

A Substitute for Gerstley Borate

FOR THE PAST 50 YEARS, GERSTLEY BORATE HAS BEEN used by many potters. A survey of books and magazine articles reveals numerous formulas requiring Gerstley borate in low fire cone 06 (1828°F) and mid range cone 6 (2232°F) glazes. Its raw colour is white to light gray with dark specks. It is essentially a flux, bringing other materials into an active melt. Unfortunately, this calcium borate has a long and troublesome history from both economic and technical perspectives. Few ceramic raw materials have generated such controversy, misuse and myth. It is not an understatement to say that over the years Gerstley borate has given potters many problems in its use and availability. The difficulties can be traced to several major faults that do not show any indication of being resolved in currently depleting stocks.

THE HISTORY OF GERSTLEY BORATE

James Mack Gerstley, a mining executive, founded the mine in 1923; the local people then called the mine Gerstley's borate. Gerstley's company, Pacific Coast Borax, merged with US Potash Company, which became US Borax and Chemical Company. Eventually, the television show, *Death Valley Days*, hosted by Ronald Reagan, was sponsored by US Borax. Mr Gerstley dedicated his remaining days to raising funds for the art community and was instrumental in organizing an endowment for the Asian Art Museum. He was nominated to the National Mining Hall of Fame in 2003 and died in 2007 at the age of 99. Since his discovery of the ore and his subsequent efforts on behalf of the arts, it is interesting to note that Gerstley borate continues to be used by potters.

The Gerstley borate mine is located near the town of Shoshone, California, population 52, near the Nevada state line, approximately 50 miles east of Death Valley. The mine is closed due to the increased cost of upgrading the safety equipment and growing environmental restrictions. The relatively small production of less than 1000 tons of ore per year, as compared to more than 1,000,000 tons per year of other borate minerals sold by the company, did not justify an

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*Jonathan Kaplan and Jeff Zamek
collaborate on their research*

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as a fire suppressant dropped from planes on forest fires but even this secondary market did not justify continued operation of the mine.

In the early days Gerstley borate was sold to Hammill & Gillespie, Industrial Minerals Company and Westwood Ceramics Supply as unprocessed ore. In 1991 Laguna Clay Company purchased the assets of Westwood and became the sole processor of Gerstley borate. At present there is an estimated 19 to 20 year supply of ore which can be ground to a 200 mesh powder that potters can use in their glaze formulas. The stockpile is estimated at 3000 tons. In early 2000 US Borax announced the closing of the Gerstley borate mine. The news was published in *Ceramics Monthly* which led to a substantial increase in sales by potters hoping to buy enough until a suitable substitute was found. Many older potters stated that they have bought enough to last a lifetime. The mine will not be re-opened and once the existing stock is depleted the only material available will be on ceramics suppliers' shelves or in potters' storage containers.

PROBLEMS WITH GERSTLEY BORATE

The naturally occurring ore suffers from the sin of complexity, meaning there are many forces acting before, during and after it produces a fired glaze. Gerstley borate is composed

of ulexite ($\text{Na}_2\text{O} \cdot 2\text{CaO} \cdot 5\text{B}_2\text{O}_3 \cdot 16\text{H}_2\text{O}$), with small amounts of colemanite ($2\text{CaO} \cdot 3\text{B}_2\text{O}_3 \cdot 5\text{H}_2\text{O}$) and probertite ($\text{Na}_2\text{O} \cdot 2\text{CaO} \cdot 5\text{B}_2\text{O}_3 \cdot 10\text{H}_2\text{O}$), resulting in low levels of pore water and much higher levels of chemically bound water. When used in a glaze it can result in excessive shrinkage, causing crawling (the glaze contracts on the clay body resulting in 'beads' of glaze and exposed clay body surfaces). The effect looks much like water on a glass tabletop. Additionally, when a kiln is fired too fast in its initial stages the glaze can pop off of the clay body surface due to the sudden release of vaporized water. This can yield areas devoid of glaze and a 'halo' of glaze debris on the kiln shelf.

Gerstley borate is partially soluble and hygroscopic. For example, it can absorb water from the atmosphere during storage, resulting in the possibility of inaccurate amounts being placed into a glaze formula. Due to its partial solubility, some of the borate can dissolve into the glaze water, causing an alteration of the glaze as it dries on the pot. The water wicks into the interior of the bisque pot during application. During drying the water containing soluble material migrates to the ridges or high areas of the form causing blistering and dry glaze areas. Many potters report Gerstley borate glazes in storage can produce different results from one glazing session to the next due to the breakdown of the glaze. It is not uncommon to find crystals growing on the surface of the wet glaze in the storage bucket due to the solubility of the minerals.

Gerstley borate glazes containing iron oxide and rutile, a potentially volatile combination, can outgas when fired, causing blisters, pinholes and cluster bubbles. Such effects occur both in oxidation or reduction kiln atmospheres. Often these types of defects are difficult to diagnose as some pots in the kiln with the same glaze are perfect in colour and glaze texture. Additionally, when the glaze is applied too thinly the lustrous colour cannot be obtained, often revealing the underlying clay body colour. Such glazes are hard taskmasters as they can produce random results which alternately exhilarate or disappoint.

Gerstley borate also contains gangue (pronounced 'gang') or 'tramp' material, often found as small black/brown specks in the raw material, causing blistering and pinholing in a fired glaze. Periodically, gypsum is present, causing glaze 'pop outs'. Obviously if Gerstley borate produced any or all of the defects described every time it was used it would have been eliminated as a glaze material many years ago. The insidious nature of its random failure rate, counterbalanced by its numerous positive attributes, has kept it in continuous use by unwary potters. Simply stated, aside from grinding the material, ceramics supply companies are selling an unrefined ore that can produce inconsistent results.

A SUBSTITUTE FOR GERSTLEY BORATE

The distinctive and much appreciated feature of Gerstley borate is its ability to produce a variegated surface in glazes. Since the postings of its limited supply, many ceramics suppliers and potters have tried to find a substitute with varying degrees of success. Part of the problem traces again to the complexity of the material, as Gerstley borate is composed of several



*Raw Samples of Gerstley borate and Gillespie borate.
Gerstley borate is a light tan/off white, whereas Gillespie borate is bright white.*

minerals. It also has wide swings in its chemical makeup making it difficult to find a one-for-one replacement. Gillespie borate, a synthetic product produced by Hammill & Gillespie of New Jersey, however, has proven to be a reliable one-for-one substitute. In many instances it is difficult to arrive at such a close match as many raw materials are not mineralogically pure when removed from the earth. Any potential substitute has to match on many points and produce the same results in fired glazes.

In determining the suitability of substitutes such as Gillespie borate, we were only able to test a few glaze formulas that require Gerstley borate. One glaze that we tested is the popular cone 6 glaze, *Floating Blue*, which is one glaze that displays the favourable characteristics produced by Gerstley borate, namely the distinctive variegated surface colours. *Floating Blue* contains a relatively high percentage of Gerstley borate and, most importantly, produces a break up of glaze colours. As a control composition for this study 26 percent Gerstley borate was used in *Floating Blue*. The same percentage of Gillespie borate was substituted, yielding *Floating Blue Revised*. All other materials were kept at their original percentages and all methods of glaze application and firing were kept consistent.

A second test glaze, *PV Variegated/Gloss Blue*, cone 6, also used Gerstley borate which was replaced with Gillespie borate on a one-for-one basis in *PV Variegated/Gloss Blue Revised*. Two variations, a casting formula and a plastic formulation of the clay body, *Scooters Special Blend (SSB)* were used in these tests. Both clay bodies contain Greenstripe Fireclay, VelvaCast or Tile 6 Kaolin, FC 340 Ball Clay or New Foundry Hill Cream Ball Clay, Silica, Custer Feldspar and Pyrophyllite.

Glazes were mixed in 200 gram test batches, 250 ml of water was added and then screened through a 200 mesh sieve. The vertical test tiles were dipped into the glaze for 10 seconds yielding a .12 mm application thickness. The glaze application was tested using a Glaze Thickness Tester or Penetrometer. The samples were fired in a Nabertherm Top 45 kiln (1.58 cubic feet interior volume) with a Bartlett CF6 Controller using the following firing cycle:

- 100°F/hour to 2200°F with a hold of 15 minutes
- 250°F/hour to 2080°F with a soak of 10 minutes = cone 6

HYPERGLAZE SCREEN

COMPARISON OF FLOATING BLUE AND /PV VARIEGATED BLUE GLOSS GLAZE

GLAZES

C 6

View Marked

Floating Blue

Color: Semi-Opaque Blue

Surface: shiny or glossy

oxidation

Tested

INGREDIENTS:	AMOUNTS:	Batch:	gm	Unity	Molecular Formula	Graph UMF
+ Gerstley Borate	26.00	260.0		RO - Flux	R2O3	RO2
+ Nepheline Syenite	48.00	480.0		0.094 K ₂ O	0.535 Al ₂ O ₃	3.598 SiO ₂
+ EPK	6.00	60.0		0.392 Na ₂ O	0.429 B ₂ O ₃	0.001
+ Flint	20.00	200.0		0.416 CaO	0.004 Fe ₂ O ₃	
				0.098 MgO	0.000 P ₂ O ₅	
				Li ₂ O	Sb ₂ O ₃	
				BaO	Cr ₂ O ₃	
				PbO	V ₂ O ₅	6.7:1
				ZnO		
				CuO		
				CoO		
				NiO		
				SrO		
Also Add:	Totals:	100	1000.0	Thermal Expansion		Estimated to be:
+ cobalt oxide	1.00	10.0		Date: 12/16/10		6.00 x10⁻⁶/deg C
+ rutile	4.00	40.0		Batch Cost \$ 0.36		
+ red iron oxide	2.00	20.0		Hide Lines		

COMPARISON BETWEEN GERSTLEY BORATE AND GILLESPIE BORATE

Using Insight Ceramic Software, we can compare the molecular formulas for Gerstley borate and Gillespie borate. In the screen below, Column 1 refers to Gerstley borate and Column 2 refers to Gillespie borate.

The screenshot shows the 'Recipe Window' in Insight Ceramic Software. It features a 'Recipe List' table with two columns for 'Gerstley Borate' and 'Gillespie Borate', both with a quantity of 100.00. Below this is a 'Chemistry' section with two columns of data for comparison. The 'Oxide' table shows the chemical composition for both materials.

Item	1	2
Formula Weight	120.86	123.98
Si:Al Ratio	11.78	11.88
SiB:Al Ratio	32.90	30.20
Thermal Expansion	9.12	9.22
Cost/lb - USA\$		
Calculated LOI	30.90	26.00
Imposed LOI		
RecipeTotal	100.00	100.00

Oxide	1	2
CaO	0.72*	0.72*
MgO	0.17*	0.17*
K2O		tr*
Na2O	0.11*	0.11*
SrO		tr*
Al2O3	0.03	0.03
B2O3	0.62	0.60
SiO2	0.34	0.39
Fe2O3		tr

Gillespie borate is comprised principally of ulexite (sodium calcium borate), with small amounts of colemanite (calcium borate) and other minerals – just like Gerstley borate. From a pre-fired perspective, the most critical element in the new material is its colloid content. Containing approximately 10 percent clay-like materials, Gillespie borate disperses well in water and makes a reasonably stable glaze slip in the neat state. Further clay addition at the point of use is required to further improve the stability of the slip and pre-fired properties such as strength and adherence. In the fired state, Gillespie borate is virtually identical

to Gerstley borate by virtue of the chemical match of oxide content.

The special behaviour of Gerstley and Gillespie borates that produces the unusual glaze effects results from two mechanisms: immiscibility and solubility. Boric oxide (B_2O_3), when provided to a glass as a coarse raw mineral (for example, ulexite), is slightly immiscible with silicate glass matrices and the differential surface energy of the molten phase drives a mass transfer process along the interface (Gibbs-Marangoni effect) that generates the characteristic variegated texture. The slight solubility of these borates also contributes to the mottled glaze surface via migration of soluble oxides, although this effect becomes exaggerated when mixed glazes are stored for long periods.

While Gillespie borate has the beneficial fluxing and glaze development properties of Gerstley borate, it does not have the variability or impurity levels that characterized Gerstley borate. Gillespie borate is a precise mixture of pure natural minerals and is manufactured under close quality control supervision. Hence, Gillespie borate does not vary over time and is a consistent, reliable raw material. Since Gillespie borate does not contain the impurity levels that provided off colour to Gerstley borate glazes, you may find your glazes whiter and brighter.²

RECOMMENDATIONS FOR USING GILLESPIE BORATE

- Do not use excess water in mixing the glaze.
- Store the wet glaze in an airtight container.
- When using any substitute material, always test it in a small batch of glaze.
- Test the glaze on the same clay body that you will use in production.
- After applying the glaze to several vertical test tiles, place them throughout the kiln.

OVERALL RAW MATERIAL ECONOMICS

Whether potters realize it or not, all raw materials are subject to economic factors in the marketplace. When a favourite clay body or glaze material suddenly is not available it is not because the geological supply is exhausted. It is because the material is not profitable to mine or process for the larger buying market. Potters represent less than 0.1 percent of the raw materials market and the other 99.9 percent dictates what materials will remain in supply. Gerstley borate is a perfect example of this dynamic. When Gerstley borate was mined and processed, it was used as a fire retardant and as a binder in grinding wheels. It is fortunate that these markets enabled the material to become available to potters. Once larger buyers discontinued their need for Gerstley

borate and stronger mining safety restrictions were enacted, the cost of production rose to unacceptable levels based on the selling price.

In a perfect world, potters would be willing to pay a much higher price for Gerstley borate, which in turn would offset the higher production costs and the decrease in market demand by larger industries. This, however, has not been the case and will not be for other raw materials that go out of production. Fortunately, Gerstley borate can be replaced on a one-for-one basis. This is a rare exception, as the development costs associated with most substitutions are prohibitive. An added factor arises when the substitute does not match the original exactly, in which case a recalculation of the glaze formula and/or many testing cycles are required to ensure an accurate result.

The history of raw materials used by potters has often resulted in a favourite clay body or glaze material going out of production. The nature of potters' limited demands compared to those of industry and the low profit margins associated with raw materials do not offer many options for a consistent source and uniform quality of any given material. Traditionally, a specific raw material will remain in supply at a constant quality only if a larger buyer(s) demand it. Future trends, however, are going downward for domestic raw material availability as ceramic production around the world increases due to low labour costs and limited environmental restrictions. Simply stated, why would a foreign manufacturer buy US raw materials when their own supply is closer and less expensive? Specifically, some ball clays, kaolins, feldspars and other raw materials used by potters will be removed from our markets. With this bleak outlook, potters can passively accept a limited array of raw materials or gain a thorough technical knowledge of the materials found in their clay and glaze formulas. The ability to recalculate a glaze using a substitute material or to develop the same glaze effect using other available raw materials will be a valuable tool for potters in the future.

FOOTNOTES

1. The exact chemical composition of Gillespie borate is proprietary to Hammill & Gillespie. Gillespie borate is a mixture of ulexite ($\text{Na}_2\text{O} \cdot 2\text{CaO} \cdot 5\text{B}_2\text{O}_3 \cdot 16\text{H}_2\text{O}$) with various clay minerals (aluminum silicates), alkaline earth carbonates and silicates. This material contains approximately 25 percent B_2O_3 , 23 percent CaO , 4 percent total alkali and 31 percent loss on ignition.
2. Richard Lehman, Technical Advisor to Hammill & Gillespie

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Jeff Zamek walked into a pottery studio 36 years ago and started his career as an amateur potter. After completing a degree in business from Monmouth University, W Long Branch, New Jersey, he earned BFA/MFA degrees in ceramics from Alfred University, College of Ceramics, New York. While there he developed the soda firing system at the college and went on to teach at Simon's Rock College and Keane College. During this time he earned his living as a professional potter. In 1980 he started Ceramics Consulting Services, a firm developing clay body and glaze formulas for ceramics supply companies throughout the US. He works with individual potters, ceramics companies and industry, offering technical advice on clays, glazes, kilns, raw materials, ceramic toxicology and product development. He is a regular contributor to *Ceramics Monthly*, *Pottery Making Illustrated*, *Pottery Production Practices*, *Clay Times*, *Studio Potter*, *Ceramics TECHNICAL* and *Craft Horizons*. Zamek's books, *The Potter's Studio Clay & Glaze Handbook*, *What Every Potter Should Know*, and *Safety in the Ceramics Studio* (featuring the safe handling of ceramic materials) and *The Potters Health & Safety Questionnaire* are available from Jeff Zamek/Ceramics Consulting Services. Zamek is currently working on several ceramics research projects and is making pots as an amateur potter. (www.jeffzamek.com)

Jonathan Kaplan has maintained an active 40 year career as a potter, ceramic artist and designer, manufacturer, educator and author. He holds a BFA from Rhode Island School of Design and an MFA from Southern Illinois University. While living the large life in the Colorado high country, he operated Ceramic Design Group, a ceramic design and manufacturing service and developed the clay program for Colorado Mountain College in Steamboat Springs. Out of necessity, he also learned to be a master mould and model maker. Jonathan has authored many articles for *Ceramics Monthly*, *Pottery Making Illustrated*, *Studio Potter*, *Production Pottery Practices* and *Ceramics TECHNICAL*. In 2006 he moved to Denver to reinvent himself as a ceramic artist. Along with his new studio practice, Kaplan is the curator of Plinth Gallery. (www.plinthgallery.com) (jonathan@plinthgallery.com)

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