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PANDORA'S HOPE

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Reality of Science Studies



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OF SCIENCE STUDIES

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Circulating Reference

Sampling the Soil in the Amazon Forest

The only way to understand the reality of science studies is to follow what science studies does best, that is, paying close attention to the details of scientific practice. Once we have described this practice from up close as other anthropologists do when they go off to live among foreign tribes, we will be able to raise again the classic question that the philosophy of science attempted to solve without the help of an empirical grounding: how do we pack the world into words? To begin with I have chosen a discipline, soil science, and a situation, a field trip in the Amazon, that will not require too much previous knowledge. As we examine in detail the practices that produce information about a state of affairs, it should become clear how very unrealistic most of the philosophical discussions about realism have been.

The old settlement started from a gap between words and the world, and then tried to construct a tiny footbridge over this chasm through a risky correspondence between what were understood as totally different ontological domains—language and nature. I want to show that there is neither correspondence, nor gaps, nor even two distinct ontological domains, but an entirely different phenomenon: circulating reference*. To capture it, we need to slow our pace a bit and set aside all our time-saving abstractions. With the help of my camera, I will attempt to bring some sort of order to the jungle of scientific practice. Let us turn now to the first freeze-frame of this photo-philosophical montage. If a picture is worth a thousand words, a map, as we shall see, can be worth a whole forest.

On the left in Figure 2.1 is a large savanna. On the right abruptly be-



Figure 2.1

gins the outskirts of a dense forest. One side is dry and empty, the other wet and teeming with life, and though it may look as if local inhabitants have created this edge, no one has ever cultivated these lands and no line has traced the border, which extends for hundreds of kilometers. Although the savanna serves as a pasture for some landowners' cattle, its limit is the natural edge of the forest, not a man-made boundary.

Little figures lost in the landscape, pushed off to the side as in a painting by Poussin, point at interesting phenomena with their fingers and pens. The first character, pointing at some trees and plants, is Edileusa Setta-Silva. She is Brazilian. She lives in this region, teaching botany at the small university in the little town of Boa Vista, the capital of the Amazonian province of Roraima. Just to her right another person looks on attentively, smiling at what Edileusa is showing him. Armand Chauvel is from France. He has been sent on this trip by ORSTOM, the research institute of the French former colonial empire, the "agency for the development of cooperative scientific research."

Armand is not a botanist but a pedologist (pedology is one of the

soil sciences, not to be confused with either geology, the science of subsoil, or podiatry, the medical art of treating feet); he resides about a thousand kilometers away in Manaus, where ORSTOM finances his laboratory in a Brazilian research center known as INPA.

The third person, taking notes in a small notebook, is Héloïsa Filizola. She is a geographer, or rather, as she insists, a geomorphologist, studying the natural and social history of the shape of the land. She is Brazilian like Edileusa, but from the south, from São Paulo, which is thousands of kilometers away, almost another country. She is also a professor at a university, though one far larger than the one in Boa Vista.

As for me, I'm the one taking this picture and describing this scene. My job as a French anthropologist is to follow these three at work. Familiar with laboratories, I decided for a change to observe a field expedition. I also decided, being something of a philosopher, to use my report on the expedition as a chance to study empirically the epistemological question of scientific reference. Through this photo-philosophical account I will bring before your eyes, dear reader, a small part of the forest of Boa Vista; I will show you some traits of my scientists' intelligence; and I will strive to make you aware of the labor required for this transport and that reference.

What are they talking about on this early morning in October 1991, after driving the jeep over terrible roads to reach this field site, which for many years now Edileusa has been carefully dividing into sections, where she has been noting the growth patterns of the trees and the sociology and demography of the plants? They are talking about the soil and the forest. Yet because they belong to two very different disciplines, they speak of them in different ways.

Edileusa is pointing to a species of fire-resistant trees that usually grow only in the savanna and that are surrounded by many small seedlings. Yet she has also found trees of this same species along the edge of the forest, where they are more vigorous but do not shade any smaller plants. To her surprise she has even managed to find a few of these trees ten meters into the forest, where they tend to die from insufficient light. Might the forest be advancing? Edileusa hesitates. For her, the large tree that you see in the background of this picture may be a scout sent by the forest as an advance guard, or perhaps a rear guard, sacrificed by the retreating forest to the merciless en-

croachment of the savanna. Is the forest advancing like Birnam Wood toward Dunsinane, or is it retreating?

This is the question that interests Armand; this is why he has come from so far away. Edileusa believes the forest is advancing, but she cannot be certain because the botanical evidence is confused: the same tree may be playing either of two contradictory roles, scout or rear guard. For Armand, the pedologist, at first glance it is the savanna that must be eating up the forest little by little, degrading the clay soil necessary for healthy trees into a sandy soil in which only grass and small shrubs can survive. If all her knowledge as a botanist makes Edileusa side with the forest, all his knowledge of pedology makes Armand lean toward the savanna. Soil goes from clay to sand, not from sand to clay—everyone knows that. Soil cannot avoid degradation; if the laws of pedology do not make this clear, then the laws of thermodynamics should.

Thus our friends are faced with an interesting cognitive and disciplinary conflict. A field expedition to resolve it was easy to justify. The entire world is interested in the Amazon forest. The news that the Boa Vista forest, on the outskirts of dense tropical zones, is advancing or retreating should indeed be of interest to businessmen. It was equally easy to justify mixing the know-how of botany with that of pedology in a single expedition, even though such a combination is unusual. The chain of translation* that allows them to obtain funding is not very long. I will not deal at length with the politics surrounding this expedition, since in this chapter I wish to concentrate on scientific reference as a philosopher, not on its “context” as a sociologist. (I apologize in advance to the reader, because I am going to omit many aspects of this field trip that pertain to the colonial situation. What I want to do here is to mimic as much as possible the problems and vocabulary of the philosophers in order to rework the question of reference. Later I will rework the notion of context, and in Chapter 3 I will correct the distinction between content and context.)

In the morning before leaving we meet on the terrace of the little hotel restaurant called Eusebio (Figure 2.2). We are in the center of Boa Vista, a rather rough frontier town where the *garimperos* sell the gold that they have extracted by shovel, by mercury, by gun, from the forest and from the Yanomami.

For this expedition, Armand (on the right) has asked for the help



Figure 2.2

of his colleague René Boulet (the man with the pipe). French like Armand, René is also a pedologist from ORSTOM but based in São Paulo. Here are two men and two women. Two Frenchmen and two Brazilians. Two pedologists, one geographer, and a botanist. Three visitors and one "native." All four are leaning over two kinds of maps and pointing at the precise location of the site marked out by Edileusa. Also on the table is an orange box, the indispensable topofil, which I will discuss later.

The first map, printed on paper, corresponds to the section of the atlas, compiled by Radambrasil on a scale of one to one million, that covers all of Amazonia. I will soon learn to put quotation marks around the word "covers," since, according to my informants, the beautiful yellow, orange, and green colors on the map do not always correspond to the pedological data. This is the reason they wish to zoom in, using black-and-white aerial photographs on a scale of one to fifty thousand. A single inscription* would not inspire trust, but the superposition of the two allows at least a quick indication of the exact location of the site.

This is a situation so trivial that we tend to forget its novelty: here

are four scientists whose gaze is able to dominate two maps of the very landscape that surrounds them. (Both of Armand's hands and Edileusa's right hand must continually smooth out the corners of the map, otherwise the comparison would be lost and the feature they are trying to find would not appear.) Remove both maps, confuse cartographic conventions, erase the tens of thousands of hours invested in Radambrasil's atlas, interfere with the radar of planes, and our four scientists would be lost in the landscape and obliged once more to begin all the work of exploration, reference marking, triangulation, and squaring performed by their hundreds of predecessors. Yes, scientists master the world, but only if the world comes to them in the form of two-dimensional, superposable, combinable inscriptions*. It has always been the same story, ever since Thales stood at the foot of the Pyramids.

Note, dear reader, that the owner of the restaurant seems to have the same problem as our researchers and Thales. If the owner had not written the number 29 in big black letters on the table on the terrace, he would be unable to navigate his own restaurant; without such markings he would not be able to keep track of the orders or distribute the bills. He looks like a mafioso as he lowers his enormous belly into a chair when he arrives in the morning, but he, even he, needs inscriptions to oversee the economy of his small world. Erase the numbers inscribed on the table, and he would be as lost in his restaurant as our scientists would be in the forest without maps.

In the previous picture our friends were immersed in a world in which distinct features could be discerned only if pointed out with a finger. Our friends fumbled. They hesitated. But in this picture they are sure of themselves. Why? Because they can point with their fingers to phenomena taken in by the eye and susceptible to the know-how of their age-old disciplines: trigonometry, cartography, geography. In accounting for knowledge thus acquired, we should not forget to mention the rocket ship Ariane, orbiting satellites, data banks, draftspeople, engravers, printers, and all those whose work here manifests itself as paper. There remains that gesture of the finger, the "index" par excellence. "Here, there, I, Edileusa, I leave words behind and I designate, on the map, on the restaurant table, the location of the site where we will go later, when Sandoval the technician comes to get us in the jeep."

How does one pass from the first image to the second—from ignorance to certainty, from weakness to strength, from inferiority in the face of the world to the domination of the world by the human eye? These are the questions that interest me, and for which I have traveled so far. Not to resolve, as my friends intend, the dynamic of the forest-savanna transition, but to describe the tiny gesture of a finger pointed toward the *referent of discourse*. Do the sciences speak of the world? This is what they claim, and yet Edileusa's finger designates a single coded point on a photograph that bears a mere resemblance, in certain traits, to figures printed on the map. At the restaurant table we are quite distant from the forest, yet she talks about it with assurance, as if she had it under her hand. The sciences do not speak of the world but, rather, construct representations that seem always to push it away, but also to bring it closer. My friends want to discover whether the forest advances or recedes, and I want to know how the sciences can be at the same time realist and constructivist, immediate and intermediary, reliable and fragile, near and far. Does the discourse of science have a referent? When I speak of Boa Vista, to what does the spoken word refer? Do science and fiction differ? And one additional query: how does my way of talking about this photomontage differ from the manner in which my informants speak of their soil?

Laboratories are excellent sites in which to understand the production of certainty, and that is why I enjoy studying them so much, but like these maps, they have the major disadvantage of relying on the indefinite sedimentation of other disciplines, instruments, languages, and practices. One no longer sees science stammer, making its debut, creating itself from nothing in direct confrontation with the world. In the laboratory there is always a preconstructed universe that is miraculously similar to that of the sciences. In consequence, since the known world and the knowing world are always performing in concert with each other, reference always resembles a tautology (Hacking 1992). But not in Boa Vista, or so it seems. Here science does not blend well with the *garimpos* and the white waters of the Rio Branco. What luck! In accompanying this expedition I will be able to follow the trail of a relatively poor and weak discipline that will, before my eyes, take its first steps, just as I would have been able to observe the teeterings and totterings of geography had I, in past centuries, run through Brazil after Jussieu or Humboldt.

Here in the great forest (Figure 2.3), a horizontal branch is fore-



Figure 2.3

grounded against an otherwise uniformly green background. On this branch, attached to a rusty nail, is a little tin tag on which is written the number 234.

In the thousands of years in which humans have traveled through this forest, slashing and burning in order to cultivate it, no one had ever before had the peculiar idea of attaching numbers to it. It took a scientist, or perhaps a forester designating trees to be felled. In either case, this numbering of trees is, we must assume, the work of a meticulous bookkeeper (Miller 1994).

After an hour in the jeep, we have arrived at the plot of land that Edileusa has been charting for many years. Like the owner of the restaurant in the previous picture, she would not be able to remember

the differences between patches of the forest for very long without marking them in some way. She has therefore placed tags at regular intervals so as to cover the few hectares of her field site in a grid of Cartesian coordinates. These numbers will allow her to register the variations of growth and the emergence of species in her notebook. Each plant possesses what is called a reference, both in geometry (through the attribution of coordinates) and in the management of stock (through the affixing of specific numbers).

Despite the pioneering quality of this expedition, it turns out, I am not assisting at the birth of a science *ex nihilo*. My pedological colleagues cannot fruitfully begin their work unless the site has already been marked out by *another* science, botany. I thought I was deep in the forest, but the implication of this sign, "234," is that we are *in a laboratory*, albeit a minimalist one, traced by the grid of coordinates. The forest, divided into squares, has already lent itself to the collection of information on paper that likewise takes a quadrilateral form. I rediscover the tautology that I believed I was escaping by coming into the field. One science always hides another. If I were to tear down these tree tags, or if I were to mix them up, Edileusa would panic like those giant ants whose paths I disturb by slowly passing my finger across their chemical freeways.

Edileusa cuts off her specimens (Figure 2.4). We always forget that the word "reference" comes from the Latin *referre*, "to bring back." Is the referent what I point to with my finger outside of discourse, or is it what I bring back inside discourse? The whole object of this montage is to answer that question. If I appear to be taking a roundabout route to the response, it is because there is no fast-forward button for un-reeling the practice of science if I want to follow the many steps between our arrival at the site and the eventual publication.

In this frame Edileusa extracts, from the broad diversity of plants, specimens that correspond to those recognized taxonomically as *Guatteria schomburgkiana*, *Curatella americana*, and *Connarus favosus*. She says she recognizes them as well as she does the members of her own family. Each plant that she removes represents thousands of the same species present in the forest, in the savanna, and on the border of the two. It is not a bouquet of flowers she is assembling but evidence that she wants to keep as a reference (using here another sense of the word). She must be able to retrieve what she writes in her notebooks



Figure 2.4

and refer to it in the future. In order to be able to say that *Afulamata diasporis*, a common forest plant, is found in the savanna but only in the shadow of a few forest plants that manage to survive there, she must preserve, not the whole population, but a sample that will serve as a silent witness for this claim.

In the bouquet she has just picked we can recognize two features of reference: on the one hand an economy, an induction, a shortcut, a funnel in which she picks one blade of grass as the sole representative of thousands of blades of grass; and on the other hand the preservation of a specimen that will later act as guarantor when she is in doubt herself or when, for various reasons, colleagues may doubt her claims.

Like the footnotes used in scholarly works to which the inquisitive or the skeptical "make reference" (yet another use of the word), this armful of specimens will guarantee the text that results from her field expedition. The forest cannot directly give its credit to Edileusa's text, but she can be credited indirectly through the extraction of a representative guarantor, neatly preserved and tagged, that can be transported, along with her notes, to her collection at the university in Boa Vista. We will be able to go from her written report to the names of the plants, from these names to the dried and classified specimens. And if there is ever a dispute, we will, with the help of her notebook, be able to go back from these specimens to the marked-out site from which she started.

A text speaks of plants. A text has plants for footnotes. A leaflet rests on a bed of leaves.

What will happen to these plants? They will be transported further, placed in a collection, a library, a museum. Let us see what will happen to them in one of these institutions, because this step is much better known and has been more often described (Law and Fyfe 1988; Lynch and Woolgar 1990; Star and Griesemer 1989; Jones and Galison 1998). Then we will focus again on the intermediary steps. In Figure 2.5 we are in a botanical institute, quite far from the forest, in Manaus. A cabinet with three ranks of shelves constitutes a work space crisscrossed in columns and rows, x- and y-axes. Each compartment shown in this photograph is used as much for classification as for tagging and preservation. This piece of furniture is a theory, only slightly heavier than the tag in Figure 2.3 but much more capable of organizing this office, a



Figure 2.5

perfect intermediary between hardware (since it shelters) and software (since it classifies), between a box and the tree of knowledge.

The tags designate the names of the collected plants. The dossiers, files, and folders shelter not text—forms or mail—but plants, the very plants that the botanist removed from the forest, that she dried in an oven at 40 degrees Celsius to kill the fungi, and that she has since pressed between newspapers.

Are we far from or near to the forest? Near, since one finds it here in the collection. The *entire* forest? No. Neither ants, nor trapdoor spiders, nor trees, nor soil, nor worms, nor the howler monkeys whose cry can be heard for miles are in attendance. Only those few specimens and representatives that are of interest to the botanist have made it into the collection. So are we, therefore, far from the forest? Let us say we are in between, possessing all of it through these delegates, as if Congress held the entire United States; a very economical metonymy in science as in politics, by which a tiny part allows the grasping of the immense whole.

And what would be the point of transporting the whole forest here? One would get lost in it. It would be hot. The botanist would in any case be unable to see beyond her small plot. Here, however, the air conditioner is humming. Here, even the walls become part of the multiple crisscrossed lines of the chart where the plants find a place that belongs to them within the taxonomy that has been standardized for many centuries. Space becomes a table chart, the table chart becomes a cabinet, the cabinet becomes a concept, and the concept becomes an institution.

Therefore we are neither very far from nor very close to the field site. We are at a good distance, and we have transported a small number of pertinent features. During the transportation something has been preserved. If I can manage to grasp this *invariant*, this *je ne sais quoi*, I believe, I will have understood scientific reference.

In this little room where the botanist shelters her collection (Figure 2.6) is a table, similar to that in the restaurant, on which the specimens brought back from distinct locations at different times are now displayed. Philosophy, the art of wonderment, should consider this table carefully, since it is where we see why the botanist gains so much more from her collection than she loses by distancing herself from the



Figure 2.6

forest. Let us first review what we know of that superiority before again attempting to follow the intermediary steps.

The first advantage: comfort. In leafing through the pages of newsprint, the researcher makes the dried stems and flowers visible so she can examine them at leisure, writing just beside them as if the stems and flowers could imprint themselves directly onto the paper or at least become compatible with the paper world. The supposedly vast distance between writing and things is now only a few centimeters.

A second advantage, just as important, is that once classified, specimens from different locations and times become contemporaries of one another on the flat table, all visible under the same unifying gaze. This plant, classified three years ago, and this other, obtained more than a thousand kilometers away, conspire on the table to form a synoptic tableau.

A third advantage, again equally decisive, is that the researcher can shift the position of specimens and substitute one for another as if shuffling cards. Plants are not exactly signs, yet they have become as mobile and recombinable as the lead monotype characters of a printing press.

Hardly surprising, then, that in the calm and cool office the botanist who patiently arranges the leaves is able to discern emerging patterns that no predecessor could see. The contrary would be much more surprising. Innovations in knowledge naturally emerge from the collection deployed on the table (Eisenstein 1979). In the forest, in the same world but with all of its trees, plants, roots, soil, and worms, the botanist could not calmly arrange the pieces of her jigsaw puzzle on her card table. Scattered through time and space, these leaves would never have met without her redistributing their traits into new combinations.

At the card table, with so many trumps in hand, every scientist becomes a structuralist. No need to look any further for the martingale that wins every time against those who sweat in the forest, those crushed beneath the complex phenomena that are maddeningly present, indiscernible, impossible to identify, reshuffle, and control. In losing the forest, we win knowledge of it. In a beautiful contradiction, the English word "oversight" exactly captures the two meanings of this domination by sight, since it means at once looking at something from above and ignoring it.

In the naturalist's collection things happen to plants that have never occurred since the dawn of the world (see Chapter 5). The plants find themselves detached, separated, preserved, classified, and tagged. They are then reassembled, reunited, redistributed according to entirely new principles that depend on the researcher, on the discipline of botany, which has been standardized for centuries, and on the institution that shelters them, but they no longer grow as they did in the great forest. The botanist learns new things, and she is transformed accordingly, but the plants are transformed also. From this point of view there is no difference between observation and experience: both are constructions. Through its displacement onto this table, the interface between forest and savanna becomes a hybrid mixture of scientist, botany, and forest, the proportions of which I will have to calculate later.

Still, the naturalist does not always succeed. In the upper-right-hand corner of the photograph something scary is brewing: an enormous pile of newspaper stuffed with plants brought back from the site and awaiting classification. The botanist has fallen behind. It is the same story in every laboratory. As soon as we go into the field or turn on an instrument, we find ourselves drowning in a sea of data. (I too have this problem, being incapable of saying all that can be said about a field trip that took only fifteen days.) Darwin moved out of his house soon after his voyage, pursued by treasure chests of data that ceaselessly arrived from the *Beagle*. Within the botanist's collection, the forest, reduced to its simplest expression, can quickly become as thick as the tangle of branches from which we started. The world can return to confusion at any point along this displacement: in the pile of leaves to be indexed, in the botanist's notes which threaten to submerge her, in the reprints sent from colleagues, in the library where the issues of journals are piling up. We have barely arrived when we must leave; the first instrument is hardly operational when we must think of a second device to absorb what its predecessor has already inscribed. The pace must be accelerated if we are to avoid being overwhelmed by worlds of trees, plants, leaves, paper, texts. Knowledge derives from such *movements*, not from simple contemplation of the forest.

We now know the advantages of being in an air-conditioned museum, but we have gone too quickly over the transformations that Edileusa made the forest undergo. I have opposed too abruptly the im-

age of the botanist pointing to the trees and that of the naturalist in control of specimens on the worktable. In passing directly from the field to the collection, I must have missed the decisive go-between. If I say that "the cat is on the mat," I may seem to be designating a cat whose actual presence on said mat would validate my statement. In actual practice, however, one never travels directly from objects to words, from the referent to the sign, but always through a risky intermediary pathway. What is no longer visible with cats and mats, because they are too familiar, becomes visible again as soon as I take a more unusual and complicated statement. If I say "the forest of Boa Vista advances on the savanna" how can I point to that whose presence would accord a truth-value to my sentence? How can one engage those sorts of objects into discourse; to use an old word, how can one "educate" them into discourse? One needs to go back to the field and carefully follow, not only what happens inside collections, but how our friends are collecting data in the forest itself.

In the photograph in Figure 2.7, everything is a blur. We have left the laboratory and are now in the midst of the virgin forest. The researchers can only be distinguished as khaki and blue spots on a green background, and at any moment they could disappear into the Green Hell of the forest if they move away from one another.

René, Armand, and Héloïsa are having a discussion around a hole in the ground. Holes and pits are to pedology what a specimen collection is to botany: the basic craft and the focus of obsessive attention. Since the structure of soil is always hidden beneath our feet, pedologists can display its profile only by digging holes. A profile is the assemblage of the successive layers of soil, designated by the beautiful word "horizon." Rainwater, plants, roots, worms, moles, and billions of bacteria transform the parent material of the bedrock (studied by geologists) into many different "horizons," which the pedologists learn to distinguish, classify, and envelop in a history that they call "pedogenesis" (Ruellan and Dosso 1993).

In accordance with the habits of their profession, the pedologists wanted to know whether the bedrock was, at a certain depth, different beneath the forest than beneath the savanna. Here was a simple hypothesis that would have put an end to the controversy between botany and pedology: neither the forest nor the savanna is receding, the border that separates them reflects a difference in soil. The superstruc-



Figure 2.7

ture would be explained by the infrastructure, to use an old Marxist metaphor. Yet, as they soon discover, at depths below fifty centimeters the soil under the savanna and the soil under the forest appear exactly the same. The hypothesis from infrastructure does not hold. Nothing in the bedrock seems to explain the difference in the superficial horizons—clayey beneath the forest and sandy beneath the savanna. The profile is “bizarre,” and that makes my friends all the more excited.

In the picture in Figure 2.8, René is standing and aiming at me with an instrument combining compass and clisimeter in order to establish a first topographic bearing. While taking advantage of the situation to snap a picture, I play the minor role, well suited to my height, of an alignment pole so that René can mark precisely where the pedologists should dig their holes. Lost in the forest, the researchers rely on one of the oldest and most primitive techniques for organizing space, claiming a place with stakes driven into the ground to delineate geometric shapes against the background noise, or at least to permit the possibility of their recognition.

Submerged in the forest again, they are forced to count on the oldest



Figure 2.8

of the sciences, the measure of angles, a geometry whose mythical origin has been recounted by Michel Serres (Serres 1993). Once more a science, pedology, must follow the tracks of an older discipline, surveying, without which we would dig our holes haphazardly, trusting to luck, incapable of creating on graph paper the precise map that René would like to draw. The succession of triangles will be used as a reference and will be added to the numbering of square sections of the field site already done by Edileusa (see Figure 2.3). In order for the botanical and pedological data to be superposed on the same diagram later, these two bodies of reference must be compatible. One should never speak of “data”—what is given—but rather of *sublata*, that is, of “achievements.”

René's standard practice is to reconstitute the surface soil along transects, the extreme limits of which contain soils that are as different as possible. Here, for example, it is very sandy beneath the savanna and very clayey beneath the forest. He proceeds by approximate gradations, first choosing two extreme soils, then taking a sample in the middle. Starting again, he continues in this way until he obtains homogeneous horizons. His method recalls both artillery (it approxi-

mates by finding medians), and anatomy (it traces the geometry of horizons, true “organs” of the soil). If I were playing the historian, not the philosopher in pursuit of reference, I would discuss at length the fascinating paradigm of what René calls “structural pedology,” how it distinguishes itself from others and the controversies that arise from it.

To get from one point to another the pedologists cannot use a surveyor’s chain of measurement; no agriculturist has ever leveled this soil. Instead they use a wonderful instrument, the Topofil Chaix™ (Figure 2.9), a device that their Brazilian colleagues have perversely named a “pedofil,” and of which Sandoval, in this photograph, reveals the mechanism by opening its orange box. So much depends upon an orange pedofil . . .

A spool of cotton thread unrolls evenly and spins a pulley that activates the cogwheel of a counter. Setting the counter to zero, then unwinding the thread of Ariadne behind him, the pedologist can get from one point to the next. Upon arrival at his destination, he simply cuts the thread with a blade set near the spool and ties off the end to prevent any untimely unrolling. A glance at the window on the counter tells the distance he has traveled to within a meter. His path becomes a single number easily transcribed into a notebook and—a double advantage—takes on material form in the thread that remains in place. Losing an expensive and distracted pedologist in the Green Hell is impossible: the cotton thread will always bring him back to camp. If Hansel and Gretel had had access to a “Topofil Chaix à fil perdu n° de référence I-8237,” their tale would have unwound very differently.

After a few days’ work the field site is littered with threads that entangle our feet. Still, as a result of the compass’s measurements of angles and the pedofil’s measurements of lines, the land has become a proto-laboratory—a Euclidean world where all phenomena can be registered by a collection of coordinates. Had Kant used this instrument, he would have recognized in it the practical form of his philosophy. For the world to become knowable, it must become a laboratory. If virgin forest is to be transformed into a laboratory, the forest must be prepared to be rendered as a diagram (Hirshauer 1991). In the extraction of a diagram from a confusion of plants, scattered locations become marked and measured points linked by cotton threads that materialize (or spiritualize) lines in a network composed of a succession



Figure 2.9

of triangles. Equipped only with the *a priori* forms of intuition, to use Kant's expression again, it would be impossible to draw these sites together, short of teaching, somehow, a limbless mind-in-a-vat how to use such equipment as compasses, clisimeters, and topofils.

Sandoval the technician, the only person on the expedition who is native to the region, has dug the largest part of the hole shown in Figure 2.10. (Of course had I not artificially severed the philosophy from the sociology, I would have to account for this division of labor between French and Brazilians, mestizos and Indians, and I would have to explain the male and female distributions of roles.) Armand, here leaning on the drill, is removing core samples by collecting earth in the small chamber at its tip. Unlike Sandoval's tool, the mattock that is lying on the ground now that its task is complete, the drill is a piece of laboratory equipment. Two rubber stoppers placed at 90 centimeters and at one meter allow it to be used both as an instrument for measuring depth and, by pushing and twisting, as a sampling tool. The pedologists examine the soil sample, then Héloïsa collects it in a plastic bag on which she writes the number of the hole and the depth at which it was taken.



Figure 2.10

As with Edileusa's specimens, most of the analyses cannot be performed in the field but must be done in the laboratory. The plastic bags here begin a long voyage that will take some of them to Paris, via Manaus and São Paulo. Even if René and Armand are able to judge on the spot the quality of the earth, its texture, its color, and the activity of earthworms, they cannot analyze the soil's chemical composition, its grain size, or the radioactivity of the carbon it contains without costly instruments and skill that one does not easily find among the poor *garimpos* or the wealthy landowners. On this expedition, the pedologists are the vanguard for the distant laboratories to which they will take their samples. The samples will remain attached to their original context solely by the fragile link of the numbers inscribed in black felt-tip pen on the little transparent bags. If, like me, you should ever run into a gang of pedologists, one word of advice: never offer to carry their suitcases, which are enormous and stuffed with the bags of earth they tote from one part of the world to another and with which they will quickly fill your refrigerator. The circulation of their samples traces a network on the Earth as dense as the cotton webs spun by their topofils.

What industrialists call the "traceability" of references depends, in this case, on the reliability of Héloïsa. Sitting in front of the hole, the group members rely on her for the careful maintenance of the field notebook. For each sample she must record the coordinates of the location, the number of the hole, the time and depths at which it was collected. In addition, she must note down all the qualitative data her two male colleagues can extract from the lumps of earth before they slide them into the bags.

The success of the entire expedition depends on this little logbook, equivalent to the protocol book that regulates the life of any laboratory. It is this book that will allow us to return to each data point in order to reconstitute its history. The list of questions that was decided on at the restaurant is imposed on each sequence of action by Héloïsa. It is a grid that we must systematically fill with information. Héloïsa acts as guarantor of the standardization of experimental protocols, so that we take the same kinds of samples from each location and in the same way. The protocols ensure the compatibility and therefore the comparability of the holes, and the notebook then allows for continuity in time as well as in space. Héloïsa does not only handle tags and

protocols. A geomorphologist, she adds her two cents to all the conversations, allowing her expatriate colleagues to “triangulate” their judgments through hers.

Listening to Héloïsa call us to order—having repeated the information dictated to us by René and twice verified the inscriptions on the bags—it seems to me that never before has the forest of Boa Vista known such discipline. The indigenous people who once traveled through this place probably imposed rites on themselves as well, perhaps as fastidious as those of Héloïsa, but surely not so strange. Sent by institutions that are thousands of kilometers away, obliged at all costs to maintain the traceability of the data we produce with minimal deformation (while transforming them totally by ridding them of their local context), we would have seemed extremely exotic to the indigenous people. Why take such care in sampling specimens whose features are visible only at such a distance that the context from which they were taken will have disappeared? Why not remain in the forest? Why not “go native”? And what about me, standing here, useless, arms dangling, incapable of distinguishing a profile from a horizon—am I not even more exotic, exacting from the hard labor of my informants the bare minimum for a philosophy of reference that will be of interest only to a very few colleagues in Paris, California, or Texas? Why not become a pedologist? Why not become an indigenous soil collector, an autochthonous botanist?

To understand these small anthropological mysteries we must draw closer to the beautiful object in Figure 2.11, the “pedocomparator.” On the savanna grass, we see a series of empty little cardboard cubes aligned to form a square. More Cartesian coordinates, more columns, more rows. These little cubes rest in a wooden frame that allows them to be stowed away in a drawer. With the cleverness of our pedologists, and with the addition of a handle, clasps, and a padded flap that serves as a flexible cover for all the cardboard cubes (not visible in the photograph), this drawer can also be transformed into a suitcase. The suitcase permits the simultaneous transportation of all the clods of earth that have since become Cartesian coordinates, and their collection in what thus becomes a pedolibrary.

Like the cabinet in Figure 2.5, the pedocomparator will help us grasp the *practical* difference between abstract and concrete, sign and furniture. With its handle, its wooden frame, its padding, and its card-

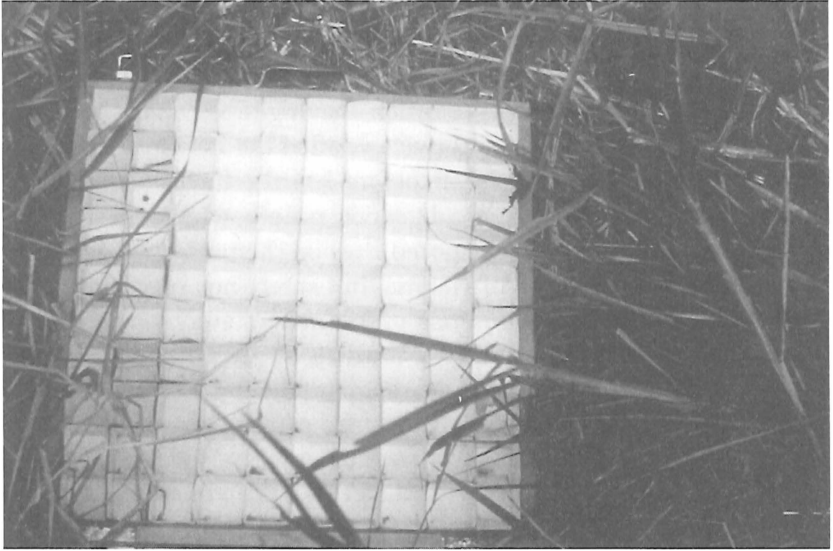


Figure 2.11

board, the pedocomparator belongs to “things.” But in the regularity of its cubes, their disposition in columns and rows, their discrete character, and the possibility of freely substituting one column for another, the pedocomparator belongs to “signs.” Or rather, it is through the cunning invention of this hybrid that the world of things may become a sign. With the next three photographs we will try to understand more concretely the practical task of abstraction and what it means to load a state of affairs into a statement.

I will be obliged to employ vague terms—we do not have as discriminating a vocabulary for speaking of the engagement of things into discourse as we do for speaking of discourse itself. Analytic philosophers keep themselves busy trying to discover how we can speak of the world in a language capable of truth (Moore 1993). Curiously, even though they attach importance to the structure, coherence, and validity of language, in all their demonstrations the world simply awaits designation by words whose truth or falsehood is guaranteed solely by its presence. The “real” cat waits quietly on its proverbial mat to confer a truth-value on the sentence “the cat is on the mat.” Yet to achieve certainty the world needs to stir and transform *itself* much more than

words (see Chapters 4 and 5). It is this, the other neglected half of analytic philosophy, that analysts must now acknowledge.

For the time being, the pedocomparator is empty. This instrument can be added to the list of empty forms that has been getting longer during the expedition: Edileusa's plot of land, divided into squares by numbers inscribed on tags that are nailed to trees; the marking of the holes with René's compass and topofil; the numbering of the samples and the disciplined sequence of the protocol controlled by Héloïsa. All these empty forms are set up *behind* the phenomena, *before* the phenomena manifest themselves, *in order* for them to be manifested. Obscured in the forest by their sheer number, phenomena will be able at last to appear, that is, to stand out against the new backgrounds we have astutely placed behind them. In my eyes and in those of my friends, pertinent traits will be bathed in a spotlight as white as the empty pedocomparator or the graph paper, very different in any case from the deep greens and grays of the vast and noisy forest, where some birds whistle so obscenely that the locals call them "flirting birds."

In Figure 2.12, René abstracts. After cutting the earth with a knife, he removes a clod, from a depth dictated by the protocol, and deposits it in one of the cardboard cubes. With a felt-tip pen Héloïsa will code the edge of the cube with a number that she will also record in her notebook.

Consider this lump of earth. Grasped by René's right hand, it retains all the materiality of soil—"ashes to ashes, dust to dust." Yet as it is placed inside the cardboard cube in René's left hand, the earth becomes a sign, takes on a geometrical form, becomes the carrier of a numbered code, and will soon be defined by a color. In the philosophy of science, which studies only the resulting abstraction, the left hand does not know what the right hand is doing! In science studies, we are ambidextrous: we focus the reader's attention on this hybrid, this moment of substitution, the very instant when the future sign is abstracted from the soil. We should never take our eyes off the material weight of this action. The earthly dimension of Platonism is revealed in this image. We are not jumping from soil to the Idea of soil, but from continuous and multiple clumps of earth to a discrete color in a geometric cube coded in x- and y-coordinates. And yet René does not *impose* predetermined categories on a shapeless horizon; he *loads* his



Figure 2.12

pedocomparator with the meaning of the piece of earth—he educes it, he articulates* it (see Chapter 4). Only the movement of substitution by which the real soil becomes the soil known to pedology counts. The immense abyss separating things and words can be found everywhere, distributed to many smaller gaps between the clods of earth and the cubes-cases-codes of the pedocomparator.

What a transformation, what a movement, what a deformation, what an invention, what a discovery! In jumping from the soil to the drawer, the piece of earth benefits from a means of transportation that no longer transforms it. In the previous photograph we could see how the soil changed states; in Figure 2.13 we see how it changes location. Having made the passage from a clump of earth to a sign, the soil is now able to travel through space without further alterations and to remain intact through time. At night, in the restaurant, René opens the cabinet-suitcases of the two pedocomparators and contemplates the series of cardboard cubes regrouped in rows corresponding to holes and columns corresponding to depths. The restaurant becomes the annex of a pedolibrary. All the transects have become compatible and comparable.

Once filled, the cubes gather clods of earth on the way to becoming signs, but we know that the empty compartments, either humble ones like these or famous ones like those of Mendeleev, are always the most important part of any classification scheme (Bensaude-Vincent 1986; Goody 1977). When we compare them, the compartments define what is left for us to find, and we are able to plan the next day's labor in advance since we know what we must gather. Thanks to the empty compartments, we see the blanks in our protocol. According to René, "It is the pedocomparator that *tells us* if we have finished a transect."

The first great advantage of the pedocomparator, as "profitable" as the botanist's classification in Figure 2.6, is that in it all the different samples from all the different depths become visible simultaneously, though they were extracted over the course of a week. Thanks to the pedocomparator, the differences in color become manifest and form a table or chart; all of the disparate samples are embraced synoptically. The forest-savanna transition has now been translated, through the arrangement of nuanced shades of brown and beige, into columns and rows—a transition now graspable because the instrument has given us a handle on the earth.



Figure 2.13

Look at René in the photograph: he is master of the phenomenon that a few days earlier was tucked away in the soil, invisible, and dispersed in an undifferentiated continuum. I have never followed a science, rich or poor, hard or soft, hot or cold, whose moment of truth was not found on a one- or two-meter-square flat surface that a researcher with pen in hand could carefully inspect (see Figures 2.2 and 2.6). The pedocomparator has made the forest-savanna transition into a laboratory phenomenon almost as two-dimensional as a diagram, as readily observed as a map, as easily reshuffled as a pack of cards, as simply transported as a suitcase, about which René jots down notes while peacefully smoking his pipe, having taken a shower to wash off the dust and earth that are no longer useful.

And I, of course, ill-equipped and thus short on rigor, I bring back to the reader, by superposing pictures and text, a phenomenon, that of the *circulating reference*^{*}, that was until now invisible, purposely muddled by epistemologists, dispersed in the practice of scientists, and sealed up in the knowledges that I now calmly display with a cup of tea in hand at my house in Paris, while reporting what I observed at the border of Boa Vista.

Another advantage of the pedocomparator, once it is saturated with data: a pattern emerges. And here again, as with Edileusa's discoveries, it would be astounding were this not the case. Invention almost always follows the new handle offered by a new translation or transportation. The most incomprehensible thing in the world would be for the pattern to remain incomprehensible after such rearrangements.

This expedition, it too, via the intermediary of the pedocomparator, discovers or constructs (we will choose between those two verbs in Chapter 4, before realizing in Chapter 9 why we do not have to choose) an extraordinary phenomenon. Between the sandy savanna and the clayey forest, it seems that a twenty-meter-wide strip of land spreads out at the border, on the savanna side. This strip of land is ambiguous, more clayey than the savanna but less so than the forest. It would appear that the forest casts its own soil before it to create conditions favorable to its expansion. Unless, on the contrary, the savanna is degrading the woodland humus as it prepares to invade the forest. The various scenarios that my friends discuss, at night in the restaurant, are now gauged by the weight of evidence. They become possible in-

terpretations of the matters of fact that are solidly in place in the grid of the pedocomparator.

One scenario will eventually become text, and the pedocomparator will become a table in an article. There now needs to be only one last, tiny transformation.

On the table, in the table/chart, in Figure 2.14, we see the forest on the left and the savanna on the right, the reverse of Figure 2.1, give or take a few transformations. (Since there are not enough compartments in the pedocomparator, the series of samples must be altered, breaking the beautiful order of the table and requiring us to devise an ad hoc reading convention.) Beside the open drawers there is a diagram drawn on millimeter-ruled graph paper and a table drawn on straight-ruled paper. The coordinates of the samples, taken by the team along a given transect, are recaptured in a vertical cross-section, while the chart sums up color variations as a function of depth at a given set of coordinates. A transparent ruler negligently placed on the drawer further ensures the transition from furniture to paper.

In Figure 2.12 René moved from concrete to abstract in one quick gesture. He was moving from thing to sign and from the three-dimensional earth to the two and a half dimensions of the table/chart. In Figure 2.13 he had slipped from the field site to the restaurant: the drawers convert into a suitcase, permitting René's movement from an uncomfortable and underequipped location to the relative comfort of a café, and in principle nothing (except Customs officers) can stop the transportation of this drawer/suitcase/chart anywhere in the world, or its comparison with all other profiles in all other pedolibraries.

In Figure 2.14 another transformation as important as the others becomes evident, but one that, under the name of inscription*, has received more attention than the others. We move now from the instrument to the diagram, from the hybrid earth/sign/drawer to paper.

People are often surprised that mathematics can be applied to the world. In this case, for once, the surprise is misplaced. For here we must ask how much the world needs to change in order for one kind of paper to be *superposed* on a geometry of another kind without suffering too much distortion. Mathematics has never crossed the great abyss between ideas and things, but it is able to cross the tiny gap between the already geometrical pedocomparator and the piece of millimeter-ruled paper on which René has recorded the data from the sam-



Figure 2.14

ples. It is easy to cross this gap—I can even measure the distance with a plastic ruler: ten centimeters!

As abstract as the pedocomparator is, it remains an object. It is lighter than the forest, yet heavier than the paper; it is less corruptible than the vibrant earth, but more corruptible than geometry; it is more mobile than the savanna, but less mobile than the diagram that I could send by phone if Boa Vista had a fax machine. As coded as the pedocomparator is, René cannot insert it into the text of his report. He can only hold it in reserve, keeping it for future comparisons if he ever begins to have doubts about his article. With the diagram, in contrast, the forest-savanna transition becomes paper, assimilable by every article in the world, and transportable to every text. The geometric form of the diagram renders it compatible with all the geometric transformations that have ever been recorded since *centers of calculation** have existed. What we lose in matter through successive reductions of the soil, we regain a hundredfold in the branching off to other forms that such reductions—written, calculated, and archival—make possible.

In the report that we are preparing to write, only one rupture will remain, a gap as tiny and as immense as all the steps we have just fol-

lowed: I mean the gap that divides our prose from the annex of diagrams it will refer to. We will write about the forest-savanna transition, which we will show within the text through the medium of a graph. The scientific text is different from all other forms of narrative. It speaks of a referent, *present* in the text, in a form other than prose: a chart, diagram, equation, map, or sketch. Mobilizing its own *internal referent**, the scientific text carries within itself its own verification.

In Figure 2.15 is the diagram that combines all the data obtained during the expedition. It appears as "figure 3" in the written report of which I am one of the proud authors and of which the title page reads:

Relations between Vegetation Dynamics and the Differentiation of Soils in the Forest-Savanna Transition Zone in the Region of Boa Vista, Roraima, Amazonia (Brazil)
Report on Expedition in Roraima Province, October 2-

14, 1991

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S. do N. Morais (4), A. Chauvel (5) and B. Latour (6)
(1) MIRR, Boa Vista RR, (2.3) USP, São Paulo, (3-5)
INPA,
Manaus, (6) CSI, ENSMP, (2.5) ORSTOM Brazil

Let us quickly retrace our steps back down the road we have traveled while following our friends. The prose of the final report speaks of a diagram, which summarizes the form displayed by the layout of the pedocomparator, which extracts, classifies, and codes the soil, which, in the end, is marked, ruled, and designated through the crisscrossing of coordinates. Notice that, at every stage, each element belongs to matter by its origin and to form by its destination; it is abstracted from a too-concrete domain before it becomes, at the next stage, too concrete again. We never detect the rupture between things and signs, and we never face the imposition of arbitrary and discrete signs on shapeless and continuous matter. We see only an unbroken series of well-nested elements, each of which plays the role of sign for the previous one and of thing for the succeeding one.

At every stage we find elementary *forms* of mathematics, which are used to collect *matter* through the mediation of a practice embodied

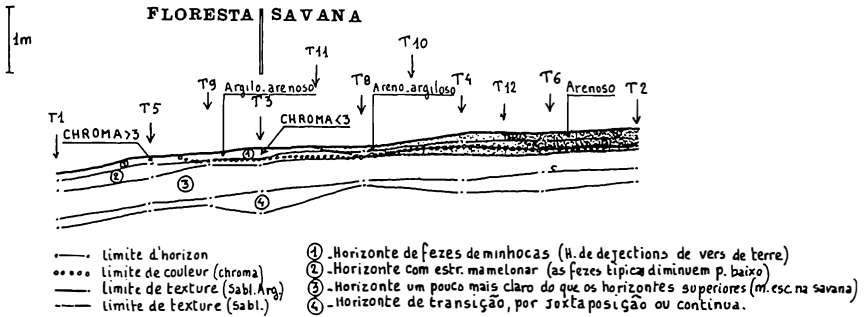


Figure 3. Coupe du transect 1

Figure 2.15

in a group of researchers. On each occasion a new phenomenon is educed from this hybrid of form, matter, skilled bodies, and groups. Let us remember René, in Figure 2.12, placing the brown earth into the white cardboard cube that was then immediately marked with a number. He did not divide the soil according to intellectual categories, as in the Kantian mythology; rather, he conveyed the meaning of each phenomenon by making matter cross the gap that separated it from form.

In fact, if we flip quickly through these photographs, we become aware that, even if my inquiry had been more meticulous, each stage would reveal a rift as complete as those which follow and precede it. Try as I might, like a new Zeno, to multiply the intermediaries, there is never a *resemblance* between stages so that we can merely superpose them. Compare the two extremes in Figures 2.1 and 2.15. The difference between them is no wider than that between the lumps of earth sampled by René (Figure 2.12) and the data-points that they become in the pedocomparator. Whether I choose the two extremes or multiply the intermediaries, I find this same discontinuity.

Yet there is also a continuity, since all the photographs say the same thing and represent the same forest-savanna transition, made ever more certain and precise at each stage. Our field report indeed refers to "figure 3," which indeed refers to the Boa Vista forest. Our report refers to the strange dynamics of vegetation that appear to allow the forest to defeat the savanna, as if the trees had turned sandy soil into

clay to prepare for growth in the twenty-meter-wide strip of land. But these acts of reference are all the more assured since they rely not so much on resemblance as on a regulated series of transformations, transmutations, and translations. A thing can remain more durable and be transported farther and more quickly if it continues to undergo transformations at each stage of this long cascade.

It seems that reference is not simply the act of pointing or a way of keeping, on the outside, some material guarantee for the truth of a statement; rather it is our way of keeping something *constant* through a series of transformations. Knowledge does not reflect a real external world that it resembles via mimesis, but rather a real interior world, the coherence and continuity of which it helps to ensure. What a beautiful move, apparently sacrificing resemblance at each stage only to settle again on the same meaning, which remains intact through sets of rapid transformations. The discovery of this strange and contradictory behavior is worthy of the discovery of a forest able to create its own soil. If I could find the solution to that puzzle, my own expedition would be no less productive than that of my happy colleagues.

In order to understand the constant that is maintained throughout these transformations, let us consider a small apparatus as ingenious as the topofil or the pedocomparator (Figure 2.16). Since our friends cannot easily bring the soil of Amazonia back to France, they must be able to transform the color of each cube using a label, and if possible a number, that will make the samples of soil compatible with the universe of calculation and allow the scientists to benefit from the advantage that all calculators lend to every manipulator of signs.

But won't relativism rear its monstrous head as we attempt to qualify the nuances of brown? How can we dispute tastes and colors? As the French saying goes, "So many heads, so many opinions." In Figure 2.16 we see René's solution for repairing the ravages of relativism.

For thirty years he has toiled in the tropical soils of the world carrying a small notebook with rigid pages: the Munsell code. Each page of this little volume groups together colors of very similar shades. There is a page for the purplish reds, another for the yellowish reds, another for the browns. The Munsell code is a relatively universalized norm; it is used as a common standard for painters, paint manufacturers, cartographers, and pedologists, since page by page it arranges all the nuances of all the colors of the spectrum by assigning each a number.

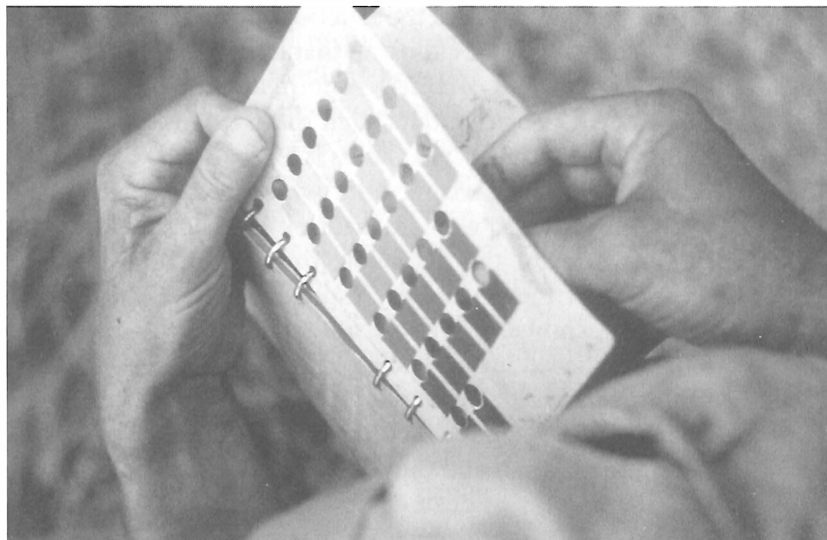


Figure 2.16

The number is a reference that is quickly understandable and reproducible by all the colorists in the world on the condition that they use the same compilation, the same code. By telephone, you and a salesperson cannot match samples of wallpaper, but you can, based on a color chart the salesperson has given you, select a reference number.

The Munsell code is a decisive advantage for René. Lost in Roraima, made so tragically local, he is able to become, through the intermediary of his code, as global as it is possible for a human being to be. The unique color of this particular soil sample becomes a (relatively) universal number.

At this moment, the power of standardization (Schaffer 1991) is less interesting to me than a stupefying technical trick—the little holes that have been pierced above the shades of color. Though seemingly always out of reach, the threshold between local and global can now be crossed instantaneously. Still, it takes some skill to insert the soil sample into the Munsell code. In order for the soil sample to qualify as a number, René must in fact be able to match, superpose, and align the local clod of earth, which he holds in his hand, with the standardized color chosen as a reference. To accomplish this, he passes the soil sam-

ple beneath the openings made in the notebook and, by successive approximations, selects the color closest to that of the sample.

There is, as I have said, a complete rupture at each stage between the “thing” part of each object and its “sign” part, between the tail end of the soil sample and its head. That abyss is all the wider because our brains are incapable of memorizing color with precision. Even if the soil sample and the standard were no farther apart than ten or fifteen centimeters, the width of the notebook, this would be enough for René’s brain to forget the precise correspondence between the two. The only way the resemblance between a standardized color and a soil sample can be established is by piercing holes in the pages that allow us to align the rough surface of the lump of soil with the bright and uniform surface of the standard. With less than a millimeter of distance separating them, then and only then can they be read synoptically. Without the holes, there can be no alignment, no precision, no reading, and therefore no transmutation of local earth into universal code. Across the abyss of matter and form, René throws a bridge. It is a footbridge, a line, a grappling hook.

“The Japanese have made one without holes,” René says; “I cannot use it.” We are always amazed by the minds of scientists, and justly so, but we should also admire their utter lack of trust in their own cognitive abilities (Hutchins 1995). They doubt their brains so much that they need to invent little tricks like this to ensure their understanding of the simple color of a soil sample. (And how could I make the reader understand this work of reference without the photographs that I have taken, images that must be viewed at exactly the same time as the story I am relating is being read? I am so afraid of making a mistake in my account that I myself do not dare lose sight of the photographs, even for an instant.)

The rupture between the handful of dust and the printed number is always there, though it has become infinitesimal because of the holes. Through the intermediary of the Munsell code, a soil sample can be read as a text: “10YR3/2”—further evidence of the practical Platonism that turns dust into an Idea via the two callused hands firmly holding a notebook/instrument/calibrator.

Let us follow in more detail the trail displayed in Figure 2.16, sketching the lost road of reference for ourselves. René has extracted his lump of earth, renouncing the too rich and too complex soil. The hole,

in turn, allows the framing of the lump and the selection of its color by ignoring its volume and texture. The little flat rectangle of color is then used as an intermediary between the earth, summarized as a color, and the number inscribed under the corresponding shade. Just as we are able to ignore the volume of the sample in order to concentrate on the color of the rectangle, we are soon able to ignore the color in order to conserve only the reference number. Later, in the report, we will omit the number, which is too concrete, too detailed, too precise, and retain only the horizon, the tendency.

Here we find the same cascade as before, of which only a tiny portion (the passage from the sample color to that of the standard) rests on resemblance, on *adequatio*. All the others depend only on the conservation of traces that establish a reversible route that makes it possible to retrace one's footsteps as needed. Across the variations of matters/forms, scientists forge a pathway. Reduction, compression, marking, continuity, reversibility, standardization, compatibility with text and numbers—all these count infinitely more than *adequatio* alone. No step—except one—resembles the one that precedes it, yet in the end, when I read the field report, I am indeed holding in my hands the forest of Boa Vista. A text truly speaks of the world. How can resemblance result from this rarely described series of exotic and minuscule transformations obsessively nested into one another so as to keep something constant?

In Figure 2.17 we see Sandoval squatting, the shaft of the mattock still resting under his arm, contemplating the new hole he has just dug. Standing, Héloïsa is thinking about the few animals in this green-gray forest. She is wearing a geologist's pouch, an ammunition belt the side of which is studded with eyelets too narrow for cartridges but well suited for carrying the colored pencils indispensable to the professional cartographer. In her hand she holds the famous notebook, the protocol book that makes it true that we are in a vast, green laboratory. She is waiting to open it and to take notes now that both pedologists have finished their examination and reached agreement.

Armand (on the left) and René (on the right) are engaged in the rather strange exercise of "earth tasting." In one hand each of them has taken a bit of soil sampled from the hole at a depth dictated by Héloïsa's protocol. They have delicately spat on the dust and now, with the other hand, they slowly knead it. Is this for the pleasure of



Figure 2.17

molding figurines? No, it is to extract another judgment, one that no longer involves color, but rather texture. Unfortunately, for this purpose there is no equivalent of the Munsell code, and if there were one, we wouldn't know how to get it here. To define granularity in a standardized manner, one would need half of a well-equipped laboratory. Consequently, our friends must content themselves with a qualitative test that rests on thirty years' experience and that they will later compare with laboratory results. If the soil is easily molded, it is clay; if it crumbles under one's fingers, then one is dealing with sand. Here is an apparently very easy trial that amounts to a sort of laboratory experiment in the hollow of one's hand. The two extremes are easily recognizable, even by a beginner like me. It is the intermediate compounds of sand and clay that make the differentiation difficult and crucial, since we are interested in qualifying the subtle modifications of the transition soils which are more clayey toward the forest and more sandy toward the savanna.

Lacking any kind of gauge, Armand and René rely on a back-and-forth discussion of their judgments of taste, as my father would do when he tasted his Corton wines.

"Sandy-clay or clayey-sand?"

"No, I would say clayey, sandy, no sandy-clay."

"Wait, mold it a bit more, give it some time."

"Okay, yes, let's say between sandy-clay and clayey-sand."

"Héloïsa, make a note: at P2, between five and seventeen centimeters, *areno-argiloso a argilo-arenoso*." (I forgot to mention that we are alternating constantly between French and Portuguese, the politics of language being added to the politics of race, gender, and disciplines.)

The combination of discussion, know-how, and physical manipulation allows for the extraction of a calibrated qualification of texture that can immediately replace, in the notebook, the soil that can now be thrown away. A word replaces a thing while conserving a trait that defines it. Is this a term-to-term correspondence? No, the judgment does not *resemble* the soil. Is this metaphorical displacement? No more so than a correspondence. Is it metonymy? Not that either, since once we take a handful of soil for the whole horizon, we keep only what is on the paper of the notebook and none of the earth that was used to qualify it. Is this compression of data? Yes, definitely, since four words occupy the location of the soil sample, but it is a change of

state so radical that now a sign appears in place of a thing. Here it is no longer a question of reduction but of transubstantiation.

Are we crossing the sacred boundary that divides the world from discourse? Obviously yes, but we have already crossed it a good ten times. This new leap is no more distant than the preceding one, in which the earth extracted by René, cleaned of blades of grass and worm feces, became evidence in a test of its resistance to molding; or the one before that, in which Sandoval dug the P2 hole with his mattock; or the following one, in which, on the diagram, the whole horizon from five to seventeen centimeters takes on a single texture, allowing, through induction, the coverage of the surface from a point; or the $n+1$ transformation that permits a diagram drawn on millimeter-ruled graph paper to play the role of internal referent for the written report. There is nothing privileged about the passage to words, and all stages can serve equally to allow us to grasp the nesting of reference. In none of the stages is it ever a question of copying the preceding stage. Rather, it is a matter of *aligning* each stage with the ones that precede and follow it; so that, beginning with the last stage, one will be able to *return* to the first.

How can we qualify this relation of representation, of delegation, when it is not mimetic yet is so regulated, so exact, so packed with reality, and, in the end, so realistic? Philosophers fool themselves when they look for a correspondence between words and things as the ultimate standard of truth. There is truth and there is reality, but there is neither correspondence nor *adequatio*. To attest to and guarantee what we say, there is a much more reliable movement—indirect, cross-wise, and crablike—through successive layers of transformations (James [1907] 1975). At each step, most of the elements are lost but also renewed, thus leaping across the straits that separate matter and form, without aid other than, occasionally, a resemblance that is more tenuous than the rails that help climbers over the most acrobatic passes.

In Figure 2.18 we are on the site, toward the end of our expedition, and René is commenting on a diagram on graph paper of a vertical cross-section of the transect that we have just dug and examined. Torn, dirty, stained with sweat, incomplete, and sketched in pencil, this diagram is the direct predecessor of the one in Figure 2.15. From the one to the other there are indeed transformations, which include processes of selection, centering, lettering, and cleaning, but these



Figure 2.18

are minor in comparison with the transformations through which we have just passed (Tufte 1984).

In the middle of the photograph René is indicating a line with his finger, a gesture we have followed from the first (see Figures 2.1 and 2.2). Unless it is pointed in anger as a prelude to a fist, the extension of the index finger always signals an access to reality even when it targets a mere piece of paper, an access which in this case nonetheless encompasses the totality of the site, which, paradoxically, has entirely disappeared even as we are sweating at the center of it. This is the same reversal of space and time we have already seen many times: thanks to inscriptions, we are able to oversee and control a situation in which we are submerged, we become superior to that which is greater than us, and we are able to gather together synoptically all the actions that occurred over many days and that we have since forgotten.

But the diagram not only redistributes the temporal flux and inverts the hierarchical order of space, it reveals to us features that previously were invisible even though they were literally under the feet of our pedologists. It is impossible for us to see the forest-savanna transition in vertical cross-sections, to qualify it in homogeneous horizons, and

to mark it with data-points and lines. René points with his finger made of flesh and attracts the gaze of the living onto a profile whose observer could never exist. The observer would have to not only reside under the earth like a mole but be able to cut the soil as if with a blade hundreds of meters long and replace the confusing variation of forms with homogeneous hatchings! To say that a scientist "occupies a standpoint" is never very useful, since she will immediately move to another through the application of an instrument. Scientists never *stand* in their standpoint.

Despite the implausible vista it offers, the diagram adds to our information. On one paper surface we combine very different sources that are blended through the intermediary of a homogeneous graphical language. The positions of the samples along the transect, the depths, the horizons, the textures, and the reference numbers of the colors can be added to one another by superposition—and the reality we had lost is replaced.

René, for instance, has just added to the diagrams the worm feces I have mentioned. According to my friends, it seems that the worms may carry the solution to the enigma within their particularly voracious digestive tracts. What produces the strip of clayey soil in the savanna at the edge of the forest? Not the forest, since this strip extends twenty meters beyond the protective shadow and nourishing humidity of the trees. Not the savanna either, since, let us remember, it always reduces clay into sand. What is this mysterious action at a distance that prepares the soil for the arrival of the forest, ascending the thermodynamic slope that continues to degrade the clay? Why not the earthworms? Might they be the catalyzing agents of the pedogenesis? In modeling the situation, the diagram allows for the imagining of new scenarios, which our friends discuss passionately while considering what is missing and where to dig the next hole to get back to the "raw data" with their pick and drill (Ochs, Jacoby, et al. 1994).

Is the diagram that René holds in his hand more abstract or more concrete than our previous stages? More abstract, since here an infinitesimal fraction of the original situation is preserved; more concrete, since we can grasp in our hands, and see with our eyes, the essence of the forest-savanna transition, summarized in a few lines. Is the diagram a construction, a discovery, an invention, or a convention? All four, as always. The diagram is *constructed* by the labors of

five people and by passing through successive geometrical constructions. We are well aware that we have *invented* it and that, without us and the pedologists, it would never have appeared. Still, it *discovers* a form that until now has been hidden but that we retrospectively feel was already there beneath the visible features of the soil. At the same time, we know that without the *conventional* coding of judgments, forms, tags, and words, all we could see in this diagram drawn from the earth would be formless scribbles.

All of these contradictory qualities—contradictory, that is, for us philosophers—ballast this diagram with reality. It is not realistic; it does not resemble anything. It does *more* than resemble. It *takes the place of the original situation*, which we can retrace, thanks to the protocol book, the tags, the pedocomparator, the record cards, the stakes, and, finally, the delicate spiderweb woven by the “pedofil.” Yet we cannot divorce this diagram from this series of transformations. In isolation, it would have no further meaning. It replaces without replacing anything. It summarizes without being able to substitute completely for what it has gathered. It is a strange transversal object, an alignment operator, truthful only on condition that it allow for *passage* between what precedes and what follows it.

On the last day of the expedition we find ourselves in the restaurant, now transformed into a meeting room for our mobile laboratory, in order to write a draft of our report (Figure 2.19). René is holding the now completed diagram in his hand and commenting on it, pointing with a pencil for the benefit of Edileusa and Héloïsa. Armand has just finished reading the only thesis that has been published on our corner of the forest, and he has opened it to pages of color photographs obtained by satellite. In the foreground rest the notebooks of the anthropologist who is taking this picture—one more form of recording amid forms of inscription. We are again among maps and signs, two-dimensional documents and published literature, already quite far from the site where we have labored for ten days. Have we, then, returned to our starting point (see Figure 2.2)? No, because we now have *gained* these diagrams, these new inscriptions we are attempting to interpret and to insert as an appendix and as evidence into a narrative we are negotiating together, paragraph by paragraph, in two languages, French and Portuguese. Let me quote a passage from page one:



Figure 2.19

The interest of this expedition report stems from the fact that, in the first phase of work, the conclusions of the approaches of botany and pedology appear contradictory. *Without the contribution of the botanical data, the pedologists would have concluded that the savanna is advancing on the forest.* The collaboration of the two disciplines in this case has forced us to ask new questions of pedology. (italics in the original)

Here we are on much more familiar terrain—rhetoric, discourse, epistemology, and the writing of articles—busy with the weighing of arguments for and against the advance of the forest. Neither philosophers of language, nor sociologists of controversy, nor semioticians, nor rhetoricians, nor scholars of literature will have much difficulty here.

As thrilling as will be the transformations that Boa Vista will undergo from text to text, I do not, for the moment, wish to follow them. What interests me now is the transformation undergone by the soil, now bound up in words. How to summarize this? I need to draw, not a diagram on graph paper like that of my colleagues, but at least a sketch, a schema that will allow me to locate and point to what I, in

my own field of science studies, have discovered: a discovery brought back from the underworld, worthy of our lowly brethren, the earth-worms.

The philosophy of language makes it seem as if there exist two disjointed spheres separated by a unique and radical gap that must be reduced through the search for correspondence, for reference, between words and the world (Figure 2.20). While following the expedition to Boa Vista, I arrived at a quite different solution (Figure 2.21). Knowledge, it seems, does not reside in the face-to-face confrontation of a mind with an object, any more than reference designates a thing by means of a sentence verified by that thing. On the contrary, at every stage we have recognized a common operator, which belongs to matter at one end, to form at the other, and which is separated from the stage that follows it by a gap that no resemblance could fill. The operators are linked in a series that *passes across* the difference between things and words, and that redistributes these two obsolete fixtures of the philosophy of language: the earth becomes a cardboard cube, words become paper, colors become numbers, and so forth.

An essential property of this chain is that it must remain *reversible*. The succession of stages must be traceable, allowing for travel in both directions. If the chain is interrupted at any point, it ceases to transport truth—ceases, that is, to produce, to construct, to trace, and to conduct it. *The word “reference” designates the quality of the chain in its entirety*, and no longer *adequatio rei et intellectus*. Truth-value *circulates* here like electricity through a wire, so long as this circuit is not interrupted.

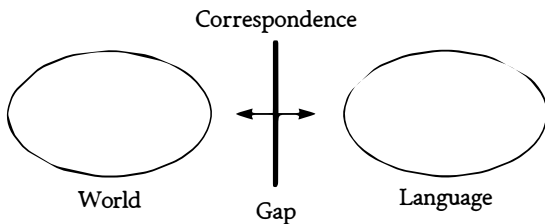
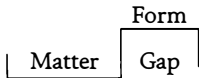


Figure 2.20 The “saltationist’s” (James [1907] 1975) conception of the feat of correspondence implies that there is a gap between world and words that reference aims to bridge.

Elements of representation



Chain of elements

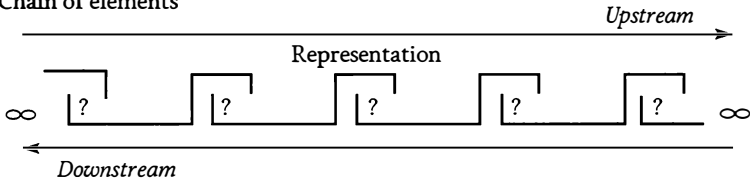


Figure 2.21 The “deambulatory” conception of reference follows a series of transformations, each of them implying a small gap between “form” and “matter”; reference, in this view, qualifies the movement back and forth as well as the quality of the transformation; the key point is that reference, in this model, grows from the center toward the two extremities.

Another property is revealed by the comparison of my two sketches: the chain has no limit at either end. In the prior model (Figure 2.20), the world and language existed as two finite spheres capable of self-enclosure. Here, on the contrary, we can elongate the chain indefinitely by extending it at both ends, by adding other stages—yet we can neither cut the line nor skip a sequence, despite our capacity to summarize them all in a single “black box.”

In order to understand the chain of transformation, and to grasp the dialectic of gain and loss that, as we have seen, characterizes each stage, we must look from above as well as at the cross-section (Figure 2.22). From forest to expedition report, we have consistently re-represented the forest-savanna transition as if drawing two isosceles triangles covering each other in reverse. Stage by stage, we lost locality, particularity, materiality, multiplicity, and continuity, such that, in the end, there was scarcely anything left but a few leaves of paper. Let us give the name *reduction* to the first triangle, whose tip is all that finally counts. But at each stage we have not only reduced, we have also gained or regained, since, with the same work of re-representation, we have been able to obtain much greater compatibility, standardization, text, calculation, circulation, and relative universality, such that by the end, inside the field report, we hold not only

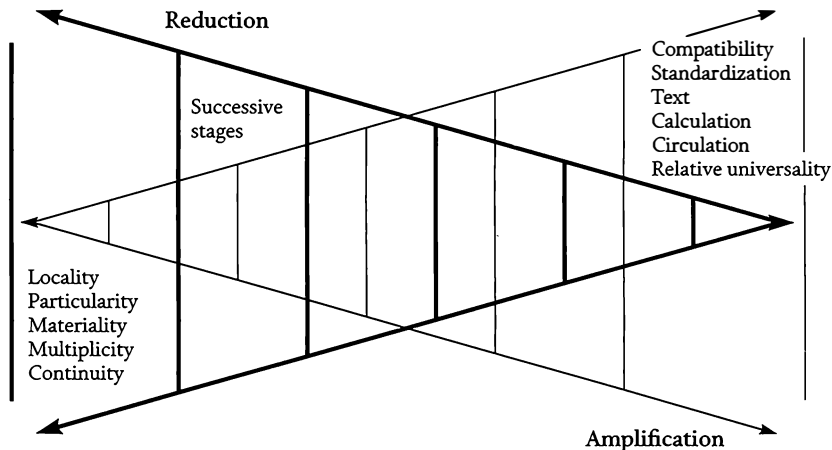


Figure 2.22 The transformation at each step of the reference (see Figure 2.21) may be pictured as a trade-off between what is gained (amplification) and what is lost (reduction) at each information-producing step.

all of Boa Vista (to which we can return), but also the explanation of its dynamic. We have been able, at every stage, to extend our link with already-established practical knowledge, starting with the old trigonometry placed “behind” phenomena and ending up with all of the new ecology, the new findings of “botanical pedology.” Let us call this second triangle, by which the tiny transect of Boa Vista has been endowed with a vast and powerful basis, *amplification*.

Our philosophical tradition has been mistaken in wanting to make phenomena* the meeting point between things-in-themselves and categories of human understanding (Figure 2.23; also see Chapter 4). Realists, empiricists, idealists, and assorted rationalists have fought ceaselessly among themselves around this bipolar model. Phenomena, however, are not found at the *meeting point* between things and the forms of the human mind; phenomena are what *circulates* all along the reversible chain of transformations, at each step losing some properties to gain others that render them compatible with already-

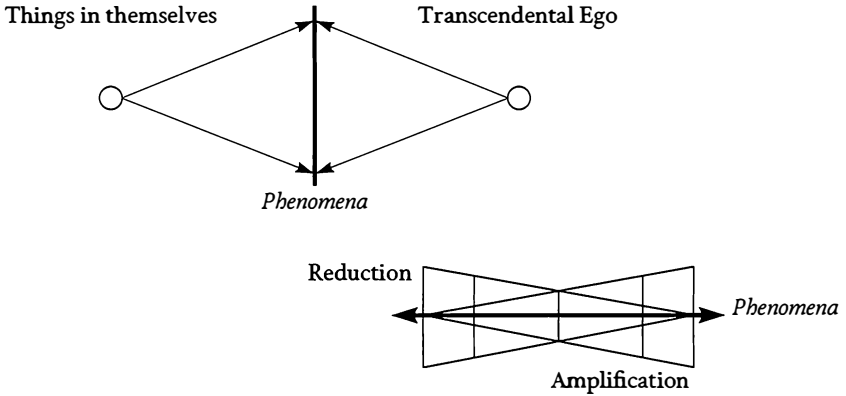


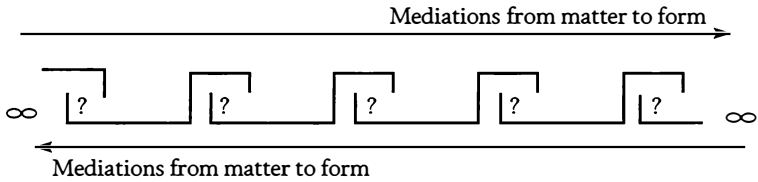
Figure 2.23 In the Kantian scenography, phenomena reside at the meeting point between the inaccessible things in themselves and the categorizing work made by the active Ego; with circulating reference, phenomena are what routinely circulates through the cascade of transformations.

established centers of calculation. Instead of growing from two fixed extremities toward a stable meeting point in the middle, the unstable reference *grows from the middle toward the ends*, which are continually pushed further away. To understand how Kantian philosophy has muddled the triangles, a fifteen-day expedition is all that is required. (All that is required, I hasten to add, on condition that I am not asked to speak of *my* work in the same lavish detail in which the pedologists report theirs: fifteen days would then become twenty-five years of hard labor at controversies with scores of dear colleagues equipped with decades worth of data, instruments, and concepts. I portray myself here, without fear of contradiction, as a simple spectator with easy access to the knowledge of my informants. A reflexivity that could follow every thread at once is, I would be the first to admit, beyond me.)

Is it possible, with the help of my schema, to understand, visualize, and detect why the original model of philosophers of language is so widespread, when this slightest inquiry quickly reveals its impossibility? Nothing could be simpler; all we need to do is obliterate, bit by bit, each of the stages we have witnessed in this photomontage (Figure 2.24).

Let us block in the extremities of the chain as if one were the refer-

Circulating reference



The canonical view

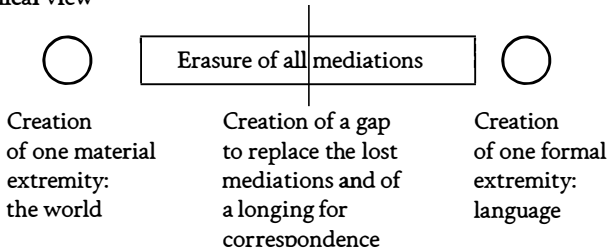


Figure 2.24 To obtain the canonical model of words and world separated by an abyss and related by the perilous bridge of correspondence, one has simply to consider the circulating reference and to eliminate all mediations as being unnecessary intermediaries that render the connection opaque. This is possible only at the (provisional) end of the process.

ent, the forest of Boa Vista, and the other were a phrase, “the forest of Boa Vista.” Let us erase all the mediations that I have delighted in describing. In place of the forgotten mediations, let us create a radical gap, one capable of covering the huge abyss that separates the statement I utter in Paris and its referent six thousand kilometers away. *Et voilà*, we have returned to the former model, searching for something to fill the void we have created, looking for some *adequatio*, some resemblance between two ontological varieties that we have made as dissimilar as possible. It is hardly surprising that philosophers have been unable to reach an understanding on the question of realism and relativism: they have taken the two provisional extremities for the entire chain, as if they had tried to understand how a lamp and a switch could “correspond” to each other after cutting the wire and making the lamp “gaze out” at the “external” switch. As William James said in his powerful style:

The intermediaries which in their concrete particularity form a bridge, evaporate ideally into an empty interval to cross, and then, the relation of the end-terms having become saltatory, the whole hocus-pocus of *erkenntnistheorie* begins, and goes on unrestrained by further concrete considerations. The idea, in 'meaning' an object separated by an 'epistemological chasm' from itself, now executes what Professor Ladd calls a 'salto mortale' . . . The relation between idea and object, thus made abstract and saltatory, is thenceforward opposed, as being more essential and previous, to its own ambulatory self, and the more concrete description is branded as either false or insufficient. (James [1907] 1975, 247-248)

The next morning, after drafting the expedition report, we load the precious cardboard boxes containing the earthworms preserved in formaldehyde, and the neatly tagged little bags of earth, into the jeep (Figure 2.25). And this is what philosophical arguments that wish to link language to the world by a single regular transformation cannot successfully explain. From text we return to things, displaced *a little further*. From the restaurant-laboratory we set out for another laboratory a thousand kilometers away, in Manaus, and from there to Jussieu University in Paris, another six thousand kilometers away. Sandoval will return to Manaus alone with the precious samples that he must preserve intact despite the arduous trek that lies ahead. As I have said, each stage is matter for what follows and form for what precedes it, each separated from the other by a gap as wide as the distance between that which counts as words and that which counts as things.

They are getting ready to leave, *but they are also preparing to return*. Each sequence flows "upstream" and "downstream," and in this way the double direction of the movement of reference is amplified. To know is not simply to explore, but rather is to be able to make your way back over your own footsteps, following the path you have just marked out. The report that we drafted the night before makes this much clear: another expedition is required, to study the activity of those suspicious earthworms at the same field site:

From a pedological point of view, admitting that the forest is advancing on the savanna implies;

1. that the forest and the biological activity particular to it transform a sandy soil into a clayey-sandy soil in the top 15 to 20 centimeters;



Figure 2.25

2. that this transformation would begin in the savanna in a 15- to 30-meter band at the edge.

While these two notions are difficult to conceive when starting from the assumptions of classical pedology, it is necessary, taking into account the solidity of the arguments derived from biological study, to test these hypotheses.

The clay enrichment of superior horizons cannot be accomplished by neoformation (lacking a known source of aluminum [aluminum is responsible for the creation of clay out of the silica contained in quartz]). The only agents capable of accomplishing this are the earthworms, whose activity on the studied site we have been able to verify, and which dispose of large quantities of koalinite contained in the horizon to a depth of 70 cm. The study of this worm population and the measure of its activity will therefore supply essential data for the continuation of this research.

Unfortunately, I will not be able to follow the next expedition. While the other members of the team say *au revoir* to Edileusa, I must say *adieu*. We are leaving by plane. Edileusa is staying in Boa Vista, pleased by an intense and friendly collaboration that was new to her, and she will continue to watch over her field site, which, because of the superposition of pedology and botany, has just increased in importance. And her plot will thicken more once we add the science of earthworms. Constructing a phenomenon in successive layers renders it more and more real within a network traced by the displacements (in both senses) of researchers, samples, graphics, specimens, maps, reports, and funding requests.

For this network to begin to lie—for it to cease to refer—it is sufficient to *interrupt* its expansion at either end, to stop providing for it, to suspend its funding, or to break it at any other point. If Sandoval's jeep swerves, breaking the jars of earthworms and scattering the little packages of earth, the whole expedition will have to be repeated. If my friends cannot find the funding to *return* to the field, we will never know if the sentence in the report about the role of the earthworms is a scientific truth, a gratuitous hypothesis, or a fiction. And if I lose all my negatives at the photo shop, how will anyone know whether I have lied?

Air conditioning at last! Finally, a space that looks more like a laboratory (Figure 2.26). We are in Manaus, at INPA, in an old work-

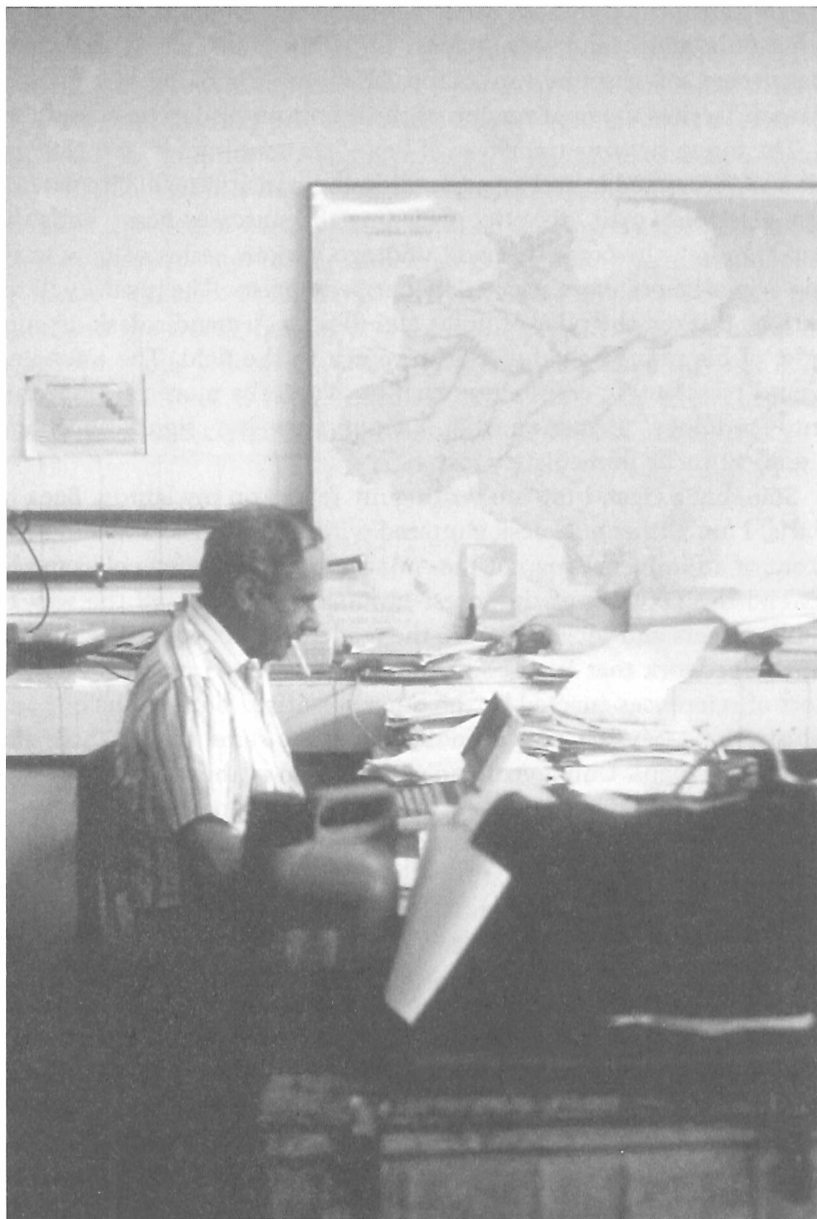


Figure 2.26

room transformed into an office. On the wall, Radambrasil's map of Amazonia and Mendeleev's chart. Offprints, files, slides, canteens, bags, cans of gasoline, an outboard motor. Smoking a cigarette, Armand writes the final version of the report on his laptop computer.

The forest-savanna transition of Boa Vista continues its transformations. Once typed in and saved on disk, the transition will circulate by fax, electronic mail, diskette, preceding the suitcases heavy with the earth and earthworms that will undergo various series of new trials in various laboratories selected by our pedologists. The results will return to thicken the piles of notes and files on Armand's desk, in support of his request for funding to return to the field. The unending round of scientific credibility: each turn absorbs more of Amazonia into pedology, a motion that cannot stop lest significance and signification be immediately lost.

Smoking a cigar, I too am writing my report on my laptop. Back in Paris, I am sitting at a desk cluttered with books, files, and slides, in front of an immense map of the Amazon basin. Like my colleagues, I extend the network of the forest-savanna transition—all the way to philosophers and sociologists, to the readers of this book. The section of the network that I am constructing, however, is made, *not* of the sort of references enacted by the other scientists, but of allusions and illustrations. My schemas do not refer in the same way as their diagrams and maps. Unlike Armand's inscription of the soil of Boa Vista, my photographs do not transport that of which I speak. I am writing a text of empirical philosophy that does not re-represent its evidence in the manner of my pedologist friends, and hence the traceability of my subject matter is not sufficiently immutable to permit the reader's return to the field. (I will leave it to the reader to measure the distance that separates the natural and social sciences, for that mystery would require another expedition, one that would study the role of the bantam empiricist that I have been playing.)

You can now look at a map of Brazil in an atlas, at the area around Boa Vista, but not for a *resemblance* between the map and the site whose story I have been recounting. This whole tired question of the correspondence between words and the world stems from a simple confusion between epistemology and the history of art. We have taken science for realist painting, imagining that it made an exact copy of the world. The sciences do something else entirely—paintings too,

for that matter. Through successive stages they link us to an aligned, transformed, constructed world. We forfeit resemblance, in this model, but there is compensation: by pointing with our index fingers to features of an entry printed in an atlas, we can, through a series of uniformly discontinuous transformations, link ourselves to Boa Vista. Let us rejoice in this long chain of transformations, this potentially endless sequence of mediators, instead of begging for the poor pleasures of *adequatio* and for the rather dangerous *salto mortale* that James so nicely ridiculed. I can never verify the resemblance between my mind and the world, but I can, if I pay the price, extend the chain of transformations wherever verified reference circulates through constant substitutions. Is this "deambulatory" philosophy of science not more realist, and certainly more *realistic*, than the old settlement?