CORES DA TERRA

PAINT PRODUCTION WITH SOIL PIGMENTS

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Organization

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PRESENTATION

This manual has the mission of disseminating the knowledge accumulated by the research and university extension project *Cores da Terra*.

Over the years, the project produced some printed materials for dissemination and training, assembling empirical knowledge. After contributing with academic research and systematizing the lessons accumulated from interactions with countless actors, we noticed the need to gather this knowledge in a publication. Such publication would approach basic information on soils and a detailed description of the paint production technique for dissemination and professional training.

Considering the relevance of communicating concepts and procedures clearly, we chose to include illustrations along with the text. We also added some practical examples to help with the understanding of the calculations and recommendations to produce paints according to the characteristics of different types of soils.

We hope to contribute to society not only with a technique for paint production, a basic material for civil construction, but also with a community interaction tool that gives a new meaning to the use of natural resources, in this case, soils.

ACKNOWLEDGMENTS

This manual's publication was only possible due to institutional support and the efforts of countless people who conducted the research and university extension project Cores da Terra.

We would first like to thank the Soils Department of the Federal University of Viçosa (UFV), where the project was born, the National Council for Scientific and Technological Development (CNPq), the Coordination for the Improvement of Higher Education Personnel (CAPES), and the Minas Gerais Research Foundation (FAPEMIG), which granted scholarships that enabled the involvement of students who conducted numerous research and university extension activities over the years.

Among the people who inspired us, we are particularly grateful to the painter Pedro Eugênio Quirino. Without him, the Cores da Terra project would not exist.

The performance of university extension activities, from which we continuously absorbed the knowledge incorporated in this manual, has been enhanced by many institutions, among them: the Alexis Dorofeef Earth Sciences Museum, an important reference point for scientific outreach inside and outside UFV; the National Institute for Colonization and Agrarian Reform (INCRA), which supported workshops in several agrarian reform settlements in Minas Gerais; the Center for Alternative Technologies of Zona da Mata (CTA), which disseminated the technique throughout the Zona da Mata region of Minas Gerais; the TerraBrasil and PROTERRA networks, dedicated to the theme of architecture and construction with earth in Brazilian and Ibero-American spheres, which favored the technique diffusion throughout Latin America through their events; and the Capixaba Research Institute of Technical Assistance and Rural Extension (INCAPER), which disseminated the technique in an exemplary manner throughout the state of Espírito Santo.

Due to the success of INCAPER to disseminate the technique of paint production with soil pigments, in 2009 the institution received the FINEP Innovation Award in the Social Technology category, thus establishing a relevant research partnership with the Cores da Terra project. This partnership represented a new phase in the history of the project. At that time, new partnerships were established, like with the Construction Materials Laboratory of the Civil Engineering Department of UFV that enabled the conduction of research in the Hercules laboratory at the University of Évora – Portugal, promoting relevant advances in understanding the performance of the paintings. Therefore, we are grateful to these institutions, without whom we would not have attained the knowledge available in this manual.

Finally, we would like to thank the International Fund for Agricultural Development (FIDA) through the AKSSAM Program, the Federal University of Viçosa, the Arthur Bernardes Foundation (FUNARBE), and the Institute of Public Policies and Sustainable Development - IPPDS/UFV for enabling the production and dissemination of this manual.

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Activity conducted in 2006 in the Nova Viçosa neighborhood, in Viçosa - MG.
Photo: Marcelo Almeida

CORES DA TERRA

The inspiration of the Cores da Terra Project was the traditional technique known as barreado, which consisted of painting walls with *tabatinga* (from Tupi language, "white earth"). The disuse of this technique was motivated by its low durability and the arrival of the paint industry, which began to offer products with better performance and a greater variety of colors.

Unlike conventional paints, the adhesion of this "paint" only occurs through the surface characteristics of the clay particles and the porosity and roughness of the substrate. Those are insufficient to guarantee its resistance to weathering and other agents, thus requiring frequent maintenance.

One possible solution to this problem would be to transform the *barreado* into a proper paint by adding binding materials, such as starch glue, popularly known as *grude*, or polyvinyl acetate (PVAc), white glue.

Once we developed the first production method, we began to disseminate the improved technique by the distribution of booklets and conduction of courses, thus fulfilling the functions of presenting the idea and mobilizing communities, members of religious institutions, social assistance, and governmental and non-governmental organizations around the possibility of themselves painting with their own paints.

The intense diffusion favored the conversation with the users, who then contributed to the development of the technique by reporting their experiences. Many claimed that when using grude as a binder, they observed the same problems presented by *barreado*. Many preferred PVAc, which guaranteed greater adherence but, on the other hand, was inaccessible to part of the population. Others reported the rapid decanting of pigments, which impaired the homogeneity of the paint and the quality of the painting.

Such situations motivated our research about the different paint production processes through the study of technical literature, contact with researchers and manufacturers, and access to performance evaluation methods recommended by the Brazilian Association of Technical Standards (ABNT) and the American Society for Testing and Materials (ASTM).

The experience accumulated between 2005 and 2010 was decisive for us to abandon grude and develop low-cost paints with soil pigments, water, and PVAc. To do so, we conducted systematic studies, accumulating knowledge to improve the production process and understand the effects of the characteristics of different pigments on the paintings' performance (CARDOSO, 2015; CARDOSO, 2020).

As a result, we were able to develop an efficient, low-cost paint production process that meets the performance standards for non-industrial paints and can be reproduced by anyone using this manual.

THE SOIL PIGMENTS IN BRAZIL

The first records of the use of paints and pigments refer to rock art, which is present throughout the Brazilian territory. The best-known records are those found in the Serra da Capivara National Park, in the state of Piauí, which stand out for their stylistic richness, for the techniques of execution of the graphics, and also for the diversity of colors (red, yellow, gray, white, and black), coming from iron oxides, clay minerals, and coal. Similar cases have also been described in archaeological sites in the states of Minas Gerais, Bahia, and Mato Grosso.

With the invasion of the Portuguese and other European nations, other materials and techniques were introduced and reproduced in the context of the domination of the territory. However, even bringing knowledge of techniques historically disseminated in other parts of the world, Europeans faced difficulties regarding the availability of knowledge of the natural sources of materials to use as pigments and binders. These difficulties were probably overcome by adaptations according to the available materials.

Lime painting, of Portuguese tradition, seems to have been the most relevant. In Brazil, lime was initially obtained from sambaquis, a source of limestone of biological origin common in coastal regions, which is easier to extract compared to the exploration of limestone deposits. Therefore, in coastal or close to the coast cities, the architecture was characterized by the white color of the mortar-stone masonry and painted with lime, while in the inland towns it appeared only in the buildings considered important, mixed with the ocher tones of the popular buildings coated only with earth mortars (RIBEIRO, 2004).

In the absence of lime, the white color could be obtained from tabatinga. Sylvio de Vasconcellos, in his study on the formation and development of Vila Rica, now Ouro Preto, cites an official document from 1728 that states that, in the absence of white lime, the walls should be "whitewashed with tabatinga" (VASCONCELLOS, 1956, p.174, our translation). The same author, in another work, refers to the city of Mariana, "where you can see an excellent yellow and white hut (sic), and this one is called tabatinga, which, after being prepared and cleaned, supplies the faults of white lead, and it is used in various paintings" (VASCONCELLOS, 1979, p.177, our translation). Other records from the end of the 18th century refer to the use of tabatinga as a substitute for lime in the city of São Paulo, extracted "in a place close to the center, known as Tabatinguera" (TELLES, 1989, p.21, our translation) where there is still a street with the same name.

Jesuit João Felipe Bettendorf made reference to the clay with different colors that existed in abundance on the gorges, but that only white was used frequently, that "letting it soak and passed through a cloth, and then well-cooked serves as first paint" to other pigments, replacing the "plaster of the Kingdom" (BETTENDORF, 1910, p. 28, apud OLIVEIRA, 2018, our translation); father João Daniel comments that the clay was "as fine,

Archaeological site Pedra Pintada, in Barão de Cocais - MG. Photo: Fernando Cardoso niveous, and precious as white lead'" (DANIEL, 2004, v.1, p. 591, apud OLIVEIRA, 2018, our translation) and that it resembled lime, thus used for painting walls and ceilings, being commonly mixed with the juice of the mutamba (Guazuma ulmifolia), to make it more resistant (DANIEL, 2004, v.1, p. 538, apud OLIVEIRA, 2018, our translation); in Solimões it was used for whitewashing buildings, added to the liquid gum extracted from the trunk of the rowan tree (Couma macrocarga or Couma utilis), to give it more firmness (BAENA, 2004, p. 37, apud OLIVEIRA, 2018); Francisco Xavier Ribeiro de Sampaio comments that "White inhabitants live in this place. Their houses, as well as those of the Indians are whitewashed with tabatinga, a type of white chalk, to which they add the liquid gum from the rowan tree, to give it greater tenacity, and cohesion "(SAMPAIO, 1825 apud GUERRA, 2001, our translation), when referring to the municipality of Nogueira - AM; Spix and Martius, on the surroundings of Ouro Preto, affirm that "lime appears very rarely, it is said, reason why the people of the province of Paraná use tabatinga in the construction of walls, which, here and there, forms a deposit on the margin from rivers and is burned with fire, becoming white "(SPIX and MARTIUS, 1938 apud GUERRA, 2001, our translation); Spix and Martius also comment that in the Tupinambarana Island - AM, "On the open banks of the river (...) there is thin tabatinga with reddish, whitish, or violet stripes, very used in the plastering of houses" (GUERRA, 2001 apud SPIX and MARTIUS, 1938, our translation); Auguste de Saint-Hilaire comments that in most camps in Minas and Goiás, all houses "(...) are covered with tiles and plastered with a white clay that in the inland of Brazil is called tabatinga" (SAINT-HILAIRE, 1975 apud GUERRA, 2001, our translation); and Hercules Florence, referring to the houses in the city of Cuiabá - MT, comments that "Houses are plastered on the outside with tabatinga, which gives them extreme whiteness" (GUERRA, 2001 apud FLORENCE, 1977, our translation).

The knowledge of the panting technique with tabatinga, the barreado, is part of the popular ideal, still being possible to find houses and ovens barreados in some regions, mainly in the inland of Minas Gerais.

Although lime and tabatinga give color and also act as a protective element for the surfaces on which they are applied, they do not constitute paints themselves, due to the absence of binding materials in their compositions.

In the case of lime, the coating layer formation occurs through the carbonation of $Ca(OH)_2$, without the need for a bonding material to adhere the particles to each other and the surfaces; and, in the case of tabatinga, adhesion is promoted only by physical interactions between the particles that compose it and the substrate. In both cases, but mainly in the latter, the paintings have limited resistance to weathering.

The use of binding materials, such as linseed oil and tempers, seems to have been limited, in colonial times, to paints intended for painting wood and metals. Being imported and expensive, such materials were applied only when indispensable for the protection of surfaces against weathering (RIBEIRO, 2004).

According to Ribeiro (2004), until the end of the 19th century, the colors of the cities remained the

Barreado practice in a rural community in São Joaquim - Araponga - MG.
Photo: Fernando Cardoso

same, even with the modernization process of colonial buildings, which resulted only in a more intense adoption of yellowish and purple ocher, limiting the spectrum of colors to those of the soils.

Therefore, even coinciding with a period marked by the development of the chemical industry in Europe and the US and, therefore, with the appearance of several types of pigments, binders, and paints, the cost of such products was probably still expensive, being accessible only to a small portion of the Brazilian population.

This scenario changed since the beginning of the 20th century, overcoming colonial white and neoclassical ocher yellow, probably due to the import of materials, such as linseed oil and pigments of other colors, which are more resistant to the effects of lime alkalinity (RIBEIRO, 2004). Such products were purchased by painters who prepared their own formulas and mixtures (TELLES, 1989).

It was also in the context of the transition from the 19th to the 20th century that the first paint factories were installed in Brazil, the first in 1886, in the city of Blumenau, Santa Catarina, and the second in 1904, in the city of Rio de Janeiro, both founded, respectively, by the German immigrants Paulo Hering and Carlos Kuenerz. The first (Tintas Hering S.A.) was dedicated exclusively to the production of materials and articles for artists. The second (Usina São Cristóvão), founded by Carlos Kuenerz, was initially dedicated to the production of powder paints extracted from minerals (TELLES, 1989).

The rare records of the manufacture of pigments in the Brazilian context place in Ouro Preto, Minas Gerais, the first ventures dedicated to the exploration of natural ocher, perhaps motivated by the exploration of gold and other minerals in that territory.

The Antônio Pereira mountain appears to have been an important location for the exploitation of pigments, where the industrialist Carlos Kuenerz had the permission to explore "paints", according to a document dated 1921, contained in Book No. 4 of Registries and Contracts of the Municipality of Ouro Preto.

The exploration records appear in requests and contracts drawn up by the Ouro Preto City Council between the end of the 19th century and the beginning of the 20th and always refer to the terms "colored earth", "ochers", "ocras" and "paints", that would be explored in "Morro do Taquaral", in the "Pedra de Amolar" region, in "Morro de São Sebastião", in "Serra da Brígida" and in "Serra de Antônio Pereira", between the years 1897 and 1928 (APMOP, 1896-1917; APMOP, 1917-1927; APMOP, 1927-1959).

In an article published in 1945, it is confirmed that "The ocras (sic), with a wide use in the manufacture of paints, has had its deposits known and exploited in the surroundings of Ouro Preto for more than twenty years, from where the product is exported to Rio de Janeiro, São Paulo, and Argentina" (MORAES, 1945, p.54, our translation).

The ruins inventory (SMCOP, 2007) refers to what would be "tanks used in the manufacture of paints" without, however, presenting more detailed descriptions, given the advanced state of degradation of the structures. It also

te pagará tão somente o imposto de tres mil
reis (3$000) de cada uma rez abatida, ficando
isento do imposto de açougues.
Eu Sebastião Maffi Salomon, secretario
da Camara o escrevi.

Randolpho José Ferr.ª Bretas

O procurador. Antonio Arcanjo dos Santos.
O Fiscal José Carlos ... Alvez

ESTADO DE MINAS GERAES SECRETARIA DAS FINANÇAS SELLO 200 REIS

Cadmo

Contracto celebrado entre a Agencia executiva Municipal e o General Joaquim da Costa Mattos, para a exploração de terras coloridas.

Aos vinte e sete dias do mez de Janeiro de 1897, na secretaria da Camara Municipal de Ouro Preto, perante o Snr. Randolpho José Ferreira Bretas, agente executivo Municipal, compareceo o Snr. General Joaquim da Costa Mattos para celebrar contracto, de accordo com a resolução da Camara de 25 do corrente mez, e,

presents information, based on reports from residents, that the factory was benefiting from barium sulfate (baryte), having ended its activities in the 1930s.

Unfortunately, the ruins recorded in such inventory in 2007 no longer existed at the time of a field survey conducted at the beginning of 2019, thus losing an important remnant of a little-known activity in Brazilian territory.

Another site of exploration was the district Rodrigo Silva, where the ruins of an old structure are still found, probably used as a deposit of pigments in raw state, since, from a general analysis, no evidence of pigment processing structures was found.

Issue 346 of Revista de Química Industrial refers to the exploitation of baryte, barite, or barium sulfate, another type of pigment, white in color, used in the formulation of paints as an inert filler. It was found in stripes in the dolomitic limestone, embedded between the quartzites and phyllites, occurring in the localities of "Igreja Velha", one kilometer southeast of the district Antônio Pereira, Timbopeba, Chacrinha, Cintra, and Bom Jesus, on the surroundings of the city of Ouro Preto (ABREU, 1961).

"According to Eng. Lacourt, the mineralized stripes with baryte vary from a few centimeters to 1.8 meters; the mineral is almost always very pure, white in color, and saccharide in aspect, and has been used by the paint factories in São Paulo and Rio de Janeiro. The known occurrences, however, form deposits of potential limited to a few thousand tons. Given the great purity of Ouro Preto's baryte, it has been possible to exploit it by manual selection" (ABREU, 1961, p.13, our translation).

Still in the Ouro Preto region, Jean-Marie Triat mentions in "Les ocres" that yellow ocher, of lateritic origin, was explored in the state of Minas Gerais, close to Ouro Preto and that it was also used as raw material to obtain red ocher by calcination in wood-fired ovens (TRIAT, 2010). The author seems to refer to the company Morgan Mineração Indústria e Comércio Ltda, founded in 1947 in the city of Rio Acima - MG by João Morgan da Costa, now succeeded by the company Óxido de Ferro Rio Acima, which still benefits and markets ocher.

With the development of the chemical industry, many pigments of mineral origin, obtained from rocks and soils, have been replaced and, currently, their industrial use is restricted to mineral fillers, pigments that do not have the function to give color but to improve the properties and the performance of the paints.


Photo: Vellozia Filmes

THE SOILS

Two words that seem to represent the same thing adorn this manual: earth and soil. However, they have different meanings: when we talk about earth, we deal with the origin and destiny of humanity, our livelihood, the planet we journey on, that is, mother earth; when we say soil, we refer to the material we dig, where we plant, which we use to build, and that has its own physical characteristics, that is, an object. So, we will address a bit of the knowledge on this object, the soil.

The origin of soils begins with the formation of the first rocks. Presumably, planet earth was once a ball of molten mass that gradually cooled and solidified in an outer layer. Hence, emerge the rocks that we know. The innermost part of the planet remains hot and molten. From time to time, this mass overflows into the cracks of the outer layer of the planet expelled by volcanoes and cools down into rocks. The exposed solid rocks decompose by the action of time. The fault blocks expand and contract with temperature variation and crack. Hence, rain, wind, plants, and animals penetrate the cracks and produce materials increasingly pulverized. The larger blocks break, gradually generating gravel and then sand. Some sands resist even with the significant impacts of the beach waves. Other sands continue to decompose and generate slightly smaller particles called silt. Soil with a lot of silt has a silky texture. The destination of the decomposition causes the silt particles to turn into clay.

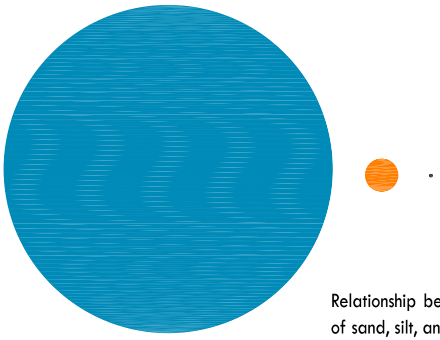
Clays are the smallest solid particles formed on the Earth's surface, dividing into two groups: oxides, which have an equidimensional shape, and silicate clays, which have a laminar shape. Oxidic clays and silt particles are largely responsible for giving color to soils. Laminar clays contribute to the physical behavior of soils and, when they occur pure, commonly confer the soil the white color. The shape of laminar clays and some types of silt can be compared with "playing cards".

In Figure 1, the laminar clay particles were magnified thousands of times in a scanning electron microscope. That is, thousands of clay particles can fit on a needle tip. Observe the laminar shape of the individual particles.

In summary, the stable mineral particles of the soils can have the size of sand, with a diameter greater than 0.2 mm, of silt, with a diameter between 0.002 and 0.02 mm, and of clay with a diameter less than 0.002 mm.

Figure 2 shows soil that was agitated intensely in a glass, separating the three particle sizes. The sand particles are heavier, so they decant faster and settle to the bottom. The silt particles are deposited in the intermediate layer and the lighter clay particles take longer to decant and accumulate in the surface layer.

In the history of soil formation, there is an especially important character. Imagine that a particle of sand rolls



Relationship between the diameters of sand, silt, and clay particles

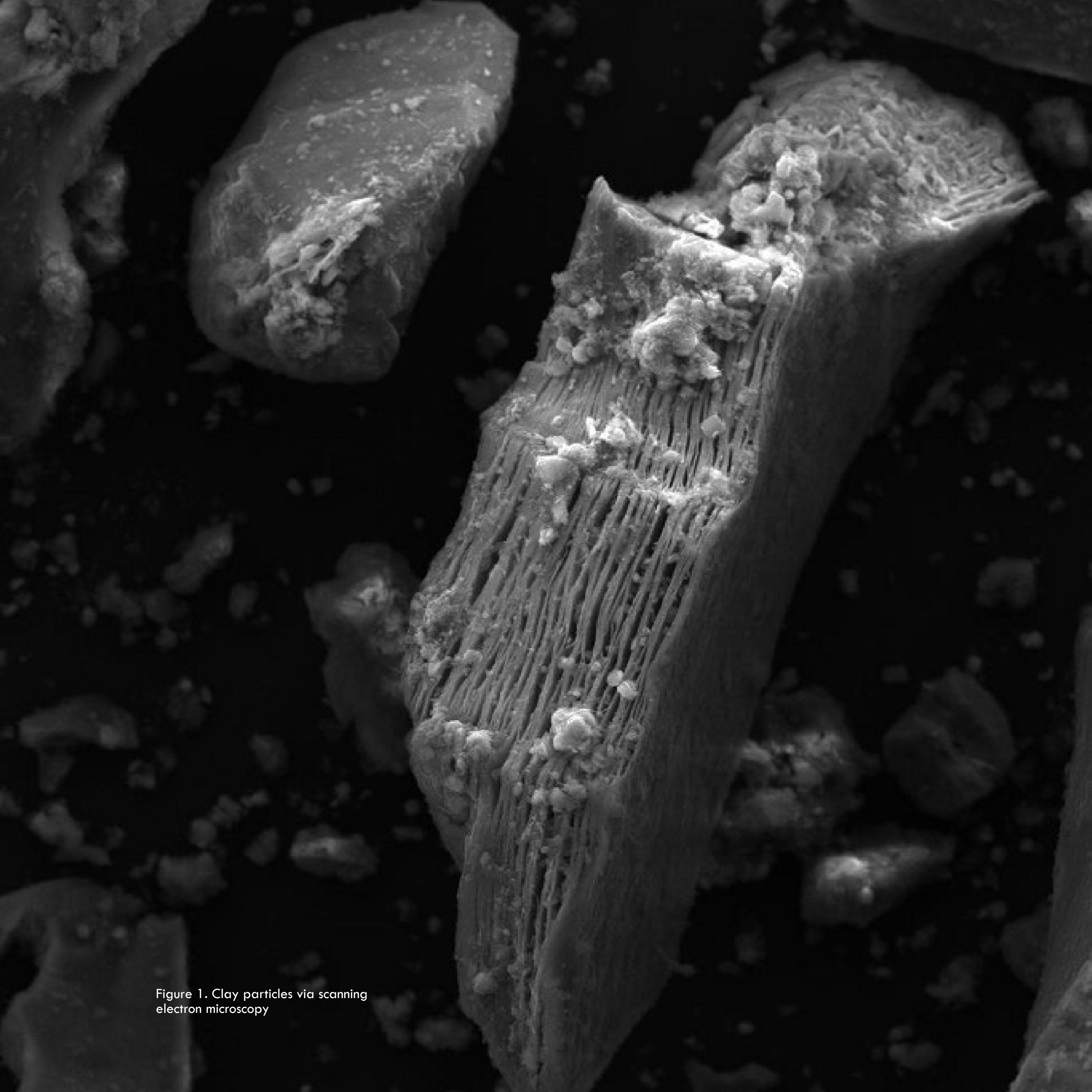


Figure 1. Clay particles via scanning electron microscopy

over a surface. As it moves, the sand particle attracts slightly smaller particles around it, called silt particles. Hence, in the spaces between the sand and the silt, fit thousands of clay particles that work as a glue.

In addition to clays, soils contain organic substances similar in size to clays, known as organic matter. Organic matter arises from the decomposition of leaves, roots, insects, and thousands of living things that inhabit soils. These substances have dark colors and adhere to sand, silt, and clay particles. Organic substances also act as a glue, that is, clays and organic matter aggregate soil particles. Thus is born the main character of the soils, which we call aggregate. Figure 3 shows aggregates that are clumps that gather larger particles of sand and silt adhered to each other by clays and organic matter.

It is noteworthy that within the aggregates there are small pores, called micropores, and between the aggregates, we have larger pores, called macropores. To observe the aggregates, we take a piece of soil in our hands and undo it with our fingers without kneading it. Aggregates are the clumps that appear in a regular format. However, although the most common form of aggregates is spherical, there are soils with cubic or columnar aggregates.

The great merit of laminar clays and organic matter is to form porous clumps. It compares to building a “card castle” in which the edges of the cards connect to the face of the other cards. In Figure 4, we see a detail of an aggregate where the laminar clays are organized in this way. Between the cards, there is a free space where water and air can pass, the micropores.

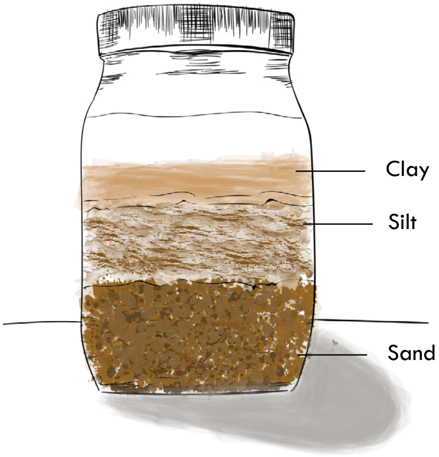
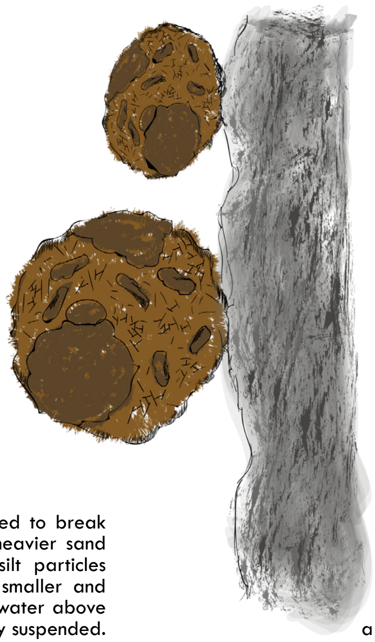


Figure 2. Glass containing soil that was heavily agitated to break up clumps of soil and left to rest for decanting. The heavier sand particles fall faster and settle on the bottom. The silt particles accumulate just above. The clay particles, which are smaller and lighter, slowly settle on top. Depending on the soil, the water above the particles may be clean or slightly cloudy with fine clay suspended.



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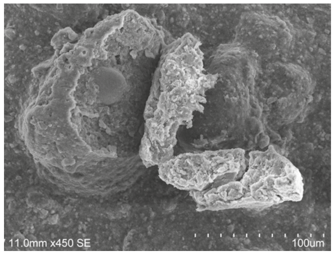


b

Figure 3a. Enlarged section of a wall showing roughness and a clump of adhered soil. The clump is an aggregate composed of large particles of sand, medium particles of silt and small, and very small particles of clay, represented by small dashes and brown organic matter. Clays and organic matter act as adhesives that bring together all the particles in a clump. The area of the clump that is adhered to the wall is small in relation to the rest of the clump area. Figure 3b. Microscopic image of particle aggregate present in paint sample adhered to mortar substrate.

Aggregates have two particularly important characteristics for farmers: they are resistant and porous clumps. A good farmer is a producer of these aggregates. However, if aggregation is beneficial for farmers, it is a problem for producing paints. To paint a wall, it is not possible to use aggregates as they are in the soil. If we use the aggregates to paint, we will put small rounded and porous clumps on the surface of the walls.

Figure 3a shows this situation indicated in the points of contact between the aggregates and a wall. Each isolated clump touches the others and the walls with a small contact surface, reducing their adhesion. The same is true of sand particles. When we put only sand on the walls without cement or glue, it will come off and fall off. Another problem of using soils with aggregates in their natural state is the absorption of water.

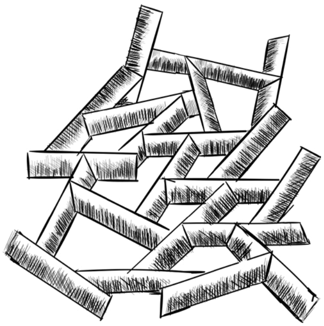


Figure 4. Clay particles are arranged in the shape of a "card castle". The edge of one lamina is attracted to the face of another. Thus, the clays form a skeleton that contains small pores within the card castle and surround the particles of silt and sand.

The high porosity of the aggregates favors water absorption that promotes its expansion. This absorption of water occurs both by contact with rain and by the humidity of the air. Variations in air humidity occur both between rainy and dry seasons and daily between day and night. The wetting and drying of the aggregates cause expansion and contraction that, repeated many times, promote the cracking of the paint.

Therefore, to prepare paints, it is important to dismantle the "card castle" of the aggregates and assemble them with another organization, to reduce porosity.

The process of dismantling the "card castle" occurs in nature. The force of the impact of raindrops that fall directly on the aggregates of soil without a vegetation cover dismantles the aggregates.

Notice that the water from roof leaks hits the ground and splashes on the walls of the houses, coloring them with the color of the earth. It is as if they "painted" the walls with the fine particles disaggregated. Another natural process that promotes this dismantling is the torrents that transport the soil and rub the aggregates against each other or obstacles in the currents. Finally, when the sediments deposit, the aggregates are disassembled and form a compact structure.

Figure 5 gives an idea of how laminar clays and silts stay organized after being disaggregated by mechanical action and reorganized. This organized accumulation occurs in a torrent that accumulates in a puddle of water and decants as well as in a layer of disintegrated soil applied on a wall. They form a compact layer with low porosity. The particles organized in this way have a high contact area with each other and with a wall, in the painting case.

Laminar-shaped clay and silt particles perfectly fit face to face, reducing total porosity (RESENDE et al., 2014). This process also happens when we produce bricks and knead the clay. The bricks have a high density and are much more compact than the soil from which the clay was removed.

The contact surface between the particles is maximum. It is as if we put two glass plates against each other and a thin layer of water between them. The two plates come together with large forces. For this reason, when we work with clay soils, the particles get under the nails or in the tools and are hard to get out. With clays, it is possible to mold figures, vases, and other objects. Sands and silts, on the other hand, do not hold like clays. With sands and silts, we are unable to produce a moldable or plastic mass.

Therefore, a farmer cultivates the structure of soils in aggregates to guarantee life, while those who produce paints dismantle the structure of aggregates to organize them in the form of a film that we call painting. The dismantling of aggregates can be done with two types of force: chemical and physical. Chemical forces involve a change in the acidity and require laboratory control of the process at an industrial level, which is not the purpose of this manual. Physical forces imitate natural forces such as the impact of raindrops or torrents, or even compaction by the continuous passage of animals or caused by the wheels of vehicles. The experience accumulated in the Cores da Terra project and perfected in research (CARDOSO, 2015; CARDOSO, 2020) demonstrated that the use of a Cowles disc (See Appendix 1) is efficient to disassemble the aggregates and reorganize the laminar particles to prepare the paints. Good quality paints have silt and clay particles well distributed in the water, forming a creamy consistency that facilitates application. After application, the water evaporates, and the particles come closer in an organized way, forming a film. Therefore, the dismantling of the aggregates is essential to suspend the silt and clay particles in the paint. As the rocks decompose, in general, parallel layers are formed.

Figure 6 shows the layers of a complete soil, including the bedrock. The topsoil has the highest levels of organic matter added by plants and other living beings. For this reason, it has a darker color, and the aggregates have a rounded shape. Organic matter is the most important aggregating agent in this layer. We call this superficial

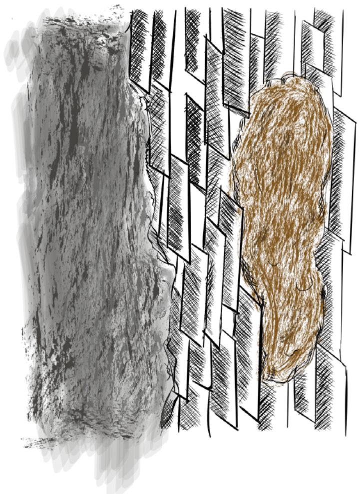


Figure 5. Enlarged section of a wall showing roughness and a paint film prepared with soil and applied to the wall. The clumps were broken up by the mechanical action of a Cowles disc driven by a drill. The sand was removed with a sieve. The silt particle is completely wrapped with clay slides. The "card castle" that existed in the soil clump was dismantled. The laminar clay particles were all arranged face to face, increasing the contact between them, between them and the silt particle, and between the paint particles and the wall surface. White glue used to make the paint works as a binder that joins the paint particles together and on the wall. Note that the porosity is smaller when compared to the porosity in the "card castle". In addition, the contact area between the soil particles and the wall is much larger than if they were round clumps, as shown in Figure 3.

Figure 6. Illustration of a complete soil profile, showing A Horizon, superficial layer with colors darkened by the addition of organic matter; B Horizon, a layer below with low content of organic matter and particles well aggregated in porous clumps; C Horizon, lower layer without organic matter and loose particles resulting from the decomposition of the bedrock; and the last layer, R Horizon, constituted by the bedrock.

layer A Horizon. In a layer below, deeper roots grow, and living beings such as ants, termites, worms, and others build their nests and move the particles. The organic matter content is much lower in this layer than in the superficial one. Therefore, this layer does not have colors as dark or grayish as A Horizon. Clays are the most important aggregating elements to form aggregates in this layer. We call this layer B Horizon.

Finally, in deeper layers, the influence of organic matter is minimal, and the number of clays decreases considerably. The higher amount of sand and silt in the deeper layers makes it difficult to form aggregates. The particles in these layers remain isolated and are easily removed by rain when exposed. That is, the aggregation is little observed in the deeper layers. We call this layer C Horizon.

Below all the layers comes the R Horizon, that is, the rock itself. A mature and developed soil has all these horizons, A, B, C, and R. Young soils have only the A Horizon resting on the rock. There are not very deep young soils that have A Horizon, C Horizon, and R Horizon, lacking the B Horizon.

The identification of soil horizons is particularly important to choose the appropriate materials to produce the paints.

The surface layer is the A Horizon, with levels of organic matter that favor the development of microorganisms, especially fungi that degrade paints and, thus, should not be a source of pigments. Subsurface layers, which are B Horizon and C Horizon, can be used. The low aggregation of particles in the C Horizon favors the production of paints with good quality.

The other important property of fine soil particles to produce paints is the color, or rather, the colors of the earth. The origin of the colors depends on the chemical elements that made up the rocks and the decomposition process that attacked them. A rock or a layer of rock that does not have iron result in light-colored particles, very often white. Oxidation occurs in rocks or layers of rock that have iron and porosity for the penetration of oxygen, which results in particles that have red color in low humidity environments and yellow in more humid ones. In places where the soil remains completely soaked throughout the year, oxygen is absent. In these cases, the iron undergoes the opposite reaction of oxidation and completely dissolves without providing the soil any color. In these environments, fine particles, especially clays, give the soil light colors. These soils are the source of white clay (tabatinga).

The fine particles of the soils, be they clay or silt, occur mainly in B and C Horizons, from where, thus, we must extract the pigments with which we will produce the paints. The enormous diversity of colors found in soils is due to their heterogeneous nature. That is, soils are composed of different materials with different characteristics and in different proportions.Therefore, the paints and paintings produced with the pigments obtained from the soils reflect the beauty and complexity of nature, not being possible to maintain a color pattern such as in industrialized paints. From an aesthetic point of view, each painting with soil pigments constitutes a unique work.

Mural painting made with soil pigments in San Pedro de Atacama - Chile.
Photo: Vincent Pierre

PAINTS

PRODUCE AND PAINT

Paints are used to beautify and protect substrates. Like our skin, the paint protects the internal parts of the walls of the buildings and will be in permanent contact with the environment. This contact can promote a series of damages to the paintings. The resistance to these damages will depend on the quality of the paint and, mainly, on the conditions of the substrate. Without this, the paintings' aesthetic dimension will be compromised through the manifestation of pathologies.

The quality of the paint will depend on the rigorous reproduction of the process presented in the following pages and also on the quality of the PVAc, which should be the same used for wood bonding (sold in construction material stores) and not that for school use (sold in stationery stores).

As for the substrate, no paint will work well if it is not in good condition. Therefore, its preparation is essential. In addition, we emphasize that paints produced according to the following instructions are recommended for painting porous mineral substrates, that is, walls and no other materials.

The paint is, therefore, only one part of a system. Thus, between the production of the paint and the painting, we must overcome many stages to achieve satisfactory results.

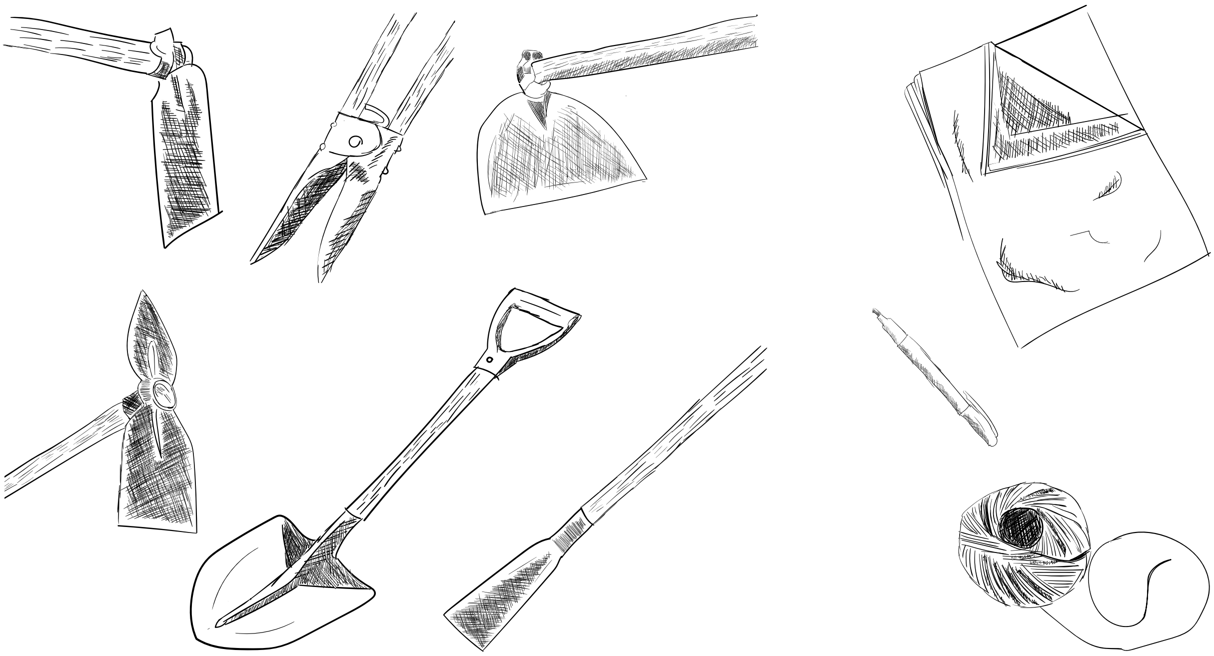
Photo: Vellozia Filmes

SOIL COLLECTION

Soil is the material in its natural state that will be collected to obtain the pigments. Its collection will be performed in two stages, the first being exploratory, to obtain samples of different types of soils for testing. The second stage is to collect selected samples to produce larger volumes of paint. Working in stages avoids the collection of large volumes of soil that may not be used to produce paints, saving time and labor, in addition to reducing impacts on the environment.

To perform the tests, small soil samples should be collected, with volumes of approximately 2 liters, in different locations and positions of the terrain, remembering that the soils present in B and C Horizons are the adequate ones. This will allow obtaining samples with different colors and granulometric compositions. After carrying out the tests, the definitive samples will be defined, which will then be collected to produce greater volumes of paint.

Materials and tools



How to collect

Situation 1 | Collection on an ravine

STEP 1. Superficially clean the ravine.

STEP 2. Remove the surface layer approximately 5 cm thick and discard.

STEP 3. Underlay the base of the ravine with a plastic bag, dig with a hoe or rake and take samples evenly in different positions without opening holes to avoid damage to the ravine›s structure and, thus, landslides and erosion. Take samples carefully to prevent contamination with materials of organic origin or other types of soil. Always clean the tools thoroughly with each collection.

Photos: Vellozia Filmes

STEP 4. Store in plastic bags, tie with string, and identify the sample.

How to collect

Situation 2 | Collection on a flat surface

STEP 1. Remove the surface layer (A Horizon) with a hoe and reserve.

STEP 2. Dig with a hoe or digger to take samples carefully to avoid contamination with materials of organic origin or other types of soil. Always cover with a plastic bag and clean the tools thoroughly with each collection.

STEP 3. Store in plastic bags, tie with string, and identify the sample.

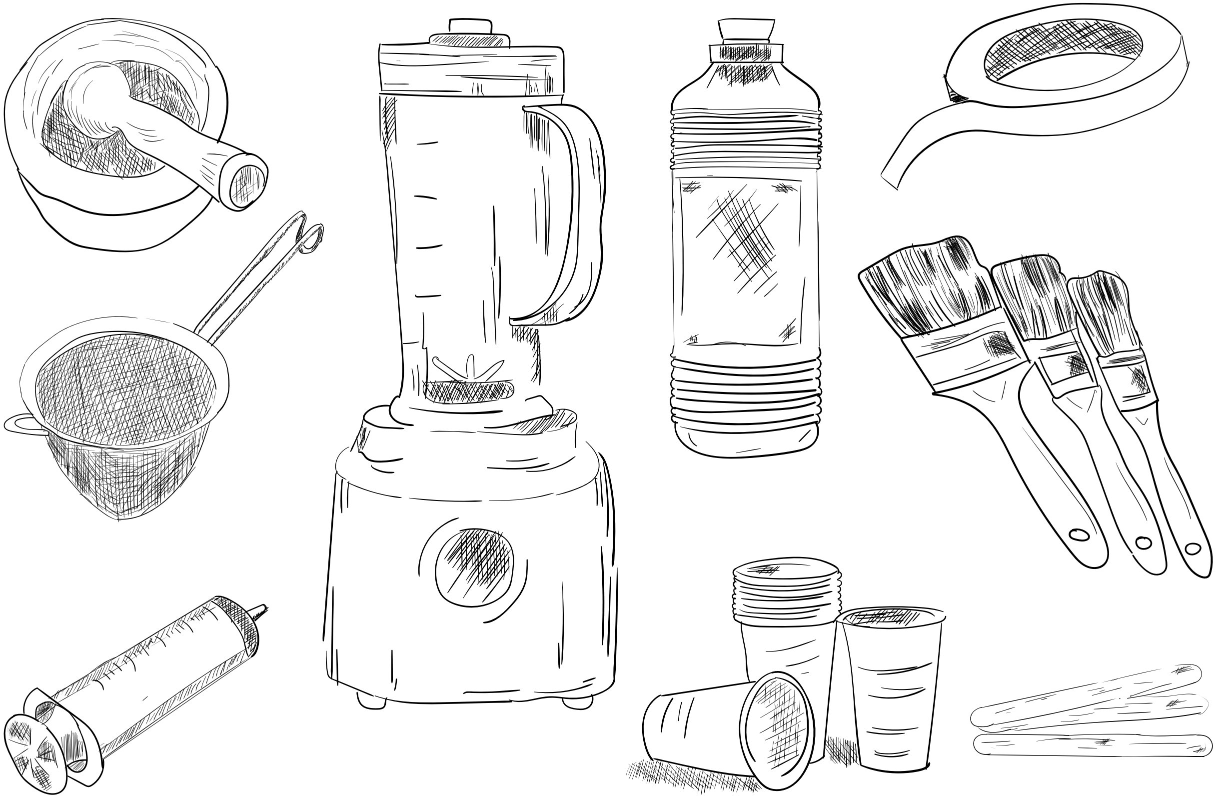
Photos: Vellozia Filmes

STEP 4. At the end of the collection, cover the open hole with the surface layer (A Horizon) that was removed in stage 1 and compact to avoid accidents and erosion.

TESTS

At this stage, we do not consider the first sample preparation as a truly paint. This stage aims to understand how each pigment behaves so that we have information to decide which ones to use depending on the color and the hiding power. It is at this stage that we will extract the pigments that will be used to produce paints from the soil material in its natural state. To perform the tests, the samples must be dry, without clumps, free from contamination, and properly identified.

Materials and tools

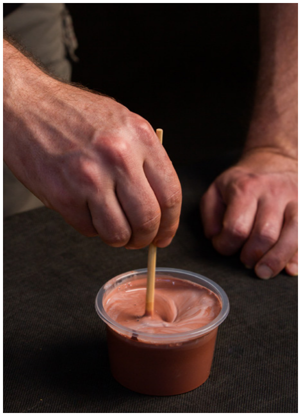


Sample preparation

STEP 1. Remove a volume of 100mL of dry soil. The more it is removed, the greater the precision of the volume measurements and the greater the homogeneity.

STEP 2. Dilute the volume of soil without clumps in 200mL of water manually or using a blender.

STEP 3. Then, sift the diluted material using a fine sieve to separate sand and organic material. The viscosity should be like that of conventional paint and should be adjusted if necessary. If it is very consistent, just add more water and if it is very liquid, just add soil, mix well, and sift.



STEP 4. Pour the material into a container, add 30mL of PVAc and mix well with a toothpick or spoon.

STEP 5. Cover the container and identify the prepared sample.

Photos: Vellozia Filmes

STEP 6. Repeat the previous operations with all collected samples and reserve, avoiding leaving the samples exposed to the sun. These samples are not themselves paints. They only serve to assess the effect of color and the hiding power of the pigments obtained from the collected soils.

Color palette

The color palette is used to evaluate the color and the pigment's ability to cover the substrate. Therefore, it is important to produce the color palette on the wall to be painted and not on other substrates.

STEP 1. Clean the substrate (wall).

STEP 2. Use adhesive tape to define the spaces for the application of each sample. Suggestion: mark 10 by 15cm rectangular spaces for each sample/color.

STEP 3. Mix each sample well and apply the first coat with a brush in the enclosed spaces, remembering to identify each sample applied on the wall. Wait to dry (the drying time depends on several aspects such as temperature, humidity, ventilation, sunlight, and porosity of the substrate). Apply the second coat, wait for it to dry, and finally apply the third coat. Remember to always mix well before painting.

Photos: Vellozia Filmes

STEP 4. Repeat the previous operations with all samples, wait to dry, and carefully remove the adhesive tape.

Color mixture

STEP 1. To mix colors it is important to precisely measure the proportion of each sample that will be mixed and always remember to mix thoroughly. To remove parts with precise volumes, we recommend the use of graduated syringes or graduated containers.

Photos: Vellozia Filmes

STEP 2. Mix well and always remember to register the proportions of each sample that compose the mixture. Example: 10mL of yellow color to 20mL of red color. Then, apply to the color palette according to the procedures indicated in the previous item.

Color and hiding power assessment

Color and hiding power serve to guide the selection of pigments that will be used in the production of paints to paint large surfaces. The color depends on the user's preferences, possibly being changed by mixing. And the hiding power is the ability of a pigment to cover the substrate. Ideally, the pigment should cover the substrate with a maximum of 3 coats. If this does not happen, the paint consumption will be very high, which makes the paint produced with this pigment uneconomical.

With the defined colors that will be used to produce larger volumes of paint, measure the area of the walls that will be painted with each color to estimate the volume of soil that should be collected.

The volume of soil to collect to produce larger amounts of paint

To find out the approximate volume to be collected, measure the area in m² that will be painted with each color and multiply by 0.2. For example: for a 10 m² wall we have: 10 x 0.2 = 2 liters of soil. Calculated the volume, return to the collection sites, and collect larger samples, remembering to remove clumps as much as possible to ensure greater accuracy of the calculated volume.

Photo: Fernando Cardoso

Photo: Fernando Cardoso

PRODUCTION

Paint is a mixture of pigment, binder, and solvent, being the first responsible for coloring and covering the substrate; the second, for recovering and adhering the pigments to each other and the surfaces; and the third, the volatile part of the paints, for diluting the pigments and binders.

Depending on the type of binder used, the paints are given different technical names. Paints produced with white glue or PVAc (Polyvinyl Acetate) are called latex paints.

The production of the paint will be done in two steps. As each soil pigment has its own characteristics, it is not possible to define a priori a single formula that can be used to produce paints with any type of pigment. Therefore, in the first stage we will produce a small volume to get to know the characteristics of the pigment of a given soil and in the second stage, already knowing the appropriate formula for the pigment in question, produce enough volume to paint a wall or an entire building. Two-step production is also important to avoid waste.

Latex paints perform better when applied indoors protected from weathering. However, the studies performed (CARDOSO, 2020) allowed us to conclude that it is also possible to apply latex paints produced with soil pigments on external surfaces, achieving good resistance to weathering.

How to produce approximately 4 liters of paint

Materials and tools

Procedures

STEP 1. Pour 1,5 liters of dry, without clumps soil into 3 liters of water and mix with a cowles disc attached to a drill for 15 minutes. See information about the cowles disc in Appendix 1.

Photos: Vellozia Filmes

Photos: Vellozia Filmes

STEP 2. Sift using a fine sieve and discard retained material (stones, sand, and organic matter).

STEP 3. Measure viscosity. See Appendix 2 for information on the viscometer and viscosity measurement. If the viscosity is high, add a known volume of water and mix; if the viscosity is low, add soil, mix again, sift, and measure the viscosity again until it reaches the proper consistency.

STEP 4. Calculate the final volume of pigment: measure the final volume of pigment + water and subtract the volume of water to get the volume of pigment.

STEP 5. Then, divide the pigment volume by the total volume (water + pigment) to calculate the PIGMENT CONTENT. This content will be used to calculate PVAc consumption and the yield of the paint according to Tables 1 and 2.

PIGMENT CONTENT	INTERNAL PAINTING	EXTERNAL PAINTING
	% of PVAc*	% of PVAc + % of Linseed oil**
Less than 15%	60	60 + 5
Between 15% and 30%	40	40 + 5
Greater than 30%	20	20 + 5

Table 1. Proportions of PVAc and Linseed Oil as a function of PIGMENT CONTENT according to the purpose of the paint: internal or external paints. *Calculated as a function of the volume of pigment; ** Calculated as a function of the volume of pigment.

PIGMENT CONTENT	APROXIMATE YIELD (m²/L) *
Less than 15%	2
Between 15% and 30%	4
Greater than 30%	6

Table 2. Approximate paint yield as a function of PIGMENT CONTENT. * Considering one coat of sealer and up to three coats of paint.

STEP 6. If the paint is used to paint external walls, add linseed oil in a volume corresponding to 5% of the pigment volume and stir with Cowles disc for 5 minutes.

STEP 7. Then, add PVAc as indicated in Table 1 and mix with a helical mixer attached to a drill, or manually, for 5 minutes (do not use Cowles disc in this step).

STEP 8. After the sample preparation is complete, cover the container and identify it.

STEP 9. To know the total volume of paint to be produced to paint a wall or an entire building, simply multiply the approximate yield by the area to be painted according to Table 2.

STEP 10. Repeat the previous procedures to produce the total volume of paint needed to paint a wall or an entire building.

Photos: Vellozia Filmes

Storage

We recommend that only the amount of paint needed to paint a certain area be produced and that an extra volume of the same soil is collected and saved to produce paint for repairs or future repainting. We do not recommend producing paint and storing it for longer than necessary to perform the painting service. The reason for storing an extra sample of the same soil, and not of the paint, is due to the possibility of degradation of the paint if it is not well stored, thus avoiding waste.

In this case, the extra volume of soil must be collected in the same location, since the natural heterogeneity of the soils may lead to color changes if a future collection is conducted in another location, even in the vicinity.

However, if there is the need to store the paint, it is important to emphasize that the soil used must be free of materials of organic origin, which can rot, and that the container to be used must be clean and could be well covered.

To use paints that have been stored, it is important to homogenize them very well, as the pigments will decant naturally and form a crust on the bottom of the container.


Photo: Fernando Cardoso

EXAMPLE OF CALCULATING THE PIGMENT CONTENT, PVAc VOLUME AND PAINT YIELD

1. Suppose that, after mixing 1,5L of dry soil without clumps with 3L of water, mixing with the Cowles disc for 15 minutes, sifting using a fine sieve, and discarding the material retained in the sieve, the final volume of pigment diluted in water is 4l.

2. And that, when measuring the viscosity of this mixture, its passage time through the orifice was 20 seconds. This means that the mixture is very viscous and needs to be diluted so that the paint reaches the ideal consistency (see Appendix 2).

3. When adding another 0,2L (200 mL) of water, mixing well, and measuring the viscosity again, the passage time through the orifice was between 12 and 14 seconds, which means that the mixture reached the ideal viscosity.

4. Now we know that the final volume of the water + pigment mixture is 4L + 0,2L, that is, 4,2L.

5. To know the volume of pigment of this mixture, just subtract the volume of water from the total volume. We know that the volume of water is the sum of the initial volume plus the 0,2L added to balance the viscosity, that is, 3L + 0,2L = 3,2L. Knowing that the final volume of the mixture was 4,2L, just subtract from this volume the 3,2 L of water, which results in 1L of pigment. The reduction in the volume of pigment is due to the disposal of that part that was retained in the sieve (sand, organic material, etc.).

6. Once this is done, it is now possible to calculate the PIGMENT CONTENT. To calculate it, just divide the final volume of pigment (1L) by the volume of the mixture of water and pigment (4,2L), which results in approximately 0,25 or 25%. This means that approximately 25% of the volume of the mixture is composed of pigment.

7. Knowing the PIGMENT CONTENT, check Table 1 to find out how much PVAc to add to the mixture to finish the paint production. As the PIGMENT CONTENT is 25%, we now know that we need to add a volume of PVAc equal to 40% of the volume of pigment, that is, 40% of 1L of pigment, which is equal to 0,4L or 400mL of PVAc.

8. If the paint is used for external painting, remember to add before the PVAc a volume of linseed oil equal to 5% of the volume of pigment, that is, 0,05L or 50mL.

9. Finally, what would be the approximate yield of this paint sample? Just check out Table 2. As the PIGMENT CONTENT is between 15% and 30%, the approximate yield will be $4m^2/L$, that is, each liter of paint is sufficient to paint approximately $4m^2$ of surface considering three coats.

10. Assuming that the area to be painted is $60m^2$, just divide that area by 4 to know how many liters of paint to produce, that is, 60 ÷ 4 = 15 liters of paint.

NOTE | When the PIGMENT CONTENT is extremely low, the hiding power is impaired, requiring several coats to cover the substrate and, therefore, greater consumption of paint. This is due to the specific characteristics of each pigment, which affect the rheological behavior of the paint. One way to solve this situation is to mix MINERAL FILLERS with pigments. They act as a filler, increasing the PIGMENT CONTENT and, therefore, the paint yield. Marble and granite cutting waste, for instance, are good options for MINERAL FILLERS that can be added. To do so, all the procedures indicated in the TESTING stage of this manual must be performed, with special attention to the item COLOR MIXTURES. To learn more about the subject, consult the works of Lopes et al. (2019) and Tressmann et al. (2020).

PREPARATION OF SUBSTRATS

This stage of the work is of fundamental importance. Without a good preparation of the substrate, the performance of the paint and the quality of the painting will be impaired. Before starting the preparation of the substrates, it is important to understand that the paint is only one part of the painting system, that is, before painting, a series of procedures must be performed to obtain good results. It is important to emphasize that this type of paint is intended for painting porous mineral substrates such as the walls of buildings, not other materials, such as wood, metals, or plastics.

The painting system consists of:

• Primer or sealer: it is a product intended for the first coat on the surface and acts as a bridge between the substrate and the paint. The primer is called a sealer when applied over mortar surfaces and is indicated to reduce and/or uniform the absorption of substrates. Thus, the paint will be absorbed homogeneously by the substrate in its entire length, avoiding stains and excessive consumption.

• Wall primer: it serves to promote the cohesion of loose particles of the substrate and, therefore, its application is recommended on surfaces without firmness or cohesion, that is, those that tend to come apart, such as weak mortars, whitewash, repainting, or plaster surfaces.

• Spackling: it is a paste used to correct irregularities, such as cracks, on the surface that has already received a sealer.

• Paint: it is the last layer of the painting system, which will fulfill the aesthetic function, as it can have different colors, and will also protect the substrate.

The application of the primer or sealer, the wall primer, or the spackling will depend on the conditions of the substrate. Therefore, before starting the substrate preparation, it is important to make a diagnosis to define which strategy should be adopted. The procedures presented below were extracted from the publication "Projeto, execução e inspeção de pinturas" [Design, execution, and inspection of paintings], by Kai Loh Uemoto.

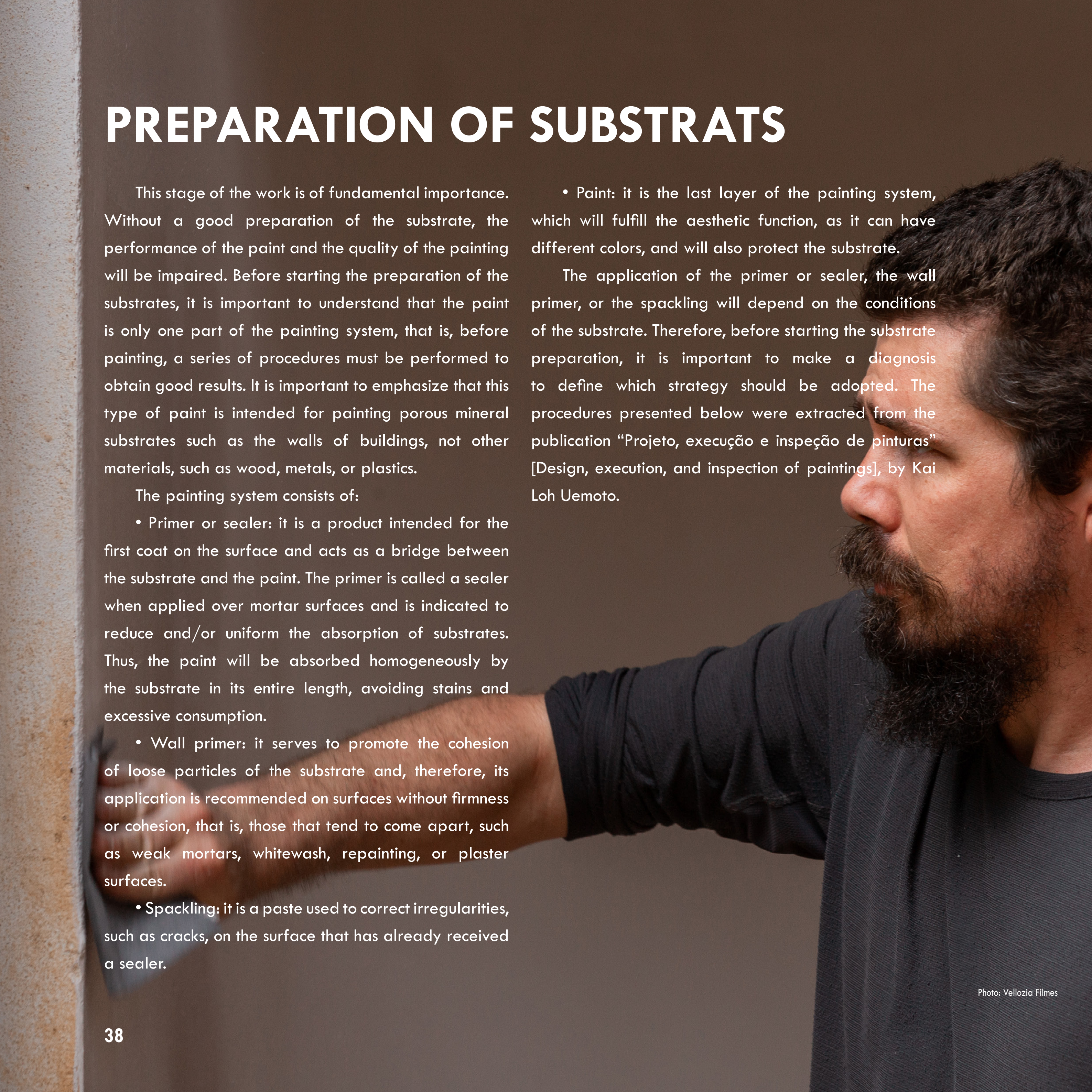
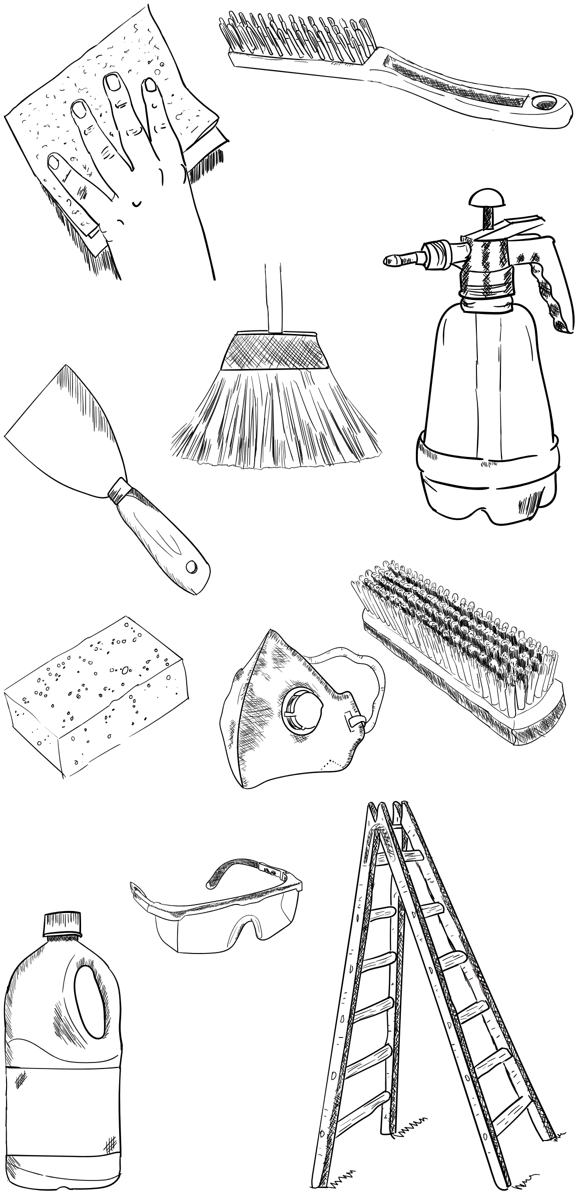


Photo: Vellozia Filmes

Materials and tools



Procedures

For the painting, the substrate must be firm and cohesive, uniform and straight, with no signs of moisture, dirt, dust, efflorescence, or loose particles, free of oil, fat, or grease, and microorganisms such as mold, fungi, algae, lichens, etc. Cement and/or lime-based surfaces must be cured for at least 30 days.

STEP 1. Cleaning the surface

• Remove dirt, dust, and loose materials in general, by brushing and eventually with the help of water jets. In the case of outdoor surfaces that are difficult to clean, use a spatula or steel brush.

• Remove grease, oil, and other fatty contaminants with soap and detergent, followed by washing with water and leaving the surface to dry.

• Remove efflorescences (white stains that may appear on the lining of the walls) by brushing the dry surface, using a soft bristle brush.

• Remove microorganisms (mold, fungi, algae, lichens, etc.) by rubbing the surface with a hard bristle brush and a bleach solution diluted with water in a 1:1 ratio. If necessary, leave the solution to act for a certain period, approximately 1 hour, and then rinse with plenty of water.

STEP 2. Correction of substrate faults

• Eliminate moisture stains caused by the infiltration of water from pierced pipes, broken tiles, clogged gutters, etc. After correcting the problems, let the surface dry.

• Repair imperfections such as cracks, fissures, protrusions, and indentations before applying paint. Imperfections of large dimensions and depth must be repaired with coating mortar in texture similar to the surface to be painted 30 days before painting. Imperfections of small dimensions must be repaired with spackling, which must be applied with a steel trowel or spatula until the desired leveling is achieved, without applying excessively thick coats. Allow it to dry and then sand it.

STEP 3. Surface treatments

• On very porous substrates, prior application of industrialized primer or sealer (acrylic/vinyl) is recommended, or the finish paint itself diluted in water in a 1:1 ratio.

• On low-resistance substrates, apply a wall primer with a roller or brush in the dilution indicated on the product packaging or the manufacturer's catalog. The resistance of the substrate can be verified by rubbing it with your fingers, exerting pressure, considered low when there is no cohesion between the grains of sand. The verification can also be performed with the aid of adhesive tape: tape is applied with pressure on the surface, removing it at once with a strong tug, then observing the amount of material that sticks to the tape. If too much material sticks, it means that the resistance of the substrate is low. And, in the worst case, if the mortar simply crumbles under pressure from the fingers, it must be redone before applying the paint.

How to get a smooth surface?

• On the prepared surface, apply successive coats of spackling, in thin layers, with a steel trowel or spatula. The spackling must be compatible with the finish paint and the type of environment. Depending on the leveling, apply one to three coats of spackling, waiting for an interval between coats of approximately 1 hour.

• After 2 to 3 hours of drying, sand the surface, clean, and paint.

To find out which procedure to adopt depending on the type of surface treatment, see Table 3.

SURFACE TREATMENTS	INTERIOR	EXTERIOR
Correction of surface imperfections	Acrylic/vinyl spackling	Acrylic spackling
Regularization of surface absorption	Acrylic/vinyl sealer	Acrylic sealer
Correction of mechanical resistance	Wall primer	
Smooth finish	Acrylic/vinyl spackling	Acrylic spackling

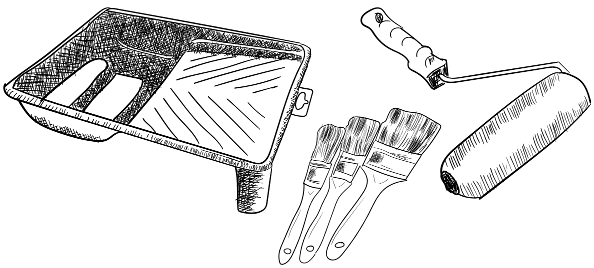
Table 3. Appropriate procedures for each type of substrate surface treatment.

Photo: Fernando Cardoso

PAINTING

Painting is the work of applying the paint to a previously prepared substrate and it is also the coating layer produced by the paint after the volatile part has evaporated, that is, the water. The procedures presented below were extracted from the publication “Projeto, execução e inspeção de pinturas” [Design, execution and inspection of paintings], by Kai Loh Uemoto.

Materials and tools



Environmental conditions for the execution of the painting

• Ideal temperature and humidity conditions: paint at room temperature between 10°C to 40°C and relative air humidity below 80%.

• Movement of air and wind: the external surfaces must be painted in the absence of strong winds, particles suspended in the atmosphere, rain, superficial or excessive air humidity, such as vapor condensation or fog. The same caution must be maintained in all coats. The internal surfaces must be painted when there is no vapor condensation on the surface to be painted and in climatic conditions that allow doors and windows to remain open.

• Seasonal factors: it is recommended to schedule the painting in the less rainy seasons, on walls without direct sunlight, and without moisture condensation.

• Air pollution: surfaces exposed to environments with high air pollution must be thoroughly cleaned before painting, and the application interval between coats must be as short as possible.

• Lighting and ventilation: the painting must be performed in an environment with good lighting and ventilation. In case of dark-colored painting or absence of color contrast between coats, the lighting level must be increased.

Procedures

Paint application

• Paint homogenization: the paint must be properly homogenized before application.

• Application with a brush, paintbrush, or thick bristle brush: they should be dipped in the paints only up to half of the bristles. The excess must be removed. The strokes should be short to apply uniform amounts of material, forming a smooth layer of uniform thickness. The leveling and smoothing of the paint must be done by long transversal strokes in relation to the first ones, being careful to smoothly pass the brush so as not to leave new marks.

• Roller application: the roller should be placed in the shallow part of the tray and rolled to the deepest part containing paint. Repeat the procedure several times so that the roll is evenly impregnated. The excess must be removed by pressing and rolling the roller through the bottom of the tray, in the shallow part. The painting should be started from the bottom up, trying to cover the most length possible.

General application technique

• The amount of paint applied in each coat must be as little as possible and spread as much as possible so that the surface coverage is obtained by applying several coats.

• Each coat must be applied with uniform thickness and free from pores, runoffs, etc. Each coat must be applied when the previous one is sufficiently dry. The last coat must provide a uniform film to the surface, without running down, without flaws or imperfections.

• Any paint flaws must be corrected, respecting the foreseen drying time before applying the next coat.

• The newly applied paint must be protected against dust and water, or even accidental contact, during drying.

• In general, each coat must be dry before applying the next coat. Water-based paints do not require long drying periods, and the next coat can be applied a few hours after the first.

Photo: Fernando Cardoso

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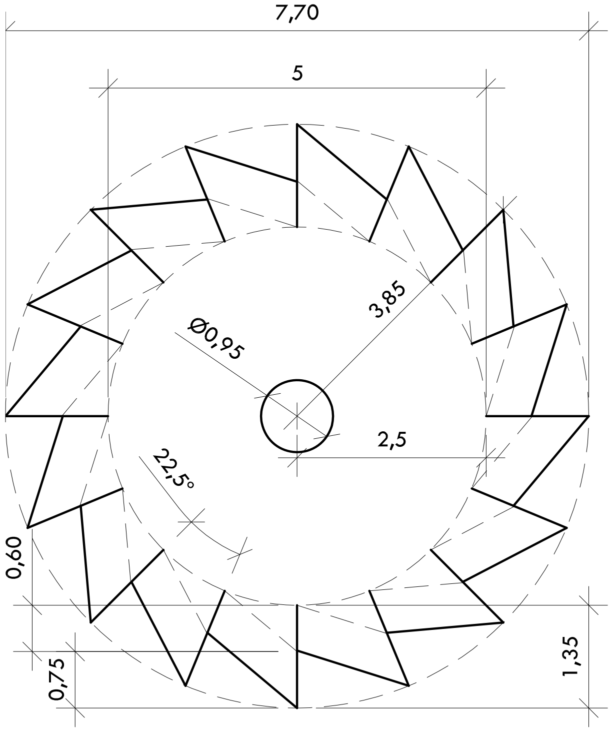
APPENDIX 1

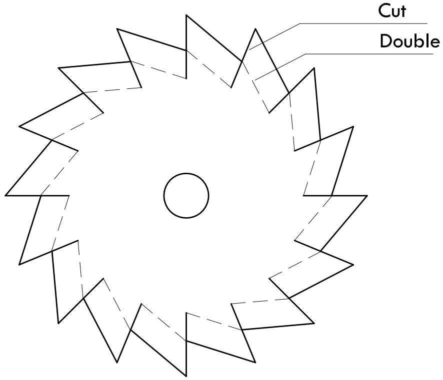
Cowles disc

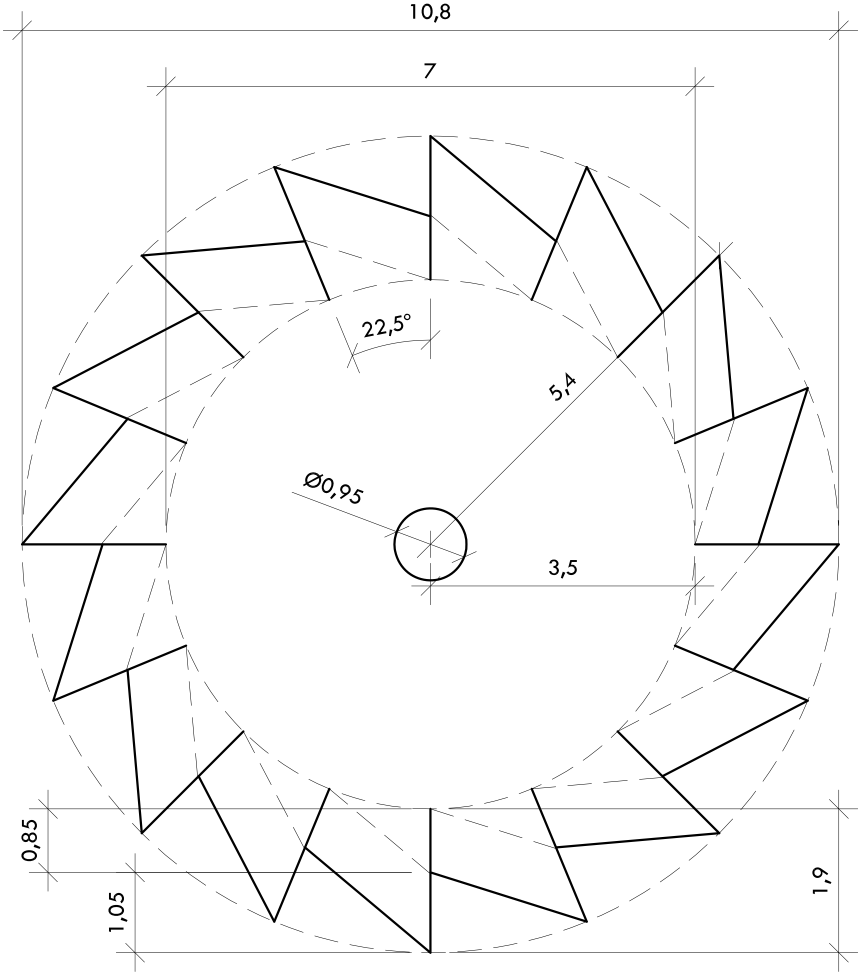
The Cowles disc is a fundamental tool to guarantee the production of quality paints and can be manufactured by any experienced locksmith. We recommend that it be manufactured with 2mm thick stainless steel plate, strictly observing the dimensions indicated in the drawings.

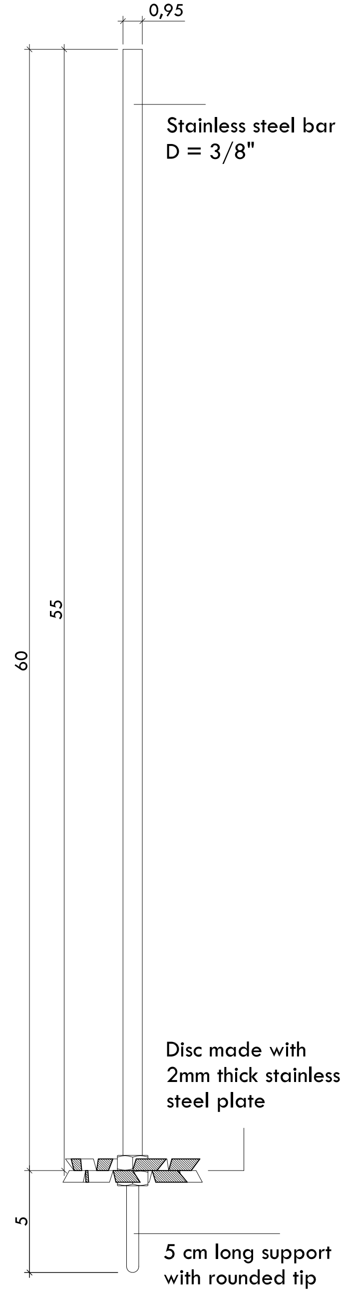


DISC 1

For buckets with a volume of up to 10 liters







DISC 2

For buckets with volume between
10 and 20 liters

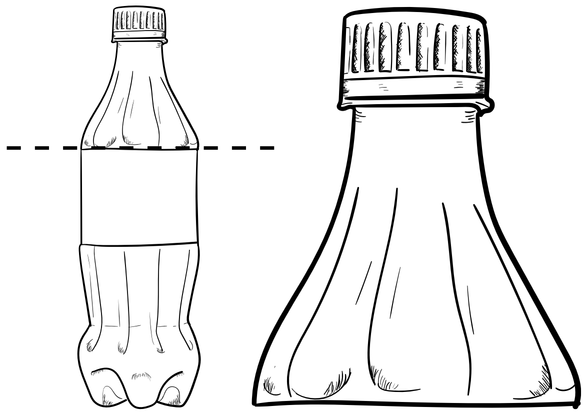
Note | The drawings of the discs types 1 and 2 are in the 1:1 scale and, therefore, can be copied and used as a template for manufacturing. Measures in centimeters.

APPENDIX 2

Viscosimeter

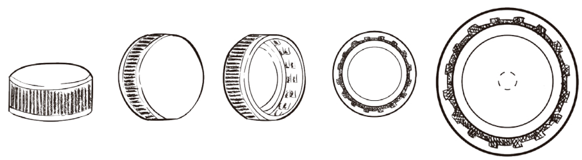
The viscometer, as well as the Cowles disc, is essential to guarantee the production of quality paints. This viscometer is an adaptation of the Ford cup and can be produced with a 600mL PET bottle according to the instructions below.

How to build the viscosimeter



STEP 1. Provide a 600mL soda bottle. It must be exactly the type of bottle shown in the illustration.

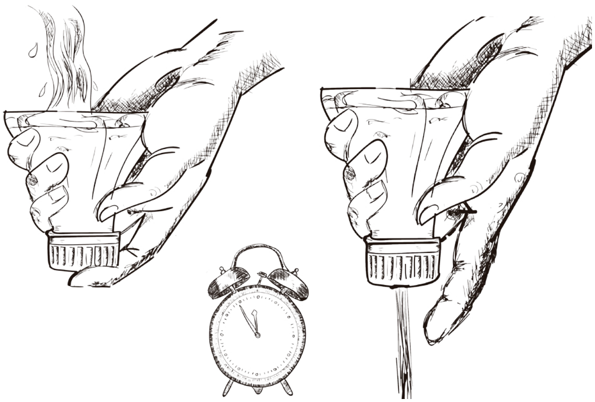
STEP 2. Cut with scissors or cutter on the line that borders the top of the label. The viscometer will be made with the top of the bottle, that is, the one that contains the cap and forms a cone.



STEP 3. Drill a hole in the center of the bottle cap. This hole must be exactly 4 mm in diameter.

STEP 4. Screw on the cap.

How to measure viscosity



STEP 1. Cover the hole in the cap with your finger and fill the container with paint to the rim.

STEP 2. Uncover the hole and measure the time it takes for the paint to pass. The time must be between 12 and 14 seconds for the viscosity to be considered ideal. If the time is less than 12 seconds, it means that the mixture is very liquid; and if it takes more than 14 seconds, it means it is too viscous. In both situations, the viscosity must be adjusted.

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