



The Memory of Earth

Summary of the initial research on making experimental ceramic glazes on the basis of local raw materials in the context of building human relation with nature

Martyna Piątek

Bogdan Kosak

Łukasz Kruszewski



* Publishing series of the Academy of Fine Arts and Design in Katowice, as part of the project "From ecological product to augmented reality experience". Publication co-financed by the European Union under the European Funds for Silesia 2021-2027 program (Just Transition Fund).

Publisher: **Academy of Fine Arts and Design in Katowice**

Photos: **Barbara Kubska, Martyna Piątek, Beata Kosak**

Proofreading and text editing: **Alicja Gorgoń**

Graphic design and layout: **Kinga Pawlik**

English translation: **Alicja Gorgoń**

Review: **PhD Magdalena Łysiak**

ISBN: 978-83-68440-20-1

Katowice 2026



Fundusze Europejskie
dla Śląskiego



Rzeczpospolita
Polska

Dofinansowane przez
Unię Europejską



Województwo
Śląskie

CONTENTS

6	Introduction
9	FIRE. Ceramics in Context
25	Process
49	Processes of natural firing on post-mining tips

Current changes in the scope of methodology (focused on interdisciplinary work, unsealing anthropocentrism, making nature-cultural networks) constitute a good starting point to thinking about educating students of humanities also in the field, which would assume learning about the world and becoming closer to reality – to the Earth/earth.¹

¹ M. Ochwat, *Więcej-niż-tylko-ludzkie lekcje języka polskiego*, Wydawnictwo Uniwersytetu Śląskiego, Katowice 2025, p. 21.

This publication, as a form of a meeting on the touchpoint of disciplines, serves to record the results of several months of research on making experimental glazes and ceramics colourings, based on local raw materials found in the area of Silesian Voivodship. It should be emphasised that the research has been conducted not from the perspective of a professional ceramicist, but a designer, whose interests oscillate around motifs related to local identity, value of manual labour, clearly desirable to a contemporary person, and human relation with nature, the quality of which is essential in the context of general well-being.

The conception of this research project originated i.a. from several modelling workshops *Wróćmy do patyka!* [Let's Return to the Stick!], which I carried out for various age groups with the aim of manual work on an object constructed of sticks found by the participants, and therefore – a specific attempt at returning to creative childhood activities. The idea was also supported by the analysis of current directions connected with ecopsychology, development of symbiotic education, and operations regarding the use of local (both natural and waste) materials as means of artistic expression, and even as complete materials to be used in product design. Projects I have observed in the recent years in the field of ceramics and the context of place, such as i.a. operations of Netherlandish researchers (Kirstie van Noort, Marte Mei and

² R. Louv, *Last Child in the Woods. Saving Our Children from Nature-Deficit Disorder*, Chapel Hill, 2008, p. 68.

many more) became a starting point to thinking about launching my own formal pursuits in the area of our voivodship, the natural landscape of which has been repeatedly violated by excavation industry. The decision, however, does not result only from fascination with material experiment itself.

The in-depth study of several locations by means of collected pieces: minerals, fragments of clays and plants, resembled becoming familiar with the nearby mountain, metaphorically formulated by Bill McKibben, and quoted by Richard Louv in his book: *Last Child in the Woods. Saving Our Children from Nature-Deficit Disorder*.² Here, the mountain serves as a defined, small geographical area, which is actually a natural, endless source of information, previously learned by people step by step throughout their lives, until it had no more secrets from them. Today, by means of the media, we obtain more knowledge about what is happening at the other end of the world than practice mindfulness to the immediate surroundings. Direct experience, nonetheless, enhances the sense of belonging to the place, which also offers other benefits connected with mental balance. Katarzyna Simonienko from the Forest Therapy Center in Białystok, in her article "Selected mechanisms of natural environment influence on mental well-being" emphasises the relational and social dimensions of development in a person staying in the nature. Among the phenomena we might experience, she lists the sense of participating in something bigger, sense of affiliation (especially important in the time of increasing loneliness), stepping out of one's role and letting go of one's everyday "masks", not being judged.

Taking care of this relation naturally brings emotional bond, and what follows, also care and will to nurture. A similar vision is presented by Dr. Ryszard Kulik, one of the founders of the Ecological Thought Club, as he formulated his statement in the conversation with Ewa Jakubowska, who asked him about his motivation to engage with caring for natural environment:

In ecopsychology we say that engagement will rise if my Self, my identity, starts to include more than myself. If I include in my sense of Self this lawn, this estate, this wood, this old forest, if I feel that it is a part of me, if I see myself in a broader context – it is much easier to be engaged.

Thus, rhythmical learning about one's surroundings by observing it in the macro scale, could also have a therapeutic dimension. I hope that my gathering of findings, recognising the scale of difficulty in preparing raw material and recipes of mixtures, will be useful in the future as a base for a workshop tool of environmental education and serve to start a discussion about ecology on the local level. In this publication, I decided to include voices that will provide the matter-of-fact substance to the story of materials, which I narrate through experiments with raw findings. There is a perspective of an experienced craftsman, Bogdan Kosak – the outstanding expert on porcelain, long-time designer for Porcelana Śląska and wch Network in Katowice, co-founder of Modelarnia Ceramiczna Kosak (Ceramic Modelling Studio, with Beata Kosak), connected as a didactic with the Academy of Fine Arts and Design in Katowice. Experiments carried out on the basis of samples of materials found in the areas of post-mining tips brought the most intensive and unexpected visual effects after high-temperature firing, which encouraged me to invite to collaboration also a scientist, Prof. Łukasz Kruszewski, connected with the Institute of Geological Sciences of the Polish Academy of Sciences, whose article discusses the problem of wildfires on mining tips, similar in character to ceramics firing.

Ceramics in Context

Bogdan Kosak

¹ R. Koziołek, *Czytać, dużo czytać*, Wydawnictwo Czarne, Wołowiec 2023, p. 129.

² M. Styczyński, *Słuchanie roślin*, [in:] *Głębokie słuchanie*, red. M. Lisok, Galeria Sztuki Współczesnej BWA, Katowice 2019, p. 39.

Not so long ago, two, three decades back, a child's dream of digging up clay with their own hands and forming it into a dish would be considered weird, and the weirder, the older the child was. Today's approval and even appreciation of such an activity has many underlying factors. A basic one is technological development and the general, systemic exclusion of a human as an agent of physical interactions, from corporal impact on the surrounding reality. Participating in complex structures and processes, the increasing portion of society are detached from the final effect of their work, a material object, or another person, while functioning in the digital reality, they have nothing to do with a person or a physical object whatsoever. The atavistic need for production, with the result of instant sense of agency, is directed to other areas. A contemporary consumer is no longer satisfied with buying and owning things – they simply are there; what becomes more attractive, is experience.

Another important factor is reflection resulting from satiety. When material needs, the real and the created ones, are satisfied, the thought turns to abstract regions, in an attempt at reflecting upon one's own place on the Earth. We notice and appreciate internal knowledge which, regardless of our role and position in society, helps us face the problems of modernity.

Such internal knowledge is defined and applied as Olga Tokarczuk would¹, not by abandoning external, acquired knowledge, but rather by coexistence of both, and their reasonable application. This is facilitated by long-present, especially appreciated in current crises, environmental awareness; also "in the pop-cultural layer, for the first time in decades, environmental problems related to climate changes have emerged from artificial and forced niches to the surface of social life."² There is a positive contemporary "image of the increasingly popular trend to link seemingly distant disciplines. The conscious Anthropocene is the time of building bridges between art and natural history. The extra-human or – following the definition of an American philosopher, David Abram – more-than-human universa are a deep well,

into which the world of art, literature and music more and more frequently reaches for fuel and metaphors."³ The effect is a *high tide* of texts and books, conferences, manifestos, and workshops. It might give the impression that art and science have found a common denominator. Emotions and facts join forces to protect, but what? The environment? The planet? Humanity?

Searching for answers to thought-provoking questions, and lacking instant solutions to burning problems, we behave like protagonists of Stanisław Lem's stories, relentlessly confronted with the unknown, where every animate and inanimate element contains a mystery, impossible to study with accessible means. Our confusion causes the feverish pursuit of solutions, which lead to another extremes, such as those used by a protagonist of Fyodor Dostoevsky's *The Devils* to describe a poem in the spirit of utopian socialism, fourierism. The narrator of this novel sums up the poem in a humorous way: "Then the scene suddenly changes and a sort of 'Festival of Life' begins in which even insects join in the singing, a tortoise appears with certain sacramental Latin words, and, if I remember rightly, even some mineral – that is, quite an inanimate object – also bursts into song about something or other."⁴ There is also a mind-losing young man, sucking juice from grass in the wilderness, while another one, the embodiment of death, is leading all nations, longing for a new hope for the completed Babel tower. They dethrone the lord and take his place. Humanity, awoken, "at once begin a new life with a new insight into things."⁵

Insatiety

We extract, process, and heap up tips – the "new mountains". This causes anxiety, often similar to the one described by Karin Lednická in *The Leaning Church*. One of the protagonists of this novel-chronicle of the turn of the 19th and 20th centuries, Žofie of Karviná, tells her dream: "On the rail sidings at the shafts stand empty wagons, gulping down whatever falls into their precipitous gullets, and it's never enough. [...] Miners extract more and more from the earth, only to fill in these hungry iron throats. Up there, on the ground, grow the ever new colonies, shops, parks, baths, and churches, with their towers almost reaching the sky. Up there, it looks like a paradise. But down here? How long will the earth allow all that? [...] What will come next? Can we really keep emptying the earth at will, and go unpunished?"⁶

³ A. Robiński, *Totalne zdziwienie*, "Tygodnik Powszechny" 2021, no. 42, p. 100

⁴ F. Dostoyevsky, *The Devils*, trans. David Magarshak, Penguin Books, Melbourne—London—Baltimore 1923, p. 24

⁵ Ibidem

⁶ K. Lednická, *The Leaning Church*, Bílá vrána, 2022, pp. 190–191

In the 21st century, one of the ways of dealing with the surrounding reality – small and big crises, individual and general, global and local, the fear resulting from insatiety – turns out to be craft. Due to the extensive offer of workshops, ranging from all types of craft to land farming, and affected by effective marketing procedures, we are spoiled for choice, and thereby constantly participate in building the capital. Some can afford to fly to the outer space, others can make something with their own hands, often from personally obtained raw materials. A discipline, which satisfies many aspects of this new demand, is ceramics. The craft, historically and culturally accompanying people for thousands of years, overgrown with meanings, could be deliberated in many contexts: philosophical, social, economic. “Pottery making historically used to serve three major cultural roles, the first within the practical needs of the daily life of real people, the second within various religious rituals, notably around funerary practices. From its earliest manifestations [...] it also served a third role, as markers for wealth and power in ostentatious displays. [...], as a sign of sophistication and prestige.⁷ This is still true today, in various proportions, though, while the above-described are joined by another role of ceramics, connected with filling the free time; pottery becomes a mass-scale pastime. The constantly fuelled appetite causes the majority of activities to lack moderation or balance, while these are some of the hardest challenges faced by people today.

Therefore, let me quote Jan Englert here: “I suffer from the lack of shame.”⁸

We all have the right to comfort, to a safe and convenient life, to do something else than the necessary physical survival. Regardless of the place on the Earth and the role in society, everybody should be entitled to luxury, to drinking coffee from a China cup. Others want to make money on it; nothing wrong with that, the problem is the lack of moderation in the name of constant profit, growth, and progress. There are places on our planet where the lack of shame is illustrated by the quantity of products, and especially garbage, waste, and wastelands. The discomfort caused by excess is described by Edmund de Waal, who visited abandoned places of porcelain production in China. I had a similar impression after my visit to the “Inter-komis” [a large-scale confinement store – trans. note] in May 2013. The number of rooms of all sizes filled with unwanted objects, was overwhelming. I went deeper and deeper into this den, surrounded by luxury, which had passed, and hopelessly asking a question – Who was all that for? Was it not for the fact that the “Inter-komis” also has a positive function as a place of exchange, material circulation, I would advocate

⁷ P. Mathieu, *Ceramics Art and Perception, Mansfield Ceramics, Cfile.org* <https://cfileonline.org/commentary-reflections-on-edmund-de-waals-phaidon-monograph/>, [accessed: 8 Nov. 2025]

⁸ A quote from Katarzyna Stoparczyk’s interview with Jan Englert [Polish theatre and film actor – trans. note], <https://trojka.polskieradio.pl/artykul/2098294,jan-englert-gosciem-audycji-myslidziecka-357>, [accessed: 8 Nov. 2025]

the warehouses to be completely moved to the waste incineration plant, hoping for the fire to purge it all, also shame.

Regardless of epoch and place, popularity of a given material and its products results in its overconsumption. Did the Chinese keep moderation? There was demand, so they manufactured, and since the needs were extensive, excavation, production, and waste grew proportionally. In “the great epoch of Chinese ceramics – the period of time comparable to our Middle Ages”,⁹ the quantity of production, mainly regarding the “grave keepers” i.e. ceramics intended to accompany the deceased and fill in the tomb, must have already raised concerns, if there was a special imperial decree issued to prescribe the number and size of figurines.¹⁰ The processed inside of the Gaoling mountain, in the form of various pieces of crockery, lies at the bottom and banks of the river, and in the form of museum objects – in storages of collections worldwide. According to Edmund de Waal, crocks of dishes are polished by the Chang Jiang river, the role of which was first to transport raw mountain materials, then bricks and other necessary elements of kilns, and finally white porcelain.¹¹ In Cieszyn, this function is met by the Olza river. At the bottom, there are broken fragments of tableware, construction, sanitary and sewerage ceramics, mixed and frequently no longer discernible – to the untrained eye – from pebbles and gravel on the river bank. The most resistant and time-intensive one, due to baking in the highest heat – is porcelain. Fragments of items made of such ceramics, regardless of the thickness of the original shard, take not one, but several centuries to merge with the surroundings, and be called the natural component of the environment.

Awareness of Material

In the 21st century, ceramics is more popular than knitting. However, as long as a botched pullover or sock can be unravelled and reknitted into something else, equally useful, processed clay cannot be reused. The report developed by Urszula Szwed¹² shows that the offer of hundreds of commercial ceramics studios in Poland, could be summed up as follows: *Looking for a place to relax after a long day and let off your creative steam? This is a studio for You! Sit comfortably and make whatever your heart desires. We guarantee relaxing and friendly atmosphere and a place, where you can be yourself and create as you please.*

⁹ J. Powidzki, *Ceramika*, Wydawnictwa Szkolne i Pedagogiczne, Warszawa 1977, p. 56

¹⁰ Ibidem, p. 59

¹¹ E. de Waal, *The White Road: A Pilgrimage Into Obsession*, Vintage Books, London 2016, p. 36

¹² U. Szwed, *Pracownie ceramiczne / warsztaty ceramiczne. Podsumowanie sytuacji rynkowej – stan na 2025 rok* https://ceramikakosak.pl/wp-content/uploads/2025/12/Urszula-Szwed_Pracownie-ceramiczne-w-Polsce_Raport-2025.pdf, [accessed: 2 Jan. 2026].

Most of people do not care what material they use. Clay is only one of many processable raw materials to them, as they are unaware of its ancient beginning and its end, the possible exhaustion of the deposit. It is common perception that the quantity of clay, argillaceous rock, is unlimited. Such thinking had led to the catastrophic condition of the Gaoling mountain slopes, reported in 1583, and the eventual discontinuation of kaolin excavation in the first decade of the 20th century.¹³

The lack of regard for the material, the energy needed to process it, and consequently, for the manufactured product, not to mention the human labour involved, results from the lack of knowledge about it. In order to achieve such awareness, it is necessary to personally, physically experience materials and processes. The multitude of places, organised over the last two decades, which offer learning the workshop skills and material, is a valuable phenomenon, under the condition of keeping moderation. The mushrooming ceramics studios, financed from public funds, are often seasonal or occasional. They close down when the funds run out, or there are no available workshop leaders. Providing such studios with tens of kilograms of clays and glazes, leaves materials unused, improperly stored, and their utility ends up in the dump, where they contribute to the “new mountains”.

Our history, as well as the history of materials which we process, started with the Big Bang. “The beginning, or else the beginning of the current phase of history of the Universe.”¹⁴ Approximately 4.5 billion years ago, the Earth is formed, and on it, in their proper order, minerals and rocks. Awareness of these processes makes me, a ceramist, excited about the haptic contact with the matter, which has been through billions of years of maturing to its present state.¹⁵ In the studio specialising in producing porcelain, the basic component is kaolin, extracted and processed thousands of kilometres away. The use of every kilogram is deliberate, not only due to production costs. Knowledge about the origin of materials used to achieve a goal helps us appreciate the value of the object, not only in the material sphere.

Respect for material comes from the conviction about the uniqueness of components, which we use, and from information we obtain about them from the discipline of materials science. Composing a fine ceramic clay based on properties of minerals is art in itself. Topped with a ceramist’s scope of knowledge, regarding rock formation processes, for instance, brings us satisfaction of the first arcanists¹⁶, developing the porcelain recipe. This happens, when we know that we deal with a material formed by kaolinising – a long-term geological process occurring under the action of heated weak solutions of salts and humid acids, circulating in thick layers of bedrock.

¹³ E. de Waal, *The White Road...*, op. cit., p. 35

¹⁴ M. Heller, *Wszystkie świat jest tylko drogą*, Wydawnictwo Copernicus, Kraków 2018, p. 3

¹⁵ Geological History of Earth https://en.wikipedia.org/wiki/Geological_history_of_Earth, [accessed: 21 Jan. 2026]

¹⁶ K. Zwolińska, Z. Malicki, *Mały słownik terminów plastycznych*, Wiedza Powszechna, Warszawa 1990, p. 28. Arcanist (from the Latin arcanum – secret) – a craftsman who knew secrets of making porcelain and other ceramic methods. The term was used especially in the 18th century.



Ceramic from Olza, photo by Barbara Kubka

Dickite, nacrite, quartz porphyries, granites, tuffs, pegmatites, and many other rocks, under pressure and biogenic factor, turned into kaolin.¹⁷

Walking along the partially dried up Olza riverbed in Cieszyn, enjoying the treasure hunt, is a prelude to reflection and pursuit of answers to questions about human impact on the environment. Penetration of river banks during environmental-and-archaeological workshops, and deliberations about findings, make participants aware that ecology without saving is an empty word. Small fragments of glass and ceramics, as waste, were thrown in the river until the mid-20th century. Over several decades, they were polished by water and pebbles, and thereby obtained archaeological nobility. At the same time, paradoxically, fragments of ceramic objects prove their positive quality of natural materials. The educational value of such workshops relies upon making participants familiar with history and processing methods of ceramics, and directing their attention to the advantages of environmentally friendly materials. Fragments of old, often hundreds-years-old bricks, furnace tiles, roof tiles, and pottery products, hardly indicate their original use. Fished out of the Olza, they look like river stones, which they actually are – porcelain, earthenware and stoneware constitute “new rocks” of man-made mineralogical composition. The majority of these “new stones”, however, are made of “wild clay”: all their craftsmen needed to work and form objects was water, without fortifying clay with other raw materials, as people would approximately thirty thousand years ago.¹⁸

Fire

“Fire is the force, which turns brittle clay into hard material. Fire is the force, which as if reinstates clays with the power, originally possessed by rocks and stones, from which clays were made.”¹⁹ Such a poetic deliberation was written in the 20th century by Professor Rudolf Krzywiec in his textbook for students of ceramics in the State Higher School of Visual Arts in Wrocław.

Transformation of clay into ceramics can be described in three subsequent stages: preparation of material – obtaining raw materials in their natural environment and processing them to the formable state, modelling the object, and finally, heat setting. Therefore, for complete understanding of how clay material turns into a ceramic object, the experience of fire is necessary. Actually seeing the amount of fuel, transformed into energy, required to change mouldable clay into hard rock, is the prerequisite to taking responsibility for what we do. Jurek Szczepkowski, a soci-

¹⁷ A.J. Awgustynik, *Ceramika*, trans. into Polish by Ignacy Płoński, Arkady, Warszawa 1980, pp. 15–16

¹⁸ A. Gubernat, M. Zarzecka-Napierała, *Zarys historii ceramiki*, Wydawnictwa AGH, Kraków 2022, p. 9

¹⁹ J. Powidzki, *Ceramika...*, op. cit., p. 12

ologist, monk, and potter, who organises ceramics workshops in Beskid Niski, goes one step further. Participants are given the task of gathering appropriate amount of wood for baking their own works. Not only must branches be found in the forest, but also transported on participants back to the studio.²⁰ Baking in an electric or gas kiln does not have a similar effect on imagination nor allows to assess how much fuel is used to obtain the required temperature. Commercial ceramics meetings are most often limited to one of the three stages mentioned above – modelling a given object with a method of choice. Clay and fire, the most important elements of the ceramics-making process, are omitted as less significant, and located on the margins of ceramic activity. As much as work and dedicated time are appreciated, along with manual skills, invention, creation, the essentials of developing respect for materials and fire, are ignored. We process resources in a naive belief that the time of predatory economics is exclusive to former generations, and we have left it behind. Enjoying creative activities, we may not notice that all we have done is replace tools and needs with new ones; insatiety has become even greater, we just satisfy it by different means.

The direct, corporal experience of fire, the temperature above 1000 °C, is best achieved by black pottery firing, the method used e.g. in the area of contemporary Subcarpathia as early as the Roman and Early Slavic periods.²¹ My participation in the project “From Ecological Product to the Experience of Augmented Reality”, carried out by the Academy of Fine Arts and Design in Katowice, allowed me to conduct research by means of the method of participatory observation in the process of firing Black Baltic Ceramics “Juodoji keramika”.

Black ceramics, also known as grey pottery, depends on its place of firing for the baking method, type of fuel material, and kiln construction, which affect the obtained colour and porosity of the shard. What stays the same for all methods is the use of substances contained in wood, and obtaining reducing atmosphere at the last stage of firing. Let me quote the entire description of the process of firing “siwaki” [grey earthen pots] in the village of Prudy in Baranowicki Province in the 1930s.: “They put dried pots on the warm kiln, fill empty spaces with pine cones, throw pine cones also on the top, and finally cover them with crocks. In the end, they cover the kiln tightly, so that smoke cannot escape, because only then pots gain uniform grey-black colour all over their surface. Otherwise, smoke escapes through cracks, and in these places pots have light patches. Also, fire is lit gradually, from weak to stronger. They use moderately fat wood, such as alder or birch, so that pots are not too sooty.²² While

²⁰ Account of a workshop participant, Aleksandra Krupa, Cieszyn 2025

²¹ J. Podgórska-Czopek, *Grodzisko Dolne, stanowisko 22 – wielokulturowe stanowisko nad dolnym Wisłokiem. Okresy rzymski i wczesnosłowiański*, Muzeum Okręgowe w Rzeszowie, Rzeszów 2009, p. 10

²² This was confirmed by firing with spruce wood in the kiln at the Academy of Fine Arts in Wrocław in 2019; jars for the *Naczynia kuchenne* [Kitchenware] installation, especially these in the bottom line, were covered with a several-millimetres thick layer of soot.

burning, flame penetrates through holes to the chamber with pots. There, pine cones burn without air, and so they only smoulder and extract gasses, which penetrate the walls of pots. This way, the pores in pots are sealed, and pots turn black-grey in colour.”²³

The type of firing we decided to use is much more demanding than the one described above regarding the required physical labour and amount of fuel wood. Observation of the course of subsequent stages of firing is insufficient to fully appreciate the value of black ceramics; it requires complete engagement, from preparing fuel to taking ceramics out of the kiln and tidying up the workspace. Regardless of participants’ skills and practice, team work is recommended in order to divide hard physical work and carry out the entire cycle efficiently. Three trained people is the minimum, and the more, the better. Our team consisted of 8 people²⁴, the Master included. We decided to conduct this experiment with one of the oldest ceramic methods in Dr. Rytis Konstantinavičius’ Studio Della Fiamma, which has been situated near the ancient stone and clay town Gubbio in Central Italy for three years. The location of the house and studio on the hill offers aesthetic as well as pragmatic advantages. Building a one-chamber kiln with a long furnace on the hill wrote into the landscape by using the natural lie of the land. Although there are no, even small, deposits of clay fit for ceramics purposes in the immediate area, working in such a place establishes physical and emotional connection with every element of the surrounding nature.

As we carried out the firing together, Rytis was teaching us not so much how to make friends with fire or control it; he was teaching us how to collaborate with fire, which restores clay to the hardness of its parent rock.

While planning the plain-air firing, it is essential to check the weather forecast. The process of kiln cooling is also important, and it should last at least 24 hours. Since the kiln is not roofed, the firing is postponed from one day to the next. In order to see the effects of our work before leaving on July 11th, it is necessary to start the firing on July 8th, regardless of the meteorological prognoses. The Master assigns tasks and leads the seven-person team. We start at ca. 2 pm from preparing firewood, different species of deciduous trees and black locust wood, to fill in the furnace of the ceramics kiln before it is closed tightly.

The fuel material includes branches of different species of deciduous trees, divided into two categories of length: from 1 to 2 m, and thickness up to 10 cm. The firewood group: Beata, Martyna, Eryka, organise them in the proper order beside

²³ S. Izdebska, *Jak się lepi garnki?*, Państwowe Wydawnictwo Książek Szkolnych, Lwów 1934, p. 30

²⁴ Eryka Vasiulytė, Marek Gajda, Rytis Konstantinavičius, Adam Kosak, Beata Kosak, Bogdan Kosak, Martyna Piątek, Mateusz Prażuch



The surroundings of Studio Della Fiamma, photo by Beata Kosak

the furnace area and pile them up next to the kiln as spare, just like specialist tools waiting their turn.

Black locust wood, chopped by Marek and Rytis into easily handled logs, is placed on the top on three sides, beside the sheet that closes the chamber.

Adam and Mateusz wheelbarrow superfine stone, which replaces sand in this region of Umbria. They pile it up in four heaps – several wheelbarrows in each, close to the furnace and the kiln chamber, in order to quickly and efficiently smother the fire, seal it maximally, “choke the furnace”.²⁵

The entire team take part in scooping up charcoal from the previous firing. Due to the high quality of the reclaimed material, diversity of its forms and colours, this activity is an inspiring practice in mindfulness. The hosts use pure coal from the chamber as barbecue fuel. Coal is removed with a three-metre shovel called “kociuba”²⁶, one of the basic tools used while firing.

Once the kiln chamber is emptied, we can put our ceramic samples inside. Lying down, Rytis takes crockery from the team and dives in the 400-litre cuboid kiln chamber, built of firebrick, to organise items and distribute them so that fire is directed onto all ceramic objects. Several minutes to 6 pm, we use a 2 mm sheet, reinforced with profiles, to cover the kiln chamber, leaving about 10 cm crack at the back wall as the outlet of fire and smoke.

The slant of the slope under the furnace, situated half a metre from the top of the hill, allows for kneeling down – such a position is the most comfortable in this place and that is how we are going to work with the fire most often. After chasing a lizard away from the brick furnace, the Master, kneeling down, lights the intricate construction of a small pile of “camp fire”, blows, moves sticks around, burns his fingers. Several minutes past 6 pm, there is the flame. It all goes according to plan, almost everything, as nature has the last say. Before 9 pm, from south and west there come black clouds, and the wind builds up, as an impulse for a quick reaction. The initial slow firing, aimed at drying the ceramics up, can be interrupted with no damage. The firebricks of the furnace lining have been heated up, so during this compulsory break, they are going to keep drying the items, which could burst due to the quick increase in temperature. Apart from safe bisques, we have put in the kiln several sun-dried objects, made three days before. The old household has everything needed for securing the kiln: canvas covers and pieces of metal junk to hold them down; the most precious finding is a several-metre chain, probably a former shipyard property.

²⁵ M. Matuszczyk, A. Oborska-Oracz, J. Wowak, *Ceramika siwa i czarna – przyczyny powstania określonej barwy na podstawie stanu badań oraz analizy procesu wypału*, ACTA UNIVERSITATIS NICOLAI COPERNICI, Zabytkoznawstwo i Konserwatorstwo L (2019), Uniwersytet Mikołaja Kopernika w Toruniu, p. 174

²⁶ *Słownik języka polskiego*, M. Szymczak, PWN, Warszawa 1978, vol. 1, p. 946. Kociuba, infor. “a tool for shovelling coals out of a bread oven; a poker” (from Turkish).

A few minutes past 9 pm, the kiln and the wood are covered. The ceramics has been given several extra hours to evaporate the mixing water.

The storm came and went fast. Next to the kiln, we have running water to spray on ash before it is scattered from the wheelbarrow, but as the rain pours on the dry slope, it helps us stick to fire regulations anyway. We also have a chance to check in practice the theories that the degree of kiln dampness has influence on the colour of shards, while the external atmospheric conditions, location of the kiln, as well as its size, have impact on the course and duration of the process inside it. Past 10 pm, we come back to firing, taking turns adding branches. First, there go middle-sized, rather short, maybe 30 cm pieces to the bottom of the furnace under the grate; the fire must not touch the ceramics yet. After midnight, branches up to two metres long fill in the entire width and length of the one-metre grate, and these sticking out can be used to regulate the layout, and pushed into the fire as they burn. The precise arrangement of branches gives us control of the flame and allows obtaining the required temperature, therefore ashes are scooped out regularly. There must be space under the grate to remove unburnt pieces of wood, in order to provide enough oxygen for firing. The cinders from the furnace, moved with “kociuba”, taken out with a shovel, sprayed with water, are transported on the wheelbarrow, displaying spectacular fireworks of sparkles, and geysers of steam. The theatrical, side light of the electric lamp, hung on the maple tree ca. 15 metres from the kiln, enhances the sense of participation in a spectacle. Adam, Marek and Mateusz, the stars of this act of the show, work in the rhythm dictated by the fire.

In the third hour, firing with long branches, distributed on the 60 cm wide grate, to the left and to the right alternately, so that fire spreads equally across the chamber without missing the objects, gives them all a chance of even sinter. The fire goes outside with short, dark red, cherry flames; the temperature inside should reach between 600 °C and 800 °C. The crack between the sheet, closing the kiln chamber, and its back wall, allows us to observe the ceramics. A few minutes to 1 am, it is as red as the fire. By 1:20 am, when we have achieved the temperature up to 1000 °C, the flame and the ceramics are orange. Fire is strong enough to go out from the kiln equally along the crack, and half a metre high. At 2 am, due to the constant adding wood to the grate, rearranging fuel all over, and removing the cinders for good air circulation – to obtain the proper draw, the flame rises up to 1 metre and turns yellow, with white at the centre of the flame. The firewood team brings more branches from the

21

previously gathered storage. The fire demands more. Around 3 am, there is probably 1000 °C in the chamber.

When the fire is yellow and white, we change, or rather add scarves, hats, shawls, jumpers and another pair of trousers to our clothing. We disappear under several layers of fabric, which is there to protect us from the temperature of 1000 °C and the acid, caustic smoke.



The furnace, photo by Beata Kosak

22

Four people on our team are equipped with expert heat-resistant elbow-high gloves. The oldest participants lie down on the left and right sides of the fire chamber, while Marek and Mateusz move back the sheet, which closes the inside of the kiln, half way through. After filling in this part with black locust logs, we have several seconds to change the heated, burning gloves, and the sheet is moved to the other side, where we continue adding wood; due to the temperature, we cannot open our eyes, so we toss logs in. The logs must fill in the space between ceramic objects, and one fourth of the chamber capacity.



The inside of the kiln chamber, photo by Beata Kosak

Working with Rytis, with fire creeping on our gloves and shoulders, we add wood carefully, not to damage the ceramics. The temperature forces us to shorten the time of action to the minimum, down to 7 minutes, whereby we do not lose the heat, which should provide for the proper course of the burning process in reducing atmosphere. The process causes the clay shards to obtain different shades of grey or black with metallic gloss.²⁷ In lower temperature, deoxidation of iron is not complete, and black iron oxide is produced. The more iron oxide is made in the chamber, the deeper the reduction will be, and thereby the objects obtain a more intense shade of black, colour much more durable and deeper than the one obtained in the presence of ferrous oxide.

“Carbon oxide combines with oxygen, which dissociates from the immediate surrounding (detaches) one atom of oxygen from iron oxide contained in clay, and then transforms into carbon dioxide, leaving black ferrous oxide (FeO) in clay. It is assumed that colour – from grey-silver to black – obtained by the crockery depends on FeO content of clay. The more iron compounds (which catalyse the reaction) it contains, the more intense black colour of ceramics is.”²⁸

The “furnace-choking” team swings into action – five people use shovels to cover the upper part of the kiln. After the chamber with ceramics is closed, the fire retreats to the furnace, and when the entire tunnel is filled in with black locust logs, which takes two people 3 minutes, the fire is controlled with a double gate of sheets and sand. At that point, the team with 5 shovels and two pairs of hands seals the kiln. It is completely covered with sand; the most material is needed on the vertical wall of the furnace. At this stage, the tightness of kiln is essential. Any cracks could suck in the air, which contains oxygen, and replaces the escaping carbon dioxide, disturbing the course of this stage of thermal setting of the ceramic clay products.²⁹ “Reducing atmosphere should be maintained in the kiln until the temperature decreases enough not to allow the reoxidation process, which could cause the change of colour.”³⁰ Rytis proves how illusive the impression of tightness is, as he attaches a lit match to the heap on the fire chamber cover: the entire surface displayed hundreds of creeping small blue flames.

We open the fire chamber after 36 hours from “furnace-choking”.

The obtained ceramics has silver-grey colour and resonant metallic sound, regardless of the place where the item was in the kiln. It would mean that we have achieved even distribution of high temperature across the fire chamber. We can also

²⁷ R. Reinfuss, *Garncarstwo ludowe*, Wydawnictwo “Sztuka”, Warszawa 1955, p. 27

²⁸ M. Matuszczyk, A. Oborska-Oracz, J. Wowak, *Ceramika siwa i czarna ...*, op. cit., p. 168

²⁹ R. Krzywiec, *Podstawy technologii ceramiki. Podręcznik dla ceramików*, Państwowy Zakład Wydawnictw Szkolnych, Poznań 1950, p. 83

³⁰ Idem, *Technologia rzemiosła garncarskiego. Cz. II*, Państwowe Wydawnictwo Naukowe Warszawa, 1954, pp. 60–62

confirm the thesis that a particular colour depends on the species of wood used for firing, especially at the final stage. Wood from coniferous trees largely contributes to obtaining darker grey of shards, while wood from deciduous trees causes the fired clay to obtain different levels of grey or leaden silvery. It is also believed that the height of temperature at the working stage of the ceramic kiln does not determine the final colour of objects³¹, yet it does have influence on the quality of the obtained sinter, which we can also confirm.

The effect of ceramic crockery was important to us, but in the end, the experience of fire remains the most significant element of the workshops in Gubbio, one of these, which reinstate the lost awareness of being part of the Cosmos. The conducted research has confirmed how important it is to participate in well-prepared and carried out workshops for developing respect for clay and fire – material and energy.

³¹ M. Matuszczyk, A. Oborska-Oracz, J. Wowak, *Ceramika siwa i czarna ...*, op. cit., p. 177

Martyna Piątek

¹ A. Lorek, *Eksploatacja surowców skalnych na terenie województwa śląskiego*, "Przegląd Górniczy" 2019, no. 7, p. 64

The research was conducted from spring to autumn 2005. The several-month process started from making a plaster mould for numbered porcelain bases, which served as foundations for samples. These were cast in 1620 g/l casting slip, prepared from "Imerys" granulate PC975B, and then fired into bisque in 930 °C in electric kiln. In parallel, there was conducted the stage of mapping locations as potential source of interesting raw materials, and their rediscovery.

Collection

Starting works on the project, I had two main assumptions – first, ingredients on which I would conduct trials should be gathered only in the area of Silesian Voivodship; second, they would be definable as "natural" or "wild". Following the definitions from the Oxford English Dictionary, "natural" means "existing in or derived from nature" and "in accordance with the nature of, or circumstances surrounding, someone or something." "Wild", on the other hand, stands for "living or growing in the natural environment; not domesticated or cultivated," and in the context of place or region "uninhabited, uncultivated, or inhospitable." Here, matters become a little complicated. Although Upper Silesia is associated, almost emblematically, with extraction of the power raw material, i.e. hard coal, the area has as many as 550 documented diverse mining deposits, the most important, apart from the obvious, being: dolomites, limestones, marlstones, sandstones, sands, and gravels.¹ The question, therefore, arises, to what extent we can consider "natural" the rocky deposits which, indeed, come entirely from inside the Earth and complement the material palette of identity of this place, but have been quite brutally extracted from it by means of man-made diggers, dredgers, and explosives. Thus, outside the natural law. A separate group of raw materials, which inapparently shape the Silesia landscape is mining and industrial waste, stored on the tips. Interestingly, these are not entirely idle

heaps. In their own rhythm, they are overgrown by wild plants over the years, or the opposite – they undergo processes of transformation by active increases in temperature and oxidation leading to self-combustion, and consequently, to self-transformation of the stored aggregate. Professor Łukasz Kruszewski of the Institute of Geological Sciences of the Polish Academy of Sciences, in his lecture "Burning tips as models of diverse geological environments" goes as far as to claim that such processes can be called "natural", since despite occurring in artificial conditions, they take course without human intervention.

In the end, as of now, I have managed to visit several diverse locations within the voivodship, including:

- › **area of the dolomite mine in Dąbrowa Górnicza** – its formation as a small open-cut object on the initiative of a geologist and the first president of Dąbrowa Górnicza, Adam Piwowar, dates as early as the end of the 19th century. Today, after many transformations, it functions as a joint-stock company PPUH "DOLOMIT" Kopalnia "Ząbkowice" s.a., extracting and processing aggregate for the needs of construction, smelting, and agriculture;
- › **Jurassic limestone and silt quarry in Niegowonice** – formerly supplying the "Wysoka" cement plant, now out of operation. Today the quarry serves only entertainment purposes, as the area of legal routes dedicated to off-roading;
- › **Kamieniołom Warszawski (The Warsaw Quarry) in Siedlec** – the limestone quarry, inactive today, but still interesting as a geological and tourist area. Its sedimentary rock is described by experts as one of the whitest, and was therefore used for facing the representative buildings in Warsaw, including the Parliament and Office of the Council of Ministers, which explains the origin of its name;
- › **area of the "Pogoria III" reservoir in Dąbrowa Górnicza** – an anthropogenic post-exploitation reservoir left after sand extraction from the nearby coal mines, one of four such reservoirs of the so-called Pogoria Lakes. Formed in the 1970s, now serves recreational functions for the residents;

- › **Kochłowice tips** – post-mining waste hills located in Kochłowice, Ruda Śląska district neighbouring Chorzów. Today, partially overgrown with plantlife, they serve mainly as a walking area for the local residents;
- › **area of Staw Marcina (Martin's Pond)** – the post-mining water reservoir, located on the border of Świętochłowice and a Ruda Śląska district, Chebzie. According to some literature, the pond is the source of the Rawa river, which is a tragic symbol of the natural environment degradation in industrial areas (due to its high pollution, it has been channelled in underground canals). The Martin's Pond is surrounded by tips in the process of rehabilitation, where industrial plants are still in operation. The reservoir area is currently leased for fishing purposes.



1



2



3



4



5



6

From the above-mentioned sites, I collected several tens of material samples, including plants, clays, rocks, aggregates, sinters, cinders, and post-industrial slags. Although part of them had been recognised, the choice of some was purely intuitive. Based on several samples, I started preparing components to conduct experiments on porcelain.

Photos of materials from the following locations: 1. Pogoria III reservoir in Dąbrowa Górnicza, 2. Warsaw Quarry in Siedlec, 3. Dolomite mine in Dąbrowa Górnicza, 4. Jurassic limestone and clay quarry in Niegowonice, 5. Kochłowice Heaps in Ruda Śląska, 6. Marcin's Pond in Świętochłowice, own photo



Photos of collected hard samples, photo by Barbara Kubska

Recipes

The collected samples were dried, sorted, and mechanically cracked and ground down by means of manual tools. The assumption was to eventually crush the material in the mortar into fine dust, possible to sieve through. The aspect of tedious physical work provided the project with the added value of concentration on a given activity. Rocks and clays of natural origin made the work pleasant not only for more brittleness and their colour palette, eliciting direct associations with nature, but also for their earthy smell, oozed especially in combination with water. The waste, post-industrial samples exhibited more caprice, their structure was much less predictable.



Crushed pigments, photo by Barbara Kubska

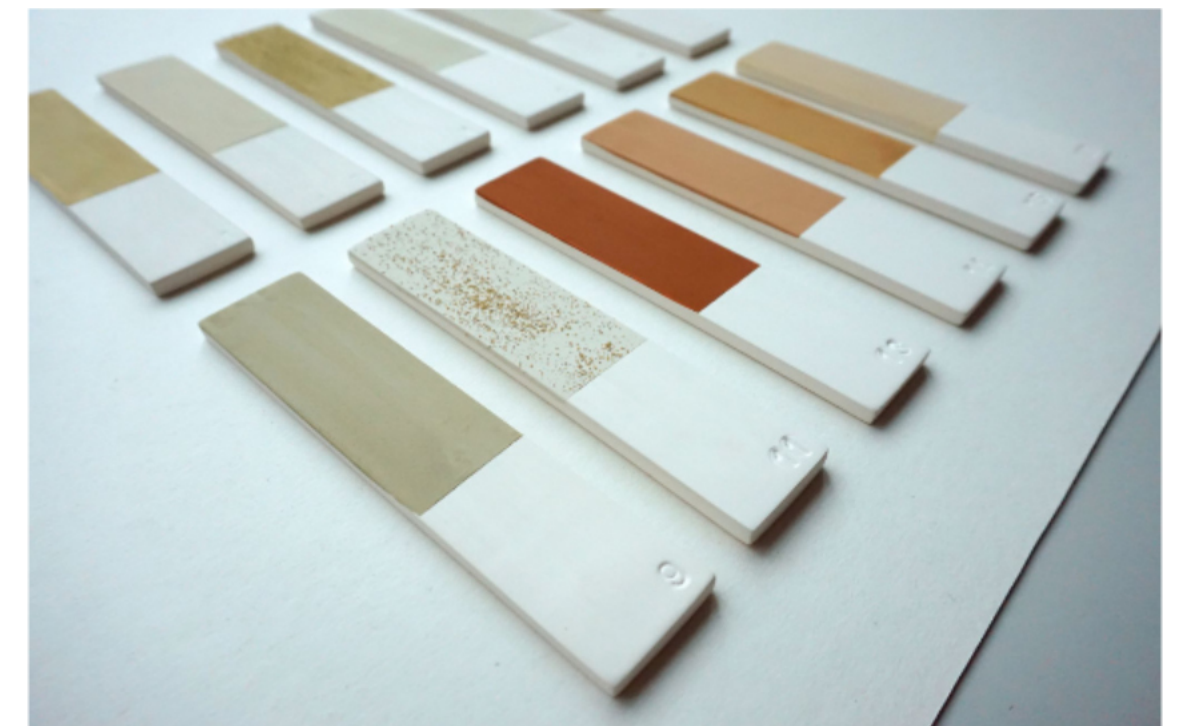
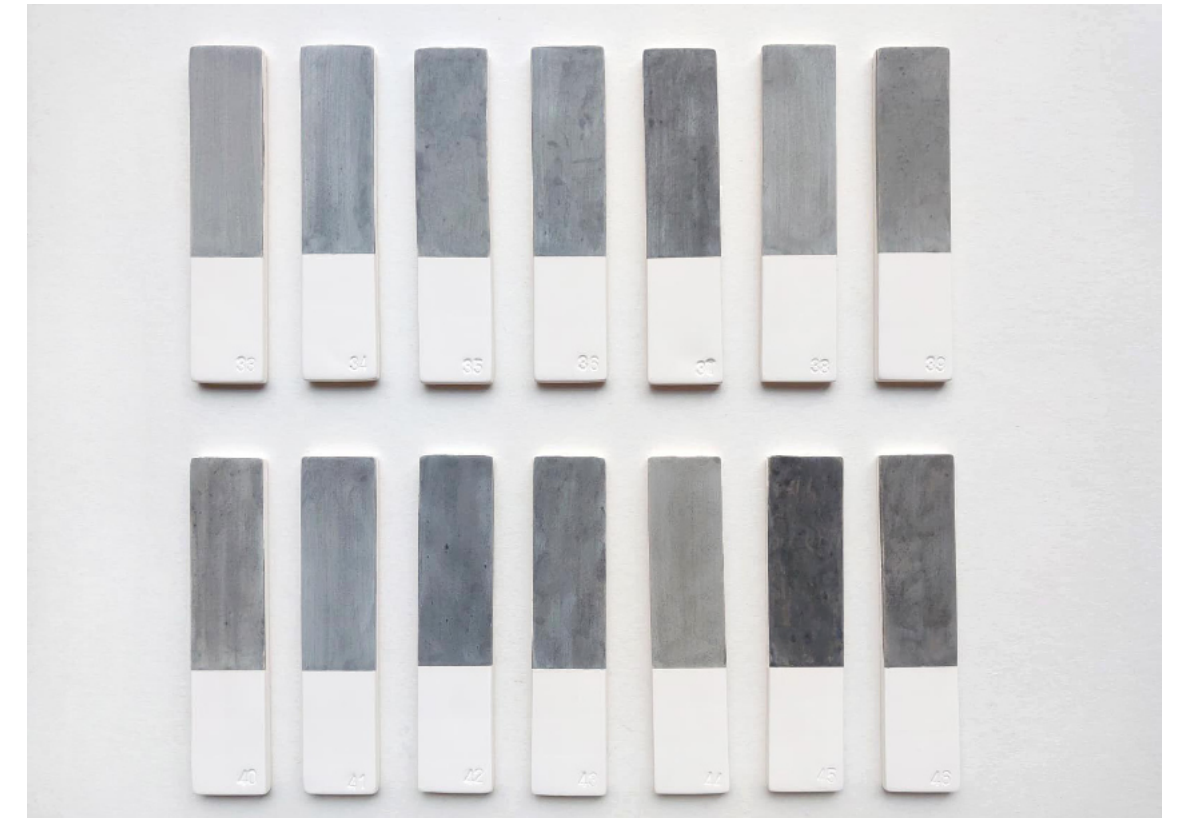
31

Aggressive chemical and physical processes, which they had undergone on the way, left a clear mark of their high denseness. These samples "resisted" grinding into small particles, scratching the surface of the mortar. The rising dust was unpleasant in character. There was also the anxiety about harmful substances possibly hidden in these unnatural aggregates. Preparation of floral samples consisted in drying, and then cutting, separate burning, and pouring the ashes off. These were mainly waste tree branches and leaves of plants present in all locations: silver birch, Scots pine, grasses and ferns, and in the case of locations at water reservoirs, also bulrush and sedges.



Prepared plant ashes, own photo

32



Tests before firing, own photo

The recipes were, by assumption, as simple as possible, as to make it easily observable how individual, essential matters behave on porcelain. Mixtures were based on prepared pigments mixed with water and powdered, recycled remnants of porcelain mass, made in the course of processing of tile moulds, in the following proportions: 1:1 (pigment + water) and 1:2:3 (porcelain dust + pigment + water).

Several recipes were also made with the addition of transparent glaze power to porcelain mass EH091T in proportions 1:1:2 (glaze + pigment + water). Considering the effort connected with the mechanical process of preparing components and the resulting small quantity of those, I decided to put mixtures on bisque bases with a brush, also testing how the number and thickness of layers influences their application and the final effect. At the pre-firing stage, the colour palette of samples was very diverse, differences in the intensity of colour with various content proportions were especially noticeable in mixtures based on clays.

Firings

The coated samples were divided into two groups:

- › samples with transparent glaze in composition prepared directly for high-temperature firing (1220 °C);
- › samples for bisque re-firing (930 °C), then fragmentarily immersed in transparent glaze EH091T of density 1230 g/l, thereby prepared for the target high-temperature firing (1220 °C).

Firings of the samples were carried out in a top-loading electric kiln.

Conclusion

Dolomite from Ząbkowice in Dąbrowa Górnicza

Samples based on local dolomite are characterised mainly by the difference between porcelain mass and aggregate contraction, which caused a typical deformation of porcelain. There occurred interesting material swelling in the samples, in places where the coat layer was thicker. Dolomite powder absorbs transparent glaze, due to which the final effect is not glossy, but semimatte. The majority of samples retained colouring and porousness of the source material, evoking direct associations with the material of natural origin.



Dolomite tests after firing, photo by Barbara Kubaska



Dolomite tests after firing, photo by Barbara Kubaska

37

Limestone from Niegowonice

Experiments on the basis of limestone did not bring expressive effects. There was an observable slight change of texture under the surface of transparent glaze and delicate smudges in places, were there had probably been more pigment.



Tests with sand particles after firing, photo by Barbara Kubska

38

Clay from Niegowonice

There was a little more intensive visual effect on the samples based on clay from the immediate surroundings of the quarry. Traces clearly smeared under transparent glaze, while the non-glazed fragment (sample no. 8) obtained the apparently glossy surface also after firing.



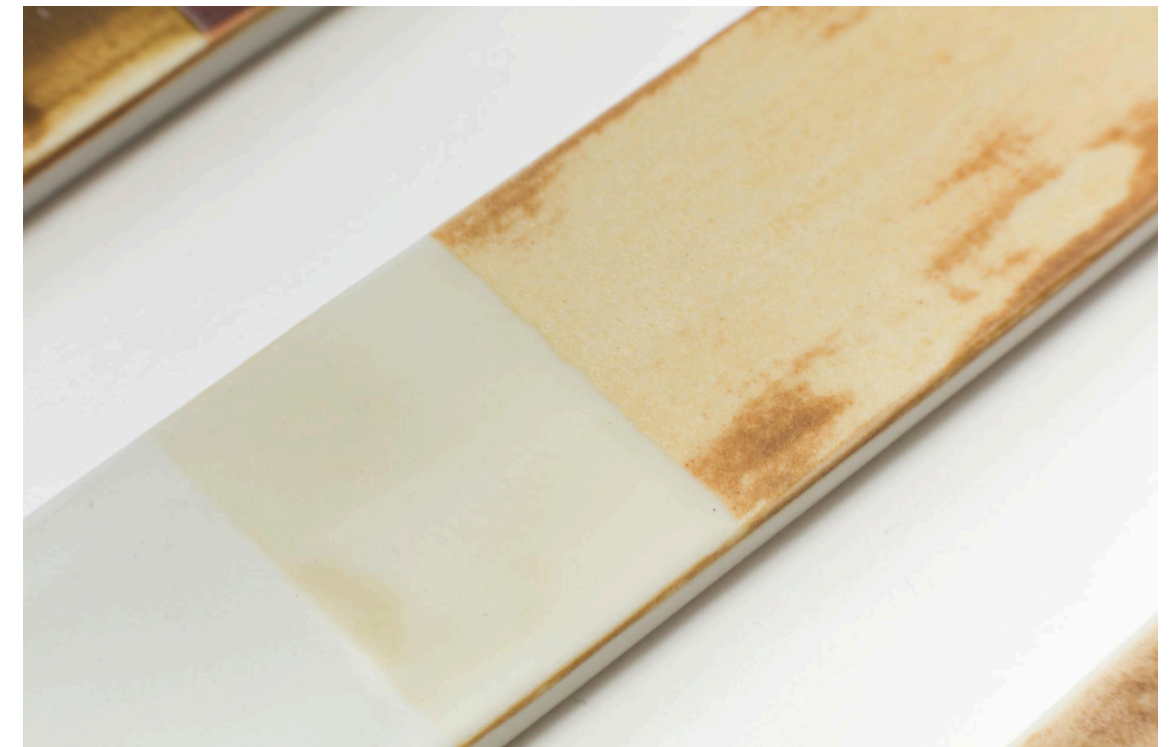
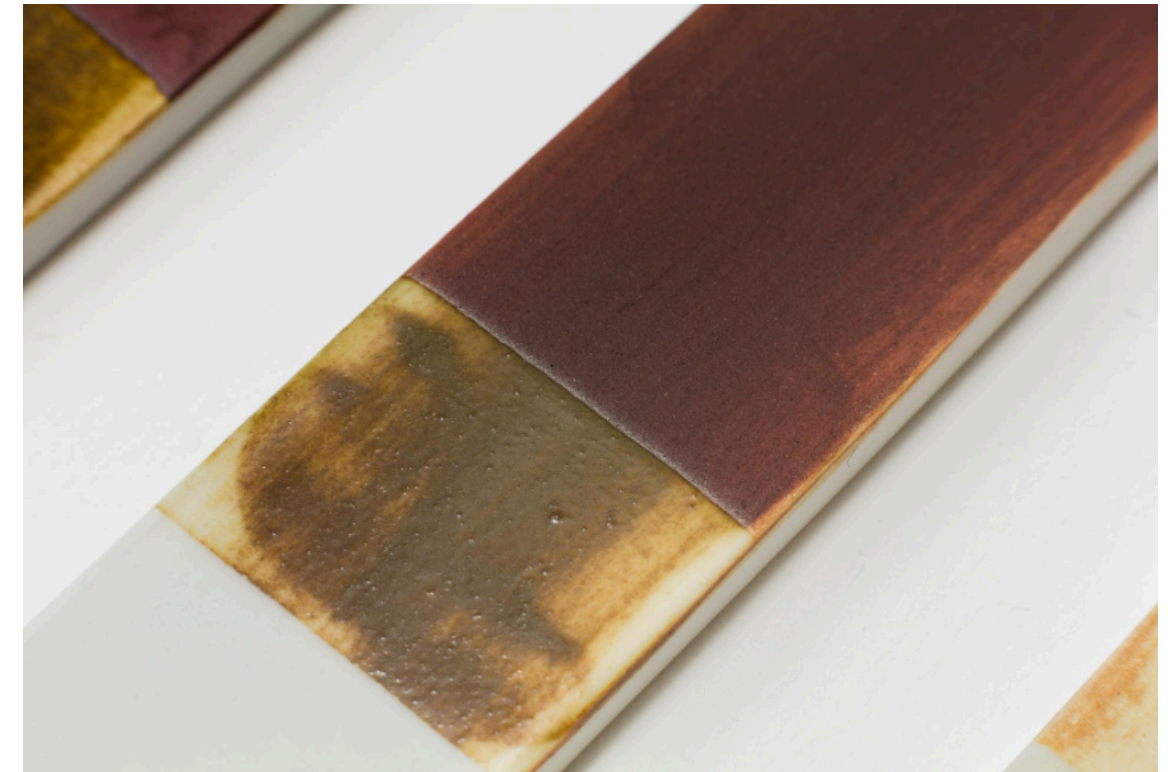
Tests with ashes after firing, photo by Barbara Kubska

Clays from the Warsaw Quarry in Siedlec

Colours and surfaces of samples differ from one another as regards saturation and reaction to glaze. In samples based on the intensely rust-coloured clay, finally there also occurs intense burgundy of full cover and high abrasion resistance, while samples based on clay of higher limestone content (nos. 15–17) are characterised by more yellowish hues, yet of more apparent, painterly brush strokes. In both cases, transparent glaze changes colour and slipwares opacity.



Tests with clay after firing, photo by Barbara Kubska



Tests with clay after firing, photo by Barbara Kubska

41

Sand from "Pogoria III" reservoir in Dąbrowa Górnicza

As expected, sand consolidated with transparent glaze, leaving the clearly grainy texture. On the non-glazed fragment, there is observable delicate colour left by iron ores, as the sand mixture was saturated with them, but the grains did not consolidate with porcelain and crumble out easily when touched.



Tests with sand particles after firing, photo by Barbara Kubska

42

Ashes

Tests involving ashes turned out a failure. The considerable majority of mixtures contained too small concentration of ashes, also disserved by mixing them with porcelain powder. Samples nos. 47–50, consisting mostly of dense ashes, brought delicate effects of colouring. These tests should be repeated.



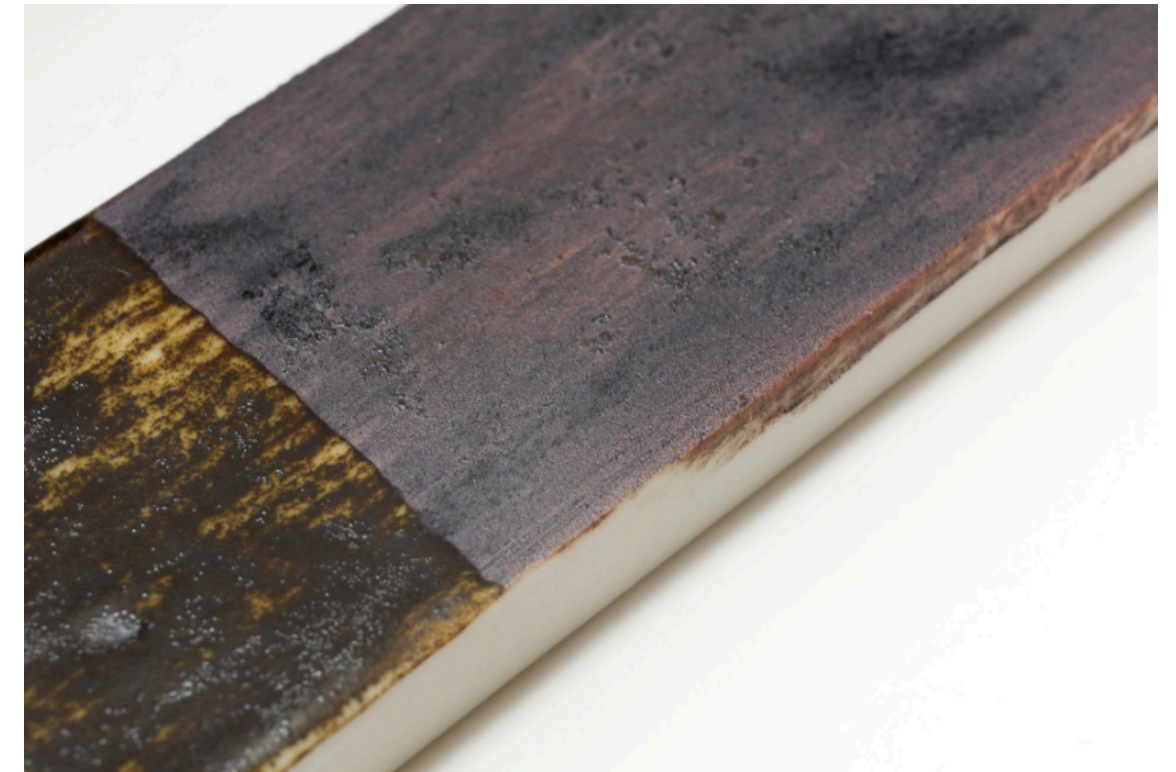
Tests with ashes after firing, photo by Barbara Kubska

Minestones from Kochłowice Tips in Ruda Śląska

Samples based on pure coal aggregate (nos. 18–19) are characterised by rather even and muted effect with pale-brown hues. There were surprising effects, in turn, of subsequent samples based on a lump of coal, undergoing the mineralisation process on the tip. These are characterised by intensive deep hues of purple and, interestingly – metallic gloss on non-glazed surfaces. In this case, transparent glaze receives this specific finishing effect, balancing colour of the sample to uniform brown.



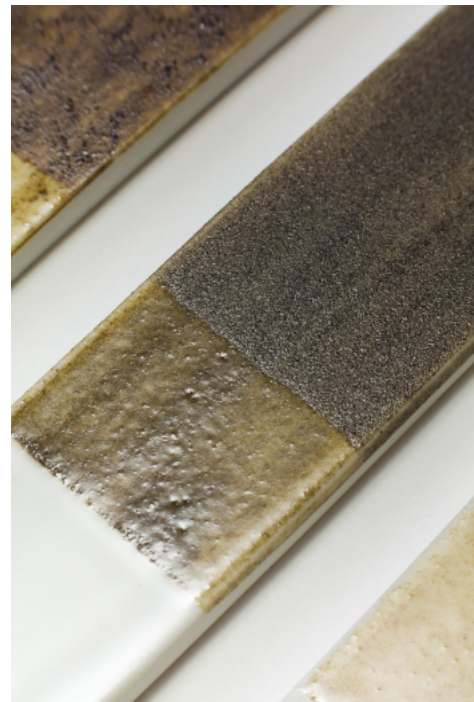
Tests with coal after firing, photo by Barbara Kubcka



Tests with coal after firing, photo by Barbara Kubcka

Sinters, gravels, and post-industrial slags from different locations in Ruda Śląska

Materials, which I previously had not taken into consideration as potentially attractive or needed in my research project, brought the most surprising results. It might seem that waste that has been through multiple transformations already, could not offer anything new. Nothing could be further from the truth. Despite using small amounts of post-industrial components, samples brought the most intensive effects both in diverse colour range (from yellow to reddish browns), and in textures. Fine grains on the porcelain surface caused traces from subtle painterly marks to thick bumpy textures and cast-iron gloss.



Tests with slag after firing, photo by Barbara Kubska



Tests with slag after firing, photo by Barbara Kubska

Follow-up on the project

The presented effects of the first edition of research on the potential of making glazes and pigments based on local raw material as a starting element of a discussion about the human relation with immediate surroundings, are merely a rudiment of possibilities opened for us by the experiment. The diversified landscape of Silesian Voivodship of strongly anthropogenic character constitutes the endless treasury of knowledge and material inspirations. My curiosity about subsequent reactions and visual effects sparked especially in the context of further studies on samples of post-industrial origin. Nonetheless, beside developing and testing the recipes around selected components from different locations, there arises a paramount question: Based on the experiments described above, is it possible to design tools supporting contemporary human in building relations with nature? How to include external users in the process? The project will be continued in the upcoming months. My other steps toward developing my research will be carrying out pilot workshops with students of the Faculty of Design of the Academy of Fine Arts and Design in Katowice within the workshop week in spring 2026, and consulting the conclusions and observations with experts in the area of ecopsychology. The goal for the future will be formulating a scenario of workshops available to the broad public.



Final effects, photo by Barbara Kubaska

Processes of natural firing on post-mining tips

Łukasz Kruszewski

Introduction – spoil tips as an element of contemporary environment

Coal mining entails mass production of post-mining waste – rocks, which are unusable from the perspective of extractive industry, at least in the context of contemporary energy technology. Such waste ends up on tips that, in turn, become the unavoidable element of the environment of coalfields worldwide. In the light of the recent attempts at establishing a new era – Anthropocene – these objects serve as its perfect markers.

These often one hundred metres tall heaps concentrate huge quantities of waste material (Srebrodolski 1989). More than 2 bn tons of gangue pile up on over 1200 tips of Donbas (Ukraine) (Panow et al. 1999). In certain regions of Russia, almost 0.5 mil tons, and in China even over 1 mil tons, annually end up on spoil tips (Nelson & Chen 2007).

Post-extractive mining tips, technically called landfill sites, are landmarks of many cities of Upper Silesia, and a few in Lower Silesia as well. In Upper Silesia alone (Upper Silesian Coal Basin, usbc), there are more than 200 tips. The most prominent examples refer to Rybnik Coal Area, with impressive, massive “Szarłota”, towering over the surroundings in Rydułtowy. It is one of the tallest tips in Europe (138 metres high). Equally interesting objects are situated nearby, in Pszów (“Wrzosa” tip) and Radlin (“Marcel” mine’s tip).

Why do the above-mentioned objects deserve particular attention? One tip is unlike the other: as much as inside the majority of tips there occurs the self-heating process, only some of them become a scope for temperature. It refers to spontaneous

coal fires, which transform an ordinary heap of “waste” into what is sometimes called a “volcano for the poor”. As it turns out, these terms are very accurate, and such “contemporary Silesian volcanoes” – both active and extinct – can also be found in the very cities of Rybnik, Katowice, Czerwionka-Leszczyny, Łaziska Górne, Gliwice, Zabrze, Ruda Śląska, Bytom, or in such towns as Michałkowice near Bytom, and Wojkowice.

Phenomena analogical to these described above occur with underground mine fires and in zones of natural fires of coal deposits, for instance in Rawat and Kuchi-Malik in Tajikistan (Bełakowski 1990, Nasdala & Pekow 1993), and in Pennsylvania (Lapham et al. 1980). Temperatures of such zones reach 1100, and even 1450 °C. Even higher temperatures – from 1650 to 2000 °C (sic!) – are noted in the environment of bituminoids (e.g. Formation Hatrurim, Israel) and oil fields (e.g. formation Monterey, California, USA; Gur et al. 1995, Sokoł et al. 2005, Sokoł & Wołkova 2007, Wapnik et al. 2007). Coal fire zones can take the area of several tens km² (Lapham et al. 1980, Sokoł et al. 2005). The fire spreads with the average speed of 5–17 m/year (Sokoł et al. 2005, Sokoł & Wołkova 2007).

Coal self-combustion on tips – what and how?

Coal self-combustion is a multicausal and multistage process. Slow heating of coal (and gangue) leads to degasification, and then, as the temperature increases, to ignition and combustion of fire gases. Fires of spoil tips and coal deposits have a character of the diffusion combustion process. Coal decomposition occurs both by pyrolysis and, with low oxygen supply, carbonisation. The initial self-combustion temperature, related to the initiation of changes in the oxygen adsorption process, is usually 70–80 °C (Sokoł et al. 2005).

An important factor of self-combustions is the appropriate quantity of fuel (here: coal) and oxygen – the self-combustion process is mainly the process of oxidation. At the beginning of coal mining in these regions, mostly still under the German rule, there were no known methods of effective separation of coal from the so-called aggregate (unusable, waste), consisting mainly of shales (mudstones, claystones) and sandstones. Consequently, spoil tips of Upper and Lower Silesia stored considerable quantities of inseparable coal. Therefore, tips could contain even several tens percent of non-separated, scattered raw material. It was only due to the introduction of technology known as flotation that the situation changed. For

this reason, it is mainly old tips that burn, and the fire processes which consume them can last even several decades.

Hot, flammable and volatile combustion gases migrate upwards through the same cracks, through which the atmospheric air is sucked into tips (the chimney effect), especially in good weather. This leads to secondary ignition and development of fire and thermal transformation in overlaying parts. Ignition temperature depends i.a. on the gas-phase chemistry. Exhalations rich in sulphuric steams, for instance, can cause ignition in the temperature 250–260 °C (Srebrodolski 1989, Czesnokow & Szczerbakowa 1991, Panow et al. 1999, Sokoł et al. 2005). As the thermal transformations progress, the seat of the fire may also migrate deeper into tips and ignite their lower situated parts. Migrations of seats of ignition, also called telescoping, provide for stability of gases flow. This way, the convectional redistribution of heat and mass becomes the main factor of waste transformations and constitutes a separate type of metamorphism – pyrometamorphism (Sokoł et al. 2002 and 2005, Grapes 2006, Sokoł & Wołkova 2007). Development of the above mentioned fires can be described as a cycle: self-ignition → gases explosion → rock crumbling → cooling down → decrease in protolith volume → shrinking cracks → oxygen supply → spark → self-ignition (Sokoł et al. 2005).

The second factor is coal petrography, i.e. its phase composition. Coals differ regarding their main components, so-called macerals. These, in turn, vary in their physical properties. Some of them ignite in the relatively low temperature, other – retain heat for a long time. Contact of two macerals leads to activating catalysis (“ignition cores”) – one maceral transfers the spark onto another, and the combustion process can spread. High porousness of waste material, facilitating the atmospheric air flow, and properties of the fuel, such as fine crumbling, gases absorption/desorption capacity, high ash content of coal and high sulphides content, make it prone to oxidation. The process is also facilitated by rain water, which soaks into tips and carries oxygen, but also erodes the surface, making oxygen supply easier (Wagner 1980, Srebrodolski 1989, Nelson & Chen 2007, Pone et al. 2007, Sokoł & Wołkova 2007). Oxidation is exothermic, causing heating of large areas within (and then also near the surface) of tips. This results in spontaneous coal self-combustion – the main cause of tips fires (Srebrodolski 1989, Panow et al. 1999, Pone et al. 2007).

The third factor is also a catalyst in the form of iron sulphides, mainly pyrite (FeS₂). This common mineral, iron(II) disulphide, abundantly encrusts some coal deposits. Its presence in the fire system drives the spiral of fire.

The fourth, final factor, is a biological one – vital functions of microorganisms, such as breathing, which also transfer heat in an exothermic manner (Świętośławski 1953, Wagner 1980, Srebrodolski 1989, Panow et al. 1999, Robertson et al. 2002).

Mineralogenic processes on burning coal mining tips

Coal fires activate three fundamental processes of waste material transformations on spoil tips:

- › high-temperature **pyrometamorphism** – a number of physico-chemical transformations processes, usually occurring in the range 330~1250 °C, which significantly liken tips to volcanoes; these are processes of partial or complete melting of rocks, and even recrystallisation thereof, with producing totally new materials, often similar to bricks in one way, to typically volcanic basalt rock in another, and also to ceramics;
- › **exhalation** processes, occurring in temperatures from ~100 to several hundred °C – causing the production of fumaroles and minerals closely resembling the volcanic ones; within fumaroles on tips there occurs crystallisation of minerals directly from gas (so-called desublimation or condensation) or through extraction of metals from the ground (so-called pneumatolysis – the element of hydro-thermal processes);
- › low-temperature (<50 °C) **hypergenic** processes (surface weathering) – which approximate tips to zones known from metallic mineral mines; the main phenomena of the hypergenic stage are oxidation and evaporation.

As much as exhalation and hypergenic processes result mostly in generation of subsurface, usually insubstantial accumulation of compounds, chemically sulphates or, rarely, chlorides and fluoride complexes, pyrometamorphism – occurring in the so-called firing zones – mainly produces various silicates and oxides. The vast majority of those as highly-incombustible substances.

Pyrometamorphism and ceramic mineralisation

The pyrometamorphic stage (firing stage) consists of the high-temperature processes of thermal transformation of tip material (Srebrodolski 1989, Sokoł et al. 2005). It includes: degradation of minerals structure, melting, and solid-phase synthesis. Based on field observations (Kruszewski 2009) and experimental research into the firing stage, the following phenomena are identified (Srebrodolski 1989, Czesnokow & Szczerbakowa 1991, Filippidis et al. 1996, Reifenstein et al. 1999, Ward 2002, Sokoł et al. 2002 and 2005):

- › dehydration and degradation of structure of the original aluminosilicate minerals, occurring in the range 500–650 °C;
- › decomposition of carbonate minerals in temperatures ~600–750 °C, with production of quicklime CaO, periclase MgO, wüstite FeO, magnetite, pyrrhotite, and calcium ferrites;
- › local melting of certain aluminosilicates, ~700 °C;
- › sanidination of microcline in the temperature 800 °C;
- › intensive melting of material in deeper parts of tips (from ~1200 °C);
- › reactions of products of carbonates and aluminosilicates decomposition with sulphur, chlorine and fluorinated gases, resulting in production of oldhamite CaS, anhydrite CaSO₄, and – rich in fluorine, sulphur and silicone – minerals form the apatite group.

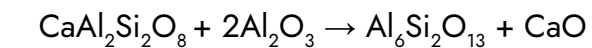
Fluorides, but also carbonates, function as eutectics in the processes of further melting and production of melts. Within cooling down of the melt, there occurs crystallisation of anhydrous silicates and oxides, and glaze is produced (Sokoł et al. 2002).

According to the experimental research of Querol et al. (1994), it is possible to distinguish the most important processes of high-temperature transformations of the mineral substance during coal combustion. The final product of decomposition of clay aluminosilicates – kaolinite, “illite”, chlorites and smectites – as well as potassium feldspars (orthoclase), is mullite $Al_{4+2x}Si_{2-2x}O_{10-x}$, the synthetic equivalent of which is the key component of ceramics. An important semi-product of these transformations, beside quartz, is silicon spinel $Al_2O_3 \cdot 3SiO_2$. It can become a pro-anorthite, if the transformation environment is rich in lime.

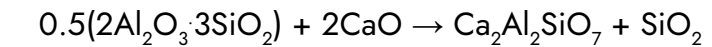
The course of calcite and dolomite decomposition is simple, while in the case of siderite and anorthite, it is more complicated, resulting in wüstite FeO, magnetite

$Fe^{2+}Fe^{3+}_2O_4$, hematite Fe_2O_3 , and calcium ferrites e.g. srebrodolskite, $Ca_2Fe_2O_5$ (Czesnokow & Szczerbakowa 1991, Sokoł et al. 2002). Common and complete melting of dehydrated and decarbonised waste rocks results in melts, which crystallise as so-called parabasalts.

The first crystalline product of thermal transformations of aluminosilicate minerals of gangues, is mullite, produced in large quantities in the temperature >650 °C. Although quartz is stable up to 1400 °C, in the course of fire it can also slowly transform into cristobalite. Tridymite, typical for high-temperature stages, is a product of recrystallisation of glazes and amorphous silica. Many of these and other processes occur in temperatures ~500–1200 °C, probably according to the reactions below (after Querol et al. 1994). One of them is synthesis of mullite from anorthite, with aluminium oxide as one of the reactants:



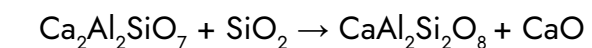
Gehlenite, a typomorphous mineral, one of the indicated types of metacarbonate parabasalts, can be synthesised from silicone spinel, in reaction with calcium:



The manner of production can be similar for esseneite – the characteristic constituent in the phase composition of metacarbonate slags clinopyroxenes; in this case, one of the reactants is iron(III) oxide:



Paragenesis of gehlenite and anorthite in metacarbonate slags can be explained by reaction of gehlenite with silica, resulting in production of anorthite and calcium:



A common semi-product of aluminosilicates transformations is silicone spinel, sometimes equated with deltalumite $Al_{(0.67 \square 0.33)}Al_2O_4$ (polymorphous with corundum). The most important of the above-described processes, especially in reference to Upper Silesian Coal Basin, are summarised in Fig. 1 (after: Kruszewski 2009).

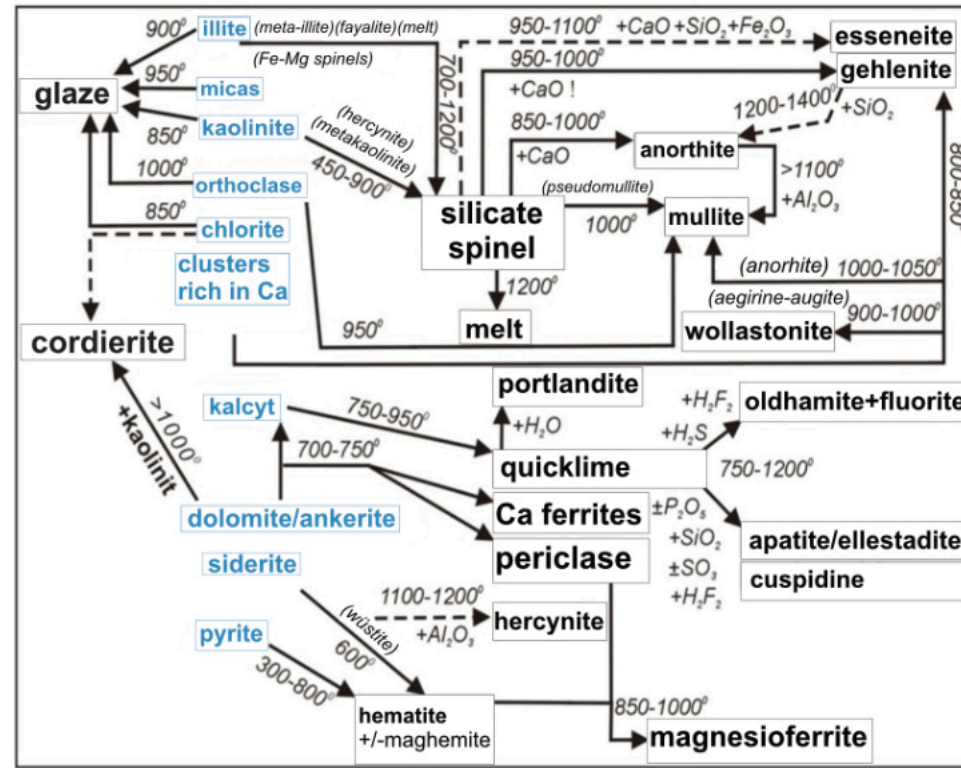


Fig. 1. Summary of pyrometamorphic reactions paths on usbc spoil tips. Temperatures and directions of transformations after: Srebrodolski 1989, Querol et al. 1994, Filippidis et al. 1996, Reifenstein et al. 1999, Sokol et al. 2002, 2005, Ward 2002. Dashed lines were used for potential reactions.

Interaction of aluminosilicates CaO and Fe_2O_3 , produced during decomposition, can lead to crystallisation of srebrodolskite, and in the case when magnesium is present in the environment, also of magnesioferrite (Ward 2002). Concreative production of the majority of metacarbonate parabasalts and their mineral inventory open them to comparison with aggregates, described in literature as *nutshell* (Sokol et al. 2005; Fig. 2). These are produced as a result of thermal transformation of carbonate formations, composed of siderite, calcite, ankerite, and dolomite. Nuclei of *nutshell*-type aggregates from Czelabiński Coal Area, are built of portlandite $\text{Ca}(\text{OH})_2$, as well as brucite $\text{Mg}(\text{OH})_2$, quicklime CaO , periclase MgO , hematite and oxyspinels, while their envelopes are dominated by anhydrite and fluorellestadite $\text{Ca}_5(\text{SiO}_4)_3\text{SO}_4$. In contact with parabasalts, clinkers and other silicate formations, these become fortified with melilite, larnite Ca_2SiO_4 , ferroan clinopyroxene (esseneite), chloric equivalents of hydrogarnets, carbonate-silicates – e.g. spurrite

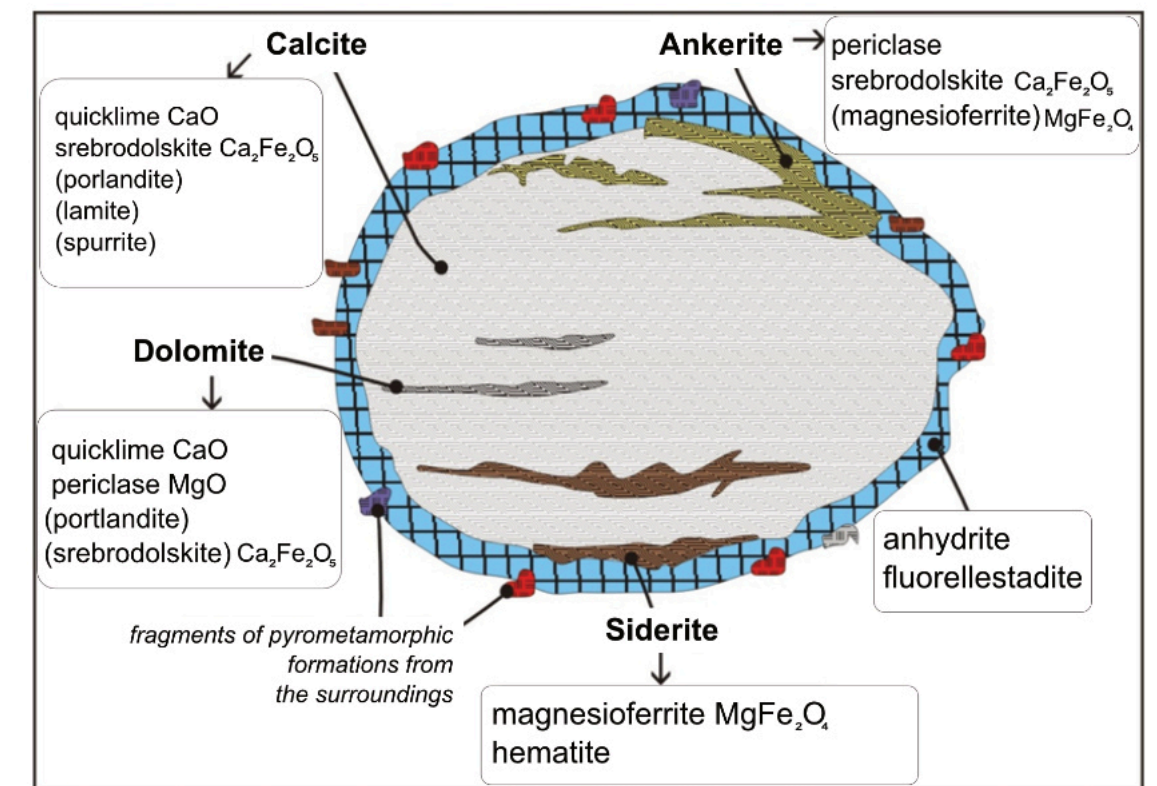


Fig. 2. Nutshell-type aggregate – type of metacarbonate slag (after Sokol et al. 2005, from Kruszewski 2009).

$\text{Ca}_5(\text{SiO}_4)_2(\text{CO}_3)$ – as well as calcium ferrites (Czesnokow & Szczerbakowa 1991, Sokol et al. 2002).

The most significant pyrometamorphous rocks formed on tips, which sometimes occupy vast spaces and volumes, make up a common group of rocks, known as metapelites (meta-argillites). Among their most important types, we include (Cosca & Peacor 1987, Cosca et al. 1989, Foit et al. 1987, Heffern & Coates 2004, Sokol et al. 2005, Žáček et al. 2005, Grapes 2006):

- › **clinkers** – sometimes called “red shales”; actually, they macroscopically retain the appearance of original coal shales, directly from which they are produced as a result of partial remelting and glazing; these rocks are necessarily red or pink-red, providing tips with real Martian looks (in fact, coal tips tend to be described as one of the Earthly analogies to Mars); associating clinker with clinker brick is accurate – these

- formations are similar; clinkers are the most common type of pyrometamorphic rocks on spoil tips, responsible for considerable volumes thereof at times; in the classification according to Sokół et al. (2005) they correspond to red metapelites – produced in temperatures >870 °C – attached to high, steep, and intensively burning tips;
- › **porcellanites** – similarly to clinkers, they look like shales, and also quite often bear well preserved fossilised fragments of plants within (from which carbons were formed in the carboniferous period); actually, they only differ from clinkers in colour – these rocks are white or cream, which results from the deficit of iron;
 - › other shale metapelites – are mostly yellow, grey and black metapelites; after Sokół et al. (2005):
 - yellow metapelites – without tridymite, and with mullite content up to 10 wt. % – they are formed in the initial stage of fire, in temperatures about 700 °C,
 - pink metapelites, in turn, result from the sintering stage and mineral synthesis from the amorphous stage – in temperatures 700–870 °C; they contain hercynite FeAl_2O_4 (oxyspinel group) and cordierite; they can demonstrate mineralogical zonation, especially in reference to iron (II,III) and magnesium, which reflects interactions of solid phase with gas phase of reductive character (fortification with CO , CH_4 , H_2 , hydrocarbons, and metal-organic compounds), and the oxygenated stream of air.
 - › **buchites** – usually rounded and strongly porous, often rich in glaze rocks in vivid orange, green, purple, often brown (almost black), even grey and white colours; apart from residual (non-reactive, waste) quartz, they contain such minerals as cordierite (actually the cordierite-sekaninaite series), hercynite or another oxyspinel, e.g. of deltalumite type, and other phases;
 - › **parabasalts** (incorrectly called “paralavas”) – relatively infrequent products of complete remelting and partial recrystallisation, visually closely resembling basalts (especially of the scoria type), with mineral composition typical of igneous rocks on the one hand, and metamorphic rocks on the other; minerals characteristic of parabasalts are anorthite,

magnetite, clinopyroxenes, olivine, as well as high-temperature cordierite-sekaninaite polymorphs – indialite-ferroindialite series;

- › **metacarbonate slags** – products of carbonate rocks calcination (mainly concretion), which accompany coal deposits, with very characteristic and unusual phase composition.

Mineral assemblages of burning tips feature the diversity of composition, dictated by petrographic character of coal and aggregates, and the dynamic of phenomena responsible for their formation (Srebrodolski 1989). There are numerous natural equivalents of these in the geological environment. They are analogical to products of volcanism and high-temperature contact metamorphism (Sokół et al. 2005, Srebrodolski 1989, Grapes 2006).

The genesis of parabasalts approximates them to products of volcanic processes (Sokół et al. 2005). Some authors, e.g. Foit et al. (1987), Hensen & Gray (1979), Žáček et al. (2005), Masalehdani et al. (2007) and Wapnik et al. (2007), describe similar formations as buchites. The chemistry of parabasalts approximates them to basalts (Sokół et al. 2002), hence the terms “pseudobasalt” (Panow et al. 1999) or “parabasalt” (Sokół et al. 2005), occurring in literature. They are highly ferruginous, which reflects presence of ferruginous oxyspinels (magnetite; magnesioferrite MgFe_2O_4), olivine $(\text{Mg,Fe})_2\text{SiO}_4$, melilites, $(\text{Ca,Na})_2(\text{Al,Mg})(\text{AlSiO}_7)$, clinopyroxenes of the esseneite type $\text{CaFe}^{3+}\text{AlSi}_2\text{O}_6$, and the cordierite-sekaninaite series $(\text{Mg,Fe}^{2+})_2\text{Al}_4\text{Si}_5\text{O}_{18}$. A typical component of parabasalts is also plagioclase, rich in anorthite $(\text{CaAl}_2\text{Si}_2\text{O}_8)$ particle. Parabasalts usually form small blocks, veins, and “stalactites”. They are fine-crystalline, porous, sometimes rounded in shape. Presence of siderite while generating parabasalts is important, as its decomposition leads to fortifying melts with iron(II) oxide, which, in turn, lowers the melting point to ~980–1050 °C. As the temperature increases, the melt fortifies, in turn, with alkalis, silica, kaolin, and MgO (Sokół et al. 2005). Parabasalts late-stage minerals are fayalites, minerals from the apatite supergroup, leucite KAlSi_2O_6 , pyrrhotite, and pyrite.

Partial melting of sedimentary rocks (shales, sandstones) in temperatures ranging 550–900 °C (rarely ~1600 °C) leads to formation of clinkers, included in the group of meta-argillites (metapelites). They consist of detrital, sometimes partially melted residual quartz, or slightly transformed feldspars, as well as mullite and hematite, resulting from e.g. decomposition of gaseous chlorocomplexes of iron present in gas phase (Sokół et al. 2005, Srebrodolski 1989). Crystals in clinkers are usually 0.5–10 µm in size. Additional minerals present are cordierite, tridymite, and cristo-

balite (some of the numerous polymorphs of natural crystalline silica), and sometimes magnetite. Another component is also glaze (up to 70 %), chemically close to granitoid melts. Clinkers can be massive and venous. Unlike typical volcanic rocks, they do not demonstrate traces of flow. There have been observed clinker xenoliths in parabasalts, distinguished with presence of green mineral from the spinel group. Clinkers can inherit their texture from protolith (Sokoł et al. 2005).

Anaerobic annealing of pelites in temperatures 600–1200 °C forms the so-called **black blocks**, which mark out in tip walls as dark lenses, clearly contrastive with red, pink, and salmon-pink metapelites (Czesnokow & Szczerbakowa 1991, Sokoł et al. 2005). There is no hematite in them, but they contain soot (graphite) from oxidation of carbohydrates and decomposition of CO, as well as fragments of thermoanthracite. There occur unusual minerals, known mostly from meteorites (e.g. native iron and iron phosphides, such as schreibersite), therefore in this context we sometimes speak of “meteoritic” mineralisation.

Rare and unusual minerals of the firing stage discovered on burning tips of Chelyabinsk Coal Basin (Ural) are i.a. anorthite polymorphs (dmisteinbergite – hexagonal, and svyatoslavite – rhombic), and dorrite $\text{Ca}_4(\text{Mg}_3\text{Fe}^{3+}_9)\text{O}_4(\text{Si}_3\text{Al}_8\text{Fe}^{3+}\text{O}_{36})$ (rhönite group; Czesnokow & Szczerbakowa 1991, Sokoł et al. 2005).

Pyrometamorphites from Upper Silesian spoil tips, studied by Kruszewski (2009), include e.g.:

- different types of metacarbonate slags from Rydułtowy: (1) the most common, ferrite-apatite, with srebrodolskite, harmunite $\text{Ca}_2\text{Fe}_2\text{O}_4$, and the fluorapatite-fluorellestadite series $\text{Ca}_5(\text{PO}_4, \text{SiO}_4, \text{SO}_4)_3\text{F}$, as well as magnesioferrite, aragonite and trace baryte $(\text{Ba}, \text{Sr})\text{SO}_4$, (2) melilite, with anorthite, maghemite, aragonite, and unspecified calcium zirconium silicate, (3) hematite-magnesioferrite-clinopyroxene, with diopside-esseneite of close to symplectitic character of intergrowths of hematite with magnesioferrite attesting to high speed of crystallisation;

- buchites from Rydułty – with crystals rarely >5 μm in diameter; large changeability of glaze content; demonstrating zonality of mineral composition, whereby hercynite, pyrite and cordierite are connected with the internal melanocratic zone of reductive character;

- parabasalts, formed both at the cost of clinkers and as a result of direct transformation of aggregate, occurring as isolated fragments of pyrometamorphic breccia, for example among clinker, and containing its xenoliths (embedded fragments of clinkers, trapped during flow);

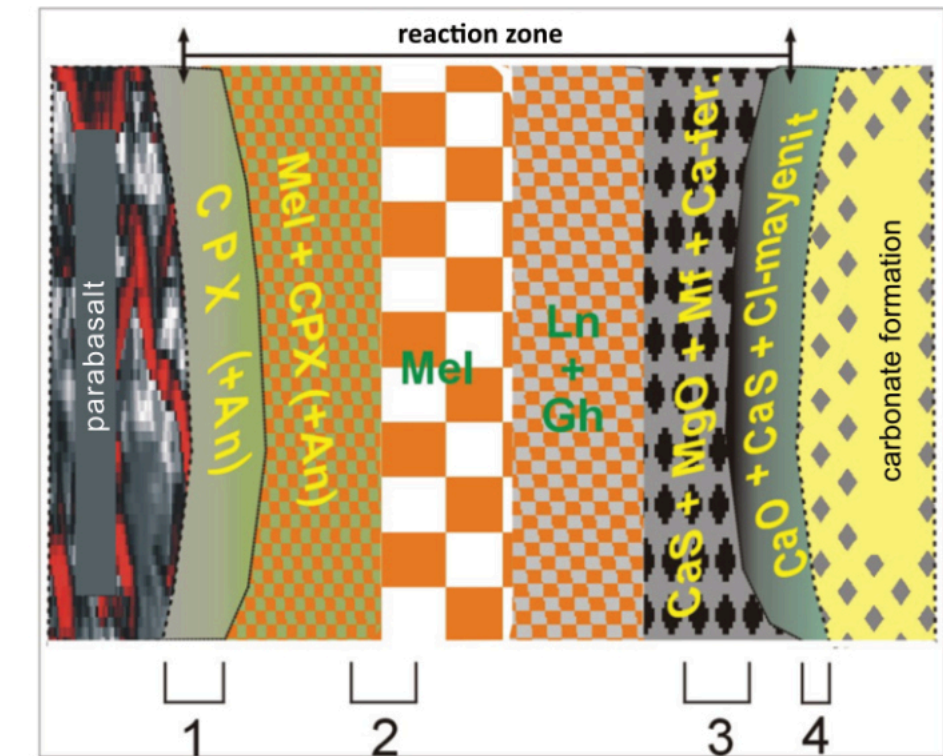


Fig. 3. Physico-chemical transformations in the contact parabasalt-carbonates (rich in ankerite). CaO – native lime, CaS – oldhamite, Ca-fer – calcium ferrites. Numbers mark out areas of potential formation of metacarbonate slags with clinopyroxene (1), melilite (2), calcium ferrites (3), and oldhamite (4) on usc spoil tips. (after: Sokoł et al. 2005, from: Kruszewski 2009).

- parabasalts from Czerwionka, containing interesting minerals in the form of celsian $\text{BaAl}_2\text{Si}_2\text{O}_8$ (feldspar group), and whitlockite $\text{Ca}_9\text{Mg}(\text{PO}_4)_6[\text{PO}_3(\text{OH})]$ (whitlockite subgroup, merrillite group, cerite supergroup), demonstrate constant transition toward parts more resemblant of buchite, and even clinker of clinker;

- metasandstone from Czerwionka, containing olivine rich in fayalite $(\text{Fe}_2\text{SiO}_4)$ particle, and pyrrhotite Fe_{1-x}S , also indicative of reductive crystallisation conditions;

- metacarbonate slag from Dąbrówka Wielka (Piekary Śląskie) – a typical example of the *nutshell*-type aggregate; very rich mineral composition – with oldhamite, periclase, fluorite CaF_2 , portlandite $\text{Ca}(\text{OH})_2$, anhydrite CaSO_4 , vaterite CaCO_3 (hexagonal polymorph), fortified with German cuspidine $\text{Ca}_4(\text{Si}_2\text{O}_7)\text{F}_2$ (rare and demanded metalloid), thaumasite, and unusual, rich in gallium, chlormayenite $\text{Ca}_{12}(\text{Al}, \text{Ga})_{14}\text{O}_{32}[\text{Cl}_2]$, which represents the group of non-metallic potential (super) conductors with an electron migrating in the network (so-called electride salts, electrides); presence of oldhamite, fluorite and cuspidine indicates high activity H_2S and H_2F_2 in

gas phase (Kruszewski 2006); this rock resembles products of “retrogressive syndrome” from the Hatrurim formation in Israel, containing i.a. portlandite, vaterite, aragonite, and thaumasite (Gur et al. 1995);

– clinker from Łaziska, corresponding to red metapelite, with mullite and cristobalite as basic components; the rock contains interesting inclusions of black and ultra-fine-crystalline (or maybe amorphous) rock, which could be approximately described as obsidian buchite.

In contact with parabasalts, clinkers and other siliceous formations, carbonate formations are fortified with melilite, larnite Ca_2SiO_4 , esseneite, chloric analogues of hydrogarnets, carbonate silicates – e.g. spurrite $\text{Ca}_5(\text{SiO}_4)_2(\text{CO}_3)$ – as well as calcium ferrites (Czesnokow & Szczerbakowa 1991, Sokoł et al. 2005; Fig. 3).

The mineral composition of parabasalts from tips corresponds to formations of the Hatrurim formation in Israel (Wapnik et al. 2007), Rawat region in Tajikistan (Szarygin et al. 2009), and Rotowaro in New Zealand (Masalehdani et al. 2007). Buchites from different parts of the world demonstrate mineralogical and genetic similarities (e.g. spinel-cordierite buchites of Stromboli, Salvioli-Mariani et al. 2005; pyroxene buchites from Ravensworth region (New South Wales, Australia), connected with coal fires and formed in temperatures $>1060^\circ\text{C}$, Hensen and Gray, 1997; clinopyroxene-melilite-hematite-oxyspinel buchites of Wyoming (usa), connected with natural fires of coal deposits, Foit et al., 1987; post-loessal-ash buchites from porcellanite deposit in Želénky region (Czechia, Žáček et al. 2005). Cosca & Peacor (1987), in turn, describe formations from Wyoming, corresponding to the above-mentioned ones, with esseneite, melilites, anorthite and magnetite-hercynite, to which the authors refer as parabasalts.

Pyrometamorphic rocks versus ceramics

The similarity of pyrometamorphic products on spoil tips to ceramics is indicated i.a. by Wyszomirski & Brylska (1996), who discuss the possibility of using waste ash from coal combustion in power plants (so-called *coal fly ash*, cfa) in production of ceramic materials. cfa is also emitted on tips, migrating with gas phase in fumaroles. A corresponding approach in the context of waste-based vitreous ceramics (i.a. cfa) is demonstrated by Rawlings et al. (2006), who list such tip-specific equivalents of minerals as esseneite, diopside, magnesioferrite, anorthite, and wollastonite. Esseneite is also one of the main components of vitreous ceramics produced from coal-combustion waste, studied by Bernardo et al. (2009). Hoeck et al. (2012), in turn,

who characterise Romanian ceramic slags from the necropolis in Lăpuș (Bronze Age), name in their phase composition i.a. olivine, cristobalite, hematite, oxyspinels (magnetite), mullite, cordierite, and clinopyroxene. In parallel, the authors also indicate the close resemblance of studied materials to buchite. This similarity is presented even more directly by Jelínek et al. (2011), who openly treat post-mining tips as a source of progenitors of industrial ceramics. By the same token, Jawrujan & Gaiszun (2023) indicate the possibility of obtaining large ceramic blocks from waste piled on tips of this type; also Eterigho-Ikelegbe et al. (2022) discuss the potential of post-coal ceramic composites in construction industry.

References

- Bełakowski D. 1990: Die Mineralien der brennenden Kohleflöze von Ravat in Tadschikistan. *Lapis*, **15**(12), 21–26
- Bernardo, E., Esposito, L., Rambaldi, E., Tucci, A., Pontikes, Y., Angelopoulos, G.N. 2009: Sintered esseneite – wollastonite – plagioclase glass-ceramics from vitrified waste. *J. Eur. Ceram. Soc.*, **29**, 2921–2927
- Cosca M.A. & Peacor D.R. 1987: Esseneite, a new pyroxene produced by pyrometamorphism. *Am. Min.*, **72**, 148–156
- Cosca M.A., Essene E.J., Geissman J.W., Simmons W.B. & Coates D.A. 1989: Pyrometamorphic rocks associated with naturally burned coal beds, Powder River Basin, Wyoming. *Am. Min.*, **74**, 850–100
- Culka A., Jehlička H. & Němec I. 2008: Raman and infrared spectroscopic study of boussingaultite and nickelboussingaultite. *Spectroch. Acta Part A: Molecular and Biomolecular Spectroscopy*, **73**(3), 420–423
- Czesnokow B.W. & Szczerbakowa J.P. 1991: Minieralogija goriełych otwałow Czeliabinskogo ugolnogo bassejna (opyt Minieralogii tiechnogeneza). Nauka, Moskwa [in Russian]
- Eterigho-Ikelegbe, O., Trammell, R., Bada, S.O. 2022: Novel ceramic composites produced from coal discards with potential application in the building and construction sectors. *J. South Afr. Inst. Min. Metall.*, **122**(8), 421–428
- Filippidis A., Georgakopoulos A., Kassoli-Fournaraki A. 1996: Mineralogical components of some thermally decomposed lignite and lignite ash from the Ptolemais basin, Greece. *Int. J. Coal Geol.*, **30**, 303–314
- Foit F.F. Jr., Hooper R.L. & Rosenberg P.E. 1987: An unusual pyroxene, melilite and iron oxide mineral assemblage in a coal-fire buchite from Buffalo, Wyoming. *Am. Min.*, **72**, 137–147

- Grapes, R., 2006: Pyrometamorphism. Springer-Verlag, Berlin Heidelberg, 281 pp.
- Gur D., Steinitz G., Kolodny Y., Starinsky A. & McWilliams M. 1995: $^{40}\text{Ar}/^{39}\text{Ar}$ dating of combustion metamorphism ("Mottled Zone", Israel). *Chem. Geol. (Isotope Geoscience Section)*, **122**, 171–184
- Heffern E.L. & Coates D.A. 2004: Geologic history of natural coal-bed fires, Powder River basin, USA. *Int. J. Coal Geol.*, **59**, 25–47
- Hensen B.J. & Gray D.R. 1979: Clinohypersthene and hypersthene from a coal fire buchite near Ravensworth, N.S.W., Australia. *Am. Min.*, **64**, 131–135
- Hoeck, V., Ionescu, C., Metzner-Nebelsick, C., Nebelsick, L.D. 2012: Mineralogy of the ceramic slags from the Bronze Age funerary site at Lăpuș (NW Romania). *Geol. Quart.*, **56(4)**, 649–664
- Jawrujan, Ch., Gaiszun, J. 2023: Production of Large-Sized Ceramic Stones Based on Screenings from Waste Heap Processing Using the Technology of Stiff Extrusion for Molding Products. *Buildings*, **13**, 845 (13 pp.)
- Jelínek, J.M., Mališ, J., Daněk, T., Thomas, J., Slivka, V., 2011: Hałdy pozostałe po wydobyciu węgla – alternatywne źródło materiałów wsadowych dla przemysłu ceramicznego. *Inż. Miner. (J. Pol. Mineral Eng. Soc.)*, January–June, 61–72
- Kruszewski Ł. 2006: Oldhamite-periclase-portlandite-fluorite assemblage and coexisting minerals of burnt dump in Siemianowice Śląskie – Dąbrówka Wielka area (Upper Silesia, Poland) – preliminary report. *Min. Pol. Spec. Pap.*, **28**, 118–120
- Kruszewski Ł. 2008: Apatite-ellestadite solid solution and associated minerals of metacarbonate slags from burning coal dump in Rydułtowy (Upper Silesia). *Min. Spec. Pap.*, **32**, 100
- Kruszewski, Ł. 2009: Zespoły mineralne powstające na objętych pożarami hałdach pogórnich Górnego Śląska. doctoral dissertation, Instytut Geochemii, Mineralogii i Petrologii, Wydział Geologii, Uniwersytet Warszawski, 136 pp.
- Masalehdani M.N.N., Black P.M. & Kobe H.W. 2007: Mineralogy and petrography of iron-rich slags and paralavas formed by spontaneous coal combustion, Rotowaro coalfield, North Island, New Zealand. *Geology of Coal Fires: Case Studies from Around the World* (edited by Glenn Stracher). The Geological Society of America, *Reviews in Engineering Geology*, vol. xviii, 117–132
- Nasdala L., Pekov I.V. 1993. Ravatite, $\text{C}_{14}\text{H}_{10}$, a new organic mineral species from Ravat, Tadzhikistan. *Eur. J. Mineral.*, **5**, 699–705
- Nelson M.I. & Chen X.D. 2007: Survey of experimental work on the self-heating and spontaneous combustion of coal. *Geology of Coal Fires: Case Studies from Around the World* (edited by Glenn B. Stracher). The Geological Society of America, *Reviews in Engineering Geology* xviii, 31–83
- Panow B.S., Dudik A.M., Shevchenko O.A. & Matlak E.S. 1999: On pollution of the biosphere in industrial areas: the example of the Donets coal Basin. *Int. J. Coal Geol.*, **40**, 199–210
- Pone J.D.N., Hein K.A.A., Stracher G.B., Annegarn H.J., Finkleman R.B., Blake D.R., McCormack J.K. & Schroeder P. 2007: The spontaneous combustion of coal and its by-products in the Witbank and Sasolburg coalfields of South Africa. *Int. J. Coal Geol.*, **72**, 124–140
- Querol X., Fernandez Turiel J.L. & Lopez Soler A. 1994: The behavior of mineral matter during combustion of Spanish subbituminous and brown coals. *Min. Mag.*, **58**, 119–133

- Rawlings, R.D., Wu, J.P., Boccaccini, A.R., 2006: Glass-ceramics: their production from wastes. A review. *J. Mater. Sci.*, **41(3)**, 733–761
- Reifenstein A.P., Kahraman H., Coin C.D.A., Calos N.J., Miller G., Uwins P., 1999: Behaviour of selected minerals in an improved ash fusion test: quartz, potassium feldspar, sodium feldspar, kaolinite, illite, calcite, dolomite, siderite, pyrite and apatite. *Fuel*, **78**, 1449–1461
- Robertson W.J., Kinnunen P.H.-M., Plumb J.J., Franzmann P.D., Puhakka J.A., Gibson J.A.E. & Nichols P.D. 2002: Moderately thermophilic iron oxidizing bacteria isolated from a pyritic coal deposit showing spontaneous combustion. *Minerals Eng.*, **15**, 815–822
- Salvioli-Mariani E., Renzulli A., Serri G., Holm P.M. & Toscani L. 2005: Glass-bearing crustal xenoliths (buchites) erupted during the recent activity of Stromboli (Aeolian Islands). *Lithos*, **81**, 255–277
- Szarygin V.V., Sokoł E.V. & Bełakowski D.I. 2009: Fayalite-sekaninaite paralava from the Ravat coal fire (central Tajikistan). *Russ. Geol. Geoph.*, **50**, 703–721
- Sokoł E.V., Nigmatulina E.N. & Wołkowa N.I. 2002: Fluorine mineralization from burning coal spoil-heaps in the Russian Urals. *Miner. Petrol.*, **13**, 791–800
- Sokoł E.V., Maksimowa N.V., Nigmatulina E.N., Szarygin V.V. & Kalugin V.M. 2005: Combustion metamorphism. Publishing House of the SB RAS, Novosibirsk [in Russian and partially in English];
- Sokoł E.V. & Wołkowa N.I. 2007: Combustion metamorphic events resulting from natural coal fires. *Geology of Coal Fires: Case Studies from Around the World* (edited by Glenn Stracher). The Geological Society of America, *Reviews in Engineering Geology* xviii, 97–115
- Srebrodolski B.I., 1989: Tajny Sezonnych Minierałow. Nauka, Moskwa, 59–119 [in Russian]
- Świętosławski W. 1953: Fizykochemia węgla kamiennych i procesu koksowania, Państwowe Wydawnictwa Techniczne, Warszawa, 38–43
- Wapnik Y., Szarygin V.V., Sokoł E.V. & Shagam R. 2007: Paralavas in a combustion metamorphic complex: Hatrurim Basin, Israel. *Geology of Coal Fires: Case Studies from Around the World* (edited by Glenn B. Stracher). The Geological Society of America, *Reviews in Engineering Geology* xviii, 133–154
- Wagner M. 1980: Przemiany termiczne węgla kamiennego w strefach pożarów hałd kopalnianych. *Zesz. Nauk. AGH – Geologia*, **6(2)**, 5–14
- Ward C.R. 2002: Analysis and significance of mineral matter in coal seams. *Int. J. Coal Geol.*, **50**, 135–138
- Wendlandt R.F. & Harrison W.J. 2006: Ammonium sulfate evaporites associated with uranium mill tailings
- Wyszomirski P. & Brylska E. 1996: Fly Ash in Polish building ceramics – threat or proecology? *Appl. Geoch.*, **11**, 351–353
- Žáček V., Skála R., Chlupáčová M. & Dvořák Z. 2005: Ca-Fe³⁺-rich Si-undersaturated buchite from Želénky, North-Bohemian Brown Coal Basin, Czech Republic. *Eur. J. Mineral.*, **17**, 623–633





Tips, Ruda Śląska, photo by Barbara Kubska



Tips, Ruda Śląska, photo by Barbara Kubska



Tips, Ruda Śląska, photo by Barbara Kubska

၄၅၂*