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Rochester Institute of Technology

A Thesis Submitted to the Faculty of  
The College of Fine and Applied Arts  
in Candidacy for the Degree of  
MASTER OF FINE ARTS

COLOR me RAKU

By

Penelope Fleming

5/1/79

APPROVALS

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\_\_\_\_\_  
\_\_\_\_\_

Date 7/15/79

This thesis is dedicated to the people behind the scenes. Firstly to Tim, my husband, who has had the patience to understand me and my various endeavors. To Hobart Cowles who encourages my spirit and realizes my frustrations. To Christina, who sat on my lap while every page of this dissertation was being composed and written. And to all seven of the stain companies who were more than generous with their written information, plant tours and consultations.

Ceramic Color & Chemical

Ferro Corporation

Harshaw Chemical Company

Hercules Incorporated

Mason Color & Chemical Works

O. Hommel Company

Pemco Products

A sincere appreciation is extended to all of those mentioned above!

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## Introduction

One has to live with the idea of writing a thesis before executing it. It's time to change the massive stacks of papers, shards, color charts and sketchbook notations into one coherent statement. Now the question is how to begin and where to end? This thesis centers around color, assumes form and relates ideas. Having felt more comfortable with form, the basic concentration will be with that uneasy area of color.

## I. In the beginning....color....frustration

It was safe to stay with old forms and ideas when first working in the RIT studio. But as I change so do my pieces. The recent move and other personal awarenenses drastically affected my thinking and therefore my work. I was now designing more subtle curves and less hard edged pieces. The forms required a more personalized palette of pastel colors as opposed to my previous involvement with metallic and lusterous raku glazes. Commercial stains had always intrigued me and seemed to be a viable way to proceed. It was decided to center my thesis around these colorants after it became apparent that they were relatively unavailable and hard to research.

RIT's selection of stains was rather limited so testing was done with stains already obtained elsewhere. One must realize that these stains are basically composed of pure colorant oxides and therefore are rather expensive (ranging from \$4.00 to \$9.00 per pound). No local distributors were available so the manufacturers were contacted by mail to obtain color charts and price lists.

Frustration seemed to grow more intensely as time marched through Rochester's long winter. Alternative markets were sought other than the direct manufacturers. Why not go to the companies who used dry inorganic stains in



quantity and buy directly from them? It was better in theory than practice. Local paint, plastic and printing industries were researched and visited for sample selections. Their dry inorganic pigments were tested at cone 08 (the temperature used for my raku glazes) but they mostly turned from primary and secondary colors to red iron oxide brown when fired. Apparently the written information which advertised them as being inorganic pigments referred only to their partial iron content and omitted the organic pigments which gave them their beautiful unfired color. In the firing cycle the inorganics burned out and iron oxide was the resulting colorant.

Two stains did work, however, and yielded a bright yellow at cone 10 ox. Miracles never cease! After one of those long rather inclusive meetings with Hobart it was discovered that the yellow came from the Drakenfeld Company, a previous supplier of RIT and producer of ceramic stains.

Since the previous alternative industries had been rather obliging to my small needs, it was decided that maybe the stain industries would also be receptive. Since previous mail correspondence with them was nearly uneventful, it was decided to go and visit them.

One must face the facts when working with industry. Potters in the U.S.A. comprise only one percent of the total nation's clay industry. To avoid being unanswered, forgotten or just overlooked, it is far better to phone companies for information rather than to write them. I went one step further and made appointments in hopes of

discovering more conclusive information.

## II. The Stain Industry

The stain manufacturers were extremely varied in size from basically being a family business of six efficient employees to being a complex of factories, loading docks and staffs of hundreds. They all, however, went through the same basic but individualized procedures for stain production. Most also produced frits and supplied inorganic chemicals.

Nearly all of the stains used today were produced as far back as the nineteenth century in Europe. Many of our seven U.S.A. stain companies are direct descendants of their European ancestors. England and Germany used to be the world centers for stain production due to Europe's heavy chinaware industry. But after World War I subsidiaries or independent individuals came from Europe to the United States to begin stain companies. Since eastern Ohio and adjoining western Pennsylvania were then our clay center for the country, most of these new companies settled in this basic area.

No new companies have been established since 1932. Similarly, relatively few new stains have been produced since 1950. Stain industries basically supply commercial factories who produce hotel china, tiles and other commercial clay products. Potters are unfortunately last on the

list of clientele since we comprise a very small percentage of the nation's clay industry.

Each factory had different types of kilns, ball mills, pulverizers, drying bins, kiln controls, etc. Most of the kilns were electric to provide a true oxidizing environment. Those that were gas fired usually fired the stains in saggers. Kilns ranged from one cubic foot to large, car-loaded, tunnel types with capacities of 200 cubic feet. Some were continuous firing, round and straight kilns while others were rotating barrel types. All factories kept the various stain colors separated by room or areas to avoid contamination and all had extensive testing laboratories.

These laboratories scaled the entire factory production down to a studio potter's level with small kilns and believably sized ball mills. Most laboratories were run by chemical engineers (some ceramic engineers) and other related staff. Extensive testing is continuously done by full time employees to improve color, to reformulate patents, to improve firing ranges and to stimulate new and better results. All laboratories had kilns with registering pyrometers, precise temperature climb read-out tapes and cards to control exact firing schedules.

All information gathered was received from the plant tours, sales brochures, priced lists, other written information plus verbal questions while touring. The general consensus from most manufacturers visited was that I would never be able to formulate my own stains in an



unsophisticated, untechnical, non-laboratory environment as typical of a studio potter. But they all wished me luck and gave me a great deal of information that I could not have been able to obtain if I had not actually visited them. At least I had a start now.

Here is a list compiled as of 1978 which states the founding dates, accessibility of color charts, price list availability and the minimum order required per stain color. Note the addresses and current telephone numbers of the seven stain companies.

For fast results it is best to call the company on the phone and relate what temperature and atmosphere (oxidation or reduction) you are firing at and what color of stain you desire. Color charts are hard to obtain due to the printing cost but price lists are somewhat more easily obtainable. Most of these companies have priced their minimum orders above what universities and especially the studio potter can financially afford.

## Chart 1. Stain Availability

Stain Company	founded in USA	color chart	price list	minimum order per stain
Ceramic Color & Chemical PO Box 297 New Brighton, Penn. 15066 412-846-4000	1927	yes	yes	10 lb.
Ferro Coatings Division 4150 East 56th St. PO Box 6550 Cleveland , Ohio 44101 216-641-8580	1931	hard to get	yes	25 lb.
Harshaw Chemical 1945 East 97th St. Cleveland, Ohio 44106 216-721-8300	1932	not current	yes	20 lb.
Hercules Incorporated Drakenfield Colors PO Box 519 Washington, Penn. 15301 412-225-5600	1919	hard to get	yes	10 lb.
Mason Color & Chemical Works PO Box 76 250 East Second St. East Liverpool, Ohio 43920 216-385-4400	1902	no	not current	1 lb.
O. Hommel Company PO Box 475 Pittsburgh, Penn. 15230 412-923-2233	1891	no	yes	20 lb.

## Chart 1. Stain Availability (cont'd.)

Stain Company	founded in USA	color chart	price list	minimum order per stain
Pemco Products 5601 Eastern Ave. Baltimore, Md. 21224 301-633-6400	unknown	yes	yes	25 lb.

### III. Zirconium-Vanadium Stain Research

A stain could be a single oxide but is usually a combination of oxides and other chemicals such as flint or alumina. These compounds are mixed, calcined and pulverized to yield a highly stable colorant which will resist the affect and attack of fluxes and molten glazes.

An easily researchable stain such as a chrometin pink would have been a wise choice. Instead a zirconium-vanadium stain was chosen as it would yield a multitude of different colors (turquoise blue, green and yellow). Confusion came when working with the many variables. Hindsight is always so much more astute than foresight.

Much research was done to uncover stain information from the past. These particular combinations of zirconium and vanadium oxides have been on the ceramic stain market for some thirty-five years. The first zirconium-vanadium stain to be used in industry was yellow.<sup>1</sup> This yields a relatively weak yellow as compared to the stronger tin-vanadium yellow. The turquoise blue, however, was the most popular zirconium-vanadium stain and dates back to 1946.<sup>2</sup> A good zirconium-vanadium green is somewhat more difficult to obtain so industry mixes together the tin-vanadium yellow and the zirconium-vanadium blue to yield a stronger green.

There is not a great deal of easily accessible

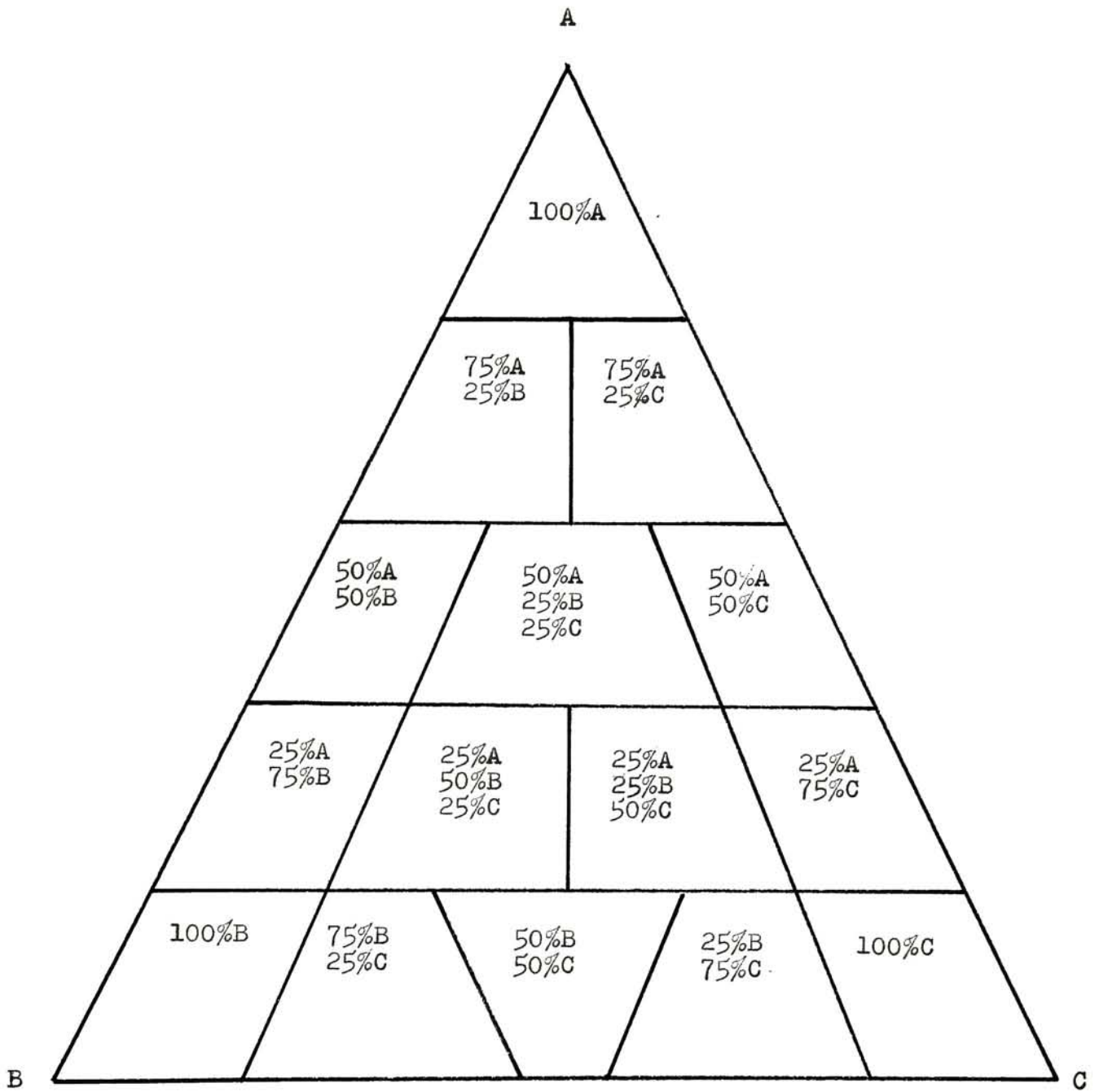


information concerning stain formulation and especially concerning zirconium-vanadium stains. But after compiling all of the data accumulated it was decided to approach this stain formulation from a triaxial method. Chart II, shows the triaxial blending chart which was used throughout my research. Within these three end points (A, B, and C) there would be twelve other possibilities calculated by the various 25%, 50%, and 75% variations of the original three end points. This triaxial blending chart is a good process to use when wanting to cover a great deal of information. It did, however, require an enormous amount of precise weighing and thorough mixing.

Through my initial research two basic approaches were followed for formulating these various zirconium-vanadium stains. No matter which route was taken the theory remained the same. Vanadium oxide was dispersed in the union of zircon and silica which when calcined formed a zirconium silicate,  $\text{ZrSiO}_4$ . When the vanadium oxide was literally protected by this outer lattice of zirconium silicate a very stable, large crystal was formed which yielded a strong colorant.<sup>3</sup> The difference of approach centered around the type of vanadium oxide used. In my color triaxials ending in odd numbers (771, 773, 781, etc.) vanadium pentoxide,  $\text{V}_2\text{O}_5$  was used. In the even triaxials (772, 774, 782, etc.) ammonium metavanadate,  $\text{NH}_4\text{VO}_3$ , was used.

Where to start? My initial research was based on patents. I remember being more than delighted to finally find them but was at the same time rather disillusioned as

## Master Triaxial Chart



their parameters of variance were so great. Clarence A. Seabright's patent for a zirconium-vanadium blue to green stated that  $\text{ZrO}_2$  could range from 35% to 80%,  $\text{SiO}_2$  could range from 10% to 55% and that  $\text{V}_2\text{O}_5$  could range from 3% to 17% parts by weight. He stated that  $\text{V}_2\text{O}_5$  or  $\text{NH}_4\text{VO}_3$  could be used. Blues occur in the presence of a fluoride while greens should not have such a reagent. Calcination could occur from  $550^\circ\text{C}$  to  $1300^\circ\text{C}$  and range from two to six hours in a neutral or oxidizing environment.<sup>4</sup>

Opax was used as my first source of zircon.

$\text{ZrO}_2$	89.84
$\text{SiO}_2$	6.74
$\text{TiO}_2$	.09
$\text{Al}_2\text{O}_3$	.61
$\text{BaO}$	.01
$\text{CaO}$	.07
$\text{MgO}$	.18
$\text{CuO}$	.002
$\text{K}_2\text{O}$	.02
$\text{Na}_2\text{O}$	.82
$\text{P}_2\text{O}_5$	.04
$\text{MnO}_2$	.001
$\text{F}$	.18
LOI	.67

This gave a 89.84% purity of zircon. Flint was used for the  $\text{SiO}_2$  and as described previously, the odd triaxial series used  $\text{V}_2\text{O}_5$  and the even series used  $\text{NH}_4\text{VO}_3$ .

For simplicity of documentation, color charts were constructed to describe the colors of the formulated stains as they appeared after calcination and particle pulverizing. Please refer to the Master Triaxial Chart for basis of percentages. Notice the position arrangements of the end points (A, B, and C) on all individually labeled color charts.

Here are the contents of triaxial 771 and 772.

## 771

	A	B	C
ZrO <sub>2</sub>	54	75	65
SiO <sub>2</sub>	40	23	31
V <sub>2</sub> O <sub>5</sub>	6	2	4

## 772

	A	B	C
NH <sub>4</sub> VO <sub>3</sub>	5	8	2
ZrO <sub>2</sub>	62.5	50	70
SiO <sub>2</sub>	30	40	23
NaF	0	2	5

Both 771 and 772 offer similar relationships between the SiO<sub>2</sub> and ZrO<sub>2</sub>. More blues were produced in areas that used more NaF. Both triaxials favored more blues in the overlapping areas where the ZrO<sub>2</sub> increased from 66 to 75 as the SiO<sub>2</sub> decreased from 30 to 26.

Blues were also more dominant in 772 where the NH<sub>4</sub>VO<sub>3</sub> was used instead of the V<sub>2</sub>O<sub>5</sub> as in 771.

Series 773 was based on the blue section (B section)

of 771.

## 773

	A	B	C
ZrO <sub>2</sub>	66	75	70
SiO <sub>2</sub>	30	23	27
V <sub>2</sub> O <sub>5</sub>	4	2	2.8

What had turned out with a bluish color in 771 turned out with a greenish tint in 773. Even the same percentages did not come out similarly. The 773 triaxial limited the variance of ZrO<sub>2</sub>, V<sub>2</sub>O<sub>5</sub> and SiO<sub>2</sub> as compared to the larger limits of 771. As a result there were more beiges and brown tones.

The 774 triaxial decreases the percentage limits of all four chemicals used as contrasted to the 772 series.

## 774

	A	B	C
NH <sub>4</sub> VO <sub>3</sub>	5	6.8	2
ZrO <sub>2</sub>	62.5	55	75
SiO <sub>2</sub>	30	36	20
NaF	0	1.2	0

It was designed to see the influence of a very small percentage of NaF as it only appeared in one of the end points. When comparing the side running from A to C which uses no NaF to the side stretching between A and B which had the larger amounts of the available NaF there was no difference. From this triaxial the small quantity (1.2%) of NaF seems to be insignificant. Again the NH<sub>4</sub>VO<sub>3</sub> yielded

stronger colors than the  $V_2O_5$ .

Treopax was used in 775 and 776.

$ZrO_2$	91.51
$SiO_2$	5.32
$TiO_2$	.68
$Fe_2O_3$	.08
$Al_2O_3$	.36
BaO	.01
CaO	.03
MgO	.02
CuO	.002
$Na_2O$	.98
$P_2O_5$	.03
$MnO_5$	.002
LOI	.97

This gave a purer  $ZrO_2$  content and changed it to 91% pure.

775 contained:

	775		
	A	B	C
$V_2O_5$	5	3	2
$ZrO_2$	62	72	75
$SiO_2$	31	23	20
NaF	1.2	0	0

Triaxial 776 used the same chemicals and percentages as 775 only substituted  $NH_4VO_3$  in for 775's usage of  $V_2O_5$ .



By comparing the above charts it can be seen that the  $\text{NH}_4\text{VO}_3$  produced more blues. The importance of flint and zirconium oxide is also stressed as the color difference does not depend greatly on the varying percentages of  $\text{V}_2\text{O}_5$  or  $\text{NH}_4\text{VO}_3$ .

The 77 group of stains displayed some repeated similarities. The odd series using  $\text{V}_2\text{O}_5$  are generally milder in color than that of the even series using  $\text{NH}_4\text{VO}_3$ . Whenever the ratios of silica to zircon approached 1 to 2 the color resulted in beiges and browns. Larger percentages of  $\text{V}_2\text{O}_5$  and  $\text{NH}_4\text{VO}_3$  (above 4 percent) do not significantly increase the color intensity.

The calcination cycles for the 77 series range from a four to six hour soak in an electric kiln at a stabilizing temperature of approximately  $900^\circ\text{C}$ . The various cycles tried did not seem to drastically alter the color if the above limits were observed.

Experimentation was done with various mixing and grinding procedures. The end points (A, B, and C) were dry ball milled from thirty minutes to two hours. Wet milling in slurry form was also tried. This particular milling process did not work well as the NaF was soluble in  $\text{H}_2\text{O}$  and would therefore migrate to the top of the mixture. Thorough mixing played a very important part in calcination as the chemicals needed to be next to each other for crystal formation.

Ball milling was done again after calcination to produce a more uniform particle size. Again dry milling worked better than wet milling.

Regardless of the calcined color the stains were then tested as a 20% mixture in my slip. Test tiles were air-brushed with the slip and glaze, and then fired via the raku process. The results were an extremely weak blue or green without approximating the intensity of the calcined color. In other words, I was making great paint stains but had not yet made a reliable kiln-fired stain.

There are so many variables when formulating these stains that it was almost impossible to detect where the mistake lay. So rereading and research was done. All this confirmed the fact that the problem might center around the oxides used. So a new batch of  $\text{NH}_4\text{VO}_3$  was purchased and Treopax was replaced with a purer form of zirconium oxide whose particle size was also larger, 10 - 14 microns.

$\text{ZrO}_2 + \text{HFO}_2$	98.0
$\text{SiO}_2$	.15
$\text{TiO}_2$	.15
$\text{Fe}_2\text{O}_3$	.02
$\text{SO}_3$	1.00
$\text{LiO}$	1.50

Triaxial 780 was then tested. It was the same as 774 with the substitution of the purer zirconium oxide. The results were not terribly exciting visually as only the sections surrounding B yielded blues and greens. But when tested as a 20% masstone (i.e. 20% stain without an opacifer) the colorants were three times stronger than the 77 series. Where more  $\text{NH}_4\text{VO}_3$  was used the



stronger the intensity of color. Also note that the blue was concentrated directly around the B point where the highest concentration of NaF (1.2) was located and that as its percentage decreased more greens evolved.

The 781 triaxial was just like the 775 triaxial with the substitution of the purer zirconium oxide. Notice that the greens were stronger with the increased percentages of  $V_2O_5$ . This was the last triaxial done using  $V_2O_5$ . It proved that  $NH_4VO_3$  yielded more intensity in colors than  $V_2O_5$ .

Triaxial 782 contained:

	A	B	C
$NH_4VO_3$	.4	3	2
$ZrO_2$	62	72	75
$SiO_2$	31	23	20
NaF	6	0	0

This triaxial stretched the limits of 780 to include a larger amount of the purest  $ZrO_2$  and NaF. It decreased the percentage limits of  $SiO_2$ . It used the largest percentage of NaF and also yielded the most intense blue thus far. Sections 4 - 6 also create a strong row of green.

But most interesting of all, there has been a total reversal of what happened in the 77 series. Previously when the range of approximately 70% of  $ZrO_2$  plus 30% of  $SiO_3$  in combination with a vanadate were used together a blue was produced. But in the 78 series this same combination yielded browns. Conversely, when the  $ZrO_2$  was used with  $SiO_2$

in a 2:1 proportion plus a vanadate and NaF in the 77 series a brown resulted. But now in the 78 series blues resulted.

Triaxials 784 and 786 zero in on this 2:1 ratio of  $\text{ZrO}_2$  to  $\text{SiO}_2$ . Triaxial 784 contained:

	A	B	C
$\text{NH}_4\text{VO}_3$	4	7	2
$\text{ZrO}_2$	62	66	58
$\text{SiO}_2$	31	27	35
NaF	10	8	6

This triaxial used the purer zirconium oxide while triaxial 786 was just the same as 784 only it used purer zirconium oxide (listed below).

$\text{ZrO}_2 + \text{HFO}_2$	99
$\text{SiO}_2$	.15
$\text{TiO}_2$	.15
$\text{Fe}_2\text{O}_3$	.02
$\text{SO}_3$	.25
LOI	.30

Both of these triaxials emphasize the necessity of NaF and  $\text{NH}_4\text{VO}_3$ . Also note the limits of the range of blue development.

The 78 triaxials had revised firing cycles. The kiln was controlled to reach the soaking temperature in three to four hours. Calcination temperatures ranged from  $760^\circ\text{C}$  to  $940^\circ\text{C}$ . Soak time ranged from four hours to four times that of the 77 triaxials. Temperature change was regulated only by cones and pyrometers and was therefore rather difficult

to record subtle changes that could have been more easily recorded on a read-out tape. The best results in soaking ranged from 790°C to 870°C for a period of eight to sixteen hours. This type of calcination resulted in better colors, larger crystal formation and stronger masstone. Only oxidizing electric kilns were used throughout the research.

The actual mixing of the materials was critical. Ball milling (wet and dry), vibramixing on a Thermolyne machine by Sybron Corporation, stirring and grinding with a pestle and mortar were all employed. Mixing times ranged from one minute to two hours. The best results came from dry milling the three end points of each triaxial separately with small amounts of grinding medium (for one-half hour). This assured a homogeneous mixture without reducing the particle size. Then the various 25%, 50% and 75%'s of A, B, and C were respectively combined and shaken up in a closed plastic container for a very few seconds. This assured homogeneous mixing of the ten gram sample amounts of all fifteen sections of each triaxial.

Extensive testing was done in the grinding procedure of the calcined stains. Those which used over 6% of NaF came out of the kiln as a fused mass and therefore required up to two hours of grinding to give uniform particle size. Dry milling and pulverizing were used. Wet milling did not serve as an advantage with such small quantities. Dry ball milling worked well with 50 gram batches while a small pulverizer worked well with the ten gram batches.

All stains were tested at 20% masstone value in my slip

and were airbrushed with glaze and raked to simulate the actual process involved. Strengthened purity of greens and blues was sought. I wanted the color of the calcined stain to match the color of the 20% masstone slipped and glazed test tile. The overall results of the 78 triaxials far surpassed those of the 77 triaxials. There were some stains which showed promising results but further testing was still needed.

Before drawing any conclusions please see triaxials 777, 778, 788 and 7810. These centered around the formulation of a vanadium yellow. These yellows can be made by a multitude of ways.<sup>5</sup> First a zirconium-vanadium yellow was tried and then a tin-vanadium yellow was explored.

Triaxial 777 contains:

	A	B	C
ZrO <sub>2</sub>	95	93	97
V <sub>2</sub> O <sub>5</sub>	4	5	6
TiO <sub>2</sub>	2	0	0
SnO <sub>2</sub>	0	3	5
SiO <sub>2</sub>	0	0	2

I used Treopax as the ZrO<sub>2</sub> source. The usage of titanium dioxide worked as a stabilizer. Best colors resulted from the combination of ZrO<sub>2</sub> + V<sub>2</sub>O<sub>5</sub> + TiO<sub>2</sub> without SnO<sub>2</sub> and SiO<sub>2</sub>.

Triaxial 778 contained the same percentages as 777 only NH<sub>4</sub>VO<sub>3</sub> was used instead of V<sub>2</sub>O<sub>5</sub>. One other change was that 778's C point of NH<sub>4</sub>VO<sub>3</sub> was reduced to 4.5. The result was brighter golds especially in sections one through six of



778.

Here are the contents of 788:

	A	B	C
$\text{SnO}_2$	95	85	90
$\text{NH}_4\text{VO}_3$	5	15	10
$\text{TiO}_2$	2	4	6

Triaxial 7810 was the same as 788 only the 99% pure  $\text{ZrO}_2$  was used instead of the tin oxide. The range of the  $\text{ZrO}_2$  and  $\text{SnO}_2$  went from 85% to 95% and was therefore more encompassing than that of 777 and 778. Larger amounts of  $\text{NH}_4\text{VO}_3$  and  $\text{TiO}_2$  were also used in the 78 series. The greater amount of golds occurs in the 788 triaxial but more yellows occur in 778. Notice how point A is very similar in its percentages in both 778 and 788.

All four yellow triaxials were calcined to  $1225^\circ\text{C}$ . The 78 series was soaked for twelve hours while the 77 series was soaked for six hours. The masstone, color purity and strength was far better in the 78 series than the 77 series.

All fifteen initial triaxials were completed, pulverized down to uniform particle size, tested as a 20% masstone in the slip, glazed and then rakued. At that time the calcined color was compared to that of the glazed test tiles. Those stains which had the highest saturation strength, color similarity and purity were retested via another elaborate series of line blends. The best results came from thorough dry mixing, purity of chemicals, kiln control and milling.

By the end of my research there had been over five-hundred tests completed. Final stains resulted in achieving an eight percent masstone. As can be seen in triaxials 782, 784, 786, 788 and 7810 yellows, greens and turquoise blues had been achieved. Great pleasure especially came from discovering the rather evasive zirconium-vanadium green without having to rely on a three to one part mixture of tin-vanadium yellow and zirconium-vanadium turquoise.

The ratio of  $ZrO_2$  to  $SiO_2$  drastically changed for all three colors. Turquoise relied on a 2 to 1 ratio while green worked best with a 3 through 3.5 to 1 ratio. Both found 4% of  $NH_4VO_3$  to be adequate. Turquoise worked best with NaF up to 6% while greens resulted best if the NaF was left out. Unnecessary fluxing resulted if more than 6% of NaF was used. Yellows were at their best without flint. Instead a large amount of  $ZrO_2$  (over 92%) was used in combination with 5% of  $NH_4VO_3$ . Titanium dioxide stabilized the reaction well from 2 to 3 percent.

Overall conclusions resulted from constant and endless testing. Assumptions were never taken for granted. Patience won over all other virtues. It is my hope that the rest of this thesis will go beyond all of this chemistry to intuitively express my ideas. Any gaps that may occur can be judged by the pieces themselves.

#### IV. Surface

The processes of raku, airbrushing and stenciling were used to achieve surface treatment. Imagery acts as the physical and emotional vehicle to carry the implied colors. Much research has been done in color theory in combination with my own intuitive color sense to control the choice of colors.<sup>6</sup>

The usage of color is presently the most direct measurement of my own aesthetic growth. When first using stains, pastel colors were employed creating an ethereal feeling. But now consideration goes to the natural grays, blacks, whites and the yellow-browns of the reduced clay body in conjunction with corresponding stain colored slips. I have come to realize that everything has color and not just the stains bought or made. Much more scrutinizing attention has been given to the colors of the reduced raku clay body. These are now taken as a premise, controlled in the reduction cycle and made to fit the stain colors.

Stains are added to the slips instead of glazes to allow for a matt appearance. Highly glossy surfaces have given way to a dry surface which implies deeper surface illusion and therefore more control over color.

The same colors could easily be used again and again but I attribute color success to always testing new



combinations. Vibrance was achieved via highly contrasting colors but low level vibrance can also be exciting by the use of more subtle hue change. Continually mixing together new stains to achieve just the right shade, tone and tint was done. New colors, different combinations and new imagery help express my changing ideas.

But most of all, one cannot get so involved with stain research or free samples of new colors that the pieces become obscured by the surface treatment. One cannot be so attuned to color theory that the form becomes camouflaged. The stains and glazes used are only effective when they show sensitivity to the forms which they cover. Each form must be evaluated in terms of pattern and color treatment. The vessel orientated pieces have the option of brighter colors and greater hue variation. More sculptural pieces require less imagery and more achromatic colors. My motto is to use less color as opposed to more and to stop while you are ahead when glazing.

Color is applied in such a way that one has to turn the piece around or pick it up to discover all of the subtleties. An evenly air brushed surface has never intrigued me. So the usage of imagery carries the color and breaks up the surface.

Non-figurative imagery is used. Sometimes the images float in and out to create depth while others seem to occupy their own space. Depending on the spacing they can be independent in nature or accumulate to create interior contours and unity. Some overlap and some are off-registered just enough to create the illusion of depth.



It could be said that these images are decorative but I prefer to think of them as personalized characters which achieve life and depth of meaning through no usage of figurative gesture. They are related to the form and the color they carry.

Air brushing starts with the hundredth piece. Even if one is lucky in the beginning they will pay for that luck sooner or later. One cannot get so caught up in the process of glazing that they become insensitive to new feelings. Therefore glazing is the one area which needs my undivided attention. When glazing I want to be free of outside thoughts and alone. It is the time when all of my testing, color theory, stain technology and intuitive senses come together to hopefully personalize the piece.

The form usually speaks for itself but the color creates the mood. Much thought is given to the imagery chosen and the specific colors applied to the piece. Paper stencils were used but I have discovered the usage of vinyl material or naugahyde to be much more efficient. Dies are made from piping which is punched through the material to give the negative imagery. The plastic side of the vinyl is then placed against the bisqued pot and secured with clothes pins. Slips are then airbrushed through the stencil to give a positive image. The stencil is removed and washed. Transparent glaze is applied where a glossy surface or white is desired.

Here are the various cone 08 slips and glazes I have formulated and used.

## Cone 08 slip variations

	#5	#6	#8	#9
Calcined EPK	15.4	24	10.9	15
EPK	5.5	9.9	12.1	12
Flint	10.5	16.2	21.1	15
Custer potash spar	12.8	12.0	10.9	
Ball clay OM#4	5.1			15
Frit 3124	9.3	14.3		25
Gerstley borate	41.2	6.0	10.9	
Whiting		5.7		
Pumice		11.8		
Frit 3466			32.9	
Total	99.8	99.9	99.6	82
Bentonite	1.5	1.5	1.5	1.5

## Cone 08 glaze variations

	7802	L series	B 7806 I	E 7807 K
3110	80			
Flint	10		2	8
EPK	10	5	7.5	
Frit 3466		90	80	75
Gerstley borate		5	15	20
Pumice				5
Total	100	100	104.5	108
Bentonite	2	2	2	2

The beauty of working with stains is that one can see the fired color of the slips while glazing. One can actually become a painter with their entire palette before them instead of trying to remember that cobalt blue slip looks pink but fires sky blue, etc. This allows for more freedom and a much larger selection of color possibilities because one can see and does not have to remember combinations.

Airbrushing is like throwing when done with care. After much practice one knows how much glaze is on or how thick the wall is without measuring.

The surface is finalized in the firing cycle and local reduction. Raku reduction is like a boxing match. One cannot afford to slip up for one second or else they will be knocked out of the ring. Before I pull that hot pot out of the chamber I must know where and how it is to be reduced. There is only one chance to make it work as refiring is not an advisable route when raku. Thermal shock is best controlled on the first firing only.

Here are the various clay bodies I have used and formulated for raku at cone 08.

## Cone 08 clay body variations

	#1	#2	#3	#4
Goldart	30		25	30
Ball clay OM#4	14	20	20	15
APG Missouri fire clay	14	25	30	25
Jordan	10			
EPK	10	25		
Sand	10		5	10
Grog, 20 mesh	10	12	5	5
Nytal talc		12	15	20
Sagger clay		5		
Spodumene			11	
Total	98	99	100	105

The moral of raku is to do what must be done to achieve the desired surface result. Therefore, I was forced to fire in electric kilns when doing thesis work because RIT's outside area was under reconstruction. It was physically impossible to carry the pieces from the inside electric kilns to the outside for reduction so I reduced in cans inside the adjacent gas kilns. This ultimately forced me to highly control my glazing as it was difficult to control reduction inside the chamber of another kiln. Grays, blacks and especially whites were sometimes regulated by glazing as opposed to carbon impregnation.

Patience was developed due to the longer electric kiln firing cycles. Small kilns were mostly used to allow for more concentration on fewer pieces fired in their chambers. If one wants to do mass production, raku is not the answer. Best results come with few pieces and much concentration. The firing cycle is too exhausting to allow for full control over many pieces during one day's firing.

Electric kilns are not designed well for raku. The elements on the front loading doors are unbearably hot on one's back when pulling the pot out of the chamber. It is like being a human piece of meatloaf wedged between the sandwiched elements of the door and even hotter chamber. A leather welder's tarp, a welder's heat reflective mask and silver surfer gloves were worn to avoid being burnt alive.

I personally feel that "electro raku" is for those who have no other available facilities. I did it only because

there was no other choice and will be happy to return to my own gas fired raku kiln once again.

## V. Don't Forget Form

If color and surface were enough, I would paint. Surface integrity is backed up by its volumetric shape along with its exterior and interior space. The uniting of surface and form creates mood, movement and the inner form or the success of the piece.

The processes of throwing and slab construction are continually interwoven. I have long since been noncommittal as to my priority of one above the other. Instead, I seem to work best when playing one off of the other.

When probing for ideas I feel more comfortable with the given symmetry of the wheel which is later altered with slabs to create a slight off balanced or asymmetrical vessel. Slab construction is more difficult due to its endless possibilities of variation. It calls for more self-direction and invention of idea and therefore is found extremely challenging.

Continual attention is given to the bowl or vessel form as its open shape is critically important from all angles. It is not like a cylinder which is rarely viewed from the top due to its relatively small opening or a plate which is rarely turned over and viewed from the bottom. A bowl form has a large enough opening and a broad outside surface so



that both the exterior and interior surfaces are critically important. That which cannot be seen, the foot, is relatively minimal. I am continually trying to push the vessel form to its furthest possibilities.

The illusions of physical weight, inside surfaces and floating volumes occur repeatedly. The usage of double wall construction gives the appearance of volume and weight, while the actual contact with the floor is minimal. The void between the two walls is not seen but implied due to its varied thickness. The result is a volume which has a great deal of lift and hopefully gives the illusion of flotation.

The edge treatment is critical as it unites the interior to the exterior space. The eye should flow easily from one surface to another. Therefore, soft edges and minimal crispness is attempted to achieve continuity. Hopefully the inside will come out to meet the outside while the more colorful exterior surface will distinguish the two.

Bigger does not mean better. But I do enjoy working with a piece that is an easily hugable circumference for my arms due to its larger surface and double walled construction potential. If larger than that I use components that will allow for easier control yet larger format.



## VI. Around and Around

To love raku one must go beyond the excitement of the fire, flames and the utter physical exhaustion of the glaze firing cycle itself. For me, it is not only the challenge of the above but more importantly, the surface obtained which enhances my forms like no other firing environment could possibly imitate. The process (raku) has to fit the form.

It is extremely difficult to discuss surface and form separately. I start off with realizing the possibilities of the raku surface potential and usually design the form with this in mind. As the piece comes alive so do the color combinations and imagery patterns. When I visualize the form first it is then matched to the colors. At other times color combinations are brought back from the surrounding environment and forms are designed to fit them. The most successful pieces, however, come from ideas and concepts where form and color express a very personal frame of mind.

I find it very difficult to think of new ideas while working in the studio. Instead much time is spent outside of the studio to idea storm and conceptualize. My mind works much faster than my hands, so extensive sketches are recorded for new ideas. Since function is not involved with

raku, the idea is foremost and directly related to the form.

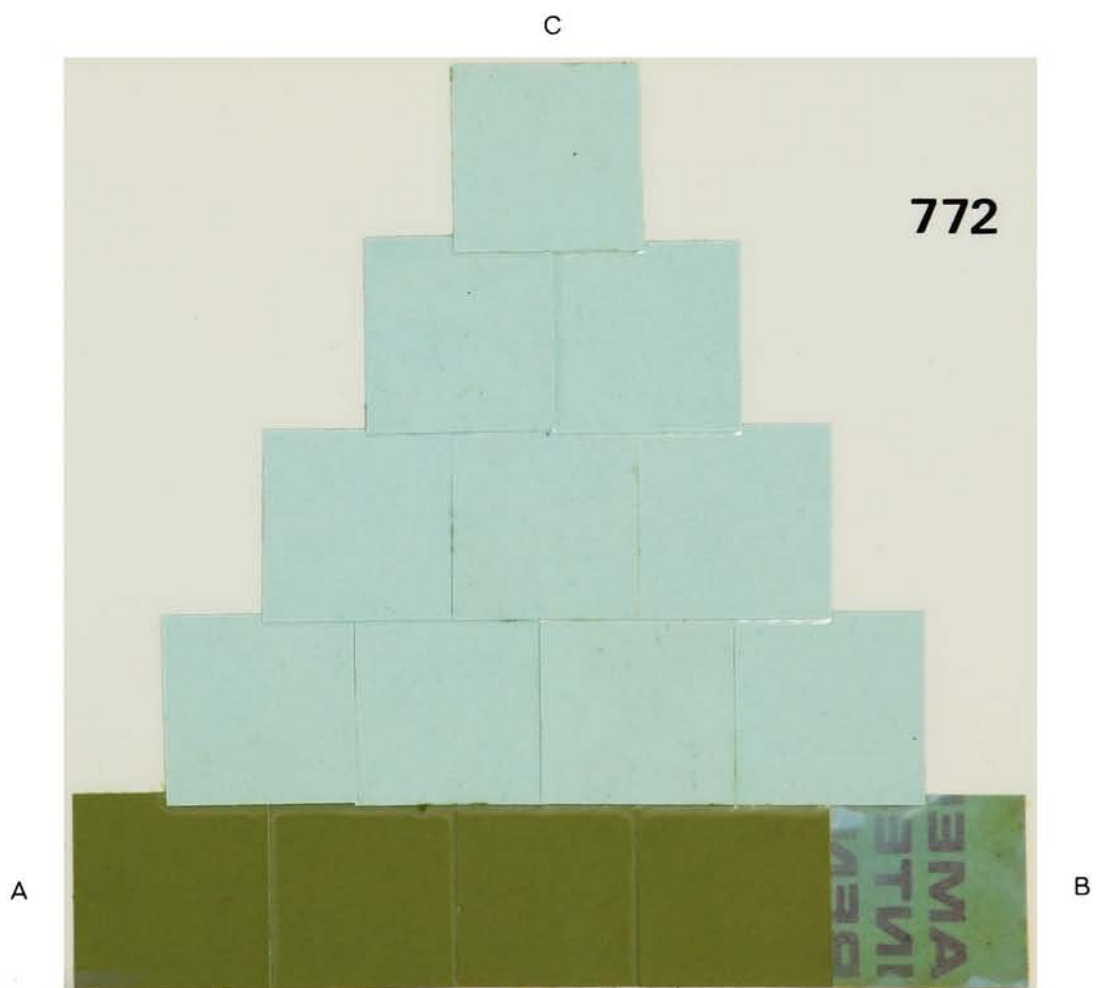
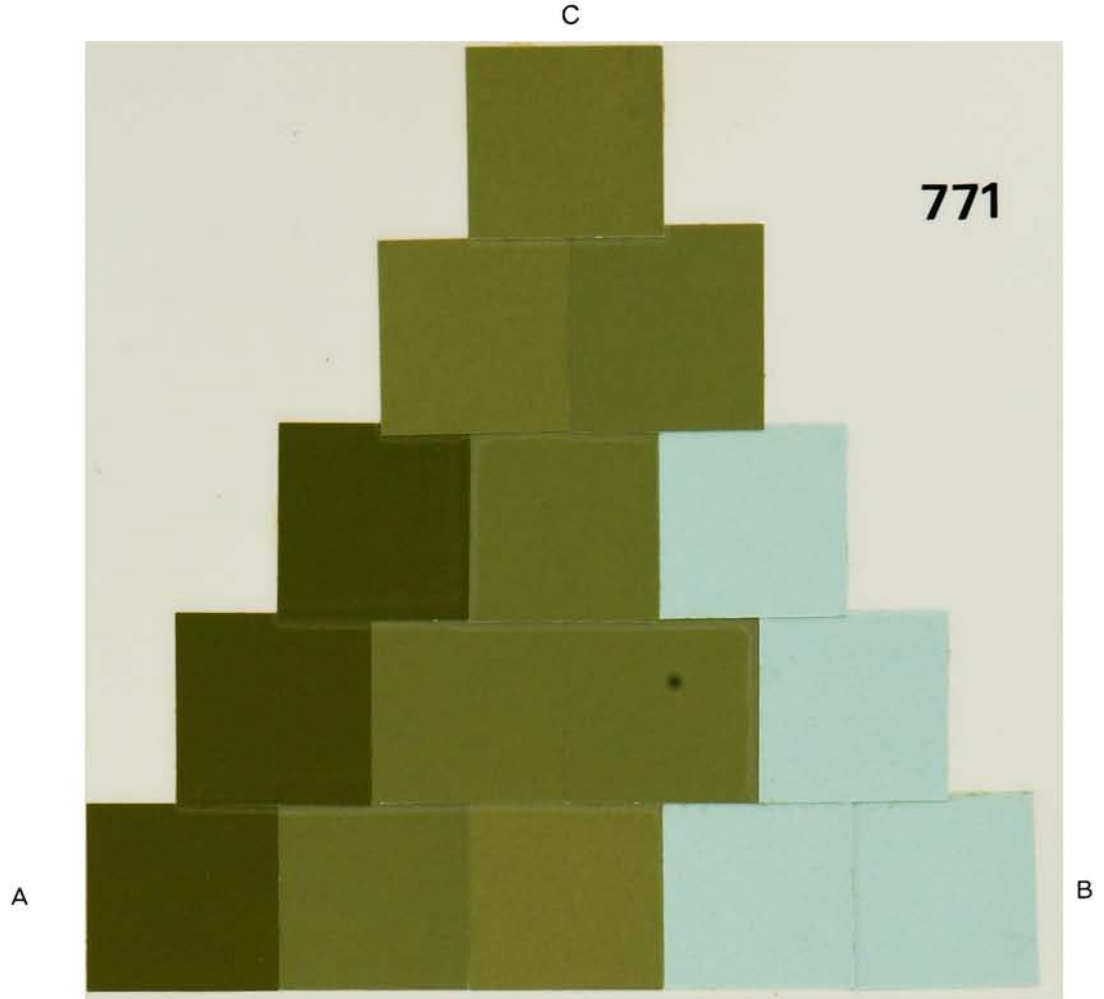
The challenge is found in new ideas while artisanship is sometimes sacrificed. It is then that I must really concentrate on slowing down the thought process to backtrack and materialize former ideas. Effort is then applied to construction control and craftspersonship.

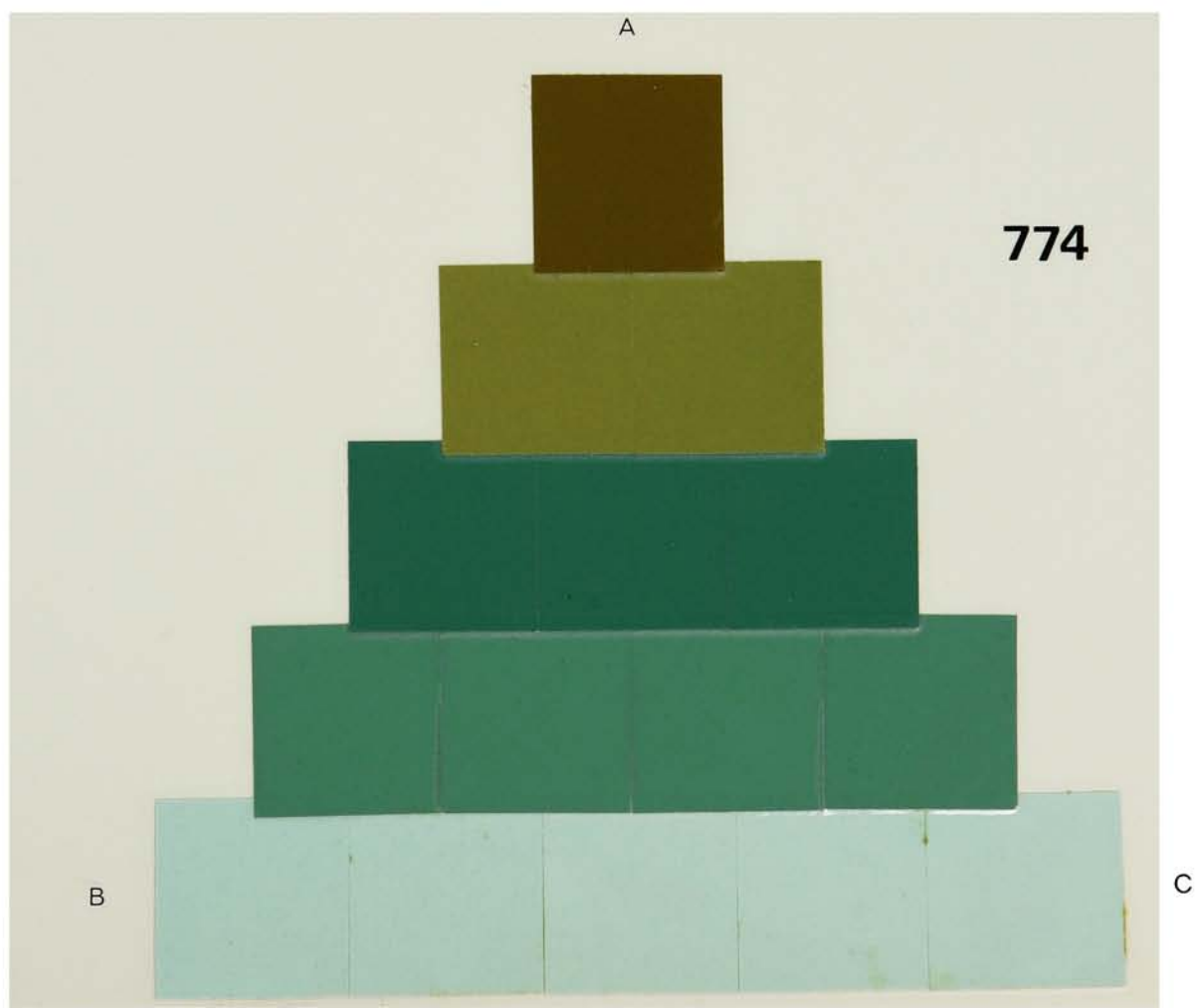
Many pieces afford me mistakes. Usually it takes a very drastic mistake to realize the actual problem. At this point the cycle must be slowed down again and retraced. Usually it is an accumulation of many problems that creates one central problem. One must constantly produce quantity to achieve quality. I make very few good pieces, many mediocre pieces and several dumpster types.

Just when I think I'm in control of color, form, the raku firing, etc., I lose it all. I seem to enjoy the difficult - the combination of form, color and imagery - a definite taboo in the sculptural sense. I am constantly thinking that I should revert back to little color. It would certainly be less complicated and easier. Does color fit the form or does form fit the color? On and on .... But it is this very tension between these elements that keeps me continuing.

If experience has taught me anything, it is that time is the best judge of it all. If that same piece one made three years ago is just as good or better today then chances are it is a successful piece. This thesis has allowed me the rare opportunity to be able to write about

my pieces but I believe that one's work must stand on its own without written documentation to support its visual validity.







A

775

B

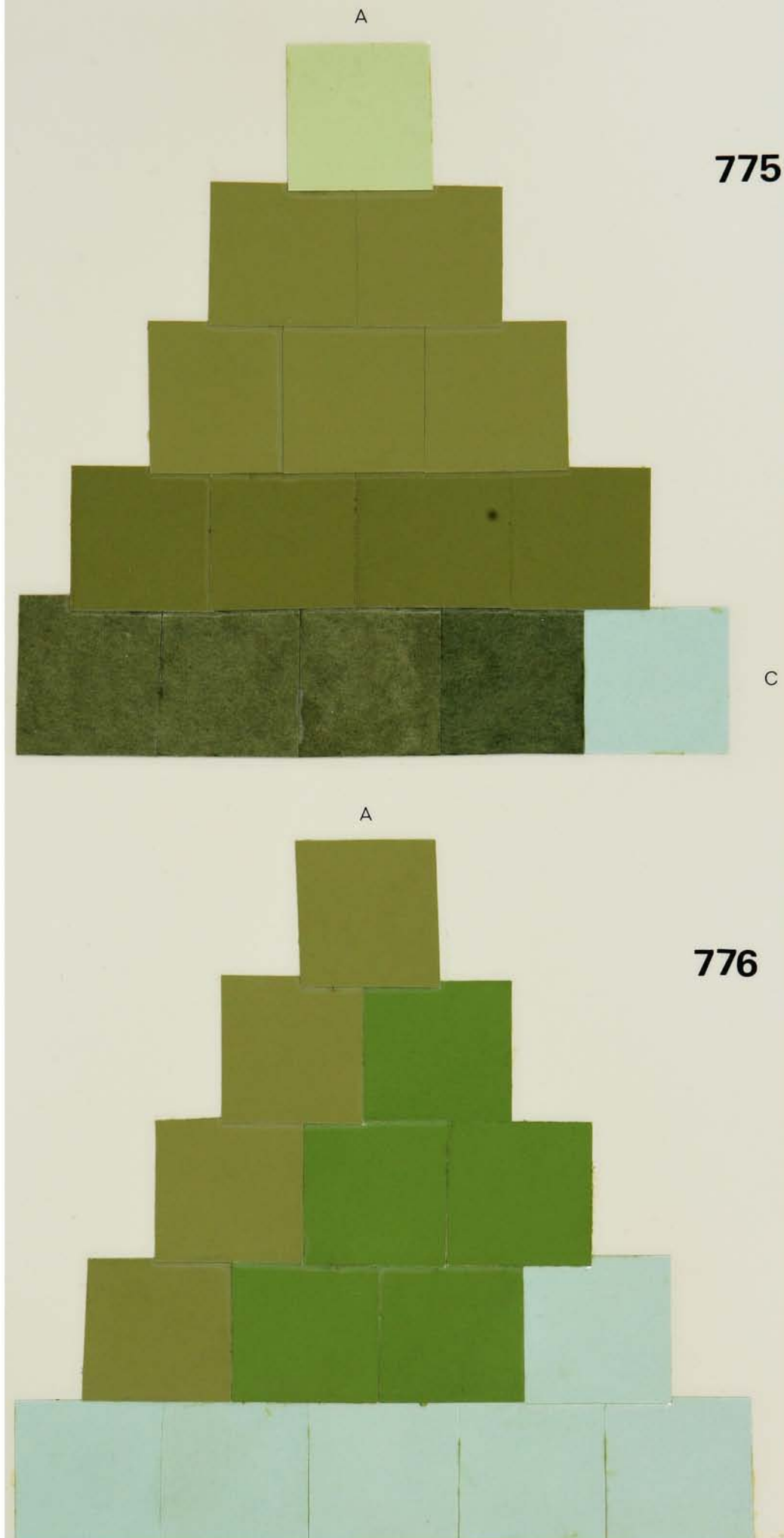
C

A

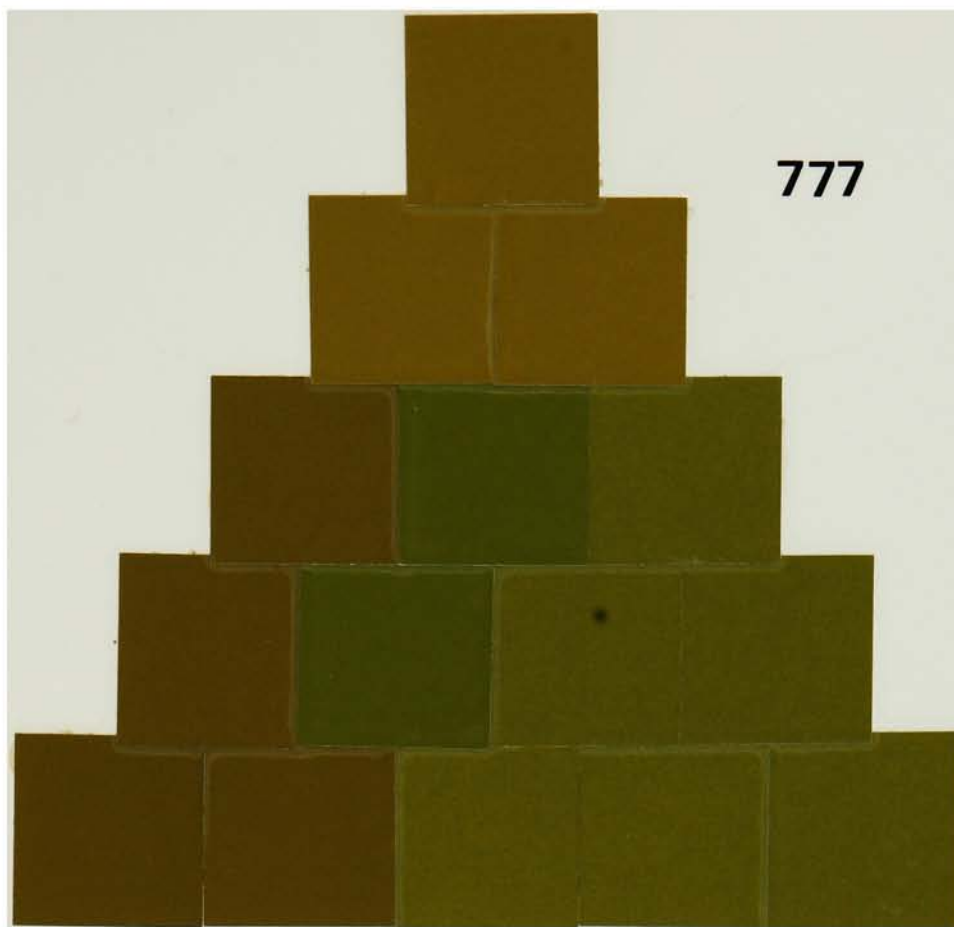
776

B

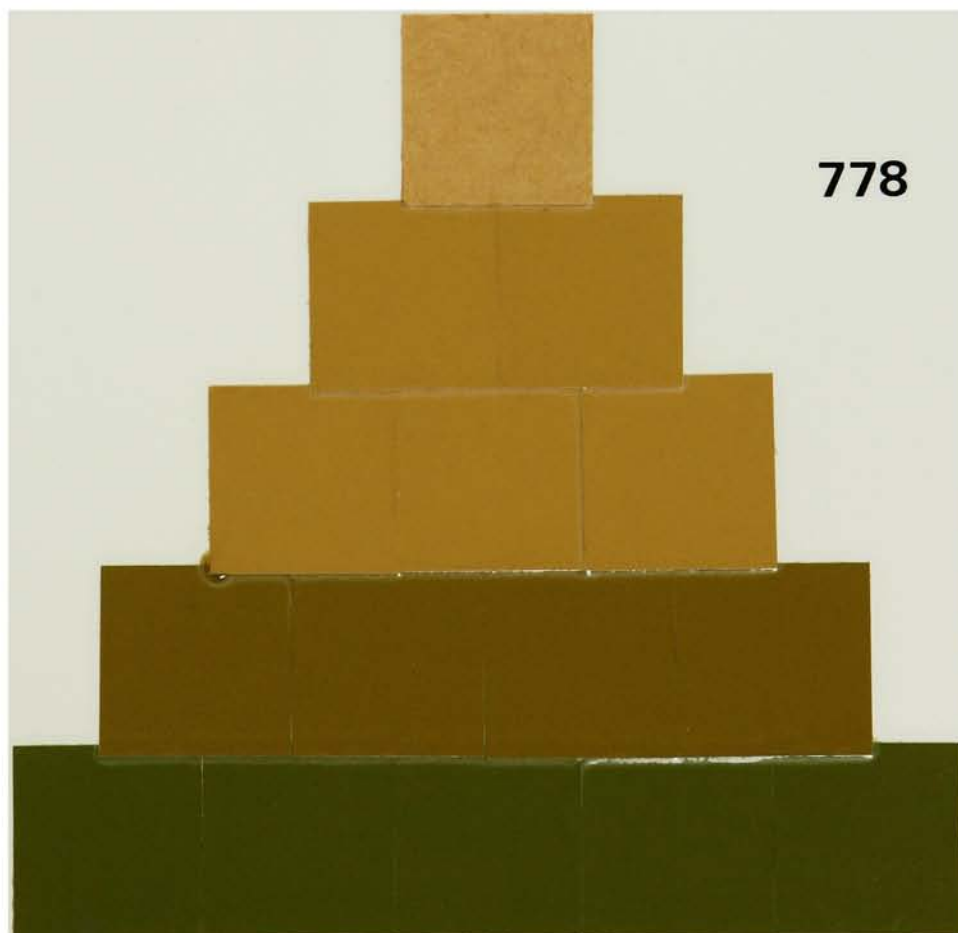
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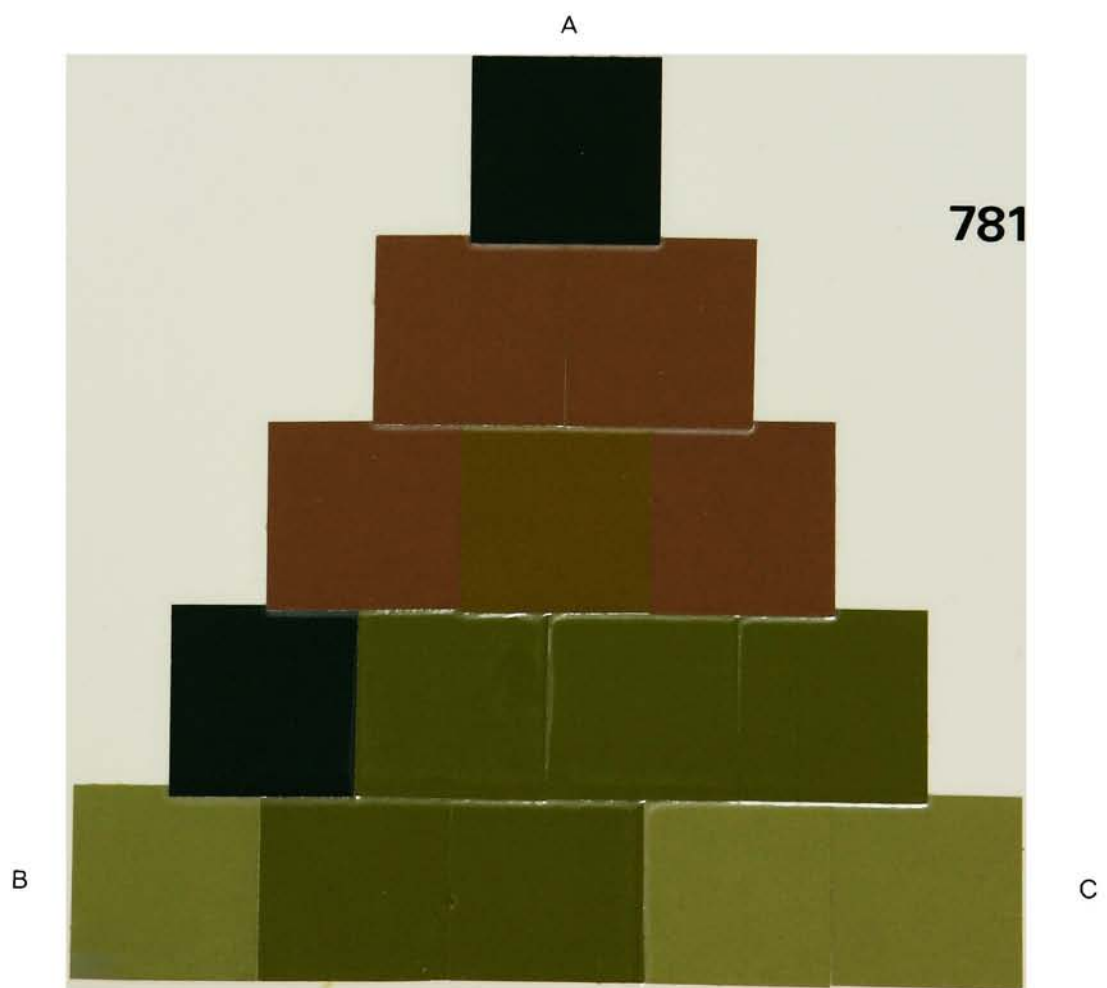
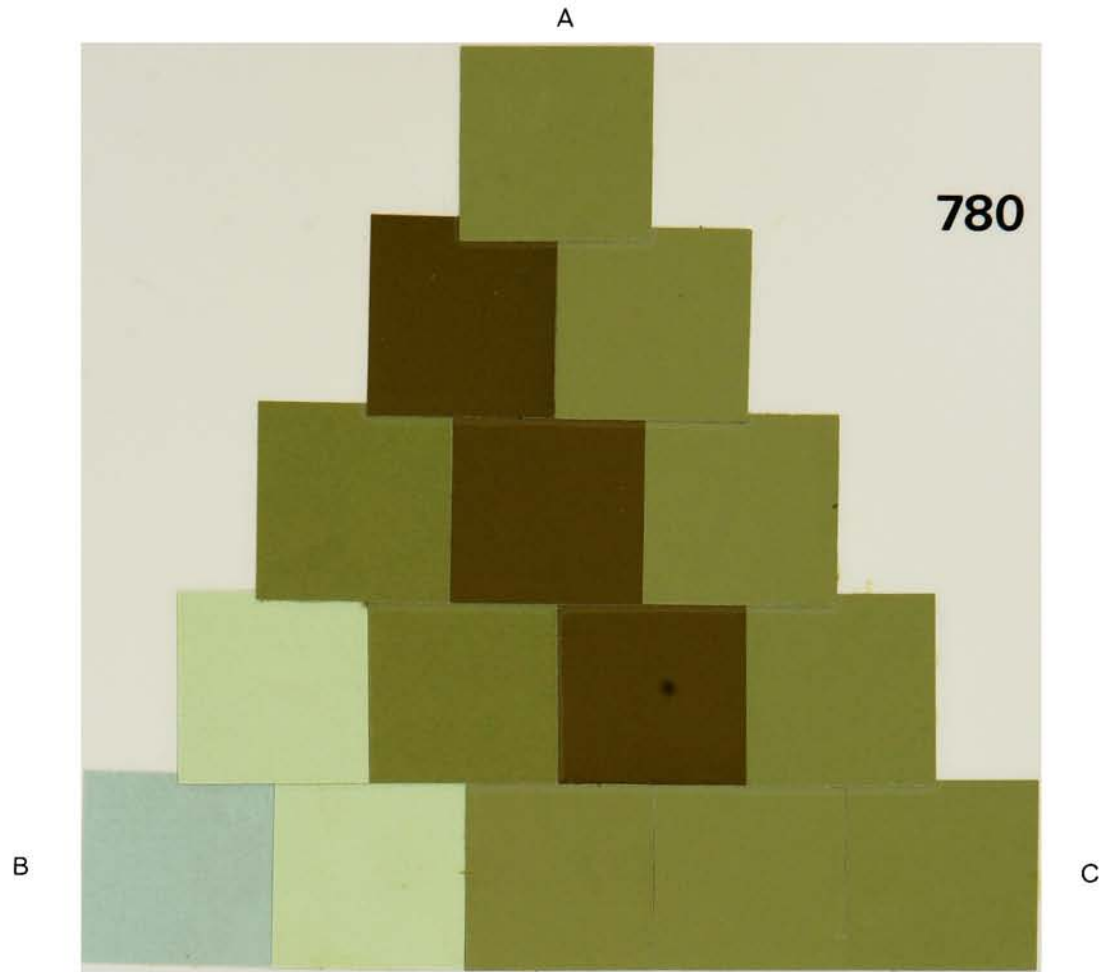


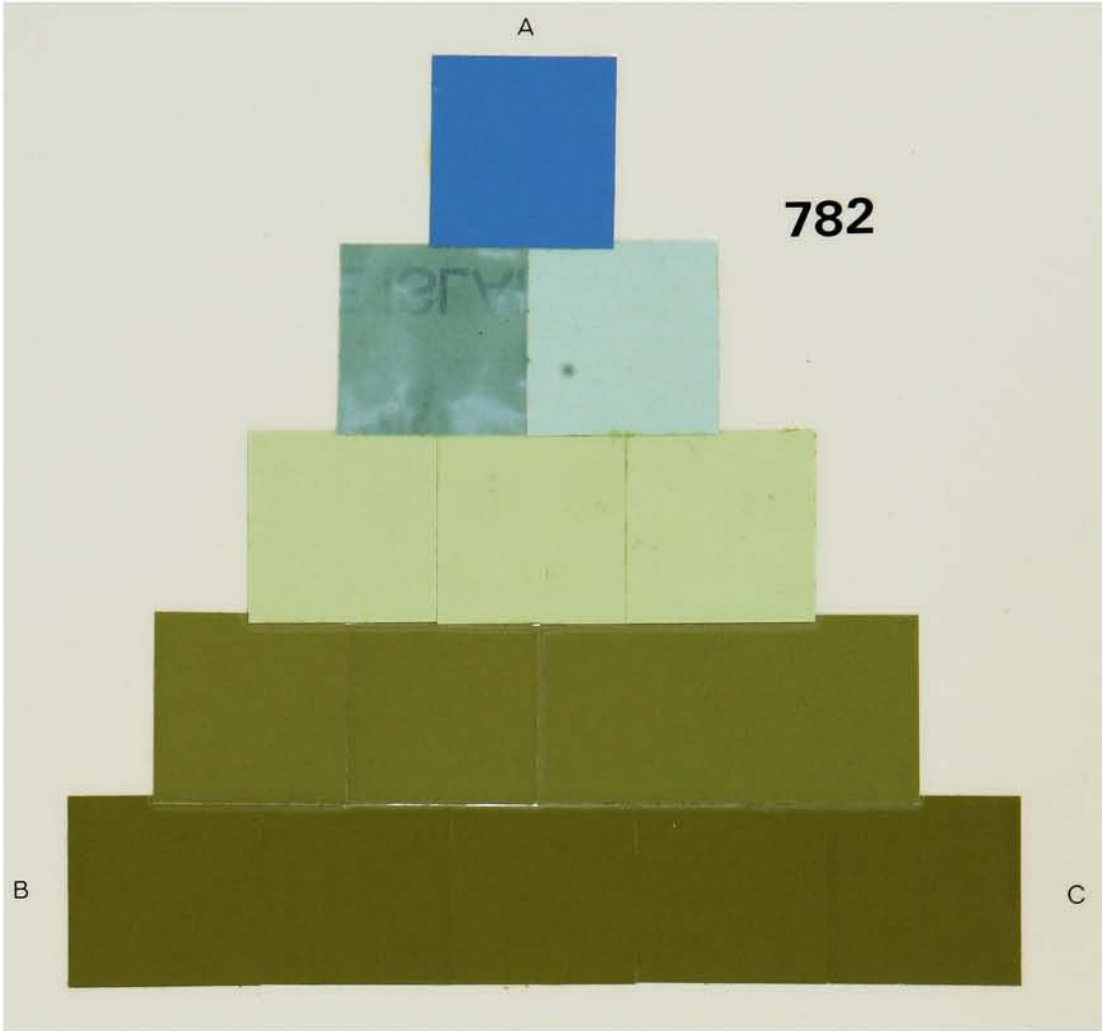
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A





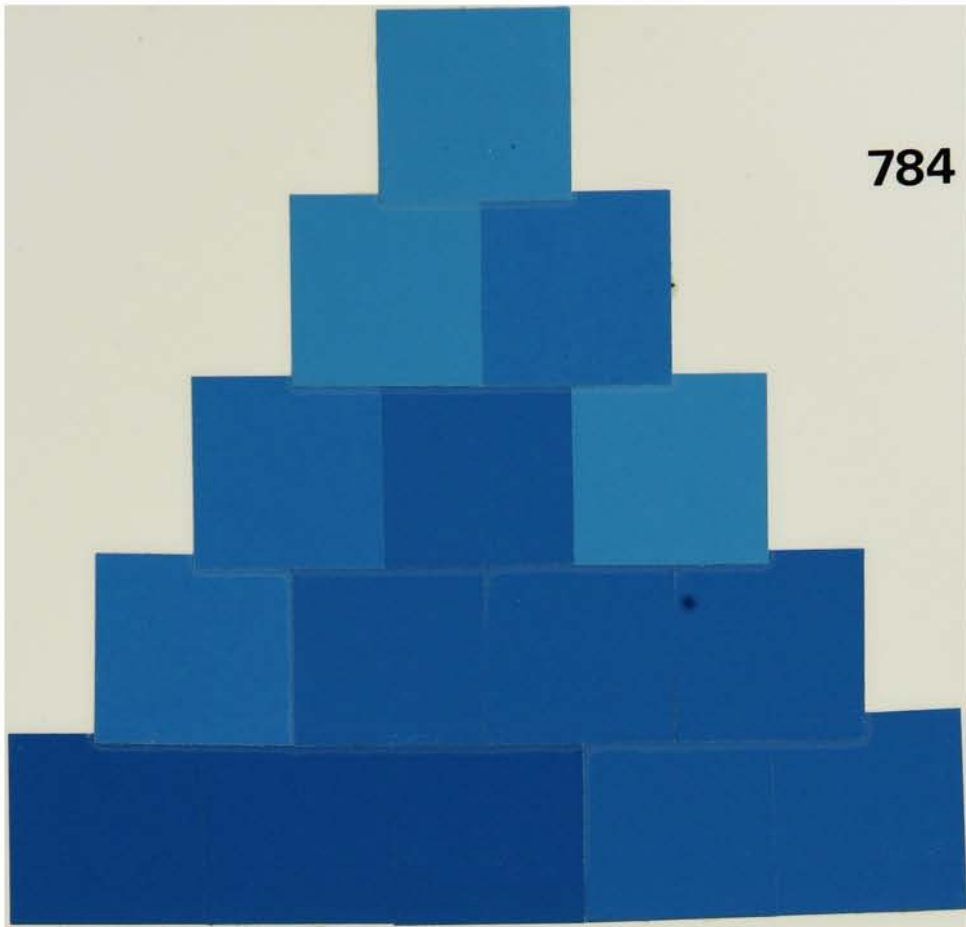


A

784

B

C

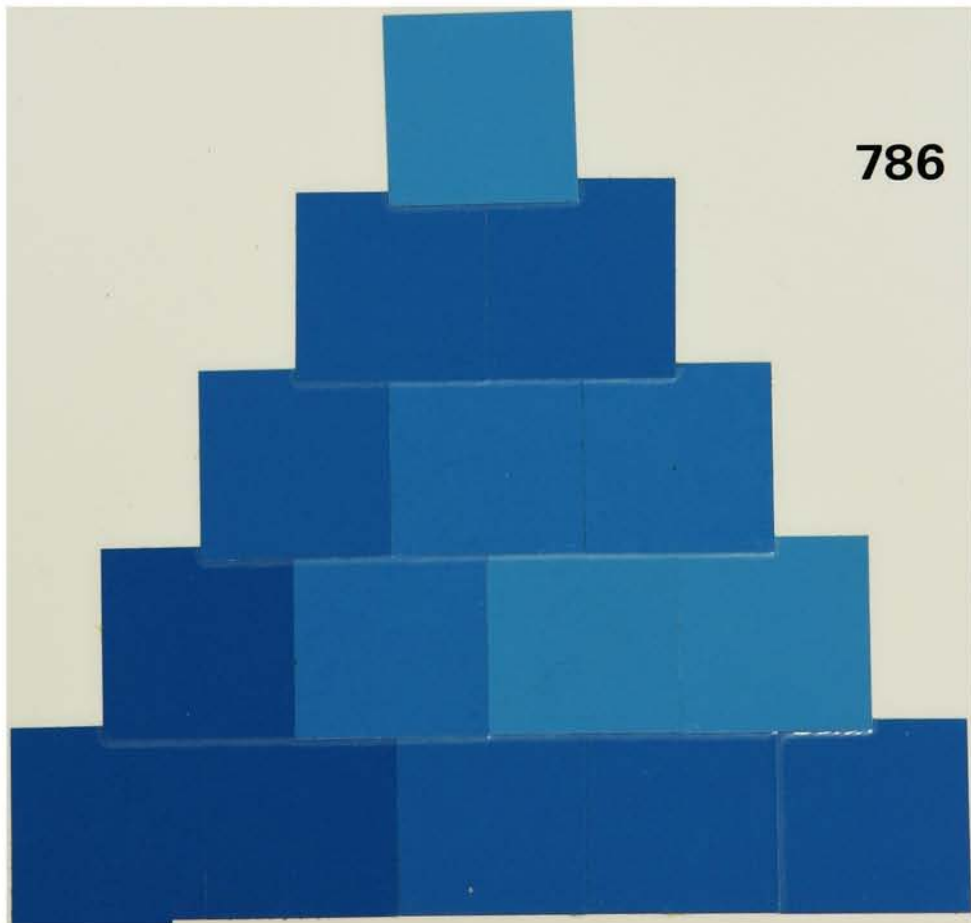


A

786

B

C





A

788

B

C

A

7810

B

C

"Celestial Horizon"

16"x14"x10"



"Or Daydream"

14"x14"x15"





"An Accession"

18"x12"x12"



"Or Aplombed"

14"x9"x9"



"Tutti"

10"x14"x12"





"Tryptic Flight"

14"x20"x6"



"This Morning"

18"x12"x18"





"Canopy #1"

view 1

17 components

hung 8' above the floor

length- $6\frac{1}{2}$ '

breadth-22"



"Canopy #1"

view 2



## FOOTNOTES

<sup>1</sup>Clarence A. Seabright and H.C. Draker, "Ceramic Stains from Zirconium and Vanadium Oxides," in American Ceramic Society Bulletin, Vol. 40, ed. by Charles S. Pearce, Jan. 1961, pp.1-4.

<sup>2</sup>Ibid., p.2.

<sup>3</sup>Ibid.

<sup>4</sup>Clarence A. Seabright, Ceramic Pigments (The Harshaw Chemical Co., US 2,441,447) (Washington, D.C. 1948), pp.1-4.

<sup>5</sup>Clarence A. Seabright, Yellow Ceramic Pigments, (The Harshaw Chemical Co., US 2,992,123) (Washington, D.C., 1961), pp.1-2.

<sup>6</sup>Josef Albers, Interaction of Color, (New Haven and London, Yale University Press, 1977), pp.1-81.

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