How do Glazes Work?

Eutectics
&
The Weight Percentage Formula

Dia2.JPG

Part one

Eutectics

Why eutectics are important

How eutectics relate to everyday glazes

The Molecular Make-up of a Glaze

The difference between Moles and Weight Percentages

The inherent limits of the UMF method

Dia3.JPG

Part two

The Weight Percentages Formula

Research findings

WPF Target Limits

WPF spread sheet calculation programs

&

Weight Percentage Diagram

Dia4.JPG

Dia5.JPG

Nigel Wood

Chinese Glazes

Lime Glazes > Lime Alkali Glazes

Lime eutectic

&

Percentage method

Dia6.JPG

Some observations:

- The readiness to fuse is not determined by their molecular make-up of a glazes alone; ingredient choice and their particle size have a big impact as well
- Within all temperature ranges neither feldspar nor nepheline syenite help to obtain full fusion (low viscosity)
- A alumina silica ratio of 1 : 10 according to the UMF (high silica content relative to alumina) is generally assumed to be working well for shiny glazes. This is true for cone 10 feldspatic glazes and mid-range zinc glazes.
- Mid-and high range calcium glazes and for low- and mid-range calcium-boron glazes need a high alumina / kaolin content to yield shiny results.
- Silica matte glazes for cone 8 and beyond are more challenging to make stable
- In contrast to what often is stated; K_2O is much less of an active flux in glazes compared to Na_2O

Knowledge about eutectics in combination with the use of the Weight Percentage Formula will help to explain the underlying logic behind these observations.

Dia8.JPG

Eutectics

Eutectics

A eutectic reaction is a phenomenon in which a specific combination of oxides yields melting at a (considerable) lower temperature than that of each oxide individually

The exact composition and temperature at which a eutectic reaction occurs is determined under very specific and well controlled laboratory conditions

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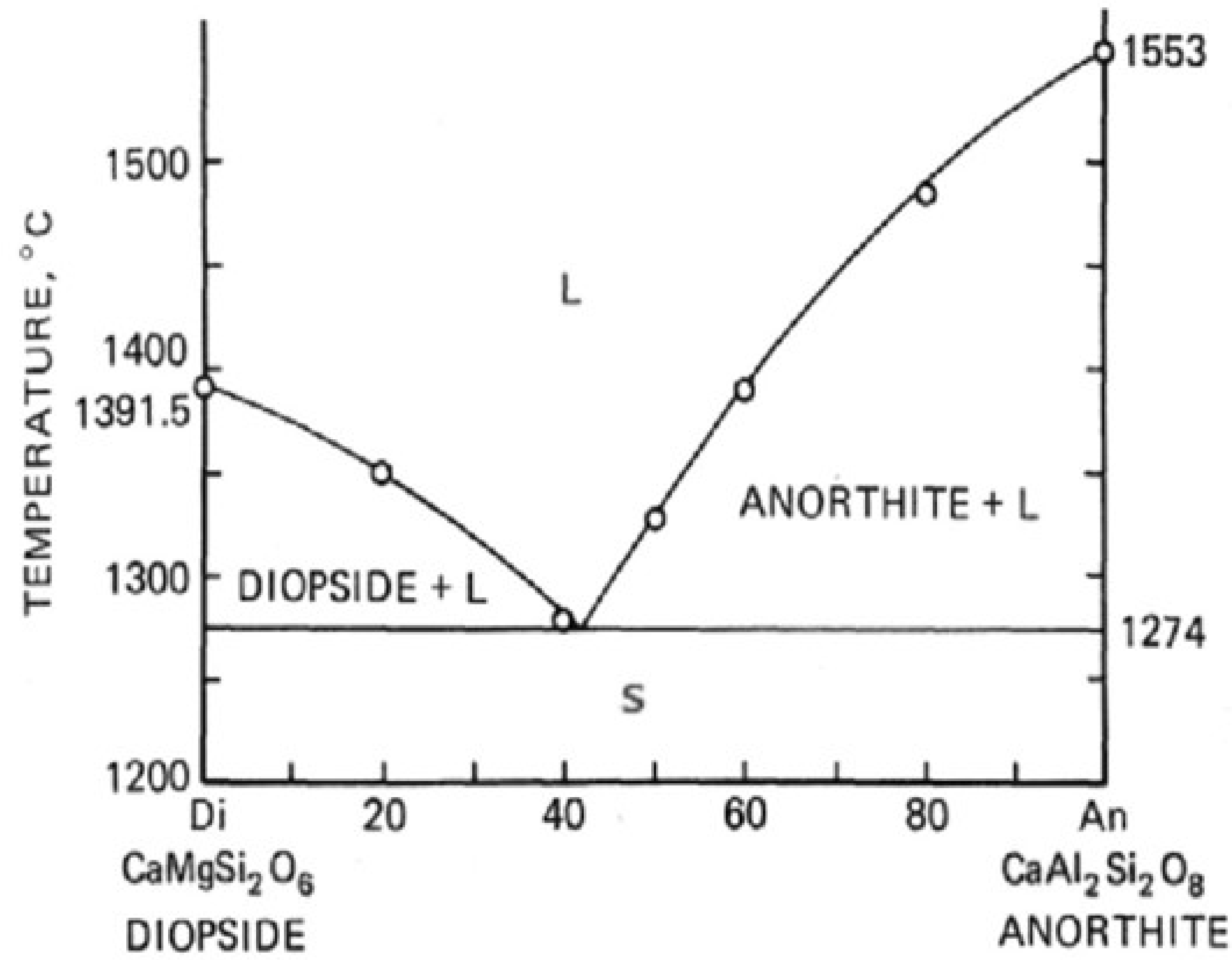
Binary Phase Diagrams



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Trinary Phase Diagrams

K_2O–Na_2O–Al_2O_3–SiO_2

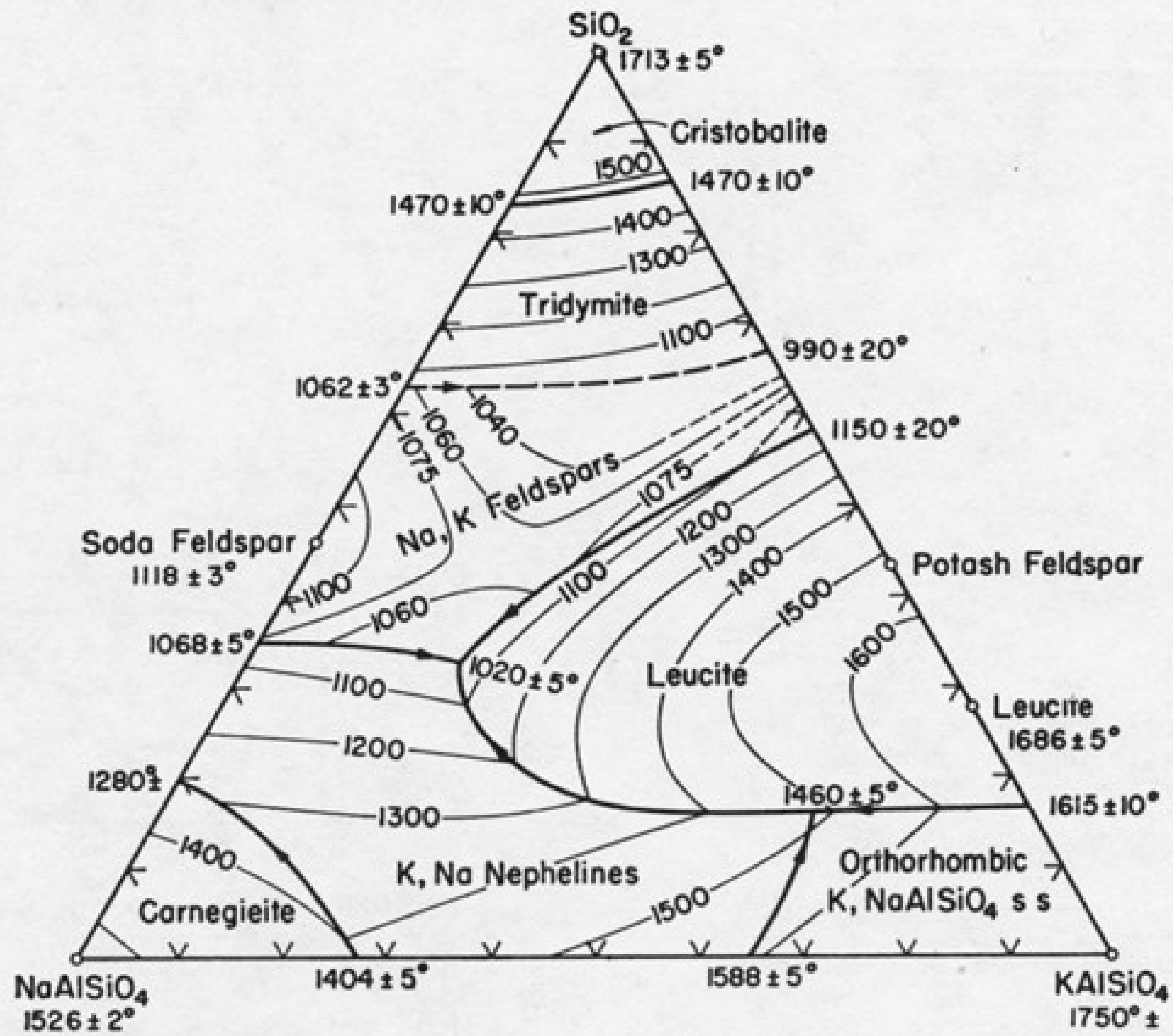

FIG. 786.—System $NaAlSiO_4$–$KAlSiO_4$–SiO_2; revised.

J. F. Schairer, *J. Geol.*, 58, No. 5, 514 (1950).

Dia12.JPG

Why are Eutectics Important?

The melting behavior of glazes are largely determined by eutectics reactions; hence they are very helpful to understand and predict the nature of glazes.

Dia13.JPG

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Knowledge of eutectics allow for a better understanding of:

- seemingly counter intuitive melting behavior
- the logic behind crystallization
- the influence of particle size on melting and crystallization
- the influence of surface tension on viscosity

Dia14.JPG

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Glazes with a composition close towards a eutectic mixture tend to be shiny because they have less of a tendency to crystalize

Dia16.JPG

But the influence of
eutectics reactions
on glazes
is…

Dia17.JPG

But the influence of
eutectics reactions
on glazes
is
not
one to one!

Dia18.JPG

Eutectics and Glazes

There is a difference between the temperature at which a "eutectic glaze" will fuse and the related eutectic point. A differences of 50°C (122°F) but also as much as 500°C (932°F) or higher can occur because glazes consist of particles.

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Particle will hamper a eutectic reaction to take place all over the glaze layer because initially molecules are only available at the surface of a particle. Hampering occurs even more so in case of larger particles and particularly in case high amount of refractory ingredients like quartz are involved.

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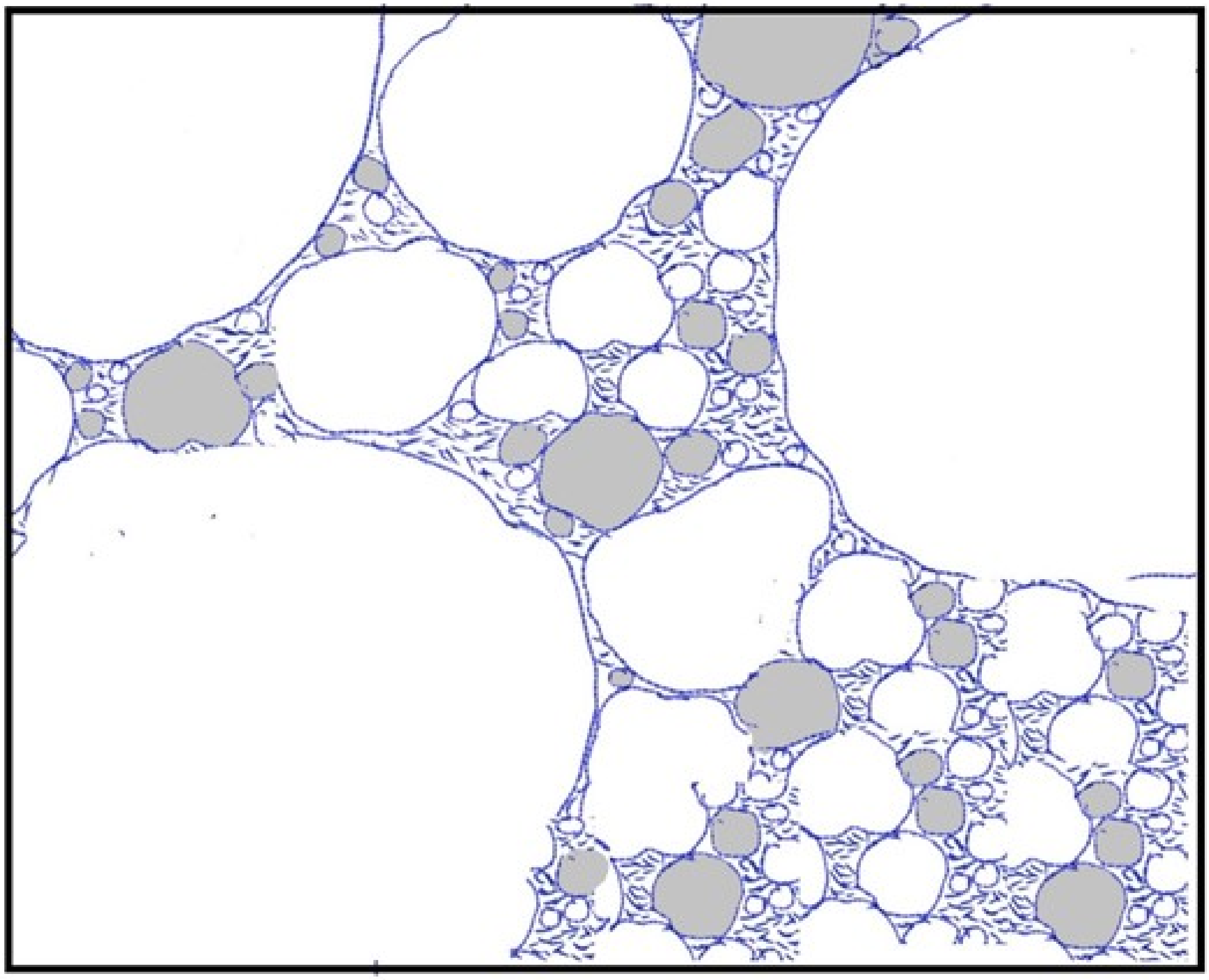
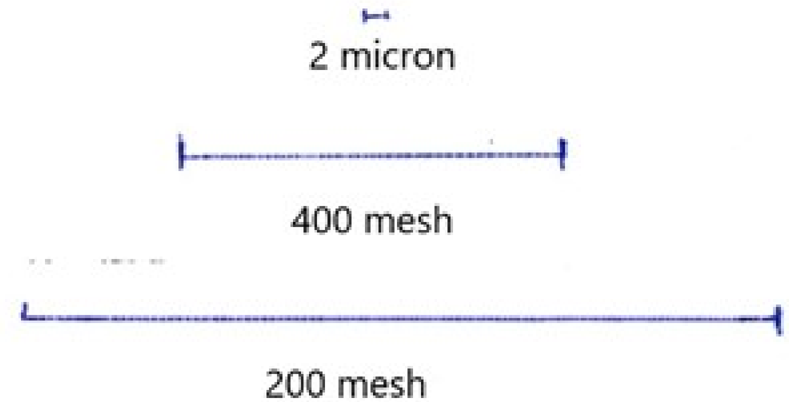


1000 x enlarged



Average ingredient 75 - 2 microns
Clay minerals less than 2 microns

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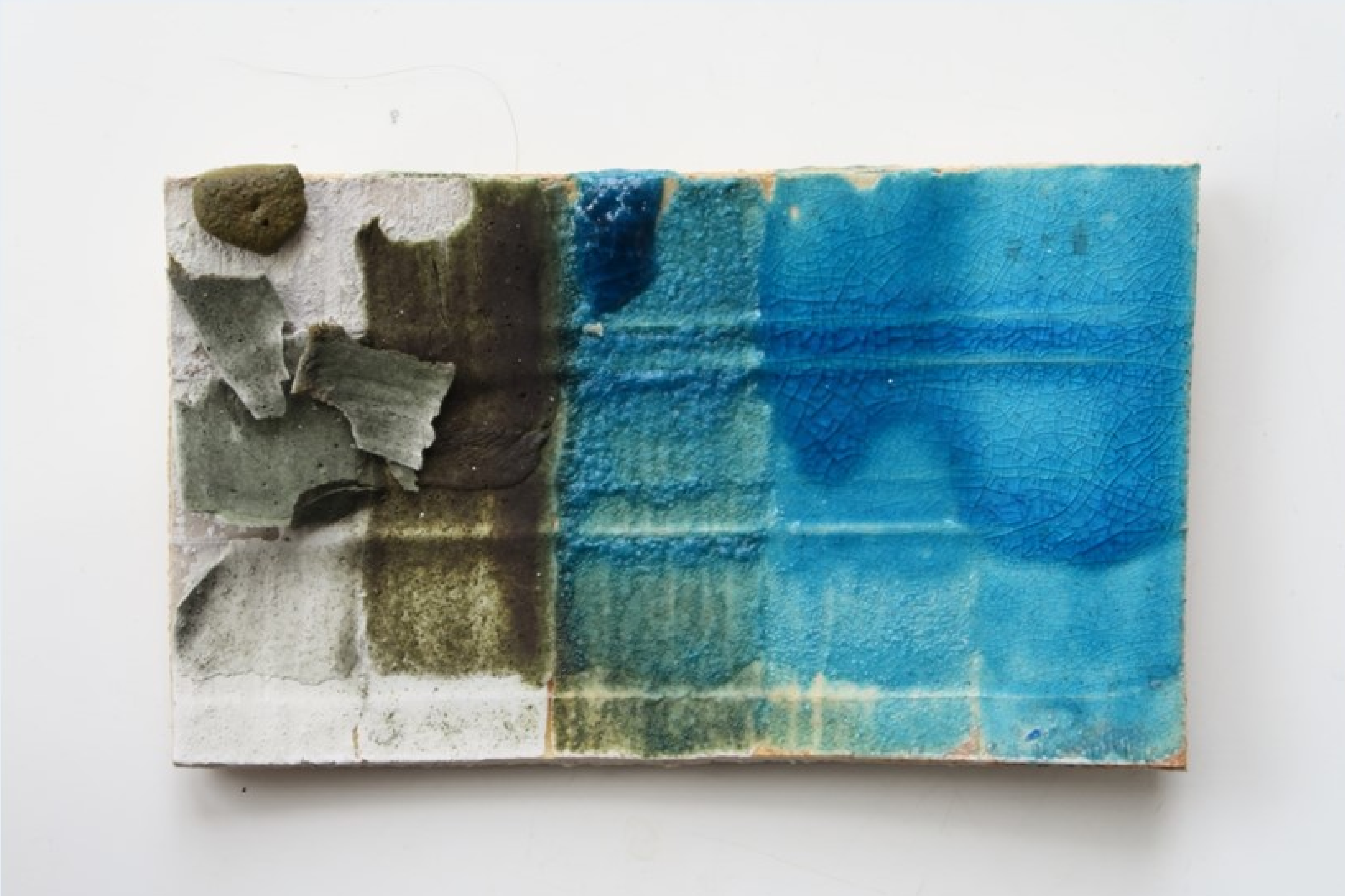

Cone 3

Potassium high silica eutectic
Eutectic point: 710°C (1310°F)

Sodium high silica eutectic
Eutectic point: 740°C (1364°F)

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Mixture 1 (100% A)		
Quartz Imsil A Alfred GEM	60,4	%
Kaolin Grolleg A Alfred	9,3	%
Quartz Sil-co-sil (63) Gem	0,0	%
Neph. Sy. Spect. A Alfred	0,0	%
Minspar 200 A Alfred	0,0	%
P Feldspar Mahavir A Alfr	0,0	%
Whiting Cast Carb A Alfred	0,0	%
Dolomite Doloc A Alfred	0,0	%
Strontium Carb	0,0	%
Barium Carbonate	0,0	%
Pearl Ash K2CO3	30,3	%
Sodium Bicarb.	0,0	%
	100,0	

Mixture 2 (75% A : 25% B)		
Quartz Imsil A Alfred GEM	57,8	%
Kaolin Grolleg A Alfred	9,0	%
Quartz Sil-co-sil (63) Gem	0,0	%
Neph. Sy. Spect. A Alfred	0,0	%
Minspar 200 A Alfred	0,0	%
P Feldspar Mahavir A Alfr	0,0	%
Whiting Cast Carb A Alfred	0,0	%
Dolomite Doloc A Alfred	0,0	%
Strontium Carb	0,0	%
Barium Carbonate	0,0	%
Pearl Ash K2CO3	22,8	%
Sodium Bicarb.	10,5	%
	100,0	

Mixture 3 (50% A : 50% B)		
Quartz Imsil A Alfred GEM	55,3	%
Kaolin Grolleg A Alfred	8,6	%
Quartz Sil-co-sil (63) Gem	0,0	%
Neph. Sy. Spect. A Alfred	0,0	%
Minspar 200 A Alfred	0,0	%
P Feldspar Mahavir A Alfr	0,0	%
Whiting Cast Carb A Alfred	0,0	%
Dolomite Doloc A Alfred	0,0	%
Strontium Carb	0,0	%
Barium Carbonate	0,0	%
Pearl Ash K2CO3	15,2	%
Sodium Bicarb.	20,9	%
	100,0	

Mixture 4 (25% A : 75% B)		
Quartz Imsil A Alfred GE	52,7	%
Kaolin Grolleg A Alfred	8,3	%
Quartz Sil-co-sil (63) Ge	0,0	%
Neph. Sy. Spect. A Alfre	0,0	%
Minspar 200 A Alfred	0,0	%
P Feldspar Mahavir A Al	0,0	%
Whiting Cast Carb A Alfr	0,0	%
Dolomite Doloc A Alfred	0,0	%
Strontium Carb	0,0	%
Barium Carbonate	0,0	%
Pearl Ash K2CO3	7,6	%
Sodium Bicarb.	31,4	%
	100,0	

Mixture 5 (100% B)		
Quartz Imsil A Alfred GEM	50,2	%
Kaolin Grolleg A Alfred	8,0	%
Quartz Sil-co-sil (63) Gem	0,0	%
Neph. Sy. Spect. A Alfred	0,0	%
Minspar 200 A Alfred	0,0	%
P Feldspar Mahavir A Alfr	0,0	%
Whiting Cast Carb A Alfred	0,0	%
Dolomite Doloc A Alfred	0,0	%
Strontium Carb	0,0	%
Barium Carbonate	0,0	%
Pearl Ash K2CO3	0,0	%
Sodium Bicarb.	41,9	%
	100,0	

Dia23.JPG

Eutectics and Glazes

Ingredients like feldspar or nepheline syenite increase the surface tension of a glaze considerably. If present in a eutectic glaze full fusion will be only obtained at a higher temperature because a high surface tension retards particles getting dissolved.

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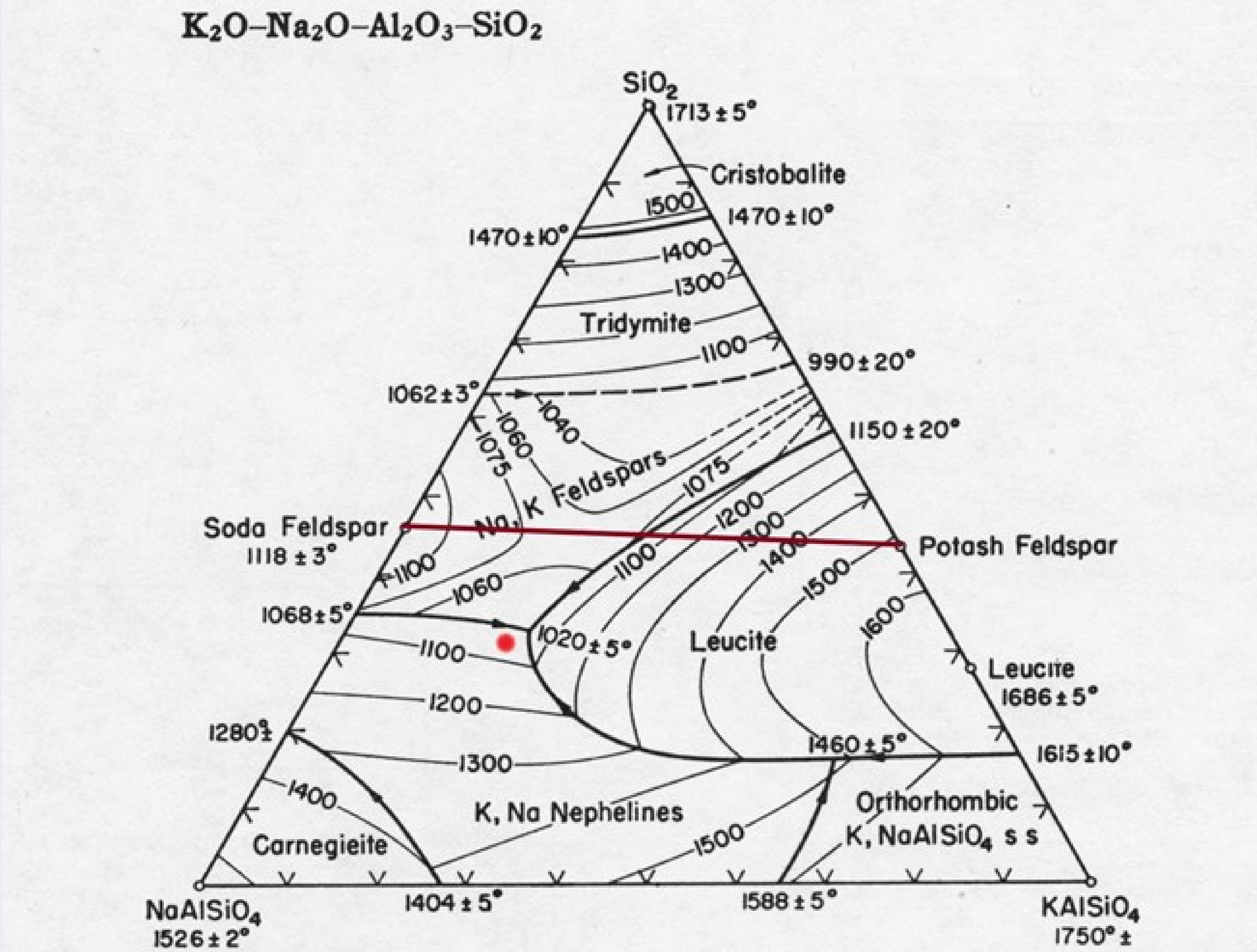
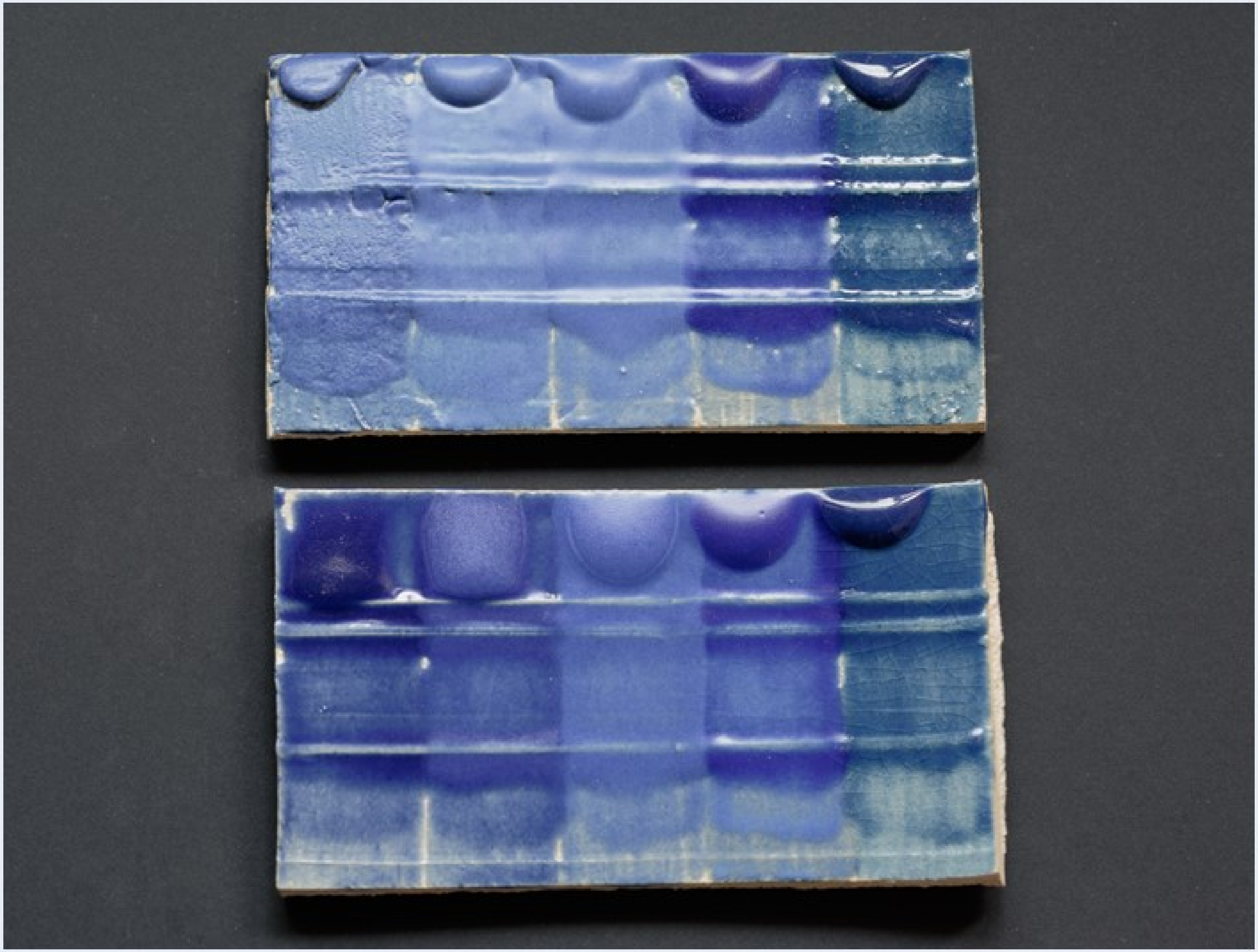


FIG. 786.—System $NaAlSiO_4$–$KAlSiO_4$–SiO_2; revised.

J. F. Schairer, *J. Geol.*, 58, No. 5, 514 (1950).

Dia25.JPG

Lime eutectic glaze – Nepheline syenite



Cone 5 and cone 7

Lime eutectic
Eutectic point: 1170°C (2138°F)

Sodium potassium high alumina eutectic
Eutectic point: 1020°C (1868°F)

Dia26.JPG

Mixture 1 (100% A)	%
Quartz 400 mesh	34,9
Kaolin Grolleg A Alfred	32,3
Cal Kaolin Grolleg	0,0
Neph. Sy. Spect. A Alfred	0,0
Minspar 200 A Alfred	0,0
P Feldspar Mahvir A Alfr	0,0
Whiting Cast Carb A Alfred	32,7
Dolomite Doloc A Alfred	0,0
Wollastonite Vansil A Alfr	0,0
Talc	0,0
Frit 3134 (High Bo and So)	0,0
Sodium Bicarb.	0,0
	100,0

Mixture 2 (75% A : 25% B)	%
Quartz 400 mesh	26,2
Kaolin Grolleg A Alfred	24,3
Cal Kaolin Grolleg	0,0
Neph. Sy. Spect. A Alfred	25,0
Minspar 200 A Alfred	0,0
P Feldspar Mahvir A Alfr	0,0
Whiting Cast Carb A Alfred	24,6
Dolomite Doloc A Alfred	0,0
Wollastonite Vansil A Alfr	0,0
Talc	0,0
Frit 3134 (High Bo and So)	0,0
Sodium Bicarb.	0,0
	100,0

Mixture 3 (50% A : 50% B)	%
Quartz 400 mesh	17,5
Kaolin Grolleg A Alfred	16,2
Cal Kaolin Grolleg	0,0
Neph. Sy. Spect. A Alfred	50,0
Minspar 200 A Alfred	0,0
P Feldspar Mahvir A Alfr	0,0
Whiting Cast Carb A Alfred	16,4
Dolomite Doloc A Alfred	0,0
Wollastonite Vansil A Alfr	0,0
Talc	0,0
Frit 3134 (High Bo and So)	0,0
Sodium Bicarb.	0,0
	100,0

Mixture 4 (25% A : 75% B)	%
Quartz 400 mesh	8,7
Kaolin Grolleg A Alfred	8,1
Cal Kaolin Grolleg	0,0
Neph. Sy. Spect. A Alfred	75,0
Minspar 200 A Alfred	0,0
P Feldspar Mahvir A Alfr	0,0
Whiting Cast Carb A Alfred	8,2
Dolomite Doloc A Alfred	0,0
Wollastonite Vansil A Alfr	0,0
Talc	0,0
Frit 3134 (High Bo and So)	0,0
Sodium Bicarb.	0,0
	100,0

Mixture 5 (100% B) B	%
Quartz 400 mesh	0,0
Kaolin Grolleg A Alfred	0,0
Cal Kaolin Grolleg	0,0
Neph. Sy. Spect. A Alfred	100,0
Minspar 200 A Alfred	0,0
P Feldspar Mahvir A Alfr	0,0
Whiting Cast Carb A Alfred	0,0
Dolomite Doloc A Alfred	0,0
Wollastonite Vansil A Alfr	0,0
Talc	0,0
Frit 3134 (High Bo and So)	0,0
Sodium Bicarb.	0,0
	100,0

Dia27.JPG

Eutectics and Glazes

Despite being less subjected to crystallization a “eutectic glaze” still can turn matte. Crystals are formed during firing as a result of an exchange of molecules between particles. These crystals, as well as not fully dissolved particles, will form seeds for crystal growth during cooling.

The tendency of this to occur increases if ingredients with a coarser particle size are used

Eutectics and Glazes

Eutectic mixtures can be used as **reference points** within an infinite amount of possible compositions.

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The Molecular Make-up of a Glaze

Dia30.JPG

Moles versus **Weight Percentages**

Dia31.JPG

Moles

The standard method for denoting the molecular make-up of glazes and crystals

Is a counting unit for molecules based on the Avogadro constant; one Mole contains 6.02×10^{23} molecules

It is a way to express very large numbers in chewable chunks like 3,153,600,00 seconds can be expressed as being 1 century

Dia32.JPG

$$\frac{\textit{Gram or \% of oxide}}{\textit{Molecular Mass of oxide}} = \textit{Mole}$$

The relative molecular mass (MM) is the mass of an atom or molecule in relation to a standard value. Historically the standard value was the smallest atom: H (Hydrogen)

Dia33.JPG

The Unity Molecular Formula

UMF		
R_2O RO	R_2O_3	RO_2
1	Al_2O_3 : SiO_2	

Dia34.JPG

Moles Versus Weight Percentages

Dia35.JPG

Weight Percentages

Weight percentages are used to denote:

- The chemical analysis of ingredients
- The molecular composition of eutectic mixtures

Dia36.JPG

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In Nigel Woods' Oriental Glazes the **percentage method,** a method based on weight percentages, is discussed as an alternative way to denote and calculate the molecular make-up of a glaze.

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Dia38.JPG

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Note! Do not confuse weight percentages and Mole percentages!

Moles Versus Weight

100g of alumina **= 0.98 Moles**

$$\frac{100}{102} = 0.98$$

100g of silica **= 1.66 Moles**

$$\frac{100}{60.1} = 1.66$$

Moles Versus Weight

1 kg of apples or 1 kg of walnuts
will contain a different number of apples or walnuts

Making a pie:

counting the individual components
< >
weighing the component

Moles Versus Weight Percentages

By using the UMF the relationship between the recipe and the molecular makeup of the final glaze becomes blurred because

- the fluxes are set into unity
- the influence of the molecular mass on the equation

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Dia44.JPG

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As a result it is more difficult to understand how glazes work

The limitations of the UMF method becomes apparent if a weight percentages approach to glaze calculation is used

Dia47.JPG

The Weight Percentage Formula

addition
or
alternative to the UMF?

UMF

Due to the influence of the molecular mass on the equation and the fact that the fluxes are set into unity:

- the relationship between a recipe and the molecular makeup of a glaze becomes blurred

Dia49.JPG

UMF

Due to the influence of the molecular mass on the equation and the fact that the fluxes are set into unity:

- the relationship between a recipe and the molecular makeup of a glaze becomes blurred
- less clarity will be obtained when comparing different type of glazes

Dia50.JPG

UMF

Due to the influence of the molecular mass on the equation and the fact that the fluxes are set into unity:

- the relationship between a recipe and the molecular makeup of a glaze becomes blurred
- less clarity will be obtained when comparing different type of glazes
- it is not possible to make more detailed distinctions between glaze types.

Dia51.JPG

The Weight Percentage Formula

WPF		
% K_2O KNaO % Na_2O % CaO % MgO % ZnO % SrO % BaO % PbO **% B_2O_3**	% Al_2O_3	% SiO_2 % P_2O_5
Total fluxes	Al_2O_3 : SiO_2 **KNaO : CaO**	

Dia52.JPG

UMF versus WPF

Two examples

Dia53.JPG

Recipe		
Quartz	35%	35%
Neph. Sy.	40%	40%
Whiting	25%	-
Barium carb.	-	25%
WPF		
KNaO	7.2%	6.8%
CaO	15,7%	0.3%
MgO	0.1%	0.1%
BaO	-	20.7%
Total fluxes:	**23.1%**	**27.9%**
Al_2O_3	10.6%	9.9%
SiO_2	66.3%	62.3%
UMF		
KNaO	0.27	0.44
CaO	0.72	0.12
MgO	0.01	0.09
BaO	-	0.35
Fluxes:	**1**	**1**
Al_2O_3	0.27	0.40
SiO_2	2.85	4.31

MM:

CaO = 56.1

BaO = 153.7

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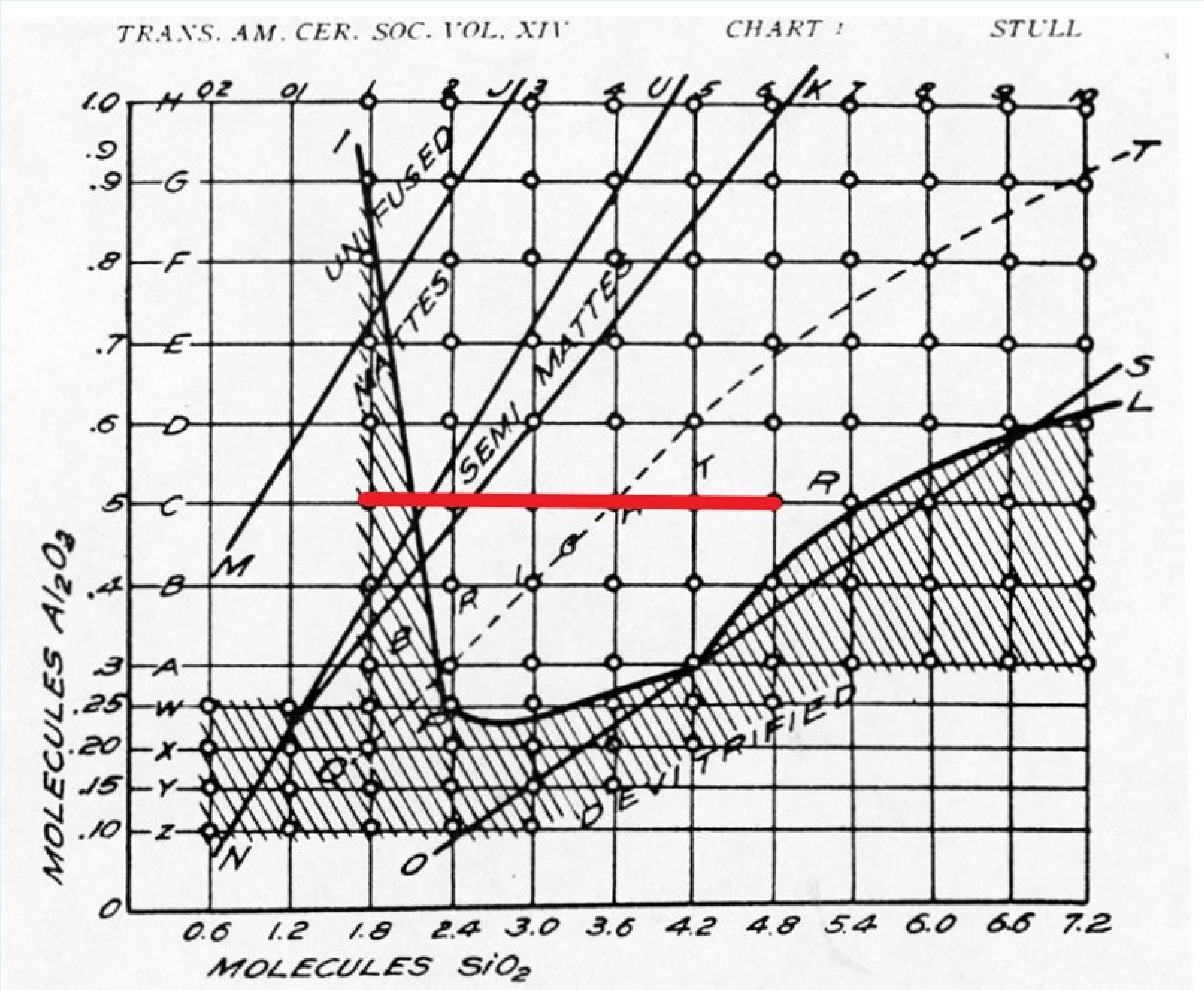


TRANS. AM. CER. SOC. VOL. XIV
CHART 1
STULL
UNFUSED
MATTES
SEMI MATTES
DEVITRIFIED
MOLECULES Al2O3
MOLECULES SiO2
1.0
.9
.8
.7
.6
.5
.4
.3
.25
.20
.15
.10
0
H
G
F
E
D
C
B
A
W
X
Y
Z
0.6
1.2
1.8
2.4
3.0
3.6
4.2
4.8
5.4
6.0
6.6
7.2

Dia55.JPG

0.5 Alumina 1.8 - 4.8 Silica

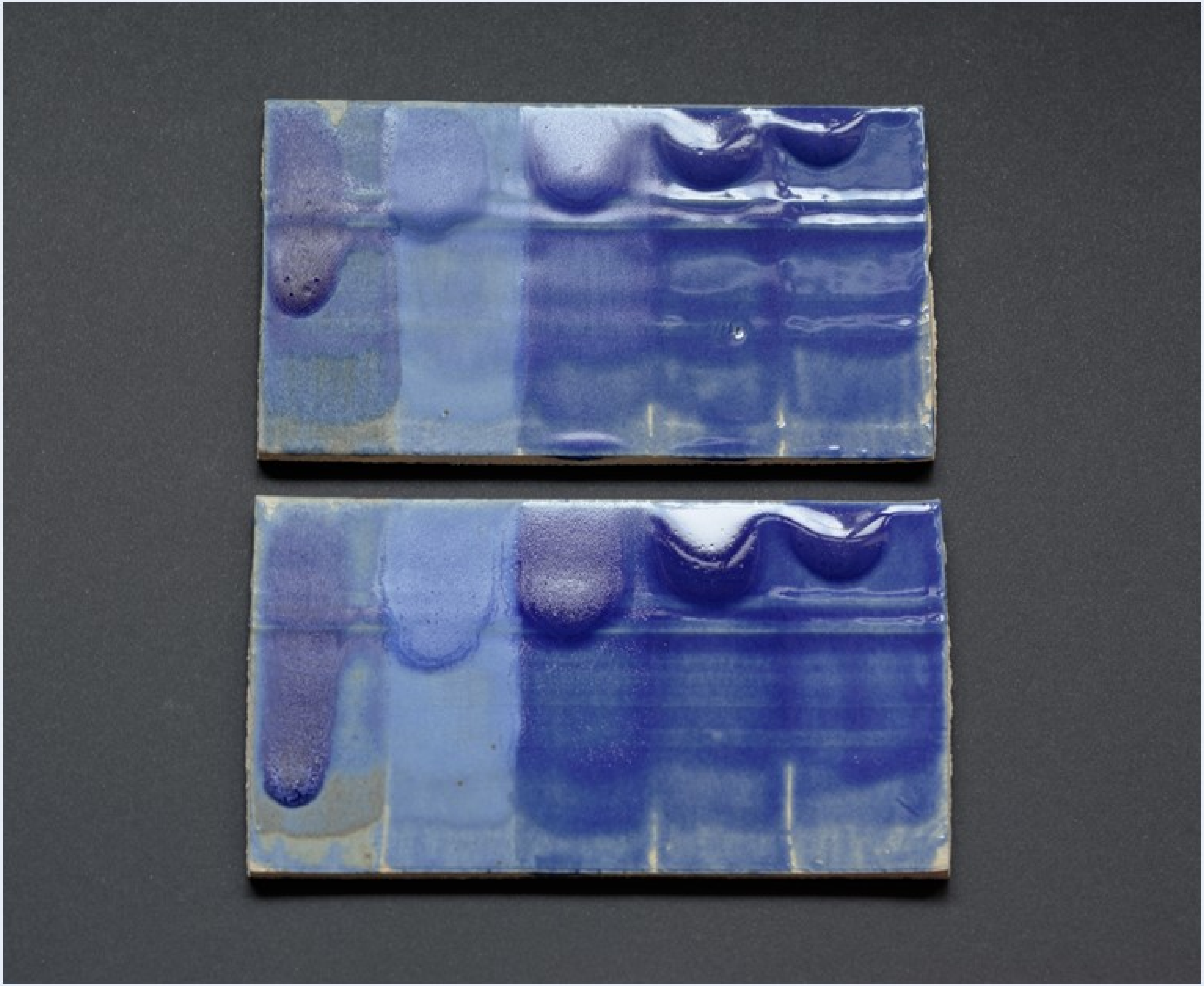
	Mixture 1	Mixture 2	Mixture 3	Mixture 4	Mixture 5
Quartz	1.3	11.7	22.0	32.3	42.6
Kaolin	22.6	20.4	18.2	16.1	13.9
Neph. Sy.	49.1	43.8	38.5	33.2	27.9
Whiting	27	24.1	21.3	18.5	15.6

UMF:		Fluxes		Fluxes		Fluxes		Fluxes		Fluxes
KNaO	**0.3**		**0.3**		**0.3**		**0.3**		**0.3**	
CaO	**0.7**	1	**0.7**	1	**0.7**	1	**0.7**	1	**0.7**	1
Al_2O_3	**0.5**		**0.5**		**0.5**		**0.5**		**0.5**	
SiO_2	**1.8**		**2.3**		**2.9**		**3.7**		**4.8**	

WPF:		Fluxes		Fluxes		Fluxes		Fluxes		Fluxes
KNaO	**9.7%**		**8.5%**		**7.3%**		**6.2%**		**5.2%**	
CaO	**17.7%**	27.5%	**15.7%**	24.2%	**13.7%**	21.0%	**11.7%**	18.0%	**9.8%**	15.0%
Al_2O_3	**23.2%**		**20.5%**		**17.8%**		**15.3%**		**12.8%**	
SiO_2	**49.3%**		**55.3%**		**61.1%**		**66.8%**		**72.2%**	

Dia56.JPG

Stull 0.5 Al_2O_3 1.8 – 4.8 SiO_2 cone 7 and cone 9



Dia57.JPG

Why bother?

Dia58.JPG

The WPF approach allows to generate target limits with higher precision and application value and as such better predict the nature of a glaze

Dia59.JPG

On top of that research has shown:

- A clear link between the total flux content and the optimal firing temperature of a glaze

Dia60.JPG

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- A total flux content up to 23% and a KNaO content limited to 6%, even more so in case of 3%:
  - Increases stability
  - Increases durability (particularly surface hardness)
  - Reduces the chance of glaze stains to destabilize
  - Reduces the tendency of crazing

Dia61.JPG

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- Up to 2.5% of magnesium oxide is having a profound influence on:
  - fusion
  - crystallization
  - the range of glaze compositions that will melt between cone 4 and 7, but also below cone 4

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  - Reduces the tendency of crazing
- Up to 2.5% of magnesium oxide is having a profound influence on:
  - fusion
  - crystallization
  - the range of glaze compositions that will melt between cone 4 and 7, but also below cone 4
- The KNaO % in relation to the KNaO : CaO ratio allows to predict the degree of crystallization and as such whether a stable shiny or matte glaze will be obtained

Dia63.JPG

WPF Target Limits

WPF Target Limits for **Stable Shiny <u>Calcium</u> Glazes Cone 4 - 10**

Cone	Total Flux*	KNaO **	CaO		B_2O_3	MgO	$Al_2O_3 : SiO_2$	Best results: High Durability: 23% fluxes or less. Not more than 6% KNaO, 3% or less works better
4	28 – 25%	2 - 3%			5 - 6%	1 -2%	1 : 4 - 1 : 4.2	Glaze stain stability:: Not more than 6% KNaO, 3% or less works better
5	26 - 23%	2 - 3%			4 - 5%	1 -2%	1 : 4 - 1 : 4.2	
6	25 - 22%	2 - 3%			2 - 3%	1 -2%	1 : 4 - 1 : 4.2	400 mesh quartz and whiting
7	24 - 20%	2 - 4%	Various amounts	0 - 5% ZnO, SrO or BaO to the expense of CaO	0 - 1%	1 - 2.4%	1 : 4.2 - 1 : 5	cone 4 - 9 (10) nepheline syenite
8	22 - 19%	3 -5%			0%	1 - 2%	1: 4.4 - 1: 5.5	cone 7 - 10 sodium feldspar
9	21 - 18%	3 - 6%			0%	1 - 1.5%	1 : 4.6 - 1: 6	cone 9 – 10 potash feldspar
10	20 – 17%	3 - 6%			0%	1 - 1.5%	1 : 4.8 - 1: 7	Up to 25% kaolin for biscuit in combination with CMC gum

* Less fluxes are needed in case of an increasing amount of Li_2O, CuO, MnO_2, FeO, Fe_2O_3, TiO_2, CoO

** Type of glazes: 1 – 3.5% KNaO Lime Glazes

3.5 – 8% KNaO Lime-Alkali Glazes

WPF Target Limits for **Stable Shiny <u>Zinc</u> Glazes Cone 3 - 5**								Best results:
Cone	Total Flux*	KNaO **	ZnO	CaO	B_2O_3	MgO	$Al_2O_3 : SiO_2$	High Durability: 23% fluxes or less. Not more than 6% KNaO, 3% or less works better
3	26 - 24%	6- 7%	8 - 10%		?	1 %	1 : 6 - 1 : 6.5	Glaze stain stability:: Not more than 6% KNaO, 3% or less works better
4	25 - 23%	6 -7%	6 – 8%	Various amounts	?	1 %	1 : 6 - 1 : 6.5	400 mesh quartz and whiting
5	24 - 21%	6 - 7%	4 – 6%		?	1 %	1 : 6 - 1 : 6.5	Nepheline syenite

* Less fluxes are needed in case of an increasing amount of Li_2O, CuO, MnO_2, FeO, Fe_2O_3, TiO_2, CoO

** Type of glazes: 3.5 – 8% KNaO Zinc-Alkali Glazes

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WPF Target Limits for **Stable <u>Calcium Alumina Matte </u>Glazes Cone 4 - 10**

Cone	Total Flux*	KNaO**	CaO	B_2O_3	$Al_2O_3 : SiO_2$	Best results:
						High Durability: 23% fluxes or less. Not more than 6% KNaO, 3% or less works better
4	31 – 27%			2 - 4%		Glaze stain stability:: Not more than 6% KNaO, 3% or less works better
5	30 - 26%	3-9%		1 -3%	**1 : 3**	
6	29 - 25%			0 - 2%		325 - 400 mesh quartz and whiting
7	28 - 23%		Various amounts	0 - 1%		cone 4 - 9 (10) nepheline syenite
8	26 - 22%			0%		cone 5 - 10 MS 200
9	23– 21%	3 - 7%		0%	1 : 3	cone 6 – 10 potash feldspar
10	22 – 20%			0%		Up to 25% kaolin for biscuit in combination with CMC gum

* Less fluxes are needed in case of an increasing amount of Li_2O, CuO, MnO_2, FeO, Fe_2O_3, TiO_2, CoO

** Type of glazes: 1 – 3.5% KNaO Lime Glazes
3.5 – 8% KNaO Lime-Alkali Glazes
8 – 10% KNaO Alkali-Lime Glazes

WPF Target Limits for **Calcium Silica Matte** Glazes **Cone 4 - 10**						Best results:
Cone	Total Flux*	KNaO **	CaO	B_2O_3	$Al_2O_3 : SiO_2$	High Durability: 23% fluxes or less. Not more than 6% KNaO, 3% or less works better
4	31 – 27%	3-9%	Various amounts	2 - 4%	**1 : 5**	Glaze stain stability: Not more than 6% KNaO, 3% or less works better
5	30 - 26%			1 -3%	**1 : 5**	
6	29 - 25%			0 - 2%	**1 : 5**	325 - 400 mesh quartz and whiting
7	28 - 23%			0 - 1%	**1 : 6**	cone 4 - 9 (10) nepheline syenite
8	26 - 22%	3 - 7%		0%	**1 : 7**	cone 5 - 10 MS 200
9	23– 21%			0%	**1 : 9**	cone 6 – 10 potash feldspar
10	22 – 20%			0%	**1 :10**	Up to 25% kaolin for biscuit in combination with CMC gum

* Less fluxes are needed in case of an increasing amount of Li_2O, CuO, MnO_2, FeO, Fe_2O_3, TiO_2, CoO

** Type of glazes: 1 – 3.5% KNaO Lime Glazes
3.5 – 8% KNaO Lime-Alkali Glazes
8 – 10% KNaO Alkali-Lime Glazes

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Low Crystallization Rate	
KNaO	KNaO : CaO
1%	1 : 22
2%	1 : 10
2.5%	1 : 7.1
3%	1 : 5.5
3.5%	1 : 4.4
4%	1 : 3.6
4.5%	1 : 2.9
5%	1 : 2.4
5.5%	1 : 2
6%	1 : 1.7
7%	1 : 1.3

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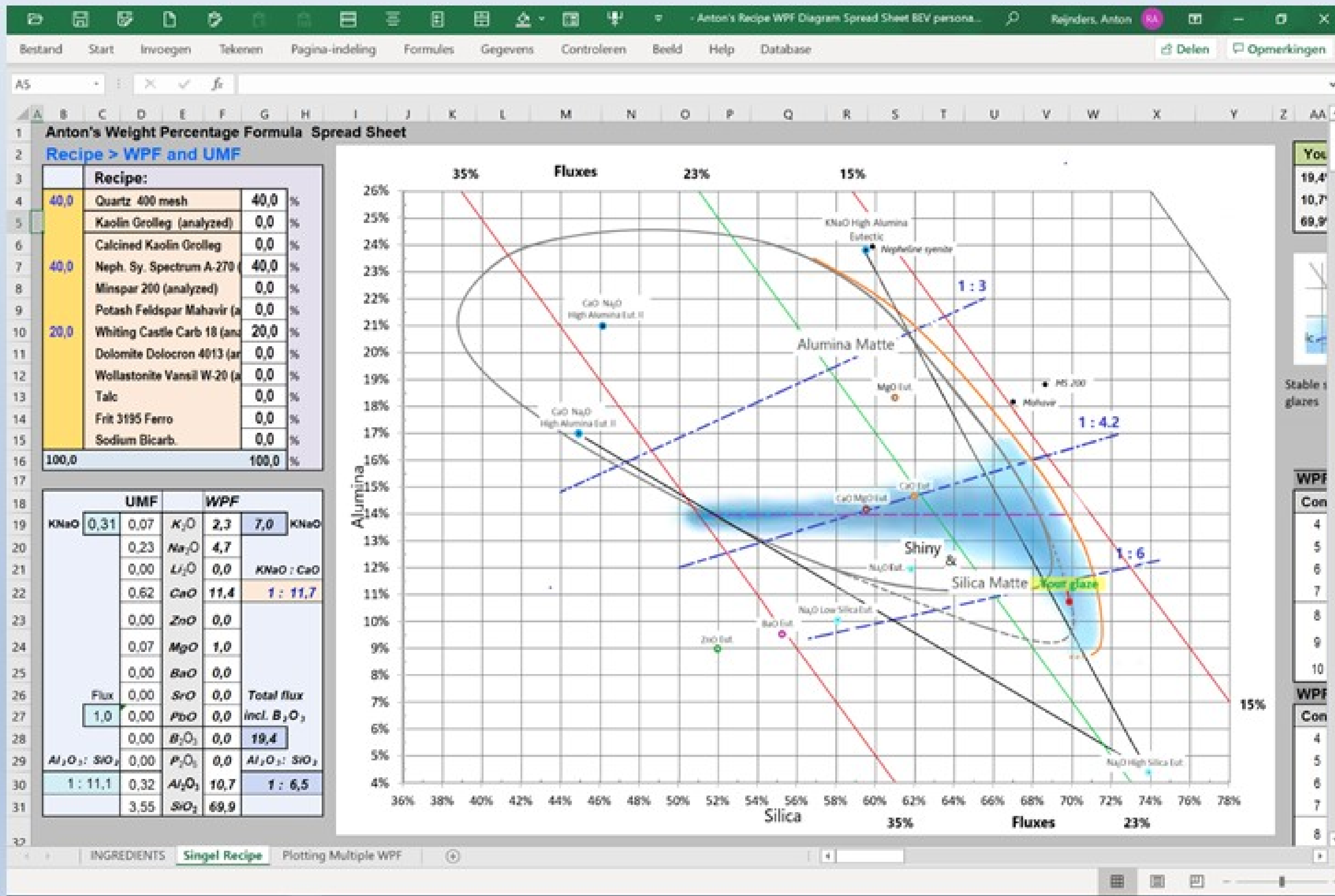
WPF Glaze Calculation Spread Sheet
&
WPF Diagram



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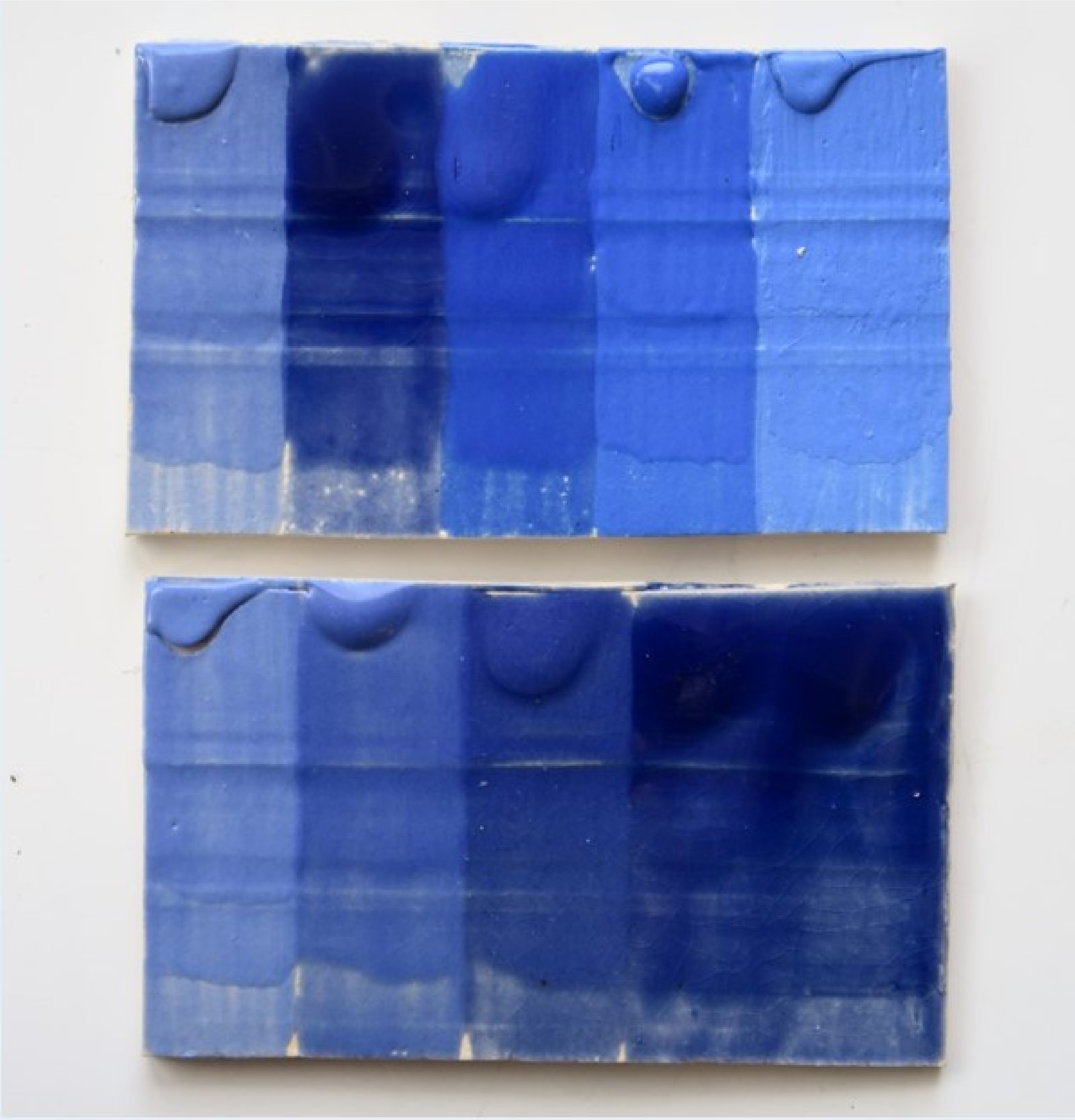
Observations:

- The readiness to fuse is not determined by their molecular make-up of a glazes alone; ingredient choice and their particle size have a big impact as well
- Within all temperature ranges neither feldspar nor nepheline syenite help to obtain full fusion (low viscosity)
- **An alumina-silica ratio of 1 : 6.2 (1 : 10 according to the UMF) is generally assumed to be working well for shiny glazes. This is true for cone 10 feldspatic glazes and mid-range zinc glazes**
- Mid-and high range Lime glazes and low- and mid-range calcium-boron glazes need a relative high alumina / kaolin content to turn shiny
- Silica matte glazes for cone 8 and beyond are more challenging to make stable

Dia71.JPG



Cone 4

40 – 40 – 20 – Quartz + ZnO

40 – 40 – 20 – Quartz + ZnO 9%

Observations:

- The readiness to fuse is not determined by their molecular make-up of a glazes alone; ingredient choice and their particle size have a big impact as well
- Within all temperature ranges neither feldspar nor nepheline syenite help to obtain full fusion (low viscosity)
- An alumina-silica ratio of 1 : 6.2 (1 : 10 according to the UMF) is generally assumed to be working well for shiny glazes. This is true for cone 10 feldspatic glazes and mid-range zinc glazes
- **Mid-and high range Lime glazes and low- and mid-range calcium-boron glazes need a relative high alumina / kaolin content to turn shiny**
- Silica matte glazes for cone 8 and beyond are more challenging to make stable

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Cone 4

40 – 40 – 20 + Fr 3124

40 – 40 – 20 + Fr 3124 + Kaolin - Quartz

Observations:

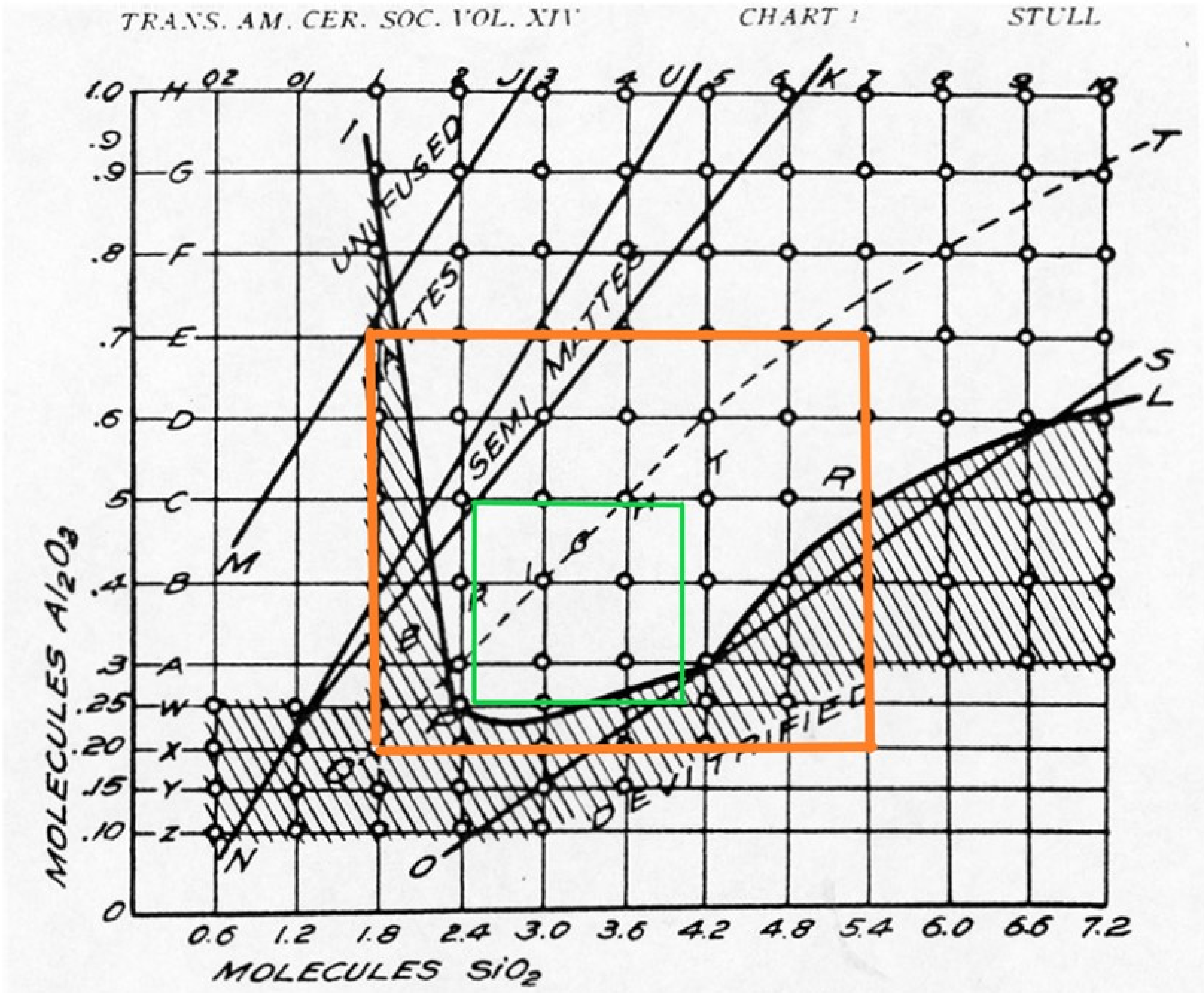
- The readiness to fuse is not determined by their molecular make-up of a glazes alone; ingredient choice and their particle size have a big impact as well
- Within all temperature ranges neither feldspar nor nepheline syenite help to obtain full fusion (low viscosity)
- An alumina-silica ratio of 1 : 6.2 (1 : 10 according to the UMF) is generally assumed to be working well for shiny glazes. This is true for cone 10 feldspatic glazes and mid-range zinc glazes
- Mid-and high range Lime glazes and low- and mid-range calcium-boron glazes need a relative high alumina / kaolin content to turn shiny
- **Silica matte glazes for cone 8 and beyond are more challenging to make stable**

Dia75.JPG

Observations:

- The readiness to fuse is not determined by their molecular make-up of a glazes alone; ingredient choice and their particle size have a big impact as well
- Within all temperature ranges neither feldspar nor nepheline syenite help to obtain full fusion (low viscosity)
- An alumina-silica ratio of 1 : 6.2 (1 : 10 according to the UMF) is generally assumed to be working well for shiny glazes. This is true for cone 10 feldspatic glazes and mid-range zinc glazes
- Mid-and high range Lime glazes and low- and mid-range calcium-boron glazes need a relative high alumina / kaolin content to turn shiny
- Silica matte glazes for cone 8 and beyond are more challenging to make stable

Dia76.JPG


TRANS. AM. CER. SOC. VOL. XIV
CHART 1
STULL
UNFUSED
MATTES
SEMI MATTES
BRIGHT
DEVITRIFIED
MOLECULES Al_2O_3
MOLECULES SiO_2
1.0 H
.9 G
.8 F
.7 E
.6 D
.5 C
.4 B
.3 A
.25 W
.20 X
.15 Y
.10 Z
0
0.6
1.2
1.8
2.4
3.0
3.6
4.2
4.8
5.4
6.0
6.6
7.2
02
01
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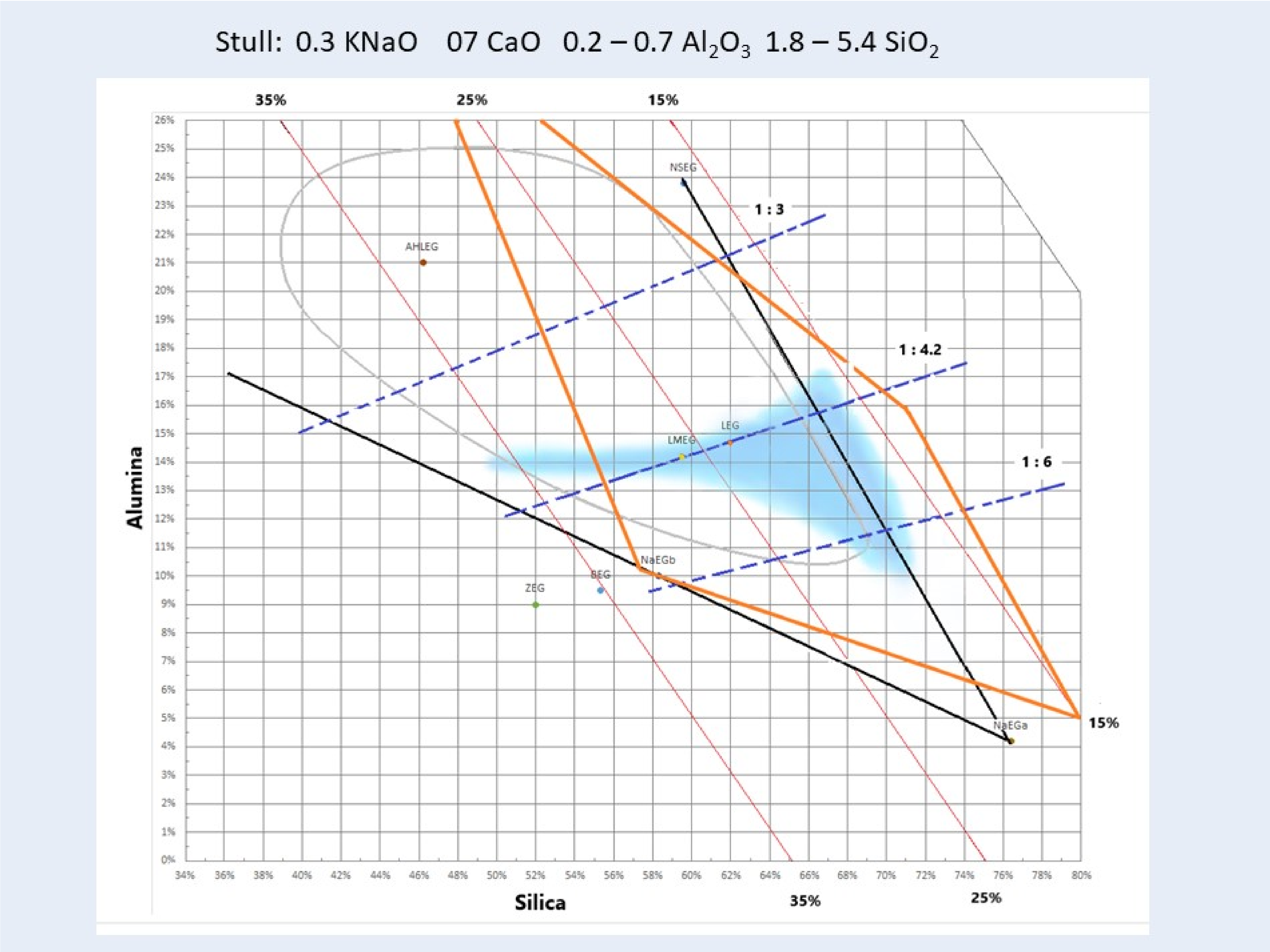
Dia77.JPG



Stull: 0.3 KNaO 07 CaO 0.2 – 0.7 Al_2O_3 1.8 – 5.4 SiO_2
35%
25%
15%
NSEG
1 : 3
AHLEG
1 : 4.2
LEG
LMEG
1 : 6
NaEGb
BEG
ZEG
15%
NaEGa
Alumina
Silica
35%
25%
26%
25%
24%
23%
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3%
2%
1%
0%
34% 36% 38% 40% 42% 44% 46% 48% 50% 52% 54% 56% 58% 60% 62% 64% 66% 68% 70% 72% 74% 76% 78% 80%