01

AFTER FIRE

The history of mankind is closely linked to the history of fire, from prehistoric times, when we learnt to cook our food over fire, to the industrial revolution, when we used fire to refine high-purity heavy metals. This project is intended to explore what is produced when a fire burns and how the materials left behind by the fire can be reused.

With this concept in mind, I contacted an ironworks in the Ruhr region to obtain a by-product of steel refining: mill scale. This material is mainly composed of iron oxide, but due to its low iron content, it is not recycled and is often disposed of at a low price for use as a raw material for roadbeds. In the course of my research I tried to explore new uses for this material and used it as a raw material for glazes in proportion to firing to observe the glaze colour effect.

EXPERIMENT

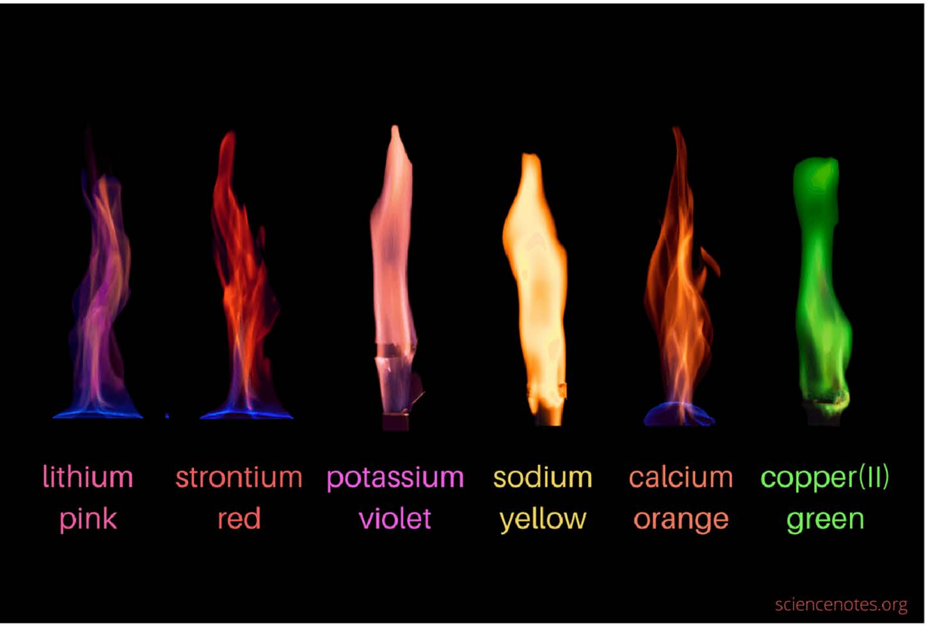
Based on the study of fire in the previous post, we tried to burn different materials in a furnace to carbonise them and see what state these materials were in when carbonised. Some of these materials had been previously modelled, some remained in their original state after the heat, and some of the modelling cracked.

EXPERIMENT

When observing the materials after carbonisation, I found that whether it was wood or bamboo or other materials, some surfaces showed blue or some metallic colours, and I was curious about this phenomenon.

It was found that some metal elements can indeed show different colours after burning. Perhaps it is because during the process of carbonisation, some metal elements attached to the material show different colours after oxidation reaction, thus leading to the metallic lustre of the carbonised material. In response to this discovery, I conducted a more in-depth study on the relationship between metals and colours.

Fire can generate colour



Flames are able to produce different colours in metallic elements, which is typical of the flame-colour reaction, where different metallic elements take on different colours at high temperatures. When the electrons become more active, a spectrum of colours is released which can be recognised to some extent by our eyes. The flame-colour reaction is a physical reaction and when the high temperature disappears, the colour returns to the original colour of the metal. However, if a metallic element undergoes an oxidation or reduction reaction at high temperatures, then the colourful colour will remain after the flame


1st to 5th century AD


beginn 3rd century B.C.

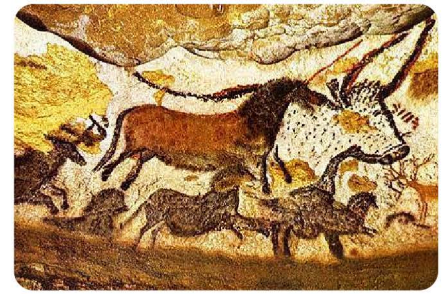
The origins of chemistry

Natural science began with the absurd desires of mankind, and methods such as alchemy and refining certain substances by means of high temperatures appeared successively in the East and the West. Unlike alchemy, Chinese alchemy is not only for the pursuit of wealth, but also for longevity. In the course of the history of mankind's quest, there was gradually a deep study of pharmacology and mineralogy, which was the beginning of the foundation of chemistry.

The history of colour

To talk about the relationship between metal and colour and fire, we must talk about the history of colour.

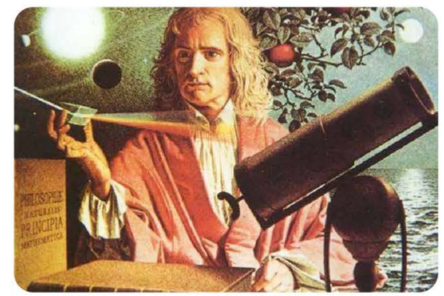
The history of colour is probably more complex than any history of painting, materials or optics. Pigmented minerals have been with mankind since the dawn of time and are still with us today. Using nature's gifts, the first people made mineral colours from natural clays and minerals, mixing them and applying them to the body or dressing up household items.
It has a place in various fields and is scattered and intertwined with different industries. At a much longer time in human history, we couldn't even explain colour with any knowledge, but only with pure visual fascination, extracting coloured minerals from nature, grinding them into powder and mixing them with water to add colour.


▲ Ochre created the famous Lascaux cave frescoes in France (17,190 ± 140 years BP and 16,000 ± 500 years BP)

As early as 14,000 years ago, human ancestors extracted pigments from plants and minerals, initially people extracted carbon black from burnt food/fuel to outline roughly, and subsequently red and yellow from iron-rich mineral soil. We call this ochre. Thus many early pigments contained iron, and the different colors came from different iron ores, which changed color depending on the valence of the iron element.

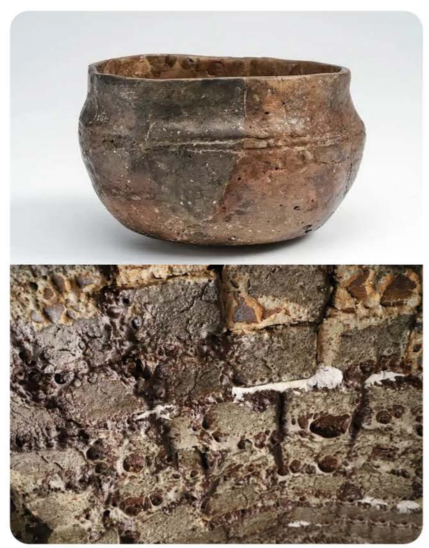

▲ Egyptian blue used for religious painting in ancient Egypt between the 6th millennium BC and the 4th century AD)

The Egyptian blue, invented by the ancient Egyptians 5000 years ago, has learned to use lime, copper, silica and bubble soda to heat and mix in precise proportions, comparable to a chemical experiment.



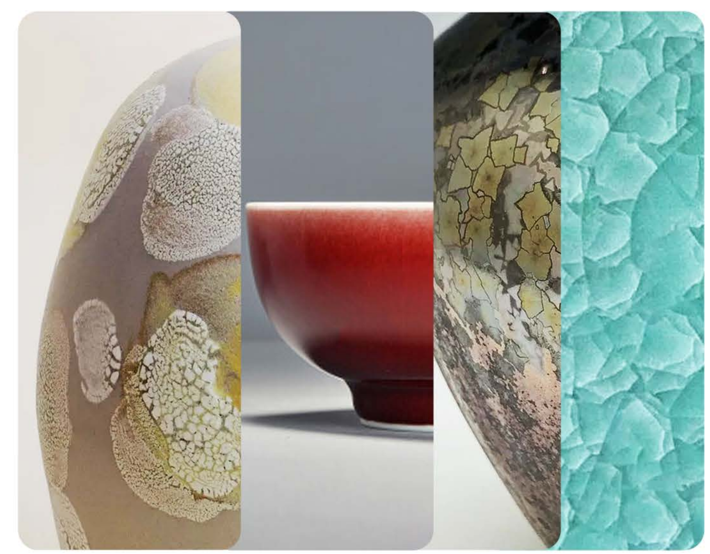

▲ Van Gogh: "Sunflowers" & "Iris

it wasn't until Newton used a prism to separate sunlight into a spectrum of red, orange, yellow, green, blue, indigo and violet in 1666 that people first really knew how color was born. Thus began the science of color.This was also fuelled by the industrial revolution of the 19th century, when more chemicals were manufactured as industrial by-products and became excellent pigments and dyes.Inexpensive synthetic pigments such as azure, chrome orange and cadmium yellow emerged, and modern science brought new colours beyond imagination, and artists began to dazzle with colour, going wild with their creations and leaving countless glimpses.



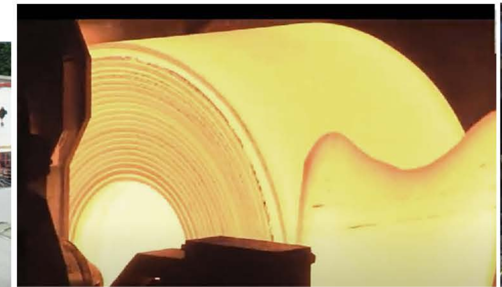
Origin of coloured glazes

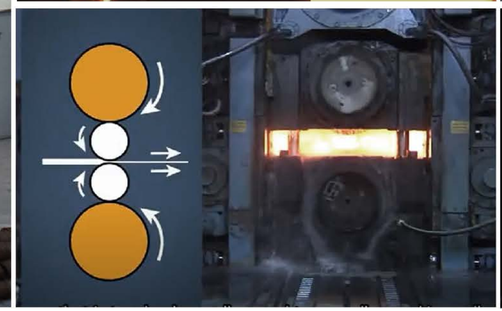
In their long practice, craftsmen have worked out a way to lower the melting point of raw materials - by increasing the amount of flux in the raw material. This flux may be the plant ash, i.e. grass ash, that falls during the kiln firing process. When the ash is melted at high temperatures, a glossy natural glaze forms on the surface of the blank. This is the source of the initial formation of glaze culture.



Human painting on utensils and implements also began with prehistoric times. It started almost simultaneously with the application of mineral pigments. With the application of fire, the natural glaze precipitated after the firing of pottery inspired people to start experimenting with glazes using different kinds of grass ash, and after the development of alchemy, the mineral metal element became an important colour-generating agent in the composition of glazes, and the colours of the wares became richer.

RESEARCH

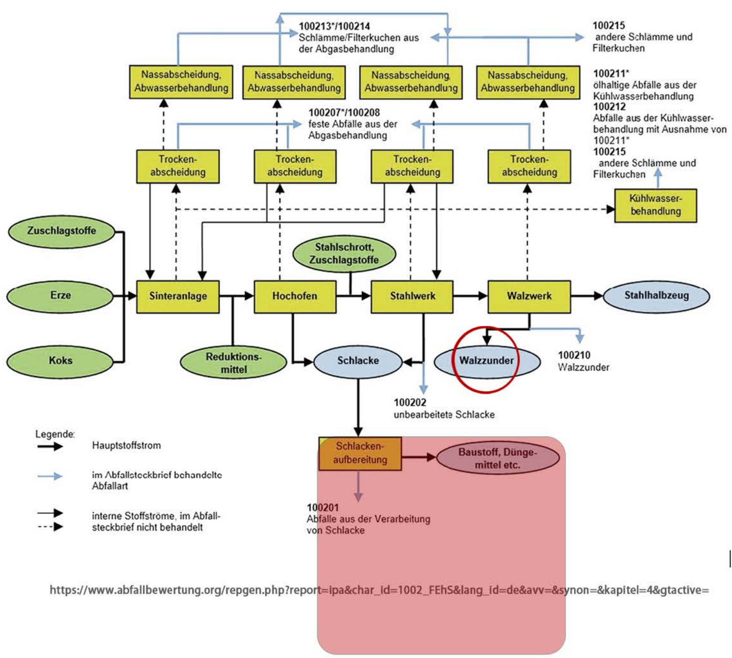




Industrial by-products - mill scales

I contacted the steel mill in kehl. Obtained their industrial by-product, mill scales. This is a material whose main component is iron oxide. During the rolling process, the steel is heated to thousands of degrees and the metal properties change. At the same time the high temperature of the surface reacts strongly with oxygen to produce iron oxide. This layer of iron oxide needs to be got rid of, otherwise it will be pressed into the steel during rolling and affect the quality. General steel rolling will have two or three times with a high-pressure water gun flushing iron oxide skin.

By-product treatment pathways in the German steel industry



https://www.abfallbewertung.org/repgen.php?report=ipa&char_id=1002_FEhS&lang_id=de&avv=&synon=&kapitel=4&gtactive=

Walzenzunder
(Eisenoxid)

Durchschnittanalyse 2021

(der Jahresmischprobe A aus 17 Proben)

(der Jahresmischprobe B aus 27 Proben)

Chemische Analyse in Gew%(Trockensubtanz,Analyse der Mischprobe)

Parameter	Zunder A	Zunder B
Fe ges.	72.6*	72.6
Öl	0.047*	0.65*
Mn	0.40	0.36
Si	0.18	0.27
CaO	0.21	0.16
Cu	0.13	0.24
Ni	0.058	0.099
Cr	0.079	0.096
C ges	0.19	0.73
S	0.013	0.032
P	0.016	0.021
Pb	0.002	0.093

*:) berechneter Durchschnitt aus den Eingangskontrollen 2021

BSN,09.02.22

Techinisches Datenblatt

Zunder A

Produkt Nummer/Product number

121.000.221

BSW Stahl-Nebenprodukte Gmbh
Graudenzer Strasse 33
77694 Kehl/Rhein
Tel:07851/83-294
Fax:07851/77376

Bezeichnung/Type: Walzenzunder / Mill scale

Rohstoffbasis/Main raw material: Eisen(II/III)oxid / Ironoxide

Anwendungstemperatur/ Application temperature

Verarbeitung/Installation: Verarbeitungsfertig im Anlieferungszustand / Ready for use as delivered

Lagerfägihkeit/Storage Life: unbegrenzt / no limit

Verpackung/Packaging: lose im LKW oder Schiff / bulk un truck or ship

Chemische Analyse/Chemical Analysis

Fe ges	Si	Cr	C ges.		
70.75	<0.9	<0.1	<0.3		

H2O(105°C)

Öl-und Fett-Gehalt/Oil and grease content 2-8%

Physikalische Eigenschften /Physical Properties 0.03-0.18%

Körmung / Grain size	0-11	mm
Körmung / Grain size >1mm	max.20	%
Körmung / Grain size >11mm	max.0.1	%
Schüttdichte/Bulk density (vom Original/from raw material)	1.6-1.8	kg/dm²

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Oxidation reaction

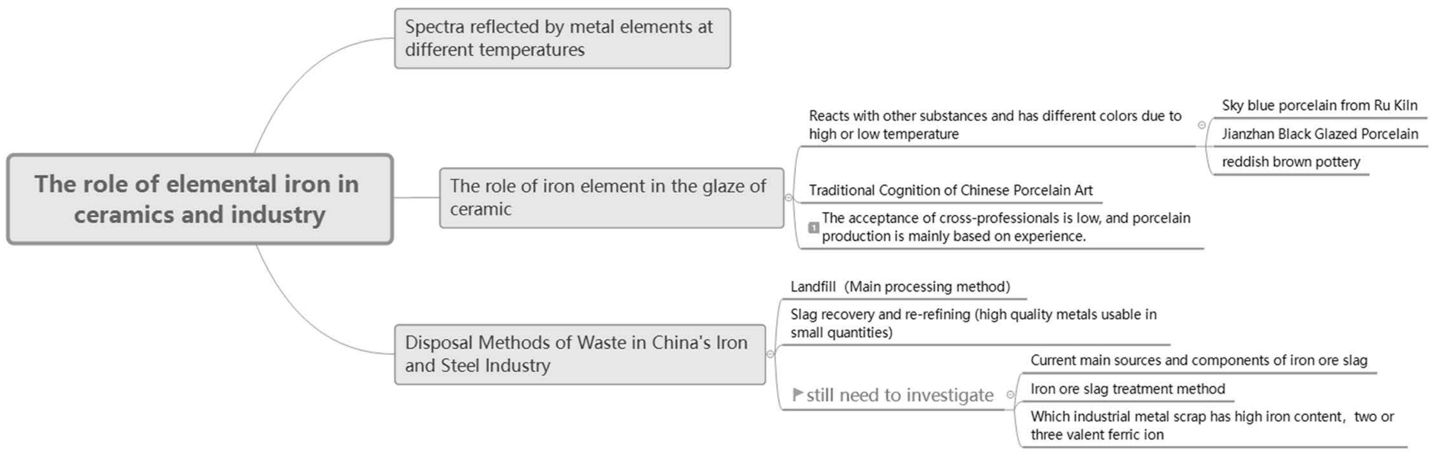
Reduction reaction

Iron glaze firing colours

Iron oxide, a material with an extremely wide range of colour variations and a long history of application, is also naturally an important metallic colouring agent in glazes. Iron is sensitive to the kiln firing atmosphere. The reduction reaction produces colours ranging from greenish-white to deep black, depending on the dosage. Oxidative firing, on the other hand, produces colours ranging from yellow to reddish brown. Iron glaze is the most common glaze, honey brown glaze, tianmu glaze, celadon glaze are representatives of iron glaze.Among them, the black glaze is more difficult to fire, because it needs to be fired to more than 1300 degrees, high purity iron crystals precipitation, so the black iron glaze has a metal-like texture, hence the name of Tianmu Jiantian, meaning starlight in the universe.

Glaze Ratio

After learning the exact composition of the mill scale and the basics of glaze proportioning, I attempted to do my own proportioning. Firstly, I added different ratios of Mill Scale directly into the clay. Then I chose transparent glaze and white glaze as the base glaze, and then added Mill Scale according to the composition and proportion after careful grinding. The initial firing was a cold firing at 900°, followed by a re-firing at 1280° to see how the colours developed.
Another batch was fired directly to 1280°, which increases the risk of cracking the clay. But I am curious if there will be a difference in colour compared to the regular firing method.



Experimental phase 1 24 groups of controlled trials

cooled-burned (with 900℃) +burned 1280℃

Original clay	transparent glaze + 3% walzzunder 5% walzzunder 10% walzzunder	white glaze + 3% walzzunder 5% walzzunder 10% walzzunder
clay+3% Walzenzunder clay+5% Walzenzunder clay+10% Walzenzunder	transparent glaze + 3% walzzunder 5% walzzunder 10% walzzunder	white glaze + 3% walzzunder 5% walzzunder 10% walzzunder +

+burned 1280℃ in one time(Risk of cracking becomes higher)

One for each of the above test pieces

MODEL

PHOTOGRAPH

Scales

Glazes proportioned with Mill Scale show a rusty colour, and because the raw materials are not ground carefully enough, they will show very uneven patches when fired at high temperatures, looking very much like scales. Therefore, when I tried to make the porcelain, I made the porcelain blanks to imitate the crocodile scales to match the special colour of the glaze.

PHOTOGRAPH

PHOTOGRAPH