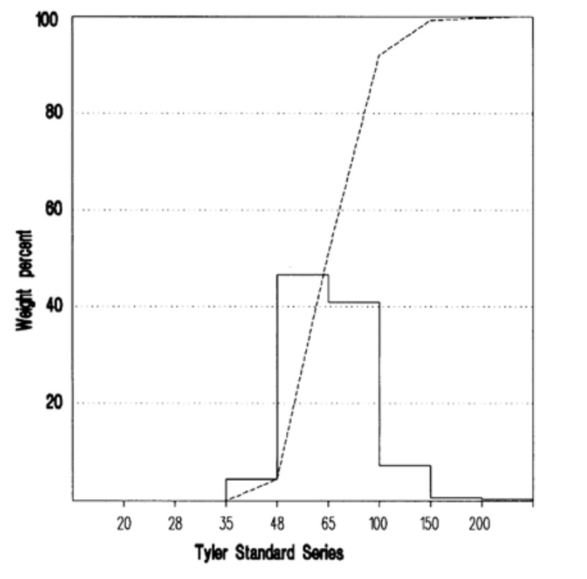
Sample no.	SiO_2	Al_2O_3	CaO	MgO	Na_2O	K_2O	Fe_2O_3	MnO	TiO_2	P_2O_5	LOI	Total
1	82.8	9.53	1.20	0.22	2.59	2.28	0.67	0.01	0.12	0.04	0.47	99.9
2	——	——	——	——	——	——	——	——	——	——	——	——
3	——	——	——	——	——	——	——	——	——	——	——	——
4	85.9	7.24	0.45	0.18	1.36	2.94	0.23	< 0.01	0.16	0.02	0.70	99.2
5	——	——	——	——	——	——	——	——	——	——	——	——
6	——	——	——	——	——	——	——	——	——	——	——	——
7	85.6	7.17	0.36	0.18	1.20	3.00	0.25	< 0.01	0.16	0.02	0.77	98.7
8	——	——	——	——	——	——	——	——	——	——	——	——
9	86.9	7.12	0.29	0.15	1.03	3.08	0.27	< 0.01	0.21	0.03	0.77	99.8
10	——	——	——	——	——	——	——	——	——	——	——	——
11	84.3	8.04	0.78	0.29	1.74	2.78	0.53	0.02	0.23	0.02	0.85	99.8
12	——	——	——	——	——	——	——	——	——	——	——	——
13	88.6	6.14	0.10	0.20	0.43	2.51	0.56	0.01	0.19	0.02	1.23	100.0
14	87.2	6.77	0.44	0.17	1.32	2.81	0.31	0.01	0.16	0.02	0.77	100.2
15	89.3	5.46	0.15	0.11	0.78	2.96	0.21	< 0.01	0.11	0.02	0.62	99.9
16	83.6	8.32	0.87	0.31	1.78	3.06	0.68	0.03	0.41	0.04	0.54	99.6
17	——	——	——	——	——	——	——	——	——	——	——	——
18	——	——	——	——	——	——	——	——	——	——	——	——
19	——	——	——	——	——	——	——	——	——	——	——	——
20	——	——	——	——	——	——	——	——	——	——	——	——
21	——	——	——	——	——	——	——	——	——	——	——	——
22	96.7	1.93	< 0.01	0.06	< 0.01	0.96	0.05	< 0.01	0.10	0.02	0.16	100.0
23	——	——	——	——	——	——	——	——	——	——	——	——
24	84.0	8.80	0.50	0.10	2.44	3.17	0.16	0.02	0.07	0.02	0.47	99.8
25	——	——	——	——	——	——	——	——	——	——	——	——
26	83.1	9.11	0.63	0.11	2.64	3.08	0.18	0.02	0.09	0.02	0.23	99.2
27	——	——	——	——	——	——	——	——	——	——	——	——
28	77.2	12.7	0.81	0.12	4.00	3.79	0.20	0.01	0.09	0.04	0.31	99.3
29	——	——	——	——	——	——	——	——	——	——	——	——
30	——	——	——	——	——	——	——	——	——	——	——	——
31	——	——	——	——	——	——	——	——	——	——	——	——
32	81.6	9.63	0.81	0.13	2.64	3.22	0.22	0.02	0.08	0.03	1.62	100.0
33	——	——	——	——	——	——	——	——	——	——	——	——
34	80.5	10.4	0.34	0.10	2.97	4.06	0.27	0.01	0.08	0.03	0.54	99.3
35	——	——	——	——	——	——	——	——	——	——	——	——
36	——	——	——	——	——	——	——	——	——	——	——	——
37	——	——	——	——	——	——	——	——	——	——	——	——
38	57.2	18.3	6.91	2.76	4.25	1.25	5.59	0.11	0.81	0.15	2.39	99.7
39	59.5	16.2	6.64	1.54	4.31	2.36	3.68	0.09	0.58	0.17	4.85	99.9
40	——	——	——	——	——	——	——	——	——	——	——	——
41	——	——	——	——	——	——	——	——	——	——	——	——
42	——	——	——	——	——	——	——	——	——	——	——	——
43	——	——	——	——	——	——	——	——	——	——	——	——
44	——	——	——	——	——	——	——	——	——	——	——	——
45	——	——	——	——	——	——	——	——	——	——	——	——

	X-ray diffraction mineralogy of -20/+200-mesh sample fraction. Relative amounts estimated from peak heights. M=major; m=minor; tr=trace.								X-ray diffraction mineralogy of minus-200-mesh sample fraction. Relative amounts estimated from peak heights. M=major; m=minor; tr=trace.								
Sample no.	Quartz	Feldspar	Kaolin	Clays (other)	Amphibole	Calcite	Mica	Remarks	Quartz	Feldspar	Kaolin	Clays (other)	Clinoptilolite	Amphibole	Calcite	Mica	Remarks
1	M	m	——	——	——	——	——	——	——	——	——	——	——	——	——	——	——
2	M	M	——	——	——	——	——	——	M	M	——	——	——	——	——	——	——
3	m	m	——	——	tr	——	——	——	m	m	——	——	——	——	——	——	Magnetite — M
4	M	tr	——	——	——	——	——	——	m	M	——	tr	——	——	——	——	Illite — tr
5	M	m	——	——	——	——	——	——	M	M	——	tr	——	——	——	——	——
6	M	m	——	——	——	——	——	——	M	——	——	——	——	——	——	——	——
7	M	m	——	——	——	——	——	——	M	M	——	tr	——	——	——	——	——
8	M	m	——	——	——	——	——	——	m	M	——	tr	——	——	——	——	——
9	M	m	——	——	——	——	——	——	M	m	——	——	——	——	——	——	——
10	M	m	——	——	——	——	——	——	m	m	——	——	——	——	——	tr	——
11	M	m	——	——	——	——	——	——	m	tr	——	——	——	——	——	——	——
12	M	m	——	tr	tr	——	——	Montmorillonite — tr	m	m	——	tr	——	——	——	——	Montmorillonite — tr
13	M	tr	——	——	——	——	——	——	m	tr	——	tr	——	——	——	——	——
14	M	m	——	——	——	——	——	——	tr	tr	——	m	——	——	——	——	Montmorillonite — m
15	M	tr	——	——	——	——	——	——	m	tr	——	tr	——	——	——	——	Chlorite and montmorillonite — tr
16	M	m	——	——	——	——	——	——	m	m	——	——	——	——	——	m	——
17	M	m	——	——	tr	——	tr	——	M	M	——	——	——	tr	——	tr	——
18	M	m	——	——	——	——	——	——	M	m	——	——	——	tr	——	tr	Chlorite — tr
19	M	m	——	——	——	——	——	——	M	m	——	——	——	tr	——	tr	Chlorite — tr
20	M	m	tr	——	——	——	——	——	M	M	m	——	——	——	——	——	——
21	M	tr	tr	——	——	——	——	——	M	M	M	——	——	——	——	——	——
22	M	tr	tr	——	——	——	——	——	M	m	M	——	——	——	——	——	——
23	M	m	——	——	——	——	——	——	tr	tr	tr	——	——	——	——	——	——
24	M	M	——	——	——	——	——	——	m	m	——	tr	——	——	——	——	Montmorillonite — tr
25	m	m	——	——	——	——	——	——	M	m	tr	——	——	——	——	——	——
26	M	m	——	tr	——	——	——	Montmorillonite — tr	tr	m	——	——	——	——	——	——	——
27	m	m	——	——	——	——	——	——	tr	tr	——	tr	——	——	——	——	——
28	M	M	——	——	——	——	——	——	M	M	——	——	——	——	——	——	——
29	M	m	——	——	——	——	——	——	m	tr	——	——	——	——	——	——	——
30	m	m	——	——	——	tr	——	——	tr	tr	——	——	m	——	——	——	——
31	m	m	——	——	——	tr	——	——	tr	tr	——	——	——	——	——	——	——
32	M	m	——	——	——	——	——	——	M	M	——	——	——	——	——	——	——
33	M	m	——	——	——	——	——	——	tr	——	——	——	M	——	——	——	——
34	M	m	——	——	——	——	——	——	M	M	——	——	——	——	——	——	——
35	——	——	——	——	——	——	——	Cristobalite — M	——	——	——	——	——	——	——	——	——
36	m	m	——	——	——	——	——	——	tr	M	——	——	——	——	——	——	——
37	tr	M	——	——	——	tr	——	——	tr	M	——	——	——	——	——	——	——
38	tr	M	——	——	——	——	——	——	tr	M	——	——	——	——	——	——	——
39	tr	m	——	——	——	——	——	——	tr	M	——	——	——	——	——	——	——
40	——	——	——	——	——	——	——	——	——	——	——	——	——	——	——	——	——
41	——	——	——	——	——	——	——	——	——	——	——	——	——	——	——	——	——
42	——	——	——	——	——	——	——	——	——	——	——	——	——	——	——	——	——
43	——	——	——	——	——	——	——	——	——	——	——	——	——	——	——	——	——
44	——	——	——	——	——	——	——	——	——	——	——	——	——	——	——	——	——
45	——	——	——	——	——	——	——	——	——	——	——	——	——	——	——	——	——

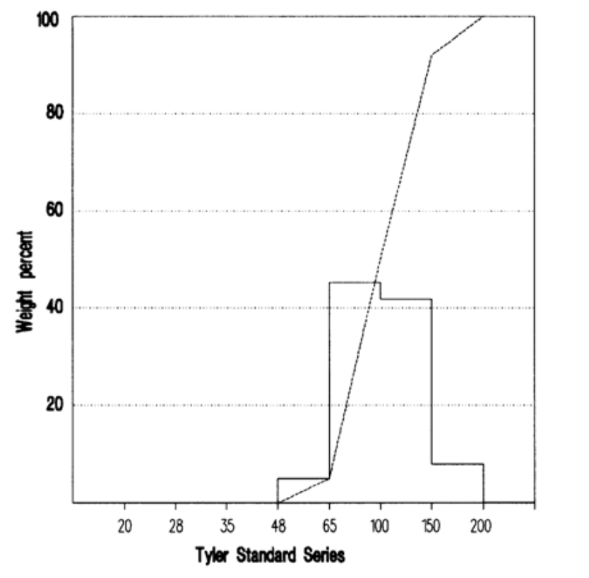
	Screen analysis (Tyler Standard Series), dry, as received. Expressed as weight percent retained on respective screen sizes.									Screen analysis (Tyler Standard Series), cumulative totals. Expressed as weight percent retained on respective screen sizes.								
	Mesh size									Mesh size								
Sample no.	20	28	35	48	65	100	150	200	<200	20	28	35	48	65	100	150	200	<200
1	——	——	2.3	27.2	55.8	13.9	0.8	——	——	——	——	2.3	29.5	85.3	99.2	99.9	99.9	99.9
2	——	——	——	4.4	46.6	41.0	7.2	0.6	0.3	——	——	——	4.4	51.0	92.0	99.2	99.7	100.0
3	——	——	——	——	5.0	45.2	41.8	7.9	0.2	——	——	——	——	5.0	50.2	92.0	99.9	100.0
4	1.5	6.5	22.4	30.3	25.3	5.8	3.1	1.9	3.3	1.5	7.9	30.3	60.6	85.9	91.7	94.8	96.7	100.0
5	15.0	10.8	20.6	22.1	17.2	5.1	3.3	2.3	3.8	15.0	25.8	46.3	68.4	85.5	90.6	93.9	96.2	100.0
6	8.5	9.8	17.7	20.3	20.9	7.5	4.7	3.4	7.2	8.5	18.3	36.0	56.4	77.3	84.7	89.4	92.8	100.0
7	8.8	8.9	17.2	23.3	22.5	7.2	4.1	2.9	5.2	8.8	17.7	34.9	58.2	80.7	87.9	91.9	94.8	100.0
8	8.7	14.7	21.7	19.9	17.3	6.4	3.6	2.4	5.3	8.7	23.4	45.1	65.0	82.3	88.7	92.3	94.7	100.0
9	10.6	7.1	13.1	15.1	14.7	8.4	7.4	6.3	17.3	10.6	17.7	30.8	45.9	60.6	69.0	76.3	82.7	100.0
10	2.3	7.0	14.3	24.7	30.5	9.3	4.2	2.8	4.9	2.3	9.2	23.5	48.3	78.7	88.0	92.3	95.1	100.0
11	10.9	15.6	13.8	24.2	14.5	9.7	4.2	3.0	4.1	10.9	26.5	40.3	64.5	79.0	88.7	92.9	95.9	100.0
12	1.3	2.1	6.9	19.1	44.6	17.3	4.1	2.0	2.8	1.3	3.4	10.4	29.4	74.0	91.2	95.3	97.3	100.0
13	11.8	15.2	32.2	22.3	9.1	2.5	2.0	1.7	3.3	11.8	27.0	59.2	81.5	90.6	93.1	95.1	96.8	100.0
14	1.0	11.7	21.0	38.3	14.5	4.6	1.9	1.9	5.1	1.0	12.7	33.7	72.0	86.5	91.1	93.0	94.9	100.0
15	2.8	9.8	11.8	29.4	20.8	9.6	3.7	3.3	8.8	2.8	12.6	24.4	53.8	74.6	84.2	87.9	91.2	100.0
16	0.2	0.7	5.0	12.6	33.9	21.5	11.9	5.7	8.5	0.2	0.9	5.9	18.5	52.4	73.9	85.8	91.5	100.0
17	0.2	2.4	9.0	18.7	24.4	26.8	11.0	6.0	1.6	0.2	2.6	11.6	30.3	54.7	81.5	92.5	98.5	100.0
18	32.3	11.6	12.6	20.2	12.5	6.7	2.3	1.1	0.7	32.3	43.9	56.5	76.7	89.2	95.9	98.2	99.3	100.0
19	0.3	0.1	0.3	1.0	3.5	13.2	21.9	34.5	25.2	0.3	0.4	0.7	1.7	5.2	18.4	40.3	74.8	100.0
20	31.4	11.0	15.9	13.6	8.8	4.5	3.9	3.2	7.7	31.4	42.4	58.3	72.0	80.7	85.2	89.1	92.3	100.0
21	37.3	12.6	14.0	8.4	6.7	4.1	4.0	3.3	9.8	37.3	49.9	63.9	72.2	79.0	83.0	87.0	90.3	100.0
22	39.8	12.9	13.0	7.1	5.6	4.1	3.9	3.3	10.2	39.8	52.7	65.8	72.8	78.4	82.6	86.4	89.8	100.0
23	8.2	5.0	6.8	9.0	27.3	24.2	11.4	4.1	4.0	8.2	13.2	20.0	29.0	56.3	80.6	92.0	96.1	100.0
24	8.0	21.2	32.5	16.2	12.8	4.5	1.9	0.9	2.0	8.0	29.2	61.7	77.9	90.7	95.1	97.0	98.0	100.0
25	9.5	3.0	3.1	3.1	4.7	7.9	21.6	19.4	27.8	9.5	12.4	15.5	18.6	23.4	31.3	52.9	72.2	100.0
26	12.8	20.6	27.3	11.7	13.2	6.1	3.3	1.9	3.1	12.8	33.4	60.7	72.4	85.6	91.7	95.0	96.9	100.0
27	15.9	3.6	4.9	7.9	23.0	18.0	12.4	5.8	8.6	15.9	19.5	24.4	32.3	55.3	73.3	85.6	91.4	100.0
28	0.5	1.4	7.1	32.0	45.6	9.7	1.8	0.5	1.2	0.5	1.9	9.0	41.1	86.7	96.4	98.2	98.7	99.9
29	54.4	23.2	13.0	4.5	2.5	0.9	0.5	0.3	0.4	54.5	77.7	90.7	95.3	97.8	98.7	99.2	99.5	100.0
30	3.9	2.1	2.7	4.3	18.7	21.8	23.9	12.1	10.5	3.9	6.0	8.7	13.1	31.7	53.5	77.4	89.5	100.0
31	7.5	2.3	4.0	10.2	25.6	21.0	16.7	8.2	4.6	7.5	9.8	13.8	23.9	49.5	70.5	87.2	95.4	100.0
32	36.6	7.9	11.9	7.6	9.3	6.8	5.6	3.7	10.5	36.6	44.5	56.5	64.1	73.4	80.2	85.8	89.5	100.0
33	0.1	11.0	41.5	30.3	11.6	2.0	1.0	0.6	1.9	0.1	11.1	52.6	82.9	94.5	96.5	97.5	98.1	100.0
34	9.3	5.1	19.4	35.5	18.2	4.7	2.6	1.8	3.5	9.3	14.4	33.7	69.2	87.3	92.1	94.7	96.5	100.0
35	——	——	——	——	——	——	——	——	——	——	——	——	——	——	——	——	——	——
36	——	0.1	0.4	3.6	20.8	29.3	28.7	11.8	5.2	——	0.1	0.5	4.1	25.0	54.2	82.9	94.7	100.0
37	0.1	0.2	1.7	6.4	22.5	26.8	28.0	11.9	2.4	0.1	0.3	2.0	8.4	30.9	57.7	85.7	97.6	100.0
38	0.7	1.4	4.0	9.8	24.1	19.7	22.2	13.9	4.4	0.7	2.1	6.1	15.8	39.9	59.6	81.8	95.7	100.0
39	0.6	0.7	1.4	2.6	5.8	9.4	21.5	31.4	26.4	0.6	1.3	2.7	5.3	11.1	20.5	42.0	73.5	99.9
40	——	——	——	——	——	——	——	——	——	——	——	——	——	——	——	——	——	——
41	——	——	——	——	——	——	——	——	——	——	——	——	——	——	——	——	——	——
42	——	——	——	——	——	——	——	——	——	——	——	——	——	——	——	——	——	——
43	——	——	——	——	——	——	——	——	——	——	——	——	——	——	——	——	——	——
44	——	——	——	——	——	——	——	——	——	——	——	——	——	——	——	——	——	——
45	——	——	——	——	——	——	——	——	——	——	——	——	——	——	——	——	——	——



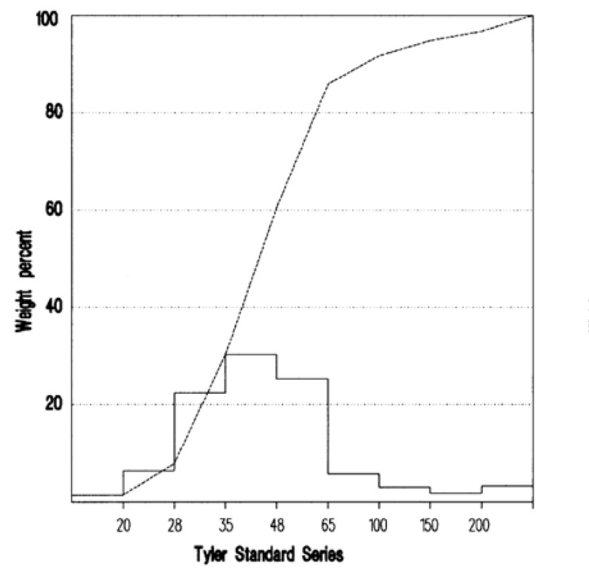
Sample Number: 1
Area: North Bend
Lithology: Dune sand
Geologic map unit: Unstabilized dune
County: Coos



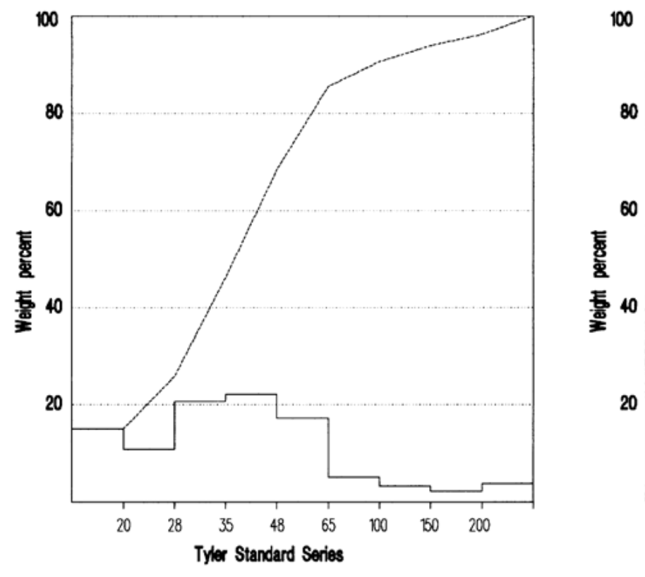
Sample Number: 2
Area: Del Rey Beach
Lithology: Beach sand
Geologic map unit: ——
County: Clatsop



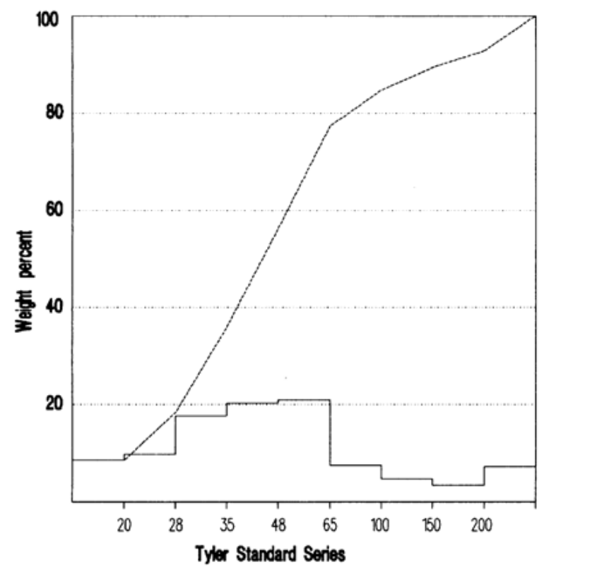
Sample Number: 3
Area: Clatsop Spit
Lithology: Beach sand
Geologic map unit: ——
County: Clatsop



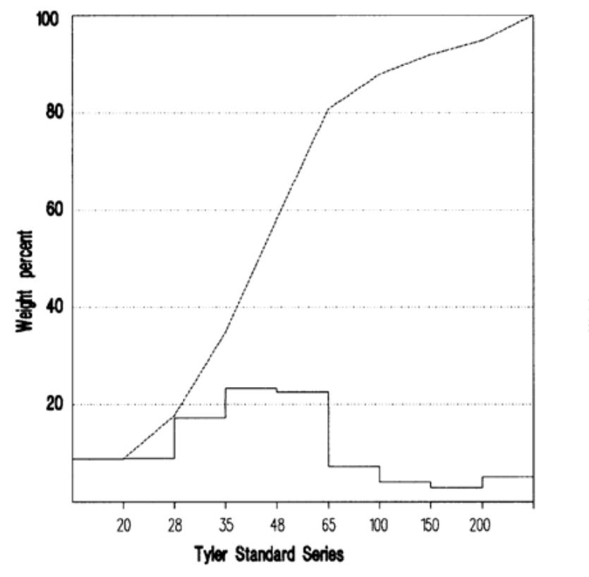
Sample Number: 4
Area: Wallooskee River
Lithology: Marine sandstone
Geologic map unit: Astoria Formation, Youngs Bay member
County: Clatsop



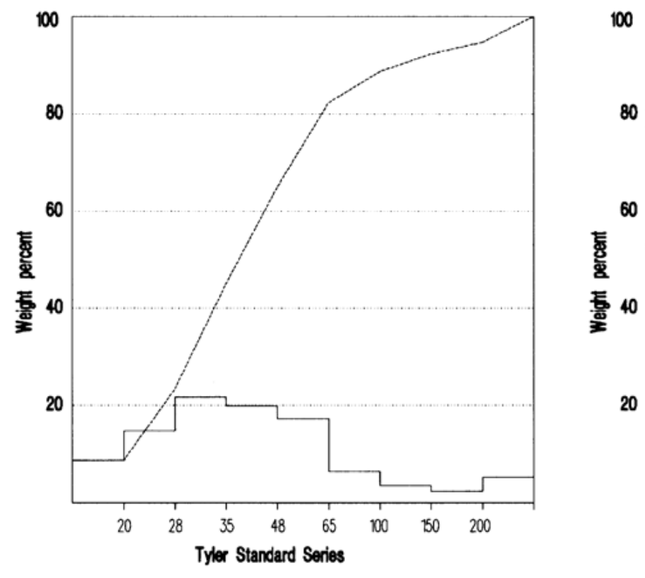
Sample Number: 5
Area: Pipeline Road
Lithology: Marine sandstone
Geologic map unit: Astoria Formation, Youngs Bay member
County: Clatsop



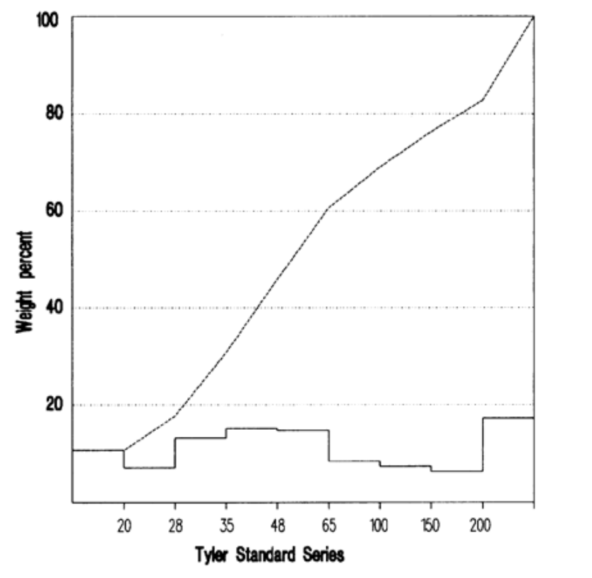
Sample Number: 6
Area: Youngs River
Lithology: Marine sandstone
Geologic map unit: Astoria Formation, Youngs Bay member
County: Clatsop



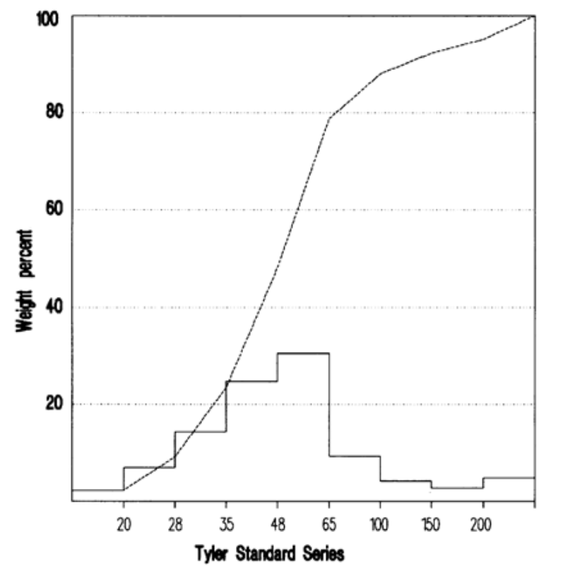
Sample Number: 7
Area: Pipeline Road
Lithology: Marine sandstone
Geologic map unit: Astoria Formation, Youngs Bay member
County: Clatsop



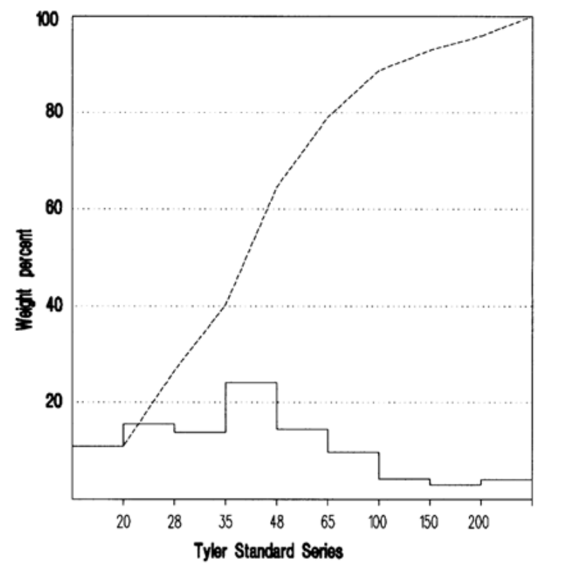
Sample Number: 8
Area: John Day River
Lithology: Marine sandstone
Geologic map unit: Astoria Formation, Youngs Bay member
County: Clatsop



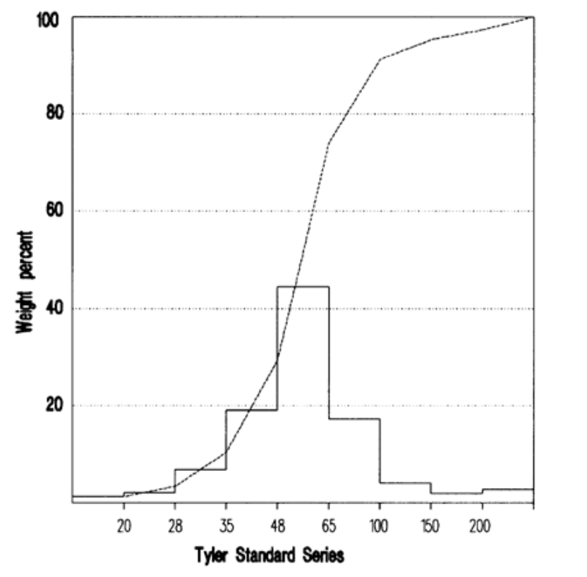
Sample Number: 9
Area: John Day River
Lithology: Marine sandstone
Geologic map unit: Astoria Formation, Youngs Bay member
County: Clatsop



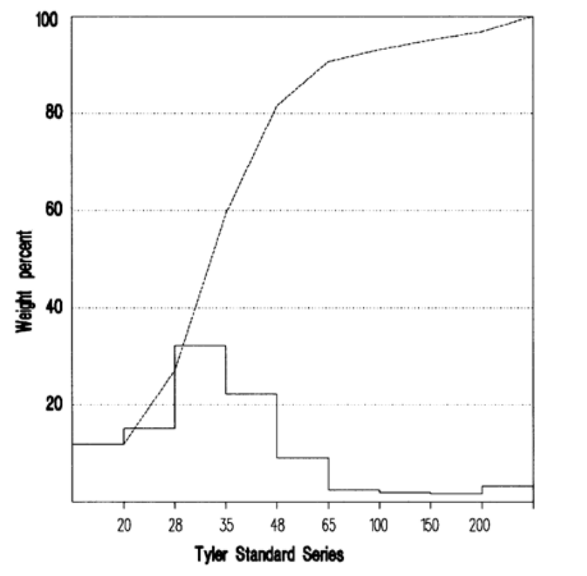
Sample Number: 10
Area: Pipeline Road
Lithology: Marine sandstone
Geologic map unit: Astoria Formation, Youngs Bay member
County: Clatsop



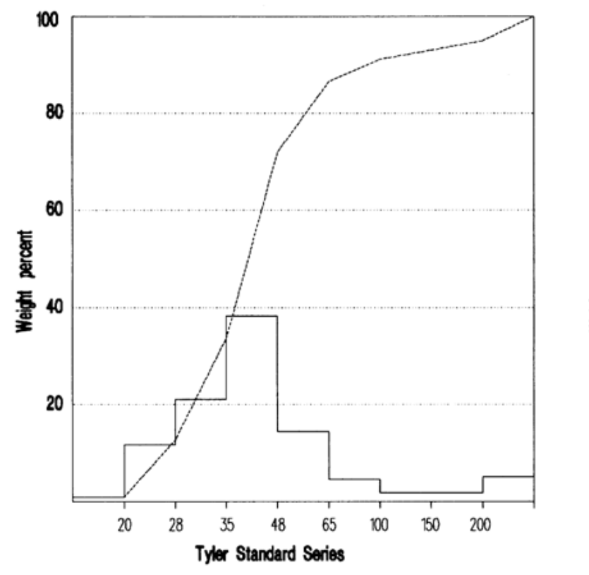
Sample Number: 11
Area: Knappa
Lithology: Sandstone
Geologic map unit: Gnat Creek formation
County: Clatsop



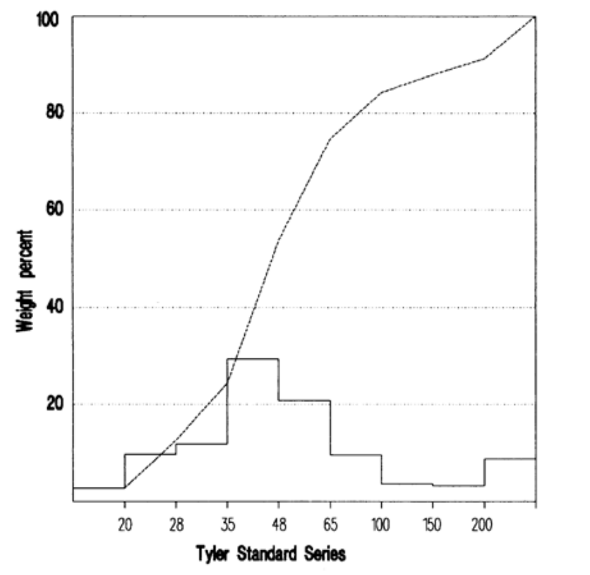
Sample Number: 12
Area: Knappa Junction
Lithology: Sandstone
Geologic map unit: Gnat Creek formation
County: Clatsop



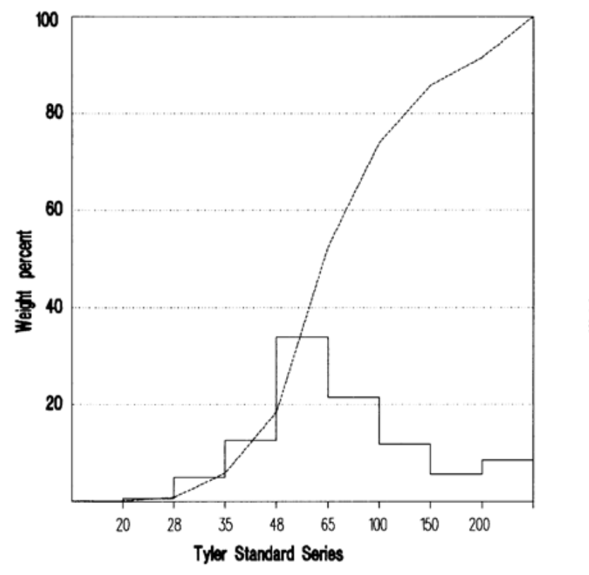
Sample Number: 13
Area: Gnat Creek
Lithology: Sandstone
Geologic map unit: Gnat Creek formation
County: Clatsop



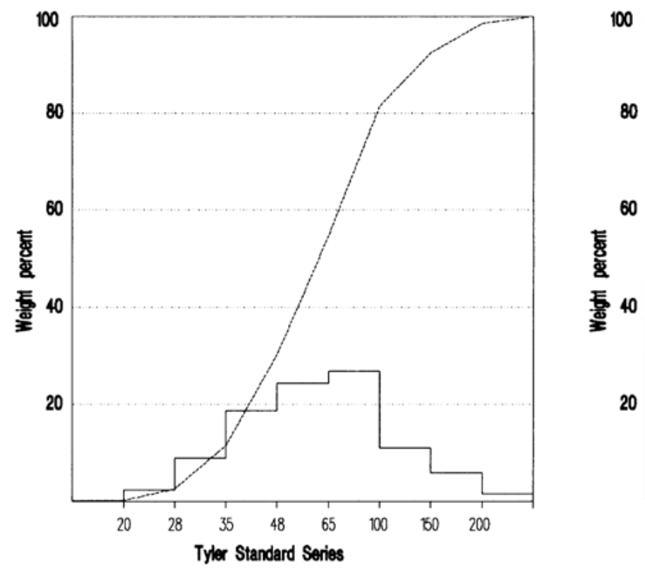
Sample Number: 14
Area: Gnat Creek
Lithology: Sandstone
Geologic map unit: Gnat Creek formation
County: Clatsop



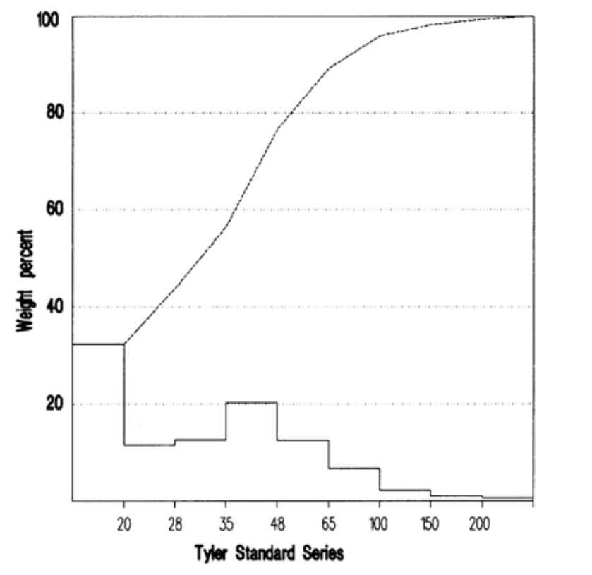
Sample Number: 15
Area: Nicolai Mountain
Lithology: Sandstone
Geologic map unit: Vantage sandstone
County: Clatsop



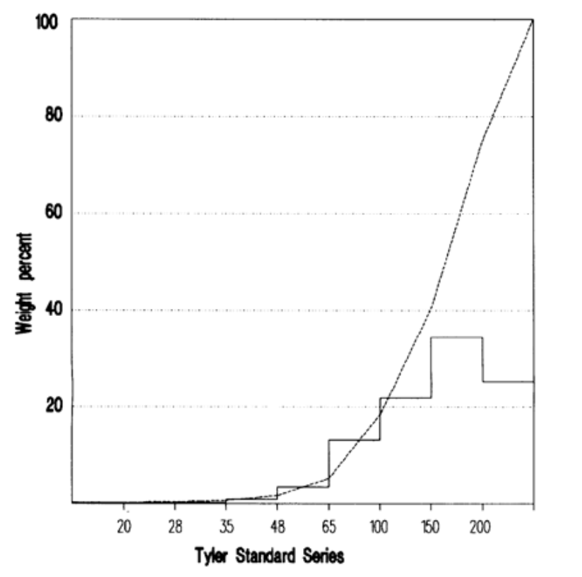
Sample Number: 16
Area: Green Point Creek
Lithology: Sandstone
Geologic map unit: Vantage sandstone
County: Hood River



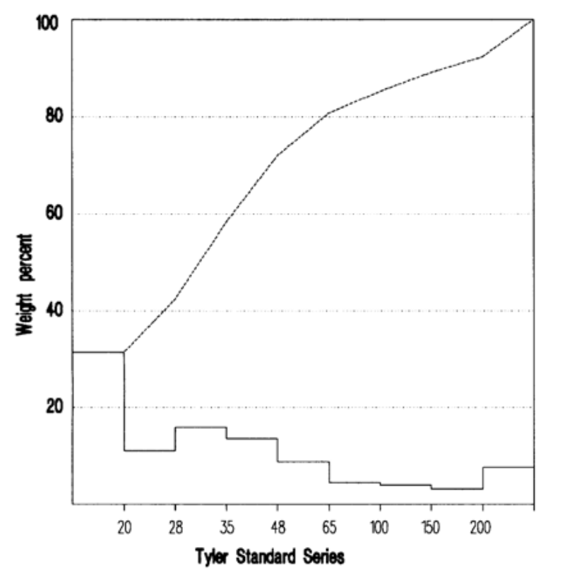
Sample Number: 17
Area: Boardman
Lithology: Dune sand
Geologic map unit: Fluvioglacial deposit
County: Morrow



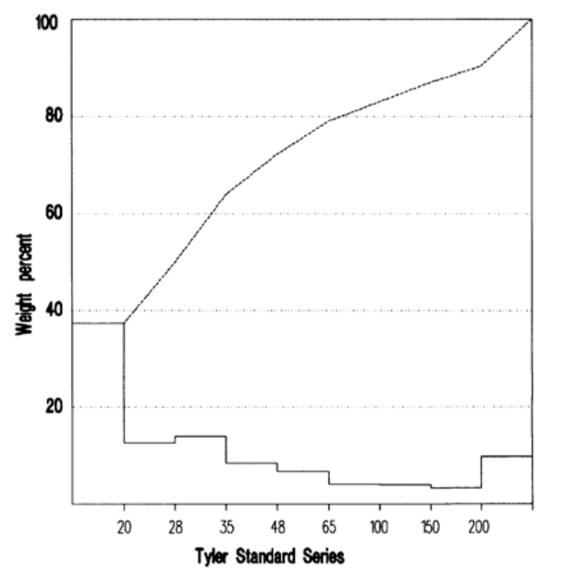
Sample Number: 18
Area: Boardman
Lithology: Sand
Geologic map unit: Fluvioglacial deposit
County: Morrow



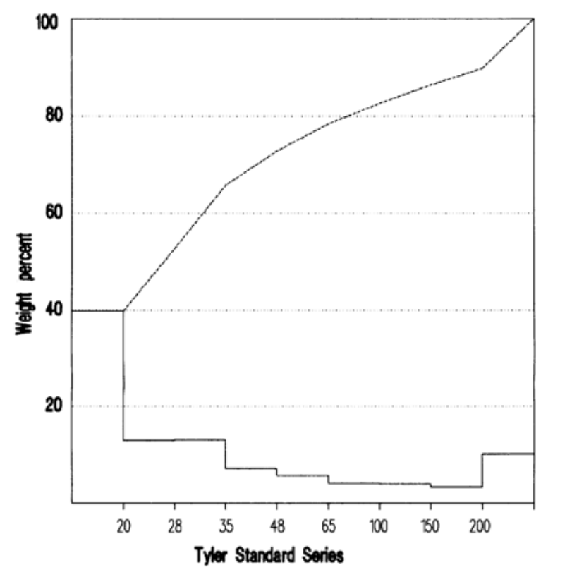
Sample Number: 19
Area: Finley Buttes
Lithology: Sand
Geologic map unit: Glacial lake sediments
County: Morrow



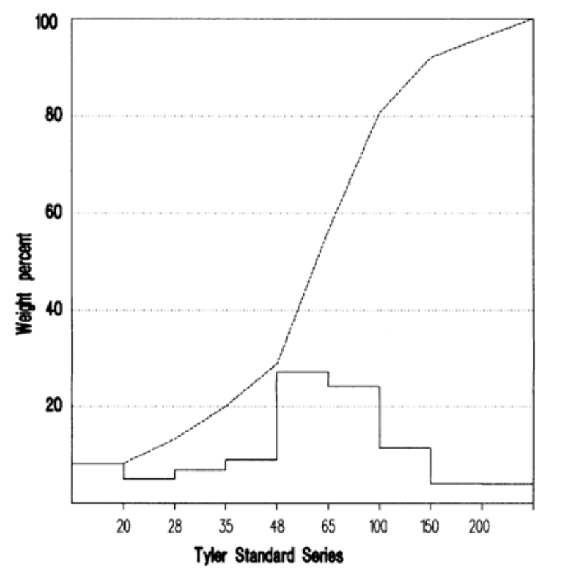
Sample Number: 20
Area: Arbuckle Mountain
Lithology: Sandstone
Geologic map unit: Herren formation
County: Morrow



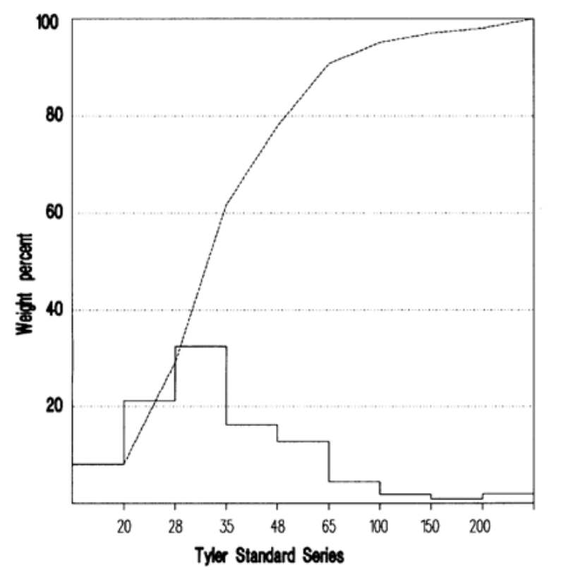
Sample Number: 21
Area: Arbuckle Mountain
Lithology: Sandstone
Geologic map unit: Herren formation
County: Morrow



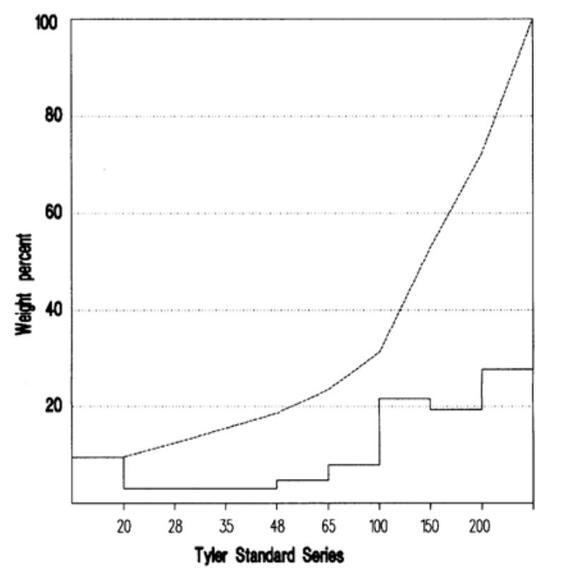
Sample Number: 22
Area: Arbuckle Mountain
Lithology: Sandstone
Geologic map unit: Herren formation
County: Morrow



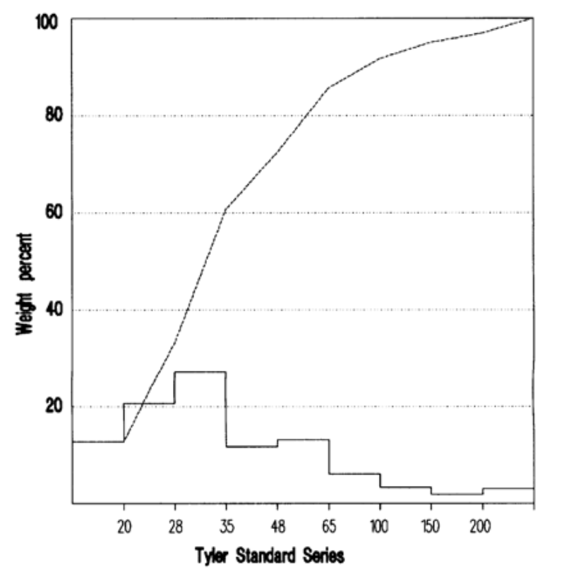
Sample Number: 23
Area: Lookout Mountain
Lithology: Sandstone
Geologic map unit: Interbed, Saddle Mtn. Basalt
County: Union



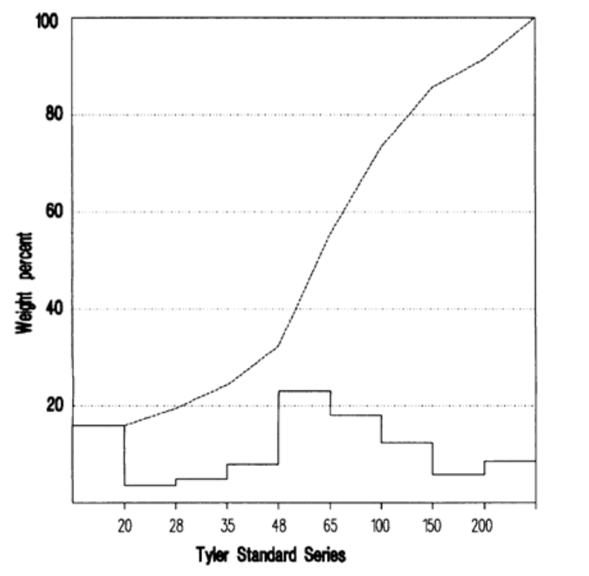
Sample Number: 24
Area: Long Meadows G.S.
Lithology: Sandstone
Geologic map unit: Grouse Creek interbed
County: Wallowa



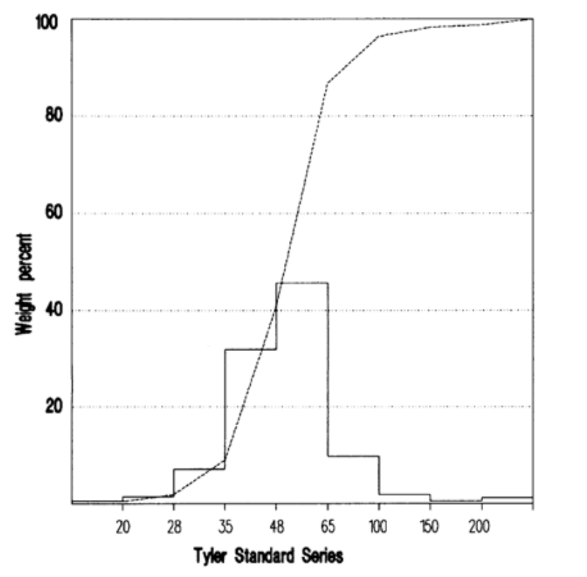
Sample Number: 25
Area: Troy
Lithology: Sandstone
Geologic map unit: Squaw Canyon interbed
County: Wallowa



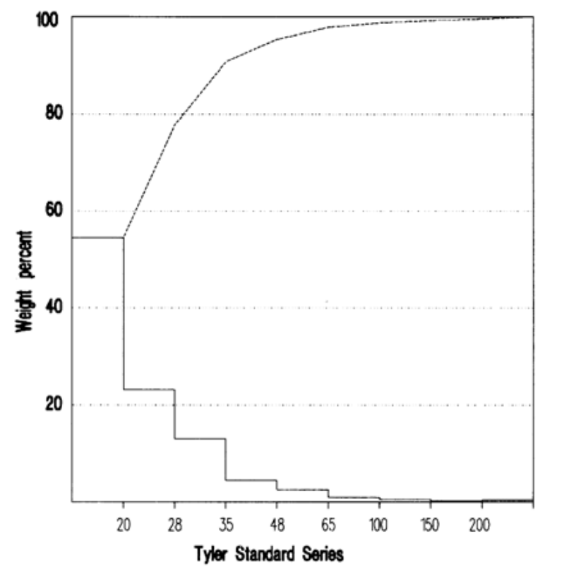
Sample Number: 26
Area: Troy
Lithology: Sandstone
Geologic map unit: Grouse Creek interbed
County: Wallowa



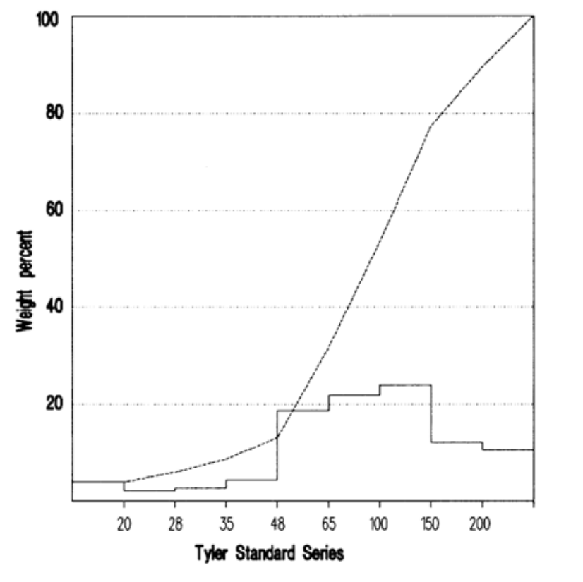
Sample Number: 27
Area: Troy
Lithology: Sandstone
Geologic map unit: Grouse Creek interbed
County: Wallowa



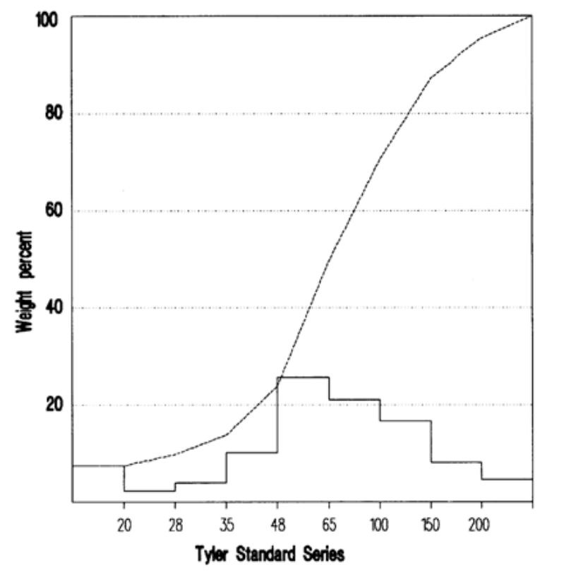
Sample Number: 28
Area: Basin Creek
Lithology: Sandstone
Geologic map unit: Grassy Mountain Formation
County: Malheur



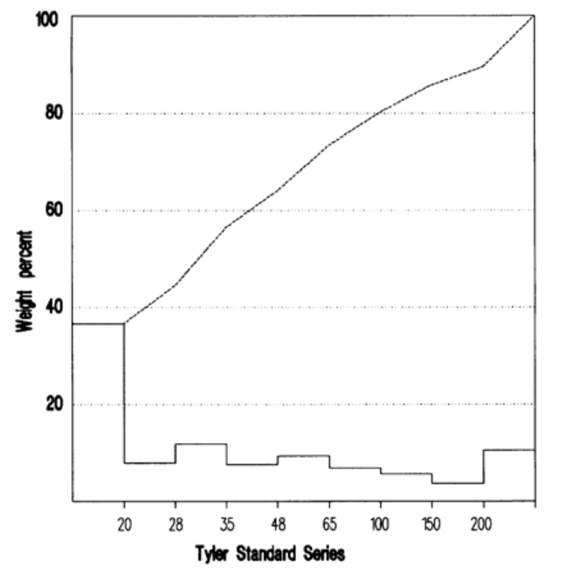
Sample Number: 29
Area: Basin Creek
Lithology: Sandstone
Geologic map unit: Grassy Mountain Formation
County: Malheur



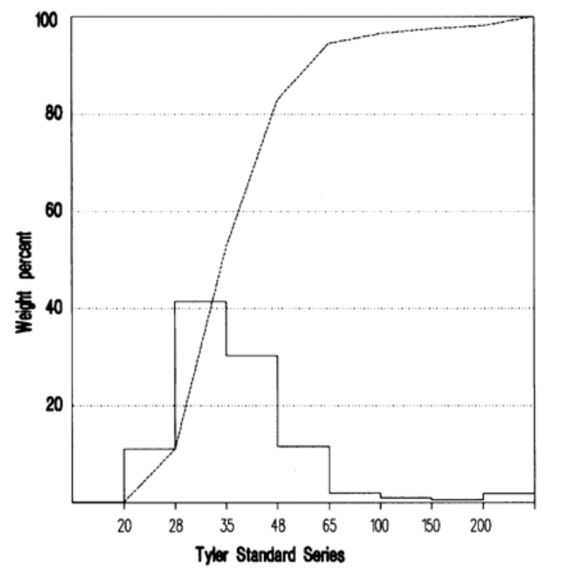
Sample Number: 30
Area: Cow Hollow
Lithology: Sandstone
Geologic map unit: Tuffaceous sandstone (Tig)
County: Malheur



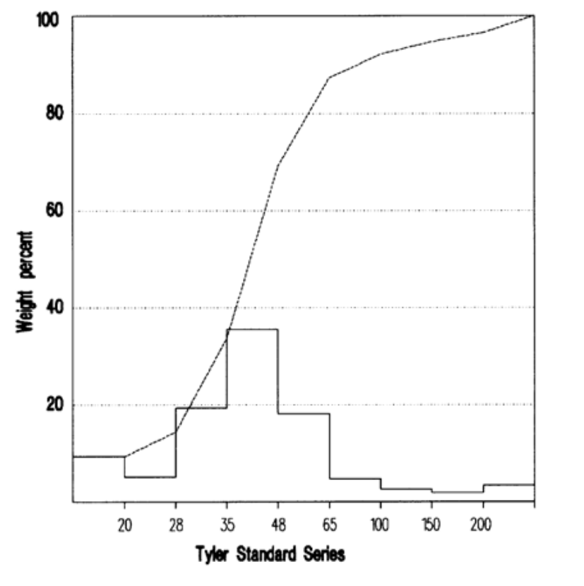
Sample Number: 31
Area: Cow Hollow
Lithology: Sandstone
Geologic map unit: Tuffaceous sandstone (Tig)
County: Malheur



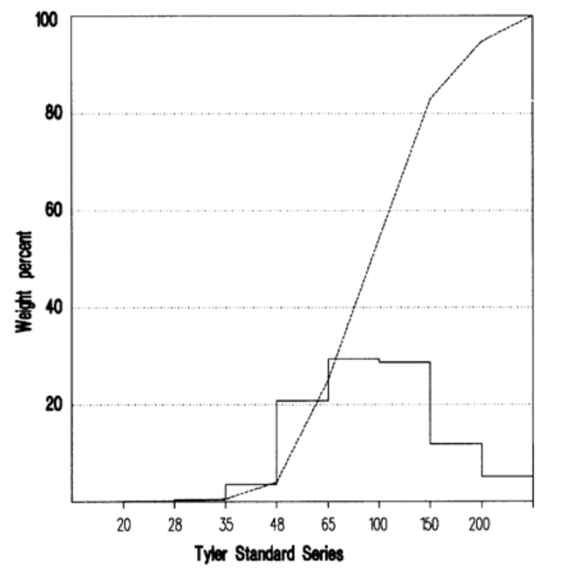
Sample Number: 32
Area: Sand Hollow
Lithology: Sandstone
Geologic map unit: Arkosic sandstone (Tas)
County: Malheur



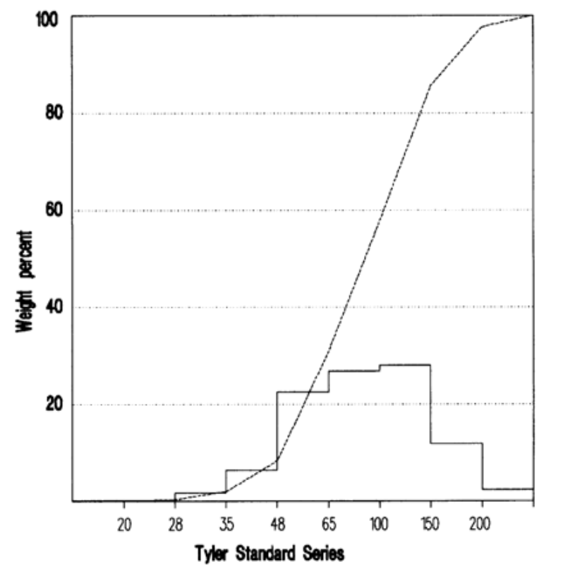
Sample Number: 33
Area: Grassy Mountain
Lithology: Sandstone
Geologic map unit: Arkosic sandstone (Tgs)
County: Malheur



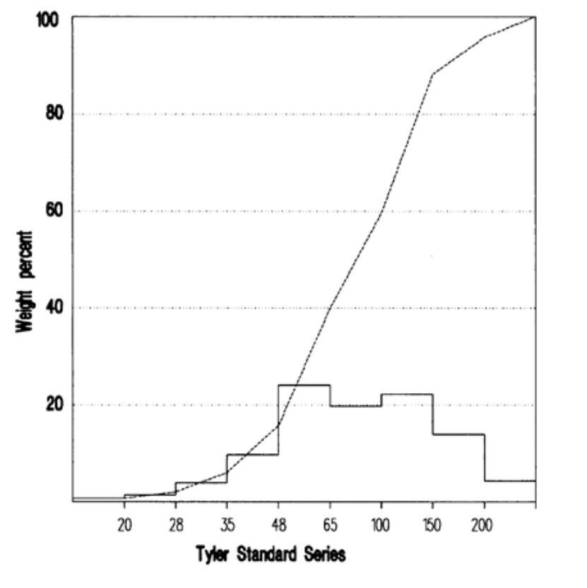
Sample Number: 34
Area: Twin Springs Creek
Lithology: Sandstone
Geologic map unit: Arkosic sandstone
County: Malheur



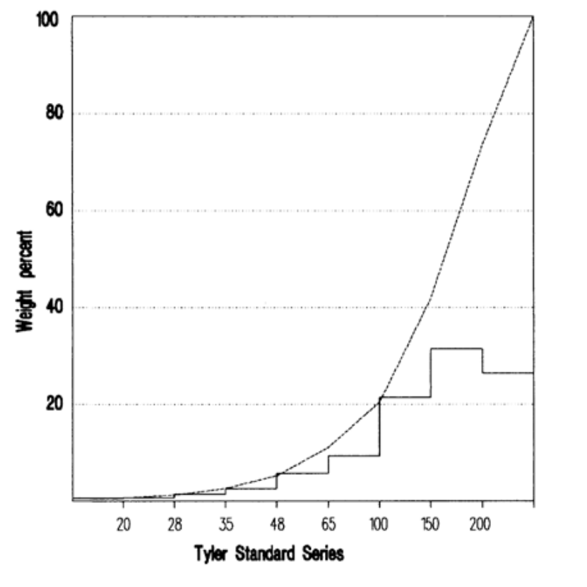
Sample Number: 36
Area: Denio
Lithology: Dune sand
Geologic map unit: ——
County: Harney



Sample Number: 37
Area: Alkali Lake
Lithology: Dune sand
Geologic map unit: ——
County: Lake



Sample Number: 38
Area: Fossil Lake
Lithology: Dune sand
Geologic map unit: ——
County: Lake



Sample Number: 39
Area: Summer Lake
Lithology: Dune sand
Geologic map unit: ——
County: Lake

REFERENCES CITED ON PLATE 2.

Beaulieu, J.D., and Hughes, P.W., 1975, Environmental geology of western Coos and Douglas Counties, Oregon: Oregon Department of Geology and Mineral Industries Bulletin 87, 148 p., map scale 1:62,500.

———1977, Land use geology of central Jackson County, Oregon: Oregon Department of Geology and Mineral Industries Bulletin 94, 87 p., map scale 1:62,500.

Cummings, M.L., 1989, Portland State University, personal communication, mapping in progress, scale 1:24,000.

Ferns, M.L., 1989a, Geology and mineral resources map of the Grassy Mountain Quadrangle, Malheur County, Oregon: Oregon Department of Geology and Mineral Industries Geological Map Series GMS-57, scale 1:24,000.

———1989b, Geology and mineral resources map of the Owyhee Dam Quadrangle, Malheur County, Oregon: Oregon Department of Geology and Mineral Industries Geological Map Series GMS-55, scale 1:24,000.

Ferns, M.L., and Brooks, H.C., 1986, Geology and coal resources of the Arbuckle Mountain coal field, Morrow County, Oregon: Oregon Department of Geology and Mineral Industries Open-File Report O-86-5, 25 p., map scales 1:24,000 and 1:100,000.

Kittleman, L.R., Green, A.R., Haddock, G.H., Hagood, A.R., Johnson, A.M., McMurray, J.M., Russell, R.G., and Weeden, D.A., 1967, Geologic map of the Owyhee region, Malheur County, Oregon: Eugene, Oreg., University of Oregon Museum of Natural History Bulletin 8, scale 1:125,000.

Niem, A.R., and Niem, W.A., 1985, Oil and gas investigation of the Astoria Basin, Clatsop and northernmost Tillamook Counties, northwest Oregon: Oregon Department of Geology and Mineral Industries Oil and Gas Investigation OGI-14, 8 p., map scale 1:100,000.

Ramp, L., 1960, The Quartz Mountain silica deposit: Oregon Department of Geology and Mineral Industries, Ore Bin, v. 22, no. 11, p. 109-114, map scale 1:21,120.

Ramp, L., and Ferns, M.L., 1989, Geology and mineral resources map of the Double Mountain Quadrangle, Malheur County, Oregon: Oregon Department of Geology and Mineral Industries Geological Map Series GMS-58, scale 1:24,000.

Ross, M.E., 1978, Stratigraphy, structure, and petrology of Columbia River basalt in a portion of the Grande Ronde River-Blue Mountains area of Oregon and Washington: Richland, Wash., Rockwell Hanford Operations Report RHO-SA-58, 460 p., map scale 1:48,000.

Swanson, D.A., Anderson, J.L., Camp, V.E., Hooper, P.R., Taubeneck, W.H., and Wright, T.L., 1981, Reconnaissance geologic map of the Columbia River Basalt Group, northern Oregon and western Idaho: U.S. Geological Survey Open-File Report 81-797, 33 p., scale 1:250,000.

Timm, S., 1979, The structure and stratigraphy of the Columbia River basalt in the Hood River Valley, Oregon: Portland, Oreg., Portland State University master's thesis, 60 p., map scale 1:31,680.

Walker, G.W., 1973, Reconnaissance geologic map of the Pendleton Quadrangle, Oregon and Washington: U.S. Geological Survey Miscellaneous Geologic Investigations Map I-727, scale 1:250,000.