

Custer Feldspar

by Ron Roy

Feldspar is an important material for potters, as we use it in both clay body and glaze recipes. Because of this widespread use, we need to have an accurate analysis of the materials in order to get the results we want.

An Accurate Analysis

Custer feldspar can be described as a natural frit because it provides us with relatively insoluble sodium and potassium oxide. Sodium and potassium oxides are important because they start their fluxing actions at 1472°F (800°C)—well before the other fluxes we commonly use and, if present in the right amounts, control the production of cristobalite.

It is important that we have accurate analysis of the materials we use in order to deal with the technical requirements of our craft. It has become relatively easy to contact the mines where our materials are produced. That, and the availability of low-cost analysis of raw materials at many labs, gives us the tools to avoid the many problems of firing clay and glazes.

For instance, looking up Custer feldspar on the web leads to many published analyses and everyone seems to assume that the historic analysis for Custer spar is accurate for all samples of the material. This particular analysis was downloaded from the Pacer Minerals web page September 1, 2013. (Pacer Minerals is the company that mines Custer Feldspar near Custer, South Dakota.)

Over the last few years, various potters began to experience problems with glazes and clays fluxed with Custer spar; some glazes did not look or work the same, and some clay bodies that worked well before developed cristobalite dunting. Gradually a pattern evolved that led some of us to suspect that the formula for Custer spar had changed.

We gathered samples of Custer spar from various ceramic studios and had them analyzed. Much to our surprise, the samples of Custer purchased after 2000 differed from those purchased before—the recent samples had about 2.5% less potassium.

We compared two samples of Custer spar purchased before 2000; sample A from a supplier in Toronto, Ontario, Canada; and sample B from a supplier in the Philadelphia, Pennsylvania area.

The lab analysis results were as follows:

TYPICAL CHEMICAL ANALYSIS*	
Silica (SiO ₂)	68.5%
Alumina (Al ₂ O ₃)	17.0%
Iron (Fe ₂ O ₃)	0.15%
Soda (Na ₂ O)	3.0%
Potash (K ₂ O)	10.0%
Lime (CaO)	0.3%
Magnesium (MgO)	Trace
Loss on Ignition	0.30
Total (added by RR)	99.25

**The information and data contained herein are believed to be accurate, but the manufacturer makes no warranty with respect thereto and disclaims responsibility for reliance thereon. This data relates only to the specific material described herein, and does not relate to use in connection with any other materials or in any process.*

Custer Feldspar Samples Prior to 2000

	SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	K ₂ O	Na ₂ O	CaO	MgO	P ₂ O ₅	LOI	Total
Custer #A	68.6	17.4	0.1	9.52	3.4	0.18	0.05	0.33	0.64	100.26
Custer #B	68.8	17.10	0.14	10.6	2.68	0.18	0.04	0.28	0.68	100.5
Average	68.7	17.25	0.12	10.06	3.04	0.18	0.05	0.31	0.66	

When compared with the official analysis from the Pacer Minerals web site, the average of these two samples compares essentially with the Pacer typical analysis, especially in the amounts of potassium and sodium (K₂O and Na₂O).

Samples were also gathered from all over North America—samples 1, 2, and 3 came from the Pacific Northwest, samples 4 and 5 came from the US Southwest, sample 6 came from the Toronto, Canada area, and sample 7 came from Florida. These samples were all purchased between 2000 and 2012 by individual potters.

Custer Feldspar Samples Purchased 2000–2012

	SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	K ₂ O	Na ₂ O	CaO	MgO	P ₂ O ₅	LOI	Total
Custer #1	72.4	15.5	0.26	7.86	2.62	0.36	0.09	0.12	0.69	99.9
Custer #2	73.5	15.1	0.17	7.57	3.13	0.23	0.06	0.19	0.66	100.61
Custer #3	71.6	15.4	0.18	7.62	3.36	0.25	0.07	0.22	0.63	99.33
Custer #4	71.36	15.1	0.31	6.97	3.38	0.31	0.10	0.24	0.74	98.51
Custer #5	72.21	15.42	0.16	7.85	3.10	0.27	0.07	0.15	0.53	99.76
Custer #6	72.5	15.2	0.19	7.53	3.44	0.24	0.05	0.21	0.59	99.5
Custer #7	73.2	15.2	0.22	7.22	3.44	0.23	0.05	0.28	0.68	100.52
Average	72.4	15.27	0.21	7.52	3.21	0.27	0.07	0.20	0.65	

Trace amounts of TiO₂, MnO, CrO₃, and V₂O₅ that appear on the lab reports have not been listed. Samples A, B, 1, 2, 3, 6, and 7 were analyzed at SGS labs by XRF (www.info@lakefield.com). Samples 4 and 5 were analyzed at ALS Minerals by XRF (www.alsglobal.com).

Results: So a quick glance tells us that SiO₂ is up, Al₂O₃ is down, iron is up, K₂O is down and the rest have not changed much except

the amount of P₂O₅, which is not mentioned in the Pacer Minerals typical analysis.

Using Custer Feldspar Now

To illustrate what is necessary to equalize two glaze recipes, one using the pre-2000 A and B Custer and one using the current Custer being mined, I have developed a cone 10 glaze with 30% A+B Custer then have adjusted the recipe using glaze calculation software, which shows lower potassium to match the original recipe.

The adjustments do not show a great difference and many potters may not even have noticed, but the calculated expansion went from 411 down to 384 in the unadjusted version. What if this glaze had

started with an expansion of 380 and dropped 27 points down to 353 into the area where shivering and glaze dunting can happen? This is especially critical in high-fired stoneware clay, which may be on the edge of cristobalite development because it already has marginal amounts of sodium and potassium. This would be even more serious if the Custer spar was used in both clay and glaze.

(These are example recipes only. I have not fired or tested these fictional glazes.)

GLAZE USING OLD CUSTER FORMULA

Cone 10

Whiting	15.0 %
Talc (Texas Pioneer)	10.0
Custer (A+B version)	30.0
EPK Kaolin	20.0
Silica	25.0
	<u>100.0 %</u>

Silica to alumina ratio: 8.02

Expansion (calculated): 411.34

GLAZE USING NEW CUSTER FORMULA

Cone 10

Whiting	15.0 %
Talc (Texas Pioneer)	10.0
New Custer (1 to 7 version)	35.0
EPK Kaolin	19.5
Silica	20.5
	<u>100.0 %</u>

Silica to alumina ratio: 8.03

The ratio would be 8.55 without the adjustment, making it shinier.

Expansion (calculated): 409.23

The expansion would be 384.46 (lower) without the adjustment.

TECHNO FILE—CUSTER FELDSPAR

The Ups and Downs of Cristobalite

Just what is the problem with cristobalite in a clay body?

There are two forms of silica that have a dramatic effect on clay bodies, quartz: the stuff we usually add to clay and cristobalite, which can be added but more typically can form during the firing in high-fired stoneware bodies.

Both of these crystal forms of silica change their size at specific temperatures—predictably and reversibly. They get bigger in a specific temperature range on the way up and change back on the way down during cooling.

The quartz inversion happens at 1063°F (573°C) and clay bodies get smaller during cooling helping to keep glazes from crazing. Firing your bisque too low can result in bisque dunting (cracking) because of the quartz inversion at 1063°F.

Cristobalite goes through the same kind of inversion, getting smaller during cooling in the 393°F (200°C) to 518°F (270°C) range. Too much of either cristobalite or quartz results in shivered or cracked ware. Shivering is the result of a clay body that has contracted more than the glaze and the results can be small slivers of razor sharp glaze falling off the ware. Think of cristobalite as increasing the thermal contraction of clays. If a glaze has a low enough coefficient of thermal contraction (CTE) and the clay a high enough CTE, then something has to give. Note that the CTE of cristobalite happens within the kitchen oven temperature range. If you make casserole dishes, you certainly don't want cristobalite in your ware. Think of it this way, if a clay body, when fired, has a high thermal expansion and contraction, if one side of a pot made with that clay body heats up faster than the other, then cracking can be expected.

For those of you who work with high-fire stoneware bodies, Peter Sohngen has written two articles on how you can avoid the perils of cristobalite. The main advice is to use at least 10% feldspar and avoid the fine silica we usually get now. Sodium and potassium are well known for melting the fine particles of silica that develop and are included in high-fired stoneware clays. These fine particles convert easily into cristobalite—the more time a firing is over 2000°F (1100°C) including cooling time, the more cristobalite can accumulate. It is a serious problem especially when combined with lower- and medium-expansion glazes and any ware that can be used in kitchens ovens.

In this case, he is talking about feldspars that include at least 12–13% sodium and potassium. Feldspars that have more potassium are preferred in clay bodies because sodium is somewhat more soluble than potassium. Potassium-dominated spars are therefore less likely to cause clay deflocculation problems.

If you are making a clay body that uses the old Custer with 13% alkalies (potassium and sodium) at 10% of the total recipe, you stand a good chance of avoiding cristobalite. If you are using the new Custer you may be only getting 10.7% alkalies (sometimes more, sometimes less.)

Is this enough to become a problem? The experience of some potters is yes—especially combined with the lower expansion of glazes made with the current Custer.

Peter Sohngen's March 1979 Ceramics Monthly article is available online—visit the Ceramics Monthly back issues page for November 2013 at <http://ceramicartsdaily.org/ceramics-monthly-2/back-issues/>. His 1999 Studio potter article is available at http://studiopotter.org/pdfs/sp28_1_sohngen.pdf.

The following three examples show what is needed to make the adjustment for the new Custer spar formula, which is lower in potassium to make sure you get enough alkali fluxes to avoid cristobalite. (These are example recipes only. I have not fired or tested these fictional bodies.)

Percent of KNaO (sodium and potassium) in #1 = 2.2, in #2 (low potash Custer) = 1.98 and % of KNaO in #3 = 2.21. When I made

that adjustment, I noticed that the alumina went down (in clay bodies the amount of alumina is a good indicator of how much melting will happen), so I had to raise that as well. The silica is up a bit and the iron is down. At this point, knowing that I would need 3% more of the low K₂O Custer to keep any cristobalite under control, I would probably reformulate to hopefully have a recipe that was either 50-pound bags or half bags.

BODY #1		BODY #2		BODY #3 (ADJUSTED FOR MORE K ₂ O AND NA ₂ O)	
Custer (10% K ₂ O)	10 %	Custer (7.5% K ₂ O)	10 %	Custer (10% K ₂ O)	13.0 %
Bell Dark Ball Clay	15	Bell Dark Ball Clay	15	Bell Dark Ball Clay	11.0
EPK Kaolin	20	EPK Kaolin	20	EPK Kaolin	35.5
Hawthorn Fireclay 50M	25	Hawthorn Fireclay 50M	25	Hawthorn Fireclay 50M	18.5
Kyanite 100M	15	Kyanite 100M	15	Kyanite 100M	11.5
Newman Fireclay	10	Newman Fireclay	10	Newman Fireclay	7.5
OM4 Ball Clay	5	OM4 Ball Clay	5	OM4 Ball Clay	3.5
	<u>100 %</u>		<u>100 %</u>		<u>100.0 %</u>

Materials Ratios in Clay Bodies #1, #2, and #3

	CaO	MgO	K ₂ O	Na ₂ O	Fe ₂ O ₃	TiO ₂	Al ₂ O ₃	SiO ₂	P2O5	Total
#1	0.24	0.23	1.71	0.49	1.86	1.33	36.86	57.17	0.11	100
#2	0.23	0.24	1.44	0.54	1.86	1.33	36.65	57.60	0.11	100
#3	0.23	0.20	1.60	0.61	1.58	1.07	36.88	57.69	0.14	100

Porcelain Clay Body Adjustments

In a typical porcelain cone 10 body, there never is a concern with cristobalite in feldspar-fluxed porcelains. All the feldspar easily melts any of the micro-sized cristobalite crystals of silica that develop. The problem that we would have to deal with would be not enough flux because of the shortage of K₂O in the current Custer. So a typical

porcelain recipe could be adjusted as follows, (note the ratio of non-plastic to plastic clay materials is somewhat changed but not by much in either stoneware and porcelain).

(These are example recipes only. I have not fired or tested these fictional glazes.)

PORCELAIN FLUXED WITH OLD CUSTER FORMULA

Cone 10

Custer (old)	25%
Bell Dark Ball Clay	25
EPK Kaolin	25
Silica	25
	<u>100 %</u>

Silica to alumina ratio: 5.69
Expansion (calculated): 234.66
(calculated expansion is only used for comparison in this case)

PORCELAIN FLUXED WITH CURRENT CUSTER FORMULA

Cone 10

Custer (new)	30.0 %
Bell Dark Ball Clay	22.0
EPK Kaolin	26.5
Silica	21.5
	<u>100.0 %</u>

Silica to alumina ratio: 5.68
Expansion (calculated): 235.41
(calculated expansion is only used for comparison in this case)

What About Cone 6?

What does all this mean to those firing at cone 6? Not a lot. There may be some noticeable differences in glazes using the current Custer, if there is enough in the glaze.

When I calculate the difference in the Glossy Base 2 from *Mastering Cone 6 Glazes* (a well balanced glaze that uses 22% of the old Custer), I don't see a big difference except in the lowering of the

expansion from 392 down to 374. Upping the low K₂O Custer to 26.0, reducing the silica to 22.5 and the EPK down to 16.5, brings the recipe into line with the original recipe. Notice how close the ratio and the calculated expansion are to the original. Cristobalite is only rarely a problem at cone 6 and then only because it is introduced in a raw material.

GLOSSY BASE 2 (ORIGINAL RECIPE)

Cone 6

Talc	5 %
Whiting	4
Ferro Frit 3134	26
Custer (old K ₂ O)	22
EPK Kaolin	17
Silica	26
	<u>100 %</u>

Silica to alumina ratio: 10.58
Expansion: 392.38

GLOSSY BASE 2 (ADJUSTED FOR LOW K₂O CUSTER)

Cone 6

Talc	5.0 %
Whiting	4.0
Ferro Frit 3134	26.0
Custer (low K ₂ O)	26.0
EPK Kaolin	16.5
Silica	22.5
	<u>100.0 %</u>

Silica to alumina ratio: 10.58
Expansion: 392.38

Conclusion

The burning question for anyone using Custer spar is, what is the real analysis of the material you have? It looks like the only way you will be able to find that information is by sending a sample to a lab. Unfortunately there is no information on the bags of Custer—when it was packaged, batch number, or any information that could be helpful in establishing the makeup of the contents. We did find information about when the bags were made and that did help somewhat in establishing some sort of time frame.

If you would like a PDF copy of the lab reports, contact the author at ronroy@ca.inter.net.

the author *Ron Roy lives and works in Ontario, Canada. Additional information on Custer feldspar can be found at his website, <http://ronroy.net>. He co-authored the book *Mastering Cone 6 Glazes* with John Hesselberth. Their book can be found at www.masteringglazes.com. The book can also be purchased as an iBook from Apple iTunes.*