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DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES

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No. 20

GLAZES FROM OREGON VOLCANIC GLASS

By

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Ceramist

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Foreword

The ceramic industry is essentially concerned with nonmetallic minerals for its raw materials. In the past their generally low cost has made them easily available to all producers in the industry. However, the increasing cost of both materials and shipping has developed a keen interest among producers in substitutes that would reduce the cost of their raw materials.

The alkali content of volcanic glass along with its cheapness makes this material an attractive possibility as a flux for use by the ceramic industry in competition with higher cost fluxes such as ground feldspar.

Oregon has widespread occurrences of volcanic glass in large, easily accessible deposits. The accompanying report is the first step in pointing out the potential value of Oregon volcanic glass to the ceramic industry.

The author of this report holds a Master's degree from the New York State College of Ceramics and is well qualified by training and experience to conduct the tests outlined and to interpret the results.

In the preparation of this report assistance in analyzing samples was rendered by Mr. Hollis Dole, petrographer, and Mr. L. L. Hoagland, chemist, both of the Department staff. Mrs. Lillian Owen multigraphed the report.

F. W. Libbey
Director

August 18, 1950

Contents

GLAZES FROM OREGON VOLCANIC GLASS

Introduction

The object of the experiments described in this report was to develop the use of Oregon material to produce a low-cost flux for commercial ceramic use. The materials tested include volcanic ash, pumice, and, a material new to the ceramic field as a flux, perlite. These materials were combined with varying amounts of colemanite, white lead, and other materials to produce a group of economical and practical glazes which could be adapted to commercial use by stoneware, terra cotta, and artware manufacturers.

History

Interest in volcanic glasses as fluxes for the ceramic industry has been slowly developing over a period of about 20 years. The Kansas Geological Survey reported in 1928[1] the use of Kansas volcanic ash in cements, as abrasives, and as insulating material. During the period 1931-1932, W. G. Worcester published "Investigation concerning the use of volcanic ash in the field of ceramics."[2] This paper discusses application of volcanic ash from British Columbia and Saskatchewan in ceramic glazes and bodies. In 1942 the Kansas Geological Survey again reported, "Recent experiments have shown that Kansas volcanic ash may be used in the ceramic industry for the manufacture of glazes, enamels, glass, and vitreous pottery. The use of volcanic ash in a pottery body solved for a Kansas City firm the problem of manufacturing a container which is impervious to water and which can be fired at a relatively low temperature."[3] In 1939 Plummer[4] reported the use of volcanic ash as a substitute for feldspar in glazes. In 1941 E. D. Kinney[5] used volcanic ash in a series of low-cost glass batches. His interest was to remove iron which discolored the glass. He found that this could not be successfully accomplished, but that the color could be hidden through the use of decolorants. In 1948, J. Sheldon Carey[6] published a report in which he explained a series of experiments using volcanic ash as a major constituent, with several fluxes, to develop a glaze suitable for firing at various temperatures. This development led to a commercial pottery using the volcanic ash glaze exclusively. In 1948 the Oregon Department of Geology and Mineral Industries started a research program on the use of Oregon volcanic glasses (ash, pumice, and perlite) in glazes. Ash and pumice from several different localities in central and eastern Oregon were tested for temperature and quality of fusion, color, and their ability to combine with other materials to form a satisfactory glaze. During this development it was determined that the perlite contained less iron than the average volcanic ash or pumice. The perlite was obtained from an established commercial source producing lightweight aggregate. Perlite provides a rather uniform raw material and a good source of $KNaO$, CaO, MgO, Al_2O_3, and SiO_2. Perlite produces good glazes in the temperature ranges C/04 to C/10 and has a P.C.E. of about C/7 (see list of P.C.E. equivalents in appendix).

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1 Kenneth K. Landes, "Volcanic Ash Resources of Kansas," Kansas Geol. Survey Bull. 14, pp. 5-57 (1928).

2 W. G. Worcester, "Investigations Concerning the Use of Volcanic Ash in the Field of Ceramics," Canadian Ceram. Soc. Jour., vol. 3, p. 48 (1934).

3 John M. Jewett and W. H. Schoewe, "Kansas Mineral Resources for Wartime Industry," Kansas Geol. Survey Bull. 41, pt. 3, p. 174 (1942).

4 Norman Plummer, "Ceramic Use of Volcanic Ash," Bull. Amer. Ceram. Soc., 18 (1) 8-11 (1939).

5 E. D. Kinney, "Control of Iron Oxide in Volcanic Ash," Bull. Amer. Ceram. Soc., 20 (4) 118-121 (1941).

6 J. Sheldon Carey, "Glazes from Kansas Volcanic Ash," Bull. Amer. Ceram. Soc., 27 (6) 225-228 (1948).

Description of Tests

Analyses* of samples follow:

Nelson ash (gray Nelson)

(The name "Nolson ash" was originally given this material, but later chemical and petrographic work shows this material to be essentially a clay.)

Location: SW¼SW¼ sec. 19, T. 5 N., R. 1 W., near St. Helens.

P.C.E.: Circa C/16 (much higher than feldspar); dark brown.

SiO_2	55.51%
Fe_2O_3	7.23
Al_2O_3	22.17
MgO	1.50
K_2O	.15
Na_2O	.20
Moisture and loss on ignition	13.10

Molecular formula

MgO	.885	Al_2O_3	SiO_2
K_2O	.039	5.34	22.4
Na_2O	.078	Fe_2O_3	
		1.11	

Mol. wt. 2313

Ash P-8373

Location: State Highway 19, 3 miles west of Spray, Wheeler County.

Analysis: Volcanic ash.

P.C.E.: Circa C/02. Good fusion; light brown color.

SiO_2	64.36%
Al_2O_3	16.43
Fe_2O_3	2.23
CaO	2.60
MgO	1.27
K_2O	2.26
Na_2O	7.10
Loss on ignition	3.72

Molecular formula

Na_2O	.528	Al_2O_3	SiO_2
K_2O	.111	.745	7.89
MgO	.148	Fe_2O_3	
CaO	.213	.065	

Mol. wt, 621.8

Ash P-8519

Location: E½SE¼ sec. 33, T. 31 S., R. 46 E., Adrian, Oregon.

Analysis: Volcanic glass 95 percent (highest percentage of volcanic glass so far submitted). Mineral grains (negligible).

P.C.E.: C/8. Gray translucent fusion. Highest temperature to date; also very light in color.

SiO_2	68.70%
Al_2O_3	13.50
Fe_2O_3	1.00
CaO	.80
MgO	.41
K_2O	4.55
Na_2O	5.65
Loss on ignition	5.49

Molecular formula

Na_2O	.554	Al_2O_3	SiO_2
K_2O	.290	.784	6.87
MgO	.072	Fe_2O_3	
CaO	.084	.036	

Mol. wt. 567

*Chemical analyses were made by L. L. Hoagland; petrographic work was by H. M. Dole, both of the Department staff.

Perlite P-9229

Location: Sec. 24, T. 6 S., R. 13 E.

Analysis: Volcanic glass 99 percent (exploded perlite)

P.C.E.: C/4. Light-colored glass, clean fusion at C/6 as glaze, bubbles present (probably caused by insufficient grinding of bubbles in the bloated perlite).

SiO_2	70.40%
Al_2O_3	15.10
Fe_2O_3	0.76
CaO	1.20
MgO	0.57
K_2O	4.63
Na_2O	5.48
Loss on ignition	1.86

Molecular formula

Na_2O	.508	Al_2O_3	SiO_2
K_2O	.282	.850	6.77
CaO	.127	Fe_2O_3	
MgO	.081	.027	

Mol. wt. 619

Ash P-8441

Location: Sec. 32, T. 2 S., R. 2 E.

Analysis: Volcanic glass 60-70%

Mineral grains 30-35%

Diatoms 2-5 %

P.C.E.: C/4; Bloating.

Ash P-8442

Location: Sec. 4, T. 7 S., R. 41 E.

Analysis: Volcanic glass est. 75-85%

Mineral grains est. 15-25% (feldspar dominant)

P.C.E.: C/2; Badly bloated.

Ash P-8443

Location: NE¼SE¼ sec. 9, T. 27 S., R. 9 E.

Analysis: Volcanic glass est. 80-85%

Mineral grains est. 15-20% (feldspar dominant)

P.C.E.: C/3; Same as P-8444.

Ash P-8444

Location: NE¼SE¼ sec. 9, T. 27 S., R. 9 E.

Analysis: Volcanic glass est. 85-90%

Mineral grains est. 10-15% (feldspar dominant)

P.C.E.: C/3; Good fusion; dark brown.

Ash P-8479

Location: Sec. 23, T. 33 S., R. 1 E.

Analysis: Volcanic glass 60-65%

Mineral grains 25-30% (feldspar dominant)

Pumice fragments 5-10%

P.C.E.: C/3; Dark color; fusion good-fair.

Ash P-8480

Location: Sec. 23, T. 33 S., R. 1 E.

Analysis: Volcanic glass 60-65%

Mineral grains 35-40% (feldspar dominant)

P.C.E.: C/2; Dark color; fusion good.

Ash P-8481

Location: Sec. 23, T. 33 S., R. 1 E.

Analysis: Volcanic glass est. 70-80%

Mineral grains est. 10-15% (feldspar dominant)

Rock grit 5%

Pumice grit 5-10%

P.C.E.: C/4; Good fusion; dark brown.

Ash P-8483

Location: Merle Sleeper pit, approximately 1 mile west of Bend, Oregon.

Analysis: Volcanic glass 85%

Mineral grains 10%

Rock fragments 5%

P.C.E.: C/4; Fusion dark brown.

Ash P-8484

Location: Merle Sleeper pit, approximately 1 mile west of Bend, Oregon.

Analysis: Volcanic glass 95%

Mineral grains 5% (feldspar dominant)

P.C.E.: C/3; Light brown fusion.

Note: Ashes P-8483, P-8484, P-8481 } All started to tip at minus C/2 but did not bend completely until given temperature was reached.

Ash P-9230

Location: Sec. 24, T. 6 S., R. 13 E.

Analysis: Volcanic glass 95%

Mineral grains 5% (mainly feldspar)

P.C.E.: C/2; dark glass; good fusion at C/6; crazing present.

Ash P-9231

Location: Secs. 1, 2, 7, 8, 11, and 12, T. 18 S., R. 12 E.

Analysis: Volcanic glass est. 95%

Mineral grains est. 5% (mainly feldspar)

P.C.E.: C/2; good glass; dark gray color at C/6 as a glaze; no crazing present.

Ashes tentatively selected for further work

P-8373
8443
8484
8519
9231
9230
9229

All others were eliminated owing to:
1. darkness
2. bloating
3. uneven fusion and/or unpleasant effects of fusion.

A series of mixtures of volcanic ash and the materials colemanite, cryolite, and white lead was tested in the temperature range C/02 - 4.

Tests were run as fusion buttons to C/03 - 6.

Nelson ash

ash 100% . . . . . infusible

a. ash 80% + colemanite 20% C/1 medium button
ash 60% + colemanite 40% C/03 low button

b. ash 80% + cryolite 20% C/2 low button
ash 70% + cryolite 30% C/2 flat
ash 60% + cryolite 40% C/01 flat

c. ash 90% + dolomite 10% C/2 high, unfused mass
ash 80% + dolomite 20% C/6 " " "
ash 70% + dolomite 30% C/2 " " "

d. ash 90% + whiting 10% hard cinter
ash 80% + whiting 20% hard cinter
ash 70% + whiting 30% hard cinter

This material was removed from further testing.

Ash P-8519

Was made as mixture with whiting and colemanite and fired to C/2.

Ash 90% + whiting 10% — Some glassy fusion; did not wet surface; crawling to marked degree.

Ash 80% + whiting 20% — Same as above but less crawling present.

Ash 95% + colemanite 5% — Some glassy fusion; did not wet surface. Crawling to marked degree.

Ash 90% + colemanite 10% — Same as above but less crawling.

Ash 85% + colemanite 15% — Good fusion. Crawling evident but less than any mixes in this group.

Test No.	Ash P-8373	Colemanite	Results C/02 - 01
A I	80	20	Texture glassy; color brown to yellow
A II	75	25	" " " " " "
A III	70	30	" " " " " " Clear dark glass; some fine bubbles present. Good fit.

	P-8373	White lead	Results C/02 - 01
B I	90	10	Texture glassy; medium brown; fit good
B II	80	20	" " olive brown " "
B III	70	30	" " " " " " Glass clear. Bubbles increase as lead increased. Solid material present in glass.

	P-8373	Cryolite	Results C/02 - 01
C I	90	10	Glassy texture; brown speckle; poor fit
C II	80	20	" " " " " "
C III	70	30	" " " " " " Crazing present; clear glass and bubbles

	Ash P-8484	Colemanite	Results C/3 - 4
A I	80	20	Glassy; olive brown; fit good
A II	75	25	" " " " fair
A III	70	30	" " " " " Less crazing than in P-8373 and cryolite; medium dark glass bubbles evident.

	P-8484	White lead	Results C/3 - 4
B I	90	10	Glassy; dark brown; crazed
B II	80	20	" medium brown; crazed
B III	70	30	" yellow brown; crazed Bubble opacity; crazing increased with lead. Glassy fusion.

Owing to excessive crazing noted in the use of cryolite as a fluxing addition to the glaze, the use of it was abandoned in this testing program.

	Ash P-8519	Colemanite	Results C/2
A I	90	10	Color gray; bubble opacity; fit good
A II	80	20	" " " " " "
A III	70	30	" " " " " " Great deal of bubbling present in glass. Odor of sulphur.

Test No.	Ash P-8519	White lead	Results C/2
B I	90	10	Yellow color; great bubbling; fit could not be determined
B II	80	20	" " " " " "
B III	70	30	" " " " " "
			Great deal of boiling

	Perlite P-9229	Colemanite	Results C/2 - 4
A I	90	10	Clear gray; orange peel texture; fit good
A II	80	20	" " slight orange peel " "
A III	70	30	" " smooth texture " "
			Smooth glassy surface and bubbles

	P-9229	White lead	Results C/2 - 4
B I	90	10	Clear gray; bubbly texture; fit not determined
B II	80	20	" " " " " " "
B III	70	30	" " " " " " "
			Bubbling high

	Ash P-8443	Colemanite	Results C/2 - 4
A I	90	10	Glassy; opaque; no craze
A II	80	20	" " " "
A III	70	30	" " " "
			Crazing less than in P-8373

	P-8443	White lead	Results C/2 - 4
B I	90	10	Dark brown; bright glaze; not crazed
B II	80	20	Speckled yellow; bright glaze; crazed
B III	70	30	" " " " "
			Crazing at higher Pb value.
			Brilliance increased with lead.

Fusion buttons

Fusion buttons were made in a 00 "Coors" porcelain crucible. One of a commercial feldspar (BS1) (Buckingham feldspar, mined and marketed by Consolidated Feldspar Corporation) and the others of ground bloated perlite (P-9229) (P2); hydro separator overflow of perlite (P3); sizer cell no. 4 (P4); volcanic ash from Adrian, Oregon, P-8519 (VA1); ground pumice from one of Merle Sleeper's pits, P-8484 (GP1). All samples were fired at the same time to C/8 (1225°C.) in a small gas test kiln in about 4 hours.

Results of fusion buttons

(BS1) The feldspar button formed to a consolidated glassy mass that had not yet started to slump but was reduced to 19 mm or a loss in size of 6 mm. The color was white to blue white and the surface was pebbly.

(P2) The ground bloated perlite (P-9229) consolidated to a greater dogree than (BS1) Buckingham feldspar. The height measured a loss of from 25 mm (the formed size) to 10 mm or a final height of 15 mm after firing. It was a warm medium gray color and very smooth and glassy.

(P3) The hydro separator overflow perlite did not consolidate as much as Sample (P2) (ground perlite). The height of the fused sample stood at 17 mm or a loss in height of consolidation of 8 mm. The color was a little darker than the bloated perlite (P2) and the button showed a smooth glassy surface.

(P4) The no. 4 sizer cell material did not give a satisfactory test. The material was too coarse to give a good physical bond to the button before the thermal bonding action took place. The button slumped and an accurate measurement is not available. However, the fusion was good though not as smooth as the other tests, probably due to large grain size.

(VA1) The ash from Adrian, Oregon (P-8519) consolidated to a height of 18 mm, a loss of 7 mm from the formed size. The color was a dark gray and the surface was glassy but not as smooth as (P3).

(GP1) The ground pumice (P-8484) produced a better glass than all buttons tested in this series, showing a slump to 13 mm or a loss of 12 mm from forming size. The fusion was very glassy and smooth; color was medium to dark gray.

Method of calculating ash analysis for glaze use

In writing the formula of many ceramic materials it is customary to use the oxide form instead of the chemical form thus

$$3MgO \cdot 4SiO_2 \cdot H_2O = H_2Mg_3(SiO_3)_4$$

This gives the ceramist a means of estimating the properties of the compound or mineral based on the amount of molecules or molecule of oxides within the formula. A modification of this practice is used in calculating a glaze formula.

In calculating a glaze formula the oxide constituents are divided into three groups:

(1) RO or R_2O group

(2) R_2O_3 group

(3) RO_2 group

The symbol of R indicates a metallic atom and the O is, of course, oxygen. Therefore from the following chemical analysis of a volcanic substance, perlite (this material has been fused), we divide the percentage of each oxide compound by its molecular weight in order to calculate the molecular formula from this analysis.

P-9229		Mol. Wt.	
SiO_2	70.40	÷ 60 =	1.173
Al_2O_3	15.10	÷ 102 =	.148
Fe_2O_3	0.76	÷ 160 =	.004
CaO	1.20	÷ 56 =	.021
MgO	0.57	÷ 40 =	.014
K_2O	4.63	÷ 94 =	.048
Na_2O	5.48	÷ 62 =	.088
Ignition loss . .	1.86		

In calculating this material to the proper form for ceramic calculation, the next step is to put the oxides into their proper columns.

RO or R_2O	R_2O_3	RO_2

It is always considered that the RO (R_2O) group is unity (1.00)and all the others are based in ratio accordingly. Therefore the formula is written

CaO	.021	Al_2O_3	SiO_2
MgO	.014	.148	1.173
K_2O	.048	Fe_2O_3	
Na_2O	.088	.004	
	.171		

Now all the molecular equivalents are divided by the total of the RO (R_2O) column.

CaO	.021 ÷ .171	=	.127
MgO	.014 ÷ .171	=	.081
K_2O	.048 ÷ .171	=	.282
Na_2O	.088 ÷ .171	=	.508
Al_2O_3	.148 ÷ .171	=	.850
Fe_2O_3	.004 ÷ .171	=	.027
SiO_2	1.173 ÷ .171	=	6.77

We now have

RO	(R_2O)	R_2O_3	RO_2
CaO	.127	Al_2O_3	SiO_2
MgO	.081	.850	6.77
K_2O	.282	Fe_2O_3	
Na_2O	.508	.027	

The molecular weight is now derived by multiplying each of the amounts of given oxide by its molecular weight and adding the sum.

CaO	.127	x	56	=	7.11
MgO	.081	x	40	=	3.24
K_2O	.282	x	94	=	26.51
Na_2O	.508	x	62	=	31.50
Al_2O_3	.850	x	102	=	86.70
Fe_2O_3	.027	x	160	=	4.32
SiO_2	6.77	x	60	=	404.20
					563.58

To incorporate this material into a glaze the following method of calculation is used:

Glaze formula (empirical formula)

Na_2O	.288	Al_2O_3	SiO_2
K_2O	.160	.487	3.88
MgO	.046	B_2O_3	
CaO	.503	.648	

As much as possible of sample P-9229 is to be included; therefore the following graph method is used:

Na_2O	K_2O	MgO	CaO	Al_2O_3	B_2O_3	SiO_2	Raw material	Batch weight
.288	.160	.046	.504	.482	.648	3.84		
			.432		.648		colemanite .432 x $\frac{412}{2}$	= 89
			.072		X			
.288	.160	.046	.072	.482		3.84	Sample P-9229 .565 x 563	= 382
X	X	X	X	X		X		

The molecules to be satisfied in the formula are written across the top of the paper, with the amounts in formula underneath. Next step is to decide from what materials you are going to obtain the oxides. Since there is no B_2O_3 in the ash we are using, we eliminate that oxide fully by using colemanite ($2CaO3B_2O_32H_2O$) molecular weight 412; using .648 molecule of B_2O_3 which carries .432 molecule of CaO with it in the mineral colemanite. The amount of CaO .432 is then multiplied by the molecular weight of the mineral. Molecular weight 412 is divided by 2 since there are 2 molecules of CaO in colemanite and only part of one molecule in the formula to be satisfied.

$$.432 \times \frac{412}{2} = 89 \text{ parts colemanite}$$

The rest of the formula is now satisfied by the perlite (P-9229) since.288 parts of Na_2O is taken in ratio to the amount of Na_2O in the perlite (P-9229), the amount of K_2O is .160, the CaO .072, MgO .0459 or .046, Al_2O_3 .482, SiO_2 3.84 The total of the molecules contained in the RO column of sample P-9229 = .565 times the molecular weight 563 = 328 parts. Therefore the batch to be weighed out is 89 parts colemanite and 349 parts P-9229; on a percentage basis roughly

21 parts colemanite
79 parts P-9229

A glaze was compounded to use perlite (P-9229) and colemanite in the same ratio as test A II and was called A2 - GMI.

Empirical formula

A2 - GMI

Na_2O	.288	Al_2O_3	SiO_2
K_2O	.160	.482	3.84
MgO	.046	B_2O_3	
CaO	.504	.648	

Batch A2 - GMI

P-9229 - 382

Colemanite - 89

Glaze A2 - GMI was mixed with metallic oxides to check the color possibilities of the glaze.

Test no. 1 was plain, no color

"	"	2	contained	1½	percent	cobalt carbonate
"	"	3	"	2	"	chrome oxide
"	"	4	"	8	"	iron oxide (red)
"	"	5	"	3	"	manganese dioxide
"	"	6	"	8	"	ground rutile
"	"	7	"	3	"	copper oxide
"	"	8	"	1	"	calcined nickel oxide

Results of tests on glaze A2 - GMI with color, fired at C/3:

Test no. 1. This test is the base glaze alone with no color added on the buff clay. It produced a clear glaze with some opacity due to a slight bubble structure plus the opacifying effect sometimes produced by B_2O_3 glasses. On a red clay the opacity and bubbling is more noticeable, yet no more intense within the glass than on the buff clay, the contrast in tones being greater.

" " 2. A typical cobalt blue was produced, rather opaque probably due to the thickness of the glaze.

" " 3. The chrome produced in this test, a green, very opaque as is expected from the opacifying effect chromium oxide has in most glazes.

" " 4. The iron oxide addition produced the typical brown.

" " 5. In this test the manganese dioxide produced an alkaline manganese color of brownish plum.

" " 6. The rutile produced an opaque warm buff color, again very typical of alkaline borosilicate glazes.

" " 7. Copper caused a slight fluxing action to the glaze and produced a typical bluish green which was almost transparent.

" " 8. Nickel oxide gave a warm gray and seemed to make the glaze more opaque.

The following empirical formula is for a typical whiteware glaze using a commercial frit:

Na_2O	.291	Al_2O_3	SiO_2
K_2O	.045	.301	2.925
CaO	.510	B_2O_3	
ZnO	.100	.349	
MgO	.050		

This glaze uses 0.7 equivalents of a commercial frit, therefore a direct substitution of 0.7 equivalents was made of perlite (P-9229) for frit. This substitution produced a glaze with the following formula:

Na_2O	.254	Al_2O_3	SiO_2
K_2O	.141	.425	3.380
CaO	.468	B_2O_3	
MgO	.050	.350	
ZnO	.100		

This glaze was called A21 - GMI

Batch composition

Perlite (P-9229)	394.1 parts
Colemanite	47.6
Dolomite	1.8
Zinc oxide	8.1
Whiting	15.9

Glaze A21 - GMI was mixed with the same percentage of metallic oxides as glaze A2 - GMI and is reported in the same way as A2 - GMI.

Results of tests on glaze A21 - GMI, fired at C/3:

Test no. 1. This base is much less opaque than test A2 - GMI. It should be more stable in reaction than the first glaze due to the greater number of fluxes interacting to give a glaze with a slightly higher SiO_2 ratio.

" " 2. Cobalt carbonate produced a more intense blue than in A2 - GMI, 2.

" " 3. Chrome oxide gave a greenish brown due to the presence of ZnO in glaze.

" " 4. The iron oxide produced a darker brown than in glaze A2 - GMI, 4.

" " 5. The manganese dioxide gave a deeper plum color and was more opaque than A2 - GMI, 5.

" " 6. Rutile did not produce as opaque a glaze as in A2 - GMI, 6.

" " 7. The copper color was more typical than in A2 - GMI, 7 and was more opaque.

" " 8. Nickel produced a warm brown and was refractory in fusion making the glaze surface feel rough.

Comparison of perlite (hydro separator overflow), volcanic ash (P-8519), and ground pumice (P-8484) with standard commercial feldspathic material

Three glazes were tested to compare hydro separator overflow perlite, sample P-8519 and sample P-8484, with standard commercial materials. All tests were fired to C/3 - 4 in an electric kiln.

Glaze 100 X
Batch composition

Cornwall stone	50 parts
White lead	19
Whiting	10

Glaze 100 C
Batch composition

Hydro separator overflow perlite	50 parts
White lead	19
Whiting	10

Glaze 100 D
Batch composition

Pumice (P-8484)	50 parts
White lead	19
Whiting	10

Glaze 100 E
Batch composition

Volcanic ash (P-8519)	50 parts
White lead	19
Whiting	10

Results of tests on Series 100, fired at C/3 - 4:

Glaze 100 X (standard ceramic material batch) was much whiter than C, D, or E owing to the lower iron content of the Cornwall stone.

Glaze 100 C did not craze as did X, D, and E. The color was yellower than 100 X.

Glaze 100 D looked the same as 100 X except for very yellow color due to higher iron content of material.

Glaze 100 E was the least opaque of group though it showed the same yellowing action from iron in material.

In general, all glazes crazed on the test body except 100 C. Volcanic glasses seem to successfully replace Cornwall stone in this glaze except for yellow color they impart to the glaze. This would be negligible in nearly all colored glazes.

Glaze 200 - Glaze 200 X is a typical artware glaze. In this glaze, Buckingham feldspar is used to provide $K_2O \cdot 1.13Al_2O_3 \cdot 6.45SiO_2$.

Glaze 200 X
Batch composition

Whiting	30.0 parts
Colemanite	102.8
Buckingham feldspar	238.4
Flint	88.8
China clay	5.1
$CuCO_3$	4%

Glaze 200 C
Batch composition

Whiting	30.0 parts
Colemanite	102.8
Hydro separator overflow perlite	238.4
Flint	88.8
China clay	5.1
$CuCO_3$	4%

Glaze 200 D
Batch composition

Whiting	30.0 parts
Colemanite	102.8
Pumice (P-8484)	238.4
Flint	88.8
China clay	5.1
$CuCO_3$	4%

Glaze 200 E
Batch composition

Whiting	30.0 parts
Colemanite	102.8
Volcanic ash (P-8519)	238.4
Flint	88.8
China clay	5.1
$CuCO_3$	4g

Results of tests on Series 200, fired at C/3-4:

Glaze 200 X produced a very good glass with a smooth fusion and a slight boron opacity. The color produced by copper carbonate was a watery blue-green semi-transparent glaze and showed a tendency to craze in heavy areas.

Glaze 200 C produced a very good glaze with smooth fusion and quite a boron opacity. Color produced by copper carbonate was more green than glaze 200 X and showed excellent texture and color interest. There was less tendency to craze in heavy areas of application than in glaze 200 X.

Glaze 200 D produced nearly the same optical and physical reaction and effect as glaze 200 C.

Glaze 200 E produced nearly the same optical and physical reaction and effect as glaze 200 C except the volcanic ash (P-8519) increased the fluidity of the glaze.

Glaze 300 - Glaze 300 X is typical artware semimat glaze. In this glaze nepheline syenite is used to provide $KNaO \cdot 1.10Al_2O_3 \cdot 4.65SiO_2$.

Glaze 300 X
Batch composition

Nepheline syenite	34 parts
Dolomite	6
Colemanite	4
Flint	6

Glaze 300 C
Batch composition

Hydro separator overflow perlite	34 parts
Dolomite	6
Colemanite	4
Flint	6

Glaze 300 D
Batch composition

Pumice (P-8484)	34 parts
Dolomite	6
Colemanite	4
Flint	6

Glaze 300 E
Batch composition

Volcanic ash (P-8519)	34 parts
Dolomite	6
Colemanite	4
Flint	6

Results of tests on Series 300, fired at C/3 - 4:

Glaze 300 X produced a fair semimat glaze with a bubble opacity and a definite whitish cast on the red clay tile. Good fusion is apparent, but tile shows a great deal of bubble opacity and some pinholing. Crazing is quite evident on this body.

Glaze 300 C produced a fair to good semimat glaze with less apparent bubbling and a much greater opacity. The color is definitely yellow (caused by iron content of perlite). Pinholing is still in evidence as in test 300 X. Crazing, while not so great as in test 300 X, is still evident.

Glaze 300 D produced a glaze much like test 300 C. A textural color effect is produced in this glaze which looks like a B_2O_3 reticulation pattern.

Glaze 300 E produced a glaze much like test 300 C. A textural color effect is produced in this glaze which looks like a B_2O_3 reticulation pattern but is not as strong as in test 300 D.

General Results

In general, hydro separator overflow perlite, volcanic ash, and crushed pumice produce results which compare favorably with feldspar, Cornwall stone, and nepheline syenite.

In glazes containing the volcanic glasses as substitute for Buckingham feldspar, Cornwall stone, and nepheline syenite, the maturing point of the glaze is somewhat reduced. When color is added to the glaze to hide the effect of iron discoloration caused by the iron content of the volcanic glasses, an improvement of color tone is rather apparent and not unpleasing.

The volcanic glasses tested do not seem to cause any undesirable effects as far as fusion, material behavior, or glaze defects are concerned. In fact, in glaze 100 C there was no crazing as in the standard 100 X, and in glaze 200 there was less apparent crazing in C, D, and E than in the standard 200 X.

The color produced by the reaction of the iron contained in the volcanic glasses tested makes the material impractical for use as a flux in the production of whiteware. However, if color is added either in the glaze or in the body, there should be no difficulty in finding volcanic glasses good and usable substitutes for the feldspathic content of a glaze or body.

Marketing is the most important part of the sale of the volcanic glasses as feldspar substitutes. The testing data may show very good results and good handling qualities, but it is necessary to have a good sales program in order to promote the use of these materials by the ceramic industry at the present time. For many years the criterion of feldspathic materials for the bulk of the ceramic industry has been whiteness; this is tradition and not at all necessary in the production of colored wares such as terra cotta, artware, stoneware, etc. Therefore producers who wish to market volcanic ash, pumice, and perlite for use in the ceramic industry must break down this illogical traditional attitude.

Appendix

End Point, Bending Interval, and Cone Intervals Of Orton Standard Pyrometric Cones

Cone No.	End Point			Bending Interval		Cone Interval	
	Rise °C. per hour 20° C.		150° C.	Rise °C. per hour 20° C.	150° C.	Rise °C. per hour 20° C.	150° C.
07	1787° F.	975° C.	990° C.	35° C.	50° C.	30° C.	25° C.
06	1841	1005	1015	25	35	25	25
05	1886	1030	1040	30	30	20	20
04	1922	1050	1060	40	40	30	55
03	1976	1080	1115	40	35	15	10
02	2003	1095	1125	35	35	15	20
01	2030	1110	1145	50	45	15	15
1	2057	1125	1160	30	45	10	5
2	2075	1135	1165	30	45	10	5
3	2093	1145	1170	30	40	20	20
4	2129	1165	1190	40	35	15	15
5	2156	1180	1205	40	50	10	25
6	2174	1190	1230	40	35	20	20
7	2210	1210	1250	40	60	15	10
8	2237	1225	1260	45	55	25	25
9	2282	1250	1285	65	115	10	20
10	2300	1260	1305	40	95	25	20
11	2345	1285	1325	70	80	25	10
12	2390	1310	1335	80	45	40	15

Definitions

P.C.E. - Pyrometric cone equivalent. The heat work accomplished; measured by heating a sample in the same shape as a known pyrometric cone and bending with increased heating to the same end point as a known cone.

Flux - A material contained or added to a ceramic mixture which increases, assists, or promotes the fusion of the mixture.

Bloating - The gaseous expansion within a fused or semifused mass which causes a deformation of the mass by increasing its volume. The reaction is usually frozen by the normal cooling of the material, and a bloated or frothy mass results.

Bubble opacity - The opacity of a glass or glaze caused by minute gas bubbles contained within the glass or glaze structure.

Crazing - The cracking of a glaze, causing hairline cracks in the glaze surface. Crazing allows moisture and gas to pass through or into a nonvitreous body.

Pinholing - The pock-marked surface of a glaze produced by an eruptive bubble or glass breaking on the surface and producing a crater in the surface of the glaze or completely through the glaze from surface to body.

PUBLICATIONS

Oregon Department of Geology and Mineral Industries

702 Woodlark Building, Portland 5, Oregon

BULLETINS

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THE ORE.-BIN: issued monthly by the staff as medium for news about the Department, mines, and minerals. (Available back issues 5¢ea.)Subscription price per year	0.40
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