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Masters of the Future. How some materials are shaping the world.
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Introduction

Look up, look around: what do you have near you?

Definitely, as far as the eye can see, something that has a screen. Our lives are dependent on digital objects. A few meters away, if not less, you will have your smartphone. Over your head, thinking of a hot summer day, the gentle hum of a running air conditioner and somewhere its digital remote control, always ready to get lost in the meanderings of the room. In the room where you are reading there will be a TV, radio or *smart* assistant-this same book could be translated into the format of an eBook. In the house you will surely have a pc or a tablet: maybe both, maybe more than one. In the bathroom an electric toothbrush with a digital display might be waiting for you, as well as in the kitchen a next-generation refrigerator with a touchscreen. Even the car, maybe electric, has a digital command dashboard with a navigator that will guide you along the route with less traffic to your workplace. Or you might use an app to rent a bike, scooter or a car in shared mobility, all through a computing device that sends pulses to data centers even thousands of miles away from where you are now.

Contemporary existence, articulated in a canonical daily routine, very much depends on digital objects. It is an addiction that has erupted in the space of a generation. Over the past two decades, you too must have often joked about it as you felt it and in small doses it entered your vein: a fascinating addiction that smelled of the future and speed. That made you feel “smart,” even if you eventually lost some skills and isolated yourself a bit more from others. And like all addictions, the pleasure of the experience was slowly replaced by a sense of necessity.

Getting our bearings without Google Maps, cooking without an online recipe, passing the time without chatting or scrolling through the feed: how much can we do without feeling, even for a moment, distressed? Even those who, like me, are old enough to say they once did without these apps could deprive themselves of them without feeling that “something” is missing? And what about those who have never lived without the digital shortcuts that relieve them of the problems and obstacles of the real world, how do they feel when the net crashes?

All the digital technologies are around you to offer you an augmented reality life, where every object throws you into a different experience – a dimension so artificial and brilliant that it is hard to get out once you enter it. Yet, at the dawn of an era that considers planets and stars as the ethereal limits of an existence freed from the physical burden of our human limitations, we have been fooled by the narrative about this new time. With all our digital endowments, we have bought no ticket to the Hyperuranium. There is nothing ethereal and incorporeal about the

current technological revolution, which is instead driven, composed and intrinsically linked to physical, concrete, material, finite and therefore valuable things. They are called critical materials, rare earths, minerals and precious metals, and they underlie the most important objects that will shape our future.

In the book *The New Digital Age*, authors Eric Schmidt, former chairman of Google's board of directors, and Jared Cohen, a former adviser to Hillary Clinton, write that "thanks to the network, the vast majority of us will be brought to live, work and be governed in two worlds at the same time."ⁱ, the physical world and the virtual world. This duplication comes at a price, based on the cost required to grab those physical goods that constitute the virtual world and provide access to it. The digital revolution requires tons of gold (6 percent of the world's demand goes to the electronics industry) and silver (here the percentage rises to 20 percent), huge quantities of rare metals such as terbium (88 percent of the world's demand), germanium (87 percent), gallium (70 percent), ruthenium (66 percent), beryllium (42 percent), antimony (41 percent), tantalum (40 percent), palladium (15 percent)ⁱⁱ. In addition to well-known critical materials such as lithium, nickel, and cobalt, each smartphone contains an average of 63 different elementsⁱⁱⁱ, also considering rare earths and precious minerals. And each of these materials involves a laborious process of extraction from the ground, with different stages and great impact on the environment: mining is estimated to contribute about 10 percent to global CO₂ equivalent emissions^{iv}. In any case, digital objects are just one application of rare earths, precious materials and minerals. The same ingredients underpin pivotal pieces of the energy transition, from solar panels to electric batteries. They make up the building blocks of machinery in health care, ranging from X-ray equipment to widely used antidepressant drugs. They are the raw materials for building the new weapons of war apparatus developed by the fourth industrial revolution, particularly drones and robots. That is why these elements are the basis of a global geopolitical rearrangement, which passes through clashes and position wars, where the map of the planet will be redrawn according to the power relations of those who control and manage the extraction and processing of critical materials.

Spoiler: it is not the West. But the West has an enormous need for these materials to be self-sufficient, regain a necessary industrial vocation and set out through a new proposal along a visionary path that addresses and overcomes its current weakness.

This proposal is not only functional for a collective mission, but must be accompanied by an individual awareness. The rate of consumption we apply to things is not proportionate to our real needs, although marketing has deluded us to the contrary. We buy everything, everywhere, more out of social stimulus, curiosity and boredom than anything else, and have closets and closets full of useless things that are also difficult to dispose of. Things that when they become waste atrophy our planet's biological systems and poison our health. Continuing to ignore the consumerist abuse of

the scarce resources that fuel the productive cycles of human commerce is a luxury that seriously jeopardizes the quality of life – if not the survival – of the next generation.

Our existence is based on complex and heavy things, which promise to be the key to elevating us in a world that does not exist, while they tend to lock us more and more into an asphyxiated and fictitious space, into which we enter by paying handsomely for access keys. These keys (smartphones, PCs, tablets, etc.) consist of items that are much more valuable than their price and consequently should be considered rare, expensive, fascinating. Even magical, thinking of science fiction writer Arthur Charles Clarke's aphorism, "Any sufficiently advanced technology is indistinguishable from magic."^v Just as a person from the Middle Ages might look up to us with the awe with which one would look up to a magician as we scroll through content on our cell phones or make a video call, so it is necessary to return to regard with great respect our digital magic wands, made from an infusion of materials and elements that require enormous effort to extract and process.

The book you have in your hands is intended to be a guide to understanding what are the material sources that constitute our technologies, how much they affect our lives, and how they will shape the near future: as I will explain later, I have defined them all by the term *matrices*, and they are marking the new evolutionary stage of human development. Take these pages as a journey to discover the tangible lintels on which the society we live in is based. A journey consisting of five parts as five perspectives of analysis of these elements.

In the first part I will describe why matrices are the ingredients of what surrounds us and how, more or less directly, they are trying to shape us. Before describing what the matrices of the future are, it is useful to explain what they are useful for. In a nutshell, we will take a leap into the new world that awaits us: digital and energy transition, warfare evolution, and health care are the four revolutionary winds blown by the matrices of the future. In the second part I will tell what these elements are from a technical point of view and what problems are involved in their procurement and subsequent processing. Major geopolitical conflicts arise from the latter two aspects. The third part is devoted to the analysis of why they are developing and who are the relevant and emerging players in the new planetary chessboard. In the fourth I will analyze the actual or potential alternatives to the use of these materials. In the fifth, finally, we will take up the discussion started in this introduction: how our relationship with things is part of the problem.

At the end of this narration, I will again invite you to look up to become aware of what you really need so that you can contribute to a different vision of life and the objects that "season" it, because the current one simply cannot go on any longer. Worldwide, we use about 7.5 billion smartphones (more than doubled in ten years)^{vi}, more than 2 billion PCs^{vii}, 1.3 billion tablets^{viii}, and these are

estimates by default. Even thinking only of a blind acquiescence to the needs of the digital world of that “immense majority” described by Schmidt and Cohen, the socio-environmental damage to gain the valuable materials useful to compensate for the commercial whims of a large part of humanity would not pass even the most trivial cost-benefit analysis related to the common interests of our species’ existence on the planet. We have long slept through a dreamless night, groggy *from sleeping pills* whose active ingredient are weapons of mass distraction. We must return to face reality, which is all around us. We must face it, before we raise those who will come after in some dystopian vision described in one of the series airing on Netflix. As Naomi Klein writes, “we must chart a credible and inspiring course for a different future. And that future cannot simply be where we were before Trump came along [...]. It must be somewhere we have never been before.”^{ix} .

Chapter 7

How to produce

“The relationship between life and production, which lowers the former to an ephemeral manifestation of the latter, is perfectly absurd.”

THEODOR ADORNO^x

Every enormous human evolutionary leap has often gone through a sacrifice. In the millennia-long histories of our species, the spark that ignites the flame arises from sometimes painful steps such as a war or a technological transition. Humanity’s discovery of the domestication of fire influenced the change of the brain and was a spark for the development of our intelligence. Of course, fire was then applied as a weapon and evolved to enter powerfully into the affairs of war. So today the adoption of artificial intelligence is undoubtedly a crucial evolutionary leap for our future, something so powerful that it can be likened to the spark ignited by the use of fire. We have seen how the fourth industrial revolution and the advent of AI are linked to improving our ability to process the matrices of the future, certainly starting with rare earths. And also how promethium-the last rare earth to be identified at the end of World War II-was named after the “atomic fire” that had enabled its isolation. In Greek legend, the titan Prometheus challenged Zeus to bestow fire on humans and was punished with eternal torment for doing so. On the other hand, the extractive process of future matrices, as is still done in much of the world today, kills ecosystems and individuals. The physical foundations of the magical wonders of contemporary technology arise from complex processes that cause environmental contamination, from large mines that generate

huge amounts of toxic waste and discards. First, metals of any kind are only a small part of the rock from which they are extracted. For example, behind a ton of nickel there is about 250 tons of mining waste, while in the case of a ton of copper it goes up to 500 tons. Let's get personal: to make a single iPhone, which weighs about 130 grams, about 35 kilograms of minerals must be mined, and to do all this will emit 50 kilograms of CO₂.^{xi}

Alongside the issue of environmental sustainability, the social issue related to matrix mining, namely the exploitation of often underage workers in some of the most deprived areas of the globe, also emerges strongly. This is the very serious cost paid by China, as well as by Congo, Indonesia and many other nations that are not aligned with international regulations in protecting the environment and people when they implement extractive processes. And it is only the beginning. In the next thirty years, thinking only of the electric car market, the demand for cobalt will be five times greater than in 2022, nickel ten times, lithium fifteen times: if we put these figures together it will go from an annual mined amount of 70,000 tons to over a million^{xii}. Although probably the extraction and refining of rare earths are the most impactful of all operations related to other future matrices.

The sacrifice required by rare earths

Rare-earth oxides are processed by separation and extraction of the rock material in which they are hosted through acidic or alkaline solutions. Separation involves a large use of solvents such as oxalic acid and ammonium bicarbonate, which are used in specific refining processes. These are substances that are very toxic to human health and seriously pollute neighboring ecosystems. And later we will see what comes instead from the residues of manufacturing processes as well as extractive ones. Spoiler: nothing better, nothing good.

In different ways and at different frequencies, similar impacts result from extractions of the wide range of all the matrices we are discussing, but for now let us focus on processes derived from rare earth production. Let us start with those extracted from bastnäsite deposits, the mineral that has the highest concentration of usable valuable rare earths. First it is extracted from the mine, then it must be processed by crushing to a form similar to sand or silt. At this point, the relevant minerals, and in this case rare earths, are separated from the low-value residues through a process called *flotation*, which involves the use of acids and solvents including those previously mentioned. This process can be put in place several times to achieve a level of purity suitable for industrial uses. In short, if we think only of rare earths from bastnäsite deposits there are different stages of processing: extraction from the subsurface, processing by crushing, separation by flotation, and identification, which will depend on the specific deposit type and the product to be obtained. In contrast, acid digestion processes

using sulfuric acid or alkaline digestion are used to extract minerals from monazite deposits (the second highest concentration of rare earths). Methods other than the processes related to bastnäsite, but with nonetheless significant harmful impacts .^{xiii}

Indeed, all of this produces enormous environmental impacts and, where it occurs without surveillance, significant harm to human health, both for those working in the plants and for those living in the surrounding areas. To give an idea, processing one ton of rare earths to the purification required for industrial uses requires 30,000 cubic meters of water, which once used will be contaminated with acids and heavy metals^{xiv} . If not properly treated, this huge amount of toxic liquid is discharged into adjacent waterways or into the ground. And – surprise! – in many of the world's large plants the water is not properly regenerated, triggering all the imaginable consequences for the healthiness of the ecosystem. It is not simply very dirty water: in many cases the residues of the mined rare earths contain radioactive thorium. The treatment required to render it inert is complex, because it involves stringent disposal and storage measures. It is not just a matter of carelessness and approximation: the chemical baths described in the various rare-earth refining operations are very expensive, as are the necessary equipment and environmental controls that are essential. For these to be effective the necessary permits require long waits for the necessary verifications^{xv} . In two words, a lot of time and a lot of money. To get a rough dimension, the price of properly disposing of all the toxic residual outline from the production of the most valuable matrices was one of the main reasons for the closure of the largest US rare earth mine .^{xvi}

That is why the West at some point decided to relegate the dirty work in producing the matrices to the “factories of the world,” that is, to those nations-which I will discuss in the next few pages-that now have an oligopoly capable of maneuvering the price leverage of minerals crucial to our future, so as to raise the margins and also the economic barriers to entry for new producing countries. Barriers to entry that are already very high at the technological level. To pull them up and keep them up took great environmental sacrifices and the effort of tens of thousands of workers, often still condemned to misery if not outright slavery. A desperate population of highly efficient workers resigned to their fate: one of the darkest aspects in the great matrix production of the future.

Chapter 8

Why they have become a problem

“Most problems are distributed roughly like this: 94 percent depend on the system (and are therefore the responsibility of management), 6 percent on special causes.”

EDWARDS DEMING^{xvii}

In 1927, the year Charles Lindbergh completed the first solo, nonstop transatlantic flight from New York to Paris, a technology that was revolutionary at the time took its first leap forward: Philo Farnsworth succeeded in building an electronic television set^{xviii} and in both the US and the UK the first television pictures were transmitted by cable^{xix}. A century later, humanity was conquered by digital visual communication, thanks in part to the new technological potential offered by the use of rare earths. This is precisely why Ding Daoheng's discovery, made precisely in 1927, assumes absolute relevance today: the Chinese geologist identified a large number of rare earth deposits in Bayan Obo, Inner Mongolia. If Xu Guangxian was the key to unlocking Chinese dominance over rare earths, Bayan Obo, the world's largest rare earth deposit, was its gateway. With 48 million tons of rare earth oxides, it covers about half of China's domestic production and just under 50 percent of the world's. The Bayan Obo mining district is about 150 kilometers north of Baotou, capital of the Inner Mongolia Autonomous Region^{xx}; yes, the very area about which Xu Guangxian was so concerned that he openly reported potential radioactive contamination to the Chinese government in 2005. Twenty years ago, Xu denounced the seepage of thorium-containing waste from mining into the soil and the Yellow River: a radioactive threat to the health of the inhabitants. If even your fame were celebrated by an asteroid circling in space, criticism of regime industrial choices is at a very high risk in the People's Republic of China (to put it mildly). But let us try to frame the scale of the environmental problem (again, to put it mildly) that Xu was dealing with.

The dark side of success

Ten kilometers north of the Yellow River, the world's largest rare earth lake came into being in the late 1950s: a 13-square-kilometer body of water containing 200 million tons of sewage, including about 70,000 tons of radioactive metals and thorium, produced by industrial discharges. During the rainy season or on particularly heavy rainy days, these materials leak out of the basin so that they are dispersed into the waters of the Yellow River and other smaller waterways. To make matters worse, the world's largest rare earth lake is located in a high-risk seismic area where an earthquake could cause one of the most serious river pollution incidents ever^{xxi}. But at Bayan Obo, the world's largest rare earth mining site, there have always been many problems (or, as economists say, *externalities*). At the atmospheric level, between 9,000 and 12,000 cubic meters of toxic gases rich in hydrofluoric acid and sulfuric acid are generated for every ton of calcined rare earth ore. Then imagine acid fumes and fine dust degrading the surrounding air, and then acidic liquid discharges contaminating

groundwater and soil. Finally, there is the waste: to extract one ton of rare earths, at least 2,000 tons of toxic waste is generated because of the solvents used in the processes. If we wanted to go into the details of two elements mined at Bayan Obo, to isolate one kilogram of cerium requires purifying 16 tons of rock. For the same amount of lutetium, the tons become 200^{xxii}, which is roughly how much 33 adult African elephants weigh; think of their corpses thrown into some landfill just to isolate a kilo of one of the most valuable rare earths. And keep in mind that in Bayan Obo the production of these matrices is measured not in kilograms but in tens of millions of tons.

Let's stop for a moment and step outside the numbers, especially since these are estimates, and when we talk about mega-plants and related controls, it is easy to imagine how these figures are likely to be underestimated. For people like me who live in Europe, air pollution of this kind has nothing comparable. Think acid rain, lost farmland, lifeless waterways, premature deaths and miscarriages induced by the effects of generalized pollution. Think of the collective name given by environmentalists and many natives to the villages near Bayan Obo: *cancer villages*. In these places, between 1990 and 1997 alone, cancer mortality rates, already well above average, skyrocketed to 46 percent. If we think specifically of lung cancer and broaden the analysis to the last 30 years, the increase flies into triple digits: +465 percent. In practice, one in four people in urban areas and one in five in rural areas in this part of the country died from this disease until the first decade of the 2000s (the period until which accurate data on the subject are available). And it should be pointed out that only at the beginning of this millennium, that is, in this last quarter century, China manifestly became the absolute leader in the export of rare earths. As a result, the extraction of rare earths from Mongolian plants has become increasingly significant since the year 2000, and between 1997 and 2006, the highly contaminated area of the Bayan Obo plants expanded threefold. But this devastating impact does not only affect Baotou's adjacencies: although with different and smaller proportions, there are 459 cancer villages in 29 of China's 31 provinces^{xxiii}. Although the rare earth industry is perhaps the main driver of pollution, there are other reasons behind the spread of these diseases, most often related to coal mining as well as other future matrices. These devastating effects are not unique to China. The Asian giant is not the only nation sacrificing lives and ecosystems on the altar of economic growth driven by the matrix technology boom. While proportionate, one does not have to go that far to understand how industrial matrix production requires, when unchecked by convenience or inertia, real human sacrifices.

Life for matter

My last name, thus the origin of my paternal family, is related to an Italian city: Taranto. All the Schinaias came from there.

Although the original name was “Schinaja,” as the inscription engraved in a matte brass plaque on the door of the apartment on Corso Umberto where some of my relatives lived read. The culture triggered in the twenty-year fascist period forced the Italianization of the term, probably of Scandinavian or Slavic origin, creating for me and my relatives more than a few anagraphic annoyances. In any case, back to Taranto. It may be because my grandfather Angelo, who always lived in that city, loved to paint it and illustrated it in vivid watercolors that to me, sadly unfit for drawing, seemed like divine works. Perhaps it is because this Apulian center has traits of noble decadence that remind me so much of Lisbon, another city to which I am attached, or because of the warmth of my relatives. In short, be that as it may, but I have always found Taranto wonderful. It is a real city, sometimes dirty and nasty but nevertheless alive and ancient, not one of these postmodern agglomerations grown out of post-capitalism that you find in so many corners of the world. A postcard that dates back to Magna Graecia, founded thirteen centuries ago by the Spartans. A city of two seas and three bridges, one of the cradles of Mediterranean culture, with a coastline as beautiful as the famous Salento stretches and a cuisine to die for. Yet, for those who are not from there but have heard of it before, Taranto is not famous for these historical, scenic and cultural qualities. It is for the disaster of the management of ILVA, what used to be the largest steel plant in Europe and is now a black hole for the national budget. And for the effects of this mismanagement on the resident population. So of Taranto there remain brutal images such as the “pink” cemetery where my grandfather Angelo rests, colored by fine dust from the blast furnaces of the industrial plant blown by the wind. Dust that should never swirl in the atmosphere because of its toxicity.

Taranto was also known until a few years ago for cancer figures above the national average, with a 30 percent higher rate when it came to children^{xxiv}. The city represents the long-standing conflict between work and health, with the sacrifice of the latter in plain sight: one does not have to go to China to look inside as humanity and understand that at different scales we have the same limitations, the same greed, the same disregard for others. In Taranto, steel is produced in the foundries: as anticipated, it may soon become a strategic raw material for the European Union. Steel, another among the materials that can be considered as one of the matrices of the future.

Clearly, health problems in Europe have the merit of being in the great spotlight, although, as in the Taranto case, still being resolved. What we don’t see why – honestly – we care less about is the health impacts derived from mining and processing other future matrices in places in the world that our Western subconscious considers less developed. We would need to better define what is meant by *development* and then why these nations do not have similar wealth to ours although they are indeed rich in raw materials. But it is an old story about exploitation. In short, you

would already know where I could go with it if I went on and on analyzing it. Instead, let's go back to the data and start with the world's largest producer of cobalt, which we have seen is the Democratic Republic of Congo.

"In 2017 I gave birth to a child with a malformation: he had only three fingers. At the hospital, when I was asked where I lived, the doctor told me that the deformity was related to pollution from the mines. Our government tells us that women should not live near mines, but they built a mine right in front of our house! All of my other children are healthy, but there are other women who have given birth to children with birth defects and all have died except mine," explained Lorraine, who a few years ago lived near the COMMUS mine: a mining site that was closed due to fears of copper and cobalt contamination, to researchers. The damage to human health from Congolese mining could fill a separate book. Explosion of genital infections and skin diseases among women and young people attributed to the use of contaminated water; high incidence of typhoid fever and gastroenteritis; eye irritation, vomiting, nausea, heart problems and thyroid damage due to inhalation or ingestion of mining particles; asthma, pneumonia and other respiratory illnesses related to contact with high concentrations of cobalt; allergic dermatitis and generalized increase in cancer risk^{xxv}. The first victims of the mining externality in the Democratic Republic of Congo are children, both because of the very low average age of the population (18.6 years compared to over 44 in the European Union) and because they are often the workers most involved in mining.

In Kazakhstan, on the other hand, chromium mining has rendered the water of the Syr Darya, the longest river in Central Asia, unfit for agricultural use and consumption^{xxvi}. On the other side of the world, in Brazil, mining of critical materials pollutes water and soil while exposure to uncontrolled manganese mining is linked to Parkinson's-like neurological disorders^{xxvii}. Mining copper and gold in Peru, through the use of chemicals such as cyanide and mercury, creates kidney and neurological damage to the resident population^{xxviii}. And while we are in South America, white gold mining in the geographical area known as the Lithium Triangle leads to gastrointestinal problems, kidney disease and neurological disorders for the resident population^{xxix}. According to a joint study by Green Cross Switzerland and the Blacksmith Institute, more than 35 million people worldwide are at risk of death or serious illness from direct exposure to mining-related toxic substances^{xxx}. And we are only dealing with direct harm to human health. If we think about socio-environmental ones, the effects are many and difficult to measure in quantitative impacts. For example, the misuse of natural resources, which among other things causes droughts given the great need for water that mining has. Or the ousting of indigenous populations who can no longer live in their ancestral territories.

Beyond the extractive impact, there are then other problematic issues to consider regarding the matrices of the future. Starting with

the fact that the world needs them more and more, and their production is increasingly concentrated in the hands of a few countries (not to say a very few). It is precisely on these issues that sparks are igniting global conflicts and the repositioning of the world's new masters.